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Nuclear Criticality Safety Evaluation for the Packaging and Storage of Fissile-Bearing Wastes at the WVDP

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SYSTEM NUMBER

Joseph C. Wolniewicz

ORIGINATOR

Daniel R Westcott

COGNIZANT MANAGER

TECHNICAL SPECIALIST

RADIATION AND SAFETY COMMITTEE CHAIRMAN (for NCSE)

ER NUMBER #4630

ECN NUMBERS _____

Westinghouse
A Member of Washington Group International, Inc.

West Valley Nuclear Services Co.
10282 Rock Springs Road
West Valley, NY 14171-9799

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NUCLEAR CRITICALITY SAFETY EVALUATION FOR THE PACKAGING AND STORAGE OF FISSILE-BEARING WASTES AT THE WVDP

1.0 INTRODUCTION

This nuclear criticality safety evaluation (NCSE) provides the criticality and contingency analyses that have been performed to support the safe packaging and storage of fissile-bearing wastes generated at the West Valley Demonstration Project (WVDP).

2.0 DESCRIPTION

Fissile material at the WVDP originated from the reprocessing of spent commercial nuclear fuel. The original NFS process involved the shearing of spent nuclear fuel into sections suitable for dissolution in acid. The dissolved fuel was contacted with an organic solvent which effected the separation of uranium and plutonium from fission products in the fuel. This fission product waste stream was ultimately transferred to high level waste tanks for storage while the product stream was further processed to separate and purify the uranium and plutonium streams.

In 1981 the WVDP Act was enacted to support the stabilization of the liquid high level waste. The selected process involved the decontamination of supernatant in the PUREX high-level waste tank 8D-2 through an ion exchange process in the Supernatant Treatment System. Decontaminated process solutions were transferred to the Liquid Waste Treatment System where the liquids were concentrated in an evaporator. Overheads from the evaporator were discharged to the site's low-level waste treatment facility while the concentrates were transferred to the Cement Solidification System where they were blended with concrete and transferred to the IRTS Drum Cell for storage in specially-designed 71 gallon drums.

High-level waste sludge remaining in tank 8D-2 following supernatant processing was washed and blended with THOREX high-level waste in tank 8D-4. This combined waste stream was homogenized and transferred to the Vitrification Facility for stabilization as a vitrified (glass) waste form in stainless steel storage canisters that are in storage in the High Level Waste Interim Storage Area.

Many of the processes associated with both the NFS and WVDP technologies generated waste streams (and product streams) containing fissile material. Primary known sources of fissile material wastes at the WVDP include the high level waste tanks, Main Plant head end, extraction, product, and analytical cells and the wastes contained in the Lag Storage Building. Analyses have been performed for a broad range of conditions of waste moderation, reflection, composition, fissile material form, and package geometry to provide the most generally applicable limits possible for the safe packaging and storage of these fissile materials.

The analyses referenced in Appendix A of this NCSE have been performed to fulfill two objectives. The first objective is to verify the adequacy of the current limits for 55-gallon drums and B-25 boxes while the second objective was to establish new limits for boxes having dimensions less than those of a B-25 box.

3.0 REQUIREMENTS DOCUMENTATION

This NCSE has been developed in accordance with WVDP-162, *WVDP Nuclear Criticality Safety Program Manual*. There are no requirements unique to this evaluation.

4.0 METHODOLOGY

The calculations that provide the basis for this NCSE were performed with Monte Carlo N-Particle (MCNP) 4A. MCNP is a general purpose, continuous energy, generalized geometry, time-dependent, coupled neutron-photon-electron Monte Carlo transport code system. MCNP treats an arbitrary three-dimensional configuration of materials in geometric cells bounded by first- and second-degree surfaces and some special fourth-degree surfaces. For neutrons, all reactions in a particular cross-section evaluation are accounted for. Both free gas and S (alpha, beta) thermal treatments are used. Criticality sources as well as fixed and surface sources are available. MCNP is distributed by the Radiation Safety Information Computational Center (RSICC) located in Oak Ridge, Tennessee. Documentation for MCNP 4A is provided in LA-12625, *MCNP - A General Monte Carlo N-Particle Transport Code*, which was issued in November 1993.

MCNP's generalized user-input source capability permits a wide variety of source conditions to be modeled. Independent probability distributions may be specified for the source variables of energy, time, position, and direction, and for other parameters such as starting cells or surfaces. Tallies such as the number of fissions, the number of absorptions, or any product of the flux times the standard ENDF reactions may be calculated. All tallies are functions of time and energy as specified by the user and are normalized to be per starting particle. The MCNP output file lists the tally mean, statistical relative error, variance, tally fluctuation charts, standard summary information, and other graphical/tabular output requested by the user.

MCNP uses continuous-energy nuclear and atomic data libraries from sources such as the Evaluated Nuclear Data File (ENDF) system. Pointwise neutron cross section data are used and, for neutrons, all reactions given in a particular cross-section evaluation are accounted for. Cross sections (whether continuous or discrete) based on ENDF/B-V evaluations are believed to be the best available to MCNP users at this time. Consequently, the ENDF/B-V cross section library was used for all evaluations referenced in this report.

The personal computer (PC) version of MCNP 4A was run on a Compaq Pentium III, 550 MHz system, operating in a Windows NT environment. *MCNP 4A Software Validation Plan and Report for Criticality Calculations* provides documentation of the validation activities that were performed to support the criticality calculations addressed in this NCSE. The bias and bias uncertainty related to the use of MCNP for evaluation of moderated and unmoderated systems containing low-enriched uranium are addressed in *MCNP 4A Software Validation Plan and Report for Criticality Calculations*. Through an evaluation of the code bias, a subcritical limit of 0.93 was selected for use in this NCSE in assessing the criticality safety of normal operations.

4.1 Evaluated Models

The objective of this analysis is to provide a set of generally applicable limits that will assure the criticality safety of packaged fissile materials regardless of the waste matrix composition, internal package moderation, external package moderation and reflection, fissile material composition, or homogeneity of fissile material within the waste matrix. To accomplish this objective, a number of parametric analyses were performed to determine the most reactive condition for several parameters including fissile material composition, waste matrix material composition, waste container moderator content, fissile material homogeneity, and external waste package reflection.

Sections 4.1.1 through 4.1.3 of this report describe the assumptions for the analyses that were performed to confirm the validity and range of applicability for the previously-established fissile mass limits for 55-gallon drums and B-25 boxes, while Section 4.1.4 describes the analyses that were performed to establish limits for boxes having dimensions different from those of a B-25 box.

4.1.1 Identification of Fissile Material Composition

The determination of the fissile mass limits for waste drums and boxes required the identification of the fissile material composition to be used in models. Fuel received by NFS for reprocessing typically contained uranium that was enriched to 3 weight percent U-235 or less. Historical records indicate that only one special campaign of thorium-based fuel contained an initial enrichment of U-235 greater than 5 weight percent and even this campaign had a U-235 enrichment only slightly greater than this level.

NFS received little mixed oxide fuel for reprocessing and therefore most fuel did not contain an initial inventory of plutonium or other fissile nuclides. However, reactor irradiation of U-238 present in the fuel generated plutonium and other fissile isotopes in this fuel in proportion to the degree of fuel burnup. Based on a review of WVDP waste and product streams, it has been concluded that the only fissile nuclides of concern at the WVDP are U-233, U-235, Pu-239, and Pu-241. While the relative proportion of these nuclides in a particular waste stream may have a significant effect on the reactivity of a system, Pu-239 was selected as the sole nuclide in all calculations for this analysis as this nuclide represents the most reactive fissile nuclide in WVDP wastes.

4.1.2 Identification of Waste Matrix Material

The analysis presented here, while developed specifically for WVDP waste streams, has, to the greatest extent possible, taken advantage of analyses and reference calculations performed by others for systems similar to those encountered at the WVDP. Through review of these references, three materials common in WVDP waste streams and known to be good moderators were selected for analysis. These materials were water, concrete, and cellulose. A series of models were prepared to assess the reactivity of a two-dimensional infinite array of 90 ft^3 boxes (i.e., B-25 boxes) and 55-gallon drums containing Pu-239 homogeneously distributed throughout the waste matrix. The analyses assumed that boxes of fissile material waste contain a total of 350 g of Pu-239 while drums of fissile debris waste were assumed to contain a total of 200 g of Pu-239. In the case of cellulose and concrete, the waste matrix was blended with varying amounts of water ranging from 100% water (no waste material) to 0% water (all waste material) to assess the effect of included moderator in the matrix. These analyses, which are documented in URS calculations BUF-2000-098 and BUF-2000-101 provided in Appendix A, concluded that the matrix material corresponding to the most reactive system was cellulose. This was expected due to the fact that this matrix material has a higher concentration of hydrogen and carbon than either water or concrete.

4.1.3 Assessment of the Effect of Fissile Material Heterogeneity

Standard criticality safety references (e.g., LA-10860-MS) have documented the potential for increased reactivity in matrix systems containing heterogeneous distributions of fissile material relative to similar homogeneous systems of similar composition and fissile mass. To assess the potential for increased reactivity in arrays of WVDP waste drums and boxes, a series of parametric analyses was performed assuming that all the fissile material in the waste package was contained either in a metal sphere or a sphere in which the fissile material is blended with cellulose. In

both cases, the balance of the waste package interior contained cellulose and both the sphere radius and density of cellulose external to the sphere were varied to determine the combination of fissile material concentration and cellulose density that corresponds to a maximum reactivity. Through these analyses it was determined that a maximum array reactivity exists for the condition in which the fissile material in each of eight adjacent waste packages is concentrated at the point of intersection of the containers. Even under these extreme circumstances, the array was found to be subcritical for all except the most reactive conditions of fissile material concentration, and even then only for the case of boxes.

4.1.4 Determination of Waste Box Fissile Mass Limits

An analysis was performed to determine the fissile mass limits for boxes of various sizes. The analysis was prepared to provide limits that were as generally applicable as possible. Because no specific fixed set of waste containers exist for modeling, it was determined to evaluate cubic waste boxes of various sizes. The limit for a waste box would then be the fissile mass limit determined for the largest analyzed box that could be fully contained within the waste box.

Calculations performed for these analyses were similar to those performed to confirm the previously-established limits for 55-gallon drums and B-25 boxes. Fissile material in the waste container was distributed uniformly throughout a cellulose sphere of uniform density with the balance of the interior of the box filled with cellulose of variable density. Several parametric analyses were then performed on container fissile mass, sphere radius, and cellulose density to determine the reactivity of an infinite 2-dimensional array of cubic boxes having cross-sectional dimensions ranging from 1-foot to 2.875-feet (the minimum cross-sectional dimension of a B-25 box). For all calculations it was assumed that the array rested on a 3-m thick concrete floor and that the array height did not exceed 12 feet. The results of these analyses are contained in URS calculations BUF-2001-009, BUF-2001-011, BUF-2001-012, BUF-2001-013, and BUF-2001-014 contained in Appendix A.

5.0 DISCUSSION OF CONTINGENCIES

A contingency is "a possible but unlikely change in a condition/control important to the nuclear criticality safety of a fissionable material operation that would, if it occurred, reduce the number of barriers (either administrative or physical) that are intended to prevent an accidental nuclear criticality" (DOE-STD-3007-93). Based on the analyses presented in Sections 6.1 and 6.2, the following contingencies exist for the storage of fissile-bearing debris generated at the WVDP. At least two of the following changes to conditions or controls would need to occur for even a very small chance of a criticality event.

(1) A significant quantity of fissile material would have to be packaged in a storage container or in multiple containers.
(2) Operations and engineering personnel would have to fail to detect that waste being packaged for storage contained a significant quantity of fissile material.
(3) A significant amount of fissile material would have to be inadvertently packaged in multiple waste containers having dimensions less than those identified in this NCSE.
(4) Waste containers would have to be stacked in a large array to an unacceptable height.

The double contingency analysis for fissile material waste packaging and storage is summarized in Table 1.

Table 1
Double Contingency Analysis for Packaging and Storage Activities

No.	Description of Abnormal or Accident Event That Could Lead to Criticality	Barriers
1	Packaging of a significant quantity of fissile material into a single waste container or multiple waste containers.	(1) Very limited number of waste streams at the WVDP that contain significant quantities of fissile material. (2) Very high radiation rates or alpha radiation contamination levels associated with known fissile waste streams facilitating identification of significant quantities of fissile material. (3) Administrative controls on the maximum amount of fissile material in a waste container
2	Packaging of fissile material waste into containers having dimensions smaller than those assumed in the criticality evaluation.	Administrative controls on fissile material waste container dimensions
3	Stacking an array of waste containers to an unacceptable height	Administrative control on height of fissile material storage array

6.0 EVALUATION AND RESULTS

This NCSE has been developed to support the critically safe packaging and storage of fissile material wastes at the WVDP. The safety of packaged fissile material has been evaluated for both normal and accident conditions. These cases are discussed individually below.

6.1 Normal Packaging and Storage

Under normal packaging and storage conditions, fissile material wastes are packaged in 55-gallon drums having an inner diameter not less than 22 inches and an outside height not less than 34 inches (with the lid in place) or in boxes whose minimum internal dimension is not less than 12 inches. The fissile mass limits for WVDP waste containers are listed in Table 2.

Table 2
Fissile Mass Limits for Waste Boxes and Drums

Minimum Box Outer Dimension		Total Fissile Mass Limit (g)
Greater than or Equal to	But less than	
0 inches	12 inches	Waste boxes of this size are not authorized
12 inches	18 inches	15
18 inches	24 inches	50
24 inches	30 inches	135
30 inches	--------	200
All 55-gallon drums		125

As indicated in Section 2.0, the analyses used to derive these fissile mass limits identified the most reactive waste matrix material and used this material in calculations when determining conditions of optimum internal and external moderation. The models assumed that waste packages were configured in an infinite 2-dimensional array stacked to a height of 4 tiers or 12 feet (whichever was greater) and assumed reflection from a 3-m thick concrete floor. (This height of the storage array was selected to correspond to the maximum height of a storage array anticipated in the Lag Storage Building.) Under normal storage conditions, it is anticipated that the wastes will have a very low free-moisture content.

6.2 Packaging and Storage Under Accident and Abnormal Conditions

Abnormal operations and accident conditions that have the potential to affect packaged fissile materials in storage include the presence of a significant undetected quantity of fissile material in a waste package, internal moderation of a fissile material waste package, external moderation of a storage array due to flooding or fire fighting, use of a container having dimensions smaller than those assumed in the referenced analyses, or crushing of a package or packages in a storage array. The implications of each of these will be analyzed individually.

6.2.1 Presence of a Significant Undetected Quantity of Fissile Material in a Waste Package

Section 2.0 of this analysis provides an overview of the processes at the WVDP involving the processing, handling, packaging, and storage of fissile materials at the site. Due to the nature of these processes, virtually all sources of fissile material are also associated with a significant quantity of fission products. Waste streams having radionuclide profiles similar to those found in high-level waste are the most common at the WVDP site. Examples of this radionuclide profile in waste streams as diverse as contaminated Main Plant equipment, STS process equipment, liquid and gaseous environmental effluents, and contaminated soil have been found throughout the site. Gamma-emitters in these waste streams are so abundant that there exists on the order of 1-100 Ci of gamma-emitting nuclides per gram of total fissile material. Consequently, for wastes exhibiting characteristics similar to high-level waste, the very high package exposure rates associated with significant quantities of fissile nuclides (on the order of tens to thousands of R/hr) would make failure to detect high concentrations of fissile material in these packages incredible.

The NFS process generated uranium and plutonium product streams that contained high concentrations of fissile materials by design. All significant inventories of this material were shipped as product by NFS and virtually all residual inventories present as tank heels or other holdups were recovered to the greatest extent possible by NFS due to the economic value of this material. Nevertheless, small but not insignificant quantities of this material remain in tanks and process piping in certain areas of the Main Plant. Detection of this material is not as straightforward as with high-level waste streams because these materials do not have associated with them the inventory of gamma emitters that would indicate their presence through elevated exposure rates as is the case with waste streams that exhibit characteristics similar to high-level waste. However, the number of locations in the Main Plant where this material may exist is limited and work in these areas anticipates the potential for residual material remaining in pipes and tanks.

Important fissile nuclides such as U-233 and Pu-239 have relatively high specific activities (that is, they represent a significant amount of alpha activity per unit mass) and consequently the presence of significant quantities of fissile material can be inferred from alpha contamination surveys. This method cannot detect the presence of fissile materials internal to process equipment; however, in the unlikely event that a process component does contain a significant undetected holdup, most process equipment in the product areas of the Main Plant are significantly larger than standard waste containers and the physical dimensions of this process equipment would serve to provide a measure of separation between waste packages. It is therefore reasonable that if significant inventories of fissile material do exist in these waste streams, they would be small in number and self-protecting to the extent that their physical size would limit interaction between units.

The presence of a significant quantity of fissile material in multiple fissile material waste storage containers, while extremely unlikely, is not incredible. Analyses in Appendix A clearly demonstrate that the criticality safety of a system of waste containers is affected by the fissile mass in the container. Because the inventory of fissile material in WVDP waste streams is variable and is not inherently safe, administrative controls must be applied to ensure that an unsafe mass of fissile material is not packaged in a waste container.

6.2.2 Internal Moderation of a Fissile Material Waste Package

Fissile material wastes at the WVDP are typically in the form of surface contaminated materials removed from analytical, head end, and product areas of the Main Plant. These materials include cell components such as piping, tanks, and pumps, as well as anticontamination clothing and tools and equipment required for cell decontamination. These wastes are not anticipated to contain a significant amount of water. Additionally, waste management considerations would require that these wastes be packaged with a minimum amount of free liquid. Nevertheless, even if significant free liquid were packaged in multiple containers that also contained fissile material at or near the limits established in Table 2, a criticality concern would not exist for two important reasons: 1) the analyses contained in Appendix A assumed the presence of water in the waste packages, and 2) these analyses concluded that under optimum conditions of fissile material concentration the most reactive condition was achieved for a low-density cellulose waste matrix that contained no water (i.e., cellulose proved to be a better moderator than water). The internal moderation of stored fissile material waste packages would therefore not result in an unsafe condition.

6.2.3 External Moderation of a Storage Array

Two mechanism exist for the external moderation of an array of fissile material waste containers: 1) flooding due to natural phenomena, and 2) flooding and misting due to fire fighting. The potential for flooding through these two mechanisms is discussed below.

The likelihood of natural phenomenon-induced flooding of an array of drums of fissile material waste is extremely small because "the site's topographic setting renders the likelihood of major flooding not credible, and local run-off and flooding is adequately accommodated by natural and man-made drainage systems in and around the WVDP," as stated in WVNS-SAR-001, *Safety Analysis Report for Project Overview and General Information*. Section A.3.4 of WVNS-SAR-001 provides an extensive discussion of surface hydrology phenomena associated with the WVDP site and surrounding area and presents facts and analyses that support the conclusion that major flooding is not considered credible. As stated in Section A.3.4.2.1 of WVNS-SAR-001: "Cattaraugus and Buttermilk creeks lie in deep, narrow valleys. Therefore, the effects on the WVDP of flooding by these creeks is negligible, as supported by historical data. Frank's Creek, Quarry Creek, and Erdman Brook are also located in deep valleys. Historical evidence and computer modeling indicate that flood conditions (including the probable maximum flood) will not result in stream flows overtopping their banks and flooding the plateau."

WVNS-SAR-001 documents the potential for facility impacts due to the probable maximum flood (PMF) and the probable maximum precipitation (PMP) event. Section A.3.4.3 of the SAR recognizes that under the conditions of the PMF the nearest stream would rise to 1347.2 feet NGVD while the lowest portion of the Main Plant is at approximately 1,410 feet NGVD, or more than 60 feet above the highest point of stream rise. The PMF would therefore not present a safety concern for the Lag Storage Facility or for other areas of the site where fissile materials may be packaged, handled, or stored.

In assessing the probable maximum precipitation (PMP) event, Section A.3.4.2.3 of WVNS-SAR-001 states that per the U.S. Weather Bureau the 24-hour PMP for the WVDP watershed is 24.9 inches. The effects of the PMP on site drainage systems would be overwhelming. Capacities of storm drain inlets at grade and in sumps would be exceeded. Ditches along open sections of roadways would overflow, flooding roadways and adjacent areas. None of the culverts within the watershed would be expected to prevent overtopping of its embankments, which raises the possibility of embankment failures. In the case of the 24-inch corrugated metal pipe (CMP) culvert beneath the railroad embankment along Frank's Creek, flow would be directed to the water supply reservoirs before the embankment elevation was exceeded. In reviewing this information the SAR concluded that failures of culvert embankments, which are down gradient from process areas of the site, did not present a potential risk to these process areas and would not threaten any safety-related facilities.

The potential for flooding due to fire fighting presents another mechanism for external moderation of a fissile material storage array. The primary location for storage of fissile material wastes at the WVDP is the Lag Storage Building. Packaged fissile material wastes generated during facility or laboratory operations or during facility decontamination operations are transferred to the Lag Storage Facility for interim storage prior to transfer off-site for final disposal. Although individual containers of waste reside at the point of generation prior to transfer to the Lag Storage Building, these inventories are small compared to the inventory in the Lag Storage Building. The greatest criticality safety concern related to firefighting in areas with stored fissile material is therefore in the Lag Storage Building.

Section B.9.2 of WVNS-SAR-002, *Safety Analysis Report for Low-Level Waste Processing and Support Activities*, assesses the potential for a fire in the Lag Storage Facility to determine the off-site consequences and probability of a fire. Wastes received in the Lag Storage Facility are contained in sealed steel boxes or drums. While the composition of some of these materials is combustible (the reference material for the evaluations contained in Appendix A is cellulose), waste management and ALARA requirements dictate that waste containers in a storage array be sealed. Furthermore, fire loading in the facility is minimal; drums and boxes are stored on steel rather than wooden pallets and good housekeeping practices ensure that storage of materials or equipment other than containerized waste is minimized.

External moderation of a fissile material storage array at the WVDP is not credible under conditions of severe natural phenomena and is unlikely as a result of steps necessary to fight a fire in the primary storage facility. Nevertheless, the analyses in Appendix A evaluated the impact to the reactivity of a storage array that is subjected to varying degrees of external water moderation, from misting conditions (as would be experienced during fire fighting operations) through the incredible condition of full array flooding. Because the analyzed array was already optimally moderated internally, the addition of external water moderation only served to increase neutron absorption and therefore in all analyzed cases the effect of external moderator was to decrease the system reactivity. It is therefore concluded that even the most reactive array of fissile material storage containers is safe under any conditions of external moderation when the container fissile mass limits specified in Table 2 are observed.

6.2.4 Use of Containers Having Dimensions Smaller than Assumed in Referenced Analyses

The analyses in Appendix A have determined safe fissile mass limits for containers having a wide range of dimensions, as indicated in Section 6.1. The analyses in Appendix A clearly demonstrate the effect of waste package geometry (i.e., spacing) on the reactivity of a storage array, particularly when the fissile material is not distributed homogeneously in the waste package. The modeled distribution that exhibited the highest reactivity was that in which the fissile material in each of eight adjacent waste packages is concentrated at the point of intersection of the containers. The reactivity of this configuration is limited by the fact that in this configuration, the individual eight-sphere systems were effectively neutronically decoupled from adjacent eight-sphere systems by the separation provided by the storage container. Should this spacing be reduced, the interaction between fissile material systems would be increased, resulting in a corresponding increase in reactivity. Because the spacing between fissile material systems is relied upon to maintain criticality safety and because this spacing is not inherent to the system, administrative controls must be in place to ensure that only containers corresponding to the safe fissile masses specified in Table 2 are used for the storage of fissile material.

6.2.5 Crushing of a Package or Packages in a Storage Array

A reduction in fissile material spacing would result from the crushing of stored waste packages. Crushing of packages could occur due to an impact with a piece of equipment such as a fork truck or an overhead crane or due to the collapse of a storage building.

The crushing of a drum or box due to an impact with a piece of equipment will not significantly reduce the margin of criticality safety because this event only has the potential to affect a small number of containers. Analyses in Appendix A have shown that the system is critically safe even when the combined fissile masses of eight optimally moderated waste containers are brought together. Furthermore, the maximum

permissible fissile mass for any container is less than half of the single parameter mass limit for Pu-239. It is therefore incredible that the crushing of a limited number of waste containers would result in a criticality accident.

A greater potential for crushing multiple containers exists in the event of the collapse of the Lag Storage Building roof. The Lag Storage Building is a pre-engineered metal structure supported by a clear span frame that is anchored to a concrete slab foundation. The building has been constructed to meet the requirements of the Uniform Building Code (UBC) and has been designed to withstand a snow loading of 40 pounds per square foot and a straight wind loading of 100 mph. Section A.4.2.6 of WVNS-SAR-001 provides an annual probability of exceedance of 2 percent for a design basis snow loading of 40 pounds per square foot. With this probability of design basis exceedance, failure of the Lag Storage Building roof would be expected to occur once in 50 years and it is therefore concluded that this event would be considered an anticipated event.

The metal sheeting that serves as roofing for the Lag Storage Building is secured to steel skip sheathing that spans the steel frame of the building. Under extreme snow loading conditions a significant amount of weight (>90 tons) would be uniformly distributed over the roof surface. Wastes in the Lag Storage Building are stored in sealed steel drums and boxes in arrays having a height limited to four tiers. Failure of the roof under conditions of extreme snow loading would have the potential to damage several of the containers in storage in the building. However, it is unlikely that this event would significantly affect the reactivity of the storage array, because although the beams that comprise the frame for the building structure are relatively massive, other roof components such as the skip sheathing and steel roof panels are relatively lightweight. In the event of a roof collapse, the failed steel beams would have the potential to crush containers on the top of the storage array but damage to lower-level containers would be limited either through the absorption of energy by the impacted container or through the distribution of force to the entire lower-level through the metal pallets on which drums in the facility rest. Furthermore, due to space constraints, most of the containers in the facility are stacked to the maximum permissible height of four tiers. At this height the container tops are near the roof surface and consequently any falling structural elements or snow pack would develop minimal momentum prior to impact with the containers. Finally, the Lag Storage Building is operated at a significant fraction of its storage capacity. In the event of a roof collapse, the force of impact of the failed structural members would be sustained by several containers, thereby limiting the damage to any specific container.

Based on this analysis, the likely consequence of a roof collapse in the Lag Storage Building would be to crush containers on the top level of the storage array. The analyses referenced in Appendix A have assumed that the total inventory of fissile material in a waste container is located in the lower corner of the waste box, adjacent to the fissile masses of seven other fissile material waste containers. These analyses determined the fissile-to-moderator ratio that corresponded to the most reactive array. In order to achieve this optimum concentration the fissile material was uniformly distributed in a sphere having a diameter that could potentially be greater than that of the crushed container. Under these conditions, the analyzed configuration would actually have a lower reactivity than for that for an intact container. An inadvertent criticality resulting from the collapse of the Lag Storage Building roof is therefore not considered to be a credible event.

7.0 ADMINISTRATIVELY CONTROLLED LIMITS AND REQUIREMENTS

The following design features and administrative controls shall exist to reduce the likelihood of a criticality event during the packaging and storage of fissile material waste.

7.1 Waste Container Specifications

Fissile waste materials shall be stored in containers having dimensions no smaller than those specified below.

Drums - Drums used for storage of fissile material waste shall have a nominal 55-gallon capacity and shall be constructed of carbon or stainless steel. The drum shall have a minimum internal diameter that is no less than 22 inches and shall have a minimum outside height of 34 inches when measured with the lid in place. These specified dimensions include all tolerances.

Boxes - Boxes used for storage of fissile material waste shall be constructed of carbon or stainless steel. The minimum outer dimension of the waste box shall be no less than 12 inches, including tolerances.

7.2 Fissile Mass Limits

The fissile mass limits for waste containers shall not exceed those specified in Table 2 of this NCSE.

7.3 Fissile Material Waste Package Storage Array Requirements

All analyses contained in Appendix A have evaluated infinite two-dimensional storage arrays having a height of 12 feet. The value of 12 feet was selected to correspond to the height of an array of 55-gallon drums stacked to a height of four tiers. The fissile mass limits specified in Table 2 do not vary for waste boxes with a minimum dimension greater than 30 inches. Consequently, the stacking requirement for arrays of fissile material waste containers is the greater of 12 feet or 4 tiers.

8.0 SUMMARY AND CONCLUSIONS

The parameters and conditions modeled in this NCSE were selected to ensure the most generally applicable set of limits possible. The most reactive fissile nuclide present in WVDP waste streams (Pu-239) was utilized in all calculations in lieu of a more realistic but less reactive mixture of uranium and plutonium fissile nuclides. Detailed parametric analyses were performed to identify the most reactive waste matrix material and to determine the conditions of material density corresponding to the optimally moderated condition. A rigorous assessment of the location of fissile material in waste packages was performed to determine the impact of a heterogeneous distribution of fissile material in multiple adjacent waste containers. The evaluated system for all calculations was an infinite two-dimensional array having a fixed height of 12 feet which corresponds to approximately a height of 4 tiers of 55-gallon drums or B-25 boxes. External reflection of the storage array by a 3-meter thick concrete floor was assumed in all cases, and additional analyses were performed to determine the effect of external water moderation of varying density on the reactivity of the storage array.

The detail, rigor, and conservatism in the models evaluated in this NCSE ensure that the fissile mass limits specified in Table 2 will provide an adequate margin of safety for all possible conditions of fissile material packaging and storage at the WVDP.

9.0 REFERENCES

URS Corporation. *MCNP 4A Software Validation Plan and Report for Criticality Calculations*. June 2000.

U. S. Department of Energy. DOE Order 420.1. *Facility Safety.* Approved October 13, 1995. Change 3 dated November 22, 2000.

_____. DOE-STD-3007-93. *Guidelines for Preparing Criticality Safety Evaluations at Department of Energy Non-Reactor Nuclear Facilities.* November 1993. Change 1 dated September 1998.

_____. LA-10860-MS. *Critical Dimensions of Systems Containing ^{235}U, ^{239}Pu, and ^{233}U.* 1986 Revision.

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_____. WVDP-162. *WVDP Nuclear Criticality Safety Program Manual.*

_____. WVNS-SAR-001. *Safety Analysis Report for Project Overview and General Information.* Revision 5.

_____. WVNS-SAR-002. *Safety Analysis Report for Low-Level Waste Processing and Support Activities.* Revision 7.

APPENDIX A

CALCULATIONS

BUF-2000-098, Rev. 0
BUF-2000-101, Rev. 0
BUF-2000-102, Rev. 0
BUF-2001-001, Rev. 1
BUF-2001-006, Rev. 0
BUF-2001-009, Rev. 0
BUF-2001-011, Rev. 0
BUF-2001-012, Rev. 0
BUF-2001-013, Rev. 1
BUF-2001-014, Rev. 1

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Calculation Cover Page

3065 Southwestern Boulevard
Suite 202
Orchard Park, NY 14127
716 675 7130 Tel
716 675 7137 Fax

Job No: **30822-244-330 /6856** Calculation No: **BUF-2000-098/Rev. 0** Date: **December 15, 2000**

Problem Statement & Calculation Objectives:

To determine the neutron multiplication factors for $\infty \times \infty \times 4$ arrays of 55 gallon drums and B-25 boxes filled with Pu-239 homogeneously mixed with variable density water, cellulose and concrete matrices. There is no water outside the containers with fissile material.

References and Data Available:

J. F. Briemiester, ed., MCNP - A General Purpose Monte Carlo N-Particle Transport Code, Version 4A, LA-12625, Los Alamos National Laboratory, Los Alamos NM, 1993
C. D. Harmon, II et al., Criticality Calculations with MCNP: A Primer, Manual LA-12827, Los Alamos National Laboratory, Los Alamos NM, 1993
D.R. Lide, CRC Handbook of Chemistry an Physics, CRC Press, Boston MA, 1991.

Attachments:

Attachment 1: Case 1 with MCNP surface and cell numbers
Attachment 2: Case 1 MCNP input file
Attachment 3: Case 1 MCNP output file
Attachment 4: Case 2 with MCNP surface and cell numbers
Attachment 5: Case 2 MCNP input file
Attachment 6: Case 2 MCNP output file

Prepared by:

Signature Igor V. Chichkov — Date 02/20/2001

Checked by:

Signature Kevin Roberts — Date 2/26/01

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Job No 30822-244-330 /6856 Job: PSR-6 By IVC Date 09/04/01
Client WVNS Subject: Homogeneous mixtures Chk'd. IVC for JRW Date 09/04/01

Analysis

Assumptions

The following assumptions were taken for the adopted model:

- Pu-239 is homogeneously mixed with matrix
- The Plutonium-matrix mixture filles the entire space inside the container
- The containers stand on the 3 m thick concrete floor
- B-25 box inside dimensions are 172.72 x 137.16 x 87.63 cm or 68 x 54 x 34.5 inches
- The B-25 box wall thickness is zero
- Every B-25 Box contains 350 g of Pu-239
- The B-25 boxes are arranged in the infinite square array, 4 tiers heigh ($\infty \times \infty \times 4$)
- The 55 gallon drum is a cylinder with 56.83 cm (22.37 inches) inside diameter and 89.11 cm (35.08 inches) height
- The drum wall is made of carbon steel and its thickness is 0.157 cm
- The drums are arranged in the infinite hexagonal array, 4 tiers heigh ($\infty \times \infty \times 4$)
- Every drum contains 200 g of Pu-239
- There is no water outside containers, air fills the space between the containers

MCNP Model

Neutron multiplication factors were calculated with MCNP4A code. Two different cases were studied:

- Case 1. $\infty \times \infty \times 4$ array of 55 gallon drums
- Case 2. $\infty \times \infty \times 4$ array of B-25 boxes

Plutonium mixtures with water, cellulose, concrete, cellulose-water and concrete-water matrices were studied. Density parametric analysis was performed for each case. Attachments 1 and 4 have the drawings of the models used for case 1 and 2 respectively. Examples of MCNP input and output files for both cases can be found in the Attachments.

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Air, Carbon Steel and Concrete Composition

Table 1 shows the element weight fractions for air (Attix F.H., 1986). Table 2 shows the element weight fractions for carbon steel (Harmon C. D., II et al., 1993) used in the drum walls. Table 3 shows the element composition of concrete (Harmon C. D., II et al., 1993) in the floor.

Table 1. Air composition

Element	Weight Fraction
Carbon (C)	0.000124
Nitrogen (N)	0.755267
Oxygen (O)	0.231781
Argon (Ar)	0.012827

Table 2. Carbon Steel Composition

Element	Weight Fraction
Iron (Fe)	0.995
Carbon (C)	0.005

Table 3. Concrete composition

Element	Weight Fraction
Hydrogen (H)	0.010
Oxygen (O)	0.532
Sodium (Na)	0.029
Aluminum (Al)	0.034
Silicon (Si)	0.337
Calcium (Ca)	0.044
Iron (Fe)	0.014

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Atom densities for Plutonium-matrix mixtures.

Atom density is the number of atoms per unit volume and can be determined using equation 1:

$$N_i = \frac{\rho_i N_A}{A_i \times 1 \times 10^{24}} = \frac{m_i N_A}{A_i V_C \times 1 \times 10^{24}} = w_{ij} \frac{m_j N_A}{A_i V_C \times 1 \times 10^{24}} \qquad (1)$$

where

N_i = the atom density of the ith element, atoms/(barn·cm)

ρ_i = the density of the ith element, g/cm^3

N_A = the Avagadro's number, 6.022×10^{23} atoms/mol

A_i = the atomic weight of the ith element, g/mol

m_i = the mass of the ith element in the container volume, g

V_c = the volume of the container (55 gallon drum or B-25 box), cm^3

w_{ij} = the weight fraction of the ith element in a molecule of matrix j

1×10^{24} = the conversion from barn to cm^2

The atomic weights of the elements used in the calculations are shown in Table 4.

Table 4. The atomic weights of the elements

Element	Atomic Weight
Hydrogen (H)	1.00794
Carbon (C)	12.0107
Oxygen (O)	15.9994

The molecular weight of cellulose ($C_6H_{10}O_5$) was calculated as the sum of all atomic weights composing the molecule. The weight fraction of an ith element was found as a ratio of the ith element weight in the molecule to the molecular weight of this molecule.

$$w_{ij} = \frac{n_i A_i}{M_j} = \frac{n_i A_i}{\sum n_i A_i} \qquad (2)$$

where

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w_{ij} = the weight fraction of ith element in a molecule of matrix j
n_i = the number of the ith elements in the jth molecule
A_i = the atomic weight of the ith element, g/mol
M_j = the molecular weight the jth molecule, g/mol

Calculated weight fractions for cellulose are shown in Table 5 and weight fractions for concrete taken from Harmon C. D., II et al., 1993 are in Table 3.

Table 5. Cellulose Weight Fractions

Element	Weight Fraction
Hydrogen (H)	0.062
Carbon (C)	0.444
Oxygen (O)	0.493

The mass of the matrix was calculated as :

$$m_j = \left(V_C - V_w - V_{Pu}\right)\rho_j = \left(\left(1 - f_w\right)V_C - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_j \qquad (3)$$

where
ρ_i = the density of the ith element, g/cm^3
V_c = the volume of the container (55 gallon drum or B-25 box), cm^3
V_{Pu} = the volume in the container occupied by Pu-239, cm^3
V_w = the volume in the container occupied by water, cm^3
f_w = the water volume fraction in the container
ρ_{Pu} = the density of the metal Plutonium, 19.78 g/cm^3
m_{Pu} = the mass of Pu-239 in the container volume, g

The atom density of Pu-239 was calculated as:

$$N_{Pu} = \frac{m_{Pu} N_A}{A_{Pu} V_C \times 1 \times 10^{24}} \qquad (4)$$

where

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N_{Pu} = the atom density of Pu-239, atoms/(barn·cm)
N_A = the Avagadro's number, 6.022×10^{23} atoms/mol
A_{Pu} = the atomic weight of Pu-239, g/mol
m_{Pu} = the mass of Pu-239 in the container volume, g
V_c = the volume of the container (55 gallon drum or B-25 box), cm^3
1×10^{24} = the conversion from barn to cm^2

In case the water is present in the homogenous mixture, the hydrogen and oxygen atom densities are determined as a sum of atomic density of the element in water and matrix. The hydrogen and oxygen atom densities from water were calculated using equation 5

$$N_{wi} = \frac{\rho_{wi} N_A}{A_i \times 1 \times 10^{24}} = \frac{m_{wi} N_A}{A_i V_C \times 1 \times 10^{24}} = w_{wi} \frac{m_w N_A}{A_i V_C \times 1 \times 10^{24}} = w_{wi} \frac{\rho_w V_w N_A}{A_i V_C \times 1 \times 10^{24}} = w_{wi} \frac{\rho_w f_w V_C N_A}{A_i V_C \times 1 \times 10^{24}} = w_{wi} \frac{\rho_w f_w N_A}{A_i \times 1 \times 10^{24}} \quad (5)$$

where
N_{wi} = the atom density of the ith element from water, atoms/(barn·cm)
ρ_{wi} = the density of the ith element from water, g/cm^3
N_A = the Avogadro's number, 6.022×10^{23} atoms/mol
A_i = the atomic weight of the ith element, g/mol
m_{wi} = the mass of the ith element in the container volume from water, g
V_c = the volume of the container (55 gallon drum or B-25 box), cm^3
w_{iw} = the weight fraction of the ith element in a molecule of water
ρ_w = the density of water, 1 g/cm^3
f_w = the water volume fraction in the container
1×10^{24} = the conversion from barn to cm^2

Water maximum density was assumed to be 1 g/cm^3, and concrete maximum density - 2.3 g/cm^3 (Harmon C. D., II et al., 1993). Cellulose maximum density was assumed to be equal to 0.9 g/cm^3 (wood density, Lide D. R., 1991). The following tables provide the homogenous mixture compositions used in the analysis. 100% density means the maximum density of the matrix: concrete, cellulose, or water (if only water is used as a matrix). 20-80% density means the density corresponding to the appropriate percentage of the maximum density of the matrix. For the case of the mixture in which water was used as a matrix, the density parametri analysis was performed on the cellulose or concrete density only - the amount of water in the container remained constant.

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Table 6. The composition of Pu-239 and water mixture in 55 gallon drum

Element	Atom Density, atoms/(barn·cm)				
	20% density	40% density	60% density	80% density	100% density
H	1.3346E-02	2.6692E-02	4.0038E-02	5.3385E-02	6.6731E-02
O	6.6731E-03	1.3346E-02	2.0019E-02	2.6692E-02	3.3365E-02
Pu	2.3977E-06	2.3977E-06	2.3977E-06	2.3977E-06	2.3977E-06
Total	2.0022E-02	4.0041E-02	6.0060E-02	8.0079E-02	1.0010E-01

Table 7. The composition of Pu-239 and dry concrete mixture in 55 gallon drum

Element	Atom Density, atoms/(barn·cm)				
	20% density	40% density	60% density	80% density	100% density
Na	3.4941E-04	6.9883E-04	1.0482E-03	1.3977E-03	1.7471E-03
Al	3.4905E-04	6.9810E-04	1.0472E-03	1.3962E-03	1.7453E-03
Si	3.3237E-03	6.6475E-03	9.9712E-03	1.3295E-02	1.6619E-02
Ca	3.0411E-04	6.0821E-04	9.1232E-04	1.2164E-03	1.5205E-03
Fe	6.9442E-05	1.3888E-04	2.0833E-04	2.7777E-04	3.4721E-04
H	2.7482E-03	5.4963E-03	8.2445E-03	1.0993E-02	1.3741E-02
O	9.2106E-03	1.8421E-02	2.7632E-02	3.6842E-02	4.6053E-02
Pu	2.3977E-06	2.3977E-06	2.3977E-06	2.3977E-06	2.3977E-06
Total	1.6357E-02	3.2711E-02	4.9066E-02	6.5420E-02	8.1775E-02

Table 8. The composition of Pu-239 and concrete with 10% (volume) of water mixture in 55 gallon drum

Element	Atom Density, atoms/(barn·cm)				
	20% density	40% density	60% density	80% density	100% density
Na	3.1447E-04	6.2894E-04	9.4341E-04	1.2579E-03	1.5724E-03
Al	3.1414E-04	6.2829E-04	9.4243E-04	1.2566E-03	1.5707E-03
Si	2.9913E-03	5.9827E-03	8.9740E-03	1.1965E-02	1.4957E-02
Ca	2.7369E-04	5.4739E-04	8.2108E-04	1.0948E-03	1.3685E-03
Fe	6.2497E-05	1.2499E-04	1.8749E-04	2.4999E-04	3.1249E-04
H	9.1467E-03	1.1620E-02	1.4093E-02	1.6567E-02	1.9040E-02
O	1.1626E-02	1.9916E-02	2.8205E-02	3.6495E-02	4.4784E-02
Pu	2.3977E-06	2.3977E-06	2.3977E-06	2.3977E-06	2.3977E-06
Total	2.4731E-02	3.9450E-02	5.4169E-02	6.8888E-02	8.3607E-02

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Table 9. The composition of Pu-239 and concrete with 20% (volume) of water mixture in 55 gallon drum

Element	Atom Density, atoms/(barn·cm)				
	20% density	40% density	60% density	80% density	100% density
Na	2.7953E-04	5.5906E-04	8.3858E-04	1.1181E-03	1.3976E-03
Al	2.7924E-04	5.5848E-04	8.3771E-04	1.1170E-03	1.3962E-03
Si	2.6590E-03	5.3179E-03	7.9769E-03	1.0636E-02	1.3295E-02
Ca	2.4328E-04	4.8656E-04	7.2984E-04	9.7313E-04	1.2164E-03
Fe	5.5553E-05	1.1111E-04	1.6666E-04	2.2221E-04	2.7776E-04
H	1.5545E-02	1.7744E-02	1.9942E-02	2.2141E-02	2.4339E-02
O	1.4042E-02	2.1410E-02	2.8778E-02	3.6147E-02	4.3515E-02
Pu	2.3977E-06	2.3977E-06	2.3977E-06	2.3977E-06	2.3977E-06
Total	3.3106E-02	4.6189E-02	5.9273E-02	7.2356E-02	8.5440E-02

Table 10. The composition of Pu-239 and concrete with 50% (volume) of water mixture in 55 gallon drum

Element	Atom Density, atoms/(barn·cm)				
	20% density	40% density	60% density	80% density	100% density
Na	1.7470E-04	3.4940E-04	5.2410E-04	6.9880E-04	8.7349E-04
Al	1.7452E-04	3.4904E-04	5.2355E-04	6.9807E-04	8.7259E-04
Si	1.6618E-03	3.3236E-03	4.9854E-03	6.6471E-03	8.3089E-03
Ca	1.5205E-04	3.0409E-04	4.5614E-04	6.0818E-04	7.6023E-04
Fe	3.4719E-05	6.9439E-05	1.0416E-04	1.3888E-04	1.7360E-04
H	3.4741E-02	3.6115E-02	3.7489E-02	3.8863E-02	4.0237E-02
O	2.1289E-02	2.5894E-02	3.0499E-02	3.5104E-02	3.9709E-02
Pu	2.3977E-06	2.3977E-06	2.3977E-06	2.3977E-06	2.3977E-06
Total	5.8230E-02	6.6407E-02	7.4583E-02	8.2760E-02	9.0937E-02

Table 11. The composition of Pu-239 and dry cellulose mixture in 55 gallon drum

Element	Atom Density, atoms/(barn·cm)				
	20% density	40% density	60% density	80% density	100% density
C	4.0110E-03	8.0220E-03	1.2033E-02	1.6044E-02	2.0055E-02
H	6.6850E-03	1.3370E-02	2.0055E-02	2.6740E-02	3.3425E-02
O	3.3425E-03	6.6850E-03	1.0027E-02	1.3370E-02	1.6712E-02
Pu	2.3977E-06	2.3977E-06	2.3977E-06	2.3977E-06	2.3977E-06
Total	1.4041E-02	2.8079E-02	4.2118E-02	5.6156E-02	7.0195E-02

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Table 12. The composition of Pu-239 and cellulose with 10% (volume) of water mixture in 55 gallon drum

Element	Atom Density, atoms/(barn·cm)				
	20% density	40% density	60% density	80% density	100% density
C	3.6099E-03	7.2197E-03	1.0830E-02	1.4439E-02	1.8049E-02
H	1.2690E-02	1.8706E-02	2.4723E-02	3.0739E-02	3.6756E-02
O	6.3449E-03	9.3532E-03	1.2361E-02	1.5370E-02	1.8378E-02
Pu	2.3977E-06	2.3977E-06	2.3977E-06	2.3977E-06	2.3977E-06
Total	2.2647E-02	3.5282E-02	4.7916E-02	6.0551E-02	7.3185E-02

Table 13. The composition of Pu-239 and cellulose with 20% (volume) of water mixture in 55 gallon drum

Element	Atom Density, atoms/(barn·cm)				
	20% density	40% density	60% density	80% density	100% density
C	3.2088E-03	6.4175E-03	9.6263E-03	1.2835E-02	1.6044E-02
H	1.8695E-02	2.4043E-02	2.9391E-02	3.4739E-02	4.0086E-02
O	9.3474E-03	1.2021E-02	1.4695E-02	1.7369E-02	2.0043E-02
Pu	2.3977E-06	2.3977E-06	2.3977E-06	2.3977E-06	2.3977E-06
Total	3.1253E-02	4.2484E-02	5.3715E-02	6.4945E-02	7.6176E-02

Table 14. The composition of Pu-239 and cellulose with 50% (volume) of water mixture in 55 gallon drum

Element	Atom Density, atoms/(barn·cm)				
	20% density	40% density	60% density	80% density	100% density
C	2.0054E-03	4.0108E-03	6.0162E-03	8.0216E-03	1.0027E-02
H	3.6709E-02	4.0052E-02	4.3394E-02	4.6736E-02	5.0079E-02
O	1.8355E-02	2.0026E-02	2.1697E-02	2.3368E-02	2.5039E-02
Pu	2.3977E-06	2.3977E-06	2.3977E-06	2.3977E-06	2.3977E-06
Total	5.7072E-02	6.4091E-02	7.1110E-02	7.8129E-02	8.5147E-02

Table 15. The composition of Pu-239 and water mixture in B-25 Box

Element	Atom Density, atoms/(barn·cm)				
	20% density	40% density	60% density	80% density	100% density
H	1.3347E-02	2.6693E-02	4.0040E-02	5.3387E-02	6.6733E-02
O	6.6733E-03	1.3347E-02	2.0020E-02	2.6693E-02	3.3367E-02
Pu	4.2471E-07	4.2471E-07	4.2471E-07	4.2471E-07	4.2471E-07
Total	2.0020E-02	4.0040E-02	6.0061E-02	8.0081E-02	1.0010E-01

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Table 16. The composition of Pu-239 and dry concrete mixture in B-25 Box

Element	Atom Density, atoms/(barn·cm)				
	20% density	40% density	60% density	80% density	100% density
Na	3.4943E-04	6.9886E-04	1.0483E-03	1.3977E-03	1.7471E-03
Al	3.4907E-04	6.9813E-04	1.0472E-03	1.3963E-03	1.7453E-03
Si	3.3239E-03	6.6477E-03	9.9716E-03	1.3295E-02	1.6619E-02
Ca	3.0412E-04	6.0824E-04	9.1235E-04	1.2165E-03	1.5206E-03
Fe	6.9445E-05	1.3889E-04	2.0833E-04	2.7778E-04	3.4722E-04
H	2.7483E-03	5.4966E-03	8.2448E-03	1.0993E-02	1.3741E-02
O	9.2109E-03	1.8422E-02	2.7633E-02	3.6844E-02	4.6055E-02
Pu	4.2471E-07	4.2471E-07	4.2471E-07	4.2471E-07	4.2471E-07
Total	1.6356E-02	3.2711E-02	4.9066E-02	6.5421E-02	8.1776E-02

Table 17. The composition of Pu-239 and concrete with 10% (volume) of water mixture in B-25 Box

Element	Atom Density, atoms/(barn·cm)				
	20% density	40% density	60% density	80% density	100% density
Na	3.1449E-04	6.2897E-04	9.4346E-04	1.2579E-03	1.5724E-03
Al	3.1416E-04	6.2832E-04	9.4248E-04	1.2566E-03	1.5708E-03
Si	2.9915E-03	5.9829E-03	8.9744E-03	1.1966E-02	1.4957E-02
Ca	2.7371E-04	5.4741E-04	8.2112E-04	1.0948E-03	1.3685E-03
Fe	6.2500E-05	1.2500E-04	1.8750E-04	2.5000E-04	3.1250E-04
H	9.1468E-03	1.1620E-02	1.4094E-02	1.6567E-02	1.9041E-02
O	1.1627E-02	1.9916E-02	2.8206E-02	3.6496E-02	4.4786E-02
Pu	4.2471E-07	4.2471E-07	4.2471E-07	4.2471E-07	4.2471E-07
Total	2.4730E-02	3.9450E-02	5.4169E-02	6.8889E-02	8.3608E-02

Table 18. The composition of Pu-239 and concrete with 20% (volume) of water mixture in B-25 Box

Element	Atom Density, atoms/(barn·cm)				
	20% density	40% density	60% density	80% density	100% density
Na	2.7954E-04	5.5908E-04	8.3863E-04	1.1182E-03	1.3977E-03
Al	2.7925E-04	5.5850E-04	8.3776E-04	1.1170E-03	1.3963E-03
Si	2.6591E-03	5.3182E-03	7.9772E-03	1.0636E-02	1.3295E-02
Ca	2.4329E-04	4.8659E-04	7.2988E-04	9.7317E-04	1.2165E-03
Fe	5.5556E-05	1.1111E-04	1.6667E-04	2.2222E-04	2.7778E-04
H	1.5545E-02	1.7744E-02	1.9943E-02	2.2141E-02	2.4340E-02
O	1.4042E-02	2.1411E-02	2.8780E-02	3.6148E-02	4.3517E-02
Pu	4.2471E-07	4.2471E-07	4.2471E-07	4.2471E-07	4.2471E-07
Total	3.3105E-02	4.6189E-02	5.9273E-02	7.2357E-02	8.5441E-02

URS

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Table 19. The composition of Pu-239 and concrete with 50% (volume) of water mixture in B-25 Box

Element	Atom Density, atoms/(barn·cm)				
	20% density	40% density	60% density	80% density	100% density
Na	1.7471E-04	3.4943E-04	5.2414E-04	6.9885E-04	8.7356E-04
Al	1.7453E-04	3.4906E-04	5.2359E-04	6.9813E-04	8.7266E-04
Si	1.6619E-03	3.3238E-03	4.9857E-03	6.6477E-03	8.3096E-03
Ca	1.5206E-04	3.0411E-04	4.5617E-04	6.0823E-04	7.6029E-04
Fe	3.4722E-05	6.9444E-05	1.0417E-04	1.3889E-04	1.7361E-04
H	3.3367E-02	3.3368E-02	3.3368E-02	3.3369E-02	3.3369E-02
O	2.1289E-02	2.5894E-02	3.0500E-02	3.5105E-02	3.9711E-02
Pu	4.2471E-07	4.2471E-07	4.2471E-07	4.2471E-07	4.2471E-07
Total	5.6855E-02	6.3659E-02	7.0462E-02	7.7266E-02	8.4070E-02

Table 20. The composition of Pu-239 and dry cellulose mixture in B-25 Box

Element	Atom Density, atoms/(barn·cm)				
	20% density	40% density	60% density	80% density	100% density
C	4.0112E-03	8.0223E-03	1.2033E-02	1.6045E-02	2.0056E-02
H	6.6853E-03	1.3371E-02	2.0056E-02	2.6741E-02	3.3426E-02
O	3.3426E-03	6.6853E-03	1.0028E-02	1.3371E-02	1.6713E-02
Pu	4.2471E-07	4.2471E-07	4.2471E-07	4.2471E-07	4.2471E-07
Total	1.4039E-02	2.8078E-02	4.2118E-02	5.6157E-02	7.0196E-02

Table 21. The composition of Pu-239 and cellulose with 10% (volume) of water mixture in B-25 Box

Element	Atom Density, atoms/(barn·cm)				
	20% density	40% density	60% density	80% density	100% density
C	3.6100E-03	7.2201E-03	1.0830E-02	1.4440E-02	1.8050E-02
H	1.2690E-02	1.8707E-02	2.4724E-02	3.0740E-02	3.6757E-02
O	6.3451E-03	9.3534E-03	1.2362E-02	1.5370E-02	1.8379E-02
Pu	4.2471E-07	4.2471E-07	4.2471E-07	4.2471E-07	4.2471E-07
Total	2.2646E-02	3.5281E-02	4.7916E-02	6.0551E-02	7.3186E-02

Table 23. The composition of Pu-239 and cellulose with 20% (volume) of water mixture in B-25 Box

Element	Atom Density, atoms/(barn·cm)				
	20% density	40% density	60% density	80% density	100% density
C	3.2089E-03	6.4178E-03	9.6267E-03	1.2836E-02	1.6045E-02
H	1.8695E-02	2.4043E-02	2.9391E-02	3.4740E-02	4.0088E-02
O	9.3475E-03	1.2022E-02	1.4696E-02	1.7370E-02	2.0044E-02
Pu	4.2471E-07	4.2471E-07	4.2471E-07	4.2471E-07	4.2471E-07
Total	3.1252E-02	4.2483E-02	5.3714E-02	6.4945E-02	7.6177E-02

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Job No 30822-244-330 /6856 Job: PSR-6 By IVC Date 02/01/2001
Client WVNS Subject: Homogeneous mixtures Chk'd. KZ Date 2/26/01

Table 24. The composition of Pu-239 and cellulose with 50% (volume) of water mixture in B-25 Box

Element	Atom Density, atoms/(barn·cm)				
	20% density	40% density	60% density	80% density	100% density
C	2.0056E-03	4.0111E-03	6.0167E-03	8.0222E-03	1.0028E-02
H	3.6710E-02	4.0052E-02	4.3395E-02	4.6737E-02	5.0080E-02
O	1.8355E-02	2.0026E-02	2.1697E-02	2.3369E-02	2.5040E-02
Pu	4.2471E-07	4.2471E-07	4.2471E-07	4.2471E-07	4.2471E-07
Total	5.7070E-02	6.4090E-02	7.1109E-02	7.8129E-02	8.5148E-02

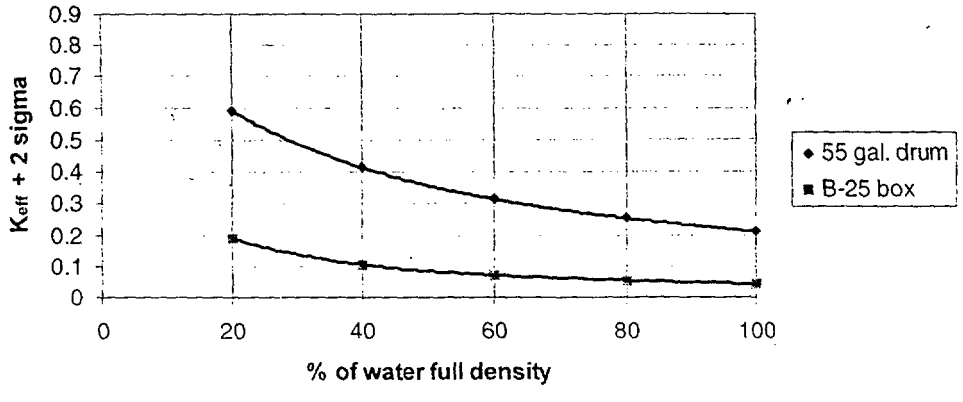
Results

The results of the calculations performed using MCNP-4A code are shown in the following tables and graphs. The tables provide the Monte Carlo determined neutron multiplication factor (k_{eff}) values and their standard deviations (σ), and the graphs plot the k_{eff} +2 σ values for all studied cases.

Table 25. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for Pu-239 mixtures with water

Water density	55 gal drum			B-25 box		
%	k_{eff}	σ	$k_{eff.} + 2\sigma$	k_{eff}	σ	$k_{eff.} + 2\sigma$
100	0.2112	0.0001	0.2114	0.0436	0.00002	0.0437
80	0.253	0.0001	0.2532	0.0541	0.00003	0.0541
60	0.3144	0.0002	0.3147	0.0713	0.00004	0.0714
40	0.4129	0.0002	0.4134	0.1051	0.00005	0.1052
20	0.5884	0.0004	0.5892	0.1898	0.00012	0.1900

Figure 1. k_{eff} +2σ for Pu-239 mixtures with water



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Client WVNS Subject: Homogeneous mixtures Chk'd. [illegible] Date 2/26/01

Table 26. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for Pu-239 mixtures with concrete

Concrete density %	55 gal drum			B-25 box		
	k_{eff}	σ	$k_{eff.} + 2\sigma$	k_{eff}	σ	$k_{eff.} + 2\sigma$
100	0.3822	0.0002	0.3826	0.0934	0.0001	0.0935
80	0.4396	0.0003	0.4401	0.1145	0.0001	0.1147
60	0.5145	0.0003	0.5152	0.1477	0.0001	0.1479
40	0.6111	0.0005	0.6120	0.2053	0.0002	0.2056
20	0.7025	0.0007	0.7039	0.3169	0.0003	0.3175

Figure 2. k_{eff} +2σ for Pu-239 mixtures with concrete

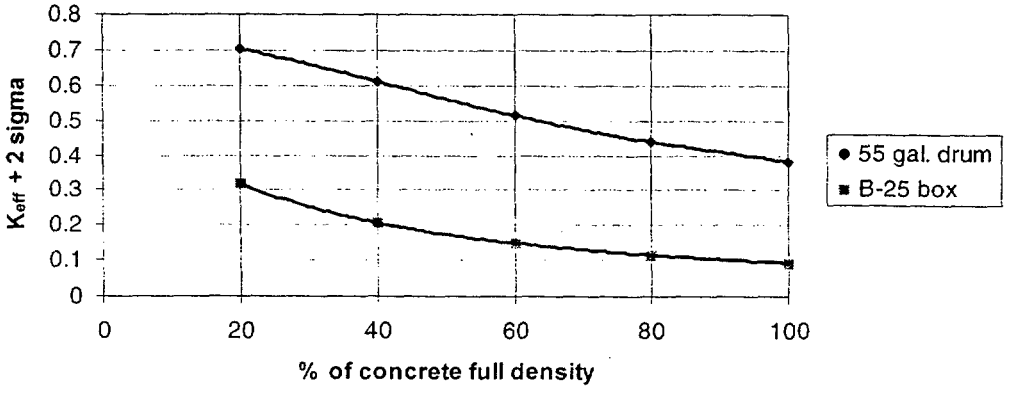

Table 27. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for Pu-239 mixtures with cellulose.

Cellulose density %	55 gal drum			B-25 box		
	k_{eff}	σ	$k_{eff.} + 2\sigma$	k_{eff}	σ	$k_{eff.} + 2\sigma$
100	0.357	0.0002	0.3574	0.0844	5E-05	0.0845
80	0.4131	0.0002	0.4136	0.1038	0.0001	0.1039
60	0.4899	0.0003	0.4904	0.1347	0.0001	0.1349
40	0.5951	0.0004	0.5958	0.1910	0.0001	0.1913
20	0.7254	0.0005	0.7264	0.3157	0.0003	0.3163

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Figure 3. k_{eff} +2σ for Pu-239 mixtures with cellulose

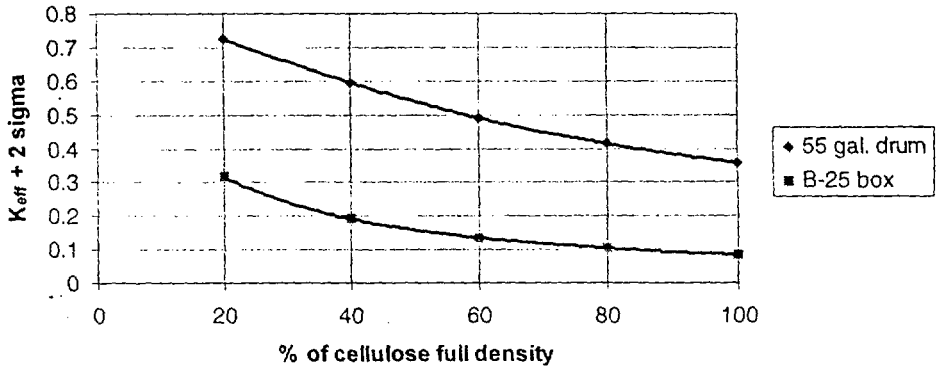
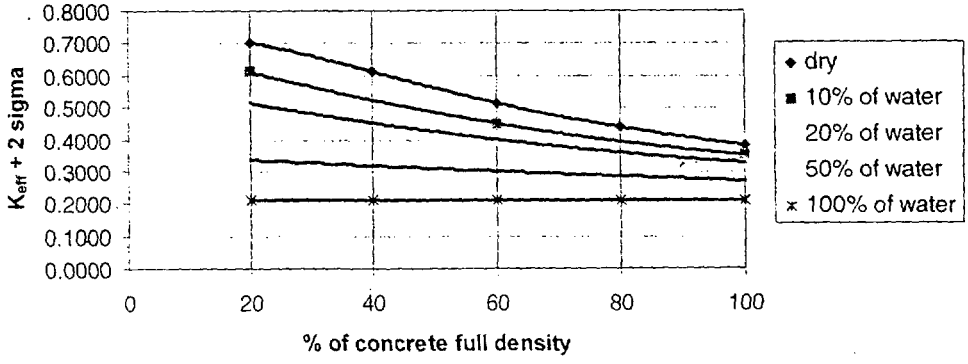


Table 27. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for Pu-239 mixtures with concrete and water.

Concrete density %	dry			10% volume of water inside			20% volume of water inside			50% volume of water inside			100% volume of water inside		
	k_{eff}	σ	k_{eff} + 2 σ	k_{eff}	σ	k_{eff} + 2 σ	k_{eff}	σ	k_{eff} + 2 σ	k_{eff}	σ	k_{eff} + 2 σ	k_{eff}	σ	k_{eff} + 2 σ
100	0.3822	0.0002	0.3826	0.3530	0.0002	0.3535	0.328	0.0002	0.3287	0.2716	0.0002	0.2720	0.21115	0.00011	0.2114
80	0.4396	0.0003	0.4401	-	-	-	-	-	-	-	-	-	0.21115	0.00011	0.2114
60	0.5145	0.0003	0.5152	0.4507	0.0003	0.4512	0.4006	0.0003	0.4011	0.3007	0.0002	0.3011	0.21115	0.00011	0.2114
40	0.6111	0.0005	0.6120	-	-	-	-	-	-	-	-	-	0.21115	0.00011	0.2114
20	0.7025	0.0007	0.7039	0.6097	0.0004	0.6105	0.5118	0.0003	0.5124	0.3356	0.0002	0.3360	0.21115	0.00011	0.2114

Figure 3. k_{eff} +2σ for Pu-239 mixtures with concrete and water



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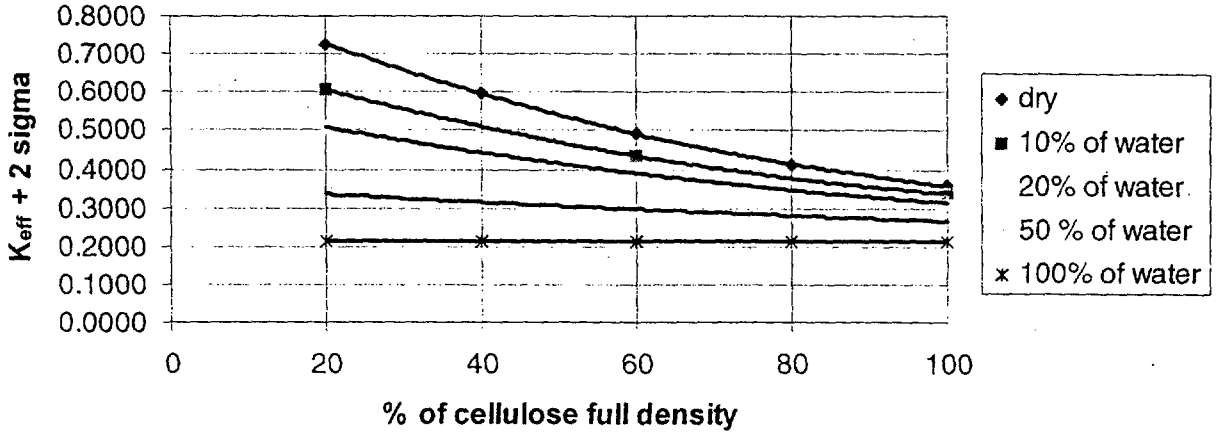
Sheet No. 15/15
Calc. No. BUF-2000-098
Rev. No. 0

Job No 30822-244-330 /6856 Job: PSR-6 By IVC Date 02/20/2001
Client WVNS Subject: Homogeneous mixtures Chk'd. KR Date 2/26/01

Table 27. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for Pu-239 mixtures with cellulose and water.

Concrete density %	dry			10% volume of water inside			20% volume of water inside			50% volume of water inside			100% volume of water inside		
	k_{eff}	σ	$k_{eff} + 2\sigma$	k_{eff}	σ	$k_{eff} + 2\sigma$	k_{eff}	σ	$k_{eff} + 2\sigma$	k_{eff}	σ	$k_{eff} + 2\sigma$	k_{eff}	σ	$k_{eff} + 2\sigma$
100	0.357	0.0002	0.3574	0.338	2E-04	0.3386	0.314	0.0002	0.3141	0.2656	0.0002	0.2659	0.21115	0.00011	0.2114
80	0.4131	0.0002	0.4136	-	-	-	-	-	-	-	-	-	0.21115	0.00011	0.2114
60	0.4899	0.0003	0.4904	0.4334	0.0002	0.4339	0.3888	0.0002	0.3893	0.2962	0.0002	0.2965	0.21115	0.00011	0.2114
40	0.5951	0.0004	0.5958	-	-	-	-	-	-	-	-	-	0.21115	0.00011	0.2114
20	0.7254	0.0005	0.7264	0.6044	0.0004	0.6051	0.5063	0.0003	0.5069	0.3342	0.0002	0.3346	0.21115	0.00011	0.2114

Figure 3. k_{eff} +2σ for Pu-239 mixtures with cellulose and water

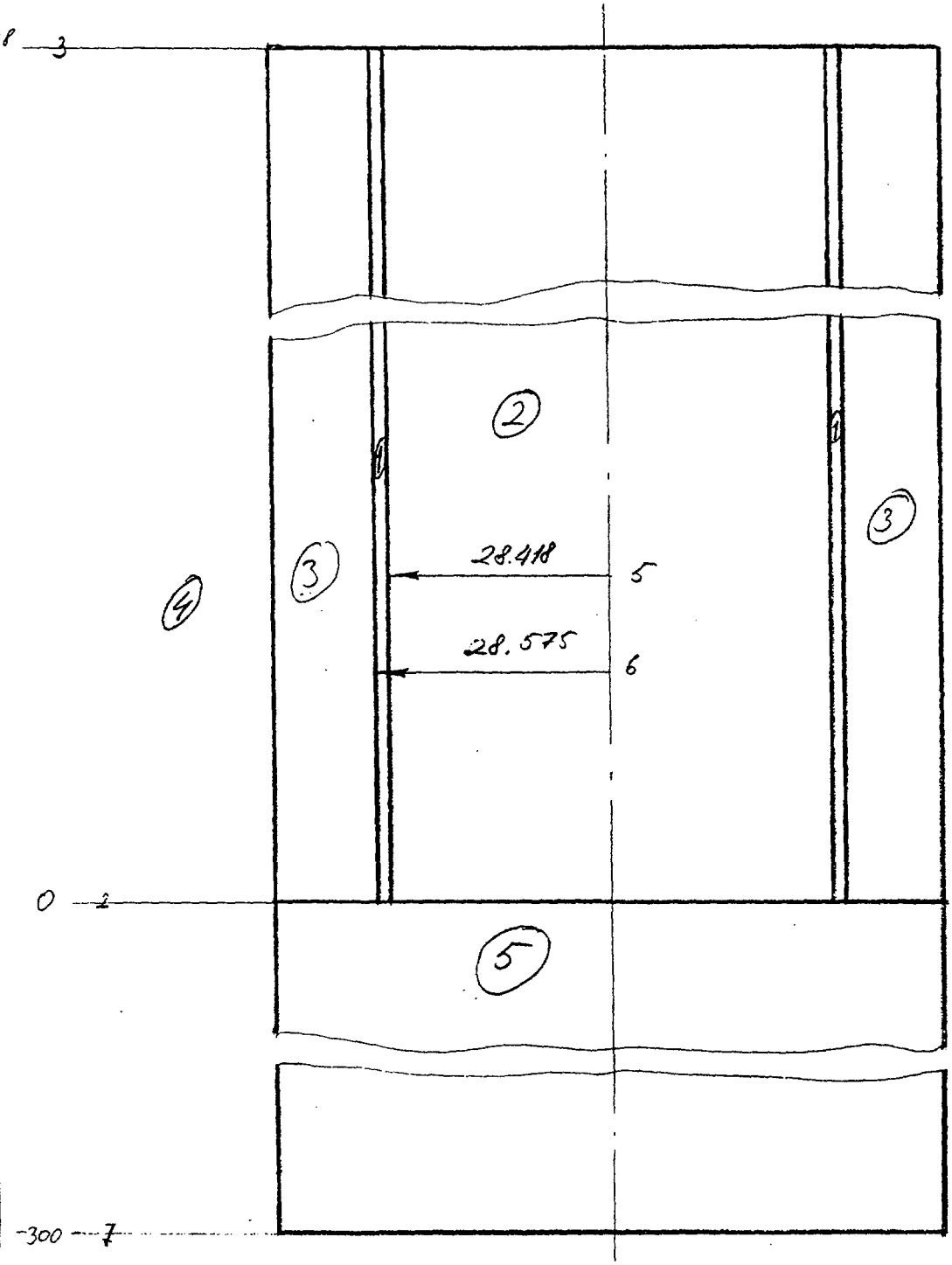


Attachment 1: Case 1 with MCNP surface and cell numbers

FILE _____

SUBJECT _____

4x89.112)



REVISIONS
BY _____ DATE _____ TO EO _____
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COPY TO EO _____

Dames & Moore

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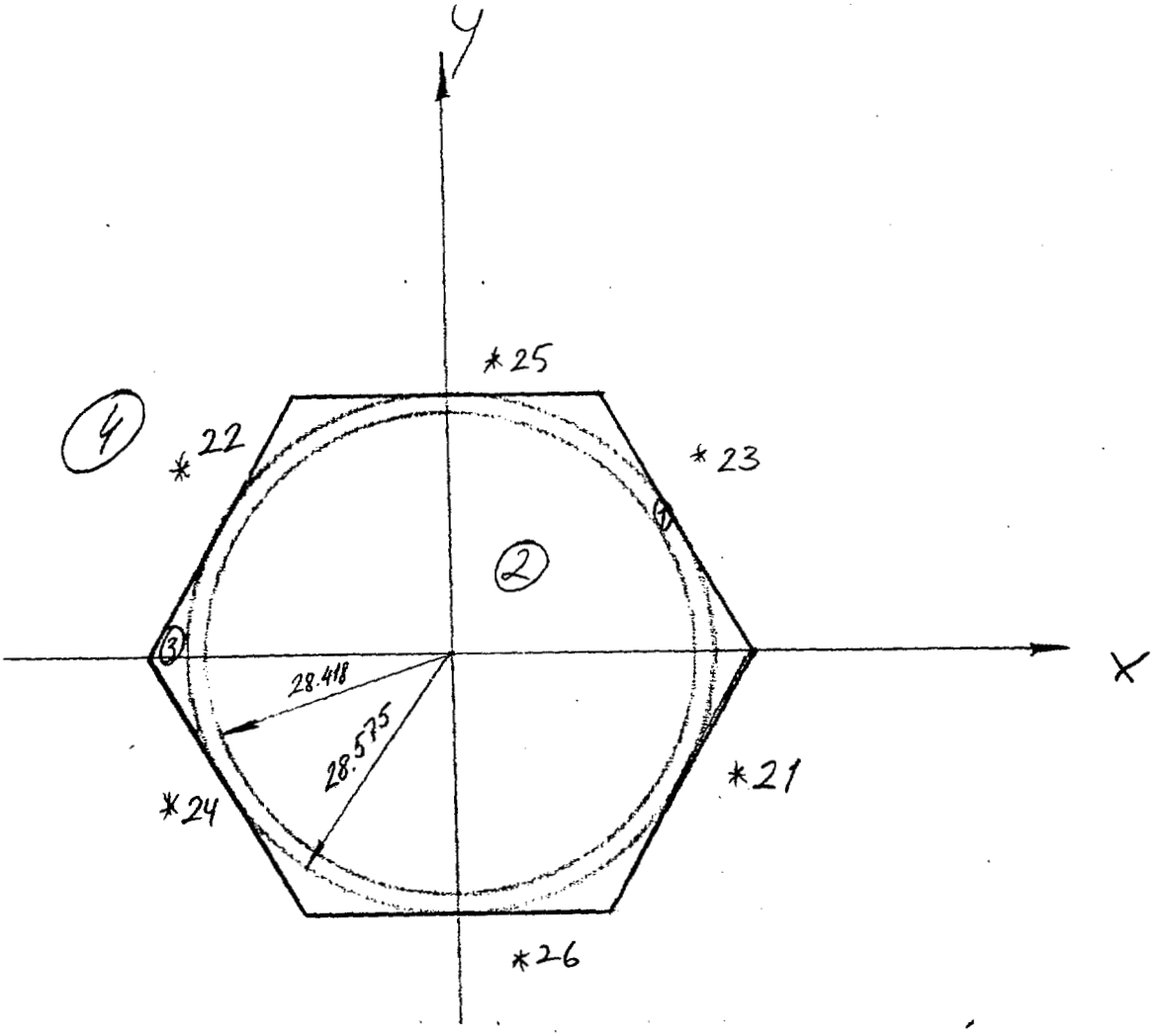

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Attachment 2: Case 1 MCNP input file

10d1

```
Pu-239 in concrete matrix. Infinite lattice of 55 gal. drums, 4 tiers
C The drum height is 35 1/12 inch (89.112 cm)
c drum wall thickness is 0.157 cm
c insert wall thickness is 0.635 cm
C Cell cards
C
C ------------------------------------------------------------------------
1  65 -7.82       5 -6 2 -3     imp:n=1 $ drum wall
2  1 8.1775e-2  -5 2 -3        imp:n=1 $ Pu-239 in concrete matrix
3  64 -0.001293 -21 22 -23 24 -25 26 2 -3 6 imp:n=1 $  air ouside the drum
4  0         21 : -22 : 23 : -24 : 25 : -26 : -7 : 3 imp:n=0 $ Outside world
5  2 -2.3      -21 22 -23 24 -25 26 -2 7    imp:n=1 $  concrete floor
C ------------------------------------------------------------------------
c
c Note: next line must be completely blank

c Surface cards
C ------------------------------------------------------------------------
2  pz 0         $ drum bottom plane
3  pz 356.448   $ drum top plane
5  cz 28.418    $ 28.418 cm radius cylinder (internal wall of the drum)
6  cz 28.575    $ 28.575 cm radius cylinder (external wall of the drum)
7  pz -300      $ concrete bottom plane
c
c hexagonal cell with reflecting surfaces outside the drum
c (simulates infinite array of the drums)
c begin the lattice surfaces
*21 p 0.8660254 -0.5 0  28.575
*22 p 0.8660254 -0.5 0 -28.575
*23 p 0.8660254  0.5 0  28.575
*24 p 0.8660254  0.5 0 -28.575
*25 py  28.575
*26 py -28.575
c end of lattice surfaces
c
C ------------------------------------------------------------------------
c
c Note: next line must be completely blank

c Data cards
c
c Materials
c
c Pu-239 in concrete matrix (Elements: H, O, Na, Si, Al, Ca, Fe, Pu-239)
m1     11023.50c  1.7471e-3
       13027.50c  1.7453e-3
       14000.50c  1.5619e-2
       20000.50c  1.5205e-3
       26000.55c  3.4721e-4
        1001.50c  1.3741e-2
        8016.50c  4.6053e-2
       94239.55c  2.3977e-6
c Concrete (KENO Regular Concrete Standard Mix) from Harmon at al.
c Criticality Calculation with MCNP. A Primer. p. C-4
c (Elements: H, O, Na, Si, Al, Ca, Fe)
m2      1001.50c -0.010
        8016.50c -0.532
       11023.50c -0.029
       13027.50c -0.034
       14000.50c -0.337
       20000.50c -0.044
       26000.55c -0.014
c Air (C, N, O, Ar) composition from Attix p.532
m64     6000.50c -0.000124
        7014.50c -0.755267
        8016.50c -0.231781
       18000.35c -0.012828
c Carbon Steel (C, Fe) composition from Crit. Calc. with MCNP p. C-10
m65     6000.50c -0.005
       26000.55c -0.995
c
mode n
print 40 60 80 100 110 126
kcode 4000 1. 20 120
ksrc  0 0 178.224
```

Attachment 3: Case 1 MCNP output file

```
lmcnp     version 4a    ld=10/01/93                    09/14/00 04:47:10
*************************************************************************          probid =   09/14/00 04:47:10
name=10d1

      Pu-239 in concrete matrix. Infinite lattice of 55 gal. drums, 4 tiers
      C The drum height is 35 1/12 inch (89.112 cm)
      c drum wall thickness is 0.157 cm
      c insert wall thickness is 0.635 cm
      C Cell cards
      C
      C ---------------------------------------------------------------------
      1  65 -7.82      5 -6 2 -3    imp:n=1 $ drum wall
      2  1 8.1775e-2  -5 2 -3       imp:n=1 $ Pu-239 in concrete matrix
      3  64 -0.001293 -21 22 -23 24 -25 26 2 -3 6 imp:n=1 $  air ouside the drum
      4  0        21 : -22 : 23 : -24 : 25 : -26 : -7 : 3 imp:n=0 $ Outside world
      5  2 -2.3     -21 22 -23 24 -25 26 -2 7   imp:n=1 $  concrete floor
      C ---------------------------------------------------------------------
      c
      c Note: next line must be completely blank

      c Surface cards
      C ---------------------------------------------------------------------
      2  pz 0         $ drum bottom plane
      3  pz 356.448   $ drum top plane
      5  cz 28.418    $ 28.418 cm radius cylinder (internal wall of the drum)
      6  cz 28.575    $ 28.575 cm radius cylinder (external wall of the drum)
      7  pz -300      $ concrete bottom plane
      c
      c hexagonal cell with reflecting surfaces outside the drum
      c (simulates infinite array of the drums)
      c begin the lattice surfaces
      *21 p 0.8660254 -0.5 0  28.575
      *22 p 0.8660254 -0.5 0 -28.575
      *23 p 0.8660254  0.5 0  28.575
      *24 p 0.8660254  0.5 0 -28.575
      *25 py  28.575
      *26 py -28.575
      c end of lattice surfaces
      c
      C ---------------------------------------------------------------------
      c
      c Note: next line must be completely blank

      c Data cards
      c
      c Materials
      c
      c Pu-239 in concrete matrix (Elements: H, O, Na, Si, Al, Ca, Fe, Pu-239)
      m1     11023.50c  1.7471e-3
             13027.50c  1.7453e-3
             14000.50c  1.6619e-2
             20000.50c  1.5205e-3
             26000.55c  3.4721e-4
              1001.50c  1.3741e-2
              8016.50c  4.6053e-2
             94239.55c  2.3977e-6
      c Concrete (KENO Regular Concrete Standard Mix) from Harmon at al.
      c Criticality Calculation with MCNP. A Primer. p. C-4
      c (Elements: H, O, Na, Si, Al, Ca, Fe)
      m2      1001.50c -0.010
              8016.50c -0.532
             11023.50c -0.029
```

```
 59-            13027.50c -0.034
 60-            14000.50c -0.337
 61-            20000.50c -0.044
 62-            26000.55c -0.014
 63-      c Air (C, N, O, Ar) composition from Attix p.532
 64-      m64    6000.50c -0.000124
 65-             7014.50c -0.755267
 66-             8016.50c -0.231781
 67-            18000.35c -0.012828
 68-      c Carbon Steel (C, Fe) composition from Crit. Calc. with MCNP p. C-10
 69-      m65    6000.50c -0.005
 70-            26000.55c -0.995
 71-      c
 72-      mode n
 73-      print 40 60 80 100 110 126
 74-      kcode 4000 1. 20 120
 75-      ksrc  0 0 178.224
 76-
 total fission nubar data are being used.
1material composition                                                                    print table 40

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  number     component nuclide, atom fraction

     1          11023,  0.02136      13027,  0.02134      14000,  0.20323      20000,  0.01859
                26000,  0.00425       1001,  0.16803       8016,  0.56316      94239,  0.00003
     2           1001,  0.16803       8016,  0.56324      11023,  0.02136      13027,  0.02134
                14000,  0.20319      20000,  0.01859      26000,  0.00425
    64           6000,  0.00015       7014,  0.78443       8016,  0.21075      18000,  0.00467
    65           6000,  0.02283      26000,  0.97717



 material
  number     component nuclide, mass fraction

     1          11023,  0.02899      13027,  0.03399      14000,  0.33691      20000,  0.04399
                26000,  0.01400       1001,  0.01000       8016,  0.53171      94239,  0.00041
     2           1001,  0.01000       8016,  0.53200      11023,  0.02900      13027,  0.03400
                14000,  0.33700      20000,  0.04400      26000,  0.01400
    64           6000,  0.00012       7014,  0.75527       8016,  0.23178      18000,  0.01283
    65           6000,  0.00500      26000,  0.99500
1cells                                                                                   print table 60

                     atom        gram                                        neutron
       cell  mat    density     density     volume       mass     pieces importance

    1     1   65  8.58651E-02 7.82000E+00 1.00200E+04 7.83563E+04     1  1.0000E+00
    2     2    1  8.17750E-02 2.30049E+00 9.04343E+05 2.08043E+06     1  1.0000E+00
    3     3   64  5.35386E-05 1.29300E-03 0.00000E+00 0.00000E+00     0  1.0000E+00
    4     4    0  0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00     0  0.0000E+00
    5     5    2  8.17913E-02 2.30000E+00 8.48564E+05 1.95170E+06     0  1.0000E+00

 total                                    1.76293E+06 4.11048E+06
1cross-section tables                                                                    print table 100

    table    length

                     tables from file critxs
```

```
 1001.50c    1153  njoy                                                          (  1301)      79/07/31.
 6000.50c   16126  njoy                                                          (  1306)      79/07/31.
 7014.50c   22772  njoy                                                          (  1275)      79/09/08.
 8016.50c   23669  njoy                                                          ( 1276)      05/14/81
11023.50c   36270  njoy                                                          (  1311)      79/06/21.
13027.50c   22891  njoy                                                          (  1313)      79/09/08.
14000.50c   48275  njoy                                                          (  1314)      79/06/21.
18000.35c    2182      end185                                                     (  18)       11/01/85
20000.50c   26104  njoy                                                          (  1320)      79/06/22.
26000.55c   84136  njoy                                                          ( 260)       10/21/82
94239.55c   67551  njoy                                  total nu                ( 1399)      02/21/85

 total      351129

warning:  neutron energy cutoff is below some cross-section tables.


decimal words of dynamically allocated storage

    general              110366
    tallies                   0
    bank                   6403
    cross sections       351129

    total                467898

*****************************************************************************************************************
dump no.    1 on file 10d1r        nps =        0     coll =              0     ctm =    0.00     nrn =              0

source distribution written to file 10d1s          cycle =     0

         1 warning message so far.
1   starting mcrun.      field length =      0      cp0 =  0.01                                    print table 110

     Pu-239 in concrete matrix. Infinite lattice of 55 gal. drums, 4 tiers
```

nps	x	y	z	cell	surf	u	v	w	energy	weight	time
1	0.000E+00	0.000E+00	1.782E+02	2	0	5.085E-01	4.733E-01	7.193E-01	2.209E+00	1.000E+00	0.000E+00
2	0.000E+00	0.000E+00	1.782E+02	2	0	8.952E-01	-4.447E-01	-2.944E-02	4.904E+00	1.000E+00	0.000E+00
3	0.000E+00	0.000E+00	1.782E+02	2	0	-6.184E-01	-4.495E-01	6.446E-01	3.809E-01	1.000E+00	0.000E+00
4	0.000E+00	0.000E+00	1.782E+02	2	0	9.710E-01	-5.665E-02	-2.323E-01	1.331E+00	1.000E+00	0.000E+00
5	0.000E+00	0.000E+00	1.782E+02	2	0	5.861E-01	1.496E-01	-7.963E-01	1.902E+00	1.000E+00	0.000E+00
6	0.000E+00	0.000E+00	1.782E+02	2	0	-6.489E-02	-1.626E-01	9.845E-01	4.410E-01	1.000E+00	0.000E+00
7	0.000E+00	0.000E+00	1.782E+02	2	0	-7.068E-02	3.263E-02	-9.970E-01	4.750E-01	1.000E+00	0.000E+00
8	0.000E+00	0.000E+00	1.782E+02	2	0	-3.915E-01	4.664E-01	-7.932E-01	4.136E+00	1.000E+00	0.000E+00
9	0.000E+00	0.000E+00	1.782E+02	2	0	-2.368E-01	9.215E-01	-3.079E-01	7.453E-02	1.000E+00	0.000E+00
10	0.000E+00	0.000E+00	1.782E+02	2	0	1.946E-01	-3.204E-01	9.271E-01	3.128E+00	1.000E+00	0.000E+00
11	0.000E+00	0.000E+00	1.782E+02	2	0	-6.698E-01	-7.177E-01	-1.905E-01	1.014E+00	1.000E+00	0.000E+00
12	0.000E+00	0.000E+00	1.782E+02	2	0	-8.398E-01	-4.129E-01	3.524E-01	1.395E+00	1.000E+00	0.000E+00
13	0.000E+00	0.000E+00	1.782E+02	2	0	-1.714E-01	-8.572E-01	4.857E-01	7.748E-01	1.000E+00	0.000E+00
14	0.000E+00	0.000E+00	1.782E+02	2	0	-2.489E-01	-5.118E-01	-8.222E-01	1.101E+00	1.000E+00	0.000E+00
15	0.000E+00	0.000E+00	1.782E+02	2	0	-2.959E-01	2.119E-01	9.314E-01	1.951E+00	1.000E+00	0.000E+00
16	0.000E+00	0.000E+00	1.782E+02	2	0	1.395E-01	-9.829E-01	1.202E-01	2.186E+00	1.000E+00	0.000E+00
17	0.000E+00	0.000E+00	1.782E+02	2	0	6.909E-01	-7.110E-01	1.307E-01	1.865E+00	1.000E+00	0.000E+00
18	0.000E+00	0.000E+00	1.782E+02	2	0	-6.580E-01	5.320E-01	-5.329E-01	1.229E+00	1.000E+00	0.000E+00
19	0.000E+00	0.000E+00	1.782E+02	2	0	-9.903E-01	-1.380E-01	1.353E-02	1.305E+00	1.000E+00	0.000E+00

```
    20  0.000E+00  0.000E+00  1.782E+02     2       0  7.462E-01  4.859E-01 -4.551E-01  1.000E+00  1.000E+00  0.000E+00
    21  0.000E+00  0.000E+00  1.782E+02     2       0 -1.977E-01  9.797E-01  3.360E-02  3.990E+00  1.000E+00  0.000E+00
    22  0.000E+00  0.000E+00  1.782E+02     2       0 -9.117E-01 -3.647E-01 -1.891E-01  2.665E-01  1.000E+00  0.000E+00
    23  0.000E+00  0.000E+00  1.782E+02     2       0 -4.287E-01  8.361E-01 -3.423E-01  1.156E+00  1.000E+00  0.000E+00
    24  0.000E+00  0.000E+00  1.782E+02     2       0  1.080E-01  3.412E-01 -9.338E-01  2.669E+00  1.000E+00  0.000E+00
    25  0.000E+00  0.000E+00  1.782E+02     2       0 -9.111E-01 -9.012E-03 -4.122E-01  2.185E+00  1.000E+00  0.000E+00
    26  0.000E+00  0.000E+00  1.782E+02     2       0 -2.568E-01 -6.391E-01 -7.249E-01  4.225E+00  1.000E+00  0.000E+00
    27  0.000E+00  0.000E+00  1.782E+02     2       0 -2.912E-01  8.086E-01  5.113E-01  1.079E+00  1.000E+00  0.000E+00
    28  0.000E+00  0.000E+00  1.782E+02     2       0  1.472E-01 -9.514E-01  2.705E-01  3.461E+00  1.000E+00  0.000E+00
    29  0.000E+00  0.000E+00  1.782E+02     2       0 -6.135E-01 -7.645E-01 -1.978E-01  1.836E+00  1.000E+00  0.000E+00
    30  0.000E+00  0.000E+00  1.782E+02     2       0 -5.702E-01  5.651E-01 -5.963E-01  4.556E-01  1.000E+00  0.000E+00
    31  0.000E+00  0.000E+00  1.782E+02     2       0 -6.607E-01  5.373E-01 -5.242E-01  6.415E-01  1.000E+00  0.000E+00
    32  0.000E+00  0.000E+00  1.782E+02     2       0 -9.742E-02 -3.639E-01 -9.263E-01  2.764E+00  1.000E+00  0.000E+00
    33  0.000E+00  0.000E+00  1.782E+02     2       0 -1.965E-01 -3.145E-01 -9.287E-01  2.785E-01  1.000E+00  0.000E+00
    34  0.000E+00  0.000E+00  1.782E+02     2       0  4.097E-01  8.465E-01 -3.399E-01  9.097E-01  1.000E+00  0.000E+00
    35  0.000E+00  0.000E+00  1.782E+02     2       0 -4.048E-02  8.831E-01  4.675E-01  3.360E-01  1.000E+00  0.000E+00
    36  0.000E+00  0.000E+00  1.782E+02     2       0  3.371E-01 -9.269E-01 -1.652E-01  6.376E-01  1.000E+00  0.000E+00
    37  0.000E+00  0.000E+00  1.782E+02     2       0 -1.867E-01  9.756E-01 -1.155E-01  2.186E+00  1.000E+00  0.000E+00
    38  0.000E+00  0.000E+00  1.782E+02     2       0 -2.616E-01  2.336E-01 -9.365E-01  7.314E-01  1.000E+00  0.000E+00
    39  0.000E+00  0.000E+00  1.782E+02     2       0  9.780E-01 -7.641E-02 -1.939E-01  2.997E-01  1.000E+00  0.000E+00
    40  0.000E+00  0.000E+00  1.782E+02     2       0  2.580E-01 -7.076E-01  6.578E-01  1.444E+00  1.000E+00  0.000E+00
    41  0.000E+00  0.000E+00  1.782E+02     2       0 -3.212E-01 -7.678E-01 -5.543E-01  1.914E+00  1.000E+00  0.000E+00
    42  0.000E+00  0.000E+00  1.782E+02     2       0  5.039E-01 -1.460E-01  8.513E-01  1.502E+00  1.000E+00  0.000E+00
    43  0.000E+00  0.000E+00  1.782E+02     2       0  6.080E-01  5.487E-01  5.738E-01  5.971E+00  1.000E+00  0.000E+00
    44  0.000E+00  0.000E+00  1.782E+02     2       0 -2.932E-01  9.304E-01 -2.199E-01  1.827E+00  1.000E+00  0.000E+00
    45  0.000E+00  0.000E+00  1.782E+02     2       0 -8.475E-01 -3.993E-01 -3.497E-01  1.928E+00  1.000E+00  0.000E+00
    46  0.000E+00  0.000E+00  1.782E+02     2       0  1.200E-01 -9.195E-01 -3.743E-01  1.351E+00  1.000E+00  0.000E+00
    47  0.000E+00  0.000E+00  1.782E+02     2       0  7.085E-01  5.879E-01  3.904E-01  2.288E+00  1.000E+00  0.000E+00
    48  0.000E+00  0.000E+00  1.782E+02     2       0  4.261E-01  9.046E-01  9.254E-03  1.230E+00  1.000E+00  0.000E+00
    49  0.000E+00  0.000E+00  1.782E+02     2       0  5.431E-01  4.270E-01 -7.230E-01  1.433E+00  1.000E+00  0.000E+00
    50  0.000E+00  0.000E+00  1.782E+02     2       0 -1.053E-01 -9.805E-01  1.658E-01  6.572E-01  1.000E+00  0.000E+00
 estimated keff results by cycle                                                                    print table 175

 source distribution written to file 10d1s          cycle =    20

 source distribution written to file 10d1s          cycle =    23

 source distribution written to file 10d1s          cycle =    26

 source distribution written to file 10d1s          cycle =    29

 source distribution written to file 10d1s          cycle =    32

 source distribution written to file 10d1s          cycle =    35

 source distribution written to file 10d1s          cycle =    38

 source distribution written to file 10d1s          cycle =    41

 source distribution written to file 10d1s          cycle =    44

 ************************************************************************************************************************
 dump no.    2 on file 10d1r        nps =    173372     coll =       21706039     ctm =   15.31     nrn =       392559637

 source distribution written to file 10d1s          cycle =    47

 source distribution written to file 10d1s          cycle =    50

 source distribution written to file 10d1s          cycle =    53

 source distribution written to file 10d1s          cycle =    56
```

```
source distribution written to file 10d1s          cycle =    59

source distribution written to file 10d1s          cycle =    62

source distribution written to file 10d1s          cycle =    65

source distribution written to file 10d1s          cycle =    68

source distribution written to file 10d1s          cycle =    71

source distribution written to file 10d1s          cycle =    74

source distribution written to file 10d1s          cycle =    77

source distribution written to file 10d1s          cycle =    80

source distribution written to file 10d1s          cycle =    83

source distribution written to file 10d1s          cycle =    86

*****************************************************************************************************************
dump no.    3 on file 10d1r        nps =    344635     coll =       43074182     ctm =   30.38     nrn =      778861681


source distribution written to file 10d1s          cycle =    89

source distribution written to file 10d1s          cycle =    92

source distribution written to file 10d1s          cycle =    95

source distribution written to file 10d1s          cycle =    98

 estimator     cycle   100   ave of    80 cycles      combination         simple average    combined average     corr
k(collision)      0.380596       0.381995 0.0009     k(col/abs)          0.382682 0.0013     0.382192 0.0007  -0.2861
k(absorption)     0.396756       0.383368 0.0028     k(abs/tk ln)        0.382646 0.0013     0.382157 0.0008  -0.3303
k(trk length)     0.380417       0.381925 0.0009     k(tk ln/col)        0.381960 0.0009     0.382024 0.0009   0.9690
rem life(col)   3.1975E+04     3.2356E+04 0.0021     k(col/abs/tk ln)    0.382429 0.0009     0.382187 0.0007
rem life(abs)   3.2030E+04     3.2383E+04 0.0019     life(col/abs)     3.2369E+04 0.0020   3.2390E+04 0.0019   0.9444
source points generated   3970

source distribution written to file 10d1s          cycle =   101

source distribution written to file 10d1s          cycle =   104

source distribution written to file 10d1s          cycle =   107

source distribution written to file 10d1s          cycle =   110

source distribution written to file 10d1s          cycle =   113

 estimator     cycle   116   ave of    96 cycles      combination         simple average    combined average     corr
k(collision)      0.382194       0.382016 0.0008     k(col/abs)          0.382547 0.0012     0.382168 0.0007  -0.3006
k(absorption)     0.382882       0.383078 0.0026     k(abs/tk ln)        0.382508 0.0012     0.382118 0.0007  -0.3309
k(trk length)     0.382181       0.381938 0.0008     k(tk ln/col)        0.381977 0.0008     0.382048 0.0008   0.9695
rem life(col)   3.2627E+04     3.2387E+04 0.0019     k(col/abs/tk ln)    0.382344 0.0008     0.382168 0.0007
rem life(abs)   3.2403E+04     3.2398E+04 0.0018     life(col/abs)     3.2393E+04 0.0018   3.2401E+04 0.0018   0.9476
source points generated   4059

source distribution written to file 10d1s          cycle =   116

 estimator     cycle   117   ave of    97 cycles      combination         simple average    combined average     corr
```

k(collision)	0.378784	0.381983	0.0008	k(col/abs)	0.382557	0.0012	0.382149	0.0007	-0.3044
k(absorption)	0.388236	0.383131	0.0025	k(abs/tk ln)	0.382520	0.0012	0.382103	0.0007	-0.3341
k(trk length)	0.379060	0.381908	0.0008	k(tk ln/col)	0.381946	0.0008	0.382012	0.0008	0.9696
rem life(col)	3.1150E+04	3.2374E+04	0.0019	k(col/abs/tk ln)	0.382341	0.0008	0.382147	0.0007	
rem life(abs)	3.1437E+04	3.2388E+04	0.0018	life(col/abs)	3.2381E+04	0.0018	3.2392E+04	0.0018	0.9490

source points generated 4026

estimator	cycle 118	ave of 98 cycles		combination	simple average		combined average		corr
k(collision)	0.382846	0.381992	0.0008	k(col/abs)	0.382558	0.0012	0.382155	0.0006	-0.3045
k(absorption)	0.382346	0.383123	0.0025	k(abs/tk ln)	0.382521	0.0012	0.382111	0.0007	-0.3342
k(trk length)	0.382981	0.381919	0.0008	k(tk ln/col)	0.381956	0.0008	0.382020	0.0008	0.9696
rem life(col)	3.2254E+04	3.2373E+04	0.0019	k(col/abs/tk ln)	0.382345	0.0008	0.382154	0.0007	
rem life(abs)	3.2366E+04	3.2388E+04	0.0017	life(col/abs)	3.2381E+04	0.0018	3.2392E+04	0.0017	0.9489

source points generated 3993

estimator	cycle 119	ave of 99 cycles		combination	simple average		combined average		corr
k(collision)	0.382976	0.382002	0.0008	k(col/abs)	0.382524	0.0012	0.382152	0.0006	-0.3061
k(absorption)	0.375584	0.383047	0.0025	k(abs/tk ln)	0.382491	0.0012	0.382112	0.0007	-0.3366
k(trk length)	0.383381	0.381934	0.0008	k(tk ln/col)	0.381968	0.0008	0.382028	0.0008	0.9696
rem life(col)	3.2281E+04	3.2372E+04	0.0019	k(col/abs/tk ln)	0.382328	0.0008	0.382151	0.0006	
rem life(abs)	3.2392E+04	3.2388E+04	0.0017	life(col/abs)	3.2380E+04	0.0018	3.2393E+04	0.0017	0.9488

source points generated 3970

source distribution written to file 10dls cycle = 119

estimator	cycle 120	ave of 100 cycles		combination	simple average		combined average		corr
k(collision)	0.383971	0.382021	0.0007	k(col/abs)	0.382493	0.0012	0.382158	0.0006	-0.3102
k(absorption)	0.374887	0.382966	0.0025	k(abs/tk ln)	0.382465	0.0012	0.382125	0.0007	-0.3423
k(trk length)	0.384956	0.381964	0.0008	k(tk ln/col)	0.381993	0.0008	0.382046	0.0007	0.9694
rem life(col)	3.2834E+04	3.2377E+04	0.0019	k(col/abs/tk ln)	0.382317	0.0008	0.382158	0.0006	
rem life(abs)	3.2663E+04	3.2391E+04	0.0017	life(col/abs)	3.2384E+04	0.0018	3.2395E+04	0.0017	0.9487

source points generated 4006

source distribution written to file 10dls cycle = 120

1problem summary

run terminated when 120 kcode cycles were done.

09/14/00 05:29:08

Pu-239 in concrete matrix. Infinite lattice of 55 gal. drums, 4 tiers probid = 09/14/00 04:47:10

0

neutron creation	tracks	weight (per source particle)	energy	neutron loss	tracks	weight (per source particle)	energy
source	476456	1.0074E+00	2.1097E+00	escape	5495	8.5742E-03	4.8789E-03
				energy cutoff	0	0.	0.
				time cutoff	0	0.	0.
weight window	0	0.	0.	weight window	0	0.	0.
cell importance	0	0.	0.	cell importance	0	0.	0.
weight cutoff	0	1.5497E-01	5.3794E-05	weight cutoff	470972	1.5462E-01	6.2752E-05
energy importance	0	0.	0.	energy importance	0	0.	0.
dxtran	0	0.	0.	dxtran	0	0.	0.
forced collisions	0	0.	0.	forced collisions	0	0.	0.
exp. transform	0	0.	0.	exp. transform	0	0.	0.
upscattering	0	0.	4.6412E-07	downscattering	0	0.	2.0208E+00
				capture	0	8.6560E-01	8.3679E-02
(n,xn)	22	3.3618E-05	5.9515E-05	loss to (n,xn)	11	1.6809E-05	1.9246E-04
fission	0	0.	0.	loss to fission	0	1.3363E-01	2.1443E-04
total	476478	1.1624E+00	2.1098E+00	total	476478	1.1624E+00	2.1098E+00

number of neutrons banked	11	average lifetime, shakes		cutoffs	
neutron tracks per source particle	1.0000E+00	escape	1.2806E+04	tco	1.0000E+34
neutron collisions per source particle	1.2491E+02	capture	3.2590E+04	eco	0.0000E+00

total neutron collisions	59512804	capture or escape	3.2422E+04
net multiplication	1.0000E+00 0.0001	any termination	3.7926E+04

wc1	-5.0000E-01		
wc2	-2.5000E-01		

computer time so far in this run	41.98 minutes	maximum number ever in bank	1
computer time in mcrun	41.97 minutes	bank overflows to backup file	0
source particles per minute	1.1352E+04	field length	0
random numbers generated	1076007760	most random numbers used was	13768 in history 314427

range of sampled source weights = 9.5420E-01 to 2.5559E+00

1neutron activity in each cell print table 126

	cell	tracks entering	population	collisions	collisions * weight (per history)	number weighted energy	flux weighted energy	average track weight (relative)	average track mfp (cm)
1	1	3389735	365158	970741	1.2432E+00	1.2064E-04	3.5370E-01	6.8436E-01	2.1753E+00
2	2	2134492	476467	57964159	7.8867E+01	1.0051E-04	3.3800E-01	6.9493E-01	2.3563E+00
3	3	1682507	358644	4291	5.5484E-03	1.1866E-04	3.5257E-01	6.8457E-01	3.7899E+03
5	5	18044	7924	573613	6.3844E-01	3.4544E-05	1.5902E-01	5.5809E-01	2.0042E+00
total		7224778	1208193	59512804	8.0755E+01				

1keff results for: Pu-239 in concrete matrix. Infinite lattice of 55 gal. drums, 4 tiers probid = 09/14/00 04:47:10

the initial fission neutron source distribution used the 1 source points that were input on the ksrc card.
the criticality problem was scheduled to skip 20 cycles and run a total of 120 cycles with nominally 4000 neutrons per cycle.
this problem has run 20 inactive cycles with 77464 neutron histories and 100 active cycles with 398992 neutron histories.

this calculation has completed the requested number of keff cycles using a total of 476456 fission neutron source histories.
all cells with fissionable material were sampled and had fission neutron source points.

the results of the w test for normality applied to the individual collision, absorption, and track-length keff cycle values are:

the k(collision) cycle values appear normally distributed at the 95 percent confidence level
the k(absorption) cycle values appear normally distributed at the 95 percent confidence level
the k(trk length) cycle values appear normally distributed at the 95 percent confidence level

the final estimated combined collision/absorption/track-length keff = 0.38216 with an estimated standard deviation of 0.00024

the estimated 68, 95, & 99 percent keff confidence intervals are 0.38191 to 0.38240, 0.38167 to 0.38264, and 0.38151 to 0.38280

the estimated collision/absorption neutron removal lifetime = 3.24E-04 seconds with an estimated standard deviation of 5.55E-07

the estimated average keffs, one standard deviations, and 68, 95, and 99 percent confidence intervals are:

keff estimator	keff	standard deviation	68% confidence	95% confidence	99% confidence	corr
collision	0.38202	0.00029	0.38174 to 0.38231	0.38145 to 0.38259	0.38127 to 0.38278	
absorption	0.38297	0.00095	0.38202 to 0.38391	0.38108 to 0.38485	0.38047 to 0.38547	
track length	0.38196	0.00030	0.38166 to 0.38227	0.38136 to 0.38257	0.38116 to 0.38277	
col/absorp	0.38216	0.00024	0.38192 to 0.38240	0.38168 to 0.38264	0.38152 to 0.38280	-0.3102
abs/trk len	0.38213	0.00025	0.38187 to 0.38238	0.38163 to 0.38262	0.38146 to 0.38279	-0.3423
col/trk len	0.38205	0.00029	0.38176 to 0.38233	0.38148 to 0.38262	0.38129 to 0.38280	0.9694
col/abs/trk len	0.38216	0.00024	0.38191 to 0.38240	0.38167 to 0.38264	0.38151 to 0.38280	

if the largest of each keff occurred on the next cycle, the keff results and 68, 95, and 99 percent confidence intervals would be:

keff estimator	keff	standard deviation	68% confidence	95% confidence	99% confidence
collision	0.38208	0.00029	0.38179 to 0.38237	0.38151 to 0.38266	0.38132 to 0.38285
absorption	0.38322	0.00097	0.38225 to 0.38420	0.38129 to 0.38516	0.38066 to 0.38579
track length	0.38203	0.00031	0.38172 to 0.38233	0.38142 to 0.38264	0.38122 to 0.38284
col/abs/trk len	0.38223	0.00026	0.38197 to 0.38249	0.38172 to 0.38275	0.38155 to 0.38292

the estimated collision/absorption neutron lifetimes, one standard deviations, and 68, 95, and 99 percent confidence intervals are:

type	lifetime(sec)	standard deviation	68% confidence	95% confidence	99% confidence
removal	3.2395E-04	5.5519E-07	3.2340E-04 to 3.2451E-04	3.2284E-04 to 3.2506E-04	3.2248E-04 to 3.2542E-04
capture	3.2566E-04	4.2183E-07	3.2524E-04 to 3.2608E-04	3.2482E-04 to 3.2650E-04	3.2454E-04 to 3.2677E-04
fission	3.0808E-04	4.1630E-07	3.0766E-04 to 3.0850E-04	3.0725E-04 to 3.0891E-04	3.0698E-04 to 3.0918E-04
escape	1.2896E-04	2.9629E-06	1.2599E-04 to 1.3192E-04	1.2305E-04 to 1.3486E-04	1.2113E-04 to 1.3678E-04

laverage individual and combined collision/absorption/track-length keff results for 7 different batch sizes

cycles per keff batch	number of k batches	average keff estimators and deviations k(col) st dev	k(abs) st dev	k(trk) st dev	normality co/ab/trk	average k(c/a/t) k(c/a/t) st dev	k(c/a/t) confidence intervals 95% confidence	99% confidence
1	100	0.3820 0.0003	0.3830 0.0009	0.3820 0.0003	95/95/95	0.38216 0.00024	0.38167-0.38264	0.38151-0.38280
2	50	0.3820 0.0003	0.3830 0.0010	0.3820 0.0003	95/95/95	0.38217 0.00025	0.38167-0.38267	0.38150-0.38283
4	25	0.3820 0.0003	0.3830 0.0011	0.3820 0.0004	95/95/95	0.38217 0.00031	0.38153-0.38282	0.38130-0.38305
5	20	0.3820 0.0003	0.3830 0.0010	0.3820 0.0003	95/95/95	0.38213 0.00031	0.38148-0.38277	0.38124-0.38302
10	10	0.3820 0.0003	0.3830 0.0012	0.3820 0.0004	95/95/95	0.38213 0.00035	0.38131-0.38296	0.38091-0.38336
20	5	0.3820 0.0002	0.3830 0.0017	0.3820 0.0002	95/95/95	0.38205 0.00019	0.38124-0.38286	0.38017-0.38392
25	4	0.3820 0.0002	0.3830 0.0012	0.3820 0.0002	95/95/95	0.38210 0.00001	0.38203-0.38218	0.38171-0.38250

lindividual and average keff estimator results by cycle

keff cycle	neutron histories	keff estimators by cycle k(coll)	k(abs)	k(track)	average keff estimators and deviations k(coll) st dev	k(abs) st dev	k(track) st dev	average k(c/a/t) k(c/a/t) st dev	fom
1	4000	0.40286	0.40921	0.40341					
2	1565	0.39483	0.38424	0.39679					
3	3900	0.38971	0.38870	0.39155					
4	3972	0.39441	0.38215	0.39451					
5	4192	0.39077	0.38517	0.39082					
6	4049	0.39100	0.38082	0.39098					
7	4069	0.38992	0.38086	0.38984					
8	3935	0.39193	0.38749	0.39186					
9	4180	0.38571	0.38341	0.38498					
10	3921	0.38353	0.39739	0.38340					
11	3912	0.39140	0.36713	0.39124					
12	3975	0.38125	0.38017	0.38191					
13	3922	0.38684	0.38397	0.38613					
14	4065	0.38526	0.38918	0.38557					
15	4005	0.38581	0.37698	0.38723					
16	4033	0.37872	0.39732	0.37848					
17	3887	0.38549	0.38409	0.38596					
18	4057	0.38170	0.38895	0.38232					
19	3874	0.38444	0.38116	0.38528					
20	3951	0.37850	0.40356	0.37856					
		begin active keff cycles							
21	3913	0.38080	0.39462	0.38077					
22	3948	0.38841	0.38611	0.38742	0.38460 0.00380	0.39036 0.00426	0.38409 0.00333		
23	3970	0.38554	0.39565	0.38507	0.38492 0.00222	0.39213 0.00302	0.38442 0.00195		

24	3935	0.38276	0.38044	0.38281	0.38438	0.00166	0.38920	0.00362	0.38402	0.00143	0.38263	0.00111	84786
25	4035	0.38776	0.38410	0.38822	0.38505	0.00145	0.38818	0.00298	0.38486	0.00139	0.38543	0.00162	32343
26	4130	0.38148	0.37767	0.38170	0.38446	0.00133	0.38643	0.00300	0.38433	0.00125	0.38442	0.00144	33688
27	3840	0.37975	0.39842	0.38084	0.38379	0.00131	0.38814	0.00306	0.38383	0.00117	0.38453	0.00124	38876
28	3907	0.38288	0.38409	0.38303	0.38367	0.00114	0.38764	0.00270	0.38373	0.00102	0.38437	0.00105	48119
29	4134	0.38005	0.39714	0.37926	0.38327	0.00108	0.38869	0.00260	0.38323	0.00103	0.38434	0.00105	42066
30	4007	0.38055	0.38247	0.38044	0.38300	0.00100	0.38807	0.00241	0.38295	0.00096	0.38391	0.00103	39271
31	4056	0.38373	0.38315	0.38362	0.38306	0.00091	0.38762	0.00223	0.38302	0.00087	0.38385	0.00091	46292
32	4022	0.37891	0.38067	0.37915	0.38272	0.00090	0.38704	0.00211	0.38269	0.00086	0.38342	0.00092	40813
33	4014	0.38197	0.39067	0.38125	0.38266	0.00083	0.38732	0.00196	0.38258	0.00080	0.38337	0.00088	41820
34	3972	0.38058	0.38911	0.38059	0.38251	0.00078	0.38745	0.00182	0.38244	0.00075	0.38331	0.00083	43082
35	3890	0.37664	0.39000	0.37800	0.38212	0.00083	0.38762	0.00170	0.38214	0.00076	0.38326	0.00080	43208
36	4068	0.38149	0.39541	0.38163	0.38208	0.00078	0.38811	0.00167	0.38211	0.00071	0.38327	0.00078	43084
37	4067	0.37938	0.37845	0.37963	0.38192	0.00075	0.38754	0.00167	0.38197	0.00068	0.38292	0.00076	42616
38	3936	0.38244	0.39104	0.38283	0.38195	0.00070	0.38773	0.00158	0.38201	0.00065	0.38299	0.00074	42552
39	4028	0.37910	0.37757	0.37926	0.38180	0.00068	0.38720	0.00159	0.38187	0.00063	0.38266	0.00073	41695
40	3879	0.37380	0.40101	0.37434	0.38140	0.00076	0.38789	0.00166	0.38149	0.00070	0.38282	0.00073	39441
41	4068	0.38381	0.37124	0.38398	0.38152	0.00073	0.38710	0.00177	0.38161	0.00068	0.38273	0.00065	47749
42	4110	0.38089	0.39217	0.38072	0.38149	0.00070	0.38733	0.00170	0.38157	0.00065	0.38272	0.00062	48755
43	3955	0.38246	0.36747	0.38352	0.38153	0.00067	0.38646	0.00184	0.38166	0.00063	0.38270	0.00057	55546
44	4024	0.38462	0.36527	0.38438	0.38166	0.00065	0.38558	0.00197	0.38177	0.00061	0.38254	0.00052	63333
45	4141	0.37843	0.37491	0.37820	0.38153	0.00064	0.38515	0.00194	0.38163	0.00060	0.38226	0.00055	55745
46	3877	0.38276	0.38196	0.38231	0.38158	0.00062	0.38503	0.00187	0.38165	0.00058	0.38224	0.00052	59135
47	4006	0.38550	0.37443	0.38557	0.38172	0.00061	0.38464	0.00184	0.38180	0.00058	0.38233	0.00050	62194
48	4008	0.37822	0.38538	0.37751	0.38160	0.00060	0.38466	0.00177	0.38164	0.00058	0.38217	0.00051	57598
49	3950	0.38336	0.37833	0.38321	0.38166	0.00058	0.38445	0.00172	0.38170	0.00056	0.38217	0.00049	60749
50	3943	0.38008	0.37950	0.38161	0.38160	0.00057	0.38428	0.00167	0.38169	0.00054	0.38218	0.00047	62269
51	3921	0.38377	0.38755	0.38444	0.38167	0.00055	0.38439	0.00162	0.38178	0.00053	0.38227	0.00047	60113
52	4054	0.37774	0.38921	0.37725	0.38155	0.00055	0.38454	0.00158	0.38164	0.00053	0.38217	0.00047	58250
53	3865	0.38176	0.36888	0.38262	0.38156	0.00053	0.38406	0.00160	0.38167	0.00052	0.38212	0.00046	60204
54	4029	0.38439	0.38098	0.38458	0.38164	0.00052	0.38397	0.00155	0.38176	0.00051	0.38219	0.00045	61238
55	4028	0.38769	0.36959	0.38780	0.38181	0.00054	0.38356	0.00156	0.38193	0.00052	0.38229	0.00044	62703
56	3958	0.38283	0.38393	0.38341	0.38184	0.00052	0.38357	0.00152	0.38197	0.00051	0.38232	0.00043	63320
57	3942	0.38391	0.37955	0.38430	0.38190	0.00051	0.38346	0.00148	0.38203	0.00050	0.38236	0.00042	64556
58	4034	0.37944	0.37587	0.37984	0.38183	0.00050	0.38326	0.00146	0.38198	0.00049	0.38228	0.00042	63356
59	3966	0.37722	0.37710	0.37768	0.38172	0.00050	0.38311	0.00143	0.38187	0.00049	0.38218	0.00042	59274
60	4041	0.38327	0.37099	0.38383	0.38175	0.00049	0.38280	0.00142	0.38191	0.00048	0.38218	0.00041	60684
61	4096	0.38729	0.36974	0.38724	0.38189	0.00050	0.38248	0.00143	0.38204	0.00049	0.38223	0.00040	62170
62	4000	0.38196	0.37948	0.38234	0.38189	0.00049	0.38241	0.00139	0.38205	0.00047	0.38223	0.00040	63409
63	3792	0.38373	0.39135	0.38213	0.38193	0.00048	0.38262	0.00138	0.38205	0.00046	0.38225	0.00038	67863
64	4181	0.38391	0.37772	0.38259	0.38198	0.00047	0.38251	0.00135	0.38207	0.00045	0.38220	0.00037	70565
65	3945	0.38196	0.39603	0.38212	0.38198	0.00046	0.38281	0.00135	0.38207	0.00044	0.38225	0.00036	70168
66	3969	0.38274	0.38028	0.38191	0.38199	0.00045	0.38275	0.00132	0.38206	0.00043	0.38222	0.00035	72193
67	4012	0.38528	0.37486	0.38502	0.38206	0.00044	0.38259	0.00131	0.38213	0.00043	0.38224	0.00035	74027
68	4035	0.38585	0.37635	0.38686	0.38214	0.00044	0.38246	0.00129	0.38222	0.00043	0.38230	0.00035	72275
69	3870	0.37562	0.38088	0.37525	0.38201	0.00045	0.38242	0.00126	0.38208	0.00044	0.38217	0.00036	64663
70	3855	0.38151	0.38797	0.38009	0.38200	0.00044	0.38254	0.00124	0.38204	0.00044	0.38214	0.00035	66403
71	4099	0.37936	0.39128	0.37861	0.38195	0.00044	0.38271	0.00123	0.38198	0.00043	0.38212	0.00035	67369
72	4000	0.37958	0.38613	0.37994	0.38190	0.00043	0.38277	0.00120	0.38194	0.00043	0.38210	0.00034	68370
73	3905	0.38126	0.39244	0.38015	0.38189	0.00042	0.38295	0.00120	0.38190	0.00042	0.38210	0.00034	69719
74	4016	0.38431	0.40892	0.38454	0.38194	0.00042	0.38344	0.00127	0.38195	0.00042	0.38219	0.00035	61166
75	4026	0.38204	0.36927	0.38186	0.38194	0.00041	0.38318	0.00127	0.38195	0.00041	0.38214	0.00035	61828
76	3962	0.38297	0.38906	0.38295	0.38196	0.00040	0.38328	0.00125	0.38197	0.00040	0.38217	0.00035	62351
77	4000	0.38072	0.38604	0.37970	0.38193	0.00040	0.38333	0.00123	0.38193	0.00040	0.38215	0.00034	63068
78	4026	0.37878	0.37854	0.37820	0.38188	0.00039	0.38325	0.00121	0.38186	0.00039	0.38208	0.00034	61676
79	3964	0.38268	0.36825	0.38274	0.38189	0.00039	0.38299	0.00122	0.38188	0.00039	0.38205	0.00034	62796
80	3993	0.37876	0.37633	0.37687	0.38184	0.00038	0.38288	0.00120	0.38179	0.00039	0.38197	0.00034	60252

81	4017	0.38630	0.37824	0.38647	0.38191	0.00038	0.38281	0.00119	0.38187	0.00039	0.38203 0.00034	59933
82	3987	0.38477	0.37634	0.38428	0.38196	0.00038	0.38270	0.00117	0.38191	0.00039	0.38205 0.00033	60756
83	3956	0.38330	0.37783	0.38307	0.38198	0.00038	0.38263	0.00115	0.38193	0.00038	0.38206 0.00033	61795
84	4039	0.38061	0.37165	0.38132	0.38196	0.00037	0.38245	0.00115	0.38192	0.00038	0.38202 0.00032	62090
85	3821	0.37916	0.38854	0.37759	0.38192	0.00037	0.38255	0.00114	0.38185	0.00038	0.38199 0.00032	62130
86	3931	0.37882	0.38883	0.37728	0.38187	0.00036	0.38264	0.00112	0.38178	0.00038	0.38197 0.00032	62032
87	4003	0.38004	0.38524	0.37937	0.38184	0.00036	0.38268	0.00111	0.38175	0.00037	0.38195 0.00032	62529
88	4013	0.37848	0.40584	0.37786	0.38179	0.00036	0.38302	0.00114	0.38169	0.00037	0.38195 0.00031	62992
89	3890	0.38412	0.38024	0.38347	0.38183	0.00035	0.38298	0.00113	0.38172	0.00037	0.38197 0.00031	63540
90	4049	0.38243	0.39832	0.38200	0.38184	0.00035	0.38320	0.00113	0.38172	0.00036	0.38200 0.00031	63061
91	3951	0.38707	0.38589	0.38708	0.38191	0.00035	0.38324	0.00112	0.38180	0.00036	0.38208 0.00031	60715
92	3941	0.38127	0.39553	0.38083	0.38190	0.00035	0.38341	0.00111	0.38178	0.00036	0.38209 0.00031	61108
93	3864	0.38643	0.36854	0.38759	0.38196	0.00035	0.38321	0.00112	0.38186	0.00036	0.38213 0.00030	62339
94	4130	0.38186	0.38714	0.38201	0.38196	0.00034	0.38326	0.00110	0.38186	0.00036	0.38214 0.00030	63160
95	4031	0.38352	0.38667	0.38557	0.38198	0.00034	0.38330	0.00109	0.38191	0.00036	0.38217 0.00029	63901
96	4041	0.38541	0.39293	0.38522	0.38203	0.00034	0.38343	0.00108	0.38196	0.00036	0.38222 0.00030	62152
97	4008	0.38264	0.38345	0.38111	0.38204	0.00033	0.38343	0.00107	0.38195	0.00035	0.38223 0.00029	62729
98	3890	0.37771	0.38492	0.37727	0.38198	0.00033	0.38345	0.00105	0.38189	0.00035	0.38219 0.00029	61819
99	3936	0.38460	0.36349	0.38650	0.38201	0.00033	0.38320	0.00107	0.38194	0.00035	0.38218 0.00029	63447
100	3995	0.38060	0.39676	0.38042	0.38200	0.00033	0.38337	0.00107	0.38192	0.00035	0.38219 0.00029	63978
101	3970	0.37699	0.39267	0.37604	0.38193	0.00033	0.38348	0.00106	0.38185	0.00035	0.38216 0.00028	63344
102	3889	0.38550	0.37900	0.38457	0.38198	0.00033	0.38343	0.00105	0.38189	0.00035	0.38219 0.00028	63487
103	4026	0.38149	0.38104	0.38001	0.38197	0.00032	0.38340	0.00104	0.38186	0.00034	0.38218 0.00028	63935
104	3860	0.38243	0.38010	0.38215	0.38198	0.00032	0.38336	0.00103	0.38187	0.00034	0.38218 0.00028	64739
105	3999	0.38362	0.36763	0.38423	0.38200	0.00032	0.38317	0.00103	0.38189	0.00034	0.38216 0.00027	65839
106	4073	0.38282	0.38273	0.38319	0.38201	0.00031	0.38317	0.00102	0.38191	0.00033	0.38217 0.00027	66674
107	3983	0.37895	0.38755	0.37894	0.38197	0.00031	0.38322	0.00101	0.38188	0.00033	0.38215 0.00027	66895
108	3931	0.38407	0.35856	0.38323	0.38199	0.00031	0.38294	0.00104	0.38189	0.00033	0.38213 0.00027	67325
109	4110	0.37849	0.37912	0.37850	0.38195	0.00031	0.38290	0.00103	0.38185	0.00033	0.38209 0.00027	66499
110	3954	0.38069	0.39153	0.38100	0.38194	0.00031	0.38299	0.00102	0.38184	0.00032	0.38209 0.00026	67262
111	4067	0.38362	0.38211	0.38299	0.38196	0.00030	0.38298	0.00101	0.38186	0.00032	0.38210 0.00026	67711
112	4081	0.38625	0.37068	0.38698	0.38201	0.00030	0.38285	0.00101	0.38191	0.00032	0.38213 0.00026	68355
113	3951	0.38551	0.39529	0.38557	0.38204	0.00030	0.38298	0.00100	0.38195	0.00032	0.38218 0.00026	66242
114	4036	0.37881	0.38264	0.37912	0.38201	0.00030	0.38298	0.00099	0.38192	0.00032	0.38215 0.00026	66080
115	3972	0.38250	0.39254	0.38336	0.38201	0.00030	0.38308	0.00099	0.38194	0.00032	0.38217 0.00026	66501
116	4132	0.38219	0.38288	0.38218	0.38202	0.00029	0.38308	0.00098	0.38194	0.00031	0.38217 0.00025	67207
117	4059	0.37878	0.38824	0.37906	0.38198	0.00029	0.38313	0.00097	0.38191	0.00031	0.38215 0.00025	67391
118	4026	0.38285	0.38235	0.38298	0.38199	0.00029	0.38312	0.00096	0.38192	0.00031	0.38215 0.00025	68100
119	3993	0.38298	0.37558	0.38338	0.38200	0.00029	0.38305	0.00095	0.38193	0.00030	0.38215 0.00025	68970
120	3970	0.38397	0.37489	0.38496	0.38202	0.00029	0.38297	0.00095	0.38196	0.00030	0.38216 0.00024	69906

the largest active cycle keffs by estimator are:

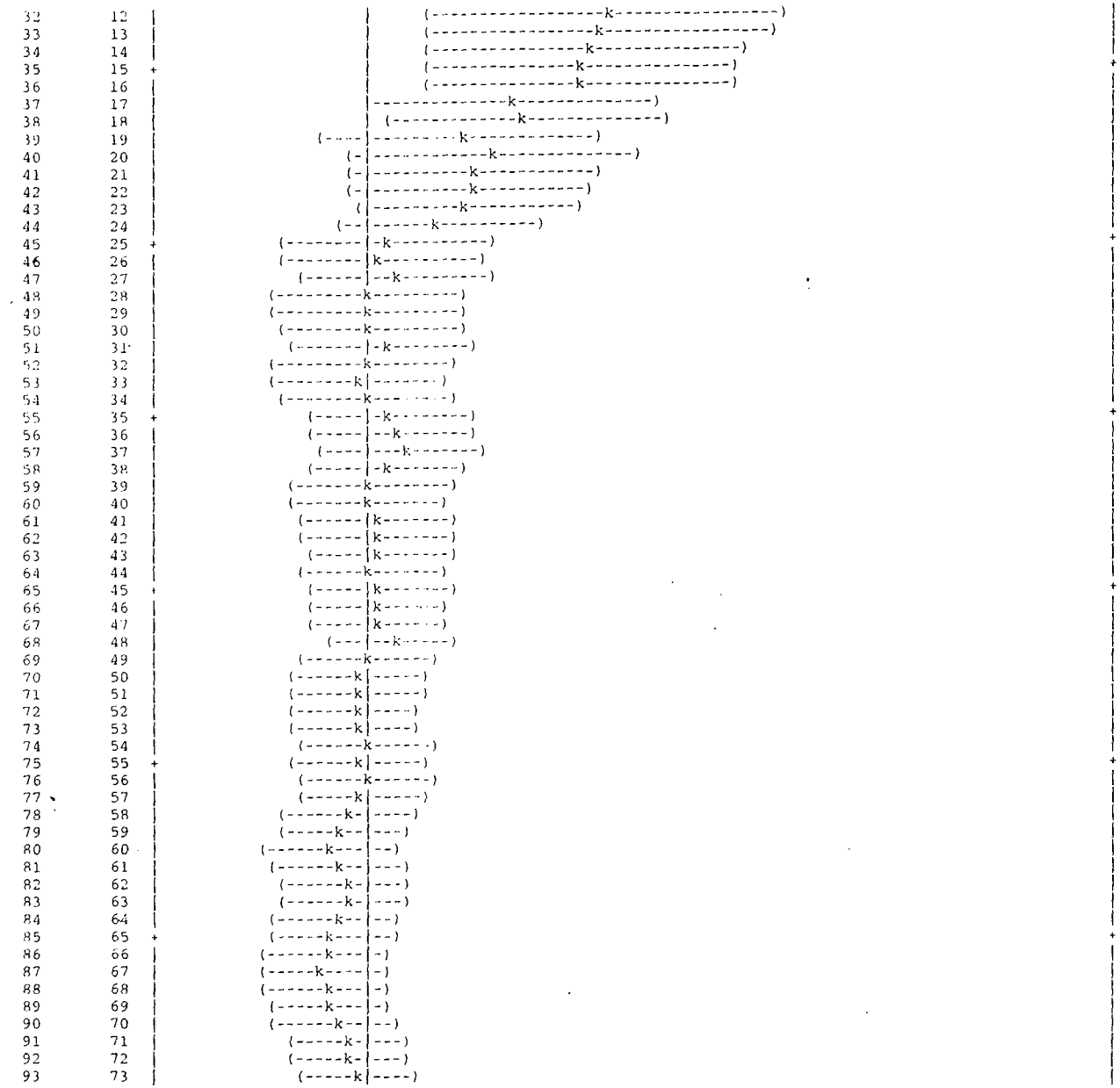
collision 0.38841 on cycle 22
absorption 0.40892 on cycle 74
track length 0.38822 on cycle 25

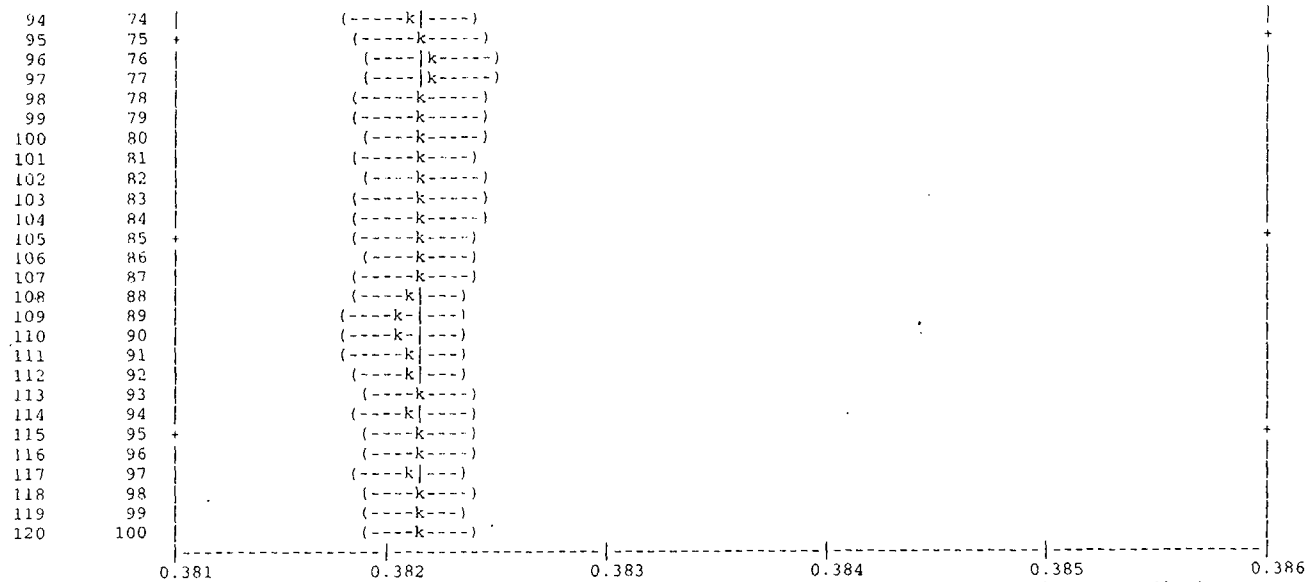
the smallest active cycle keffs by estimator are:

collision 0.37380 on cycle 40
absorption 0.35856 on cycle 108
track length 0.37434 on cycle 40

lplot of the estimated col/abs/track-length keff one standard deviation interval versus cycle number (| = final keff = 0.38216)

```
 cycle   active 0.381          0.382          0.383          0.384          0.385          0.386
number   cycles  |--------------|--------------|--------------|--------------|--------------|
    26        6  |              |              (-------------------------k-------------------------)
    27        7  |              |                    (-------------------------k-------------------------)
    28        8  |              |                     (-------------------k-------------------)
    29        9  |              |                    (-------------------k-------------------)
    30       10  |              |              (-------------------k-------------------)
    31       11  |              |               (-----------------k-----------------)
```





Individual and collision/absorption/track-length keffs for different numbers of inactive cycles skipped for fission source settling

skip cycles	active cycles	active neutrons	average keff estimators and deviations k(col)	st dev	k(abs)	st dev	k(trk)	st dev	normality co/ab/tl	average k(c/a/t) k(c/a/t)	st dev	k(c/a/t) confidence intervals 95% confidence	99% confidence
0	120	476456	0.3830	0.0004	0.3836	0.0009	0.3830	0.0004	no/95/no	0.38307	0.00033	0.38241-0.38373	0.38219-0.38394
1	119	472456	0.3828	0.0003	0.3834	0.0008	0.3828	0.0004	99/95/99	0.38290	0.00028	0.38234-0.38347	0.38215-0.38365
2	118	470891	0.3827	0.0003	0.3833	0.0009	0.3827	0.0003	95/95/95	0.38282	0.00027	0.38227-0.38336	0.38210-0.38354
3	117	466991	0.3826	0.0003	0.3833	0.0009	0.3826	0.0003	95/95/95	0.38276	0.00027	0.38222-0.38330	0.38205-0.38347
4	116	463019	0.3825	0.0003	0.3833	0.0009	0.3825	0.0003	95/95/95	0.38267	0.00026	0.38215-0.38319	0.38199-0.38336
5	115	458827	0.3825	0.0003	0.3833	0.0009	0.3824	0.0003	95/95/95	0.38261	0.00025	0.38210-0.38311	0.38194-0.38328
6	114	454778	0.3824	0.0003	0.3833	0.0009	0.3824	0.0003	95/95/95	0.38254	0.00025	0.38205-0.38304	0.38188-0.38320
7	113	450709	0.3823	0.0003	0.3833	0.0009	0.3823	0.0003	95/95/95	0.38249	0.00025	0.38200-0.38298	0.38184-0.38314
8	112	446774	0.3822	0.0003	0.3833	0.0009	0.3822	0.0003	95/95/95	0.38241	0.00024	0.38194-0.38287	0.38178-0.38303
9	111	442594	0.3822	0.0003	0.3833	0.0009	0.3822	0.0003	95/95/95	0.38238	0.00024	0.38191-0.38285	0.38176-0.38300
10	110	438673	0.3822	0.0003	0.3832	0.0009	0.3822	0.0003	95/95/95	0.38235	0.00024	0.38188-0.38282	0.38173-0.38298
11	109	434761	0.3821	0.0003	0.3833	0.0009	0.3821	0.0003	95/95/95	0.38229	0.00023	0.38183-0.38276	0.38168-0.38291
12	108	430786	0.3821	0.0003	0.3833	0.0009	0.3821	0.0003	95/95/95	0.38230	0.00024	0.38183-0.38277	0.38168-0.38293
13	107	426864	0.3821	0.0003	0.3833	0.0009	0.3821	0.0003	95/95/95	0.38226	0.00023	0.38180-0.38273	0.38164-0.38288
14	106	422799	0.3820	0.0003	0.3833	0.0009	0.3820	0.0003	95/95/95	0.38223	0.00023	0.38176-0.38270	0.38161-0.38285
15	105	418794	0.3820	0.0003	0.3833	0.0009	0.3820	0.0003	95/95/95	0.38221	0.00024	0.38174-0.38268	0.38158-0.38283
16	104	414761	0.3820	0.0003	0.3832	0.0009	0.3820	0.0003	95/95/95	0.38221	0.00024	0.38174-0.38269	0.38159-0.38284
17	103	410874	0.3820	0.0003	0.3832	0.0009	0.3820	0.0003	95/95/95	0.38218	0.00024	0.38171-0.38266	0.38155-0.38281
18	102	406817	0.3820	0.0003	0.3831	0.0009	0.3820	0.0003	95/95/95	0.38218	0.00024	0.38170-0.38265	0.38154-0.38281
19	101	402943	0.3820	0.0003	0.3832	0.0010	0.3819	0.0003	95/95/95	0.38216	0.00024	0.38168-0.38264	0.38152-0.38280
20	100	398992	0.3820	0.0003	0.3830	0.0009	0.3820	0.0003	95/95/95	0.38216	0.00024	0.38167-0.38264	0.38151-0.38280
22	98	391131	0.3820	0.0003	0.3828	0.0010	0.3819	0.0003	95/95/95	0.38209	0.00024	0.38161-0.38257	0.38146-0.38273
24	96	383226	0.3819	0.0003	0.3827	0.0010	0.3819	0.0003	95/95/95	0.38204	0.00024	0.38157-0.38252	0.38141-0.38268
26	94	375061	0.3819	0.0003	0.3827	0.0010	0.3818	0.0003	95/95/95	0.38200	0.00024	0.38152-0.38247	0.38137-0.38263
28	92	367314	0.3819	0.0003	0.3826	0.0010	0.3818	0.0003	95/95/95	0.38198	0.00024	0.38150-0.38247	0.38134-0.38263
30	90	359173	0.3819	0.0003	0.3824	0.0010	0.3819	0.0003	95/95/95	0.38199	0.00025	0.38149-0.38248	0.38133-0.38264

32	88	351095	0.3819	0.0003	0.3824	0.0010	0.3819	0.0003	95/95/95	0.38200	0.00025	0.38150-0.38250	0.38134-0.38267
34	86	343109	0.3819	0.0003	0.3822	0.0010	0.3819	0.0003	95/95/95	0.38199	0.00026	0.38148-0.38250	0.38131-0.38267
36	84	335151	0.3820	0.0003	0.3820	0.0011	0.3819	0.0003	95/95/95	0.38202	0.00026	0.38151-0.38254	0.38134-0.38271
38	82	327148	0.3820	0.0003	0.3819	0.0011	0.3820	0.0003	95/95/95	0.38204	0.00026	0.38152-0.38256	0.38135-0.38273
40	80	319241	0.3822	0.0003	0.3817	0.0011	0.3821	0.0003	95/95/95	0.38216	0.00026	0.38164-0.38267	0.38147-0.38284
42	78	311063	0.3822	0.0003	0.3817	0.0011	0.3821	0.0003	95/95/95	0.38215	0.00027	0.38162-0.38268	0.38145-0.38286
44	76	303084	0.3821	0.0003	0.3821	0.0011	0.3820	0.0004	95/95/95	0.38218	0.00027	0.38164-0.38272	0.38146-0.38290
46	74	295066	0.3822	0.0003	0.3822	0.0011	0.3821	0.0004	95/95/95	0.38223	0.00027	0.38168-0.38277	0.38150-0.38295
48	72	287052	0.3822	0.0003	0.3823	0.0011	0.3821	0.0004	95/95/95	0.38224	0.00028	0.38169-0.38279	0.38151-0.38297
50	70	279159	0.3822	0.0003	0.3824	0.0011	0.3821	0.0004	95/95/95	0.38228	0.00028	0.38172-0.38285	0.38153-0.38303
52	68	271184	0.3822	0.0003	0.3822	0.0012	0.3821	0.0004	95/95/95	0.38230	0.00029	0.38172-0.38287	0.38153-0.38306
54	66	263290	0.3822	0.0003	0.3824	0.0012	0.3821	0.0004	95/95/95	0.38232	0.00029	0.38173-0.38290	0.38154-0.38309
56	64	255304	0.3821	0.0003	0.3826	0.0012	0.3820	0.0004	95/95/95	0.38226	0.00030	0.38166-0.38286	0.38146-0.38305
58	62	247328	0.3821	0.0003	0.3828	0.0012	0.3820	0.0004	95/95/95	0.38230	0.00030	0.38170-0.38291	0.38150-0.38311
60	60	239321	0.3822	0.0003	0.3831	0.0013	0.3820	0.0004	95/95/95	0.38243	0.00030	0.38182-0.38303	0.38162-0.38323
62	58	231225	0.3821	0.0003	0.3834	0.0013	0.3819	0.0004	95/95/95	0.38239	0.00031	0.38177-0.38301	0.38157-0.38321
64	56	223252	0.3821	0.0004	0.3833	0.0013	0.3819	0.0004	95/95/95	0.38233	0.00031	0.38172-0.38295	0.38151-0.38315
66	54	215338	0.3820	0.0004	0.3831	0.0014	0.3819	0.0004	95/95/99	0.38230	0.00032	0.38166-0.38294	0.38145-0.38315
68	52	207291	0.3819	0.0004	0.3834	0.0014	0.3817	0.0004	95/95/99	0.38221	0.00033	0.38155-0.38287	0.38134-0.38309
70	50	199566	0.3820	0.0004	0.3834	0.0014	0.3819	0.0004	95/95/95	0.38230	0.00031	0.38167-0.38294	0.38146-0.38315
72	48	191467	0.3821	0.0004	0.3832	0.0015	0.3820	0.0004	95/95/95	0.38238	0.00032	0.38173-0.38303	0.38151-0.38324
74	46	183546	0.3821	0.0004	0.3824	0.0014	0.3820	0.0004	95/95/95	0.38226	0.00032	0.38162-0.38291	0.38140-0.38312
76	44	175558	0.3821	0.0004	0.3826	0.0015	0.3820	0.0005	95/95/95	0.38226	0.00033	0.38160-0.38293	0.38137-0.38316
78	42	167532	0.3822	0.0004	0.3826	0.0015	0.3821	0.0005	95/95/95	0.38234	0.00034	0.38166-0.38301	0.38143-0.38324
80	40	159575	0.3823	0.0004	0.3831	0.0015	0.3822	0.0005	95/95/95	0.38243	0.00034	0.38174-0.38312	0.38151-0.38336
82	38	151571	0.3821	0.0004	0.3834	0.0016	0.3821	0.0005	95/95/95	0.38231	0.00035	0.38160-0.38302	0.38136-0.38327
84	36	143576	0.3821	0.0004	0.3839	0.0017	0.3820	0.0005	95/95/95	0.38241	0.00036	0.38168-0.38314	0.38142-0.38339
86	34	135824	0.3823	0.0005	0.3836	0.0018	0.3823	0.0005	95/95/95	0.38248	0.00037	0.38172-0.38324	0.38146-0.38351
88	32	127808	0.3825	0.0005	0.3828	0.0017	0.3825	0.0005	95/95/95	0.38254	0.00039	0.38173-0.38334	0.38145-0.38362
90	30	119869	0.3825	0.0005	0.3824	0.0018	0.3825	0.0006	95/95/95	0.38242	0.00041	0.38157-0.38326	0.38128-0.38356
92	28	111977	0.3823	0.0005	0.3818	0.0018	0.3824	0.0006	95/95/95	0.38222	0.00041	0.38138-0.38305	0.38109-0.38335
94	26	103983	0.3822	0.0005	0.3821	0.0019	0.3823	0.0006	95/95/95	0.38216	0.00043	0.38127-0.38306	0.38095-0.38338
96	24	95911	0.3820	0.0005	0.3815	0.0020	0.3820	0.0006	95/95/95	0.38193	0.00042	0.38105-0.38281	0.38073-0.38313
98	22	88013	0.3822	0.0005	0.3812	0.0021	0.3822	0.0006	95/95/95	0.38202	0.00044	0.38110-0.38293	0.38077-0.38327
100	20	80082	0.3821	0.0006	0.3814	0.0020	0.3821	0.0006	95/95/95	0.38201	0.00048	0.38101-0.38301	0.38063-0.38339
102	18	72223	0.3822	0.0005	0.3809	0.0022	0.3823	0.0006	95/95/95	0.38199	0.00049	0.38095-0.38304	0.38055-0.38343
104	16	64337	0.3823	0.0006	0.3809	0.0024	0.3825	0.0006	95/95/95	0.38191	0.00061	0.38059-0.38322	0.38007-0.38374
106	14	56265	0.3821	0.0007	0.3817	0.0026	0.3823	0.0007	95/95/95	0.38189	0.00067	0.38042-0.38337	0.37981-0.38398
108	12	48351	0.3822	0.0007	0.3832	0.0022	0.3825	0.0008	95/95/95	0.38225	0.00089	0.38024-0.38426	0.37936-0.38514
110	10	40287	0.3827	0.0008	0.3827	0.0025	0.3831	0.0008	95/95/95	0.38280	0.00093	0.38061-0.38500	0.37956-0.38605
112	8	32139	0.3822	0.0008	0.3843	0.0026	0.3826	0.0009	95/95/95	0.38228	0.00153	0.37834-0.38622	0.37610-0.38846
114	6	24152	0.3822	0.0007	0.3827	0.0028	0.3827	0.0008	95/95/95	0.38168	0.00094	0.37869-0.38468	0.37619-0.38718
116	4	16048	0.3821	0.0011	0.3803	0.0031	0.3826	0.0013	95/95/95	0.38206	0.00113	0.36771-0.39640	0.31021-0.45390
117	3	11989	0.3833	0.0004	0.3776	0.0024	0.3838	0.0006					
118	2	7963	0.3835	0.0005	0.3752	0.0003	0.3842	0.0008					

the minimum estimated standard deviation for the col/abs/tl keff estimator occurs with 11 inactive cycles and 109 active cycles.

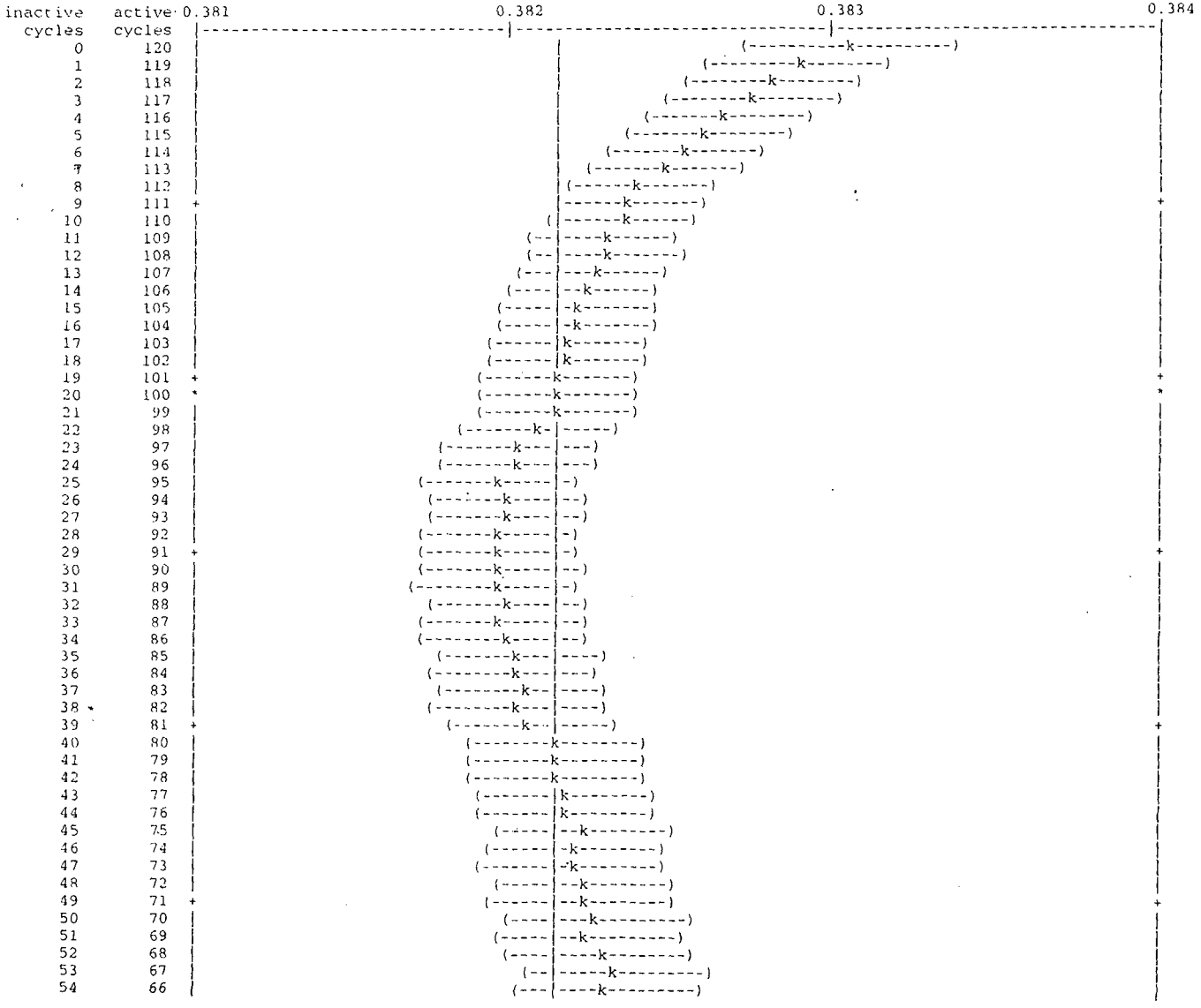
the first active half of the problem skips 20 cycles and uses 50 active cycles; the second half skips 70 and uses 50 cycles.
the col/abs/trk-len keff, one standard deviation, and 68, 95, and 99 percent intervals for each active half of the problem are:

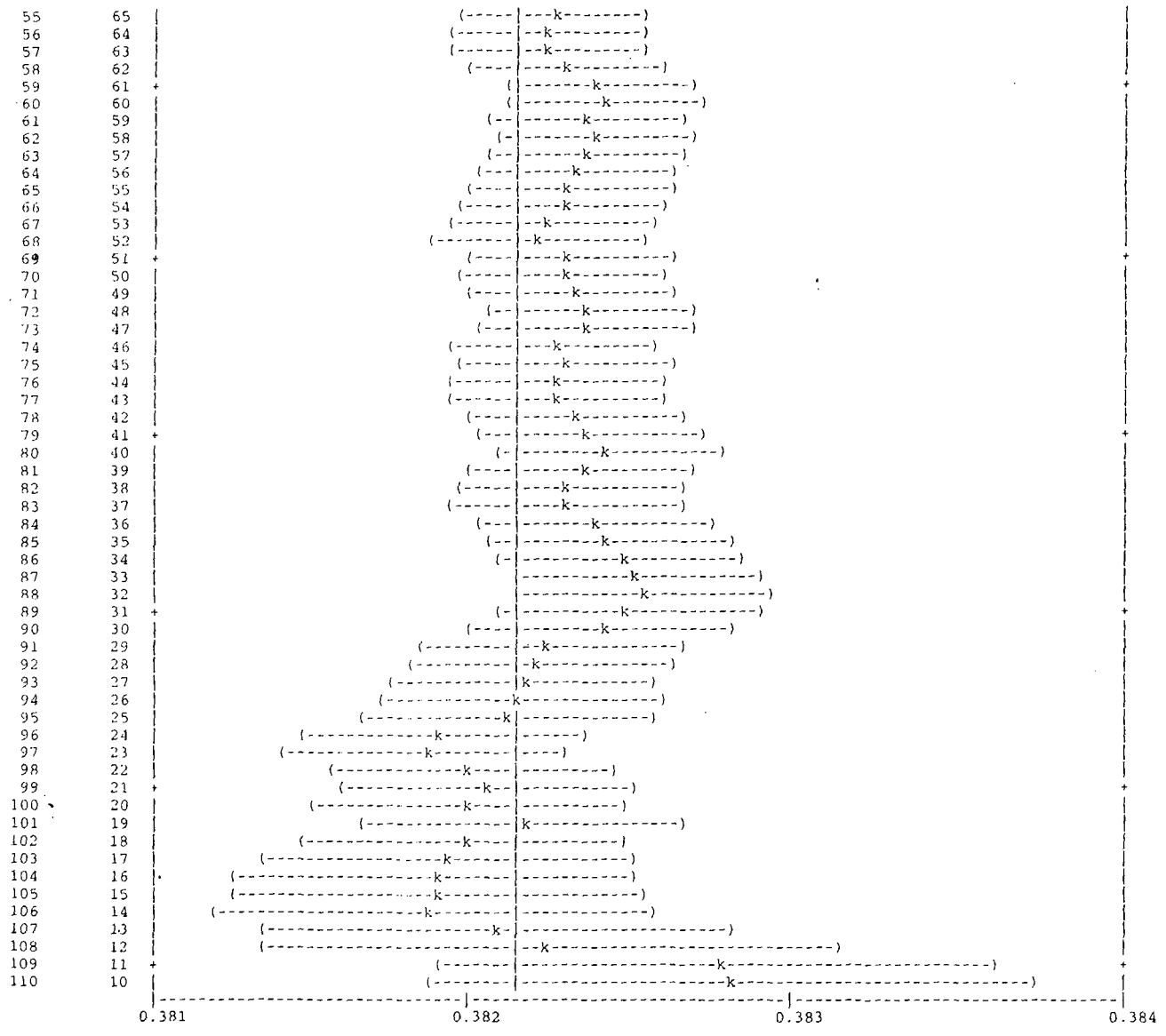
problem	keff	standard deviation	68% confidence	95% confidence	99% confidence
first half	0.38214	0.00035	0.38179 to 0.38250	0.38143 to 0.38286	0.38119 to 0.38309
second half	0.38230	0.00031	0.38199 to 0.38262	0.38167 to 0.38294	0.38146 to 0.38315

final result	0.38216	0.00024	0.38191 to 0.38240	0.38167 to 0.38264	0.38151 to 0.38280

the first and second half values of k(collision/absorption/track length) appear to be the same at the 68 percent confidence level.

plot of the estimated col/abs/track-length keff one standard deviation interval by active cycle number (| = final keff = 0.38216)





dump no. 4 on file 10d1r nps = 476456 coll = 59512804 ctm = 41.97 nrn = 1076007760

1 warning message so far.

run terminated when 120 kcode cycles were done.

computer time = 41.98 minutes

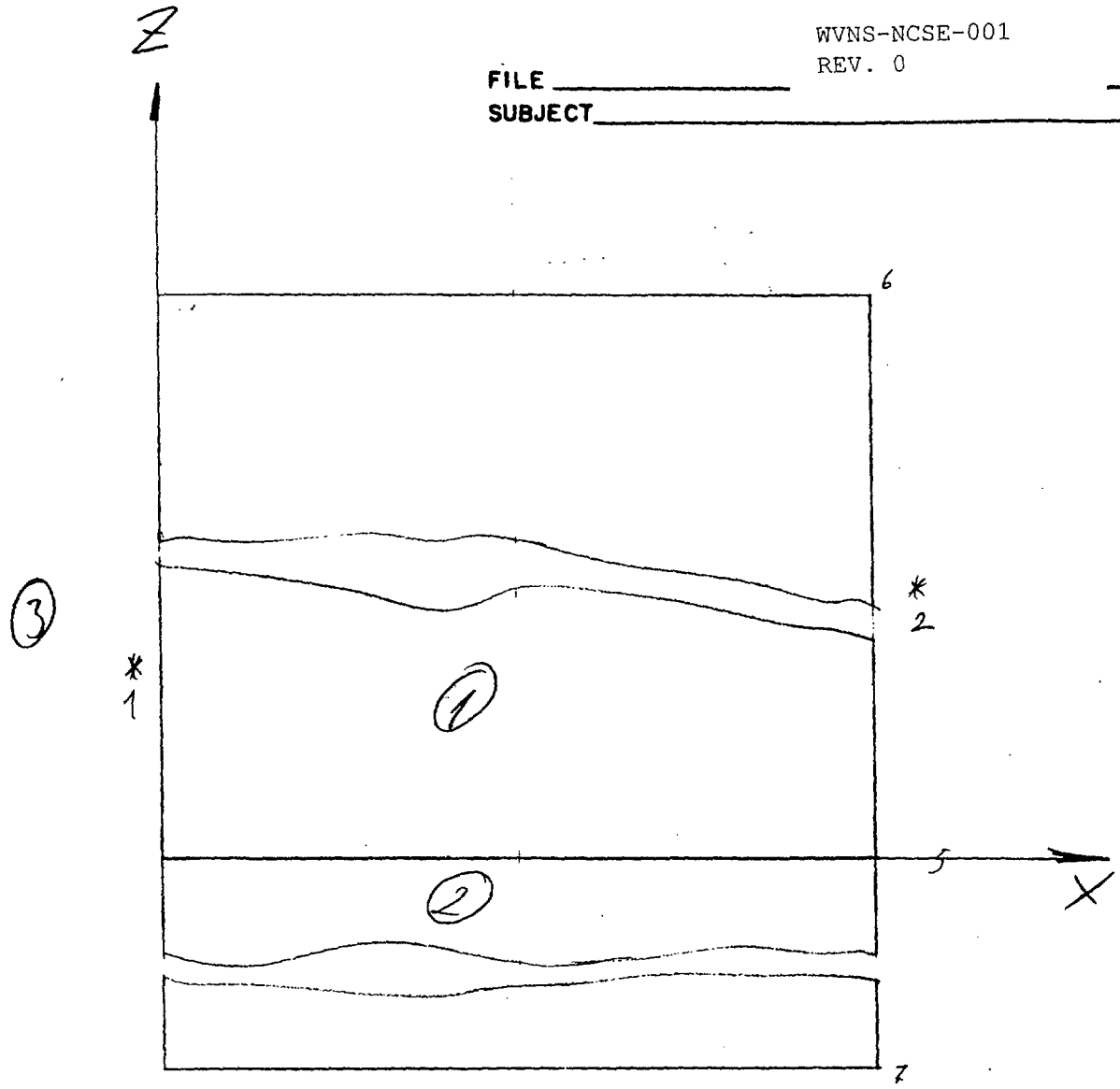
mcnp version 4a 10/01/93 09/14/00 05:29:09 probid = 09/14/00 04:47:10

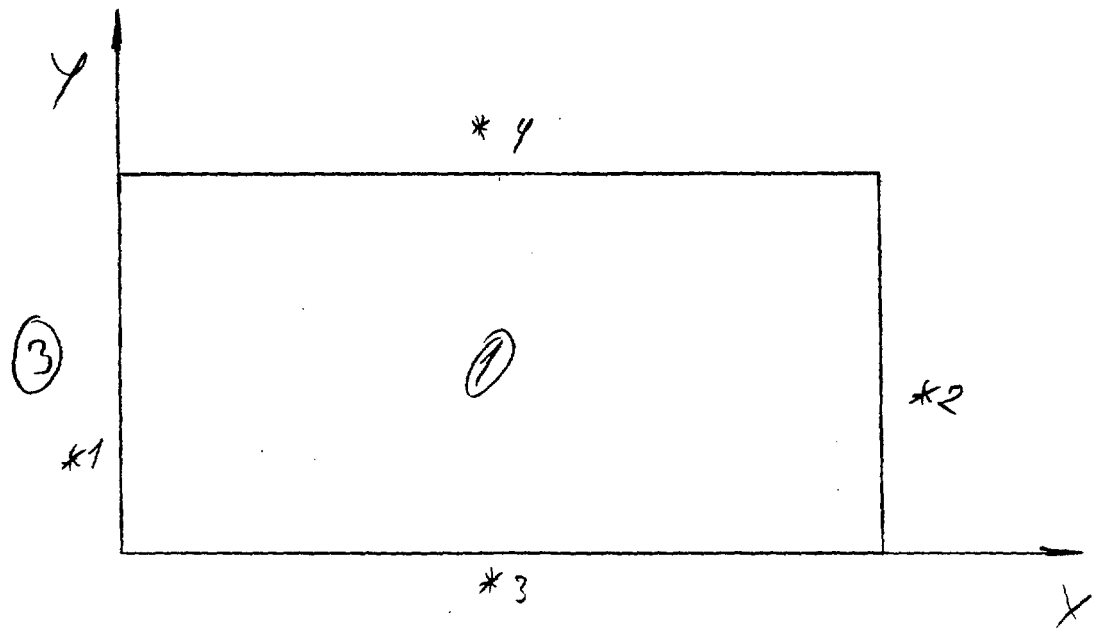
Attachment 4: Case 2 with MCNP surface and cell numbers

FILE _____

SUBJECT _____

REVISIONS
BY _____ DATE _____ TO EO ____
BY _____ DATE _____ TO EO ____





BY _____ DATE _____
CHECKED BY _____
COPY TO EO _____

Dames & Moore

Attachment 5: Case 2 MCNP input file

```
                                                                    10b1
k eff, 350g Pu-239 in concrete matrix in TRU-waste box.
C
C Cell cards
C
C ---------------------------------------------------------------------
1 1   8.1776e-2  1 -2 3 -4 5 -6 imp:n=1 $ TRU box with concrete-Pu-239 mix
2 2  -2.3       1 -2 3 -4 -5 7 imp:n=1 $ Concrete floor
3 0  -1 : 2 : -3 : 4 : -7 : 6 imp:n=0 $ Outside world
C ---------------------------------------------------------------------
c
c Note: next line must be completely blank

c Surface cards
C ---------------------------------------------------------------------
*1 px 0
*2 px 172.72
*3 py 0
*4 py 137.16
5 pz 0
6 pz 350.52
7 pz -300
C ---------------------------------------------------------------------
c
c Note: next line must be completely blank

c Data cards
c
c Materials
c
c
c Pu-239 in concrete matrix (Elements: H, O, Na, Si, Al, Ca, Fe, Pu-239)
m1     11023.50c  1.7471e-3
       13027.50c  1.7453e-3
       14000.50c  1.6619e-2
       20000.50c  1.5206e-3
       26000.55c  3.4722e-4
        1001.50c  1.3741e-2
        8016.50c  4.6055e-2
       94239.55c  4.2471e-7
c Concrete (KENO Regular Concrete Standard Mix) from Harmon at al.
c Criticality Calculation with MCNP. A Primer. p. C-4
c (Elements: H, O, Na, Si, Al, Ca, Fe)
m2      1001.50c -0.010
        8016.50c -0.532
       11023.50c -0.029
       13027.50c -0.034
       14000.50c -0.337
       20000.50c -0.044
       26000.55c -0.014
c
mode n
print 40 60 80 100 110 126
kcode 4000 1. 20 120
ksrc  86 68 175
```

Attachment 6: Case 2 MCNP output file

```
lmcnp     version 4a     ld=10/01/93                    09/14/00 15:01:29
 ***********************************************************************          probid =    09/14/00 15:01:29
 name=10b1

    1-       k eff, 350g Pu-239 in concrete matrix in TRU-waste box.
    2-       C
    3-       C Cell cards
    4-       C
    5-       C -------------------------------------------------------------------------
    6-       1 1   8.1776e-2  1 -2 3 -4 5 -6 imp:n=1 $ TRU box with concrete-Pu-239 mix
    7-       2 2  -2.3       1 -2 3 -4 -5 7 imp:n=1 $ Concrete floor
    8-       3 0  -1 : 2 : -3 : 4 : -7 : 6 imp:n=0 $ Outside world
    9-       C -------------------------------------------------------------------------
   10-       c
   11-       c Note: next line must be completely blank
   12-
   13-       c Surface cards
   14-       C -------------------------------------------------------------------------
   15-       *1 px 0
   16-       *2 px 172.72
   17-       *3 py 0
   18-       *4 py 137.16
   19-       5 pz 0
   20-       6 pz 350.52
   21-       7 pz -300
   22-       C -------------------------------------------------------------------------
   23-       c
   24-       c Note: next line must be completely blank
   25-
   26-       c Data cards
   27-       c
   28-       c Materials
   29-       c
   30-       c
   31-       c Pu-239 in concrete matrix (Elements: H, O, Na, Si, Al, Ca, Fe, Pu-239)
   32-       m1     11023.50c  1.7471e-3
   33                13027.50c  1.7453e-3
   34-               14000.50c  1.6619e-2
   35-               20000.50c  1.5206e-3
   36-               26000.55c  3.4722e-4
   37-                1001.50c  1.3741e-2
   38-                8016.50c  4.6055e-2
   39-               94239.55c  4.2471e-7
   40-       c Concrete (KENO Regular Concrete Standard Mix) from Harmon at al.
   41-       c Criticality Calculation with MCNP. A Primer. p. C-4
   42-       c (Elements: H, O, Na, Si, Al, Ca, Fe)
   43-       m2      1001.50c -0.010
   44-                8016.50c -0.532
   45-               11023.50c -0.029
   46-               13027.50c -0.034
   47-               14000.50c -0.337
   48-               20000.50c -0.044
   49-               26000.55c -0.014
   50-       c
   51-       mode n
   52-       print 40 60 80 100 110 126
   53-       kcode 4000 1. 20 120
   54-       ksrc  86 68 175
```

material
 number component nuclide, atom fraction

1	11023,	0.02136	13027,	0.02134	14000,	0.20323	20000,	0.01859
	26000,	0.00425	1001,	0.16803	8016,	0.56319	94239,	0.00001
2	1001,	0.16803	8016,	0.56324	11023,	0.02136	13027,	0.02134
	14000,	0.20319	20000,	0.01859	26000,	0.00425		

material
 number component nuclide, mass fraction

1	11023,	0.02900	13027,	0.03400	14000,	0.33702	20000,	0.04400
	26000,	0.01400	1001,	0.01000	8016,	0.53190	94239,	0.00007
2	1001,	0.01000	8016,	0.53200	11023,	0.02900	13027,	0.03400
	14000,	0.33700	20000,	0.04400	26000,	0.01400		

lcells print table 60

cell	mat	atom density	gram density	volume	mass	pieces	neutron importance
1	1	8.17760E-02	2.29979E+00	8.30392E+06	1.90973E+07	0	1.0000E+00
2	2	8.17913E-02	2.30000E+00	7.10708E+06	1.63463E+07	0	1.0000E+00
3	0	0.00000E+00	0.00000E+00	0.00000E+00	0.00000E+00	0	0.0000E+00

total 1.54110E+07 3.54436E+07

lcross-section tables print table 100

table	length				
tables from file critxs					
1001.50c	1153	njoy		(1301)	79/07/31.
8016.50c	23669	njoy		(1276)	05/14/81
11023.50c	36270	njoy		(1311)	79/06/21.
13027.50c	22891	njoy		(1313)	79/09/08.
14000.50c	48275	njoy		(1314)	79/06/21.
20000.50c	26104	njoy		(1320)	79/06/22.
26000.55c	84136	njoy		(260)	10/21/82
94239.55c	67551	njoy	total nu	(1399)	02/21/85
total	310049				

warning. neutron energy cutoff is below some cross-section tables.

decimal words of dynamically allocated storage

general	108656
tallies	0
bank	6403
cross sections	310049
total	425108

dump no. 1 on file 10blr nps = 0 coll = 0 ctm = 0.00 nrn = 0

source distribution written to file 10bls cycle = 0

1 warning message so far.

1 starting mcrun. field length = 0 cp0 = 0.01 print table 110

k eff, 350g Pu-239 in concrete matrix in TRU-waste box.

nps	x	y	z	cell	surf	u	v	w	energy	weight	time
1	8.600E+01	6.800E+01	1.750E+02	1	0	5.085E-01	4.733E-01	7.193E-01	2.209E+00	1.000E+00	0.000E+00
2	8.600E+01	6.800E+01	1.750E+02	1	0	8.952E-01	-4.447E-01	-2.944E-02	4.904E+00	1.000E+00	0.000E+00
3	8.600E+01	6.800E+01	1.750E+02	1	0	-6.184E-01	-4.495E-01	6.446E-01	3.809E-01	1.000E+00	0.000E+00
4	8.600E+01	6.800E+01	1.750E+02	1	0	9.710E-01	-5.665E-02	-2.323E-01	1.331E+00	1.000E+00	0.000E+00
5	8.600E+01	6.800E+01	1.750E+02	1	0	5.861E-01	1.496E-01	-7.963E-01	1.902E+00	1.000E+00	0.000E+00
6	8.600E+01	6.800E+01	1.750E+02	1	0	-6.489E-02	-1.626E-01	9.845E-01	4.410E-01	1.000E+00	0.000E+00
7	8.600E+01	6.800E+01	1.750E+02	1	0	-7.068E-02	3.263E-02	-9.970E-01	4.750E-01	1.000E+00	0.000E+00
8	8.600E+01	6.800E+01	1.750E+02	1	0	-3.915E-01	4.664E-01	-7.932E-01	4.136E+00	1.000E+00	0.000E+00
9	8.600E+01	6.800E+01	1.750E+02	1	0	-2.368E-01	9.215E-01	-3.079E-01	7.453E-02	1.000E+00	0.000E+00
10	8.600E+01	6.800E+01	1.750E+02	1	0	1.946E-01	-3.204E-01	9.271E-01	3.128E+00	1.000E+00	0.000E+00
11	8.600E+01	6.800E+01	1.750E+02	1	0	-6.698E-01	-7.177E-01	-1.905E-01	1.014E+00	1.000E+00	0.000E+00
12	8.600E+01	6.800E+01	1.750E+02	1	0	-8.398E-01	-4.129E-01	3.524E-01	1.395E+00	1.000E+00	0.000E+00
13	8.600E+01	6.800E+01	1.750E+02	1	0	-1.714E-01	-8.572E-01	4.857E-01	7.748E-01	1.000E+00	0.000E+00
14	8.600E+01	6.800E+01	1.750E+02	1	0	-2.489E-01	-5.118E-01	-8.222E-01	1.101E+00	1.000E+00	0.000E+00
15	8.600E+01	6.800E+01	1.750E+02	1	0	-2.959E-01	2.119E-01	9.314E-01	1.951E+00	1.000E+00	0.000E+00
16	8.600E+01	6.800E+01	1.750E+02	1	0	1.395E-01	-9.829E-01	1.202E-01	2.186E+00	1.000E+00	0.000E+00
17	8.600E+01	6.800E+01	1.750E+02	1	0	6.909E-01	-7.110E-01	1.307E-01	1.865E+00	1.000E+00	0.000E+00
18	8.600E+01	6.800E+01	1.750E+02	1	0	-6.580E-01	5.320E-01	-5.329E-01	1.229E+00	1.000E+00	0.000E+00
19	8.600E+01	6.800E+01	1.750E+02	1	0	-9.903E-01	-1.380E-01	1.353E-02	1.305E+00	1.000E+00	0.000E+00
20	8.600E+01	6.800E+01	1.750E+02	1	0	7.462E-01	4.859E-01	-4.551E-01	1.000E+00	1.000E+00	0.000E+00
21	8.600E+01	6.800E+01	1.750E+02	1	0	-1.977E-01	9.797E-01	3.360E-02	3.990E+00	1.000E+00	0.000E+00
22	8.600E+01	6.800E+01	1.750E+02	1	0	-9.117E-01	-3.647E-01	-1.891E-01	2.665E-01	1.000E+00	0.000E+00
23	8.600E+01	6.800E+01	1.750E+02	1	0	-4.287E-01	8.361E-01	-3.423E-01	1.156E+00	1.000E+00	0.000E+00
24	8.600E+01	6.800E+01	1.750E+02	1	0	1.080E-01	3.412E-01	-9.338E-01	2.669E+00	1.000E+00	0.000E+00
25	8.600E+01	6.800E+01	1.750E+02	1	0	-9.111E-01	-9.012E-03	-4.122E-01	2.185E+00	1.000E+00	0.000E+00
26	8.600E+01	6.800E+01	1.750E+02	1	0	-2.568E-01	-6.391E-01	-7.249E-01	4.225E+00	1.000E+00	0.000E+00
27	8.600E+01	6.800E+01	1.750E+02	1	0	-2.912E-01	8.086E-01	5.113E-01	1.079E+00	1.000E+00	0.000E+00
28	8.600E+01	6.800E+01	1.750E+02	1	0	1.472E-01	-9.514E-01	2.705E-01	3.461E+00	1.000E+00	0.000E+00
29	8.600E+01	6.800E+01	1.750E+02	1	0	-6.135E-01	-7.645E-01	-1.978E-01	1.836E+00	1.000E+00	0.000E+00
30	8.600E+01	6.800E+01	1.750E+02	1	0	-5.702E-01	5.651E-01	-5.963E-01	4.556E-01	1.000E+00	0.000E+00
31	8.600E+01	6.800E+01	1.750E+02	1	0	-6.607E-01	5.373E-01	-5.242E-01	6.415E-01	1.000E+00	0.000E+00
32	8.600E+01	6.800E+01	1.750E+02	1	0	-9.742E-02	-3.639E-01	-9.263E-01	2.764E+00	1.000E+00	0.000E+00
33	8.600E+01	6.800E+01	1.750E+02	1	0	-1.965E-01	-3.145E-01	-9.287E-01	2.785E-01	1.000E+00	0.000E+00
34	8.600E+01	6.800E+01	1.750E+02	1	0	4.097E-01	8.465E-01	-3.399E-01	9.097E-01	1.000E+00	0.000E+00
35	8.600E+01	6.800E+01	1.750E+02	1	0	-4.048E-02	8.831E-01	4.675E-01	3.360E-01	1.000E+00	0.000E+00
36	8.600E+01	6.800E+01	1.750E+02	1	0	3.371E-01	-9.269E-01	-1.652E-01	6.376E-01	1.000E+00	0.000E+00
37	8.600E+01	6.800E+01	1.750E+02	1	0	-1.867E-01	9.756E-01	-1.155E-01	2.186E+00	1.000E+00	0.000E+00
38	8.600E+01	6.800E+01	1.750E+02	1	0	-2.616E-01	2.336E-01	-9.365E-01	7.314E-01	1.000E+00	0.000E+00
39	8.600E+01	6.800E+01	1.750E+02	1	0	9.780E-01	-7.641E-02	-1.939E-01	2.997E-01	1.000E+00	0.000E+00
40	8.600E+01	6.800E+01	1.750E+02	1	0	2.580E-01	-7.076E-01	6.578E-01	1.444E+00	1.000E+00	0.000E+00
41	8.600E+01	6.800E+01	1.750E+02	1	0	-3.212E-01	-7.678E-01	-5.543E-01	1.914E+00	1.000E+00	0.000E+00
42	8.600E+01	6.800E+01	1.750E+02	1	0	5.039E-01	-1.460E-01	8.513E-01	1.502E+00	1.000E+00	0.000E+00
43	8.600E+01	6.800E+01	1.750E+02	1	0	6.080E-01	5.487E-01	5.738E-01	5.971E+00	1.000E+00	0.000E+00
44	8.600E+01	6.800E+01	1.750E+02	1	0	-2.932E-01	9.304E-01	-2.199E-01	1.827E+00	1.000E+00	0.000E+00
45	8.600E+01	6.800E+01	1.750E+02	1	0	-8.475E-01	-3.993E-01	-3.497E-01	1.928E+00	1.000E+00	0.000E+00
46	8.600E+01	6.800E+01	1.750E+02	1	0	1.200E-01	-9.195E-01	-3.743E-01	1.351E+00	1.000E+00	0.000E+00
47	8.600E+01	6.800E+01	1.750E+02	1	0	7.085E-01	5.879E-01	3.904E-01	2.288E+00	1.000E+00	0.000E+00
48	8.600E+01	6.800E+01	1.750E+02	1	0	4.261E-01	9.046E-01	9.254E-03	1.230E+00	1.000E+00	0.000E+00
49	8.600E+01	6.800E+01	1.750E+02	1	0	5.431E-01	4.270E-01	-7.230E-01	1.433E+00	1.000E+00	0.000E+00

```
    50  8.600E+01  6.800E+01  1.750E+02     1      0 -1.053E-01 -9.805E-01  1.658E-01  6.572E-01  1.000E+00  0.000E+00
estimated keff results by cycle                                                                              print table 175

 source distribution written to file 10b1s          cycle =    20

 source distribution written to file 10b1s          cycle =    23

 source distribution written to file 10b1s          cycle =    26

 source distribution written to file 10b1s          cycle =    29

 source distribution written to file 10b1s          cycle =    32

 ************************************************************************************************************
 dump no.    2 on file 10b1r        nps =    128597     coll =       21450846     ctm =   15.18     nrn =      393931077

 source distribution written to file 10b1s          cycle =    35

 source distribution written to file 10b1s          cycle =    38

 source distribution written to file 10b1s          cycle =    41

 source distribution written to file 10b1s          cycle =    44

 source distribution written to file 10b1s          cycle =    47

 source distribution written to file 10b1s          cycle =    50

 source distribution written to file 10b1s          cycle =    53

 source distribution written to file 10b1s          cycle =    56

 source distribution written to file 10b1s          cycle =    59

 source distribution written to file 10b1s          cycle =    62

 source distribution written to file 10b1s          cycle =    65

 ************************************************************************************************************
 dump no.    3 on file 10b1r        nps =    255993     coll =       42658625     ctm =   30.18     nrn =      783210319

 source distribution written to file 10b1s          cycle =    68

 source distribution written to file 10b1s          cycle =    71

 source distribution written to file 10b1s          cycle =    74

 source distribution written to file 10b1s          cycle =    77

 source distribution written to file 10b1s          cycle =    80

 source distribution written to file 10b1s          cycle =    83

 source distribution written to file 10b1s          cycle =    86

 source distribution written to file 10b1s          cycle =    89

 source distribution written to file 10b1s          cycle =    92

 source distribution written to file 10b1s          cycle =    95
```

dump no. 4 on file 10b1r nps = 384175 coll = 63957787 ctm = 45.50 nrn = 1174177290

source distribution written to file 10b1s cycle = 98

estimator	cycle 100	ave of 80 cycles	combination	simple average	combined average	corr
k(collision)	0.093539	0.093356 0.0007	k(col/abs)	0.093364 0.0031	0.093357 0.0007	-0.1362
k(absorption)	0.092453	0.093372 0.0063	k(abs/tk ln)	0.093363 0.0031	0.093354 0.0007	-0.0983
k(trk length)	0.093482	0.093353 0.0007	k(tk ln/col)	0.093355 0.0007	0.093355 0.0007	0.9747
rem life(col)	4.1641E+04	4.1586E+04 0.0022	k(col/abs/tk ln)	0.093361 0.0021	0.093356 0.0007	
rem life(abs)	4.1663E+04	4.1580E+04 0.0022	life(col/abs)	4.1583E+04 0.0022	4.1580E+04 0.0022	0.9768

source points generated 4022

source distribution written to file 10b1s cycle = 101

source distribution written to file 10b1s cycle = 104

source distribution written to file 10b1s cycle = 107

source distribution written to file 10b1s cycle = 110

source distribution written to file 10b1s cycle = 113

estimator	cycle 116	ave of 96 cycles	combination	simple average	combined average	corr
k(collision)	0.094439	0.093374 0.0007	k(col/abs)	0.093238 0.0028	0.093365 0.0007	-0.1638
k(absorption)	0.085197	0.093102 0.0058	k(abs/tk ln)	0.093236 0.0029	0.093362 0.0007	-0.1527
k(trk length)	0.094713	0.093370 0.0007	k(tk ln/col)	0.093372 0.0007	0.093372 0.0007	0.9728
rem life(col)	4.3254E+04	4.1637E+04 0.0020	k(col/abs/tk ln)	0.093282 0.0019	0.093363 0.0007	
rem life(abs)	4.2792E+04	4.1626E+04 0.0020	life(col/abs)	4.1631E+04 0.0020	4.1624E+04 0.0020	0.9777

source points generated 3933

source distribution written to file 10b1s cycle = 116

estimator	cycle 117	ave of 97 cycles	combination	simple average	combined average	corr
k(collision)	0.093632	0.093377 0.0007	k(col/abs)	0.093249 0.0028	0.093368 0.0007	-0.1620
k(absorption)	0.095010	0.093122 0.0057	k(abs/tk ln)	0.093247 0.0028	0.093364 0.0007	-0.1518
k(trk length)	0.093494	0.093372 0.0007	k(tk ln/col)	0.093374 0.0007	0.093373 0.0007	0.9726
rem life(col)	4.2456E+04	4.1645E+04 0.0020	k(col/abs/tk ln)	0.093290 0.0019	0.093366 0.0007	
rem life(abs)	4.2282E+04	4.1632E+04 0.0020	life(col/abs)	4.1639E+04 0.0020	4.1630E+04 0.0020	0.9778

source points generated 3932

estimator	cycle 118	ave of 98 cycles	combination	simple average	combined average	corr
k(collision)	0.094094	0.093384 0.0007	k(col/abs)	0.093247 0.0028	0.093375 0.0007	-0.1634
k(absorption)	0.092025	0.093111 0.0057	k(abs/tk ln)	0.093244 0.0028	0.093369 0.0007	-0.1531
k(trk length)	0.093959	0.093378 0.0007	k(tk ln/col)	0.093381 0.0007	0.093380 0.0007	0.9727
rem life(col)	4.2281E+04	4.1652E+04 0.0020	k(col/abs/tk ln)	0.093291 0.0019	0.093371 0.0007	
rem life(abs)	4.2173E+04	4.1638E+04 0.0020	life(col/abs)	4.1645E+04 0.0020	4.1635E+04 0.0020	0.9778

source points generated 3921

estimator	cycle 119	ave of 99 cycles	combination	simple average	combined average	corr
k(collision)	0.093523	0.093385 0.0007	k(col/abs)	0.093240 0.0028	0.093376 0.0007	-0.1639
k(absorption)	0.091492	0.093094 0.0056	k(abs/tk ln)	0.093237 0.0028	0.093371 0.0007	-0.1541
k(trk length)	0.093622	0.093380 0.0007	k(tk ln/col)	0.093383 0.0007	0.093382 0.0007	0.9725
rem life(col)	4.2002E+04	4.1655E+04 0.0020	k(col/abs/tk ln)	0.093287 0.0018	0.093373 0.0007	
rem life(abs)	4.1861E+04	4.1640E+04 0.0019	life(col/abs)	4.1648E+04 0.0020	4.1637E+04 0.0020	0.9778

source points generated 3924

source distribution written to file 10b1s cycle = 119

estimator	cycle 120	ave of 100 cycles	combination	simple average	combined average	corr

k(collision)	0.092316	0.093375	0.0007	k(col/abs)	0.093232	0.0027	0.093365	0.0007	-0.1602
k(absorption)	0.092656	0.093090	0.0056	k(abs/tk ln)	0.093231	0.0027	0.093363	0.0007	-0.1516
k(trk length)	0.092527	0.093372	0.0007	k(tk ln/col)	0.093373	0.0007	0.093372	0.0007	0.9727
rem life(col)	4.0665E+04	4.1645E+04	0.0020	k(col/abs/tk ln)	0.093279	0.0018	0.093363	0.0007	
rem life(abs)	4.0564E+04	4.1629E+04	0.0019	life(col/abs)	4.1637E+04	0.0020	4.1626E+04	0.0020	0.9780

source points generated 3907

source distribution written to file 10b1s cycle = 120

1problem summary

run terminated when 120 kcode cycles were done.

09/14/00 15:57:47

k eff, 350g Pu-239 in concrete matrix in TRU-waste box. probid = 09/14/00 15:01:29

0

neutron creation	tracks	weight (per source particle)	energy	neutron loss	tracks	weight (per source particle)	energy
source	475712	1.0090E+00	2.1069E+00	escape	4608	6.7299E-03	3.3970E-03
				energy cutoff	0	0.	0.
				time cutoff	0	0.	0.
weight window	0	0.	0.	weight window	0	0.	0.
cell importance	0	0.	0.	cell importance	0	0.	0.
weight cutoff	0	2.1686E-01	7.3342E-05	weight cutoff	471106	2.1701E-01	6.8718E-05
energy importance	0	0.	0.	energy importance	0	0.	0.
dxtran	0	0.	0.	dxtran	0	0.	0.
forced collisions	0	0.	0.	forced collisions	0	0.	0.
exp. transform	0	0.	0.	exp. transform	0	0.	0.
upscattering	0	0.	6.4984E-07	downscattering	0	0.	2.0191E+00
				capture	0	9.6960E-01	8.4322E-02
(n,xn)	4	6.3663E-06	6.8787E-06	loss to (n,xn)	2	3.1831E-06	3.2872E-05
fission	0	0.	0.	loss to fission	0	3.2539E-02	4.1612E-05
total	475716	1.2259E+00	2.1070E+00	total	475716	1.2259E+00	2.1070E+00

number of neutrons banked	2	average lifetime, shakes	cutoffs
neutron tracks per source particle	1.0000E+00	escape 1.7769E+04	tco 1.0000E+34
neutron collisions per source particle	1.6653E+02	capture 4.1814E+04	eco 0.0000E+00
total neutron collisions	79219392	capture or escape 4.1653E+04	wc1 -5.0000E-01
net multiplication	1.0000E+00 0.0004	any termination 4.9867E+04	wc2 -2.5000E-01

computer time so far in this run	56.31 minutes	maximum number ever in bank	1
computer time in mcrun	56.30 minutes	bank overflows to backup file	0
source particles per minute	8.4497E+03	field length	0
random numbers generated	1454346371	most random numbers used was	19581 in history 43979

range of sampled source weights = 9.6061E-01 to 1.0256E+01

1neutron activity in each cell print table 126

cell		tracks entering	population	collisions	collisions * weight (per history)	number weighted energy	flux weighted energy	average track weight (relative)	average track mfp (cm)
1	1	488733	475714	78726439	9.8305E+01	7.2245E-05	2.8516E-01	6.3583E-01	2.2413E+00
2	2	16686	6552	492953	5.2520E-01	2.9661E-05	1.4616E-01	5.3150E-01	1.9693E+00
total		505419	482266	79219392	9.8831E+01				

1keff results for: k eff, 350g Pu-239 in concrete matrix in TRU-waste box. probid = 09/14/00 15:01:29

the initial fission neutron source distribution used the 1 source points that were input on the ksrc card.
the criticality problem was scheduled to skip 20 cycles and run a total of 120 cycles with nominally 4000 neutrons per cycle.
this problem has run 20 inactive cycles with 76841 neutron histories and 100 active cycles with 398871 neutron histories.

this calculation has completed the requested number of keff cycles using a total of 475712 fission neutron source histories.
all cells with fissionable material were sampled and had fission neutron source points.

the results of the w test for normality applied to the individual collision, absorption, and track-length keff cycle values are:

the k(collision) cycle values appear normally distributed at the 95 percent confidence level
the k(absorption) cycle values appear normally distributed at the 95 percent confidence level
the k(trk length) cycle values appear normally distributed at the 95 percent confidence level

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the final estimated combined collision/absorption/track-length keff = 0.09336 with an estimated standard deviation of 0.00006

the estimated 68, 95, & 99 percent keff confidence intervals are 0.09330 to 0.09342, 0.09324 to 0.09349, and 0.09320 to 0.09353

the estimated collision/absorption neutron removal lifetime = 4.16E-04 seconds with an estimated standard deviation of 8.12E-07

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the estimated average keffs, one standard deviations, and 68, 95, and 99 percent confidence intervals are:

keff estimator	keff	standard deviation	68% confidence	95% confidence	99% confidence	corr
collision	0.09337	0.00006	0.09331 to 0.09344	0.09325 to 0.09350	0.09321 to 0.09354	
absorption	0.09309	0.00052	0.09257 to 0.09361	0.09206 to 0.09412	0.09172 to 0.09445	
track length	0.09337	0.00006	0.09331 to 0.09343	0.09325 to 0.09350	0.09321 to 0.09354	
col/absorp	0.09337	0.00006	0.09330 to 0.09343	0.09324 to 0.09349	0.09320 to 0.09353	-0.1602
abs/trk len	0.09336	0.00006	0.09330 to 0.09342	0.09324 to 0.09348	0.09320 to 0.09352	-0.1516
col/trk len	0.09337	0.00006	0.09331 to 0.09344	0.09325 to 0.09350	0.09321 to 0.09354	0.9727
col/abs/trk len	0.09336	0.00006	0.09330 to 0.09342	0.09324 to 0.09349	0.09320 to 0.09353	

if the largest of each keff occurred on the next cycle, the keff results and 68, 95, and 99 percent confidence intervals would be:

keff estimator	keff	standard deviation	68% confidence	95% confidence	99% confidence
collision	0.09339	0.00007	0.09333 to 0.09346	0.09326 to 0.09352	0.09322 to 0.09356
absorption	0.09322	0.00053	0.09269 to 0.09374	0.09217 to 0.09427	0.09182 to 0.09461
track length	0.09339	0.00006	0.09332 to 0.09345	0.09326 to 0.09352	0.09322 to 0.09356
col/abs/trk len	0.09338	0.00006	0.09332 to 0.09345	0.09326 to 0.09351	0.09322 to 0.09355

the estimated collision/absorption neutron lifetimes, one standard deviations, and 68, 95, and 99 percent confidence intervals are:

type	lifetime(sec)	standard deviation	68% confidence	95% confidence	99% confidence
removal	4.1626E-04	8.1240E-07	4.1545E-04 to 4.1707E-04	4.1464E-04 to 4.1788E-04	4.1412E-04 to 4.1841E-04
capture	4.1810E-04	5.7919E-07	4.1752E-04 to 4.1868E-04	4.1695E-04 to 4.1926E-04	4.1657E-04 to 4.1963E-04
fission	4.0145E-04	5.5609E-07	4.0089E-04 to 4.0200E-04	4.0034E-04 to 4.0256E-04	3.9998E-04 to 4.0292E-04
escape	1.8057E-04	4.6350E-06	1.7593E-04 to 1.8521E-04	1.7133E-04 to 1.8980E-04	1.6832E-04 to 1.9281E-04

laverage individual and combined collision/absorption/track-length keff results for 7 different batch sizes

cycles per keff batch	number of k batches	average keff estimators and deviations k(col) st dev	k(abs) st dev	k(trk) st dev	normality co/ab/trk	average k(c/a/t) k(c/a/t) st dev	k(c/a/t) confidence intervals 95% confidence	99% confidence
1	100	0.0934 0.0001	0.0931 0.0005	0.0934 0.0001	95/95/95	0.09336 0.00006	0.09324-0.09349	0.09320-0.09353
2	50	0.0934 0.0001	0.0931 0.0005	0.0934 0.0001	95/95/95	0.09336 0.00006	0.09324-0.09349	0.09320-0.09353
4	25	0.0934 0.0001	0.0931 0.0005	0.0934 0.0001	95/95/95	0.09336 0.00007	0.09323-0.09350	0.09318-0.09355

5	20	0.0934 0.0001	0.0931 0.0003	0.0934 0.0001	95/95/95	0.09336 0.00006	0.09322-0.09349	0.09317-0.09354		
10	10	0.0934 0.0001	0.0931 0.0003	0.0934 0.0001	95/95/95	0.09334 0.00006	0.09319-0.09349	0.09312-0.09356		
20	5	0.0934 0.0001	0.0931 0.0005	0.0934 0.0001	95/95/95	0.09335 0.00004	0.09318-0.09353	0.09296-0.09375		
25	4	0.0934 0.0001	0.0931 0.0004	0.0934 0.0001	99/95/no	0.09334 0.00009	0.09222-0.09445	0.08777-0.09890		

1individual and average keff estimator results by cycle

keff cycle	neutron histories	keff estimators by cycle k(coll)	k(abs)	k(track)	average keff estimators and deviations k(coll)	st dev	k(abs)	st dev	k(track)	st dev	average k(c/a/t) k(c/a/t)	st dev	fom
1	4000	0.09398	0.09436	0.09404									
2	390	0.09383	0.08878	0.09414									
3	3950	0.09487	0.08816	0.09496									
4	4055	0.09521	0.09092	0.09529									
5	4164	0.09420	0.10151	0.09409									
6	3993	0.09428	0.09309	0.09439									
7	3995	0.09410	0.09860	0.09402									
8	4030	0.09472	0.08525	0.09498									
9	4150	0.09448	0.08433	0.09437									
10	4024	0.09442	0.10171	0.09450									
11	3958	0.09458	0.09523	0.09446									
12	4041	0.09432	0.09229	0.09430									
13	4041	0.09485	0.08782	0.09489									
14	4131	0.09404	0.09593	0.09415									
15	3995	0.09404	0.09539	0.09410									
16	4088	0.09377	0.08682	0.09383									
17	3844	0.09251	0.10562	0.09257									
18	3959	0.09219	0.09563	0.09234									
19	3990	0.09255	0.10573	0.09280									
20	4043	0.09405	0.09618	0.09396									
		begin active keff cycles											
21	4003	0.09407	0.08627	0.09390									
22	4028	0.09319	0.09109	0.09324	0.09363	0.00044	0.08868	0.00241	0.09357	0.00033			
23	3975	0.09311	0.09137	0.09306	0.09346	0.00031	0.08958	0.00166	0.09340	0.00025			
24	3908	0.09295	0.09442	0.09314	0.09333	0.00025	0.09079	0.00168	0.09333	0.00019	0.09287	0.00019	125064
25	4078	0.09297	0.09827	0.09307	0.09326	0.00021	0.09229	0.00198	0.09328	0.00016	0.09324	0.00015	168175
26	3997	0.09367	0.08978	0.09361	0.09333	0.00018	0.09187	0.00167	0.09334	0.00014	0.09327	0.00012	206065
27	3890	0.09370	0.09134	0.09376	0.09338	0.00016	0.09179	0.00142	0.09340	0.00013	0.09327	0.00014	137665
28	3935	0.09279	0.10549	0.09292	0.09331	0.00016	0.09350	0.00211	0.09334	0.00013	0.09336	0.00010	237122
29	4074	0.09387	0.09343	0.09387	0.09337	0.00015	0.09350	0.00186	0.09340	0.00013	0.09342	0.00011	176856
30	4056	0.09283	0.09632	0.09260	0.09332	0.00015	0.09378	0.00168	0.09332	0.00014	0.09334	0.00011	163353
31	3949	0.09388	0.08305	0.09379	0.09337	0.00014	0.09280	0.00181	0.09336	0.00013	0.09333	0.00010	183134
32	3996	0.09364	0.09460	0.09367	0.09339	0.00013	0.09295	0.00166	0.09339	0.00012	0.09336	0.00009	179507
33	3867	0.09429	0.09730	0.09408	0.09346	0.00014	0.09329	0.00156	0.09344	0.00013	0.09343	0.00012	104937
34	3965	0.09424	0.09061	0.09423	0.09351	0.00014	0.09310	0.00146	0.09350	0.00013	0.09347	0.00012	94432
35	3987	0.09322	0.08955	0.09321	0.09350	0.00013	0.09286	0.00138	0.09348	0.00012	0.09345	0.00011	95069
36	4019	0.09324	0.08554	0.09338	0.09348	0.00013	0.09240	0.00137	0.09347	0.00011	0.09343	0.00011	97782
37	3999	0.09272	0.09750	0.09271	0.09343	0.00013	0.09270	0.00132	0.09343	0.00012	0.09339	0.00011	96259
38	3971	0.09417	0.09363	0.09402	0.09348	0.00013	0.09275	0.00125	0.09346	0.00012	0.09342	0.00011	93038
39	4070	0.09368	0.10149	0.09360	0.09349	0.00012	0.09321	0.00126	0.09347	0.00011	0.09344	0.00010	94268
40	3936	0.09307	0.09842	0.09321	0.09347	0.00012	0.09347	0.00123	0.09345	0.00010	0.09344	0.00010	102098
41	4157	0.09331	0.09194	0.09311	0.09346	0.00011	0.09340	0.00117	0.09344	0.00010	0.09342	0.00010	97634
42	3880	0.09401	0.09912	0.09396	0.09348	0.00011	0.09366	0.00115	0.09346	0.00010	0.09345	0.00010	90533
43	3935	0.09291	0.09295	0.09289	0.09346	0.00011	0.09363	0.00109	0.09344	0.00010	0.09343	0.00010	87902
44	3895	0.09357	0.09007	0.09340	0.09346	0.00010	0.09348	0.00106	0.09343	0.00009	0.09342	0.00009	89567
45	4049	0.09347	0.10018	0.09373	0.09346	0.00010	0.09375	0.00105	0.09345	0.00009	0.09345	0.00009	90297
46	4020	0.09405	0.09655	0.09405	0.09349	0.00010	0.09386	0.00101	0.09347	0.00009	0.09348	0.00009	86141
47	3998	0.09357	0.09803	0.09349	0.09349	0.00009	0.09401	0.00099	0.09347	0.00009	0.09348	0.00009	88408
48	3950	0.09240	0.09800	0.09259	0.09345	0.00010	0.09415	0.00096	0.09344	0.00009	0.09345	0.00009	84743
49	3893	0.09291	0.09389	0.09309	0.09343	0.00010	0.09415	0.00093	0.09343	0.00009	0.09344	0.00009	88183

50	4067	0.09208	0.08748	0.09196	0.09339	0.00010	0.09392	0.00092	0.09338	0.00010	0.09338	0.00010	62569
51	3922	0.09346	0.09707	0.09350	0.09339	0.00010	0.09402	0.00090	0.09338	0.00009	0.09339	0.00010	64388
52	4047	0.09162	0.08442	0.09161	0.09333	0.00011	0.09372	0.00092	0.09333	0.00011	0.09332	0.00011	48250
53	3858	0.09309	0.09525	0.09316	0.09333	0.00011	0.09377	0.00089	0.09332	0.00010	0.09332	0.00011	49855
54	4004	0.09218	0.09344	0.09231	0.09329	0.00011	0.09376	0.00087	0.09329	0.00010	0.09329	0.00011	48083
55	3936	0.09338	0.09178	0.09334	0.09329	0.00011	0.09370	0.00084	0.09329	0.00010	0.09329	0.00010	49685
56	3999	0.09258	0.10594	0.09256	0.09327	0.00011	0.09404	0.00089	0.09327	0.00010	0.09328	0.00010	48235
57	3955	0.09375	0.08868	0.09378	0.09329	0.00010	0.09390	0.00088	0.09329	0.00010	0.09329	0.00010	49269
58	4030	0.09392	0.09641	0.09392	0.09330	0.00010	0.09396	0.00086	0.09330	0.00010	0.09331	0.00010	49005
59	4040	0.09248	0.10530	0.09273	0.09328	0.00010	0.09426	0.00088	0.09329	0.00010	0.09330	0.00010	49413
60	3980	0.09497	0.08659	0.09506	0.09333	0.00011	0.09406	0.00088	0.09333	0.00010	0.09335	0.00010	42911
61	4052	0.09298	0.09615	0.09296	0.09332	0.00011	0.09411	0.00086	0.09332	0.00010	0.09335	0.00010	43626
62	3917	0.09357	0.08372	0.09340	0.09332	0.00010	0.09387	0.00088	0.09333	0.00010	0.09334	0.00010	45109
63	4018	0.09371	0.09227	0.09362	0.09333	0.00010	0.09383	0.00086	0.09333	0.00010	0.09334	0.00010	46116
64	3967	0.09430	0.08672	0.09430	0.09335	0.00010	0.09367	0.00085	0.09335	0.00010	0.09336	0.00010	45925
65	3880	0.09238	0.10082	0.09232	0.09333	0.00010	0.09383	0.00085	0.09333	0.00010	0.09335	0.00010	45219
66	3984	0.09203	0.08678	0.09170	0.09330	0.00010	0.09367	0.00084	0.09330	0.00010	0.09332	0.00010	39656
67	3950	0.09344	0.09394	0.09334	0.09331	0.00010	0.09368	0.00083	0.09330	0.00010	0.09332	0.00010	40408
68	4088	0.09351	0.09027	0.09367	0.09331	0.00010	0.09361	0.00081	0.09330	0.00010	0.09332	0.00010	41617
69	3885	0.09375	0.09730	0.09378	0.09332	0.00010	0.09368	0.00080	0.09331	0.00010	0.09333	0.00010	41875
70	4012	0.09278	0.09948	0.09279	0.09331	0.00010	0.09380	0.00079	0.09330	0.00010	0.09333	0.00009	42370
71	3974	0.09246	0.09887	0.09256	0.09329	0.00010	0.09390	0.00078	0.09329	0.00009	0.09331	0.00009	42374
72	4021	0.09373	0.09253	0.09372	0.09330	0.00009	0.09387	0.00077	0.09330	0.00009	0.09332	0.00009	43010
73	4080	0.09377	0.08506	0.09373	0.09331	0.00009	0.09371	0.00077	0.09331	0.00009	0.09332	0.00009	44100
74	4054	0.09305	0.09175	0.09308	0.09331	0.00009	0.09367	0.00076	0.09330	0.00009	0.09332	0.00009	44820
75	3946	0.09228	0.09054	0.09238	0.09329	0.00009	0.09361	0.00074	0.09329	0.00009	0.09330	0.00009	43388
76	3897	0.09412	0.08829	0.09428	0.09330	0.00009	0.09352	0.00074	0.09330	0.00009	0.09331	0.00009	43513
77	4035	0.09301	0.09232	0.09292	0.09330	0.00009	0.09350	0.00072	0.09330	0.00009	0.09330	0.00009	44084
78	3968	0.09322	0.08652	0.09326	0.09329	0.00009	0.09338	0.00072	0.09330	0.00009	0.09330	0.00008	44734
79	4042	0.09380	0.09998	0.09406	0.09330	0.00009	0.09349	0.00072	0.09331	0.00009	0.09331	0.00008	44366
80	4093	0.09387	0.09591	0.09377	0.09331	0.00009	0.09353	0.00071	0.09332	0.00009	0.09332	0.00008	44437
81	4109	0.09421	0.09824	0.09391	0.09333	0.00009	0.09361	0.00070	0.09333	0.00008	0.09334	0.00008	43556
82	3925	0.09292	0.08637	0.09296	0.09332	0.00008	0.09349	0.00070	0.09332	0.00008	0.09333	0.00008	43792
83	3977	0.09334	0.09480	0.09349	0.09332	0.00008	0.09351	0.00069	0.09332	0.00008	0.09333	0.00008	44504
84	3987	0.09376	0.09219	0.09401	0.09333	0.00008	0.09349	0.00068	0.09333	0.00008	0.09333	0.00008	44761
85	3894	0.09271	0.09590	0.09257	0.09332	0.00008	0.09353	0.00067	0.09332	0.00008	0.09333	0.00008	44937
86	3973	0.09363	0.09961	0.09368	0.09332	0.00008	0.09362	0.00066	0.09333	0.00008	0.09333	0.00008	45141
87	4041	0.09413	0.08764	0.09406	0.09334	0.00008	0.09353	0.00066	0.09334	0.00008	0.09334	0.00008	45331
88	4024	0.09384	0.09318	0.09362	0.09334	0.00008	0.09353	0.00065	0.09334	0.00008	0.09335	0.00008	45760
89	4032	0.09334	0.08005	0.09335	0.09334	0.00008	0.09333	0.00067	0.09334	0.00008	0.09334	0.00008	46204
90	4021	0.09414	0.09807	0.09390	0.09335	0.00008	0.09340	0.00066	0.09335	0.00008	0.09335	0.00008	45777
91	3990	0.09310	0.09385	0.09317	0.09335	0.00008	0.09340	0.00065	0.09335	0.00008	0.09335	0.00007	46401
92	4069	0.09343	0.09508	0.09362	0.09335	0.00008	0.09343	0.00065	0.09335	0.00007	0.09335	0.00007	46994
93	4029	0.09383	0.09048	0.09385	0.09336	0.00007	0.09339	0.00064	0.09336	0.00007	0.09336	0.00007	47397
94	4024	0.09337	0.09216	0.09358	0.09336	0.00007	0.09337	0.00063	0.09336	0.00007	0.09336	0.00007	48041
95	4060	0.09247	0.09654	0.09237	0.09335	0.00007	0.09341	0.00062	0.09335	0.00007	0.09335	0.00007	47561
96	3931	0.09416	0.09680	0.09422	0.09336	0.00007	0.09346	0.00062	0.09336	0.00007	0.09336	0.00007	46858
97	4067	0.09330	0.08984	0.09301	0.09336	0.00007	0.09341	0.00061	0.09336	0.00007	0.09336	0.00007	47395
98	4062	0.09333	0.09330	0.09301	0.09336	0.00007	0.09341	0.00060	0.09335	0.00007	0.09336	0.00007	47929
99	3914	0.09318	0.09142	0.09344	0.09335	0.00007	0.09338	0.00059	0.09335	0.00007	0.09335	0.00007	48626
100	4061	0.09354	0.09245	0.09348	0.09336	0.00007	0.09337	0.00059	0.09335	0.00007	0.09336	0.00007	49230
101	4022	0.09335	0.09526	0.09339	0.09336	0.00007	0.09340	0.00058	0.09335	0.00007	0.09336	0.00007	49874
102	4040	0.09288	0.09632	0.09280	0.09335	0.00007	0.09343	0.00057	0.09335	0.00007	0.09335	0.00007	50201
103	3981	0.09435	0.08401	0.09437	0.09336	0.00007	0.09332	0.00058	0.09336	0.00007	0.09336	0.00007	50043
104	3999	0.09246	0.09850	0.09241	0.09335	0.00007	0.09338	0.00058	0.09335	0.00007	0.09335	0.00007	49796
105	3861	0.09297	0.08549	0.09295	0.09335	0.00007	0.09329	0.00058	0.09334	0.00007	0.09334	0.00007	49766

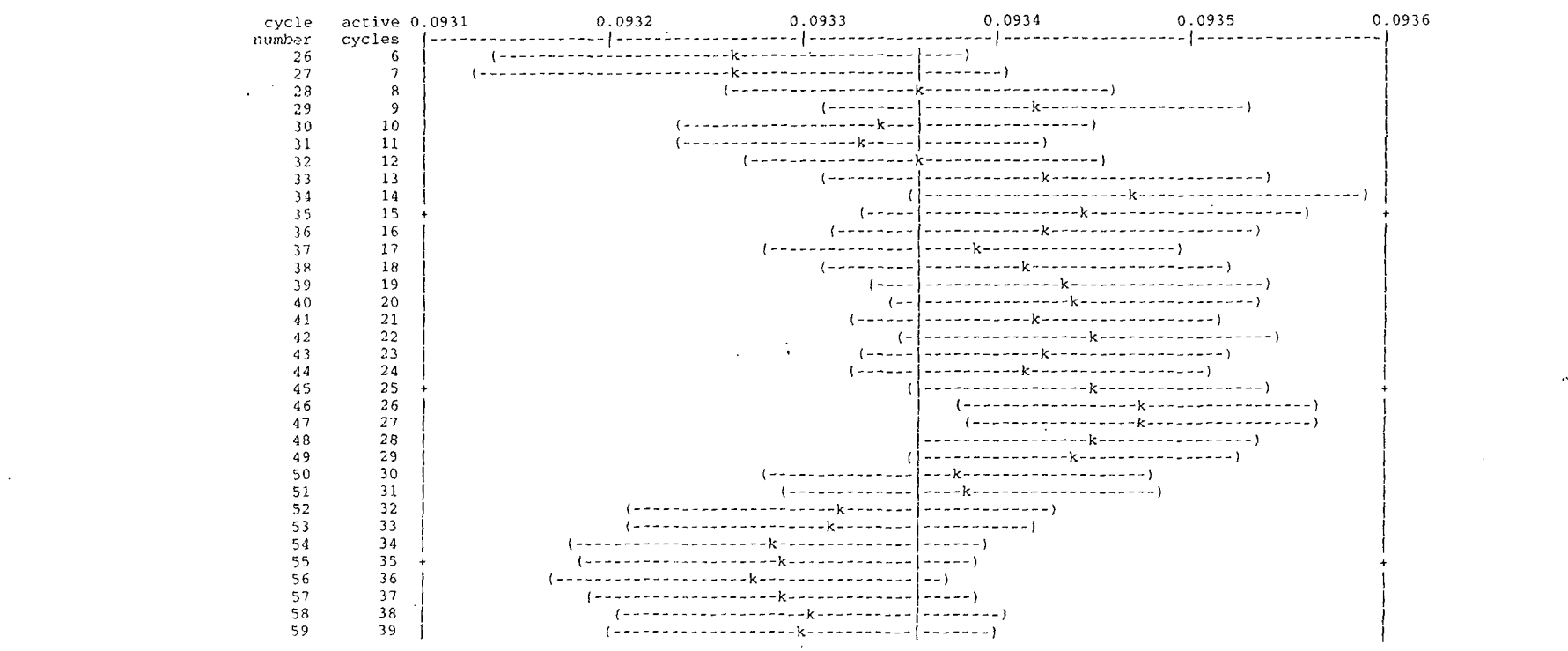
106	3992	0.09297	0.09662	0.09304	0.09334	0.00007	0.09332	0.00057	0.09334 0.00007	0.09334 0.00007	0.09334 0.00007	50299
107	4026	0.09354	0.09434	0.09331	0.09335	0.00007	0.09334	0.00056	0.09334 0.00007	0.09334 0.00007	0.09334 0.00006	50804
108	3968	0.09243	0.08814	0.09248	0.09333	0.00007	0.09328	0.00056	0.09333 0.00007	0.09333 0.00007	0.09333 0.00006	49717
109	3978	0.09241	0.08839	0.09283	0.09332	0.00007	0.09322	0.00056	0.09332 0.00007	0.09332 0.00007	0.09332 0.00006	49248
110	3932	0.09329	0.09524	0.09327	0.09332	0.00007	0.09325	0.00055	0.09332 0.00007	0.09332 0.00007	0.09332 0.00006	49840
111	4095	0.09408	0.09961	0.09369	0.09333	0.00007	0.09332	0.00055	0.09333 0.00006	0.09333 0.00006	0.09333 0.00006	49721
112	3980	0.09416	0.08601	0.09413	0.09334	0.00007	0.09324	0.00055	0.09334 0.00006	0.09333 0.00006	0.09333 0.00006	49749
113	3953	0.09403	0.09470	0.09409	0.09335	0.00007	0.09325	0.00054	0.09334 0.00006	0.09334 0.00006	0.09334 0.00006	49491
114	4045	0.09401	0.08661	0.09379	0.09336	0.00007	0.09318	0.00054	0.09335 0.00006	0.09335 0.00006	0.09335 0.00006	49813
115	3937	0.09404	0.09362	0.09401	0.09336	0.00006	0.09319	0.00054	0.09336 0.00006	0.09335 0.00006	0.09335 0.00006	49716
116	3981	0.09444	0.08520	0.09471	0.09337	0.00007	0.09310	0.00054	0.09337 0.00006	0.09336 0.00006	0.09336 0.00006	48869
117	3933	0.09363	0.09501	0.09349	0.09338	0.00006	0.09312	0.00053	0.09337 0.00006	0.09337 0.00006	0.09337 0.00006	49298
118	3932	0.09409	0.09203	0.09396	0.09338	0.00006	0.09311	0.00053	0.09338 0.00006	0.09337 0.00006	0.09337 0.00006	49296
119	3921	0.09352	0.09149	0.09362	0.09339	0.00006	0.09309	0.00052	0.09338 0.00006	0.09337 0.00006	0.09337 0.00006	49795
120	3924	0.09232	0.09266	0.09253	0.09337	0.00006	0.09309	0.00052	0.09337 0.00006	0.09336 0.00006	0.09336 0.00006	49233

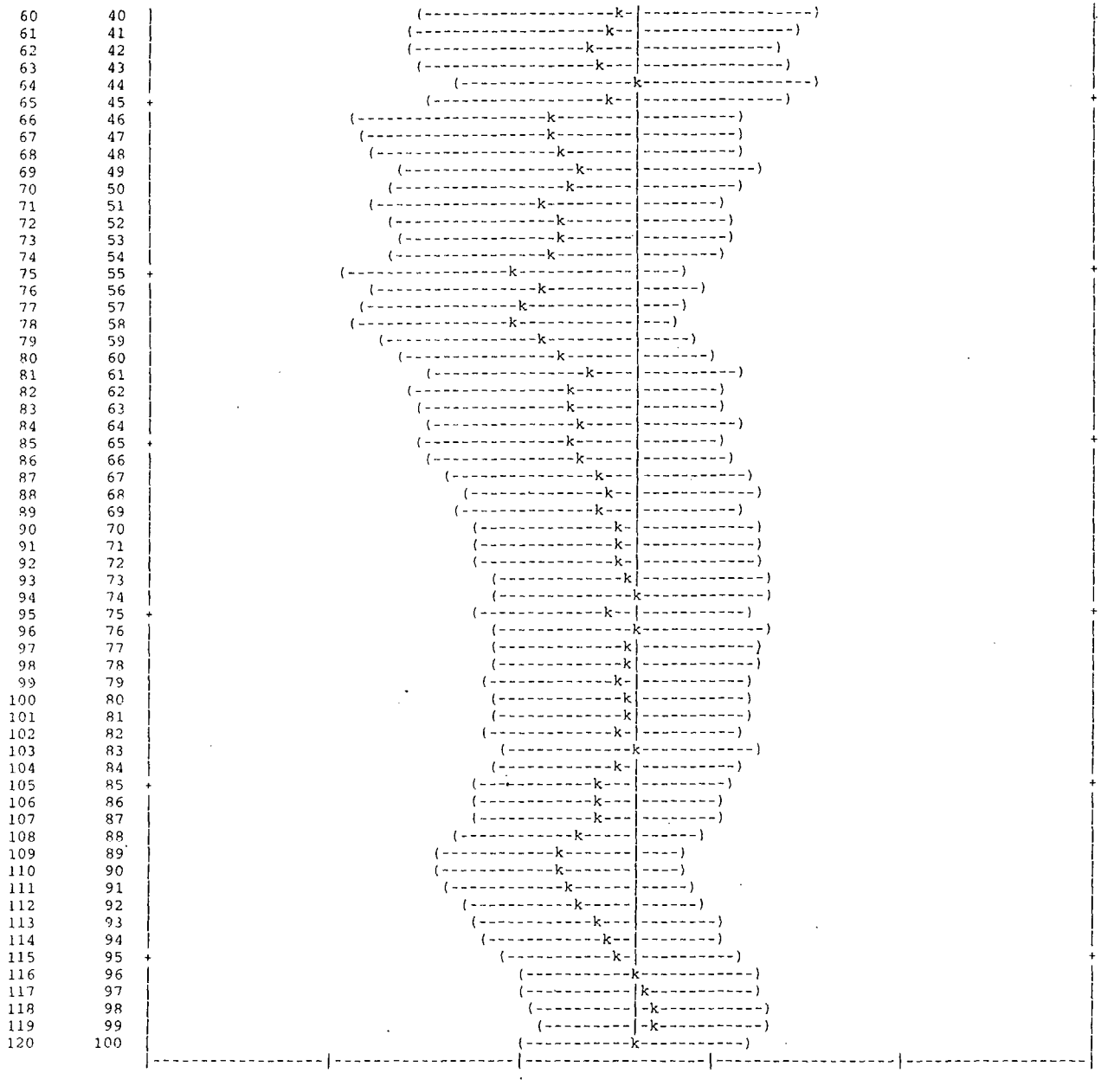
the largest active cycle keffs by estimator are:

collision 0.09497 on cycle 60
absorption 0.10594 on cycle 56
track length 0.09506 on cycle 60

the smallest active cycle keffs by estimator are:

collision 0.09162 on cycle 52
absorption 0.08005 on cycle 89
track length 0.09161 on cycle 52





0.0931 0.0932 0.0933 0.0934 0.0935 0.0936

lindividual and collision/absorption/track-length keffs for different numbers of inactive cycles skipped for fission source settling

skip cycles	active cycles	active neutrons	average keff estimators and deviations k(col)	st dev	k(abs)	st dev	k(trk)	st dev	normality co/ab/tl	average k(c/a/t)	st dev	k(c/a/t) confidence intervals 95% confidence	99% confidence
0	120	475712	0.0935	0.0001	0.0933	0.0005	0.0935	0.0001	95/95/95	0.09348	0.00006	0.09336-0.09360	0.09332-0.09364
1	119	471712	0.0935	0.0001	0.0933	0.0005	0.0935	0.0001	95/95/95	0.09348	0.00006	0.09335-0.09360	0.09331-0.09364
2	118	471322	0.0935	0.0001	0.0933	0.0005	0.0935	0.0001	95/95/95	0.09348	0.00006	0.09335-0.09360	0.09331-0.09364
3	117	467372	0.0935	0.0001	0.0933	0.0005	0.0935	0.0001	95/95/95	0.09347	0.00006	0.09334-0.09359	0.09330-0.09363
4	116	463317	0.0935	0.0001	0.0934	0.0005	0.0935	0.0001	95/95/95	0.09345	0.00006	0.09333-0.09357	0.09329-0.09361
5	115	459153	0.0934	0.0001	0.0933	0.0005	0.0935	0.0001	95/95/95	0.09344	0.00006	0.09332-0.09356	0.09328-0.09360
6	114	455160	0.0934	0.0001	0.0933	0.0005	0.0934	0.0001	95/95/95	0.09344	0.00006	0.09331-0.09356	0.09328-0.09360
7	113	451165	0.0934	0.0001	0.0932	0.0005	0.0934	0.0001	95/95/95	0.09343	0.00006	0.09331-0.09355	0.09327-0.09359
8	112	447135	0.0934	0.0001	0.0933	0.0005	0.0934	0.0001	95/95/95	0.09342	0.00006	0.09330-0.09354	0.09326-0.09358
9	111	442985	0.0934	0.0001	0.0934	0.0005	0.0934	0.0001	95/95/95	0.09341	0.00006	0.09329-0.09354	0.09325-0.09357
10	110	438961	0.0934	0.0001	0.0933	0.0005	0.0934	0.0001	95/95/95	0.09340	0.00006	0.09328-0.09352	0.09324-0.09356
11	109	435003	0.0934	0.0001	0.0933	0.0005	0.0934	0.0001	95/95/95	0.09339	0.00006	0.09327-0.09351	0.09323-0.09355
12	108	430962	0.0934	0.0001	0.0933	0.0005	0.0934	0.0001	95/95/95	0.09338	0.00006	0.09326-0.09350	0.09323-0.09354
13	107	426921	0.0934	0.0001	0.0934	0.0005	0.0934	0.0001	95/95/95	0.09337	0.00006	0.09325-0.09349	0.09322-0.09353
14	106	422790	0.0934	0.0001	0.0933	0.0005	0.0934	0.0001	95/95/95	0.09336	0.00006	0.09325-0.09348	0.09321-0.09352
15	105	418795	0.0934	0.0001	0.0933	0.0005	0.0934	0.0001	95/95/95	0.09336	0.00006	0.09324-0.09348	0.09320-0.09351
16	104	414707	0.0934	0.0001	0.0934	0.0005	0.0934	0.0001	95/95/95	0.09336	0.00006	0.09324-0.09347	0.09320-0.09351
17	103	410863	0.0934	0.0001	0.0933	0.0005	0.0934	0.0001	95/95/95	0.09336	0.00006	0.09324-0.09348	0.09320-0.09352
18	102	406904	0.0934	0.0001	0.0932	0.0005	0.0934	0.0001	95/95/95	0.09337	0.00006	0.09325-0.09349	0.09321-0.09353
19	101	402914	0.0934	0.0001	0.0931	0.0005	0.0934	0.0001	95/95/95	0.09337	0.00006	0.09325-0.09349	0.09321-0.09353
20	100*	398871	0.0934	0.0001	0.0931	0.0005	0.0934	0.0001	95/95/95	0.09336	0.00006	0.09324-0.09349	0.09320-0.09353
22	98	390840	0.0934	0.0001	0.0932	0.0005	0.0934	0.0001	95/95/95	0.09336	0.00006	0.09324-0.09349	0.09320-0.09353
24	96	382957	0.0934	0.0001	0.0932	0.0005	0.0934	0.0001	95/95/95	0.09337	0.00006	0.09324-0.09349	0.09320-0.09354
26	94	374882	0.0934	0.0001	0.0932	0.0005	0.0934	0.0001	95/95/95	0.09337	0.00006	0.09324-0.09350	0.09320-0.09354
28	92	367057	0.0934	0.0001	0.0931	0.0005	0.0934	0.0001	95/95/95	0.09337	0.00007	0.09323-0.09350	0.09319-0.09354
30	90	358927	0.0934	0.0001	0.0930	0.0005	0.0934	0.0001	95/95/95	0.09337	0.00007	0.09323-0.09350	0.09319-0.09355
32	88	350982	0.0934	0.0001	0.0931	0.0005	0.0934	0.0001	95/95/95	0.09336	0.00007	0.09323-0.09350	0.09318-0.09354
34	86	343150	0.0934	0.0001	0.0931	0.0006	0.0934	0.0001	95/95/95	0.09334	0.00007	0.09321-0.09348	0.09316-0.09353
36	84	335144	0.0934	0.0001	0.0932	0.0006	0.0934	0.0001	95/95/95	0.09335	0.00007	0.09321-0.09349	0.09316-0.09354
38	82	327174	0.0934	0.0001	0.0932	0.0006	0.0934	0.0001	95/95/95	0.09335	0.00007	0.09321-0.09349	0.09316-0.09354
40	80	319168	0.0934	0.0001	0.0930	0.0006	0.0934	0.0001	95/95/95	0.09334	0.00007	0.09320-0.09349	0.09315-0.09353
42	78	311131	0.0933	0.0001	0.0929	0.0006	0.0933	0.0001	95/95/95	0.09333	0.00007	0.09318-0.09348	0.09314-0.09353
44	76	303301	0.0933	0.0001	0.0930	0.0006	0.0934	0.0001	95/95/95	0.09334	0.00008	0.09319-0.09349	0.09314-0.09354
46	74	295232	0.0933	0.0001	0.0928	0.0006	0.0933	0.0001	95/95/95	0.09332	0.00008	0.09317-0.09347	0.09311-0.09352
48	72	287284	0.0933	0.0001	0.0927	0.0006	0.0933	0.0001	95/95/95	0.09332	0.00008	0.09317-0.09348	0.09311-0.09353
50	70	279324	0.0934	0.0001	0.0927	0.0006	0.0934	0.0001	95/95/95	0.09335	0.00008	0.09319-0.09350	0.09314-0.09355
52	68	271355	0.0934	0.0001	0.0928	0.0006	0.0934	0.0001	95/95/95	0.09337	0.00007	0.09322-0.09351	0.09317-0.09356
54	66	263493	0.0934	0.0001	0.0927	0.0006	0.0934	0.0001	95/95/95	0.09339	0.00007	0.09324-0.09353	0.09319-0.09358
56	64	255558	0.0934	0.0001	0.0926	0.0006	0.0934	0.0001	95/95/95	0.09339	0.00008	0.09324-0.09355	0.09319-0.09360
58	62	247573	0.0934	0.0001	0.0926	0.0006	0.0934	0.0001	95/95/95	0.09338	0.00008	0.09322-0.09354	0.09317-0.09359
60	60	239553	0.0934	0.0001	0.0924	0.0006	0.0934	0.0001	95/95/95	0.09337	0.00008	0.09321-0.09353	0.09316-0.09358
62	58	231584	0.0934	0.0001	0.0925	0.0006	0.0934	0.0001	95/95/95	0.09338	0.00008	0.09322-0.09354	0.09316-0.09359
64	56	223599	0.0934	0.0001	0.0926	0.0006	0.0934	0.0001	95/95/95	0.09336	0.00008	0.09320-0.09353	0.09314-0.09358
66	54	215735	0.0934	0.0001	0.0926	0.0006	0.0934	0.0001	95/95/95	0.09341	0.00008	0.09325-0.09356	0.09320-0.09361
68	52	207697	0.0934	0.0001	0.0926	0.0007	0.0934	0.0001	95/95/95	0.09341	0.00008	0.09325-0.09357	0.09319-0.09362
70	50	199800	0.0934	0.0001	0.0924	0.0007	0.0934	0.0001	99/95/95	0.09340	0.00008	0.09324-0.09357	0.09318-0.09363
72	48	191805	0.0935	0.0001	0.0922	0.0007	0.0935	0.0001	99/95/95	0.09342	0.00009	0.09325-0.09359	0.09319-0.09365
74	46	183671	0.0935	0.0001	0.0924	0.0007	0.0935	0.0001	99/95/95	0.09343	0.00009	0.09325-0.09360	0.09319-0.09367
76	44	175828	0.0935	0.0001	0.0925	0.0007	0.0935	0.0001	95/95/95	0.09344	0.00009	0.09326-0.09361	0.09320-0.09367
78	42	167825	0.0935	0.0001	0.0927	0.0007	0.0935	0.0001	99/95/95	0.09346	0.00009	0.09328-0.09364	0.09321-0.09370
80	40	159690	0.0935	0.0001	0.0924	0.0007	0.0935	0.0001	95/95/95	0.09342	0.00009	0.09323-0.09360	0.09317-0.09367

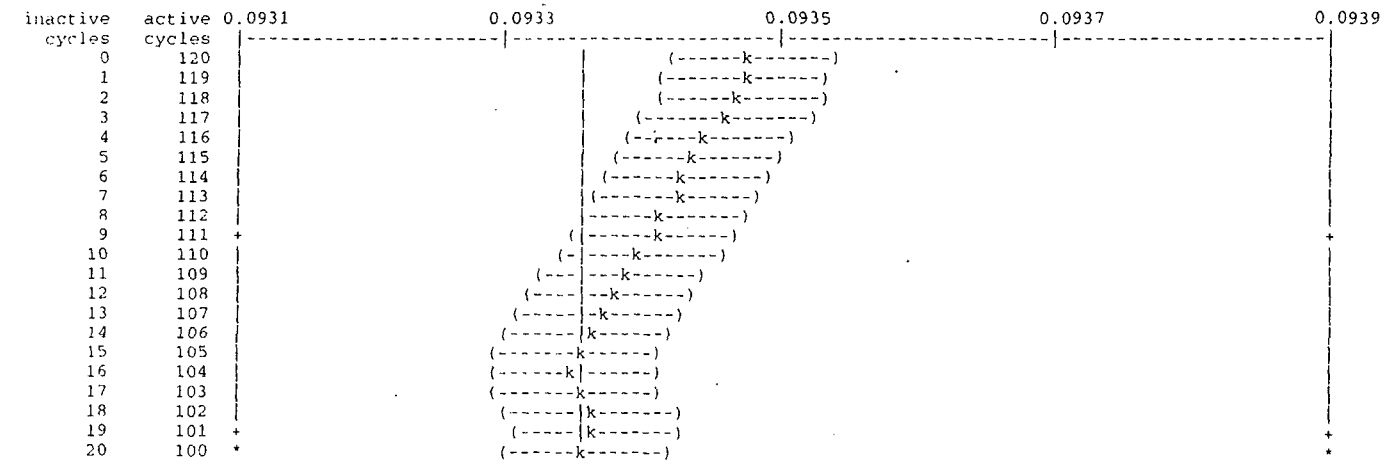
82	38	151656	0.0935 0.0001	0.0924 0.0007	0.0935 0.0001	95/95/95	0.09341	0.00009	0.09322-0.09360	0.09316-0.09367
84	36	143692	0.0935 0.0001	0.0924 0.0008	0.0934 0.0001	95/95/95	0.09339	0.00010	0.09319-0.09359	0.09312-0.09366
86	34	135825	0.0935 0.0001	0.0921 0.0008	0.0935 0.0001	95/95/95	0.09339	0.00010	0.09318-0.09360	0.09311-0.09367
88	32	127760	0.0934 0.0001	0.0922 0.0008	0.0934 0.0001	95/95/95	0.09338	0.00011	0.09316-0.09359	0.09308-0.09367
90	30	119707	0.0934 0.0001	0.0924 0.0008	0.0934 0.0001	95/95/95	0.09336	0.00011	0.09314-0.09357	0.09306-0.09365
92	28	111648	0.0934 0.0001	0.0922 0.0008	0.0934 0.0001	95/95/95	0.09334	0.00012	0.09311-0.09358	0.09302-0.09366
94	26	103595	0.0934 0.0001	0.0923 0.0009	0.0934 0.0001	95/95/95	0.09332	0.00012	0.09307-0.09358	0.09298-0.09367
96	24	95604	0.0934 0.0001	0.0919 0.0009	0.0934 0.0001	95/95/95	0.09330	0.00012	0.09304-0.09356	0.09295-0.09365
98	22	87475	0.0934 0.0001	0.0920 0.0010	0.0934 0.0001	95/95/95	0.09334	0.00012	0.09308-0.09360	0.09299-0.09369
100	20	79500	0.0934 0.0002	0.0920 0.0011	0.0934 0.0001	95/95/95	0.09333	0.00014	0.09304-0.09362	0.09293-0.09372
102	18	71438	0.0935 0.0002	0.0915 0.0011	0.0935 0.0002	99/95/95	0.09333	0.00016	0.09300-0.09367	0.09288-0.09379
104	16	63458	0.0935 0.0002	0.0916 0.0011	0.0935 0.0002	95/95/95	0.09340	0.00017	0.09303-0.09377	0.09288-0.09392
106	14	55605	0.0936 0.0002	0.0916 0.0011	0.0936 0.0002	99/95/95	0.09342	0.00019	0.09302-0.09383	0.09285-0.09400
108	12	47611	0.0937 0.0002	0.0917 0.0013	0.0937 0.0002	99/95/95	0.09353	0.00017	0.09315-0.09391	0.09299-0.09407
110	10	39701	0.0938 0.0002	0.0917 0.0014	0.0938 0.0002	no/95/95	0.09363	0.00020	0.09317-0.09410	0.09294-0.09433
112	8	31626	0.0938 0.0002	0.0914 0.0013	0.0938 0.0002	99/95/95	0.09357	0.00026	0.09291-0.09423	0.09253-0.09460
114	6	23628	0.0937 0.0003	0.0917 0.0014	0.0937 0.0003	95/95/95	0.09341	0.00016	0.09291-0.09390	0.09250-0.09432
116	4	15710	0.0934 0.0004	0.0928 0.0008	0.0934 0.0003	95/95/95	0.09330	0.00015	0.09143-0.09517	0.08394-0.10267
117	3	11777	0.0933 0.0005	0.0921 0.0003	0.0934 0.0004					
118	2	7845	0.0929 0.0006	0.0921 0.0006	0.0931 0.0005					

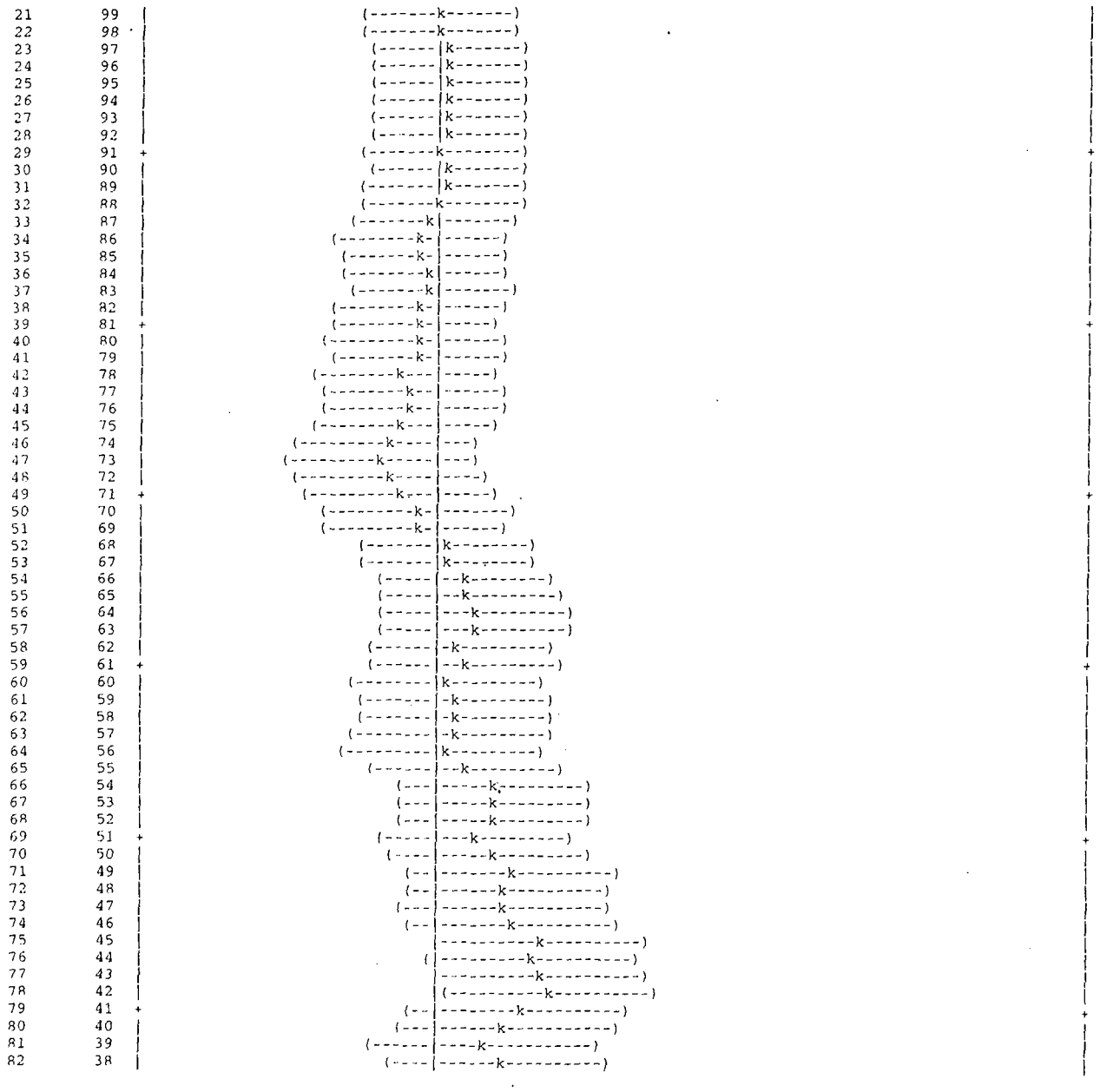
the minimum estimated standard deviation for the col/abs/tl keff estimator occurs with 13 inactive cycles and 107 active cycles.

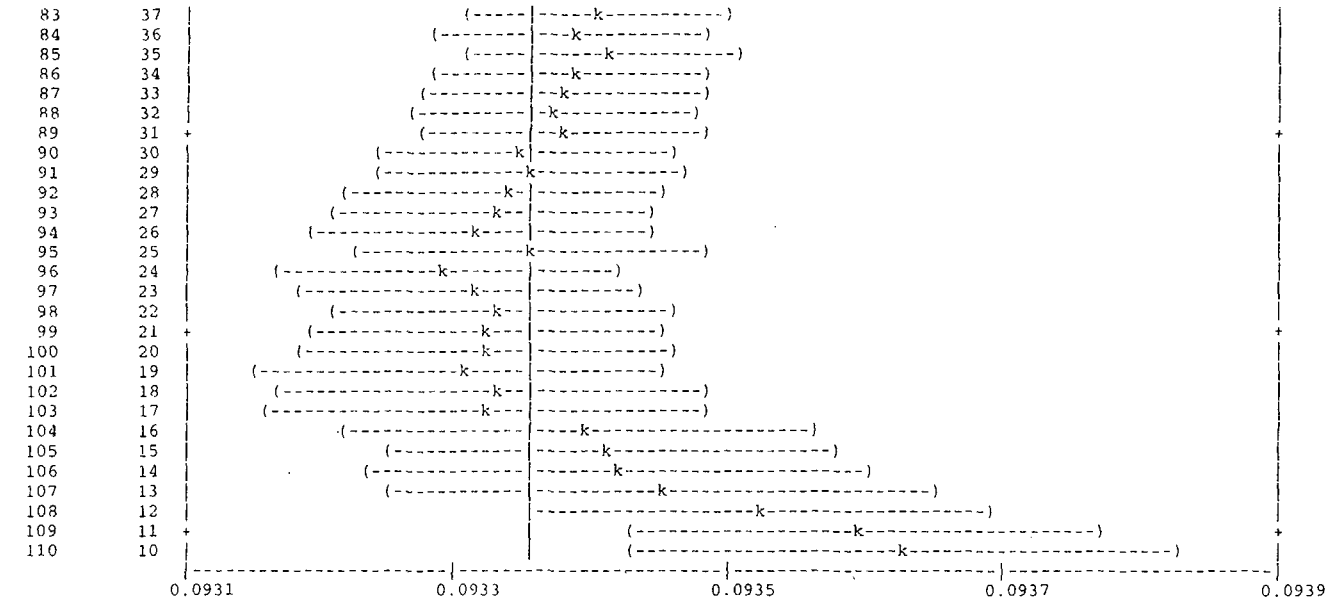
the first active half of the problem skips 20 cycles and uses 50 active cycles; the second half skips 70 and uses 50 cycles.
the col/abs/trk-len keff, one standard deviation, and 68, 95, and 99 percent intervals for each active half of the problem are:

problem	keff	standard deviation	68% confidence	95% confidence	99% confidence
first half	0.09333	0.00009	0.09323 to 0.09342	0.09314 to 0.09351	0.09307 to 0.09358
second half	0.09340	0.00008	0.09332 to 0.09349	0.09324 to 0.09357	0.09318 to 0.09363
final result	0.09336	0.00006	0.09330 to 0.09342	0.09324 to 0.09349	0.09320 to 0.09353

the first and second half values of k(collision/absorption/track length) appear to be the same at the 68 percent confidence level.
plot of the estimated col/abs/track-length keff one standard deviation interval by active cycle number (| = final keff = 0.09336)







dump no. 5 on file 10b1r nps = 475712 coll = 79219392 ctm = 56.30 nrn = 1454346371

1 warning message so far.

run terminated when 120 kcode cycles were done.

computer time = 56.31 minutes

mcnp version 4a 10/01/93 09/14/00 15:57:47 probid = 09/14/00 15:01:29

URS

Calculation Cover Page

3065 Southwestern Boulevard
Suite 202
Orchard Park, NY 14127
716 675 7130 Tel
716 675 7137 Fax

Job No: **30822-244-330 /6856** Calculation No: **BUF-2000-101/Rev. 0** Date: **December 19, 2000**

Problem Statement & Calculation Objectives:

To determine the neutron multiplication factors for $\infty \times \infty \times 4$ arrays of 55 gallon drums filled with Pu-239 homogeneously mixed with variable density water, cellulose and concrete matrices. Water of various density fills the space outside the containers with fissile material.

References and Data Available:

J. F. Briemiester, ed., MCNP - A General Purpose Monte Carlo N-Particle Transport Code, Version 4A, LA-12625, Los Alamos National Laboratory, Los Alamos NM, 1993
C. D. Harmon, II et al., Criticality Calculations with MCNP: A Primer, Manual LA-12827, Los Alamos National Laboratory, Los Alamos NM, 1993
D. R. Lide, CRC Handbook of Chemistry an Physics, CRC Press, Boston MA, 1991.
F. H. Attix, Introduction to Radiological Physics and Radiation Dosimetry. John Wiley & Sons, Inc., New York NY, 1986

Attachments:

Attachment 1: MCNP model with surface and cell numbers
Attachment 2: MCNP input file
Attachment 3: MCNP output file

Prepared by:

Signature Igor V. Chichkov — Date 02/20/2001

Checked by:

Signature Kevin Roberts — Date 2/26/01

URS

Job No 30822-244-330 /6856 Job: PSR-6 By IVC Date 09/04/01
Client WVNS Subject: Homogeneous mixtures Chk'd. IVC Date 09/04/01
for JCW

Analysis

Assumptions

The following assumptions were taken for the adopted model:

- Pu-239 is homogeneously mixed with matrix
- The Plutonium-matrix mixture filles the entire space inside the container
- The containers stand on the 3 m thick concrete floor
- The 55 gallon drum is a cylinder with 56.83 cm (22.37 inches) inside diameter and 89.11 cm (35.08 inches) height
- The drum wall is made of carbon steel and its thickness is 0.157 cm
- The drums are arranged in the infinite hexagonal array, 4 tiers heigh ($\infty \times \infty \times 4$)
- Every drum contains 200 g of Pu-239
- Water of various density fills the space outside the drum

MCNP Model

Neutron multiplication factors were calculated with MCNP4A code. Plutonium mixtures with water, cellulose, concrete, cellulose-water and concrete-water matrices were studied. Matrix density parametric analysis was performed. Attachments 1 has the drawings of the MCNP model. Examples of MCNP input and output files are in Attachments 2 and 3 respectively.

Air, Carbon Steel and Concrete Composition

Table 1 shows the element weight fractions for air (Attix F.H., 1986). Table 2 shows the element weight fractions for carbon steel (Harmon C. D., II et al., 1993) used in the drum walls. Table 3 shows the element composition of concrete (Harmon C. D., II et al., 1993) in the floor.

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Table 1. Air composition

Element	Weight Fraction
Carbon (C)	0.000124
Nitrogen (N)	0.755267
Oxygen (O)	0.231781
Argon (Ar)	0.012827

Table 2. Carbon Steel Composition

Element	Weight Fraction
Iron (Fe)	0.995
Carbon (C)	0.005

Table 3. Concrete composition

Element	Weight Fraction
Hydrogen (H)	0.010
Oxygen (O)	0.532
Sodium (Na)	0.029
Aluminum (Al)	0.034
Silicon (Si)	0.337
Calcium (Ca)	0.044
Iron (Fe)	0.014

Atom densities for Plutonium-matrix mixtures.

Atom density is the number of atoms per unit volume and can be determined using equation 1:

$$N_i = \frac{\rho_i N_A}{A_i \times 1 \times 10^{24}} = \frac{m_i N_A}{A_i V_C \times 1 \times 10^{24}} = w_{ij} \frac{m_j N_A}{A_i V_C \times 1 \times 10^{24}} \qquad (1)$$

where

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N_i = the atom density of the ith element, atoms/(barn·cm)
ρ_i = the density of the ith element, g/cm^3
N_A = the Avagadro's number, 6.022×10^{23} atoms/mol
A_i = the atomic weight of the ith element, g/mol
m_i = the mass of the ith element in the container volume, g
V_c = the volume of the container (55 gallon drum or B-25 box), cm^3
w_{ij} = the weight fraction of the ith element in a molecule of matrix j
1×10^{24} = the conversion from barn to cm^2

The atomic weights of the elements used in the calculations are shown in Table 4.

Table 4. The atomic weights of the elements

Element	Atomic Weight
Hydrogen (H)	1.00794
Carbon (C)	12.0107
Oxygen (O)	15.9994

The molecular weight of cellulose ($C_6H_{10}O_5$) was calculated as the sum of all atomic weights composing the molecule. The weight fraction of an ith element was found as a ratio of the ith element weight in the molecule to the molecular weight of this molecule.

$$w_{ij} = \frac{n_i A_i}{M_j} = \frac{n_i A_i}{\sum n_i A_i} \qquad (2)$$

where
w_{ij} = the weight fraction of ith element in a molecule of matrix j
n_i = the number of the ith elements in the jth molecule
A_i = the atomic weight of the ith element, g/mol
M_j = the molecular weight the jth molecule, g/mol

Calculated weight fractions for cellulose are shown in Table 5 and weight fractions for concrete taken from Harmon C. D., II et al., 1993 are in Table 3.

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Table 5. Cellulose Weight Fractions

Element	Weight Fraction
Hydrogen (H)	0.062
Carbon (C)	0.444
Oxygen (O)	0.493

The mass of the matrix was calculated as :

$$m_j = \left(V_C - V_w - V_{Pu}\right)\rho_j = \left(\left(1 - f_w\right)V_C - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_j \qquad (3)$$

where

ρ_i = the density of the ith element, g/cm^3

V_c = the volume of the container (55 gallon drum or B-25 box), cm^3

V_{Pu} = the volume in the container occupied by Pu-239, cm^3

V_w = the volume in the container occupied by water, cm^3

f_w = the water volume fraction in the container

ρ_{Pu} = the density of the metal Plutonium, 19.78 g/cm^3

m_{Pu} = the mass of Pu-239 in the container volume, g

The atom density of Pu-239 was calculated as:

$$N_{Pu} = \frac{m_{Pu} N_A}{A_{Pu} V_C \times 1 \times 10^{24}} \qquad (4)$$

where

N_{Pu} = the atom density of Pu-239, atoms/(barn·cm)

N_A = the Avagadro's number, 6.022 × 10^{23} atoms/mol

A_{Pu} = the atomic weight of Pu-239, g/mol

m_{Pu} = the mass of Pu-239 in the container volume, g

V_c = the volume of the container (55 gallon drum or B-25 box), cm^3

1×10^{24} = the conversion from barn to cm^2

In case the water is present in the homogenous mixture, the hydrogen and oxygen atom densities are

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determined as a sum of atomic density of the element in water and matrix. The hydrogen and oxygen atom densities from water were calculated using equation 5

$$N_{wi} = \frac{\rho_{wi} N_A}{A_i \times 1 \times 10^{24}} = \frac{m_{wi} N_A}{A_i V_C \times 1 \times 10^{24}} = w_{wi} \frac{m_w N_A}{A_i V_C \times 1 \times 10^{24}} = w_{wi} \frac{\rho_w V_w N_A}{A_i V_C \times 1 \times 10^{24}} = w_{wi} \frac{\rho_w f_w V_C N_A}{A_i V_C \times 1 \times 10^{24}} = w_{wi} \frac{\rho_w f_w N_A}{A_i \times 1 \times 10^{24}} \quad (5)$$

where

N_{wi} = the atom density of the ith element from water, atoms/(barn·cm)

ρ_{wi} = the density of the ith element from water, g/cm^3

N_A = the Avagadro's number, 6.022 × 10^{23} atoms/mol

A_i = the atomic weight of the ith element, g/mol

m_{wi} = the mass of the ith element in the container volume from water, g

V_c = the volume of the container (55 gallon drum or B-25 box), cm^3

w_{iw} = the weight fraction of the ith element in a molecule of water

ρ_w = the density of water, 1 g/cm^3

f_w = the water volume fraction in the container

1 × 10^{24} = the conversion from barn to cm^2

Water maximum density was assumed to be 1 g/cm^3, and concrete maximum density - 2.3 g/cm^3 (Harmon C. D., II et al., 1993). Cellulose maximum density was assumed to be equal to 0.9 g/cm^3 (wood density, Lide D. R., 1991). The following tables provide the homogenous mixture compositions used in the analysis. 100% density means the maximum density of the matrix (concrete, or cellulose, or water if water only used as a matrix), and 20-80% density means the density corresponding to the appropriate percentage of the maximum density of the matrix. In case of the mixture with water used as a matrix, the density parametric analysis was performed on the cellulose or concrete density only, the amount of water in the container remained constant.

Table 6. The composition of Pu-239 and water mixture in 55 gallon drum

Element	Atom Density, atoms/(barn·cm)				
	20% density	40% density	60% density	80% density	100% density
H	1.3346E-02	2.6692E-02	4.0038E-02	5.3385E-02	6.6731E-02
O	6.6731E-03	1.3346E-02	2.0019E-02	2.6692E-02	3.3365E-02
Pu	2.3977E-06	2.3977E-06	2.3977E-06	2.3977E-06	2.3977E-06
Total	2.0022E-02	4.0041E-02	6.0060E-02	8.0079E-02	1.0010E-01

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Table 7. The composition of Pu-239 and dry concrete mixture in 55 gallon drum

Element	Atom Density, atoms/(barn·cm)				
	20% density	40% density	60% density	80% density	100% density
Na	3.4941E-04	6.9883E-04	1.0482E-03	1.3977E-03	1.7471E-03
Al	3.4905E-04	6.9810E-04	1.0472E-03	1.3962E-03	1.7453E-03
Si	3.3237E-03	6.6475E-03	9.9712E-03	1.3295E-02	1.6619E-02
Ca	3.0411E-04	6.0821E-04	9.1232E-04	1.2164E-03	1.5205E-03
Fe	6.9442E-05	1.3888E-04	2.0833E-04	2.7777E-04	3.4721E-04
H	2.7482E-03	5.4963E-03	8.2445E-03	1.0993E-02	1.3741E-02
O	9.2106E-03	1.8421E-02	2.7632E-02	3.6842E-02	4.6053E-02
Pu	2.3977E-06	2.3977E-06	2.3977E-06	2.3977E-06	2.3977E-06
Total	1.6357E-02	3.2711E-02	4.9066E-02	6.5420E-02	8.1775E-02

Table 8. The composition of Pu-239 and concrete with 10% (volume) of water mixture in 55 gallon drum

Element	Atom Density, atoms/(barn·cm)				
	20% density	40% density	60% density	80% density	100% density
Na	3.1447E-04	6.2894E-04	9.4341E-04	1.2579E-03	1.5724E-03
Al	3.1414E-04	6.2829E-04	9.4243E-04	1.2566E-03	1.5707E-03
Si	2.9913E-03	5.9827E-03	8.9740E-03	1.1965E-02	1.4957E-02
Ca	2.7369E-04	5.4739E-04	8.2108E-04	1.0948E-03	1.3685E-03
Fe	6.2497E-05	1.2499E-04	1.8749E-04	2.4999E-04	3.1249E-04
H	9.1467E-03	1.1620E-02	1.4093E-02	1.6567E-02	1.9040E-02
O	1.1626E-02	1.9916E-02	2.8205E-02	3.6495E-02	4.4784E-02
Pu	2.3977E-06	2.3977E-06	2.3977E-06	2.3977E-06	2.3977E-06
Total	2.4731E-02	3.9450E-02	5.4169E-02	6.8888E-02	8.3607E-02

Table 9. The composition of Pu-239 and concrete with 20% (volume) of water mixture in 55 gallon drum

Element	Atom Density, atoms/(barn·cm)				
	20% density	40% density	60% density	80% density	100% density
Na	2.7953E-04	5.5906E-04	8.3858E-04	1.1181E-03	1.3976E-03
Al	2.7924E-04	5.5848E-04	8.3771E-04	1.1170E-03	1.3962E-03
Si	2.6590E-03	5.3179E-03	7.9769E-03	1.0636E-02	1.3295E-02
Ca	2.4328E-04	4.8656E-04	7.2984E-04	9.7313E-04	1.2164E-03
Fe	5.5553E-05	1.1111E-04	1.6666E-04	2.2221E-04	2.7776E-04
H	1.5545E-02	1.7744E-02	1.9942E-02	2.2141E-02	2.4339E-02
O	1.4042E-02	2.1410E-02	2.8778E-02	3.6147E-02	4.3515E-02
Pu	2.3977E-06	2.3977E-06	2.3977E-06	2.3977E-06	2.3977E-06
Total	3.3106E-02	4.6189E-02	5.9273E-02	7.2356E-02	8.5440E-02

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Table 10. The composition of Pu-239 and concrete with 50% (volume) of water mixture in 55 gallon drum

Element	Atom Density, atoms/(barn·cm)				
	20% density	40% density	60% density	80% density	100% density
Na	1.7470E-04	3.4940E-04	5.2410E-04	6.9880E-04	8.7349E-04
Al	1.7452E-04	3.4904E-04	5.2355E-04	6.9807E-04	8.7259E-04
Si	1.6618E-03	3.3236E-03	4.9854E-03	6.6471E-03	8.3089E-03
Ca	1.5205E-04	3.0409E-04	4.5614E-04	6.0818E-04	7.6023E-04
Fe	3.4719E-05	6.9439E-05	1.0416E-04	1.3888E-04	1.7360E-04
H	3.4741E-02	3.6115E-02	3.7489E-02	3.8863E-02	4.0237E-02
O	2.1289E-02	2.5894E-02	3.0499E-02	3.5104E-02	3.9709E-02
Pu	2.3977E-06	2.3977E-06	2.3977E-06	2.3977E-06	2.3977E-06
Total	5.8230E-02	6.6407E-02	7.4583E-02	8.2760E-02	9.0937E-02

Table 11. The composition of Pu-239 and dry cellulose mixture in 55 gallon drum

Element	Atom Density, atoms/(barn·cm)				
	20% density	40% density	60% density	80% density	100% density
C	4.0110E-03	8.0220E-03	1.2033E-02	1.6044E-02	2.0055E-02
H	6.6850E-03	1.3370E-02	2.0055E-02	2.6740E-02	3.3425E-02
O	3.3425E-03	6.6850E-03	1.0027E-02	1.3370E-02	1.6712E-02
Pu	2.3977E-06	2.3977E-06	2.3977E-06	2.3977E-06	2.3977E-06
Total	1.4041E-02	2.8079E-02	4.2118E-02	5.6156E-02	7.0195E-02

Table 12. The composition of Pu-239 and cellulose with 10% (volume) of water mixture in 55 gallon drum

Element	Atom Density, atoms/(barn·cm)				
	20% density	40% density	60% density	80% density	100% density
C	3.6099E-03	7.2197E-03	1.0830E-02	1.4439E-02	1.8049E-02
H	1.2690E-02	1.8706E-02	2.4723E-02	3.0739E-02	3.6756E-02
O	6.3449E-03	9.3532E-03	1.2361E-02	1.5370E-02	1.8378E-02
Pu	2.3977E-06	2.3977E-06	2.3977E-06	2.3977E-06	2.3977E-06
Total	2.2647E-02	3.5282E-02	4.7916E-02	6.0551E-02	7.3185E-02

Table 13. The composition of Pu-239 and cellulose with 20% (volume) of water mixture in 55 gallon drum

Element	Atom Density, atoms/(barn·cm)				
	20% density	40% density	60% density	80% density	100% density
C	3.2088E-03	6.4175E-03	9.6263E-03	1.2835E-02	1.6044E-02
H	1.8695E-02	2.4043E-02	2.9391E-02	3.4739E-02	4.0086E-02
O	9.3474E-03	1.2021E-02	1.4695E-02	1.7369E-02	2.0043E-02
Pu	2.3977E-06	2.3977E-06	2.3977E-06	2.3977E-06	2.3977E-06
Total	3.1253E-02	4.2484E-02	5.3715E-02	6.4945E-02	7.6176E-02

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Table 14. The composition of Pu-239 and cellulose with 50% (volume) of water mixture in 55 gallon drum

Element	Atom Density, atoms/(barn·cm)				
	20% density	40% density	60% density	80% density	100% density
C	2.0054E-03	4.0108E-03	6.0162E-03	8.0216E-03	1.0027E-02
H	3.6709E-02	4.0052E-02	4.3394E-02	4.6736E-02	5.0079E-02
O	1.8355E-02	2.0026E-02	2.1697E-02	2.3368E-02	2.5039E-02
Pu	2.3977E-06	2.3977E-06	2.3977E-06	2.3977E-06	2.3977E-06
Total	5.7072E-02	6.4091E-02	7.1110E-02	7.8129E-02	8.5147E-02

Results

The results of the calculations performed using MCNP-4A code are shown in the following tables and graphs. The tables provide the Monte Carlo determined neutron multiplication factor (k_{eff}) values and their standard deviations (σ), and the graphs plot the k_{eff} +2 σ values for all studied cases.

Table 15. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for Pu-239 mixtures with water inside the drums

Inside water density %	Air outside			10% density water outside			50% density water outside			100% density water outside		
	k_{eff}	σ	k_{eff}+ 2σ	k_{eff}	σ	k_{eff}+ 2σ	k_{eff}	σ	k_{eff}+ 2σ	k_{eff}	σ	k_{eff}+ 2σ
100	0.2112	0.0001	0.2114	0.2102	0.0001	0.2104	0.2057	0.0001	0.2060	0.2016	0.00012	0.2019
80	0.253	0.0001	0.2532	0.2509	0.0001	0.2512	0.2441	0.0002	0.2445	0.2370	0.00017	0.2373
60	0.3144	0.0002	0.3147	0.3111	0.0002	0.3115	0.2985	0.0002	0.2989	0.2867	0.00020	0.2871
40	0.4129	0.0002	0.4134	0.4063	0.0002	0.4068	0.3831	0.0003	0.3836	0.3590	0.00027	0.3595
20	0.5884	0.0004	0.5892	0.576	0.0004	0.5765	0.5226	0.0004	0.5233	0.4666	0.00043	0.4675

Figure 1. k_{eff} +2σ for Pu-239 mixtures with water inside the drums

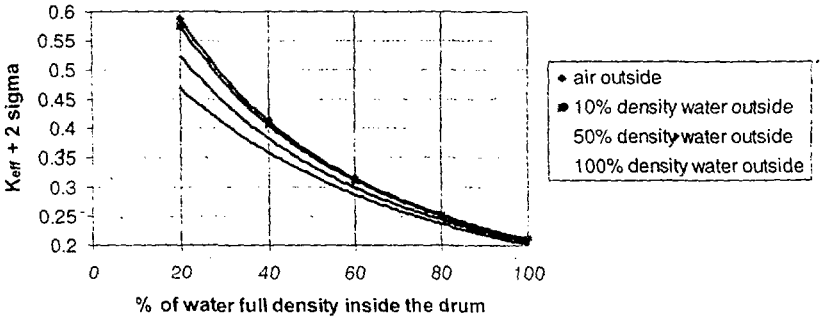

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Table 16. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for Pu-239 mixtures with dry concrete inside the drums

Concrete density %	Air outside			10% density water outside			50% density water outside			100% density water outside		
	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$
100	0.3822	0.0002	0.3826	0.3764	0.0003	0.3769	0.3503	0.0003	0.3508	0.3261	0.0003	0.3267
60	0.5145	0.0003	0.5152	0.5018	0.0003	0.5025	0.4526	0.0003	0.4532	0.4020	0.0004	0.4028
20	0.7025	0.0007	0.7039	0.6905	0.0007	0.6918	0.6048	0.0005	0.6059	0.5053	0.0005	0.5062

Figure 2. $k_{eff}+2\sigma$ for Pu-239 mixtures with dry concrete inside the drums

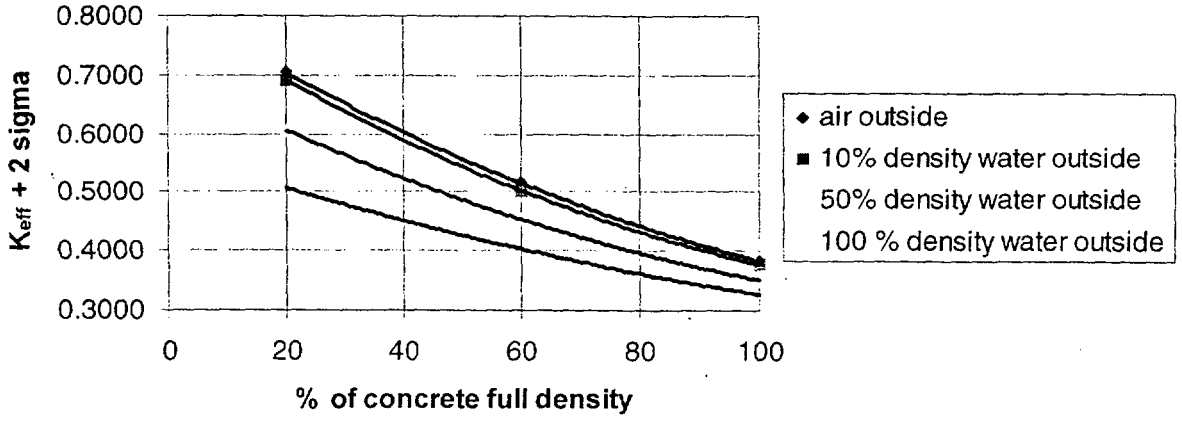

Table 27. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for Pu-239 mixtures with concrete and 10% volume of water inside the drums

Concrete density %	Air outside			10% density water outside			50% density water outside			100% density water outside		
	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$
100	0.3530	0.0002	0.3535	0.3478	0.0002	0.3483	0.3283	0.0002	0.3287	0.3096	0.0003	0.310
60	0.4507	0.0003	0.4512	0.4421	0.0003	0.4427	0.4079	0.0003	0.4085	0.3746	0.0003	0.375
20	0.6097	0.0004	0.6105	0.5941	0.0004	0.5949	0.5334	0.0004	0.5343	0.4688	0.0004	0.4696

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Figure 3. k_{eff} +2σ for Pu-239 mixtures with concrete and 10% volume of water inside the drums

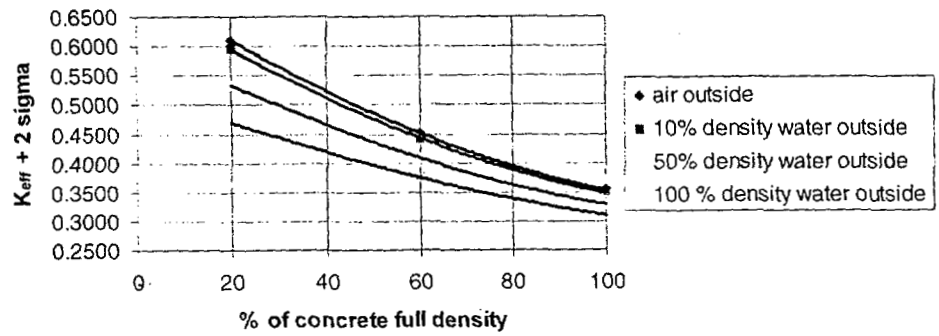

Table 18. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for Pu-239 mixtures with concrete and 20% volume of water inside the drums

Concrete density %	Air outside			10% density water outside			50% density water outside			100% density water outside		
	k_{eff}	σ	k_{eff} + 2σ	k_{eff}	σ	k_{eff} + 2σ	k_{eff}	σ	k_{eff} + 2σ	k_{eff}	σ	k_{eff} + 2σ
100	0.3283	0.0002	0.3287	0.3241	0.0002	0.3246	0.3091	0.0002	0.3095	0.2938	0.0002	0.2942
60	0.4006	0.0003	0.4011	0.3945	0.0003	0.3950	0.3700	0.0003	0.3705	0.3455	0.0003	0.3461
20	0.5118	0.0003	0.5124	0.5011	0.0003	0.5017	0.4606	0.0003	0.4612	0.4185	0.0004	0.4192

Figure 4. k_{eff} +2σ for Pu-239 mixtures with concrete and 20% volume of water inside the drums

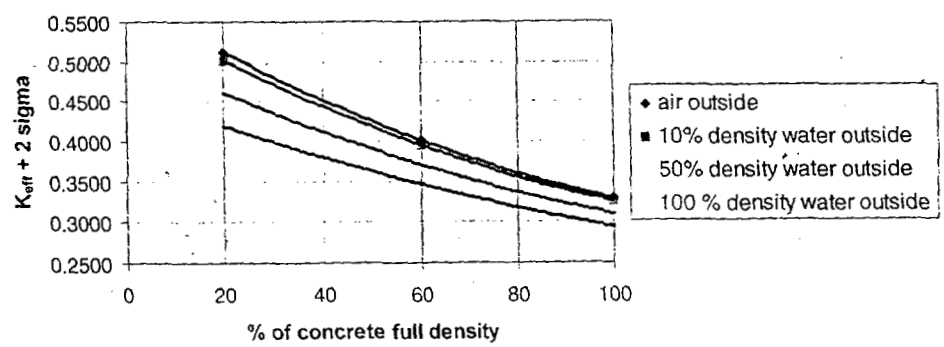

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Table 19. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for Pu-239 mixtures with concrete and 50% volume of water inside the drums

Concrete density %	Air outside			10% density water outside			50% density water outside			100% density water outside		
	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$
100	0.2716	0.0002	0.2720	0.2694	0.0001	0.2696	0.2607	0.0002	0.2611	0.2519	0.0002	0.2522
60	0.3007	0.0002	0.3011	0.2979	0.0002	0.2982	0.2865	0.0002	0.2869	0.2753	0.0002	0.2757
20	0.3356	0.0002	0.3360	0.3317	0.0002	0.3321	0.3172	0.0002	0.3177	0.3026	0.0002	0.3030

Figure 5. $k_{eff}+2\sigma$ for Pu-239 mixtures with concrete and 50% volume of water inside the drums

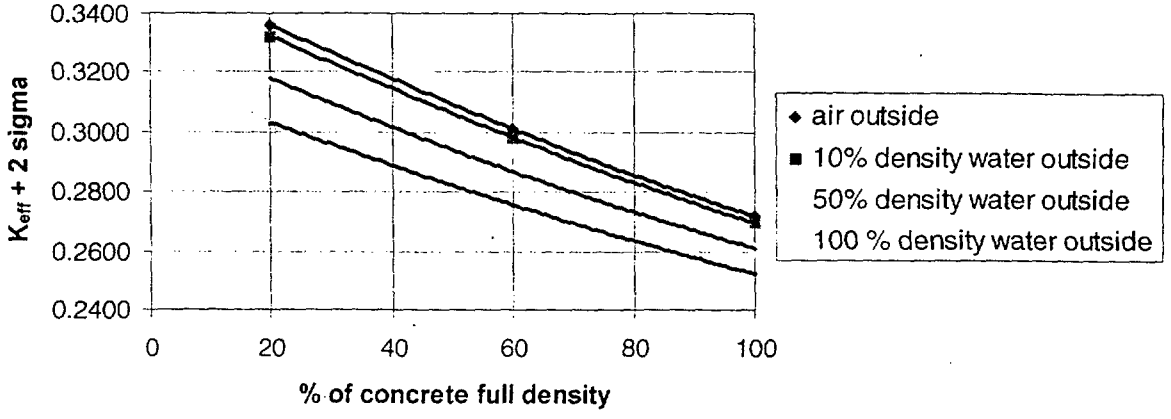


Table 20. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for Pu-239 mixtures with dry cellulose inside the drums

Cellulose density %	Air outside			10% density water outside			50% density water outside			100% density water outside		
	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$
100	0.357	0.0002	0.3574	0.35298	0.00021	0.3534	0.33748	0.0002	0.3379	0.3226	0.0002	0.3230
60	0.4899	0.0003	0.4904	0.4811	0.0003	0.4817	0.4465	0.0002	0.4470	0.4135	0.0003	0.41
20	0.7254	0.0005	0.7264	0.7069	0.0005	0.7079	0.6248	0.0005	0.6259	0.5363	0.0006	0.53

URS

Job No 30822-244-330 /6856 Job: PSR-6 By IVC Date 02/20/2001
Client WVNS Subject: Homogeneous mixtures Chk'd. KR Date 2/26/01

Figure 6. k_{eff} +2σ for Pu-239 mixtures with dry cellulose inside the drums

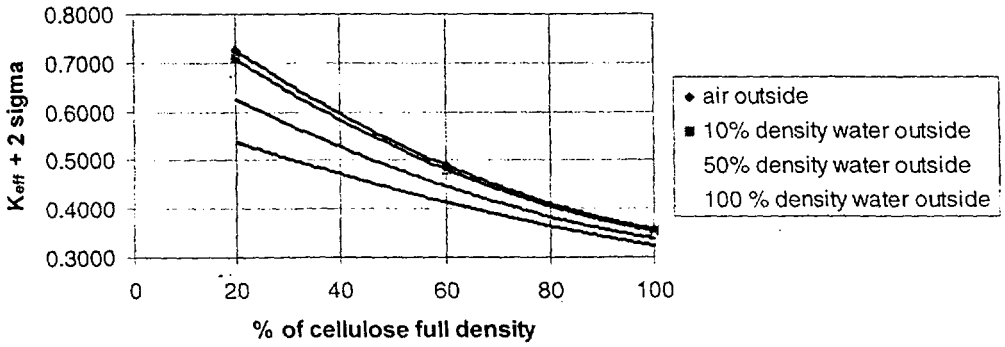
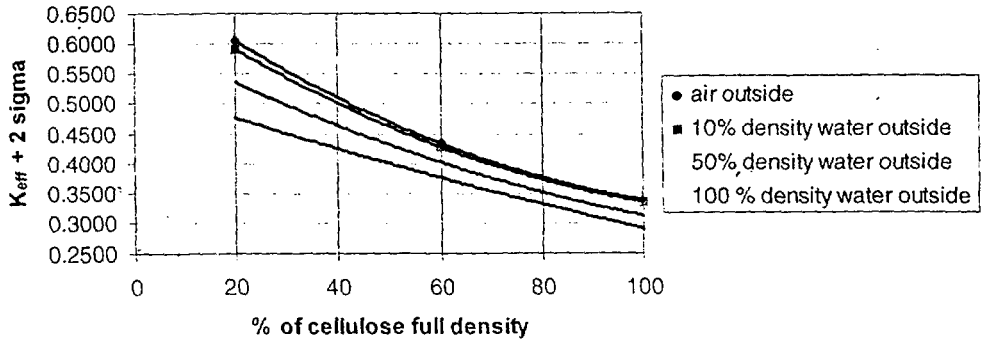


Table 21. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for Pu-239 mixtures with cellulose and 10% volume of water inside the drums

Cellulose density %	Air outside			10% density water outside			50% density water outside			100% density water outside		
	k_{eff}	σ	k_{eff}+ 2σ	k_{eff}	σ	k_{eff}+ 2σ	k_{eff}	σ	k_{eff}+ 2σ	k_{eff}	σ	k_{eff}+ 2σ
100	0.3382	0.0002	0.3386	0.33556	0.00021	0.3360	0.3116	0.0002	0.3121	0.29	0.0002	0.2907
60	0.4334	0.0002	0.4339	0.4273	0.0003	0.4278	0.4019	0.0003	0.4024	0.3760	0.0002	0.3765
20	0.6044	0.0004	0.6051	0.5903	0.0004	0.5911	0.5345	0.0004	0.5353	0.4758	0.0004	0.4767

Figure 7. k_{eff} +2σ for Pu-239 mixtures with cellulose and 10% volume of water inside the drums



URS

Job No 30822-244-330 /6856 Job: PSR-6 By IVC Date 02/20/2001
Client WVNS Subject: Homogeneous mixtures Chk'd. IK2 Date 2/20/01

Table 22. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for Pu-239 mixtures with cellulose and 20% volume of water inside the drums

Cellulose density %	Air outside			10% density water outside			50% density water outside			100% density water outside		
	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$
100	0.3137	0.0002	0.3141	0.31043	0.0002	0.3108	0.29974	0.0002	0.3001	0.2889	0.0002	0.2893
60	0.3888	0.0002	0.3893	0.38389	0.00021	0.3843	0.3639	0.0003	0.3644	0.3434	0.0003	0.3439
20	0.5063	0.0003	0.5069	0.4969	0.0004	0.4976	0.4591	0.0003	0.4597	0.4204	0.0004	0.4212

Figure 8. k_{eff} +2σ for Pu-239 mixtures with cellulose and 20% volume of water inside the drums

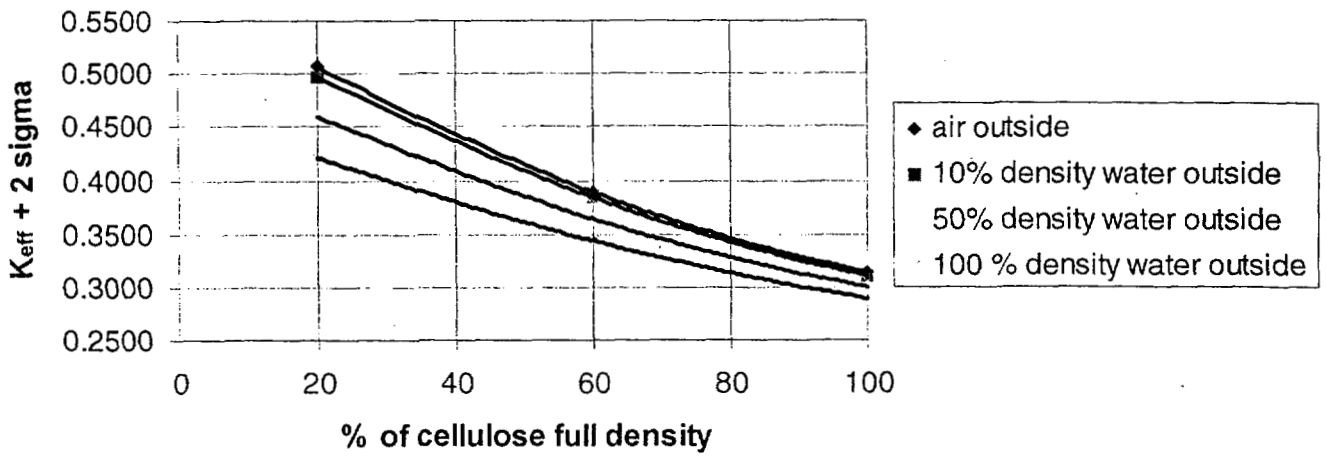


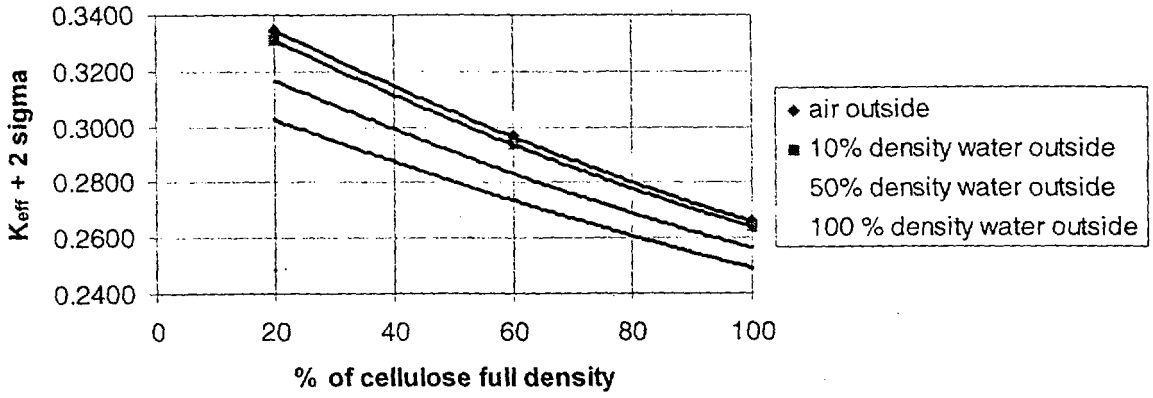
Table 23. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for Pu-239 mixtures with cellulose and 50% volume of water inside the drums

Cellulose density %	Air outside			10% density water outside			50% density water outside			100% density water outside		
	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$
100	0.2656	0.0002	0.2659	0.26359	0.00018	0.2640	0.25603	0.0002	0.2563	0.2489	0.0002	0.2492
60	0.2962	0.0002	0.2965	0.2934	0.0001	0.2937	0.2830	0.0002	0.2833	0.2733	0.0002	0.2737
20	0.3342	0.0002	0.3346	0.3306	0.0002	0.3309	0.3162	0.0002	0.3166	0.3021	0.0002	0.3025

URS

Job No 30822-244-330 /6856 Job: PSR-6 By IVC Date 02/20/2001
Client WVNS Subject: Homogeneous mixtures Chk'd. [illegible] Date 2/26/01

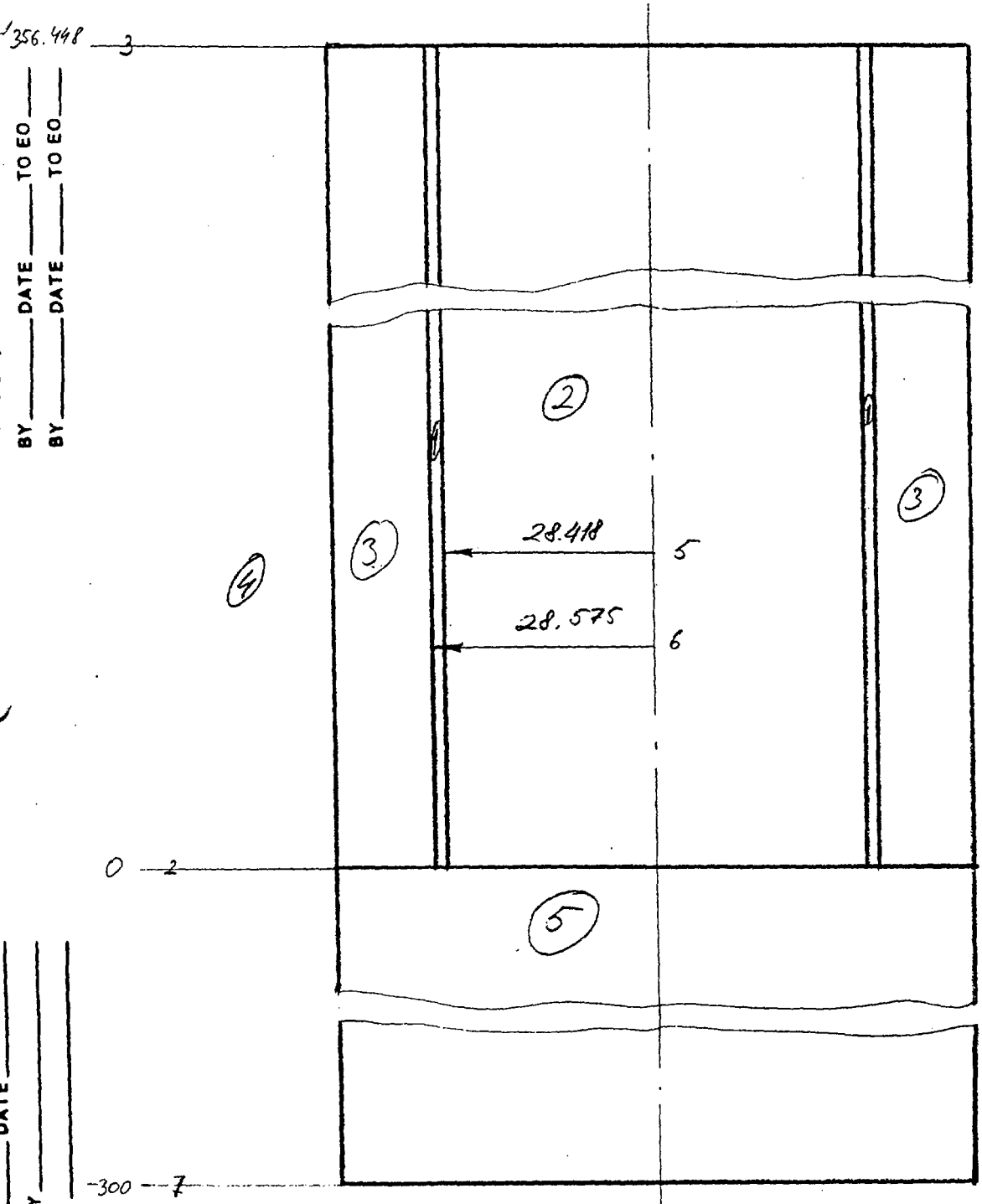
Figure 8. k_{eff} +2σ for Pu-239 mixtures with cellulose and 50% volume of water inside the drums



Attachment 1: MCNP model with surface and cell numbers

FILE _____
SUBJECT _____

4×89.112)



REVISIONS
BY _____ DATE _____ TO EO _____
BY _____ DATE _____ TO EO _____

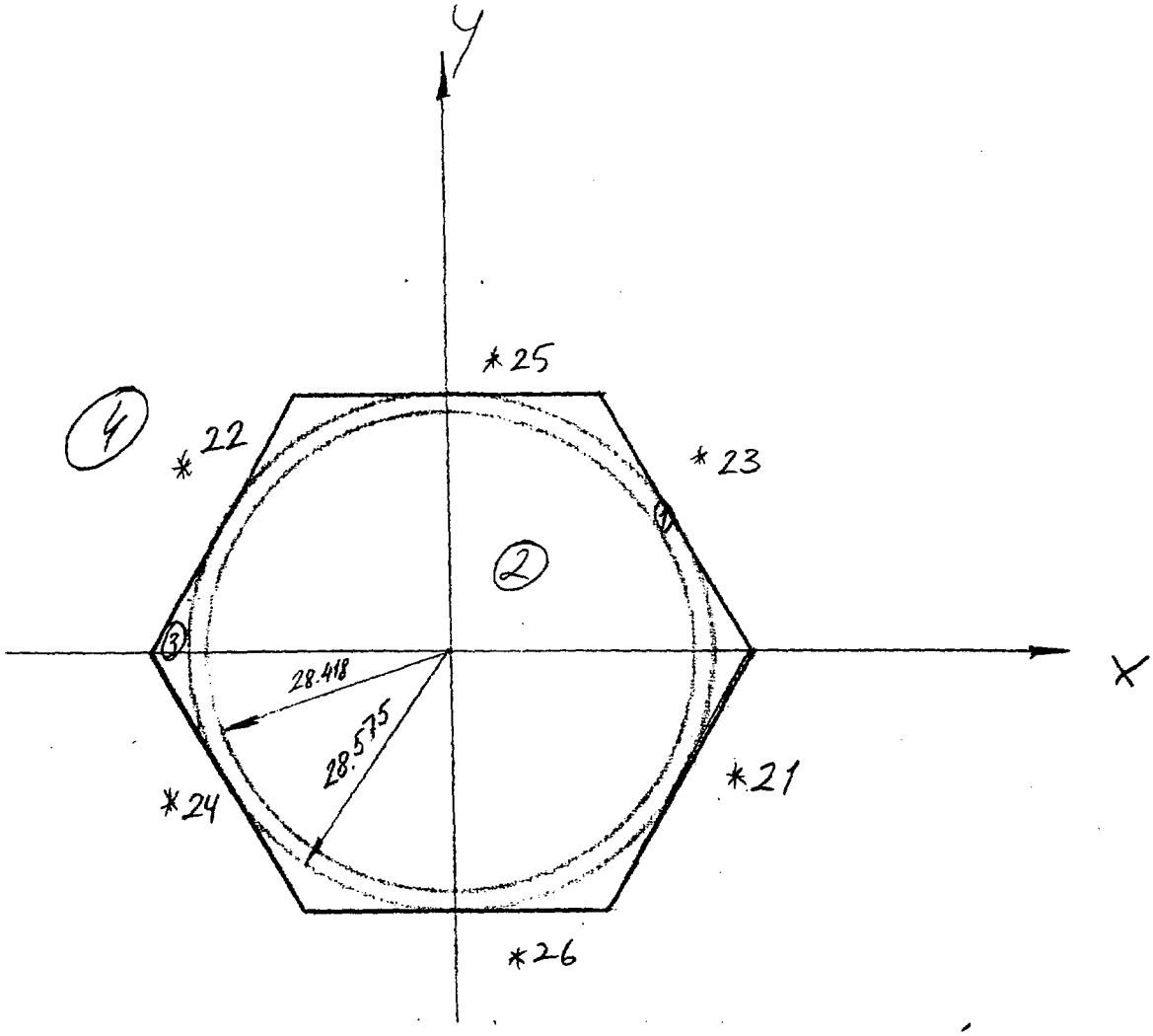
BY _____ DATE _____
CHECKED BY _____
COPY TO EO _____

Dames & Moore

FILE _____

SUBJECT _____

REVISIONS
BY _____ DATE _____ TO EO ____
BY _____ DATE _____ TO EO ____
BY _____ DATE _____ TO EO ____



BY _____ DATE _____
CHECKED BY _____
COPY TO EO _____

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Attachment 2: MCNP input file

```
                                                    1d20010
Pu-239 in cellulose matrix. Infinite lattice of 55 gal. drums, 4 tiers
C The drum height is 35 1/12 inch (89.112 cm)
c drum wall thickness is 0.157 cm
C Cell cards
C
C ---------------------------------------------------------------------------
1  65 -7.82       5 -6 2 -3     imp:n=1 $ drum wall
2  1 7.0195e-2  -5 2 -3        imp:n=1 $ Pu-239 in cellulose matrix
3  64 -1.0 -21 22 -23 24 -25 26 2 -3 6 imp:n=1 $  water ouside the drum
4  0         21 : -22 : 23 : -24 : 25 : -26 : -7 : 3 imp:n=0 $ Outside world
5  2 -2.3      -21 22 -23 24 -25 26 -2 7    imp:n=1 $  concrete floor
C ---------------------------------------------------------------------------
c
c Note: next line must be completely blank

c Surface cards
C ---------------------------------------------------------------------------
2  pz 0          $ drum bottom plane
3  pz 356.448    $ drum top plane
5  cz 28.418     $ 28.418 cm radius cylinder (internal wall of the drum)
6  cz 28.575     $ 28.575 cm radius cylinder (external wall of the drum)
7  pz -300       $ concrete bottom plane
c
c hexagonal cell with reflecting surfaces outside the drum
c (simulates infinite array of the drums)
c begin the lattice surfaces
*21 p 0.8660254 -0.5 0  28.575
*22 p 0.8660254 -0.5 0 -28.575
*23 p 0.8660254  0.5 0  28.575
*24 p 0.8660254  0.5 0 -28.575
*25 py  28.575
*26 py -28.575
c end of lattice surfaces
c
C ---------------------------------------------------------------------------
c
c Note: next line must be completely blank

c Data cards
c
c Materials
c
c Pu-239 in celulose matrix (Elements: C, H, O, Pu-239)
m1      6000.50c  2.0055e-2
        1001.50c  3.3425e-2
        8016.50c  1.6712e-2
       94239.55c  2.3977e-6
c Concrete (KENO Regular Concrete Standard Mix) from Harmon at al.
c Criticality Calculation with MCNP. A Primer. p. C-4
c (Elements: H, O, Na, Si, Al, Ca, Fe)
m2      1001.50c -0.010
        8016.50c -0.532
       11023.50c -0.029
       13027.50c -0.034
       14000.50c -0.337
       20000.50c -0.044
       26000.55c -0.014
c Water (H, O)
m64     1001.50c 0.666667
        8016.50c 0.333333
c Carbon Steel (C, Fe) composition from Crit. Calc. with MCNP p. C-10
m65     6000.50c -0.005
       26000.55c -0.995
c
mode n
print 40 60 80 100 110 126
kcode 4000 1. 20 120
ksrc  0 0 178.224
```

Attachment 3: MCNP output file

```
1mcnp     version 4a    ld=10/01/93                    11/11/00 11:15:43
*************************************************************************          probid =   11/11/00 11:15:43
name=1d20010

      Pu-239 in cellulose matrix. Infinite lattice of 55 gal. drums, 4 tiers
      C The drum height is 35 1/12 inch (89.112 cm)
      c drum wall thickness is 0.157 cm
      C Cell cards
      C
      C ---------------------------------------------------------------------
      1  65 -7.82       5 -6 2 -3     imp:n=1 $ drum wall
      2  1 7.0195e-2  -5 2 -3        imp:n=1 $ Pu-239 in cellulose matrix
      3  64 -1.0 -21 22 -23 24 -25 26 2 -3 6 imp:n=1 $  water ouside the drum
      4  0         21 : -22 : 23 : -24 : 25 : -26 : -7 : 3 imp:n=0 $ Outside world
      5  2 -2.3      -21 22 -23 24 -25 26 -2 7   imp:n=1 $  concrete floor
      C ---------------------------------------------------------------------
      c
      c Note: next line must be completely blank

      c Surface cards
      C ---------------------------------------------------------------------
      2  pz 0         $ drum bottom plane
      3  pz 356.448   $ drum top plane
      5  cz 28.418    $ 28.418 cm radius cylinder (internal wall of the drum)
      6  cz 28.575    $ 28.575 cm radius cylinder (external wall of the drum)
      7  pz -300      $ concrete bottom plane
      c
      c hexagonal cell with reflecting surfaces outside the drum
      c (simulates infinite array of the drums)
      c begin the lattice surfaces
      *21 p 0.8660254 -0.5 0  28.575
      *22 p 0.8660254 -0.5 0 -28.575
      *23 p 0.8660254  0.5 0  28.575
      *24 p 0.8660254  0.5 0 -28.575
      *25 py  28.575
      *26 py -28.575
      c end of lattice surfaces
      c
      C ---------------------------------------------------------------------
      c
      c Note: next line must be completely blank

      c Data cards
      c
      c Materials
      c
      c Pu-239 in celulose matrix (Elements: C, H, O, Pu-239)
      m1      6000.50c  2.0055e-2
              1001.50c  3.3425e-2
              8016.50c  1.6712e-2
             94239.55c  2.3977e-6
      c Concrete (KENO Regular Concrete Standard Mix) from Harmon at al.
      c Criticality Calculation with MCNP. A Primer. p. C-4
      c (Elements: H, O, Na, Si, Al, Ca, Fe)
      m2      1001.50c -0.010
              8016.50c -0.532
             11023.50c -0.029
             13027.50c -0.034
             14000.50c -0.337
             20000.50c -0.044
             26000.55c -0.014
      c Water (H, O)
```

```
 59-        m64     1001.50c 0.666667
 60-                8016.50c 0.333333
 61-        c Carbon Steel (C, Fe) composition from Crit. Calc. with MCNP p. C-10
 62-        m65     6000.50c -0.005
 63-               26000.55c -0.995
 64-        c
 65-        mode n
 66-        print 40 60 80 100 110 126
 67-        kcode 4000 1. 20 120
 68-        ksrc  0 0 178.224
 69-
 total fission nubar data are being used.
1material composition                                                                    print table 40

 material
  number     component nuclide, atom fraction

    1            6000,  0.28571       1001,  0.47618       8016,  0.23808      94239,  0.00003
    2            1001,  0.16803       8016,  0.56324      11023,  0.02136      13027,  0.02134
                14000,  0.20319      20000,  0.01859      26000,  0.00425
   64            1001,  0.66667       8016,  0.33333
   65            6000,  0.02283      26000,  0.97717



 material
  number     component nuclide, mass fraction

    1            6000,  0.44406       1001,  0.06210       8016,  0.49278      94239,  0.00106
    2            1001,  0.01000       8016,  0.53200      11023,  0.02900      13027,  0.03400
                14000,  0.33700      20000,  0.04400      26000,  0.01400
   64            1001,  0.11191       8016,  0.88809
   65            6000,  0.00500      26000,  0.99500
1cells                                                                                   print table 60

                     atom        gram                                        neutron
       cell  mat    density     density     volume       mass     pieces importance

    1     1   65  8.58651E-02 7.82000E+00 1.00200E+04 7.83563E+04     1  1.0000E+00
    2     2    1  7.01950E-02 9.00779E-01 9.04343E+05 8.14613E+05     1  1.0000E+00
    3     3   64  1.00309E-01 1.00000E+00 0.00000E+00 0.00000E+00     0  1.0000E+00
    4     4    0  0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00     0  0.0000E+00
    5     5    2  8.17913E-02 2.30000E+00 8.48564E+05 1.95170E+06     0  1.0000E+00

 total                                    1.76293E+06 2.84466E+06
1cross-section tables                                                                    print table 100

    table    length

                     tables from file critxs

  1001.50c    1153  njoy                                                          (  1301)      79/07/31.
  6000.50c   16126  njoy                                                          (  1306)      79/07/31.
  8016.50c   23669  njoy                                                          ( 1276)      05/14/81
 11023.50c   36270  njoy                                                          (  1311)      79/06/21.
 13027.50c   22891  njoy                                                          (  1313)      79/09/08.
 14000.50c   48275  njoy                                                          (  1314)      79/06/21.
 20000.50c   26104  njoy                                                          (  1320)      79/06/22.
 26000.55c   84136  njoy                                                          ( 260)       10/21/82
 94239.55c   67551  njoy                                          total nu        ( 1399)      02/21/85
```

total 326175

warning. neutron energy cutoff is below some cross-section tables.

decimal words of dynamically allocated storage

general	109732
tallies	0
bank	6403
cross sections	326175
total	442310

dump no. 1 on file ld20010r nps = 0 coll = 0 ctm = 0.00 nrn = 0

source distribution written to file ld20010s cycle = 0

1 warning message so far.

1 starting mcrun. field length = 0 cp0 = 0.01 print table 110

Pu-239 in cellulose matrix. Infinite lattice of 55 gal. drums, 4 tiers

nps	x	y	z	cell	surf	u	v	w	energy	weight	time
1	0.000E+00	0.000E+00	1.782E+02	2	0	5.085E-01	4.733E-01	7.193E-01	2.209E+00	1.000E+00	0.000E+00
2	0.000E+00	0.000E+00	1.782E+02	2	0	8.952E-01	-4.447E-01	-2.944E-02	4.904E+00	1.000E+00	0.000E+00
3	0.000E+00	0.000E+00	1.782E+02	2	0	-6.184E-01	-4.495E-01	6.446E-01	3.809E-01	1.000E+00	0.000E+00
4	0.000E+00	0.000E+00	1.782E+02	2	0	9.710E-01	-5.665E-02	-2.323E-01	1.331E+00	1.000E+00	0.000E+00
5	0.000E+00	0.000E+00	1.782E+02	2	0	5.861E-01	1.496E-01	-7.963E-01	1.902E+00	1.000E+00	0.000E+00
6	0.000E+00	0.000E+00	1.782E+02	2	0	-6.489E-02	-1.626E-01	9.845E-01	4.410E-01	1.000E+00	0.000E+00
7	0.000E+00	0.000E+00	1.782E+02	2	0	-7.068E-02	3.263E-02	-9.970E-01	4.750E-01	1.000E+00	0.000E+00
8	0.000E+00	0.000E+00	1.782E+02	2	0	-3.915E-01	4.664E-01	-7.932E-01	4.136E+00	1.000E+00	0.000E+00
9	0.000E+00	0.000E+00	1.782E+02	2	0	-2.368E-01	9.215E-01	-3.079E-01	7.453E-02	1.000E+00	0.000E+00
10	0.000E+00	0.000E+00	1.782E+02	2	0	1.946E-01	-3.204E-01	9.271E-01	3.128E+00	1.000E+00	0.000E+00
11	0.000E+00	0.000E+00	1.782E+02	2	0	-6.698E-01	-7.177E-01	-1.905E-01	1.014E+00	1.000E+00	0.000E+00
12	0.000E+00	0.000E+00	1.782E+02	2	0	-8.398E-01	-4.129E-01	3.524E-01	1.395E+00	1.000E+00	0.000E+00
13	0.000E+00	0.000E+00	1.782E+02	2	0	-1.714E-01	-8.572E-01	4.857E-01	7.748E-01	1.000E+00	0.000E+00
14	0.000E+00	0.000E+00	1.782E+02	2	0	-2.489E-01	-5.118E-01	-8.222E-01	1.101E+00	1.000E+00	0.000E+00
15	0.000E+00	0.000E+00	1.782E+02	2	0	-2.959E-01	2.119E-01	9.314E-01	1.951E+00	1.000E+00	0.000E+00
16	0.000E+00	0.000E+00	1.782E+02	2	0	1.395E-01	-9.829E-01	1.202E-01	2.186E+00	1.000E+00	0.000E+00
17	0.000E+00	0.000E+00	1.782E+02	2	0	6.909E-01	-7.110E-01	1.307E-01	1.865E+00	1.000E+00	0.000E+00
18	0.000E+00	0.000E+00	1.782E+02	2	0	-6.580E-01	5.320E-01	-5.329E-01	1.229E+00	1.000E+00	0.000E+00
19	0.000E+00	0.000E+00	1.782E+02	2	0	-9.903E-01	-1.380E-01	1.353E-02	1.305E+00	1.000E+00	0.000E+00
20	0.000E+00	0.000E+00	1.782E+02	2	0	7.462E-01	4.859E-01	-4.551E-01	1.000E+00	1.000E+00	0.000E+00
21	0.000E+00	0.000E+00	1.782E+02	2	0	-1.977E-01	9.797E-01	3.360E-02	3.990E+00	1.000E+00	0.000E+00
22	0.000E+00	0.000E+00	1.782E+02	2	0	-9.117E-01	-3.647E-01	-1.891E-01	2.665E-01	1.000E+00	0.000E+00
23	0.000E+00	0.000E+00	1.782E+02	2	0	-4.287E-01	8.361E-01	-3.423E-01	1.156E+00	1.000E+00	0.000E+00
24	0.000E+00	0.000E+00	1.782E+02	2	0	1.080E-01	3.412E-01	-9.338E-01	2.669E+00	1.000E+00	0.000E+00
25	0.000E+00	0.000E+00	1.782E+02	2	0	-9.111E-01	-9.012E-03	-4.122E-01	2.185E+00	1.000E+00	0.000E+00
26	0.000E+00	0.000E+00	1.782E+02	2	0	-2.568E-01	-6.391E-01	-7.249E-01	4.225E+00	1.000E+00	0.000E+00
27	0.000E+00	0.000E+00	1.782E+02	2	0	-2.912E-01	8.086E-01	5.113E-01	1.079E+00	1.000E+00	0.000E+00
28	0.000E+00	0.000E+00	1.782E+02	2	0	1.472E-01	-9.514E-01	2.705E-01	3.461E+00	1.000E+00	0.000E+00
29	0.000E+00	0.000E+00	1.782E+02	2	0	-6.135E-01	-7.645E-01	-1.978E-01	1.836E+00	1.000E+00	0.000E+00
30	0.000E+00	0.000E+00	1.782E+02	2	0	-5.702E-01	5.651E-01	-5.963E-01	4.556E-01	1.000E+00	0.000E+00

```
     31  0.000E+00  0.000E+00  1.782E+02     2      0 -6.607E-01  5.373E-01 -5.242E-01  6.415E-01  1.000E+00  0.000E+00
     32  0.000E+00  0.000E+00  1.782E+02     2      0 -9.742E-02 -3.639E-01 -9.263E-01  2.764E+00  1.000E+00  0.000E+00
     33  0.000E+00  0.000E+00  1.782E+02     2      0 -1.965E-01 -3.145E-01 -9.287E-01  2.785E-01  1.000E+00  0.000E+00
     34  0.000E+00  0.000E+00  1.782E+02     2      0  4.097E-01  8.465E-01 -3.399E-01  9.097E-01  1.000E+00  0.000E+00
     35  0.000E+00  0.000E+00  1.782E+02     2      0 -4.048E-02  8.831E-01  4.675E-01  3.360E-01  1.000E+00  0.000E+00
     36  0.000E+00  0.000E+00  1.782E+02     2      0  3.371E-01 -9.269E-01 -1.652E-01  6.376E-01  1.000E+00  0.000E+00
     37  0.000E+00  0.000E+00  1.782E+02     2      0 -1.867E-01  9.756E-01 -1.155E-01  2.186E+00  1.000E+00  0.000E+00
     38  0.000E+00  0.000E+00  1.782E+02     2      0 -2.616E-01  2.336E-01 -9.365E-01  7.314E-01  1.000E+00  0.000E+00
     39  0.000E+00  0.000E+00  1.782E+02     2      0  9.780E-01 -7.641E-02 -1.939E-01  2.997E-01  1.000E+00  0.000E+00
     40  0.000E+00  0.000E+00  1.782E+02     2      0  2.580E-01 -7.076E-01  6.578E-01  1.444E+00  1.000E+00  0.000E+00
     41  0.000E+00  0.000E+00  1.782E+02     2      0 -3.212E-01 -7.678E-01 -5.543E-01  1.914E+00  1.000E+00  0.000E+00
     42  0.000E+00  0.000E+00  1.782E+02     2      0  5.039E-01 -1.460E-01  8.513E-01  1.502E+00  1.000E+00  0.000E+00
     43  0.000E+00  0.000E+00  1.782E+02     2      0  6.080E-01  5.487E-01  5.738E-01  5.971E+00  1.000E+00  0.000E+00
     44  0.000E+00  0.000E+00  1.782E+02     2      0 -2.932E-01  9.304E-01 -2.199E-01  1.827E+00  1.000E+00  0.000E+00
     45  0.000E+00  0.000E+00  1.782E+02     2      0 -8.475E-01 -3.993E-01 -3.497E-01  1.928E+00  1.000E+00  0.000E+00
     46  0.000E+00  0.000E+00  1.782E+02     2      0  1.200E-01 -9.195E-01 -3.743E-01  1.351E+00  1.000E+00  0.000E+00
     47  0.000E+00  0.000E+00  1.782E+02     2      0  7.085E-01  5.879E-01  3.904E-01  2.288E+00  1.000E+00  0.000E+00
     48  0.000E+00  0.000E+00  1.782E+02     2      0  4.261E-01  9.046E-01  9.254E-03  1.230E+00  1.000E+00  0.000E+00
     49  0.000E+00  0.000E+00  1.782E+02     2      0  5.431E-01  4.270E-01 -7.230E-01  1.433E+00  1.000E+00  0.000E+00
     50  0.000E+00  0.000E+00  1.782E+02     2      0 -1.053E-01 -9.805E-01  1.658E-01  6.572E-01  1.000E+00  0.000E+00
lestimated keff results by cycle                                                                    print table 175

 source distribution written to file 1d20010s        cycle =    20

 source distribution written to file 1d20010s        cycle =    23

 source distribution written to file 1d20010s        cycle =    26

 source distribution written to file 1d20010s        cycle =    29

 source distribution written to file 1d20010s        cycle =    32

 source distribution written to file 1d20010s        cycle =    35

 ************************************************************************************************************************
 dump no.     2 on file 1d20010r     nps =     141131     coll =       26670803     ctm =    15.03     nrn =       501150590

 source distribution written to file 1d20010s        cycle =    38

 source distribution written to file 1d20010s        cycle =    41

 source distribution written to file 1d20010s        cycle =    44

 source distribution written to file 1d20010s        cycle =    47

 source distribution written to file 1d20010s        cycle =    50

 source distribution written to file 1d20010s        cycle =    53

 source distribution written to file 1d20010s        cycle =    56

 source distribution written to file 1d20010s        cycle =    59

 source distribution written to file 1d20010s        cycle =    62

 source distribution written to file 1d20010s        cycle =    65

 source distribution written to file 1d20010s        cycle =    68

 source distribution written to file 1d20010s        cycle =    71
```

```
dump no.     3 on file 1d20010r      nps =     284351      coll =       53526091      ctm =    30.18      nrn =      1005481443

source distribution written to file 1d20010s        cycle =    74

source distribution written to file 1d20010s        cycle =    77

source distribution written to file 1d20010s        cycle =    80

source distribution written to file 1d20010s        cycle =    83

source distribution written to file 1d20010s        cycle =    86

source distribution written to file 1d20010s        cycle =    89

source distribution written to file 1d20010s        cycle =    92

source distribution written to file 1d20010s        cycle =    95

source distribution written to file 1d20010s        cycle =    98

 estimator      cycle   100   ave of     80 cycles      combination          simple average     combined average      corr
k(collision)       0.321637       0.322656 0.0011     k(col/abs)          0.322830 0.0014     0.322721 0.0008   -0.4816
k(absorption)      0.316937       0.323004 0.0032     k(abs/tk ln)        0.322879 0.0014     0.322803 0.0008   -0.4631
k(trk length)      0.321700       0.322755 0.0011     k(tk ln/col)        0.322705 0.0011     0.322594 0.0011    0.9833
rem life(col)    2.7720E+04     2.8174E+04 0.0023     k(col/abs/tk ln)    0.322805 0.0010     0.322671 0.0008
rem life(abs)    2.7686E+04     2.8176E+04 0.0020     life(col/abs)     2.8175E+04 0.0021   2.8178E+04 0.0020    0.9574
source points generated   3951

source distribution written to file 1d20010s        cycle =   101

source distribution written to file 1d20010s        cycle =   104

source distribution written to file 1d20010s        cycle =   107

dump no.     4 on file 1d20010r      nps =     428361      coll =       80432555      ctm =    45.35      nrn =      1510775471

source distribution written to file 1d20010s        cycle =   110

source distribution written to file 1d20010s        cycle =   113

 estimator      cycle   116   ave of     96 cycles      combination          simple average     combined average      corr
k(collision)       0.329569       0.322566 0.0010     k(col/abs)          0.322507 0.0013     0.322543 0.0007   -0.4659
k(absorption)      0.317048       0.322449 0.0028     k(abs/tk ln)        0.322553 0.0013     0.322616 0.0007   -0.4535
k(trk length)      0.329227       0.322656 0.0010     k(tk ln/col)        0.322611 0.0010     0.322530 0.0010    0.9836
rem life(col)    2.9203E+04     2.8200E+04 0.0021     k(col/abs/tk ln)    0.322557 0.0009     0.322517 0.0007
rem life(abs)    2.9099E+04     2.8196E+04 0.0019     life(col/abs)     2.8198E+04 0.0020   2.8193E+04 0.0018    0.9608
source points generated   4125

source distribution written to file 1d20010s        cycle =   116

 estimator      cycle   117   ave of     97 cycles      combination          simple average     combined average      corr
k(collision)       0.325173       0.322593 0.0010     k(col/abs)          0.322583 0.0013     0.322589 0.0007   -0.4482
k(absorption)      0.334424       0.322573 0.0028     k(abs/tk ln)        0.322630 0.0013     0.322665 0.0008   -0.4342
k(trk length)      0.325665       0.322687 0.0010     k(tk ln/col)        0.322640 0.0010     0.322553 0.0010    0.9837
rem life(col)    2.7999E+04     2.8198E+04 0.0021     k(col/abs/tk ln)    0.322618 0.0009     0.322556 0.0007
rem life(abs)    2.8208E+04     2.8196E+04 0.0018     life(col/abs)     2.8197E+04 0.0019   2.8195E+04 0.0018    0.9601
source points generated   3979
```

estimator	cycle 118	ave of 98 cycles		combination	simple average		combined average		corr
k(collision)	0.324366	0.322611	0.0010	k(col/abs)	0.322598	0.0013	0.322606	0.0007	-0.4466
k(absorption)	0.323787	0.322585	0.0028	k(abs/tk ln)	0.322645	0.0013	0.322681	0.0007	-0.4327
k(trk length)	0.324369	0.322704	0.0010	k(tk ln/col)	0.322658	0.0010	0.322572	0.0010	0.9837
rem life(col)	2.8782E+04	2.8204E+04	0.0021	k(col/abs/tk ln)	0.322633	0.0009	0.322574	0.0007	
rem life(abs)	2.8749E+04	2.8202E+04	0.0018	life(col/abs)	2.8203E+04	0.0019	2.8200E+04	0.0018	0.9605

source points generated 4093

estimator	cycle 119	ave of 99 cycles		combination	simple average		combined average		corr
k(collision)	0.321740	0.322602	0.0009	k(col/abs)	0.322608	0.0012	0.322604	0.0007	-0.4471
k(absorption)	0.325400	0.322613	0.0028	k(abs/tk ln)	0.322653	0.0013	0.322677	0.0007	-0.4334
k(trk length)	0.321485	0.322692	0.0010	k(tk ln/col)	0.322647	0.0010	0.322563	0.0010	0.9837
rem life(col)	2.8185E+04	2.8204E+04	0.0020	k(col/abs/tk ln)	0.322636	0.0009	0.322573	0.0007	
rem life(abs)	2.8440E+04	2.8204E+04	0.0018	life(col/abs)	2.8204E+04	0.0019	2.8205E+04	0.0018	0.9592

source points generated 3830

source distribution written to file 1d20010s cycle = 119

estimator	cycle 120	ave of 100 cycles		combination	simple average		combined average		corr
k(collision)	0.324269	0.322619	0.0009	k(col/abs)	0.322619	0.0012	0.322619	0.0007	-0.4461
k(absorption)	0.323167	0.322619	0.0027	k(abs/tk ln)	0.322666	0.0012	0.322694	0.0007	-0.4321
k(trk length)	0.324718	0.322712	0.0010	k(tk ln/col)	0.322666	0.0009	0.322577	0.0010	0.9837
rem life(col)	2.8607E+04	2.8208E+04	0.0020	k(col/abs/tk ln)	0.322650	0.0009	0.322585	0.0007	
rem life(abs)	2.8657E+04	2.8209E+04	0.0018	life(col/abs)	2.8208E+04	0.0019	2.8209E+04	0.0017	0.9593

source points generated 4093

source distribution written to file 1d20010s cycle = 120

1problem summary

run terminated when 120 kcode cycles were done.

11/11/00 12:06:09

Pu-239 in cellulose matrix. Infinite lattice of 55 gal. drums, 4 tiers probid = 11/11/00 11:15:43

0

neutron creation	tracks	weight (per source particle)	energy (per source particle)	neutron loss	tracks	weight (per source particle)	energy (per source particle)
source	476537	1.0073E+00	2.1090E+00	escape	2085	3.2025E-03	2.4399E-03
				energy cutoff	0	0.	0.
				time cutoff	0	0.	0.
weight window	0	0.	0.	weight window	0	0.	0.
cell importance	0	0.	0.	cell importance	0	0.	0.
weight cutoff	0	1.7135E-01	1.0363E-08	weight cutoff	474454	1.7216E-01	1.1094E-08
energy importance	0	0.	0.	energy importance	0	0.	0.
dxtran	0	0.	0.	dxtran	0	0.	0.
forced collisions	0	0.	0.	forced collisions	0	0.	0.
exp. transform	0	0.	0.	exp. transform	0	0.	0.
upscattering	0	0.	9.7878E-07	downscattering	0	0.	2.0865E+00
				capture	0	8.9064E-01	1.9781E-02
(n,xn)	4	7.5574E-06	5.8282E-06	loss to (n,xn)	2	3.7787E-06	5.0894E-05
fission	0	0.	0.	loss to fission	0	1.1262E-01	1.7339E-04
total	476541	1.1786E+00	2.1090E+00	total	476541	1.1786E+00	2.1090E+00

number of neutrons banked	2	average lifetime, shakes	cutoffs
neutron tracks per source particle	1.0000E+00	escape 1.1323E+04	tco 1.0000E+34
neutron collisions per source particle	1.8769E+02	capture 2.8323E+04	eco 0.0000E+00
total neutron collisions	89443586	capture or escape 2.8269E+04	wc1 -5.0000E-01
net multiplication	1.0000E+00 0.0001	any termination 3.3326E+04	wc2 -2.5000E-01

computer time so far in this run	50.45 minutes	maximum number ever in bank	1
computer time in mcrun	50.44 minutes	bank overflows to backup file	0
source particles per minute	9.4480E+03	field length	0
random numbers generated	1680032944	most random numbers used was	24185 in history 155935

range of sampled source weights = 9.4429E-01 to 2.6560E+00
1neutron activity in each cell print table 126

	cell	tracks entering	population	collisions	collisions * weight (per history)	number weighted energy	flux weighted energy	average track weight (relative)	average track mfp (cm)
1	1	2143775	294047	672054	7.6157E-01	6.5811E-05	3.1845E-01	5.9222E-01	1.7292E+00
2	2	1487487	476539	77322109	9.3303E+01	6.6192E-05	3.3084E-01	6.2884E-01	1.7380E+00
3	3	1081676	287424	11282712	1.2526E+01	4.4671E-05	2.4739E-01	5.7336E-01	9.2056E-01
5	5	5414	2203	166711	1.7869E-01	3.6742E-05	1.9113E-01	5.3837E-01	2.0207E+00
total		4718352	1060213	89443586	1.0677E+02				

1keff results for: Pu-239 in cellulose matrix. Infinite lattice of 55 gal. drums, 4 tiers probid = 11/11/00 11:15:43

the initial fission neutron source distribution used the 1 source points that were input on the ksrc card.
the criticality problem was scheduled to skip 20 cycles and run a total of 120 cycles with nominally 4000 neutrons per cycle.
this problem has run 20 inactive cycles with 76989 neutron histories and 100 active cycles with 399548 neutron histories.

this calculation has completed the requested number of keff cycles using a total of 476537 fission neutron source histories.
all cells with fissionable material were sampled and had fission neutron source points.

the results of the w test for normality applied to the individual collision, absorption, and track-length keff cycle values are:

the k(collision) cycle values appear normally distributed at the 95 percent confidence level
the k(absorption) cycle values appear normally distributed at the 95 percent confidence level
the k(trk length) cycle values appear normally distributed at the 95 percent confidence level

---

the final estimated combined collision/absorption/track-length keff = 0.32258 with an estimated standard deviation of 0.00023

the estimated 68, 95, & 99 percent keff confidence intervals are 0.32235 to 0.32282, 0.32212 to 0.32305, and 0.32197 to 0.32320

the estimated collision/absorption neutron removal lifetime = 2.82E-04 seconds with an estimated standard deviation of 4.93E-07

---

the estimated average keffs, one standard deviations, and 68, 95, and 99 percent confidence intervals are:

keff estimator	keff	standard deviation	68% confidence	95% confidence	99% confidence	corr
collision	0.32262	0.00030	0.32232 to 0.32292	0.32202 to 0.32322	0.32182 to 0.32342	
absorption	0.32262	0.00089	0.32173 to 0.32351	0.32085 to 0.32438	0.32028 to 0.32496	
track length	0.32271	0.00031	0.32240 to 0.32302	0.32209 to 0.32333	0.32189 to 0.32354	
col/absorp	0.32262	0.00023	0.32239 to 0.32285	0.32216 to 0.32307	0.32202 to 0.32322	-0.4461
abs/trk len	0.32269	0.00024	0.32246 to 0.32293	0.32222 to 0.32317	0.32207 to 0.32332	-0.4321
col/trk len	0.32258	0.00031	0.32227 to 0.32288	0.32197 to 0.32319	0.32177 to 0.32339	0.9837
col/abs/trk len	0.32258	0.00023	0.32235 to 0.32282	0.32212 to 0.32305	0.32197 to 0.32320	

if the largest of each keff occurred on the next cycle, the keff results and 68, 95, and 99 percent confidence intervals would be:

keff estimator	keff	standard deviation	68% confidence	95% confidence	99% confidence
collision	0.32269	0.00031	0.32238 to 0.32299	0.32208 to 0.32330	0.32188 to 0.32350

absorption	0.32281	0.00090	0.32191 to 0.32371	0.32102 to 0.32460	0.32044 to 0.32519
track length	0.32278	0.00032	0.32246 to 0.32309	0.32215 to 0.32341	0.32194 to 0.32361
col/abs/trk len	0.32269	0.00025	0.32244 to 0.32294	0.32219 to 0.32318	0.32203 to 0.32334

the estimated collision/absorption neutron lifetimes, one standard deviations, and 68, 95, and 99 percent confidence intervals are:

type	lifetime(sec)	standard deviation	68% confidence	95% confidence	99% confidence
removal	2.8209E-04	4.9274E-07	2.8160E-04 to 2.8259E-04	2.8111E-04 to 2.8308E-04	2.8079E-04 to 2.8340E-04
capture	2.8292E-04	3.9765E-07	2.8252E-04 to 2.8332E-04	2.8213E-04 to 2.8371E-04	2.8187E-04 to 2.8397E-04
fission	2.8107E-04	4.0761E-07	2.8066E-04 to 2.8148E-04	2.8026E-04 to 2.8188E-04	2.7999E-04 to 2.8215E-04
escape	1.1791E-04	4.8651E-06	1.1304E-04 to 1.2278E-04	1.0822E-04 to 1.2760E-04	1.0505E-04 to 1.3076E-04

laverage individual and combined collision/absorption/track-length keff results for 7 different batch sizes

cycles per keff batch	number of k batches	average keff estimators and deviations k(col) st dev	k(abs) st dev	k(trk) st dev	normality co/ab/trk	average k(c/a/t) k(c/a/t) st dev	k(c/a/t) confidence intervals 95% confidence	99% confidence
1	100	0.3226 0.0003	0.3226 0.0009	0.3227 0.0003	95/95/95	0.32258 0.00023	0.32212-0.32305	0.32197-0.32320
2	50	0.3226 0.0003	0.3226 0.0008	0.3227 0.0003	95/95/95	0.32259 0.00026	0.32207-0.32312	0.32189-0.32330
4	25	0.3226 0.0003	0.3226 0.0009	0.3227 0.0003	95/95/95	0.32268 0.00029	0.32208-0.32328	0.32186-0.32350
5	20	0.3226 0.0003	0.3226 0.0009	0.3227 0.0003	95/95/95	0.32271 0.00031	0.32205-0.32337	0.32181-0.32362
10	10	0.3226 0.0003	0.3226 0.0011	0.3227 0.0003	95/95/95	0.32272 0.00034	0.32191-0.32353	0.32152-0.32393
20	5	0.3226 0.0004	0.3226 0.0014	0.3227 0.0004	95/95/95	0.32183 0.00069	0.31889-0.32478	0.31503-0.32863
25	4	0.3226 0.0004	0.3226 0.0007	0.3227 0.0004	95/95/95	0.31886 0.00086	0.30799-0.32973	0.26442-0.37331

lindividual and average keff estimator results by cycle

keff cycle	neutron histories	keff estimators by cycle k(coll)	k(abs)	k(track)	average keff estimators and deviations k(coll) st dev	k(abs) st dev	k(track) st dev	average k(c/a/t) k(c/a/t) st dev	fom
1	4000	0.37062	0.35645	0.37073					
2	1506	0.34245	0.33070	0.34331					
3	3602	0.32610	0.33978	0.32574					
4	3746	0.32318	0.31748	0.32235					
5	3960	0.32610	0.33046	0.32623					
6	3975	0.32531	0.32927	0.32537					
7	3993	0.32713	0.30791	0.32644					
8	4025	0.32256	0.33285	0.32368					
9	4136	0.32724	0.31943	0.32786					
10	4063	0.32556	0.32891	0.32581					
11	4095	0.32328	0.32944	0.32347					
12	3959	0.32389	0.32801	0.32404					
13	4005	0.32605	0.31494	0.32589					
14	3978	0.32236	0.32306	0.32293					
15	3928	0.32486	0.34502	0.32549					
16	4057	0.32250	0.33399	0.32217					
17	3852	0.32522	0.31982	0.32518					
18	4037	0.32214	0.31699	0.32251					
19	4046	0.32361	0.32469	0.32456					
20	4026	0.32844	0.31905	0.32824					
		begin active keff cycles							
21	4079	0.32655	0.33028	0.32687					
22	3957	0.32800	0.30769	0.32733	0.32728 0.00072	0.31899 0.01129	0.32710 0.00023		
23	3921	0.32074	0.32700	0.32107	0.32510 0.00222	0.32166 0.00705	0.32509 0.00201		
24	3854	0.32383	0.32768	0.32403	0.32478 0.00160	0.32316 0.00520	0.32482 0.00145	0.32149 0.00370	4470
25	4166	0.32372	0.31500	0.32368	0.32457 0.00126	0.32153 0.00435	0.32460 0.00115	0.32451 0.00268	6908
26	4032	0.32700	0.32989	0.32696	0.32497 0.00110	0.32292 0.00381	0.32499 0.00102	0.32546 0.00128	25202
27	4127	0.32075	0.33092	0.32096	0.32437 0.00111	0.32407 0.00342	0.32441 0.00103	0.32451 0.00112	27968
28	3880	0.32367	0.32565	0.32375	0.32428 0.00097	0.32426 0.00297	0.32433 0.00090	0.32445 0.00094	34981
29	4022	0.32431	0.31781	0.32428	0.32428 0.00085	0.32355 0.00271	0.32432 0.00079	0.32441 0.00085	38273
30	4085	0.32215	0.31763	0.32199	0.32407 0.00079	0.32296 0.00250	0.32409 0.00075	0.32403 0.00082	36402

31	4117	0.31945	0.33663	0.32039	0.32365	0.00083	0.32420	0.00258	0.32375	0.00075	0.32403	0.00077	37456
32	3880	0.32567	0.30948	0.32579	0.32382	0.00078	0.32297	0.00266	0.32392	0.00071	0.32399	0.00072	39797
33	4049	0.32021	0.32788	0.32007	0.32354	0.00077	0.32335	0.00247	0.32363	0.00072	0.32355	0.00065	45392
34	3892	0.32568	0.31395	0.32532	0.32369	0.00073	0.32268	0.00238	0.32375	0.00067	0.32355	0.00059	50620
35	4058	0.32449	0.33041	0.32489	0.32375	0.00068	0.32319	0.00228	0.32383	0.00063	0.32366	0.00058	49308
36	4023	0.32643	0.31460	0.32790	0.32391	0.00066	0.32266	0.00220	0.32408	0.00064	0.32363	0.00054	52812
37	4000	0.32631	0.31851	0.32670	0.32405	0.00063	0.32241	0.00208	0.32423	0.00062	0.32367	0.00052	53327
38	4028	0.32572	0.31892	0.32586	0.32415	0.00060	0.32222	0.00197	0.32432	0.00060	0.32370	0.00050	55353
39	3939	0.32102	0.33581	0.32219	0.32398	0.00059	0.32293	0.00200	0.32421	0.00057	0.32370	0.00048	56362
40	3908	0.31923	0.32472	0.31920	0.32374	0.00061	0.32302	0.00190	0.32396	0.00060	0.32345	0.00049	52013
41	4071	0.31880	0.31550	0.31935	0.32351	0.00063	0.32266	0.00184	0.32374	0.00061	0.32331	0.00057	35995
42	3924	0.32285	0.31478	0.32229	0.32348	0.00060	0.32231	0.00179	0.32368	0.00059	0.32317	0.00054	38771
43	3969	0.32179	0.33448	0.32182	0.32341	0.00058	0.32284	0.00179	0.32360	0.00057	0.32324	0.00050	42330
44	3994	0.32939	0.31663	0.32907	0.32366	0.00061	0.32258	0.00173	0.32382	0.00059	0.32342	0.00051	39200
45	3995	0.32467	0.32351	0.32457	0.32370	0.00058	0.32261	0.00166	0.32385	0.00056	0.32347	0.00049	41222
46	3836	0.32245	0.32405	0.32308	0.32365	0.00056	0.32267	0.00160	0.32382	0.00054	0.32345	0.00048	41833
47	3911	0.32330	0.32256	0.32352	0.32364	0.00054	0.32267	0.00154	0.32381	0.00052	0.32344	0.00046	43264
48	3965	0.32272	0.32533	0.32259	0.32360	0.00052	0.32276	0.00149	0.32377	0.00051	0.32343	0.00044	46183
49	3931	0.32339	0.32837	0.32349	0.32360	0.00050	0.32295	0.00145	0.32376	0.00049	0.32347	0.00042	48158
50	4119	0.32385	0.30289	0.32250	0.32360	0.00049	0.32229	0.00155	0.32372	0.00047	0.32330	0.00041	48197
51	4009	0.31943	0.33387	0.32026	0.32347	0.00049	0.32266	0.00154	0.32361	0.00047	0.32325	0.00040	48718
52	3937	0.32776	0.31375	0.32911	0.32360	0.00049	0.32238	0.00152	0.32378	0.00049	0.32324	0.00040	48623
53	4086	0.31888	0.33040	0.31876	0.32346	0.00050	0.32262	0.00149	0.32363	0.00050	0.32315	0.00039	50464
54	3803	0.32419	0.30769	0.32404	0.32348	0.00048	0.32218	0.00151	0.32364	0.00048	0.32310	0.00038	49753
55	4063	0.32540	0.30246	0.32523	0.32354	0.00047	0.32162	0.00157	0.32368	0.00047	0.32306	0.00038	48896
56	3898	0.31650	0.33075	0.31722	0.32334	0.00050	0.32187	0.00155	0.32350	0.00049	0.32294	0.00039	44596
57	3879	0.31964	0.31855	0.31970	0.32324	0.00050	0.32178	0.00151	0.32340	0.00049	0.32283	0.00040	42616
58	3934	0.32175	0.31816	0.32200	0.32320	0.00048	0.32169	0.00147	0.32336	0.00048	0.32279	0.00039	42490
59	3995	0.32552	0.31066	0.32550	0.32326	0.00048	0.32141	0.00146	0.32342	0.00047	0.32278	0.00038	43064
60	3999	0.32741	0.31237	0.32886	0.32336	0.00048	0.32118	0.00144	0.32355	0.00048	0.32278	0.00038	43258
61	4085	0.32682	0.31966	0.32800	0.32345	0.00047	0.32114	0.00141	0.32366	0.00048	0.32278	0.00038	42694
62	4121	0.32398	0.32776	0.32444	0.32346	0.00046	0.32130	0.00138	0.32368	0.00047	0.32282	0.00037	42986
63	3981	0.31754	0.33477	0.31697	0.32332	0.00047	0.32161	0.00139	0.32353	0.00048	0.32276	0.00035	46645
64	3850	0.31870	0.34226	0.31851	0.32322	0.00047	0.32208	0.00143	0.32341	0.00048	0.32280	0.00034	49287
65	3987	0.32581	0.31690	0.32572	0.32328	0.00046	0.32197	0.00141	0.32346	0.00047	0.32283	0.00033	50068
66	4041	0.32142	0.32879	0.32084	0.32324	0.00046	0.32212	0.00138	0.32341	0.00047	0.32285	0.00032	52526
67	3958	0.32567	0.33191	0.32574	0.32329	0.00045	0.32232	0.00137	0.32346	0.00046	0.32295	0.00033	49677
68	4039	0.32349	0.32706	0.32346	0.32329	0.00044	0.32242	0.00134	0.32346	0.00045	0.32298	0.00032	50633
69	3948	0.32079	0.32887	0.31980	0.32324	0.00043	0.32256	0.00132	0.32338	0.00045	0.32299	0.00031	53387
70	3998	0.31863	0.32923	0.31778	0.32315	0.00043	0.32269	0.00130	0.32327	0.00045	0.32295	0.00030	55080
71	4084	0.31920	0.32857	0.31929	0.32307	0.00043	0.32280	0.00128	0.32319	0.00045	0.32291	0.00030	55328
72	3935	0.31926	0.33666	0.31972	0.32300	0.00043	0.32307	0.00129	0.32312	0.00045	0.32290	0.00029	56210
73	4051	0.32017	0.33156	0.31930	0.32294	0.00043	0.32323	0.00127	0.32305	0.00044	0.32291	0.00028	58097
74	4082	0.32178	0.31220	0.32209	0.32292	0.00042	0.32303	0.00126	0.32303	0.00044	0.32285	0.00029	56071
75	4096	0.31983	0.33957	0.32019	0.32287	0.00041	0.32333	0.00128	0.32298	0.00043	0.32286	0.00028	56808
76	3842	0.32847	0.31560	0.32788	0.32297	0.00042	0.32319	0.00126	0.32307	0.00043	0.32294	0.00028	55461
77	4137	0.32281	0.33319	0.32211	0.32296	0.00041	0.32336	0.00125	0.32305	0.00043	0.32299	0.00028	55484
78	3959	0.32874	0.31904	0.32886	0.32306	0.00042	0.32329	0.00123	0.32315	0.00043	0.32305	0.00028	53465
79	4108	0.32450	0.31369	0.32562	0.32309	0.00041	0.32313	0.00122	0.32319	0.00042	0.32304	0.00028	53501
80	3922	0.31851	0.34052	0.31844	0.32301	0.00041	0.32342	0.00124	0.32312	0.00042	0.32304	0.00027	54493
81	3868	0.32024	0.32154	0.32020	0.32297	0.00041	0.32339	0.00122	0.32307	0.00042	0.32299	0.00027	54167
82	4036	0.32275	0.33629	0.32188	0.32296	0.00040	0.32359	0.00121	0.32305	0.00041	0.32305	0.00027	53726
83	3998	0.32113	0.33076	0.32137	0.32293	0.00039	0.32371	0.00120	0.32302	0.00041	0.32305	0.00027	54473
84	4061	0.32453	0.32499	0.32449	0.32296	0.00039	0.32373	0.00118	0.32304	0.00040	0.32308	0.00027	54898
85	3992	0.31799	0.32077	0.31821	0.32288	0.00039	0.32368	0.00116	0.32297	0.00040	0.32301	0.00027	51632
86	3852	0.32209	0.33746	0.32206	0.32287	0.00038	0.32389	0.00117	0.32296	0.00040	0.32304	0.00027	51545

87	4019	0.32037	0.32707	0.31915	0.32283	0.00038	0.32394	0.00115	0.32290	0.00040	0.32302	0.00026	52656
88	3966	0.32207	0.31146	0.32156	0.32282	0.00038	0.32376	0.00115	0.32288	0.00039	0.32297	0.00026	52435
89	3876	0.32280	0.33102	0.32377	0.32282	0.00037	0.32386	0.00113	0.32289	0.00038	0.32298	0.00026	52797
90	4022	0.32170	0.31243	0.32150	0.32281	0.00036	0.32370	0.00113	0.32287	0.00038	0.32294	0.00026	52284
91	3988	0.32451	0.31345	0.32515	0.32283	0.00036	0.32355	0.00112	0.32291	0.00038	0.32292	0.00026	52852
92	4005	0.32087	0.31337	0.32038	0.32280	0.00036	0.32341	0.00112	0.32287	0.00037	0.32287	0.00026	52186
93	3976	0.32448	0.32011	0.32493	0.32283	0.00035	0.32337	0.00110	0.32290	0.00037	0.32288	0.00025	52809
94	3959	0.32444	0.31382	0.32518	0.32285	0.00035	0.32324	0.00109	0.32293	0.00036	0.32287	0.00025	53284
95	4090	0.31552	0.31838	0.31558	0.32275	0.00036	0.32317	0.00108	0.32283	0.00037	0.32278	0.00026	47215
96	3887	0.31787	0.33030	0.31828	0.32269	0.00036	0.32327	0.00107	0.32277	0.00037	0.32275	0.00026	46731
97	4084	0.32107	0.32419	0.32123	0.32266	0.00035	0.32328	0.00106	0.32275	0.00037	0.32273	0.00026	47141
98	4136	0.32265	0.31261	0.32354	0.32266	0.00035	0.32314	0.00105	0.32276	0.00036	0.32270	0.00026	46807
99	3968	0.32303	0.31829	0.32328	0.32267	0.00035	0.32308	0.00104	0.32277	0.00036	0.32270	0.00026	47329
100	3939	0.32164	0.31694	0.32170	0.32266	0.00034	0.32300	0.00103	0.32275	0.00035	0.32267	0.00025	47496
101	3951	0.32441	0.32046	0.32517	0.32268	0.00034	0.32297	0.00102	0.32278	0.00035	0.32268	0.00025	47850
102	4032	0.31988	0.32515	0.31932	0.32264	0.00034	0.32300	0.00101	0.32274	0.00035	0.32266	0.00025	48405
103	3944	0.32418	0.31264	0.32442	0.32266	0.00033	0.32287	0.00100	0.32276	0.00035	0.32265	0.00025	48916
104	4069	0.32243	0.32634	0.32202	0.32266	0.00033	0.32292	0.00099	0.32275	0.00034	0.32266	0.00024	49605
105	4064	0.32105	0.33049	0.32106	0.32264	0.00032	0.32300	0.00098	0.32273	0.00034	0.32266	0.00024	50188
106	4060	0.32310	0.31438	0.32303	0.32265	0.00032	0.32290	0.00098	0.32274	0.00033	0.32264	0.00024	50696
107	4049	0.32118	0.31435	0.32072	0.32263	0.00032	0.32281	0.00097	0.32271	0.00033	0.32261	0.00024	50710
108	3922	0.31828	0.32743	0.31859	0.32258	0.00032	0.32286	0.00096	0.32267	0.00033	0.32258	0.00024	50222
109	4028	0.32145	0.31256	0.32292	0.32257	0.00031	0.32274	0.00096	0.32267	0.00033	0.32256	0.00024	48983
110	4116	0.32031	0.31882	0.32082	0.32254	0.00031	0.32270	0.00095	0.32265	0.00032	0.32253	0.00024	48541
111	3989	0.31973	0.32996	0.31969	0.32251	0.00031	0.32278	0.00094	0.32262	0.00032	0.32252	0.00024	49011
112	3910	0.31749	0.32676	0.31754	0.32246	0.00031	0.32282	0.00093	0.32256	0.00032	0.32248	0.00024	48294
113	4035	0.32776	0.31301	0.32726	0.32251	0.00031	0.32272	0.00093	0.32261	0.00032	0.32252	0.00023	48327
114	4236	0.32119	0.31736	0.32117	0.32250	0.00031	0.32266	0.00092	0.32260	0.00032	0.32250	0.00023	48420
115	3930	0.32186	0.30807	0.32168	0.32249	0.00031	0.32251	0.00092	0.32259	0.00032	0.32246	0.00023	47987
116	3905	0.32957	0.31705	0.32923	0.32257	0.00031	0.32245	0.00091	0.32266	0.00032	0.32252	0.00024	46296
117	4125	0.32517	0.33442	0.32566	0.32259	0.00031	0.32257	0.00091	0.32269	0.00032	0.32256	0.00024	45011
118	3979	0.32437	0.32379	0.32437	0.32261	0.00031	0.32258	0.00090	0.32270	0.00032	0.32257	0.00024	45248
119	4093	0.32174	0.32540	0.32149	0.32260	0.00030	0.32261	0.00090	0.32269	0.00031	0.32257	0.00023	45799
120	3830	0.32427	0.32317	0.32472	0.32262	0.00030	0.32262	0.00089	0.32271	0.00031	0.32258	0.00023	46028

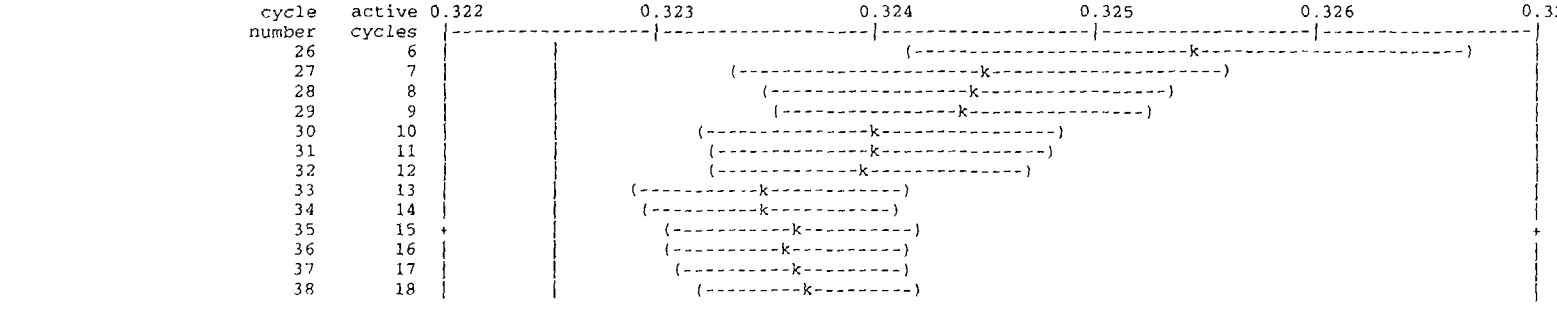
the largest active cycle keffs by estimator are:

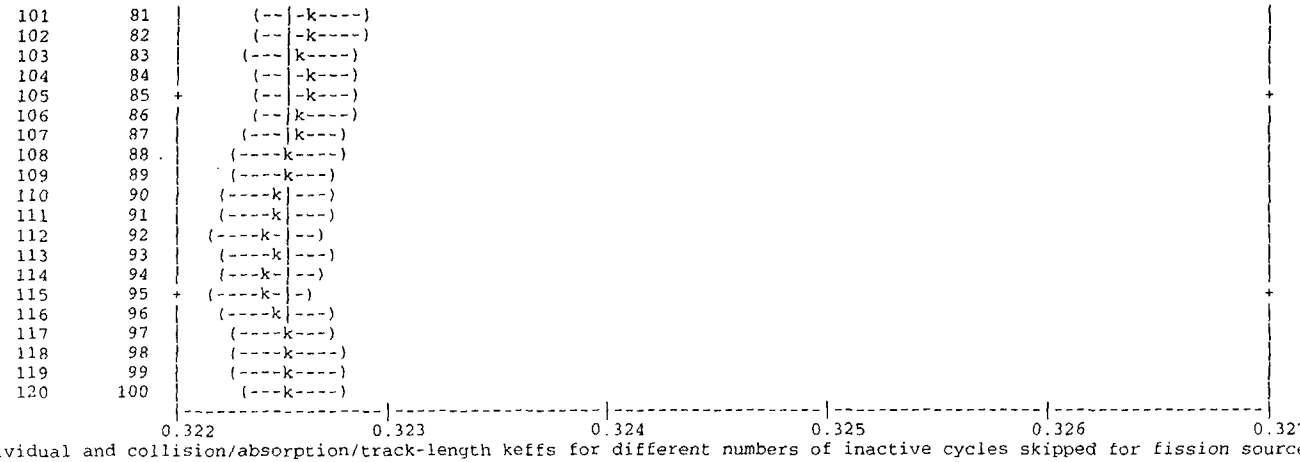
collision 0.32957 on cycle 116
absorption 0.34226 on cycle 64
track length 0.32923 on cycle 116

the smallest active cycle keffs by estimator are:

collision 0.31552 on cycle 95
absorption 0.30246 on cycle 55
track length 0.31558 on cycle 95

1plot of the estimated col/abs/track-length keff one standard deviation interval versus cycle number (| = final keff = 0.32258)





lindividual and collision/absorption/track-length keffs for different numbers of inactive cycles skipped for fission source settling

skip cycles	active cycles	active neutrons	average keff estimators and deviations k(col)	st dev	k(abs)	st dev	k(trk)	st dev	normality co/ab/tl	average k(c/a/t) k(c/a/t)	st dev	k(c/a/t) confidence intervals 95% confidence	99% confidence
0	120	476537	0.3235	0.0005	0.3234	0.0009	0.3236	0.0005	no/95/no	0.32340	0.00046	0.32248-0.32433	0.32218-0.32463
1	119	472537	0.3231	0.0003	0.3231	0.0008	0.3232	0.0003	no/95/no	0.32304	0.00027	0.32251-0.32357	0.32233-0.32374
2	118	471031	0.3229	0.0003	0.3231	0.0008	0.3230	0.0003	95/95/95	0.32293	0.00022	0.32249-0.32337	0.32234-0.32352
3	117	467429	0.3229	0.0003	0.3229	0.0008	0.3230	0.0003	95/95/95	0.32287	0.00022	0.32244-0.32331	0.32229-0.32345
4	116	463683	0.3229	0.0003	0.3230	0.0008	0.3230	0.0003	95/95/95	0.32288	0.00022	0.32243-0.32332	0.32229-0.32346
5	115	459723	0.3229	0.0003	0.3229	0.0008	0.3230	0.0003	95/95/95	0.32284	0.00022	0.32240-0.32328	0.32226-0.32343
6	114	455748	0.3229	0.0003	0.3229	0.0008	0.3230	0.0003	95/95/95	0.32281	0.00022	0.32237-0.32326	0.32223-0.32340
7	113	451755	0.3228	0.0003	0.3230	0.0008	0.3229	0.0003	95/95/95	0.32280	0.00022	0.32236-0.32325	0.32221-0.32339
8	112	447730	0.3228	0.0003	0.3229	0.0008	0.3229	0.0003	95/95/95	0.32280	0.00022	0.32235-0.32324	0.32220-0.32339
9	111	443594	0.3228	0.0003	0.3229	0.0008	0.3229	0.0003	95/95/95	0.32277	0.00022	0.32233-0.32322	0.32218-0.32337
10	110	439531	0.3228	0.0003	0.3229	0.0008	0.3229	0.0003	95/95/95	0.32275	0.00022	0.32230-0.32319	0.32215-0.32334
11	109	435436	0.3228	0.0003	0.3228	0.0009	0.3229	0.0003	95/95/95	0.32273	0.00023	0.32228-0.32318	0.32214-0.32333
12	108	431477	0.3228	0.0003	0.3228	0.0009	0.3229	0.0003	95/95/95	0.32272	0.00023	0.32226-0.32317	0.32211-0.32332
13	107	427472	0.3227	0.0003	0.3228	0.0009	0.3228	0.0003	95/95/95	0.32270	0.00023	0.32224-0.32316	0.32210-0.32331
14	106	423494	0.3227	0.0003	0.3228	0.0009	0.3228	0.0003	95/95/95	0.32270	0.00023	0.32224-0.32317	0.32209-0.32332
15	105	419566	0.3227	0.0003	0.3226	0.0009	0.3228	0.0003	95/95/95	0.32266	0.00023	0.32221-0.32311	0.32206-0.32326
16	104	415509	0.3227	0.0003	0.3225	0.0009	0.3228	0.0003	95/95/95	0.32264	0.00023	0.32218-0.32309	0.32204-0.32324
17	103	411657	0.3227	0.0003	0.3225	0.0009	0.3228	0.0003	95/95/95	0.32262	0.00023	0.32216-0.32308	0.32201-0.32323
18	102	407620	0.3227	0.0003	0.3226	0.0009	0.3228	0.0003	95/95/95	0.32264	0.00023	0.32218-0.32310	0.32202-0.32325
19	101	403574	0.3227	0.0003	0.3226	0.0009	0.3228	0.0003	95/95/95	0.32263	0.00023	0.32217-0.32309	0.32201-0.32324
20	100*	399548	0.3226	0.0003	0.3226	0.0009	0.3227	0.0003	95/95/95	0.32258	0.00023	0.32212-0.32305	0.32197-0.32320
22	98	391512	0.3225	0.0003	0.3227	0.0009	0.3226	0.0003	95/95/95	0.32252	0.00023	0.32206-0.32298	0.32191-0.32313
24	96	383737	0.3225	0.0003	0.3226	0.0009	0.3226	0.0003	95/95/95	0.32251	0.00023	0.32204-0.32297	0.32189-0.32312
26	94	375539	0.3225	0.0003	0.3226	0.0009	0.3226	0.0003	95/95/95	0.32245	0.00023	0.32199-0.32292	0.32184-0.32307
28	92	367532	0.3225	0.0003	0.3225	0.0009	0.3226	0.0003	95/95/95	0.32244	0.00024	0.32196-0.32291	0.32181-0.32306
30	90	359425	0.3225	0.0003	0.3226	0.0009	0.3226	0.0003	95/95/95	0.32244	0.00024	0.32196-0.32292	0.32180-0.32308
32	88	351428	0.3225	0.0003	0.3226	0.0009	0.3225	0.0003	95/95/95	0.32244	0.00025	0.32195-0.32293	0.32179-0.32309
34	86	343487	0.3224	0.0003	0.3226	0.0010	0.3225	0.0003	95/95/95	0.32243	0.00025	0.32193-0.32294	0.32176-0.32310
36	84	335406	0.3224	0.0003	0.3226	0.0010	0.3225	0.0003	95/95/95	0.32239	0.00026	0.32188-0.32290	0.32172-0.32307
38	82	327378	0.3223	0.0003	0.3227	0.0010	0.3224	0.0003	95/95/95	0.32234	0.00026	0.32182-0.32285	0.32166-0.32302
40	80	319531	0.3223	0.0003	0.3225	0.0010	0.3224	0.0004	95/95/95	0.32236	0.00026	0.32183-0.32288	0.32166-0.32305
42	78	311536	0.3224	0.0003	0.3227	0.0010	0.3224	0.0004	95/95/95	0.32242	0.00026	0.32189-0.32294	0.32172-0.32311

44	76	303573	0.3223 0.0003	0.3226 0.0010	0.3224 0.0004	95/95/95	0.32233 0.00026	0.32181-0.32285	0.32164-0.32302
46	74	295742	0.3223 0.0003	0.3226 0.0011	0.3223 0.0004	95/95/95	0.32229 0.00027	0.32176-0.32283	0.32159-0.32300
48	72	287866	0.3222 0.0004	0.3226 0.0011	0.3223 0.0004	95/95/95	0.32227 0.00027	0.32172-0.32282	0.32155-0.32299
50	70	279816	0.3222 0.0004	0.3228 0.0011	0.3223 0.0004	95/95/95	0.32228 0.00028	0.32172-0.32284	0.32154-0.32303
52	68	271870	0.3222 0.0004	0.3227 0.0011	0.3222 0.0004	95/95/95	0.32225 0.00028	0.32169-0.32282	0.32150-0.32301
54	66	263981	0.3222 0.0004	0.3228 0.0011	0.3222 0.0004	95/95/95	0.32229 0.00029	0.32171-0.32288	0.32151-0.32307
56	64	256020	0.3222 0.0004	0.3230 0.0011	0.3223 0.0004	95/95/95	0.32235 0.00030	0.32176-0.32294	0.32156-0.32314
58	62	248207	0.3223 0.0004	0.3232 0.0011	0.3223 0.0004	95/95/95	0.32242 0.00030	0.32181-0.32302	0.32162-0.32322
60	60	240213	0.3221 0.0004	0.3236 0.0011	0.3222 0.0004	95/95/95	0.32238 0.00031	0.32175-0.32300	0.32155-0.32321
62	58	232007	0.3220 0.0004	0.3236 0.0011	0.3220 0.0004	95/95/95	0.32229 0.00031	0.32166-0.32291	0.32145-0.32312
64	56	224176	0.3221 0.0004	0.3230 0.0011	0.3222 0.0004	95/95/95	0.32231 0.00032	0.32166-0.32295	0.32145-0.32316
66	54	216148	0.3221 0.0004	0.3230 0.0012	0.3221 0.0004	95/95/95	0.32226 0.00033	0.32160-0.32293	0.32137-0.32315
68	52	208151	0.3220 0.0004	0.3228 0.0012	0.3220 0.0004	95/95/95	0.32215 0.00033	0.32148-0.32281	0.32126-0.32303
70	50	200205	0.3221 0.0004	0.3225 0.0012	0.3222 0.0004	95/99/95	0.32219 0.00034	0.32150-0.32288	0.32127-0.32311
72	48	192186	0.3222 0.0004	0.3221 0.0012	0.3223 0.0004	95/99/95	0.32221 0.00035	0.32150-0.32293	0.32126-0.32317
74	46	184053	0.3223 0.0004	0.3221 0.0012	0.3223 0.0004	95/99/95	0.32227 0.00037	0.32152-0.32301	0.32127-0.32326
76	44	176115	0.3222 0.0004	0.3219 0.0012	0.3223 0.0004	95/95/95	0.32214 0.00037	0.32138-0.32290	0.32113-0.32315
78	42	168019	0.3220 0.0004	0.3217 0.0013	0.3221 0.0004	95/95/95	0.32195 0.00037	0.32120-0.32270	0.32095-0.32295
80	40	159989	0.3220 0.0004	0.3214 0.0012	0.3221 0.0004	95/95/95	0.32194 0.00039	0.32116-0.32272	0.32089-0.32298
82	38	152085	0.3221 0.0004	0.3210 0.0012	0.3222 0.0005	95/95/95	0.32186 0.00040	0.32104-0.32267	0.32076-0.32295
84	36	144026	0.3220 0.0005	0.3206 0.0012	0.3221 0.0005	95/95/95	0.32175 0.00042	0.32090-0.32260	0.32061-0.32289
86	34	136182	0.3221 0.0005	0.3201 0.0012	0.3222 0.0005	95/95/95	0.32171 0.00042	0.32085-0.32258	0.32055-0.32288
88	32	128197	0.3222 0.0005	0.3202 0.0012	0.3224 0.0005	95/95/95	0.32175 0.00047	0.32079-0.32270	0.32046-0.32303
90	30	120299	0.3222 0.0005	0.3201 0.0012	0.3223 0.0005	95/95/95	0.32175 0.00048	0.32077-0.32273	0.32043-0.32307
92	28	112306	0.3221 0.0006	0.3206 0.0013	0.3223 0.0006	95/95/95	0.32187 0.00050	0.32084-0.32290	0.32048-0.32326
94	26	104371	0.3220 0.0006	0.3209 0.0014	0.3221 0.0006	95/95/95	0.32181 0.00052	0.32073-0.32288	0.32035-0.32326
96	24	96394	0.3224 0.0006	0.3206 0.0014	0.3225 0.0006	95/95/95	0.32212 0.00050	0.32109-0.32316	0.32072-0.32353
98	22	88174	0.3225 0.0006	0.3208 0.0015	0.3225 0.0006	95/95/95	0.32216 0.00053	0.32104-0.32328	0.32063-0.32369
100	20	80267	0.3225 0.0007	0.3211 0.0016	0.3225 0.0007	95/95/95	0.32222 0.00058	0.32100-0.32345	0.32054-0.32390
102	18	72284	0.3225 0.0007	0.3209 0.0018	0.3226 0.0007	95/95/95	0.32228 0.00063	0.32093-0.32363	0.32041-0.32415
104	16	64271	0.3224 0.0008	0.3211 0.0019	0.3225 0.0008	95/95/95	0.32224 0.00072	0.32068-0.32381	0.32007-0.32442
106	14	56147	0.3225 0.0009	0.3209 0.0020	0.3226 0.0009	95/95/95	0.32224 0.00084	0.32038-0.32410	0.31962-0.32486
108	12	48176	0.3229 0.0010	0.3209 0.0022	0.3230 0.0010	95/95/95	0.32272 0.00095	0.32056-0.32488	0.31962-0.32582
110	10	40032	0.3233 0.0012	0.3219 0.0025	0.3233 0.0011	95/95/95	0.32300 0.00102	0.32059-0.32541	0.31944-0.32657
112	8	32133	0.3245 0.0011	0.3203 0.0029	0.3244 0.0010	95/95/95	0.32396 0.00137	0.32044-0.32748	0.31843-0.32948
114	6	23862	0.3245 0.0012	0.3220 0.0036	0.3245 0.0012	95/95/95	0.32420 0.00160	0.31910-0.32930	0.31484-0.33356
116	4	16027	0.3239 0.0007	0.3267 0.0026	0.3241 0.0009	95/95/95	0.32332 0.00089	0.31205-0.33458	0.26691-0.37972
117	3	11902	0.3235 0.0009	0.3241 0.0007	0.3235 0.0010				
118	2	7923	0.3230 0.0013	0.3243 0.0011	0.3231 0.0016				

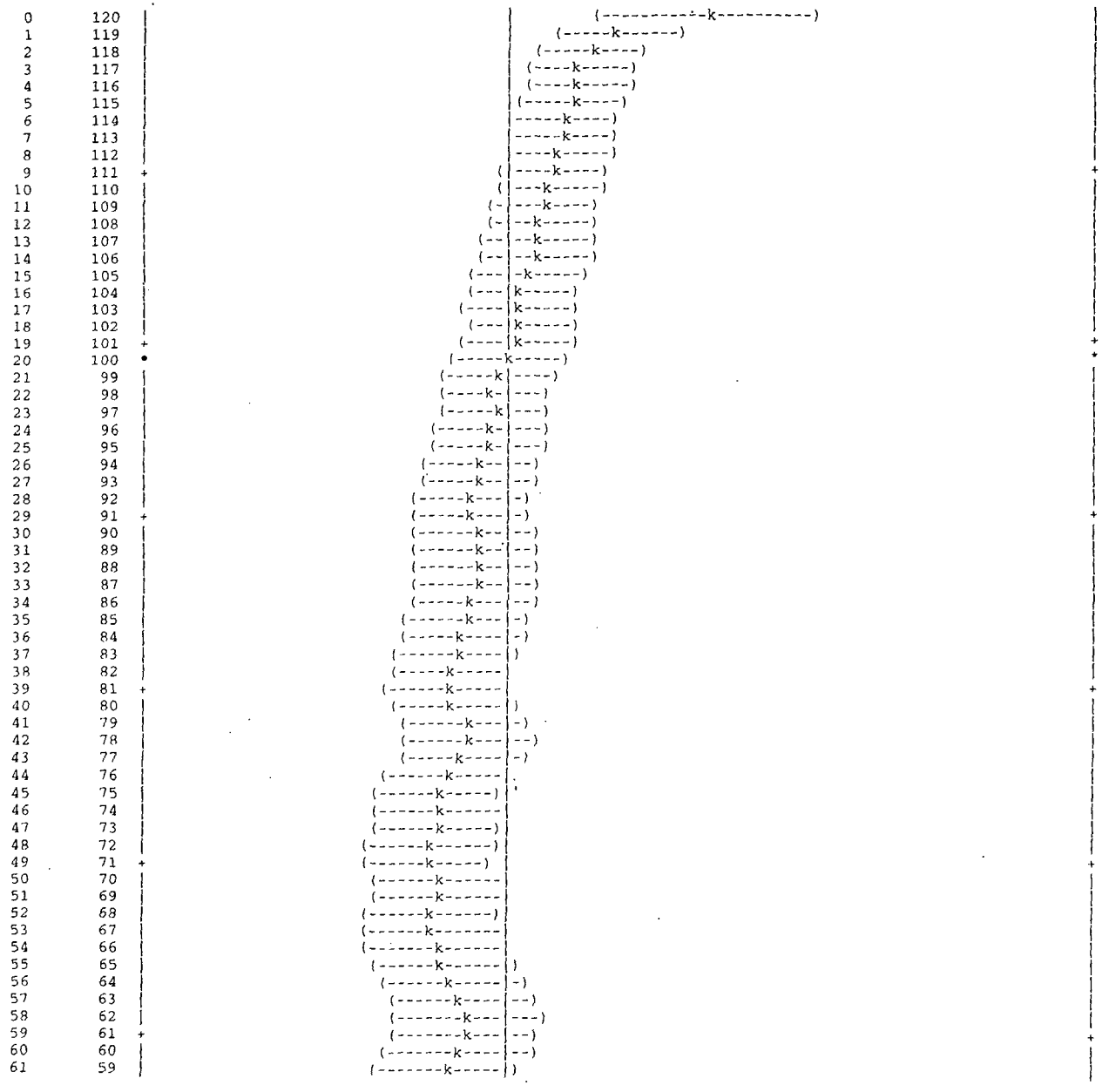
the minimum estimated standard deviation for the col/abs/tl keff estimator occurs with 3 inactive cycles and 117 active cycles.

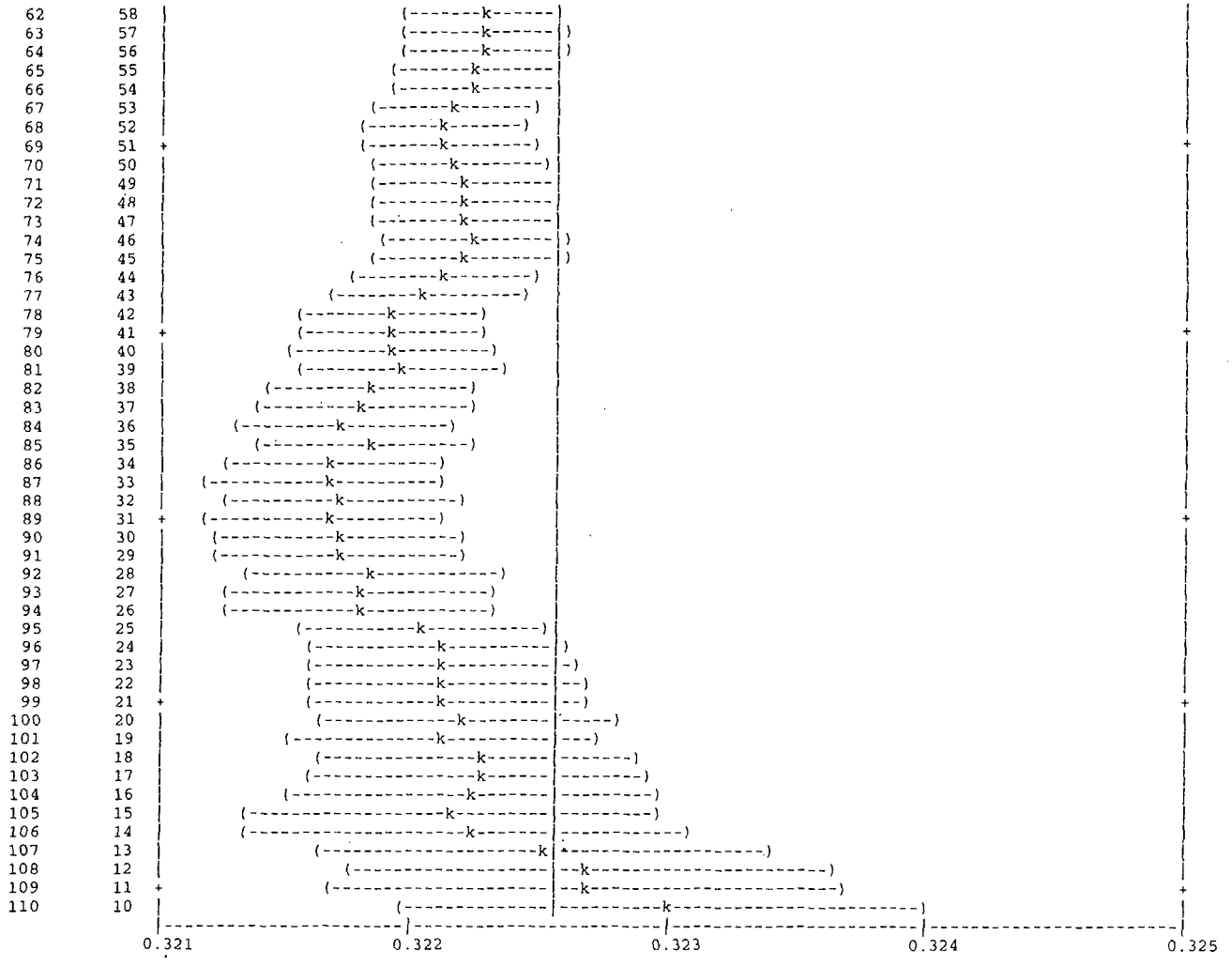
the first active half of the problem skips 20 cycles and uses 50 active cycles; the second half skips 70 and uses 50 cycles.
the col/abs/trk-len keff, one standard deviation, and 68, 95, and 99 percent intervals for each active half of the problem are:

problem	keff	standard deviation	68% confidence	95% confidence	99% confidence
first half	0.32295	0.00030	0.32264 to 0.32325	0.32234 to 0.32355	0.32214 to 0.32375
second half	0.32219	0.00034	0.32185 to 0.32254	0.32150 to 0.32288	0.32127 to 0.32311
final result	0.32258	0.00023	0.32235 to 0.32282	0.32212 to 0.32305	0.32197 to 0.32320

the first and second half values of k(collision/absorption/track length) appear to be the same at the 95 percent confidence level.
1plot of the estimated col/abs/track-length keff one standard deviation interval by active cycle number (| = final keff = 0.32258)

```
inactive   active 0.321                0.322                0.323                0.324                0.325
  cycles   cycles  |--------------------|--------------------|--------------------|--------------------|
```





dump no. 5 on file 1d20010r nps = 476537 coll = 89443586 ctm = 50.44 nrn = 1680032944

1 warning message so far.

run terminated when 120 kcode cycles were done.

computer time = 50.45 minutes

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Calculation Cover Page

3065 Southwestern Boulevard
Suite 202
Orchard Park, NY 14127
716 675 7130 Tel
716 675 7137 Fax

Job No: **30822-244-330 /6856** Calculation No: **BUF-2000-102/Rev. 0** Date: **December 27, 2000**

Problem Statement & Calculation Objectives:

To determine the neutron multiplication factors for $\infty \times \infty \times 4$ arrays of 55 gallon drums and B-25 boxes with Pu-239 metal spheres and variable density cellulose outside the sphere. There is no water outside the containers with fissile material.

References and Data Available:

J. F. Briemiester, ed., MCNP - A General Purpose Monte Carlo N-Particle Transport Code, Version 4A, LA-12625, Los Alamos National Laboratory, Los Alamos NM, 1993
C. D. Harmon, II et al., Criticality Calculations with MCNP: A Primer, Manual LA-12827, Los Alamos National Laboratory, Los Alamos NM, 1993
D. R. Lide, CRC Handbook of Chemistry an Physics, CRC Press, Boston MA, 1991.
F. H. Attix, Introduction to Radiological Physics and Radiation Dosimetry. John Wiley & Sons, Inc., New York NY, 1986

Attachments:

Attachment 1: Case 1 with MCNP surface and cell numbers
Attachment 2: Case 1 MCNP input file
Attachment 3: Case 1 MCNP output file
Attachment 4: Case 2 with MCNP surface and cell numbers
Attachment 5: Case 2 MCNP input file
Attachment 6: Case 2 MCNP output file

Prepared by:

Signature Igor V. Chichkov — Date 02/20/2001

Checked by:

Signature Kevin Roberts — Date 2/26/01

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Sheet No. 2/9
Calc. No. BUF-2000-102
Rev. No. 0

Job No 30822-244-330 /6856 Job: PSR-6 By IVC Date 09/04/01
Client WVNS Subject: Pu-239 metal spheres Chk'd. IVC for JCW Date 09/04/01

Analysis

Assumptions

- Pu-239 inside the sphere is a pure metal.
- The density of the metal Plutonium is 19.78 g/cm^3
- The cellulose fills the entire space inside the container and outside the Plutonium sphere.
- The containers stand on the 3 m thick concrete floor
- B-25 box inside dimensions are 172.72 x 137.16 x 87.63 cm or 68 x 54 x 34.5 inches
- The B-25 box wall thickness is zero
- Every B-25 Box contains 350 g of Pu-239
- The B-25 boxes are arranged in the infinite square array, 4 tiers heigh ($\infty \times \infty \times 4$)
- The 55 gallon drum is a cylinder with 56.83 cm (22.37 inches) inside diameter and 89.11 cm (35.08 inches) height
- The drum wall is made of carbon steel and its thickness is 0.157 cm
- The drums are arranged in the infinite hexagonal array, 4 tiers heigh ($\infty \times \infty \times 4$)
- Every drum contains 200 g of Pu-239
- There is no water outside containers, air fills the space between the containers

MCNP Model

Neutron multiplication factors were calculated with MCNP4A code. Two different cases were studied:

- Case 1. $\infty \times \infty \times 4$ array of 55 gallon drums
- Case 2. $\infty \times \infty \times 4$ array of B-25 boxes

The plutonium spheres located in different positions on the vertical axis of the containers and different positions on the drum radius and box diagonal were studied. The cellulose density parametric analysis was performed for each case. Attachments 1 and 4 have the drawings of the models used for case 1 and 2 respectively. Examples of MCNP input and output files for both cases can also be found in the Attachmen.

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Job No 30822-244-330 /6856 Job: PSR-6 By IVC Date 02/06/2001
Client WVNS Subject: Pu-239 metal spheres Chk'd. RC Date 2/26/01

Air, Carbon Steel, Concrete and Cellulose Composition

Table 1 shows the element weight fractions for air (Attix F.H., 1986). Table 2 shows the element weight fractions for carbon steel (Harmon C. D., II et al., 1993) used in the drum walls. Table 3 shows the element composition of concrete (Harmon C. D., II et al., 1993) in the floor.

Table 1. Air composition

Element	Weight Fraction
Carbon (C)	0.000124
Nitrogen (N)	0.755267
Oxygen (O)	0.231781
Argon (Ar)	0.012827

Table 2. Carbon Steel Composition

Element	Weight Fraction
Iron (Fe)	0.995
Carbon (C)	0.005

Table 3. Concrete composition

Element	Weight Fraction
Hydrogen (H)	0.010
Oxygen (O)	0.532
Sodium (Na)	0.029
Aluminum (Al)	0.034
Silicon (Si)	0.337
Calcium (Ca)	0.044
Iron (Fe)	0.014

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The weight fractions of the elements composing the cellulose were determined based on the known atomic weights of the elements (Table 4) and the cellulose chemical formula - $C_6H_{10}O_5$.

Table 4. The atomic weights of the elements

Element	Atomic Weight
Hydrogen (H)	1.00794
Carbon (C)	12.0107
Oxygen (O)	15.9994

The molecular weight of cellulose ($C_6H_{10}O_5$) was calculated as the sum of all atomic weights composing the molecule. The weight fraction of an ith element was found as a ratio of the ith element weight in the molecule to the molecular weight of this molecule.

$$w_{ij} = \frac{n_i A_i}{M_j} = \frac{n_i A_i}{\sum n_i A_i} \qquad (1)$$

where

w_{ij} = the weight fraction of ith element in a molecule j

n_i = the number of the ith elements in the jth molecule

A_i = the atomic weight of the ith element, g/mol

M_j = the molecular weight the jth molecule, g/mol

Calculated weight fractions for cellulose are shown in Table 5.

Table 5. Cellulose Weight Fractions

Element	Weight Fraction
Hydrogen (H)	0.062
Carbon (C)	0.444
Oxygen (O)	0.493

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Job No 30822-244-330 /6856 Job: PSR-6 By IVC Date 02/20/2001
Client WVNS Subject: Pu-239 metal spheres Chk'd. K L Date 2/26/01

Results

To find the spheres' locations where k_{eff} reaches its maximum, cases with different coordinates of the sphere centers were studied. First the plutonium spheres "were moved" along the vertical axis of the containers. After the Z- (vertical axis) coordinate for maximum k_{eff} was found, the vertical location of the spheres "was fixed" and they " were moved" radially along X- axis in case of the 55 gallon drum and along the diagonal in case of the B-25 box.

The results of the calculations performed using MCNP-4A code are shown in the following tables and graphs. The tables provide the Monte Carlo determined neutron multiplication factor (k_{eff}) values and their standard deviations (σ), and the graphs plot the $k_{eff}+2\sigma$ values for all studied cases.

Table 6. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for 200 g Pu-239 spheres in the 55 gallon drums with cellulose. The spheres are located on the drums' vertical axis.

case number	z2-z1	z4-z3	Z coordinates for the center of the sphere, cm				100% density cellulose			80% density cellulose		
			1st drum	2nd drum	3rd drum	4th drum	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$
1	175.54	175.54	1.34	176.88	179.56	355.1	0.3894	0.0007	0.3908	0.3732	0.0007	0.3746
2	148.22	148.22	15.00	163.22	193.22	341.44	0.3331	0.0006	0.3343	0.3224	0.0006	0.3237
3	118.22	118.22	30.00	148.22	208.22	326.44	0.3337	0.0006	0.3348	0.3231	0.0006	0.3243
4	88.22	88.22	45.00	133.22	223.22	311.44	0.3323	0.0006	0.3335	0.3228	0.0005	0.3239
5	58.22	58.22	60.00	118.22	238.22	296.44	0.3333	0.0005	0.3343	0.3227	0.0005	0.3237
6	28.22	28.22	75.00	103.22	253.22	281.44	0.3348	0.0006	0.3359	0.3239	0.0005	0.3248
7	2.68	2.68	87.77	90.45	265.99	268.67	0.3897	0.0007	0.3910	0.3732	0.0007	0.3746

case number	z2-z1	z4-z3	Z coordinates for the center of the sphere, cm				60% density cellulose			40% density cellulose			20% density cellulose		
			1st drum	2nd drum	3rd drum	4th drum	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$
1	175.54	175.54	1.34	176.88	179.56	355.1	0.3581	0.0006	0.3593	0.3473	0.0005	0.3478	0.3386	0.0005	0.3396
2	148.22	148.22	15.00	163.22	193.22	341.44	0.3149	0.0004	0.3158	0.3103	0.0005	0.3108	0.3063	0.0004	0.3071
3	118.22	118.22	30.00	148.22	208.22	326.44	0.3139	0.0005	0.3148	0.3073	0.0005	0.3077	0.3042	0.0004	0.3050
4	88.22	88.22	45.00	133.22	223.22	311.44	0.3142	0.0005	0.3152	0.3081	0.0004	0.3085	0.3051	0.0005	0.3061
5	58.22	58.22	60.00	118.22	238.22	296.44	0.3136	0.0004	0.3145	0.3082	0.0004	0.3087	0.3055	0.0005	0.3064
6	28.22	28.22	75.00	103.22	253.22	281.44	0.3169	0.0005	0.3178	0.3107	0.0005	0.3112	0.3071	0.0004	0.3079
7	2.68	2.68	87.77	90.45	265.99	268.67	0.3582	0.0005	0.3592	0.3474	0.0005	0.3479	0.3408	0.0004	0.3417

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Client WVNS Subject: Pu-239 metal spheres Chk'd. KR Date 2/26/01

Figure 1. k_{eff} +2σ for 200 g Pu-239 spheres in the 55 gallon drums with cellulose. Spheres are located on the drums' vertical axis.

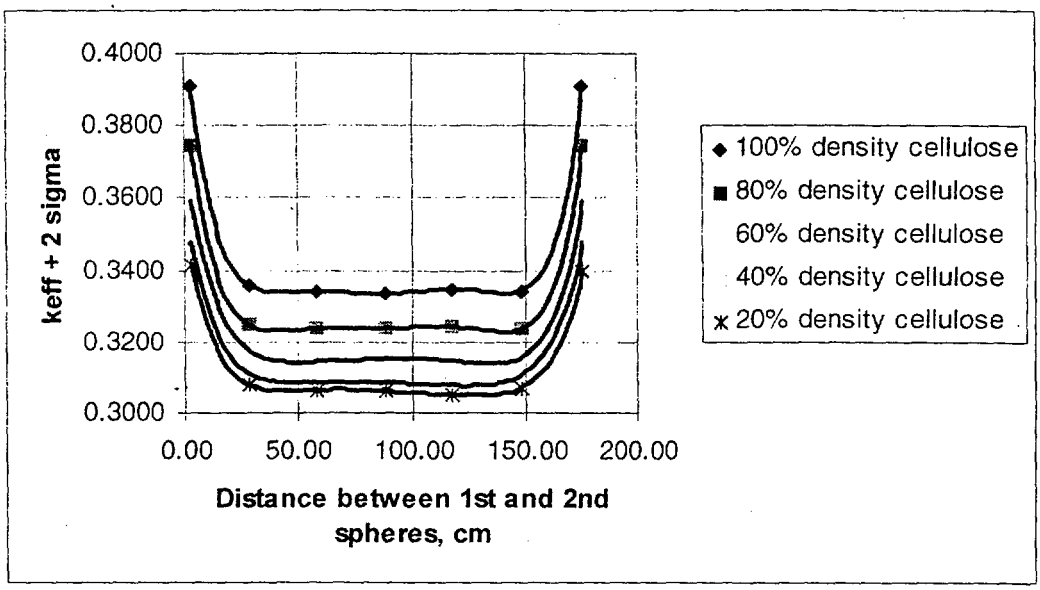

Table 7. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for 350 g Pu-239 spheres in the B-25 boxes with cellulose. The spheres are located on the boxes' vertical axis.

case number	z2-z1	z4-z3	Z coordinates for the center of the sphere, cm				100% density cellulose			80% density cellulose		
			1st drum	2nd drum	3rd drum	4th drum	k_{eff}	σ	k_{eff}+ 2σ	k_{eff}	σ	k_{eff}+ 2σ
1	172.026	172.026	1.617	173.643	176.877	348.903	0.4723	0.0008	0.4740	0.4508	0.0008	0.4523
2	145.260	145.260	15.000	160.26	190.26	335.52	0.4044	0.0007	0.4058	0.3923	0.0006	0.3936
3	115.260	115.260	30.000	145.26	205.26	320.52	0.4047	0.0007	0.4061	0.3908	0.0006	0.3920
4	85.260	85.260	45.000	130.26	220.26	305.52	0.4043	0.0007	0.4057	0.3909	0.0006	0.3921
5	55.260	55.260	60.000	115.26	235.26	290.52	0.4055	0.0006	0.4067	0.3904	0.0006	0.3915
6	25.260	25.260	75.000	100.26	250.26	275.52	0.4074	0.0007	0.4087	0.3951	0.0006	0.3962
7	3.234	3.234	86.013	89.247	261.273	264.507	0.4724	0.0008	0.4740	0.4520	0.0008	0.4536

case number	z2-z1	z4-z3	Z coordinates for the center of the sphere, cm				60% density cellulose			40% density cellulose			20% density cellulose		
			1st drum	2nd drum	3rd drum	4th drum	k_{eff}	σ	k_{eff}+ 2σ	k_{eff}	σ	k_{eff}+ 2σ	k_{eff}	σ	k_{eff}+ 2σ
1	172.026	172.026	1.617	173.643	176.877	348.903	0.4297	0.0006	0.4309	0.4119	0.0006	0.4124	0.3976	0.0005	0.3987
2	145.260	145.260	15.000	160.26	190.26	335.52	0.3796	0.0005	0.3805	0.3683	0.0004	0.3687	0.3597	0.0005	0.3607
3	115.260	115.260	30.000	145.26	205.26	320.52	0.3779	0.0005	0.3790	0.3671	0.0005	0.3676	0.3591	0.0004	0.3599
4	85.260	85.260	45.000	130.26	220.26	305.52	0.3784	0.0005	0.3794	0.3682	0.0005	0.3688	0.3601	0.0004	0.3609
5	55.260	55.260	60.000	115.26	235.26	290.52	0.3782	0.0006	0.3793	0.3678	0.0005	0.3682	0.3600	0.0004	0.3607
6	25.260	25.260	75.000	100.26	250.26	275.52	0.3831	0.0006	0.3842	0.3712	0.0005	0.3717	0.3608	0.0005	0.3618
7	3.234	3.234	86.013	89.247	261.273	264.507	0.4315	0.0006	0.4328	0.4131	0.0005	0.4135	0.3984	0.0005	0.3994

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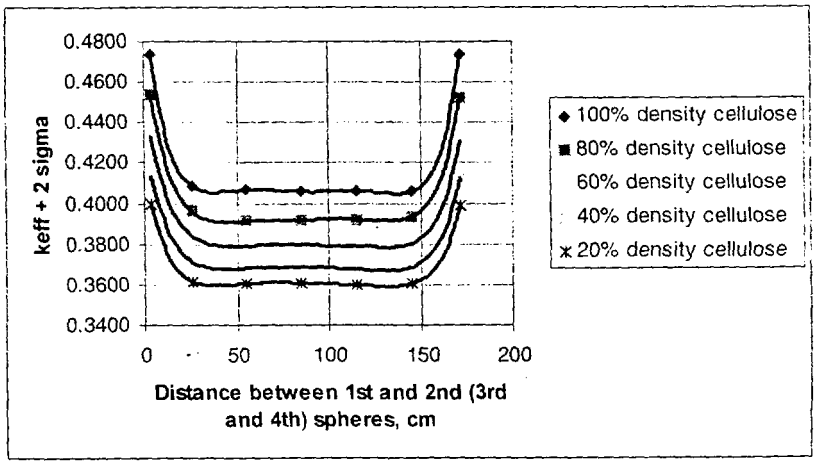
Job No 30822-244-330 /6856 Job: PSR-6 By IVC Date 08/20/2001
Client WVNS Subject: Pu-239 metal spheres Chk'd. [illegible] Date 2/26/01

Figure 2. k_{eff} +2σ for 350 g Pu-239 spheres in the B-25 boxes with cellulose. The spheres are located on the boxes' vertical axis.



The data from Table 6 and 7 shows that the neutron multiplication factor reaches its maximum when the 1st tier sphere is located at the top of the container and at the same time the 2nd tier sphere is located at the bottom, the 3rd tier sphere is located at the top and 4th tier sphere is located at the bottom, i.e. 1st tier - 2nd tier sphere contact, and 3rd - 4th tier sphere contact.

Table 8. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for 200 g Pu-239 spheres in the 55 gallon drums with cellulose. The spheres "are moved" along the radius of the drum. The Z-coordinates spheres' centers correspond to the location of 1st tier - 2nd tier sphere contact, and 3rd - 4th tier sphere contact.

case number	X coordinates for the center of the sphere, cm				100% density cellulose			80% density cellulose		
	1st drum	2nd drum	3rd drum	4th drum	k_{eff}	σ	k_{eff}+ 2σ	k_{eff}	σ	k_{eff}+ 2σ
1	0.00	0.00	0.00	0.00	0.3897	0.0007	0.3910	0.3732	0.0007	0.3746
2	5.00	5.00	5.00	5.00	0.3891	0.0007	0.3905	0.3735	0.0006	0.3747
3	10.00	10.00	10.00	10.00	0.3899	0.0007	0.3912	0.3740	0.0007	0.3753
4	15.00	15.00	15.00	15.00	0.3927	0.0007	0.3941	0.3768	0.0007	0.3781
5	20.00	20.00	20.00	20.00	0.3969	0.0007	0.3982	0.3813	0.0007	0.3827
6	25.00	25.00	25.00	25.00	0.4059	0.0007	0.4073	0.3884	0.0007	0.3897
7	27.07	27.07	27.07	27.07	0.4030	0.0007	0.4044	0.3884	0.0007	0.3898

case number	X coordinates for the center of the sphere, cm				60% density cellulose			40% density cellulose			20% density cellulose		
	1st drum	2nd drum	3rd drum	4th drum	k_{eff}	σ	k_{eff}+ 2σ	k_{eff}	σ	k_{eff}+ 2σ	k_{eff}	σ	k_{eff}+ 2σ
1	0.00	0.00	0.00	0.00	0.3582	0.0005	0.3592	0.3474	0.0005	0.3479	0.3408	0.0004	0.3417
2	5.00	5.00	5.00	5.00	0.3575	0.0006	0.3586	0.3470	0.0005	0.3475	0.3399	0.0005	0.3409
3	10.00	10.00	10.00	10.00	0.3596	0.0005	0.3607	0.3483	0.0005	0.3489	0.3403	0.0005	0.3413
4	15.00	15.00	15.00	15.00	0.3619	0.0006	0.3631	0.3506	0.0005	0.3510	0.3408	0.0005	0.3418
5	20.00	20.00	20.00	20.00	0.3675	0.0006	0.3687	0.3518	0.0005	0.3524	0.3411	0.0005	0.3422
6	25.00	25.00	25.00	25.00	0.3708	0.0006	0.3720	0.3567	0.0006	0.3573	0.3436	0.0005	0.3445
7	27.07	27.07	27.07	27.07	0.3739	0.0006	0.3750	0.3582	0.0005	0.3588	0.3475	0.0005	0.3485

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Job No 30822-244-330 /6856 Job: PSR-6 By IVC Date 02/20/2001
Client WVNS Subject: Pu-239 metal spheres Chk'd. JR Date 2/26/01

Figure 3. k_{eff} +2σ for 200 g Pu-239 spheres in the 55 gallon drums with cellulose. The spheres "are moved" along the radius of the drum. The Z-coordinates spheres' centers correspond to the location of 1st tier - 2nd tier sphere contact, and 3rd - 4th tier sphere contact.

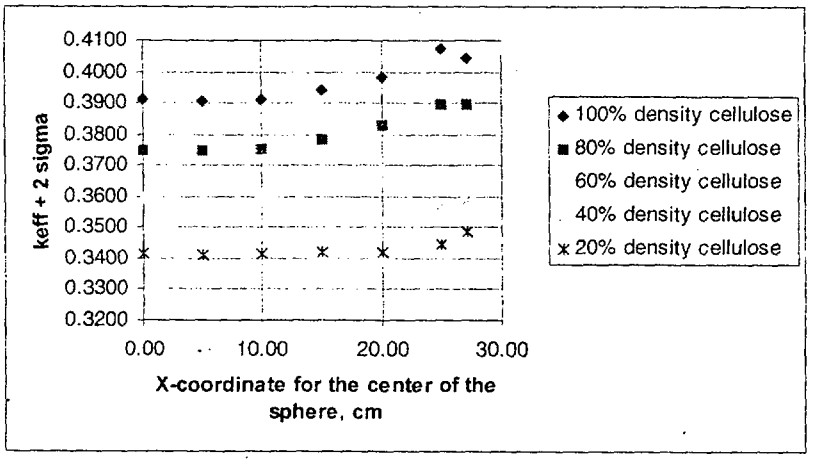


Table 9. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for 350 g Pu-239 spheres in the B-25 box with cellulose. The spheres "are moved" along the diagonal of the box. The Z-coordinates spheres' centers correspond to the location of 1st tier - 2nd tier sphere contact, and 3rd - 4th tier sphere contact.

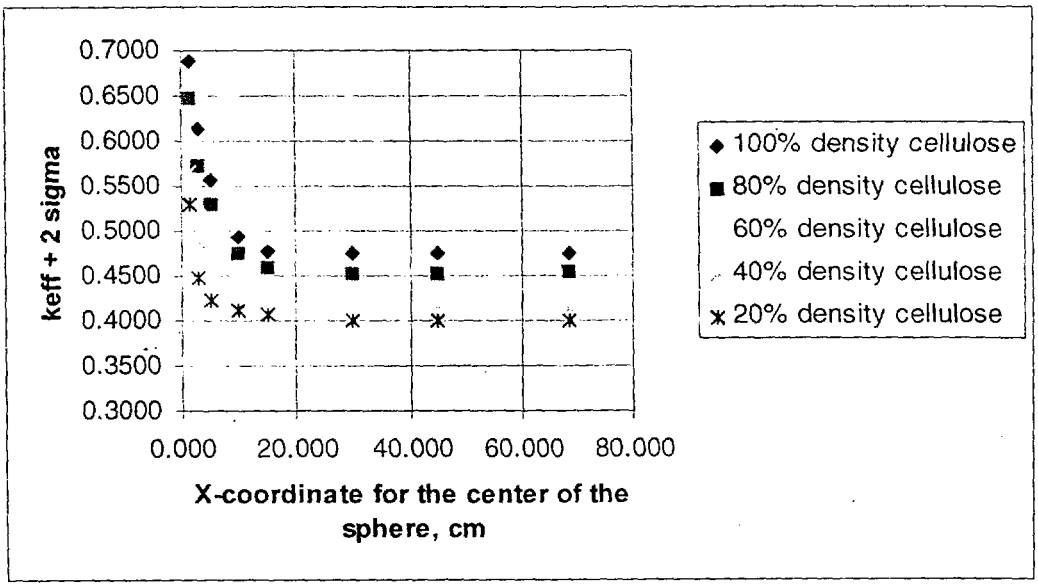
case number	X-coordinate	Y-coordinate	100% density cellulose			80% density cellulose		
			k_{eff}	σ	k_{eff}+ 2σ	k_{eff}	σ	k_{eff}+ 2σ
0	1.617	1.617	0.7064	0.0009	0.7083	0.6693	0.0009	0.6712
1	2.036	1.617	0.6859	0.0011	0.6881	0.6463	0.0010	0.6482
1a	3.778	3.000	0.6124	0.0012	0.6147	0.5711	0.0008	0.5727
1b	6.296	5.000	0.5550	0.0010	0.5569	0.5278	0.0010	0.5297
1c	12.593	10.000	0.4911	0.0009	0.4928	0.4743	0.0008	0.4758
2	18.889	15.000	0.4758	0.0009	0.4776	0.4581	0.0007	0.4595
3	37.778	30.000	0.4736	0.0008	0.4751	0.4516	0.0007	0.4529
4	56.667	45.000	0.4737	0.0009	0.4754	0.4513	0.0008	0.4529
5	86.360	68.580	0.4724	0.0008	0.4740	0.4520	0.0008	0.4536

case number	X-coordinate	Y-coordinate	60% density cellulose			40% density cellulose			20% density cellulose		
			k_{eff}	σ	k_{eff}+ 2σ	k_{eff}	σ	k_{eff}+ 2σ	k_{eff}	σ	k_{eff}+ 2σ
0	1.617	1.617	0.6306	0.0009	0.6323	0.5917	0.0008	0.5925	0.5558	0.0007	0.5571
1	2.036	1.617	0.6063	0.0009	0.6080	0.5642	0.0008	0.5650	0.5274	0.0006	0.5286
1a	3.778	3.000	0.5285	0.0010	0.5304	0.4846	0.0007	0.4853	0.4464	0.0006	0.4475
1b	6.296	5.000	0.4945	0.0008	0.4961	0.4564	0.0007	0.4571	0.4226	0.0006	0.4238
1c	12.593	10.000	0.4562	0.0007	0.4577	0.4352	0.0007	0.4359	0.4101	0.0005	0.4111
2	18.889	15.000	0.4397	0.0007	0.4411	0.4232	0.0006	0.4237	0.4063	0.0005	0.4072
3	37.778	30.000	0.4324	0.0007	0.4337	0.4144	0.0006	0.4150	0.3991	0.0005	0.4001
4	56.667	45.000	0.4318	0.0006	0.4329	0.4141	0.0006	0.4146	0.3986	0.0004	0.3[illegible]
5	86.360	68.580	0.4315	0.0006	0.4328	0.4131	0.0005	0.4135	0.3984	0.0005	0.3[illegible]

URS

Job No 30822-244-330 /6856 Job: PSR-6 By IVC Date 02/20/2001
Client WVNS Subject: Pu-239 metal spheres Chk'd. KR Date 2/20/01

Figure 4. k_{eff} +2σ for 350 g Pu-239 spheres in the B-25 box with cellulose. The spheres "are moved" along the diagonal of the box. The Z-coordinates spheres' centers correspond to the location of 1st tier - 2nd tier sphere contact, and 3rd - 4th tier sphere contact.

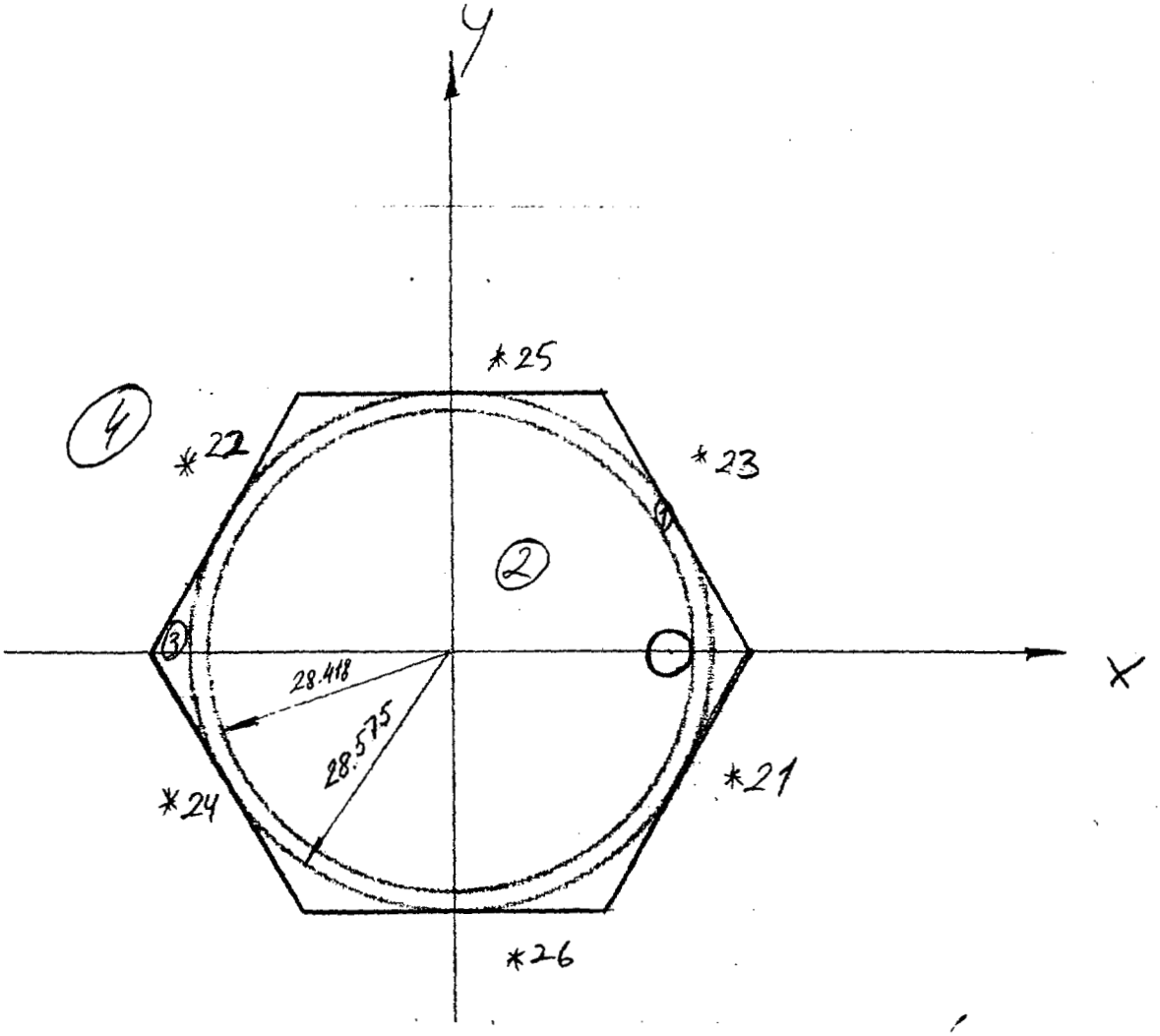


Attachment 1: Case 1 with MCNP surface and cell numbers

FILE _____

SUBJECT _____

REVISIONS
BY _____ DATE _____ TO EO ____
BY _____ DATE _____ TO EO ____

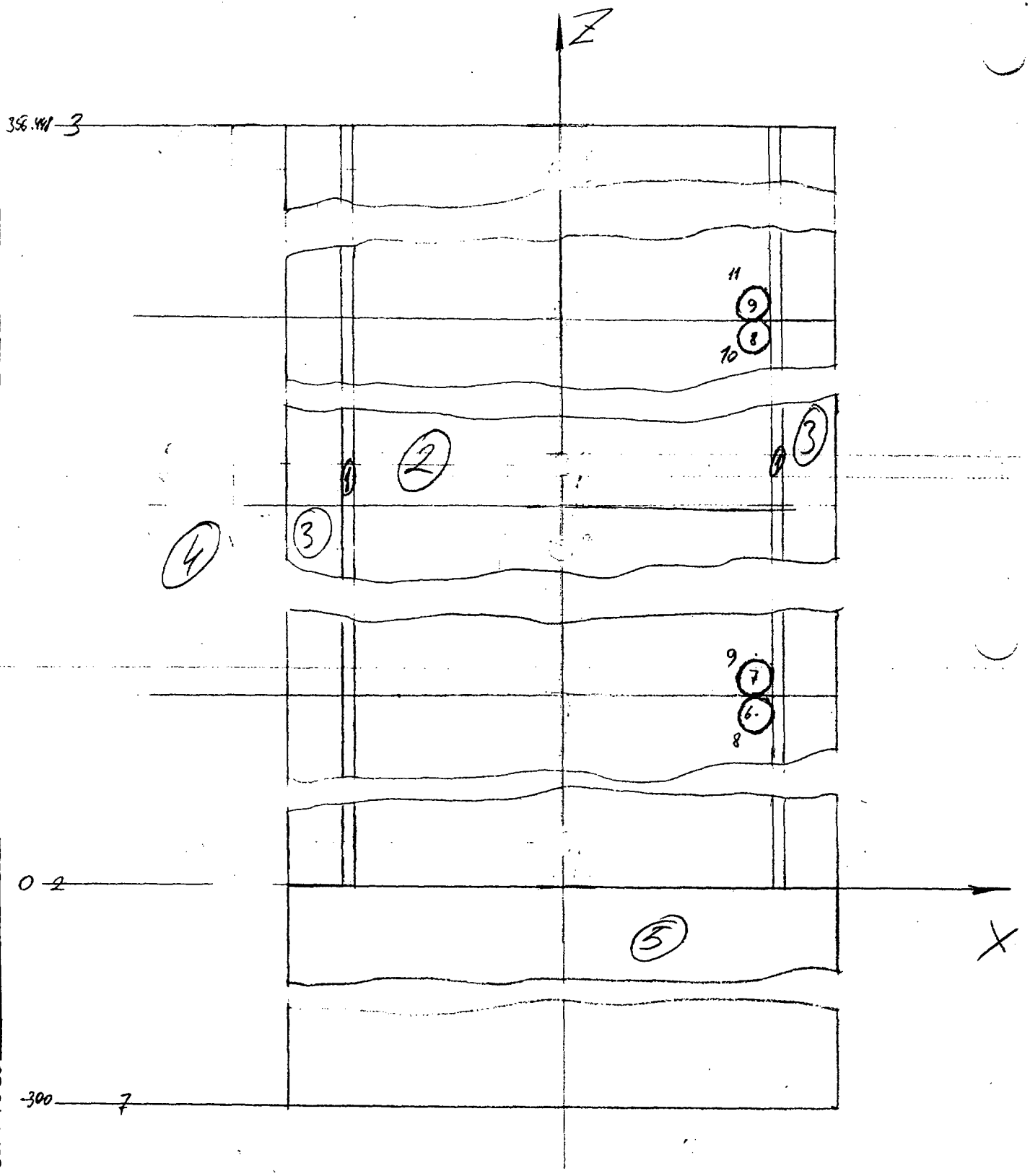


BY _____ DATE _____
CHECKED BY _____
COPY TO EO _____

FILE _____

SUBJECT _____

REVISIONS
BY _____ DATE _____ TO EO _____
BY _____ DATE _____ TO EO _____



BY _____ DATE _____
CHECKED BY _____
COPY TO EO _____

Attachment 2: Case 1 MCNP input file

```
                                                    ls110
Pu-239 in cellulose matrix. Infinite lattice of 55 gal. drums, 4 tiers
C The drum height is 35 1/12 inch (89.112 cm)
c drum wall thickness is 0.157 cm
C Cell cards
C
C ------------------------------------------------------------------------
1  65 -7.82       5 -6  2 -3                    imp:n=1 $ drum wall
2  1  -0.9       -5  2 -3  8 9 10 11           imp:n=1 $ cellulose matrix
3  64 -0.001293 -21 22 -23 24 -25 26 2 -3 6    imp:n=1 $ air ouside the drum
4  0         21 : -22 : 23 : -24 : 25 : -26 : -7 : 3 imp:n=0 $ Outside world
5  2 -2.3        -21 22 -23 24 -25 26 -2 7     imp:n=1 $ concrete floor
6  3 -19.78      -8                            imp:n=1 $ Plutonium sphere
7  3 -19.78      -9                            imp:n=1 $ Plutonium sphere
8  3 -19.78      -10                           imp:n=1 $ Plutonium sphere
9  3 -19.78      -11                           imp:n=1 $ Plutonium sphere
C ------------------------------------------------------------------------
c
c Note: next line must be completely blank

c Surface cards
C ------------------------------------------------------------------------
2  pz 0         $ drum bottom plane
3  pz 356.448   $ drum top plane
5  cz 28.418    $ 28.418 cm radius cylinder (internal wall of the drum)
6  cz 28.575    $ 28.575 cm radius cylinder (external wall of the drum)
7  pz -300      $ concrete bottom plane
8  sz 1.341  1.34 $ plutonium sphere
9  sz 176.88 1.34 $ plutonium sphere
10 sz 179.56 1.34 $ plutonium sphere
11 sz 355.09 1.34 $ plutonium sphere
c
c hexagonal cell with reflecting surfaces outside the drum
c (simulates infinite array of the drums)
c begin the lattice surfaces
*21 p 0.8660254 -0.5 0  28.575
*22 p 0.8660254 -0.5 0 -28.575
*23 p 0.8660254  0.5 0  28.575
*24 p 0.8660254  0.5 0 -28.575
*25 py  28.575
*26 py -28.575
c end of lattice surfaces
c
C ------------------------------------------------------------------------
c
c Note: next line must be completely blank

c Data cards
c
c Materials
c
c Celulose (Elements: C, H, O)
m1      6000.50c  -0.444
        1001.50c  -0.062
        8016.50c  -0.493
c Concrete (KENO Regular Concrete Standard Mix) from Harmon at al.
c Criticality Calculation with MCNP. A Primer. p. C-4
c (Elements: H, O, Na, Si, Al, Ca, Fe)
m2      1001.50c -0.010
        8016.50c -0.532
       11023.50c -0.029
       13027.50c -0.034
       14000.50c -0.337
       20000.50c -0.044
       26000.55c -0.014
c Plutonium-239
m3     94239.55c  1
c Air (C, N, O, Ar) composition from Attix p.532
m64     6000.50c -0.000124
        7014.50c -0.755267
        8016.50c -0.231781
       18000.35c -0.012828
c Carbon Steel (C, Fe) composition from Crit. Calc. with MCNP p. C-10
m65     6000.50c -0.005
       26000.55c -0.995
c
mode n
print 40 60 80 100 110 126
kcode 4000 1. 20 120
```

ls110

```
ksrc  0 0 1.34
      0 0 176.88
      0 0 179.56
      0 0 355.1
```

Attachment 3: Case 1 MCNP output file

```
lmcnp     version 4a     ld=10/01/93                    11/28/00 22:06:07
 ***********************************************************************          probid =   11/28/00 22:06:07
 name=1s110

    1-       Pu-239 in cellulose matrix. Infinite lattice of 55 gal. drums, 4 tiers
    2-       C The drum height is 35 1/12 inch (89.112 cm)
    3-       c drum wall thickness is 0.157 cm
    4-       C Cell cards
    5-       C
    6-       C ---------------------------------------------------------------------
    7-       1  65 -7.82       5 -6  2 -3                  imp:n=1 $ drum wall
    8-       2  1  -0.9       -5  2 -3  8 9 10 11         imp:n=1 $ cellulose matrix
    9-       3  64 -0.001293 -21 22 -23 24 -25 26 2 -3 6   imp:n=1 $ air ouside the drum
   10-       4  0         21 : -22 : 23 : -24 : 25 : -26 : -7 : 3 imp:n=0 $ Outside world
   11-       5  2 -2.3        -21 22 -23 24 -25 26 -2 7     imp:n=1 $ concrete floor
   12-       6  3 -19.78      -8                            imp:n=1 $ Plutonium sphere
   13-       7  3 -19.78      -9                            imp:n=1 $ Plutonium sphere
   14-       8  3 -19.78      -10                           imp:n=1 $ Plutonium sphere
   15-       9  3 -19.78      -11                           imp:n=1 $ Plutonium sphere
   16-       C ---------------------------------------------------------------------
   17-       c
   18-       c Note: next line must be completely blank
   19-
   20-       c Surface cards
   21-       C ---------------------------------------------------------------------
   22-       2  pz 0         $ drum bottom plane
   23-       3  pz 356.448   $ drum top plane
   24-       5  cz 28.418    $ 28.418 cm radius cylinder (internal wall of the drum)
   25-       6  cz 28.575    $ 28.575 cm radius cylinder (external wall of the drum)
   26-       7  pz -300      $ concrete bottom plane
   27-       8  sz 1.341  1.34 $ plutonium sphere
   28-       9  sz 176.88 1.34 $ plutonium sphere
   29-       10 sz 179.56 1.34 $ plutonium sphere
   30-       11 sz 355.09 1.34 $ plutonium sphere
   31-       c
   32-       c hexagonal cell with reflecting surfaces outside the drum
   33-       c (simulates infinite array of the drums)
   34-       c begin the lattice surfaces
   35-       *21 p 0.8660254 -0.5 0  28.575
   36-       *22 p 0.8660254 -0.5 0 -28.575
   37-       *23 p 0.8660254  0.5 0  28.575
   38-       *24 p 0.8660254  0.5 0 -28.575
   39-       *25 py  28.575
   40-       *26 py -28.575
   41-       c end of lattice surfaces
   42-       c
   43-       C ---------------------------------------------------------------------
   44-       c
   45-       c Note: next line must be completely blank
   46-
   47-       c Data cards
   48-       c
   49-       c Materials
   50-       c
   51-       c Celulose (Elements: C, H, O)
   52-       m1      6000.50c  -0.444
   53-               1001.50c  -0.062
   54-               8016.50c  -0.493
   55-       c Concrete (KENO Regular Concrete Standard Mix) from Harmon at al.
   56-       c Criticality Calculation with MCNP. A Primer. p. C-4
   57-       c (Elements: H, O, Na, Si, Al, Ca, Fe)
   58-       m2      1001.50c -0.010
```

```
   59-              8016.50c -0.532
   60-             11023.50c -0.029
   61-             13027.50c -0.034
   62-             14000.50c -0.337
   63-             20000.50c -0.044
   64-             26000.55c -0.014
   65-        c Plutonium-239
   66-        m3     94239.55c  1
   67-        c Air (C, N, O, Ar) composition from Attix p.532
   68-        m64     6000.50c -0.000124
   69-              7014.50c -0.755267
   70-              8016.50c -0.231781
   71-             18000.35c -0.012828
   72-        c Carbon Steel (C, Fe) composition from Crit. Calc. with MCNP p. C-10
   73-        m65     6000.50c -0.005
   74-             26000.55c -0.995
   75-        c
   76-        mode n
   77-        print 40 60 80 100 110 126
   78-        kcode 4000 1. 20 120
   79-        ksrc  0 0 1.34
   80-              0 0 176.88
   81-              0 0 179.56
   82-              0 0 355.1
   83-
 total fission nubar data are being used.
1material composition                                                    print table 40

 the sum of the fractions of material     1 was 9.990000E-01

 material
  number      component nuclide, atom fraction

     1            6000,  0.28588       1001,  0.47576       8016,  0.23837
     2            1001,  0.16803       8016,  0.56324      11023,  0.02136      13027,  0.02134
                 14000,  0.20319      20000,  0.01859      26000,  0.00425
     3           94239,  1.00000
    64            6000,  0.00015       7014,  0.78443       8016,  0.21075      18000,  0.00467
    65            6000,  0.02283      26000,  0.97717


 material
  number      component nuclide, mass fraction

     1            6000,  0.44444       1001,  0.06206       8016,  0.49349
     2            1001,  0.01000       8016,  0.53200      11023,  0.02900      13027,  0.03400
                 14000,  0.33700      20000,  0.04400      26000,  0.01400
     3           94239,  1.00000
    64            6000,  0.00012       7014,  0.75527       8016,  0.23178      18000,  0.01283
    65            6000,  0.00500      26000,  0.99500

 warning.     1 of the materials had unnormalized fractions.
1cells                                                                   print table 60

                          atom        gram                                      neutron
        cell  mat       density     density      volume        mass      pieces importance

     1     1   65  8.58651E-02 7.82000E+00 1.00200E+04 7.83563E+04       1  1.0000E+00
     2     2    1  7.01524E-02 9.00000E-01 9.04302E+05 8.13872E+05       0  1.0000E+00
```

```
    3     3   64  5.35386E-05 1.29300E-03 0.00000E+00 0.00000E+00     0  1.0000E+00
    4     4    0  0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00     0  0.0000E+00
    5     5    2  8.17913E-02 2.30000E+00 8.48564E+05 1.95170E+06     0  1.0000E+00
    6     6    3  4.98285E-02 1.97800E+01 1.00787E+01 1.99356E+02     1  1.0000E+00
    7     7    3  4.98285E-02 1.97800E+01 1.00787E+01 1.99356E+02     1  1.0000E+00
    8     8    3  4.98285E-02 1.97800E+01 1.00787E+01 1.99356E+02     1  1.0000E+00
    9     9    3  4.98285E-02 1.97800E+01 1.00787E+01 1.99356E+02     1  1.0000E+00

 total                                   1.76293E+06 2.84472E+06

         1 warning message so far.
1cross-section tables                                                                  print table 100

    table    length

                      tables from file critxs

  1001.50c    1153  njoy                                                        (  1301)      79/07/31.
  6000.50c   16126  njoy                                                        (  1306)      79/07/31.
  7014.50c   22772  njoy                                                        (  1275)      79/09/08.
  8016.50c   23669  njoy                                                         ( 1276)     05/14/81
 11023.50c   36270  njoy                                                        (  1311)      79/06/21.
 13027.50c   22891  njoy                                                        (  1313)      79/09/08.
 14000.50c   48275  njoy                                                        (  1314)      79/06/21.
 18000.35c    2182      endl85                                                    (  18)       11/01/85
 20000.50c   26104  njoy                                                        (  1320)      79/06/22.
 26000.55c   84136  njoy                                                        ( 260)       10/21/82
 94239.55c   67551  njoy                                  total nu               ( 1399)     02/21/85

 total      351129

 warning.  neutron energy cutoff is below some cross-section tables.



 decimal words of dynamically allocated storage

    general             111994
    tallies                  0
    bank                  6403
    cross sections      351129

    total               469526

*****************************************************************************************************************
 dump no.    1 on file 1s110r       nps =         0     coll =              0     ctm =    0.00     nrn =              0


 source distribution written to file 1s110s          cycle =     0

         2 warning messages so far.
1   starting mcrun.      field length =      0      cp0 =  0.01                                  print table 110

     Pu-239 in cellulose matrix. Infinite lattice of 55 gal. drums, 4 tiers


    nps     x          y          z        cell   surf     u          v          w        energy     weight      time

     1  0.000E+00  0.000E+00  1.340E+00     6      0  5.085E-01  4.733E-01  7.193E-01  2.209E+00  1.000E+00  0.000E+00
     2  0.000E+00  0.000E+00  1.340E+00     6      0  8.952E-01 -4.447E-01 -2.944E-02  4.904E+00  1.000E+00  0.000E+00
```

3	0.000E+00	0.000E+00	1.340E+00	6	0	-6.184E-01	-4.495E-01	6.446E-01	3.809E-01	1.000E+00	0.000E+00
4	0.000E+00	0.000E+00	1.340E+00	6	0	9.710E-01	-5.665E-02	-2.323E-01	1.331E+00	1.000E+00	0.000E+00
5	0.000E+00	0.000E+00	1.340E+00	6	0	5.861E-01	1.496E-01	-7.963E-01	1.902E+00	1.000E+00	0.000E+00
6	0.000E+00	0.000E+00	1.340E+00	6	0	-6.489E-02	-1.626E-01	9.845E-01	4.410E-01	1.000E+00	0.000E+00
7	0.000E+00	0.000E+00	1.340E+00	6	0	-7.068E-02	3.263E-02	-9.970E-01	4.750E-01	1.000E+00	0.000E+00
8	0.000E+00	0.000E+00	1.340E+00	6	0	-3.915E-01	4.664E-01	-7.932E-01	4.136E+00	1.000E+00	0.000E+00
9	0.000E+00	0.000E+00	1.340E+00	6	0	-2.368E-01	9.215E-01	-3.079E-01	7.453E-02	1.000E+00	0.000E+00
10	0.000E+00	0.000E+00	1.340E+00	6	0	1.946E-01	-3.204E-01	9.271E-01	3.128E+00	1.000E+00	0.000E+00
11	0.000E+00	0.000E+00	1.340E+00	6	0	-6.698E-01	-7.177E-01	-1.905E-01	1.014E+00	1.000E+00	0.000E+00
12	0.000E+00	0.000E+00	1.340E+00	6	0	-8.398E-01	-4.129E-01	3.524E-01	1.395E+00	1.000E+00	0.000E+00
13	0.000E+00	0.000E+00	1.340E+00	6	0	-1.714E-01	-8.572E-01	4.857E-01	7.748E-01	1.000E+00	0.000E+00
14	0.000E+00	0.000E+00	1.340E+00	6	0	-2.489E-01	-5.118E-01	-8.222E-01	1.101E+00	1.000E+00	0.000E+00
15	0.000E+00	0.000E+00	1.340E+00	6	0	-2.959E-01	2.119E-01	9.314E-01	1.951E+00	1.000E+00	0.000E+00
16	0.000E+00	0.000E+00	1.340E+00	6	0	1.395E-01	-9.829E-01	1.202E-01	2.186E+00	1.000E+00	0.000E+00
17	0.000E+00	0.000E+00	1.340E+00	6	0	6.909E-01	-7.110E-01	1.307E-01	1.865E+00	1.000E+00	0.000E+00
18	0.000E+00	0.000E+00	1.340E+00	6	0	-6.580E-01	5.320E-01	-5.329E-01	1.229E+00	1.000E+00	0.000E+00
19	0.000E+00	0.000E+00	1.340E+00	6	0	-9.903E-01	-1.380E-01	1.353E-02	1.305E+00	1.000E+00	0.000E+00
20	0.000E+00	0.000E+00	1.340E+00	6	0	7.462E-01	4.859E-01	-4.551E-01	1.000E+00	1.000E+00	0.000E+00
21	0.000E+00	0.000E+00	1.340E+00	6	0	-1.977E-01	9.797E-01	3.360E-02	3.990E+00	1.000E+00	0.000E+00
22	0.000E+00	0.000E+00	1.340E+00	6	0	-9.117E-01	-3.647E-01	-1.891E-01	2.665E-01	1.000E+00	0.000E+00
23	0.000E+00	0.000E+00	1.340E+00	6	0	-4.287E-01	8.361E-01	-3.423E-01	1.156E+00	1.000E+00	0.000E+00
24	0.000E+00	0.000E+00	1.340E+00	6	0	1.080E-01	3.412E-01	-9.338E-01	2.669E+00	1.000E+00	0.000E+00
25	0.000E+00	0.000E+00	1.340E+00	6	0	-9.111E-01	-9.012E-03	-4.122E-01	2.185E+00	1.000E+00	0.000E+00
26	0.000E+00	0.000E+00	1.340E+00	6	0	-2.568E-01	-6.391E-01	-7.249E-01	4.225E+00	1.000E+00	0.000E+00
27	0.000E+00	0.000E+00	1.340E+00	6	0	-2.912E-01	8.086E-01	5.113E-01	1.079E+00	1.000E+00	0.000E+00
28	0.000E+00	0.000E+00	1.340E+00	6	0	1.472E-01	-9.514E-01	2.705E-01	3.461E+00	1.000E+00	0.000E+00
29	0.000E+00	0.000E+00	1.340E+00	6	0	-6.135E-01	-7.645E-01	-1.978E-01	1.836E+00	1.000E+00	0.000E+00
30	0.000E+00	0.000E+00	1.340E+00	6	0	-5.702E-01	5.651E-01	-5.963E-01	4.556E-01	1.000E+00	0.000E+00
31	0.000E+00	0.000E+00	1.340E+00	6	0	-6.607E-01	5.373E-01	-5.242E-01	6.415E-01	1.000E+00	0.000E+00
32	0.000E+00	0.000E+00	1.340E+00	6	0	-9.742E-02	-3.639E-01	-9.263E-01	2.764E+00	1.000E+00	0.000E+00
33	0.000E+00	0.000E+00	1.340E+00	6	0	-1.965E-01	-3.145E-01	-9.287E-01	2.785E-01	1.000E+00	0.000E+00
34	0.000E+00	0.000E+00	1.340E+00	6	0	4.097E-01	8.465E-01	-3.399E-01	9.097E-01	1.000E+00	0.000E+00
35	0.000E+00	0.000E+00	1.340E+00	6	0	-4.048E-02	8.831E-01	4.675E-01	3.360E-01	1.000E+00	0.000E+00
36	0.000E+00	0.000E+00	1.340E+00	6	0	3.371E-01	-9.269E-01	-1.652E-01	6.376E-01	1.000E+00	0.000E+00
37	0.000E+00	0.000E+00	1.340E+00	6	0	-1.867E-01	9.756E-01	-1.155E-01	2.186E+00	1.000E+00	0.000E+00
38	0.000E+00	0.000E+00	1.340E+00	6	0	-2.616E-01	2.336E-01	-9.365E-01	7.314E-01	1.000E+00	0.000E+00
39	0.000E+00	0.000E+00	1.340E+00	6	0	9.780E-01	-7.641E-02	-1.939E-01	2.997E-01	1.000E+00	0.000E+00
40	0.000E+00	0.000E+00	1.340E+00	6	0	2.580E-01	-7.076E-01	6.578E-01	1.444E+00	1.000E+00	0.000E+00
41	0.000E+00	0.000E+00	1.340E+00	6	0	-3.212E-01	-7.678E-01	-5.543E-01	1.914E+00	1.000E+00	0.000E+00
42	0.000E+00	0.000E+00	1.340E+00	6	0	5.039E-01	-1.460E-01	8.513E-01	1.502E+00	1.000E+00	0.000E+00
43	0.000E+00	0.000E+00	1.340E+00	6	0	6.080E-01	5.487E-01	5.738E-01	5.971E+00	1.000E+00	0.000E+00
44	0.000E+00	0.000E+00	1.340E+00	6	0	-2.932E-01	9.304E-01	-2.199E-01	1.827E+00	1.000E+00	0.000E+00
45	0.000E+00	0.000E+00	1.340E+00	6	0	-8.475E-01	-3.993E-01	-3.497E-01	1.928E+00	1.000E+00	0.000E+00
46	0.000E+00	0.000E+00	1.340E+00	6	0	1.200E-01	-9.195E-01	-3.743E-01	1.351E+00	1.000E+00	0.000E+00
47	0.000E+00	0.000E+00	1.340E+00	6	0	7.085E-01	5.879E-01	3.904E-01	2.288E+00	1.000E+00	0.000E+00
48	0.000E+00	0.000E+00	1.340E+00	6	0	4.261E-01	9.046E-01	9.254E-03	1.230E+00	1.000E+00	0.000E+00
49	0.000E+00	0.000E+00	1.340E+00	6	0	5.431E-01	4.270E-01	-7.230E-01	1.433E+00	1.000E+00	0.000E+00
50	0.000E+00	0.000E+00	1.340E+00	6	0	-1.053E-01	-9.805E-01	1.658E-01	6.572E-01	1.000E+00	0.000E+00

lestimated keff results by cycle print table 175

source distribution written to file ls110s cycle = 20

source distribution written to file ls110s cycle = 23

source distribution written to file ls110s cycle = 26

source distribution written to file ls110s cycle = 29

source distribution written to file ls110s cycle = 32

source distribution written to file ls110s cycle = 35

```
*****************************************************************************************************************
dump no.    2 on file 1s110r       nps =    145194     coll =       30642655     ctm =   15.29     nrn =      522748724

source distribution written to file 1s110s          cycle =    38

source distribution written to file 1s110s          cycle =    41

source distribution written to file 1s110s          cycle =    44

source distribution written to file 1s110s          cycle =    47

source distribution written to file 1s110s          cycle =    50

source distribution written to file 1s110s          cycle =    53

source distribution written to file 1s110s          cycle =    56

source distribution written to file 1s110s          cycle =    59

source distribution written to file 1s110s          cycle =    62

source distribution written to file 1s110s          cycle =    65

source distribution written to file 1s110s          cycle =    68

source distribution written to file 1s110s          cycle =    71

*****************************************************************************************************************
dump no.    3 on file 1s110r       nps =    285357     coll =       61219354     ctm =   30.47     nrn =     1044688848

source distribution written to file 1s110s          cycle =    74

source distribution written to file 1s110s          cycle =    77

source distribution written to file 1s110s          cycle =    80

source distribution written to file 1s110s          cycle =    83

source distribution written to file 1s110s          cycle =    86

source distribution written to file 1s110s          cycle =    89

source distribution written to file 1s110s          cycle =    92

source distribution written to file 1s110s          cycle =    95

source distribution written to file 1s110s          cycle =    98

 estimator      cycle.  100   ave of    80 cycles      combination          simple average    combined average     corr
k(collision)       0.387234       0.390631 0.0024     k(col/abs)           0.390631 0.0024     0.390631 0.0024   1.0000
k(absorption)      0.387234       0.390631 0.0024     k(abs/tk ln)         0.389986 0.0020     0.389877 0.0020   0.4180
k(trk length)      0.384588       0.389342 0.0022     k(tk ln/col)         0.389986 0.0020     0.389877 0.0020   0.4180
rem life(col)    3.3436E+04     3.3754E+04 0.0024     k(col/abs/tk ln)     0.390201 0.0020     0.389877 0.0020
rem life(abs)    3.3440E+04     3.3753E+04 0.0024     life(col/abs)      3.3754E+04 0.0024   3.3748E+04 0.0023   0.9997
source points generated   4113

source distribution written to file 1s110s          cycle =   101

source distribution written to file 1s110s          cycle =   104
```

source distribution written to file 1s110s cycle = 107

****

dump no. 4 on file 1s110r nps = 425430 coll = 91805014 ctm = 45.66 nrn = 1566799191

source distribution written to file 1s110s cycle = 110

source distribution written to file 1s110s cycle = 113

estimator	cycle 116	ave of 96 cycles		combination	simple average		combined average		corr
k(collision)	0.374745	0.389566	0.0023	k(col/abs)	0.389566	0.0023	0.389566	0.0023	1.0000
k(absorption)	0.374745	0.389566	0.0023	k(abs/tk ln)	0.389307	0.0018	0.389237	0.0018	0.4255
k(trk length)	0.385357	0.389048	0.0020	k(tk ln/col)	0.389307	0.0018	0.389237	0.0018	0.4255
rem life(col)	3.3797E+04	3.3741E+04	0.0021	k(col/abs/tk ln)	0.389393	0.0019	0.389237	0.0018	
rem life(abs)	3.3801E+04	3.3740E+04	0.0021	life(col/abs)	3.3741E+04	0.0021	3.3736E+04	0.0021	0.9997

source points generated 3786

source distribution written to file 1s110s cycle = 116

estimator	cycle 117	ave of 97 cycles		combination	simple average		combined average		corr
k(collision)	0.377047	0.389437	0.0023	k(col/abs)	0.389437	0.0023	0.389437	0.0023	1.0000
k(absorption)	0.377047	0.389437	0.0023	k(abs/tk ln)	0.389296	0.0018	0.389260	0.0018	0.3972
k(trk length)	0.399539	0.389156	0.0020	k(tk ln/col)	0.389296	0.0018	0.389260	0.0018	0.3972
rem life(col)	3.3464E+04	3.3738E+04	0.0021	k(col/abs/tk ln)	0.389343	0.0019	0.389260	0.0018	
rem life(abs)	3.3459E+04	3.3737E+04	0.0021	life(col/abs)	3.3738E+04	0.0021	3.3733E+04	0.0020	0.9997

source points generated 4036

estimator	cycle 118	ave of 98 cycles		combination	simple average		combined average		corr
k(collision)	0.401105	0.389556	0.0023	k(col/abs)	0.389556	0.0023	0.389556	0.0023	1.0000
k(absorption)	0.401105	0.389556	0.0023	k(abs/tk ln)	0.389364	0.0018	0.389312	0.0018	0.3964
k(trk length)	0.390717	0.389172	0.0020	k(tk ln/col)	0.389364	0.0018	0.389312	0.0018	0.3964
rem life(col)	3.2875E+04	3.3729E+04	0.0021	k(col/abs/tk ln)	0.389428	0.0019	0.389312	0.0018	
rem life(abs)	3.2871E+04	3.3728E+04	0.0021	life(col/abs)	3.3729E+04	0.0021	3.3724E+04	0.0020	0.9997

source points generated 4246

estimator	cycle 119	ave of 99 cycles		combination	simple average		combined average		corr
k(collision)	0.382792	0.389488	0.0023	k(col/abs)	0.389488	0.0023	0.389488	0.0023	1.0000
k(absorption)	0.382792	0.389488	0.0023	k(abs/tk ln)	0.389332	0.0018	0.389290	0.0018	0.3947
k(trk length)	0.389665	0.389177	0.0020	k(tk ln/col)	0.389332	0.0018	0.389290	0.0018	0.3947
rem life(col)	3.2686E+04	3.3719E+04	0.0021	k(col/abs/tk ln)	0.389384	0.0019	0.389290	0.0018	
rem life(abs)	3.2706E+04	3.3718E+04	0.0021	life(col/abs)	3.3718E+04	0.0021	3.3714E+04	0.0020	0.9997

source points generated 3801

source distribution written to file 1s110s cycle = 119

estimator	cycle 120	ave of 100 cycles		combination	simple average		combined average		corr
k(collision)	0.404231	0.389635	0.0023	k(col/abs)	0.389635	0.0023	0.389635	0.0023	1.0000
k(absorption)	0.404231	0.389635	0.0023	k(abs/tk ln)	0.389446	0.0018	0.389392	0.0018	0.4047
k(trk length)	0.397284	0.389258	0.0019	k(tk ln/col)	0.389446	0.0018	0.389392	0.0018	0.4047
rem life(col)	3.3329E+04	3.3715E+04	0.0020	k(col/abs/tk ln)	0.389509	0.0019	0.389392	0.0018	
rem life(abs)	3.3349E+04	3.3714E+04	0.0020	life(col/abs)	3.3715E+04	0.0020	3.3712E+04	0.0020	0.9997

source points generated 4189

source distribution written to file 1s110s cycle = 120

1problem summary

run terminated when 120 kcode cycles were done.

11/28/00 22:57:24

Pu-239 in cellulose matrix. Infinite lattice of 55 gal. drums, 4 tiers probid = 11/28/00 22:06:07

0

neutron creation	tracks	weight	energy	neutron loss	tracks	weight	energy

		(per source particle)	
source	477311	1.0056E+00	2.1503E+00
weight window	0	0.	0.
cell importance	0	0.	0.
weight cutoff	0	2.3309E-01	3.2813E-04
energy importance	0	0.	0.
dxtran	0	0.	0.
forced collisions	0	0.	0.
exp. transform	0	0.	0.
upscattering	0	0.	1.0440E-06
(n,xn)	330	4.3063E-04	2.6765E-04
fission	0	0.	0.
total	477641	1.2392E+00	2.1509E+00

		(per source particle)	
escape	4719	8.9909E-03	1.1049E-02
energy cutoff	0	0.	0.
time cutoff	0	0.	0.
weight window	0	0.	0.
cell importance	0	0.	0.
weight cutoff	472757	2.3332E-01	2.7506E-04
energy importance	0	0.	0.
dxtran	0	0.	0.
forced collisions	0	0.	0.
exp. transform	0	0.	0.
downscattering	0	0.	1.9078E+00
capture	0	8.7097E-01	2.0097E-02
loss to (n,xn)	165	2.1532E-04	1.6955E-03
loss to fission	0	1.2566E-01	2.0995E-01
total	477641	1.2392E+00	2.1509E+00

number of neutrons banked	165
neutron tracks per source particle	1.0007E+00
neutron collisions per source particle	2.1602E+02
total neutron collisions	103110690
net multiplication	1.0002E+00 0.0001

average lifetime, shakes	
escape	3.1473E+03
capture	3.3699E+04
capture or escape	3.3426E+04
any termination	4.1165E+04

cutoffs	
tco	1.0000E+34
eco	0.0000E+00
wc1	-5.0000E-01
wc2	-2.5000E-01

computer time so far in this run	51.28 minutes
computer time in mcrun	51.27 minutes
source particles per minute	9.3094E+03
random numbers generated	1759789542

maximum number ever in bank	1
bank overflows to backup file	0
field length	0
most random numbers used was	23278 in history 377417

range of sampled source weights = 9.2829E-01 to 2.1413E+00

1neutron activity in each cell print table 126

	cell	tracks entering	population	collisions	collisions * weight (per history)	number weighted energy	flux weighted energy	average track weight (relative)	average track mfp (cm)
1	1	1533385	190805	500616	4.6284E-01	3.3262E-05	2.1155E-01	4.6857E-01	1.3544E+00
2	2	1284392	477283	101721759	1.0885E+02	5.1949E-05	2.8125E-01	5.5193E-01	1.6145E+00
3	3	752229	182436	2239	2.0585E-03	3.3107E-05	2.1159E-01	4.6891E-01	2.7352E+03
5	5	18381	6959	606876	7.0540E-01	5.4499E-05	2.4322E-01	5.8947E-01	2.1407E+00
6	6	9286	8635	4547	9.1009E-03	3.6552E-01	1.9192E+00	9.7826E-01	2.5691E+00
7	7	279198	260226	136825	2.4806E-01	2.5172E-01	1.9239E+00	8.9739E-01	2.5511E+00
8	8	274866	256454	134778	2.4398E-01	2.5355E-01	1.9284E+00	8.9724E-01	2.5511E+00
9	9	6169	5919	3050	6.3923E-03	6.3576E-01	1.9505E+00	1.0156E+00	2.5757E+00
total		4157906	1388717	103110690	1.1053E+02				

1keff results for: Pu-239 in cellulose matrix. Infinite lattice of 55 gal. drums, 4 tiers probid = 11/28/00 22:06:07

the initial fission neutron source distribution used the 4 source points that were input on the ksrc card.
the criticality problem was scheduled to skip 20 cycles and run a total of 120 cycles with nominally 4000 neutrons per cycle.
this problem has run 20 inactive cycles with 77195 neutron histories and 100 active cycles with 400116 neutron histories.

this calculation has completed the requested number of keff cycles using a total of 477311 fission neutron source histories.
all cells with fissionable material were sampled and had fission neutron source points.

the results of the w test for normality applied to the individual collision, absorption, and track-length keff cycle values are:

the k(collision) cycle values appear normally distributed at the 95 percent confidence level
the k(absorption) cycle values appear normally distributed at the 95 percent confidence level

the k(trk length) cycle values appear normally distributed at the 95 percent confidence level

the final estimated combined collision/absorption/track-length keff = 0.38939 with an estimated standard deviation of 0.00069

the estimated 68, 95, & 99 percent keff confidence intervals are 0.38870 to 0.39008, 0.38802 to 0.39076, and 0.38757 to 0.39121

the estimated collision/absorption neutron removal lifetime = 3.37E-04 seconds with an estimated standard deviation of 6.78E-07

the estimated average keffs, one standard deviations, and 68, 95, and 99 percent confidence intervals are:

keff estimator	keff	standard deviation	68% confidence	95% confidence	99% confidence	corr
collision	0.38964	0.00090	0.38873 to 0.39054	0.38784 to 0.39143	0.38725 to 0.39202	
absorption	0.38964	0.00090	0.38873 to 0.39054	0.38784 to 0.39143	0.38725 to 0.39202	
track length	0.38926	0.00076	0.38850 to 0.39002	0.38775 to 0.39077	0.38726 to 0.39126	
col/absorp	0.38964	0.00090	0.38873 to 0.39054	0.38784 to 0.39143	0.38725 to 0.39202	1.0000
abs/trk len	0.38939	0.00069	0.38870 to 0.39008	0.38802 to 0.39076	0.38757 to 0.39121	0.4047
col/trk len	0.38939	0.00069	0.38870 to 0.39008	0.38802 to 0.39076	0.38757 to 0.39121	0.4047
col/abs/trk len	0.38939	0.00069	0.38870 to 0.39008	0.38802 to 0.39076	0.38757 to 0.39121	

if the largest of each keff occurred on the next cycle, the keff results and 68, 95, and 99 percent confidence intervals would be:

keff estimator	keff	standard deviation	68% confidence	95% confidence	99% confidence
collision	0.38986	0.00092	0.38894 to 0.39079	0.38803 to 0.39170	0.38743 to 0.39230
absorption	0.38986	0.00092	0.38894 to 0.39079	0.38803 to 0.39170	0.38743 to 0.39230
track length	0.38949	0.00078	0.38870 to 0.39027	0.38793 to 0.39105	0.38742 to 0.39156
col/abs/trk len	0.38962	0.00072	0.38890 to 0.39034	0.38819 to 0.39106	0.38772 to 0.39152

the estimated collision/absorption neutron lifetimes, one standard deviations, and 68, 95, and 99 percent confidence intervals are:

type	lifetime(sec)	standard deviation	68% confidence	95% confidence	99% confidence
removal	3.3712E-04	6.7757E-07	3.3644E-04 to 3.3780E-04	3.3577E-04 to 3.3847E-04	3.3533E-04 to 3.3891E-04
capture	3.3723E-04	5.1162E-07	3.3672E-04 to 3.3774E-04	3.3621E-04 to 3.3825E-04	3.3588E-04 to 3.3858E-04
fission	2.2902E-05	2.3012E-07	2.2672E-05 to 2.3132E-05	2.2444E-05 to 2.3361E-05	2.2294E-05 to 2.3510E-05
escape	1.8119E-04	4.4883E-05	1.3627E-04 to 2.2612E-04	9.1787E-05 to 2.7060E-04	6.2613E-05 to 2.9978E-04

laverage individual and combined collision/absorption/track-length keff results for 7 different batch sizes

cycles per keff batch	number of k batches	average keff estimators and deviations k(col)	st dev	k(abs)	st dev	k(trk)	st dev	normality co/ab/trk	average k(c/a/t)	st dev	k(c/a/t) confidence intervals 95% confidence	99% confidence
1	100	0.3896	0.0009	0.3896	0.0009	0.3893	0.0008	95/95/95	0.38939	0.00069	0.38802-0.39076	0.38757-0.39121
2	50	0.3896	0.0010	0.3896	0.0010	0.3893	0.0007	95/95/95	0.38932	0.00065	0.38802-0.39063	0.38758-0.39106
4	25	0.3896	0.0012	0.3896	0.0012	0.3893	0.0007	95/95/95	0.38931	0.00074	0.38778-0.39084	0.38723-0.39139
5	20	0.3896	0.0011	0.3896	0.0011	0.3893	0.0008	95/95/95	0.38935	0.00080	0.38766-0.39104	0.38702-0.39168
10	10	0.3896	0.0009	0.3896	0.0009	0.3893	0.0008	95/95/95	0.38942	0.00064	0.38790-0.39094	0.38718-0.39166
20	5	0.3896	0.0011	0.3896	0.0011	0.3893	0.0009	95/95/95	0.38943	0.00070	0.38643-0.39243	0.38251-0.39635
25	4	0.3896	0.0014	0.3896	0.0014	0.3893	0.0005	95/95/95	0.38935	0.00020	0.38675-0.39194	0.37635-0.40234

lindividual and average keff estimator results by cycle

keff cycle	neutron histories	keff estimators by cycle k(coll)	k(abs)	k(track)	average keff estimators and deviations k(coll)	st dev	k(abs)	st dev	k(track)	st dev	average k(c/a/t) k(c/a/t)	st dev	fom

1	4000	0.46537	0.46537	0.45137								
2	1868	0.38436	0.38436	0.38974								
3	3301	0.37122	0.37122	0.37940								
4	3853	0.37641	0.37641	0.37793								
5	4071	0.37096	0.37096	0.37469								
6	3960	0.36659	0.36659	0.36920								
7	3881	0.38065	0.38065	0.37590								
8	4149	0.38425	0.38425	0.37970								
9	4023	0.37967	0.37967	0.37950								
10	3974	0.39340	0.39340	0.39026								
11	4158	0.37710	0.37710	0.38277								
12	3830	0.38310	0.38310	0.38511								
13	4074	0.36826	0.36826	0.38132								
14	3849	0.36896	0.36896	0.38287								
15	4016	0.37562	0.37562	0.36926								
16	4088	0.40238	0.40238	0.39449								
17	4263	0.38362	0.38362	0.38095								
18	3843	0.39647	0.39647	0.39490								
19	4100	0.38688	0.38688	0.37738								
20	3894	0.39651	0.39651	0.39069								
		begin active keff cycles										
21	4056	0.38730	0.38730	0.38472								
22	3907	0.40433	0.40433	0.39657	0.39582	0.00851	0.39582	0.00851	0.39065	0.00593		
23	4153	0.39864	0.39864	0.38552	0.39676	0.00501	0.39676	0.00501	0.38894	0.00382		
24	3917	0.40300	0.40300	0.39361	0.39832	0.00387	0.39832	0.00387	0.39011	0.00295	0.38882 0.00856	1195
25	4034	0.38601	0.38601	0.38571	0.39586	0.00388	0.39586	0.00388	0.38923	0.00245	0.38695 0.00466	3203
26	3824	0.38880	0.38880	0.37471	0.39468	0.00338	0.39468	0.00338	0.38681	0.00314	0.38954 0.00628	1497
27	4053	0.38087	0.38087	0.38110	0.39271	0.00347	0.39271	0.00347	0.38599	0.00277	0.38643 0.00480	2151
28	3917	0.39086	0.39086	0.38478	0.39248	0.00301	0.39248	0.00301	0.38584	0.00241	0.38626 0.00425	2406
29	4113	0.40638	0.40638	0.38527	0.39402	0.00307	0.39402	0.00307	0.38578	0.00212	0.38620 0.00361	2947
30	4194	0.38940	0.38940	0.38871	0.39356	0.00279	0.39356	0.00279	0.38607	0.00192	0.38675 0.00304	3740
31	3859	0.39302	0.39302	0.38414	0.39351	0.00252	0.39351	0.00252	0.38590	0.00175	0.38662 0.00285	3890
32	4022	0.40001	0.40001	0.39310	0.39405	0.00237	0.39405	0.00237	0.38650	0.00170	0.38729 0.00282	3646
33	4038	0.39597	0.39597	0.38817	0.39420	0.00218	0.39420	0.00218	0.38662	0.00157	0.38742 0.00266	3782
34	3967	0.39749	0.39749	0.39113	0.39443	0.00203	0.39443	0.00203	0.38695	0.00149	0.38781 0.00255	3830
35	4001	0.38293	0.38293	0.38523	0.39367	0.00204	0.39367	0.00204	0.38683	0.00139	0.38729 0.00218	4857
36	3840	0.39067	0.39067	0.39339	0.39348	0.00192	0.39348	0.00192	0.38724	0.00137	0.38819 0.00196	5663
37	4104	0.39021	0.39021	0.40364	0.39329	0.00181	0.39329	0.00181	0.38821	0.00161	0.39025 0.00175	6787
38	3983	0.39242	0.39242	0.38798	0.39324	0.00171	0.39324	0.00171	0.38819	0.00151	0.39022 0.00166	7137
39	4019	0.38431	0.38431	0.38417	0.39277	0.00168	0.39277	0.00168	0.38798	0.00145	0.38978 0.00159	7287
40	3933	0.37408	0.37408	0.39050	0.39184	0.00185	0.39184	0.00185	0.38811	0.00138	0.38922 0.00140	8911
41	3884	0.39389	0.39389	0.38224	0.39193	0.00176	0.39193	0.00176	0.38783	0.00134	0.38913 0.00137	8917
42	4224	0.38973	0.38973	0.39019	0.39183	0.00168	0.39183	0.00168	0.38794	0.00128	0.38918 0.00130	9491
43	3961	0.38708	0.38708	0.38153	0.39163	0.00162	0.39163	0.00162	0.38766	0.00126	0.38895 0.00128	9303
44	3994	0.39360	0.39360	0.39429	0.39171	0.00156	0.39171	0.00156	0.38793	0.00123	0.38922 0.00124	9520
45	4065	0.40171	0.40171	0.39117	0.39211	0.00155	0.39211	0.00155	0.38806	0.00119	0.38935 0.00123	9266
46	4095	0.38093	0.38093	0.36831	0.39168	0.00155	0.39168	0.00155	0.38730	0.00137	0.38906 0.00141	6739
47	3812	0.39172	0.39172	0.38762	0.39168	0.00149	0.39168	0.00149	0.38732	0.00132	0.38907 0.00136	6971
48	4118	0.38528	0.38528	0.39466	0.39145	0.00145	0.39145	0.00145	0.38758	0.00130	0.38919 0.00127	7708
49	3904	0.39437	0.39437	0.38778	0.39155	0.00140	0.39155	0.00140	0.38758	0.00126	0.38922 0.00124	7873
50	4096	0.39449	0.39449	0.38895	0.39165	0.00136	0.39165	0.00136	0.38763	0.00121	0.38928 0.00121	8035
51	4019	0.39678	0.39678	0.38971	0.39182	0.00133	0.39182	0.00133	0.38770	0.00118	0.38937 0.00118	8095
52	4011	0.39087	0.39087	0.38202	0.39179	0.00128	0.39179	0.00128	0.3875 2	0.00115	0.38929 0.00116	8085
53	3934	0.40816	0.40816	0.38585	0.39228	0.00134	0.39228	0.00134	0.38747	0.00112	0.38925 0.00116	7896
54	4180	0.39712	0.39712	0.39751	0.39242	0.00131	0.39242	0.00131	0.38776	0.00112	0.38957 0.00115	7772
55	3907	0.40486	0.40486	0.40396	0.39278	0.00132	0.39278	0.00132	0.38823	0.00119	0.39010 0.00122	6777
56	4082	0.38215	0.38215	0.38619	0.39248	0.00131	0.39248	0.00131	0.38817	0.00115	0.38986 0.00118	6998
57	3789	0.38075	0.38075	0.37669	0.39217	0.00132	0.39217	0.00132	0.38786	0.00116	0.38954 0.00121	6515

58	4000	0.36775	0.36775	0.39082	0.39152	0.00143	0.39152	0.00143	0.38794	0.00114	0.38909	0.00113	7250
59	3902	0.39304	0.39304	0.38748	0.39156	0.00140	0.39156	0.00140	0.38793	0.00111	0.38910	0.00110	7398
60	4248	0.38453	0.38453	0.38212	0.39139	0.00137	0.39139	0. 00137	0.38778	0.00109	0.38894	0.00109	7390
61	3900	0.39295	0.39295	0.39676	0.39143	0.00134	0.39143	0.00134	0.38800	0.00108	0.38915	0.00107	7493
62	4085	0.39910	0.39910	0.39402	0.39161	0.00132	0.39161	0.00132	0.38814	0.00107	0.38929	0.00106	7442
63	4027	0.39556	0.39556	0.39366	0.39170	0.00129	0.39170	0.00129	0.38827	0.00105	0.38942	0.00104	7518
64	3979	0.39072	0.39072	0.38318	0.39168	0.00126	0.39168	0.00126	0.38816	0.00103	0.38935	0.00103	7560
65	3951	0.40013	0.40013	0.40344	0.39187	0.00125	0.39187	0.00125	0.38850	0.00106	0.38973	0.00104	7149
66	4096	0.39798	0.39798	0.39144	0.39200	0.00123	0.39200	0.00123	0.38856	0.00104	0.38981	0.00103	7186
67	3978	0.39517	0.39517	0.38856	0.39207	0.00120	0.39207	0.00120	0.38856	0.00102	0.38983	0.00101	7283
68	3989	0.39452	0.39452	0.39334	0.39212	0.00118	0.39212	0.00118	0.38866	0.00100	0.38992	0.00099	7399
69	3986	0.38927	0.38927	0.38511	0.39206	0.00116	0.39206	0.00116	0.38859	0.00099	0.38985	0.00098	7481
70	3940	0.38417	0.38417	0.38531	0.39190	0.00114	0.39190	0.00114	0.38852	0.00097	0.38973	0.00096	7585
71	3957	0.39702	0.39702	0.39354	0.39200	0.00113	0.39200	0.00113	0.38862	0.00095	0.38983	0.00095	7619
72	4115	0.38738	0.38738	0.38581	0.39191	0.00111	0.39191	0.00111	0.38857	0.00094	0.38976	0.00093	7724
73	3912	0.38278	0.38278	0.37623	0.39174	0.00110	0.39174	0.00110	0.38833	0.00095	0.38958	0.00095	7340
74	3959	0.37569	0.37569	0.38594	0.39144	0.00112	0.39144	0.00112	0.38829	0.00093	0.38935	0.00093	7502
75	3932	0.38280	0.38280	0.38569	0.39129	0.00111	0.39129	0.00111	0.38824	0.00092	0.38925	0.00091	7628
76	4068	0.38565	0.38565	0.38840	0.39119	0.00110	0.39119	0.00110	0.38824	0.00090	0.38921	0.00089	7818
77	4053	0.39921	0.39921	0.39634	0.39133	0.00109	0.39133	0.00109	0.38839	0.00089	0.38935	0.00089	7718
78	4131	0.39127	0.39127	0.37631	0.39133	0.00107	0.39133	0.00107	0.38818	0.00090	0.38929	0.00090	7522
79	3944	0.38810	0.38810	0.39503	0.39127	0.00105	0.39127	0.00105	0.38829	0.00090	0.38937	0.00087	7746
80	3987	0.38573	0.38573	0.38025	0.39118	0.00104	0.39118	0.00104	0.38816	0.00089	0.38927	0.00087	7666
81	3995	0.39470	0.39470	0.39795	0.39124	0.00102	0.39124	0.00102	0.38832	0.00089	0.38943	0.00086	7685
82	4092	0.38336	0.38336	0.38151	0.39111	0.00101	0.39111	0.00101	0.38821	0.00088	0.38930	0.00086	7638
83	3889	0.41274	0.41274	0.41270	0.39145	0.00105	0.39145	0.00105	0.38860	0.00095	0.38973	0.00093	6378
84	4309	0.38910	0.38910	0.38590	0.39142	0.00104	0.39142	0.00104	0.38856	0.00094	0.38969	0.00092	6448
85	3774	0.39522	0.39522	0.40605	0.39147	0.00102	0.39147	0.00102	0.38883	0.00096	0.38998	0.00092	6407
86	4063	0.38106	0.38106	0.38776	0.39132	0.00102	0.39132	0.00102	0.38881	0.00095	0.38987	0.00090	6523
87	3851	0.39471	0.39471	0.37858	0.39137	0.00101	0.39137	0.00101	0.38866	0.00095	0.38985	0.00090	6506
88	4119	0.40157	0.40157	0.39964	0.39152	0.00100	0.39152	0.00100	0.38882	0.00095	0.39001	0.00090	6379
89	4080	0.37451	0.37451	0.38884	0.39127	0.00102	0.39127	0.00102	0.38882	0.00093	0.38983	0.00088	6515
90	3724	0.37000	0.37000	0.39049	0.39097	0.00105	0.39097	0.00105	0.38884	0.00092	0.38965	0.00087	6682
91	3973	0.38996	0.38996	0.38867	0.39095	0.00103	0.39095	0.00103	0.38884	0.00091	0.38964	0.00085	6779
92	4186	0.38329	0.38329	0.39839	0.39085	0.00102	0.39085	0.00102	0.38897	0.00090	0.38970	0.00084	6960
93	3943	0.38968	0.38968	0.39567	0.39083	0.00101	0.39083	0.00101	0.38907	0.00089	0.38976	0.00082	7069
94	4058	0.38357	0.38357	0.38940	0.39073	0.00100	0.39073	0.00100	0.38907	0.00088	0.38972	0.00081	7184
95	3932	0.39243	0.39243	0.38513	0.39076	0.00099	0.39076	0.00099	0.38902	0.00087	0.38970	0.00080	7251
96	4104	0.38826	0.38826	0.39376	0.39072	0.00098	0.39072	0.00098	0.38908	0.00086	0.38973	0.00079	7372
97	3944	0.38800	0.38800	0.38613	0.39069	0.00096	0.39069	0.00096	0.38904	0.00085	0.38969	0.00078	7450
98	4010	0.40215	0.40215	0.40689	0.39083	0.00096	0.39083	0.00096	0.38927	0.00087	0.38991	0.00080	7101
99	4172	0.37818	0.37818	0.39967	0.39067	0.00096	0.39067	0.00096	0.38940	0.00087	0.38993	0.00078	7285
100	3736	0.38723	0.38723	0.38459	0.39063	0.00095	0.39063	0.00095	0.38934	0.00086	0.38988	0.00077	7339
101	4113	0.37344	0.37344	0.39168	0.39042	0.00096	0.39042	0.00096	0.38937	0.00085	0.38979	0.00076	7424
102	3869	0.39315	0.39315	0.39127	0.39045	0.00095	0.39045	0.00095	0.38939	0.00084	0.38981	0.00075	7507
103	4197	0.38547	0.38547	0.39895	0.39039	0.00094	0.39039	0.00094	0.38951	0.00084	0.38987	0.00075	7607
104	3896	0.38396	0.38396	0.37633	0.39032	0.00094	0.39032	0.00094	0.38935	0.00084	0.38975	0.00075	7468
105	3980	0.38310	0.38310	0.38928	0.39023	0.00093	0.39023	0.00093	0.38935	0.00083	0.38971	0.00074	7554
106	4007	0.38833	0.38833	0.38860	0.39021	0.00092	0.39021	0.00092	0.38934	0.00082	0.38970	0.00073	7644
107	4071	0.39150	0.39150	0.38660	0.39022	0.00091	0.39022	0.00091	0.38931	0.00082	0.38969	0.00072	7722
108	4031	0.38842	0.38842	0.39092	0.39020	0.00090	0.39020	0.00090	0.38933	0.00081	0.38969	0.00071	7819
109	3983	0.40208	0.40208	0.39003	0.39034	0.00090	0.39034	0.00090	0.38934	0.00080	0.38974	0.00071	7832
110	4138	0.37909	0.37909	0.39048	0.39021	0.00090	0.39021	0.00090	0.38935	0.00079	0.38969	0.00070	7916
111	3778	0.38319	0.38319	0.37809	0.39013	0.00089	0.39013	0.00089	0.38923	0.00079	0.38959	0.00070	7811
112	4012	0.38795	0.38795	0.38856	0.39011	0.00088	0.39011	0.00088	0.38922	0.00078	0.38958	0.00069	7898
113	4033	0.37341	0.37341	0.37374	0.38993	0.00089	0.38993	0.00089	0.38905	0.00079	0.38940	0.00071	7501

114	3836	0.36687	0.36687	0.38266	0.38969	0.00091	0.38969	0.00091	0.38898	0.00078	0.38924	0.00071	7323
115	3896	0.39318	0.39318	0.39872	0.38972	0.00090	0.38972	0.00090	0.38909	0.00078	0.38933	0.00071	7324
116	4305	0.37475	0.37475	0.38536	0.38957	0.00091	0.38957	0.00091	0.38905	0.00078	0.38924	0.00071	7307
117	3786	0.37705	0.37705	0.39954	0.38944	0.00091	0.38944	0.00091	0.38916	0.00078	0.38926	0.00070	7399
118	4036	0.40111	0.40111	0.39072	0.38956	0.00091	0.38956	0.00091	0.38917	0.00077	0.38931	0.00069	7428
119	4246	0.38279	0.38279	0.38966	0.38949	0.00090	0.38949	0.00090	0.38918	0.00076	0.38929	0.00069	7500
120	3801	0.40423	0.40423	0.39728	0.38964	0.00090	0.38964	0.00090	0.38926	0.00076	0.38939	0.00069	7401

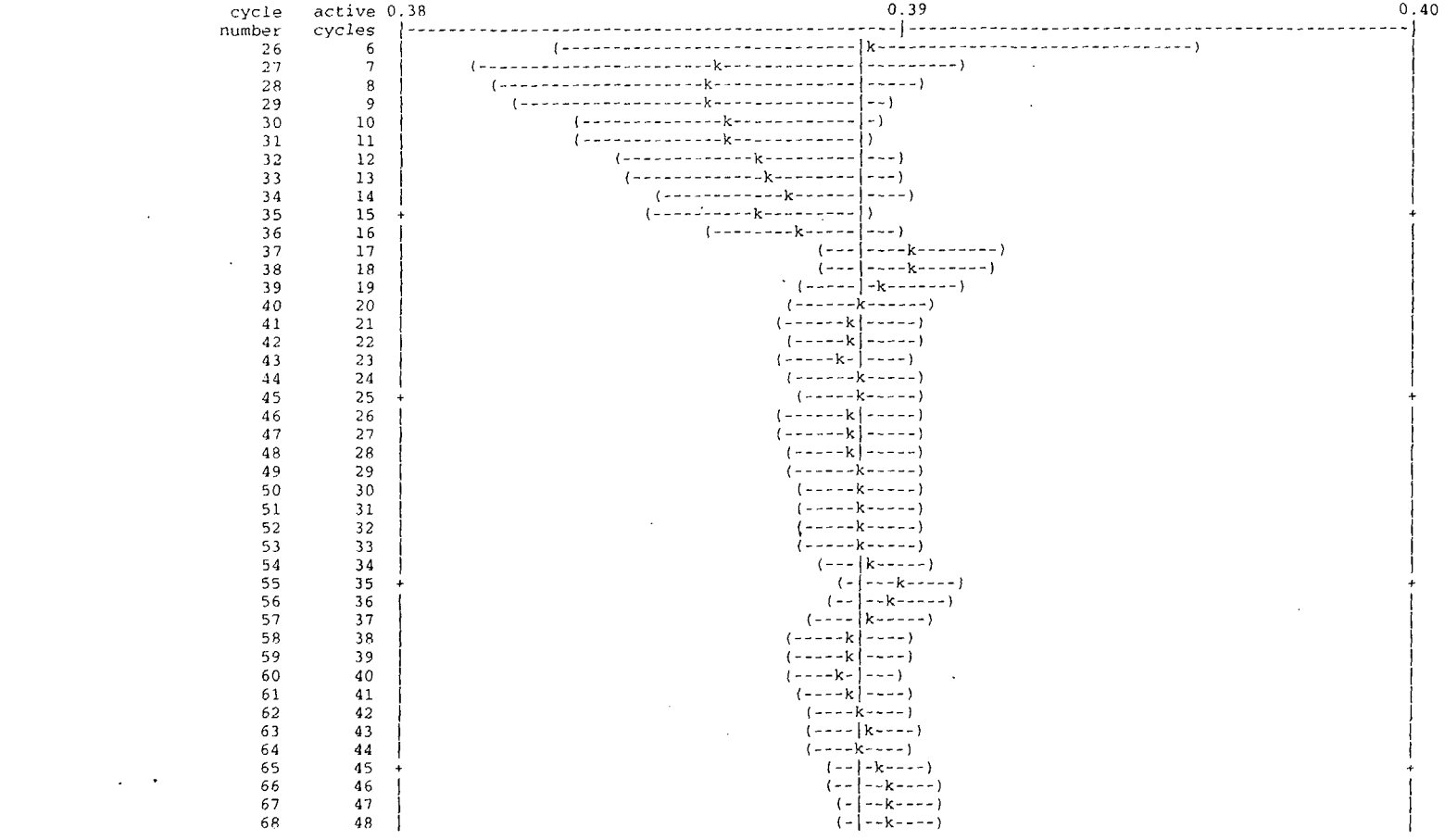
the largest active cycle keffs by estimator are:

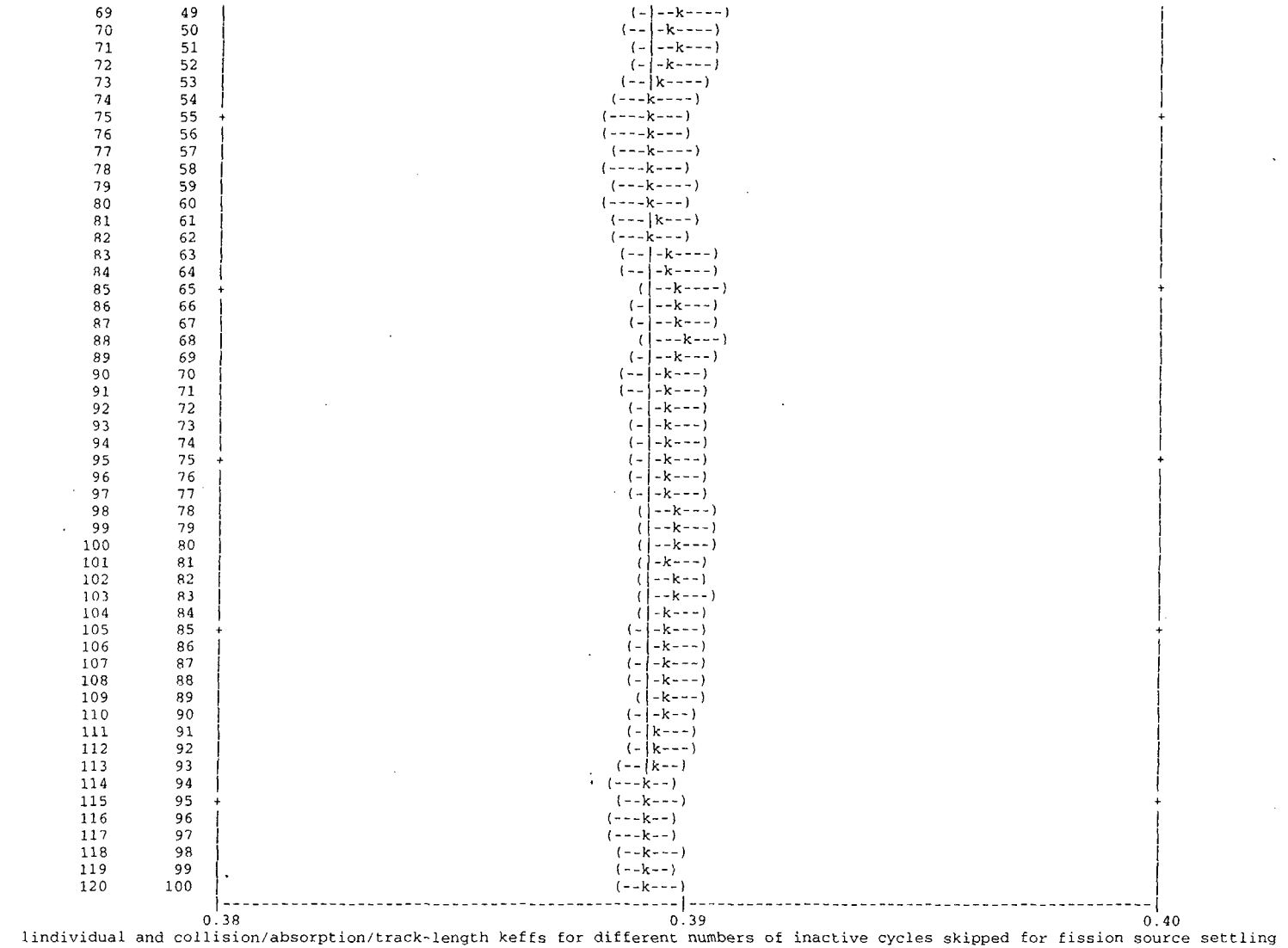
collision 0.41274 on cycle 83
absorption 0.41274 on cycle 83
track length 0.41270 on cycle 83

the smallest active cycle keffs by estimator are:

collision 0.36687 on cycle 114
absorption 0.36687 on cycle 114
track length 0.36831 on cycle 46

1plot of the estimated col/abs/track-length keff one standard deviation interval versus cycle number (| = final keff = 0.38939)





lindividual and collision/absorption/track-length keffs for different numbers of inactive cycles skipped for fission source settling

skip cycles	active cycles	active neutrons	average keff estimators and deviations k(col)	st dev	k(abs)	st dev	k(trk)	st dev	normality co/ab/tl	average k(c/a/t) k(c/a/t)	st dev	k(c/a/t) confidence intervals 95% confidence	99% confidence
0	120	477311	0.3890	0.0011	0.3890	0.0011	0.3886	0.0009	no/no/no	0.38868	0.00089	0.38692-0.39045	0.38634-0.39103
1	119	473311	0.3883	0.0009	0.3883	0.0009	0.3881	0.0007	95/95/95	0.38815	0.00069	0.38677-0.38954	0.38632-0.38999
2	118	471443	0.3884	0.0009	0.3884	0.0009	0.3881	0.0007	95/95/95	0.38816	0.00070	0.38676-0.38955	0.38631-0.39000

3	117	468142	0.3885	0.0009	0.3885	0.0009	0.3881	0.0007	95/95/95	0.38826	0.00070	0.38686-0.38965	0.38641-0.39010
4	116	464289	0.3886	0.0009	0.3886	0.0009	0.3882	0.0007	95/95/95	0.38835	0.00070	0.38696-0.38974	0.38650-0.39020
5	115	460218	0.3888	0.0009	0.3888	0.0009	0.3883	0.0007	95/95/95	0.38848	0.00069	0.38710-0.38986	0.38665-0.39031
6	114	456258	0.3890	0.0009	0.3890	0.0009	0.3885	0.0007	95/95/95	0.38866	0.00068	0.38731-0.39001	0.38687-0.39045
7	113	452377	0.3890	0.0009	0.3890	0.0009	0.3886	0.0007	95/95/95	0.38876	0.00067	0.38741-0.39010	0.38698-0.39054
8	112	448228	0.3891	0.0009	0.3891	0.0009	0.3887	0.0007	95/95/95	0.38882	0.00068	0.38748-0.39017	0.38704-0.39061
9	111	444205	0.3892	0.0009	0.3892	0.0009	0.3888	0.0007	95/95/95	0.38891	0.00068	0.38756-0.39026	0.38712-0.39070
10	110	440231	0.3891	0.0009	0.3891	0.0009	0.3888	0.0007	95/95/95	0.38889	0.00068	0.38752-0.39025	0.38708-0.39069
11	109	436073	0.3892	0.0009	0.3892	0.0009	0.3888	0.0007	95/95/95	0.38896	0.00069	0.38759-0.39033	0.38715-0.39077
12	108	432243	0.3893	0.0009	0.3893	0.0009	0.3889	0.0007	95/95/95	0.38900	0.00069	0.38763-0.39038	0.38718-0.39083
13	107	428169	0.3895	0.0009	0.3895	0.0009	0.3889	0.0007	95/95/95	0.38913	0.00069	0.38775-0.39050	0.38731-0.39095
14	106	424320	0.3897	0.0009	0.3897	0.0009	0.3890	0.0008	95/95/95	0.38924	0.00069	0.38787-0.39061	0.38743-0.39106
15	105	420304	0.3898	0.0009	0.3898	0.0009	0.3892	0.0007	95/95/95	0.38940	0.00067	0.38806-0.39074	0.38763-0.39118
16	104	416216	0.3897	0.0009	0.3897	0.0009	0.3891	0.0007	95/95/95	0.38933	0.00067	0.38799-0.39067	0.38755-0.39111
17	103	411953	0.3897	0.0009	0.3897	0.0009	0.3892	0.0007	95/95/95	0.38940	0.00068	0.38805-0.39075	0.38761-0.39119
18	102	408110	0.3897	0.0009	0.3897	0.0009	0.3892	0.0008	95/95/95	0.38934	0.00068	0.38799-0.39070	0.38755-0.39114
19	101	404010	0.3897	0.0009	0.3897	0.0009	0.3893	0.0007	95/95/95	0.38942	0.00068	0.38807-0.39078	0.38762-0.39123
20	100*	400116	0.3896	0.0009	0.3896	0.0009	0.3893	0.0008	95/95/95	0.38939	0.00069	0.38802-0.39076	0.38757-0.39121
22	98	392153	0.3895	0.0009	0.3895	0.0009	0.3892	0.0008	95/95/95	0.38933	0.00069	0.38795-0.39071	0.38750-0.39116
24	96	384083	0.3893	0.0009	0.3893	0.0009	0.3892	0.0008	95/95/95	0.38924	0.00070	0.38784-0.39064	0.38739-0.39110
26	94	376225	0.3893	0.0009	0.3893	0.0009	0.3894	0.0008	95/95/95	0.38938	0.00071	0.38797-0.39079	0.38750-0.39125
28	92	368255	0.3894	0.0009	0.3894	0.0009	0.3896	0.0008	95/95/95	0.38950	0.00072	0.38806-0.39093	0.38760-0.39139
30	90	359948	0.3892	0.0009	0.3892	0.0009	0.3896	0.0008	95/95/95	0.38946	0.00073	0.38800-0.39092	0.38752-0.39140
32	88	352067	0.3890	0.0010	0.3890	0.0010	0.3896	0.0008	95/95/95	0.38941	0.00075	0.38792-0.39090	0.38744-0.39139
34	86	344062	0.3889	0.0010	0.3889	0.0010	0.3896	0.0008	95/95/95	0.38934	0.00077	0.38782-0.39087	0.38732-0.39136
36	84	336221	0.3889	0.0010	0.3889	0.0010	0.3896	0.0009	95/95/95	0.38937	0.00078	0.38781-0.39092	0.38730-0.39143
38	82	328134	0.3888	0.0010	0.3888	0.0010	0.3895	0.0009	95/95/95	0.38926	0.00079	0.38769-0.39083	0.38717-0.39135
40	80	320182	0.3891	0.0010	0.3891	0.0010	0.3895	0.0009	95/95/95	0.38938	0.00080	0.38777-0.39098	0.38725-0.39150
42	78	312074	0.3890	0.0010	0.3890	0.0010	0.3896	0.0009	95/95/95	0.38941	0.00083	0.38776-0.39105	0.38723-0.39159
44	76	304119	0.3890	0.0011	0.3890	0.0011	0.3897	0.0009	95/95/95	0.38943	0.00084	0.38775-0.39111	0.38720-0.39165
46	74	295959	0.3889	0.0011	0.3889	0.0011	0.3899	0.0009	95/95/95	0.38961	0.00083	0.38794-0.39127	0.38740-0.39181
48	72	288029	0.3889	0.0011	0.3889	0.0011	0.3899	0.0009	95/95/95	0.38959	0.00086	0.38788-0.39130	0.38732-0.39186
50	70	280029	0.3888	0.0011	0.3888	0.0011	0.3900	0.0009	95/95/95	0.38957	0.00088	0.38780-0.39133	0.38723-0.39191
52	68	271999	0.3886	0.0012	0.3886	0.0012	0.3901	0.0010	95/95/95	0.38961	0.00091	0.38779-0.39142	0.38719-0.39202
54	66	263885	0.3882	0.0012	0.3882	0.0012	0.3900	0.0010	95/95/95	0.38940	0.00094	0.38753-0.39127	0.38692-0.39189
56	64	255896	0.3880	0.0012	0.3880	0.0012	0.3899	0.0010	95/95/95	0.38922	0.00093	0.38736-0.39108	0.38675-0.39170
58	62	248107	0.3885	0.0011	0.3885	0.0011	0.3901	0.0010	95/95/95	0.38948	0.00093	0.38762-0.39134	0.38700-0.39196
60	60	239957	0.3885	0.0012	0.3885	0.0012	0.3902	0.0010	95/95/95	0.38960	0.00096	0.38767-0.39152	0.38704-0.39216
62	58	231972	0.3882	0.0012	0.3882	0.0012	0.3901	0.0010	95/95/95	0.38938	0.00098	0.38740-0.39135	0.38675-0.39200
64	56	223966	0.3880	0.0012	0.3880	0.0012	0.3901	0.0011	95/95/95	0.38935	0.00102	0.38731-0.39140	0.38663-0.39208
66	54	215919	0.3876	0.0012	0.3876	0.0012	0.3899	0.0011	95/95/95	0.38902	0.00103	0.38696-0.39108	0.38628-0.39176
68	52	207952	0.3873	0.0013	0.3873	0.0013	0.3898	0.0011	95/95/95	0.38887	0.00107	0.38672-0.39101	0.38601-0.39173
70	50	200026	0.3874	0.0013	0.3874	0.0013	0.3900	0.0012	95/95/95	0.38900	0.00111	0.38677-0.39124	0.38603-0.39198
72	48	191954	0.3872	0.0014	0.3872	0.0014	0.3900	0.0012	95/95/95	0.38892	0.00115	0.38659-0.39125	0.38581-0.39202
74	46	184083	0.3875	0.0014	0.3875	0.0014	0.3904	0.0012	95/95/95	0.38932	0.00117	0.38696-0.39169	0.38617-0.39248
76	44	176083	0.3877	0.0015	0.3877	0.0015	0.3905	0.0013	95/95/95	0.38948	0.00122	0.38702-0.39193	0.38619-0.39276
78	42	167899	0.3873	0.0015	0.3873	0.0015	0.3907	0.0013	95/95/95	0.38955	0.00127	0.38698-0.39212	0.38611-0.39299
80	40	159968	0.3873	0.0016	0.3873	0.0016	0.3909	0.0013	95/95/95	0.38974	0.00132	0.38706-0.39242	0.38615-0.39333
82	38	151881	0.3872	0.0017	0.3872	0.0017	0.3910	0.0013	95/95/95	0.38980	0.00136	0.38703-0.39256	0.38609-0.39351
84	36	143683	0.3865	0.0016	0.3865	0.0016	0.3905	0.0013	95/95/95	0.38915	0.00126	0.38659-0.39172	0.38571-0.39260
86	34	135846	0.3864	0.0016	0.3864	0.0016	0.3901	0.0013	95/95/95	0.38897	0.00124	0.38644-0.39149	0.38556-0.39237
88	32	127876	0.3856	0.0017	0.3856	0.0017	0.3902	0.0013	95/95/95	0.38884	0.00129	0.38620-0.39149	0.38528-0.39241
90	30	120072	0.3865	0.0016	0.3865	0.0016	0.3902	0.0013	95/95/95	0.38896	0.00132	0.38625-0.39166	0.38530-0.39261
92	28	111913	0.3865	0.0018	0.3865	0.0018	0.3900	0.0014	95/95/95	0.38887	0.00139	0.38600-0.39174	0.38498-0.39276
94	26	103912	0.3865	0.0019	0.3865	0.0019	0.3898	0.0015	95/95/95	0.38875	0.00147	0.38570-0.39180	0.38461-0.39289
96	24	95876	0.3862	0.0020	0.3862	0.0020	0.3898	0.0016	95/95/95	0.38870	0.00161	0.38535-0.39205	0.38414-0.39326
98	22	87922	0.3854	0.0021	0.3854	0.0021	0.3892	0.0015	95/95/95	0.38808	0.00154	0.38486-0.39129	0.38368-0.39247

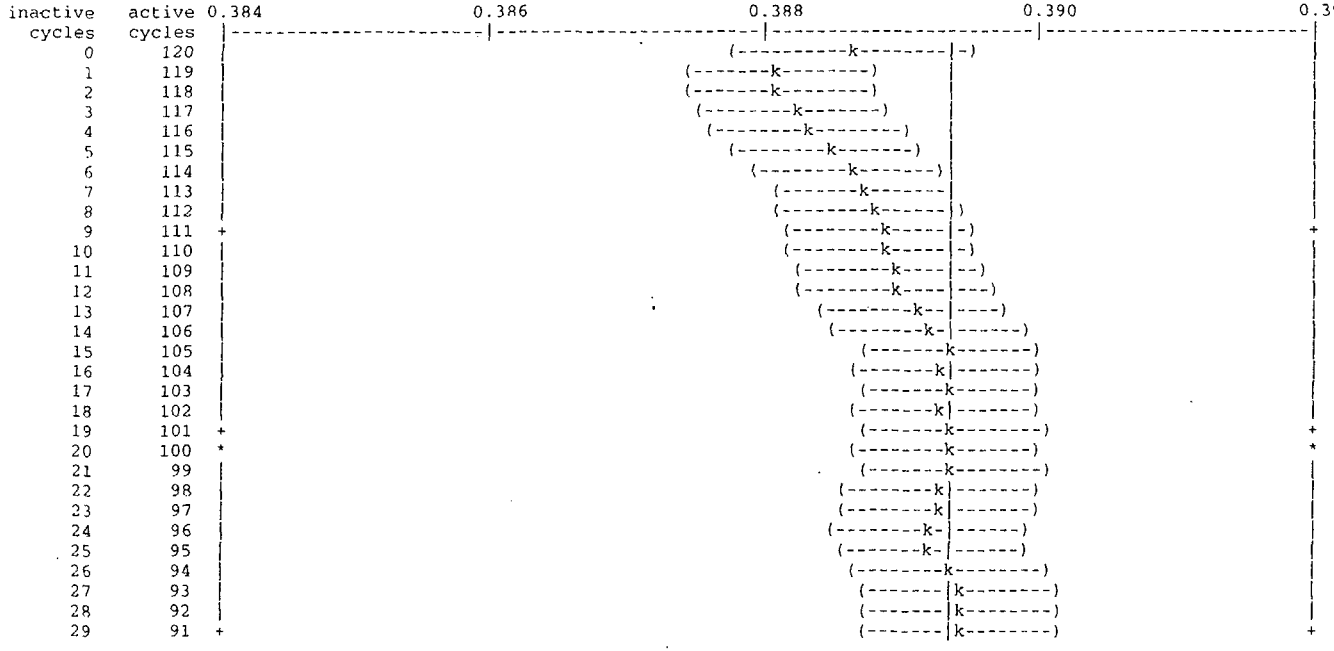
100	20	80014	0.3857	0.0023	0.3857	0.0023	0.3889	0.0016	95/95/95	0.38815	0.00164	0.38469-0.39160	0.38340-0.39290
102	18	72032	0.3859	0.0024	0.3859	0.0024	0.3886	0.0018	95/95/95	0.38794	0.00179	0.38413-0.39176	0.38267-0.39322
104	16	63939	0.3861	0.0027	0.3861	0.0027	0.3888	0.0017	95/95/95	0.38844	0.00181	0.38453-0.39235	0.38298-0.39389
106	14	55952	0.3861	0.0031	0.3861	0.0031	0.3887	0.0020	95/95/95	0.38842	0.00208	0.38385-0.39299	0.38197-0.39487
108	12	47850	0.3855	0.0036	0.3855	0.0036	0.3887	0.0023	95/95/95	0.38836	0.00248	0.38276-0.39397	0.38031-0.39641
110	10	39729	0.3845	0.0039	0.3845	0.0039	0.3884	0.0027	95/95/95	0.38780	0.00309	0.38050-0.39510	0.37699-0.39861
112	8	31939	0.3842	0.0049	0.3842	0.0049	0.3897	0.0032	95/95/95	0.38942	0.00387	0.37948-0.39936	0.37383-0.40501
114	6	24070	0.3889	0.0051	0.3889	0.0051	0.3935	0.0024	95/95/95	0.39320	0.00283	0.38418-0.40222	0.37665-0.40975
116	4	15869	0.3913	0.0067	0.3913	0.0067	0.3943	0.0024	95/95/95	0.39384	0.00269	0.35961-0.42808	0.22238-0.56530
117	3	12083	0.3960	0.0067	0.3960	0.0067	0.3926	0.0024					
118	2	8047	0.3935	0.0107	0.3935	0.0107	0.3935	0.0038					

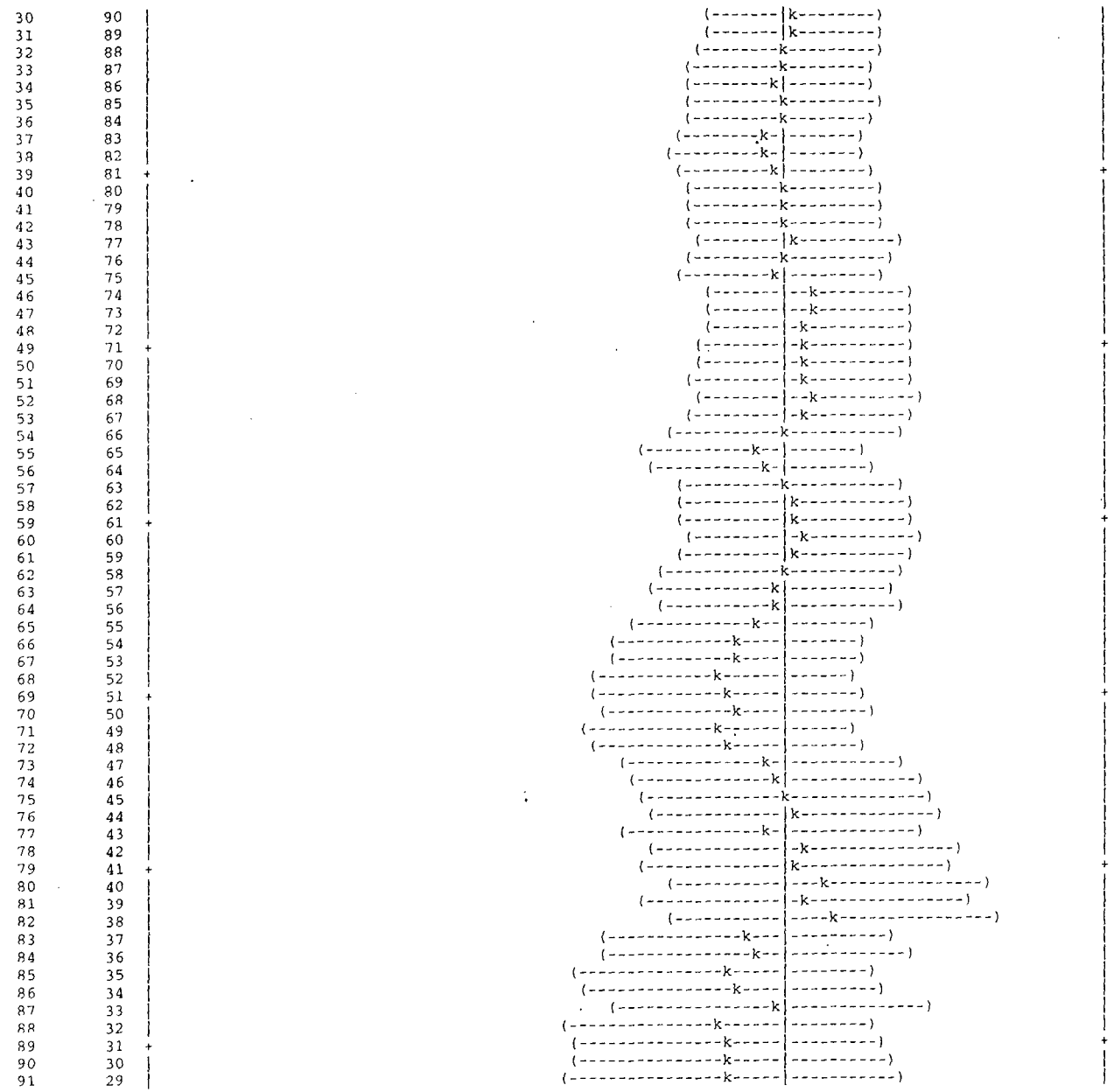
the minimum estimated standard deviation for the col/abs/tl keff estimator occurs with 15 inactive cycles and 105 active cycles.

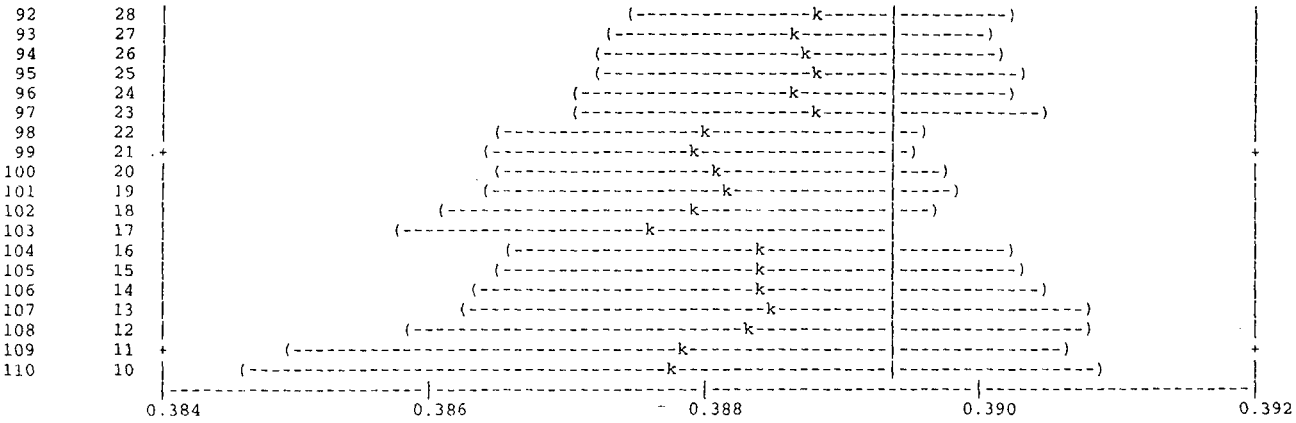
the first active half of the problem skips 20 cycles and uses 50 active cycles; the second half skips 70 and uses 50 cycles.
the col/abs/trk-len keff, one standard deviation, and 68, 95, and 99 percent intervals for each active half of the problem are:

problem	keff	standard deviation	68% confidence	95% confidence	99% confidence
first half	0.38973	0.00096	0.38876 to 0.39070	0.38780 to 0.39167	0.38715 to 0.39231
second half	0.38900	0.00111	0.38789 to 0.39012	0.38677 to 0.39124	0.38603 to 0.39198
final result	0.38939	0.00069	0.38870 to 0.39008	0.38802 to 0.39076	0.38757 to 0.39121

the first and second half values of k(collision/absorption/track length) appear to be the same at the 68 percent confidence level.
1plot of the estimated col/abs/track-length keff one standard deviation interval by active cycle number (| = final keff = 0.38939)







dump no. 5 on file 1s110r nps = 477311 coll = 103110690 ctm = 51.27 nrn = 1759789542

2 warning messages so far.

run terminated when 120 kcode cycles were done.

computer time = 51.29 minutes

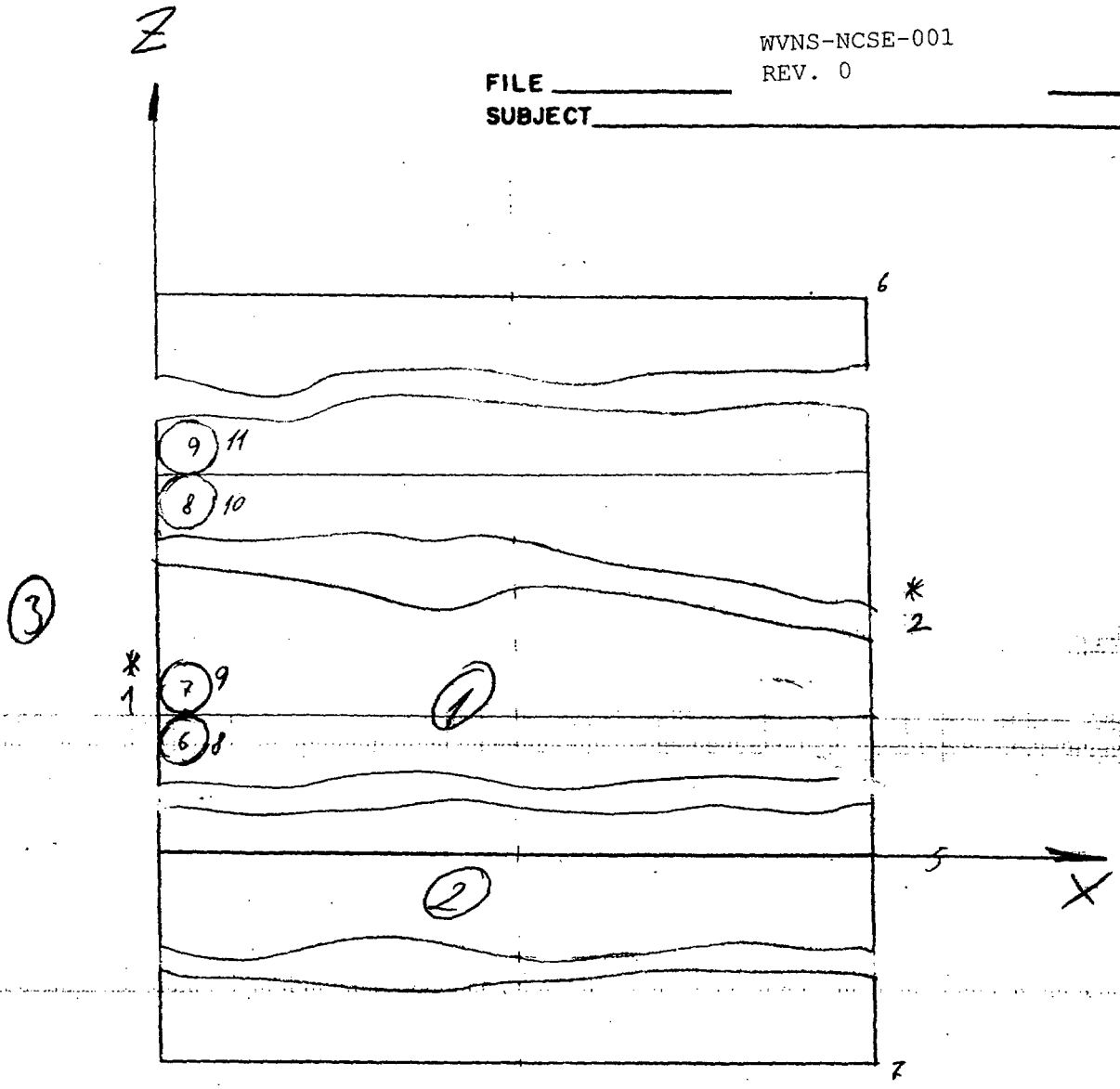
mcnp version 4a 10/01/93 11/28/00 22:57:24 probid = 11/28/00 22:06:07

Attachment 4: Case 2 with MCNP surface and cell numbers

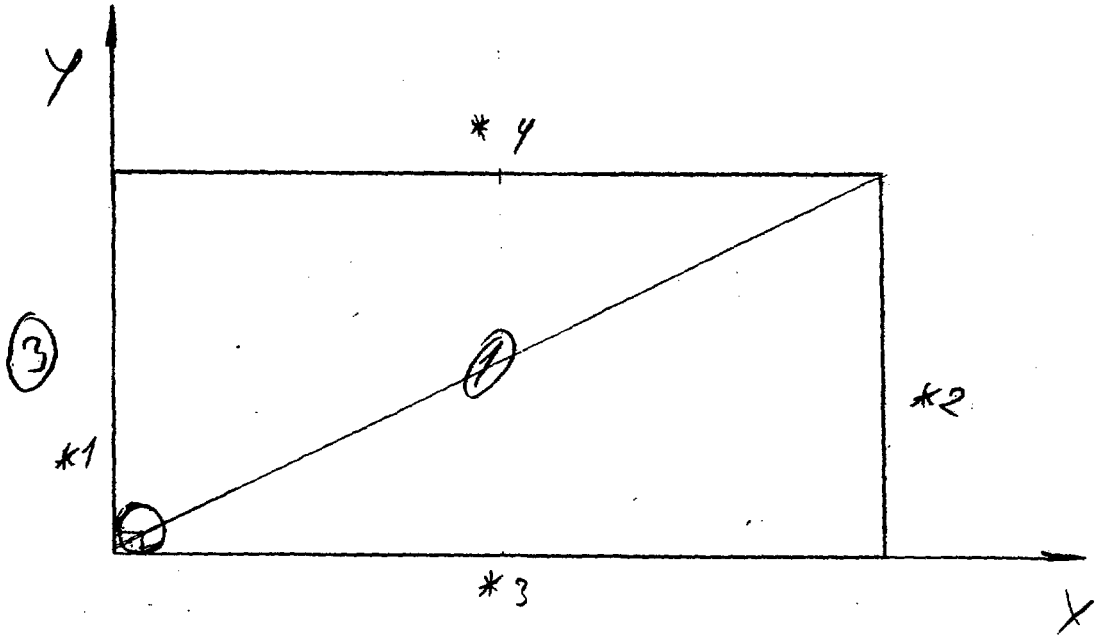
FILE _____

SUBJECT _____

REVISIONS
BY _____ DATE _____ TO EO ____
BY _____ DATE _____ TO EO ____



BY _____ DATE _____
CHECKED BY _____
COPY TO EO _____



Dames & Moore

Attachment 5: Case 2 MCNP input file

1s310

```
k eff, 350g Pu-239 spheres in celulose matrix in B-25 box (68"x54"x34.5").
C
C Cell cards
C
C ------------------------------------------------------------------------
1 1  -0.9    1 -2 3 -4 5 -6 8 9 10 11 imp:n=1 $ TRU box with celulose
2 2  -2.3    1 -2 3 -4 -5 7           imp:n=1 $ Concrete floor
3 0         -1 : 2 : -3 : 4 : -7 : 6  imp:n=0 $ Outside world
4 3  -19.78 -8                       imp:n=1 $ 1st Plutonium sphere
5 3  -19.78 -9                       imp:n=1 $ 2nd Plutonium sphere
6 3  -19.78 -10                      imp:n=1 $ 3rd Plutonium sphere
7 3  -19.78 -11                      imp:n=1 $ 4th Plutonium sphere
C ------------------------------------------------------------------------
c
c Note: next line must be completely blank

c Surface cards
C ------------------------------------------------------------------------
*1 px 0
*2 px 172.72  $ B-25 box length (68")
*3 py 0
*4 py 137.16  $ B-25 box width (54")
5  pz 0
6  pz 350.52  $ 4 tiers of B-25 box height (4x34.5" or 4x87.63 cm)
7  pz -300
8  s 86.36 68.58   1.617 1.617 $ 1st Plutonium sphere
9  s 86.36 68.58 173.643 1.617 $ 2nd Plutonium sphere
10 s 86.36 68.58 176.877 1.617 $ 3rd Plutonium sphere
11 s 86.36 68.58 348.903 1.617 $ 4th Plutonium sphere
C ------------------------------------------------------------------------
c
c Note: next line must be completely blank

c Data cards
c
c Materials
c
c
c Celulose matrix (Elements: C, H, O)
m1      6000.50c  -0.444
        1001.50c  -0.062
        8016.50c  -0.493
c Concrete (KENO Regular Concrete Standard Mix) from Harmon at al.
c Criticality Calculation with MCNP. A Primer. p. C-4
c (Elements: H, O, Na, Si, Al, Ca, Fe)
m2      1001.50c -0.010
        8016.50c -0.532
       11023.50c -0.029
       13027.50c -0.034
       14000.50c -0.337
       20000.50c -0.044
       26000.55c -0.014
c Plutonium-239
m3     94239.55c -1.0
c
mode n
print 40 60 80 100 110 126
kcode 4000 1. 20 120
ksrc  86.36 68.58   1.617
      86.36 68.58 173.643
      86.36 68.58 176.877
      86.36 68.58 348.903
```

Attachment 6: Case 2 MCNP output file

```
1mcnp     version 4a    ld=10/01/93                    12/05/00 16:57:33
 ***********************************************************************          probid =   12/05/00 16:57:33
 name=1s310

      k eff, 350g Pu-239 spheres in celulose matrix in B-25 box (68"x54"x34.5").
      C
      C Cell cards
      C
      C ---------------------------------------------------------------------
      1 1  -0.9    1 -2 3 -4 5 -6 8 9 10 11 imp:n=1 $ TRU box with celulose
      2 2  -2.3    1 -2 3 -4 -5 7           imp:n=1 $ Concrete floor
      3 0         -1 : 2 : -3 : 4 : -7 : 6  imp:n=0 $ Outside world
      4 3  -19.78 -8                        imp:n=1 $ 1st Plutonium sphere
      5 3  -19.78 -9                        imp:n=1 $ 2nd Plutonium sphere
      6 3  -19.78 -10                       imp:n=1 $ 3rd Plutonium sphere
      7 3  -19.78 -11                       imp:n=1 $ 4th Plutonium sphere
      C ---------------------------------------------------------------------
      c
      c Note: next line must be completely blank

      c Surface cards
      C ---------------------------------------------------------------------
      *1 px 0
      *2 px 172.72  $ B-25 box length (68")
      *3 py 0
      *4 py 137.16  $ B-25 box width (54")
      5  pz 0
      6  pz 350.52  $ 4 tiers of B-25 box height (4x34.5" or 4x87.63 cm)
      7  pz -300
      8  s 86.36 68.58   1.617 1.617 $ 1st Plutonium sphere
      9  s 86.36 68.58 173.643 1.617 $ 2nd Plutonium sphere
      10 s 86.36 68.58 176.877 1.617 $ 3rd Plutonium sphere
      11 s 86.36 68.58 348.903 1.617 $ 4th Plutonium sphere
      C ---------------------------------------------------------------------
      c
      c Note: next line must be completely blank

      c Data cards
      c
      c Materials
      c
      c
      c Celulose matrix (Elements: C, H, O)
      m1      6000.50c  -0.444
              1001.50c  -0.062
              8016.50c  -0.493
      c Concrete (KENO Regular Concrete Standard Mix) from Harmon at al.
      c Criticality Calculation with MCNP, A Primer, p. C-4
      c (Elements: H, O, Na, Si, Al, Ca, Fe)
      m2      1001.50c -0.010
              8016.50c -0.532
             11023.50c -0.029
             13027.50c -0.034
             14000.50c -0.337
             20000.50c -0.044
             26000.55c -0.014
      c Plutonium-239
      m3     94239.55c -1.0
```

```
 55-        c
 56-        mode n
 57-        print 40 60 80 100 110 126
 58-        kcode 4000 1. 20 120
 59-        ksrc  86.36 68.58   1.617
 60-              86.36 68.58 173.643
 61-              86.36 68.58 176.877
 62-              86.36 68.58 348.903
 63-
total fission nubar data are being used.
1material composition                                                                    print table 40

the sum of the fractions of material    1 was 9.990000E-01

material
 number     component nuclide, atom fraction

    1            6000,  0.28588       1001,  0.47576       8016,  0.23837
    2            1001,  0.16803       8016,  0.56324      11023,  0.02136      13027,  0.02134
                14000,  0.20319      20000,  0.01859      26000,  0.00425
    3           94239,  1.00000


material
 number     component nuclide, mass fraction

    1            6000,  0.44444       1001,  0.06206       8016,  0.49349
    2            1001,  0.01000       8016,  0.53200      11023,  0.02900      13027,  0.03400
                14000,  0.33700      20000,  0.04400      26000,  0.01400
    3           94239,  1.00000

warning.    1 of the materials had unnormalized fractions.
1cells                                                                                   print table 60

                     atom        gram                                          neutron
       cell  mat    density     density     volume       mass     pieces importance

    1     1    1  7.01524E-02 9.00000E-01 0.00000E+00 0.00000E+00     0  1.0000E+00
    2     2    2  8.17913E-02 2.30000E+00 7.10708E+06 1.63463E+07     0  1.0000E+00
    3     3    0  0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00     0  0.0000E+00
    4     4    3  4.98285E-02 1.97800E+01 1.77100E+01 3.50304E+02     1  1.0000E+00
    5     5    3  4.98285E-02 1.97800E+01 1.77100E+01 3.50304E+02     1  1.0000E+00
    6     6    3  4.98285E-02 1.97800E+01 1.77100E+01 3.50304E+02     1  1.0000E+00
    7     7    3  4.98285E-02 1.97800E+01 1.77100E+01 3.50304E+02     1  1.0000E+00

total                                     7.10715E+06 1.63477E+07

        1 warning message so far.
1cross-section tables                                                                    print table 100

    table    length

                     tables from file critxs

  1001.50c    1153  njoy                                                    ( 1301)      79/07/31.
```

```
  6000.50c   16126  njoy                                                    ( 1306)      79/07/31.
  8016.50c   23669  njoy                                                     ( 1276)     05/14/81
 11023.50c   36270  njoy                                                    ( 1311)      79/06/21.
 13027.50c   22891  njoy                                                    ( 1313)      79/09/08.
 14000.50c   48275  njoy                                                    ( 1314)      79/06/21.
 20000.50c   26104  njoy                                                    ( 1320)      79/06/22.
 26000.55c   84136  njoy                                                    ( 260)       10/21/82
 94239.55c   67551  njoy                                  total nu           ( 1399)      02/21/85

 total      326175

warning.  neutron energy cutoff is below some cross-section tables.



decimal words of dynamically allocated storage

    general             110448
    tallies                  0
    bank                  6403
    cross sections      326175

    total               443026

*****************************************************************************************************************
dump no.    1 on file 1s310r       nps =         0     coll =              0     ctm =    0.00     nrn =              0

source distribution written to file 1s310s          cycle =     0

        2 warning messages so far.
1   starting mcrun.      field length =      0      cp0 =  0.01                                    print table 110

     k eff, 350g Pu-239 spheres in celulose matrix in B-25 box (68"x54"x34.5").
```

nps	x	y	z	cell	surf	u	v	w	energy	weight	time
1	8.636E+01	6.858E+01	1.617E+00	4	0	5.085E-01	4.733E-01	7.193E-01	2.209E+00	1.000E+00	0.000E+00
2	8.636E+01	6.858E+01	1.617E+00	4	0	8.952E-01	-4.447E-01	-2.944E-02	4.904E+00	1.000E+00	0.000E+00
3	8.636E+01	6.858E+01	1.617E+00	4	0	-6.184E-01	-4.495E-01	6.446E-01	3.809E-01	1.000E+00	0.000E+00
4	8.636E+01	6.858E+01	1.617E+00	4	0	9.710E-01	-5.665E-02	-2.323E-01	1.331E+00	1.000E+00	0.000E+00
5	8.636E+01	6.858E+01	1.617E+00	4	0	5.861E-01	1.496E-01	-7.963E-01	1.902E+00	1.000E+00	0.000E+00
6	8.636E+01	6.858E+01	1.617E+00	4	0	-6.489E-02	-1.626E-01	9.845E-01	4.410E-01	1.000E+00	0.000E+00
7	8.636E+01	6.858E+01	1.617E+00	4	0	-7.068E-02	3.263E-02	-9.970E-01	4.750E-01	1.000E+00	0.000E+00
8	8.636E+01	6.858E+01	1.617E+00	4	0	-3.915E-01	4.664E-01	-7.932E-01	4.136E+00	1.000E+00	0.000E+00
9	8.636E+01	6.858E+01	1.617E+00	4	0	-2.368E-01	9.215E-01	-3.079E-01	7.453E-02	1.000E+00	0.000E+00
10	8.636E+01	6.858E+01	1.617E+00	4	0	1.946E-01	-3.204E-01	9.271E-01	3.128E+00	1.000E+00	0.000E+00
11	8.636E+01	6.858E+01	1.617E+00	4	0	-6.698E-01	-7.177E-01	-1.905E-01	1.014E+00	1.000E+00	0.000E+00
12	8.636E+01	6.858E+01	1.617E+00	4	0	-8.398E-01	-4.129E-01	3.524E-01	1.395E+00	1.000E+00	0.000E+00
13	8.636E+01	6.858E+01	1.617E+00	4	0	-1.714E-01	-8.572E-01	4.857E-01	7.748E-01	1.000E+00	0.000E+00
14	8.636E+01	6.858E+01	1.617E+00	4	0	-2.489E-01	-5.118E-01	-8.222E-01	1.101E+00	1.000E+00	0.000E+00
15	8.636E+01	6.858E+01	1.617E+00	4	0	-2.959E-01	2.119E-01	9.314E-01	1.951E+00	1.000E+00	0.000E+00
16	8.636E+01	6.858E+01	1.617E+00	4	0	1.395E-01	-9.829E-01	1.202E-01	2.186E+00	1.000E+00	0.000E+00
17	8.636E+01	6.858E+01	1.617E+00	4	0	6.909E-01	-7.110E-01	1.307E-01	1.865E+00	1.000E+00	0.000E+00
18	8.636E+01	6.858E+01	1.617E+00	4	0	-6.580E-01	5.320E-01	-5.329E-01	1.229E+00	1.000E+00	0.000E+00

```
    19  8.636E+01  6.858E+01  1.617E+00     4       0 -9.903E-01 -1.380E-01  1.353E-02  1.305E+00  1.000E+00  0.000E+00
    20  8.636E+01  6.858E+01  1.617E+00     4       0  7.462E-01  4.859E-01 -4.551E-01  1.000E+00  1.000E+00  0.000E+00
    21  8.636E+01  6.858E+01  1.617E+00     4       0 -1.977E-01  9.797E-01  3.360E-02  3.990E+00  1.000E+00  0.000E+00
    22  8.636E+01  6.858E+01  1.617E+00     4       0 -9.117E-01 -3.647E-01 -1.891E-01  2.665E-01  1.000E+00  0.000E+00
    23  8.636E+01  6.858E+01  1.617E+00     4       0 -4.287E-01  8.361E-01 -3.423E-01  1.156E+00  1.000E+00  0.000E+00
    24  8.636E+01  6.858E+01  1.617E+00     4       0  1.080E-01  3.412E-01 -9.338E-01  2.669E+00  1.000E+00  0.000E+00
    25  8.636E+01  6.858E+01  1.617E+00     4       0 -9.111E-01 -9.012E-03 -4.122E-01  2.185E+00  1.000E+00  0.000E+00
    26  8.636E+01  6.858E+01  1.617E+00     4       0 -2.568E-01 -6.391E-01 -7.249E-01  4.225E+00  1.000E+00  0.000E+00
    27  8.636E+01  6.858E+01  1.617E+00     4       0 -2.912E-01  8.086E-01  5.113E-01  1.079E+00  1.000E+00  0.000E+00
    28  8.636E+01  6.858E+01  1.617E+00     4       0  1.472E-01 -9.514E-01  2.705E-01  3.461E+00  1.000E+00  0.000E+00
    29  8.636E+01  6.858E+01  1.617E+00     4       0 -6.135E-01 -7.645E-01 -1.978E-01  1.836E+00  1.000E+00  0.000E+00
    30  8.636E+01  6.858E+01  1.617E+00     4       0 -5.702E-01  5.651E-01 -5.963E-01  4.556E-01  1.000E+00  0.000E+00
    31  8.636E+01  6.858E+01  1.617E+00     4       0 -6.607E-01  5.373E-01 -5.242E-01  6.415E-01  1.000E+00  0.000E+00
    32  8.636E+01  6.858E+01  1.617E+00     4       0 -9.742E-02 -3.639E-01 -9.263E-01  2.764E+00  1.000E+00  0.000E+00
    33  8.636E+01  6.858E+01  1.617E+00     4       0 -1.965E-01 -3.145E-01 -9.287E-01  2.785E-01  1.000E+00  0.000E+00
    34  8.636E+01  6.858E+01  1.617E+00     4       0  4.097E-01  8.465E-01 -3.399E-01  9.097E-01  1.000E+00  0.000E+00
    35  8.636E+01  6.858E+01  1.617E+00     4       0 -4.048E-02  8.831E-01  4.675E-01  3.360E-01  1.000E+00  0.000E+00
    36  8.636E+01  6.858E+01  1.617E+00     4       0  3.371E-01 -9.269E-01 -1.652E-01  6.376E-01  1.000E+00  0.000E+00
    37  8.636E+01  6.858E+01  1.617E+00     4       0 -1.867E-01  9.756E-01 -1.155E-01  2.186E+00  1.000E+00  0.000E+00
    38  8.636E+01  6.858E+01  1.617E+00     4       0 -2.616E-01  2.336E-01 -9.365E-01  7.314E-01  1.000E+00  0.000E+00
    39  8.636E+01  6.858E+01  1.617E+00     4       0  9.780E-01 -7.641E-02 -1.939E-01  2.997E-01  1.000E+00  0.000E+00
    40  8.636E+01  6.858E+01  1.617E+00     4       0  2.580E-01 -7.076E-01  6.578E-01  1.444E+00  1.000E+00  0.000E+00
    41  8.636E+01  6.858E+01  1.617E+00     4       0 -3.212E-01 -7.678E-01 -5.543E-01  1.914E+00  1.000E+00  0.000E+00
    42  8.636E+01  6.858E+01  1.617E+00     4       0  5.039E-01 -1.460E-01  8.513E-01  1.502E+00  1.000E+00  0.000E+00
    43  8.636E+01  6.858E+01  1.617E+00     4       0  6.080E-01  5.487E-01  5.738E-01  5.971E+00  1.000E+00  0.000E+00
    44  8.636E+01  6.858E+01  1.617E+00     4       0 -2.932E-01  9.304E-01 -2.199E-01  1.827E+00  1.000E+00  0.000E+00
    45  8.636E+01  6.858E+01  1.617E+00     4       0 -8.475E-01 -3.993E-01 -3.497E-01  1.928E+00  1.000E+00  0.000E+00
    46  8.636E+01  6.858E+01  1.617E+00     4       0  1.200E-01 -9.195E-01 -3.743E-01  1.351E+00  1.000E+00  0.000E+00
    47  8.636E+01  6.858E+01  1.617E+00     4       0  7.085E-01  5.879E-01  3.904E-01  2.288E+00  1.000E+00  0.000E+00
    48  8.636E+01  6.858E+01  1.617E+00     4       0  4.261E-01  9.046E-01  9.254E-03  1.230E+00  1.000E+00  0.000E+00
    49  8.636E+01  6.858E+01  1.617E+00     4       0  5.431E-01  4.270E-01 -7.230E-01  1.433E+00  1.000E+00  0.000E+00
    50  8.636E+01  6.858E+01  1.617E+00     4       0 -1.053E-01 -9.805E-01  1.658E-01  6.572E-01  1.000E+00  0.000E+00
lestimated keff results by cycle                                                                    print table 175

 source distribution written to file 1s310s          cycle =    20

 source distribution written to file 1s310s          cycle =    23

 source distribution written to file 1s310s          cycle =    26

 source distribution written to file 1s310s          cycle =    29

 source distribution written to file 1s310s          cycle =    32

 source distribution written to file 1s310s          cycle =    35

 ************************************************************************************************************
 dump no.    2 on file 1s310r       nps =    137530     coll =       30592611     ctm =   15.24     nrn =       521187554

 source distribution written to file 1s310s          cycle =    38

 source distribution written to file 1s310s          cycle =    41

 source distribution written to file 1s310s          cycle =    44

 source distribution written to file 1s310s          cycle =    47
```

```
 source distribution written to file ls310s          cycle =    50

 source distribution written to file ls310s          cycle =    53

 source distribution written to file ls310s          cycle =    56

 source distribution written to file ls310s          cycle =    59

 source distribution written to file ls310s          cycle =    62

 source distribution written to file ls310s          cycle =    65

 source distribution written to file ls310s          cycle =    68

 ************************************************************************************************************************
 dump no.    3 on file ls310r       nps =    269968     coll =       61167132     ctm =   30.41     nrn =      1042373273

 source distribution written to file ls310s          cycle =    71

 source distribution written to file ls310s          cycle =    74

 source distribution written to file ls310s          cycle =    77

 source distribution written to file ls310s          cycle =    80

 source distribution written to file ls310s          cycle =    83

 source distribution written to file ls310s          cycle =    86

 source distribution written to file ls310s          cycle =    89

 source distribution written to file ls310s          cycle =    92

 source distribution written to file ls310s          cycle =    95

 source distribution written to file ls310s          cycle =    98

  estimator      cycle   100    ave of    80 cycles       combination          simple average     combined average      corr
 k(collision)       0.458830        0.471868 0.0021     k(col/abs)          0.471868 0.0021     0.471868 0.0021    1.0000
 k(absorption)      0.458830        0.471868 0.0021     k(abs/tk ln)        0.472555 0.0019     0.472519 0.0019    0.5686
 k(trk length)      0.457022        0.473243 0.0021     k(tk ln/col)        0.472555 0.0019     0.472519 0.0019    0.5686
 rem life(col)   3.4829E+04      3.3728E+04 0.0022     k(col/abs/tk ln)    0.472326 0.0019     0.472519 0.0019
 rem life(abs)   3.4784E+04      3.3729E+04 0.0022     life(col/abs)      3.3729E+04 0.0022   3.3732E+04 0.0022    0.9996
 source points generated   3951

 source distribution written to file ls310s          cycle =   101

 ************************************************************************************************************************
 dump no.    4 on file ls310r       nps =    401489     coll =       91510152     ctm =   45.47     nrn =      1559667761

 source distribution written to file ls310s          cycle =   104

 source distribution written to file ls310s          cycle =   107

 source distribution written to file ls310s          cycle =   110
```

source distribution written to file ls310s cycle = 113

estimator	cycle 116	ave of 96 cycles		combination	simple average		combined average		corr
k(collision)	0.447289	0.471452	0.0020	k(col/abs)	0.471452	0.0020	0.471452	0.0020	1.0000
k(absorption)	0.447289	0.471452	0.0020	k(abs/tk ln)	0.472327	0.0017	0.472445	0.0018	0.5516
k(trk length)	0.465414	0.473202	0.0019	k(tk ln/col)	0.472327	0.0017	0.472445	0.0018	0.5516
rem life(col)	3.4498E+04	3.3776E+04	0.0021	k(col/abs/tk ln)	0.472035	0.0018	0.472445	0.0018	
rem life(abs)	3.4514E+04	3.3776E+04	0.0021	life(col/abs)	3.3776E+04	0.0021	3.3776E+04	0.0020	0.9996

source points generated 3783

source distribution written to file ls310s cycle = 116

estimator	cycle 117	ave of 97 cycles		combination	simple average		combined average		corr
k(collision)	0.473051	0.471468	0.0020	k(col/abs)	0.471468	0.0020	0.471468	0.0020	1.0000
k(absorption)	0.473051	0.471468	0.0020	k(abs/tk ln)	0.472350	0.0017	0.472468	0.0018	0.5517
k(trk length)	0.475997	0.473231	0.0019	k(tk ln/col)	0.472350	0.0017	0.472468	0.0018	0.5517
rem life(col)	3.3039E+04	3.3769E+04	0.0021	k(col/abs/tk ln)	0.472056	0.0018	0.472468	0.0018	
rem life(abs)	3.3030E+04	3.3768E+04	0.0021	life(col/abs)	3.3768E+04	0.0021	3.3768E+04	0.0020	0.9996

source points generated 4242

estimator	cycle 118	ave of 98 cycles		combination	simple average		combined average		corr
k(collision)	0.475767	0.471512	0.0020	k(col/abs)	0.471512	0.0020	0.471512	0.0020	1.0000
k(absorption)	0.475767	0.471512	0.0020	k(abs/tk ln)	0.472338	0.0017	0.472443	0.0017	0.5460
k(trk length)	0.466567	0.473163	0.0019	k(tk ln/col)	0.472338	0.0017	0.472443	0.0017	0.5460
rem life(col)	3.2673E+04	3.3757E+04	0.0021	k(col/abs/tk ln)	0.472062	0.0018	0.472443	0.0017	
rem life(abs)	3.2679E+04	3.3757E+04	0.0021	life(col/abs)	3.3757E+04	0.0021	3.3757E+04	0.0020	0.9996

source points generated 4016

estimator	cycle 119	ave of 99 cycles		combination	simple average		combined average		corr
k(collision)	0.462495	0.471421	0.0020	k(col/abs)	0.471421	0.0020	0.471421	0.0020	1.0000
k(absorption)	0.462495	0.471421	0.0020	k(abs/tk ln)	0.472240	0.0017	0.472342	0.0017	0.5511
k(trk length)	0.462802	0.473059	0.0019	k(tk ln/col)	0.472240	0.0017	0.472342	0.0017	0.5511
rem life(col)	3.3657E+04	3.3756E+04	0.0020	k(col/abs/tk ln)	0.471967	0.0018	0.472342	0.0017	
rem life(abs)	3.3636E+04	3.3756E+04	0.0020	life(col/abs)	3.3756E+04	0.0020	3.3755E+04	0.0020	0.9996

source points generated 3842

source distribution written to file ls310s cycle = 119

estimator	cycle 120	ave of 100 cycles		combination	simple average		combined average		corr
k(collision)	0.471552	0.471422	0.0020	k(col/abs)	0.471422	0.0020	0.471422	0.0020	1.0000
k(absorption)	0.471552	0.471422	0.0020	k(abs/tk ln)	0.472233	0.0017	0.472333	0.0017	0.5510
k(trk length)	0.471503	0.473043	0.0019	k(tk ln/col)	0.472233	0.0017	0.472333	0.0017	0.5510
rem life(col)	3.4286E+04	3.3762E+04	0.0020	k(col/abs/tk ln)	0.471962	0.0017	0.472333	0.0017	
rem life(abs)	3.4289E+04	3.3761E+04	0.0020	life(col/abs)	3.3762E+04	0.0020	3.3760E+04	0.0020	0.9996

source points generated 4114

source distribution written to file ls310s cycle = 120

1problem summary

run terminated when 120 kcode cycles were done. 12/05/00 17:51:45

k eff, 350g Pu-239 spheres in celulose matrix in B-25 box (68"x54"x34.5"). probid = 12/05/00 16:57:33

0

neutron creation	tracks	weight (per source particle)	energy	neutron loss	tracks	weight (per source particle)	energy
source	477491	1.0053E+00	2.1525E+00	escape	4799	8.8460E-03	1.1270E-02
				energy cutoff	0	0.	0.

weight window	0	0.	0.
cell importance	0	0.	0.
weight cutoff	0	2.3368E-01	5.6388E-04
energy importance	0	0.	0.
dxtran	0	0.	0.
forced collisions	0	0.	0.
exp. transform	0	0.	0.
upscattering	0	0.	1.0911E-06
(n,xn)	371	4.7581E-04	2.9933E-04
fission	0	0.	0.
total	477862	1.2394E+00	2.1534E+00

time cutoff	0	0.	0.
weight window	0	0.	0.
cell importance	0	0.	0.
weight cutoff	472878	2.3359E-01	5.7029E-04
energy importance	0	0.	0.
dxtran	0	0.	0.
forced collisions	0	0.	0.
exp. transform	0	0.	0.
downscattering	0	0.	1.8713E+00
capture	0	8.4461E-01	2.0074E-02
loss to (n,xn)	185	2.3732E-04	1.8687E-03
loss to fission	0	1.5212E-01	2.4834E-01
total	477862	1.2394E+00	2.1534E+00

number of neutrons banked 186
neutron tracks per source particle 1.0008E+00
neutron collisions per source particle 2.2847E+02
total neutron collisions 109094259
net multiplication 1.0002E+00 0.0001

average lifetime, shakes
escape 2.9126E+03
capture 3.3727E+04
capture or escape 3.3456E+04
any termination 4.1569E+04

cutoffs
tco 1.0000E+34
eco 0.0000E+00
wc1 -5.0000E-01
wc2 -2.5000E-01

computer time so far in this run 54.20 minutes
computer time in mcrun 54.19 minutes
source particles per minute 8.8107E+03
random numbers generated 1859430912

maximum number ever in bank 2
bank overflows to backup file 0
field length 0
most random numbers used was 32659 in history 93912

range of sampled source weights = 9.0806E-01 to 1.7817E+00

1neutron activity in each cell print table 126

cell		tracks entering	population	collisions	collisions * weight (per history)	number weighted energy	flux weighted energy	average track weight (relative)	average track mfp (cm)
1	1	569261	477273	108098749	1.1247E+02	4.8444E-05	2.6810E-01	5.3520E-01	1.5810E+00
2	2	19339	7362	646971	7.3024E-01	5.4243E-05	2.4111E-01	5.7228E-01	2.1414E+00
4	4	10486	9520	6229	1.1926E-02	3.1800E-01	1.8988E+00	9.3979E-01	2.5588E+00
5	5	280971	258171	167988	2.9612E-01	2.3457E-01	1.8900E+00	8.7544E-01	2.5393E+00
6	6	284876	261509	170444	3.0040E-01	2.3114E-01	1.8960E+00	8.7574E-01	2.5410E+00
7	7	6426	6125	3878	7.8219E-03	6.6394E-01	1.9629E+00	9.7742E-01	2.5654E+00
total		1171359	1019960	109094259	1.1382E+02				

1keff results for: k eff, 350g Pu-239 spheres in celulose matrix in B-25 box (68"x54"x34.5"). probid = 12/05/00 16:57:33

the initial fission neutron source distribution used the 4 source points that were input on the ksrc card.
the criticality problem was scheduled to skip 20 cycles and run a total of 120 cycles with nominally 4000 neutrons per cycle.
this problem has run 20 inactive cycles with 77589 neutron histories and 100 active cycles with 399902 neutron histories.

this calculation has completed the requested number of keff cycles using a total of 477491 fission neutron source histories.
all cells with fissionable material were sampled and had fission neutron source points.

the results of the w test for normality applied to the individual collision, absorption, and track-length keff cycle values are:

the k(collision) cycle values appear normally distributed at the 95 percent confidence level
the k(absorption) cycle values appear normally distributed at the 95 percent confidence level
the k(trk length) cycle values appear normally distributed at the 95 percent confidence level

the final estimated combined collision/absorption/track-length keff = 0.47233 with an estimated standard deviation of 0.00081

the estimated 68, 95, & 99 percent keff confidence intervals are 0.47152 to 0.47315, 0.47071 to 0.47395, and 0.47018 to 0.47448

the estimated collision/absorption neutron removal lifetime = 3.38E-04 seconds with an estimated standard deviation of 6.78E-07

the estimated average keffs, one standard deviations, and 68, 95, and 99 percent confidence intervals are:

keff estimator	keff	standard deviation	68% confidence	95% confidence	99% confidence	corr
collision	0.47142	0.00093	0.47049 to 0.47235	0.46957 to 0.47328	0.46896 to 0.47388	
absorption	0.47142	0.00093	0.47049 to 0.47235	0.46957 to 0.47328	0.46896 to 0.47388	
track length	0.47304	0.00088	0.47216 to 0.47392	0.47129 to 0.47480	0.47072 to 0.47537	
col/absorp	0.47142	0.00093	0.47049 to 0.47235	0.46957 to 0.47328	0.46896 to 0.47388	1.0000
abs/trk len	0.47233	0.00081	0.47152 to 0.47315	0.47071 to 0.47395	0.47018 to 0.47448	0.5510
col/trk len	0.47233	0.00081	0.47152 to 0.47315	0.47071 to 0.47395	0.47018 to 0.47448	0.5510
col/abs/trk len	0.47233	0.00081	0.47152 to 0.47315	0.47071 to 0.47395	0.47018 to 0.47448	

if the largest of each keff occurred on the next cycle, the keff results and 68, 95, and 99 percent confidence intervals would be:

keff estimator	keff	standard deviation	68% confidence	95% confidence	99% confidence
collision	0.47165	0.00095	0.47070 to 0.47260	0.46976 to 0.47354	0.46914 to 0.47416
absorption	0.47165	0.00095	0.47070 to 0.47260	0.46976 to 0.47354	0.46914 to 0.47416
track length	0.47326	0.00090	0.47236 to 0.47416	0.47147 to 0.47505	0.47089 to 0.47563
col/abs/trk len	0.47256	0.00084	0.47172 to 0.47340	0.47089 to 0.47423	0.47035 to 0.47477

the estimated collision/absorption neutron lifetimes, one standard deviations, and 68, 95, and 99 percent confidence intervals are:

type	lifetime(sec)	standard deviation	68% confidence	95% confidence	99% confidence
removal	3.3760E-04	6.7752E-07	3.3692E-04 to 3.3828E-04	3.3625E-04 to 3.3895E-04	3.3581E-04 to 3.3939E-04
capture	3.3750E-04	5.1225E-07	3.3699E-04 to 3.3801E-04	3.3648E-04 to 3.3852E-04	3.3615E-04 to 3.3885E-04
fission	2.3394E-05	2.1987E-07	2.3174E-05 to 2.3614E-05	2.2956E-05 to 2.3832E-05	2.2813E-05 to 2.3975E-05
escape	1.6769E-06	1.0034E-06	6.7256E-07 to 2.6813E-06	0.0000E+00 to 3.6756E-06	0.0000E+00 to 4.3278E-06

laverage individual and combined collision/absorption/track-length keff results for 7 different batch sizes

cycles per keff batch	number of k batches	average keff estimators and deviations k(col) st dev	k(abs) st dev	k(trk) st dev	normality co/ab/trk	average k(c/a/t) k(c/a/t) st dev	k(c/a/t) confidence intervals 95% confidence	99% confidence
1	100	0.4714 0.0009	0.4714 0.0009	0.4730 0.0009	95/95/95	0.47233 0.00081	0.47071-0.47395	0.47018-0.47448
2	50	0.4714 0.0009	0.4714 0.0009	0.4730 0.0009	95/95/95	0.47222 0.00080	0.47061-0.47383	0.47008-0.47437
4	25	0.4714 0.0010	0.4714 0.0010	0.4730 0.0009	95/95/95	0.47237 0.00092	0.47046-0.47428	0.46977-0.47497
5	20	0.4714 0.0009	0.4714 0.0009	0.4730 0.0011	95/95/95	0.47176 0.00097	0.46971-0.47381	0.46895-0.47458
10	10	0.4714 0.0008	0.4714 0.0008	0.4730 0.0013	95/95/95	0.47115 0.00106	0.46864-0.47366	0.46743-0.47486
20	5	0.4714 0.0008	0.4714 0.0008	0.4730 0.0015	95/95/95	0.47125 0.00109	0.46657-0.47592	0.46046-0.48203
25	4	0.4714 0.0010	0.4714 0.0010	0.4730 0.0016	95/95/95	0.47157 0.00151	0.45236-0.49079	0.37533-0.56781

lindividual and average keff estimator results by cycle

keff	neutron	keff estimators by cycle	average keff estimators and deviations	average k(c/a/t)

cycle	histories	k(coll)	k(abs)	k(track)	k(coll)	st dev	k(abs)	st dev	k(track)	st dev	k(c/a/t)	st dev	fom
1	4000	0.55994	0.55994	0.54632									
2	2245	0.46881	0.46881	0.46669									
3	3356	0.46029	0.46029	0.46626									
4	3931	0.42778	0.42778	0.43524									
5	3747	0.45242	0.45242	0.46136									
6	4231	0.45032	0.45032	0.45190									
7	3956	0.44204	0.44204	0.44790									
8	3881	0.45337	0.45337	0.44872									
9	4055	0.45835	0.45835	0.45679									
10	4030	0.46122	0.46122	0.45866									
11	4036	0.46328	0.46328	0.48059									
12	4031	0.46206	0.46206	0.46693									
13	3993	0.47084	0.47084	0.47298									
14	4101	0.44982	0.44982	0.46463									
15	3803	0.47217	0.47217	0.46362									
16	4209	0.49248	0.49248	0.47094									
17	4175	0.44738	0.44738	0.44817									
18	3607	0.45712	0.45712	0.46374									
19	4089	0.47337	0.47337	0.46568									
20	4113	0.46438	0.46438	0.46637									
		begin active keff cycles											
21	3870	0.49327	0.49327	0.47305									
22	4294	0.48293	0.48293	0.46972	0.48810	0.00517	0.48810	0.00517	0.47139	0.00166			
23	3926	0.48350	0.48350	0.47252	0.48656	0.00336	0.48656	0.00336	0.47177	0.00103			
24	3970	0.47387	0.47387	0.47558	0.48339	0.00396	0.48339	0.00396	0.47272	0.00120	0.47442	0.00197	32061
25	3918	0.46621	0.46621	0.46700	0.47996	0.00461	0.47996	0.00461	0.47158	0.00147	0.47128	0.00239	17190
26	3984	0.47602	0.47602	0.47538	0.47930	0.00382	0.47930	0.00382	0.47221	0.00136	0.47242	0.00200	20421
27	4088	0.47650	0.47650	0.48179	0.47890	0.00325	0.47890	0.00325	0.47358	0.00179	0.47470	0.00208	16412
28	3946	0.45884	0.45884	0.46135	0.47639	0.00377	0.47639	0.00377	0.47205	0.00218	0.47227	0.00262	8898
29	3863	0.46956	0.46956	0.46685	0.47563	0.00341	0.47563	0.00341	0.47147	0.00200	0.47163	0.00240	9418
30	4097	0.47114	0.47114	0.48457	0.47518	0.00308	0.47518	0.00308	0.47278	0.00222	0.47341	0.00226	9638
31	4006	0.45817	0.45817	0.44922	0.47364	0.00319	0.47364	0.00319	0.47064	0.00294	0.47186	0.00299	4965
32	3897	0.47105	0.47105	0.47000	0.47342	0.00292	0.47342	0.00292	0.47059	0.00268	0.47173	0.00271	5530
33	4108	0.46309	0.46309	0.46360	0.47263	0.00280	0.47263	0.00280	0.47005	0.00252	0.47102	0.00257	5671
34	3909	0.46764	0.46764	0.46332	0.47227	0.00262	0.47227	0.00262	0.46957	0.00239	0.47061	0.00244	5851
35	4065	0.47578	0.47578	0.47342	0.47250	0.00245	0.47250	0.00245	0.46983	0.00224	0.47086	0.00228	6212
36	4028	0.46492	0.46492	0.45918	0.47203	0.00234	0.47203	0.00234	0.46916	0.00219	0.47036	0.00225	5981
37	3896	0.46660	0.46660	0.47350	0.47171	0.00222	0.47171	0.00222	0.46942	0.00208	0.47038	0.00206	6725
38	4015	0.47957	0.47957	0.46910	0.47215	0.00214	0.47215	0.00214	0.46940	0.00196	0.47049	0.00198	6878
39	4090	0.47164	0.47164	0.47012	0.47212	0.00202	0.47212	0.00202	0.46944	0.00185	0.47050	0.00187	7304
40	3947	0.47221	0.47221	0.46922	0.47212	0.00192	0.47212	0.00192	0.46943	0.00176	0.47050	0.00178	7681
41	4045	0.47976	0.47976	0.47224	0.47249	0.00186	0.47249	0.00186	0.46956	0.00168	0.47067	0.00173	7752
42	4079	0.45641	0.45641	0.45762	0.47176	0.00192	0.47176	0.00192	0.46902	0.00169	0.46992	0.00176	7052
43	3809	0.46753	0.46753	0.47375	0.47157	0.00184	0.47157	0.00184	0.46922	0.00163	0.47003	0.00166	7671
44	4151	0.47804	0.47804	0.47601	0.47184	0.00178	0.47184	0.00178	0.46950	0.00158	0.47031	0.00161	7735
45	4103	0.48102	0.48102	0.48124	0.47221	0.00175	0.47221	0.00175	0.46997	0.00159	0.47079	0.00161	7464
46	4060	0.46758	0.46758	0.47742	0.47203	0.00169	0.47203	0.00169	0.47026	0.00155	0.47096	0.00152	8060
47	3905	0.45307	0.45307	0.45258	0.47133	0.00177	0.47133	0.00177	0.46961	0.00163	0.47025	0.00162	6793
48	3883	0.45355	0.45355	0.45546	0.47069	0.00182	0.47069	0.00182	0.46910	0.00165	0.46964	0.00166	6241
49	3989	0.46704	0.46704	0.46762	0.47057	0.00176	0.47057	0.00176	0.46905	0.00159	0.46956	0.00160	6484
50	4165	0.48267	0.48267	0.47811	0.47097	0.00175	0.47097	0.00175	0.46935	0.00157	0.46986	0.00159	6349
51	4139	0.48151	0.48151	0.47295	0.47131	0.00173	0.47131	0.00173	0.46947	0.00152	0.46999	0.00156	6375

52	3984	0.46045	0.46045	0.47075	0.47097	0.00171	0.47097	0.00171	0.46951 0.00148	0.46990 0.00149 6770
53	3809	0.48353	0.48353	0.45981	0.47135	0.00170	0.47135	0.00170	0.46921 0.00146	0.46987 0.00147 6771
54	4208	0.47625	0.47625	0.47780	0.47150	0.00165	0.47150	0.00165	0.46947 0.00144	0.47012 0.00144 6849
55	3935	0.46419	0.46419	0.46831	0.47129	0.00162	0.47129	0.00162	0.46943 0.00140	0.47001 0.00139 7099
56	3924	0.46836	0.46836	0.48551	0.47121	0.00157	0.47121	0.00157	0.46988 0.00143	0.47039 0.00136 7260
57	4047	0.47451	0.47451	0.46650	0.47130	0.00153	0.47130	0.00153	0.46979 0.00139	0.47038 0.00133 7412
58	4101	0.46508	0.46508	0.47929	0.47113	0.00150	0.47113	0.00150	0.47004 0.00138	0.47049 0.00128 7714
59	3931	0.46101	0.46101	0.46155	0.47087	0.00149	0.47087	0.00149	0.46982 0.00136	0.47025 0.00127 7648
60	3979	0.47275	0.47275	0.47654	0.47092	0.00145	0.47092	0.00145	0.46999 0.00134	0.47037 0.00124 7808
61	4073	0.46233	0.46233	0.46636	0.47071	0.00143	0.47071	0.00143	0.46990 0.00131	0.47023 0.00122 7923
62	3912	0.47338	0.47338	0.46477	0.47077	0.00140	0.47077	0.00140	0.46978 0.00128	0.47018 0.00119 8075
63	4053	0.47347	0.47347	0.46897	0.47084	0.00136	0.47084	0.00136	0.46976 0.00125	0.47020 0.00117 8252
64	3989	0.45553	0.45553	0.46652	0.47049	0.00138	0.47049	0.00138	0.46969 0.00122	0.46999 0.00115 8295
65	3877	0.46837	0.46837	0.47030	0.47044	0.00135	0.47044	0.00135	0.46970 0.00120	0.46998 0.00112 8503
66	4136	0.47760	0.47760	0.48955	0.47060	0.00133	0.47060	0.00133	0.47013 0.00125	0.47033 0.00114 8049
67	4054	0.48718	0.48718	0.48240	0.47095	0.00135	0.47095	0.00135	0.47039 0.00125	0.47062 0.00116 7662
68	4122	0.47073	0.47073	0.47641	0.47095	0.00132	0.47095	0.00132	0.47052 0.00123	0.47070 0.00113 7816
69	3845	0.46411	0.46411	0.47273	0.47081	0.00130	0.47081	0.00130	0.47056 0.00120	0.47066 0.00111 7996
70	3928	0.47765	0.47765	0.48987	0.47094	0.00128	0.47094	0.00128	0.47095 0.00124	0.47095 0.00112 7680
71	4096	0.46634	0.46634	0.47127	0.47085	0.00126	0.47085	0.00126	0.47096 0.00122	0.47091 0.00110 7827
72	3898	0.46894	0.46894	0.48200	0.47082	0.00123	0.47082	0.00123	0.47117 0.00121	0.47100 0.00108 7918
73	4040	0.49274	0.49274	0.49504	0.47123	0.00128	0.47123	0.00128	0.47162 0.00127	0.47143 0.00115 6919
74	4194	0.46873	0.46873	0.46443	0.47118	0.00125	0.47118	0.00125	0.47148 0.00125	0.47133 0.00113 7008
75	3752	0.48188	0.48188	0.48723	0.47138	0.00125	0.47138	0.00125	0.47177 0.00126	0.47157 0.00114 6822
76	4120	0.48947	0.48947	0.49172	0.47170	0.00127	0.47170	0.00127	0.47213 0.00129	0.47190 0.00117 6359
77	4065	0.47202	0.47202	0.47457	0.47171	0.00124	0.47171	0.00124	0.47217 0.00127	0.47193 0.00115 6469
78	3848	0.48193	0.48193	0.47798	0.47188	0.00124	0.47188	0.00124	0.47227 0.00125	0.47207 0.00114 6498
79	4077	0.46376	0.46376	0.49001	0.47174	0.00122	0.47174	0.00122	0.47257 0.00127	0.47212 0.00112 6544
80	3827	0.48057	0.48057	0.47686	0.47189	0.00121	0.47189	0.00121	0.47264 0.00125	0.47224 0.00111 6606
81	4172	0.47041	0.47041	0.47690	0.47187	0.00119	0.47187	0.00119	0.47271 0.00123	0.47226 0.00109 6701
82	3899	0.46856	0.46856	0.47393	0.47181	0.00117	0.47181	0.00117	0.47273 0.00121	0.47224 0.00107 6800
83	3966	0.48362	0.48362	0.47109	0.47200	0.00117	0.47200	0.00117	0.47271 0.00119	0.47234 0.00106 6901
84	4104	0.47331	0.47331	0.47260	0.47202	0.00115	0.47202	0.00115	0.47270 0.00117	0.47235 0.00104 7015
85	3959	0.46963	0.46963	0.47029	0.47199	0.00113	0.47199	0.00113	0.47267 0.00115	0.47231 0.00103 7120
86	3947	0.47195	0.47195	0.47365	0.47198	0.00112	0.47198	0.00112	0.47268 0.00114	0.47232 0.00101 7232
87	3988	0.46820	0.46820	0.47258	0.47193	0.00110	0.47193	0.00110	0.47268 0.00112	0.47229 0.00100 7329
88	3985	0.47600	0.47600	0.48397	0.47199	0.00109	0.47199	0.00109	0.47285 0.00111	0.47239 0.00099 7331
89	4062	0.46387	0.46387	0.47530	0.47187	0.00108	0.47187	0.00108	0.47288 0.00110	0.47235 0.00098 7396
90	3866	0.46541	0.46541	0.47848	0.47178	0.00107	0.47178	0.00107	0.47296 0.00109	0.47234 0.00097 7469
91	4008	0.47274	0.47274	0.46776	0.47179	0.00105	0.47179	0.00105	0.47289 0.00107	0.47231 0.00095 7591
92	4050	0.47654	0.47654	0.48058	0.47186	0.00104	0.47186	0.00104	0.47300 0.00106	0.47240 0.00094 7626
93	4025	0.46898	0.46898	0.47336	0.47182	0.00102	0.47182	0.00102	0.47300 0.00105	0.47238 0.00093 7719
94	3871	0.47948	0.47948	0.48297	0.47192	0.00102	0.47192	0.00102	0.47314 0.00104	0.47249 0.00093 7691
95	4108	0.47290	0.47290	0.46849	0.47194	0.00100	0.47194	0.00100	0.47307 0.00103	0.47247 0.00091 7810
96	3945	0.48901	0.48901	0.48341	0.47216	0.00101	0.47216	0.00101	0.47321 0.00103	0.47267 0.00092 7623
97	4132	0.47333	0.47333	0.48009	0.47217	0.00100	0.47217	0.00100	0.47330 0.00102	0.47272 0.00091 7681
98	3899	0.46916	0.46916	0.48008	0.47214	0.00099	0.47214	0.00099	0.47339 0.00101	0.47273 0.00090 7749
99	3958	0.46394	0.46394	0.47834	0.47203	0.00098	0.47203	0.00098	0.47345 0.00100	0.47272 0.00089 7800
100	3936	0.45883	0.45883	0.45702	0.47187	0.00098	0.47187	0.00098	0.47324 0.00101	0.47252 0.00090 7558
101	3951	0.46019	0.46019	0.47948	0.47172	0.00098	0.47172	0.00098	0.47332 0.00100	0.47250 0.00089 7580
102	4006	0.47353	0.47353	0.47947	0.47175	0.00097	0.47175	0.00097	0.47340 0.00099	0.47254 0.00088 7633
103	4129	0.44919	0.44919	0.45535	0.47147	0.00100	0.47147	0.00100	0.47318 0.00100	0.47232 0.00091 7105
104	3766	0.49433	0.49433	0.47786	0.47175	0.00102	0.47175	0.00102	0.47323 0.00099	0.47255 0.00091 7044

105	4405	0.48522	0.48522	0.48230	0.47190	0.00102	0.47190	0.00102	0.47334	0.00098	0.47269	0.00091	6987
106	3900	0.46754	0.46754	0.46672	0.47185	0.00101	0.47185	0.00101	0.47326	0.00097	0.47262	0.00090	7036
107	3857	0.46857	0.46857	0.46853	0.47182	0.00100	0.47182	0.00100	0.47321	0.00096	0.47257	0.00089	7102
108	4001	0.46669	0.46669	0.46907	0.47176	0.00099	0.47176	0.00099	0.47316	0.00095	0.47252	0.00088	7153
109	3984	0.47742	0.47742	0.46983	0.47182	0.00098	0.47182	0.00098	0.47312	0.00094	0.47253	0.00087	7264
110	4107	0.46243	0.46243	0.48276	0.47172	0.00098	0.47172	0.00098	0.47323	0.00094	0.47254	0.00086	7297
111	3892	0.47587	0.47587	0.47367	0.47176	0.00097	0.47176	0.00097	0.47324	0.00093	0.47256	0.00085	7386
112	4096	0.47314	0.47314	0.46254	0.47178	0.00095	0.47178	0.00095	0.47312	0.00093	0.47249	0.00084	7471
113	4005	0.45705	0.45705	0.46892	0.47162	0.00096	0.47162	0.00096	0.47307	0.00092	0.47242	0.00084	7415
114	3856	0.47619	0.47619	0.48783	0.47167	0.00095	0.47167	0.00095	0.47323	0.00092	0.47250	0.00084	7342
115	4159	0.47529	0.47529	0.47822	0.47171	0.00094	0.47171	0.00094	0.47328	0.00091	0.47255	0.00083	7391
116	3956	0.44729	0.44729	0.46541	0.47145	0.00096	0.47145	0.00096	0.47320	0.00091	0.47244	0.00084	7139
117	3783	0.47305	0.47305	0.47600	0.47147	0.00095	0.47147	0.00095	0.47323	0.00090	0.47247	0.00084	7205
118	4242	0.47577	0.47577	0.46657	0.47151	0.00095	0.47151	0.00095	0.47316	0.00089	0.47244	0.00082	7313
119	4016	0.46249	0.46249	0.46280	0.47142	0.00094	0.47142	0.00094	0.47306	0.00089	0.47234	0.00082	7275
120	3842	0.47155	0.47155	0.47150	0.47142	0.00093	0.47142	0.00093	0.47304	0.00088	0.47233	0.00081	7353

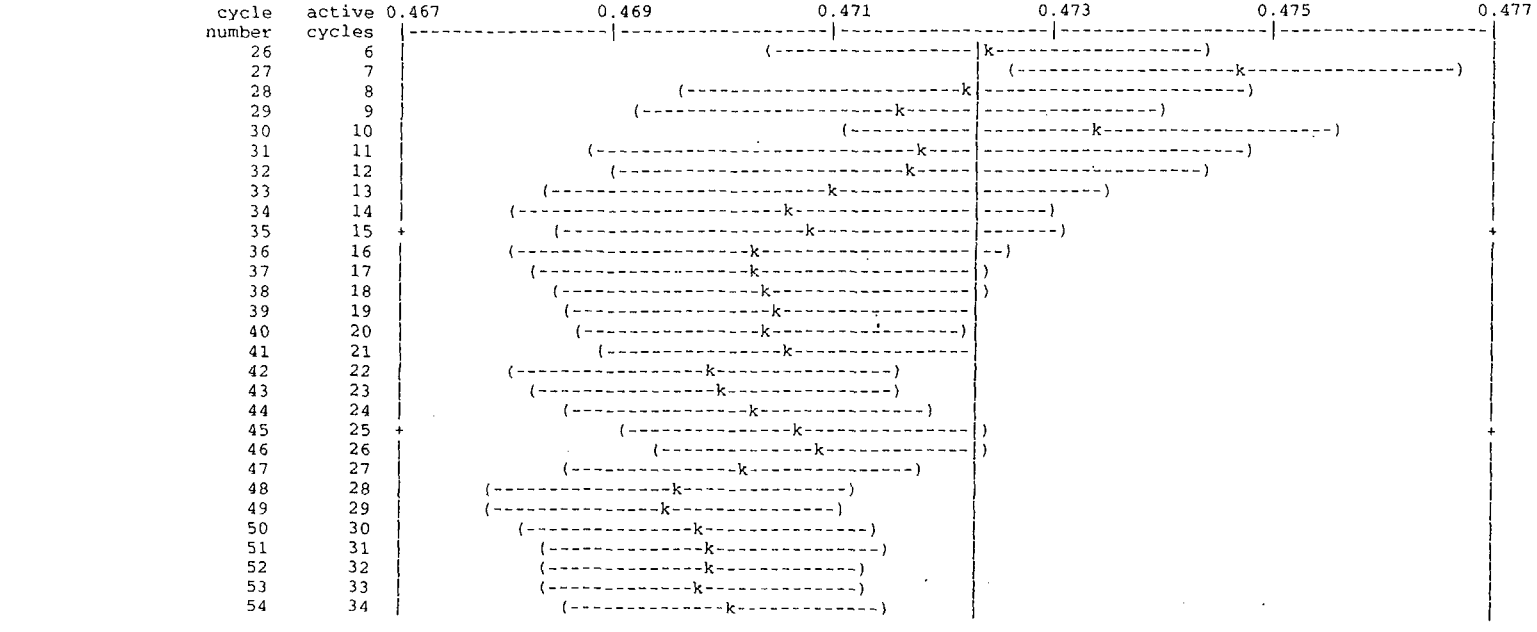
the largest active cycle keffs by estimator are:

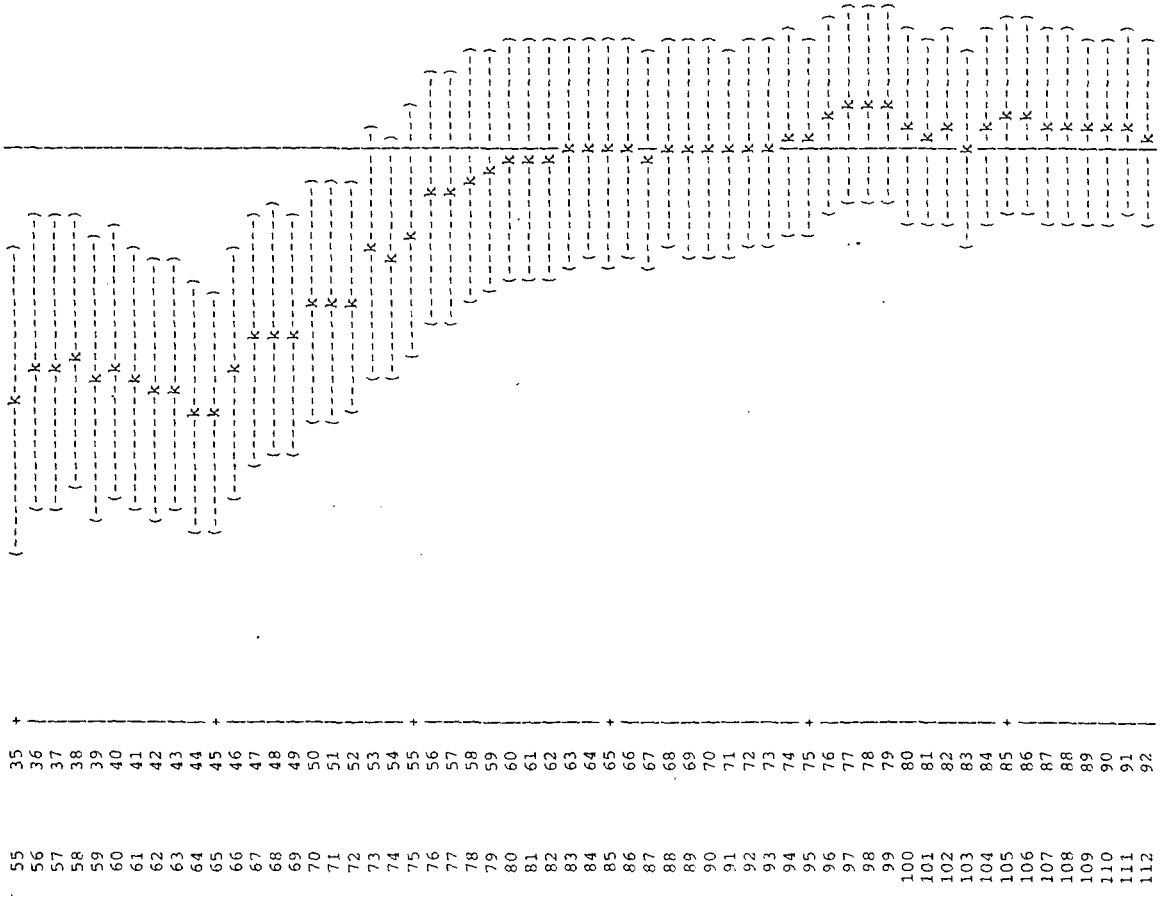
collision 0.49433 on cycle 104
absorption 0.49433 on cycle 104
track length 0.49504 on cycle 73

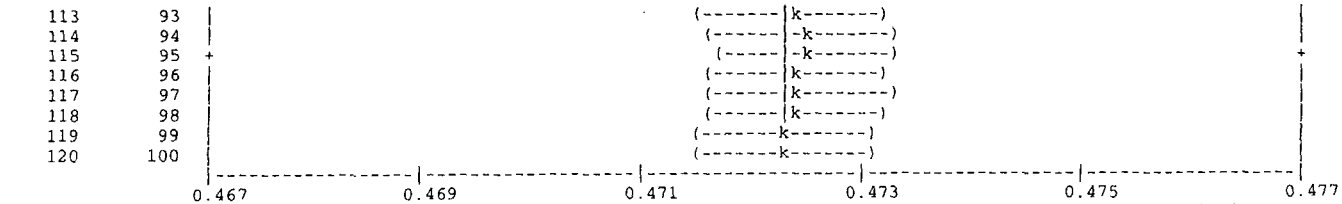
the smallest active cycle keffs by estimator are:

collision 0.44729 on cycle 116
absorption 0.44729 on cycle 116
track length 0.44922 on cycle 31

1plot of the estimated col/abs/track-length keff one standard deviation interval versus cycle number (| = final keff = 0.47233)







lindividual and collision/absorption/track-length keffs for different numbers of inactive cycles skipped for fission source settling

skip cycles	active cycles	active neutrons	average keff estimators and deviations k(col)	st dev	k(abs)	st dev	k(trk)	st dev	normality co/ab/tl	average k(c/a/t) k(c/a/t)	st dev	k(c/a/t) confidence intervals 95% confidence	99% confidence
0	120	477491	0.4702	0.0013	0.4702	0.0013	0.4717	0.0011	no/no/no	0.47139	0.00112	0.46916-0.47361	0.46843-0.47434
1	119	473491	0.4695	0.0010	0.4695	0.0010	0.4711	0.0009	99/99/95	0.47051	0.00090	0.46872-0.47230	0.46813-0.47289
2	118	471246	0.4695	0.0010	0.4695	0.0010	0.4711	0.0009	95/95/95	0.47054	0.00091	0.46873-0.47234	0.46814-0.47293
3	117	467890	0.4696	0.0010	0.4696	0.0010	0.4712	0.0009	99/99/95	0.47059	0.00091	0.46877-0.47241	0.46817-0.47300
4	116	463959	0.4699	0.0010	0.4699	0.0010	0.4715	0.0009	95/95/95	0.47087	0.00086	0.46917-0.47258	0.46862-0.47313
5	115	460212	0.4701	0.0010	0.4701	0.0010	0.4716	0.0009	95/95/95	0.47097	0.00085	0.46927-0.47267	0.46872-0.47323
6	114	455981	0.4703	0.0010	0.4703	0.0010	0.4718	0.0009	95/95/95	0.47114	0.00084	0.46947-0.47282	0.46892-0.47337
7	113	452025	0.4705	0.0009	0.4705	0.0009	0.4720	0.0009	95/95/95	0.47135	0.00082	0.46973-0.47298	0.46920-0.47351
8	112	448144	0.4707	0.0009	0.4707	0.0009	0.4722	0.0009	95/95/95	0.47156	0.00080	0.46996-0.47316	0.46944-0.47368
9	111	444089	0.4708	0.0009	0.4708	0.0009	0.4723	0.0009	95/95/95	0.47169	0.00080	0.47010-0.47329	0.46958-0.47381
10	110	440059	0.4709	0.0009	0.4709	0.0009	0.4724	0.0009	95/95/95	0.47181	0.00080	0.47022-0.47340	0.46970-0.47392
11	109	436023	0.4709	0.0009	0.4709	0.0009	0.4724	0.0009	95/95/95	0.47180	0.00080	0.47020-0.47340	0.46967-0.47393
12	108	431992	0.4710	0.0009	0.4710	0.0009	0.4724	0.0009	95/95/95	0.47186	0.00081	0.47025-0.47347	0.46972-0.47400
13	107	427999	0.4710	0.0010	0.4710	0.0010	0.4724	0.0009	95/95/95	0.47186	0.00082	0.47023-0.47348	0.46970-0.47401
14	106	423898	0.4712	0.0009	0.4712	0.0009	0.4725	0.0009	95/95/95	0.47195	0.00081	0.47033-0.47357	0.46981-0.47410
15	105	420095	0.4712	0.0009	0.4712	0.0009	0.4726	0.0009	95/95/95	0.47201	0.00082	0.47037-0.47364	0.46984-0.47417
16	104	415886	0.4710	0.0009	0.4710	0.0009	0.4726	0.0009	95/95/95	0.47189	0.00083	0.47024-0.47354	0.46970-0.47408
17	103	411711	0.4712	0.0009	0.4712	0.0009	0.4728	0.0009	95/95/95	0.47213	0.00080	0.47053-0.47373	0.47001-0.47425
18	102	408104	0.4714	0.0009	0.4714	0.0009	0.4729	0.0009	95/95/95	0.47223	0.00080	0.47063-0.47382	0.47011-0.47434
19	101	404015	0.4714	0.0009	0.4714	0.0009	0.4730	0.0009	95/95/95	0.47227	0.00081	0.47065-0.47388	0.47013-0.47440
20	100*	399902	0.4714	0.0009	0.4714	0.0009	0.4730	0.0009	95/95/95	0.47233	0.00081	0.47071-0.47395	0.47018-0.47448
22	98	391738	0.4711	0.0009	0.4711	0.0009	0.4731	0.0009	95/95/95	0.47212	0.00083	0.47047-0.47378	0.46993-0.47432
24	96	383842	0.4709	0.0009	0.4709	0.0009	0.4731	0.0009	95/95/95	0.47201	0.00085	0.47032-0.47371	0.46977-0.47426
26	94	375940	0.4709	0.0009	0.4709	0.0009	0.4731	0.0009	95/95/95	0.47203	0.00087	0.47030-0.47376	0.46974-0.47432
28	92	367906	0.4710	0.0010	0.4710	0.0010	0.4731	0.0009	95/95/95	0.47209	0.00087	0.47036-0.47382	0.46979-0.47439
30	90	359946	0.4710	0.0010	0.4710	0.0010	0.4731	0.0009	95/95/95	0.47209	0.00088	0.47033-0.47385	0.46976-0.47443
32	88	352043	0.4711	0.0010	0.4711	0.0010	0.4734	0.0009	95/95/95	0.47240	0.00088	0.47065-0.47415	0.47008-0.47472
34	86	344026	0.4713	0.0010	0.4713	0.0010	0.4736	0.0009	95/95/95	0.47261	0.00089	0.47084-0.47439	0.47026-0.47497
36	84	335933	0.4713	0.0010	0.4713	0.0010	0.4738	0.0009	95/95/95	0.47276	0.00091	0.47095-0.47456	0.47037-0.47515
38	82	328022	0.4713	0.0010	0.4713	0.0010	0.4738	0.0010	95/95/95	0.47277	0.00093	0.47091-0.47462	0.47031-0.47523
40	80	319985	0.4712	0.0011	0.4712	0.0011	0.4739	0.0010	95/95/95	0.47283	0.00096	0.47093-0.47474	0.47030-0.47536
42	78	311861	0.4713	0.0011	0.4713	0.0011	0.4742	0.0010	95/95/95	0.47300	0.00096	0.47108-0.47492	0.47046-0.47554
44	76	303901	0.4713	0.0011	0.4713	0.0011	0.4742	0.0010	95/95/95	0.47296	0.00099	0.47100-0.47492	0.47036-0.47557
46	74	295738	0.4712	0.0011	0.4712	0.0011	0.4740	0.0010	95/95/95	0.47284	0.00100	0.47084-0.47483	0.47018-0.47549
48	72	287950	0.4717	0.0011	0.4717	0.0011	0.4746	0.0010	95/95/95	0.47341	0.00095	0.47152-0.47530	0.47090-0.47592
50	70	279796	0.4716	0.0011	0.4716	0.0011	0.4746	0.0010	95/95/95	0.47338	0.00097	0.47145-0.47532	0.47081-0.47596
52	68	271673	0.4716	0.0011	0.4716	0.0011	0.4747	0.0010	95/95/95	0.47339	0.00099	0.47141-0.47538	0.47075-0.47603
54	66	263656	0.4714	0.0011	0.4714	0.0011	0.4749	0.0010	95/95/95	0.47345	0.00105	0.47136-0.47554	0.47067-0.47623
56	64	255797	0.4715	0.0012	0.4715	0.0012	0.4748	0.0011	95/95/95	0.47353	0.00106	0.47141-0.47565	0.47071-0.47635
58	62	247649	0.4716	0.0012	0.4716	0.0012	0.4749	0.0011	95/95/95	0.47362	0.00109	0.47143-0.47581	0.47071-0.47654

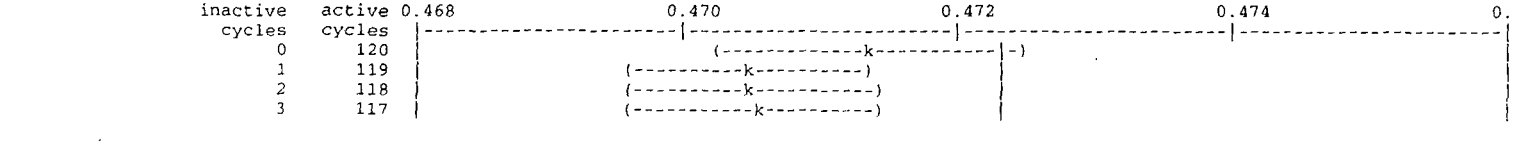
60	60	239739	0.4718	0.0012	0.4718	0.0012	0.4751	0.0011	95/95/95	0.47383	0.00111	0.47161-0.47605	0.47088-0.47678
62	58	231754	0.4719	0.0013	0.4719	0.0013	0.4754	0.0011	95/95/95	0.47415	0.00114	0.47186-0.47643	0.47111-0.47718
64	56	223712	0.4722	0.0013	0.4722	0.0013	0.4757	0.0011	95/95/95	0.47436	0.00115	0.47205-0.47668	0.47128-0.47745
66	54	215699	0.4721	0.0013	0.4721	0.0013	0.4755	0.0011	95/95/95	0.47434	0.00116	0.47200-0.47668	0.47123-0.47746
68	52	207523	0.4719	0.0013	0.4719	0.0013	0.4754	0.0012	95/95/95	0.47408	0.00120	0.47167-0.47648	0.47087-0.47728
70	50	199750	0.4719	0.0014	0.4719	0.0014	0.4751	0.0012	95/95/95	0.47401	0.00120	0.47160-0.47643	0.47079-0.47723
72	48	191756	0.4721	0.0014	0.4721	0.0014	0.4751	0.0012	95/95/95	0.47405	0.00123	0.47157-0.47654	0.47074-0.47737
74	46	183522	0.4717	0.0014	0.4717	0.0014	0.4749	0.0012	95/95/95	0.47383	0.00119	0.47144-0.47622	0.47064-0.47703
76	44	175650	0.4711	0.0014	0.4711	0.0014	0.4742	0.0011	95/95/95	0.47319	0.00112	0.47092-0.47545	0.47016-0.47622
78	42	167737	0.4708	0.0014	0.4708	0.0014	0.4741	0.0012	95/95/95	0.47299	0.00117	0.47062-0.47535	0.46982-0.47615
80	40	159833	0.4707	0.0015	0.4707	0.0015	0.4736	0.0012	95/95/95	0.47282	0.00119	0.47041-0.47523	0.46959-0.47605
82	38	151762	0.4708	0.0015	0.4708	0.0015	0.4736	0.0012	95/95/95	0.47278	0.00124	0.47025-0.47530	0.46939-0.47616
84	36	143692	0.4704	0.0016	0.4704	0.0016	0.4736	0.0013	95/95/95	0.47269	0.00134	0.46996-0.47542	0.46902-0.47635
86	34	135786	0.4703	0.0017	0.4703	0.0017	0.4737	0.0014	95/95/95	0.47276	0.00142	0.46986-0.47566	0.46886-0.47666
88	32	127813	0.4702	0.0018	0.4702	0.0018	0.4735	0.0014	95/95/95	0.47258	0.00146	0.46958-0.47557	0.46854-0.47662
90	30	119885	0.4706	0.0019	0.4706	0.0019	0.4732	0.0015	95/95/95	0.47254	0.00153	0.46939-0.47568	0.46829-0.47678
92	28	111827	0.4703	0.0020	0.4703	0.0020	0.4732	0.0016	95/95/95	0.47246	0.00163	0.46911-0.47581	0.46792-0.47699
94	26	103931	0.4700	0.0021	0.4700	0.0021	0.4728	0.0017	95/95/95	0.47210	0.00170	0.46859-0.47561	0.46733-0.47687
96	24	95878	0.4691	0.0021	0.4691	0.0021	0.4725	0.0017	95/95/95	0.47152	0.00178	0.46782-0.47522	0.46648-0.47656
98	22	87847	0.4689	0.0023	0.4689	0.0023	0.4718	0.0018	95/95/95	0.47108	0.00186	0.46718-0.47497	0.46575-0.47640
100	20	79953	0.4696	0.0025	0.4696	0.0025	0.4722	0.0018	95/95/95	0.47172	0.00188	0.46775-0.47568	0.46627-0.47716
102	18	71996	0.4699	0.0027	0.4699	0.0027	0.4714	0.0019	95/95/95	0.47123	0.00199	0.46698-0.47548	0.46536-0.47710
104	16	64101	0.4697	0.0023	0.4697	0.0023	0.4720	0.0019	95/95/95	0.47128	0.00184	0.46731-0.47525	0.46574-0.47682
106	14	55796	0.4688	0.0023	0.4688	0.0023	0.4717	0.0020	99/99/95	0.47060	0.00188	0.46646-0.47473	0.46476-0.47643
108	12	47938	0.4690	0.0027	0.4690	0.0027	0.4722	0.0023	99/99/95	0.47099	0.00220	0.46601-0.47598	0.46383-0.47815
110	10	39847	0.4688	0.0031	0.4688	0.0031	0.4713	0.0025	no/no/95	0.47060	0.00260	0.46445-0.47675	0.46150-0.47970
112	8	31859	0.4673	0.0038	0.4673	0.0038	0.4722	0.0029	95/95/95	0.47124	0.00358	0.46203-0.48044	0.45680-0.48568
114	6	23998	0.4676	0.0045	0.4676	0.0045	0.4701	0.0025	95/95/95	0.47017	0.00295	0.46079-0.47954	0.45296-0.48737
116	4	15883	0.4707	0.0029	0.4707	0.0029	0.4692	0.0029	95/95/95	0.46997	0.00329	0.42817-0.51177	0.26061-0.67933
117	3	12100	0.4699	0.0039	0.4699	0.0039	0.4670	0.0025					
118	2	7858	0.4670	0.0045	0.4670	0.0045	0.4672	0.0044					

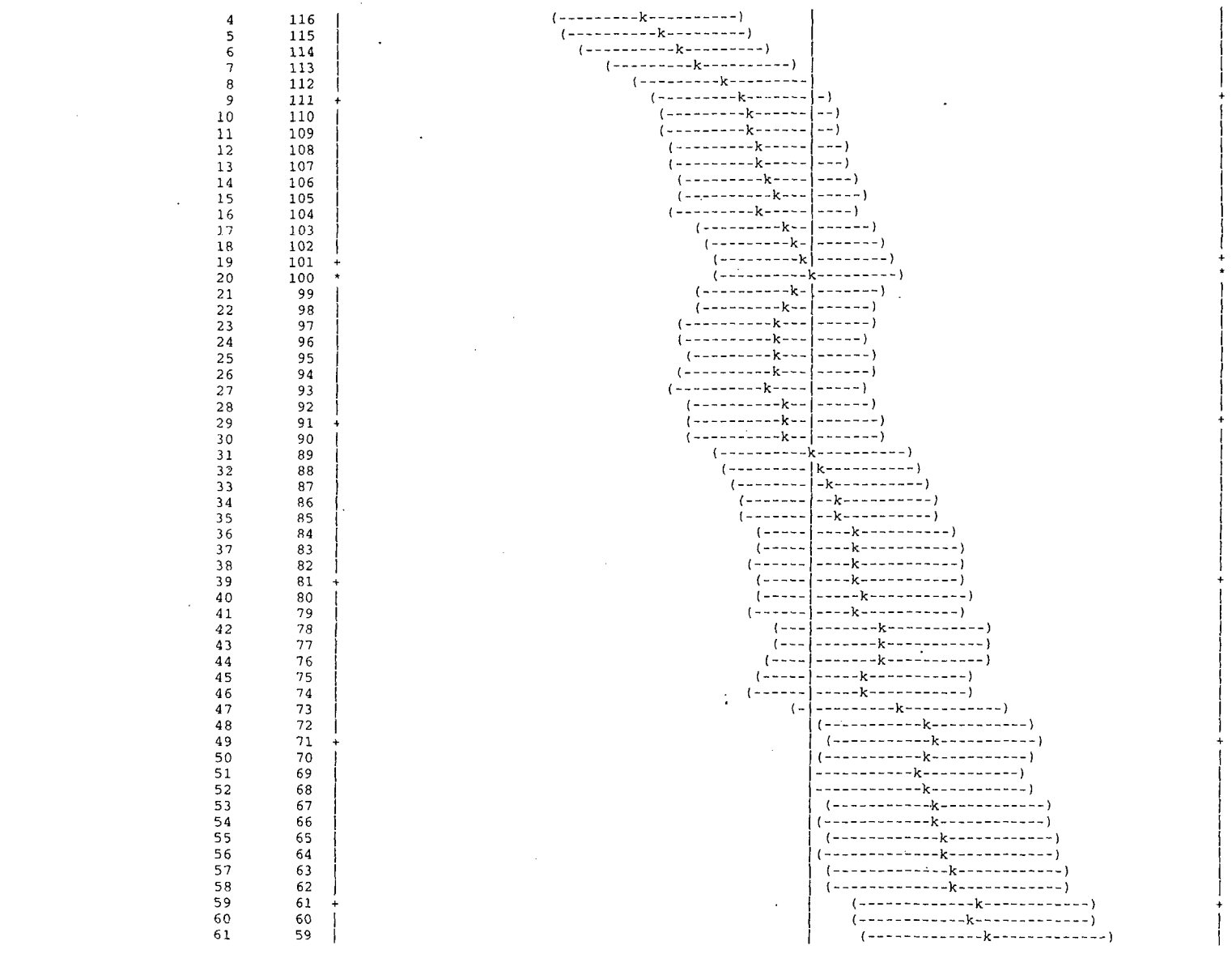
the minimum estimated standard deviation for the col/abs/tl keff estimator occurs with 10 inactive cycles and 110 active cycles.

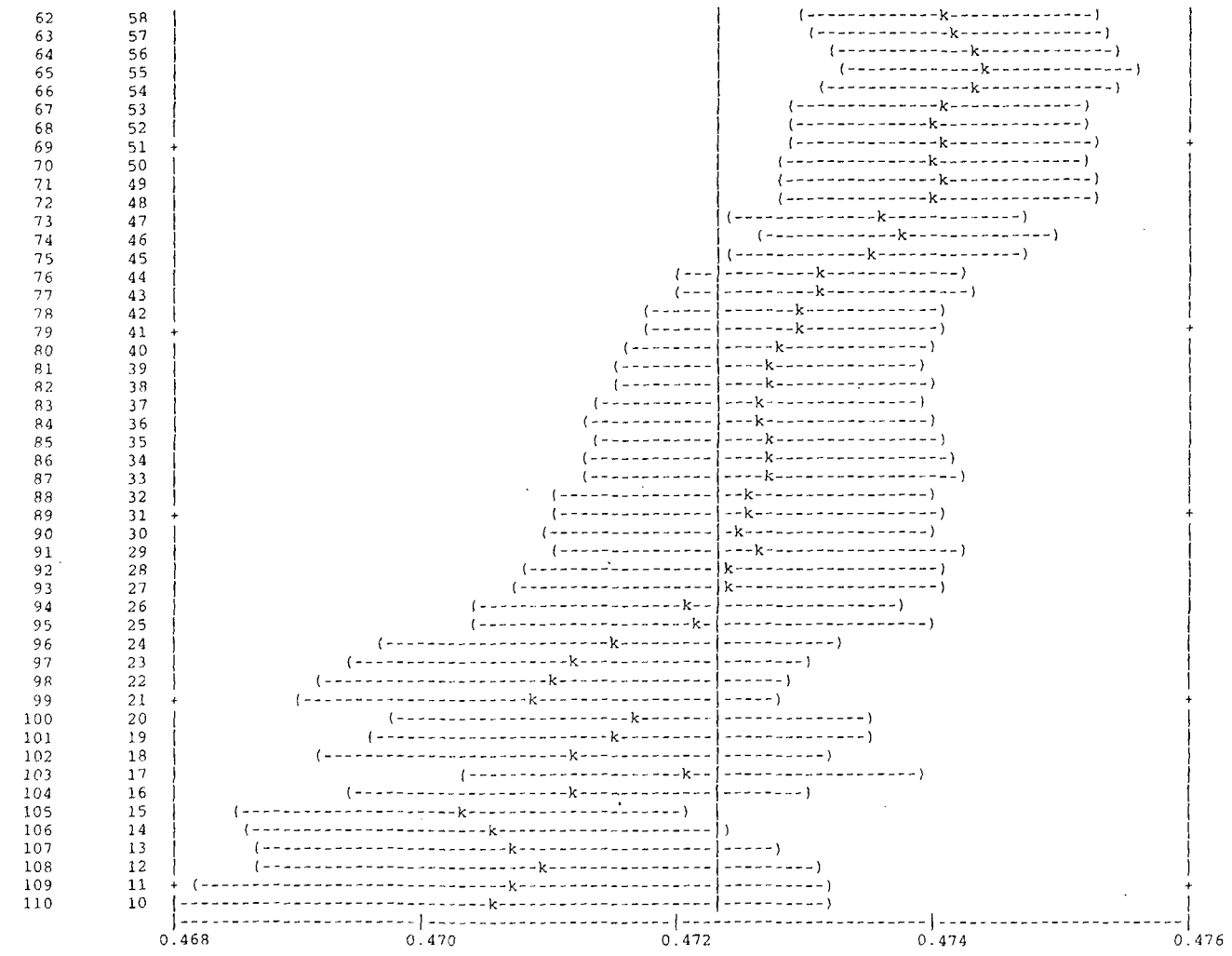
the first active half of the problem skips 20 cycles and uses 50 active cycles; the second half skips 70 and uses 50 cycles.
the col/abs/trk-len keff, one standard deviation, and 68, 95, and 99 percent intervals for each active half of the problem are:

problem	keff	standard deviation	68% confidence	95% confidence	99% confidence
first half	0.47095	0.00112	0.46982 to 0.47208	0.46869 to 0.47320	0.46793 to 0.47396
second half	0.47401	0.00120	0.47280 to 0.47522	0.47160 to 0.47643	0.47079 to 0.47723
final result	0.47233	0.00081	0.47152 to 0.47315	0.47071 to 0.47395	0.47018 to 0.47448

the first and second half values of k(collision/absorption/track length) appear to be the same at the 95 percent confidence level.
1plot of the estimated col/abs/track-length keff one standard deviation interval by active cycle number (| = final keff = 0.47233)







dump no. 5 on file 1s310r nps = 477491 coll = 109094259 ctm = 54.19 nrn = 1859430912

2 warning messages so far.

run terminated when 120 kcode cycles were done.

computer time = 54.21 minutes

mcnp version 4a 10/01/93 12/05/00 17:51:45 probid = 12/05/00 16:57:33

URS

Calculation Cover Page

3065 Southwestern Boulevard
Suite 202
Orchard Park, NY 14127
716 675 7130 Tel
716 675 7137 Fax

Job No: **30822-244-330 /6860** Calculation No: **BUF-2001-001/Rev. 1** Date: **January 5, 2000**

Problem Statement & Calculation Objectives:

To determine the neutron multiplication factors for $\infty \times \infty \times 4$ arrays of 55 gallon drums and B-25 boxes with Pu-239-cellulose spheres and variable density cellulose outside the sphere. The cellulose inside the sphere with Plutonium has a constant density. There is no water outside the containers with fissile material.

References and Data Available:

J. F. Briemiester, ed., MCNP - A General Purpose Monte Carlo N-Particle Transport Code, Version 4A, LA-12625, Los Alamos National Laboratory, Los Alamos NM, 1993
C. D. Harmon, II et al., Criticality Calculations with MCNP: A Primer, Manual LA-12827, Los Alamos National Laboratory, Los Alamos NM, 1993
D. R. Lide, CRC Handbook of Chemistry an Physics, CRC Press, Boston MA, 1991.
F. H. Attix, Introduction to Radiological Physics and Radiation Dosimetry. John Wiley & Sons, Inc., New York NY, 1986

Attachments:

Attachment 1: Case 1 with MCNP surface and cell numbers
Attachment 2: Case 1 MCNP input file
Attachment 3: Case 1 MCNP output file
Attachment 4: Case 2 with MCNP surface and cell numbers
Attachment 5: Case 2 MCNP input file
Attachment 6: Case 2 MCNP output file

Prepared by:

Signature Igor V. Chichkov — Date 10/4/2001

Checked by:

Signature Kevin Roberts — Date 10/4/2001

URS

Job No 30822-244-330 /6860 Job: PSR-6 By IVC Date 10/4/01
Client WVNS Subject: cellulose-Pu-239 spheres Chk'd. RR Date 10/4/01

Analysis

Assumptions

- Pu-239 inside the sphere is uniformly mixed with 0.9 g/cm^3 cellulose
- The pure cellulose fills the entire space inside the container and outside the Plutonium sphere.
- The containers stand on the 3 m thick concrete floor
- B-25 box inside dimensions are 172.72 x 137.16 x 87.63 cm or 68 x 54 x 34.5 inches
- The B-25 box wall thickness is zero
- Every B-25 Box contains 350 g of Pu-239
- The B-25 boxes are arranged in the infinite square array, 4 tiers heigh ($\infty \times \infty \times 4$)
- The 55 gallon drum is a cylinder with 56.83 cm (22.37 inches) inside diameter and 89.11 cm (35.08 inches) height
- The drum wall is made of carbon steel and its thickness is 0.157 cm
- The drums are arranged in the infinite hexagonal array, 4 tiers heigh ($\infty \times \infty \times 4$)
- Every drum contains 200 g of Pu-239
- There is no water outside containers, air fills the space between the containers

MCNP Model

Neutron multiplication factors were calculated with MCNP4A code. Two different cases were studied:

- Case 1. $\infty \times \infty \times 4$ array of 55 gallon drums
- Case 2. $\infty \times \infty \times 4$ array of B-25 boxes

Attachments 1 and 4 have the drawings of the models used for case 1 and 2 respectively. Examples of MCNP input and output files for both cases can also be found in the Attachments. The plutonium spheres were located in the different positions on the drum's radius and on the box's angle bisector as it shown in Attachments 1 and 4. The Z-coordinates for the spheres' centers were chosen so that the 1st tier sphere is located at the top of the container and at the same time the 2nd tier sphere is located at the bottom, the 3rd tier sphere is located at the top and 4th tier sphere is located at the bottom, i.e. the 1st tier - 2nd tier sphere contact and 3rd - 4th tier sphere contact. The density parametric analysis for the cellulose outside the sphere with Plutonium was performed for each case.

Air, Carbon Steel, Concrete and Cellulose Composition

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Job No 30822-244-330 /6860 Job: PSR-6 By JVC Date 10/4/01
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Table 1 shows the element weight fractions for air (Attix F.H., 1986). Table 2 shows the element weight fractions for carbon steel (Harmon C. D., II et al., 1993) used in the drum walls. Table 3 shows the element composition of concrete (Harmon C. D., II et al., 1993) in the floor.

Table 1. Air composition

Element	Weight Fraction
Carbon (C)	0.000124
Nitrogen (N)	0.755267
Oxygen (O)	0.231781
Argon (Ar)	0.012827

Table 2. Carbon Steel Composition

Element	Weight Fraction
Iron (Fe)	0.995
Carbon (C)	0.005

Table 3. Concrete composition

Element	Weight Fraction
Hydrogen (H)	0.010
Oxygen (O)	0.532
Sodium (Na)	0.029
Aluminum (Al)	0.034
Silicon (Si)	0.337
Calcium (Ca)	0.044
Iron (Fe)	0.014

The weight fractions of the elements composing the cellulose were determined based on the known atomic weights of the elements (Table 4) and the cellulose chemical formula - $C_6H_{10}O_5$.

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Table 4. The atomic weights of the elements

Element	Atomic Weight
Hydrogen (H)	1.00794
Carbon (C)	12.0107
Oxygen (O)	15.9994

The molecular weight of cellulose ($C_6H_{10}O_5$) was calculated as the sum of all atomic weights composing the molecule. The weight fraction of an ith element was found as a ratio of the ith element weight in the molecule to the molecular weight of this molecule.

$$(w_i)_{cel} = \frac{n_i A_i}{M_{cel}} = \frac{n_i A_i}{\sum n_i A_i} \qquad (1)$$

where

$(w_i)_{cel}$ = the weight fraction of ith element in a molecule of cellulose

n_i = the number of the ith elements in a cellulose molecule

A_i = the atomic weight of the ith element, g/mol

M_{cel} = the molecular weight a cellulose molecule, g/mol

Calculated weight fractions for cellulose are shown in Table 5.

Table 5. Cellulose Weight Fractions

Element	Weight Fraction
Hydrogen (H)	0.062
Carbon (C)	0.444
Oxygen (O)	0.493

Radii of the Plutonium containing spheres.

The spheres with several different radii were studied. The minimum size of the Plutonium containing sphere

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corresponded to the sphere with pure Pu-239 and the maximum size was limited by the dimensions of the container: drum radius or half-height of B-25 box. The minimum radius equation (3) was derived from the volume of a sphere equation (2)

$$V_{Pu} = \frac{4\pi\left(R_{Pu}\right)^3}{3} \qquad (2)$$

$$R_{\min} = R_{Pu} = \sqrt[3]{\frac{3V_{Pu}}{4\pi}} = \sqrt[3]{\frac{3m_{Pu}}{4\pi\rho_{Pu}}} \qquad (3)$$

where:

R_{min} = the minimum possible radius of the sphere containing Pu-239, cm

R_{Pu} = the radius of the metal Plutonium sphere, cm

V_{Pu} = the volume of the sphere with Pu-239, cm^3

m_{Pu} = the mass of the Plutonium sphere, g

ρ_{Pu} = the density of the metal Plutonium, 19.78 g/cm^3

Composition of the Plutonium containing spheres

The weight fractions of the elements composing the mixture are defined as the ratio of the mass of the element in the mixture to the total mass of the mixture. Total mass of the mixture was determined using equation (4):

$$M_{total} = m_{Pu} + m_{cel} = m_{Pu} + V_{cel}\rho_{cel} =$$
$$= m_{Pu} + \left(V_{Total} - V_{Pu}\right)\rho_{cel} = m_{Pu} + \left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel} \qquad (4)$$

where

M_{Total} = the total mass of the mixture, g

m_{Pu} = the mass of Pu-239 in a sphere, g

m_{cel} = the mass of a cellulose in a sphere, g

V_{Total} = the total volume of a sphere, cm^3

V_{cel} = the volume of a cellulose in the sphere, cm^3

ρ_{cel} = the density of a cellulose, 0.9 g/cm^3

V_{Pu} = the volume of Pu-239 in the sphere, cm^3

ρ_{Pu} = the density of the metal Plutonium, 19.78 g/cm^3

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R = the radius of a Plutonium containing sphere, cm

In the Plutonium-cellulose mixture, the weight fraction of Pu-239 was calculated using equation 5, and the weight fractions of elements composing cellulose were calculated using equation 7 as a product of the weight fraction of a cellulose in the Plutonium-cellulose mixture (equation 6) and the weight fraction of an element in a pure cellulose (equation 1).

$$w_{Pu} = \frac{m_{Pu}}{M_{total}} = \frac{m_{Pu}}{m_{Pu} + \left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel}} \qquad (5)$$

$$w_{cel} = \frac{m_{cel}}{M_{total}} = \frac{\left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel}}{m_{Pu} + \left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel}} \qquad (6)$$

$$w_i = w_{cel}(w_i)_{cel} = \frac{\left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel} n_i A_i}{\left[m_{Pu} + \left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel}\right]\sum n_i A_i} \qquad (7)$$

All variables in equations 5-7 are as described above. Table 6 shows the composition of the Plutonium containing spheres for case 1 (drum) and Table 7 shows the composition of the Plutonium containing spheres for case 2 (B-25 box).

Table 6. The composition of the Plutonium containing spheres for case 1 (55 gallon drums with 200 g of Pu-239 in each one).

	Radius of the sphere, cm				
	5	10	15	20	28.41

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Mixture density, g/cm^3	1.2646	0.9456	0.9135	0.9057	0.9020
Pu-239 weight fraction	0.302051	0.050495	0.015487	0.00659	0.002308
Carbon (C) weight fraction	0.310207	0.422012	0.437572	0.441526	0.443429
Hydrogen (H)weight fraction	0.043388	0.059026	0.061202	0.061755	0.062021
Oxygen (O) weight fraction	0.344354	0.468467	0.48574	0.490129	0.492241

Table 7. The composition of the Plutonium containing spheres for case 2 (B-25 boxes with 350 g of Pu-239 in each one).

	Radius of the sphere, cm				
	5	10	20	30	43.815
Mixture density, g/cm^3	1.5380	0.9798	0.9100	0.9030	0.9010
Pu-239 weight fraction	0.434613	0.085283	0.011478	0.003427	0.001103
Carbon (C) weight fraction	0.251289	0.406551	0.439354	0.442932	0.443965
Hydrogen (H)weight fraction	0.035147	0.056863	0.061451	0.061952	0.062096
Oxygen (O) weight fraction	0.278951	0.451304	0.487717	0.491689	0.492836

Results

The results of the calculations performed using MCNP-4A code are shown in the following tables and graphs. The tables provide the Monte Carlo determined neutron multiplication factor (k_{eff}) values and their standard deviations (σ), and the graphs plot the k_{eff} +2 σ values for all studied cases. The 55 gallon drum dimensions tolerance analysis was performed for the case of void space outside the plutonium-cellulose mixture. Table 8 and Figure 2 show the comparison of the k_{eff} values for the drum with 56.83 cm (22.37 inches) inside diameter and 89.11 cm (35.08 inches) height against the drum with 56.83 cm (22 inches) inside diameter and 89.11 cm (35 inches) height.

Table 7. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for 200 g Pu-239 spheres in the 55 gallon drums with cellulose. The spheres are located so that they touch the drum wall. The Z-coordinates spheres' centers correspond to the location of 1st tier - 2nd tier sphere contact, and 3rd - 4th tier sphere contact.

R and X-, Y-, Z- coordinates for the center of the sphere, cm							100% density cellulose			80% density cellulose			60% density cellulose		
R	X	Y	Z1	Z2	Z3	Z4	k_{eff}	σ	k_{eff}+ 2σ	k_{eff}	σ	k_{eff}+ 2σ	k_{eff}	σ	k_{eff}+ 2σ
5	23.41	0	84.112	94.112	262.336	272.336	0.4989	0.0012	0.5013	0.4465	0.0011	0.4488	0.3837	0.0011	0.3859
10	18.41	0	79.112	99.112	257.336	277.336	0.7807	0.0014	0.7834	0.7529	0.0014	0.7557	0.7138	0.0013	0.7163
15	13.41	0	74.112	104.112	252.336	282.336	0.8000	0.0010	0.8019	0.7995	0.0011	0.8016	0.7929	0.0012	0.7952
20	8.41	0	69.112	109.112	247.336	287.336	0.6907	0.0007	0.6920	0.6999	0.0008	0.7016	0.7126	0.0008	0.7143
28.41	0	0	60.702	117.522	238.926	295.746	0.4949	0.0005	0.4958	0.5026	0.0004	0.5035	0.5142	0.0004	0.5151

R and X-, Y-, Z- coordinates for the center of the sphere, cm							40% density cellulose			20% density cellulose			void		
R	X	Y	Z1	Z2	Z3	Z4	k_{eff}	σ	k_{eff}+ 2σ	k_{eff}	σ	k_{eff}+ 2σ	k_{eff}	σ	k_{eff}+ 2σ
5	23.41	0	84.112	94.112	262.336	272.336	0.3080	0.0010	0.3090	0.2364	0.0010	0.2383	0.1495	0.0007	0.1509
10	18.41	0	79.112	99.112	257.336	277.336	0.6623	0.0013	0.6635	0.6013	0.0015	0.6044	0.5742	0.0014	0.5770

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15	13.41	0	74.112	104.112	252.336	282.336	0.7846	0.0012	0.7857	0.7772	0.0010	0.7792	0.8278	0.0010	0.8299
20	8.41	0	69.112	109.112	247.336	287.336	0.7259	0.0008	0.7267	0.7492	0.0008	0.7508	0.8099	0.0008	0.8115
28.41	0	0	60.702	117.522	238.926	295.746	0.5271	0.0005	0.5276	0.5457	0.0004	0.5465	0.5768	0.0004	0.5776

Figure 1. k_{eff} +2σ for 200 g Pu-239 spheres in the 55 gallon drums with cellulose. The spheres are located so that they touch the drum wall. The Z-coordinates spheres' centers correspond to the location of 1st tier - 2nd tier sphere contact, and 3rd - 4th tier sphere contact.

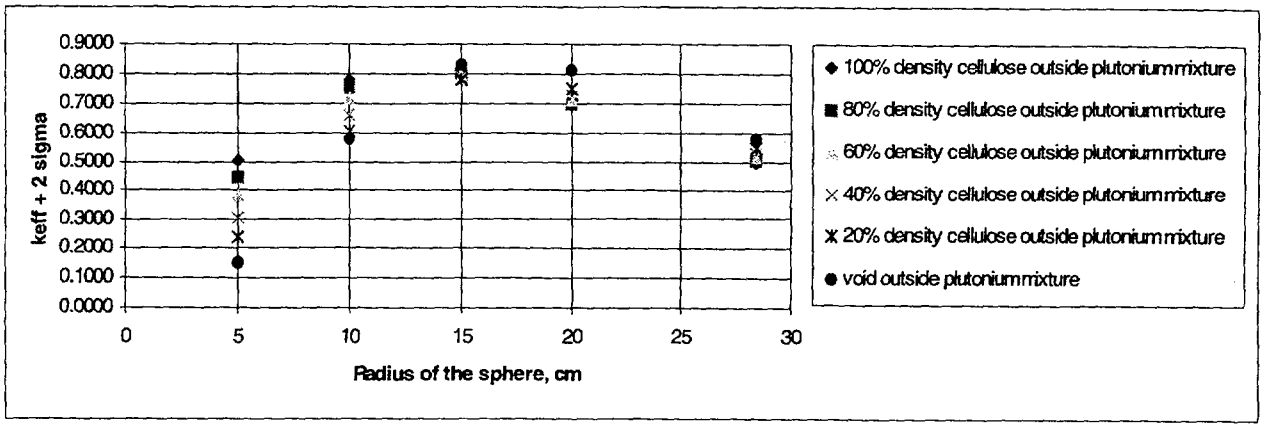

Table 8. Comparison of the k_{eff} values for the drum with 56.83 cm (22.37 inches) inside diameter and 89.11 cm (35.08 inches) height against the drum with 56.83 cm (22 inches) inside diameter and 89.11 cm (35 inches) height

R and X-, Y-, Z- coordinates for the center of the sphere, cm							22.37 inches diameter and 35.08 inches height		
R	X	Y	Z1	Z2	Z3	Z4	k_{eff}	σ	k_{eff}+ 2σ
5	23.41	0	84.112	94.112	262.336	272.336	0.1495	0.0007	0.1509
10	18.41	0	79.112	99.112	257.336	277.336	0.5742	0.0014	0.5770
15	13.41	0	74.112	104.112	252.336	282.336	0.8278	0.0010	0.8299
20	8.41	0	69.112	109.112	247.336	287.336	0.8099	0.0008	0.8115
28.41	0	0	60.702	117.522	238.926	295.746	0.5768	0.0004	0.5776

R and X-, Y-, Z- coordinates for the center of the sphere, cm							22 inches diameter and 34 inches height		
R	X	Y	Z1	Z2	Z3	Z4	k_{eff}	σ	k_{eff}+ 2σ
5	22.783	0	81.360	91.360	254.080	264.080	0.15464	0.00062	0.15588
10	17.783	0	76.360	96.360	249.080	269.080	0.5891	0.0014	0.59188
15	12.783	0	71.360	101.360	244.080	274.080	0.8447	0.0011	0.84692
20	7.783	0	66.360	106.360	239.080	279.080	0.8218	0.0008	0.8234
27.783	0	0	58.577	114.143	231.297	286.863	0.5734	0.0004	0.57415

Figure 2. Comparison of the k_{eff} values for the drum with 56.83 cm (22.37 inches) inside diameter and 89.11 cm (35.08 inches) height against the drum with 56.83 cm (22 inches) inside diameter and 89.11 cm (35 inches) height

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Job No 30822-244-330 /6860 Job: PSR-6 By IVC Date 10/4/01
Client WVNS Subject: cellulose-Pu-239 spheres Chk'd. KL Date 10/4/01

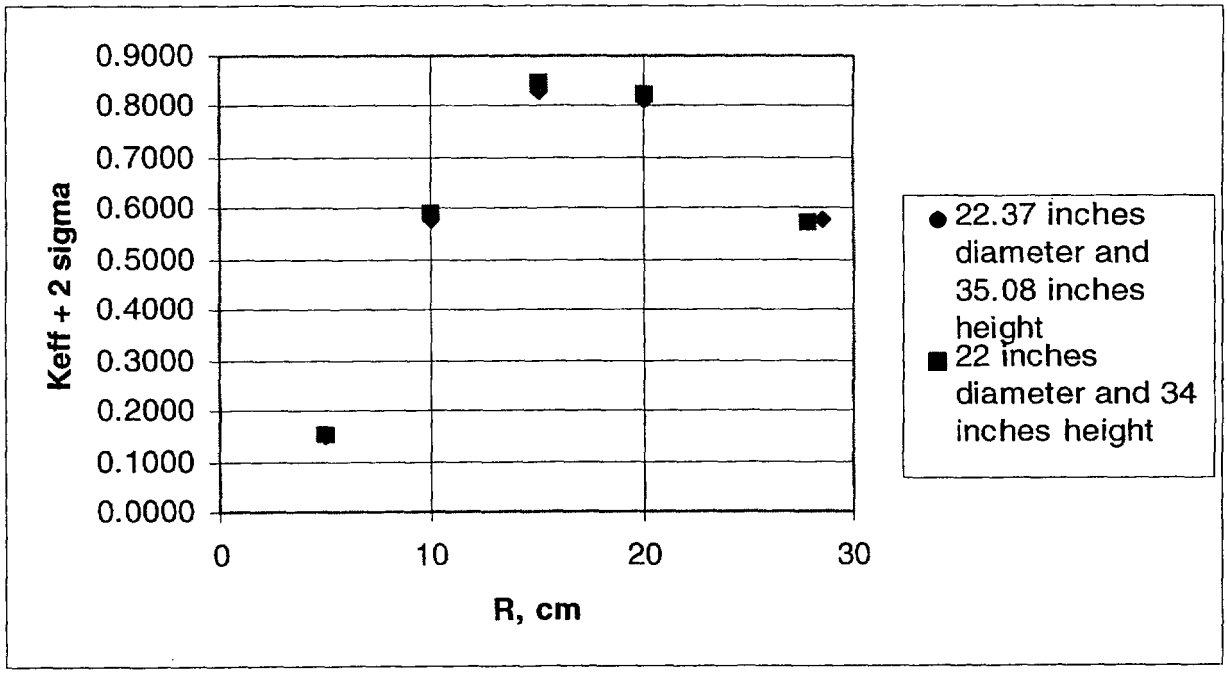

Table 9. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for 350 g Pu-239 spheres in the B-25 box with cellulose. The spheres are located so that they touch the box wall in two points. The Z-coordinates spheres' centers correspond to the location of 1st tier - 2nd tier sphere contact, and 3rd - 4th tier sphere contact.

R and X-, Y-, Z- coordinates for the center of the sphere, cm							100% density cellulose			80% density cellulose			60% density cellulose		
R	X	Y	Z1	Z2	Z3	Z4	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$
5	5	5	82.63	92.63	257.89	267.89	0.7294	0.0014	0.7323	0.6639	0.0014	0.6666	0.5739	0.0012	0.5762
10	10	10	77.63	97.63	252.89	272.89	1.0240	0.0013	1.0266	0.9897	0.0013	0.9923	0.9355	0.0013	0.9381
15	15	15	72.63	102.63	247.89	277.89	1.0425	0.0011	1.0448	1.0426	0.0012	1.0450	1.0308	0.0012	1.0331
20	20	20	67.63	107.63	242.89	282.89	0.9198	0.0009	0.9215	0.9304	0.0009	0.9321	0.9383	0.0010	0.9403
30	30	30	57.63	117.63	232.89	292.89	0.6050	0.0006	0.6062	0.6098	0.0006	0.6109	0.6181	0.0006	0.6193

R and X-, Y-, Z- coordinates for the center of the sphere, cm							40% density cellulose			20% density cellulose			void		
R	X	Y	Z1	Z2	Z3	Z4	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$
5	5	5	82.63	92.63	257.89	267.89	0.4591	0.0012	0.4603	0.3064	0.0010	0.3084	0.1669	0.0006	0.1682
10	10	10	77.63	97.63	252.89	272.89	0.8421	0.0014	0.8436	0.6783	0.0015	0.6813	0.4302	0.0012	0.4326
15	15	15	72.63	102.63	247.89	277.89	0.9894	0.0012	0.9906	0.8843	0.0015	0.8872	0.6618	0.0015	0.6647
20	20	20	67.63	107.63	242.89	282.89	0.9295	0.0010	0.9304	0.8794	0.0012	0.8818	0.7224	0.0011	0.7247
30	30	30	57.63	117.63	232.89	292.89	0.6281	0.0006	0.6287	0.6286	0.0006	0.6298	0.5805	0.0007	0.5818

Figure 3. k_{eff} +2σ for 350 g Pu-239 spheres in the B-25 box with cellulose. The spheres are located so that they touch the box wall in two points. The Z-coordinates spheres' centers correspond to the location of 1st tier - 2nd tier sphere contact, and 3rd - 4th tier sphere contact.

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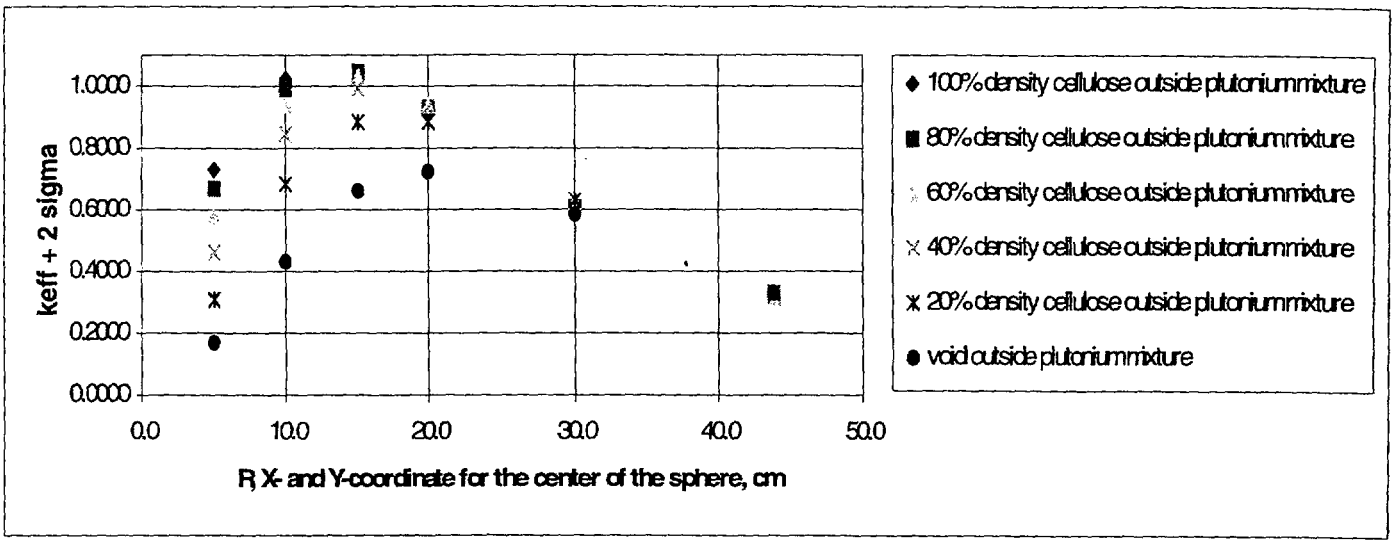
Job No 30822-244-330 /6860 Job: PSR-6 By JVC Date 10/4/01
Client WVNS Subject: cellulose-Pu-239 spheres Chk'd. JC2 Date 10/4/01

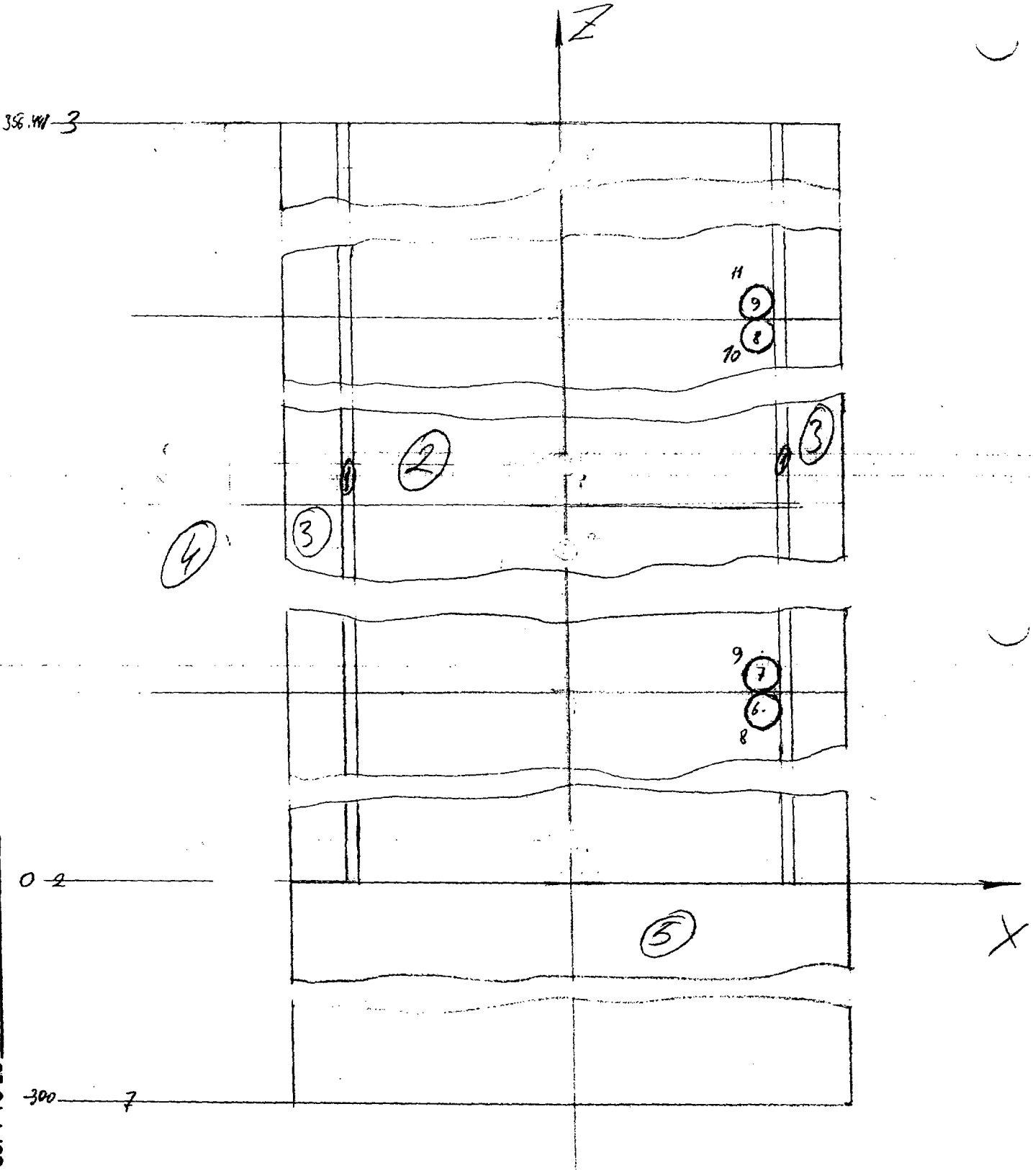


Attachment 1: Case 1 with MCNP surface and cell numbers

FILE _____

SUBJECT _____

REVISIONS
BY _____ DATE _____ TO EO _____
BY _____ DATE _____ TO EO _____



BY _____ DATE _____
CHECKED BY _____
COPY TO EO _____

Dames & Moore

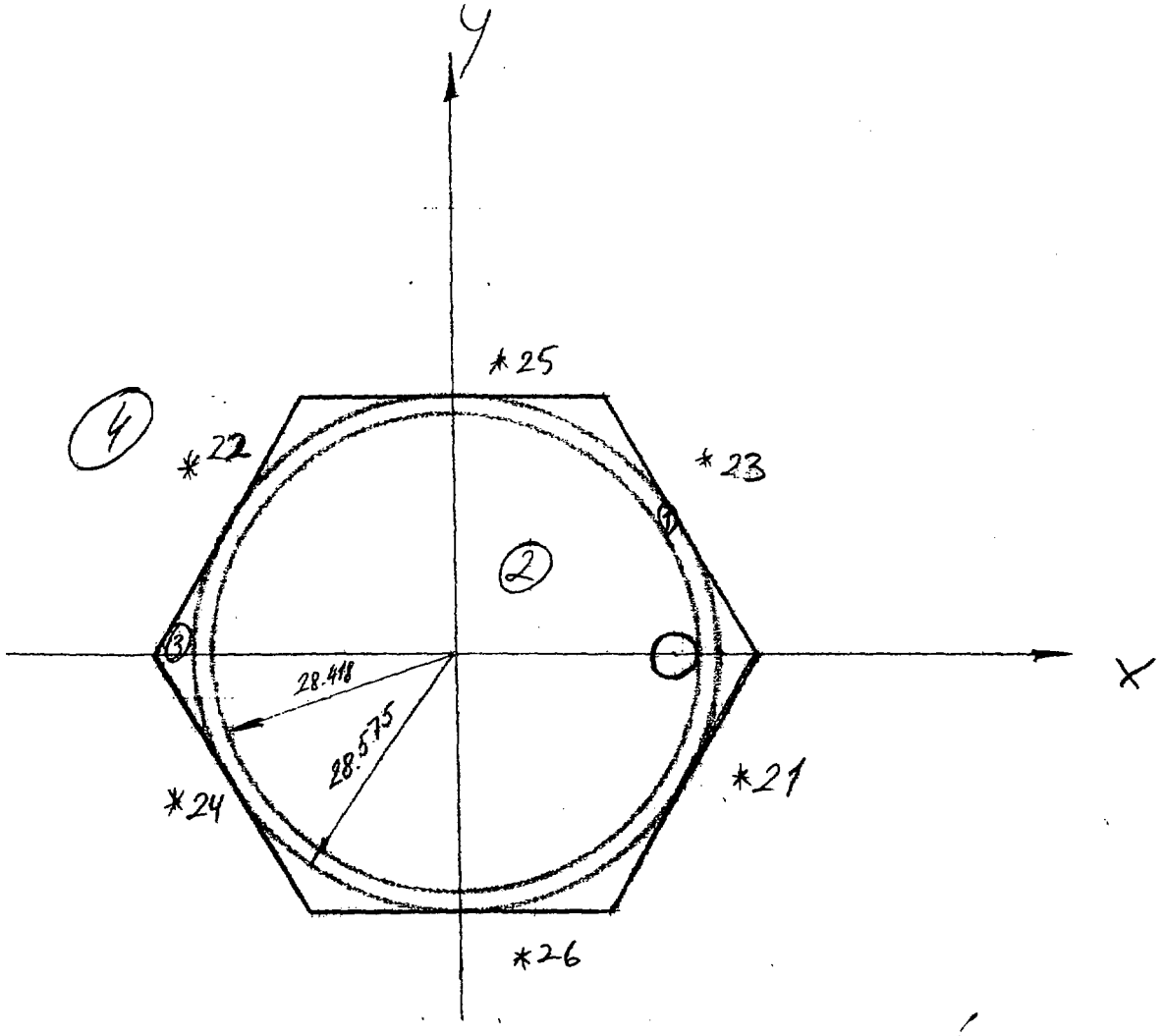
FILE _____

SUBJECT _____

REVISIONS

BY _____ DATE _____ TO EO _____

BY _____ DATE _____ TO EO _____



BY _____ DATE _____

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Attachment 2: Case 1 MCNP input file

3s610

```
Pu-239 in cellulose matrix. Infinite lattice of 55 gal. drums, 4 tiers
C The drum height is 35 1/12 inch (89.112 cm)
c drum wall thickness is 0.157 cm
C Cell cards
C
C ------------------------------------------------------------------------
1  65 -7.82       5 -6  2 -3                    imp:n=1 $ drum wall
2  1  -0.90    -5  2 -3  8 9 10 11             imp:n=1 $ pure cellulose
3  64 -0.001293 -21 22 -23 24 -25 26 2 -3 6    imp:n=1 $ air ouside the drum
4  0         21 : -22 : 23 : -24 : 25 : -26 : -7 : 3 imp:n=0 $ Outside world
5  2 -2.3       -21 22 -23 24 -25 26 -2 7      imp:n=1 $ concrete floor
6  3 -0.9135     -8                             imp:n=1 $ Plutonium sphere
7  3 -0.9135     -9                             imp:n=1 $ Plutonium sphere
8  3 -0.9135     -10                            imp:n=1 $ Plutonium sphere
9  3 -0.9135     -11                            imp:n=1 $ Plutonium sphere
C ------------------------------------------------------------------------
c
c Note: next line must be completely blank

c Surface cards
C ------------------------------------------------------------------------
2  pz 0         $ drum bottom plane
3  pz 356.448   $ drum top plane
5  cz 28.418    $ 28.418 cm radius cylinder (internal wall of the drum)
6  cz 28.575    $ 28.575 cm radius cylinder (external wall of the drum)
7  pz -300      $ concrete bottom plane
8  s 13.41 0 74.112  15.0 $ plutonium sphere
9  s 13.41 0 104.112  15.0 $ plutonium sphere
10 s 13.41 0 252.336 15.0 $ plutonium sphere
11 s 13.41 0 282.336 15.0 $ plutonium sphere
c
c hexagonal cell with reflecting surfaces outside the drum
c (simulates infinite array of the drums)
c begin the lattice surfaces
*21 p 0.8660254 -0.5 0  28.575
*22 p 0.8660254 -0.5 0 -28.575
*23 p 0.8660254  0.5 0  28.575
*24 p 0.8660254  0.5 0 -28.575
*25 py  28.575
*26 py -28.575
c end of lattice surfaces
c
C ------------------------------------------------------------------------
c
c Note: next line must be completely blank

c Data cards
c
c Materials
c
c Celulose (Elements: C, H, O)
m1     6000.50c  -0.444
       1001.50c  -0.062
       8016.50c  -0.493
c Concrete (KENO Regular Concrete Standard Mix) from Harmon at al.
c Criticality Calculation with MCNP. A Primer. p. C-4
c (Elements: H, O, Na, Si, Al, Ca, Fe)
m2     1001.50c -0.010
       8016.50c -0.532
      11023.50c -0.029
      13027.50c -0.034
      14000.50c -0.337
      20000.50c -0.044
      26000.55c -0.014
c Plutonium-239 with cellulose
m3    94239.55c  -0.015487
       6000.50c  -0.437572
       1001.50c  -0.061202
       8016.50c  -0.48574
c Air (C, N, O, Ar) composition from Attix p.532
m64    6000.50c -0.000124
       7014.50c -0.755267
       8016.50c -0.231781
      18000.35c -0.012828
c Carbon Steel (C, Fe) composition from Crit. Calc. with MCNP p. C-10
m65    6000.50c -0.005
      26000.55c -0.995
c
```

3s610

```
mode n
print 40 60 80 100 110 126
kcode 4000 1. 20 120
ksrc  13.41 0 74.112
      13.41 0 104.112
      13.41 0 252.336
      13.41 0 282.336
```

Attachment 3: Case 1 MCNP output file

```
lmcnp     version 4a    ld=10/01/93                    12/19/00 11:13:29
*************************************************************************          probid =   12/19/00 11:13:29
name=3s610

      Pu-239 in cellulose matrix. Infinite lattice of 55 gal. drums, 4 tiers
      C The drum height is 35 1/12 inch (89.112 cm)
      c drum wall thickness is 0.157 cm
      C Cell cards
      C
      C ---------------------------------------------------------------------
      1  65 -7.82      5 -6  2 -3                    imp:n=1 $ drum wall
      2  1  -0.90    -5  2 -3  8 9 10 11            imp:n=1 $ pure cellulose
      3  64 -0.001293 -21 22 -23 24 -25 26 2 -3 6   imp:n=1 $ air ouside the drum
      4  0        21 : -22 : 23 : -24 : 25 : -26 : -7 : 3 imp:n=0 $ Outside world
      5  2 -2.3       -21 22 -23 24 -25 26 -2 7     imp:n=1 $ concrete floor
      6  3 -0.9135     -8                            imp:n=1 $ Plutonium sphere
      7  3 -0.9135     -9                            imp:n=1 $ Plutonium sphere
      8  3 -0.9135     -10                           imp:n=1 $ Plutonium sphere
      9  3 -0.9135     -11                           imp:n=1 $ Plutonium sphere
      C ---------------------------------------------------------------------
      c
      c Note: next line must be completely blank

      c Surface cards
      C ---------------------------------------------------------------------
      2  pz 0          $ drum bottom plane
      3  pz 356.448    $ drum top plane
      5  cz 28.418     $ 28.418 cm radius cylinder (internal wall of the drum)
      6  cz 28.575     $ 28.575 cm radius cylinder (external wall of the drum)
      7  pz -300       $ concrete bottom plane
      8  s 13.41 0 74.112  15.0 $ plutonium sphere
      9  s 13.41 0 104.112  15.0 $ plutonium sphere
      10 s 13.41 0 252.336 15.0 $ plutonium sphere
      11 s 13.41 0 282.336 15.0 $ plutonium sphere
      c
      c hexagonal cell with reflecting surfaces outside the drum
      c (simulates infinite array of the drums)
      c begin the lattice surfaces
      *21 p 0.8660254 -0.5 0  28.575
      *22 p 0.8660254 -0.5 0 -28.575
      *23 p 0.8660254  0.5 0  28.575
      *24 p 0.8660254  0.5 0 -28.575
      *25 py  28.575
      *26 py -28.575
      c end of lattice surfaces
      c
      C ---------------------------------------------------------------------
      c
      c Note: next line must be completely blank

      c Data cards
      c
      c Materials
      c
      c Celulose (Elements: C, H, O)
      m1      6000.50c  -0.444
              1001.50c  -0.062
              8016.50c  -0.493
      c Concrete (KENO Regular Concrete Standard Mix) from Harmon at al.
      c Criticality Calculation with MCNP. A Primer. p. C-4
      c (Elements: H, O, Na, Si, Al, Ca, Fe)
      m2      1001.50c -0.010
```

```
59-              8016.50c -0.532
60-             11023.50c -0.029
61-             13027.50c -0.034
62-             14000.50c -0.337
63-             20000.50c -0.044
64-             26000.55c -0.014
65-       c Plutonium-239 with cellulose
66-       m3    94239.55c  -0.015487
67-              6000.50c  -0.437572
68-              1001.50c  -0.061202
69-              8016.50c  -0.48574
70-       c Air (C, N, O, Ar) composition from Attix p.532
71-       m64    6000.50c -0.000124
72-              7014.50c -0.755267
73-              8016.50c -0.231781
74-             18000.35c -0.012828
75-       c Carbon Steel (C, Fe) composition from Crit. Calc. with MCNP p. C-10
76-       m65    6000.50c -0.005
77-             26000.55c -0.995
78-       c
79-       mode n
80-       print 40 60 80 100 110 126
81-       kcode 4000 1. 20 120
82-       ksrc  13.41 0 74.112
83-             13.41 0 104.112
84-             13.41 0 252.336
85-             13.41 0 282.336
86-
 total fission nubar data are being used.
1material composition                                                                    print table 40

 the sum of the fractions of material    1 was 9.990000E-01

 material
  number     component nuclide, atom fraction

    1            6000,  0.28588      1001,  0.47576      8016,  0.23837
    2            1001,  0.16803      8016,  0.56324     11023,  0.02136     13027,  0.02134
                14000,  0.20319     20000,  0.01859     26000,  0.00425
    3           94239,  0.00051      6000,  0.28553      1001,  0.47595      8016,  0.23801
   64            6000,  0.00015      7014,  0.78443      8016,  0.21075     18000,  0.00467
   65            6000,  0.02283     26000,  0.97717


 material
  number     component nuclide, mass fraction

    1            6000,  0.44444      1001,  0.06206      8016,  0.49349
    2            1001,  0.01000      8016,  0.53200     11023,  0.02900     13027,  0.03400
                14000,  0.33700     20000,  0.04400     26000,  0.01400
    3           94239,  0.01549      6000,  0.43757      1001,  0.06120      8016,  0.48574
   64            6000,  0.00012      7014,  0.75527      8016,  0.23178     18000,  0.01283
   65            6000,  0.00500     26000,  0.99500

 warning.    1 of the materials had unnormalized fractions.
1cells                                                                                   print table 60

                     atom        gram                                        neutron
       cell  mat    density     density     volume       mass     pieces importance
```

```
     1      1    65  8.58651E-02 7.82000E+00 1.00200E+04 7.83563E+04      1  1.0000E+00
     2      2     1  7.01524E-02 9.00000E-01 0.00000E+00 0.00000E+00      0  1.0000E+00
     3      3    64  5.35386E-05 1.29300E-03 0.00000E+00 0.00000E+00      0  1.0000E+00
     4      4     0  0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00      0  0.0000E+00
     5      5     2  8.17913E-02 2.30000E+00 8.48564E+05 1.95170E+06      0  1.0000E+00
     6      6     3  7.01894E-02 9.13500E-01 1.41372E+04 1.29143E+04      1  1.0000E+00
     7      7     3  7.01894E-02 9.13500E-01 1.41372E+04 1.29143E+04      1  1.0000E+00
     8      8     3  7.01894E-02 9.13500E-01 1.41372E+04 1.29143E+04      1  1.0000E+00
     9      9     3  7.01894E-02 9.13500E-01 1.41372E+04 1.29143E+04      1  1.0000E+00

 total                                       9.15132E+05 2.08171E+06

         1 warning message so far.
1cross-section tables                                                          print table 100

     table    length

                        tables from file critxs

   1001.50c     1153  njoy                                                ( 1301)      79/07/31.
   6000.50c    16126  njoy                                                ( 1306)      79/07/31.
   7014.50c    22772  njoy                                                ( 1275)      79/09/08.
   8016.50c    23669  njoy                                                ( 1276)      05/14/81
  11023.50c    36270  njoy                                                ( 1311)      79/06/21.
  13027.50c    22891  njoy                                                ( 1313)      79/09/08.
  14000.50c    48275  njoy                                                ( 1314)      79/06/21.
  18000.35c     2182      end185                                           ( 18)       11/01/85
  20000.50c    26104  njoy                                                ( 1320)      79/06/22.
  26000.55c    84136  njoy                                                ( 260)       10/21/82
  94239.55c    67551  njoy                                 total nu       ( 1399)      02/21/85

 total       351129

 warning.  neutron energy cutoff is below some cross-section tables.



 decimal words of dynamically allocated storage

     general              112612
     tallies                   0
     bank                   6403
     cross sections       351129

     total                470144

 ********************************************************************************************************************
 dump no.     1 on file 3s610r       nps =          0      coll =              0      ctm =     0.00      nrn =              0

 source distribution written to file 3s610s          cycle =      0

         2 warning messages so far.
1   starting mcrun.       field length =       0      cp0 =  0.01                                          print table 110

      Pu-239 in cellulose matrix. Infinite lattice of 55 gal. drums, 4 tiers

     nps     x          y          z        cell   surf      u          v          w        energy     weight      time
```

1	1.341E+01	0.000E+00	7.411E+01	6	0	5.085E-01	4.733E-01	7.193E-01	2.209E+00	1.000E+00	0.000E+00
2	1.341E+01	0.000E+00	7.411E+01	6	0	8.952E-01	-4.447E-01	-2.944E-02	4.904E+00	1.000E+00	0.000E+00
3	1.341E+01	0.000E+00	7.411E+01	6	0	-6.184E-01	-4.495E-01	6.446E-01	3.809E-01	1.000E+00	0.000E+00
4	1.341E+01	0.000E+00	7.411E+01	6	0	9.710E-01	-5.665E-02	-2.323E-01	1.331E+00	1.000E+00	0.000E+00
5	1.341E+01	0.000E+00	7.411E+01	6	0	5.861E-01	1.496E-01	-7.963E-01	1.902E+00	1.000E+00	0.000E+00
6	1.341E+01	0.000E+00	7.411E+01	6	0	-6.489E-02	-1.626E-01	9.845E-01	4.410E-01	1.000E+00	0.000E+00
7	1.341E+01	0.000E+00	7.411E+01	6	0	-7.068E-02	3.263E-02	-9.970E-01	4.750E-01	1.000E+00	0.000E+00
8	1.341E+01	0.000E+00	7.411E+01	6	0	-3.915E-01	4.664E-01	-7.932E-01	4.136E+00	1.000E+00	0.000E+00
9	1.341E+01	0.000E+00	7.411E+01	6	0	-2.368E-01	9.215E-01	-3.079E-01	7.453E-02	1.000E+00	0.000E+00
10	1.341E+01	0.000E+00	7.411E+01	6	0	1.946E-01	-3.204E-01	9.271E-01	3.128E+00	1.000E+00	0.000E+00
11	1.341E+01	0.000E+00	7.411E+01	6	0	-6.698E-01	-7.177E-01	-1.905E-01	1.014E+00	1.000E+00	0.000E+00
12	1.341E+01	0.000E+00	7.411E+01	6	0	-8.398E-01	-4.129E-01	3.524E-01	1.395E+00	1.000E+00	0.000E+00
13	1.341E+01	0.000E+00	7.411E+01	6	0	-1.714E-01	-8.572E-01	4.857E-01	7.748E-01	1.000E+00	0.000E+00
14	1.341E+01	0.000E+00	7.411E+01	6	0	-2.489E-01	-5.118E-01	-8.222E-01	1.101E+00	1.000E+00	0.000E+00
15	1.341E+01	0.000E+00	7.411E+01	6	0	-2.959E-01	2.119E-01	9.314E-01	1.951E+00	1.000E+00	0.000E+00
16	1.341E+01	0.000E+00	7.411E+01	6	0	1.395E-01	-9.829E-01	1.202E-01	2.186E+00	1.000E+00	0.000E+00
17	1.341E+01	0.000E+00	7.411E+01	6	0	6.909E-01	-7.110E-01	1.307E-01	1.865E+00	1.000E+00	0.000E+00
18	1.341E+01	0.000E+00	7.411E+01	6	0	-6.580E-01	5.320E-01	-5.329E-01	1.229E+00	1.000E+00	0.000E+00
19	1.341E+01	0.000E+00	7.411E+01	6	0	-9.903E-01	-1.380E-01	1.353E-02	1.305E+00	1.000E+00	0.000E+00
20	1.341E+01	0.000E+00	7.411E+01	6	0	7.462E-01	4.859E-01	-4.551E-01	1.000E+00	1.000E+00	0.000E+00
21	1.341E+01	0.000E+00	7.411E+01	6	0	-1.977E-01	9.797E-01	3.360E-02	3.990E+00	1.000E+00	0.000E+00
22	1.341E+01	0.000E+00	7.411E+01	6	0	-9.117E-01	-3.647E-01	-1.891E-01	2.665E-01	1.000E+00	0.000E+00
23	1.341E+01	0.000E+00	7.411E+01	6	0	-4.287E-01	8.361E-01	-3.423E-01	1.156E+00	1.000E+00	0.000E+00
24	1.341E+01	0.000E+00	7.411E+01	6	0	1.080E-01	3.412E-01	-9.338E-01	2.669E+00	1.000E+00	0.000E+00
25	1.341E+01	0.000E+00	7.411E+01	6	0	-9.111E-01	-9.012E-03	-4.122E-01	2.185E+00	1.000E+00	0.000E+00
26	1.341E+01	0.000E+00	7.411E+01	6	0	-2.568E-01	-6.391E-01	-7.249E-01	4.225E+00	1.000E+00	0.000E+00
27	1.341E+01	0.000E+00	7.411E+01	6	0	-2.912E-01	8.086E-01	5.113E-01	1.079E+00	1.000E+00	0.000E+00
28	1.341E+01	0.000E+00	7.411E+01	6	0	1.472E-01	-9.514E-01	2.705E-01	3.461E+00	1.000E+00	0.000E+00
29	1.341E+01	0.000E+00	7.411E+01	6	0	-6.135E-01	-7.645E-01	-1.978E-01	1.836E+00	1.000E+00	0.000E+00
30	1.341E+01	0.000E+00	7.411E+01	6	0	-5.702E-01	5.651E-01	-5.963E-01	4.556E-01	1.000E+00	0.000E+00
31	1.341E+01	0.000E+00	7.411E+01	6	0	-6.607E-01	5.373E-01	-5.242E-01	6.415E-01	1.000E+00	0.000E+00
32	1.341E+01	0.000E+00	7.411E+01	6	0	-9.742E-02	-3.639E-01	-9.263E-01	2.764E+00	1.000E+00	0.000E+00
33	1.341E+01	0.000E+00	7.411E+01	6	0	-1.965E-01	-3.145E-01	-9.287E-01	2.785E-01	1.000E+00	0.000E+00
34	1.341E+01	0.000E+00	7.411E+01	6	0	4.097E-01	8.465E-01	-3.399E-01	9.097E-01	1.000E+00	0.000E+00
35	1.341E+01	0.000E+00	7.411E+01	6	0	-4.048E-02	8.831E-01	4.675E-01	3.360E-01	1.000E+00	0.000E+00
36	1.341E+01	0.000E+00	7.411E+01	6	0	3.371E-01	-9.269E-01	-1.652E-01	6.376E-01	1.000E+00	0.000E+00
37	1.341E+01	0.000E+00	7.411E+01	6	0	-1.867E-01	9.756E-01	-1.155E-01	2.186E+00	1.000E+00	0.000E+00
38	1.341E+01	0.000E+00	7.411E+01	6	0	-2.616E-01	2.336E-01	-9.365E-01	7.314E-01	1.000E+00	0.000E+00
39	1.341E+01	0.000E+00	7.411E+01	6	0	9.780E-01	-7.641E-02	-1.939E-01	2.997E-01	1.000E+00	0.000E+00
40	1.341E+01	0.000E+00	7.411E+01	6	0	2.580E-01	-7.076E-01	6.578E-01	1.444E+00	1.000E+00	0.000E+00
41	1.341E+01	0.000E+00	7.411E+01	6	0	-3.212E-01	-7.678E-01	-5.543E-01	1.914E+00	1.000E+00	0.000E+00
42	1.341E+01	0.000E+00	7.411E+01	6	0	5.039E-01	-1.460E-01	8.513E-01	1.502E+00	1.000E+00	0.000E+00
43	1.341E+01	0.000E+00	7.411E+01	6	0	6.080E-01	5.487E-01	5.738E-01	5.971E+00	1.000E+00	0.000E+00
44	1.341E+01	0.000E+00	7.411E+01	6	0	-2.932E-01	9.304E-01	-2.199E-01	1.827E+00	1.000E+00	0.000E+00
45	1.341E+01	0.000E+00	7.411E+01	6	0	-8.475E-01	-3.993E-01	-3.497E-01	1.928E+00	1.000E+00	0.000E+00
46	1.341E+01	0.000E+00	7.411E+01	6	0	1.200E-01	-9.195E-01	-3.743E-01	1.351E+00	1.000E+00	0.000E+00
47	1.341E+01	0.000E+00	7.411E+01	6	0	7.085E-01	5.879E-01	3.904E-01	2.288E+00	1.000E+00	0.000E+00
48	1.341E+01	0.000E+00	7.411E+01	6	0	4.261E-01	9.046E-01	9.254E-03	1.230E+00	1.000E+00	0.000E+00
49	1.341E+01	0.000E+00	7.411E+01	6	0	5.431E-01	4.270E-01	-7.230E-01	1.433E+00	1.000E+00	0.000E+00
50	1.341E+01	0.000E+00	7.411E+01	6	0	-1.053E-01	-9.805E-01	1.658E-01	6.572E-01	1.000E+00	0.000E+00

lestimated keff results by cycle print table 175

source distribution written to file 3s610s cycle = 20

source distribution written to file 3s610s cycle = 24

source distribution written to file 3s610s cycle = 28

source distribution written to file 3s610s cycle = 32

source distribution written to file 3s610s cycle = 36

```
source distribution written to file 3s610s          cycle =    40

source distribution written to file 3s610s          cycle =    44

source distribution written to file 3s610s          cycle =    48

source distribution written to file 3s610s          cycle =    52

*****************************************************************************************************************
dump no.    2 on file 3s610r       nps =    215230     coll =       28632831     ctm =   15.05     nrn =      497095909

source distribution written to file 3s610s          cycle =    56

source distribution written to file 3s610s          cycle =    60

source distribution written to file 3s610s          cycle =    64

source distribution written to file 3s610s          cycle =    68

source distribution written to file 3s610s          cycle =    72

source distribution written to file 3s610s          cycle =    76

source distribution written to file 3s610s          cycle =    80

source distribution written to file 3s610s          cycle =    84

source distribution written to file 3s610s          cycle =    88

source distribution written to file 3s610s          cycle =    92

source distribution written to file 3s610s          cycle =    96

 estimator      cycle   100   ave of    80 cycles      combination          simple average    combined average     corr
k(collision)      0.786170       0.800184 0.0020     k(col/abs)           0.800684 0.0014     0.800758 0.0014   0.0893
k(absorption)     0.799770       0.801183 0.0017     k(abs/tk ln)         0.800657 0.0014     0.800736 0.0014   0.0495
k(trk length)     0.783800       0.800131 0.0020     k(tk ln/col)         0.800158 0.0020     0.800165 0.0020   0.9743
rem life(col)   2.2752E+04     2.2779E+04 0.0026     k(col/abs/tk ln)     0.800500 0.0015     0.800735 0.0014
rem life(abs)   2.2624E+04     2.2798E+04 0.0023     life(col/abs)      2.2789E+04 0.0024   2.2822E+04 0.0022   0.9738
source points generated   3895

source distribution written to file 3s610s          cycle =   100

source distribution written to file 3s610s          cycle =   104

source distribution written to file 3s610s          cycle =   108

*****************************************************************************************************************
dump no.    3 on file 3s610r       nps =    431036     coll =       57335473     ctm =   30.15     nrn =      995377056

source distribution written to file 3s610s          cycle =   112

 estimator      cycle   116   ave of    96 cycles      combination          simple average    combined average     corr
k(collision)      0.786300       0.799338 0.0019     k(col/abs)           0.799975 0.0012     0.800080 0.0012   0.0348
k(absorption)     0.809848       0.800611 0.0016     k(abs/tk ln)         0.799958 0.0012     0.800054 0.0012  -0.0158
k(trk length)     0.782519       0.799304 0.0018     k(tk ln/col)         0.799321 0.0018     0.799315 0.0019   0.9734
rem life(col)   2.2212E+04     2.2773E+04 0.0025     k(col/abs/tk ln)     0.799751 0.0013     0.800058 0.0012
rem life(abs)   2.2397E+04     2.2788E+04 0.0022     life(col/abs)      2.2781E+04 0.0023   2.2809E+04 0.0020   0.9733
source points generated   3931
```

source distribution written to file 3s610s cycle = 116

estimator	cycle 117	ave of 97 cycles		combination	simple average		combined average		corr
k(collision)	0.804812	0.799396	0.0018	k(col/abs)	0.800136	0.0012	0.800244	0.0012	0.0420
k(absorption)	0.826476	0.800878	0.0016	k(abs/tk ln)	0.800133	0.0012	0.800229	0.0012	-0.0035
k(trk length)	0.807416	0.799388	0.0018	k(tk ln/col)	0.799391	0.0018	0.799390	0.0018	0.9733
rem life(col)	2.1622E+04	2.2762E+04	0.0025	k(col/abs/tk ln)	0.799887	0.0013	0.800242	0.0012	
rem life(abs)	2.1857E+04	2.2778E+04	0.0022	life(col/abs)	2.2770E+04	0.0023	2.2804E+04	0.0020	0.9743

source points generated 4063

estimator	cycle 118	ave of 98 cycles		combination	simple average		combined average		corr
k(collision)	0.780958	0.799206	0.0018	k(col/abs)	0.800010	0.0012	0.800133	0.0012	0.0480
k(absorption)	0.794613	0.800814	0.0016	k(abs/tk ln)	0.799991	0.0012	0.800106	0.0012	0.0041
k(trk length)	0.777785	0.799168	0.0018	k(tk ln/col)	0.799187	0.0018	0.799183	0.0018	0.9735
rem life(col)	2.2657E+04	2.2761E+04	0.0025	k(col/abs/tk ln)	0.799729	0.0013	0.800111	0.0012	
rem life(abs)	2.2861E+04	2.2779E+04	0.0022	life(col/abs)	2.2770E+04	0.0023	2.2807E+04	0.0020	0.9737

source points generated 3795

estimator	cycle 119	ave of 99 cycles		combination	simple average		combined average		corr
k(collision)	0.778107	0.798993	0.0018	k(col/abs)	0.799903	0.0012	0.800052	0.0012	0.0475
k(absorption)	0.800783	0.800814	0.0016	k(abs/tk ln)	0.799896	0.0012	0.800033	0.0012	0.0041
k(trk length)	0.780474	0.798979	0.0018	k(tk ln/col)	0.798986	0.0018	0.798984	0.0018	0.9739
rem life(col)	2.2683E+04	2.2760E+04	0.0025	k(col/abs/tk ln)	0.799595	0.0013	0.800045	0.0012	
rem life(abs)	2.2840E+04	2.2780E+04	0.0021	life(col/abs)	2.2770E+04	0.0023	2.2809E+04	0.0019	0.9733

source points generated 3972

estimator	cycle 120	ave of 100 cycles		combination	simple average		combined average		corr
k(collision)	0.770707	0.798710	0.0019	k(col/abs)	0.799796	0.0012	0.799990	0.0012	0.0363
k(absorption)	0.807580	0.800881	0.0016	k(abs/tk ln)	0.799813	0.0012	0.799983	0.0012	-0.0046
k(trk length)	0.775641	0.798745	0.0018	k(tk ln/col)	0.798728	0.0018	0.798737	0.0018	0.9742
rem life(col)	2.2422E+04	2.2756E+04	0.0025	k(col/abs/tk ln)	0.799446	0.0013	0.800010	0.0012	
rem life(abs)	2.2764E+04	2.2780E+04	0.0021	life(col/abs)	2.2768E+04	0.0023	2.2812E+04	0.0019	0.9717

source points generated 3944

source distribution written to file 3s610s cycle = 120

1problem summary

run terminated when 120 kcode cycles were done.

12/19/00 11:46:59

Pu-239 in cellulose matrix. Infinite lattice of 55 gal. drums, 4 tiers probid = 12/19/00 11:13:29

0

neutron creation	tracks	weight (per source particle)	energy	neutron loss	tracks	weight (per source particle)	energy
source	478718	1.0027E+00	2.1111E+00	escape	678	7.8873E-04	4.6275E-04
				energy cutoff	0	0.	0.
				time cutoff	0	0.	0.
weight window	0	0.	0.	weight window	0	0.	0.
cell importance	0	0.	0.	cell importance	0	0.	0.
weight cutoff	0	1.1073E-01	3.2513E-08	weight cutoff	478042	1.1116E-01	2.7930E-08
energy importance	0	0.	0.	energy importance	0	0.	0.
dxtran	0	0.	0.	dxtran	0	0.	0.
forced collisions	0	0.	0.	forced collisions	0	0.	0.
exp. transform	0	0.	0.	exp. transform	0	0.	0.
upscattering	0	0.	6.8249E-07	downscattering	0	0.	2.0894E+00
				capture	0	7.2347E-01	1.9870E-02
(n,xn)	4	5.5269E-06	1.8832E-06	loss to (n,xn)	2	2.7634E-06	1.7574E-05
fission	0	0.	0.	loss to fission	0	2.7800E-01	1.3158E-03
total	478722	1.1134E+00	2.1111E+00	total	478722	1.1134E+00	2.1111E+00

number of neutrons banked 2 average lifetime, shakes cutoffs

neutron tracks per source particle	1.0000E+00	escape	3.7798E+04	tco	1.0000E+34
neutron collisions per source particle	1.3303E+02	capture	2.2756E+04	eco	0.0000E+00
total neutron collisions	63684233	capture or escape	2.2768E+04	wc1	-5.0000E-01
net multiplication	1.0000E+00 0.0001	any termination	2.7526E+04	wc2	-2.5000E-01

computer time so far in this run	33.50 minutes	maximum number ever in bank	1
computer time in mcrun	33.48 minutes	bank overflows to backup file	0
source particles per minute	1.4297E+04	field length	0
random numbers generated	1105545149	most random numbers used was	21364 in history 348480

range of sampled source weights = 9.0950E-01 to 1.2099E+00

1neutron activity in each cell print table 126

cell		tracks entering	population	collisions	collisions * weight (per history)	number weighted energy	flux weighted energy	average track weight (relative)	average track mfp (cm)
1	1	1965051	235850	602030	7.0233E-01	7.6710E-05	3.4077E-01	6.1699E-01	1.8188E+00
2	2	1850640	409749	49832375	5.8754E+01	5.0007E-05	2.6490E-01	6.0927E-01	1.5852E+00
3	3	972076	230414	2611	3.0176E-03	7.9908E-05	3.5316E-01	6.2067E-01	3.4829E+03
5	5	1108	499	29685	2.7490E-02	2.1462E-05	1.3746E-01	4.6200E-01	1.8879E+00
6	6	261265	124389	2941131	4.9002E+00	2.5552E-04	6.6218E-01	8.6584E-01	2.5445E+00
7	7	252255	119683	2814383	4.6765E+00	2.5396E-04	6.5884E-01	8.6424E-01	2.5380E+00
8	8	327966	156386	3680854	6.1189E+00	2.5475E-04	6.6062E-01	8.6437E-01	2.5411E+00
9	9	337769	160204	3781164	6.2916E+00	2.5660E-04	6.6336E-01	8.6516E-01	2.5461E+00
total		5968130	1437174	63684233	8.1474E+01				

1keff results for: Pu-239 in cellulose matrix. Infinite lattice of 55 gal. drums, 4 tiers probid = 12/19/00 11:13:29

the initial fission neutron source distribution used the 4 source points that were input on the ksrc card.
the criticality problem was scheduled to skip 20 cycles and run a total of 120 cycles with nominally 4000 neutrons per cycle.
this problem has run 20 inactive cycles with 78769 neutron histories and 100 active cycles with 399949 neutron histories.

this calculation has completed the requested number of keff cycles using a total of 478718 fission neutron source histories.
all cells with fissionable material were sampled and had fission neutron source points.

the results of the w test for normality applied to the individual collision, absorption, and track-length keff cycle values are:

the k(collision) cycle values appear normally distributed at the 95 percent confidence level
the k(absorption) cycle values appear normally distributed at the 95 percent confidence level
the k(trk length) cycle values appear normally distributed at the 95 percent confidence level

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the final estimated combined collision/absorption/track-length keff = 0.80001 with an estimated standard deviation of 0.00096

the estimated 68, 95, & 99 percent keff confidence intervals are 0.79905 to 0.80097, 0.79810 to 0.80192, and 0.79747 to 0.80255

the estimated collision/absorption neutron removal lifetime = 2.28E-04 seconds with an estimated standard deviation of 4.43E-07

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the estimated average keffs, one standard deviations, and 68, 95, and 99 percent confidence intervals are:

keff estimator	keff	standard deviation	68% confidence	95% confidence	99% confidence	corr
collision	0.79871	0.00149	0.79722 to 0.80020	0.79575 to 0.80167	0.79478 to 0.80264	

absorption	0.80088	0.00125	0.79963 to 0.80213	0.79839 to 0.80337	0.79758 to 0.80418	
track length	0.79875	0.00147	0.79728 to 0.80021	0.79582 to 0.80167	0.79487 to 0.80262	
col/absorp	0.79999	0.00098	0.79900 to 0.80098	0.79803 to 0.80195	0.79739 to 0.80259	0.0363
abs/trk len	0.79998	0.00096	0.79902 to 0.80094	0.79807 to 0.80189	0.79745 to 0.80252	-0.0046
col/trk len	0.79874	0.00147	0.79726 to 0.80021	0.79580 to 0.80167	0.79485 to 0.80263	0.9742
col/abs/trk len	0.80001	0.00096	0.79905 to 0.80097	0.79810 to 0.80192	0.79747 to 0.80255	

if the largest of each keff occurred on the next cycle, the keff results and 68, 95, and 99 percent confidence intervals would be:

keff estimator	keff	standard deviation	68% confidence	95% confidence	99% confidence
collision	0.79905	0.00151	0.79754 to 0.80056	0.79604 to 0.80206	0.79506 to 0.80304
absorption	0.80113	0.00126	0.79987 to 0.80240	0.79862 to 0.80365	0.79780 to 0.80447
track length	0.79907	0.00149	0.79758 to 0.80056	0.79611 to 0.80204	0.79514 to 0.80301
col/abs/trk len	0.80031	0.00099	0.79931 to 0.80130	0.79833 to 0.80228	0.79769 to 0.80293

the estimated collision/absorption neutron lifetimes, one standard deviations, and 68, 95, and 99 percent confidence intervals are:

type	lifetime(sec)	standard deviation	68% confidence	95% confidence	99% confidence
removal	2.2812E-04	4.4313E-07	2.2768E-04 to 2.2856E-04	2.2724E-04 to 2.2900E-04	2.2695E-04 to 2.2929E-04
capture	2.2775E-04	3.9868E-07	2.2735E-04 to 2.2815E-04	2.2696E-04 to 2.2855E-04	2.2670E-04 to 2.2880E-04
fission	1.3115E-04	3.1053E-07	1.3084E-04 to 1.3146E-04	1.3053E-04 to 1.3177E-04	1.3033E-04 to 1.3197E-04
escape	4.0674E-04	2.2491E-05	3.8423E-04 to 4.2926E-04	3.6194E-04 to 4.5155E-04	3.4732E-04 to 4.6616E-04

laverage individual and combined collision/absorption/track-length keff results for 7 different batch sizes

cycles per keff batch	number of k batches	average keff estimators and deviations k(col)	st dev	k(abs)	st dev	k(trk)	st dev	normality co/ab/trk	average k(c/a/t) k(c/a/t)	st dev	k(c/a/t) confidence intervals 95% confidence	99% confidence
1	100	0.7987	0.0015	0.8009	0.0012	0.7987	0.0015	|95/95/95|	0.80001	0.00096	0.79810-0.80192	0.79747-0.80255
2	50	0.7987	0.0016	0.8009	0.0012	0.7987	0.0015	|95/95/95|	0.80004	0.00092	0.79819-0.80188	0.79757-0.80250
4	25	0.7987	0.0018	0.8009	0.0013	0.7987	0.0017	|95/95/95|	0.80008	0.00110	0.79781-0.80236	0.79699-0.80317
5	20	0.7987	0.0017	0.8009	0.0014	0.7987	0.0015	|95/95/95|	0.79983	0.00112	0.79746-0.80220	0.79658-0.80309
10	10	0.7987	0.0021	0.8009	0.0012	0.7987	0.0019	|95/95/95|	0.80030	0.00132	0.79717-0.80344	0.79567-0.80494
20	5	0.7987	0.0019	0.8009	0.0016	0.7987	0.0017	|95/95/95|	0.79959	0.00020	0.79873-0.80045	0.79761-0.80157
25	4	0.7987	0.0014	0.8009	0.0007	0.7987	0.0012	|95/95/95|	0.80079	0.00192	0.77638-0.82521	0.67851-0.92308

lindividual and average keff estimator results by cycle

keff cycle	neutron histories	keff estimators by cycle k(coll)	k(abs)	k(track)	average keff estimators and deviations k(coll)	st dev	k(abs)	st dev	k(track)	st dev	average k(c/a/t) k(c/a/t)	st dev	fom
1	4000	0.96316	0.98244	0.96408									
2	3894	0.81153	0.83235	0.81736									
3	3306	0.76123	0.76468	0.76091									
4	3700	0.80278	0.77856	0.80496									
5	4306	0.77929	0.80659	0.77758									
6	3891	0.78436	0.80238	0.78027									
7	3922	0.84038	0.80131	0.83635									
8	4342	0.82017	0.80526	0.82001									
9	3849	0.80760	0.79348	0.80938									
10	3910	0.78732	0.81186	0.78813									
11	3871	0.79576	0.81278	0.79783									
12	4082	0.81299	0.79743	0.81322									
13	3988	0.77941	0.77541	0.78197									
14	3854	0.81660	0.80200	0.82123									
15	4084	0.77881	0.80957	0.78182									
16	3775	0.78873	0.77799	0.78766									
17	4100	0.79340	0.79999	0.79648									
18	4012	0.78212	0.81043	0.78063									

19	3992	0.77087	0.77454	0.77611							
20	3891	0.78775	0.79183	0.78642							
begin active keff cycles											
21	4166	0.81658	0.82020	0.81357							
22	4284	0.79753	0.79615	0.79904	0.80706	0.00953	0.80818	0.01202	0.80630	0.00726	
23	3832	0.82040	0.80710	0.82104	0.81151	0.00707	0.80782	0.00695	0.81121	0.00646	
24	4066	0.78091	0.79626	0.78127	0.80386	0.00914	0.80493	0.00570	0.80373	0.00877	0.80466 0.00033 5127192
25	3754	0.79676	0.80372	0.79457	0.80244	0.00722	0.80469	0.00442	0.80190	0.00703	0.80325 0.00274 61476
26	3976	0.82436	0.80310	0.82654	0.80609	0.00694	0.80442	0.00362	0.80600	0.00706	0.80323 0.00197 98950
27	4181	0.82527	0.77756	0.83193	0.80883	0.00647	0.80058	0.00491	0.80971	0.00702	0.80268 0.00245 54309
28	4034	0.79394	0.80205	0.79193	0.80697	0.00590	0.80077	0.00426	0.80748	0.00648	0.80138 0.00243 48469
29	3886	0.80637	0.80134	0.80371	0.80690	0.00521	0.80083	0.00375	0.80707	0.00573	0.80067 0.00285 31242
30	3962	0.77550	0.78701	0.77271	0.80376	0.00562	0.79945	0.00363	0.80363	0.00617	0.79831 0.00365 16969
31	3831	0.79976	0.79874	0.80125	0.80340	0.00509	0.79938	0.00328	0.80341	0.00558	0.79893 0.00317 20646
32	4127	0.81057	0.78843	0.81040	0.80400	0.00469	0.79847	0.00313	0.80400	0.00513	0.79870 0.00323 18160
33	3997	0.78721	0.76737	0.79047	0.80270	0.00450	0.79608	0.00375	0.80296	0.00483	0.79690 0.00368 12837
34	3898	0.79409	0.80848	0.79320	0.80209	0.00421	0.79697	0.00358	0.80226	0.00453	0.79786 0.00329 14916
35	4055	0.78971	0.80473	0.79417	0.80126	0.00401	0.79748	0.00337	0.80172	0.00425	0.79910 0.00302 16608
36	3928	0.78029	0.78667	0.77741	0.79995	0.00397	0.79681	0.00323	0.80020	0.00426	0.79790 0.00303 15475
37	3948	0.79298	0.80778	0.79333	0.79954	0.00375	0.79745	0.00310	0.79980	0.00402	0.79828 0.00283 16731
38	4101	0.80104	0.81177	0.80078	0.79963	0.00354	0.79825	0.00303	0.79985	0.00379	0.79886 0.00271 17257
39	4119	0.79590	0.79902	0.79553	0.79943	0.00335	0.79829	0.00286	0.79962	0.00359	0.79880 0.00255 18412
40	4006	0.79924	0.79706	0.79596	0.79942	0.00318	0.79823	0.00272	0.79944	0.00341	0.79866 0.00242 19469
41	4014	0.78790	0.79859	0.78380	0.79887	0.00308	0.79824	0.00259	0.79869	0.00333	0.79840 0.00232 20182
42	3885	0.80892	0.79627	0.80910	0.79933	0.00297	0.79815	0.00247	0.79917	0.00321	0.79850 0.00221 21109
43	4187	0.79822	0.80061	0.79619	0.79928	0.00284	0.79826	0.00236	0.79904	0.00307	0.79852 0.00212 22020
44	3918	0.81009	0.80834	0.80755	0.79973	0.00275	0.79868	0.00230	0.79939	0.00296	0.79883 0.00208 21913
45	4159	0.79397	0.81570	0.79626	0.79950	0.00265	0.79936	0.00231	0.79927	0.00284	0.79936 0.00200 22757
46	3955	0.77411	0.78770	0.78024	0.79852	0.00273	0.79891	0.00226	0.79854	0.00283	0.79880 0.00198 22311
47	3908	0.81631	0.79231	0.82096	0.79918	0.00271	0.79867	0.00219	0.79937	0.00284	0.79897 0.00191 23005
48	4123	0.79280	0.77990	0.79710	0.79896	0.00262	0.79800	0.00221	0.79929	0.00274	0.79861 0.00190 22520
49	3906	0.79992	0.81154	0.80198	0.79899	0.00253	0.79847	0.00219	0.79938	0.00265	0.79895 0.00188 22331
50	4094	0.77302	0.80973	0.77043	0.79812	0.00259	0.79884	0.00215	0.79841	0.00273	0.79883 0.00181 23038
51	3875	0.82641	0.79335	0.83030	0.79904	0.00267	0.79866	0.00208	0.79944	0.00284	0.79908 0.00178 23301
52	4398	0.82243	0.79738	0.81969	0.79977	0.00268	0.79862	0.00202	0.80008	0.00282	0.79921 0.00171 24194
53	3977	0.79275	0.80598	0.78960	0.79955	0.00261	0.79885	0.00197	0.79976	0.00275	0.79922 0.00165 25206
54	3911	0.80057	0.77496	0.80483	0.79958	0.00253	0.79814	0.00203	0.79991	0.00267	0.79890 0.00166 24379
55	4067	0.78982	0.78201	0.79032	0.79930	0.00247	0.79768	0.00203	0.79963	0.00261	0.79851 0.00166 23524
56	3894	0.81103	0.78879	0.80426	0.79963	0.00243	0.79744	0.00199	0.79976	0.00254	0.79830 0.00163 23801
57	4136	0.81213	0.80332	0.80887	0.79997	0.00238	0.79759	0.00194	0.80001	0.00248	0.79844 0.00159 24169
58	4003	0.79675	0.80419	0.79240	0.79988	0.00232	0.79777	0.00189	0.79981	0.00242	0.79844 0.00155 24890
59	3942	0.80038	0.81532	0.80165	0.79990	0.00226	0.79822	0.00190	0.79985	0.00236	0.79881 0.00154 24659
60	3982	0.77995	0.81068	0.78236	0.79940	0.00226	0.79853	0.00188	0.79942	0.00234	0.79887 0.00149 25548
61	3921	0.80723	0.81705	0.81035	0.79959	0.00221	0.79898	0.00189	0.79968	0.00230	0.79927 0.00151 24392
62	4075	0.78122	0.79533	0.78705	0.79915	0.00220	0.79889	0.00184	0.79938	0.00226	0.79913 0.00148 24677
63	3815	0.80052	0.78796	0.79604	0.79918	0.00215	0.79864	0.00182	0.79931	0.00221	0.79892 0.00146 24874
64	4076	0.79089	0.80455	0.79564	0.79899	0.00211	0.79877	0.00178	0.79922	0.00216	0.79897 0.00143 25382
65	3765	0.79851	0.81069	0.80033	0.79898	0.00206	0.79904	0.00176	0.79925	0.00212	0.79913 0.00141 25588
66	3992	0.82511	0.80844	0.82575	0.79955	0.00210	0.79924	0.00173	0.79982	0.00215	0.79948 0.00142 24517
67	4161	0.80895	0.82616	0.80597	0.79975	0.00206	0.79982	0.00179	0.79995	0.00211	0.79990 0.00145 23249
68	3820	0.83281	0.81534	0.83144	0.80044	0.00213	0.80014	0.00178	0.80061	0.00216	0.80036 0.00149 21589
69	4034	0.77999	0.81056	0.78039	0.80002	0.00213	0.80035	0.00176	0.80020	0.00216	0.80034 0.00146 22045
70	3736	0.79860	0.81932	0.79297	0.79999	0.00209	0.80073	0.00176	0.80005	0.00212	0.80049 0.00143 22344
71	4150	0.79966	0.80242	0.80188	0.79999	0.00204	0.80076	0.00173	0.80009	0.00208	0.80054 0.00140 22757
72	4043	0.82542	0.80983	0.82066	0.80048	0.00206	0.80094	0.00170	0.80048	0.00208	0.80077 0.00139 22687
73	4124	0.81932	0.79358	0.81757	0.80083	0.00206	0.80080	0.00168	0.80081	0.00206	0.80079 0.00137 23153
74	3919	0.81272	0.80773	0.81041	0.80105	0.00203	0.80093	0.00165	0.80098	0.00203	0.80092 0.00135 23401

75	3987	0.80974	0.81604	0.80657	0.80121	0.00200	0.80120	0.00164	0.80109 0.00200	0.80109 0.00133	23386
76	3990	0.80301	0.80955	0.79962	0.80124	0.00196	0.80135	0.00162	0.80106 0.00196	0.80114 0.00131	23762
77	3987	0.81782	0.80002	0.82037	0.80153	0.00195	0.80133	0.00159	0.80140 0.00196	0.80128 0.00130	23975
78	4080	0.78392	0.80905	0.78567	0.80123	0.00194	0.80146	0.00157	0.80113 0.00194	0.80129 0.00127	24443
79	3811	0.77934	0.79720	0.77880	0.80086	0.00194	0.80139	0.00155	0.80075 0.00194	0.80111 0.00126	24319
80	3960	0.81386	0.79641	0.81326	0.80108	0.00192	0.80131	0.00152	0.80096 0.00192	0.80112 0.00124	24766
81	4231	0.79354	0.81010	0.79318	0.80095	0.00189	0.80145	0.00150	0.80083 0.00190	0.80117 0.00122	25131
82	3867	0.77875	0.81023	0.77910	0.80059	0.00190	0.80159	0.00149	0.80048 0.00190	0.80114 0.00120	25511
83	3897	0.80081	0.81822	0.80172	0.80060	0.00187	0.80186	0.00149	0.80050 0.00187	0.80132 0.00120	25285
84	4009	0.77825	0.79344	0.77965	0.80025	0.00187	0.80173	0.00147	0.80017 0.00187	0.80114 0.00120	24991
85	3843	0.81724	0.80928	0.82245	0.80051	0.00186	0.80184	0.00145	0.80052 0.00187	0.80139 0.00120	24458
86	4219	0.80382	0.78367	0.79889	0.80056	0.00183	0.80157	0.00145	0.80049 0.00184	0.80116 0.00120	24067
87	3997	0.80834	0.81391	0.80429	0.80068	0.00181	0.80175	0.00144	0.80055 0.00181	0.80127 0.00119	24167
88	4101	0.81015	0.75903	0.80888	0.80082	0.00179	0.80112	0.00156	0.80067 0.00179	0.80090 0.00122	22615
89	4026	0.79241	0.78245	0.78813	0.80069	0.00176	0.80085	0.00156	0.80049 0.00177	0.80067 0.00123	21974
90	3930	0.78347	0.81320	0.77774	0.80045	0.00176	0.80103	0.00154	0.80016 0.00178	0.80064 0.00121	22188
91	3918	0.80303	0.79628	0.80292	0.80048	0.00173	0.80096	0.00152	0.80020 0.00175	0.80061 0.00120	22516
92	4089	0.79987	0.82386	0.79873	0.80048	0.00171	0.80128	0.00154	0.80018 0.00173	0.80078 0.00119	22327
93	3955	0.78302	0.79767	0.78930	0.80024	0.00170	0.80123	0.00152	0.80003 0.00171	0.80068 0.00118	22611
94	4035	0.79948	0.80383	0.80006	0.80023	0.00168	0.80126	0.00150	0.80003 0.00169	0.80071 0.00116	22927
95	4121	0.78997	0.78963	0.79319	0.80009	0.00166	0.80111	0.00148	0.79994 0.00167	0.80058 0.00115	23005
96	3960	0.79864	0.80282	0.79758	0.80007	0.00164	0.80113	0.00146	0.79991 0.00165	0.80058 0.00114	23312
97	3969	0.82276	0.80096	0.82217	0.80036	0.00164	0.80113	0.00144	0.80020 0.00165	0.80070 0.00113	23393
98	4019	0.79429	0.80589	0.80067	0.80029	0.00163	0.80119	0.00143	0.80021 0.00163	0.80076 0.00111	23685
99	3829	0.80621	0.80199	0.81055	0.80036	0.00161	0.80120	0.00141	0.80034 0.00161	0.80083 0.00110	23934
100	4086	0.78617	0.79977	0.78380	0.80018	0.00160	0.80118	0.00139	0.80013 0.00161	0.80073 0.00109	23998
101	3895	0.78138	0.78797	0.78799	0.79995	0.00159	0.80102	0.00138	0.79998 0.00159	0.80059 0.00109	23857
102	3957	0.79724	0.79213	0.80013	0.79992	0.00157	0.80091	0.00137	0.79998 0.00157	0.80054 0.00108	24095
103	4188	0.81974	0.80086	0.81369	0.80016	0.00157	0.80091	0.00135	0.80015 0.00156	0.80059 0.00106	24381
104	4172	0.78052	0.81462	0.77954	0.79992	0.00157	0.80107	0.00135	0.79990 0.00156	0.80058 0.00105	24623
105	3843	0.83055	0.77688	0.82751	0.80028	0.00159	0.80079	0.00136	0.80023 0.00158	0.80054 0.00104	24965
106	4235	0.81870	0.78454	0.82130	0.80050	0.00159	0.80060	0.00136	0.80047 0.00158	0.80054 0.00103	25275
107	3996	0.80101	0.82032	0.79591	0.80050	0.00157	0.80083	0.00136	0.80042 0.00156	0.80063 0.00102	25350
108	3949	0.79912	0.80010	0.79756	0.80049	0.00155	0.80082	0.00135	0.80039 0.00155	0.80061 0.00101	25635
109	4050	0.79574	0.79931	0.79252	0.80044	0.00154	0.80080	0.00133	0.80030 0.00153	0.80055 0.00100	25817
110	3921	0.79568	0.79450	0.79879	0.80038	0.00152	0.80073	0.00132	0.80028 0.00151	0.80051 0.00099	26104
111	4012	0.78699	0.80750	0.78308	0.80024	0.00151	0.80081	0.00131	0.80009 0.00151	0.80047 0.00098	26297
112	3932	0.78765	0.78817	0.79043	0.80010	0.00150	0.80067	0.00130	0.79999 0.00150	0.80035 0.00097	26225
113	4134	0.77360	0.78068	0.77608	0.79981	0.00151	0.80045	0.00130	0.79973 0.00150	0.80012 0.00099	25113
114	3897	0.78875	0.79790	0.79136	0.79970	0.00150	0.80043	0.00129	0.79964 0.00149	0.80008 0.00098	25346
115	4007	0.77872	0.80868	0.78434	0.79948	0.00150	0.80051	0.00128	0.79948 0.00148	0.80009 0.00097	25591
116	3968	0.78630	0.80985	0.78252	0.79934	0.00149	0.80061	0.00127	0.79930 0.00148	0.80006 0.00096	25806
117	3931	0.80481	0.82648	0.80742	0.79939	0.00148	0.80088	0.00128	0.79939 0.00146	0.80024 0.00097	24952
118	4063	0.78096	0.79461	0.77778	0.79921	0.00147	0.80081	0.00127	0.79917 0.00147	0.80011 0.00097	24647
119	3795	0.77811	0.80078	0.78047	0.79899	0.00147	0.80081	0.00126	0.79898 0.00146	0.80004 0.00097	24716
120	3972	0.77071	0.80758	0.77564	0.79871	0.00149	0.80088	0.00125	0.79875 0.00147	0.80001 0.00096	24830

the largest active cycle keffs by estimator are:

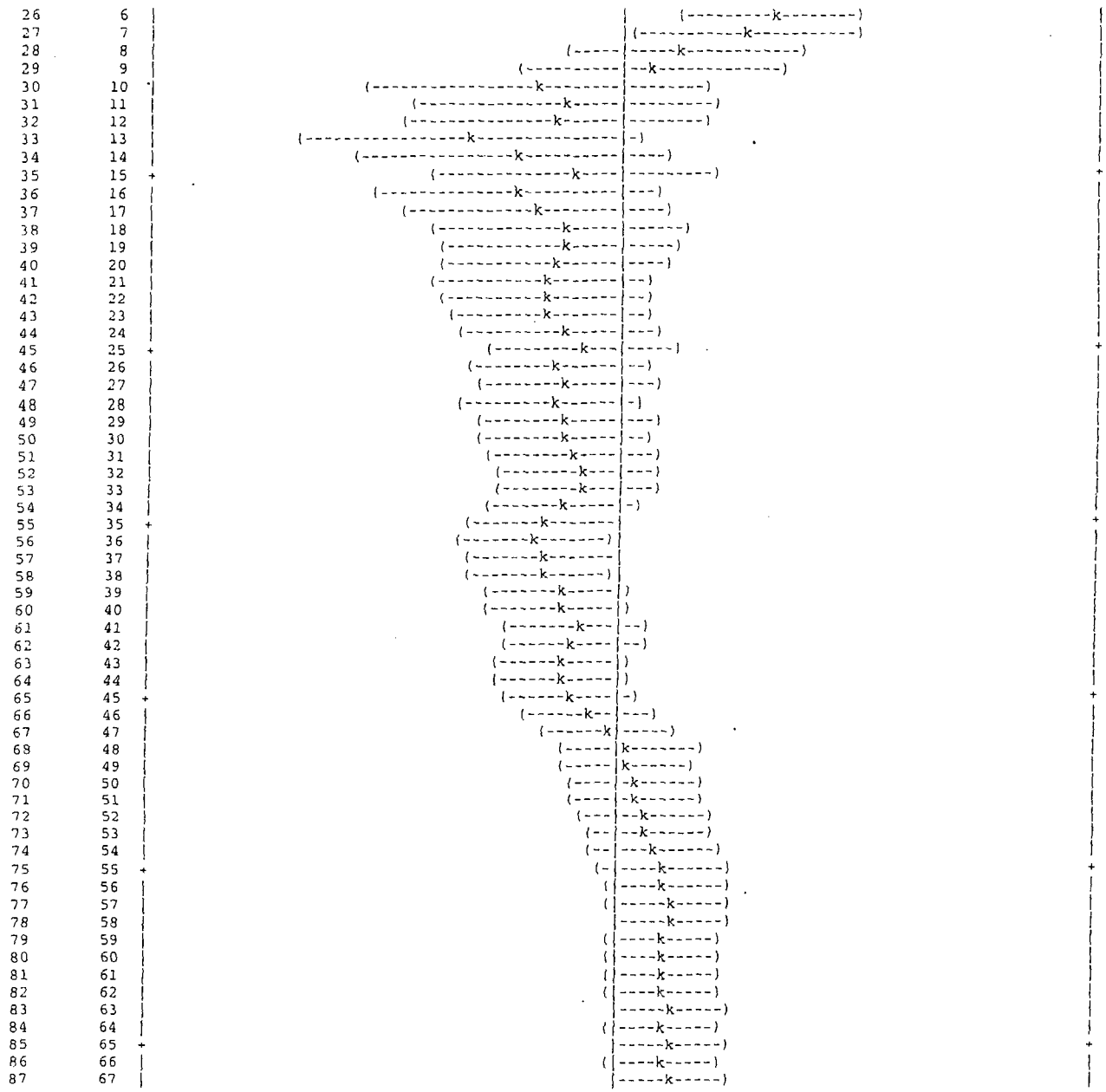
collision 0.83281 on cycle 68
absorption 0.82648 on cycle 117
track length 0.83193 on cycle 27

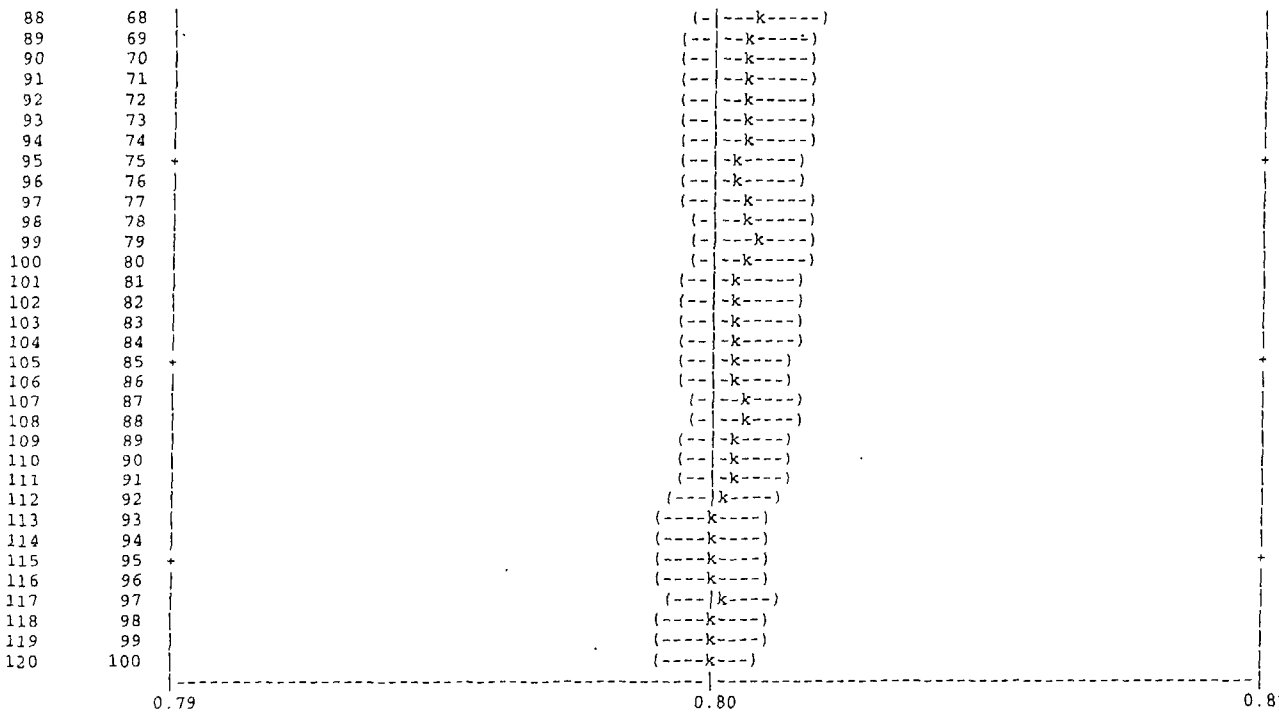
the smallest active cycle keffs by estimator are:

collision 0.77071 on cycle 120
absorption 0.75903 on cycle 88
track length 0.77043 on cycle 50

1plot of the estimated col/abs/track-length keff one standard deviation interval versus cycle number (| = final keff = 0.80001)

cycle number | active cycles | 0.79 | 0.80 | 0.81 |





lindividual and collision/absorption/track-length keffs for different numbers of inactive cycles skipped for fission source settling

skip cycles	active cycles	active neutrons	average keff estimators and deviations k(col)	st dev	k(abs)	st dev	k(trk)	st dev	normality co/ab/tl	average k(c/a/t) k(c/a/t)	st dev	k(c/a/t) confidence intervals 95% confidence	99% confidence
0	120	478718	0.7995	0.0020	0.8018	0.0019	0.7996	0.0020	no/no/no	0.80080	0.00178	0.79727-0.80434	0.79611-0.80550
1	119	474718	0.7981	0.0014	0.8003	0.0012	0.7983	0.0014	95/95/95	0.79952	0.00098	0.79756-0.80147	0.79692-0.80211
2	118	470824	0.7980	0.0014	0.8000	0.0012	0.7981	0.0014	95/95/95	0.79932	0.00096	0.79741-0.80123	0.79679-0.80185
3	117	467518	0.7983	0.0014	0.8003	0.0012	0.7984	0.0014	95/95/95	0.79963	0.00091	0.79781-0.80144	0.79722-0.80204
4	116	463818	0.7982	0.0014	0.8005	0.0012	0.7984	0.0014	95/95/95	0.79972	0.00092	0.79790-0.80155	0.79730-0.80215
5	115	459512	0.7984	0.0014	0.8005	0.0012	0.7985	0.0014	95/95/95	0.79976	0.00092	0.79792-0.80160	0.79732-0.80220
6	114	455621	0.7985	0.0014	0.8005	0.0012	0.7987	0.0014	95/95/95	0.79983	0.00093	0.79798-0.80168	0.79737-0.80228
7	113	451699	0.7982	0.0014	0.8004	0.0012	0.7984	0.0014	95/95/95	0.79966	0.00093	0.79781-0.80152	0.79721-0.80212
8	112	447357	0.7980	0.0014	0.8004	0.0012	0.7982	0.0014	95/95/95	0.79955	0.00093	0.79769-0.80141	0.79708-0.80202
9	111	443508	0.7979	0.0014	0.8005	0.0012	0.7981	0.0014	95/95/95	0.79954	0.00094	0.79766-0.80142	0.79704-0.80203
10	110	439598	0.7980	0.0014	0.8004	0.0012	0.7982	0.0014	95/95/95	0.79952	0.00095	0.79762-0.80141	0.79700-0.80203
11	109	435727	0.7980	0.0014	0.8003	0.0012	0.7982	0.0014	95/95/95	0.79945	0.00096	0.79755-0.80136	0.79693-0.80198
12	108	431645	0.7979	0.0014	0.8003	0.0012	0.7980	0.0014	95/95/95	0.79941	0.00096	0.79748-0.80133	0.79686-0.80195
13	107	427657	0.7980	0.0015	0.8005	0.0012	0.7982	0.0014	95/95/95	0.79960	0.00095	0.79770-0.80150	0.79708-0.80212
14	106	423803	0.7979	0.0015	0.8005	0.0012	0.7980	0.0014	95/95/95	0.79948	0.00096	0.79757-0.80138	0.79695-0.80200
15	105	419719	0.7980	0.0015	0.8004	0.0012	0.7981	0.0014	95/95/95	0.79948	0.00096	0.79756-0.80140	0.79693-0.80203
16	104	415944	0.7981	0.0015	0.8006	0.0012	0.7982	0.0014	95/95/95	0.79967	0.00096	0.79776-0.80158	0.79714-0.80220
17	103	411844	0.7982	0.0015	0.8006	0.0012	0.7982	0.0015	95/95/95	0.79967	0.00097	0.79774-0.80159	0.79712-0.80222
18	102	407832	0.7983	0.0015	0.8005	0.0013	0.7984	0.0015	95/95/95	0.79969	0.00097	0.79774-0.80163	0.79711-0.80226
19	101	403840	0.7986	0.0015	0.8008	0.0012	0.7986	0.0015	95/95/95	0.79990	0.00096	0.79800-0.80181	0.79738-0.80243
20	100*	399949	0.7987	0.0015	0.8009	0.0012	0.7987	0.0015	95/95/95	0.80001	0.00096	0.79810-0.80192	0.79747-0.80255

22	98	391499	0.7985	0.0015	0.8007	0.0013	0.7986	0.0015	95/95/95	0.79986	0.00096	0.79794-0.80178	0.79732-0.80241
24	96	383601	0.7985	0.0015	0.8007	0.0013	0.7985	0.0015	95/95/95	0.79981	0.00097	0.79788-0.80174	0.79725-0.80237
26	94	375871	0.7982	0.0015	0.8007	0.0013	0.7983	0.0015	95/95/95	0.79965	0.00098	0.79770-0.80160	0.79706-0.80223
28	92	367656	0.7980	0.0015	0.8009	0.0013	0.7980	0.0015	95/95/95	0.79962	0.00100	0.79762-0.80162	0.79697-0.80227
30	90	359808	0.7981	0.0015	0.8010	0.0013	0.7982	0.0015	95/95/95	0.79980	0.00100	0.79781-0.80180	0.79716-0.80245
32	88	351850	0.7980	0.0016	0.8012	0.0014	0.7980	0.0015	95/95/95	0.79982	0.00103	0.79778-0.80186	0.79711-0.80253
34	86	343955	0.7982	0.0016	0.8015	0.0013	0.7982	0.0015	95/95/95	0.80011	0.00102	0.79808-0.80214	0.79741-0.80280
36	84	335972	0.7985	0.0016	0.8017	0.0013	0.7985	0.0016	95/95/95	0.80030	0.00102	0.79827-0.80232	0.79761-0.80299
38	82	327923	0.7985	0.0016	0.8015	0.0014	0.7985	0.0016	95/95/95	0.80021	0.00104	0.79814-0.80227	0.79747-0.80294
40	80	319798	0.7985	0.0017	0.8015	0.0014	0.7986	0.0016	95/95/95	0.80030	0.00106	0.79819-0.80241	0.79750-0.80310
42	78	311899	0.7985	0.0017	0.8017	0.0014	0.7986	0.0017	95/95/95	0.80039	0.00108	0.79824-0.80255	0.79754-0.80325
44	76	303794	0.7984	0.0018	0.8016	0.0015	0.7985	0.0017	95/95/95	0.80033	0.00111	0.79813-0.80254	0.79741-0.80326
46	74	295680	0.7988	0.0018	0.8016	0.0015	0.7988	0.0017	95/95/95	0.80041	0.00111	0.79819-0.80263	0.79747-0.80336
48	72	287649	0.7986	0.0018	0.8020	0.0015	0.7985	0.0017	95/95/95	0.80051	0.00113	0.79825-0.80277	0.79751-0.80351
50	70	279649	0.7990	0.0018	0.8018	0.0015	0.7989	0.0018	95/95/95	0.80049	0.00115	0.79819-0.80279	0.79744-0.80354
52	68	271376	0.7982	0.0018	0.8019	0.0016	0.7981	0.0017	95/95/95	0.80017	0.00118	0.79781-0.80253	0.79703-0.80330
54	66	263488	0.7983	0.0018	0.8023	0.0016	0.7981	0.0018	95/95/95	0.80043	0.00121	0.79801-0.80285	0.79721-0.80364
56	64	255527	0.7982	0.0019	0.8028	0.0016	0.7982	0.0018	95/95/95	0.80082	0.00123	0.79837-0.80328	0.79757-0.80408
58	62	247388	0.7980	0.0019	0.8028	0.0016	0.7981	0.0019	95/95/95	0.80080	0.00126	0.79827-0.80333	0.79744-0.80417
60	60	239464	0.7983	0.0020	0.8024	0.0016	0.7983	0.0019	95/95/95	0.80069	0.00129	0.79811-0.80327	0.79725-0.80412
62	58	231468	0.7984	0.0020	0.8023	0.0017	0.7983	0.0019	95/95/95	0.80055	0.00130	0.79795-0.80316	0.79709-0.80402
64	56	223577	0.7985	0.0021	0.8025	0.0017	0.7984	0.0020	95/95/95	0.80073	0.00133	0.79806-0.80340	0.79717-0.80429
66	54	215820	0.7980	0.0021	0.8023	0.0018	0.7978	0.0020	95/95/95	0.80026	0.00135	0.79756-0.80296	0.79666-0.80386
68	52	207839	0.7971	0.0021	0.8016	0.0018	0.7970	0.0020	95/95/95	0.79951	0.00129	0.79693-0.80210	0.79607-0.80296
70	50	200069	0.7974	0.0021	0.8010	0.0018	0.7974	0.0020	95/95/99	0.79945	0.00132	0.79680-0.80211	0.79591-0.80299
72	48	191876	0.7968	0.0021	0.8008	0.0019	0.7969	0.0021	95/95/99	0.79904	0.00134	0.79634-0.80175	0.79543-0.80266
74	46	183833	0.7960	0.0021	0.8008	0.0019	0.7961	0.0021	95/95/99	0.79866	0.00139	0.79585-0.80147	0.79491-0.80242
76	44	175856	0.7955	0.0022	0.8003	0.0020	0.7958	0.0022	95/95/99	0.79823	0.00142	0.79537-0.80109	0.79440-0.80206
78	42	167789	0.7952	0.0022	0.8001	0.0021	0.7955	0.0022	95/95/99	0.79790	0.00146	0.79495-0.80084	0.79396-0.80184
80	40	160018	0.7952	0.0023	0.8002	0.0022	0.7954	0.0022	95/95/95	0.79790	0.00150	0.79485-0.80094	0.79381-0.80198
82	38	151920	0.7956	0.0023	0.7997	0.0022	0.7959	0.0023	95/95/95	0.79786	0.00156	0.79469-0.80104	0.79360-0.80212
84	36	144014	0.7960	0.0024	0.7994	0.0023	0.7962	0.0023	95/95/95	0.79784	0.00157	0.79464-0.80103	0.79354-0.80213
86	34	135952	0.7951	0.0025	0.7996	0.0024	0.7954	0.0023	95/95/95	0.79753	0.00155	0.79436-0.80070	0.79327-0.80179
88	32	127854	0.7942	0.0025	0.8004	0.0021	0.7947	0.0024	95/95/95	0.79803	0.00157	0.79481-0.80124	0.79369-0.80236
90	30	119898	0.7947	0.0027	0.8005	0.0021	0.7954	0.0025	95/95/95	0.79880	0.00159	0.79553-0.80207	0.79439-0.80321
92	28	111891	0.7942	0.0029	0.7999	0.0021	0.7950	0.0027	95/95/95	0.79836	0.00161	0.79504-0.80168	0.79387-0.80286
94	26	103901	0.7944	0.0030	0.7998	0.0023	0.7951	0.0029	95/95/95	0.79822	0.00171	0.79468-0.80177	0.79342-0.80303
96	24	95820	0.7944	0.0033	0.8001	0.0024	0.7951	0.0031	95/95/95	0.79837	0.00184	0.79454-0.80219	0.79316-0.80358
98	22	87832	0.7931	0.0033	0.7998	0.0026	0.7936	0.0032	95/95/95	0.79738	0.00190	0.79341-0.80135	0.79196-0.80280
100	20	79917	0.7928	0.0036	0.7997	0.0029	0.7932	0.0033	95/95/95	0.79707	0.00197	0.79291-0.80122	0.79135-0.80278
102	18	72065	0.7932	0.0039	0.8007	0.0031	0.7931	0.0037	95/95/95	0.79731	0.00221	0.79261-0.80202	0.79080-0.80382
104	16	63705	0.7923	0.0040	0.7999	0.0034	0.7927	0.0038	95/95/95	0.79675	0.00246	0.79143-0.80207	0.78933-0.80417
106	14	55627	0.7877	0.0028	0.8026	0.0032	0.7881	0.0026	95/95/95	0.79303	0.00422	0.78376-0.80231	0.77994-0.80613
108	12	47682	0.7857	0.0029	0.8013	0.0034	0.7867	0.0028	95/95/95	0.79136	0.00472	0.78067-0.80205	0.77601-0.80671
110	10	39711	0.7837	0.0031	0.8022	0.0041	0.7849	0.0030	95/95/95	0.78757	0.00676	0.77158-0.80356	0.76390-0.81124
112	8	31767	0.7827	0.0038	0.8033	0.0047	0.7845	0.0037	95/95/99	0.78639	0.01044	0.75955-0.81323	0.74429-0.82849
114	6	23736	0.7833	0.0048	0.8080	0.0044	0.7847	0.0047	95/95/99	0.80613	0.02541	0.72524-0.88703	0.65769-0.95458
116	4	15761	0.7836	0.0074	0.8074	0.0069	0.7853	0.0074	95/95/95	0.83547	0.04304	0.28843-1.38252	0.00000-3.57543
117	3	11830	0.7766	0.0031	0.8010	0.0037	0.7780	0.0014					
118	2	7767	0.7744	0.0037	0.8042	0.0034	0.7781	0.0024					

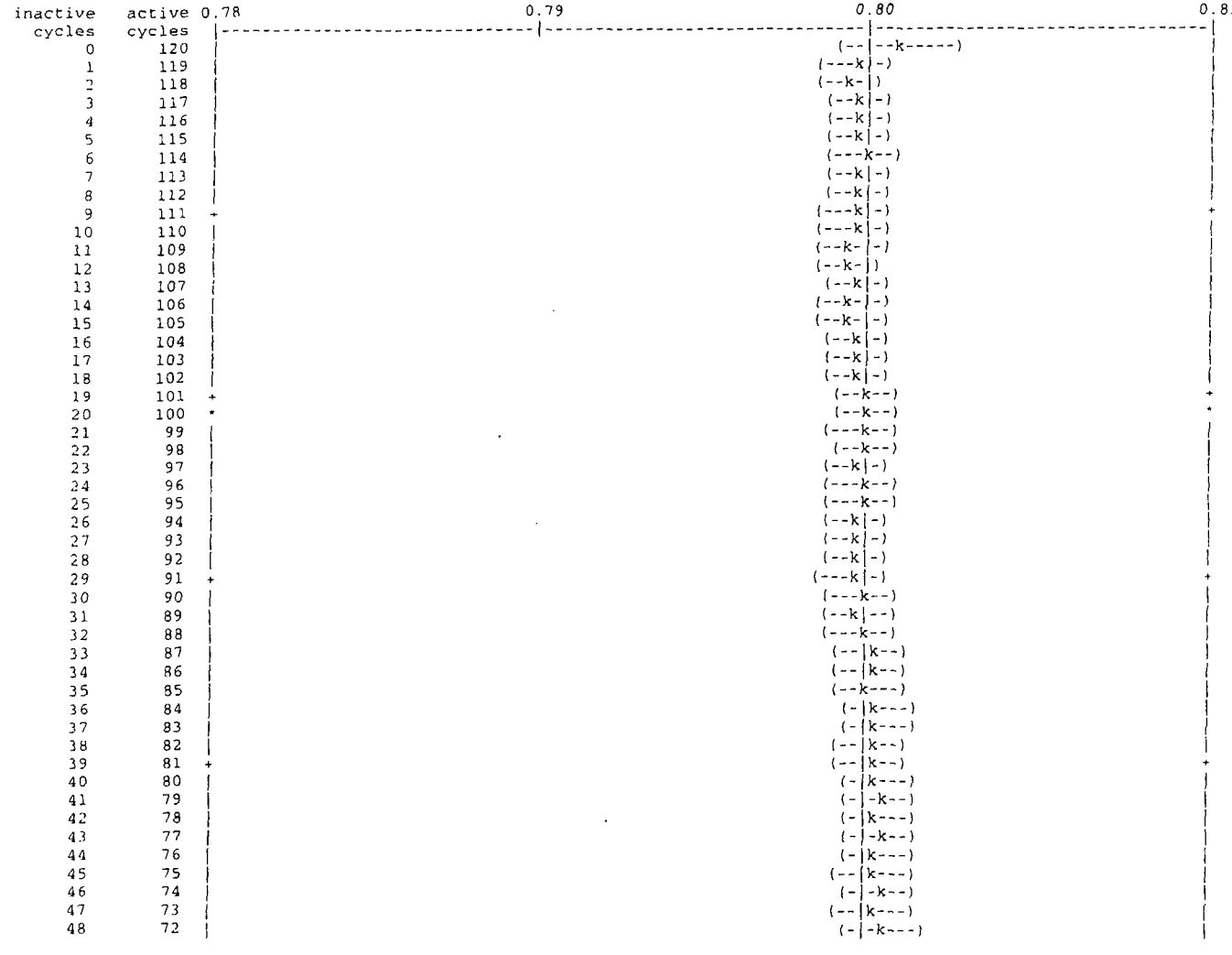
the minimum estimated standard deviation for the col/abs/tl keff estimator occurs with 3 inactive cycles and 117 active cycles.

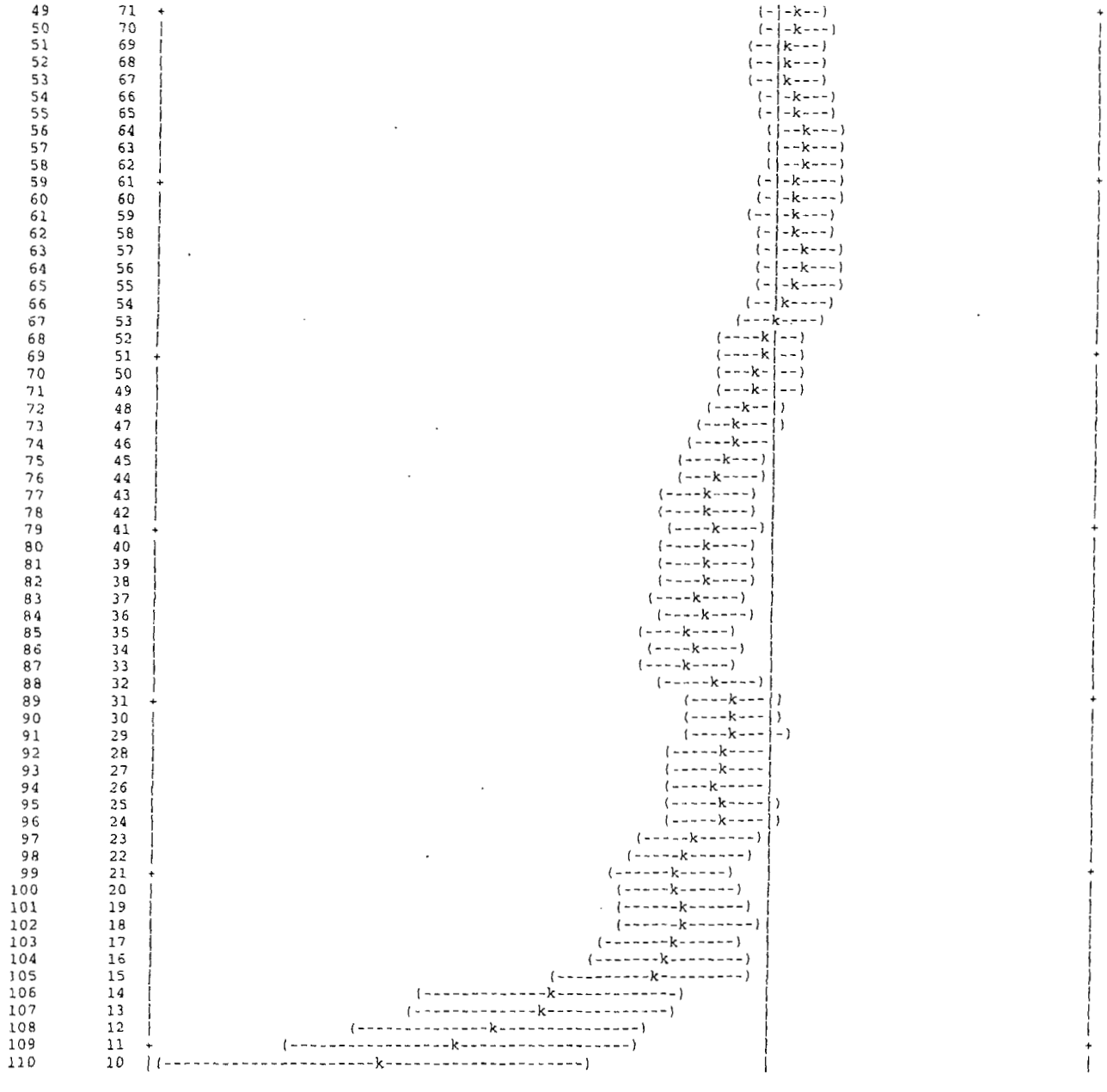
the first active half of the problem skips 20 cycles and uses 50 active cycles; the second half skips 70 and uses 50 cycles.

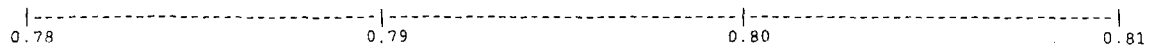
the col/abs/trk-len keff, one standard deviation, and 68, 95, and 99 percent intervals for each active half of the problem are:

problem	keff	standard deviation	68% confidence	95% confidence	99% confidence
first half	0.80049	0.00143	0.79905 to 0.80193	0.79761 to 0.80337	0.79665 to 0.80434
second half	0.79945	0.00132	0.79812 to 0.80078	0.79680 to 0.80211	0.79591 to 0.80299
final result	0.80001	0.00096	0.79905 to 0.80097	0.79810 to 0.80192	0.79747 to 0.80255

the first and second half values of k(collision/absorption/track length) appear to be the same at the 68 percent confidence level.
1plot of the estimated col/abs/track-length keff one standard deviation interval by active cycle number (| = final keff = 0.80001)







dump no. 4 on file 3s610r nps = 478718 coll = 63684233 ctm = 33.48 nrn = 1105545149

2 warning messages so far.

run terminated when 120 kcode cycles were done.

computer time = 33.50 minutes

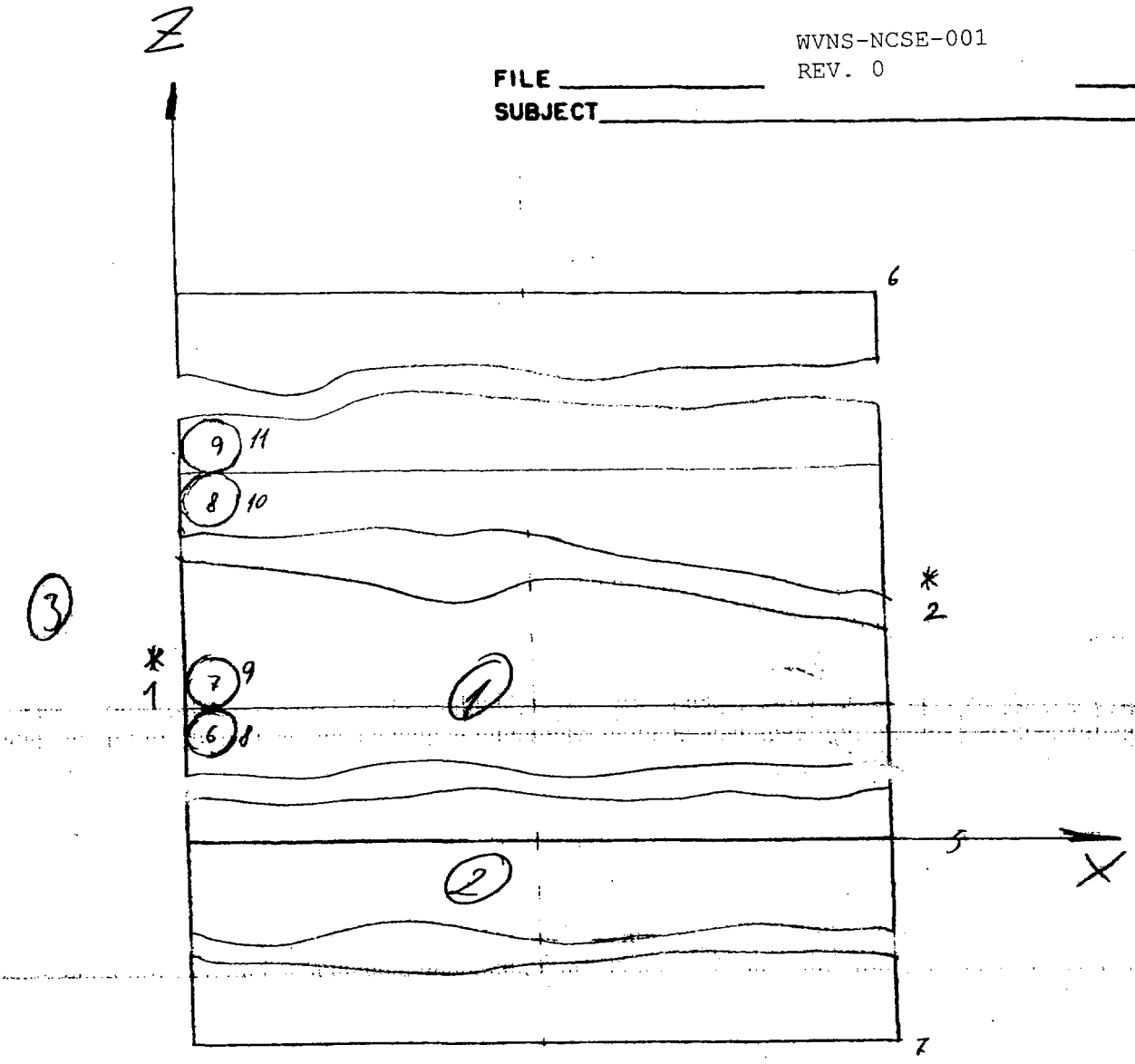
mcnp version 4a 10/01/93 12/19/00 11:46:59 probid = 12/19/00 11:13:29

Attachment 4: Case 2 with MCNP surface and cell numbers

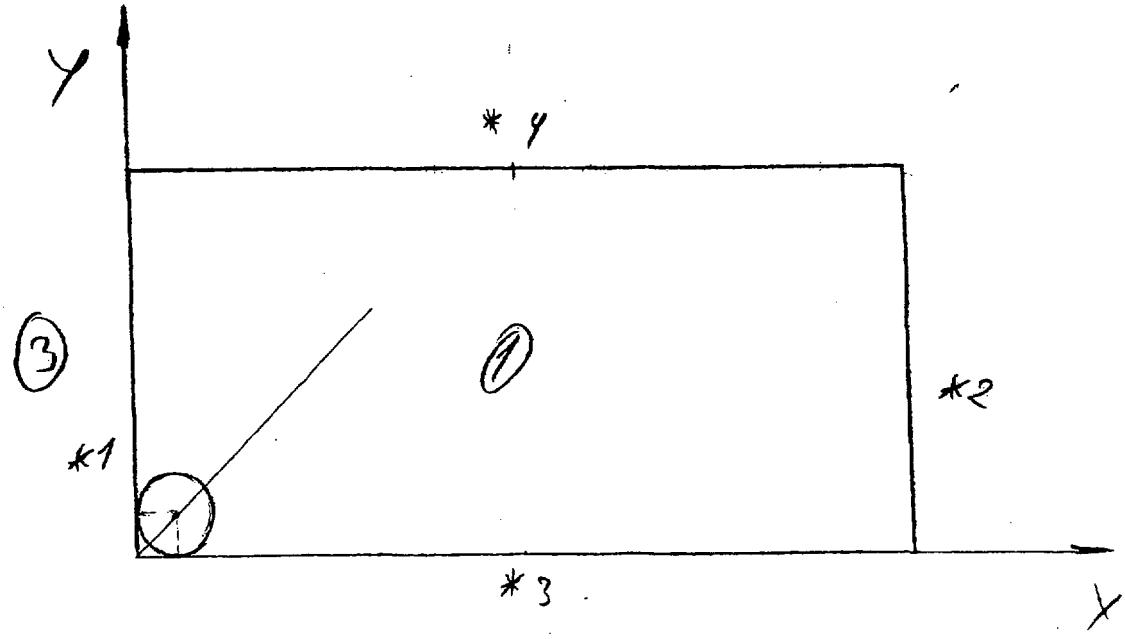
FILE _____

SUBJECT _____

REVISIONS
BY _____ DATE _____ TO EO _____
BY _____ DATE _____ TO EO _____
BY _____



BY _____ DATE _____
CHECKED BY _____
COPY TO EO _____



Dames & Moore

Attachment 5: Case 2 MCNP input file

```
                                                        3s510
k eff, 350g Pu-239 in cellulose spheres and pure celulose
c in the rest of B-25 box (68"x54"x34.5").
C
C Cell cards
C
C ------------------------------------------------------------------------
1 1  -0.90     1 -2 3 -4 5 -6 8 9 10 11 imp:n=1 $ TRU box with cellulose
2 2  -2.3     1 -2 3 -4 -5 7            imp:n=1 $ Concrete floor
3 0          -1 : 2 : -3 : 4 : -7 : 6  imp:n=0 $ Outside world
4 3  -0.909969 -8                      imp:n=1 $ 1 Pu-239 and cellulose sphere
5 3  -0.909969 -9                      imp:n=1 $ 2 Pu-239 and cellulose sphere
6 3  -0.909969 -10                     imp:n=1 $ 3 Pu-239 and cellulose sphere
7 3  -0.909969 -11                     imp:n=1 $ 4 Pu-239 and cellulose sphere
C ------------------------------------------------------------------------
c
c Note: next line must be completely blank

c Surface cards
C ------------------------------------------------------------------------
*1 px 0
*2 px 172.72  $ B-25 box length (68")
*3 py 0
*4 py 137.16  $ B-25 box width (54")
5  pz 0
6  pz 350.52  $ 4 tiers of B-25 box height (4x34.5" or 4x87.63 cm)
7  pz -300
8  s 20.0 20.0  67.63 20.0 $ 1st Pu-239 and cellulose sphere
9  s 20.0 20.0 107.63 20.0 $ 2nd Pu-239 and cellulose sphere
10 s 20.0 20.0 242.89 20.0 $ 3rd Pu-239 and cellulose sphere
11 s 20.0 20.0 282.89 20.0 $ 4th Pu-239 and cellulose sphere
C ------------------------------------------------------------------------
c
c Note: next line must be completely blank

c Data cards
c
c Materials
c
c
c Celulose matrix (Elements: C, H, O)
m1      6000.50c  -0.444
        1001.50c  -0.062
        8016.50c  -0.493
c Concrete (KENO Regular Concrete Standard Mix) from Harmon at al.
c Criticality Calculation with MCNP. A Primer. p. C-4
c (Elements: H, O, Na, Si, Al, Ca, Fe)
m2      1001.50c -0.010
        8016.50c -0.532
       11023.50c -0.029
       13027.50c -0.034
       14000.50c -0.337
       20000.50c -0.044
       26000.55c -0.014
c Pu-239 and cellulose
m3     94239.55c  -0.011478
        6000.50c  -0.439354
        1001.50c  -0.061451
        8016.50c  -0.487717
c
mode n
print 40 60 80 100 110 126
kcode 4000 1. 20 120
ksrc  20.0 20.0  67.63
      20.0 20.0 107.63
      20.0 20.0 242.89
      20.0 20.0 282.89
```

Attachment 6: Case 2 MCNP output file

```
lmcnp     version 4a    ld=10/01/93                    12/13/00 04:12:29
*************************************************************************          probid =   12/13/00 04:12:29
name=3s510

      k eff, 350g Pu-239 in cellulose spheres and pure celulose
      c in the rest of B-25 box (68"x54"x34.5").
      C
      C Cell cards
      C
      C ---------------------------------------------------------------------
      1 1  -0.90    1 -2 3 -4 5 -6 8 9 10 11 imp:n=1 $ TRU box with cellulose
      2 2  -2.3    1 -2 3 -4 -5 7           imp:n=1 $ Concrete floor
      3 0         -1 : 2 : -3 : 4 : -7 : 6  imp:n=0 $ Outside world
      4 3  -0.909969 -8                     imp:n=1 $ 1 Pu-239 and cellulose sphere
      5 3  -0.909969 -9                     imp:n=1 $ 2 Pu-239 and cellulose sphere
      6 3  -0.909969 -10                    imp:n=1 $ 3 Pu-239 and cellulose sphere
      7 3  -0.909969 -11                    imp:n=1 $ 4 Pu-239 and cellulose sphere
      C ---------------------------------------------------------------------
      c
      c Note: next line must be completely blank

      c Surface cards
      C ---------------------------------------------------------------------
      *1 px 0
      *2 px 172.72  $ B-25 box length (68")
      *3 py 0
      *4 py 137.16  $ B-25 box width (54")
      5  pz 0
      6  pz 350.52  $ 4 tiers of B-25 box height (4x34.5" or 4x87.63 cm)
      7  pz -300
      8  s 20.0 20.0  67.63 20.0 $ 1st Pu-239 and cellulose sphere
      9  s 20.0 20.0 107.63 20.0 $ 2nd Pu-239 and cellulose sphere
      10 s 20.0 20.0 242.89 20.0 $ 3rd Pu-239 and cellulose sphere
      11 s 20.0 20.0 282.89 20.0 $ 4th Pu-239 and cellulose sphere
      C ---------------------------------------------------------------------
      c
      c Note: next line must be completely blank

      c Data cards
      c
      c Materials
      c
      c
      c Celulose matrix (Elements: C, H, O)
      m1      6000.50c  -0.444
              1001.50c  -0.062
              8016.50c  -0.493
      c Concrete (KENO Regular Concrete Standard Mix) from Harmon at al.
      c Criticality Calculation with MCNP. A Primer. p. C-4
      c (Elements: H, O, Na, Si, Al, Ca, Fe)
      m2      1001.50c -0.010
              8016.50c -0.532
             11023.50c -0.029
             13027.50c -0.034
             14000.50c -0.337
             20000.50c -0.044
             26000.55c -0.014
      c Pu-239 and cellulose
```

```
   55-        m3    94239.55c  -0.011478
   56-              6000.50c  -0.439354
   57-              1001.50c  -0.061451
   58-              8016.50c  -0.487717
   59-        c
   60-        mode n
   61-        print 40 60 80 100 110 126
   62-        kcode 4000 1. 20 120
   63-        ksrc  20.0 20.0  67.63
   64-              20.0 20.0 107.63
   65-              20.0 20.0 242.89
   66-              20.0 20.0 282.89
   67-
 total fission nubar data are being used.
1material composition                                                    print table 40

 the sum of the fractions of material     1 was 9.990000E-01

 material
  number      component nuclide, atom fraction

      1            6000,  0.28588       1001,  0.47576       8016,  0.23837
      2            1001,  0.16803       8016,  0.56324      11023,  0.02136      13027,  0.02134
                  14000,  0.20319      20000,  0.01859      26000,  0.00425
      3           94239,  0.00037       6000,  0.28557       1001,  0.47601       8016,  0.23805



 material
  number      component nuclide, mass fraction

      1            6000,  0.44444       1001,  0.06206       8016,  0.49349
      2            1001,  0.01000       8016,  0.53200      11023,  0.02900      13027,  0.03400
                  14000,  0.33700      20000,  0.04400      26000,  0.01400
      3           94239,  0.01148       6000,  0.43935       1001,  0.06145       8016,  0.48772

 warning.     1 of the materials had unnormalized fractions.
1cells                                                                   print table 60

                          atom          gram                                        neutron
        cell  mat        density       density        volume          mass        pieces importance

      1     1    1  7.01524E-02 9.00000E-01 0.00000E+00 0.00000E+00      0  1.0000E+00
      2     2    2  8.17913E-02 2.30000E+00 7.10708E+06 1.63463E+07      0  1.0000E+00
      3     3    0  0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00      0  0.0000E+00
      4     4    3  7.01934E-02 9.09969E-01 3.35103E+04 3.04934E+04      1  1.0000E+00
      5     5    3  7.01934E-02 9.09969E-01 3.35103E+04 3.04934E+04      1  1.0000E+00
      6     6    3  7.01934E-02 9.09969E-01 3.35103E+04 3.04934E+04      1  1.0000E+00
      7     7    3  7.01934E-02 9.09969E-01 3.35103E+04 3.04934E+04      1  1.0000E+00

 total                                      7.24112E+06 1.64683E+07

         1 warning message so far.
1cross-section tables                                                    print table 100

     table    length
```

tables from file critxs

1001.50c	1153	njoy		(1301)	79/07/31.
6000.50c	16126	njoy		(1306)	79/07/31.
8016.50c	23669	njoy		(1276)	05/14/81
11023.50c	36270	njoy		(1311)	79/06/21.
13027.50c	22891	njoy		(1313)	79/09/08.
14000.50c	48275	njoy		(1314)	79/06/21.
20000.50c	26104	njoy		(1320)	79/06/22.
26000.55c	84136	njoy		(260)	10/21/82
94239.55c	67551	njoy	total nu	(1399)	02/21/85
total	326175				

warning. neutron energy cutoff is below some cross-section tables.

decimal words of dynamically allocated storage

general	111050
tallies	0
bank	6403
cross sections	326175
total	443628

dump no. 1 on file 3s510r nps = 0 coll = 0 ctm = 0.00 nrn = 0

source distribution written to file 3s510s cycle = 0

2 warning messages so far.
starting mcrun. field length = 0 cp0 = 0.01 print table 110

k eff, 350g Pu-239 in cellulose spheres and pure celulose

nps	x	y	z	cell	surf	u	v	w	energy	weight	time
1	2.000E+01	2.000E+01	6.763E+01	4	0	5.085E-01	4.733E-01	7.193E-01	2.209E+00	1.000E+00	0.000E+00
2	2.000E+01	2.000E+01	6.763E+01	4	0	8.952E-01	-4.447E-01	-2.944E-02	4.904E+00	1.000E+00	0.000E+00
3	2.000E+01	2.000E+01	6.763E+01	4	0	-6.184E-01	-4.495E-01	6.446E-01	3.809E-01	1.000E+00	0.000E+00
4	2.000E+01	2.000E+01	6.763E+01	4	0	9.710E-01	-5.665E-02	-2.323E-01	1.331E+00	1.000E+00	0.000E+00
5	2.000E+01	2.000E+01	6.763E+01	4	0	5.861E-01	1.496E-01	-7.963E-01	1.902E+00	1.000E+00	0.000E+00
6	2.000E+01	2.000E+01	6.763E+01	4	0	-6.489E-02	-1.626E-01	9.845E-01	4.410E-01	1.000E+00	0.000E+00
7	2.000E+01	2.000E+01	6.763E+01	4	0	-7.068E-02	3.263E-02	-9.970E-01	4.750E-01	1.000E+00	0.000E+00
8	2.000E+01	2.000E+01	6.763E+01	4	0	-3.915E-01	4.664E-01	-7.932E-01	4.136E+00	1.000E+00	0.000E+00
9	2.000E+01	2.000E+01	6.763E+01	4	0	-2.368E-01	9.215E-01	-3.079E-01	7.453E-02	1.000E+00	0.000E+00
10	2.000E+01	2.000E+01	6.763E+01	4	0	1.946E-01	-3.204E-01	9.271E-01	3.128E+00	1.000E+00	0.000E+00
11	2.000E+01	2.000E+01	6.763E+01	4	0	-6.698E-01	-7.177E-01	-1.905E-01	1.014E+00	1.000E+00	0.000E+00
12	2.000E+01	2.000E+01	6.763E+01	4	0	-8.398E-01	-4.129E-01	3.524E-01	1.395E+00	1.000E+00	0.000E+00
13	2.000E+01	2.000E+01	6.763E+01	4	0	-1.714E-01	-8.572E-01	4.857E-01	7.748E-01	1.000E+00	0.000E+00
14	2.000E+01	2.000E+01	6.763E+01	4	0	-2.489E-01	-5.118E-01	-8.222E-01	1.101E+00	1.000E+00	0.000E+00

15	2.000E+01	2.000E+01	6.763E+01	4	0	-2.959E-01	2.119E-01	9.314E-01	1.951E+00	1.000E+00	0.000E+00
16	2.000E+01	2.000E+01	6.763E+01	4	0	1.395E-01	-9.829E-01	1.202E-01	2.186E+00	1.000E+00	0.000E+00
17	2.000E+01	2.000E+01	6.763E+01	4	0	6.909E-01	-7.110E-01	1.307E-01	1.865E+00	1.000E+00	0.000E+00
18	2.000E+01	2.000E+01	6.763E+01	4	0	-6.580E-01	5.320E-01	-5.329E-01	1.229E+00	1.000E+00	0.000E+00
19	2.000E+01	2.000E+01	6.763E+01	4	0	-9.903E-01	-1.380E-01	1.353E-02	1.305E+00	1.000E+00	0.000E+00
20	2.000E+01	2.000E+01	6.763E+01	4	0	7.462E-01	4.859E-01	-4.551E-01	1.000E+00	1.000E+00	0.000E+00
21	2.000E+01	2.000E+01	6.763E+01	4	0	-1.977E-01	9.797E-01	3.360E-02	3.990E+00	1.000E+00	0.000E+00
22	2.000E+01	2.000E+01	6.763E+01	4	0	-9.117E-01	-3.647E-01	-1.891E-01	2.665E-01	1.000E+00	0.000E+00
23	2.000E+01	2.000E+01	6.763E+01	4	0	-4.287E-01	8.361E-01	-3.423E-01	1.156E+00	1.000E+00	0.000E+00
24	2.000E+01	2.000E+01	6.763E+01	4	0	1.080E-01	3.412E-01	-9.338E-01	2.669E+00	1.000E+00	0.000E+00
25	2.000E+01	2.000E+01	6.763E+01	4	0	-9.111E-01	-9.012E-03	-4.122E-01	2.185E+00	1.000E+00	0.000E+00
26	2.000E+01	2.000E+01	6.763E+01	4	0	-2.568E-01	-6.391E-01	-7.249E-01	4.225E+00	1.000E+00	0.000E+00
27	2.000E+01	2.000E+01	6.763E+01	4	0	-2.912E-01	8.086E-01	5.113E-01	1.079E+00	1.000E+00	0.000E+00
28	2.000E+01	2.000E+01	6.763E+01	4	0	1.472E-01	-9.514E-01	2.705E-01	3.461E+00	1.000E+00	0.000E+00
29	2.000E+01	2.000E+01	6.763E+01	4	0	-6.135E-01	-7.645E-01	-1.978E-01	1.836E+00	1.000E+00	0.000E+00
30	2.000E+01	2.000E+01	6.763E+01	4	0	-5.702E-01	5.651E-01	-5.963E-01	4.556E-01	1.000E+00	0.000E+00
31	2.000E+01	2.000E+01	6.763E+01	4	0	-6.607E-01	5.373E-01	-5.242E-01	6.415E-01	1.000E+00	0.000E+00
32	2.000E+01	2.000E+01	6.763E+01	4	0	-9.742E-02	-3.639E-01	-9.263E-01	2.764E+00	1.000E+00	0.000E+00
33	2.000E+01	2.000E+01	6.763E+01	4	0	-1.965E-01	-3.145E-01	-9.287E-01	2.785E-01	1.000E+00	0.000E+00
34	2.000E+01	2.000E+01	6.763E+01	4	0	4.097E-01	8.465E-01	-3.399E-01	9.097E-01	1.000E+00	0.000E+00
35	2.000E+01	2.000E+01	6.763E+01	4	0	-4.048E-02	8.831E-01	4.675E-01	3.360E-01	1.000E+00	0.000E+00
36	2.000E+01	2.000E+01	6.763E+01	4	0	3.371E-01	-9.269E-01	-1.652E-01	6.376E-01	1.000E+00	0.000E+00
37	2.000E+01	2.000E+01	6.763E+01	4	0	-1.867E-01	9.756E-01	-1.155E-01	2.186E+00	1.000E+00	0.000E+00
38	2.000E+01	2.000E+01	6.763E+01	4	0	-2.616E-01	2.336E-01	-9.365E-01	7.314E-01	1.000E+00	0.000E+00
39	2.000E+01	2.000E+01	6.763E+01	4	0	9.780E-01	-7.641E-02	-1.939E-01	2.997E-01	1.000E+00	0.000E+00
40	2.000E+01	2.000E+01	6.763E+01	4	0	2.580E-01	-7.076E-01	6.578E-01	1.444E+00	1.000E+00	0.000E+00
41	2.000E+01	2.000E+01	6.763E+01	4	0	-3.212E-01	-7.678E-01	-5.543E-01	1.914E+00	1.000E+00	0.000E+00
42	2.000E+01	2.000E+01	6.763E+01	4	0	5.039E-01	-1.460E-01	8.513E-01	1.502E+00	1.000E+00	0.000E+00
43	2.000E+01	2.000E+01	6.763E+01	4	0	6.080E-01	5.487E-01	5.738E-01	5.971E+00	1.000E+00	0.000E+00
44	2.000E+01	2.000E+01	6.763E+01	4	0	-2.932E-01	9.304E-01	-2.199E-01	1.827E+00	1.000E+00	0.000E+00
45	2.000E+01	2.000E+01	6.763E+01	4	0	-8.475E-01	-3.993E-01	-3.497E-01	1.928E+00	1.000E+00	0.000E+00
46	2.000E+01	2.000E+01	6.763E+01	4	0	1.200E-01	-9.195E-01	-3.743E-01	1.351E+00	1.000E+00	0.000E+00
47	2.000E+01	2.000E+01	6.763E+01	4	0	7.085E-01	5.879E-01	3.904E-01	2.288E+00	1.000E+00	0.000E+00
48	2.000E+01	2.000E+01	6.763E+01	4	0	4.261E-01	9.046E-01	9.254E-03	1.230E+00	1.000E+00	0.000E+00
49	2.000E+01	2.000E+01	6.763E+01	4	0	5.431E-01	4.270E-01	-7.230E-01	1.433E+00	1.000E+00	0.000E+00
50	2.000E+01	2.000E+01	6.763E+01	4	0	-1.053E-01	-9.805E-01	1.658E-01	6.572E-01	1.000E+00	0.000E+00

lestimated keff results by cycle print table 175

source distribution written to file 3s510s cycle = 20

source distribution written to file 3s510s cycle = 24

source distribution written to file 3s510s cycle = 28

source distribution written to file 3s510s cycle = 32

source distribution written to file 3s510s cycle = 36

source distribution written to file 3s510s cycle = 40

source distribution written to file 3s510s cycle = 44

source distribution written to file 3s510s cycle = 48

source distribution written to file 3s510s cycle = 52

dump no. 2 on file 3s510r nps = 211671 coll = 28800280 ctm = 15.16 nrn = 504049187

source distribution written to file 3s510s cycle = 56

source distribution written to file 3s510s cycle = 60

source distribution written to file 3s510s cycle = 64

source distribution written to file 3s510s cycle = 68

source distribution written to file 3s510s cycle = 72

source distribution written to file 3s510s cycle = 76

source distribution written to file 3s510s cycle = 80

source distribution written to file 3s510s cycle = 84

source distribution written to file 3s510s cycle = 88

source distribution written to file 3s510s cycle = 92

source distribution written to file 3s510s cycle = 96

estimator	cycle 100	ave of 80 cycles		combination	simple average		combined average		corr
k(collision)	0.918349	0.920144	0.0017	k(col/abs)	0.920745	0.0011	0.920893	0.0011	0.0755
k(absorption)	0.922627	0.921347	0.0013	k(abs/tk ln)	0.920949	0.0011	0.921058	0.0011	0.0960
k(trk length)	0.916271	0.920550	0.0017	k(tk ln/col)	0.920347	0.0017	0.920147	0.0017	0.9773
rem life(col)	2.2191E+04	2.2096E+04	0.0028	k(col/abs/tk ln)	0.920680	0.0013	0.920800	0.0011	
rem life(abs)	2.2347E+04	2.2099E+04	0.0025	life(col/abs)	2.2097E+04	0.0027	2.2101E+04	0.0025	0.9644

source points generated 3951

source distribution written to file 3s510s cycle = 100

source distribution written to file 3s510s cycle = 104

****

dump no. 3 on file 3s510r nps = 423162 coll = 57733422 ctm = 30.39 nrn = 1010199787

source distribution written to file 3s510s cycle = 108

source distribution written to file 3s510s cycle = 112

estimator	cycle 116	ave of 96 cycles		combination	simple average		combined average		corr
k(collision)	0.893006	0.918439	0.0016	k(col/abs)	0.919656	0.0010	0.920030	0.0010	0.0909
k(absorption)	0.921940	0.920873	0.0012	k(abs/tk ln)	0.919798	0.0010	0.920161	0.0010	0.1069
k(trk length)	0.892840	0.918723	0.0016	k(tk ln/col)	0.918581	0.0016	0.918414	0.0016	0.9790
rem life(col)	2.1762E+04	2.2117E+04	0.0025	k(col/abs/tk ln)	0.919345	0.0012	0.919965	0.0010	
rem life(abs)	2.1850E+04	2.2126E+04	0.0023	life(col/abs)	2.2121E+04	0.0024	2.2133E+04	0.0022	0.9657

source points generated 3865

source distribution written to file 3s510s cycle = 116

estimator	cycle 117	ave of 97 cycles		combination	simple average		combined average		corr
k(collision)	0.911225	0.918365	0.0015	k(col/abs)	0.919600	0.0010	0.919981	0.0010	0.0926
k(absorption)	0.917287	0.920836	0.0012	k(abs/tk ln)	0.919726	0.0010	0.920104	0.0010	0.1091
k(trk length)	0.908431	0.918617	0.0016	k(tk ln/col)	0.918491	0.0016	0.918336	0.0016	0.9788

rem life(col)	2.1807E+04	2.2114E+04	0.0025	k(col/abs/tk ln)	0.919273	0.0011	0.919921	0.0010	
rem life(abs)	2.2022E+04	2.2125E+04	0.0023	life(col/abs)	2.2119E+04	0.0023	2.2133E+04	0.0022	0.9651

source points generated 4041

estimator	cycle 118	ave of 98 cycles		combination	simple average		combined average		corr
k(collision)	0.911258	0.918293	0.0015	k(col/abs)	0.919482	0.0010	0.919838	0.0010	0.0993
k(absorption)	0.904671	0.920671	0.0012	k(abs/tk ln)	0.919625	0.0010	0.919969	0.0010	0.1119
k(trk length)	0.914845	0.918578	0.0016	k(tk ln/col)	0.918435	0.0015	0.918268	0.0016	0.9786
rem life(col)	2.2313E+04	2.2116E+04	0.0025	k(col/abs/tk ln)	0.919181	0.0011	0.919783	0.0010	
rem life(abs)	2.2236E+04	2.2126E+04	0.0022	life(col/abs)	2.2121E+04	0.0023	2.2134E+04	0.0022	0.9650

source points generated 3899

estimator	cycle 119	ave of 99 cycles		combination	simple average		combined average		corr
k(collision)	0.912979	0.918239	0.0015	k(col/abs)	0.919448	0.0010	0.919811	0.0010	0.0997
k(absorption)	0.919294	0.920657	0.0011	k(abs/tk ln)	0.919583	0.0010	0.919939	0.0010	0.1124
k(trk length)	0.911797	0.918510	0.0016	k(tk ln/col)	0.918374	0.0015	0.918213	0.0015	0.9786
rem life(col)	2.2083E+04	2.2115E+04	0.0024	k(col/abs/tk ln)	0.919135	0.0011	0.919758	0.0010	
rem life(abs)	2.2233E+04	2.2127E+04	0.0022	life(col/abs)	2.2121E+04	0.0023	2.2135E+04	0.0022	0.9646

source points generated 3982

estimator	cycle 120	ave of 100 cycles		combination	simple average		combined average		corr
k(collision)	0.918433	0.918241	0.0015	k(col/abs)	0.919451	0.0010	0.919815	0.0010	0.0997
k(absorption)	0.921112	0.920661	0.0011	k(abs/tk ln)	0.919594	0.0010	0.919947	0.0010	0.1124
k(trk length)	0.920086	0.918526	0.0015	k(tk ln/col)	0.918383	0.0015	0.918214	0.0015	0.9785
rem life(col)	2.1646E+04	2.2111E+04	0.0024	k(col/abs/tk ln)	0.919143	0.0011	0.919759	0.0010	
rem life(abs)	2.1606E+04	2.2122E+04	0.0022	life(col/abs)	2.2116E+04	0.0023	2.2130E+04	0.0022	0.9648

source points generated 4097

source distribution written to file 3s510s cycle = 120

1problem summary

run terminated when 120 kcode cycles were done.

12/13/00 04:46:55

k eff, 350g Pu-239 in cellulose spheres and pure celulose probid = 12/13/00 04:12:29

0

neutron creation	tracks	weight (per source particle)	energy (per source particle)	neutron loss	tracks	weight (per source particle)	energy (per source particle)
source	478984	1.0021E+00	2.1132E+00	escape	246	2.7996E-04	2.7947E-04
				energy cutoff	0	0.	0.
				time cutoff	0	0.	0.
weight window	0	0.	0.	weight window	0	0.	0.
cell importance	0	0.	0.	cell importance	0	0.	0.
weight cutoff	0	8.9224E-02	2.7488E-08	weight cutoff	478739	8.9111E-02	2.7733E-08
energy importance	0	0.	0.	energy importance	0	0.	0.
dxtran	0	0.	0.	dxtran	0	0.	0.
forced collisions	0	0.	0.	forced collisions	0	0.	0.
exp. transform	0	0.	0.	exp. transform	0	0.	0.
upscattering	0	0.	7.1800E-07	downscattering	0	0.	2.0923E+00
				capture	0	6.8222E-01	1.9475E-02
(n,xn)	2	2.7135E-06	2.8009E-06	loss to (n,xn)	1	1.3568E-06	1.0252E-05
fission	0	0.	0.	loss to fission	0	3.1973E-01	1.2158E-03
total	478986	1.0913E+00	2.1132E+00	total	478986	1.0913E+00	2.1132E+00

number of neutrons banked	1	average lifetime, shakes		cutoffs	
neutron tracks per source particle	1.0000E+00	escape	4.2552E+04	tco	1.0000E+34
neutron collisions per source particle	1.3652E+02	capture	2.2066E+04	eco	0.0000E+00
total neutron collisions	65391126	capture or escape	2.2072E+04	wc1	-5.0000E-01

net multiplication 1.0000E+00 0.0000 any termination 2.6408E+04 wc2 -2.5000E-01

computer time so far in this run 34.43 minutes maximum number ever in bank 1
computer time in mcrun 34.42 minutes bank overflows to backup file 0
source particles per minute 1.3917E+04 field length 0
random numbers generated 1144136583 most random numbers used was 31665 in history 197102

range of sampled source weights = 9.1806E-01 to 1.1737E+00
1neutron activity in each cell print table 126

	cell	tracks entering	population	collisions	collisions * weight (per history)	number weighted energy	flux weighted energy	average track weight (relative)	average track mfp (cm)
1	1	906014	367017	45934632	5.2947E+01	4.3392E-05	2.4319E-01	5.9250E-01	1.5252E+00
2	2	604	256	15936	1.4749E-02	3.6688E-05	2.4138E-01	4.6611E-01	2.0500E+00
4	4	352065	153498	5576874	8.9115E+00	1.8947E-04	5.8220E-01	8.3301E-01	2.3540E+00
5	5	336787	146353	5252668	8.3846E+00	1.9048E-04	5.8508E-01	8.3271E-01	2.3597E+00
6	6	268651	117150	4216496	6.7303E+00	1.8961E-04	5.8445E-01	8.3224E-01	2.3559E+00
7	7	279517	121580	4394520	7.0275E+00	1.9157E-04	5.8576E-01	8.3375E-01	2.3618E+00
total		2143638	905854	65391126	8.4016E+01				

1keff results for: k eff, 350g Pu-239 in cellulose spheres and pure celulose probid = 12/13/00 04:12:29

the initial fission neutron source distribution used the 4 source points that were input on the ksrc card.
the criticality problem was scheduled to skip 20 cycles and run a total of 120 cycles with nominally 4000 neutrons per cycle.
this problem has run 20 inactive cycles with 79906 neutron histories and 100 active cycles with 399078 neutron histories.

this calculation has completed the requested number of keff cycles using a total of 478984 fission neutron source histories.
all cells with fissionable material were sampled and had fission neutron source points.

the results of the w test for normality applied to the individual collision, absorption, and track-length keff cycle values are:

the k(collision) cycle values appear normally distributed at the 95 percent confidence level
the k(absorption) cycle values appear normally distributed at the 95 percent confidence level
the k(trk length) cycle values appear normally distributed at the 95 percent confidence level

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the final estimated combined collision/absorption/track-length keff = 0.91976 with an estimated standard deviation of 0.00089

the estimated 68, 95, & 99 percent keff confidence intervals are 0.91886 to 0.92065, 0.91798 to 0.92154, and 0.91740 to 0.92212

the estimated collision/absorption neutron removal lifetime = 2.21E-04 seconds with an estimated standard deviation of 4.81E-07

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the estimated average keffs, one standard deviations, and 68, 95, and 99 percent confidence intervals are:

keff estimator	keff	standard deviation	68% confidence	95% confidence	99% confidence	corr
collision	0.91824	0.00138	0.91686 to 0.91962	0.91549 to 0.92099	0.91459 to 0.92189	
absorption	0.92066	0.00105	0.91961 to 0.92171	0.91858 to 0.92275	0.91790 to 0.92343	

track length	0.91853	0.00142	0.91711 to 0.91995	0.91570 to 0.92135	0.91478 to 0.92227	
col/absorp	0.91981	0.00089	0.91893 to 0.92070	0.91805 to 0.92158	0.91747 to 0.92216	0.0997
abs/trk len	0.91995	0.00090	0.91905 to 0.92085	0.91816 to 0.92173	0.91758 to 0.92232	0.1124
col/trk len	0.91821	0.00140	0.91682 to 0.91961	0.91543 to 0.92099	0.91453 to 0.92190	0.9785
col/abs/trk len	0.91976	0.00089	0.91886 to 0.92065	0.91798 to 0.92154	0.91740 to 0.92212	

if the largest of each keff occurred on the next cycle, the keff results and 68, 95, and 99 percent confidence intervals would be:

keff estimator	keff	standard deviation	68% confidence	95% confidence	99% confidence
collision	0.91856	0.00141	0.91715 to 0.91997	0.91576 to 0.92136	0.91485 to 0.92227
absorption	0.92092	0.00107	0.91985 to 0.92199	0.91879 to 0.92305	0.91810 to 0.92374
track length	0.91890	0.00145	0.91745 to 0.92036	0.91601 to 0.92180	0.91506 to 0.92274
col/abs/trk len	0.91998	0.00093	0.91906 to 0.92091	0.91814 to 0.92183	0.91754 to 0.92243

the estimated collision/absorption neutron lifetimes, one standard deviations, and 68, 95, and 99 percent confidence intervals are:

type	lifetime(sec)	standard deviation	68% confidence	95% confidence	99% confidence
removal	2.2130E-04	4.8106E-07	2.2082E-04 to 2.2178E-04	2.2034E-04 to 2.2226E-04	2.2003E-04 to 2.2257E-04
capture	2.2122E-04	4.1922E-07	2.2080E-04 to 2.2164E-04	2.2039E-04 to 2.2206E-04	2.2011E-04 to 2.2233E-04
fission	1.4597E-04	2.6756E-07	1.4571E-04 to 1.4624E-04	1.4544E-04 to 1.4651E-04	1.4527E-04 to 1.4668E-04
escape	4.6106E-04	5.2933E-05	4.0807E-04 to 5.1404E-04	3.5562E-04 to 5.6650E-04	3.2121E-04 to 6.0091E-04

laverage individual and combined collision/absorption/track-length keff results for 7 different batch sizes

cycles per keff batch	number of k batches	average keff estimators and deviations k(col) st dev	k(abs) st dev	k(trk) st dev	normality co/ab/trk	average k(c/a/t) k(c/a/t) st dev	k(c/a/t) confidence intervals 95% confidence	99% confidence
1	100	0.9182 0.0014	0.9207 0.0010	0.9185 0.0014	95/95/95	0.91976 0.00089	0.91798-0.92154	0.91740-0.92212
2	50	0.9182 0.0014	0.9207 0.0009	0.9185 0.0015	95/95/95	0.91996 0.00090	0.91814-0.92178	0.91753-0.92239
4	25	0.9182 0.0018	0.9207 0.0011	0.9185 0.0018	95/95/95	0.91995 0.00113	0.91761-0.92230	0.91677-0.92314
5	20	0.9182 0.0018	0.9207 0.0010	0.9185 0.0018	95/95/95	0.92003 0.00097	0.91800-0.92207	0.91723-0.92283
10	10	0.9182 0.0022	0.9207 0.0012	0.9185 0.0023	95/95/95	0.91968 0.00089	0.91757-0.92180	0.91655-0.92282
20	5	0.9182 0.0025	0.9207 0.0014	0.9185 0.0027	95/95/95	0.91940 0.00117	0.91435-0.92444	0.90776-0.93103
25	4	0.9182 0.0026	0.9207 0.0012	0.9185 0.0028	95/95/95	0.92042 0.00058	0.91310-0.92775	0.88374-0.95711

lindividual and average keff estimator results by cycle

keff cycle	neutron histories	keff estimators by cycle k(coll)	k(abs)	k(track)	average keff estimators and deviations k(coll) st dev	k(abs) st dev	k(track) st dev	average k(c/a/t) k(c/a/t) st dev	fom
1	4000	1.09700	1.15219	1.09820					
2	4357	0.94285	0.95860	0.94374					
3	3408	0.93490	0.93608	0.92944					
4	4022	0.91633	0.91562	0.91666					
5	3911	0.89366	0.91911	0.89277					
6	3821	0.91850	0.92369	0.92043					
7	4072	0.91822	0.90587	0.91925					
8	4056	0.91032	0.91772	0.91301					
9	4037	0.88826	0.90552	0.89121					
10	3907	0.93952	0.93405	0.94043					
11	4302	0.92557	0.92789	0.92776					
12	3929	0.92464	0.92037	0.92562					
13	4037	0.93195	0.91367	0.93032					
14	4017	0.88406	0.92385	0.88550					
15	3779	0.90869	0.92901	0.90849					

16	4027	0.92136	0.93282	0.92357							
17	4044	0.90852	0.91991	0.90522							
18	3909	0.91097	0.92109	0.91169							
19	4085	0.94696	0.88768	0.95017							
20	4186	0.89337	0.91980	0.89341							
		begin active keff cycles									
21	3676	0.91926	0.91472	0.91636							
22	4178	0.92954	0.92372	0.93054	0.92440	0.00514	0.91922	0.00450	0.92345	0.00709	
23	4068	0.92704	0.93448	0.92812	0.92528	0.00310	0.92431	0.00571	0.92501	0.00438	
24	3836	0.93905	0.92644	0.94232	0.92872	0.00408	0.92484	0.00407	0.92934	0.00532	0.92590 0.00054 2618589
25	4001	0.93093	0.91361	0.93240	0.92916	0.00319	0.92260	0.00387	0.92995	0.00417	0.92590 0.00117 442228
26	3892	0.94853	0.94111	0.95649	0.93239	0.00415	0.92568	0.00442	0.93437	0.00558	0.92588 0.00097 537500
27	4069	0.93608	0.91043	0.93717	0.93292	0.00354	0.92350	0.00432	0.93477	0.00473	0.92571 0.00099 432967
28	3961	0.93953	0.93604	0.93883	0.93374	0.00318	0.92507	0.00406	0.93528	0.00413	0.92904 0.00305 40566
29	4065	0.91303	0.94614	0.91419	0.93144	0.00363	0.92741	0.00428	0.93294	0.00433	0.92670 0.00240 57821
30	3858	0.92007	0.92877	0.92394	0.93031	0.00344	0.92755	0.00383	0.93204	0.00398	0.92597 0.00264 43199
31	3929	0.91202	0.94689	0.91447	0.92864	0.00353	0.92931	0.00388	0.93044	0.00394	0.92574 0.00241 46948
32	3994	0.93732	0.92632	0.93565	0.92937	0.00330	0.92906	0.00355	0.93087	0.00362	0.92703 0.00226 49258
33	4131	0.92053	0.92057	0.91992	0.92869	0.00311	0.92840	0.00333	0.93003	0.00343	0.92643 0.00208 53423
34	3961	0.90517	0.90603	0.90121	0.92701	0.00333	0.92681	0.00348	0.92797	0.00379	0.92479 0.00208 49449
35	4006	0.90956	0.93156	0.91192	0.92584	0.00331	0.92712	0.00325	0.92690	0.00369	0.92430 0.00207 46746
36	4038	0.91403	0.90972	0.91580	0.92510	0.00319	0.92603	0.00323	0.92621	0.00352	0.92337 0.00227 36226
37	4051	0.92591	0.92717	0.92692	0.92515	0.00299	0.92610	0.00303	0.92625	0.00330	0.92344 0.00213 38607
38	4042	0.92362	0.91632	0.92489	0.92507	0.00282	0.92556	0.00291	0.92618	0.00312	0.92311 0.00205 39342
39	4028	0.92962	0.91442	0.93259	0.92531	0.00268	0.92497	0.00282	0.92651	0.00297	0.92287 0.00201 38628
40	4050	0.92455	0.93260	0.92718	0.92527	0.00254	0.92535	0.00270	0.92655	0.00281	0.92289 0.00193 39887
41	3900	0.91310	0.89904	0.91526	0.92469	0.00249	0.92410	0.00286	0.92601	0.00273	0.92215 0.00218 29563
42	4055	0.90394	0.93612	0.90379	0.92375	0.00255	0.92465	0.00278	0.92500	0.00279	0.92192 0.00207 31412
43	3926	0.91642	0.91095	0.91780	0.92343	0.00246	0.92405	0.00272	0.92469	0.00269	0.92147 0.00206 30466
44	4025	0.93936	0.91544	0.94101	0.92409	0.00245	0.92369	0.00263	0.92537	0.00266	0.92164 0.00199 31191
45	4077	0.94076	0.93126	0.93528	0.92476	0.00244	0.92400	0.00254	0.92576	0.00258	0.92353 0.00202 29117
46	4017	0.92543	0.91641	0.92619	0.92478	0.00234	0.92370	0.00246	0.92578	0.00248	0.92341 0.00195 30135
47	3880	0.94113	0.91365	0.94238	0.92539	0.00234	0.92333	0.00239	0.92639	0.00247	0.92351 0.00189 30741
48	4097	0.92356	0.93308	0.92459	0.92532	0.00225	0.92368	0.00233	0.92633	0.00238	0.92366 0.00183 31796
49	3992	0.92381	0.91813	0.92140	0.92527	0.00217	0.92349	0.00226	0.92616	0.00230	0.92363 0.00173 34120
50	4027	0.95049	0.91130	0.94219	0.92611	0.00226	0.92308	0.00222	0.92669	0.00228	0.92426 0.00169 34631
51	4024	0.90707	0.92207	0.91117	0.92550	0.00227	0.92305	0.00215	0.92619	0.00227	0.92395 0.00168 33853
52	3891	0.91791	0.90261	0.91633	0.92526	0.00221	0.92241	0.00218	0.92589	0.00222	0.92350 0.00169 32387
53	4020	0.93031	0.92694	0.93188	0.92541	0.00215	0.92255	0.00211	0.92607	0.00215	0.92362 0.00165 32986
54	4022	0.92135	0.92261	0.92464	0.92529	0.00209	0.92255	0.00205	0.92602	0.00209	0.92355 0.00161 33513
55	3941	0.94278	0.92672	0.94503	0.92579	0.00209	0.92267	0.00199	0.92657	0.00210	0.92372 0.00161 32735
56	4105	0.91555	0.92534	0.91169	0.92551	0.00205	0.92274	0.00194	0.92615	0.00208	0.92368 0.00153 35212
57	3871	0.92270	0.92332	0.92066	0.92543	0.00200	0.92276	0.00189	0.92601	0.00203	0.92369 0.00148 36801
58	3908	0.90192	0.89570	0.90369	0.92482	0.00204	0.92205	0.00197	0.92542	0.00206	0.92311 0.00162 29793
59	3804	0.91954	0.91320	0.91575	0.92468	0.00199	0.92182	0.00193	0.92517	0.00203	0.92293 0.00157 30828
60	4064	0.88253	0.91213	0.88575	0.92363	0.00221	0.92158	0.00190	0.92419	0.00221	0.92219 0.00166 26951
61	3840	0.91511	0.91297	0.91974	0.92342	0.00216	0.92137	0.00186	0.92408	0.00215	0.92203 0.00165 26625
62	4071	0.90968	0.93622	0.91231	0.92309	0.00214	0.92172	0.00185	0.92380	0.00212	0.92211 0.00161 27389
63	3949	0.90976	0.94246	0.90403	0.92278	0.00211	0.92220	0.00187	0.92334	0.00212	0.92241 0.00155 28913
64	4020	0.91322	0.92176	0.91276	0.92256	0.00207	0.92219	0.00183	0.92310	0.00209	0.92230 0.00151 29583
65	3974	0.92281	0.91479	0.92679	0.92257	0.00203	0.92203	0.00180	0.92318	0.00204	0.92223 0.00149 29847
66	4062	0.92338	0.92314	0.92270	0.92259	0.00198	0.92205	0.00176	0.92317	0.00200	0.92225 0.00145 30628
67	4007	0.92931	0.94425	0.93160	0.92273	0.00194	0.92253	0.00178	0.92335	0.00196	0.92255 0.00146 29569
68	4105	0.92127	0.92103	0.91722	0.92270	0.00190	0.92249	0.00174	0.92322	0.00192	0.92253 0.00142 30609

69	4021	0.91610	0.91472	0.91627	0.92256	0.00187	0.92234 0.00172	0.92308 0.00189	0.92238 0.00140	30905
70	3982	0.89345	0.92503	0.89702	0.92198	0.00192	0.92239 0.00168	0.92256 0.00192	0.92218 0.00139	30484
71	3898	0.91475	0.92744	0.91719	0.92184	0.00189	0.92249 0.00165	0.92245 0.00189	0.92218 0.00137	30984
72	3996	0.92028	0.89859	0.92496	0.92181	0.00185	0.92203 0.00168	0.92250 0.00185	0.92199 0.00138	29951
73	3986	0.93225	0.91308	0.93189	0.92201	0.00183	0.92186 0.00166	0.92268 0.00183	0.92198 0.00135	30586
74	3886	0.91923	0.91158	0.91540	0.92196	0.00179	0.92167 0.00164	0.92254 0.00180	0.92181 0.00133	31210
75	3952	0.88818	0.92402	0.88637	0.92134	0.00186	0.92171 0.00161	0.92188 0.00188	0.92152 0.00132	30892
76	3849	0.93055	0.91219	0.92349	0.92151	0.00184	0.92154 0.00159	0.92191 0.00185	0.92149 0.00129	31957
77	4140	0.94230	0.91893	0.94432	0.92187	0.00184	0.92150 0.00156	0.92231 0.00186	0.92160 0.00127	32110
78	4012	0.90870	0.93563	0.90623	0.92164	0.00182	0.92174 0.00156	0.92203 0.00185	0.92167 0.00125	32830
79	3945	0.92361	0.90837	0.92156	0.92168	0.00179	0.92151 0.00155	0.92202 0.00182	0.92154 0.00123	33194
80	4065	0.90511	0.91501	0.90382	0.92140	0.00179	0.92140 0.00152	0.92172 0.00181	0.92136 0.00122	33108
81	3903	0.89064	0.91889	0.88860	0.92090	0.00183	0.92136 0.00150	0.92118 0.00186	0.92112 0.00122	32599
82	3907	0.90907	0.93473	0.91495	0.92071	0.00181	0.92158 0.00149	0.92107 0.00183	0.92115 0.00120	32936
83	4145	0.92586	0.92931	0.92782	0.92079	0.00178	0.92170 0.00147	0.92118 0.00181	0.92124 0.00119	33164
84	4003	0.90801	0.89816	0.91110	0.92059	0.00176	0.92133 0.00149	0.92102 0.00179	0.92096 0.00121	31294
85	3964	0.89998	0.92918	0.89939	0.92027	0.00176	0.92145 0.00148	0.92069 0.00179	0.92091 0.00120	31714
86	4049	0.91806	0.91783	0.91763	0.92024	0.00174	0.92140 0.00145	0.92065 0.00176	0.92086 0.00118	32201
87	3989	0.93016	0.91685	0.92970	0.92039	0.00172	0.92133 0.00143	0.92078 0.00174	0.92089 0.00116	32770
88	4061	0.88481	0.92271	0.88377	0.91986	0.00177	0.92135 0.00141	0.92024 0.00180	0.92071 0.00116	32283
89	3815	0.91771	0.92315	0.91259	0.91983	0.00175	0.92138 0.00139	0.92013 0.00178	0.92073 0.00114	32954
90	4170	0.92080	0.90924	0.92242	0.91985	0.00172	0.92120 0.00138	0.92016 0.00175	0.92063 0.00113	33124
91	3900	0.92652	0.91144	0.92680	0.91994	0.00170	0.92107 0.00137	0.92025 0.00173	0.92058 0.00111	33599
92	4022	0.92773	0.92036	0.92733	0.92005	0.00168	0.92106 0.00135	0.92035 0.00171	0.92061 0.00110	34099
93	3999	0.93116	0.92982	0.93728	0.92020	0.00166	0.92118 0.00134	0.92058 0.00170	0.92071 0.00109	34025
94	4116	0.92082	0.92555	0.92235	0.92021	0.00164	0.92124 0.00132	0.92061 0.00168	0.92074 0.00108	34400
95	4004	0.91577	0.92571	0.91352	0.92015	0.00162	0.92130 0.00131	0.92051 0.00166	0.92077 0.00106	34932
96	3991	0.90628	0.91846	0.90856	0.91997	0.00161	0.92126 0.00129	0.92035 0.00164	0.92068 0.00105	34977
97	3980	0.93764	0.93175	0.93892	0.92020	0.00160	0.92140 0.00128	0.92060 0.00164	0.92084 0.00105	34506
98	4185	0.90873	0.91524	0.91055	0.92005	0.00159	0.92132 0.00126	0.92047 0.00162	0.92074 0.00105	34475
99	3794	0.92930	0.92245	0.93138	0.92017	0.00157	0.92133 0.00125	0.92060 0.00161	0.92079 0.00104	34827
100	3966	0.91835	0.92263	0.91627	0.92014	0.00155	0.92135 0.00123	0.92055 0.00159	0.92080 0.00102	35369
101	3951	0.93016	0.92037	0.93123	0.92027	0.00154	0.92133 0.00122	0.92068 0.00158	0.92084 0.00101	35778
102	4003	0.91613	0.91886	0.91724	0.92022	0.00152	0.92130 0.00120	0.92064 0.00156	0.92080 0.00100	36124
103	4018	0.90112	0.91629	0.89629	0.91999	0.00152	0.92124 0.00119	0.92035 0.00157	0.92067 0.00099	36279
104	3903	0.92047	0.91986	0.91755	0.91999	0.00150	0.92123 0.00118	0.92031 0.00155	0.92068 0.00098	36850
105	4179	0.90274	0.92928	0.90560	0.91979	0.00150	0.92132 0.00117	0.92014 0.00154	0.92066 0.00097	37097
106	3999	0.91561	0.90103	0.91714	0.91974	0.00148	0.92109 0.00118	0.92011 0.00152	0.92048 0.00097	36340
107	4140	0.91209	0.91548	0.91004	0.91965	0.00147	0.92102 0.00116	0.91999 0.00151	0.92041 0.00096	36647
108	4038	0.88760	0.91321	0.88936	0.91929	0.00150	0.92093 0.00115	0.91964 0.00153	0.92025 0.00097	35383
109	3830	0.92300	0.92592	0.92232	0.91933	0.00148	0.92099 0.00114	0.91967 0.00151	0.92031 0.00096	35712
110	4118	0.90109	0.92322	0.90525	0.91913	0.00148	0.92101 0.00113	0.91951 0.00151	0.92026 0.00096	35746
111	3943	0.90827	0.91280	0.90818	0.91901	0.00147	0.92092 0.00112	0.91939 0.00149	0.92016 0.00095	35733
112	4031	0.90841	0.92288	0.90608	0.91889	0.00145	0.92095 0.00111	0.91924 0.00148	0.92014 0.00094	36126
113	4023	0.89980	0.91374	0.89749	0.91869	0.00145	0.92087 0.00110	0.91901 0.00149	0.92002 0.00094	35940
114	3909	0.91375	0.93068	0.90959	0.91864	0.00144	0.92097 0.00109	0.91891 0.00147	0.92009 0.00093	36188
115	4009	0.92544	0.91045	0.92719	0.91871	0.00143	0.92086 0.00109	0.91900 0.00146	0.92003 0.00092	36525
116	3994	0.89301	0.92194	0.89284	0.91844	0.00144	0.92087 0.00108	0.91872 0.00147	0.91997 0.00092	36441
117	3865	0.91123	0.91729	0.90843	0.91837	0.00142	0.92084 0.00107	0.91862 0.00146	0.91992 0.00091	36790
118	4041	0.91126	0.90467	0.91484	0.91829	0.00141	0.92067 0.00107	0.91858 0.00145	0.91978 0.00091	36207
119	3899	0.91298	0.91929	0.91180	0.91824	0.00140	0.92066 0.00106	0.91851 0.00143	0.91976 0.00090	36559
120	3982	0.91843	0.92111	0.92009	0.91824	0.00138	0.92066 0.00105	0.91853 0.00142	0.91976 0.00089	36902

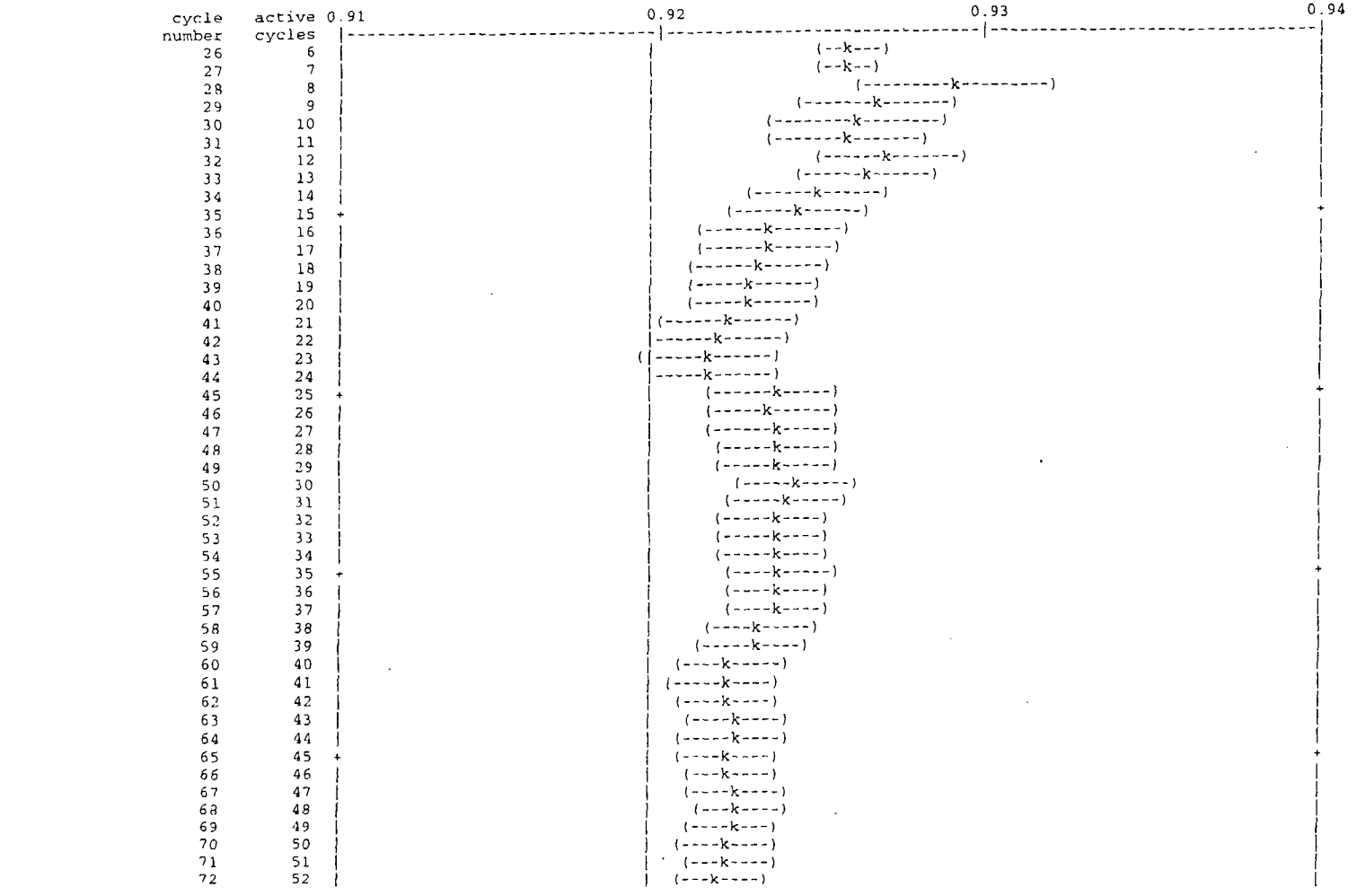
the largest active cycle keffs by estimator are:

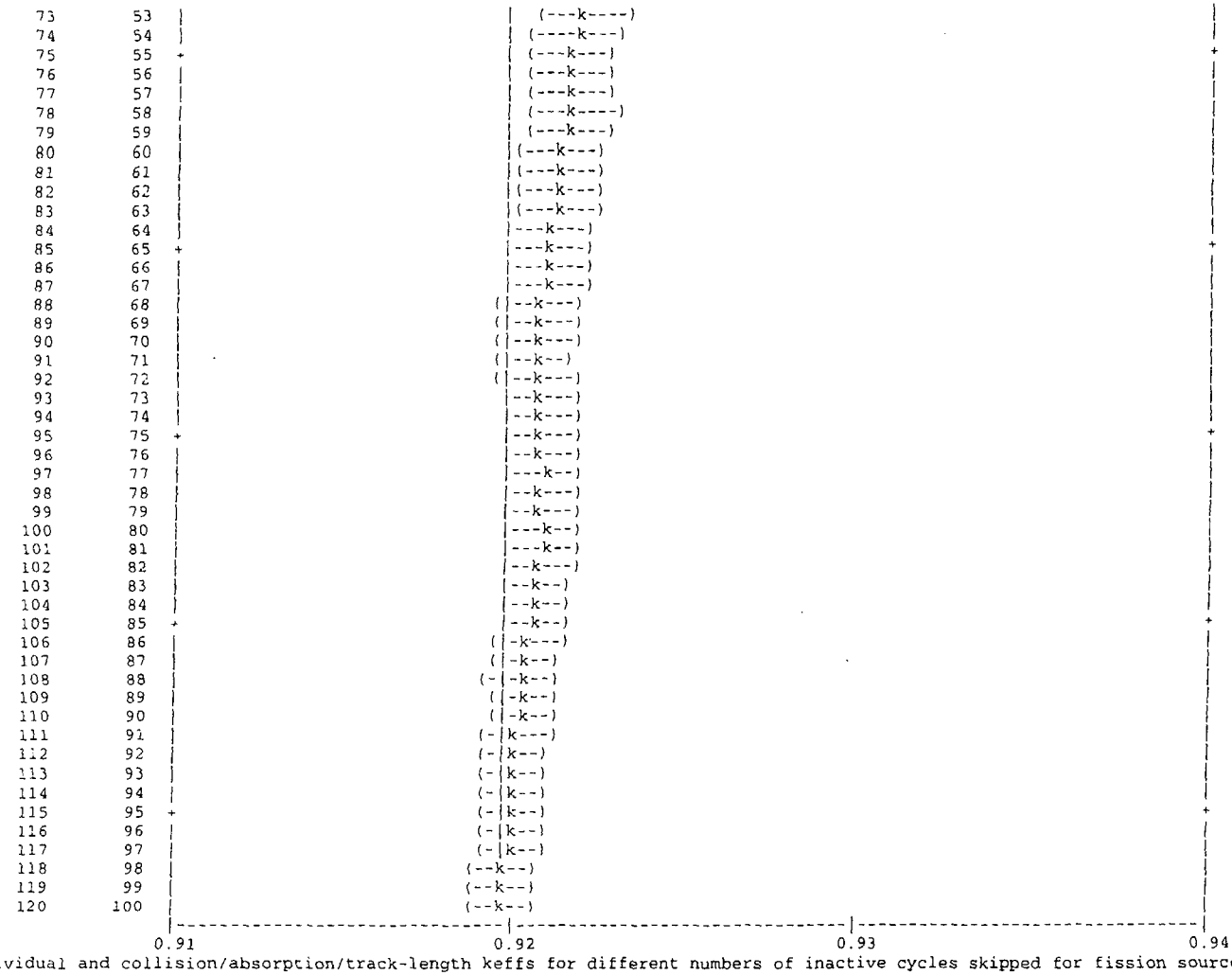
collision 0.95049 on cycle 50
absorption 0.94689 on cycle 31
track length 0.95649 on cycle 26

the smallest active cycle keffs by estimator are:

collision 0.88253 on cycle 60
absorption 0.89570 on cycle 58
track length 0.88377 on cycle 88

1plot of the estimated col/abs/track-length keff one standard deviation interval versus cycle number (| = final keff = 0.91976)





individual and collision/absorption/track-length keffs for different numbers of inactive cycles skipped for fission source settling

skip cycles	active cycles	active neutrons	average keff estimators and deviations k(col)	st dev	k(abs)	st dev	k(trk)	st dev	normality co/ab/tl	average k(c/a/t)	st dev	k(c/a/t) confidence intervals 95% confidence	99% confidence
0	120	478984	0.9195	0.0020	0.9228	0.0022	0.9198	0.0020	no/no/no	0.92058	0.00197	0.91666-0.92450	0.91538-0.92578
1	*119*	474984	0.9180	0.0013	*0.9208*	*0.0010*	0.9183	*0.0014*	*95/99/95*	0.91982	0.00088	0.91806-0.92157	0.91749-0.92214
2	118	470627	0.9178	0.0013	0.9205	0.0010	0.9181	0.0014	95/95/95	0.91957	0.00084	0.91791-0.92124	0.91736-0.92179

3	117	467219	0.9176	0.0013	0.9204	0.0010	0.9180	0.0014	95/95/95	0.91939	0.00083	0.91773-0.92105	0.91719-0.92160
4	116	463197	0.9177	0.0013	0.9204	0.0010	0.9180	0.0014	95/95/95	0.91943	0.00084	0.91775-0.92110	0.91721-0.92165
5	115	459286	0.9179	0.0013	0.9204	0.0010	0.9182	0.0014	95/95/95	0.91949	0.00084	0.91781-0.92117	0.91727-0.92172
6	114	455465	0.9179	0.0013	0.9204	0.0010	0.9182	0.0014	95/95/95	0.91948	0.00085	0.91778-0.92117	0.91723-0.92172
7	113	451393	0.9179	0.0014	0.9205	0.0010	0.9182	0.0014	95/95/95	0.91957	0.00085	0.91787-0.92127	0.91732-0.92182
8	112	447337	0.9179	0.0014	0.9206	0.0010	0.9183	0.0014	95/95/95	0.91960	0.00086	0.91790-0.92131	0.91734-0.92187
9	111	443300	0.9182	0.0014	0.9207	0.0010	0.9185	0.0014	95/95/95	0.91975	0.00084	0.91807-0.92143	0.91752-0.92197
10	110	439393	0.9180	0.0014	0.9206	0.0010	0.9183	0.0014	95/95/95	0.91959	0.00084	0.91793-0.92126	0.91738-0.92181
11	109	435091	0.9179	0.0014	0.9205	0.0010	0.9182	0.0014	95/95/95	0.91953	0.00084	0.91786-0.92121	0.91731-0.92176
12	108	431162	0.9179	0.0014	0.9205	0.0010	0.9182	0.0014	95/95/95	0.91951	0.00085	0.91782-0.92121	0.91727-0.92176
13	107	427125	0.9177	0.0014	0.9206	0.0010	0.9180	0.0014	95/95/95	0.91950	0.00086	0.91779-0.92122	0.91723-0.92177
14	106	423108	0.9181	0.0014	0.9205	0.0010	0.9184	0.0014	95/95/95	0.91956	0.00086	0.91785-0.92128	0.91729-0.92184
15	105	419329	0.9181	0.0014	0.9205	0.0011	0.9184	0.0014	95/95/95	0.91955	0.00087	0.91782-0.92127	0.91726-0.92184
16	104	415302	0.9181	0.0014	0.9203	0.0011	0.9184	0.0014	95/95/95	0.91948	0.00087	0.91774-0.92121	0.91718-0.92177
17	103	411258	0.9182	0.0014	0.9203	0.0011	0.9185	0.0014	95/95/95	0.91951	0.00088	0.91776-0.92126	0.91719-0.92183
18	102	407349	0.9183	0.0014	0.9203	0.0011	0.9186	0.0014	95/95/95	0.91953	0.00089	0.91776-0.92129	0.91719-0.92187
19	101	403264	0.9180	0.0014	0.9207	0.0010	0.9183	0.0014	95/95/95	0.91969	0.00089	0.91791-0.92146	0.91733-0.92204
20	100	399078	0.9182	0.0014	0.9207	0.0010	0.9185	0.0014	95/95/95	0.91976	0.00089	0.91798-0.92154	0.91740-0.92212
22	98	391224	0.9181	0.0014	0.9207	0.0011	0.9184	0.0014	95/95/95	0.91973	0.00091	0.91792-0.92155	0.91732-0.92214
24	96	383320	0.9178	0.0014	0.9205	0.0011	0.9181	0.0014	95/95/95	0.91950	0.00091	0.91768-0.92132	0.91709-0.92191
26	94	375427	0.9173	0.0014	0.9203	0.0011	0.9175	0.0014	95/95/95	0.91926	0.00090	0.91748-0.92104	0.91690-0.92162
28	92	367397	0.9169	0.0014	0.9203	0.0011	0.9171	0.0014	95/95/95	0.91904	0.00090	0.91725-0.92082	0.91667-0.92140
30	90	359474	0.9169	0.0014	0.9199	0.0011	0.9170	0.0014	95/95/95	0.91886	0.00089	0.91708-0.92063	0.91651-0.92121
32	88	351551	0.9167	0.0014	0.9195	0.0010	0.9168	0.0015	95/95/95	0.91860	0.00088	0.91684-0.92035	0.91627-0.92092
34	86	343459	0.9168	0.0015	0.9197	0.0010	0.9170	0.0015	95/95/95	0.91875	0.00089	0.91698-0.92051	0.91641-0.92109
36	84	335415	0.9169	0.0015	0.9196	0.0011	0.9171	0.0015	95/95/95	0.91878	0.00090	0.91699-0.92057	0.91641-0.92115
38	82	327322	0.9167	0.0015	0.9196	0.0011	0.9168	0.0015	95/95/95	0.91868	0.00091	0.91685-0.92050	0.91626-0.92109
40	80	319244	0.9165	0.0016	0.9195	0.0011	0.9165	0.0016	95/95/95	0.91851	0.00093	0.91667-0.92036	0.91607-0.92096
42	78	311289	0.9167	0.0016	0.9195	0.0011	0.9167	0.0016	95/95/95	0.91867	0.00092	0.91683-0.92051	0.91623-0.92111
44	76	303338	0.9164	0.0016	0.9197	0.0011	0.9164	0.0016	95/95/95	0.91867	0.00095	0.91678-0.92056	0.91616-0.92118
46	74	295244	0.9159	0.0016	0.9196	0.0011	0.9160	0.0016	95/95/95	0.91843	0.00096	0.91653-0.92034	0.91590-0.92097
48	72	287267	0.9155	0.0016	0.9195	0.0011	0.9155	0.0016	95/95/95	0.91820	0.00097	0.91626-0.92014	0.91562-0.92077
50	70	279248	0.9149	0.0016	0.9196	0.0011	0.9150	0.0016	95/95/95	0.91804	0.00101	0.91601-0.92007	0.91535-0.92073
52	68	271333	0.9149	0.0016	0.9198	0.0011	0.9151	0.0017	95/95/95	0.91827	0.00103	0.91620-0.92034	0.91553-0.92102
54	66	263291	0.9146	0.0016	0.9197	0.0012	0.9147	0.0017	95/95/95	0.91803	0.00105	0.91593-0.92013	0.91524-0.92083
56	64	255245	0.9142	0.0016	0.9195	0.0012	0.9142	0.0017	95/95/95	0.91766	0.00106	0.91554-0.91978	0.91484-0.92048
58	62	247466	0.9142	0.0017	0.9198	0.0012	0.9143	0.0017	95/95/95	0.91795	0.00104	0.91587-0.92003	0.91518-0.92072
60	60	239598	0.9147	0.0016	0.9201	0.0012	0.9148	0.0017	95/95/95	0.91812	0.00103	0.91605-0.92019	0.91537-0.92087
62	58	231687	0.9147	0.0017	0.9199	0.0012	0.9147	0.0018	95/95/95	0.91812	0.00105	0.91602-0.92022	0.91533-0.92092
64	56	223718	0.9148	0.0017	0.9195	0.0012	0.9149	0.0018	95/95/95	0.91798	0.00104	0.91589-0.92008	0.91520-0.92077
66	54	215682	0.9145	0.0018	0.9195	0.0012	0.9146	0.0019	95/95/95	0.91790	0.00108	0.91573-0.92007	0.91501-0.92080
68	52	207570	0.9141	0.0018	0.9190	0.0012	0.9142	0.0019	95/95/95	0.91750	0.00103	0.91544-0.91956	0.91475-0.92025
70	50	199567	0.9145	0.0019	0.9189	0.0012	0.9145	0.0019	95/95/95	0.91757	0.00106	0.91544-0.91970	0.91473-0.92041
72	48	191673	0.9144	0.0019	0.9192	0.0012	0.9142	0.0020	95/95/95	0.91789	0.00106	0.91575-0.92003	0.91503-0.92075
74	46	183801	0.9139	0.0020	0.9195	0.0012	0.9138	0.0021	95/95/95	0.91797	0.00112	0.91570-0.92023	0.91494-0.92100
76	44	176000	0.9141	0.0019	0.9195	0.0012	0.9142	0.0020	95/95/95	0.91797	0.00118	0.91558-0.92036	0.91477-0.92117
78	42	167848	0.9135	0.0019	0.9192	0.0012	0.9137	0.0020	95/95/95	0.91754	0.00120	0.91511-0.91998	0.91428-0.92081
80	40	159838	0.9135	0.0020	0.9195	0.0013	0.9137	0.0021	95/95/95	0.91787	0.00127	0.91528-0.92045	0.91441-0.92132
82	38	152028	0.9142	0.0020	0.9192	0.0013	0.9144	0.0021	95/95/95	0.91793	0.00126	0.91536-0.92050	0.91449-0.92137
84	36	143880	0.9141	0.0021	0.9195	0.0012	0.9141	0.0022	95/95/95	0.91827	0.00118	0.91586-0.92067	0.91503-0.92150
86	34	135867	0.9144	0.0021	0.9192	0.0012	0.9144	0.0023	95/95/95	0.91824	0.00123	0.91572-0.92076	0.91485-0.92163
88	32	127817	0.9148	0.0020	0.9192	0.0013	0.9149	0.0021	95/95/95	0.91817	0.00131	0.91549-0.92085	0.91456-0.92178
90	30	119832	0.9145	0.0021	0.9194	0.0013	0.9147	0.0023	95/95/95	0.91832	0.00140	0.91545-0.92120	0.91444-0.92221

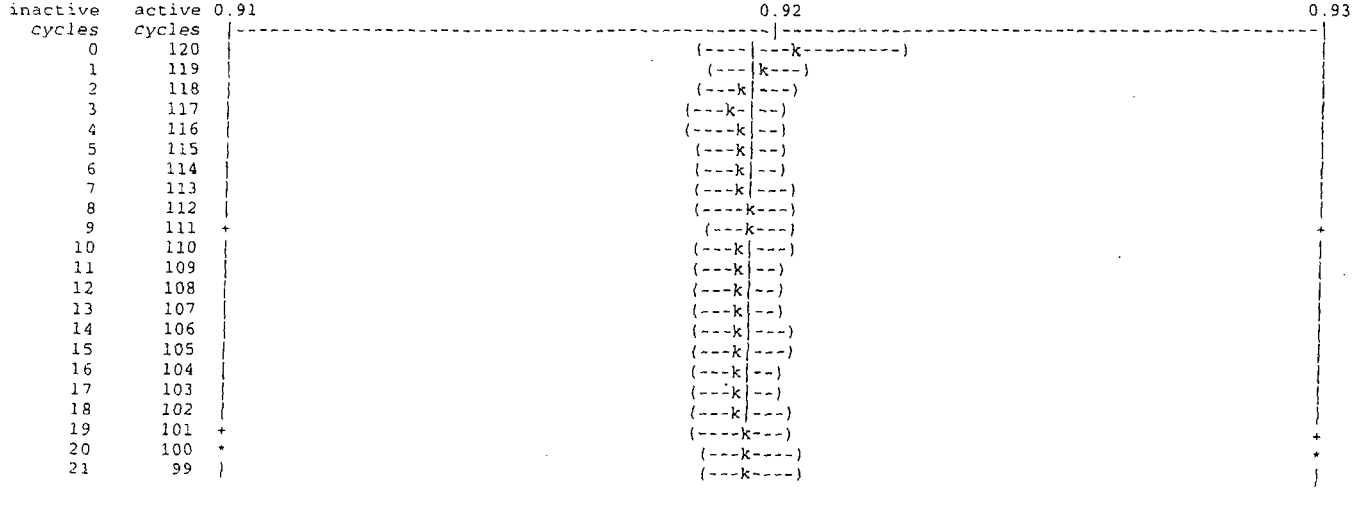
92	28	111910	0.9136	0.0022	0.9196	0.0014	0.9138	0.0023	95/95/95	0.91837	0.00157	0.91514-0.92159	0.91400-0.92273
94	26	103795	0.9126	0.0022	0.9190	0.0014	0.9126	0.0023	95/95/95	0.91763	0.00154	0.91444-0.92081	0.91331-0.92194
96	24	95800	0.9128	0.0024	0.9188	0.0015	0.9127	0.0025	95/95/95	0.91746	0.00162	0.91409-0.92083	0.91287-0.92205
98	22	87635	0.9118	0.0024	0.9183	0.0015	0.9116	0.0024	95/95/95	0.91650	0.00154	0.91328-0.91973	0.91210-0.92091
100	20	79875	0.9106	0.0024	0.9179	0.0017	0.9104	0.0025	95/95/95	0.91556	0.00162	0.91214-0.91898	0.91086-0.92026
102	18	71921	0.9092	0.0024	0.9177	0.0018	0.9089	0.0024	95/95/95	0.91441	0.00176	0.91066-0.91816	0.90923-0.91960
104	16	64000	0.9090	0.0025	0.9177	0.0021	0.9091	0.0025	95/95/95	0.91438	0.00188	0.91031-0.91844	0.90871-0.92004
106	14	55822	0.9090	0.0028	0.9180	0.0018	0.9088	0.0028	95/95/95	0.91563	0.00199	0.91125-0.92000	0.90945-0.92180
108	12	47644	0.9106	0.0027	0.9187	0.0021	0.9103	0.0028	95/95/95	0.91586	0.00207	0.91118-0.92054	0.90914-0.92258
110	10	39696	0.9103	0.0029	0.9175	0.0023	0.9097	0.0032	95/95/95	0.91489	0.00198	0.91021-0.91957	0.90796-0.92182
112	8	31722	0.9107	0.0036	0.9174	0.0028	0.9103	0.0040	95/95/95	0.91522	0.00243	0.90898-0.92146	0.90543-0.92501
114	6	23790	0.9121	0.0044	0.9158	0.0028	0.9125	0.0048	95/95/95	0.91531	0.00240	0.90767-0.92295	0.90129-0.92933
116	4	15787	0.9135	0.0017	0.9156	0.0037	0.9138	0.0025	95/95/95	0.91027	0.00165	0.88935-0.93119	0.80550-1.01504
117	3	11922	0.9142	0.0022	0.9150	0.0052	0.9156	0.0024					
118	2	7881	0.9157	0.0027	0.9202	0.0009	0.9159	0.0041					

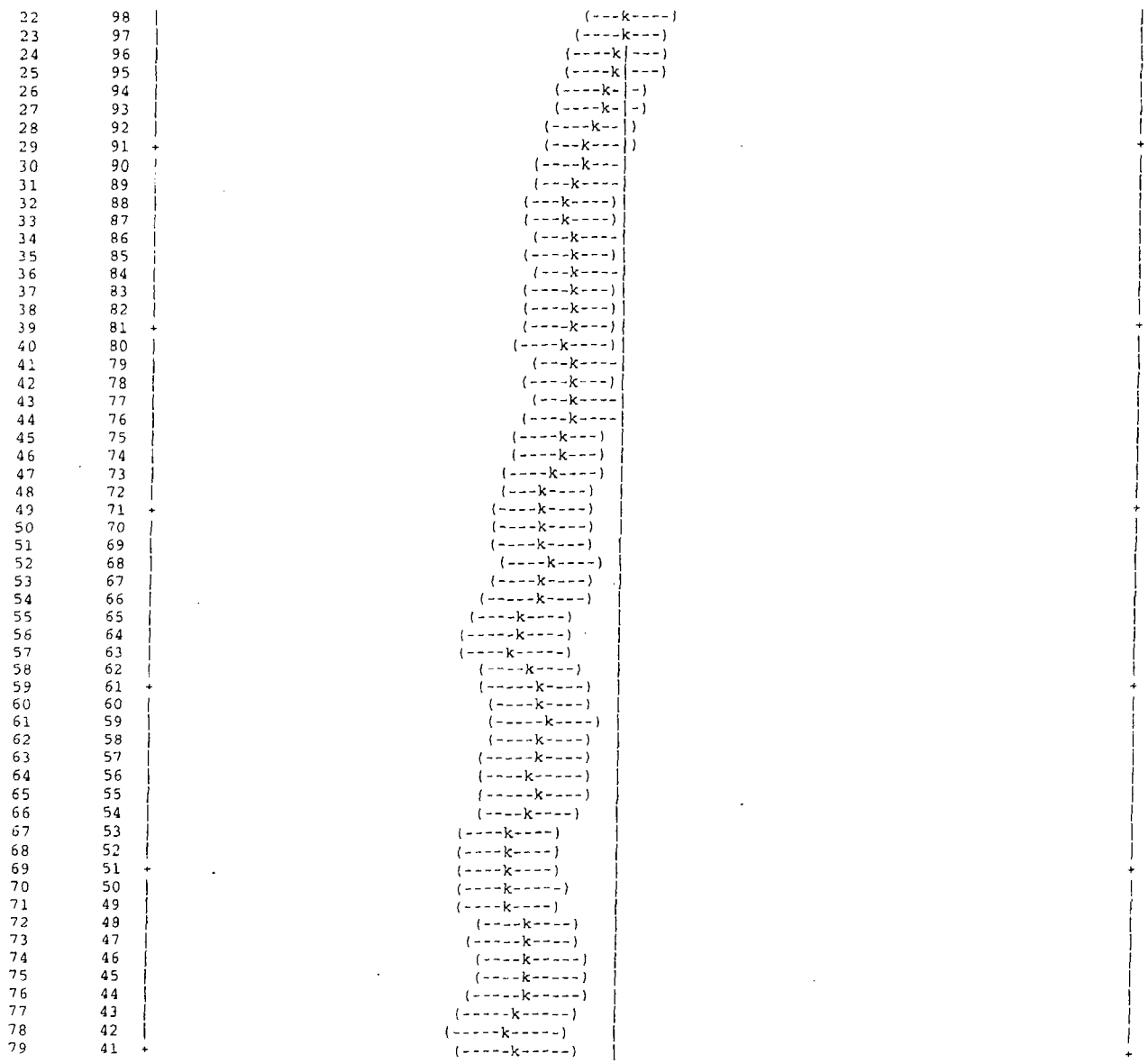
the minimum estimated standard deviation for the col/abs/tl keff estimator occurs with 3 inactive cycles and 117 active cycles.

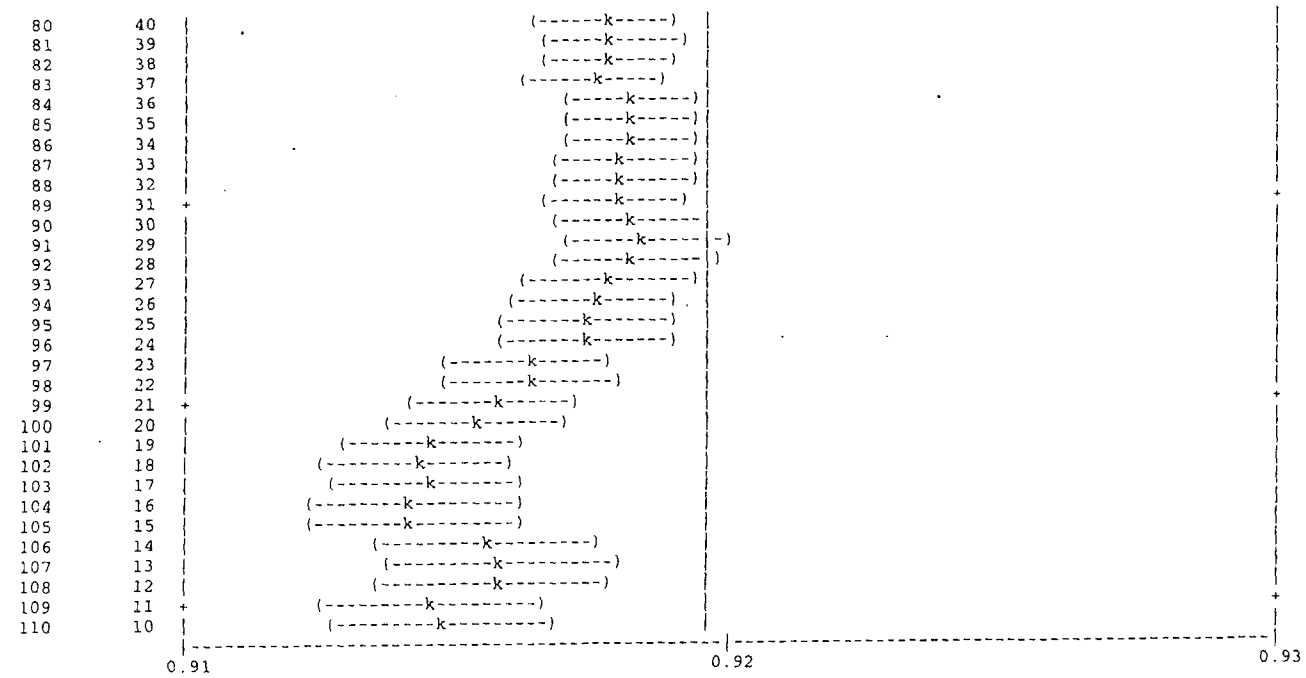
the first active half of the problem skips 20 cycles and uses 50 active cycles; the second half skips 70 and uses 50 cycles.
the col/abs/trk-len keff, one standard deviation, and 68, 95, and 99 percent intervals for each active half of the problem are:

problem	keff	standard deviation	68% confidence	95% confidence	99% confidence
first half	0.92218	0.00139	0.92078 to 0.92358	0.91938 to 0.92499	0.91844 to 0.92593
second half	0.91757	0.00106	0.91651 to 0.91864	0.91544 to 0.91970	0.91473 to 0.92041
final result	0.91976	0.00089	0.91886 to 0.92065	0.91798 to 0.92154	0.91740 to 0.92212

the first and second half values of k(collision/absorption/track length) appear to be the same at the 99 percent confidence level.
lplot of the estimated col/abs/track-length keff one standard deviation interval by active cycle number (| = final keff = 0.91976)







dump no. 4 on file 3s510r nps = 478984 coll = 65391126 ctm = 34.42 nrn = 1144136583

2 warning messages so far.

run terminated when 120 kcode cycles were done.

computer time = 34.43 minutes

mcnp version 4a 10/01/93 12/13/00 04:46:55 probid = 12/13/00 04:12:29

URS

Calculation Cover Page

3065 Southwestern Boulevard
Suite 202
Orchard Park, NY 14127
716 675 7130 Tel
716 675 7137 Fax

Job No: **30822-244-330 /6860** Calculation No: **BUF-2001-006/Rev. 0** Date: **January 29, 2001**

Problem Statement & Calculation Objectives:

To determine the neutron multiplication factors for $\infty \times \infty \times 4$ arrays of B-25 boxes with Pu-239-cellulose spheres and variable density cellulose outside the sphere. The cellulose inside the sphere with Plutonium has a constant density. Each sphere contains 200g of Pu-239.

References and Data Available:

J. F. Briemiester, ed., MCNP - A General Purpose Monte Carlo N-Particle Transport Code, Version 4A, LA-12625, Los Alamos National Laboratory, Los Alamos NM, 1993
C. D. Harmon, II et al., Criticality Calculations with MCNP: A Primer, Manual LA-12827, Los Alamos National Laboratory, Los Alamos NM, 1993
D. R. Lide, CRC Handbook of Chemistry an Physics, CRC Press, Boston MA, 1991.
F. H. Attix, Introduction to Radiological Physics and Radiation Dosimetry. John Wiley & Sons, Inc., New York NY, 1986

Attachments:

Attachment 1: MCNP surface and cell numbers
Attachment 2: MCNP input file
Attachment 3: MCNP output file

Prepared by:

Signature Igor V. Chichkov — Date 02/21/2001

Checked by:

Signature Kevin Roberts — Date 2/26/01

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Job No 30822-244-330 /6860 Job: PSR-6 By JVC Date 02/21/2007
Client WVNS Subject: cellulose-Pu-239 spheres Chk'd. KR Date 2/26/07

Analysis

Assumptions

- Pu-239 inside the sphere is uniformly mixed with 0.9 g/cm^3 cellulose
- The pure cellulose fills the entire space inside the container and outside the Plutonium sphere.
- The containers stand on the 3 m thick concrete floor
- B-25 box inside dimensions are 172.72 x 137.16 x 87.63 cm or 68 x 54 x 34.5 inches
- The B-25 box wall thickness is zero
- Every B-25 Box contains 200 g of Pu-239
- The B-25 boxes are arranged in the infinite square array, 4 tiers heigh ($\infty \times \infty \times 4$)

MCNP Model

Neutron multiplication factors were calculated with MCNP4A code. Attachments 1 has the drawings of the models used. Examples of MCNP input and output files for both cases can also be found in the Attachments. The plutonium spheres were located in the different positions on the box's angle bisector Attachments 1. The Z-coordinates for the spheres' centers were chosen so that the 1st tier sphere is located at the top of the container and at the same time the 2nd tier sphere is located at the bottom, the 3rd tier sphere is located at the top and 4th tier sphere is located at the bottom, i.e. the 1st tier - 2nd tier sphere contact, and 3rd - 4th tier sphere contact. The density parametric analysis for the cellulose outside the sphere with Plutonium was performed for each case.

Air, Carbon Steel, Concrete and Cellulose Composition

Table 1 shows the element weight fractions for air (Attix F.H., 1986). Table 2 shows the element weight fractions for carbon steel (Harmon C. D., II et al., 1993) used in the drum walls. Table 3 shows the element composition of concrete (Harmon C. D., II et al., 1993) in the floor.

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Job No 30822-244-330 /6860 Job: PSR-6 By IVC Date 02/21/2001
Client WVNS Subject: cellulose-Pu-239 spheres Chk'd. KZ Date 2/26/01

Table 1. Air composition

Element	Weight Fraction
Carbon (C)	0.000124
Nitrogen (N)	0.755267
Oxygen (O)	0.231781
Argon (Ar)	0.012827

Table 2. Carbon Steel Composition

Element	Weight Fraction
Iron (Fe)	0.995
Carbon (C)	0.005

Table 3. Concrete composition

Element	Weight Fraction
Hydrogen (H)	0.010
Oxygen (O)	0.532
Sodium (Na)	0.029
Aluminum (Al)	0.034
Silicon (Si)	0.337
Calcium (Ca)	0.044
Iron (Fe)	0.014

The weight fractions of the elements composing the cellulose were determined based on the known atomic weights of the elements (Table 4) and the cellulose chemical formula - $C_6H_{10}O_5$.

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Job No 30822-244-330 /6860 Job: PSR-6 By IVC Date 02/21/2007
Client WVNS Subject: cellulose-Pu-239 spheres Chk'd. KR Date 2/26/07

Table 4. The atomic weights of the elements

Element	Atomic Weight
Hydrogen (H)	1.00794
Carbon (C)	12.0107
Oxygen (O)	15.9994

The molecular weight of cellulose ($C_6H_{10}O_5$) was calculated as the sum of all atomic weights composing the molecule. The weight fraction of an ith element was found as a ratio of the ith element weight in the molecule to the molecular weight of this molecule.

$$(w_i)_{cel} = \frac{n_i A_i}{M_{cel}} = \frac{n_i A_i}{\sum n_i A_i} \qquad (1)$$

where

$(w_i)_{cel}$ = the weight fraction of ith element in a molecule of cellulose

n_i = the number of the ith elements in a cellulose molecule

A_i = the atomic weight of the ith element, g/mol

M_{cel} = the molecular weight a cellulose molecule, g/mol

Calculated weight fractions for cellulose are shown in Table 5.

Table 5. Cellulose Weight Fractions

Element	Weight Fraction
Hydrogen (H)	0.062
Carbon (C)	0.444
Oxygen (O)	0.493

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Radii of the Plutonium containing spheres.

The spheres with several different radii were studied. The minimum size of the Plutonium containing sphere corresponded to the sphere with pure Pu-239 and the maximum size was limited by the dimensions of the container, i.e. half of the box height. The minimum radius equation (3) was derived from the volume of a sphere equation (2)

$$V_{Pu} = \frac{4\pi\left(R_{Pu}\right)^3}{3} \qquad (2)$$

$$R_{\min} = R_{Pu} = \sqrt[3]{\frac{3V_{Pu}}{4\pi}} = \sqrt[3]{\frac{3m_{Pu}}{4\pi\rho_{Pu}}} \qquad (3)$$

where:

R_{min} = the minimum possible radius of the sphere containing Pu-239, cm

R_{Pu} = the radius of the metal Plutonium sphere, cm

V_{Pu} = the volume of the sphere with Pu-239, cm^3

m_{Pu} = the mass of the Plutonium sphere, g

ρ_{Pu} = the density of the metal Plutonium, 19.78 g/cm^3

Composition of the Plutonium containing spheres

The weight fractions of the elements composing the mixture are defined as the ratio of the mass of the element in the mixture to the total mass of the mixture. Total mass of the mixture was determined using equation (4):

$$M_{total} = m_{Pu} + m_{cel} = m_{Pu} + V_{cel}\rho_{cel} =$$

$$= m_{Pu} + \left(V_{Total} - V_{Pu}\right)\rho_{cel} = m_{Pu} + \left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel} \qquad (4)$$

where

M_{Total} = the total mass of the mixture, g

m_{Pu} = the mass of Pu-239 in a sphere, g

m_{cel} = the mass of a cellulose in a sphere, g

V_{Total} = the total volume of a sphere, cm^3

V_{cel} = the volume of a cellulose in the sphere, cm^3

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Job No 30822-244-330 /6860 Job: PSR-6 By IVC Date 02/21/2001
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ρ_{cel} = the density of a cellulose, 0.9 g/cm^3

V_{Pu} = the volume of Pu-239 in the sphere, cm^3

ρ_{Pu} = the density of the metal Plutonium, 19.78 g/cm^3

R = the radius of a Plutonium containing sphere, cm

In the Plutonium-cellulose mixture, the weight fraction of Pu-239 was calculated using equation 5, and the weight fractions of elements composing cellulose were calculated using equation 7 as a product of the weight fraction of a cellulose in the Plutonium-cellulose mixture (equation 6) and the weight fraction of an element in a pure cellulose (equation 1).

$$w_{Pu} = \frac{m_{Pu}}{M_{total}} = \frac{m_{Pu}}{m_{Pu} + \left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel}} \tag{5}$$

$$w_{cel} = \frac{m_{cel}}{M_{total}} = \frac{\left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel}}{m_{Pu} + \left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel}} \tag{6}$$

$$w_i = w_{cel}(w_i)_{cel} = \frac{\left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel} n_i A_i}{\left[m_{Pu} + \left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel}\right]\sum n_i A_i} \tag{7}$$

All variables in equations 5-7 are as described above. Table 6 shows the composition of the Plutonium containing spheres.

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Job No 30822-244-330 /6860 Job: PSR-6 By IVC Date 02/21/2001
Client WVNS Subject: cellulose-Pu-239 spheres Chk'd. [illegible] Date 2/26/01

Table 6. The composition of the Plutonium containing spheres

Radius of the sphere, cm	5.00	10.00	15.00	20.00	30.00	43.82
Mixture density, g/cm^3	1.2646	0.9456	0.9135	0.9057	0.9017	0.9005
Pu-239 weight fraction	3.02e-01	5.05e-02	1.55e-02	6.59e-03	1.96e-03	6.30e-04
Carbon (C) weight fraction	3.10e-01	4.22e-01	4.38e-01	4.42e-01	4.44e-01	4.44e-01
Hydrogen (H)weight fraction	4.34e-02	5.90e-02	6.12e-02	6.18e-02	6.20e-02	6.21e-02
Oxygen (O) weight fraction	3.44e-01	4.68e-01	4.86e-01	4.90e-01	4.92e-01	4.93e-01

Results

The results of the calculations performed using MCNP-4A code are shown in the following tables and graphs. Table 7 provide the Monte Carlo determined neutron multiplication factor (k_{eff}) values and their standard deviations (σ), and Figure 1 plots the k_{eff} +2 σ values for all studied cases.

Table 7. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for 200 g Pu-239 spheres in the B-25 box with cellulose. The spheres are located so that they touch the box wall in two points. The Z-coordinates spheres' centers correspond to the location of 1st tier - 2nd tier sphere contact, and 3rd - 4th tier sphere contact.

R and X-, Y-, Z- coordinates for the center of the sphere, cm							100% density cellulose			80% density cellulose			60% density cellulose		
R	X	Y	Z1	Z2	Z3	Z4	k_{eff}	σ	k_{eff}+ 2σ	k_{eff}	σ	k_{eff}+ 2σ	k_{eff}	σ	k_{eff}+ 2σ
5.00	5.00	5.00	82.63	92.63	257.89	267.89	0.7007	0.0014	0.7035	0.6312	0.0012	0.6337	0.5418	0.0014	0.5447
10.00	10.00	10.00	77.63	97.63	252.89	272.89	0.9585	0.0013	0.9610	0.9272	0.0013	0.9298	0.8779	0.0013	0.8805
15.00	15.00	15.00	72.63	102.63	247.89	277.89	0.8931	0.0010	0.8951	0.8950	0.0012	0.8973	0.8863	0.0010	0.8883
20.00	20.00	20.00	67.63	107.63	242.89	282.89	0.7180	0.0009	0.7197	0.7278	0.0008	0.7295	0.7362	0.0009	0.7379
30.00	30.00	30.00	57.63	117.63	232.89	292.89	0.4102	0.0004	0.4110	0.4151	0.0004	0.4159	0.4210	0.0004	0.4218
43.82	43.82	43.82	43.82	131.45	219.08	306.71	0.1925	0.0002	0.1929	0.1936	0.0002	0.1940	0.1961	0.0002	0.1964

R and X-, Y-, Z- coordinates for the center of the sphere, cm							40% density cellulose			20% density cellulose			void		
R	X	Y	Z1	Z2	Z3	Z4	k_{eff}	σ	k_{eff}+ 2σ	k_{eff}	σ	k_{eff}+ 2σ	k_{eff}	σ	k_{eff}+ 2σ
5.00	5.00	5.00	82.63	92.63	257.89	267.89	0.4271	0.0011	0.4282	0.2711	0.0010	0.2730	0.1322	0.0007	0.1336
10.00	10.00	10.00	77.63	97.63	252.89	272.89	0.7900	0.0015	0.7915	0.6286	0.0015	0.6315	0.3907	0.0012	0.3931
15.00	15.00	15.00	72.63	102.63	247.89	277.89	0.8507	0.0012	0.8520	0.7588	0.0013	0.7613	0.5527	0.0012	0.5551
20.00	20.00	20.00	67.63	107.63	242.89	282.89	0.7301	0.0009	0.7310	0.6923	0.0009	0.6941	0.5548	0.0009	0.5566
30.00	30.00	30.00	57.63	117.63	232.89	292.89	0.4267	0.0005	0.4271	0.4285	0.0005	0.4294	0.3926	0.0005	0.3935
43.82	43.82	43.82	43.82	131.45	219.08	306.71	0.1989	0.0002	0.1991	0.2041	0.0002	0.2044	0.2052	0.0002	0.2056

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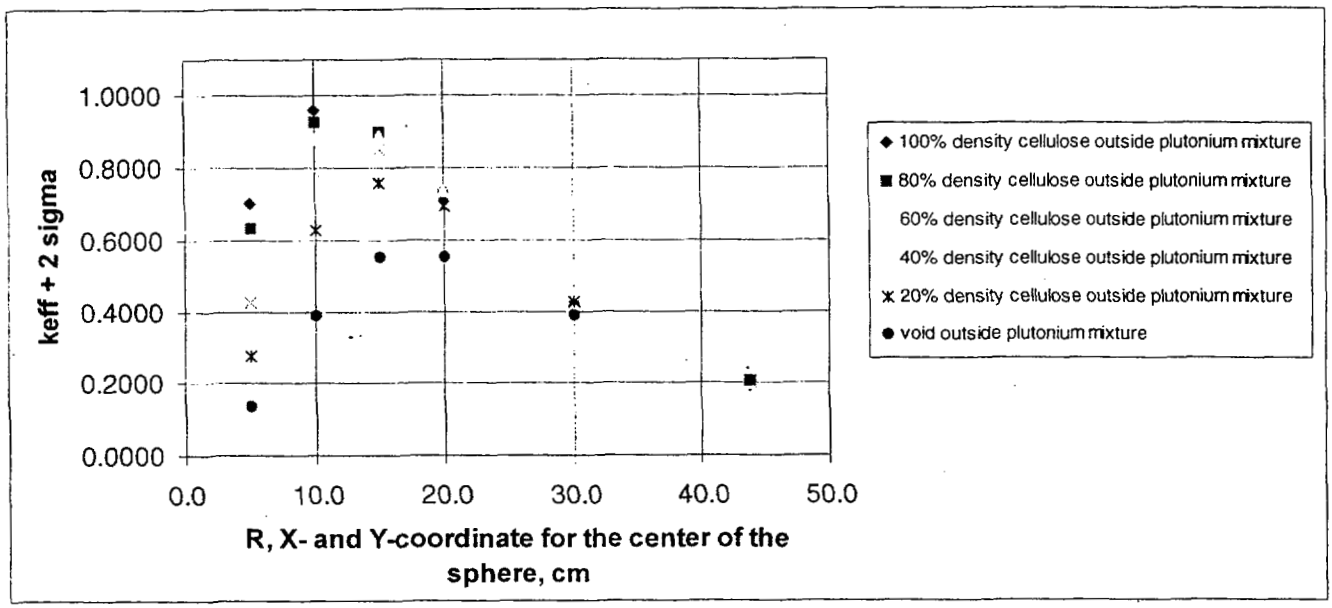
Sheet No. 8/8
Calc. No. BUF-2006-001
Rev. No. 0

Job No 30822-244-330 /6860 Job: PSR-6 By IVC Date 02/21/2001
Client WVNS Subject: cellulose-Pu-239 spheres Chk'd. [illegible] Date 2/26/01

Figure 1. k_{eff} +2σ for 200 g Pu-239 spheres in the B-25 box with cellulose. The spheres are located so that they touch the box wall in two points. The Z-coordinates spheres' centers correspond to the location of 1st tier - 2nd tier sphere contact, and 3rd - 4th tier sphere contact.

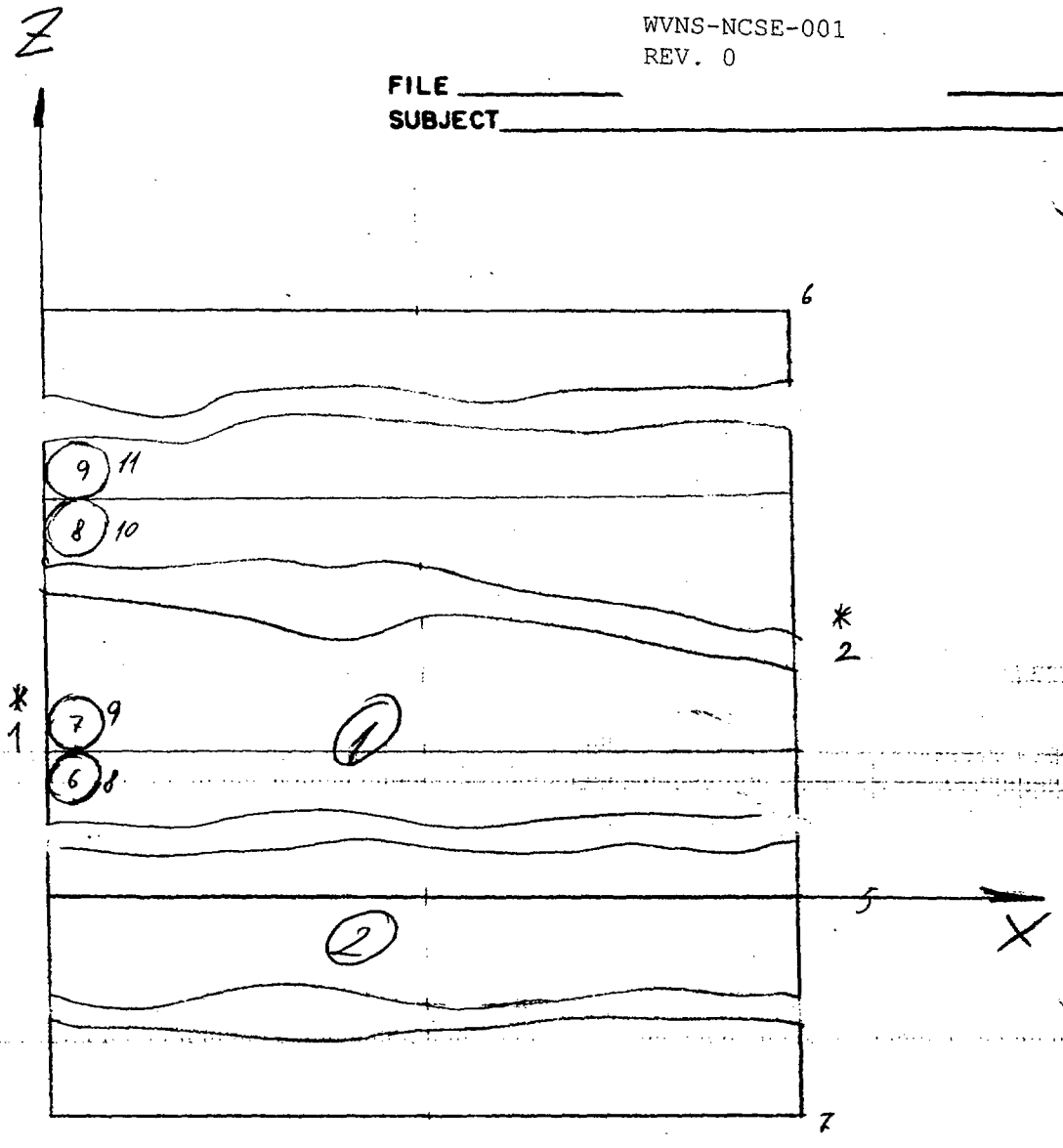


Attachment 1: MCNP model with surface and cell numbers

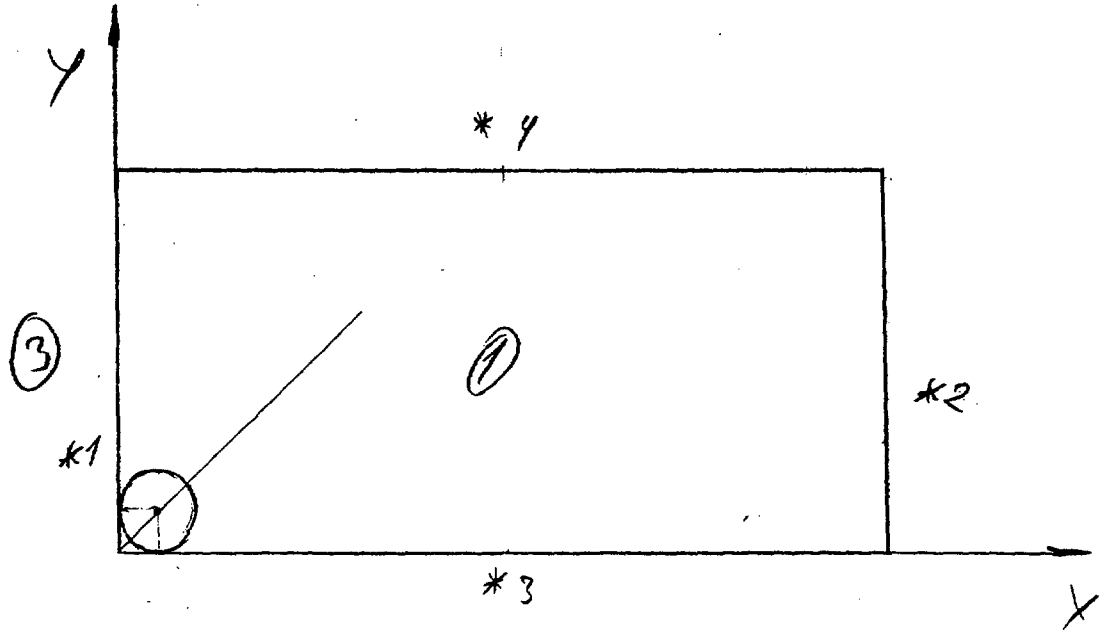
FILE _____

SUBJECT _____

REVISIONS
BY _____ DATE _____ TO EO _____
BY _____ DATE _____ TO EO _____



BY _____ DATE _____
CHECKED BY _____
COPY TO EO _____



Attachment 2: MCNP input file

```
                                                        3s810
k eff, 200g Pu-239 in cellulose spheres and pure celulose
c in the rest of B-25 box (68"x54"x34.5").
C
C Cell cards
C
C ------------------------------------------------------------------------
1 1  -0.90    1 -2 3 -4 5 -6 8 9 10 11 imp:n=1 $ TRU box with cellulose
2 2  -2.3     1 -2 3 -4 -5 7           imp:n=1 $ Concrete floor
3 0         -1 : 2 : -3 : 4 : -7 : 6  imp:n=0 $ Outside world
4 3  -0.905697 -8                     imp:n=1 $ 1 Pu-239 and cellulose sphere
5 3  -0.905697 -9                     imp:n=1 $ 2 Pu-239 and cellulose sphere
6 3  -0.905697 -10                    imp:n=1 $ 3 Pu-239 and cellulose sphere
7 3  -0.905697 -11                    imp:n=1 $ 4 Pu-239 and cellulose sphere
C ------------------------------------------------------------------------
c
c Note: next line must be completely blank

c Surface cards
C ------------------------------------------------------------------------
*1 px 0
*2 px 172.72  $ B-25 box length (68")
*3 py 0
*4 py 137.16  $ B-25 box width (54")
5  pz 0
6  pz 350.52  $ 4 tiers of B-25 box height (4x34.5" or 4x87.63 cm)
7  pz -300
8  s 20.0 20.0  67.63 20.0 $ 1st Pu-239 and cellulose sphere
9  s 20.0 20.0 107.63 20.0 $ 2nd Pu-239 and cellulose sphere
10 s 20.0 20.0 242.89 20.0 $ 3rd Pu-239 and cellulose sphere
11 s 20.0 20.0 282.89 20.0 $ 4th Pu-239 and cellulose sphere
C ------------------------------------------------------------------------
c
c Note: next line must be completely blank

c Data cards
c
c Materials
c
c
c Celulose matrix (Elements: C, H, O)
m1      6000.50c  -0.444
        1001.50c  -0.062
        8016.50c  -0.493
c Concrete (KENO Regular Concrete Standard Mix) from Harmon at al.
c Criticality Calculation with MCNP. A Primer. p. C-5
c (Elements: H, O, Na, Si, Al, Ca, Fe)
m2      1001.50c -0.010
        8016.50c -0.532
       11023.50c -0.029
       13027.50c -0.034
       14000.50c -0.337
       20000.50c -0.044
       26000.55c -0.014
c Pu-239 and cellulose
m3     94239.55c  -0.006590
        6000.50c  -0.441526
        1001.50c  -0.061755
        8016.50c  -0.490129
c
mode n
print 40 60 80 100 110 126
kcode 4000 1. 20 120
ksrc  20.0 20.0  67.63
      20.0 20.0 107.63
      20.0 20.0 242.89
      20.0 20.0 282.89
```

Attachment 3: MCNP output file

```
1mcnp     version 4a     ld=10/01/93                    01/15/01 07:38:39
 ***********************************************************************          probid =    01/15/01 07:38:39
 name=3s810

    1-       k eff, 200g Pu-239 in cellulose spheres and pure celulose
    2-       c in the rest of B-25 box (68"x54"x34.5").
    3-       C
    4-       C Cell cards
    5-       C
    6-       C ---------------------------------------------------------------------
    7-       1 1  -0.90    1 -2 3 -4 5 -6 8 9 10 11 imp:n=1 $ TRU box with cellulose
    8-       2 2  -2.3     1 -2 3 -4 -5 7           imp:n=1 $ Concrete floor
    9-       3 0          -1 : 2 : -3 : 4 : -7 : 6  imp:n=0 $ Outside world
   10-       4 3  -0.905697 -8                     imp:n=1 $ 1 Pu-239 and cellulose sphere
   11-       5 3  -0.905697 -9                     imp:n=1 $ 2 Pu-239 and cellulose sphere
   12-       6 3  -0.905697 -10                    imp:n=1 $ 3 Pu-239 and cellulose sphere
   13-       7 3  -0.905697 -11                    imp:n=1 $ 4 Pu-239 and cellulose sphere
   14-       C ---------------------------------------------------------------------
   15-       c
   16-       c Note: next line must be completely blank
   17-
   18-       c Surface cards
   19-       C ---------------------------------------------------------------------
   20-       *1 px 0
   21-       *2 px 172.72  $ B-25 box length (68")
   22-       *3 py 0
   23-       *4 py 137.16  $ B-25 box width (54")
   24-       5  pz 0
   25-       6  pz 350.52  $ 4 tiers of B-25 box height (4x34.5" or 4x87.63 cm)
   26-       7  pz -300
   27-       8  s 20.0 20.0  67.63 20.0 $ 1st Pu-239 and cellulose sphere
   28-       9  s 20.0 20.0 107.63 20.0 $ 2nd Pu-239 and cellulose sphere
   29-       10 s 20.0 20.0 242.89 20.0 $ 3rd Pu-239 and cellulose sphere
   30-       11 s 20.0 20.0 282.89 20.0 $ 4th Pu-239 and cellulose sphere
   31-       C ---------------------------------------------------------------------
   32-       c
   33-       c Note: next line must be completely blank
   34-
   35-       c Data cards
   36-       c
   37-       c Materials
   38-       c
   39-       c
   40-       c Celulose matrix (Elements: C, H, O)
   41-       m1     6000.50c  -0.444
   42-              1001.50c  -0.062
   43-              8016.50c  -0.493
   44-       c Concrete (KENO Regular Concrete Standard Mix) from Harmon at al.
   45-       c Criticality Calculation with MCNP. A Primer. p. C-4
   46-       c (Elements: H, O, Na, Si, Al, Ca, Fe)
   47-       m2     1001.50c -0.010
   48-              8016.50c -0.532
   49-             11023.50c -0.029
   50-             13027.50c -0.034
   51-             14000.50c -0.337
   52-             20000.50c -0.044
   53-             26000.55c -0.014
   54-       c Pu-239 and cellulose
```

```
   55-        m3     94239.55c  -0.006590
   56-                6000.50c  -0.441526
   57-                1001.50c  -0.061755
   58-                8016.50c  -0.490129
   59-        c
   60-        mode n
   61-        print 40 60 80 100 110 126
   62-        kcode 4000 1. 20 120
   63-        ksrc  20.0 20.0  67.63
   64-              20.0 20.0 107.63
   65-              20.0 20.0 242.89
   66-              20.0 20.0 282.89
   67-
 total fission nubar data are being used.
1material composition                                                    print table 40

 the sum of the fractions of material     1 was 9.990000E-01

 material
  number      component nuclide, atom fraction

     1            6000,  0.28588       1001,  0.47576       8016,  0.23837
     2            1001,  0.16803       8016,  0.56324      11023,  0.02136      13027,  0.02134
                 14000,  0.20319      20000,  0.01859      26000,  0.00425
     3           94239,  0.00021       6000,  0.28561       1001,  0.47609       8016,  0.23808



 material
  number      component nuclide, mass fraction

     1            6000,  0.44444       1001,  0.06206       8016,  0.49349
     2            1001,  0.01000       8016,  0.53200      11023,  0.02900      13027,  0.03400
                 14000,  0.33700      20000,  0.04400      26000,  0.01400
     3           94239,  0.00659       6000,  0.44153       1001,  0.06176       8016,  0.49013

 warning.     1 of the materials had unnormalized fractions.
1cells                                                                   print table 60

                      atom         gram                                        neutron
        cell   mat    density      density      volume        mass        pieces importance

     1     1     1  7.01524E-02 9.00000E-01 0.00000E+00 0.00000E+00      0  1.0000E+00
     2     2     2  8.17913E-02 2.30000E+00 7.10708E+06 1.63463E+07      0  1.0000E+00
     3     3     0  0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00      0  0.0000E+00
     4     4     3  7.01981E-02 9.05697E-01 3.35103E+04 3.03502E+04      1  1.0000E+00
     5     5     3  7.01981E-02 9.05697E-01 3.35103E+04 3.03502E+04      1  1.0000E+00
     6     6     3  7.01981E-02 9.05697E-01 3.35103E+04 3.03502E+04      1  1.0000E+00
     7     7     3  7.01981E-02 9.05697E-01 3.35103E+04 3.03502E+04      1  1.0000E+00

 total                                     7.24112E+06 1.64677E+07

         1 warning message so far.
1cross-section tables                                                    print table 100

     table    length
```

tables from file critxs

1001.50c	1153	njoy		(1301)	79/07/31.
6000.50c	16126	njoy		(1306)	79/07/31.
8016.50c	23669	njoy		(1276)	05/14/81
11023.50c	36270	njoy		(1311)	79/06/21.
13027.50c	22891	njoy		(1313)	79/09/08.
14000.50c	48275	njoy		(1314)	79/06/21.
20000.50c	26104	njoy		(1320)	79/06/22.
26000.55c	84136	njoy		(260)	10/21/82
94239.55c	67551	njoy	total nu	(1399)	02/21/85
total	326175				

warning. neutron energy cutoff is below some cross-section tables.

decimal words of dynamically allocated storage

general	111050
tallies	0
bank	6403
cross sections	326175
total	443628

****

dump no. 1 on file 3s810r nps = 0 coll = 0 ctm = 0.00 nrn = 0

source distribution written to file 3s810s cycle = 0

2 warning messages so far.

1 starting mcrun. field length = 0 cp0 = 0.01 print table 110

k eff, 350g Pu-239 in cellulose spheres and pure celulose

nps	x	y	z	cell	surf	u	v	w	energy	weight	time
1	2.000E+01	2.000E+01	6.763E+01	4	0	5.085E-01	4.733E-01	7.193E-01	2.209E+00	1.000E+00	0.000E+00
2	2.000E+01	2.000E+01	6.763E+01	4	0	8.952E-01	-4.447E-01	-2.944E-02	4.904E+00	1.000E+00	0.000E+00
3	2.000E+01	2.000E+01	6.763E+01	4	0	-6.184E-01	-4.495E-01	6.446E-01	3.809E-01	1.000E+00	0.000E+00
4	2.000E+01	2.000E+01	6.763E+01	4	0	9.710E-01	-5.665E-02	-2.323E-01	1.331E+00	1.000E+00	0.000E+00
5	2.000E+01	2.000E+01	6.763E+01	4	0	5.861E-01	1.496E-01	-7.963E-01	1.902E+00	1.000E+00	0.000E+00
6	2.000E+01	2.000E+01	6.763E+01	4	0	-6.489E-02	-1.626E-01	9.845E-01	4.410E-01	1.000E+00	0.000E+00
7	2.000E+01	2.000E+01	6.763E+01	4	0	-7.068E-02	3.263E-02	-9.970E-01	4.750E-01	1.000E+00	0.000E+00
8	2.000E+01	2.000E+01	6.763E+01	4	0	-3.915E-01	4.664E-01	-7.932E-01	4.136E+00	1.000E+00	0.000E+00
9	2.000E+01	2.000E+01	6.763E+01	4	0	-2.368E-01	9.215E-01	-3.079E-01	7.453E-02	1.000E+00	0.000E+00
10	2.000E+01	2.000E+01	6.763E+01	4	0	1.946E-01	-3.204E-01	9.271E-01	3.128E+00	1.000E+00	0.000E+00
11	2.000E+01	2.000E+01	6.763E+01	4	0	-6.698E-01	-7.177E-01	-1.905E-01	1.014E+00	1.000E+00	0.000E+00
12	2.000E+01	2.000E+01	6.763E+01	4	0	-8.398E-01	-4.129E-01	3.524E-01	1.395E+00	1.000E+00	0.000E+00
13	2.000E+01	2.000E+01	6.763E+01	4	0	-1.714E-01	-8.572E-01	4.857E-01	7.748E-01	1.000E+00	0.000E+00
14	2.000E+01	2.000E+01	6.763E+01	4	0	-2.489E-01	-5.118E-01	-8.222E-01	1.101E+00	1.000E+00	0.000E+00

15	2.000E+01	2.000E+01	6.763E+01	4	0	-2.959E-01	2.119E-01	9.314E-01	1.951E+00	1.000E+00	0.000E+00
16	2.000E+01	2.000E+01	6.763E+01	4	0	1.395E-01	-9.829E-01	1.202E-01	2.186E+00	1.000E+00	0.000E+00
17	2.000E+01	2.000E+01	6.763E+01	4	0	6.909E-01	-7.110E-01	1.307E-01	1.865E+00	1.000E+00	0.000E+00
18	2.000E+01	2.000E+01	6.763E+01	4	0	-6.580E-01	5.320E-01	-5.329E-01	1.229E+00	1.000E+00	0.000E+00
19	2.000E+01	2.000E+01	6.763E+01	4	0	-9.903E-01	-1.380E-01	1.353E-02	1.305E+00	1.000E+00	0.000E+00
20	2.000E+01	2.000E+01	6.763E+01	4	0	7.462E-01	4.859E-01	-4.551E-01	1.000E+00	1.000E+00	0.000E+00
21	2.000E+01	2.000E+01	6.763E+01	4	0	-1.977E-01	9.797E-01	3.360E-02	3.990E+00	1.000E+00	0.000E+00
22	2.000E+01	2.000E+01	6.763E+01	4	0	-9.117E-01	-3.647E-01	-1.891E-01	2.665E-01	1.000E+00	0.000E+00
23	2.000E+01	2.000E+01	6.763E+01	4	0	-4.287E-01	8.361E-01	-3.423E-01	1.156E+00	1.000E+00	0.000E+00
24	2.000E+01	2.000E+01	6.763E+01	4	0	1.080E-01	3.412E-01	-9.338E-01	2.669E+00	1.000E+00	0.000E+00
25	2.000E+01	2.000E+01	6.763E+01	4	0	-9.111E-01	-9.012E-03	-4.122E-01	2.185E+00	1.000E+00	0.000E+00
26	2.000E+01	2.000E+01	6.763E+01	4	0	-2.568E-01	-6.391E-01	-7.249E-01	4.225E+00	1.000E+00	0.000E+00
27	2.000E+01	2.000E+01	6.763E+01	4	0	-2.912E-01	8.086E-01	5.113E-01	1.079E+00	1.000E+00	0.000E+00
28	2.000E+01	2.000E+01	6.763E+01	4	0	1.472E-01	-9.514E-01	2.705E-01	3.461E+00	1.000E+00	0.000E+00
29	2.000E+01	2.000E+01	6.763E+01	4	0	-6.135E-01	-7.645E-01	-1.978E-01	1.836E+00	1.000E+00	0.000E+00
30	2.000E+01	2.000E+01	6.763E+01	4	0	-5.702E-01	5.651E-01	-5.963E-01	4.556E-01	1.000E+00	0.000E+00
31	2.000E+01	2.000E+01	6.763E+01	4	0	-6.607E-01	5.373E-01	-5.242E-01	6.415E-01	1.000E+00	0.000E+00
32	2.000E+01	2.000E+01	6.763E+01	4	0	-9.742E-02	-3.639E-01	-9.263E-01	2.764E+00	1.000E+00	0.000E+00
33	2.000E+01	2.000E+01	6.763E+01	4	0	-1.965E-01	-3.145E-01	-9.287E-01	2.785E-01	1.000E+00	0.000E+00
34	2.000E+01	2.000E+01	6.763E+01	4	0	4.097E-01	8.465E-01	-3.399E-01	9.097E-01	1.000E+00	0.000E+00
35	2.000E+01	2.000E+01	6.763E+01	4	0	-4.048E-02	8.831E-01	4.675E-01	3.360E-01	1.000E+00	0.000E+00
36	2.000E+01	2.000E+01	6.763E+01	4	0	3.371E-01	-9.269E-01	-1.652E-01	6.376E-01	1.000E+00	0.000E+00
37	2.000E+01	2.000E+01	6.763E+01	4	0	-1.867E-01	9.756E-01	-1.155E-01	2.186E+00	1.000E+00	0.000E+00
38	2.000E+01	2.000E+01	6.763E+01	4	0	-2.616E-01	2.336E-01	-9.365E-01	7.314E-01	1.000E+00	0.000E+00
39	2.000E+01	2.000E+01	6.763E+01	4	0	9.780E-01	-7.641E-02	-1.939E-01	2.997E-01	1.000E+00	0.000E+00
40	2.000E+01	2.000E+01	6.763E+01	4	0	2.580E-01	-7.076E-01	6.578E-01	1.444E+00	1.000E+00	0.000E+00
41	2.000E+01	2.000E+01	6.763E+01	4	0	-3.212E-01	-7.678E-01	-5.543E-01	1.914E+00	1.000E+00	0.000E+00
42	2.000E+01	2.000E+01	6.763E+01	4	0	5.039E-01	-1.460E-01	8.513E-01	1.502E+00	1.000E+00	0.000E+00
43	2.000E+01	2.000E+01	6.763E+01	4	0	6.080E-01	5.487E-01	5.738E-01	5.971E+00	1.000E+00	0.000E+00
44	2.000E+01	2.000E+01	6.763E+01	4	0	-2.932E-01	9.304E-01	-2.199E-01	1.827E+00	1.000E+00	0.000E+00
45	2.000E+01	2.000E+01	6.763E+01	4	0	-8.475E-01	-3.993E-01	-3.497E-01	1.928E+00	1.000E+00	0.000E+00
46	2.000E+01	2.000E+01	6.763E+01	4	0	1.200E-01	-9.195E-01	-3.743E-01	1.351E+00	1.000E+00	0.000E+00
47	2.000E+01	2.000E+01	6.763E+01	4	0	7.085E-01	5.879E-01	3.904E-01	2.288E+00	1.000E+00	0.000E+00
48	2.000E+01	2.000E+01	6.763E+01	4	0	4.261E-01	9.046E-01	9.254E-03	1.230E+00	1.000E+00	0.000E+00
49	2.000E+01	2.000E+01	6.763E+01	4	0	5.431E-01	4.270E-01	-7.230E-01	1.433E+00	1.000E+00	0.000E+00
50	2.000E+01	2.000E+01	6.763E+01	4	0	-1.053E-01	-9.805E-01	1.658E-01	6.572E-01	1.000E+00	0.000E+00

lestimated keff results by cycle print table 175

source distribution written to file 3s810s cycle = 20

source distribution written to file 3s810s cycle = 23

source distribution written to file 3s810s cycle = 26

source distribution written to file 3s810s cycle = 29

source distribution written to file 3s810s cycle = 32

source distribution written to file 3s810s cycle = 35

source distribution written to file 3s810s cycle = 38

source distribution written to file 3s810s cycle = 41

source distribution written to file 3s810s cycle = 44

****

dump no. 2 on file 3s810r nps = 178779 coll = 28783745 ctm = 15.25 nrn = 508076271

source distribution written to file 3s810s cycle = 47

source distribution written to file 3s810s cycle = 50

source distribution written to file 3s810s cycle = 53

source distribution written to file 3s810s cycle = 56

source distribution written to file 3s810s cycle = 59

source distribution written to file 3s810s cycle = 62

source distribution written to file 3s810s cycle = 65

source distribution written to file 3s810s cycle = 68

source distribution written to file 3s810s cycle = 71

source distribution written to file 3s810s cycle = 74

source distribution written to file 3s810s cycle = 77

source distribution written to file 3s810s cycle = 80

source distribution written to file 3s810s cycle = 83

source distribution written to file 3s810s cycle = 86

source distribution written to file 3s810s cycle = 89

****

dump no. 3 on file 3s810r nps = 354525 coll = 57198312 ctm = 30.31 nrn = 1009626300

source distribution written to file 3s810s cycle = 92

source distribution written to file 3s810s cycle = 95

source distribution written to file 3s810s cycle = 98

estimator	cycle 100	ave of 80 cycles		combination	simple average		combined average		corr
k(collision)	0.716838	0.718757	0.0019	k(col/abs)	0.718643	0.0013	0.718639	0.0014	0.0714
k(absorption)	0.715541	0.718530	0.0018	k(abs/tk ln)	0.718444	0.0014	0.718447	0.0014	0.0711
k(trk length)	0.715640	0.718358	0.0019	k(tk ln/col)	0.718558	0.0019	0.718611	0.0019	0.9865
rem life(col)	2.6750E+04	2.6112E+04	0.0023	k(col/abs/tk ln)	0.718548	0.0014	0.718568	0.0014	
rem life(abs)	2.6603E+04	2.6121E+04	0.0020	life(col/abs)	2.6116E+04	0.0021	2.6125E+04	0.0020	0.9461

source points generated 3959

source distribution written to file 3s810s cycle = 101

source distribution written to file 3s810s cycle = 104

source distribution written to file 3s810s cycle = 107

source distribution written to file 3s810s cycle = 110

source distribution written to file 3s810s cycle = 113

estimator	cycle 116	ave of 96 cycles		combination	simple average		combined average		corr
k(collision)	0.712301	0.718574	0.0017	k(col/abs)	0.718308	0.0012	0.718293	0.0012	0.0747
k(absorption)	0.716014	0.718041	0.0016	k(abs/tk ln)	0.718086	0.0012	0.718083	0.0012	0.0555
k(trk length)	0.710001	0.718131	0.0017	k(tk ln/col)	0.718353	0.0017	0.718482	0.0017	0.9848
rem life(col)	2.6249E+04	2.6117E+04	0.0020	k(col/abs/tk ln)	0.718249	0.0013	0.718111	0.0012	
rem life(abs)	2.6170E+04	2.6115E+04	0.0019	life(col/abs)	2.6116E+04	0.0019	2.6115E+04	0.0019	0.9478

source points generated 3996

source distribution written to file 3s810s cycle = 116

estimator	cycle 117	ave of 97 cycles		combination	simple average		combined average		corr
k(collision)	0.696806	0.718350	0.0017	k(col/abs)	0.718108	0.0012	0.718093	0.0012	0.1000
k(absorption)	0.701116	0.717866	0.0016	k(abs/tk ln)	0.717903	0.0012	0.717900	0.0012	0.0775
k(trk length)	0.699502	0.717939	0.0017	k(tk ln/col)	0.718145	0.0017	0.718201	0.0017	0.9849
rem life(col)	2.6182E+04	2.6118E+04	0.0020	k(col/abs/tk ln)	0.718052	0.0013	0.717870	0.0013	
rem life(abs)	2.6161E+04	2.6116E+04	0.0018	life(col/abs)	2.6117E+04	0.0019	2.6115E+04	0.0018	0.9478

source points generated 3925

estimator	cycle 118	ave of 98 cycles		combination	simple average		combined average		corr
k(collision)	0.725436	0.718422	0.0017	k(col/abs)	0.718171	0.0012	0.718155	0.0012	0.1025
k(absorption)	0.723155	0.717920	0.0016	k(abs/tk ln)	0.717963	0.0012	0.717960	0.0012	0.0799
k(trk length)	0.724521	0.718006	0.0017	k(tk ln/col)	0.718214	0.0017	0.718268	0.0017	0.9849
rem life(col)	2.5757E+04	2.6114E+04	0.0020	k(col/abs/tk ln)	0.718116	0.0013	0.717927	0.0013	
rem life(abs)	2.5659E+04	2.6111E+04	0.0018	life(col/abs)	2.6113E+04	0.0019	2.6110E+04	0.0018	0.9478

source points generated 4154

estimator	cycle 119	ave of 99 cycles		combination	simple average		combined average		corr
k(collision)	0.718419	0.718422	0.0017	k(col/abs)	0.718226	0.0012	0.718214	0.0012	0.1021
k(absorption)	0.728673	0.718029	0.0016	k(abs/tk ln)	0.718011	0.0012	0.718012	0.0012	0.0786
k(trk length)	0.716764	0.717994	0.0017	k(tk ln/col)	0.718208	0.0017	0.718264	0.0017	0.9849
rem life(col)	2.6716E+04	2.6120E+04	0.0020	k(col/abs/tk ln)	0.718148	0.0013	0.717973	0.0012	
rem life(abs)	2.6942E+04	2.6120E+04	0.0018	life(col/abs)	2.6120E+04	0.0019	2.6119E+04	0.0018	0.9472

source points generated 3985

source distribution written to file 3s810s cycle = 119

estimator	cycle 120	ave of 100 cycles		combination	simple average		combined average		corr
k(collision)	0.710737	0.718345	0.0017	k(col/abs)	0.718213	0.0012	0.718205	0.0012	0.0988
k(absorption)	0.723193	0.718081	0.0016	k(abs/tk ln)	0.718005	0.0012	0.718010	0.0012	0.0759
k(trk length)	0.711560	0.717929	0.0017	k(tk ln/col)	0.718137	0.0017	0.718183	0.0017	0.9849
rem life(col)	2.6234E+04	2.6121E+04	0.0020	k(col/abs/tk ln)	0.718119	0.0013	0.717972	0.0012	
rem life(abs)	2.6305E+04	2.6121E+04	0.0018	life(col/abs)	2.6121E+04	0.0019	2.6121E+04	0.0018	0.9471

source points generated 3979

source distribution written to file 3s810s cycle = 120

1problem summary

run terminated when 120 kcode cycles were done.

01/15/01 08:19:35

k eff, 350g Pu-239 in cellulose spheres and pure celulose probid = 01/15/01 07:38:39

0

neutron creation	tracks	weight (per source particle)	energy (per source particle)	neutron loss	tracks	weight (per source particle)	energy (per source particle)
source	478047	1.0041E+00	2.1147E+00	escape	234	2.6610E-04	2.1808E-04
				energy cutoff	0	0.	0.

weight window	0	0.	0.
cell importance	0	0.	0.
weight cutoff	0	1.1247E-01	1.7411E-08
energy importance	0	0.	0.
dxtran	0	0.	0.
forced collisions	0	0.	0.
exp. transform	0	0.	0.
upscattering	0	0.	8.5366E-07
(n,xn)	0	0.	0.
fission	0	0.	0.
total	478047	1.1166E+00	2.1147E+00

time cutoff	0	0.	0.
weight window	0	0.	0.
cell importance	0	0.	0.
weight cutoff	477813	1.1345E-01	1.7037E-08
energy importance	0	0.	0.
dxtran	0	0.	0.
forced collisions	0	0.	0.
exp. transform	0	0.	0.
downscattering	0	0.	2.0941E+00
capture	0	7.5274E-01	1.9749E-02
loss to (n,xn)	0	0.	0.
loss to fission	0	2.5010E-01	6.1184E-04
total	478047	1.1166E+00	2.1147E+00

number of neutrons banked	0
neutron tracks per source particle	1.0000E+00
neutron collisions per source particle	1.6154E+02
total neutron collisions	77225971
net multiplication	1.0000E+00 0.0001

average lifetime, shakes	
escape	4.0010E+04
capture	2.6099E+04
capture or escape	2.6103E+04
any termination	3.1213E+04

cutoffs	
tco	1.0000E+34
eco	0.0000E+00
wc1	-5.0000E-01
wc2	-2.5000E-01

computer time so far in this run	40.93 minutes
computer time in mcrun	40.92 minutes
source particles per minute	1.1682E+04
random numbers generated	1363119709

maximum number ever in bank	0
bank overflows to backup file	0
field length	0
most random numbers used was	27944 in history 214537

range of sampled source weights = 9.0293E-01 to 1.2055E+00

1neutron activity in each cell print table 126

cell		tracks entering	population	collisions	collisions * weight (per history)	number weighted energy	flux weighted energy	average track weight (relative)	average track mfp (cm)
1	1	1088141	384768	51062368	5.7414E+01	3.8826E-05	2.2382E-01	5.7502E-01	1.4769E+00
2	2	615	262	16741	1.5300E-02	3.1932E-05	1.9712E-01	4.6079E-01	2.0393E+00
4	4	377041	147217	7100982	1.0435E+01	1.3764E-04	5.0805E-01	7.7192E-01	2.1693E+00
5	5	374802	146596	7079481	1.0398E+01	1.3683E-04	5.0404E-01	7.7143E-01	2.1648E+00
6	6	318278	124120	5989953	8.8040E+00	1.3767E-04	5.0781E-01	7.7207E-01	2.1692E+00
7	7	318622	123678	5976446	8.7727E+00	1.3730E-04	5.0731E-01	7.7145E-01	2.1675E+00
total		2477499	926641	77225971	9.5838E+01				

1keff results for: k eff, 350g Pu-239 in cellulose spheres and pure celulose probid = 01/15/01 07:38:39

the initial fission neutron source distribution used the 4 source points that were input on the ksrc card.
the criticality problem was scheduled to skip 20 cycles and run a total of 120 cycles with nominally 4000 neutrons per cycle.
this problem has run 20 inactive cycles with 78720 neutron histories and 100 active cycles with 399327 neutron histories.

this calculation has completed the requested number of keff cycles using a total of 478047 fission neutron source histories.
all cells with fissionable material were sampled and had fission neutron source points.

the results of the w test for normality applied to the individual collision, absorption, and track-length keff cycle values are:

the k(collision) cycle values appear normally distributed at the 95 percent confidence level
the k(absorption) cycle values appear normally distributed at the 95 percent confidence level
the k(trk length) cycle values appear normally distributed at the 95 percent confidence level

the final estimated combined collision/absorption/track-length keff = 0.71797 with an estimated standard deviation of 0.00088

the estimated 68, 95, & 99 percent keff confidence intervals are 0.71709 to 0.71885, 0.71622 to 0.71973, and 0.71564 to 0.72030

the estimated collision/absorption neutron removal lifetime = 2.61E-04 seconds with an estimated standard deviation of 4.76E-07

the estimated average keffs, one standard deviations, and 68, 95, and 99 percent confidence intervals are:

keff estimator	keff	standard deviation	68% confidence	95% confidence	99% confidence	corr
collision	0.71835	0.00120	0.71715 to 0.71954	0.71596 to 0.72073	0.71518 to 0.72151	
absorption	0.71808	0.00113	0.71695 to 0.71922	0.71582 to 0.72034	0.71508 to 0.72108	
track length	0.71793	0.00120	0.71673 to 0.71913	0.71554 to 0.72032	0.71476 to 0.72110	
col/absorp	0.71821	0.00087	0.71734 to 0.71907	0.71648 to 0.71993	0.71591 to 0.72050	0.0988
abs/trk len	0.71801	0.00086	0.71715 to 0.71887	0.71630 to 0.71972	0.71574 to 0.72028	0.0759
col/trk len	0.71818	0.00122	0.71696 to 0.71941	0.71574 to 0.72062	0.71495 to 0.72142	0.9849
col/abs/trk len	0.71797	0.00088	0.71709 to 0.71885	0.71622 to 0.71973	0.71564 to 0.72030	

if the largest of each keff occurred on the next cycle, the keff results and 68, 95, and 99 percent confidence intervals would be:

keff estimator	keff	standard deviation	68% confidence	95% confidence	99% confidence
collision	0.71869	0.00123	0.71746 to 0.71993	0.71623 to 0.72115	0.71543 to 0.72195
absorption	0.71834	0.00115	0.71719 to 0.71950	0.71605 to 0.72064	0.71530 to 0.72139
track length	0.71830	0.00124	0.71705 to 0.71954	0.71582 to 0.72077	0.71501 to 0.72158
col/abs/trk len	0.71834	0.00093	0.71741 to 0.71926	0.71649 to 0.72018	0.71588 to 0.72079

the estimated collision/absorption neutron lifetimes, one standard deviations, and 68, 95, and 99 percent confidence intervals are:

type	lifetime(sec)	standard deviation	68% confidence	95% confidence	99% confidence
removal	2.6121E-04	4.7604E-07	2.6074E-04 to 2.6169E-04	2.6027E-04 to 2.6216E-04	2.5996E-04 to 2.6247E-04
capture	2.6139E-04	3.8444E-07	2.6101E-04 to 2.6177E-04	2.6062E-04 to 2.6216E-04	2.6037E-04 to 2.6241E-04
fission	1.8681E-04	3.2196E-07	1.8649E-04 to 1.8713E-04	1.8617E-04 to 1.8745E-04	1.8596E-04 to 1.8766E-04
escape	4.5390E-04	4.5224E-05	4.0863E-04 to 4.9917E-04	3.6382E-04 to 5.4399E-04	3.3442E-04 to 5.7338E-04

average individual and combined collision/absorption/track-length keff results for 7 different batch sizes

cycles per keff batch	number of k batches	average keff estimators and deviations k(col) st dev	k(abs) st dev	k(trk) st dev	normality co/ab/trk	average k(c/a/t) k(c/a/t) st dev	k(c/a/t) confidence intervals 95% confidence	99% confidence
1	100	0.7183 0.0012	0.7181 0.0011	0.7179 0.0012	95/95/95	0.71797 0.00088	0.71622-0.71973	0.71564-0.72030
2	50	0.7183 0.0011	0.7181 0.0011	0.7179 0.0011	95/95/95	0.71807 0.00077	0.71653-0.71961	0.71601-0.72013
4	25	0.7183 0.0012	0.7181 0.0010	0.7179 0.0011	95/95/95	0.71791 0.00065	0.71656-0.71926	0.71607-0.71974
5	20	0.7183 0.0013	0.7181 0.0011	0.7179 0.0013	95/95/99	0.71813 0.00091	0.71620-0.72005	0.71548-0.72077
10	10	0.7183 0.0016	0.7181 0.0008	0.7179 0.0015	95/95/95	0.71805 0.00116	0.71530-0.72080	0.71399-0.72211
20	5	0.7183 0.0012	0.7181 0.0005	0.7179 0.0011	95/95/95	0.71864 0.00134	0.71286-0.72442	0.70532-0.73196
25	4	0.7183 0.0022	0.7181 0.0012	0.7179 0.0021	95/95/95	0.72038 0.00464	0.66147-0.77930	0.42528-1.01549

individual and average keff estimator results by cycle

keff	neutron	keff estimators by cycle	average keff estimators and deviations	average k(c/a/t)

cycle	histories	k(coll)	k(abs)	k(track)	k(coll) st dev	k(abs) st dev	k(track) st dev	k(c/a/t) st dev	fom
1	4000	0.88597	0.90462	0.88691					
2	3520	0.72690	0.74409	0.73017					
3	3318	0.70367	0.72508	0.70187					
4	3854	0.70165	0.72466	0.70009					
5	4015	0.73528	0.71760	0.73439					
6	4103	0.71715	0.72636	0.71591					
7	3980	0.72361	0.72411	0.72702					
8	3982	0.70175	0.74081	0.70292					
9	3902	0.70528	0.71491	0.70436					
10	4019	0.72759	0.71572	0.72611					
11	4174	0.72250	0.73788	0.72278					
12	3905	0.71995	0.73196	0.71832					
13	3888	0.71545	0.70384	0.71494					
14	4097	0.72385	0.73247	0.72278					
15	4035	0.72159	0.70958	0.72246					
16	3861	0.72450	0.71910	0.72678					
17	4031	0.70078	0.71131	0.70264					
18	3843	0.70847	0.70488	0.70959					
19	4057	0.71916	0.73177	0.71824					
20	4136	0.70399	0.72183	0.70424					
		begin active keff cycles							
21	3892	0.72236	0.71365	0.72467					
22	4078	0.70508	0.72453	0.70450	0.71372 0.00864	0.71909 0.00544	0.71458 0.01008		
23	3814	0.71647	0.72567	0.71645	0.71464 0.00507	0.72128 0.00383	0.71520 0.00586		
24	3975	0.72016	0.72509	0.71961	0.71602 0.00384	0.72223 0.00287	0.71631 0.00428	0.72362 0.00250	62276
25	3985	0.71159	0.73425	0.71332	0.71514 0.00311	0.72464 0.00327	0.71571 0.00337	0.71933 0.00330	28117
26	3964	0.70302	0.73249	0.70312	0.71312 0.00324	0.72595 0.00298	0.71361 0.00346	0.71952 0.00277	33338
27	3958	0.73373	0.71093	0.73531	0.71606 0.00402	0.72380 0.00331	0.71671 0.00426	0.72002 0.00194	58213
28	4210	0.70688	0.72831	0.70836	0.71491 0.00367	0.72436 0.00292	0.71567 0.00384	0.72013 0.00177	61061
29	3928	0.72274	0.71036	0.72691	0.71578 0.00335	0.72281 0.00301	0.71692 0.00361	0.72042 0.00172	57344
30	4104	0.73378	0.71042	0.73360	0.71758 0.00349	0.72157 0.00296	0.71858 0.00363	0.72047 0.00123	100010
31	3943	0.71801	0.69630	0.71804	0.71762 0.00316	0.71927 0.00353	0.71854 0.00329	0.71820 0.00189	38569
32	3905	0.71869	0.72700	0.71653	0.71771 0.00289	0.71992 0.00329	0.71837 0.00300	0.71889 0.00160	49078
33	4109	0.71316	0.71814	0.71010	0.71736 0.00268	0.71978 0.00302	0.71773 0.00284	0.71844 0.00141	58683
34	3872	0.70557	0.69534	0.70267	0.71652 0.00262	0.71803 0.00330	0.71666 0.00284	0.71697 0.00172	36333
35	3990	0.72728	0.73045	0.72773	0.71724 0.00254	0.71886 0.00318	0.71739 0.00274	0.71769 0.00179	31554
36	4063	0.70580	0.72051	0.70663	0.71652 0.00248	0.71896 0.00298	0.71672 0.00265	0.71732 0.00174	31056
37	3911	0.70360	0.72701	0.70441	0.71576 0.00245	0.71944 0.00284	0.71600 0.00259	0.71712 0.00168	31405
38	3930	0.71640	0.72124	0.71696	0.71580 0.00231	0.71954 0.00268	0.71605 0.00245	0.71716 0.00158	33367
39	4166	0.73442	0.71692	0.73350	0.71678 0.00240	0.71940 0.00254	0.71697 0.00249	0.71787 0.00157	32080
40	4252	0.69679	0.71317	0.69776	0.71578 0.00248	0.71909 0.00243	0.71601 0.00255	0.71732 0.00168	26654
41	3750	0.70663	0.73478	0.70726	0.71534 0.00240	0.71984 0.00243	0.71559 0.00246	0.71741 0.00162	27184
42	4139	0.70295	0.73711	0.70117	0.71478 0.00236	0.72062 0.00244	0.71494 0.00244	0.71751 0.00158	27548
43	3953	0.70440	0.73888	0.70612	0.71433 0.00230	0.72142 0.00246	0.71455 0.00236	0.71754 0.00154	27689
44	3933	0.71984	0.70292	0.71758	0.71456 0.00221	0.72064 0.00248	0.71468 0.00226	0.71728 0.00144	30122
45	4235	0.71807	0.72529	0.71976	0.71470 0.00213	0.72083 0.00239	0.71488 0.00218	0.71738 0.00139	30978
46	3949	0.71674	0.71894	0.71273	0.71478 0.00205	0.72076 0.00230	0.71480 0.00210	0.71753 0.00134	32295
47	3889	0.72417	0.71121	0.72301	0.71512 0.00200	0.72040 0.00224	0.71510 0.00204	0.71760 0.00127	34388
48	4180	0.72479	0.69767	0.72454	0.71547 0.00196	0.71959 0.00230	0.71544 0.00199	0.71734 0.00122	36138
49	3977	0.73271	0.72665	0.73088	0.71606 0.00198	0.71984 0.00224	0.71597 0.00200	0.71783 0.00127	32009
50	4193	0.70218	0.71363	0.69961	0.71560 0.00197	0.71963 0.00217	0.71543 0.00200	0.71760 0.00128	30623
51	3694	0.71537	0.71223	0.71416	0.71559 0.00190	0.71939 0.00211	0.71539 0.00194	0.71750 0.00124	31567

52	4113	0.72358	0.69502	0.72285	0.71584	0.00186	0.71863	0.00218	0.71562	0.00189	0.71724	0.00121	32251
53	4034	0.72063	0.71428	0.71849	0.71599	0.00181	0.71850	0.00212	0.71571	0.00184	0.71729	0.00117	33042
54	3931	0.72600	0.72481	0.72129	0.71628	0.00178	0.71868	0.00206	0.71587	0.00179	0.71745	0.00119	30992
55	4036	0.72991	0.71381	0.72923	0.71667	0.00177	0.71854	0.00201	0.71625	0.00178	0.71762	0.00117	31545
56	4109	0.71398	0.72273	0.71452	0.71660	0.00172	0.71866	0.00196	0.71620	0.00173	0.71763	0.00113	32578
57	3899	0.72768	0.71046	0.72646	0.71690	0.00170	0.71844	0.00192	0.71648	0.00170	0.71770	0.00110	33456
58	4041	0.71097	0.71745	0.70929	0.71674	0.00166	0.71841	0.00186	0.71629	0.00167	0.71763	0.00108	33779
59	3785	0.72190	0.73145	0.72371	0.71687	0.00163	0.71875	0.00185	0.71648	0.00164	0.71789	0.00107	33745
60	4045	0.71196	0.71105	0.71749	0.71675	0.00159	0.71855	0.00181	0.71651	0.00160	0.71759	0.00104	34609
61	4026	0.71335	0.71813	0.71693	0.71667	0.00155	0.71854	0.00177	0.71652	0.00156	0.71752	0.00101	35749
62	4053	0.70673	0.71993	0.70695	0.71643	0.00153	0.71858	0.00172	0.71629	0.00154	0.71741	0.00100	36019
63	3998	0.72669	0.73336	0.72466	0.71667	0.00152	0.71892	0.00172	0.71649	0.00151	0.71766	0.00102	33659
64	4114	0.69771	0.71373	0.69627	0.71624	0.00154	0.71880	0.00168	0.71603	0.00155	0.71743	0.00104	31312
65	3800	0.71668	0.71403	0.71790	0.71625	0.00151	0.71870	0.00165	0.71607	0.00151	0.71738	0.00102	32199
66	4121	0.71203	0.73168	0.71505	0.71616	0.00148	0.71898	0.00164	0.71605	0.00148	0.71746	0.00100	32661
67	3920	0.71293	0.71303	0.71489	0.71609	0.00145	0.71885	0.00161	0.71602	0.00145	0.71735	0.00098	33190
68	4036	0.70683	0.69844	0.70547	0.71590	0.00143	0.71843	0.00163	0.71580	0.00143	0.71703	0.00101	30821
69	3962	0.70304	0.69741	0.70229	0.71563	0.00142	0.71800	0.00165	0.71552	0.00143	0.71668	0.00104	28065
70	3916	0.70912	0.72597	0.70862	0.71550	0.00140	0.71816	0.00163	0.71539	0.00141	0.71668	0.00103	28506
71	4040	0.72007	0.72718	0.71805	0.71559	0.00138	0.71833	0.00160	0.71544	0.00138	0.71679	0.00102	28437
72	4007	0.73503	0.72922	0.73500	0.71597	0.00140	0.71854	0.00159	0.71582	0.00141	0.71712	0.00104	26533
73	4086	0.75337	0.71792	0.75490	0.71667	0.00155	0.71853	0.00156	0.71655	0.00157	0.71763	0.00108	24338
74	4102	0.71624	0.69408	0.71437	0.71666	0.00152	0.71808	0.00159	0.71651	0.00154	0.71740	0.00108	23818
75	3747	0.73727	0.72833	0.73364	0.71704	0.00153	0.71827	0.00157	0.71682	0.00154	0.71766	0.00111	22365
76	4052	0.72561	0.72260	0.72440	0.71719	0.00151	0.71834	0.00155	0.71696	0.00152	0.71777	0.00109	22486
77	3946	0.71283	0.72419	0.71356	0.71711	0.00149	0.71845	0.00152	0.71690	0.00149	0.71778	0.00107	22903
78	3873	0.71557	0.72897	0.71244	0.71709	0.00146	0.71863	0.00151	0.71682	0.00147	0.71784	0.00106	23018
79	3856	0.73038	0.73745	0.72787	0.71731	0.00146	0.71895	0.00152	0.71701	0.00146	0.71805	0.00108	21772
80	4080	0.72255	0.71005	0.72367	0.71740	0.00144	0.71880	0.00150	0.71712	0.00144	0.71803	0.00106	22295
81	3994	0.68455	0.71111	0.68208	0.71686	0.00151	0.71867	0.00148	0.71655	0.00152	0.71781	0.00111	20219
82	3709	0.73416	0.73194	0.73335	0.71714	0.00151	0.71889	0.00147	0.71682	0.00152	0.71805	0.00112	19504
83	4430	0.72304	0.74466	0.71983	0.71723	0.00149	0.71929	0.00150	0.71686	0.00150	0.71820	0.00114	18582
84	4013	0.73781	0.71375	0.73776	0.71756	0.00150	0.71921	0.00148	0.71719	0.00151	0.71834	0.00112	18795
85	4002	0.71811	0.72027	0.72002	0.71756	0.00148	0.71922	0.00146	0.71724	0.00149	0.71836	0.00110	19209
86	3985	0.71386	0.70626	0.71283	0.71751	0.00146	0.71903	0.00145	0.71717	0.00147	0.71823	0.00109	19209
87	4005	0.72238	0.71966	0.71909	0.71758	0.00144	0.71904	0.00143	0.71720	0.00145	0.71826	0.00108	19360
88	3996	0.72797	0.71024	0.72920	0.71773	0.00142	0.71891	0.00141	0.71737	0.00144	0.71828	0.00106	19807
89	4002	0.70329	0.69662	0.70131	0.71752	0.00142	0.71859	0.00143	0.71714	0.00143	0.71804	0.00108	18699
90	3829	0.73365	0.71086	0.73340	0.71776	0.00142	0.71847	0.00141	0.71737	0.00143	0.71811	0.00107	18970
91	4209	0.73884	0.72109	0.73628	0.71805	0.00143	0.71851	0.00139	0.71764	0.00144	0.71824	0.00107	18675
92	4023	0.73133	0.71977	0.73165	0.71824	0.00142	0.71853	0.00138	0.71783	0.00143	0.71835	0.00105	18815
93	3810	0.71497	0.71226	0.71920	0.71819	0.00140	0.71844	0.00136	0.71785	0.00141	0.71827	0.00103	19287
94	3893	0.72772	0.73433	0.72844	0.71832	0.00139	0.71866	0.00136	0.71800	0.00140	0.71846	0.00104	19021
95	3938	0.74023	0.70051	0.73972	0.71861	0.00140	0.71842	0.00136	0.71829	0.00141	0.71847	0.00102	19280
96	3987	0.73653	0.72590	0.73419	0.71885	0.00140	0.71851	0.00135	0.71849	0.00141	0.71861	0.00102	18958
97	3946	0.71362	0.72123	0.71375	0.71878	0.00139	0.71855	0.00133	0.71843	0.00139	0.71859	0.00101	19235
98	3841	0.72868	0.73238	0.72682	0.71891	0.00137	0.71873	0.00132	0.71854	0.00138	0.71872	0.00101	18995
99	4129	0.70898	0.70613	0.70687	0.71878	0.00136	0.71857	0.00132	0.71839	0.00137	0.71860	0.00101	18718
100	3880	0.71684	0.71554	0.71564	0.71876	0.00134	0.71853	0.00130	0.71836	0.00135	0.71857	0.00100	18898
101	3959	0.71042	0.70676	0.71086	0.71865	0.00133	0.71838	0.00129	0.71827	0.00134	0.71844	0.00099	18854
102	3947	0.73251	0.70115	0.73298	0.71882	0.00133	0.71817	0.00129	0.71845	0.00133	0.71841	0.00098	19095
103	4054	0.70786	0.72006	0.70562	0.71869	0.00132	0.71820	0.00128	0.71829	0.00132	0.71836	0.00097	19185
104	3791	0.72095	0.73137	0.71517	0.71872	0.00130	0.71835	0.00127	0.71825	0.00131	0.71840	0.00097	19109

105	4061	0.72558	0.71693	0.72388	0.71880	0.00129	0.71834	0.00126	0.71832	0.00130	0.71842	0.00096	19249
106	4021	0.70018	0.72579	0.69856	0.71858	0.00129	0.71842	0.00125	0.71809	0.00130	0.71836	0.00095	19332
107	3867	0.71512	0.70755	0.71894	0.71854	0.00128	0.71830	0.00124	0.71810	0.00129	0.71826	0.00094	19696
108	4012	0.71538	0.71534	0.71253	0.71851	0.00126	0.71826	0.00122	0.71804	0.00127	0.71823	0.00093	19775
109	4051	0.74043	0.70550	0.74375	0.71875	0.00127	0.71812	0.00122	0.71833	0.00129	0.71830	0.00092	20079
110	4268	0.70877	0.71276	0.70985	0.71864	0.00126	0.71806	0.00121	0.71823	0.00128	0.71821	0.00091	20200
111	3864	0.72578	0.73055	0.72455	0.71872	0.00125	0.71820	0.00120	0.71830	0.00127	0.71831	0.00091	20105
112	4072	0.69601	0.69799	0.69762	0.71847	0.00126	0.71798	0.00121	0.71808	0.00127	0.71804	0.00093	19126
113	3838	0.71483	0.71858	0.71469	0.71843	0.00125	0.71799	0.00120	0.71804	0.00126	0.71803	0.00092	19349
114	4080	0.72956	0.72416	0.73074	0.71855	0.00124	0.71805	0.00118	0.71817	0.00125	0.71814	0.00091	19379
115	4127	0.72689	0.71907	0.72217	0.71864	0.00123	0.71806	0.00117	0.71822	0.00124	0.71815	0.00090	19427
116	3965	0.71230	0.71601	0.71000	0.71857	0.00122	0.71804	0.00116	0.71813	0.00123	0.71811	0.00090	19498
117	3996	0.69681	0.70112	0.69950	0.71835	0.00123	0.71787	0.00116	0.71794	0.00123	0.71787	0.00090	18973
118	3925	0.72544	0.72316	0.72452	0.71842	0.00122	0.71792	0.00115	0.71801	0.00122	0.71793	0.00090	19065
119	4154	0.71842	0.72867	0.71676	0.71842	0.00121	0.71803	0.00114	0.71799	0.00121	0.71797	0.00089	19153
120	3985	0.71074	0.72319	0.71156	0.71835	0.00120	0.71808	0.00113	0.71793	0.00120	0.71797	0.00088	19403

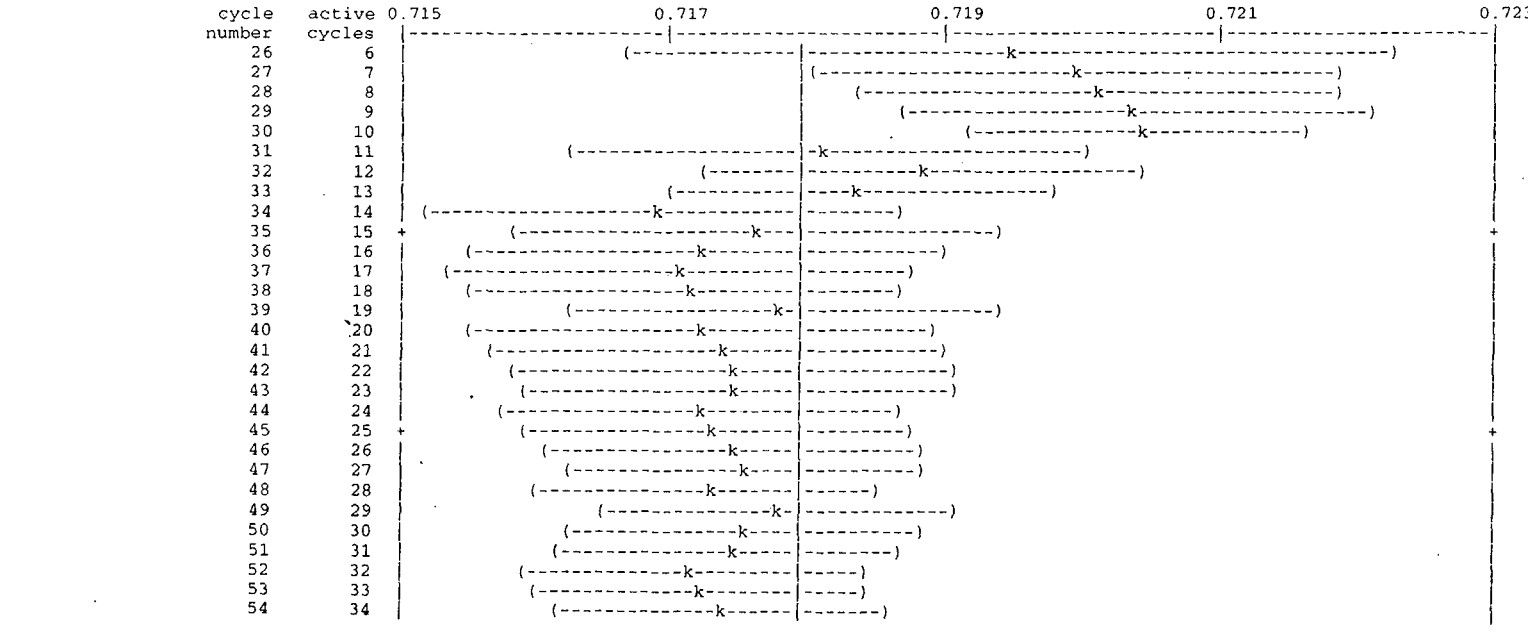
the largest active cycle keffs by estimator are:

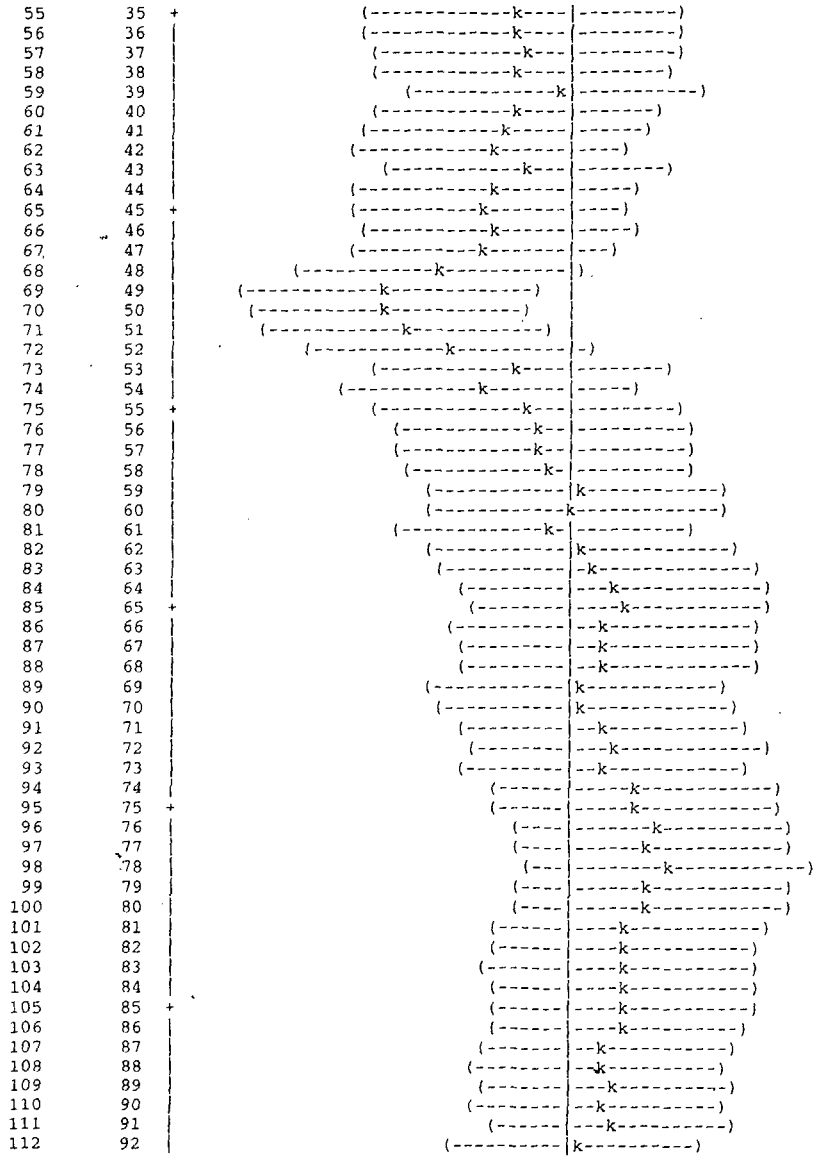
collision 0.75337 on cycle 73
absorption 0.74466 on cycle 83
track length 0.75490 on cycle 73

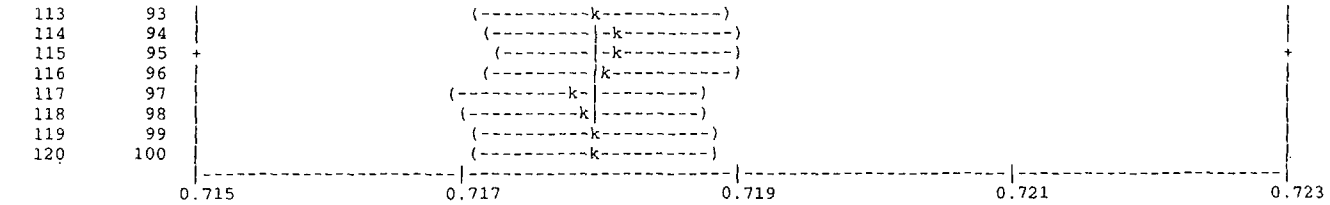
the smallest active cycle keffs by estimator are:

collision 0.68455 on cycle 81
absorption 0.69408 on cycle 74
track length 0.68208 on cycle 81

1plot of the estimated col/abs/track-length keff one standard deviation interval versus cycle number (| = final keff = 0.71797)







1individual and collision/absorption/track-length keffs for different numbers of inactive cycles skipped for fission source settling

skip cycles	active cycles	active neutrons	average keff k(col)	st dev	k(abs)	st dev	k(trk)	st dev	normality co/ab/tl	average k(c/a/t)	st dev	k(c/a/t) confidence intervals 95% confidence	99% confidence
0	120	478047	0.7194	0.0018	0.7204	0.0019	0.7190	0.0018	no/no/no	0.71981	0.00170	0.71643-0.72320	0.71532-0.72431
1	119	474047	0.7180	0.0011	0.7189	0.0011	0.7176	0.0011	95/95/95	0.71830	0.00080	0.71670-0.71989	0.71618-0.72041
2	118	470527	0.7179	0.0011	0.7187	0.0010	0.7175	0.0011	95/95/95	0.71809	0.00079	0.71652-0.71967	0.71600-0.72019
3	117	467209	0.7180	0.0011	0.7186	0.0010	0.7177	0.0011	95/95/95	0.71812	0.00080	0.71654-0.71971	0.71602-0.72023
4	116	463355	0.7182	0.0011	0.7186	0.0011	0.7178	0.0011	95/95/95	0.71816	0.00080	0.71657-0.71976	0.71605-0.72028
5	115	459340	0.7180	0.0011	0.7186	0.0011	0.7177	0.0011	95/95/95	0.71810	0.00081	0.71650-0.71970	0.71597-0.72023
6	114	455237	0.7180	0.0011	0.7185	0.0011	0.7177	0.0011	95/95/95	0.71808	0.00081	0.71646-0.71969	0.71593-0.72022
7	113	451257	0.7180	0.0011	0.7184	0.0011	0.7176	0.0011	95/95/95	0.71798	0.00082	0.71636-0.71961	0.71582-0.72014
8	112	447275	0.7181	0.0011	0.7182	0.0011	0.7177	0.0011	95/95/95	0.71794	0.00082	0.71629-0.71958	0.71576-0.72012
9	111	443373	0.7182	0.0011	0.7183	0.0011	0.7179	0.0011	95/95/95	0.71801	0.00083	0.71636-0.71966	0.71582-0.72020
10	110	439354	0.7181	0.0011	0.7183	0.0011	0.7178	0.0011	95/95/95	0.71799	0.00083	0.71633-0.71965	0.71578-0.72019
11	109	435180	0.7181	0.0011	0.7181	0.0011	0.7177	0.0011	95/95/95	0.71786	0.00083	0.71620-0.71953	0.71566-0.72007
12	108	431275	0.7181	0.0011	0.7180	0.0011	0.7177	0.0011	95/95/95	0.71780	0.00084	0.71613-0.71947	0.71559-0.72002
13	107	427387	0.7181	0.0011	0.7181	0.0011	0.7178	0.0011	95/95/95	0.71788	0.00084	0.71621-0.71956	0.71566-0.72011
14	106	423290	0.7180	0.0012	0.7180	0.0011	0.7177	0.0012	95/95/95	0.71780	0.00084	0.71612-0.71948	0.71557-0.72003
15	105	419255	0.7180	0.0012	0.7181	0.0011	0.7177	0.0012	95/95/95	0.71782	0.00085	0.71612-0.71952	0.71557-0.72007
16	104	415394	0.7180	0.0012	0.7181	0.0011	0.7176	0.0012	95/95/95	0.71776	0.00086	0.71604-0.71947	0.71548-0.72003
17	103	411363	0.7181	0.0012	0.7181	0.0011	0.7177	0.0012	95/95/95	0.71788	0.00086	0.71615-0.71960	0.71559-0.72016
18	102	407520	0.7182	0.0012	0.7183	0.0011	0.7178	0.0012	95/95/95	0.71800	0.00087	0.71627-0.71972	0.71570-0.72029
19	101	403463	0.7182	0.0012	0.7181	0.0011	0.7178	0.0012	95/95/95	0.71793	0.00087	0.71619-0.71966	0.71562-0.72023
20	100*	399327	0.7183	0.0012	0.7181	0.0011	0.7179	0.0012	95/95/95	0.71797	0.00088	0.71622-0.71973	0.71564-0.72030
22	98	391357	0.7184	0.0012	0.7181	0.0012	0.7180	0.0012	95/95/95	0.71799	0.00090	0.71619-0.71978	0.71561-0.72037
24	96	383568	0.7184	0.0012	0.7179	0.0012	0.7180	0.0012	95/95/95	0.71790	0.00092	0.71607-0.71973	0.71548-0.72033
26	94	375619	0.7187	0.0013	0.7176	0.0012	0.7182	0.0013	95/95/95	0.71779	0.00094	0.71592-0.71967	0.71531-0.72028
28	92	367451	0.7186	0.0013	0.7175	0.0012	0.7181	0.0013	95/95/95	0.71771	0.00096	0.71580-0.71963	0.71517-0.72026
30	90	359419	0.7184	0.0013	0.7177	0.0012	0.7179	0.0013	95/95/95	0.71766	0.00099	0.71569-0.71963	0.71504-0.72028
32	88	351571	0.7184	0.0013	0.7178	0.0012	0.7179	0.0013	95/95/95	0.71775	0.00100	0.71576-0.71974	0.71511-0.72039
34	86	343590	0.7186	0.0013	0.7181	0.0012	0.7181	0.0013	95/95/95	0.71794	0.00099	0.71597-0.71990	0.71533-0.72055
36	84	335537	0.7187	0.0013	0.7179	0.0012	0.7182	0.0013	95/95/95	0.71783	0.00100	0.71584-0.71983	0.71518-0.72048
38	82	327696	0.7189	0.0014	0.7178	0.0013	0.7183	0.0014	95/95/95	0.71782	0.00103	0.71576-0.71987	0.71509-0.72055
40	80	319278	0.7190	0.0014	0.7178	0.0013	0.7184	0.0014	95/95/95	0.71794	0.00105	0.71585-0.72002	0.71517-0.72070
42	78	311389	0.7194	0.0014	0.7174	0.0013	0.7188	0.0014	95/95/95	0.71782	0.00108	0.71567-0.71997	0.71497-0.72067
44	76	303503	0.7195	0.0014	0.7173	0.0013	0.7190	0.0014	95/95/95	0.71771	0.00110	0.71552-0.71991	0.71480-0.72063
46	74	295319	0.7196	0.0014	0.7171	0.0013	0.7190	0.0014	95/95/95	0.71762	0.00113	0.71537-0.71987	0.71463-0.72061
48	72	287250	0.7195	0.0015	0.7175	0.0013	0.7189	0.0015	95/95/95	0.71773	0.00115	0.71545-0.72002	0.71470-0.72077
50	70	279080	0.7195	0.0015	0.7174	0.0013	0.7190	0.0015	95/95/95	0.71777	0.00115	0.71547-0.72007	0.71472-0.72083
52	68	271273	0.7195	0.0015	0.7178	0.0013	0.7190	0.0015	95/95/95	0.71796	0.00116	0.71564-0.72028	0.71488-0.72104
54	66	263308	0.7194	0.0016	0.7178	0.0014	0.7190	0.0016	95/95/95	0.71798	0.00118	0.71561-0.72034	0.71483-0.72112
56	64	255163	0.7193	0.0016	0.7178	0.0014	0.7189	0.0016	95/95/95	0.71792	0.00122	0.71548-0.72037	0.71468-0.72117
58	62	247223	0.7193	0.0016	0.7179	0.0014	0.7189	0.0016	95/95/95	0.71802	0.00125	0.71552-0.72053	0.71469-0.72136

60	60	239393	0.7194	0.0017	0.7178	0.0015	0.7189	0.0017	95/95/95	0.71777	0.00130	0.71516-0.72038	0.71429-0.72124
62	58	231314	0.7197	0.0017	0.7177	0.0015	0.7191	0.0017	95/95/95	0.71774	0.00137	0.71499-0.72050	0.71408-0.72141
64	56	223202	0.7200	0.0017	0.7175	0.0015	0.7194	0.0018	95/95/95	0.71781	0.00139	0.71502-0.72059	0.71409-0.72152
66	54	215281	0.7202	0.0018	0.7173	0.0016	0.7195	0.0018	95/95/95	0.71743	0.00147	0.71448-0.72038	0.71350-0.72136
68	52	207325	0.7206	0.0018	0.7178	0.0016	0.7199	0.0019	95/95/95	0.71774	0.00148	0.71476-0.72073	0.71377-0.72172
70	50	199447	0.7212	0.0019	0.7180	0.0016	0.7205	0.0019	95/95/95	0.71805	0.00149	0.71506-0.72104	0.71406-0.72205
72	48	191400	0.7209	0.0019	0.7176	0.0016	0.7202	0.0019	95/95/95	0.71768	0.00151	0.71463-0.72072	0.71361-0.72174
74	46	183212	0.7203	0.0019	0.7181	0.0016	0.7196	0.0019	95/95/95	0.71760	0.00144	0.71469-0.72050	0.71371-0.72148
76	44	175413	0.7198	0.0019	0.7177	0.0017	0.7192	0.0019	95/95/95	0.71746	0.00147	0.71449-0.72043	0.71348-0.72143
78	42	167594	0.7201	0.0020	0.7173	0.0017	0.7195	0.0020	95/95/95	0.71727	0.00155	0.71413-0.72040	0.71307-0.72146
80	40	159658	0.7198	0.0021	0.7170	0.0017	0.7191	0.0021	95/95/95	0.71700	0.00157	0.71381-0.72019	0.71273-0.72127
82	38	151955	0.7203	0.0019	0.7168	0.0018	0.7197	0.0019	95/95/95	0.71729	0.00151	0.71422-0.72036	0.71317-0.72141
84	36	143512	0.7197	0.0020	0.7161	0.0017	0.7192	0.0020	95/95/95	0.71670	0.00151	0.71363-0.71977	0.71258-0.72082
86	34	135525	0.7200	0.0021	0.7162	0.0018	0.7194	0.0021	95/95/95	0.71669	0.00157	0.71348-0.71989	0.71237-0.72100
88	32	127524	0.7196	0.0022	0.7163	0.0019	0.7191	0.0022	95/95/95	0.71667	0.00165	0.71329-0.72004	0.71212-0.72122
90	30	119693	0.7197	0.0022	0.7172	0.0019	0.7192	0.0022	95/95/95	0.71715	0.00155	0.71398-0.72033	0.71286-0.72144
92	28	111461	0.7186	0.0023	0.7169	0.0020	0.7182	0.0022	95/95/95	0.71681	0.00160	0.71352-0.72010	0.71235-0.72126
94	26	103758	0.7184	0.0024	0.7164	0.0020	0.7177	0.0024	95/95/95	0.71572	0.00162	0.71237-0.71906	0.71118-0.72026
96	24	95833	0.7168	0.0023	0.7167	0.0021	0.7161	0.0023	95/95/95	0.71557	0.00165	0.71214-0.71900	0.71090-0.72024
98	22	88046	0.7164	0.0024	0.7158	0.0021	0.7158	0.0024	95/95/95	0.71489	0.00168	0.71137-0.71841	0.71008-0.71970
100	20	80037	0.7167	0.0027	0.7163	0.0023	0.7162	0.0027	95/95/95	0.71542	0.00170	0.71182-0.71901	0.71048-0.72036
102	18	72131	0.7162	0.0028	0.7177	0.0023	0.7156	0.0028	95/95/95	0.71617	0.00182	0.71229-0.72004	0.71081-0.72152
104	16	64286	0.7164	0.0031	0.7166	0.0024	0.7162	0.0031	95/95/95	0.71627	0.00201	0.71193-0.72060	0.71022-0.72231
106	14	56204	0.7169	0.0033	0.7160	0.0027	0.7169	0.0032	95/95/95	0.71624	0.00233	0.71111-0.72137	0.70901-0.72347
108	12	48325	0.7172	0.0038	0.7167	0.0030	0.7171	0.0038	95/95/95	0.71675	0.00268	0.71069-0.72281	0.70805-0.72545
110	10	40006	0.7157	0.0038	0.7182	0.0034	0.7152	0.0034	95/95/95	0.71577	0.00372	0.70696-0.72458	0.70273-0.72880
112	8	32070	0.7169	0.0038	0.7192	0.0029	0.7162	0.0034	95/95/95	0.71767	0.00363	0.70835-0.72700	0.70305-0.73230
114	6	24152	0.7151	0.0045	0.7185	0.0039	0.7141	0.0037	95/95/95	0.71219	0.00473	0.69714-0.72723	0.68458-0.73979
116	4	16060	0.7128	0.0061	0.7190	0.0061	0.7131	0.0053	95/95/95	0.71708	0.00472	0.65705-0.77711	0.41639-1.01777
117	3	12064	0.7182	0.0042	0.7250	0.0018	0.7176	0.0038					
118	2	8139	0.7146	0.0038	0.7259	0.0027	0.7142	0.0026					

the minimum estimated standard deviation for the col/abs/tl keff estimator occurs with 2 inactive cycles and 118 active cycles.

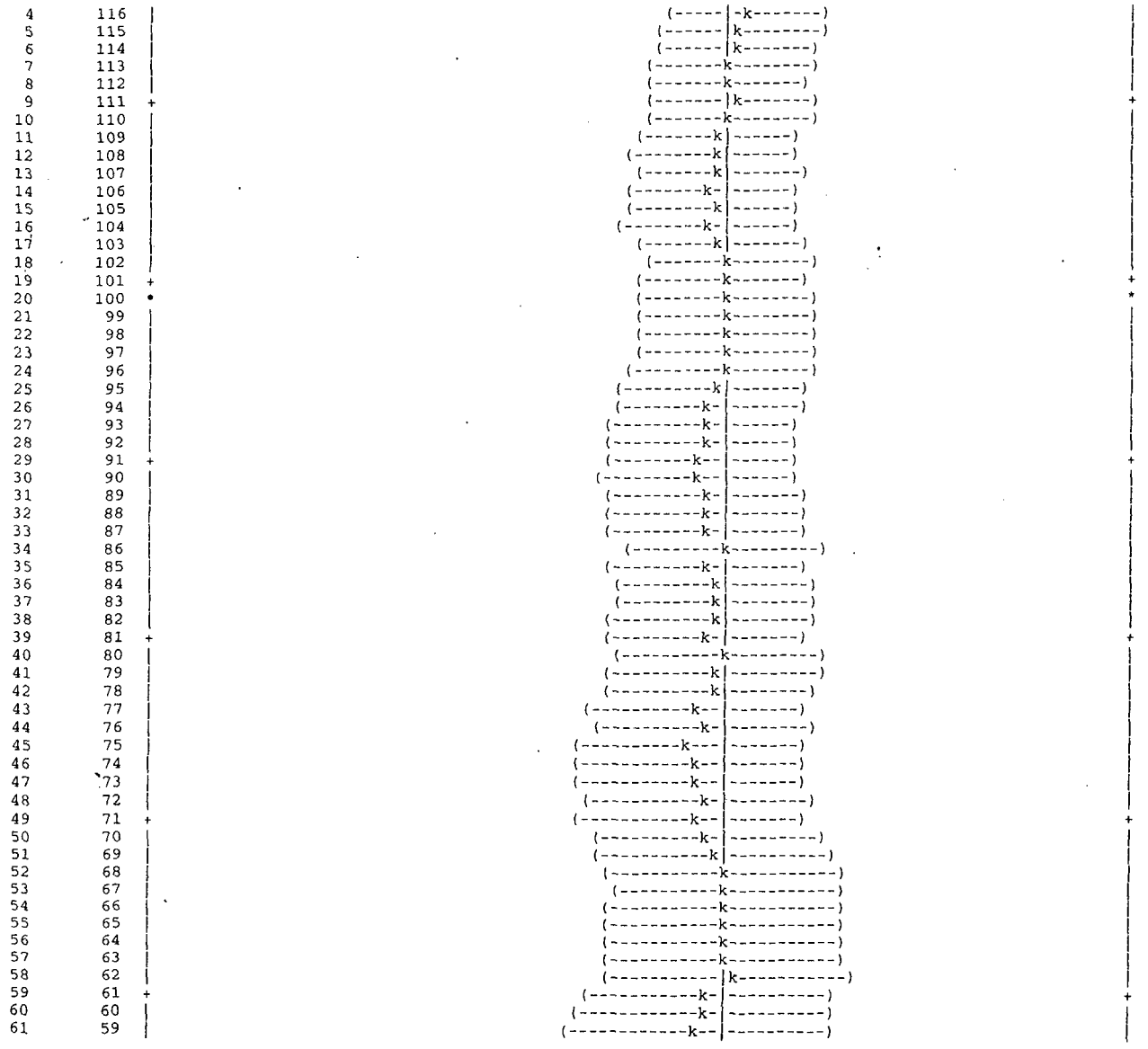
the first active half of the problem skips 20 cycles and uses 50 active cycles; the second half skips 70 and uses 50 cycles.
the col/abs/trk-len keff, one standard deviation, and 68, 95, and 99 percent intervals for each active half of the problem are:

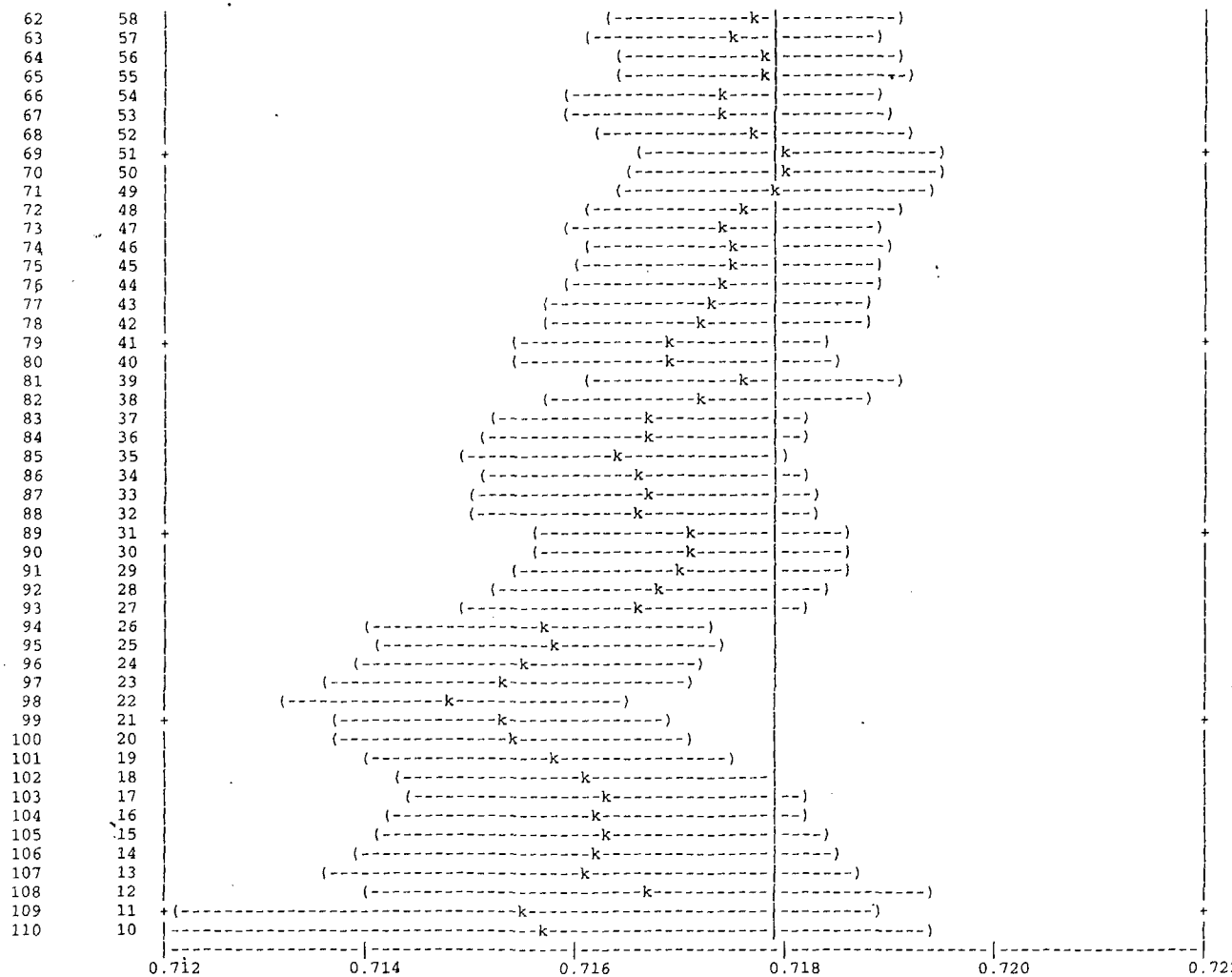
problem	keff	standard deviation	68% confidence	95% confidence	99% confidence
first half	0.71668	0.00103	0.71564 to 0.71771	0.71461 to 0.71874	0.71392 to 0.71943
second half	0.71805	0.00149	0.71656 to 0.71955	0.71506 to 0.72104	0.71406 to 0.72205
final result	0.71797	0.00088	0.71709 to 0.71885	0.71622 to 0.71973	0.71564 to 0.72030

the first and second half values of k(collision/absorption/track length) appear to be the same at the 68 percent confidence level.
lplot of the estimated col/abs/track-length keff one standard deviation interval by active cycle number (| = final keff = 0.71797)

```
inactive   active 0.712          0.714          0.716          0.718          0.720          0.722
  cycles   cycles |---------------|--------------|--------------|--------------|--------------|
       0      120 |                                            | (-------------k-------------)  |
       1      119 |                                       (----|--k-------)                    |
       2      118 |                                       (-----|k-------)                     |
       3      117 |                                       (-----|-k-------)                    |
```

WVNS-NCSE-001
REV. 0





dump no. 4 on file 3s810r nps = 478047 coll = 77225971 ctm = 40.92 nrn = 1363119709

2 warning messages so far.

run terminated when 120 kcode cycles were done.

computer time = 40.93 minutes

mcnp version 4a 10/01/93 01/15/01 08:19:35 probid = 01/15/01 07:38:39

URS

Calculation Cover Page

3065 Southwestern Boulevard
Suite 202
Orchard Park, NY 14127
716 675 7130 Tel
716 675 7137 Fax

Job No: **30822-244-330 /6860** Calculation No: **BUF-2001-009/Rev. 0** Date: **February 24, 2001**

Problem Statement & Calculation Objectives:

To determine the Pu-239 mass sub-critical limit for $\infty \times \infty \times 12$ ft arrays of 1-cubic-foot boxes with Pu-239-cellulose spheres and pure cellulose or void outside the sphere. Every box has 1 sphere containing the same amount of Pu-239.

References and Data Available:

J. F. Briemiester, ed., MCNP - A General Purpose Monte Carlo N-Particle Transport Code, Version 4A, LA-12625, Los Alamos National Laboratory, Los Alamos NM, 1993
C. D. Harmon, II et al., Criticality Calculations with MCNP: A Primer, Manual LA-12827, Los Alamos National Laboratory, Los Alamos NM, 1993
D. R. Lide, CRC Handbook of Chemistry an Physics, CRC Press, Boston MA, 1991.
F. H. Attix, Introduction to Radiological Physics and Radiation Dosimetry. John Wiley & Sons, Inc., New York NY, 1986

Attachments:

Attachment 1: MCNP surface and cell numbers
Attachment 2: MCNP input file
Attachment 3: MCNP output file

Prepared by:

Signature Igor V. Chichkov — Date 02/24/2001

Checked by:

Signature — Date 02/27/01

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Job No 30822-244-330 /6860 Job: PSR-6 By IVC Date 02/24/2001
Client WVNS Subject: cellulose-Pu-239 spheres Chk'd. CW Date 02/27/01

Analysis

Assumptions

- Pu-239 inside the sphere is uniformly mixed with 0.72 g/cm^3 cellulose
- The pure cellulose (0.72 g/cm^3) fills the entire space inside the container and outside the Plutonium sphere.
- The containers stand on the 3 m thick concrete floor
- The box inside dimensions are 30.48 x 30.48 x 30.48 cm or 1 x 1 x 1 foot
- The box wall thickness is zero
- Every box in the array contains the same mass of Pu-239
- The boxes are arranged in the infinite square array, 12 feet heigh ($\infty \times \infty \times 12$ ft)

MCNP Model

Neutron multiplication factors were calculated with MCNP4A code. Attachments 1 has the drawings of the models used. Examples of MCNP input and output files for both cases can also be found in the Attachments. The plutonium spheres were located in the box's corner as shown in Attachments 1.

Air, Carbon Steel, Concrete and Cellulose Composition

Table 1 shows the element weight fractions for air (Attix F.H., 1986). Table 2 shows the element composition of concrete (Harmon C. D., II et al., 1993) in the floor.

Table 1. Air composition

Element	Weight Fraction
Carbon (C)	0.000124
Nitrogen (N)	0.755267
Oxygen (O)	0.231781
Argon (Ar)	0.012827

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Client WVNS Subject: cellulose-Pu-239 spheres Chk'd [illegible] Date 02/27/01

Table 2. Concrete composition

Element	Weight Fraction
Hydrogen (H)	0.010
Oxygen (O)	0.532
Sodium (Na)	0.029
Aluminum (Al)	0.034
Silicon (Si)	0.337
Calcium (Ca)	0.044
Iron (Fe)	0.014

The weight fractions of the elements composing the cellulose were determined based on the known atomic weights of the elements (Table 3) and the cellulose chemical formula - $C_6H_{10}O_5$.

Table 3. The atomic weights of the elements

Element	Atomic Weight
Hydrogen (H)	1.00794
Carbon (C)	12.0107
Oxygen (O)	15.9994

The molecular weight of cellulose ($C_6H_{10}O_5$) was calculated as the sum of all atomic weights composing the molecule. The weight fraction of an ith element was found as a ratio of the ith element weight in the molecule to the molecular weight of this molecule.

$$(w_i)_{cel} = \frac{n_i A_i}{M_{cel}} = \frac{n_i A_i}{\sum n_i A_i} \qquad (1)$$

where

$(w_i)_{cel}$ = the weight fraction of ith element in a molecule of cellulose

n_i = the number of the ith elements in a cellulose molecule

A_i = the atomic weight of the ith element, g/mol

M_{cel} = the molecular weight a cellulose molecule, g/mol

Calculated weight fractions for cellulose are shown in Table 4.

Table 4. Cellulose Weight Fractions

Element	Weight Fraction
Hydrogen (H)	0.062
Carbon (C)	0.444
Oxygen (O)	0.493

Radii of the Plutonium containing spheres.

The spheres with several different radii were studied. The minimum size of the Plutonium containing sphere corresponded to the sphere with pure Pu-239 and the maximum size was limited by the dimensions of the container, i.e. half of the box height. The minimum radius equation (3) was derived from the volume of a sphere equation (2)

$$V_{Pu} = \frac{4\pi\left(R_{Pu}\right)^3}{3} \qquad (2)$$

$$R_{\min} = R_{Pu} = \sqrt[3]{\frac{3V_{Pu}}{4\pi}} = \sqrt[3]{\frac{3m_{Pu}}{4\pi\rho_{Pu}}} \qquad (3)$$

where:

R_{min} = the minimum possible radius of the sphere containing Pu-239, cm

R_{Pu} = the radius of the metal Plutonium sphere, cm

V_{Pu} = the volume of the sphere with Pu-239, cm^3

m_{Pu} = the mass of the Plutonium sphere, g

ρ_{Pu} = the density of the metal Plutonium, 19.78 g/cm^3

Composition of the Plutonium containing spheres

The weight fractions of the elements composing the mixture are defined as the ratio of the mass of the element in the mixture to the total mass of the mixture. Total mass of the mixture was determined using

equation (4):

$$M_{total} = m_{Pu} + m_{cel} = m_{Pu} + V_{cel}\rho_{cel} =$$

$$= m_{Pu} + \left(V_{Total} - V_{Pu}\right)\rho_{cel} = m_{Pu} + \left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel} \qquad (4)$$

where

M_{Total} = the total mass of the mixture, g

m_{Pu} = the mass of Pu-239 in a sphere, g

m_{cel} = the mass of a cellulose in a sphere, g

V_{Total} = the total volume of a sphere, cm^3

V_{cel} = the volume of a cellulose in the sphere, cm^3

ρ_{cel} = the density of a cellulose, 0.72 g/cm^3

V_{Pu} = the volume of Pu-239 in the sphere, cm^3

ρ_{Pu} = the density of the metal Plutonium, 19.78 g/cm^3

R = the radius of a Plutonium containing sphere, cm

In the Plutonium-cellulose mixture, the weight fraction of Pu-239 was calculated using equation 5, and the weight fractions of elements composing cellulose were calculated using equation 7 as a product of the weight fraction of a cellulose in the Plutonium-cellulose mixture (equation 6) and the weight fraction of an element in a pure cellulose (equation 1).

$$w_{Pu} = \frac{m_{Pu}}{M_{total}} = \frac{m_{Pu}}{m_{Pu} + \left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel}} \qquad (5)$$

$$w_{cel} = \frac{m_{cel}}{M_{total}} = \frac{\left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel}}{m_{Pu} + \left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel}} \qquad (6)$$

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Client WVNS Subject: cellulose-Pu-239 spheres Chk'd. JW Date 02/27/01

$$w_i = w_{cel}(w_i)_{cel} = \frac{\left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel} n_i A_i}{\left[m_{Pu} + \left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel}\right]\sum n_i A_i} \qquad (7)$$

All variables in equations 5-7 are as described above. Table 6 shows the composition of the Plutonium containing spheres.

The cases for spheres with 10g, 20g, and 30g of Pu-239 were studied and based on the calculated neutron multiplication factors, the Pu-239 sub-critical mass limit was determined. Tables 5-7 show the composition of the spheres used in the models.

Table 5. The composition of the spheres with 10g of Pu-239.

Radius of the sphere, cm	3	6	9	12	15.24
Mixture density, g/cm^3	0.80520091 ✓	0.730650114	0.723155589	0.721331264	0.72064991
Pu-239 weight fraction	0.109810374 ✓	0.015126839	0.00452848	0.00191528	0.000935906
Carbon (C) weight fraction	0.395649228	0.437731799	0.442442294	0.443603741	0.44403903
Hydrogen (H)weight fraction	0.055338252	0.061224212	0.061883055	0.062045503	0.062106386
Oxygen (O) weight fraction	0.439202146	0.48591715	0.491146175	0.492435473	0.492918679

Table 6. The composition of the spheres with 20g of Pu-239.

Radius of the sphere, cm	3	6	9	12	15.24
Mixture density, g/cm^3	0.890401821	0.741300228	0.726311179	0.722662528	0.72129982
Pu-239 weight fraction	0.198605642	0.029819029	0.0090176	0.00382351	0.00187013
Carbon (C) weight fraction	0.356183727	0.431201781	0.440447079	0.44275562	0.443623811
Hydrogen (H)weight fraction	0.049818332	0.060310879	0.06160399	0.061926879	0.06204831
Oxygen (O) weight fraction	0.395392298	0.478668311	0.488931327	0.491493992	0.492457753

Table 7. The composition of the spheres with 30g of Pu-239.

Radius of the sphere, cm	3	6	9	12	15.24
Mixture density, g/cm^3	0.975602731	0.751950341	0.729466768	0.723993793	0.721949729
Pu-239 weight fraction	0.271891652	0.044095039	0.013467891	0.00572472	0.00280266
Carbon (C) weight fraction	0.323611394	0.424856737	0.438469126	0.441910618	0.44320934
Hydrogen (H)weight fraction	0.045262539	0.059423417	0.06132734	0.061808691	0.06199034
Oxygen (O) weight fraction	0.359234414	0.471624807	0.486735642	0.490555973	0.49199765

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Results

The results of the calculations performed using MCNP-4A code are shown in the following tables and graphs. Tables 8-10 provide the Monte Carlo determined neutron multiplication factor (k_{eff}) values and their standard deviations (σ), and Figures 1-3 plot the k_{eff} +2 σ values for all studied cases (10g, 20g, and 30g).

Table 8. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for the boxes with 10 g of Pu-239.

R and X-, Y-, Z- coordinates for the center of the sphere, cm					cellulose outside the sphere			void outside the sphere		
R	X	Y	Z1	Z2	k_{eff}	σ	k_{eff}+ 2σ	k_{eff}	σ	k_{eff}+ 2σ
3	3	3	27.48	33.48	0.2524	0.0009	0.2543	0.0737	0.0005	0.0747
6	6	6	24.48	36.48	0.3253	0.0008	0.3268	0.4078	0.0010	0.4098
9	9	9	21.48	39.48	0.2753	0.0005	0.2764	0.6062	0.0008	0.6077
12	12	12	18.48	42.48	0.2258	0.0003	0.2264	0.5108	0.0004	0.5116
15.24	15.24	15.24	15.24	45.72	0.2061	0.0002	0.2065	0.3436	0.0002	0.3440

Table 9. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for the boxes with 20 g of Pu-239.

R and X-, Y-, Z- coordinates for the center of the sphere, cm					cellulose outside the sphere			void outside the sphere		
R	X	Y	Z1	Z2	k_{eff}	σ	k_{eff}+ 2σ	k_{eff}	σ	k_{eff}+ 2σ
3	3	3	27.48	33.48	0.29341	0.00088	0.2952	0.0956	0.0006	0.0969
6	6	6	24.48	36.48	0.4491	0.0009	0.4509	0.5444	0.0013	0.5470
9	9	9	21.48	39.48	0.4382	0.0007	0.4396	0.8707	0.0010	0.8727
12	12	12	18.48	42.48	0.3897	0.0005	0.3907	0.8044	0.0005	0.8054
15.24	15.24	15.24	15.24	45.72	0.3709	0.0003	0.3715	0.5885	0.0003	0.5891

Table 10. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for the boxes with 30 g of Pu-239.

R and X-, Y-, Z- coordinates for the center of the sphere, cm					cellulose outside the sphere			void outside the sphere		
R	X	Y	Z1	Z2	k_{eff}	σ	k_{eff}+ 2σ	k_{eff}	σ	k_{eff}+ 2σ
3	3	3	27.48	33.48	0.31358	0.00094	0.3155	0.11193	0.00064	0.1132
6	6	6	24.48	36.48	0.5183	0.0010	0.5204	0.6087	0.0013	0.6113
9	9	9	21.48	39.48	0.5474	0.0009	0.5491	1.0139	0.0013	1.0165
12	12	12	18.48	42.48	0.5142	0.0005	0.5153	0.9930	0.0007	0.9943
15.24	15.24	15.24	15.24	45.72	0.5043	0.0004	0.5051	0.7715	0.0004	0.7723

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Sheet No. 8/11
Calc. No. BUF-2001-009
Rev. No. 0

Job No 30822-244-330 /6860 Job: PSR-6 By IVC Date 02/24/2001
Client WVNS Subject: cellulose-Pu-239 spheres Chk'd. JW Date 02/27/01

Figure 1. k_{eff} +2σ for the boxes with 10 g of Pu-239 .

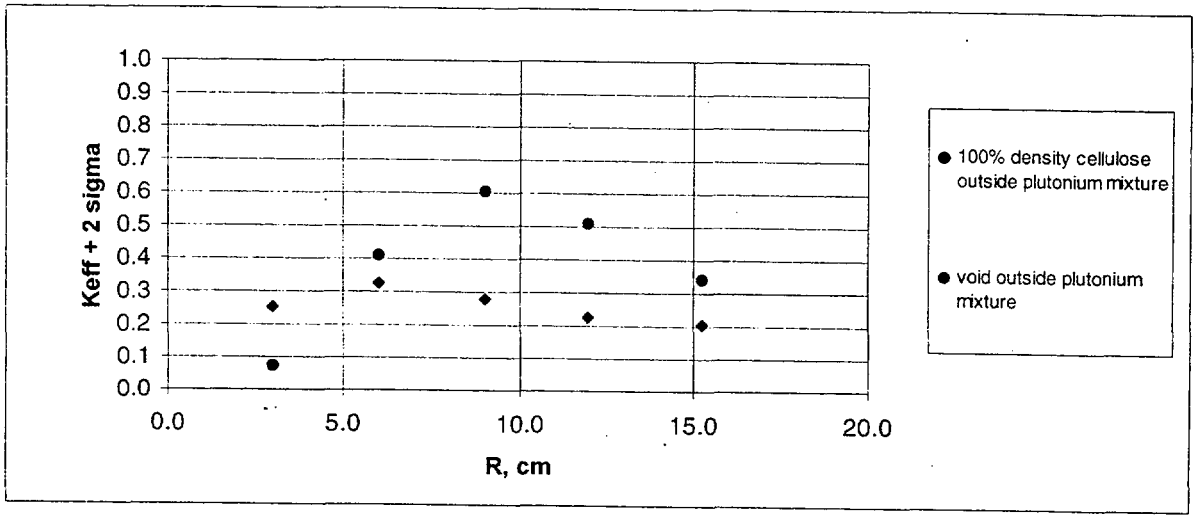
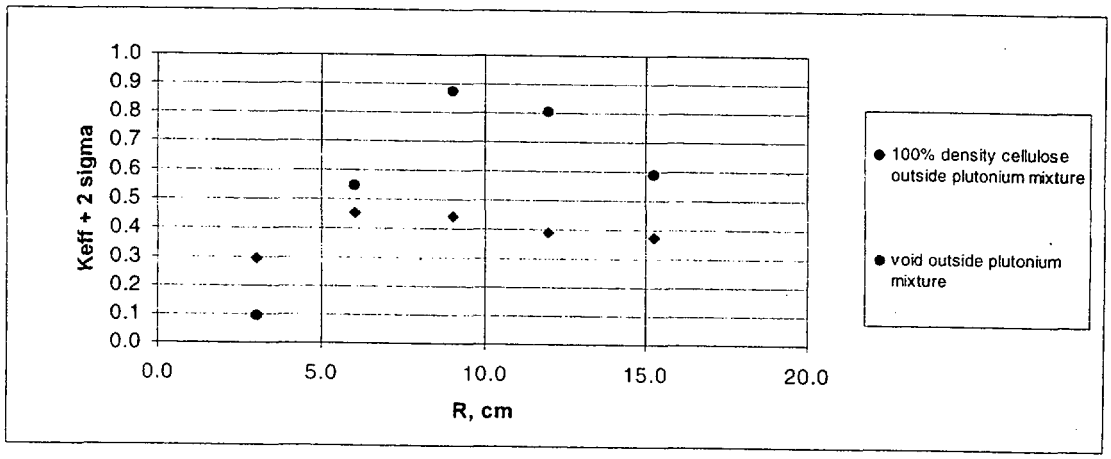


Figure 2. k_{eff} +2σ for the boxes with 20 g of Pu-239 .



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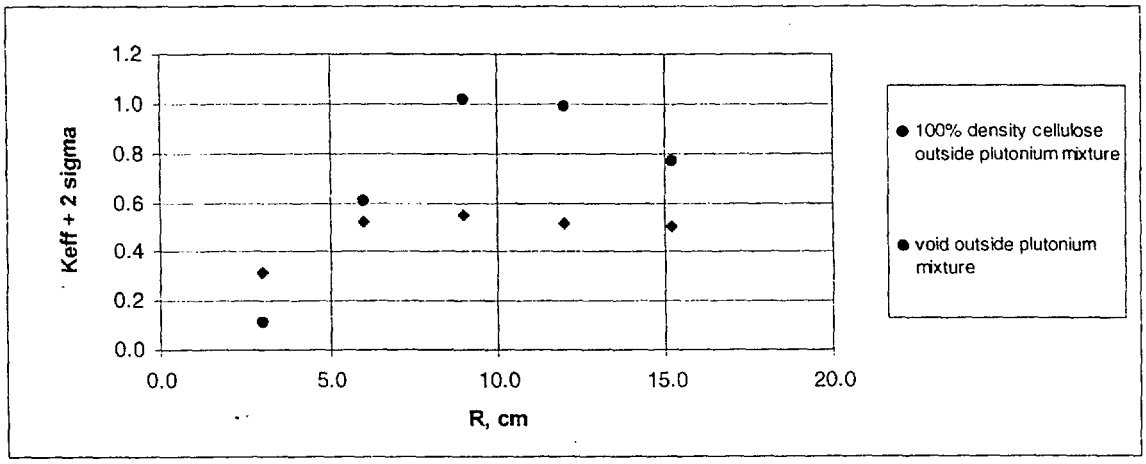
Client WVNS Subject: cellulose-Pu-239 spheres Chk'd. Date 02/27/01

Figure 3. k_{eff} +2σ for the boxes with 30 g of Pu-239.



The criterion for the Pu-239 mass limit is:

$$k_{eff} + 2\sigma \leq k_a - \Delta k_b - \sigma_b \quad (8)$$

Where:

k_{eff} = neutron multiplication factor predicted by MCNP

σ = standard deviation of predicted k_{eff}

$k_a = 0.95$ = established allowable limiting neutron multiplication factor

Δk_b = calculation method bias

σ_b = bias uncertainty

The calculation method bias together with bias uncertainty ($\Delta k_b + \sigma_b$) is no more than 0.02. Thus the criterion (8) can be modified as:

$$k_{eff} + 2\sigma \leq 0.93 \quad (9)$$

Where:

k_{eff} = neutron multiplication factor predicted by MCNP

σ = standard deviation of predicted k_{eff}

To determine the Pu-239 mass limit, the maximum values of k_{eff} +2σ as a function of Pu-239 mass (Table 11) were approximated with a polynomial equation, which is shown on Figure 4.

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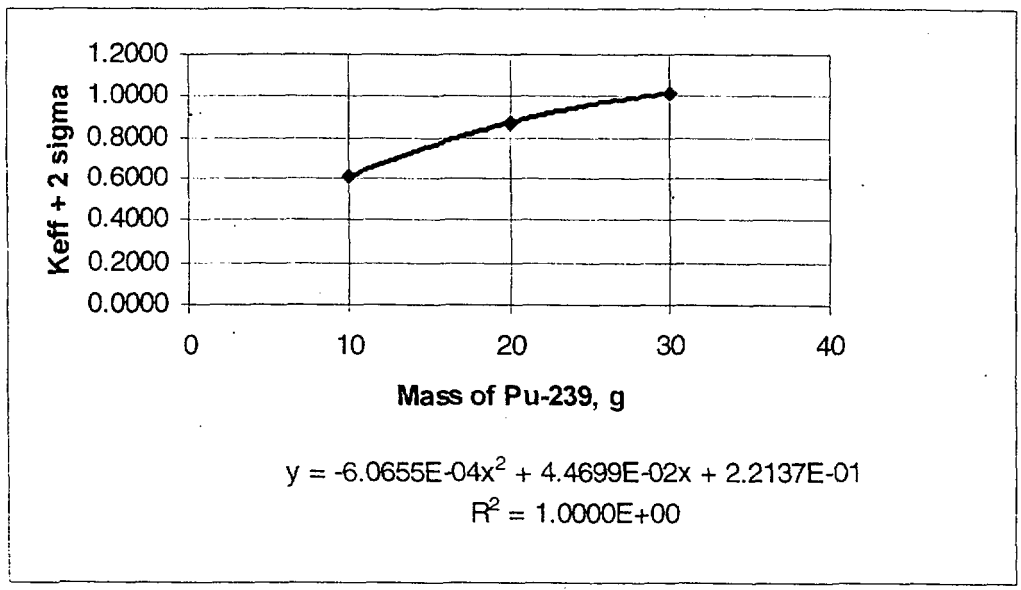
Job No 30822-244-330 /6860 Job: PSR-6 By IVC Date 02/24/2001
Client WVNS Subject: cellulose-Pu-239 spheres Chk'd. Date 02/27/01

Table 11. The maximum values of k_{eff} +2σ as a function of Pu-239 mass.

Mass of Pu-239, g	k_{eff}	σ	k_{eff} + 2σ
10	0.6062	0.0008	0.6077
20	0.8707	0.0010	0.8727
30	1.0139	0.0013	1.0165

Figure 4. The maximum values of k_{eff} +2σ as a function of Pu-239 mass.



Solving the polynomial equation from Figure 4 determines the Pu-239 mass limit as 23g per box. To check this result, another set of MCNP runs was performed. Table 12 shows the composition of the Plutonium containing spheres, and Table 13 and Figure 5 show the calculation results for the arrays of boxes with 23g of Pu-239.

Table 12. The composition of the spheres with 23g of Pu-239

Radius of the sphere, cm	3	6	9	12	15.24
Mixture density, g/cm^3	0.915962094	0.744495262	0.727257855	0.723061908	0.721494793
Pu-239 weight fraction	0.222022997	0.034144719	0.010356745	0.00439461	0.00215006
Carbon (C) weight fraction	0.345775767	0.429279207	0.439851891	0.442501793	0.443499392
Hydrogen (H)weight fraction	0.048362603	0.060041974	0.061520743	0.061891377	0.062030908
Oxygen (O) weight fraction	0.383838633	0.4765341	0.488270621	0.491212224	0.49231963

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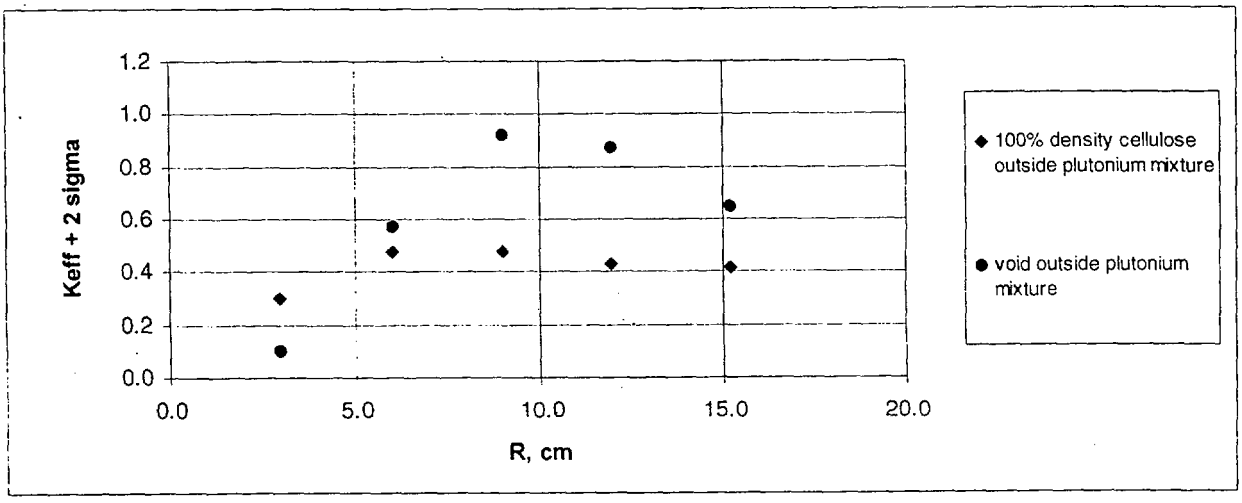
Job No 30822-244-330 /6860 Job: PSR-6 By IVC Date 02/24/2001
Client WVNS Subject: cellulose-Pu-239 spheres Chk'd Date 02/27/01

Table 13. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for the boxes with 23 g of Pu-239.

R and X-, Y-, Z- coordinates for the center of the sphere, cm					cellulose outside the sphere			void outside the sphere		
R	X	Y	Z1	Z2	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$
3	3	3	27.48	33.48	0.29933	0.00098	0.3013	0.1013	0.0005	0.1023
6	6	6	24.48	36.48	0.47656	0.00108	0.4787	0.5685	0.0012	0.5709
9	9	9	21.48	39.48	0.4759	0.0008	0.4775	0.9209	0.0010	0.9228
12	12	12	18.48	42.48	0.4305	0.0006	0.4317	0.8694	0.0007	0.8708
15.24	15.24	15.24	15.24	45.72	0.4129	0.0003	0.4135	0.6493	0.0003	0.6500

Figure 5. $k_{eff}+2\sigma$ for the boxes with 23g of Pu-239.



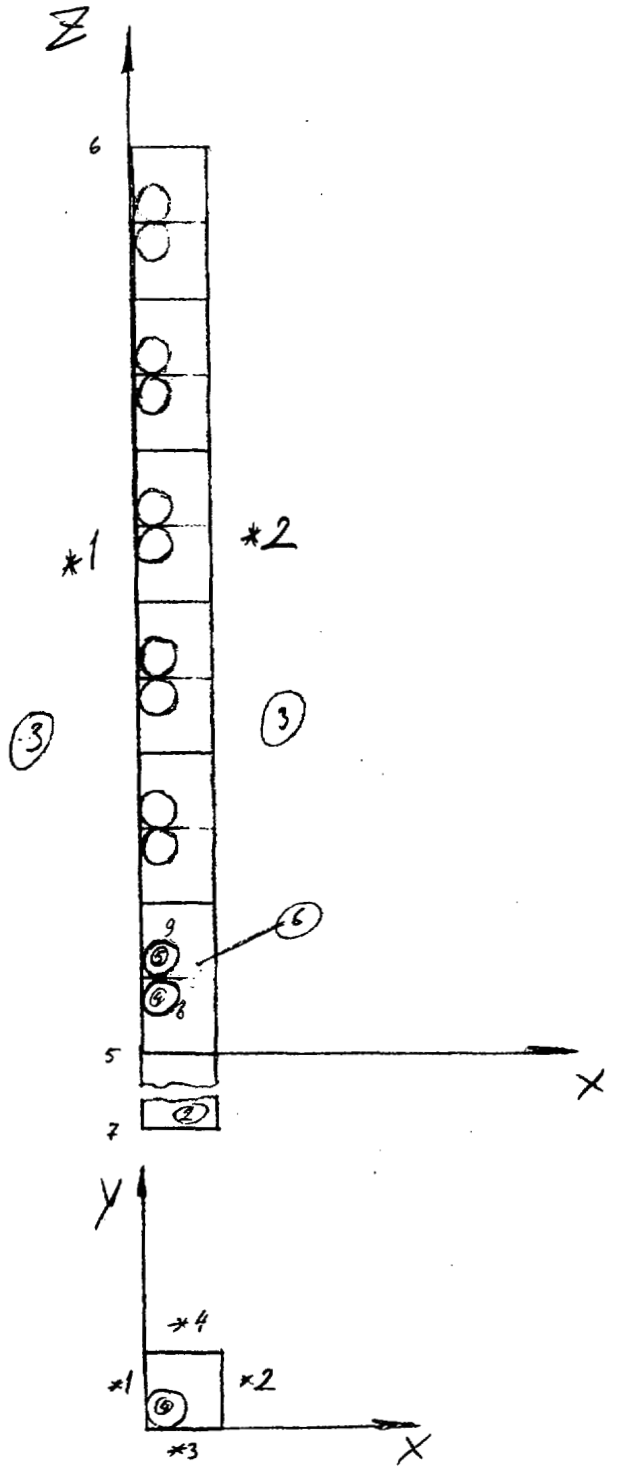
The $k_{eff}+2\sigma$ values in Table 13 confirm that 23g of Pu-239 is a sub-critical mass limit for $\infty \times \infty \times 12$ ft arrays of 1-cubic-foot boxes with Pu-239-cellulose spheres and pure cellulose or void outside the sphere.

Attachment 1: MCNP model with surface and cell numbers

FILE _____

SUBJECT _____

REVISIONS
BY _____ DATE _____ TO EO _____
BY _____ DATE _____ TO EO _____



BY _____ DATE _____
CHECKED BY _____
COPY TO EO _____

Dames & Moore

Attachment 2: MCNP input file

3b091

```
k eff, 23g of Pu-239 in cellulose spheres in 1 cubic foot of pure celulose
C
C Cell cards
C
C ------------------------------------------------------------------------
1 0   1 -2 3 -4 5 -6 fill=2          imp:n=1 $ box with lattice
2 2  -2.3    1 -2 3 -4 -5 7          imp:n=1 $ Concrete floor
3 0         -1 : 2 : -3 : 4 : -7 : 6  imp:n=0 $ Outside world
c
c Universe 1
4 3  -0.744495 -8              u=1    imp:n=1 $ 1 Pu-239 and cellulose sphere
5 3  -0.744495 -9              u=1    imp:n=1 $ 2 Pu-239 and cellulose sphere
6 1  -0.72       8 9            u=1    imp:n=1 $ Pure Cellulose
c
c Lattice (2 spheres with Pu-239 in 2 cubic feet of cellulose matrix)
7 0 10 -11 12 -13 14 -15 lat=1 fill=1 u=2 imp:n=1 $ Lattice
C ------------------------------------------------------------------------
c
c Note: next line must be completely blank

c Surface cards
C ------------------------------------------------------------------------
*1 px 0.001
*2 px 30.481  $  box length (1 foot)
*3 py 0.001
*4 py 30.481  $  box width (1 foot)
5  pz 0.001
6  pz 365.761 $  box height (12 feet)
c                More thnan 350.52cm (11.5 feet) - 4 tiers of B-25 box height
c                (4x34.5" or 4x87.63 cm)
7  pz -300 $ concrete floor boundary
8  s 6.0 6.0  24.48 6.0 $ 1st Pu-239 containing sphere
9  s 6.0 6.0  36.48 6.0 $ 2nd Pu-239 containing sphere
c
c Lattice surfases:
10 px 0
11 px 30.48
12 py 0
13 py 30.48
14 pz 0
15 pz 60.96 $ 2 feet
C ------------------------------------------------------------------------
c
c Note: next line must be completely blank

c Data cards
c
c Materials
c
c
c Celulose matrix (Elements: C, H, O)
m1      6000.50c  -0.444
        1001.50c  -0.062
        8016.50c  -0.493
c Concrete (KENO Regular Concrete Standard Mix) from Harmon at al.
c Criticality Calculation with MCNP. A Primer. p. C-4
c (Elements: H, O, Na, Si, Al, Ca, Fe)
m2      1001.50c -0.010
        8016.50c -0.532
       11023.50c -0.029
       13027.50c -0.034
       14000.50c -0.337
       20000.50c -0.044
       26000.55c -0.014
c Pu-239 and cellulose
m3     94239.55c  -0.034144719
        6000.50c  -0.429279207
        1001.50c  -0.060041974
        8016.50c  -0.4765341
c
mode n
print 40 60 80 100 110 126
kcode 4000 1. 20 120
ksrc  6.0 6.0  24.48
      6.0 6.0  36.48
```

Attachment 3: MCNP output file

```
1mcnp     version 4a    ld=10/01/93                    02/14/01 01:32:16
*************************************************************************          probid =   02/14/01 01:32:16
name=3b091

      k eff, 23g of Pu-239 in cellulose spheres in 1 cubic foot of pure celulose
      C
      C Cell cards
      C
      C ---------------------------------------------------------------------
      1 0   1 -2 3 -4 5 -6 fill=2          imp:n=1 $ box with lattice
      2 2  -2.3    1 -2 3 -4 -5 7          imp:n=1 $ Concrete floor
      3 0         -1 : 2 : -3 : 4 : -7 : 6  imp:n=0 $ Outside world
      c
      c Universe 1
      4 3  -0.744495 -8              u=1    imp:n=1 $ 1 Pu-239 and cellulose sphere
      5 3  -0.744495 -9              u=1    imp:n=1 $ 2 Pu-239 and cellulose sphere
      6 1  -0.72       8 9            u=1    imp:n=1 $ Pure Cellulose
      c
      c Lattice (2 spheres with Pu-239 in 2 cubic feet of cellulose matrix)
      7 0 10 -11 12 -13 14 -15 lat=1 fill=1 u=2 imp:n=1 $ Lattice
      C ---------------------------------------------------------------------
      c
      c Note: next line must be completely blank

      c Surface cards
      C ---------------------------------------------------------------------
      *1 px 0.001
      *2 px 30.481  $  box length (1 foot)
      *3 py 0.001
      *4 py 30.481  $  box width (1 foot)
      5  pz 0.001
      6  pz 365.761 $  box height (12 feet)
      c                More thnan 350.52cm (11.5 feet) - 4 tiers of B-25 box height
      c                (4x34.5" or 4x87.63 cm)
      7  pz -300 $ concrete floor boundary
      8  s 6.0 6.0  24.48 6.0 $ 1st Pu-239 containing sphere
      9  s 6.0 6.0  36.48 6.0 $ 2nd Pu-239 containing sphere
      c
      c Lattice surfases:
      10 px 0
      11 px 30.48
      12 py 0
      13 py 30.48
      14 pz 0
      15 pz 60.96 $ 2 feet
      C ---------------------------------------------------------------------
      c
      c Note: next line must be completely blank

      c Data cards
      c
      c Materials
      c
      c
      c Celulose matrix (Elements: C, H, O)
      m1     6000.50c  -0.444
             1001.50c  -0.062
             8016.50c  -0.493
      c Concrete (KENO Regular Concrete Standard Mix) from Harmon at al.
      c Criticality Calculation with MCNP. A Primer. p. C-4
      c (Elements: H, O, Na, Si, Al, Ca, Fe)
      m2     1001.50c -0.010
```

```
 59-              8016.50c -0.532
 60-             11023.50c -0.029
 61-             13027.50c -0.034
 62-             14000.50c -0.337
 63-             20000.50c -0.044
 64-             26000.55c -0.014
 65-       c Pu-239 and cellulose
 66-       m3    94239.55c  -0.034144719
 67-              6000.50c  -0.429279207
 68-              1001.50c  -0.060041974
 69-              8016.50c  -0.4765341
 70-       c
 71-       mode n
 72-       print 40 60 80 100 110 126
 73-       kcode 4000 1. 20 120
 74-       ksrc  6.0 6.0  24.48
 75-             6.0 6.0  36.48
 76-
 total fission nubar data are being used.
1material composition                                                    print table 40

 the sum of the fractions of material     1 was 9.990000E-01

 material
  number      component nuclide, atom fraction

      1            6000,  0.28588       1001,  0.47576       8016,  0.23837
      2            1001,  0.16803       8016,  0.56324      11023,  0.02136      13027,  0.02134
                  14000,  0.20319      20000,  0.01859      26000,  0.00425
      3           94239,  0.00114       6000,  0.28535       1001,  0.47565       8016,  0.23786


 material
  number      component nuclide, mass fraction

      1            6000,  0.44444       1001,  0.06206       8016,  0.49349
      2            1001,  0.01000       8016,  0.53200      11023,  0.02900      13027,  0.03400
                  14000,  0.33700      20000,  0.04400      26000,  0.01400
      3           94239,  0.03414       6000,  0.42928       1001,  0.06004       8016,  0.47653

 warning.     1 of the materials had unnormalized fractions.
1cells                                                                   print table 60

                          atom          gram                                          neutron
        cell  mat        density       density        volume          mass       pieces importance

      1     1    0  0.00000E+00  0.00000E+00  3.39802E+05  0.00000E+00       0  1.0000E+00
      2     2    2  8.17913E-02  2.30000E+00  2.78710E+05  6.41033E+05       0  1.0000E+00
      3     3    0  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00       0  0.0000E+00
      4     4    3  5.61552E-02  7.44495E-01  9.04779E+02  6.73603E+02       1  1.0000E+00
      5     5    3  5.61552E-02  7.44495E-01  9.04779E+02  6.73603E+02       1  1.0000E+00
      6     6    1  5.61219E-02  7.20000E-01  0.00000E+00  0.00000E+00       0  1.0000E+00
      7     7    0  0.00000E+00  0.00000E+00  5.66337E+04  0.00000E+00       0  1.0000E+00

   total                                     6.76955E+05  6.42380E+05

         1 warning message so far.
1cross-section tables                                                    print table 100
```

```
   table    length

                    tables from file critxs

  1001.50c    1153  njoy                                                  ( 1301)      79/07/31.
  6000.50c   16126  njoy                                                  ( 1306)      79/07/31.
  8016.50c   23669  njoy                                                  ( 1276)     05/14/81
 11023.50c   36270  njoy                                                  ( 1311)      79/06/21.
 13027.50c   22891  njoy                                                  ( 1313)      79/09/08.
 14000.50c   48275  njoy                                                  ( 1314)      79/06/21.
 20000.50c   26104  njoy                                                  ( 1320)      79/06/22.
 26000.55c   84136  njoy                                                  ( 260)      10/21/82
 94239.55c   67551  njoy                                  total nu        ( 1399)     02/21/85

 total      326175

warning.  neutron energy cutoff is below some cross-section tables.



decimal words of dynamically allocated storage

    general             111136
    tallies                  0
    bank                 12403
    cross sections      326175

    total               449714

*****************************************************************************************************************
dump no.    1 on file 3b091r       nps =         0     coll =              0     ctm =    0.00     nrn =              0

source distribution written to file 3b091s          cycle =     0

        2 warning messages so far.
1   starting mcrun.      field length =      0      cp0 =  0.01                                    print table 110

     k eff, 23g of Pu-239 in cellulose spheres in 1 cubic foot of pure celulose

nps   x          y          z       cell lattice(i,j,k)  surface    u          v          w          energy     weight      time

 1  6.000E+00  6.000E+00  2.448E+01    1                          5.085E-01  4.733E-01  7.193E-01  2.209E+00  1.000E+00  0.000E+00
    6.000E+00  6.000E+00  2.448E+01    7(   0,    0,    0)        5.085E-01  4.733E-01  7.193E-01
    6.000E+00  6.000E+00  2.448E+01    4                      0  5.085E-01  4.733E-01  7.193E-01
 2  6.000E+00  6.000E+00  2.448E+01    1                          8.952E-01 -4.447E-01 -2.944E-02  4.904E+00  1.000E+00  0.000E+00
    6.000E+00  6.000E+00  2.448E+01    7(   0,    0,    0)        8.952E-01 -4.447E-01 -2.944E-02
    6.000E+00  6.000E+00  2.448E+01    4                      0  8.952E-01 -4.447E-01 -2.944E-02
 3  6.000E+00  6.000E+00  2.448E+01    1                         -6.184E-01 -4.495E-01  6.446E-01  3.809E-01  1.000E+00  0.000E+00
    6.000E+00  6.000E+00  2.448E+01    7(   0,    0,    0)       -6.184E-01 -4.495E-01  6.446E-01
    6.000E+00  6.000E+00  2.448E+01    4                      0 -6.184E-01 -4.495E-01  6.446E-01
 4  6.000E+00  6.000E+00  2.448E+01    1                          9.710E-01 -5.665E-02 -2.323E-01  1.331E+00  1.000E+00  0.000E+00
    6.000E+00  6.000E+00  2.448E+01    7(   0,    0,    0)        9.710E-01 -5.665E-02 -2.323E-01
    6.000E+00  6.000E+00  2.448E+01    4                      0  9.710E-01 -5.665E-02 -2.323E-01
 5  6.000E+00  6.000E+00  2.448E+01    1                          5.861E-01  1.496E-01 -7.963E-01  1.902E+00  1.000E+00  0.000E+00
    6.000E+00  6.000E+00  2.448E+01    7(   0,    0,    0)        5.861E-01  1.496E-01 -7.963E-01
    6.000E+00  6.000E+00  2.448E+01    4                      0  5.861E-01  1.496E-01 -7.963E-01
 6  6.000E+00  6.000E+00  2.448E+01    1                         -6.489E-02 -1.626E-01  9.845E-01  4.410E-01  1.000E+00  0.000E+00
    6.000E+00  6.000E+00  2.448E+01    7(   0,    0,    0)       -6.489E-02 -1.626E-01  9.845E-01
```

```
      6.000E+00  6.000E+00  2.448E+01    4                                    0 -6.489E-02 -1.626E-01  9.845E-01
    7 6.000E+00  6.000E+00  2.448E+01    1                                      -7.068E-02  3.263E-02 -9.970E-01  4.750E-01  1.000E+00  0.000E+00
      6.000E+00  6.000E+00  2.448E+01    7(   0,   0,   0)                     -7.068E-02  3.263E-02 -9.970E-01
      6.000E+00  6.000E+00  2.448E+01    4                                    0 -7.068E-02  3.263E-02 -9.970E-01
    8 6.000E+00  6.000E+00  2.448E+01    1                                      -3.915E-01  4.664E-01 -7.932E-01  4.136E+00  1.000E+00  0.000E+00
      6.000E+00  6.000E+00  2.448E+01    7(   0,   0,   0)                     -3.915E-01  4.664E-01 -7.932E-01
      6.000E+00  6.000E+00  2.448E+01    4                                    0 -3.915E-01  4.664E-01 -7.932E-01
    9 6.000E+00  6.000E+00  2.448E+01    1                                      -2.368E-01  9.215E-01 -3.079E-01  7.453E-02  1.000E+00  0.000E+00
      6.000E+00  6.000E+00  2.448E+01    7(   0,   0,   0)                     -2.368E-01  9.215E-01 -3.079E-01
      6.000E+00  6.000E+00  2.448E+01    4                                    0 -2.368E-01  9.215E-01 -3.079E-01
   10 6.000E+00  6.000E+00  2.448E+01    1                                       1.946E-01 -3.204E-01  9.271E-01  3.128E+00  1.000E+00  0.000E+00
      6.000E+00  6.000E+00  2.448E+01    7(   0,   0,   0)                     1.946E-01 -3.204E-01  9.271E-01
      6.000E+00  6.000E+00  2.448E+01    4                                    0  1.946E-01 -3.204E-01  9.271E-01
   11 6.000E+00  6.000E+00  2.448E+01    1                                      -6.698E-01 -7.177E-01 -1.905E-01  1.014E+00  1.000E+00  0.000E+00
      6.000E+00  6.000E+00  2.448E+01    7(   0,   0,   0)                     -6.698E-01 -7.177E-01 -1.905E-01
      6.000E+00  6.000E+00  2.448E+01    4                                    0 -6.698E-01 -7.177E-01 -1.905E-01
   12 6.000E+00  6.000E+00  2.448E+01    1                                      -8.398E-01 -4.129E-01  3.524E-01  1.395E+00  1.000E+00  0.000E+00
      6.000E+00  6.000E+00  2.448E+01    7(   0,   0,   0)                     -8.398E-01 -4.129E-01  3.524E-01
      6.000E+00  6.000E+00  2.448E+01    4                                    0 -8.398E-01 -4.129E-01  3.524E-01
   13 6.000E+00  6.000E+00  2.448E+01    1                                      -1.714E-01 -8.572E-01  4.857E-01  7.748E-01  1.000E+00  0.000E+00
      6.000E+00  6.000E+00  2.448E+01    7(   0,   0,   0)                     -1.714E-01 -8.572E-01  4.857E-01
      6.000E+00  6.000E+00  2.448E+01    4                                    0 -1.714E-01 -8.572E-01  4.857E-01
   14 6.000E+00  6.000E+00  2.448E+01    1                                      -2.489E-01 -5.118E-01 -8.222E-01  1.101E+00  1.000E+00  0.000E+00
      6.000E+00  6.000E+00  2.448E+01    7(   0,   0,   0)                     -2.489E-01 -5.118E-01 -8.222E-01
      6.000E+00  6.000E+00  2.448E+01    4                                    0 -2.489E-01 -5.118E-01 -8.222E-01
   15 6.000E+00  6.000E+00  2.448E+01    1                                      -2.959E-01  2.119E-01  9.314E-01  1.951E+00  1.000E+00  0.000E+00
      6.000E+00  6.000E+00  2.448E+01    7(   0,   0,   0)                     -2.959E-01  2.119E-01  9.314E-01
      6.000E+00  6.000E+00  2.448E+01    4                                    0 -2.959E-01  2.119E-01  9.314E-01
   16 6.000E+00  6.000E+00  2.448E+01    1                                       1.395E-01 -9.829E-01  1.202E-01  2.186E+00  1.000E+00  0.000E+00
      6.000E+00  6.000E+00  2.448E+01    7(   0,   0,   0)                     1.395E-01 -9.829E-01  1.202E-01
      6.000E+00  6.000E+00  2.448E+01    4                                    0  1.395E-01 -9.829E-01  1.202E-01
   17 6.000E+00  6.000E+00  2.448E+01    1                                       6.909E-01 -7.110E-01  1.307E-01  1.865E+00  1.000E+00  0.000E+00
      6.000E+00  6.000E+00  2.448E+01    7(   0,   0,   0)                     6.909E-01 -7.110E-01  1.307E-01
      6.000E+00  6.000E+00  2.448E+01    4                                    0  6.909E-01 -7.110E-01  1.307E-01
   18 6.000E+00  6.000E+00  2.448E+01    1                                      -6.580E-01  5.320E-01 -5.329E-01  1.229E+00  1.000E+00  0.000E+00
      6.000E+00  6.000E+00  2.448E+01    7(   0,   0,   0)                     -6.580E-01  5.320E-01 -5.329E-01
      6.000E+00  6.000E+00  2.448E+01    4                                    0 -6.580E-01  5.320E-01 -5.329E-01
   19 6.000E+00  6.000E+00  2.448E+01    1                                      -9.903E-01 -1.380E-01  1.353E-02  1.305E+00  1.000E+00  0.000E+00
      6.000E+00  6.000E+00  2.448E+01    7(   0,   0,   0)                     -9.903E-01 -1.380E-01  1.353E-02
      6.000E+00  6.000E+00  2.448E+01    4                                    0 -9.903E-01 -1.380E-01  1.353E-02
   20 6.000E+00  6.000E+00  2.448E+01    1                                       7.462E-01  4.859E-01 -4.551E-01  1.000E+00  1.000E+00  0.000E+00
      6.000E+00  6.000E+00  2.448E+01    7(   0,   0,   0)                     7.462E-01  4.859E-01 -4.551E-01
      6.000E+00  6.000E+00  2.448E+01    4                                    0  7.462E-01  4.859E-01 -4.551E-01
   21 6.000E+00  6.000E+00  2.448E+01    1                                      -1.977E-01  9.797E-01  3.360E-02  3.990E+00  1.000E+00  0.000E+00
      6.000E+00  6.000E+00  2.448E+01    7(   0,   0,   0)                     -1.977E-01  9.797E-01  3.360E-02
      6.000E+00  6.000E+00  2.448E+01    4                                    0 -1.977E-01  9.797E-01  3.360E-02
   22 6.000E+00  6.000E+00  2.448E+01    1                                      -9.117E-01 -3.647E-01 -1.891E-01  2.665E-01  1.000E+00  0.000E+00
      6.000E+00  6.000E+00  2.448E+01    7(   0,   0,   0)                     -9.117E-01 -3.647E-01 -1.891E-01
      6.000E+00  6.000E+00  2.448E+01    4                                    0 -9.117E-01 -3.647E-01 -1.891E-01
   23 6.000E+00  6.000E+00  2.448E+01    1                                      -4.287E-01  8.361E-01 -3.423E-01  1.156E+00  1.000E+00  0.000E+00
      6.000E+00  6.000E+00  2.448E+01    7(   0,   0,   0)                     -4.287E-01  8.361E-01 -3.423E-01
      6.000E+00  6.000E+00  2.448E+01    4                                    0 -4.287E-01  8.361E-01 -3.423E-01
   24 6.000E+00  6.000E+00  2.448E+01    1                                       1.080E-01  3.412E-01 -9.338E-01  2.669E+00  1.000E+00  0.000E+00
      6.000E+00  6.000E+00  2.448E+01    7(   0,   0,   0)                     1.080E-01  3.412E-01 -9.338E-01
      6.000E+00  6.000E+00  2.448E+01    4                                    0  1.080E-01  3.412E-01 -9.338E-01
   25 6.000E+00  6.000E+00  2.448E+01    1                                      -9.111E-01 -9.012E-03 -4.122E-01  2.185E+00  1.000E+00  0.000E+00
      6.000E+00  6.000E+00  2.448E+01    7(   0,   0,   0)                     -9.111E-01 -9.012E-03 -4.122E-01
      6.000E+00  6.000E+00  2.448E+01    4                                    0 -9.111E-01 -9.012E-03 -4.122E-01
   26 6.000E+00  6.000E+00  2.448E+01    1                                      -2.568E-01 -6.391E-01 -7.249E-01  4.225E+00  1.000E+00  0.000E+00
      6.000E+00  6.000E+00  2.448E+01    7(   0,   0,   0)                     -2.568E-01 -6.391E-01 -7.249E-01
      6.000E+00  6.000E+00  2.448E+01    4                                    0 -2.568E-01 -6.391E-01 -7.249E-01
   27 6.000E+00  6.000E+00  2.448E+01    1                                      -2.912E-01  8.086E-01  5.113E-01  1.079E+00  1.000E+00  0.000E+00
```

	6.000E+00	6.000E+00	2.448E+01	7(	0,	0,	0)		-2.912E-01	8.086E-01	5.113E-01			
	6.000E+00	6.000E+00	2.448E+01	4				0	-2.912E-01	8.086E-01	5.113E-01			
28	6.000E+00	6.000E+00	2.448E+01	1					1.472E-01	-9.514E-01	2.705E-01	3.461E+00	1.000E+00	0.000E+00
	6.000E+00	6.000E+00	2.448E+01	7(	0,	0,	0)		1.472E-01	-9.514E-01	2.705E-01			
	6.000E+00	6.000E+00	2.448E+01	4				0	1.472E-01	-9.514E-01	2.705E-01			
29	6.000E+00	6.000E+00	2.448E+01	1					-6.135E-01	-7.645E-01	-1.978E-01	1.836E+00	1.000E+00	0.000E+00
	6.000E+00	6.000E+00	2.448E+01	7(	0,	0,	0)		-6.135E-01	-7.645E-01	-1.978E-01			
	6.000E+00	6.000E+00	2.448E+01	4				0	-6.135E-01	-7.645E-01	-1.978E-01			
30	6.000E+00	6.000E+00	2.448E+01	1					-5.702E-01	5.651E-01	-5.963E-01	4.556E-01	1.000E+00	0.000E+00
	6.000E+00	6.000E+00	2.448E+01	7(	0,	0,	0)		-5.702E-01	5.651E-01	-5.963E-01			
	6.000E+00	6.000E+00	2.448E+01	4				0	-5.702E-01	5.651E-01	-5.963E-01			
31	6.000E+00	6.000E+00	2.448E+01	1					-6.607E-01	5.373E-01	-5.242E-01	6.415E-01	1.000E+00	0.000E+00
	6.000E+00	6.000E+00	2.448E+01	7(	0,	0,	0)		-6.607E-01	5.373E-01	-5.242E-01			
	6.000E+00	6.000E+00	2.448E+01	4				0	-6.607E-01	5.373E-01	-5.242E-01			
32	6.000E+00	6.000E+00	2.448E+01	1					-9.742E-02	-3.639E-01	-9.263E-01	2.764E+00	1.000E+00	0.000E+00
	6.000E+00	6.000E+00	2.448E+01	7(	0,	0,	0)		-9.742E-02	-3.639E-01	-9.263E-01			
	6.000E+00	6.000E+00	2.448E+01	4				0	-9.742E-02	-3.639E-01	-9.263E-01			
33	6.000E+00	6.000E+00	2.448E+01	1					-1.965E-01	-3.145E-01	-9.287E-01	2.785E-01	1.000E+00	0.000E+00
	6.000E+00	6.000E+00	2.448E+01	7(	0,	0,	0)		-1.965E-01	-3.145E-01	-9.287E-01			
	6.000E+00	6.000E+00	2.448E+01	4				0	-1.965E-01	-3.145E-01	-9.287E-01			
34	6.000E+00	6.000E+00	2.448E+01	1					4.097E-01	8.465E-01	-3.399E-01	9.097E-01	1.000E+00	0.000E+00
	6.000E+00	6.000E+00	2.448E+01	7(	0,	0,	0)		4.097E-01	8.465E-01	-3.399E-01			
	6.000E+00	6.000E+00	2.448E+01	4				0	4.097E-01	8.465E-01	-3.399E-01			
35	6.000E+00	6.000E+00	2.448E+01	1					-4.048E-02	8.831E-01	4.675E-01	3.360E-01	1.000E+00	0.000E+00
	6.000E+00	6.000E+00	2.448E+01	7(	0,	0,	0)		-4.048E-02	8.831E-01	4.675E-01			
	6.000E+00	6.000E+00	2.448E+01	4				0	-4.048E-02	8.831E-01	4.675E-01			
36	6.000E+00	6.000E+00	2.448E+01	1					3.371E-01	-9.269E-01	-1.652E-01	6.376E-01	1.000E+00	0.000E+00
	6.000E+00	6.000E+00	2.448E+01	7(	0,	0,	0)		3.371E-01	-9.269E-01	-1.652E-01			
	6.000E+00	6.000E+00	2.448E+01	4				0	3.371E-01	-9.269E-01	-1.652E-01			
37	6.000E+00	6.000E+00	2.448E+01	1					-1.867E-01	9.756E-01	-1.155E-01	2.186E+00	1.000E+00	0.000E+00
	6.000E+00	6.000E+00	2.448E+01	7(	0,	0,	0)		-1.867E-01	9.756E-01	-1.155E-01			
	6.000E+00	6.000E+00	2.448E+01	4				0	-1.867E-01	9.756E-01	-1.155E-01			
38	6.000E+00	6.000E+00	2.448E+01	1					-2.616E-01	2.336E-01	-9.365E-01	7.314E-01	1.000E+00	0.000E+00
	6.000E+00	6.000E+00	2.448E+01	7(	0,	0,	0)		-2.616E-01	2.336E-01	-9.365E-01			
	6.000E+00	6.000E+00	2.448E+01	4				0	-2.616E-01	2.336E-01	-9.365E-01			
39	6.000E+00	6.000E+00	2.448E+01	1					9.780E-01	-7.641E-02	-1.939E-01	2.997E-01	1.000E+00	0.000E+00
	6.000E+00	6.000E+00	2.448E+01	7(	0,	0,	0)		9.780E-01	-7.641E-02	-1.939E-01			
	6.000E+00	6.000E+00	2.448E+01	4				0	9.780E-01	-7.641E-02	-1.939E-01			
40	6.000E+00	6.000E+00	2.448E+01	1					2.580E-01	-7.076E-01	6.578E-01	1.444E+00	1.000E+00	0.000E+00
	6.000E+00	6.000E+00	2.448E+01	7(	0,	0,	0)		2.580E-01	-7.076E-01	6.578E-01			
	6.000E+00	6.000E+00	2.448E+01	4				0	2.580E-01	-7.076E-01	6.578E-01			
41	6.000E+00	6.000E+00	2.448E+01	1					-3.212E-01	-7.678E-01	-5.543E-01	1.914E+00	1.000E+00	0.000E+00
	6.000E+00	6.000E+00	2.448E+01	7(	0,	0,	0)		-3.212E-01	-7.678E-01	-5.543E-01			
	6.000E+00	6.000E+00	2.448E+01	4				0	-3.212E-01	-7.678E-01	-5.543E-01			
42	6.000E+00	6.000E+00	2.448E+01	1					5.039E-01	-1.460E-01	8.513E-01	1.502E+00	1.000E+00	0.000E+00
	6.000E+00	6.000E+00	2.448E+01	7(	0,	0,	0)		5.039E-01	-1.460E-01	8.513E-01			
	6.000E+00	6.000E+00	2.448E+01	4				0	5.039E-01	-1.460E-01	8.513E-01			
43	6.000E+00	6.000E+00	2.448E+01	1					6.080E-01	5.487E-01	5.738E-01	5.971E+00	1.000E+00	0.000E+00
	6.000E+00	6.000E+00	2.448E+01	7(	0,	0,	0)		6.080E-01	5.487E-01	5.738E-01			
	6.000E+00	6.000E+00	2.448E+01	4				0	6.080E-01	5.487E-01	5.738E-01			
44	6.000E+00	6.000E+00	2.448E+01	1					-2.932E-01	9.304E-01	-2.199E-01	1.827E+00	1.000E+00	0.000E+00
	6.000E+00	6.000E+00	2.448E+01	7(	0,	0,	0)		-2.932E-01	9.304E-01	-2.199E-01			
	6.000E+00	6.000E+00	2.448E+01	4				0	-2.932E-01	9.304E-01	-2.199E-01			
45	6.000E+00	6.000E+00	2.448E+01	1					-8.475E-01	-3.993E-01	-3.497E-01	1.928E+00	1.000E+00	0.000E+00
	6.000E+00	6.000E+00	2.448E+01	7(	0,	0,	0)		-8.475E-01	-3.993E-01	-3.497E-01			
	6.000E+00	6.000E+00	2.448E+01	4				0	-8.475E-01	-3.993E-01	-3.497E-01			
46	6.000E+00	6.000E+00	2.448E+01	1					1.200E-01	-9.195E-01	-3.743E-01	1.351E+00	1.000E+00	0.000E+00
	6.000E+00	6.000E+00	2.448E+01	7(	0,	0,	0)		1.200E-01	-9.195E-01	-3.743E-01			
	6.000E+00	6.000E+00	2.448E+01	4				0	1.200E-01	-9.195E-01	-3.743E-01			
47	6.000E+00	6.000E+00	2.448E+01	1					7.085E-01	5.879E-01	3.904E-01	2.288E+00	1.000E+00	0.000E+00
	6.000E+00	6.000E+00	2.448E+01	7(	0,	0,	0)		7.085E-01	5.879E-01	3.904E-01			
	6.000E+00	6.000E+00	2.448E+01	4				0	7.085E-01	5.879E-01	3.904E-01			

```
 48  6.000E+00  6.000E+00  2.448E+01    1                          4.261E-01  9.046E-01  9.254E-03  1.230E+00  1.000E+00  0.000E+00
     6.000E+00  6.000E+00  2.448E+01    7(   0,   0,   0)         4.261E-01  9.046E-01  9.254E-03
     6.000E+00  6.000E+00  2.448E+01    4                      0  4.261E-01  9.046E-01  9.254E-03
 49  6.000E+00  6.000E+00  2.448E+01    1                          5.431E-01  4.270E-01 -7.230E-01  1.433E+00  1.000E+00  0.000E+00
     6.000E+00  6.000E+00  2.448E+01    7(   0,   0,   0)         5.431E-01  4.270E-01 -7.230E-01
     6.000E+00  6.000E+00  2.448E+01    4                      0  5.431E-01  4.270E-01 -7.230E-01
 50  6.000E+00  6.000E+00  2.448E+01    1                         -1.053E-01 -9.805E-01  1.658E-01  6.572E-01  1.000E+00  0.000E+00
     6.000E+00  6.000E+00  2.448E+01    7(   0,   0,   0)        -1.053E-01 -9.805E-01  1.658E-01
     6.000E+00  6.000E+00  2.448E+01    4                      0 -1.053E-01 -9.805E-01  1.658E-01
lestimated keff results by cycle                                                                    print table 175

 source distribution written to file 3b091s          cycle =    20

 source distribution written to file 3b091s          cycle =    22

 source distribution written to file 3b091s          cycle =    24

 source distribution written to file 3b091s          cycle =    26

 source distribution written to file 3b091s          cycle =    28

 source distribution written to file 3b091s          cycle =    30

 ********************************************************************************************************************
 dump no.     2 on file 3b091r       nps =     121796     coll =       23434846     ctm =    15.48     nrn =       402731811

 source distribution written to file 3b091s          cycle =    32

 source distribution written to file 3b091s          cycle =    35

 source distribution written to file 3b091s          cycle =    37

 source distribution written to file 3b091s          cycle =    39

 source distribution written to file 3b091s          cycle =    42

 source distribution written to file 3b091s          cycle =    44

 source distribution written to file 3b091s          cycle =    46

 source distribution written to file 3b091s          cycle =    48

 source distribution written to file 3b091s          cycle =    50

 source distribution written to file 3b091s          cycle =    52

 source distribution written to file 3b091s          cycle =    54

 source distribution written to file 3b091s          cycle =    56

 source distribution written to file 3b091s          cycle =    58

 source distribution written to file 3b091s          cycle =    60

 ********************************************************************************************************************
 dump no.     3 on file 3b091r       nps =     241868     coll =       46581731     ctm =    30.79     nrn =       800491263

 source distribution written to file 3b091s          cycle =    62

 source distribution written to file 3b091s          cycle =    64
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```
source distribution written to file 3b091s          cycle =    66

source distribution written to file 3b091s          cycle =    68

source distribution written to file 3b091s          cycle =    70

source distribution written to file 3b091s          cycle =    72

source distribution written to file 3b091s          cycle =    74

source distribution written to file 3b091s          cycle =    76

source distribution written to file 3b091s          cycle =    78

source distribution written to file 3b091s          cycle =    80

source distribution written to file 3b091s          cycle =    82

source distribution written to file 3b091s          cycle =    84

source distribution written to file 3b091s          cycle =    86

source distribution written to file 3b091s          cycle =    88

source distribution written to file 3b091s          cycle =    90

*****************************************************************************************************************
dump no.    4 on file 3b091r        nps =    362064     coll =       69787976     ctm =   46.20     nrn =      1199359392

source distribution written to file 3b091s          cycle =    92

source distribution written to file 3b091s          cycle =    94

source distribution written to file 3b091s          cycle =    96

source distribution written to file 3b091s          cycle =    98

 estimator      cycle   100   ave of    80 cycles       combination          simple average     combined average      corr
k(collision)       0.461653        0.477773 0.0029     k(col/abs)           0.476537 0.0024     0.476507 0.0025    0.4291
k(absorption)      0.460661        0.475302 0.0028     k(abs/tk ln)         0.476951 0.0024     0.476855 0.0025    0.3534
k(trk length)      0.460616        0.478601 0.0029     k(tk ln/col)         0.478187 0.0029     0.477981 0.0029    0.9524
rem life(col)    3.9599E+04      3.8559E+04 0.0025     k(col/abs/tk ln)     0.477225 0.0024     0.476858 0.0025
rem life(abs)    3.9570E+04      3.8558E+04 0.0024     life(col/abs)      3.8558E+04 0.0025   3.8557E+04 0.0024    0.9810
source points generated   3779

source distribution written to file 3b091s          cycle =   100

source distribution written to file 3b091s          cycle =   102

source distribution written to file 3b091s          cycle =   105

source distribution written to file 3b091s          cycle =   107

source distribution written to file 3b091s          cycle =   109

source distribution written to file 3b091s          cycle =   111

source distribution written to file 3b091s          cycle =   113

source distribution written to file 3b091s          cycle =   115
```

estimator	cycle 116	ave of 96 cycles		combination	simple average		combined average		corr
k(collision)	0.469375	0.477921	0.0027	k(col/abs)	0.476518	0.0022	0.476347	0.0023	0.4697
k(absorption)	0.474786	0.475115	0.0025	k(abs/tk ln)	0.476945	0.0022	0.476648	0.0023	0.4134
k(trk length)	0.475075	0.478775	0.0028	k(tk ln/col)	0.478348	0.0027	0.478057	0.0028	0.9549
rem life(col)	3.9388E+04	3.8497E+04	0.0023	k(col/abs/tk ln)	0.477270	0.0023	0.476593	0.0023	
rem life(abs)	3.9514E+04	3.8495E+04	0.0022	life(col/abs)	3.8496E+04	0.0023	3.8493E+04	0.0022	0.9826

source points generated 3864

estimator	cycle 117	ave of 97 cycles		combination	simple average		combined average		corr
k(collision)	0.460728	0.477743	0.0027	k(col/abs)	0.476382	0.0022	0.476198	0.0023	0.4746
k(absorption)	0.465985	0.475021	0.0025	k(abs/tk ln)	0.476800	0.0022	0.476485	0.0023	0.4193
k(trk length)	0.459830	0.478580	0.0028	k(tk ln/col)	0.478161	0.0027	0.477859	0.0027	0.9558
rem life(col)	3.8392E+04	3.8496E+04	0.0023	k(col/abs/tk ln)	0.477115	0.0023	0.476427	0.0023	
rem life(abs)	3.8399E+04	3.8494E+04	0.0022	life(col/abs)	3.8495E+04	0.0023	3.8492E+04	0.0022	0.9826

source points generated 3891

source distribution written to file 3b091s cycle = 117

estimator	cycle 118	ave of 98 cycles		combination	simple average		combined average		corr
k(collision)	0.478320	0.477749	0.0026	k(col/abs)	0.476316	0.0022	0.476142	0.0023	0.4709
k(absorption)	0.461495	0.474883	0.0025	k(abs/tk ln)	0.476715	0.0022	0.476411	0.0023	0.4192
k(trk length)	0.475415	0.478547	0.0027	k(tk ln/col)	0.478148	0.0027	0.477860	0.0027	0.9554
rem life(col)	3.9022E+04	3.8501E+04	0.0023	k(col/abs/tk ln)	0.477060	0.0023	0.476344	0.0023	
rem life(abs)	3.8749E+04	3.8496E+04	0.0022	life(col/abs)	3.8499E+04	0.0022	3.8493E+04	0.0022	0.9822

source points generated 4070

estimator	cycle 119	ave of 99 cycles		combination	simple average		combined average		corr
k(collision)	0.476132	0.477733	0.0026	k(col/abs)	0.476373	0.0022	0.476225	0.0022	0.4665
k(absorption)	0.487853	0.475014	0.0025	k(abs/tk ln)	0.476741	0.0022	0.476471	0.0023	0.4090
k(trk length)	0.470695	0.478468	0.0027	k(tk ln/col)	0.478100	0.0026	0.477827	0.0027	0.9543
rem life(col)	3.9214E+04	3.8508E+04	0.0023	k(col/abs/tk ln)	0.477071	0.0023	0.476419	0.0023	
rem life(abs)	3.9221E+04	3.8504E+04	0.0022	life(col/abs)	3.8506E+04	0.0022	3.8500E+04	0.0022	0.9823

source points generated 3970

source distribution written to file 3b091s cycle = 119

estimator	cycle 120	ave of 100 cycles		combination	simple average		combined average		corr
k(collision)	0.482516	0.477781	0.0026	k(col/abs)	0.476489	0.0022	0.476375	0.0022	0.4665
k(absorption)	0.493342	0.475197	0.0025	k(abs/tk ln)	0.476873	0.0022	0.476638	0.0022	0.4130
k(trk length)	0.486540	0.478549	0.0027	k(tk ln/col)	0.478165	0.0026	0.477870	0.0027	0.9541
rem life(col)	3.8532E+04	3.8509E+04	0.0023	k(col/abs/tk ln)	0.477175	0.0022	0.476560	0.0023	
rem life(abs)	3.8691E+04	3.8506E+04	0.0022	life(col/abs)	3.8507E+04	0.0022	3.8504E+04	0.0021	0.9821

source points generated 4059

source distribution written to file 3b091s cycle = 120

1problem summary

run terminated when 120 kcode cycles were done.

+ 02/14/01 02:33:28

k eff, 23g of Pu-239 in cellulose spheres in 1 cubic foot of pure celulose probid = 02/14/01 01:32:16

0

neutron creation	tracks	weight (per source particle)	energy (per source particle)	neutron loss	tracks	weight (per source particle)	energy (per source particle)
source	478329	1.0035E+00	2.1171E+00	escape	1	7.7091E-07	3.3148E-15
				energy cutoff	0	0.	0.
				time cutoff	0	0.	0.
weight window	0	0.	0.	weight window	0	0.	0.
cell importance	0	0.	0.	cell importance	0	0.	0.
weight cutoff	0	1.6655E-01	4.1050E-06	weight cutoff	478328	1.6674E-01	2.5120E-08
energy importance	0	0.	0.	energy importance	0	0.	0.

dxtran	0	0.	0.	dxtran	0	0.	0.
forced collisions	0	0.	0.	forced collisions	0	0.	0.
exp. transform	0	0.	0.	exp. transform	0	0.	0.
upscattering	0	0.	9.8846E-07	downscattering	0	0.	2.0938E+00
				capture	0	8.3840E-01	2.1780E-02
(n,xn)	0	0.	0.	loss to (n,xn)	0	0.	0.
fission	0	0.	0.	loss to fission	0	1.6490E-01	1.4658E-03
total	478329	1.1700E+00	2.1171E+00	total	478329	1.1700E+00	2.1171E+00

number of neutrons banked	0	average lifetime, shakes		cutoffs
neutron tracks per source particle	1.0000E+00	escape	8.3050E+04	tco 1.0000E+34
neutron collisions per source particle	1.9285E+02	capture	3.8501E+04	eco 0.0000E+00
total neutron collisions	92248037	capture or escape	3.8501E+04	wc1 -5.0000E-01
net multiplication	1.0000E+00 0.0001	any termination	4.7211E+04	wc2 -2.5000E-01

computer time so far in this run	61.19 minutes	maximum number ever in bank	0
computer time in mcrun	61.18 minutes	bank overflows to backup file	0
source particles per minute	7.8187E+03	field length	0
random numbers generated	1585406429	most random numbers used was	25752 in history 116468

range of sampled source weights = 8.9047E-01 to 2.1075E+00

1neutron activity in each cell print table 126

	cell	tracks entering	population	collisions	collisions * weight (per history)	number weighted energy	flux weighted energy	average track weight (relative)	average track mfp (cm)
1	1	0	0	0	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2	2	124800	47845	3323677	3.2437E+00	2.5327E-05	1.5422E-01	4.8676E-01	1.9277E+00
4	4	647884	317146	2148009	3.6449E+00	4.8420E-04	8.9274E-01	8.9390E-01	3.8132E+00
5	5	635668	311677	2107966	3.5894E+00	4.8531E-04	8.9735E-01	8.9577E-01	3.8222E+00
6	6	4264792	476624	84668385	9.7347E+01	4.7584E-05	2.5670E-01	5.9354E-01	1.9554E+00
7	7	0	0	0	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
total		5673144	1153292	92248037	1.0783E+02				

1keff results for: k eff, 23g of Pu-239 in cellulose spheres in 1 cubic foot of pure celulose probid = 02/14/01 01:32:16

the initial fission neutron source distribution used the 2 source points that were input on the ksrc card.
the criticality problem was scheduled to skip 20 cycles and run a total of 120 cycles with nominally 4000 neutrons per cycle.
this problem has run 20 inactive cycles with 77946 neutron histories and 100 active cycles with 400383 neutron histories.

this calculation has completed the requested number of keff cycles using a total of 478329 fission neutron source histories.
all cells with fissionable material were sampled and had fission neutron source points.

the results of the w test for normality applied to the individual collision, absorption, and track-length keff cycle values are:

the k(collision) cycle values appear normally distributed at the 95 percent confidence level
the k(absorption) cycle values appear normally distributed at the 95 percent confidence level
the k(trk length) cycle values appear normally distributed at the 95 percent confidence level

---

the final estimated combined collision/absorption/track-length keff = 0.47656 with an estimated standard deviation of 0.00108

the estimated 68, 95, & 99 percent keff confidence intervals are 0.47548 to 0.47764, 0.47441 to 0.47871, and 0.47370 to 0.47942

the estimated collision/absorption neutron removal lifetime = 3.85E-04 seconds with an estimated standard deviation of 8.27E-07

the estimated average keffs, one standard deviations, and 68, 95, and 99 percent confidence intervals are:

keff estimator	keff	standard deviation	68% confidence	95% confidence	99% confidence	corr
collision	0.47778	0.00124	0.47654 to 0.47902	0.47531 to 0.48025	0.47450 to 0.48106	
absorption	0.47520	0.00118	0.47401 to 0.47638	0.47284 to 0.47755	0.47207 to 0.47832	
track length	0.47855	0.00129	0.47726 to 0.47984	0.47599 to 0.48111	0.47515 to 0.48194	
col/absorp	0.47638	0.00106	0.47531 to 0.47744	0.47426 to 0.47849	0.47356 to 0.47919	0.4665
abs/trk len	0.47664	0.00107	0.47557 to 0.47771	0.47450 to 0.47877	0.47381 to 0.47947	0.4130
col/trk len	0.47787	0.00127	0.47660 to 0.47914	0.47534 to 0.48040	0.47451 to 0.48123	0.9541
col/abs/trk len	0.47656	0.00108	0.47548 to 0.47764	0.47441 to 0.47871	0.47370 to 0.47942	

if the largest of each keff occurred on the next cycle, the keff results and 68, 95, and 99 percent confidence intervals would be:

keff estimator	keff	standard deviation	68% confidence	95% confidence	99% confidence
collision	0.47811	0.00127	0.47684 to 0.47938	0.47558 to 0.48064	0.47475 to 0.48146
absorption	0.47549	0.00121	0.47428 to 0.47670	0.47308 to 0.47789	0.47230 to 0.47868
track length	0.47892	0.00133	0.47759 to 0.48025	0.47628 to 0.48156	0.47542 to 0.48242
col/abs/trk len	0.47679	0.00112	0.47566 to 0.47791	0.47455 to 0.47903	0.47382 to 0.47976

the estimated collision/absorption neutron lifetimes, one standard deviations, and 68, 95, and 99 percent confidence intervals are:

type	lifetime(sec)	standard deviation	68% confidence	95% confidence	99% confidence
removal	3.8504E-04	8.2742E-07	3.8421E-04 to 3.8586E-04	3.8339E-04 to 3.8668E-04	3.8285E-04 to 3.8722E-04
capture	3.8514E-04	6.8747E-07	3.8445E-04 to 3.8582E-04	3.8377E-04 to 3.8651E-04	3.8332E-04 to 3.8695E-04
fission	1.9017E-04	5.9711E-07	1.8958E-04 to 1.9077E-04	1.8898E-04 to 1.9136E-04	1.8860E-04 to 1.9175E-04
escape	8.3050E-06	8.3050E-06	0.0000E+00 to 1.6618E-05	0.0000E+00 to 2.4849E-05	0.0000E+00 to 3.0247E-05

laverage individual and combined collision/absorption/track-length keff results for 7 different batch sizes

cycles per keff batch	number of k batches	average keff estimators and deviations k(col) st dev	k(abs) st dev	k(trk) st dev	normality co/ab/trk	average k(c/a/t) k(c/a/t) st dev	k(c/a/t) confidence intervals 95% confidence	99% confidence
1	100	0.4778 0.0012	0.4752 0.0012	0.4785 0.0013	95/95/95	0.47656 0.00108	0.47441-0.47871	0.47370-0.47942
2	50	0.4778 0.0012	0.4752 0.0012	0.4785 0.0013	95/95/95	0.47659 0.00115	0.47428-0.47890	0.47351-0.47967
4	25	0.4778 0.0012	0.4752 0.0010	0.4785 0.0013	95/95/95	0.47640 0.00110	0.47411-0.47869	0.47329-0.47951
5	20	0.4778 0.0012	0.4752 0.0011	0.4785 0.0012	95/95/95	0.47671 0.00095	0.47470-0.47873	0.47395-0.47948
10	10	0.4778 0.0009	0.4752 0.0012	0.4785 0.0007	95/95/95	0.47774 0.00044	0.47670-0.47879	0.47619-0.47930
20	5	0.4778 0.0008	0.4752 0.0013	0.4785 0.0008	95/95/95	0.47760 0.00057	0.47515-0.48005	0.47195-0.48326
25	4	0.4778 0.0013	0.4752 0.0008	0.4785 0.0011	95/95/95	0.47719 0.00033	0.47299-0.48140	0.45615-0.49824

lindividual and average keff estimator results by cycle

keff cycle	neutron histories	keff estimators by cycle k(coll)	k(abs)	k(track)	average keff estimators and deviations k(coll) st dev	k(abs) st dev	k(track) st dev	average k(c/a/t) k(c/a/t) st dev	fom
1	4000	0.47850	0.51053	0.47306					
2	1898	0.44056	0.45620	0.44490					
3	3672	0.47478	0.46809	0.47857					
4	4317	0.46509	0.47972	0.46854					
5	3973	0.48144	0.48117	0.48173					
6	4159	0.49628	0.47874	0.49154					
7	4237	0.49010	0.46700	0.49360					
8	3923	0.48102	0.48916	0.48577					
9	3909	0.48101	0.46828	0.47898					
10	3993	0.46153	0.46578	0.46274					

11	3860	0.47593	0.47016	0.47779								
12	4131	0.49014	0.47912	0.48517								
13	4129	0.47041	0.47287	0.46752								
14	3951	0.47530	0.47588	0.47453								
15	4000	0.46988	0.46539	0.46744								
16	3955	0.46486	0.49218	0.46924								
17	3905	0.49191	0.47718	0.49426								
18	4189	0.47817	0.48697	0.48454								
19	3846	0.47280	0.46885	0.47070								
20	3899	0.48564	0.46347	0.48114								
		begin active keff cycles										
21	4162	0.48869	0.46832	0.49628								
22	4087	0.47247	0.47774	0.48141	0.48058	0.00811	0.47303	0.00471	0.48885	0.00744		
23	3873	0.48982	0.48721	0.49014	0.48366	0.00560	0.47775	0.00545	0.48928	0.00432		
24	4094	0.45347	0.47030	0.45658	0.47611	0.00852	0.47589	0.00428	0.48110	0.00873	0.48176 0.01128	897
25	3630	0.48327	0.45802	0.48044	0.47754	0.00676	0.47232	0.00488	0.48097	0.00676	0.47298 0.00818	1326
26	4223	0.47159	0.47259	0.47168	0.47655	0.00560	0.47236	0.00398	0.47942	0.00573	0.47278 0.00565	2298
27	3990	0.47988	0.48637	0.48043	0.47703	0.00476	0.47436	0.00392	0.47957	0.00485	0.47533 0.00485	2699
28	3977	0.47961	0.47135	0.47952	0.47735	0.00414	0.47399	0.00341	0.47956	0.00420	0.47520 0.00403	3428
29	3881	0.47014	0.45570	0.46804	0.47655	0.00373	0.47195	0.00363	0.47828	0.00392	0.47337 0.00396	3140
30	4016	0.45840	0.47756	0.46215	0.47473	0.00380	0.47252	0.00330	0.47667	0.00386	0.47265 0.00347	3670
31	3917	0.49073	0.48963	0.48832	0.47619	0.00373	0.47407	0.00336	0.47773	0.00365	0.47523 0.00352	3271
32	4193	0.48116	0.48151	0.48254	0.47660	0.00343	0.47469	0.00313	0.47813	0.00335	0.47579 0.00326	3503
33	3865	0.48381	0.47793	0.47717	0.47716	0.00321	0.47494	0.00289	0.47805	0.00308	0.47621 0.00280	4388
34	3929	0.47966	0.48553	0.47899	0.47734	0.00297	0.47570	0.00278	0.47812	0.00286	0.47677 0.00258	4806
35	3902	0.47789	0.49447	0.47109	0.47737	0.00277	0.47695	0.00288	0.47765	0.00270	0.47733 0.00235	5454
36	4085	0.48409	0.48466	0.48777	0.47779	0.00262	0.47743	0.00273	0.47828	0.00260	0.47785 0.00228	5453
37	4108	0.46663	0.48871	0.46558	0.47714	0.00255	0.47809	0.00265	0.47754	0.00256	0.47777 0.00213	5858
38	3814	0.46603	0.46770	0.47095	0.47652	0.00248	0.47752	0.00257	0.47717	0.00244	0.47736 0.00208	5808
39	4001	0.47926	0.48030	0.47776	0.47666	0.00235	0.47766	0.00243	0.47720	0.00231	0.47745 0.00195	6224
40	4034	0.45252	0.47142	0.45167	0.47546	0.00254	0.47735	0.00233	0.47593	0.00253	0.47676 0.00204	5401
41	3700	0.48857	0.49565	0.48525	0.47608	0.00249	0.47822	0.00238	0.47637	0.00245	0.47743 0.00206	5087
42	4342	0.46840	0.47228	0.46760	0.47573	0.00240	0.47795	0.00228	0.47597	0.00237	0.47709 0.00199	5157
43	3799	0.46934	0.45965	0.47573	0.47545	0.00231	0.47716	0.00232	0.47596	0.00227	0.47673 0.00194	5201
44	4076	0.45645	0.44610	0.45731	0.47466	0.00235	0.47586	0.00257	0.47518	0.00230	0.47559 0.00214	4071
45	3851	0.47551	0.49249	0.48381	0.47470	0.00226	0.47653	0.00256	0.47553	0.00224	0.47584 0.00215	3888
46	4086	0.48205	0.46335	0.48690	0.47498	0.00219	0.47602	0.00251	0.47597	0.00219	0.47590 0.00206	4041
47	4038	0.49318	0.48107	0.49867	0.47565	0.00221	0.47621	0.00242	0.47681	0.00227	0.47634 0.00208	3817
48	4051	0.48273	0.48093	0.48922	0.47591	0.00214	0.47638	0.00234	0.47725	0.00223	0.47652 0.00205	3796
49	4002	0.45262	0.47188	0.45348	0.47510	0.00222	0.47622	0.00226	0.47643	0.00231	0.47606 0.00206	3616
50	3670	0.46419	0.45671	0.47165	0.47474	0.00217	0.47557	0.00228	0.47627	0.00223	0.47582 0.00207	3474
51	4049	0.47524	0.47405	0.47464	0.47475	0.00210	0.47552	0.00221	0.47622	0.00216	0.47577 0.00199	3628
52	4115	0.47497	0.47966	0.47900	0.47476	0.00204	0.47565	0.00214	0.47631	0.00209	0.47584 0.00195	3680
53	4109	0.49086	0.50462	0.48839	0.47525	0.00203	0.47653	0.00225	0.47667	0.00206	0.47658 0.00199	3424
54	4167	0.48513	0.48478	0.48483	0.47554	0.00199	0.47677	0.00220	0.47691	0.00201	0.47686 0.00194	3493
55	3966	0.49408	0.46966	0.49467	0.47607	0.00201	0.47657	0.00214	0.47742	0.00202	0.47711 0.00188	3618
56	4083	0.46239	0.45538	0.46367	0.47569	0.00199	0.47598	0.00217	0.47704	0.00200	0.47662 0.00190	3442
57	3828	0.46766	0.46676	0.46816	0.47547	0.00194	0.47573	0.00212	0.47680	0.00196	0.47635 0.00186	3474
58	4049	0.48135	0.47701	0.47479	0.47563	0.00190	0.47576	0.00206	0.47674	0.00191	0.47632 0.00178	3717
59	4266	0.49650	0.48868	0.49541	0.47616	0.00193	0.47609	0.00204	0.47722	0.00192	0.47680 0.00178	3622
60	4080	0.47091	0.48094	0.47364	0.47603	0.00188	0.47622	0.00199	0.47713	0.00187	0.47681 0.00174	3692
61	3814	0.46788	0.47046	0.46863	0.47583	0.00185	0.47608	0.00195	0.47693	0.00184	0.47663 0.00171	3740
62	3941	0.45362	0.47831	0.45705	0.47530	0.00188	0.47613	0.00190	0.47645	0.00186	0.47648 0.00169	3718
63	3908	0.46779	0.44083	0.47359	0.47513	0.00184	0.47531	0.00203	0.47639	0.00181	0.47618 0.00171	3531
64	4175	0.47075	0.47475	0.46850	0.47503	0.00180	0.47530	0.00198	0.47621	0.00178	0.47602 0.00167	3631
65	4001	0.46899	0.46708	0.46580	0.47490	0.00177	0.47511	0.00195	0.47598	0.00176	0.47572 0.00164	3689
66	4048	0.47405	0.47774	0.47657	0.47488	0.00173	0.47517	0.00190	0.47599	0.00172	0.47575 0.00160	3751
67	3985	0.51010	0.46689	0.51601	0.47563	0.00185	0.47499	0.00187	0.47684	0.00188	0.47602 0.00163	3567

68	4341	0.47707	0.47627	0.47974	0.47566	0.00181	0.47502	0.00183	0.47690	0.00185	0.47606	0.00160	3619
69	3721	0.50049	0.48275	0.50403	0.47616	0.00184	0.47518	0.00180	0.47745	0.00189	0.47634	0.00162	3476
70	4202	0.47748	0.46751	0.47630	0.47619	0.00181	0.47503	0.00177	0.47743	0.00185	0.47622	0.00158	3551
71	3838	0.47337	0.45067	0.47613	0.47613	0.00177	0.47455	0.00180	0.47741	0.00182	0.47601	0.00158	3479
72	3909	0.48920	0.47698	0.48700	0.47639	0.00176	0.47459	0.00177	0.47759	0.00179	0.47615	0.00155	3561
73	4072	0.46687	0.47389	0.47080	0.47621	0.00173	0.47458	0.00173	0.47746	0.00176	0.47610	0.00153	3597
74	3794	0.48153	0.48532	0.47642	0.47630	0.00170	0.47478	0.00171	0.47744	0.00173	0.47622	0.00148	3743
75	4166	0.50673	0.48854	0.50802	0.47686	0.00176	0.47503	0.00170	0.47800	0.00178	0.47657	0.00152	3512
76	4199	0.49503	0.46323	0.49932	0.47718	0.00176	0.47482	0.00168	0.47838	0.00179	0.47660	0.00150	3523
77	3970	0.47901	0.46916	0.48081	0.47721	0.00173	0.47472	0.00165	0.47842	0.00176	0.47657	0.00148	3569
78	3884	0.47851	0.46688	0.48140	0.47724	0.00170	0.47458	0.00163	0.47847	0.00173	0.47653	0.00146	3602
79	4007	0.45533	0.45144	0.45840	0.47687	0.00171	0.47419	0.00165	0.47813	0.00174	0.47623	0.00149	3385
80	3833	0.49387	0.48805	0.49361	0.47715	0.00170	0.47442	0.00164	0.47839	0.00173	0.47649	0.00149	3353
81	4242	0.47962	0.48337	0.47432	0.47719	0.00168	0.47457	0.00162	0.47832	0.00170	0.47653	0.00145	3481
82	3881	0.47885	0.47412	0.47365	0.47722	0.00165	0.47456	0.00159	0.47825	0.00167	0.47644	0.00142	3579
83	4035	0.48880	0.48913	0.49667	0.47740	0.00163	0.47479	0.00158	0.47854	0.00167	0.47659	0.00143	3445
84	4092	0.47194	0.46199	0.47471	0.47731	0.00161	0.47459	0.00157	0.47848	0.00165	0.47649	0.00142	3440
85	3842	0.48419	0.48714	0.48732	0.47742	0.00159	0.47479	0.00156	0.47862	0.00163	0.47664	0.00141	3428
86	4081	0.48952	0.48657	0.49010	0.47760	0.00158	0.47497	0.00155	0.47879	0.00161	0.47682	0.00140	3420
87	4160	0.47424	0.48856	0.47208	0.47755	0.00155	0.47517	0.00154	0.47869	0.00159	0.47691	0.00138	3511
88	3786	0.47902	0.46270	0.47593	0.47758	0.00153	0.47499	0.00152	0.47865	0.00157	0.47677	0.00136	3543
89	4024	0.48900	0.47968	0.48311	0.47774	0.00152	0.47505	0.00150	0.47871	0.00155	0.47685	0.00133	3627
90	4106	0.47557	0.46915	0.47303	0.47771	0.00149	0.47497	0.00148	0.47863	0.00153	0.47675	0.00132	3672
91	3953	0.49398	0.47973	0.49029	0.47794	0.00149	0.47504	0.00147	0.47880	0.00151	0.47687	0.00130	3705
92	4193	0.47670	0.48095	0.47224	0.47792	0.00147	0.47512	0.00145	0.47871	0.00150	0.47686	0.00128	3795
93	3837	0.46515	0.48722	0.46388	0.47775	0.00146	0.47528	0.00144	0.47850	0.00149	0.47685	0.00125	3898
94	3865	0.48374	0.48892	0.48324	0.47783	0.00144	0.47547	0.00143	0.47857	0.00147	0.47699	0.00124	3924
95	4146	0.47309	0.47841	0.47069	0.47776	0.00143	0.47551	0.00141	0.47846	0.00145	0.47695	0.00122	3997
96	4005	0.47660	0.48341	0.48465	0.47775	0.00141	0.47561	0.00140	0.47854	0.00144	0.47703	0.00121	4000
97	3973	0.47274	0.46695	0.47750	0.47768	0.00139	0.47550	0.00138	0.47853	0.00142	0.47698	0.00120	4017
98	3963	0.49226	0.48278	0.49550	0.47787	0.00138	0.47559	0.00137	0.47875	0.00142	0.47710	0.00120	3978
99	4119	0.48620	0.46729	0.48512	0.47798	0.00137	0.47549	0.00135	0.47883	0.00140	0.47709	0.00118	4016
100	3902	0.46165	0.46066	0.46062	0.47777	0.00137	0.47530	0.00135	0.47860	0.00140	0.47686	0.00119	3938
101	3779	0.51079	0.49601	0.51089	0.47818	0.00141	0.47556	0.00136	0.47900	0.00144	0.47714	0.00122	3678
102	4492	0.47741	0.47454	0.47339	0.47817	0.00139	0.47554	0.00134	0.47893	0.00142	0.47709	0.00120	3735
103	3787	0.45899	0.46100	0.45843	0.47794	0.00140	0.47537	0.00134	0.47868	0.00143	0.47685	0.00121	3666
104	3861	0.49225	0.48248	0.48935	0.47811	0.00139	0.47545	0.00132	0.47881	0.00142	0.47696	0.00120	3688
105	4386	0.45682	0.46135	0.45385	0.47786	0.00140	0.47529	0.00132	0.47852	0.00143	0.47668	0.00120	3607
106	3798	0.47858	0.46189	0.47299	0.47787	0.00138	0.47513	0.00131	0.47845	0.00142	0.47656	0.00120	3612
107	4198	0.46076	0.47738	0.46330	0.47767	0.00138	0.47516	0.00130	0.47828	0.00141	0.47649	0.00118	3659
108	3874	0.48828	0.46541	0.48737	0.47779	0.00137	0.47505	0.00129	0.47838	0.00140	0.47647	0.00117	3684
109	4147	0.48932	0.48374	0.49260	0.47792	0.00136	0.47515	0.00128	0.47854	0.00139	0.47658	0.00117	3669
110	3979	0.48070	0.47657	0.48672	0.47795	0.00134	0.47516	0.00126	0.47863	0.00138	0.47661	0.00116	3687
111	3994	0.47980	0.47821	0.47729	0.47797	0.00133	0.47519	0.00125	0.47862	0.00136	0.47663	0.00114	3738
112	3947	0.46744	0.46457	0.47051	0.47786	0.00132	0.47508	0.00124	0.47853	0.00135	0.47654	0.00114	3734
113	3947	0.47851	0.46430	0.48214	0.47787	0.00131	0.47496	0.00123	0.47857	0.00134	0.47650	0.00113	3743
114	4108	0.47581	0.48004	0.47833	0.47784	0.00129	0.47502	0.00122	0.47857	0.00132	0.47653	0.00112	3782
115	3989	0.49373	0.48463	0.50203	0.47801	0.00129	0.47512	0.00121	0.47881	0.00133	0.47662	0.00112	3711
116	4181	0.46938	0.47479	0.47507	0.47792	0.00128	0.47511	0.00120	0.47877	0.00132	0.47659	0.00111	3736
117	3864	0.46073	0.46598	0.45983	0.47774	0.00128	0.47502	0.00119	0.47858	0.00132	0.47643	0.00111	3726
118	3891	0.47832	0.46149	0.47541	0.47775	0.00126	0.47488	0.00119	0.47855	0.00131	0.47634	0.00110	3731
119	4070	0.47613	0.48785	0.47069	0.47773	0.00125	0.47501	0.00118	0.47847	0.00130	0.47642	0.00108	3808
120	3970	0.48252	0.49334	0.48654	0.47778	0.00124	0.47520	0.00118	0.47855	0.00129	0.47656	0.00108	3789

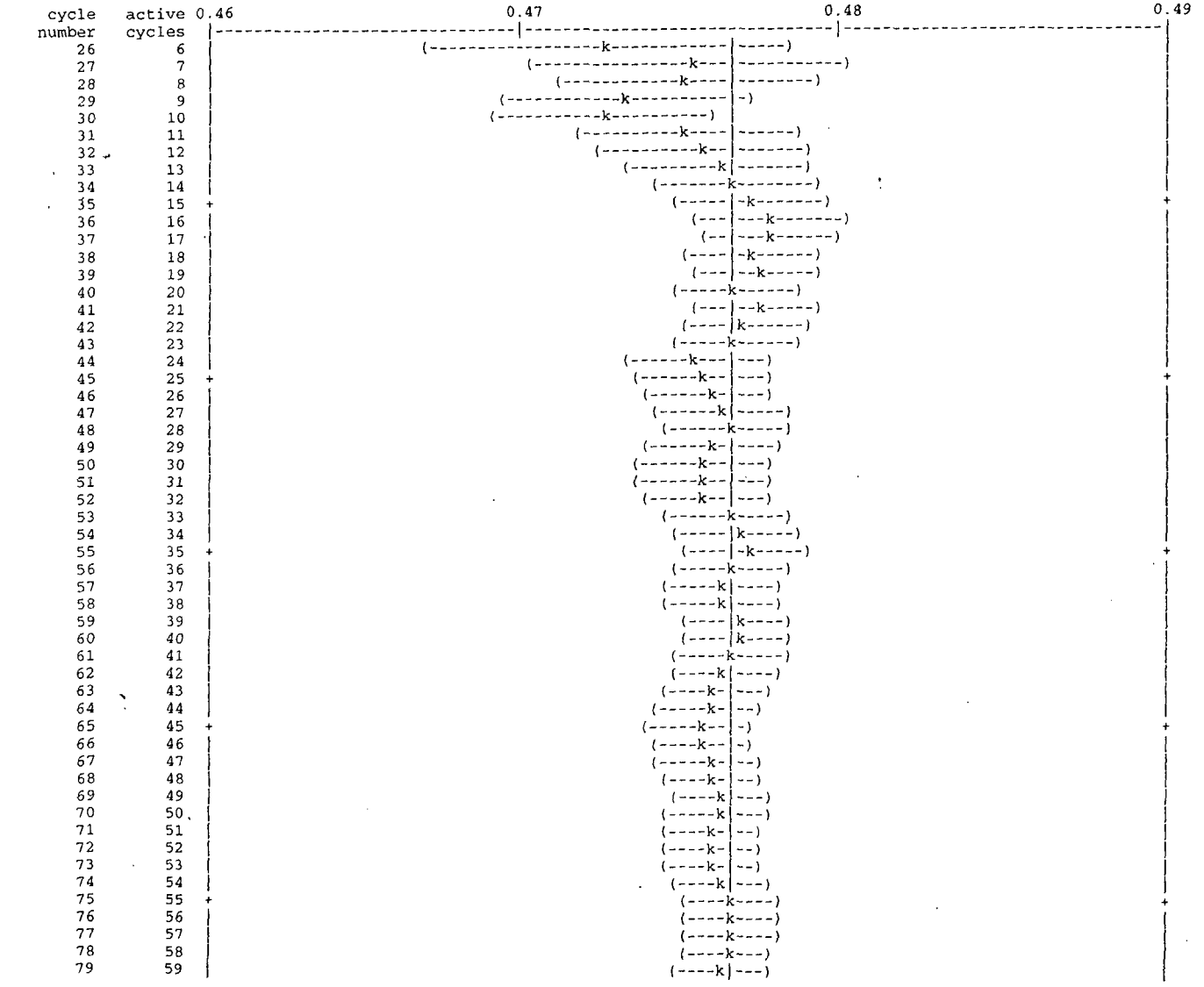
the largest active cycle keffs by estimator are:

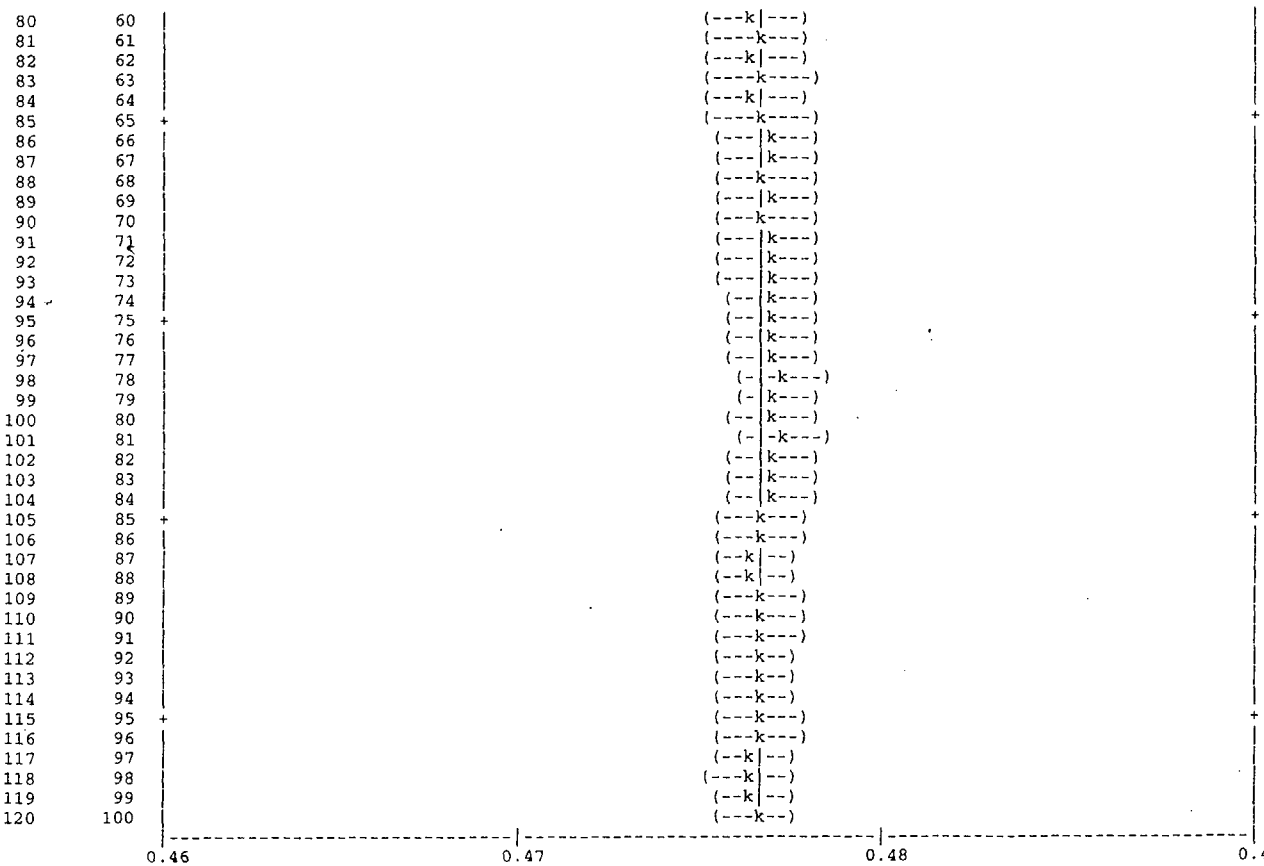
the smallest active cycle keffs by estimator are:

collision 0.51079 on cycle 101
absorption 0.50462 on cycle 53
track length 0.51601 on cycle 67

collision 0.45252 on cycle 40
absorption 0.44083 on cycle 63
track length 0.45167 on cycle 40

lplot of the estimated col/abs/track-length keff one standard deviation interval versus cycle number (| = final keff = 0.47656)





lindividual and collision/absorption/track-length keffs for different numbers of inactive cycles skipped for fission source settling

skip cycles	active cycles	active neutrons	average keff estimators and deviations k(col)	st dev	k(abs)	st dev	k(trk)	st dev	normality co/ab/tl	average k(c/a/t)	st dev	k(c/a/t) confidence intervals 95% confidence	99% confidence
0	120	478329	0.4775	0.0011	0.4753	0.0011	0.4782	0.0012	95/95/95	0.47655	0.00097	0.47462-0.47847	0.47400-0.47910
1	119	474329	0.4775	0.0011	0.4750	0.0011	0.4783	0.0012	95/95/95	0.47627	0.00097	0.47434-0.47820	0.47371-0.47883
2	118	472431	0.4778	0.0011	0.4752	0.0010	0.4785	0.0011	95/95/95	0.47651	0.00095	0.47462-0.47841	0.47401-0.47902
3	117	468759	0.4779	0.0011	0.4752	0.0011	0.4785	0.0011	95/95/95	0.47654	0.00095	0.47464-0.47845	0.47402-0.47907
4	116	464442	0.4780	0.0011	0.4752	0.0011	0.4786	0.0012	95/95/95	0.47657	0.00096	0.47465-0.47849	0.47403-0.47912
5	115	460469	0.4779	0.0011	0.4751	0.0011	0.4786	0.0012	95/95/95	0.47653	0.00097	0.47459-0.47846	0.47396-0.47910
6	114	456310	0.4778	0.0011	0.4751	0.0011	0.4785	0.0012	95/95/95	0.47645	0.00098	0.47450-0.47839	0.47387-0.47903
7	113	452073	0.4777	0.0011	0.4752	0.0011	0.4784	0.0012	95/95/95	0.47644	0.00098	0.47448-0.47839	0.47384-0.47903
8	112	448150	0.4776	0.0011	0.4751	0.0011	0.4783	0.0012	95/95/95	0.47635	0.00099	0.47439-0.47832	0.47375-0.47896
9	111	444241	0.4776	0.0012	0.4751	0.0011	0.4783	0.0012	95/95/95	0.47637	0.00099	0.47439-0.47835	0.47375-0.47900
10	110	440248	0.4778	0.0012	0.4752	0.0011	0.4784	0.0012	95/95/95	0.47650	0.00100	0.47451-0.47848	0.47386-0.47913
11	109	436388	0.4778	0.0012	0.4752	0.0011	0.4784	0.0012	95/95/95	0.47652	0.00100	0.47452-0.47852	0.47387-0.47918
12	108	432257	0.4777	0.0012	0.4752	0.0011	0.4784	0.0012	95/95/95	0.47645	0.00101	0.47444-0.47847	0.47378-0.47913

13	107	428128	0.4777	0.0012	0.4752	0.0011	0.4785	0.0012	95/95/95	0.47651	0.00102	0.47448-0.47855	0.47381-0.47921
14	106	424177	0.4777	0.0012	0.4752	0.0011	0.4785	0.0012	95/95/95	0.47652	0.00103	0.47447-0.47858	0.47379-0.47925
15	105	420177	0.4778	0.0012	0.4753	0.0012	0.4786	0.0012	95/95/95	0.47663	0.00104	0.47455-0.47870	0.47388-0.47937
16	104	416222	0.4779	0.0012	0.4752	0.0012	0.4787	0.0012	95/95/95	0.47658	0.00105	0.47448-0.47867	0.47380-0.47936
17	103	412317	0.4778	0.0012	0.4751	0.0012	0.4786	0.0013	95/95/95	0.47652	0.00106	0.47442-0.47863	0.47373-0.47932
18	102	408128	0.4778	0.0012	0.4750	0.0012	0.4785	0.0013	95/95/95	0.47645	0.00106	0.47433-0.47857	0.47364-0.47926
19	101	404282	0.4779	0.0012	0.4751	0.0012	0.4786	0.0013	95/95/95	0.47652	0.00107	0.47438-0.47866	0.47369-0.47935
20	100*	400383	0.4778	0.0012	0.4752	0.0012	0.4785	0.0013	95/95/95	0.47656	0.00108	0.47441-0.47871	0.47370-0.47942
22	98	392134	0.4777	0.0013	0.4752	0.0012	0.4783	0.0013	95/95/95	0.47654	0.00110	0.47435-0.47872	0.47364-0.47943
24	96	384167	0.4779	0.0013	0.4752	0.0012	0.4784	0.0013	95/95/95	0.47658	0.00110	0.47438-0.47878	0.47366-0.47949
26	94	376314	0.4779	0.0013	0.4754	0.0012	0.4785	0.0013	95/95/95	0.47669	0.00112	0.47446-0.47892	0.47373-0.47965
28	92	368347	0.4778	0.0013	0.4753	0.0013	0.4785	0.0014	95/95/95	0.47662	0.00114	0.47434-0.47890	0.47360-0.47964
30	90	360450	0.4781	0.0013	0.4755	0.0013	0.4788	0.0014	95/95/95	0.47687	0.00115	0.47456-0.47917	0.47381-0.47992
32	88	352340	0.4779	0.0013	0.4753	0.0013	0.4786	0.0014	95/95/95	0.47665	0.00117	0.47431-0.47898	0.47355-0.47974
34	86	344546	0.4779	0.0014	0.4751	0.0013	0.4786	0.0014	95/95/95	0.47653	0.00120	0.47413-0.47892	0.47335-0.47971
36	84	336559	0.4778	0.0014	0.4748	0.0013	0.4786	0.0015	95/95/95	0.47625	0.00123	0.47380-0.47870	0.47300-0.47950
38	82	328637	0.4781	0.0014	0.4747	0.0013	0.4789	0.0015	95/95/95	0.47629	0.00126	0.47377-0.47880	0.47295-0.47963
40	80	320602	0.4784	0.0014	0.4747	0.0014	0.4792	0.0015	95/95/95	0.47650	0.00130	0.47392-0.47908	0.47308-0.47992
42	78	312560	0.4784	0.0014	0.4744	0.0014	0.4793	0.0015	95/95/95	0.47631	0.00132	0.47368-0.47894	0.47282-0.47980
44	76	304685	0.4788	0.0014	0.4750	0.0013	0.4796	0.0015	95/95/95	0.47668	0.00128	0.47412-0.47923	0.47328-0.48007
46	74	296748	0.4788	0.0015	0.4749	0.0013	0.4795	0.0016	95/95/95	0.47655	0.00130	0.47395-0.47915	0.47310-0.48000
48	72	288659	0.4785	0.0015	0.4747	0.0014	0.4791	0.0016	95/95/95	0.47639	0.00132	0.47376-0.47902	0.47290-0.47988
50	70	280987	0.4791	0.0015	0.4750	0.0014	0.4795	0.0016	95/95/95	0.47682	0.00133	0.47417-0.47948	0.47330-0.48035
52	68	272823	0.4792	0.0015	0.4750	0.0014	0.4796	0.0016	95/95/95	0.47684	0.00137	0.47410-0.47958	0.47321-0.48048
54	66	264547	0.4789	0.0016	0.4744	0.0014	0.4794	0.0016	95/95/95	0.47617	0.00137	0.47343-0.47891	0.47253-0.47982
56	64	256498	0.4790	0.0016	0.4748	0.0014	0.4794	0.0017	95/95/95	0.47641	0.00137	0.47367-0.47914	0.47277-0.48004
58	62	248621	0.4791	0.0016	0.4748	0.0014	0.4797	0.0017	95/95/95	0.47653	0.00141	0.47372-0.47934	0.47279-0.48027
60	60	240275	0.4789	0.0016	0.4745	0.0015	0.4795	0.0017	95/95/95	0.47628	0.00143	0.47341-0.47914	0.47246-0.48009
62	58	232520	0.4796	0.0016	0.4745	0.0015	0.4801	0.0017	95/95/95	0.47669	0.00149	0.47370-0.47969	0.47270-0.48068
64	56	224437	0.4799	0.0017	0.4751	0.0014	0.4804	0.0018	95/95/95	0.47684	0.00146	0.47392-0.47976	0.47295-0.48073
66	54	216388	0.4803	0.0017	0.4752	0.0015	0.4807	0.0018	95/95/95	0.47705	0.00151	0.47402-0.48007	0.47301-0.48108
68	52	208062	0.4797	0.0017	0.4754	0.0015	0.4801	0.0018	95/95/95	0.47712	0.00155	0.47400-0.48023	0.47296-0.48127
70	50	200139	0.4794	0.0017	0.4754	0.0016	0.4797	0.0018	95/95/95	0.47709	0.00157	0.47394-0.48024	0.47288-0.48129
72	48	192392	0.4793	0.0017	0.4758	0.0016	0.4796	0.0019	95/99/95	0.47713	0.00156	0.47399-0.48027	0.47294-0.48132
74	46	184526	0.4795	0.0018	0.4757	0.0016	0.4798	0.0019	95/99/95	0.47709	0.00163	0.47381-0.48037	0.47270-0.48148
76	44	176161	0.4785	0.0017	0.4757	0.0016	0.4788	0.0018	95/95/95	0.47688	0.00161	0.47363-0.48012	0.47254-0.48122
78	42	168307	0.4785	0.0018	0.4760	0.0017	0.4787	0.0019	95/99/95	0.47704	0.00166	0.47369-0.48040	0.47256-0.48153
80	40	160467	0.4787	0.0018	0.4764	0.0017	0.4788	0.0019	95/99/95	0.47731	0.00156	0.47415-0.48048	0.47307-0.48155
82	38	152344	0.4787	0.0019	0.4762	0.0017	0.4790	0.0020	95/99/95	0.47707	0.00165	0.47373-0.48041	0.47259-0.48156
84	36	144217	0.4786	0.0019	0.4763	0.0017	0.4787	0.0021	95/99/95	0.47712	0.00167	0.47373-0.48051	0.47256-0.48167
86	34	136294	0.4781	0.0020	0.4756	0.0018	0.4781	0.0022	95/99/95	0.47657	0.00172	0.47306-0.48007	0.47185-0.48129
88	32	128348	0.4782	0.0021	0.4756	0.0018	0.4783	0.0023	95/95/95	0.47639	0.00180	0.47270-0.48008	0.47142-0.48137
90	30	120218	0.4779	0.0023	0.4757	0.0019	0.4784	0.0024	95/95/95	0.47626	0.00190	0.47237-0.48015	0.47100-0.48151
92	28	112072	0.4774	0.0023	0.4754	0.0020	0.4781	0.0026	95/95/95	0.47566	0.00201	0.47152-0.47979	0.47006-0.48125
94	26	104370	0.4776	0.0025	0.4744	0.0021	0.4785	0.0027	95/95/95	0.47464	0.00218	0.47013-0.47915	0.46852-0.48076
96	24	96219	0.4779	0.0027	0.4739	0.0022	0.4786	0.0029	95/95/95	0.47430	0.00240	0.46932-0.47929	0.46752-0.48109
98	22	88283	0.4775	0.0028	0.4738	0.0024	0.4778	0.0030	95/95/95	0.47436	0.00248	0.46917-0.47955	0.46727-0.48145
100	20	80262	0.4778	0.0030	0.4748	0.0025	0.4783	0.0032	95/95/95	0.47514	0.00260	0.46965-0.48063	0.46760-0.48268
102	18	71991	0.4760	0.0027	0.4736	0.0025	0.4768	0.0030	95/95/95	0.47394	0.00238	0.46887-0.47902	0.46693-0.48096
104	16	64343	0.4761	0.0027	0.4738	0.0026	0.4772	0.0031	95/95/95	0.47393	0.00231	0.46893-0.47893	0.46696-0.48091
106	14	56159	0.4772	0.0027	0.4756	0.0027	0.4791	0.0031	95/95/95	0.47543	0.00259	0.46974-0.48113	0.46739-0.48347
108	12	48087	0.4777	0.0026	0.4763	0.0030	0.4798	0.0032	95/95/95	0.47593	0.00289	0.46939-0.48247	0.46654-0.48532
110	10	39961	0.4762	0.0029	0.4755	0.0035	0.4778	0.0035	95/95/95	0.47516	0.00314	0.46774-0.48258	0.46418-0.48614
112	8	32020	0.4769	0.0034	0.4766	0.0042	0.4788	0.0044	95/95/95	0.47526	0.00367	0.46581-0.48470	0.46044-0.49007
114	6	23965	0.4768	0.0046	0.4780	0.0052	0.4783	0.0059	95/95/95	0.47594	0.00518	0.45944-0.49243	0.44567-0.50621
116	4	15795	0.4744	0.0048	0.4772	0.0079	0.4731	0.0055	95/95/95	0.47545	0.00893	0.36198-0.58892	0.00000-1.04379
117	3	11931	0.4790	0.0019	0.4809	0.0098	0.4776	0.0047					

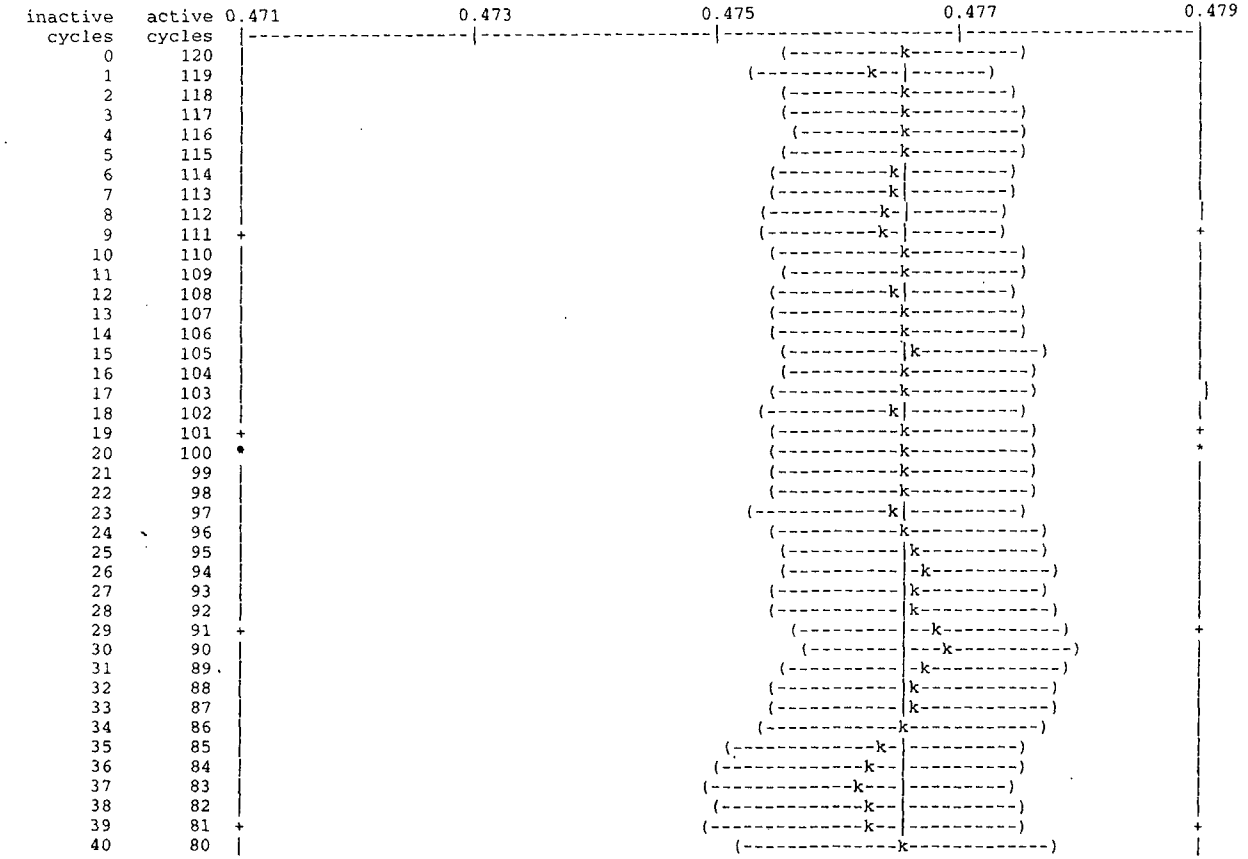
118	2	8040	0.4793	0.0032	0.4906	0.0027	0.4786	0.0079

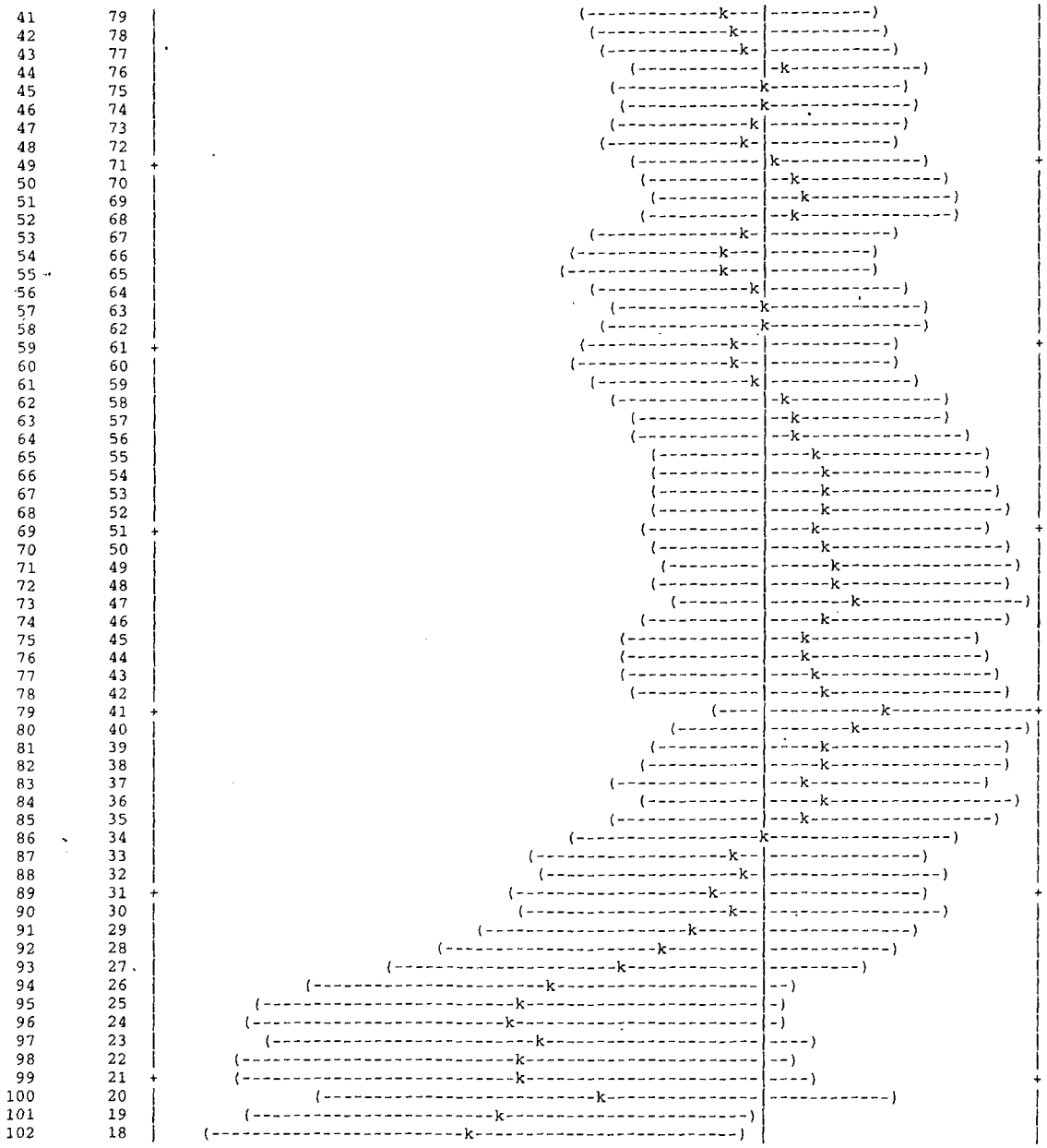
the minimum estimated standard deviation for the col/abs/tl keff estimator occurs with 2 inactive cycles and 118 active cycles.

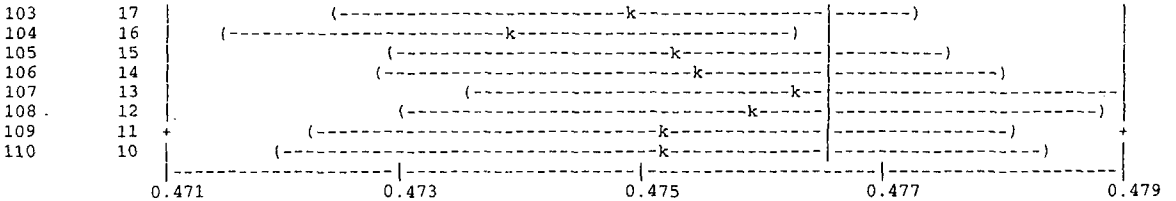
the first active half of the problem skips 20 cycles and uses 50 active cycles; the second half skips 70 and uses 50 cycles.
the col/abs/trk-len keff, one standard deviation, and 68, 95, and 99 percent intervals for each active half of the problem are:

problem	keff	standard deviation	68% confidence	95% confidence	99% confidence
first half	0.47622	0.00158	0.47463 to 0.47781	0.47304 to 0.47941	0.47197 to 0.48047
second half	0.47709	0.00157	0.47551 to 0.47866	0.47394 to 0.48024	0.47288 to 0.48129
final result	0.47656	0.00108	0.47548 to 0.47764	0.47441 to 0.47871	0.47370 to 0.47942

the first and second half values of k(collision/absorption/track length) appear to be the same at the 68 percent confidence level.
1plot of the estimated col/abs/track-length keff one standard deviation interval by active cycle number (| = final keff = 0.47656)







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2 warning messages so far.

run terminated when 120 kcode cycles were done.

computer time = 61.19 minutes

mcnp version 4a 10/01/93 02/14/01 02:33:28 probid = 02/14/01 01:32:16

URS

Calculation Cover Page

3065 Southwestern Boulevard
Suite 202
Orchard Park, NY 14127
716 675 7130 Tel
716 675 7137 Fax

Job No: **30822-244-330 /6860** Calculation No: **BUF-2001-011/Rev. 0** Date: **February 24, 2001**

Problem Statement & Calculation Objectives:

To determine the Pu-239 mass sub-critical limit for $\infty \times \infty \times 12$ ft arrays of 1.5-cubic-foot boxes with Pu-239-cellulose spheres and pure cellulose or void outside the sphere. Every box has 1 sphere containing the same amount of Pu-239.

References and Data Available:

J. F. Briemiester, ed., MCNP - A General Purpose Monte Carlo N-Particle Transport Code, Version 4A, LA-12625, Los Alamos National Laboratory, Los Alamos NM, 1993
C. D. Harmon, II et al., Criticality Calculations with MCNP: A Primer, Manual LA-12827, Los Alamos National Laboratory, Los Alamos NM, 1993
D. R. Lide, CRC Handbook of Chemistry an Physics, CRC Press, Boston MA, 1991.
F. H. Attix, Introduction to Radiological Physics and Radiation Dosimetry. John Wiley & Sons, Inc., New York NY, 1986

Attachments:

Attachment 1: MCNP surface and cell numbers
Attachment 2: MCNP input file
Attachment 3: MCNP output file

Prepared by:

Signature Igor V. Chichkov — Date 02/24/2001

Checked by:

Signature — Date 02/27/01

URS

Job No 30822-244-330 /6860 Job: PSR-6 By IVC Date 02/24/2001
Client WVNS Subject: cellulose-Pu-239 spheres Chk'd. Date 02/27/01

Analysis

Assumptions

- Pu-239 inside the sphere is uniformly mixed with 0.72 g/cm^3 cellulose
- The pure cellulose (0.72 g/cm^3) fills the entire space inside the container and outside the Plutonium sphere.
- The containers stand on the 3 m thick concrete floor
- The box inside dimensions are 1.5 x 1.5 x 1.5 foot
- The box wall thickness is zero
- Every box in the array contains the same mass of Pu-239
- The boxes are arranged in the infinite square array, 12 feet heigh ($\infty \times \infty \times$ 12 ft)

MCNP Model

Neutron multiplication factors were calculated with MCNP4A code. Attachments 1 has the drawings of the models used. Examples of MCNP input and output files for both cases can also be found in the Attachments. The plutonium spheres were located in the box's corner as shown in Attachments 1.

Air, Carbon Steel, Concrete and Cellulose Composition

Table 1 shows the element weight fractions for air (Attix F.H., 1986). Table 2 shows the element composition of concrete (Harmon C. D., II et al., 1993) in the floor.

Table 1. Air composition

Element	Weight Fraction
Carbon (C)	0.000124
Nitrogen (N)	0.755267
Oxygen (O)	0.231781
Argon (Ar)	0.012827

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Job No 30822-244-330 /6860 Job: PSR-6 By JVC Date 02/24/2001
Client WVNS Subject: cellulose-Pu-239 spheres Chk'd. [illegible] Date 02/27/01

Table 2. Concrete composition

Element	Weight Fraction
Hydrogen (H)	0.010
Oxygen (O)	0.532
Sodium (Na)	0.029
Aluminum (Al)	0.034
Silicon (Si)	0.337
Calcium (Ca)	0.044
Iron (Fe)	0.014

The weight fractions of the elements composing the cellulose were determined based on the known atomic weights of the elements (Table 3) and the cellulose chemical formula - $C_6H_{10}O_5$.

Table 3. The atomic weights of the elements

Element	Atomic Weight
Hydrogen (H)	1.00794
Carbon (C)	12.0107
Oxygen (O)	15.9994

The molecular weight of cellulose ($C_6H_{10}O_5$) was calculated as the sum of all atomic weights composing the molecule. The weight fraction of an ith element was found as a ratio of the ith element weight in the molecule to the molecular weight of this molecule.

$$(w_i)_{cel} = \frac{n_i A_i}{M_{cel}} = \frac{n_i A_i}{\sum n_i A_i} \qquad (1)$$

where

$(w_i)_{cel}$ = the weight fraction of ith element in a molecule of cellulose

n_i = the number of the ith elements in a cellulose molecule

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A_i = the atomic weight of the ith element, g/mol

M_{cel} = the molecular weight a cellulose molecule, g/mol

Calculated weight fractions for cellulose are shown in Table 4.

Table 4. Cellulose Weight Fractions

Element	Weight Fraction
Hydrogen (H)	0.062
Carbon (C)	0.444
Oxygen (O)	0.493

Radii of the Plutonium containing spheres.

The spheres with several different radii were studied. The minimum size of the Plutonium containing sphere corresponded to the sphere with pure Pu-239 and the maximum size was limited by the dimensions of the container, i.e. half of the box height. The minimum radius equation (3) was derived from the volume of a sphere equation (2)

$$V_{Pu} = \frac{4\pi\left(R_{Pu}\right)^3}{3} \qquad (2)$$

$$R_{\min} = R_{Pu} = \sqrt[3]{\frac{3V_{Pu}}{4\pi}} = \sqrt[3]{\frac{3m_{Pu}}{4\pi\rho_{Pu}}} \qquad (3)$$

where:

R_{min} = the minimum possible radius of the sphere containing Pu-239, cm

R_{Pu} = the radius of the metal Plutonium sphere, cm

V_{Pu} = the volume of the sphere with Pu-239, cm^3

m_{Pu} = the mass of the Plutonium sphere, g

ρ_{Pu} = the density of the metal Plutonium, 19.78 g/cm^3

Composition of the Plutonium containing spheres

The weight fractions of the elements composing the mixture are defined as the ratio of the mass of the element in the mixture to the total mass of the mixture. Total mass of the mixture was determined using

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Job No 30822-244-330 /6860 Job: PSR-6 By IVC Date 02/24/2001
Client WVNS Subject: cellulose-Pu-239 spheres Chk'd. [illegible] Date 02/27/01

equation (4):

$$M_{total} = m_{Pu} + m_{cel} = m_{Pu} + V_{cel}\rho_{cel} =$$

$$= m_{Pu} + \left(V_{Total} - V_{Pu}\right)\rho_{cel} = m_{Pu} + \left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel} \qquad (4)$$

where

M_{Total} = the total mass of the mixture, g

m_{Pu} = the mass of Pu-239 in a sphere, g

m_{cel} = the mass of a cellulose in a sphere, g

V_{Total} = the total volume of a sphere, cm^3

V_{cel} = the volume of a cellulose in the sphere, cm^3

ρ_{cel} = the density of a cellulose, 0.72 g/cm^3

V_{Pu} = the volume of Pu-239 in the sphere, cm^3

ρ_{Pu} = the density of the metal Plutonium, 19.78 g/cm^3

R = the radius of a Plutonium containing sphere, cm

In the Plutonium-cellulose mixture, the weight fraction of Pu-239 was calculated using equation 5, and the weight fractions of elements composing cellulose were calculated using equation 7 as a product of the weight fraction of a cellulose in the Plutonium-cellulose mixture (equation 6) and the weight fraction of an element in a pure cellulose (equation 1).

$$w_{Pu} = \frac{m_{Pu}}{M_{total}} = \frac{m_{Pu}}{m_{Pu} + \left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel}} \qquad (5)$$

$$w_{cel} = \frac{m_{cel}}{M_{total}} = \frac{\left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel}}{m_{Pu} + \left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel}} \qquad (6)$$

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$$w_i = w_{cel}(w_i)_{cel} = \frac{\left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel} n_i A_i}{\left[m_{Pu} + \left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel}\right]\sum n_i A_i} \qquad (7)$$

All variables in equations 5-7 are as described above. Table 6 shows the composition of the Plutonium containing spheres.

The cases for spheres with 25g, 50g, and 100g of Pu-239 were studied and based on the calculated neutron multiplication factors, the Pu-239 sub-critical mass limit was determined. Tables 5-7 show the composition of the spheres used in the models.

Table 5. The composition of the spheres with 25g of Pu-239.

Radius of the sphere, cm	5	10	15	20	22.86
Mixture density, g/cm^3	0.766008492	0.725751061	0.721704018	0.720718883	0.720481415
Pu-239 weight fraction	0.062331532	0.00822363	0.0024503	0.00103513	0.0006934
Carbon (C) weight fraction	0.416751437	0.440799963	0.443365952	0.443994928	0.444146801
Hydrogen (H)weight fraction	0.058289753	0.061653347	0.062012244	0.062100217	0.062121459
Oxygen (O) weight fraction	0.462627278	0.489323057	0.492171509	0.492869723	0.493038314

Table 6. The composition of the spheres with 50g of Pu-239.

Radius of the sphere, cm	5	10	15	20	22.86
Mixture density, g/cm^3	0.812016983	0.731502123	0.723408036	0.721437765	0.720962829
Pu-239 weight fraction	0.117599715	0.016317958	0.00488905	0.0020682	0.00138593
Carbon (C) weight fraction	0.392187217	0.4372024	0.442282036	0.443535776	0.443839016
Hydrogen (H)weight fraction	0.054854031	0.061150167	0.06186064	0.062035997	0.06207841
Oxygen (O) weight fraction	0.435359038	0.485329475	0.490968276	0.492360027	0.492696648

Table 7. The composition of the spheres with 100g of Pu-239.

Radius of the sphere, cm	5	10	15	20	22.86
Mixture density, g/cm^3	0.904033967	0.743004246	0.726816073	0.722875531	0.721925659
Pu-239 weight fraction	0.211259686	0.032130693	0.009732246	0.004128173	0.002768154
Carbon (C) weight fraction	0.350559575	0.430174351	0.440129452	0.442620211	0.443224678
Hydrogen (H)weight fraction	0.049031699	0.060167175	0.061559565	0.06190794	0.06199248
Oxygen (O) weight fraction	0.389149041	0.477527781	0.488578737	0.4913437	0.4920146

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Results

The results of the calculations performed using MCNP-4A code are shown in the following tables and graphs. Tables 8-10 provide the Monte Carlo determined neutron multiplication factor (k_{eff}) values and their standard deviations (σ), and Figures 1-3 plot the $k_{eff} + 2\sigma$ values for all studied cases (25g, 50g, and 100g).

Table 8. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for the boxes with 25 g of Pu-239.

R and X-, Y-, Z- coordinates for the center of the sphere, cm					cellulose outside the sphere			void outside the sphere		
R	X	Y	Z1	Z2	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$
5	5	5	40.72	50.72	0.4019	0.0010	0.4039	0.1176	0.0006	0.1188
10	10	10	35.72	55.72	0.41672	0.00073	0.4182	0.43865	0.00093	0.4405
15	15	15	30.72	60.72	0.2700	0.0004	0.2708	0.4756	0.0005	0.4765
20	20	20	25.72	65.72	0.1825	0.0002	0.1829	0.3411	0.0002	0.3415
22.86	22.86	22.86	22.86	68.58	0.1639	0.0002	0.1642	0.2644	0.0002	0.2647

Table 9. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for the boxes with 50 g of Pu-239.

R and X-, Y-, Z- coordinates for the center of the sphere, cm					cellulose outside the sphere			void outside the sphere		
R	X	Y	Z1	Z2	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$
5	5	5	40.72	50.72	0.4991	0.0012	0.5015	0.1470	0.0008	0.1486
10	10	10	35.72	55.72	0.5914	0.0012	0.5937	0.6162	0.0011	0.6184
15	15	15	30.72	60.72	0.4472	0.0006	0.4485	0.7437	0.0007	0.7451
20	20	20	25.72	65.72	0.3261	0.0004	0.3268	0.5811	0.0004	0.5819
22.86	22.86	22.86	22.86	68.58	0.3002	0.0003	0.3007	0.4681	0.0003	0.4686

Table 10. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for the boxes with 100 g of Pu-239.

R and X-, Y-, Z- coordinates for the center of the sphere, cm					cellulose outside the sphere			void outside the sphere		
R	X	Y	Z1	Z2	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$
5	5	5	40.72	50.72	0.5455	0.0013	0.5481	0.1792	0.0007	0.1806
10	10	10	35.72	55.72	0.7510	0.0013	0.7536	0.76628	0.00136	0.7690
15	15	15	30.72	60.72	0.66627	0.00096	0.6682	1.0259	0.0008	1.0276
20	20	20	25.72	65.72	0.5379	0.0006	0.5391	0.8960	0.0005	0.8971
22.86	22.86	22.86	22.86	68.58	0.5120	0.0005	0.5129	0.7602	0.0004	0.7610

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Figure 1. k_{eff} +2σ for the boxes with 25 g of Pu-239 .

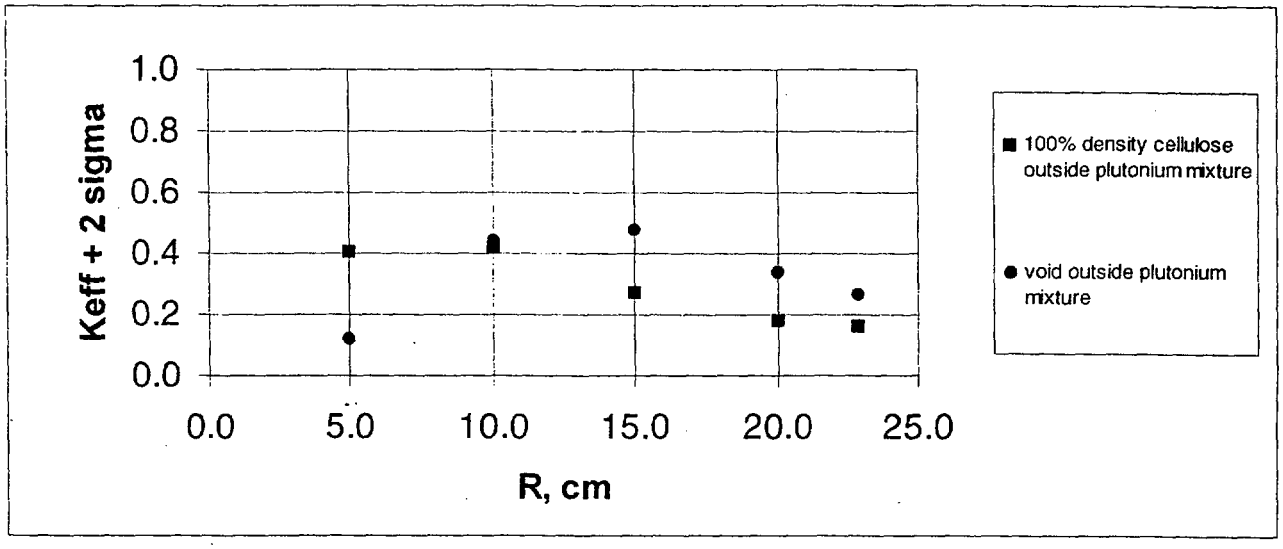
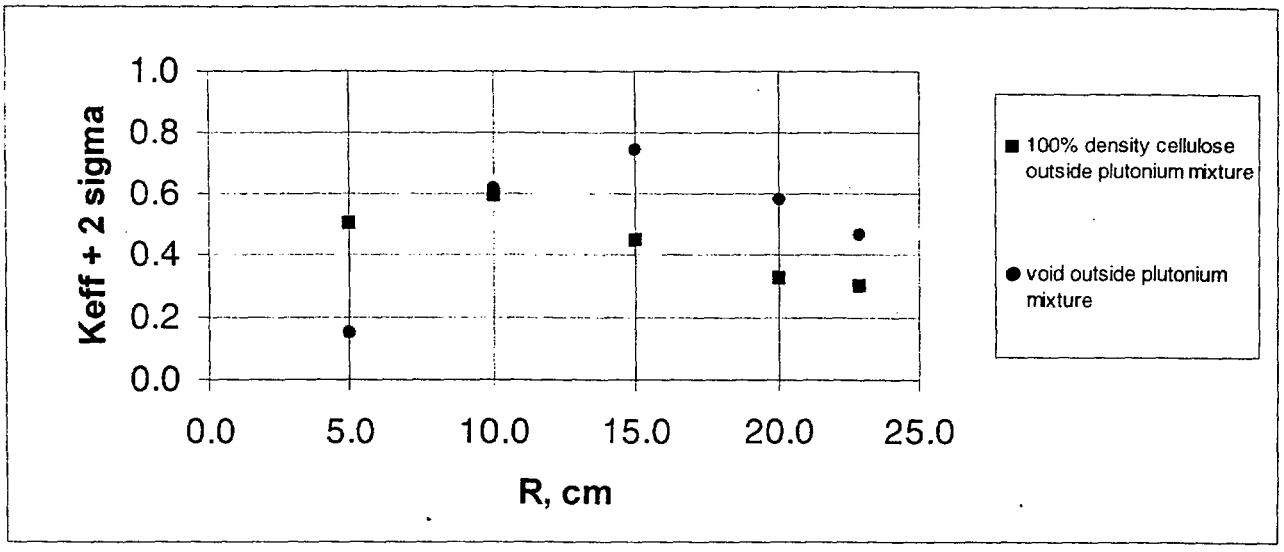


Figure 2. k_{eff} +2σ for the boxes with 50 g of Pu-239 .



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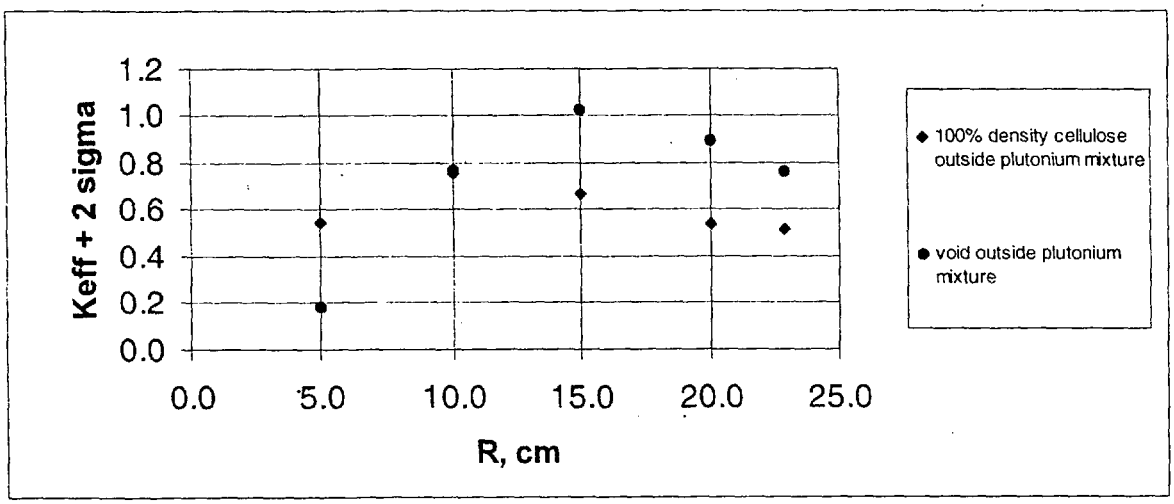
Client WVNS Subject: cellulose-Pu-239 spheres Chk'd. Date 02/27/01

Figure 3. k_{eff} +2σ for the boxes with 100 g of Pu-239.



The criterion for the Pu-239 mass limit is:

$$k_{eff} + 2\sigma \leq k_a - \Delta k_b - \sigma_b \qquad (8)$$

Where:

k_{eff} = neutron multiplication factor predicted by MCNP

σ = standard deviation of predicted k_{eff}

$k_a = 0.95$ = established allowable limiting neutron multiplication factor

Δk_b = calculation method bias

σ_b = bias uncertainty

The calculation method bias together with bias uncertainty ($\Delta k_b + \sigma_b$) is no more than 0.02. Thus the criterion (8) can be modified as:

$$k_{eff} + 2\sigma \leq 0.93 \qquad (9)$$

Where:

k_{eff} = neutron multiplication factor predicted by MCNP

σ = standard deviation of predicted k_{eff}

To determine the Pu-239 mass limit, the maximum values of k_{eff} +2σ as a function of Pu-239 mass (Table 11) were approximated with a polynomial equation, which is shown on Figure 4.

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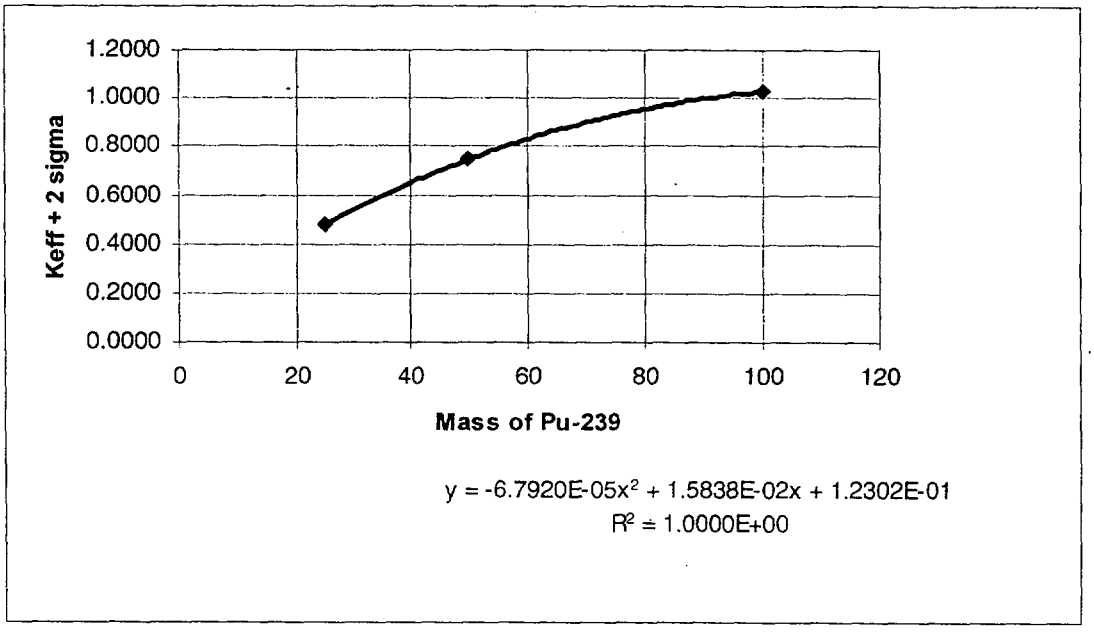
Table 11. The maximum values of k_{eff} +2σ as a function of Pu-239 mass.

Mass of Pu-239, g	k_{eff}	σ	k_{eff}+ 2σ
25	0.4756	0.0005	0.4765
50	0.7437	0.0007	0.7451
100	1.0259	0.0008	1.0276

Figure 4. The maximum values of k_{eff} +2σ as a function of Pu-239 mass.



Solving the polynomial equation from Figure 4 determines the Pu-239 mass limit as 74g per box. To check this result, another set of MCNP runs was performed. Table 12 shows the composition of the Plutonium containing spheres, and Table 13 and Figure 5 show the calculation results for the arrays of boxes with 74g of Pu-239.

Table 12. The composition of the spheres with 74g of Pu-239

Radius of the sphere, cm	5	10	15	20	22.86
Mixture density, g/cm³	0.856185135	0.737023142	0.725043894	0.722127893	0.721424987
Pu-239 weight fraction	0.16506896	0.023969666	0.00721947	0.00305801	0.00204986
Carbon (C) weight fraction	0.371089274	0.43380156	0.44124627	0.44309585	0.44354392
Hydrogen (H)weight fraction	0.051903126	0.060674502	0.061715771	0.061974466	0.062037137
Oxygen (O) weight fraction	0.41193641	0.481554272	0.489818494	0.491871674	0.492369078

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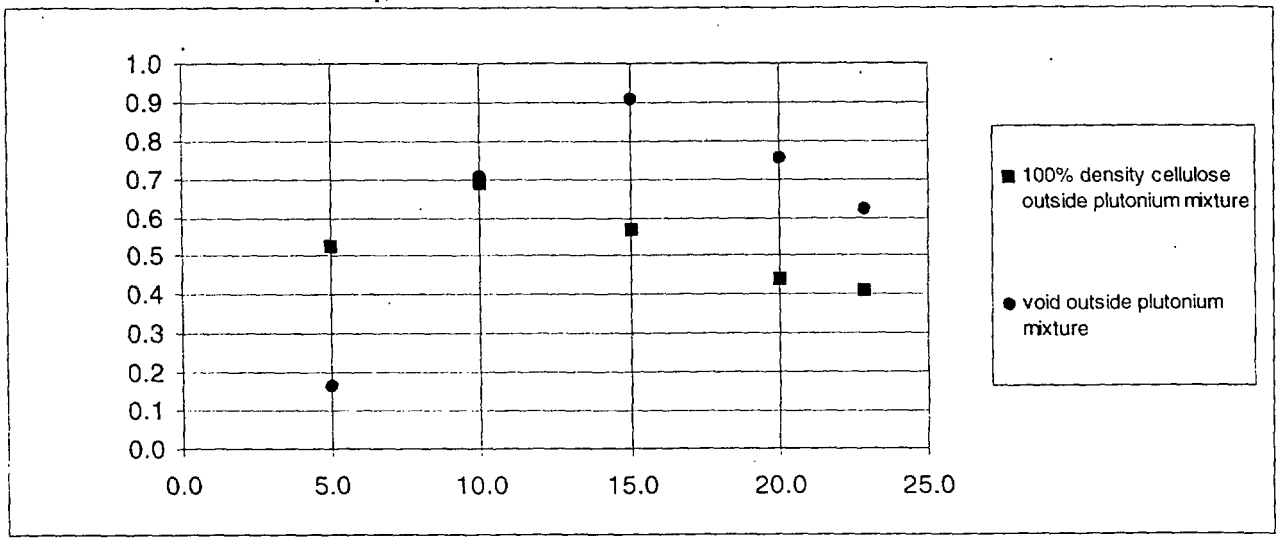
Table 13. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for the boxes with 74 g of Pu-239.

R and X-, Y-, Z- coordinates for the center of the sphere, cm					cellulose outside the sphere			void outside the sphere		
R	X	Y	Z1	Z2	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$
5	5	5	40.72	50.72	0.5256	0.0012	0.5280	0.1652	0.0008	0.1668
10	10	10	35.72	55.72	0.68578	0.00113	0.6880	0.70688	0.00142	0.7097
15	15	15	30.72	60.72	0.5688	0.0008	0.5705	0.9096	0.0008	0.9111
20	20	20	25.72	65.72	0.4382	0.0005	0.4393	0.7531	0.0006	0.7542
22.86	22.86	22.86	22.86	68.58	0.4110	0.0004	0.4118	0.6233	0.0003	0.6240

Figure 5. $k_{eff}+2\sigma$ for the boxes with 74g of Pu-239.



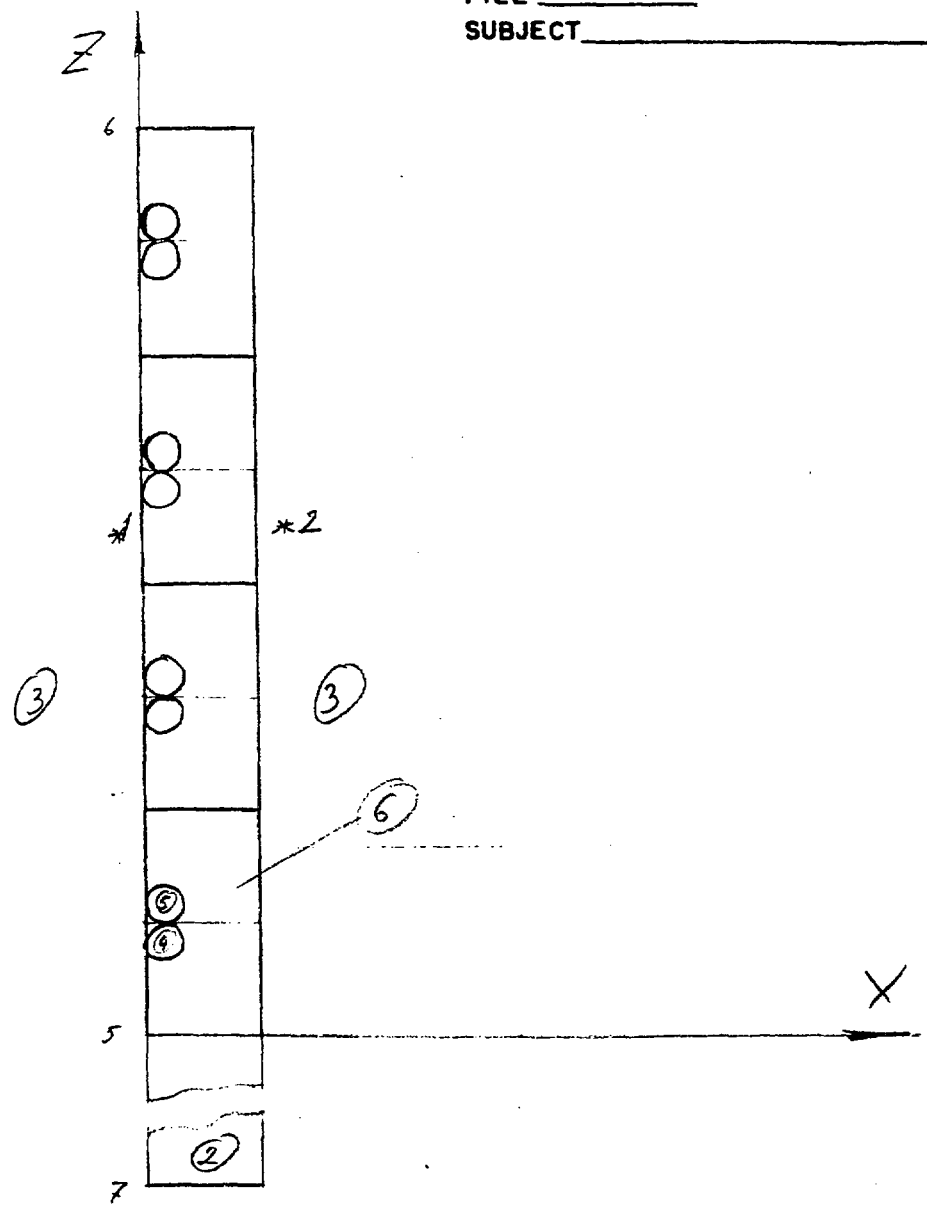
The $k_{eff}+2\sigma$ values in Table 13 confirm that 74g of Pu-239 is a sub-critical mass limit for $\infty \times \infty \times 12$ ft arrays of 1.5-cubic-foot boxes with Pu-239-cellulose spheres and pure cellulose or void outside the sphere.

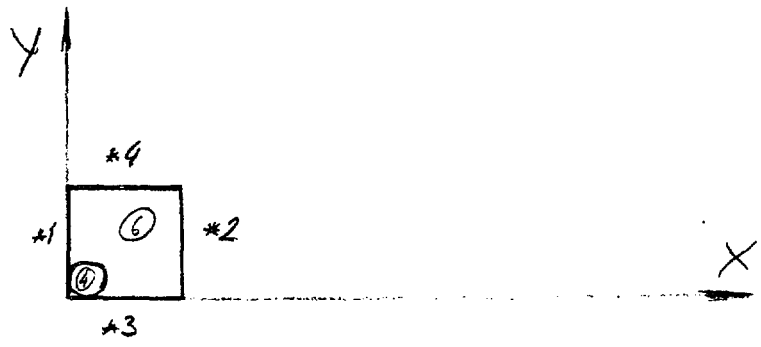
Attachment 1: MCNP model with surface and cell numbers

FILE _____

SUBJECT _____

REVISIONS
BY _____ DATE _____ TO EO _____
BY _____ DATE _____ TO EO _____





BY _____ DATE _____
CHECKED BY _____
COPY TO EO _____

Dames & Moore

Attachment 2: MCNP input file

3c900

```
k eff, 74g of Pu-239 in cellulose spheres in 1.5 cubic foot of pure celulose
C
C Cell cards
C
C ---------------------------------------------------------------------------
1 0   1 -2 3 -4 5 -6 fill=2           imp:n=1 $ box with lattice
2 2  -2.3    1 -2 3 -4 -5 7           imp:n=1 $ Concrete floor
3 0         -1 : 2 : -3 : 4 : -7 : 6  imp:n=0 $ Outside world
c
c Universe 1
4 3  -0.725044 -8              u=1    imp:n=1 $ 1 Pu-239 and cellulose sphere
5 3  -0.725044 -9              u=1    imp:n=1 $ 2 Pu-239 and cellulose sphere
6 0       8 9            u=1    imp:n=1 $
c
c Lattice (2 spheres with Pu-239 in 2 cubic feet of cellulose matrix)
7 0 10 -11 12 -13 14 -15 lat=1 fill=1 u=2 imp:n=1 $ Lattice
C ---------------------------------------------------------------------------
c
c Note: next line must be completely blank

c Surface cards
C ---------------------------------------------------------------------------
*1 px 0.001
*2 px 45.721  $  box length (1.5 foot)
*3 py 0.001
*4 py 45.721  $  box width (1.5 foot)
5  pz 0.001
6  pz 365.761 $  box height (12 feet)
c                More thnan 350.52cm (11.5 feet) - 4 tiers of B-25 box height
c                (4x34.5" or 4x87.63 cm)
7  pz -300 $ concrete floor boundary
8  s 15.0 15.0  30.72 15.0 $ 1st Pu-239 containing sphere
9  s 15.0 15.0  60.72 15.0 $ 2nd Pu-239 containing sphere
c
c Lattice surfases:
10 px 0
11 px 45.72  $ 1.5 feet
12 py 0
13 py 45.72  $ 1.5 feet
14 pz 0
15 pz 91.44 $ 2 x 1.5 feet
C ---------------------------------------------------------------------------
c
c Note: next line must be completely blank

c Data cards
c
c Materials
c
c
c Celulose matrix (Elements: C, H, O)
m1      6000.50c  -0.444
        1001.50c  -0.062
        8016.50c  -0.493
c Concrete (KENO Regular Concrete Standard Mix) from Harmon at al.
c Criticality Calculation with MCNP. A Primer. p. C-4
c (Elements: H, O, Na, Si, Al, Ca, Fe)
m2      1001.50c -0.010
        8016.50c -0.532
       11023.50c -0.029
       13027.50c -0.034
       14000.50c -0.337
       20000.50c -0.044
       26000.55c -0.014
c Pu-239 and cellulose
m3     94239.55c  -0.007219
        6000.50c  -0.441246
        1001.50c  -0.061715
        8016.50c  -0.488982
c
mode n
print 40 60 80 100 110 126
kcode 4000 1. 20 120
ksrc  15.0 15.0  30.72
      15.0 15.0  60.72
```

Attachment 3: MCNP output file

```
1mcnp     version 4a     ld=10/01/93                    02/08/01 21:10:07
 ******************************************************************************          probid =    02/08/01 21:10:07
 name=3c900

    1-       k eff, 74g of Pu-239 in cellulose spheres in 1.5 cubic foot of pure celulose
    2-       C
    3-       C Cell cards
    4-       C
    5-       C ------------------------------------------------------------------------
    6-       1 0   1 -2 3 -4 5 -6 fill=2          imp:n=1 $ box with lattice
    7-       2 2  -2.3    1 -2 3 -4 -5 7          imp:n=1 $ Concrete floor
    8-       3 0         -1 : 2 : -3 : 4 : -7 : 6  imp:n=0 $ Outside world
    9-       c
   10-       c Universe 1
   11-       4 3  -0.725044 -8             u=1    imp:n=1 $ 1 Pu-239 and cellulose sphere
   12-       5 3  -0.725044 -9             u=1    imp:n=1 $ 2 Pu-239 and cellulose sphere
   13-       6 0       8 9           u=1    imp:n=1 $
   14-       c
   15-       c Lattice (2 spheres with Pu-239 in 2 cubic feet of cellulose matrix)
   16-       7 0 10 -11 12 -13 14 -15 lat=1 fill=1 u=2 imp:n=1 $ Lattice
   17-       C ------------------------------------------------------------------------
   18-       c
   19-       c Note: next line must be completely blank
   20-
   21-       c Surface cards
   22-       C ------------------------------------------------------------------------
   23-       *1 px 0.001
   24-       *2 px 45.721  $  box length (1.5 foot)
   25-       *3 py 0.001
   26-       *4 py 45.721  $  box width (1.5 foot)
   27-       5  pz 0.001
   28-       6  pz 365.761 $  box height (12 feet)
   29-       c               More thnan 350.52cm (11.5 feet) - 4 tiers of B-25 box height
   30-       c               (4x34.5" or 4x87.63 cm)
   31-       7  pz -300 $ concrete floor boundary
   32-       8  s 15.0 15.0  30.72 15.0 $ 1st Pu-239 containing sphere
   33-       9  s 15.0 15.0  60.72 15.0 $ 2nd Pu-239 containing sphere
   34-       c
   35-       c Lattice surfases:
   36-       10 px 0
   37-       11 px 45.72  $ 1.5 feet
   38-       12 py 0
   39-       13 py 45.72  $ 1.5 feet
   40-       14 pz 0
   41-       15 pz 91.44 $ 2 x 1.5 feet
   42-       C ------------------------------------------------------------------------
   43-       c
   44-       c Note: next line must be completely blank
   45-
   46-       c Data cards
   47-       c
   48-       c Materials
   49-       c
   50-       c
   51-       c Celulose matrix (Elements: C, H, O)
   52-       m1     6000.50c  -0.444
warning.  material   1 is not used in the problem.
   53-              1001.50c  -0.062
   54-              8016.50c  -0.493
   55-       c Concrete (KENO Regular Concrete Standard Mix) from Harmon at al.
   56-       c Criticality Calculation with MCNP. A Primer. p. C-4
   57-       c (Elements: H, O, Na, Si, Al, Ca, Fe)
```

```
   58-        m2      1001.50c -0.010
   59-                8016.50c -0.532
   60-               11023.50c -0.029
   61-               13027.50c -0.034
   62-               14000.50c -0.337
   63-               20000.50c -0.044
   64-               26000.55c -0.014
   65-        c Pu-239 and cellulose
   66-        m3     94239.55c  -0.007219
   67-                6000.50c  -0.441246
   68-                1001.50c  -0.061715
   69-                8016.50c  -0.488982
   70-        c
   71-        mode n
   72-        print 40 60 80 100 110 126
   73-        kcode 4000 1. 20 120
   74-        ksrc  15.0 15.0  30.72
   75-              15.0 15.0  60.72
   76-
 total fission nubar data are being used.
1material composition                                                    print table 40

 the sum of the fractions of material     3 was 9.991620E-01

 material
  number      component nuclide, atom fraction

     2            1001,  0.16803       8016,  0.56324      11023,  0.02136      13027,  0.02134
                 14000,  0.20319      20000,  0.01859      26000,  0.00425
     3           94239,  0.00023       6000,  0.28572       1001,  0.47627       8016,  0.23777


 material
  number      component nuclide, mass fraction

     2            1001,  0.01000       8016,  0.53200      11023,  0.02900      13027,  0.03400
                 14000,  0.33700      20000,  0.04400      26000,  0.01400
     3           94239,  0.00723       6000,  0.44162       1001,  0.06177       8016,  0.48939

 warning.     1 of the materials had unnormalized fractions.
1cells                                                                   print table 60

                          atom          gram                                        neutron
        cell  mat        density       density        volume          mass       pieces importance

     1     1    0  0.00000E+00  0.00000E+00  7.64555E+05  0.00000E+00      0  1.0000E+00
     2     2    2  8.17913E-02  2.30000E+00  6.27098E+05  1.44232E+06      0  1.0000E+00
     3     3    0  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00      0  0.0000E+00
     4     4    3  5.61856E-02  7.25044E-01  1.41372E+04  1.02501E+04      1  1.0000E+00
     5     5    3  5.61856E-02  7.25044E-01  1.41372E+04  1.02501E+04      1  1.0000E+00
     6     6    0  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00      0  1.0000E+00
     7     7    0  0.00000E+00  0.00000E+00  1.91139E+05  0.00000E+00      0  1.0000E+00

 total                                      1.61107E+06  1.46282E+06

        2 warning messages so far.
1cross-section tables                                                    print table 100

     table    length
```

tables from file critxs

1001.50c	1153	njoy		(1301)	79/07/31.
6000.50c	16126	njoy		(1306)	79/07/31.
8016.50c	23669	njoy		(1276)	05/14/81
11023.50c	36270	njoy		(1311)	79/06/21.
13027.50c	22891	njoy		(1313)	79/09/08.
14000.50c	48275	njoy		(1314)	79/06/21.
20000.50c	26104	njoy		(1320)	79/06/22.
26000.55c	84136	njoy		(260)	10/21/82
94239.55c	67551	njoy	total nu	(1399)	02/21/85

total 326175

warning. neutron energy cutoff is below some cross-section tables.

decimal words of dynamically allocated storage

general	110992
tallies	0
bank	12403
cross sections	326175
total	449570

****

dump no. 1 on file 3c900r nps = 0 coll = 0 ctm = 0.00 nrn = 0

source distribution written to file 3c900s cycle = 0

3 warning messages so far.

1 starting mcrun. field length = 0 cp0 = 0.01 print table 110

k eff, 74g of Pu-239 in cellulose spheres in 1.5 cubic foot of pure celulose

nps	x	y	z	cell	lattice(i,j,k)	surface	u	v	w	energy	weight	time
1	1.500E+01	1.500E+01	3.072E+01	1			5.085E-01	4.733E-01	7.193E-01	2.209E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	3.072E+01	7(0, 0, 0)			5.085E-01	4.733E-01	7.193E-01			
	1.500E+01	1.500E+01	3.072E+01	4		0	5.085E-01	4.733E-01	7.193E-01			
2	1.500E+01	1.500E+01	3.072E+01	1			8.952E-01	-4.447E-01	-2.944E-02	4.904E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	3.072E+01	7(0, 0, 0)			8.952E-01	-4.447E-01	-2.944E-02			
	1.500E+01	1.500E+01	3.072E+01	4		0	8.952E-01	-4.447E-01	-2.944E-02			
3	1.500E+01	1.500E+01	3.072E+01	1			-6.184E-01	-4.495E-01	6.446E-01	3.809E-01	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	3.072E+01	7(0, 0, 0)			-6.184E-01	-4.495E-01	6.446E-01			
	1.500E+01	1.500E+01	3.072E+01	4		0	-6.184E-01	-4.495E-01	6.446E-01			
4	1.500E+01	1.500E+01	3.072E+01	1			9.710E-01	-5.665E-02	-2.323E-01	1.331E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	3.072E+01	7(0, 0, 0)			9.710E-01	-5.665E-02	-2.323E-01			
	1.500E+01	1.500E+01	3.072E+01	4		0	9.710E-01	-5.665E-02	-2.323E-01			
5	1.500E+01	1.500E+01	3.072E+01	1			5.861E-01	1.496E-01	-7.963E-01	1.902E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	3.072E+01	7(0, 0, 0)			5.861E-01	1.496E-01	-7.963E-01			
	1.500E+01	1.500E+01	3.072E+01	4		0	5.861E-01	1.496E-01	-7.963E-01			
6	1.500E+01	1.500E+01	3.072E+01	1			-6.489E-02	-1.626E-01	9.845E-01	4.410E-01	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	3.072E+01	7(0, 0, 0)			-6.489E-02	-1.626E-01	9.845E-01			
	1.500E+01	1.500E+01	3.072E+01	4		0	-6.489E-02	-1.626E-01	9.845E-01			

7	1.500E+01	1.500E+01	3.072E+01	1						-7.068E-02	3.263E-02	-9.970E-01	4.750E-01	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	3.072E+01	7(	0,	0,	0)			-7.068E-02	3.263E-02	-9.970E-01			
	1.500E+01	1.500E+01	3.072E+01	4					0	-7.068E-02	3.263E-02	-9.970E-01			
8	1.500E+01	1.500E+01	3.072E+01	1						-3.915E-01	4.664E-01	-7.932E-01	4.136E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	3.072E+01	7(	0,	0,	0)			-3.915E-01	4.664E-01	-7.932E-01			
	1.500E+01	1.500E+01	3.072E+01	4					0	-3.915E-01	4.664E-01	-7.932E-01			
9	1.500E+01	1.500E+01	3.072E+01	1						-2.368E-01	9.215E-01	-3.079E-01	7.453E-02	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	3.072E+01	7(	0,	0,	0)			-2.368E-01	9.215E-01	-3.079E-01			
	1.500E+01	1.500E+01	3.072E+01	4					0	-2.368E-01	9.215E-01	-3.079E-01			
10	1.500E+01	1.500E+01	3.072E+01	1						1.946E-01	-3.204E-01	9.271E-01	3.128E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	3.072E+01	7(	0,	0,	0)			1.946E-01	-3.204E-01	9.271E-01			
	1.500E+01	1.500E+01	3.072E+01	4					0	1.946E-01	-3.204E-01	9.271E-01			
11	1.500E+01	1.500E+01	3.072E+01	1						-6.698E-01	-7.177E-01	-1.905E-01	1.014E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	3.072E+01	7(	0,	0,	0)			-6.698E-01	-7.177E-01	-1.905E-01			
	1.500E+01	1.500E+01	3.072E+01	4					0	-6.698E-01	-7.177E-01	-1.905E-01			
12	1.500E+01	1.500E+01	3.072E+01	1						-8.398E-01	-4.129E-01	3.524E-01	1.395E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	3.072E+01	7(	0,	0,	0)			-8.398E-01	-4.129E-01	3.524E-01			
	1.500E+01	1.500E+01	3.072E+01	4					0	-8.398E-01	-4.129E-01	3.524E-01			
13	1.500E+01	1.500E+01	3.072E+01	1						-1.714E-01	-8.572E-01	4.857E-01	7.748E-01	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	3.072E+01	7(	0,	0,	0)			-1.714E-01	-8.572E-01	4.857E-01			
	1.500E+01	1.500E+01	3.072E+01	4					0	-1.714E-01	-8.572E-01	4.857E-01			
14	1.500E+01	1.500E+01	3.072E+01	1						-2.489E-01	-5.118E-01	-8.222E-01	1.101E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	3.072E+01	7(	0,	0,	0)			-2.489E-01	-5.118E-01	-8.222E-01			
	1.500E+01	1.500E+01	3.072E+01	4					0	-2.489E-01	-5.118E-01	-8.222E-01			
15	1.500E+01	1.500E+01	3.072E+01	1						-2.959E-01	2.119E-01	9.314E-01	1.951E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	3.072E+01	7(	0,	0,	0)			-2.959E-01	2.119E-01	9.314E-01			
	1.500E+01	1.500E+01	3.072E+01	4					0	-2.959E-01	2.119E-01	9.314E-01			
16	1.500E+01	1.500E+01	3.072E+01	1						1.395E-01	-9.829E-01	1.202E-01	2.186E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	3.072E+01	7(	0,	0,	0)			1.395E-01	-9.829E-01	1.202E-01			
	1.500E+01	1.500E+01	3.072E+01	4					0	1.395E-01	-9.829E-01	1.202E-01			
17	1.500E+01	1.500E+01	3.072E+01	1						6.909E-01	-7.110E-01	1.307E-01	1.865E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	3.072E+01	7(	0,	0,	0)			6.909E-01	-7.110E-01	1.307E-01			
	1.500E+01	1.500E+01	3.072E+01	4					0	6.909E-01	-7.110E-01	1.307E-01			
18	1.500E+01	1.500E+01	3.072E+01	1						-6.580E-01	5.320E-01	-5.329E-01	1.229E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	3.072E+01	7(	0,	0,	0)			-6.580E-01	5.320E-01	-5.329E-01			
	1.500E+01	1.500E+01	3.072E+01	4					0	-6.580E-01	5.320E-01	-5.329E-01			
19	1.500E+01	1.500E+01	3.072E+01	1						-9.903E-01	-1.380E-01	1.353E-02	1.305E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	3.072E+01	7(	0,	0,	0)			-9.903E-01	-1.380E-01	1.353E-02			
	1.500E+01	1.500E+01	3.072E+01	4					0	-9.903E-01	-1.380E-01	1.353E-02			
20	1.500E+01	1.500E+01	3.072E+01	1						7.462E-01	4.859E-01	-4.551E-01	1.000E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	3.072E+01	7(	0,	0,	0)			7.462E-01	4.859E-01	-4.551E-01			
	1.500E+01	1.500E+01	3.072E+01	4					0	7.462E-01	4.859E-01	-4.551E-01			
21	1.500E+01	1.500E+01	3.072E+01	1						-1.977E-01	9.797E-01	3.360E-02	3.990E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	3.072E+01	7(	0,	0,	0)			-1.977E-01	9.797E-01	3.360E-02			
	1.500E+01	1.500E+01	3.072E+01	4					0	-1.977E-01	9.797E-01	3.360E-02			
22	1.500E+01	1.500E+01	3.072E+01	1						-9.117E-01	-3.647E-01	-1.891E-01	2.665E-01	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	3.072E+01	7(	0,	0,	0)			-9.117E-01	-3.647E-01	-1.891E-01			
	1.500E+01	1.500E+01	3.072E+01	4					0	-9.117E-01	-3.647E-01	-1.891E-01			
23	1.500E+01	1.500E+01	3.072E+01	1						-4.287E-01	8.361E-01	-3.423E-01	1.156E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	3.072E+01	7(	0,	0,	0)			-4.287E-01	8.361E-01	-3.423E-01			
	1.500E+01	1.500E+01	3.072E+01	4					0	-4.287E-01	8.361E-01	-3.423E-01			
24	1.500E+01	1.500E+01	3.072E+01	1						1.080E-01	3.412E-01	-9.338E-01	2.669E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	3.072E+01	7(	0,	0,	0)			1.080E-01	3.412E-01	-9.338E-01			
	1.500E+01	1.500E+01	3.072E+01	4					0	1.080E-01	3.412E-01	-9.338E-01			
25	1.500E+01	1.500E+01	3.072E+01	1						-9.111E-01	-9.012E-03	-4.122E-01	2.185E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	3.072E+01	7(	0,	0,	0)			-9.111E-01	-9.012E-03	-4.122E-01			
	1.500E+01	1.500E+01	3.072E+01	4					0	-9.111E-01	-9.012E-03	-4.122E-01			
26	1.500E+01	1.500E+01	3.072E+01	1						-2.568E-01	-6.391E-01	-7.249E-01	4.225E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	3.072E+01	7(	0,	0,	0)			-2.568E-01	-6.391E-01	-7.249E-01			
	1.500E+01	1.500E+01	3.072E+01	4					0	-2.568E-01	-6.391E-01	-7.249E-01			
27	1.500E+01	1.500E+01	3.072E+01	1						-2.912E-01	8.086E-01	5.113E-01	1.079E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	3.072E+01	7(	0,	0,	0)			-2.912E-01	8.086E-01	5.113E-01			

```
     1.500E+01  1.500E+01  3.072E+01    4
28   1.500E+01  1.500E+01  3.072E+01    1
     1.500E+01  1.500E+01  3.072E+01    7(   0,   0,   0)
     1.500E+01  1.500E+01  3.072E+01    4
29   1.500E+01  1.500E+01  3.072E+01    1
     1.500E+01  1.500E+01  3.072E+01    7(   0,   0,   0)
     1.500E+01  1.500E+01  3.072E+01    4
30   1.500E+01  1.500E+01  3.072E+01    1
     1.500E+01  1.500E+01  3.072E+01    7(   0,   0,   0)
     1.500E+01  1.500E+01  3.072E+01    4
31   1.500E+01  1.500E+01  3.072E+01    1
     1.500E+01  1.500E+01  3.072E+01    7(   0,   0,   0)
     1.500E+01  1.500E+01  3.072E+01    4
32   1.500E+01  1.500E+01  3.072E+01    1
     1.500E+01  1.500E+01  3.072E+01    7(   0,   0,   0)
     1.500E+01  1.500E+01  3.072E+01    4
33   1.500E+01  1.500E+01  3.072E+01    1
     1.500E+01  1.500E+01  3.072E+01    7(   0,   0,   0)
     1.500E+01  1.500E+01  3.072E+01    4
34   1.500E+01  1.500E+01  3.072E+01    1
     1.500E+01  1.500E+01  3.072E+01    7(   0,   0,   0)
     1.500E+01  1.500E+01  3.072E+01    4
35   1.500E+01  1.500E+01  3.072E+01    1
     1.500E+01  1.500E+01  3.072E+01    7(   0,   0,   0)
     1.500E+01  1.500E+01  3.072E+01    4
36   1.500E+01  1.500E+01  3.072E+01    1
     1.500E+01  1.500E+01  3.072E+01    7(   0,   0,   0)
     1.500E+01  1.500E+01  3.072E+01    4
37   1.500E+01  1.500E+01  3.072E+01    1
     1.500E+01  1.500E+01  3.072E+01    7(   0,   0,   0)
     1.500E+01  1.500E+01  3.072E+01    4
38   1.500E+01  1.500E+01  3.072E+01    1
     1.500E+01  1.500E+01  3.072E+01    7(   0,   0,   0)
     1.500E+01  1.500E+01  3.072E+01    4
39   1.500E+01  1.500E+01  3.072E+01    1
     1.500E+01  1.500E+01  3.072E+01    7(   0,   0,   0)
     1.500E+01  1.500E+01  3.072E+01    4
40   1.500E+01  1.500E+01  3.072E+01    1
     1.500E+01  1.500E+01  3.072E+01    7(   0,   0,   0)
     1.500E+01  1.500E+01  3.072E+01    4
41   1.500E+01  1.500E+01  3.072E+01    1
     1.500E+01  1.500E+01  3.072E+01    7(   0,   0,   0)
     1.500E+01  1.500E+01  3.072E+01    4
42   1.500E+01  1.500E+01  3.072E+01    1
     1.500E+01  1.500E+01  3.072E+01    7(   0,   0,   0)
     1.500E+01  1.500E+01  3.072E+01    4
43   1.500E+01  1.500E+01  3.072E+01    1
     1.500E+01  1.500E+01  3.072E+01    7(   0,   0,   0)
     1.500E+01  1.500E+01  3.072E+01    4
44   1.500E+01  1.500E+01  3.072E+01    1
     1.500E+01  1.500E+01  3.072E+01    7(   0,   0,   0)
     1.500E+01  1.500E+01  3.072E+01    4
45   1.500E+01  1.500E+01  3.072E+01    1
     1.500E+01  1.500E+01  3.072E+01    7(   0,   0,   0)
     1.500E+01  1.500E+01  3.072E+01    4
46   1.500E+01  1.500E+01  3.072E+01    1
     1.500E+01  1.500E+01  3.072E+01    7(   0,   0,   0)
     1.500E+01  1.500E+01  3.072E+01    4
47   1.500E+01  1.500E+01  3.072E+01    1
     1.500E+01  1.500E+01  3.072E+01    7(   0,   0,   0)
     1.500E+01  1.500E+01  3.072E+01    4
48   1.500E+01  1.500E+01  3.072E+01    1
```

```
 0 -2.912E-01  8.086E-01  5.113E-01
    1.472E-01 -9.514E-01  2.705E-01  3.461E+00  1.000E+00  0.000E+00
    1.472E-01 -9.514E-01  2.705E-01
 0  1.472E-01 -9.514E-01  2.705E-01
   -6.135E-01 -7.645E-01 -1.978E-01  1.836E+00  1.000E+00  0.000E+00
   -6.135E-01 -7.645E-01 -1.978E-01
 0 -6.135E-01 -7.645E-01 -1.978E-01
   -5.702E-01  5.651E-01 -5.963E-01  4.556E-01  1.000E+00  0.000E+00
   -5.702E-01  5.651E-01 -5.963E-01
 0 -5.702E-01  5.651E-01 -5.963E-01
   -6.607E-01  5.373E-01 -5.242E-01  6.415E-01  1.000E+00  0.000E+00
   -6.607E-01  5.373E-01 -5.242E-01
 0 -6.607E-01  5.373E-01 -5.242E-01
   -9.742E-02 -3.639E-01 -9.263E-01  2.764E+00  1.000E+00  0.000E+00
   -9.742E-02 -3.639E-01 -9.263E-01
 0 -9.742E-02 -3.639E-01 -9.263E-01
   -1.965E-01 -3.145E-01 -9.287E-01  2.785E-01  1.000E+00  0.000E+00
   -1.965E-01 -3.145E-01 -9.287E-01
 0 -1.965E-01 -3.145E-01 -9.287E-01
    4.097E-01  8.465E-01 -3.399E-01  9.097E-01  1.000E+00  0.000E+00
    4.097E-01  8.465E-01 -3.399E-01
 0  4.097E-01  8.465E-01 -3.399E-01
   -4.048E-02  8.831E-01  4.675E-01  3.360E-01  1.000E+00  0.000E+00
   -4.048E-02  8.831E-01  4.675E-01
 0 -4.048E-02  8.831E-01  4.675E-01
    3.371E-01 -9.269E-01 -1.652E-01  6.376E-01  1.000E+00  0.000E+00
    3.371E-01 -9.269E-01 -1.652E-01
 0  3.371E-01 -9.269E-01 -1.652E-01
   -1.867E-01  9.756E-01 -1.155E-01  2.186E+00  1.000E+00  0.000E+00
   -1.867E-01  9.756E-01 -1.155E-01
 0 -1.867E-01  9.756E-01 -1.155E-01
   -2.616E-01  2.336E-01 -9.365E-01  7.314E-01  1.000E+00  0.000E+00
   -2.616E-01  2.336E-01 -9.365E-01
 0 -2.616E-01  2.336E-01 -9.365E-01
    9.780E-01 -7.641E-02 -1.939E-01  2.997E-01  1.000E+00  0.000E+00
    9.780E-01 -7.641E-02 -1.939E-01
 0  9.780E-01 -7.641E-02 -1.939E-01
    2.580E-01 -7.076E-01  6.578E-01  1.444E+00  1.000E+00  0.000E+00
    2.580E-01 -7.076E-01  6.578E-01
 0  2.580E-01 -7.076E-01  6.578E-01
   -3.212E-01 -7.678E-01 -5.543E-01  1.914E+00  1.000E+00  0.000E+00
   -3.212E-01 -7.678E-01 -5.543E-01
 0 -3.212E-01 -7.678E-01 -5.543E-01
    5.039E-01 -1.460E-01  8.513E-01  1.502E+00  1.000E+00  0.000E+00
    5.039E-01 -1.460E-01  8.513E-01
 0  5.039E-01 -1.460E-01  8.513E-01
    6.080E-01  5.487E-01  5.738E-01  5.971E+00  1.000E+00  0.000E+00
    6.080E-01  5.487E-01  5.738E-01
 0  6.080E-01  5.487E-01  5.738E-01
   -2.932E-01  9.304E-01 -2.199E-01  1.827E+00  1.000E+00  0.000E+00
   -2.932E-01  9.304E-01 -2.199E-01
 0 -2.932E-01  9.304E-01 -2.199E-01
   -8.475E-01 -3.993E-01 -3.497E-01  1.928E+00  1.000E+00  0.000E+00
   -8.475E-01 -3.993E-01 -3.497E-01
 0 -8.475E-01 -3.993E-01 -3.497E-01
    1.200E-01 -9.195E-01 -3.743E-01  1.351E+00  1.000E+00  0.000E+00
    1.200E-01 -9.195E-01 -3.743E-01
 0  1.200E-01 -9.195E-01 -3.743E-01
    7.085E-01  5.879E-01  3.904E-01  2.288E+00  1.000E+00  0.000E+00
    7.085E-01  5.879E-01  3.904E-01
 0  7.085E-01  5.879E-01  3.904E-01
    4.261E-01  9.046E-01  9.254E-03  1.230E+00  1.000E+00  0.000E+00
```

```
     1.500E+01   1.500E+01   3.072E+01    7(   0,    0,    0)          4.261E-01   9.046E-01   9.254E-03
     1.500E+01   1.500E+01   3.072E+01    4                          0  4.261E-01   9.046E-01   9.254E-03
 49  1.500E+01   1.500E+01   3.072E+01    1                             5.431E-01   4.270E-01  -7.230E-01   1.433E+00   1.000E+00   0.000E+00
     1.500E+01   1.500E+01   3.072E+01    7(   0,    0,    0)          5.431E-01   4.270E-01  -7.230E-01
     1.500E+01   1.500E+01   3.072E+01    4                          0  5.431E-01   4.270E-01  -7.230E-01
 50  1.500E+01   1.500E+01   3.072E+01    1                            -1.053E-01  -9.805E-01   1.658E-01   6.572E-01   1.000E+00   0.000E+00
     1.500E+01   1.500E+01   3.072E+01    7(   0,    0,    0)         -1.053E-01  -9.805E-01   1.658E-01
     1.500E+01   1.500E+01   3.072E+01    4                          0 -1.053E-01  -9.805E-01   1.658E-01
1estimated keff results by cycle                                                                    print table 175

 source distribution written to file 3c900s          cycle =    20

 source distribution written to file 3c900s          cycle =    24

 source distribution written to file 3c900s          cycle =    28

 source distribution written to file 3c900s          cycle =    32

 source distribution written to file 3c900s          cycle =    36

 source distribution written to file 3c900s          cycle =    40

 source distribution written to file 3c900s          cycle =    44

 source distribution written to file 3c900s          cycle =    48

 source distribution written to file 3c900s          cycle =    52

 source distribution written to file 3c900s          cycle =    56

 ************************************************************************************************************************
 dump no.    2 on file 3c900r        nps =    235183     coll =       18259513     ctm =   15.21     nrn =       331176655

 source distribution written to file 3c900s          cycle =    60

 source distribution written to file 3c900s          cycle =    64

 source distribution written to file 3c900s          cycle =    68

 source distribution written to file 3c900s          cycle =    72

 source distribution written to file 3c900s          cycle =    76

 source distribution written to file 3c900s          cycle =    80

 source distribution written to file 3c900s          cycle =    84

 source distribution written to file 3c900s          cycle =    88

 source distribution written to file 3c900s          cycle =    92

 source distribution written to file 3c900s          cycle =    96

  estimator      cycle   100   ave of    80 cycles       combination          simple average     combined average      corr
 k(collision)        0.914137        0.906731 0.0016    k(col/abs)          0.909152 0.0010     0.909555 0.0010  -0.1134
 k(absorption)       0.922896        0.911572 0.0013    k(abs/tk ln)        0.909105 0.0010     0.909547 0.0010  -0.1366
 k(trk length)       0.915361        0.906639 0.0016    k(tk ln/col)        0.906685 0.0016     0.906729 0.0016   0.9806
 rem life(col)    8.2387E+04     8.0165E+04 0.0035      k(col/abs/tk ln)    0.908314 0.0011     0.909542 0.0010
 rem life(abs)    8.1730E+04     8.0136E+04 0.0026      life(col/abs)    8.0150E+04 0.0029   8.0121E+04 0.0024   0.8915
 source points generated   3948
```

source distribution written to file 3c900s cycle = 100

source distribution written to file 3c900s cycle = 104

source distribution written to file 3c900s cycle = 108

source distribution written to file 3c900s cycle = 112

estimator	cycle 116	ave of 96 cycles		combination	simple average	combined average	corr
k(collision)	0.896183	0.907270	0.0015	k(col/abs)	0.909167 0.0009	0.909518 0.0009	-0.0997
k(absorption)	0.931431	0.911065	0.0012	k(abs/tk ln)	0.909191 0.0009	0.909559 0.0009	-0.1223
k(trk length)	0.897626	0.907317	0.0015	k(tk ln/col)	0.907293 0.0015	0.907270 0.0015	0.9821
rem life(col)	7.5723E+04	8.0210E+04	0.0032	k(col/abs/tk ln)	0.908550 0.0010	0.909547 0.0009	
rem life(abs)	7.7463E+04	8.0203E+04	0.0024	life(col/abs)	8.0207E+04 0.0027	8.0200E+04 0.0022	0.8927

source points generated 3968

source distribution written to file 3c900s cycle = 116

estimator	cycle 117	ave of 97 cycles		combination	simple average	combined average	corr
k(collision)	0.894256	0.907136	0.0014	k(col/abs)	0.909107 0.0009	0.909480 0.0009	-0.1005
k(absorption)	0.912422	0.911079	0.0012	k(abs/tk ln)	0.909132 0.0009	0.909522 0.0009	-0.1230
k(trk length)	0.894585	0.907185	0.0015	k(tk ln/col)	0.907161 0.0015	0.907136 0.0015	0.9823
rem life(col)	8.1235E+04	8.0221E+04	0.0031	k(col/abs/tk ln)	0.908467 0.0010	0.909510 0.0009	
rem life(abs)	8.1300E+04	8.0215E+04	0.0023	life(col/abs)	8.0218E+04 0.0027	8.0212E+04 0.0022	0.8929

source points generated 3938

estimator	cycle 118	ave of 98 cycles		combination	simple average	combined average	corr
k(collision)	0.915981	0.907226	0.0014	k(col/abs)	0.909152 0.0009	0.909520 0.0009	-0.1004
k(absorption)	0.910963	0.911077	0.0012	k(abs/tk ln)	0.909180 0.0009	0.909565 0.0009	-0.1227
k(trk length)	0.916706	0.907283	0.0015	k(tk ln/col)	0.907254 0.0014	0.907226 0.0014	0.9824
rem life(col)	8.3905E+04	8.0258E+04	0.0031	k(col/abs/tk ln)	0.908529 0.0010	0.909552 0.0009	
rem life(abs)	8.2909E+04	8.0242E+04	0.0023	life(col/abs)	8.0250E+04 0.0027	8.0234E+04 0.0022	0.8952

source points generated 4132

****

dump no. 3 on file 3c900r nps = 470495 coll = 36369048 ctm = 30.33 nrn = 659778394

estimator	cycle 119	ave of 99 cycles		combination	simple average	combined average	corr
k(collision)	0.924226	0.907398	0.0014	k(col/abs)	0.909264 0.0009	0.909636 0.0009	-0.0927
k(absorption)	0.916330	0.911130	0.0011	k(abs/tk ln)	0.909281 0.0009	0.909666 0.0009	-0.1161
k(trk length)	0.921996	0.907431	0.0015	k(tk ln/col)	0.907414 0.0014	0.907400 0.0014	0.9824
rem life(col)	8.1932E+04	8.0275E+04	0.0031	k(col/abs/tk ln)	0.908653 0.0010	0.909662 0.0009	
rem life(abs)	8.0433E+04	8.0244E+04	0.0023	life(col/abs)	8.0260E+04 0.0026	8.0228E+04 0.0022	0.8938

source points generated 4077

estimator	cycle 120	ave of 100 cycles		combination	simple average	combined average	corr
k(collision)	0.907659	0.907400	0.0014	k(col/abs)	0.909184 0.0009	0.909521 0.0009	-0.0919
k(absorption)	0.894923	0.910968	0.0011	k(abs/tk ln)	0.909217 0.0009	0.909563 0.0009	-0.1186
k(trk length)	0.910792	0.907465	0.0014	k(tk ln/col)	0.907433 0.0014	0.907404 0.0014	0.9822
rem life(col)	8.2829E+04	8.0301E+04	0.0031	k(col/abs/tk ln)	0.908611 0.0010	0.909564 0.0009	
rem life(abs)	8.1995E+04	8.0262E+04	0.0023	life(col/abs)	8.0281E+04 0.0026	8.0241E+04 0.0022	0.8948

source points generated 3950

source distribution written to file 3c900s cycle = 120

1problem summary

run terminated when 120 kcode cycles were done.

02/08/01 21:41:00

k eff, 74g of Pu-239 in cellulose spheres in 1.5 cubic foot of pure celulose probid = 02/08/01 21:10:07

0

neutron creation	tracks	weight	energy	neutron loss	tracks	weight	energy

		(per source particle)				(per source particle)	
source	478704	1.0027E+00	2.1114E+00	escape	112813	1.9857E-01	1.2551E-01
				energy cutoff	0	0.	0.
				time cutoff	0	0.	0.
weight window	0	0.	0.	weight window	0	0.	0.
cell importance	0	0.	0.	cell importance	0	0.	0.
weight cutoff	0	3.4100E-02	2.0635E-08	weight cutoff	365891	3.4132E-02	4.1910E-06
energy importance	0	0.	0.	energy importance	0	0.	0.
dxtran	0	0.	0.	dxtran	0	0.	0.
forced collisions	0	0.	0.	forced collisions	0	0.	0.
exp. transform	0	0.	0.	exp. transform	0	0.	0.
upscattering	0	0.	3.9717E-07	downscattering	0	0.	1.9605E+00
				capture	0	4.8813E-01	2.4402E-02
(n,xn)	0	0.	0.	loss to (n,xn)	0	0.	0.
fission	0	0.	0.	loss to fission	0	3.1598E-01	9.4770E-04
total	478704	1.0368E+00	2.1114E+00	total	478704	1.0368E+00	2.1114E+00

number of neutrons banked	0		
neutron tracks per source particle	1.0000E+00		
neutron collisions per source particle	7.7321E+01		
total neutron collisions	37013641		
net multiplication	1.0000E+00	0.0000	

average lifetime, shakes		cutoffs	
escape	7.2729E+04	tco	1.0000E+34
capture	8.2471E+04	eco	0.0000E+00
capture or escape	8.0541E+04	wc1	-5.0000E-01
any termination	8.4923E+04	wc2	-2.5000E-01

computer time so far in this run	30.87 minutes	maximum number ever in bank	0
computer time in mcrun	30.86 minutes	bank overflows to backup file	0
source particles per minute	1.5510E+04	field length	0
random numbers generated	671472018	most random numbers used was	13759 in history 443804

range of sampled source weights = 9.3941E-01 to 1.0689E+00

1neutron activity in each cell print table 126

cell		tracks entering	population	collisions	collisions * weight (per history)	number weighted energy	flux weighted energy	average track weight (relative)	average track mfp (cm)
1	1	0	0	0	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2	2	214129	139225	7850790	9.5053E+00	4.9894E-05	2.2953E-01	6.1306E-01	2.1160E+00
4	4	1291594	420991	15488439	2.4695E+01	1.5857E-04	5.3282E-01	8.2570E-01	2.7947E+00
5	5	1138770	410004	13674412	2.1987E+01	1.6360E-04	5.4380E-01	8.3176E-01	2.8245E+00
6	6	9177993	452621	0	0.0000E+00	1.5978E-04	5.3041E-01	8.2042E-01	0.0000E+00
7	7	0	0	0	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
total		11822486	1422841	37013641	5.6188E+01				

1keff results for: k eff, 74g of Pu-239 in cellulose spheres in 1.5 cubic foot of pure celulose probid = 02/08/01 21:10:07

the initial fission neutron source distribution used the 2 source points that were input on the ksrc card.
the criticality problem was scheduled to skip 20 cycles and run a total of 120 cycles with nominally 4000 neutrons per cycle.
this problem has run 20 inactive cycles with 79695 neutron histories and 100 active cycles with 399009 neutron histories.

this calculation has completed the requested number of keff cycles using a total of 478704 fission neutron source histories.
all cells with fissionable material were sampled and had fission neutron source points.

the results of the w test for normality applied to the individual collision, absorption, and track-length keff cycle values are:

the k(collision) cycle values appear normally distributed at the 95 percent confidence level
the k(absorption) cycle values appear normally distributed at the 95 percent confidence level
the k(trk length) cycle values appear normally distributed at the 95 percent confidence level

the final estimated combined collision/absorption/track-length keff = 0.90956 with an estimated standard deviation of 0.00079

the estimated 68, 95, & 99 percent keff confidence intervals are 0.90877 to 0.91036, 0.90798 to 0.91114, and 0.90747 to 0.91166

the estimated collision/absorption neutron removal lifetime = 8.02E-04 seconds with an estimated standard deviation of 1.75E-06

the estimated average keffs, one standard deviations, and 68, 95, and 99 percent confidence intervals are:

keff estimator	keff	standard deviation	68% confidence	95% confidence	99% confidence	corr
collision	0.90740	0.00129	0.90611 to 0.90869	0.90483 to 0.90997	0.90400 to 0.91081	
absorption	0.91097	0.00105	0.90992 to 0.91202	0.90888 to 0.91305	0.90820 to 0.91373	
track length	0.90746	0.00131	0.90615 to 0.90878	0.90486 to 0.91007	0.90401 to 0.91092	
col/absorp	0.90952	0.00080	0.90872 to 0.91032	0.90794 to 0.91110	0.90742 to 0.91162	-0.0919
abs/trk len	0.90956	0.00079	0.90877 to 0.91035	0.90799 to 0.91113	0.90748 to 0.91164	-0.1186
col/trk len	0.90740	0.00130	0.90611 to 0.90870	0.90482 to 0.90999	0.90398 to 0.91083	0.9822
col/abs/trk len	0.90956	0.00079	0.90877 to 0.91036	0.90798 to 0.91114	0.90747 to 0.91166	

if the largest of each keff occurred on the next cycle, the keff results and 68, 95, and 99 percent confidence intervals would be:

keff estimator	keff	standard deviation	68% confidence	95% confidence	99% confidence
collision	0.90767	0.00131	0.90637 to 0.90898	0.90507 to 0.91027	0.90423 to 0.91112
absorption	0.91122	0.00107	0.91015 to 0.91228	0.90909 to 0.91334	0.90840 to 0.91403
track length	0.90774	0.00133	0.90642 to 0.90907	0.90510 to 0.91038	0.90424 to 0.91125
col/abs/trk len	0.90983	0.00083	0.90900 to 0.91066	0.90818 to 0.91148	0.90764 to 0.91202

the estimated collision/absorption neutron lifetimes, one standard deviations, and 68, 95, and 99 percent confidence intervals are:

type	lifetime(sec)	standard deviation	68% confidence	95% confidence	99% confidence
removal	8.0241E-04	1.7499E-06	8.0066E-04 to 8.0417E-04	7.9893E-04 to 8.0590E-04	7.9779E-04 to 8.0704E-04
capture	8.2239E-04	1.7615E-06	8.2063E-04 to 8.2416E-04	8.1889E-04 to 8.2590E-04	8.1774E-04 to 8.2705E-04
fission	7.9294E-04	1.7449E-06	7.9119E-04 to 7.9468E-04	7.8946E-04 to 7.9641E-04	7.8833E-04 to 7.9755E-04
escape	7.2310E-04	4.3600E-06	7.1874E-04 to 7.2747E-04	7.1442E-04 to 7.3179E-04	7.1158E-04 to 7.3462E-04

1average individual and combined collision/absorption/track-length keff results for 7 different batch sizes

cycles per keff batch	number of k batches	average keff estimators and deviations k(col)	st dev	k(abs)	st dev	k(trk)	st dev	normality co/ab/trk	average k(c/a/t) k(c/a/t)	st dev	k(c/a/t) confidence intervals 95% confidence	99% confidence
1	100	0.9074	0.0013	0.9110	0.0010	0.9075	0.0013	95/95/95	0.90956	0.00079	0.90798-0.91114	0.90747-0.91166
2	50	0.9074	0.0013	0.9110	0.0010	0.9075	0.0013	95/95/95	0.90976	0.00080	0.90815-0.91138	0.90761-0.91192
4	25	0.9074	0.0014	0.9110	0.0009	0.9075	0.0014	95/95/95	0.90996	0.00082	0.90825-0.91166	0.90764-0.91228
5	20	0.9074	0.0014	0.9110	0.0011	0.9075	0.0014	95/95/95	0.90957	0.00081	0.90786-0.91128	0.90722-0.91192
10	10	0.9074	0.0013	0.9110	0.0008	0.9075	0.0013	95/95/95	0.91045	0.00054	0.90918-0.91172	0.90857-0.91233
20	5	0.9074	0.0014	0.9110	0.0008	0.9075	0.0014	95/95/95	0.91055	0.00055	0.90818-0.91292	0.90508-0.91602
25	4	0.9074	0.0013	0.9110	0.0013	0.9075	0.0015	95/95/95	0.90982	0.00019	0.90744-0.91220	0.89791-0.92173

1individual and average keff estimator results by cycle

keff cycle	neutron histories	keff estimators by cycle k(coll)	k(abs)	k(track)	average keff estimators and deviations k(coll)	st dev	k(abs)	st dev	k(track)	st dev	average k(c/a/t) k(c/a/t)	st dev	fom
1	4000	0.96748	0.98696	0.96709									
2	3794	0.93827	0.92339	0.93995									

3	3894	0.92078	0.90873	0.92443							
4	3919	0.90901	0.91922	0.90803							
5	3967	0.89108	0.92279	0.89252							
6	3865	0.90149	0.89925	0.89587							
7	4088	0.91314	0.90255	0.91482							
8	4091	0.92797	0.90174	0.92102							
9	3992	0.90975	0.88319	0.91096							
10	3946	0.90681	0.91178	0.90856							
11	4130	0.92592	0.90989	0.92674							
12	3980	0.92612	0.90250	0.92681							
13	3961	0.91623	0.91091	0.91574							
14	3988	0.88260	0.90944	0.88395							
15	3780	0.91932	0.90207	0.91715							
16	4159	0.91335	0.90395	0.91889							
17	3897	0.91852	0.91640	0.92187							
18	4088	0.91279	0.92348	0.91201							
19	4006	0.94281	0.89964	0.93820							
20	4150	0.89947	0.93070	0.90399							
		begin active keff cycles									
21	3781	0.90930	0.92371	0.90797							
22	3907	0.91031	0.88623	0.91458	0.90981	0.00051	0.90497	0.01874	0.91128	0.00331	
23	3970	0.90830	0.91256	0.91148	0.90931	0.00058	0.90750	0.01111	0.91134	0.00191	
24	3935	0.88828	0.91164	0.89108	0.90405	0.00527	0.90853	0.00792	0.90628	0.00524	0.91329 0.00748 14848
25	3956	0.89551	0.91571	0.89773	0.90234	0.00443	0.90997	0.00630	0.90457	0.00441	0.91329 0.00529 23794
26	4063	0.87757	0.90387	0.88112	0.89821	0.00549	0.90895	0.00525	0.90066	0.00531	0.91542 0.00558 17858
27	3913	0.91824	0.90909	0.92152	0.90107	0.00545	0.90897	0.00443	0.90364	0.00539	0.91737 0.00579 14215
28	4258	0.89284	0.92721	0.89396	0.90004	0.00483	0.91125	0.00447	0.90243	0.00482	0.91784 0.00540 14213
29	3871	0.90271	0.89399	0.90158	0.90034	0.00427	0.90933	0.00438	0.90233	0.00425	0.90773 0.00491 15009
30	4061	0.90057	0.91349	0.89544	0.90036	0.00382	0.90975	0.00394	0.90164	0.00387	0.90608 0.00349 26491
31	3919	0.91674	0.91002	0.92018	0.90185	0.00376	0.90977	0.00356	0.90333	0.00388	0.90700 0.00338 25753
32	4015	0.89918	0.91441	0.89626	0.90163	0.00344	0.91016	0.00328	0.90274	0.00359	0.90685 0.00296 30703
33	3797	0.91067	0.91391	0.91033	0.90232	0.00324	0.91045	0.00303	0.90332	0.00336	0.90744 0.00271 33872
34	4055	0.91777	0.89841	0.91831	0.90343	0.00320	0.90959	0.00293	0.90439	0.00329	0.90743 0.00235 41886
35	4032	0.91210	0.90224	0.90989	0.90401	0.00303	0.90910	0.00277	0.90476	0.00308	0.90720 0.00207 50287
36	4082	0.86864	0.91948	0.87247	0.90180	0.00360	0.90975	0.00267	0.90274	0.00352	0.90728 0.00205 47869
37	3797	0.90493	0.90256	0.90564	0.90198	0.00338	0.90932	0.00255	0.90291	0.00331	0.90705 0.00192 51451
38	4159	0.91309	0.91891	0.91707	0.90260	0.00325	0.90986	0.00246	0.90370	0.00322	0.90747 0.00201 44393
39	4059	0.91602	0.90684	0.91689	0.90330	0.00315	0.90970	0.00233	0.90439	0.00312	0.90770 0.00189 47621
40	4028	0.89180	0.91610	0.89029	0.90273	0.00305	0.91002	0.00224	0.90369	0.00304	0.90762 0.00179 50051
41	3764	0.91617	0.92726	0.91585	0.90337	0.00297	0.91084	0.00228	0.90427	0.00295	0.90840 0.00191 42191
42	4160	0.91483	0.91349	0.90865	0.90389	0.00288	0.91096	0.00218	0.90447	0.00282	0.90856 0.00175 48076
43	3924	0.91074	0.91069	0.91091	0.90419	0.00276	0.91095	0.00208	0.90475	0.00271	0.90868 0.00166 50784
44	4009	0.93411	0.90030	0.93551	0.90543	0.00293	0.91050	0.00204	0.90603	0.00290	0.90902 0.00156 55107
45	3989	0.90755	0.91038	0.90843	0.90552	0.00281	0.91050	0.00196	0.90612	0.00278	0.90906 0.00150 57495
46	3977	0.88905	0.92647	0.89118	0.90489	0.00277	0.91111	0.00198	0.90555	0.00273	0.90913 0.00148 57010
47	3875	0.91625	0.89900	0.91641	0.90531	0.00270	0.91067	0.00196	0.90595	0.00266	0.90896 0.00141 60424
48	4102	0.89286	0.92128	0.88860	0.90486	0.00264	0.91104	0.00192	0.90533	0.00264	0.90892 0.00136 62674
49	4025	0.90383	0.91270	0.90139	0.90483	0.00255	0.91110	0.00186	0.90520	0.00255	0.90889 0.00131 65332
50	4092	0.91039	0.93405	0.91021	0.90501	0.00247	0.91187	0.00195	0.90536	0.00247	0.90926 0.00140 55047
51	3986	0.92301	0.90967	0.92133	0.90559	0.00246	0.91180	0.00189	0.90588	0.00244	0.90949 0.00134 57744
52	4033	0.92332	0.91805	0.92269	0.90615	0.00244	0.91199	0.00184	0.90640	0.00242	0.90988 0.00134 56386
53	4053	0.91522	0.90361	0.91661	0.90642	0.00238	0.91174	0.00180	0.90671	0.00237	0.90985 0.00129 58922
54	3870	0.90042	0.90546	0.89884	0.90624	0.00232	0.91155	0.00175	0.90648	0.00231	0.90961 0.00127 58957
55	3980	0.91279	0.92345	0.90964	0.90643	0.00226	0.91189	0.00174	0.90657	0.00224	0.90983 0.00125 58651
56	4063	0.89480	0.89816	0.89159	0.90611	0.00222	0.91151	0.00173	0.90616	0.00222	0.90939 0.00130 53362
57	3890	0.91016	0.90779	0.91110	0.90622	0.00216	0.91141	0.00169	0.90629	0.00216	0.90938 0.00126 55203
58	4078	0.91030	0.89887	0.90996	0.90633	0.00211	0.91108	0.00167	0.90639	0.00211	0.90918 0.00123 56370
59	3960	0.88689	0.91674	0.88896	0.90583	0.00211	0.91123	0.00164	0.90594	0.00210	0.90913 0.00121 56663

60	3840	0.91984	0.91559	0.92420	0.90618	0.00209	0.91133	0.00160	0.90640 0.00210	0.90939 0.00121	55435
61	4209	0.90175	0.90509	0.90448	0.90607	0.00204	0.91118	0.00157	0.90635 0.00205	0.90929 0.00118	56017
62	3916	0.89767	0.91914	0.89770	0.90587	0.00200	0.91137	0.00154	0.90614 0.00201	0.90931 0.00116	56785
63	3917	0.89214	0.91880	0.88903	0.90555	0.00198	0.91154	0.00151	0.90574 0.00200	0.90928 0.00114	57447
64	3976	0.91215	0.90710	0.91644	0.90570	0.00194	0.91144	0.00148	0.90599 0.00197	0.90931 0.00112	58798
65	4001	0.91378	0.90062	0.91512	0.90588	0.00190	0.91120	0.00147	0.90619 0.00194	0.90922 0.00109	60598
66	4000	0.89634	0.90837	0.89743	0.90567	0.00187	0.91114	0.00144	0.90600 0.00190	0.90913 0.00107	60755
67	3974	0.90642	0.90587	0.90920	0.90569	0.00183	0.91103	0.00141	0.90607 0.00186	0.90909 0.00105	61817
68	4059	0.90405	0.91183	0.90149	0.90565	0.00179	0.91105	0.00138	0.90597 0.00183	0.90906 0.00103	63343
69	3981	0.90344	0.89728	0.90189	0.90561	0.00176	0.91077	0.00138	0.90589 0.00179	0.90879 0.00103	62526
70	3946	0.93259	0.92076	0.93184	0.90615	0.00180	0.91097	0.00137	0.90641 0.00183	0.90923 0.00106	57768
71	4156	0.87935	0.89480	0.88016	0.90562	0.00185	0.91065	0.00138	0.90589 0.00187	0.90892 0.00112	50297
72	3742	0.91111	0.90091	0.91113	0.90573	0.00181	0.91046	0.00137	0.90599 0.00183	0.90882 0.00110	51537
73	4153	0.90272	0.89142	0.90313	0.90567	0.00178	0.91010	0.00139	0.90594 0.00180	0.90851 0.00110	50043
74	3848	0.92484	0.90833	0.92276	0.90603	0.00178	0.91007	0.00136	0.90625 0.00179	0.90865 0.00108	51439
75	4109	0.93508	0.91369	0.93561	0.90656	0.00183	0.91013	0.00134	0.90679 0.00184	0.90896 0.00108	50230
76	4043	0.90650	0.92529	0.90205	0.90655	0.00179	0.91041	0.00134	0.90670 0.00181	0.90909 0.00107	50252
77	3762	0.90403	0.92650	0.90166	0.90651	0.00176	0.91069	0.00135	0.90661 0.00178	0.90920 0.00106	49983
78	3868	0.91004	0.93339	0.91466	0.90657	0.00173	0.91108	0.00138	0.90675 0.00175	0.90938 0.00110	46098
79	4008	0.91939	0.91749	0.92023	0.90679	0.00172	0.91119	0.00136	0.90698 0.00174	0.90955 0.00109	45947
80	3946	0.92281	0.90571	0.92636	0.90706	0.00171	0.91110	0.00134	0.90730 0.00174	0.90963 0.00107	46823
81	4003	0.88000	0.92322	0.87632	0.90661	0.00174	0.91130	0.00133	0.90679 0.00178	0.90959 0.00106	46922
82	3817	0.90120	0.91479	0.89908	0.90652	0.00171	0.91135	0.00131	0.90667 0.00176	0.90958 0.00105	47624
83	4164	0.88869	0.92441	0.88896	0.90624	0.00171	0.91156	0.00131	0.90639 0.00175	0.90959 0.00104	47786
84	3896	0.89737	0.90856	0.89085	0.90610	0.00169	0.91151	0.00129	0.90615 0.00174	0.90947 0.00102	48043
85	4084	0.91114	0.91582	0.91129	0.90618	0.00166	0.91158	0.00127	0.90623 0.00172	0.90955 0.00101	48496
86	4107	0.91466	0.91581	0.91492	0.90631	0.00164	0.91164	0.00125	0.90636 0.00170	0.90964 0.00100	48865
87	3954	0.90141	0.93606	0.90091	0.90624	0.00162	0.91201	0.00129	0.90628 0.00167	0.90973 0.00101	47013
88	3924	0.90432	0.88885	0.90694	0.90621	0.00160	0.91167	0.00131	0.90629 0.00165	0.90946 0.00102	45884
89	3999	0.90163	0.90799	0.90076	0.90614	0.00157	0.91161	0.00130	0.90621 0.00163	0.90940 0.00100	46344
90	3985	0.91201	0.91008	0.90842	0.90622	0.00155	0.91159	0.00128	0.90624 0.00160	0.90941 0.00099	47285
91	4086	0.91639	0.90825	0.91521	0.90637	0.00154	0.91154	0.00126	0.90636 0.00158	0.90944 0.00097	48231
92	3892	0.90674	0.91393	0.90613	0.90637	0.00152	0.91158	0.00124	0.90636 0.00156	0.90946 0.00096	48837
93	3939	0.89501	0.91414	0.89341	0.90622	0.00150	0.91161	0.00123	0.90618 0.00155	0.90942 0.00095	49103
94	4050	0.88532	0.91578	0.88659	0.90594	0.00151	0.91167	0.00121	0.90592 0.00155	0.90938 0.00094	48942
95	3955	0.91706	0.93513	0.91518	0.90608	0.00150	0.91198	0.00123	0.90604 0.00154	0.90957 0.00097	45909
96	4171	0.92630	0.90169	0.92117	0.90635	0.00150	0.91185	0.00123	0.90624 0.00153	0.90958 0.00095	47280
97	4011	0.91938	0.89901	0.92088	0.90652	0.00149	0.91168	0.00122	0.90643 0.00152	0.90955 0.00093	48455
98	3861	0.90468	0.89815	0.90562	0.90650	0.00147	0.91151	0.00122	0.90642 0.00150	0.90942 0.00092	48572
99	3970	0.91776	0.90537	0.91493	0.90664	0.00146	0.91143	0.00120	0.90653 0.00149	0.90942 0.00091	49502
100	3913	0.91414	0.92290	0.91536	0.90673	0.00145	0.91157	0.00120	0.90664 0.00147	0.90954 0.00091	48964
101	3948	0.89001	0.89335	0.88924	0.90652	0.00144	0.91135	0.00120	0.90642 0.00147	0.90932 0.00093	46474
102	3889	0.90041	0.90862	0.90230	0.90645	0.00143	0.91131	0.00119	0.90637 0.00145	0.90928 0.00092	46879
103	4015	0.90740	0.91624	0.90588	0.90646	0.00141	0.91137	0.00118	0.90637 0.00143	0.90931 0.00091	47281
104	4060	0.90366	0.90629	0.90376	0.90643	0.00139	0.91131	0.00116	0.90634 0.00142	0.90926 0.00090	47702
105	4083	0.92324	0.91142	0.92358	0.90663	0.00139	0.91131	0.00115	0.90654 0.00142	0.90936 0.00089	48096
106	4139	0.92754	0.91473	0.92966	0.90687	0.00140	0.91135	0.00114	0.90681 0.00142	0.90953 0.00089	47819
107	4023	0.90849	0.91194	0.90694	0.90689	0.00138	0.91136	0.00113	0.90681 0.00141	0.90954 0.00088	48364
108	3969	0.90777	0.90189	0.91099	0.90690	0.00136	0.91125	0.00112	0.90686 0.00139	0.90948 0.00087	48910
109	3964	0.90979	0.91349	0.91074	0.90693	0.00135	0.91128	0.00111	0.90690 0.00138	0.90951 0.00086	49390
110	4025	0.91753	0.90568	0.92178	0.90705	0.00134	0.91122	0.00109	0.90707 0.00137	0.90954 0.00085	50118
111	3998	0.93483	0.91350	0.93451	0.90735	0.00136	0.91124	0.00108	0.90737 0.00139	0.90973 0.00084	49719
112	4154	0.89901	0.90813	0.90070	0.90726	0.00135	0.91121	0.00107	0.90730 0.00138	0.90968 0.00084	49940
113	3785	0.92793	0.89154	0.92758	0.90749	0.00135	0.91100	0.00108	0.90751 0.00138	0.90962 0.00082	51034
114	4147	0.89452	0.89934	0.89691	0.90735	0.00134	0.91087	0.00108	0.90740 0.00137	0.90950 0.00083	50324
115	3869	0.91110	0.90886	0.90909	0.90739	0.00133	0.91085	0.00107	0.90742 0.00136	0.90950 0.00082	50977

116	4103	0.89618	0.93143	0.89763	0.90727	0.00132	0.91106	0.00108	0.90732	0.00134	0.90955	0.00082	50547
117	3968	0.89426	0.91242	0.89458	0.90714	0.00131	0.91108	0.00106	0.90719	0.00134	0.90951	0.00081	50725
118	3938	0.91598	0.91096	0.91671	0.90723	0.00130	0.91108	0.00105	0.90728	0.00133	0.90955	0.00080	51231
119	4132	0.92423	0.91633	0.92200	0.90740	0.00130	0.91113	0.00104	0.90743	0.00132	0.90966	0.00080	51186
120	4077	0.90766	0.89492	0.91079	0.90740	0.00129	0.91097	0.00105	0.90746	0.00131	0.90956	0.00079	51206

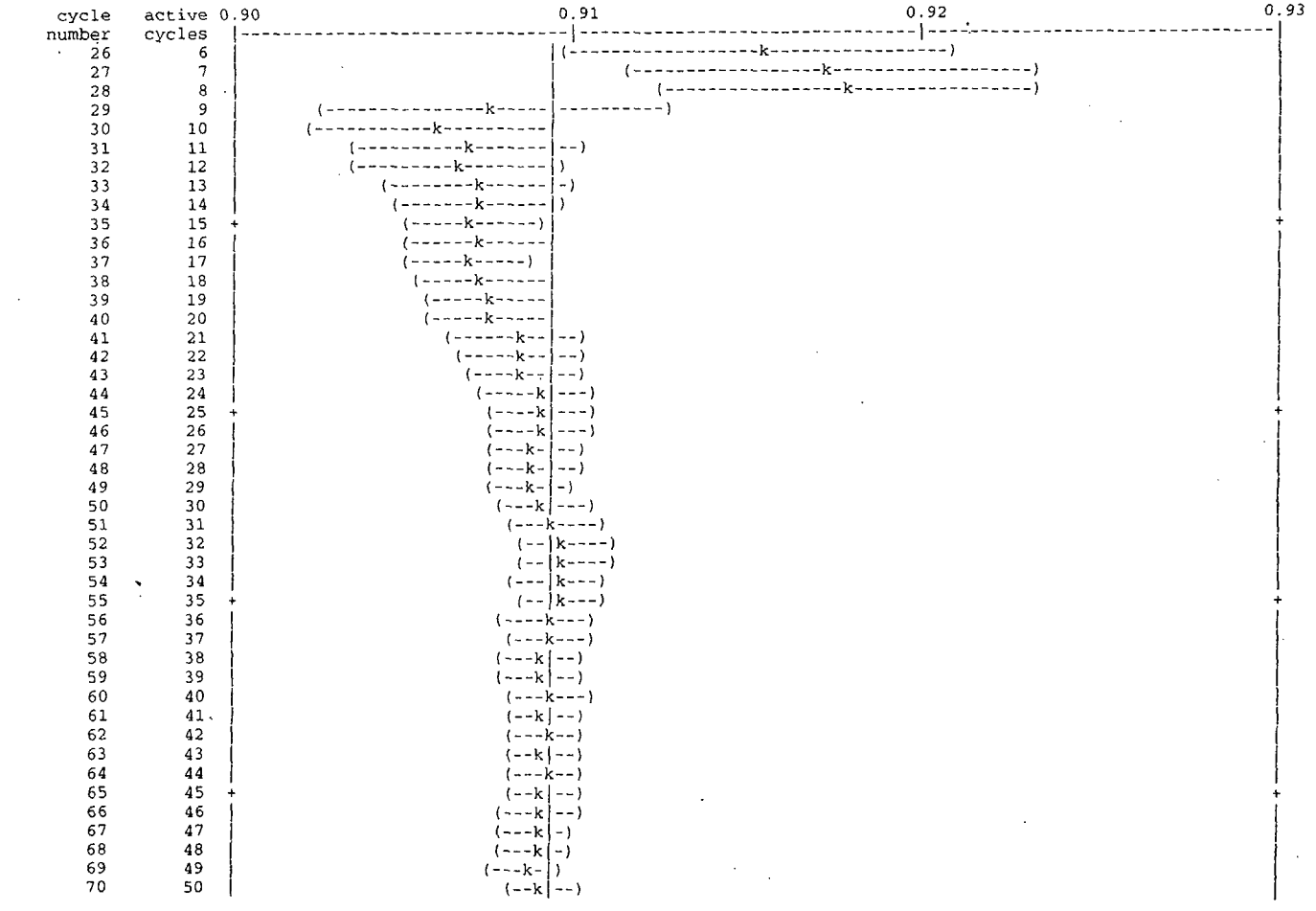
the largest active cycle keffs by estimator are:

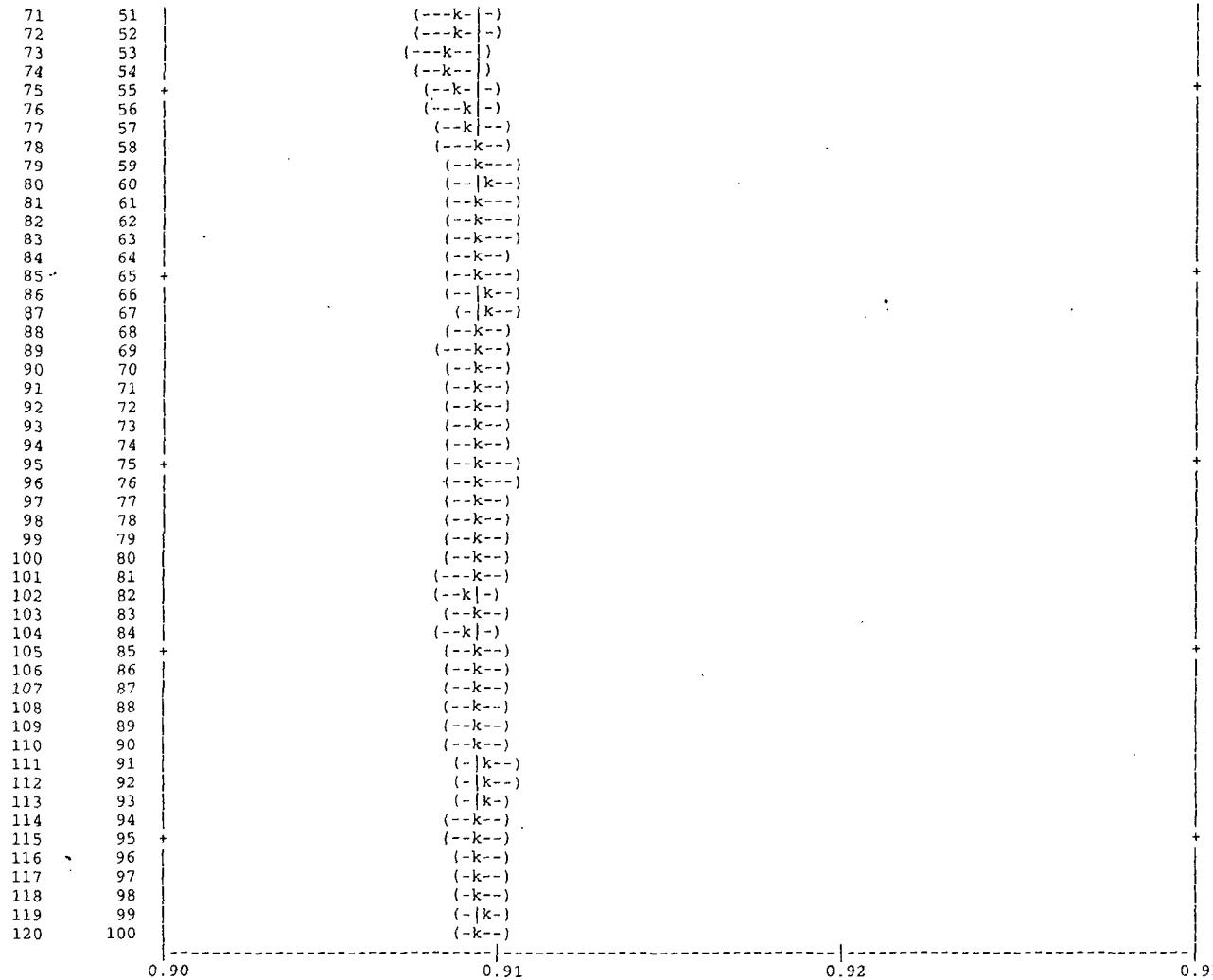
collision 0.93508 on cycle 75
absorption 0.93606 on cycle 87
track length 0.93561 on cycle 75

the smallest active cycle keffs by estimator are:

collision 0.86864 on cycle 36
absorption 0.88623 on cycle 22
track length 0.87247 on cycle 36

1plot of the estimated col/abs/track-length keff one standard deviation interval versus cycle number (| = final keff = 0.90956)





1individual and collision/absorption/track-length keffs for different numbers of inactive cycles skipped for fission source settling

skip cycles	active cycles	active neutrons	average keff estimators and deviations k(col)	st dev	k(abs)	st dev	k(trk)	st dev	normality co/ab/tl	average k(c/a/t) k(c/a/t)	st dev	k(c/a/t) confidence intervals 95% confidence	99% confidence
0	120	478704	0.9090	0.0013	0.9114	0.0012	0.9091	0.0013	99/no/95	0.91040	0.00093	0.90855-0.91225	0.90795-0.91285
1	119	474704	0.9085	0.0012	0.9107	0.0010	0.9086	0.0012	95/95/95	0.90989	0.00073	0.90845-0.91134	0.90798-0.91181
2	118	470910	0.9083	0.0012	0.9106	0.0010	0.9084	0.0012	95/95/95	0.90971	0.00071	0.90829-0.91113	0.90783-0.91159
3	117	467016	0.9082	0.0012	0.9107	0.0010	0.9082	0.0012	95/95/95	0.90966	0.00072	0.90824-0.91109	0.90777-0.91156
4	116	463097	0.9082	0.0012	0.9106	0.0010	0.9082	0.0012	95/95/95	0.90962	0.00072	0.90818-0.91106	0.90772-0.91153

5	115	459130	0.9083	0.0012	0.9105	0.0010	0.9084	0.0012	95/95/95	0.90962	0.00073	0.90817-0.91106	0.90770-0.91154
6	114	455265	0.9084	0.0012	0.9106	0.0010	0.9085	0.0012	95/95/95	0.90973	0.00073	0.90828-0.91117	0.90781-0.91164
7	113	451177	0.9083	0.0013	0.9106	0.0010	0.9084	0.0013	95/95/95	0.90975	0.00073	0.90829-0.91121	0.90781-0.91168
8	112	447086	0.9082	0.0012	0.9107	0.0010	0.9083	0.0013	95/95/95	0.90975	0.00074	0.90827-0.91123	0.90779-0.91171
9	111	443094	0.9081	0.0013	0.9110	0.0010	0.9083	0.0013	95/95/95	0.90992	0.00074	0.90845-0.91139	0.90797-0.91186
10	110	439148	0.9082	0.0013	0.9110	0.0010	0.9083	0.0013	95/95/95	0.90991	0.00074	0.90844-0.91139	0.90795-0.91188
11	109	435018	0.9080	0.0013	0.9110	0.0010	0.9081	0.0013	95/95/95	0.90984	0.00075	0.90835-0.91133	0.90787-0.91182
12	108	431038	0.9078	0.0013	0.9111	0.0010	0.9079	0.0013	95/95/95	0.90982	0.00076	0.90831-0.91133	0.90782-0.91182
13	107	427077	0.9077	0.0013	0.9111	0.0010	0.9079	0.0013	95/95/95	0.90979	0.00076	0.90827-0.91131	0.90777-0.91181
14	106	423089	0.9080	0.0013	0.9111	0.0010	0.9081	0.0013	95/95/95	0.90986	0.00076	0.90834-0.91138	0.90785-0.91187
15	105	419309	0.9079	0.0013	0.9112	0.0010	0.9080	0.0013	95/95/95	0.90988	0.00077	0.90834-0.91142	0.90784-0.91192
16	104	415150	0.9078	0.0013	0.9112	0.0010	0.9079	0.0013	95/95/95	0.90988	0.00078	0.90833-0.91143	0.90782-0.91194
17	103	411253	0.9077	0.0013	0.9112	0.0010	0.9078	0.0013	95/95/95	0.90980	0.00078	0.90824-0.91135	0.90773-0.91186
18	102	407165	0.9077	0.0013	0.9111	0.0010	0.9077	0.0013	95/95/95	0.90971	0.00078	0.90815-0.91128	0.90764-0.91178
19	101	403159	0.9073	0.0013	0.9112	0.0011	0.9074	0.0013	95/95/95	0.90962	0.00080	0.90804-0.91120	0.90752-0.91172
20	100*	399009	0.9074	0.0013	0.9110	0.0010	0.9075	0.0013	95/95/95	0.90956	0.00079	0.90798-0.91114	0.90747-0.91166
22	98	391321	0.9074	0.0013	0.9111	0.0010	0.9074	0.0013	95/95/95	0.90965	0.00080	0.90807-0.91124	0.90755-0.91176
24	96	383416	0.9075	0.0013	0.9111	0.0011	0.9075	0.0014	95/95/95	0.90968	0.00081	0.90807-0.91129	0.90755-0.91181
26	94	375397	0.9080	0.0013	0.9111	0.0011	0.9079	0.0013	95/95/95	0.90982	0.00080	0.90822-0.91142	0.90769-0.91194
28	92	367226	0.9080	0.0013	0.9109	0.0011	0.9079	0.0014	95/95/95	0.90974	0.00082	0.90811-0.91137	0.90758-0.91190
30	90	359294	0.9082	0.0013	0.9111	0.0011	0.9081	0.0014	95/95/95	0.90992	0.00082	0.90828-0.91156	0.90775-0.91210
32	88	351360	0.9082	0.0014	0.9111	0.0011	0.9081	0.0014	95/95/95	0.90990	0.00084	0.90822-0.91157	0.90768-0.91212
34	86	343508	0.9080	0.0014	0.9112	0.0011	0.9080	0.0014	95/95/95	0.90992	0.00086	0.90821-0.91163	0.90765-0.91219
36	84	335394	0.9085	0.0014	0.9112	0.0011	0.9084	0.0014	95/95/95	0.91004	0.00087	0.90831-0.91177	0.90775-0.91233
38	82	327438	0.9085	0.0014	0.9112	0.0012	0.9083	0.0014	95/95/95	0.91003	0.00088	0.90827-0.91179	0.90770-0.91236
40	80	319351	0.9086	0.0014	0.9112	0.0012	0.9084	0.0014	95/95/95	0.91006	0.00090	0.90827-0.91186	0.90768-0.91244
42	78	311427	0.9084	0.0014	0.9110	0.0012	0.9083	0.0015	95/95/95	0.90988	0.00091	0.90808-0.91169	0.90749-0.91228
44	76	303494	0.9080	0.0014	0.9111	0.0012	0.9079	0.0015	95/95/95	0.90978	0.00093	0.90792-0.91165	0.90731-0.91225
46	74	295528	0.9083	0.0014	0.9109	0.0012	0.9081	0.0015	95/95/95	0.90977	0.00096	0.90787-0.91168	0.90724-0.91231
48	72	287551	0.9084	0.0015	0.9109	0.0013	0.9083	0.0015	95/95/95	0.90985	0.00098	0.90789-0.91181	0.90725-0.91245
50	70	279434	0.9084	0.0015	0.9106	0.0012	0.9084	0.0015	95/95/95	0.90970	0.00098	0.90774-0.91166	0.90709-0.91231
52	68	271415	0.9080	0.0015	0.9105	0.0013	0.9080	0.0016	95/95/95	0.90946	0.00100	0.90746-0.91145	0.90680-0.91211
54	66	263492	0.9080	0.0016	0.9107	0.0013	0.9080	0.0016	95/95/95	0.90956	0.00103	0.90751-0.91162	0.90684-0.91229
56	64	255449	0.9081	0.0016	0.9107	0.0013	0.9082	0.0016	95/95/95	0.90966	0.00103	0.90761-0.91171	0.90693-0.91239
58	62	247481	0.9081	0.0016	0.9109	0.0014	0.9081	0.0017	95/95/95	0.90979	0.00106	0.90767-0.91190	0.90697-0.91260
60	60	239681	0.9082	0.0016	0.9107	0.0014	0.9082	0.0017	95/95/95	0.90968	0.00107	0.90753-0.91184	0.90682-0.91255
62	58	231556	0.9085	0.0017	0.9107	0.0014	0.9084	0.0017	95/95/95	0.90976	0.00111	0.90754-0.91197	0.90680-0.91271
64	56	223663	0.9087	0.0017	0.9106	0.0015	0.9086	0.0018	95/95/95	0.90978	0.00114	0.90748-0.91207	0.90672-0.91283
66	54	215662	0.9089	0.0018	0.9108	0.0015	0.9087	0.0018	95/95/95	0.90995	0.00118	0.90758-0.91232	0.90679-0.91311
68	52	207629	0.9090	0.0018	0.9109	0.0016	0.9088	0.0019	95/95/95	0.91005	0.00123	0.90759-0.91251	0.90676-0.91333
70	50	199702	0.9087	0.0018	0.9110	0.0016	0.9085	0.0019	95/95/95	0.90994	0.00122	0.90749-0.91239	0.90667-0.91320
72	48	191804	0.9092	0.0018	0.9115	0.0016	0.9091	0.0019	95/95/95	0.91046	0.00117	0.90809-0.91282	0.90730-0.91361
74	46	183803	0.9090	0.0019	0.9120	0.0016	0.9089	0.0019	95/95/95	0.91069	0.00118	0.90830-0.91308	0.90749-0.91388
76	44	175651	0.9085	0.0018	0.9117	0.0017	0.9084	0.0019	95/95/95	0.91023	0.00120	0.90781-0.91264	0.90699-0.91346
78	42	168021	0.9085	0.0019	0.9108	0.0016	0.9085	0.0020	95/95/95	0.90983	0.00118	0.90744-0.91223	0.90663-0.91304
80	40	160067	0.9079	0.0020	0.9108	0.0017	0.9077	0.0020	95/95/95	0.90945	0.00122	0.90697-0.91193	0.90612-0.91277
82	38	152247	0.9088	0.0019	0.9103	0.0017	0.9088	0.0019	95/95/95	0.90961	0.00126	0.90705-0.91217	0.90618-0.91304
84	36	144187	0.9097	0.0019	0.9100	0.0018	0.9098	0.0019	95/95/95	0.90998	0.00128	0.90738-0.91258	0.90649-0.91347
86	34	135996	0.9095	0.0020	0.9097	0.0019	0.9096	0.0020	95/95/95	0.90971	0.00134	0.90698-0.91244	0.90603-0.91338
88	32	128118	0.9099	0.0021	0.9095	0.0017	0.9100	0.0021	95/95/95	0.90970	0.00133	0.90697-0.91242	0.90603-0.91336
90	30	120134	0.9101	0.0023	0.9095	0.0018	0.9103	0.0022	95/95/95	0.90996	0.00142	0.90705-0.91287	0.90604-0.91388
92	28	112156	0.9100	0.0024	0.9094	0.0019	0.9103	0.0024	95/95/95	0.90993	0.00153	0.90678-0.91308	0.90566-0.91419
94	26	104167	0.9116	0.0023	0.9090	0.0021	0.9119	0.0022	95/95/95	0.91048	0.00165	0.90708-0.91389	0.90586-0.91511
96	24	96041	0.9107	0.0024	0.9082	0.0019	0.9113	0.0024	95/95/95	0.90967	0.00171	0.90611-0.91324	0.90483-0.91452
98	22	88169	0.9106	0.0026	0.9091	0.0020	0.9112	0.0026	95/95/95	0.91006	0.00179	0.90632-0.91380	0.90495-0.91517
100	20	80286	0.9101	0.0028	0.9086	0.0021	0.9108	0.0028	95/95/95	0.90975	0.00192	0.90571-0.91380	0.90419-0.91531

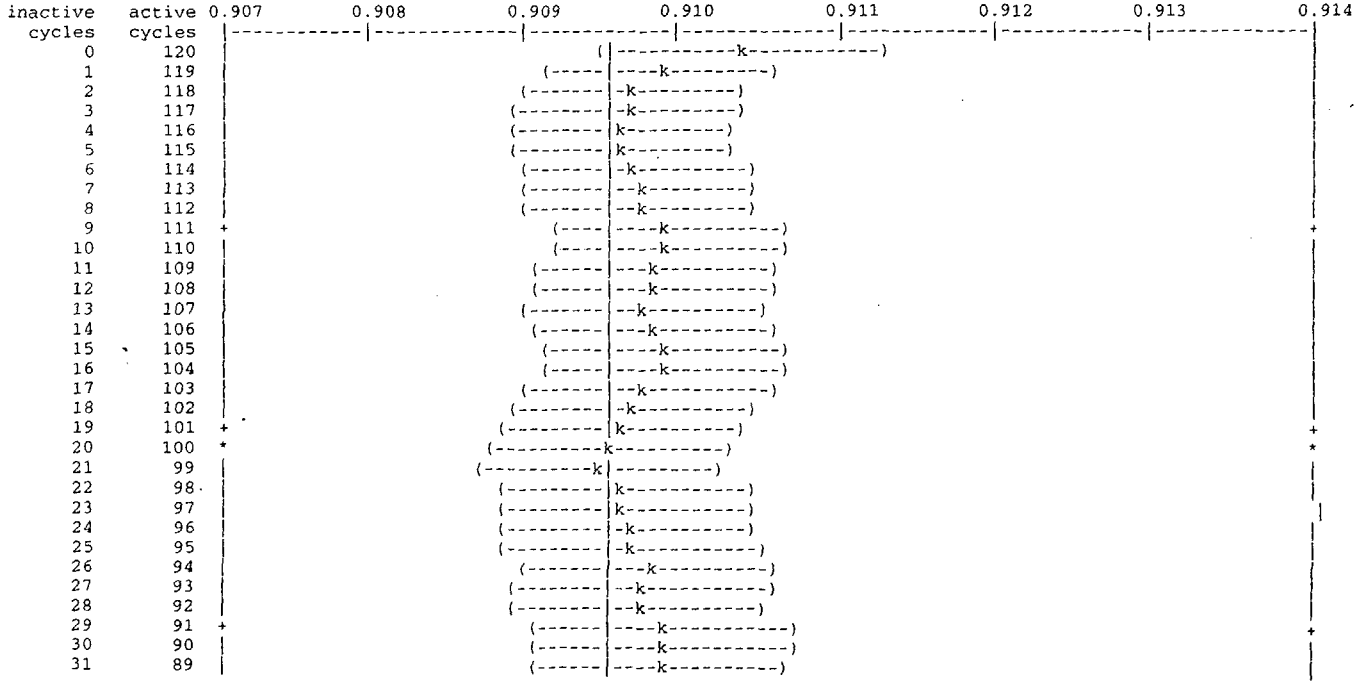
102	18	72449	0.9117	0.0029	0.9094	0.0021	0.9124	0.0028	95/95/95	0.91123	0.00174	0.90751-0.91495	0.90609-0.91638
104	16	64374	0.9125	0.0032	0.9092	0.0023	0.9134	0.0031	95/95/95	0.91174	0.00203	0.90736-0.91612	0.90563-0.91785
106	14	56152	0.9107	0.0033	0.9086	0.0026	0.9115	0.0032	95/95/95	0.91093	0.00198	0.90658-0.91528	0.90480-0.91707
108	12	48160	0.9111	0.0039	0.9089	0.0030	0.9119	0.0037	95/95/95	0.91140	0.00236	0.90607-0.91673	0.90375-0.91905
110	10	40171	0.9106	0.0047	0.9087	0.0036	0.9110	0.0044	95/95/95	0.91108	0.00245	0.90528-0.91688	0.90250-0.91966
112	8	32019	0.9090	0.0047	0.9082	0.0046	0.9094	0.0043	95/95/95	0.90985	0.00236	0.90378-0.91592	0.90033-0.91937
114	6	24087	0.9082	0.0047	0.9125	0.0048	0.9085	0.0043	95/95/95	0.91067	0.00302	0.90106-0.92027	0.89304-0.92829
116	4	16115	0.9105	0.0064	0.9087	0.0047	0.9110	0.0059	95/95/95	0.91085	0.00231	0.88153-0.94017	0.76401-1.05769
117	3	12147	0.9160	0.0048	0.9074	0.0064	0.9165	0.0032					
118	2	8209	0.9159	0.0083	0.9056	0.0107	0.9164	0.0056					

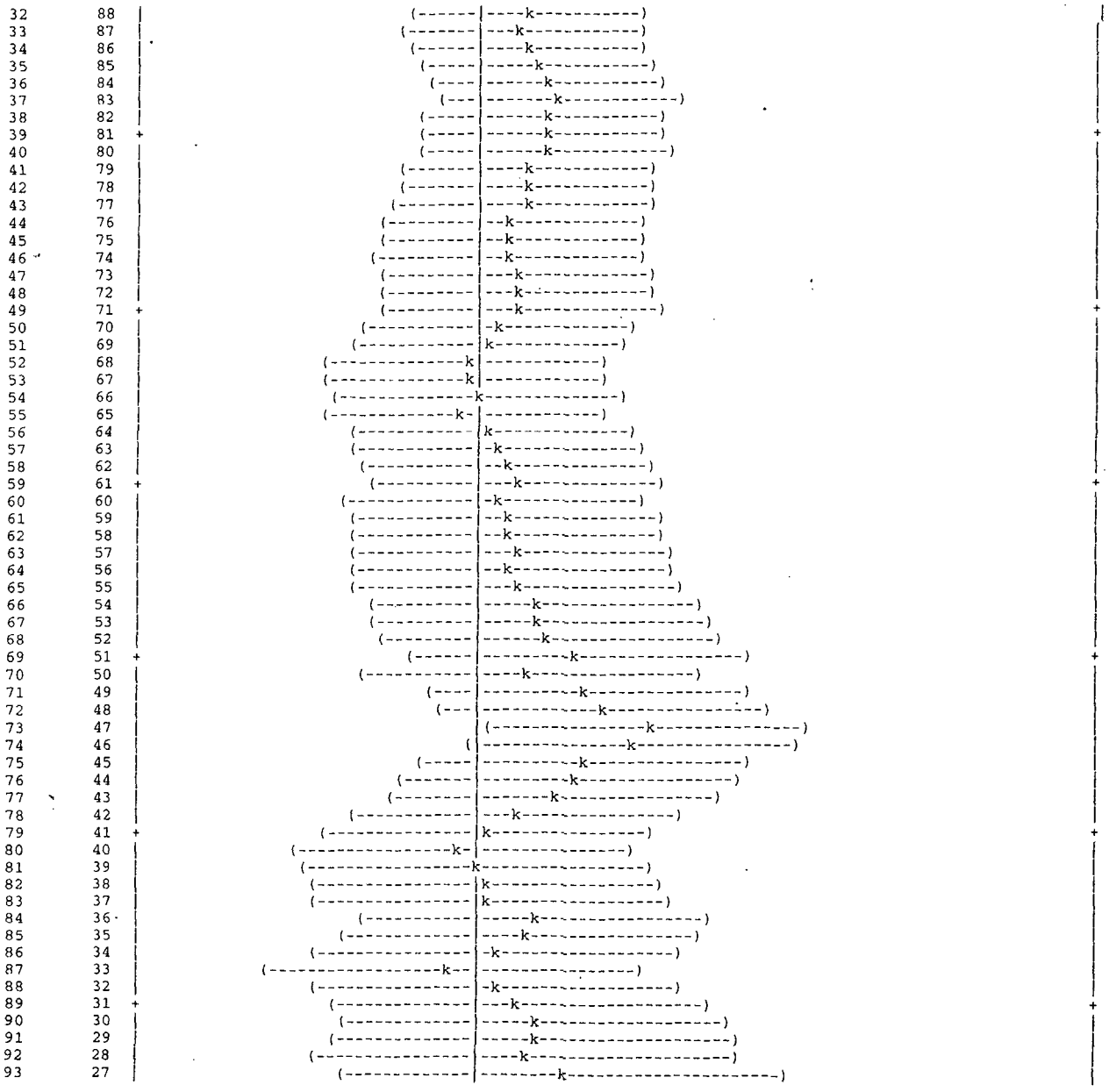
the minimum estimated standard deviation for the col/abs/tl keff estimator occurs with 2 inactive cycles and 118 active cycles.

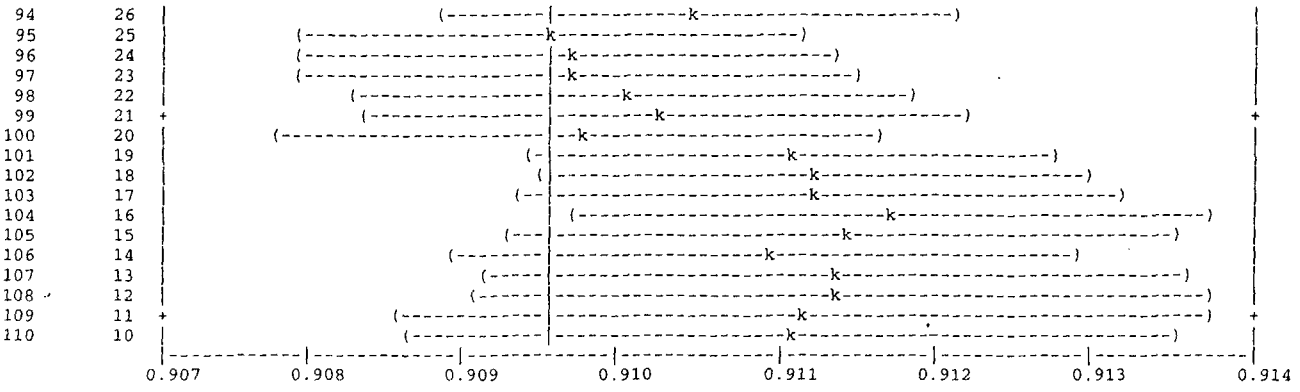
the first active half of the problem skips 20 cycles and uses 50 active cycles; the second half skips 70 and uses 50 cycles.
the col/abs/trk-len keff, one standard deviation, and 68, 95, and 99 percent intervals for each active half of the problem are:

problem	keff	standard deviation	68% confidence	95% confidence	99% confidence
first half	0.90923	0.00106	0.90817 to 0.91029	0.90710 to 0.91136	0.90639 to 0.91207
second half	0.90994	0.00122	0.90871 to 0.91116	0.90749 to 0.91239	0.90667 to 0.91320
final result	0.90956	0.00079	0.90877 to 0.91036	0.90798 to 0.91114	0.90747 to 0.91166

the first and second half values of k(collision/absorption/track length) appear to be the same at the 68 percent confidence level.
1plot of the estimated col/abs/track-length keff one standard deviation interval by active cycle number (| = final keff = 0.90956)







dump no. 4 on file 3c900r nps = 478704 coll = 37013641 ctm = 30.86 nrn = 671472018

3 warning messages so far.

run terminated when 120 kcode cycles were done.

computer time = 30.88 minutes

mcnp version 4a 10/01/93 02/08/01 21:41:00 probid = 02/08/01 21:10:07

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Calculation Cover Page

3065 Southwestern Boulevard
Suite 202
Orchard Park, NY 14127
716 675 7130 Tel
716 675 7137 Fax

Job No: **30822-244-330 /6860** Calculation No: **BUF-2001-012/Rev. 0** Date: **February 25, 2001**

Problem Statement & Calculation Objectives:

To determine the Pu-239 mass sub-critical limit for $\infty \times \infty \times 12$ ft arrays of 2.0-cubic-foot boxes with Pu-239-cellulose spheres and pure cellulose or void outside the sphere. Every box has 1 sphere containing the same amount of Pu-239.

References and Data Available:

J. F. Briemiester, ed., MCNP - A General Purpose Monte Carlo N-Particle Transport Code, Version 4A, LA-12625, Los Alamos National Laboratory, Los Alamos NM, 1993
C. D. Harmon, II et al., Criticality Calculations with MCNP: A Primer, Manual LA-12827, Los Alamos National Laboratory, Los Alamos NM, 1993
D. R. Lide, CRC Handbook of Chemistry an Physics, CRC Press, Boston MA, 1991.
F. H. Attix, Introduction to Radiological Physics and Radiation Dosimetry. John Wiley & Sons, Inc., New York NY, 1986

Attachments:

Attachment 1: MCNP surface and cell numbers
Attachment 2: MCNP input file
Attachment 3: MCNP output file

Prepared by:

Signature Igor V. Chichkov — Date 02/25/2001

Checked by:

Signature Joseph C. Wolniewicz — Date 02/27/01

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Client WVNS Subject: cellulose-Pu-239 spheres Chk'd Date 02/27/01

Analysis

Assumptions

- Pu-239 inside the sphere is uniformly mixed with 0.72 g/cm^3 cellulose
- The pure cellulose (0.72 g/cm^3) fills the entire space inside the container and outside the Plutonium sphere.
- The containers stand on the 3 m thick concrete floor
- The box inside dimensions are 2.0 x 2.0 x 2.0 foot
- The box wall thickness is zero
- Every box in the array contains the same mass of Pu-239
- The boxes are arranged in the infinite square array, 12 feet heigh ($\infty \times \infty \times 12$ ft)

MCNP Model

Neutron multiplication factors were calculated with MCNP4A code. Attachments 1 has the drawings of the models used. Examples of MCNP input and output files for both cases can also be found in the Attachments. The plutonium spheres were located in the box's corner as shown in Attachments 1.

Air, Carbon Steel, Concrete and Cellulose Composition

Table 1 shows the element weight fractions for air (Attix F.H., 1986). Table 2 shows the element composition of concrete (Harmon C. D., II et al., 1993) in the floor.

Table 1. Air composition

Element	Weight Fraction
Carbon (C)	0.000124
Nitrogen (N)	0.755267
Oxygen (O)	0.231781
Argon (Ar)	0.012827

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Table 2. Concrete composition

Element	Weight Fraction
Hydrogen (H)	0.010
Oxygen (O)	0.532
Sodium (Na)	0.029
Aluminum (Al)	0.034
Silicon (Si)	0.337
Calcium (Ca)	0.044
Iron (Fe)	0.014

The weight fractions of the elements composing the cellulose were determined based on the known atomic weights of the elements (Table 3) and the cellulose chemical formula - $C_6H_{10}O_5$.

Table 3. The atomic weights of the elements

Element	Atomic Weight
Hydrogen (H)	1.00794
Carbon (C)	12.0107
Oxygen (O)	15.9994

The molecular weight of cellulose ($C_6H_{10}O_5$) was calculated as the sum of all atomic weights composing the molecule. The weight fraction of an ith element was found as a ratio of the ith element weight in the molecule to the molecular weight of this molecule.

$$(w_i)_{cel} = \frac{n_i A_i}{M_{cel}} = \frac{n_i A_i}{\sum n_i A_i} \qquad (1)$$

where

$(w_i)_{cel}$ = the weight fraction of ith element in a molecule of cellulose

n_i = the number of the ith elements in a cellulose molecule

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A_i = the atomic weight of the ith element, g/mol

M_{cel} = the molecular weight a cellulose molecule, g/mol

Calculated weight fractions for cellulose are shown in Table 4.

Table 4. Cellulose Weight Fractions

Element	Weight Fraction
Hydrogen (H)	0.062
Carbon (C)	0.444
Oxygen (O)	0.493

Radii of the Plutonium containing spheres.

The spheres with several different radii were studied. The minimum size of the Plutonium containing sphere corresponded to the sphere with pure Pu-239 and the maximum size was limited by the dimensions of the container, i.e. half of the box height. The minimum radius equation (3) was derived from the volume of a sphere equation (2)

$$V_{Pu} = \frac{4\pi\left(R_{Pu}\right)^3}{3} \qquad (2)$$

$$R_{\min} = R_{Pu} = \sqrt[3]{\frac{3V_{Pu}}{4\pi}} = \sqrt[3]{\frac{3m_{Pu}}{4\pi\rho_{Pu}}} \qquad (3)$$

where:

R_{min} = the minimum possible radius of the sphere containing Pu-239, cm

R_{Pu} = the radius of the metal Plutonium sphere, cm

V_{Pu} = the volume of the sphere with Pu-239, cm^3

m_{Pu} = the mass of the Plutonium sphere, g

ρ_{Pu} = the density of the metal Plutonium, 19.78 g/cm^3

Composition of the Plutonium containing spheres

The weight fractions of the elements composing the mixture are defined as the ratio of the mass of the element in the mixture to the total mass of the mixture. Total mass of the mixture was determined using

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equation (4):

$$M_{total} = m_{Pu} + m_{cel} = m_{Pu} + V_{cel}\rho_{cel} =$$

$$= m_{Pu} + \left(V_{Total} - V_{Pu}\right)\rho_{cel} = m_{Pu} + \left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel} \qquad (4)$$

where

M_{Total} = the total mass of the mixture, g

m_{Pu} = the mass of Pu-239 in a sphere, g

m_{cel} = the mass of a cellulose in a sphere, g

V_{Total} = the total volume of a sphere, cm^3

V_{cel} = the volume of a cellulose in the sphere, cm^3

ρ_{cel} = the density of a cellulose, 0.72 g/cm^3

V_{Pu} = the volume of Pu-239 in the sphere, cm^3

ρ_{Pu} = the density of the metal Plutonium, 19.78 g/cm^3

R = the radius of a Plutonium containing sphere, cm

In the Plutonium-cellulose mixture, the weight fraction of Pu-239 was calculated using equation 5, and the weight fractions of elements composing cellulose were calculated using equation 7 as a product of the weight fraction of a cellulose in the Plutonium-cellulose mixture (equation 6) and the weight fraction of an element in a pure cellulose (equation 1).

$$w_{Pu} = \frac{m_{Pu}}{M_{total}} = \frac{m_{Pu}}{m_{Pu} + \left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel}} \qquad (5)$$

$$w_{cel} = \frac{m_{cel}}{M_{total}} = \frac{\left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel}}{m_{Pu} + \left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel}} \qquad (6)$$

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$$w_i = w_{cel}(w_i)_{cel} = \frac{\left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel} n_i A_i}{\left[m_{Pu} + \left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel}\right]\sum n_i A_i} \qquad (7)$$

All variables in equations 5-7 are as described above. Table 6 shows the composition of the Plutonium containing spheres.

The cases for spheres with 100g, 150g, and 200g of Pu-239 were studied and based on the calculated neutron multiplication factors, the Pu-239 sub-critical mass limit was determined. Tables 5-7 show the composition of the spheres used in the models.

Table 5. The composition of the spheres with 100g of Pu-239.

Radius of the sphere, cm	5	10	15	20	30.48
Mixture density, g/cm^3	0.904033967	0.743004246	0.726816073	0.722875531	0.720812387
Pu-239 weight fraction	0.211259686	0.032130693	0.00973225	0.00412817	0.00116962
Carbon (C) weight fraction	0.350559575	0.430174351	0.440129452	0.442620211	0.443935155
Hydrogen (H)weight fraction	0.049031699	0.060167175	0.061559565	0.06190794	0.062091857
Oxygen (O) weight fraction	0.389149041	0.477527781	0.488578737	0.491343677	0.49280337

Table 6. The composition of the spheres with 150g of Pu-239.

Radius of the sphere, cm	5	10	15	20	30.48
Mixture density, g/cm^3	0.99605095	0.754506369	0.730224109	0.724313296	0.721218581
Pu-239 weight fraction	0.287614702	0.047461312	0.014530237	0.006179968	0.00175344
Carbon (C) weight fraction	0.316623206	0.42336058	0.437996961	0.44170828	0.443675673
Hydrogen (H)weight fraction	0.044285123	0.059214154	0.0612613	0.061780391	0.062055564
Oxygen (O) weight fraction	0.351476969	0.469963954	0.486211502	0.490331361	0.492515324

Table 7. The composition of the spheres with 200g of Pu-239.

Radius of the sphere, cm	5	10	15	20	30.48
Mixture density, g/cm^3	1.088067933	0.766008492	0.733632146	0.725751061	0.721624775
Pu-239 weight fraction	0.351055161	0.062331532	0.019283654	0.008223633	0.0023366
Carbon (C) weight fraction	0.288426777	0.416751437	0.435884283	0.440799963	0.443416482
Hydrogen (H)weight fraction	0.040341374	0.058289753	0.060965806	0.061653347	0.062019312
Oxygen (O) weight fraction	0.320176688	0.462627278	0.48386626	0.489323057	0.49222760

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Results

The results of the calculations performed using MCNP-4A code are shown in the following tables and graphs. Tables 8-10 provide the Monte Carlo determined neutron multiplication factor (k_{eff}) values and their standard deviations (σ), and Figures 1-3 plot the k_{eff} +2 σ values for all studied cases (100g, 150g, and 200g).

Table 8. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for the boxes with 100 g of Pu-239.

R and X-, Y-, Z- coordinates for the center of the sphere, cm					cellulose outside the sphere			void outside the sphere		
R	X	Y	Z1	Z2	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$
5	5	5	55.96	65.96	0.5412	0.0012	0.5435	0.1056	0.0006	0.1068
10	10	10	50.96	70.96	0.7450	0.0012	0.7473	0.4390	0.0012	0.4414
15	15	15	45.96	75.96	0.6463	0.0010	0.6484	0.6750	0.0010	0.6770
20	20	20	40.96	80.96	0.4827	0.0006	0.4838	0.6769	0.0007	0.6783
30.48	30.48	30.48	30.48	91.44	0.2773	0.0003	0.2778	0.4076	0.0002	0.4081

Table 9. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for the boxes with 150 g of Pu-239.

R and X-, Y-, Z- coordinates for the center of the sphere, cm					cellulose outside the sphere			void outside the sphere		
R	X	Y	Z1	Z2	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$
5	5	5	55.96	65.96	0.5653	0.00113	0.5676	0.1225	0.0006	0.1237
10	10	10	50.96	70.96	0.81627	0.00129	0.8189	0.48937	0.00134	0.4921
15	15	15	45.96	75.96	0.7708	0.0011	0.7730	0.8009	0.0012	0.8033
20	20	20	40.96	80.96	0.6187	0.0008	0.6203	0.8459	0.0008	0.8474
30.48	30.48	30.48	30.48	91.44	0.3858	0.0004	0.3866	0.5557	0.0003	0.5563

Table 10. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for the boxes with 200 g of Pu-239.

R and X-, Y-, Z- coordinates for the center of the sphere, cm					cellulose outside the sphere			void outside the sphere		
R	X	Y	Z1	Z2	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$
5	5	5	55.96	65.96	0.5798	0.0013	0.5823	0.1371	0.0006	0.1384
10	10	10	50.96	70.96	0.8555	0.0015	0.8586	0.52236	0.00139	0.5251
15	15	15	45.96	75.96	0.8524	0.0011	0.8546	0.8769	0.0014	0.8797
20	20	20	40.96	80.96	0.7179	0.0008	0.7196	0.9654	0.0009	0.9671
30.48	30.48	30.48	30.48	91.44	0.4797	0.0004	0.4804	0.6783	0.0003	0.6789

URS

Sheet No. 8/11
Calc. No. BUF-2001-012
Rev. No. 0

Job No 30822-244-330 /6860 Job: PSR-6 By JVC Date 02/25/2001
Client WVNS Subject: cellulose-Pu-239 spheres Chk'd. Date 02/27/01

Figure 1. k_{eff} +2σ for the boxes with 100 g of Pu-239 .

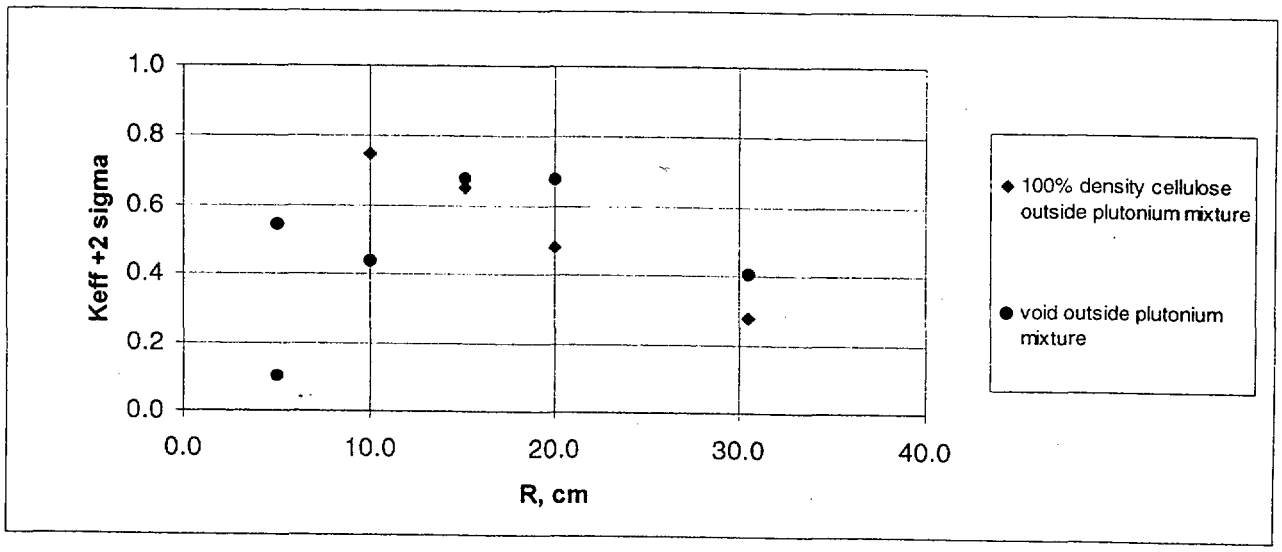
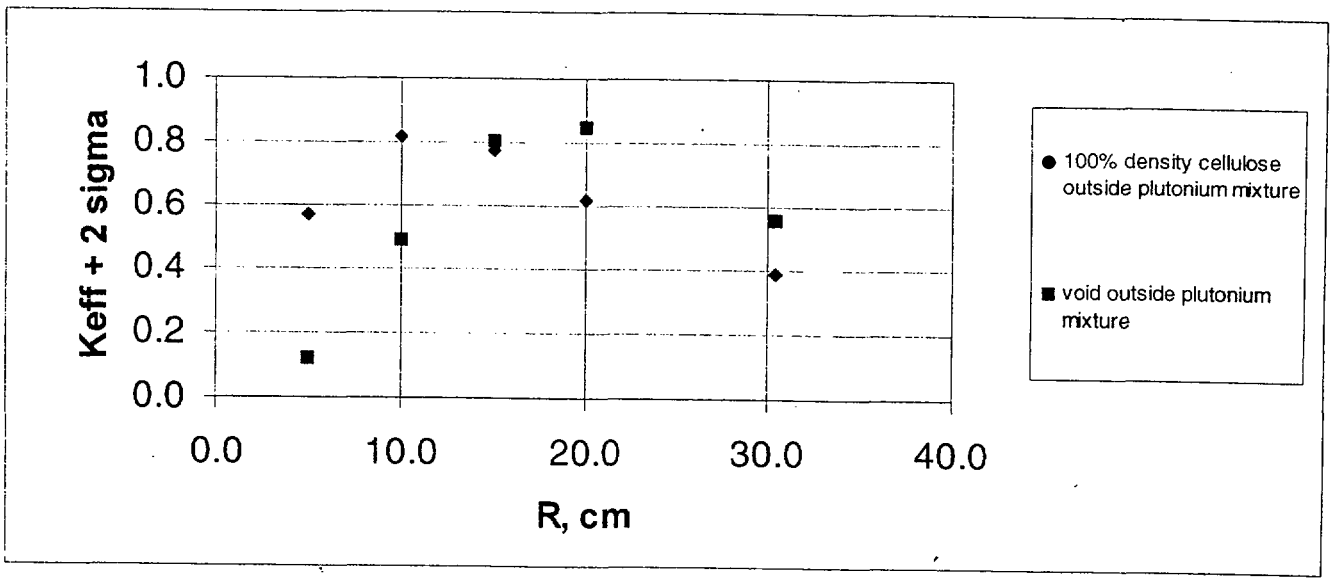


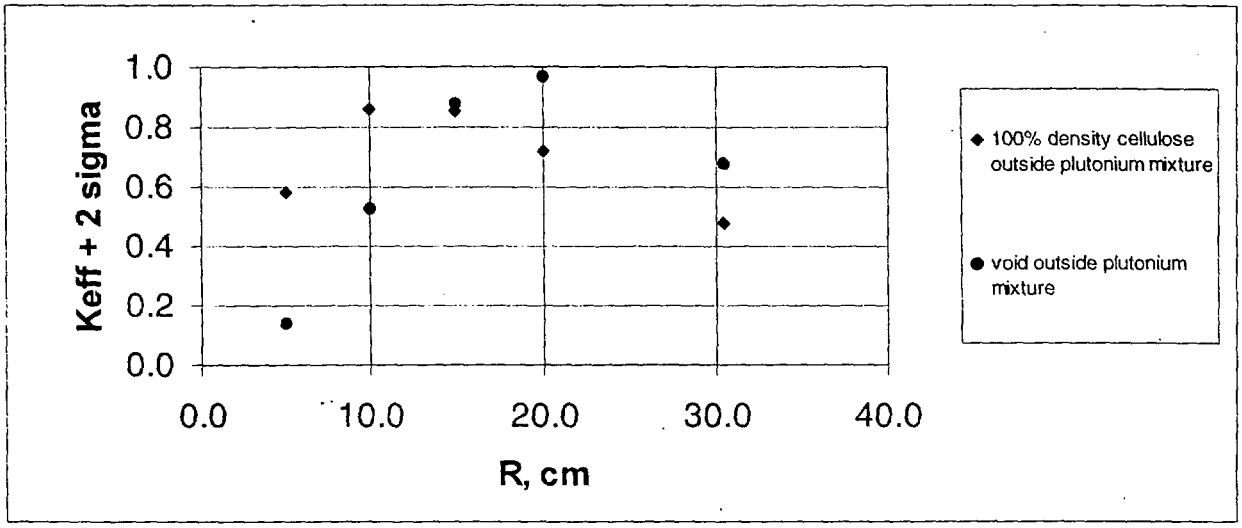
Figure 2. k_{eff} +2σ for the boxes with 150 g of Pu-239 .



URS

Job No 30822-244-330 /6860 Job: PSR-6 By IVC Date 02/25/2001
Client WVNS Subject: cellulose-Pu-239 spheres Chk'd Date 02/27/01

Figure 3. k_{eff} +2σ for the boxes with 200 g of Pu-239.



The criterion for the Pu-239 mass limit is:

$$k_{eff} + 2\sigma \leq k_a - \Delta k_b - \sigma_b \quad (8)$$

Where:

k_{eff} = neutron multiplication factor predicted by MCNP

σ = standard deviation of predicted k_{eff}

$k_a = 0.95$ = established allowable limiting neutron multiplication factor

Δk_b = calculation method bias

σ_b = bias uncertainty

The calculation method bias together with bias uncertainty ($\Delta k_b + \sigma_b$) is no more than 0.02. Thus the criterion (8) can be modified as:

$$k_{eff} + 2\sigma \leq 0.93 \quad (9)$$

Where:

k_{eff} = neutron multiplication factor predicted by MCNP

σ = standard deviation of predicted k_{eff}

To determine the Pu-239 mass limit, the maximum values of k_{eff} +2σ as a function of Pu-239 mass (Table 11) were approximated with a polynomial equation, which is shown on Figure 4.

URS

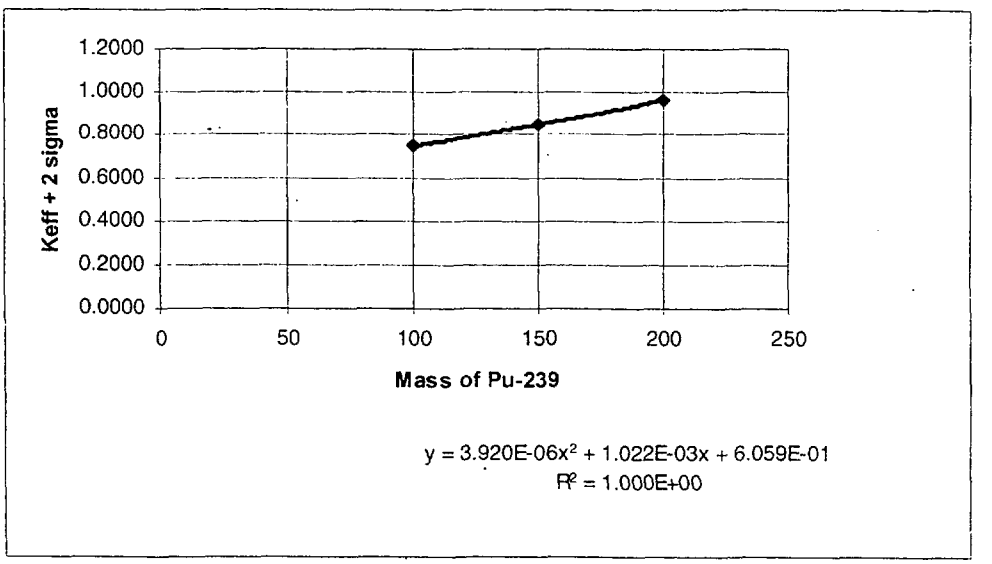
Sheet No. 10/11
Calc. No. BUF-2001-012
Rev. No. 0

Job No 30822-244-330 /6860 Job: PSR-6 By IVC Date 02/25/2001
Client WVNS Subject: cellulose-Pu-239 spheres Chk'd. [illegible] Date 02/27/01

Table 11. The maximum values of k_{eff} +2σ as a function of Pu-239 mass.

Mass of Pu-239, g	k_{eff}	σ	k_{eff} + 2σ
100	0.7450	0.0012	0.7473
150	0.8459	0.0008	0.8474
200	0.9654	0.0009	0.9671

Figure 4. The maximum values of k_{eff} +2σ as a function of Pu-239 mass.



Solving the polynomial equation from Figure 4 determines the Pu-239 mass limit as 183g per box. To check this result, another set of MCNP runs was performed. Table 12 shows the composition of the Plutonium containing spheres, and Table 13 and Figure 5 show the calculation results for the arrays of boxes with 183g of Pu-239.

Table 12. The composition of the spheres with 183g of Pu-239

Radius of the sphere, cm	5	10	15	20	30.48
Mixture density, g/cm³	1.056782159	0.76209777	0.732473413	0.725262221	0.721486669
Pu-239 weight fraction	0.330724977	0.05732602	0.017672453	0.0075297	0.0021384
Carbon (C) weight fraction	0.297462629	0.418976162	0.436600388	0.441108387	0.443504574
Hydrogen (H)weight fraction	0.041605191	0.058600919	0.061065965	0.061696486	0.062031633
Oxygen (O) weight fraction	0.330207203	0.4650969	0.484661194	0.489665432	0.492325391

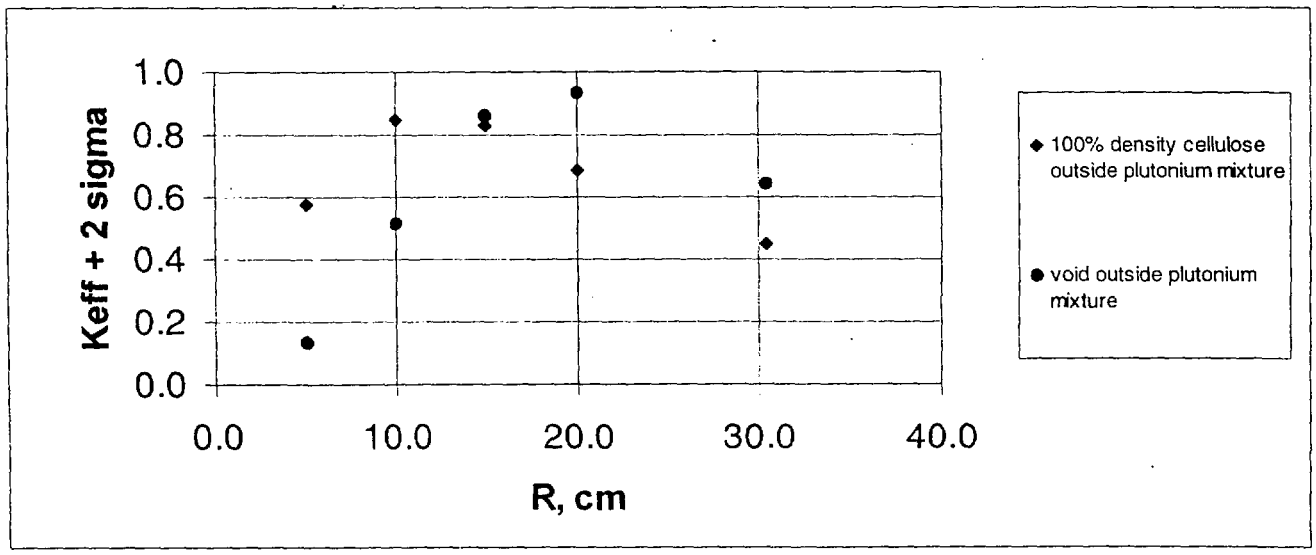
URS

Job No 30822-244-330 /6860 Job: PSR-6 By IVC Date 02/25/2001
Client WVNS Subject: cellulose-Pu-239 spheres Chk'd Date 02/27/01

Table 13. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for the boxes with 183 g of Pu-239.

R and X-, Y-, Z- coordinates for the center of the sphere, cm					cellulose outside the sphere			void outside the sphere		
R	X	Y	Z1	Z2	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$
5	5	5	55.96	65.96	0.5751	0.0011	0.5774	0.1335	0.0006	0.1348
10	10	10	50.96	70.96	0.8427	0.0015	0.8456	0.51305	0.00139	0.5158
15	15	15	45.96	75.96	0.8274	0.0012	0.8297	0.8561	0.0012	0.8585
20	20	20	40.96	80.96	0.6857	0.0008	0.6873	0.9293	0.0008	0.9308
30.48	30.48	30.48	30.48	91.44	0.4490	0.0004	0.4499	0.6393	0.0004	0.6400

Figure 5. $k_{eff}+2\sigma$ for the boxes with 183g of Pu-239.



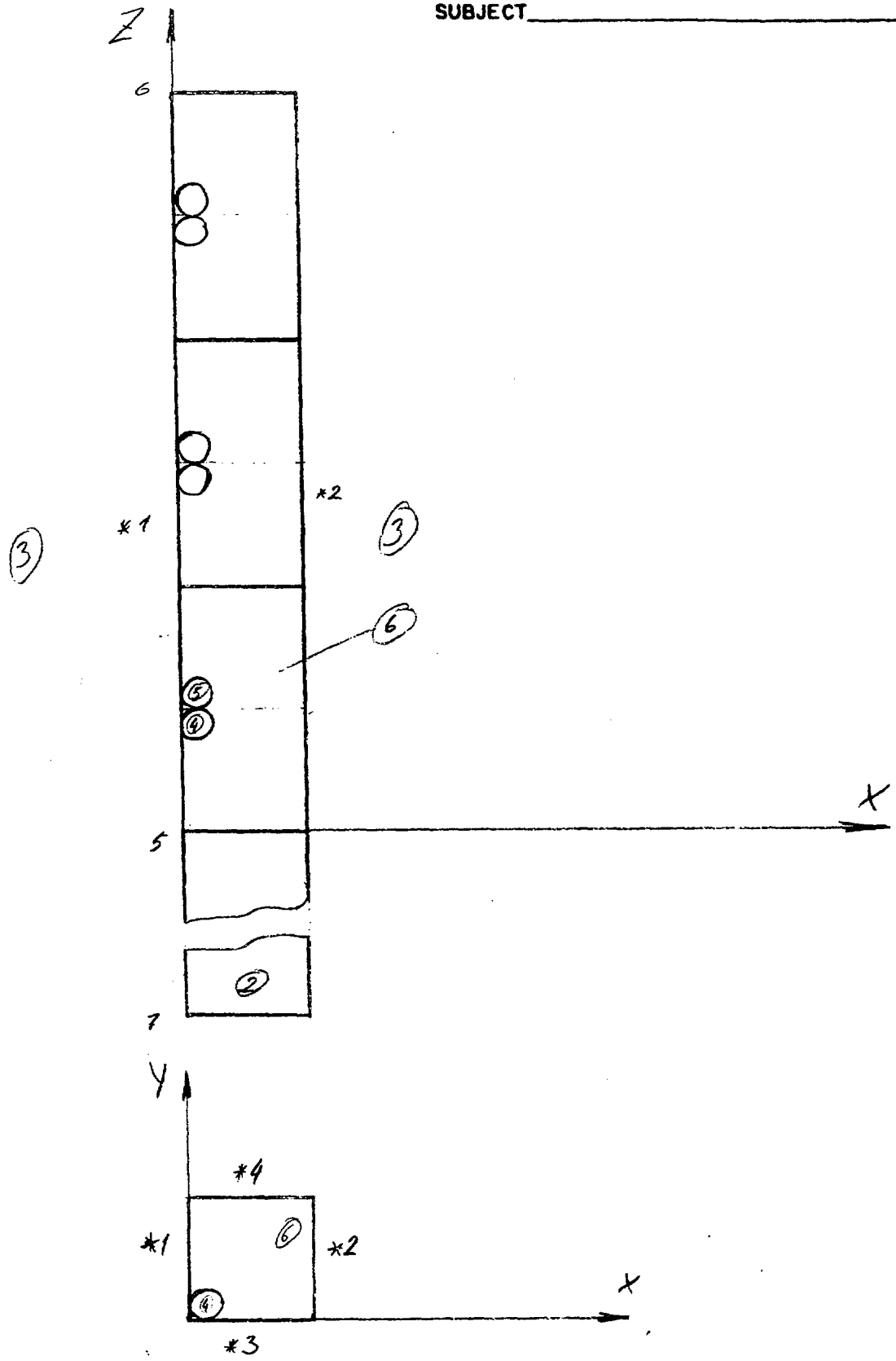
The $k_{eff}+2\sigma$ values in Table 13 confirm that 183g of Pu-239 is a sub-critical mass limit for $\infty \times \infty \times 12$ ft arrays of 2.0-cubic-foot boxes with Pu-239-cellulose spheres and pure cellulose or void outside the sphere.

Attachment 1: MCNP model with surface and cell numbers

FILE _____

SUBJECT _____

REVISIONS
BY _____ DATE _____ TO EO ____
BY _____ DATE _____ TO EO ____



BY _____ DATE _____
CHECKED BY _____
COPY TO EO _____

Dames & Moore

Attachment 2: MCNP input file

```
                                                    4c100
k eff, 183g of Pu-239 in cellulose spheres in 2.0 cubic foot of pure celulose
C
C Cell cards
C
C ---------------------------------------------------------------------------
1 0   1 -2 3 -4 5 -6 fill=2          imp:n=1 $ box with lattice
2 2  -2.3    1 -2 3 -4 -5 7          imp:n=1 $ Concrete floor
3 0         -1 : 2 : -3 : 4 : -7 : 6  imp:n=0 $ Outside world
c
c Universe 1
4 3  -0.725262 -8              u=1    imp:n=1 $ 1 Pu-239 and cellulose sphere
5 3  -0.725262 -9              u=1    imp:n=1 $ 2 Pu-239 and cellulose sphere
6 0       8 9            u=1    imp:n=1 $
c
c Lattice (2 spheres with Pu-239 in 2 cubes of cellulose matrix)
7 0 10 -11 12 -13 14 -15 lat=1 fill=1 u=2 imp:n=1 $ Lattice
C ---------------------------------------------------------------------------
c
c Note: next line must be completely blank

c Surface cards
C ---------------------------------------------------------------------------
*1 px 0.001
*2 px 60.961  $  box length (2.0 foot)
*3 py 0.001
*4 py 60.961  $  box width (2.0 foot)
5  pz 0.001
6  pz 365.761 $  box height (12 feet)
c                More thnan 350.52cm (11.5 feet) - 4 tiers of B-25 box height
c                (4x34.5" or 4x87.63 cm)
7  pz -300 $ concrete floor boundary
8  s 20.0 20.0  40.96 20.0 $ 1st Pu-239 containing sphere
9  s 20.0 20.0  80.96 20.0 $ 2nd Pu-239 containing sphere
c
c Lattice surfases:
10 px 0
11 px 60.96  $ 2.0 feet
12 py 0
13 py 60.96  $ 2.0 feet
14 pz 0
15 pz 121.92 $ 2 x 2.0 feet
C ---------------------------------------------------------------------------
c
c Note: next line must be completely blank

c Data cards
c
c Materials
c
c
c Celulose matrix (Elements: C, H, O)
m1      6000.50c  -0.444
        1001.50c  -0.062
        8016.50c  -0.493
c Concrete (KENO Regular Concrete Standard Mix) from Harmon at al.
c Criticality Calculation with MCNP. A Primer. p. C-4
c (Elements: H, O, Na, Si, Al, Ca, Fe)
m2      1001.50c -0.010
        8016.50c -0.532
       11023.50c -0.029
       13027.50c -0.034
       14000.50c -0.337
       20000.50c -0.044
       26000.55c -0.014
c Pu-239 and cellulose
m3     94239.55c  -0.007530
        6000.50c  -0.441108
        1001.50c  -0.061696
        8016.50c  -0.489665
c
mode n
print 40 60 80 100 110 126
kcode 4000 1. 20 120
ksrc  20.0 20.0  40.96
      20.0 20.0  80.96
```

Attachment 3: MCNP output file

```
1mcnp     version 4a    ld=10/01/93                    02/11/01 03:16:03
*************************************************************************          probid =   02/11/01 03:16:03
 name=4c100

      k eff, 183g of Pu-239 in cellulose spheres in 2.0 cubic foot of pure celulose
      C
      C Cell cards
      C
      C ---------------------------------------------------------------------------
      1 0   1 -2 3 -4 5 -6 fill=2            imp:n=1 $ box with lattice
      2 2  -2.3    1 -2 3 -4 -5 7            imp:n=1 $ Concrete floor
      3 0         -1 : 2 : -3 : 4 : -7 : 6   imp:n=0 $ Outside world
      c
      c Universe 1
      4 3  -0.725262 -8              u=1    imp:n=1 $ 1 Pu-239 and cellulose sphere
      5 3  -0.725262 -9              u=1    imp:n=1 $ 2 Pu-239 and cellulose sphere
      6 0       8 9            u=1    imp:n=1 $
      c
      c Lattice (2 spheres with Pu-239 in 2 cubes of cellulose matrix)
      7 0 10 -11 12 -13 14 -15 lat=1 fill=1 u=2 imp:n=1 $ Lattice
      C ---------------------------------------------------------------------------
      c
      c Note: next line must be completely blank

      c Surface cards
      C ---------------------------------------------------------------------------
      *1 px 0.001
      *2 px 60.961  $  box length (2.0 foot)
      *3 py 0.001
      *4 py 60.961  $  box width (2.0 foot)
      5  pz 0.001
      6  pz 365.761 $  box height (12 feet)
      c                More thnan 350.52cm (11.5 feet) - 4 tiers of B-25 box height
      c                (4x34.5" or 4x87.63 cm)
      7  pz -300 $ concrete floor boundary
      8  s 20.0 20.0  40.96 20.0 $ 1st Pu-239 containing sphere
      9  s 20.0 20.0  80.96 20.0 $ 2nd Pu-239 containing sphere
      c
      c Lattice surfases:
      10 px 0
      11 px 60.96  $ 2.0 feet
      12 py 0
      13 py 60.96  $ 2.0 feet
      14 pz 0
      15 pz 121.92 $ 2 x 2.0 feet
      C ---------------------------------------------------------------------------
      c
      c Note: next line must be completely blank

      c Data cards
      c
      c Materials
      c
      c
      c Celulose matrix (Elements: C, H, O)
      m1      6000.50c  -0.444
 warning.  material   1 is not used in the problem.
                1001.50c  -0.062
```

```
     8016.50c  -0.493
c Concrete (KENO Regular Concrete Standard Mix) from Harmon at al.
c Criticality Calculation with MCNP. A Primer. p. C-4
c (Elements: H, O, Na, Si, Al, Ca, Fe)
m2      1001.50c -0.010
        8016.50c -0.532
       11023.50c -0.029
       13027.50c -0.034
       14000.50c -0.337
       20000.50c -0.044
       26000.55c -0.014
c Pu-239 and cellulose
m3     94239.55c  -0.007530
        6000.50c  -0.441108
        1001.50c  -0.061696
        8016.50c  -0.489665
c
mode n
print 40 60 80 100 110 126
kcode 4000 1. 20 120
ksrc  20.0 20.0  40.96
      20.0 20.0  80.96

 total fission nubar data are being used.
1material composition                                                    print table 40

 material
  number      component nuclide, atom fraction

     2           1001,  0.16803       8016,  0.56324      11023,  0.02136      13027,  0.02134
                14000,  0.20319      20000,  0.01859      26000,  0.00425
     3          94239,  0.00024       6000,  0.28560       1001,  0.47607       8016,  0.23808




 material
  number      component nuclide, mass fraction

     2           1001,  0.01000       8016,  0.53200      11023,  0.02900      13027,  0.03400
                14000,  0.33700      20000,  0.04400      26000,  0.01400
     3          94239,  0.00753       6000,  0.44111       1001,  0.06170       8016,  0.48967
1cells                                                                   print table 60

                          atom          gram                                          neutron
        cell  mat        density       density        volume          mass        pieces importance

     1     1    0  0.00000E+00  0.00000E+00  1.35921E+06  0.00000E+00      0  1.0000E+00
     2     2    2  8.17913E-02  2.30000E+00  1.11484E+06  2.56413E+06      0  1.0000E+00
     3     3    0  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00      0  0.0000E+00
     4     4    3  5.61614E-02  7.25262E-01  3.35103E+04  2.43038E+04      1  1.0000E+00
     5     5    3  5.61614E-02  7.25262E-01  3.35103E+04  2.43038E+04      1  1.0000E+00
     6     6    0  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00      0  1.0000E+00
     7     7    0  0.00000E+00  0.00000E+00  4.53070E+05  0.00000E+00      0  1.0000E+00

 total                                      2.99414E+06  2.61274E+06
```

1 warning message so far.

1cross-section tables print table 100

table	length				
		tables from file critxs			
1001.50c	1153	njoy		(1301)	79/07/31.
6000.50c	16126	njoy		(1306)	79/07/31.
8016.50c	23669	njoy		(1276)	05/14/81
11023.50c	36270	njoy		(1311)	79/06/21.
13027.50c	22891	njoy		(1313)	79/09/08.
14000.50c	48275	njoy		(1314)	79/06/21.
20000.50c	26104	njoy		(1320)	79/06/22.
26000.55c	84136	njoy		(260)	10/21/82
94239.55c	67551	njoy	total nu	(1399)	02/21/85
total	326175				

warning. neutron energy cutoff is below some cross-section tables.

decimal words of dynamically allocated storage

general	110992
tallies	0
bank	12403
cross sections	326175
total	449570

****

dump no. 1 on file 4c100r nps = 0 coll = 0 ctm = 0.00 nrn = 0

source distribution written to file 4c100s cycle = 0

2 warning messages so far.

1 starting mcrun. field length = 0 cp0 = 0.01 print table 110

k eff, 183g of Pu-239 in cellulose spheres in 2.0 cubic foot of pure celulose

nps	x	y	z	cell	lattice(i,j,k)	surface	u	v	w	energy	weight	time
1	2.000E+01	2.000E+01	4.096E+01	1			5.085E-01	4.733E-01	7.193E-01	2.209E+00	1.000E+00	0.000E+00
	2.000E+01	2.000E+01	4.096E+01	7(0, 0, 0)			5.085E-01	4.733E-01	7.193E-01			
	2.000E+01	2.000E+01	4.096E+01	4		0	5.085E-01	4.733E-01	7.193E-01			
2	2.000E+01	2.000E+01	4.096E+01	1			8.952E-01	-4.447E-01	-2.944E-02	4.904E+00	1.000E+00	0.000E+00
	2.000E+01	2.000E+01	4.096E+01	7(0, 0, 0)			8.952E-01	-4.447E-01	-2.944E-02			
	2.000E+01	2.000E+01	4.096E+01	4		0	8.952E-01	-4.447E-01	-2.944E-02			
3	2.000E+01	2.000E+01	4.096E+01	1			-6.184E-01	-4.495E-01	6.446E-01	3.809E-01	1.000E+00	0.000E+00
	2.000E+01	2.000E+01	4.096E+01	7(0, 0, 0)			-6.184E-01	-4.495E-01	6.446E-01			
	2.000E+01	2.000E+01	4.096E+01	4		0	-6.184E-01	-4.495E-01	6.446E-01			
4	2.000E+01	2.000E+01	4.096E+01	1			9.710E-01	-5.665E-02	-2.323E-01	1.331E+00	1.000E+00	0.000E+00

```
      2.000E+01  2.000E+01  4.096E+01   7(   0,   0,   0)          9.710E-01 -5.665E-02 -2.323E-01
      2.000E+01  2.000E+01  4.096E+01   4                     0  9.710E-01 -5.665E-02 -2.323E-01
  5   2.000E+01  2.000E+01  4.096E+01   1                        5.861E-01  1.496E-01 -7.963E-01  1.902E+00  1.000E+00  0.000E+00
      2.000E+01  2.000E+01  4.096E+01   7(   0,   0,   0)          5.861E-01  1.496E-01 -7.963E-01
      2.000E+01  2.000E+01  4.096E+01   4                     0  5.861E-01  1.496E-01 -7.963E-01
  6   2.000E+01  2.000E+01  4.096E+01   1                       -6.489E-02 -1.626E-01  9.845E-01  4.410E-01  1.000E+00  0.000E+00
      2.000E+01  2.000E+01  4.096E+01   7(   0,   0,   0)         -6.489E-02 -1.626E-01  9.845E-01
      2.000E+01  2.000E+01  4.096E+01   4                     0 -6.489E-02 -1.626E-01  9.845E-01
  7   2.000E+01  2.000E+01  4.096E+01   1                       -7.068E-02  3.263E-02 -9.970E-01  4.750E-01  1.000E+00  0.000E+00
      2.000E+01  2.000E+01  4.096E+01   7(   0,   0,   0)         -7.068E-02  3.263E-02 -9.970E-01
      2.000E+01  2.000E+01  4.096E+01   4                     0 -7.068E-02  3.263E-02 -9.970E-01
  8   2.000E+01  2.000E+01  4.096E+01   1                       -3.915E-01  4.664E-01 -7.932E-01  4.136E+00  1.000E+00  0.000E+00
      2.000E+01  2.000E+01  4.096E+01   7(   0,   0,   0)         -3.915E-01  4.664E-01 -7.932E-01
      2.000E+01  2.000E+01  4.096E+01   4                     0 -3.915E-01  4.664E-01 -7.932E-01
  9   2.000E+01  2.000E+01  4.096E+01   1                       -2.368E-01  9.215E-01 -3.079E-01  7.453E-02  1.000E+00  0.000E+00
      2.000E+01  2.000E+01  4.096E+01   7(   0,   0,   0)         -2.368E-01  9.215E-01 -3.079E-01
      2.000E+01  2.000E+01  4.096E+01   4                     0 -2.368E-01  9.215E-01 -3.079E-01
 10   2.000E+01  2.000E+01  4.096E+01   1                        1.946E-01 -3.204E-01  9.271E-01  3.128E+00  1.000E+00  0.000E+00
      2.000E+01  2.000E+01  4.096E+01   7(   0,   0,   0)          1.946E-01 -3.204E-01  9.271E-01
      2.000E+01  2.000E+01  4.096E+01   4                     0  1.946E-01 -3.204E-01  9.271E-01
 11   2.000E+01  2.000E+01  4.096E+01   1                       -6.698E-01 -7.177E-01 -1.905E-01  1.014E+00  1.000E+00  0.000E+00
      2.000E+01  2.000E+01  4.096E+01   7(   0,   0,   0)         -6.698E-01 -7.177E-01 -1.905E-01
      2.000E+01  2.000E+01  4.096E+01   4                     0 -6.698E-01 -7.177E-01 -1.905E-01
 12   2.000E+01  2.000E+01  4.096E+01   1                       -8.398E-01 -4.129E-01  3.524E-01  1.395E+00  1.000E+00  0.000E+00
      2.000E+01  2.000E+01  4.096E+01   7(   0,   0,   0)         -8.398E-01 -4.129E-01  3.524E-01
      2.000E+01  2.000E+01  4.096E+01   4                     0 -8.398E-01 -4.129E-01  3.524E-01
 13   2.000E+01  2.000E+01  4.096E+01   1                       -1.714E-01 -8.572E-01  4.857E-01  7.748E-01  1.000E+00  0.000E+00
      2.000E+01  2.000E+01  4.096E+01   7(   0,   0,   0)         -1.714E-01 -8.572E-01  4.857E-01
      2.000E+01  2.000E+01  4.096E+01   4                     0 -1.714E-01 -8.572E-01  4.857E-01
 14   2.000E+01  2.000E+01  4.096E+01   1                       -2.489E-01 -5.118E-01 -8.222E-01  1.101E+00  1.000E+00  0.000E+00
      2.000E+01  2.000E+01  4.096E+01   7(   0,   0,   0)         -2.489E-01 -5.118E-01 -8.222E-01
      2.000E+01  2.000E+01  4.096E+01   4                     0 -2.489E-01 -5.118E-01 -8.222E-01
 15   2.000E+01  2.000E+01  4.096E+01   1                       -2.959E-01  2.119E-01  9.314E-01  1.951E+00  1.000E+00  0.000E+00
      2.000E+01  2.000E+01  4.096E+01   7(   0,   0,   0)         -2.959E-01  2.119E-01  9.314E-01
      2.000E+01  2.000E+01  4.096E+01   4                     0 -2.959E-01  2.119E-01  9.314E-01
 16   2.000E+01  2.000E+01  4.096E+01   1                        1.395E-01 -9.829E-01  1.202E-01  2.186E+00  1.000E+00  0.000E+00
      2.000E+01  2.000E+01  4.096E+01   7(   0,   0,   0)          1.395E-01 -9.829E-01  1.202E-01
      2.000E+01  2.000E+01  4.096E+01   4                     0  1.395E-01 -9.829E-01  1.202E-01
 17   2.000E+01  2.000E+01  4.096E+01   1                        6.909E-01 -7.110E-01  1.307E-01  1.865E+00  1.000E+00  0.000E+00
      2.000E+01  2.000E+01  4.096E+01   7(   0,   0,   0)          6.909E-01 -7.110E-01  1.307E-01
      2.000E+01  2.000E+01  4.096E+01   4                     0  6.909E-01 -7.110E-01  1.307E-01
 18   2.000E+01  2.000E+01  4.096E+01   1                       -6.580E-01  5.320E-01 -5.329E-01  1.229E+00  1.000E+00  0.000E+00
      2.000E+01  2.000E+01  4.096E+01   7(   0,   0,   0)         -6.580E-01  5.320E-01 -5.329E-01
      2.000E+01  2.000E+01  4.096E+01   4                     0 -6.580E-01  5.320E-01 -5.329E-01
 19   2.000E+01  2.000E+01  4.096E+01   1                       -9.903E-01 -1.380E-01  1.353E-02  1.305E+00  1.000E+00  0.000E+00
      2.000E+01  2.000E+01  4.096E+01   7(   0,   0,   0)         -9.903E-01 -1.380E-01  1.353E-02
      2.000E+01  2.000E+01  4.096E+01   4                     0 -9.903E-01 -1.380E-01  1.353E-02
 20   2.000E+01  2.000E+01  4.096E+01   1                        7.462E-01  4.859E-01 -4.551E-01  1.000E+00  1.000E+00  0.000E+00
      2.000E+01  2.000E+01  4.096E+01   7(   0,   0,   0)          7.462E-01  4.859E-01 -4.551E-01
      2.000E+01  2.000E+01  4.096E+01   4                     0  7.462E-01  4.859E-01 -4.551E-01
 21   2.000E+01  2.000E+01  4.096E+01   1                       -1.977E-01  9.797E-01  3.360E-02  3.990E+00  1.000E+00  0.000E+00
      2.000E+01  2.000E+01  4.096E+01   7(   0,   0,   0)         -1.977E-01  9.797E-01  3.360E-02
      2.000E+01  2.000E+01  4.096E+01   4                     0 -1.977E-01  9.797E-01  3.360E-02
 22   2.000E+01  2.000E+01  4.096E+01   1                       -9.117E-01 -3.647E-01 -1.891E-01  2.665E-01  1.000E+00  0.000E+00
      2.000E+01  2.000E+01  4.096E+01   7(   0,   0,   0)         -9.117E-01 -3.647E-01 -1.891E-01
      2.000E+01  2.000E+01  4.096E+01   4                     0 -9.117E-01 -3.647E-01 -1.891E-01
 23   2.000E+01  2.000E+01  4.096E+01   1                       -4.287E-01  8.361E-01 -3.423E-01  1.156E+00  1.000E+00  0.000E+00
      2.000E+01  2.000E+01  4.096E+01   7(   0,   0,   0)         -4.287E-01  8.361E-01 -3.423E-01
```

```
    2.000E+01  2.000E+01  4.096E+01   4                                    0 -4.287E-01  8.361E-01 -3.423E-01
24  2.000E+01  2.000E+01  4.096E+01   1                                      1.080E-01  3.412E-01 -9.338E-01  2.669E+00  1.000E+00  0.000E+00
    2.000E+01  2.000E+01  4.096E+01   7(   0,   0,   0)                     1.080E-01  3.412E-01 -9.338E-01
    2.000E+01  2.000E+01  4.096E+01   4                                    0  1.080E-01  3.412E-01 -9.338E-01
25  2.000E+01  2.000E+01  4.096E+01   1                                     -9.111E-01 -9.012E-03 -4.122E-01  2.185E+00  1.000E+00  0.000E+00
    2.000E+01  2.000E+01  4.096E+01   7(   0,   0,   0)                    -9.111E-01 -9.012E-03 -4.122E-01
    2.000E+01  2.000E+01  4.096E+01   4                                    0 -9.111E-01 -9.012E-03 -4.122E-01
26  2.000E+01  2.000E+01  4.096E+01   1                                     -2.568E-01 -6.391E-01 -7.249E-01  4.225E+00  1.000E+00  0.000E+00
    2.000E+01  2.000E+01  4.096E+01   7(   0,   0,   0)                    -2.568E-01 -6.391E-01 -7.249E-01
    2.000E+01  2.000E+01  4.096E+01   4                                    0 -2.568E-01 -6.391E-01 -7.249E-01
27  2.000E+01  2.000E+01  4.096E+01   1                                     -2.912E-01  8.086E-01  5.113E-01  1.079E+00  1.000E+00  0.000E+00
    2.000E+01  2.000E+01  4.096E+01   7(   0,   0,   0)                    -2.912E-01  8.086E-01  5.113E-01
    2.000E+01  2.000E+01  4.096E+01   4                                    0 -2.912E-01  8.086E-01  5.113E-01
28  2.000E+01  2.000E+01  4.096E+01   1                                      1.472E-01 -9.514E-01  2.705E-01  3.461E+00  1.000E+00  0.000E+00
    2.000E+01  2.000E+01  4.096E+01   7(   0,   0,   0)                     1.472E-01 -9.514E-01  2.705E-01
    2.000E+01  2.000E+01  4.096E+01   4                                    0  1.472E-01 -9.514E-01  2.705E-01
29  2.000E+01  2.000E+01  4.096E+01   1                                     -6.135E-01 -7.645E-01 -1.978E-01  1.836E+00  1.000E+00  0.000E+00
    2.000E+01  2.000E+01  4.096E+01   7(   0,   0,   0)                    -6.135E-01 -7.645E-01 -1.978E-01
    2.000E+01  2.000E+01  4.096E+01   4                                    0 -6.135E-01 -7.645E-01 -1.978E-01
30  2.000E+01  2.000E+01  4.096E+01   1                                     -5.702E-01  5.651E-01 -5.963E-01  4.556E-01  1.000E+00  0.000E+00
    2.000E+01  2.000E+01  4.096E+01   7(   0,   0,   0)                    -5.702E-01  5.651E-01 -5.963E-01
    2.000E+01  2.000E+01  4.096E+01   4                                    0 -5.702E-01  5.651E-01 -5.963E-01
31  2.000E+01  2.000E+01  4.096E+01   1                                     -6.607E-01  5.373E-01 -5.242E-01  6.415E-01  1.000E+00  0.000E+00
    2.000E+01  2.000E+01  4.096E+01   7(   0,   0,   0)                    -6.607E-01  5.373E-01 -5.242E-01
    2.000E+01  2.000E+01  4.096E+01   4                                    0 -6.607E-01  5.373E-01 -5.242E-01
32  2.000E+01  2.000E+01  4.096E+01   1                                     -9.742E-02 -3.639E-01 -9.263E-01  2.764E+00  1.000E+00  0.000E+00
    2.000E+01  2.000E+01  4.096E+01   7(   0,   0,   0)                    -9.742E-02 -3.639E-01 -9.263E-01
    2.000E+01  2.000E+01  4.096E+01   4                                    0 -9.742E-02 -3.639E-01 -9.263E-01
33  2.000E+01  2.000E+01  4.096E+01   1                                     -1.965E-01 -3.145E-01 -9.287E-01  2.785E-01  1.000E+00  0.000E+00
    2.000E+01  2.000E+01  4.096E+01   7(   0,   0,   0)                    -1.965E-01 -3.145E-01 -9.287E-01
    2.000E+01  2.000E+01  4.096E+01   4                                    0 -1.965E-01 -3.145E-01 -9.287E-01
34  2.000E+01  2.000E+01  4.096E+01   1                                      4.097E-01  8.465E-01 -3.399E-01  9.097E-01  1.000E+00  0.000E+00
    2.000E+01  2.000E+01  4.096E+01   7(   0,   0,   0)                     4.097E-01  8.465E-01 -3.399E-01
    2.000E+01  2.000E+01  4.096E+01   4                                    0  4.097E-01  8.465E-01 -3.399E-01
35  2.000E+01  2.000E+01  4.096E+01   1                                     -4.048E-02  8.831E-01  4.675E-01  3.360E-01  1.000E+00  0.000E+00
    2.000E+01  2.000E+01  4.096E+01   7(   0,   0,   0)                    -4.048E-02  8.831E-01  4.675E-01
    2.000E+01  2.000E+01  4.096E+01   4                                    0 -4.048E-02  8.831E-01  4.675E-01
36  2.000E+01  2.000E+01  4.096E+01   1                                      3.371E-01 -9.269E-01 -1.652E-01  6.376E-01  1.000E+00  0.000E+00
    2.000E+01  2.000E+01  4.096E+01   7(   0,   0,   0)                     3.371E-01 -9.269E-01 -1.652E-01
    2.000E+01  2.000E+01  4.096E+01   4                                    0  3.371E-01 -9.269E-01 -1.652E-01
37  2.000E+01  2.000E+01  4.096E+01   1                                     -1.867E-01  9.756E-01 -1.155E-01  2.186E+00  1.000E+00  0.000E+00
    2.000E+01  2.000E+01  4.096E+01   7(   0,   0,   0)                    -1.867E-01  9.756E-01 -1.155E-01
    2.000E+01  2.000E+01  4.096E+01   4                                    0 -1.867E-01  9.756E-01 -1.155E-01
38  2.000E+01  2.000E+01  4.096E+01   1                                     -2.616E-01  2.336E-01 -9.365E-01  7.314E-01  1.000E+00  0.000E+00
    2.000E+01  2.000E+01  4.096E+01   7(   0,   0,   0)                    -2.616E-01  2.336E-01 -9.365E-01
    2.000E+01  2.000E+01  4.096E+01   4                                    0 -2.616E-01  2.336E-01 -9.365E-01
39  2.000E+01  2.000E+01  4.096E+01   1                                      9.780E-01 -7.641E-02 -1.939E-01  2.997E-01  1.000E+00  0.000E+00
    2.000E+01  2.000E+01  4.096E+01   7(   0,   0,   0)                     9.780E-01 -7.641E-02 -1.939E-01
    2.000E+01  2.000E+01  4.096E+01   4                                    0  9.780E-01 -7.641E-02 -1.939E-01
40  2.000E+01  2.000E+01  4.096E+01   1                                      2.580E-01 -7.076E-01  6.578E-01  1.444E+00  1.000E+00  0.000E+00
    2.000E+01  2.000E+01  4.096E+01   7(   0,   0,   0)                     2.580E-01 -7.076E-01  6.578E-01
    2.000E+01  2.000E+01  4.096E+01   4                                    0  2.580E-01 -7.076E-01  6.578E-01
41  2.000E+01  2.000E+01  4.096E+01   1                                     -3.212E-01 -7.678E-01 -5.543E-01  1.914E+00  1.000E+00  0.000E+00
    2.000E+01  2.000E+01  4.096E+01   7(   0,   0,   0)                    -3.212E-01 -7.678E-01 -5.543E-01
    2.000E+01  2.000E+01  4.096E+01   4                                    0 -3.212E-01 -7.678E-01 -5.543E-01
42  2.000E+01  2.000E+01  4.096E+01   1                                      5.039E-01 -1.460E-01  8.513E-01  1.502E+00  1.000E+00  0.000E+00
    2.000E+01  2.000E+01  4.096E+01   7(   0,   0,   0)                     5.039E-01 -1.460E-01  8.513E-01
    2.000E+01  2.000E+01  4.096E+01   4                                    0  5.039E-01 -1.460E-01  8.513E-01
```

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 43  2.000E+01  2.000E+01  4.096E+01    1                          6.080E-01  5.487E-01  5.738E-01  5.971E+00  1.000E+00  0.000E+00
     2.000E+01  2.000E+01  4.096E+01    7(   0,   0,   0)         6.080E-01  5.487E-01  5.738E-01
     2.000E+01  2.000E+01  4.096E+01    4                    0     6.080E-01  5.487E-01  5.738E-01
 44  2.000E+01  2.000E+01  4.096E+01    1                         -2.932E-01  9.304E-01 -2.199E-01  1.827E+00  1.000E+00  0.000E+00
     2.000E+01  2.000E+01  4.096E+01    7(   0,   0,   0)        -2.932E-01  9.304E-01 -2.199E-01
     2.000E+01  2.000E+01  4.096E+01    4                    0    -2.932E-01  9.304E-01 -2.199E-01
 45  2.000E+01  2.000E+01  4.096E+01    1                         -8.475E-01 -3.993E-01 -3.497E-01  1.928E+00  1.000E+00  0.000E+00
     2.000E+01  2.000E+01  4.096E+01    7(   0,   0,   0)        -8.475E-01 -3.993E-01 -3.497E-01
     2.000E+01  2.000E+01  4.096E+01    4                    0    -8.475E-01 -3.993E-01 -3.497E-01
 46  2.000E+01  2.000E+01  4.096E+01    1                          1.200E-01 -9.195E-01 -3.743E-01  1.351E+00  1.000E+00  0.000E+00
     2.000E+01  2.000E+01  4.096E+01    7(   0,   0,   0)         1.200E-01 -9.195E-01 -3.743E-01
     2.000E+01  2.000E+01  4.096E+01    4                    0     1.200E-01 -9.195E-01 -3.743E-01
 47  2.000E+01  2.000E+01  4.096E+01    1                          7.085E-01  5.879E-01  3.904E-01  2.288E+00  1.000E+00  0.000E+00
     2.000E+01  2.000E+01  4.096E+01    7(   0,   0,   0)         7.085E-01  5.879E-01  3.904E-01
     2.000E+01  2.000E+01  4.096E+01    4                    0     7.085E-01  5.879E-01  3.904E-01
 48  2.000E+01  2.000E+01  4.096E+01    1                          4.261E-01  9.046E-01  9.254E-03  1.230E+00  1.000E+00  0.000E+00
     2.000E+01  2.000E+01  4.096E+01    7(   0,   0,   0)         4.261E-01  9.046E-01  9.254E-03
     2.000E+01  2.000E+01  4.096E+01    4                    0     4.261E-01  9.046E-01  9.254E-03
 49  2.000E+01  2.000E+01  4.096E+01    1                          5.431E-01  4.270E-01 -7.230E-01  1.433E+00  1.000E+00  0.000E+00
     2.000E+01  2.000E+01  4.096E+01    7(   0,   0,   0)         5.431E-01  4.270E-01 -7.230E-01
     2.000E+01  2.000E+01  4.096E+01    4                    0     5.431E-01  4.270E-01 -7.230E-01
 50  2.000E+01  2.000E+01  4.096E+01    1                         -1.053E-01 -9.805E-01  1.658E-01  6.572E-01  1.000E+00  0.000E+00
     2.000E+01  2.000E+01  4.096E+01    7(   0,   0,   0)        -1.053E-01 -9.805E-01  1.658E-01
     2.000E+01  2.000E+01  4.096E+01    4                    0    -1.053E-01 -9.805E-01  1.658E-01
1estimated keff results by cycle                                                                    print table 175

 source distribution written to file 4c100s          cycle =    20

 source distribution written to file 4c100s          cycle =    25

 source distribution written to file 4c100s          cycle =    30

 source distribution written to file 4c100s          cycle =    35

 source distribution written to file 4c100s          cycle =    40

 source distribution written to file 4c100s          cycle =    45

 source distribution written to file 4c100s          cycle =    50

 source distribution written to file 4c100s          cycle =    55

 source distribution written to file 4c100s          cycle =    60

 ************************************************************************************************************************
 dump no.     2 on file 4c100r        nps =     247075     coll =       18623277     ctm =    15.01     nrn =       337493008

 source distribution written to file 4c100s          cycle =    65

 source distribution written to file 4c100s          cycle =    70

 source distribution written to file 4c100s          cycle =    75

 source distribution written to file 4c100s          cycle =    80

 source distribution written to file 4c100s          cycle =    85
```

source distribution written to file 4c100s cycle = 90

source distribution written to file 4c100s cycle = 95

estimator	cycle 100	ave of 80 cycles		combination	simple average		combined average		corr
k(collision)	0.899734	0.931730	0.0015	k(col/abs)	0.929890	0.0009	0.929690	0.0009	-0.1051
k(absorption)	0.940690	0.928050	0.0013	k(abs/tk ln)	0.929973	0.0009	0.929739	0.0009	-0.1457
k(trk length)	0.900105	0.931896	0.0015	k(tk ln/col)	0.931813	0.0015	0.931733	0.0015	0.9803
rem life(col)	6.9995E+04	7.3830E+04	0.0034	k(col/abs/tk ln)	0.930559	0.0010	0.929742	0.0009	
rem life(abs)	7.0072E+04	7.3667E+04	0.0028	life(col/abs)	7.3748E+04	0.0030	7.3622E+04	0.0028	0.8872

source points generated 3782

source distribution written to file 4c100s cycle = 100

source distribution written to file 4c100s cycle = 105

source distribution written to file 4c100s cycle = 110

source distribution written to file 4c100s cycle = 115

estimator	cycle 116	ave of 96 cycles		combination	simple average		combined average		corr
k(collision)	0.913791	0.930251	0.0013	k(col/abs)	0.929265	0.0008	0.929173	0.0008	-0.1404
k(absorption)	0.930724	0.928278	0.0012	k(abs/tk ln)	0.929330	0.0008	0.929218	0.0008	-0.1852
k(trk length)	0.913064	0.930382	0.0014	k(tk ln/col)	0.930317	0.0013	0.930250	0.0013	0.9802
rem life(col)	7.3786E+04	7.3594E+04	0.0031	k(col/abs/tk ln)	0.929637	0.0009	0.929226	0.0008	
rem life(abs)	7.3733E+04	7.3589E+04	0.0025	life(col/abs)	7.3591E+04	0.0027	7.3588E+04	0.0024	0.8779

source points generated 4022

estimator	cycle 117	ave of 97 cycles		combination	simple average		combined average		corr
k(collision)	0.913547	0.930079	0.0013	k(col/abs)	0.929189	0.0008	0.929099	0.0008	-0.1417
k(absorption)	0.930353	0.928299	0.0012	k(abs/tk ln)	0.929268	0.0008	0.929159	0.0008	-0.1862
k(trk length)	0.916219	0.930236	0.0013	k(tk ln/col)	0.930157	0.0013	0.930089	0.0013	0.9803
rem life(col)	7.3819E+04	7.3596E+04	0.0031	k(col/abs/tk ln)	0.929538	0.0009	0.929175	0.0008	
rem life(abs)	7.4152E+04	7.3595E+04	0.0024	life(col/abs)	7.3595E+04	0.0027	7.3594E+04	0.0024	0.8777

source points generated 4120

estimator	cycle 118	ave of 98 cycles		combination	simple average		combined average		corr
k(collision)	0.944390	0.930225	0.0013	k(col/abs)	0.929279	0.0008	0.929178	0.0008	-0.1368
k(absorption)	0.931690	0.928334	0.0012	k(abs/tk ln)	0.929364	0.0008	0.929242	0.0008	-0.1806
k(trk length)	0.945667	0.930393	0.0013	k(tk ln/col)	0.930309	0.0013	0.930231	0.0013	0.9806
rem life(col)	7.6915E+04	7.3630E+04	0.0031	k(col/abs/tk ln)	0.929651	0.0009	0.929257	0.0008	
rem life(abs)	7.5834E+04	7.3618E+04	0.0024	life(col/abs)	7.3624E+04	0.0027	7.3614E+04	0.0024	0.8798

source points generated 4108

estimator	cycle 119	ave of 99 cycles		combination	simple average		combined average		corr
k(collision)	0.915264	0.930074	0.0013	k(col/abs)	0.929123	0.0008	0.929022	0.0008	-0.1159
k(absorption)	0.912265	0.928172	0.0012	k(abs/tk ln)	0.929220	0.0008	0.929099	0.0008	-0.1627
k(trk length)	0.917962	0.930268	0.0013	k(tk ln/col)	0.930171	0.0013	0.930093	0.0013	0.9806
rem life(col)	7.9018E+04	7.3684E+04	0.0032	k(col/abs/tk ln)	0.929504	0.0009	0.929126	0.0008	
rem life(abs)	7.8149E+04	7.3663E+04	0.0025	life(col/abs)	7.3674E+04	0.0027	7.3656E+04	0.0024	0.8867

source points generated 3841

estimator	cycle 120	ave of 100 cycles		combination	simple average		combined average		corr
k(collision)	0.924392	0.930017	0.0013	k(col/abs)	0.929231	0.0008	0.929169	0.0008	-0.1237
k(absorption)	0.955560	0.928445	0.0012	k(abs/tk ln)	0.929341	0.0008	0.929262	0.0008	-0.1637
k(trk length)	0.927239	0.930237	0.0013	k(tk ln/col)	0.930127	0.0013	0.930044	0.0013	0.9803
rem life(col)	7.6138E+04	7.3709E+04	0.0032	k(col/abs/tk ln)	0.929567	0.0009	0.929283	0.0008	
rem life(abs)	7.4223E+04	7.3669E+04	0.0025	life(col/abs)	7.3689E+04	0.0027	7.3655E+04	0.0024	0.8846

source points generated 4089

source distribution written to file 4c100s cycle = 120

1problem summary

run terminated when 120 kcode cycles were done.

+ 02/11/01 03:45:03

k eff, 183g of Pu-239 in cellulose spheres in 2.0 cubic foot of pure celulose probid = 02/11/01 03:16:03

0

neutron creation	tracks	weight (per source particle)	energy (per source particle)	neutron loss	tracks	weight (per source particle)	energy (per source particle)
source	478709	1.0027E+00	2.1131E+00	escape	114884	2.0207E-01	1.2433E-01
				energy cutoff	0	0.	0.
				time cutoff	0	0.	0.
weight window	0	0.	0.	weight window	0	0.	0.
cell importance	0	0.	0.	cell importance	0	0.	0.
weight cutoff	0	3.1186E-02	6.4218E-06	weight cutoff	363827	3.1262E-02	6.9755E-06
energy importance	0	0.	0.	energy importance	0	0.	0.
dxtran	0	0.	0.	dxtran	0	0.	0.
forced collisions	0	0.	0.	forced collisions	0	0.	0.
exp. transform	0	0.	0.	exp. transform	0	0.	0.
upscattering	0	0.	3.8515E-07	downscattering	0	0.	1.9633E+00
				capture	0	4.7854E-01	2.4501E-02
(n,xn)	4	4.6106E-06	7.1581E-06	loss to (n,xn)	2	2.3053E-06	2.2520E-05
fission	0	0.	0.	loss to fission	0	3.2201E-01	9.4106E-04
total	478713	1.0339E+00	2.1131E+00	total	478713	1.0339E+00	2.1131E+00

number of neutrons banked	2	average lifetime, shakes		cutoffs	
neutron tracks per source particle	1.0000E+00	escape	8.0550E+04	tco	1.0000E+34
neutron collisions per source particle	7.5032E+01	capture	7.2131E+04	eco	0.0000E+00
total neutron collisions	35918342	capture or escape	7.3828E+04	wc1	-5.0000E-01
net multiplication	1.0000E+00 0.0000	any termination	7.7651E+04	wc2	-2.5000E-01

computer time so far in this run	28.99 minutes	maximum number ever in bank	1
computer time in mcrun	28.98 minutes	bank overflows to backup file	0
source particles per minute	1.6518E+04	field length	0
random numbers generated	650997706	most random numbers used was	13619 in history 66714

range of sampled source weights = 9.3045E-01 to 1.0917E+00

1neutron activity in each cell print table 126

cell		tracks entering	population	collisions	collisions * weight (per history)	number weighted energy	flux weighted energy	average track weight (relative)	average track mfp (cm)
1	1	0	0	0	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2	2	197980	132957	7255340	8.8572E+00	5.1678E-05	2.3615E-01	6.1850E-01	2.1281E+00
4	4	996268	395598	15439971	2.4796E+01	1.6240E-04	5.3850E-01	8.3074E-01	2.8133E+00
5	5	849529	376725	13223031	2.1409E+01	1.6758E-04	5.4944E-01	8.3663E-01	2.8438E+00
6	6	6398381	418381	0	0.0000E+00	1.6566E-04	5.4039E-01	8.2355E-01	0.0000E+00
7	7	0	0	0	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
total		8442158	1323661	35918342	5.5063E+01				

1keff results for: k eff, 183g of Pu-239 in cellulose spheres in 2.0 cubic foot of pure celulose probid = 02/11/01 03:16:03

the initial fission neutron source distribution used the 2 source points that were input on the ksrc card.

the criticality problem was scheduled to skip 20 cycles and run a total of 120 cycles with nominally 4000 neutrons per cycle.
this problem has run 20 inactive cycles with 79803 neutron histories and 100 active cycles with 398906 neutron histories.

this calculation has completed the requested number of keff cycles using a total of 478709 fission neutron source histories.
all cells with fissionable material were sampled and had fission neutron source points.

the results of the w test for normality applied to the individual collision, absorption, and track-length keff cycle values are:

the k(collision) cycle values appear normally distributed at the 95 percent confidence level
the k(absorption) cycle values appear normally distributed at the 95 percent confidence level
the k(trk length) cycle values appear normally distributed at the 95 percent confidence level

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the final estimated combined collision/absorption/track-length keff = 0.92928 with an estimated standard deviation of 0.00077

the estimated 68, 95, & 99 percent keff confidence intervals are 0.92851 to 0.93005, 0.92775 to 0.93081, and 0.92725 to 0.93131

the estimated collision/absorption neutron removal lifetime = 7.37E-04 seconds with an estimated standard deviation of 1.78E-06

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the estimated average keffs, one standard deviations, and 68, 95, and 99 percent confidence intervals are:

keff estimator	keff	standard deviation	68% confidence	95% confidence	99% confidence	corr
collision	0.93002	0.00122	0.92880 to 0.93123	0.92760 to 0.93244	0.92681 to 0.93323	
absorption	0.92845	0.00111	0.92733 to 0.92956	0.92623 to 0.93066	0.92551 to 0.93138	
track length	0.93024	0.00123	0.92900 to 0.93147	0.92778 to 0.93269	0.92698 to 0.93350	
col/absorp	0.92917	0.00078	0.92839 to 0.92995	0.92763 to 0.93071	0.92712 to 0 .93122	-0.1237
abs/trk len	0.92926	0.00076	0.92850 to 0.93003	0.92774 to 0.93078	0.92725 to 0.93128	-0.1637
col/trk len	0.93004	0.00123	0.92882 to 0.93127	0.92760 to 0.93249	0.92680 to 0.93328	0.9803
col/abs/trk len	0.92928	0.00077	0.92851 to 0.93005	0.92775 to 0.93081	0.92725 to 0.93131	

if the largest of each keff occurred on the next cycle, the keff results and 68, 95, and 99 percent confidence intervals would be:

keff estimator	keff	standard deviation	68% confidence	95% confidence	99% confidence
collision	0.93031	0.00124	0.92907 to 0.93155	0.92784 to 0.93278	0.92704 to 0.93358
absorption	0.92871	0.00113	0.92758 to 0.92985	0.92646 to 0.93097	0.92572 to 0.93171
track length	0.93052	0.00125	0.92927 to 0.93178	0.92802 to 0.93302	0.92721 to 0.93383
col/abs/trk len	0.92956	0.00081	0.92875 to 0.93037	0.92795 to 0.93118	0.92742 to 0.93170

the estimated collision/absorption neutron lifetimes, one standard deviations, and 68, 95, and 99 percent confidence intervals are:

type	lifetime(sec)	standard deviation	68% confidence	95% confidence	99% confidence
removal	7.3655E-04	1.7829E-06	7.3476E-04 to 7.3833E-04	7.3300E-04 to 7.4010E-04	7.3184E-04 to 7.4126E-04
capture	7.2153E-04	1.7126E-06	7.1982E-04 to 7.2325E-04	7.1812E-04 to 7.2495E-04	7.1701E-04 to 7.2606E-04
fission	6.7991E-04	1.7130E-06	6.7819E-04 to 6.8162E-04	6.7650E-04 to 6.8332E-04	6.7538E-04 to 6.8443E-04
escape	7.9643E-04	4.8690E-06	7.9155E-04 to 8.0130E-04	7.8673E-04 to 8.0612E-04	7.8356E-04 to 8.0929E-04

laverage individual and combined collision/absorption/track-length keff results for 7 different batch sizes

cycles per keff batch	number of k batches	average keff estimators and deviations k(col) st dev	k(abs) st dev	k(trk) st dev	normality co/ab/trk	average k(c/a/t) k(c/a/t) st dev	k(c/a/t) confidence intervals 95% confidence	99% confidence
1	100	0.9300 0.0012	0.9284 0.0011	0.9302 0.0012	95/95/95	0.92928 0.00077	0.92775-0.93081	0.92725-0.93131
2	50	0.9300 0.0013	0.9284 0.0011	0.9302 0.0013	95/95/95	0.92928 0.00073	0.92781-0.93075	0.92732-0.93125
4	25	0.9300 0.0013	0.9284 0.0011	0.9302 0.0013	95/95/95	0.92918 0.00084	0.92745-0.93092	0.92682-0.93155
5	20	0.9300 0.0014	0.9284 0.0013	0.9302 0.0013	95/95/95	0.92948 0.00085	0.92768-0.93128	0.92700-0.93195
10	10	0.9300 0.0016	0.9284 0.0012	0.9302 0.0015	95/95/95	0.92958 0.00082	0.92763-0.93153	0.92669-0.93247
20	5	0.9300 0.0018	0.9284 0.0005	0.9302 0.0018	95/95/95	0.92875 0.00049	0.92662-0.93088	0.92384-0.93367
25	4	0.9300 0.0025	0.9284 0.0006	0.9302 0.0023	95/95/95	0.92766 0.00030	0.92383-0.93149	0.90847-0.94685

lindividual and average keff estimator results by cycle

keff cycle	neutron histories	keff estimators by cycle k(coll)	k(abs)	k(track)	average keff estimators and deviations k(coll) st dev	k(abs) st dev	k(track) st dev	average k(c/a/t) k(c/a/t) st dev	fom
1	4000	1.04165	1.04814	1.03818					
2	4042	0.94835	0.94779	0.95466					
3	3664	0.97046	0.89935	0.97002					
4	4161	0.93384	0.93230	0.93356					
5	3926	0.93690	0.92063	0.93758					
6	4067	0.92830	0.92927	0.92337					
7	3975	0.94939	0.93980	0.94610					
8	4114	0.92812	0.92635	0.92421					
9	3940	0.93138	0.90221	0.92918					
10	4024	0.94396	0.91704	0.93980					
11	4024	0.92389	0.92143	0.92104					
12	3911	0.94230	0.93294	0.94145					
13	4089	0.93906	0.90736	0.93918					
14	4015	0.95588	0.94117	0.96268					
15	3985	0.94308	0.93059	0.94176					
16	3967	0.93795	0.90719	0.93986					
17	4053	0.92952	0.92748	0.92449					
18	3826	0.92195	0.93479	0.92309					
19	3969	0.92938	0.89903	0.92908					
20	4051	0.91439	0.94370	0.91063					
		begin active keff cycles							
21	3870	0.92484	0.92738	0.92529					
22	4094	0.93499	0.92425	0.93783	0.92992 0.00507	0.92581 0.00156	0.93156 0.00627		
23	3946	0.94767	0.92186	0.94898	0.93584 0.00660	0.92450 0.00160	0.93737 0.00684		
24	4004	0.92008	0.92959	0.92633	0.93190 0.00611	0.92577 0.00170	0.93461 0.00557	0.92673 0.00071	1790787
25	3829	0.93650	0.93597	0.93754	0.93282 0.00482	0.92781 0.00243	0.93519 0.00435	0.93122 0.00417	41771
26	4007	0.93770	0.93644	0.93679	0.93363 0.00402	0.92925 0.00245	0.93546 0.00356	0.93320 0.00275	80192
27	3904	0.95959	0.92523	0.95897	0.93734 0.00503	0.92867 0.00215	0.93882 0.00451	0.93328 0.00251	82692
28	4019	0.92432	0.90721	0.92635	0.93571 0.00465	0.92599 0.00326	0.93726 0.00421	0.93311 0.00484	19449
29	3953	0.93719	0.90867	0.93624	0.93588 0.00410	0.92407 0.00346	0.93715 0.00371	0.93207 0.00518	15034
30	4046	0.92702	0.93115	0.92488	0.93499 0.00378	0.92477 0.00318	0.93592 0.00354	0.93036 0.00367	26855
31	3937	0.91406	0.91127	0.91836	0.93309 0.00391	0.92355 0.00313	0.93432 0.00358	0.92986 0.00387	21991
32	3927	0.93142	0.93779	0.93091	0.93295 0.00357	0.92473 0.00309	0.93404 0.00328	0.93063 0.00322	29102
33	3980	0.93265	0.92312	0.92980	0.93293 0.00329	0.92461 0.00285	0.93371 0.00303	0.92963 0.00292	32472
34	3933	0.92221	0.92355	0.91891	0.93216 0.00314	0.92453 0.00264	0.93266 0.00300	0.92818 0.00268	35811
35	3909	0.91844	0.93374	0.91898	0.93125 0.00306	0.92515 0.00253	0.93174 0.00294	0.92814 0.00235	43622
36	4019	0.92527	0.92965	0.92678	0.93087 0.00289	0.92543 0.00238	0.93143 0.00277	0.92822 0.00217	47771
37	4004	0.94455	0.95220	0.94366	0.93168 0.00283	0.92700 0.00274	0.93215 0.00270	0.92992 0.00237	37910
38	4020	0.94110	0.93964	0.94338	0.93220 0.00272	0.92771 0.00267	0.93278 0.00262	0.93057 0.00239	34970
39	3953	0.89419	0.92671	0.89380	0.93020 0.00326	0.92765 0.00253	0.93073 0.00321	0.92895 0.00238	33556

40	3866	0.95027	0.93675	0.95201	0.93120	0.00325	0.92811	0.00244	0.93179	0.00323	0.92945	0.00240	31357
41	4299	0.92430	0.94186	0.92448	0.93087	0.00311	0.92876	0.00241	0.93144	0.00309	0.92986	0.00228	33112
42	3947	0.93114	0.94805	0.92719	0.93089	0.00296	0.92964	0.00246	0.93125	0.00295	0.93046	0.00215	35497
43	4037	0.94460	0.90673	0.94544	0.93148	0.00289	0.92864	0.00256	0.93187	0.00289	0.93020	0.00210	35374
44	4055	0.93316	0.92216	0.93347	0.93155	0.00277	0.92837	0.00246	0.93193	0.00277	0.93008	0.00202	36629
45	3898	0.91099	0.93578	0.90990	0.93073	0.00278	0.92867	0.00238	0.93105	0.00280	0.92979	0.00193	38836
46	3913	0.90830	0.94037	0.90602	0.92987	0.00281	0.92912	0.00233	0.93009	0.00285	0.92960	0.00184	41132
47	3948	0.93708	0.93387	0.93788	0.93013	0.00272	0.92930	0.00225	0.93038	0.00276	0.92982	0.00178	42059
48	4082	0.94328	0.93693	0.94269	0.93060	0.00266	0.92957	0.00218	0.93082	0.00270	0.93015	0.00175	42241
49	4055	0.91239	0.93018	0.91002	0.92998	0.00264	0.92959	0.00211	0.93010	0.00270	0.92983	0.00170	42816
50	3981	0.94562	0.92647	0.94625	0.93050	0.00260	0.92949	0.00204	0.93064	0.00266	0.92996	0.00165	44023
51	4089	0.94513	0.91624	0.94692	0.93097	0.00256	0.92906	0.00202	0.93116	0.00263	0.92990	0.00160	45099
52	3957	0.93668	0.91394	0.93605	0.93115	0.00249	0.92859	0.00201	0.93132	0.00255	0.92968	0.00158	45098
53	3934	0.93069	0.92152	0.92770	0.93113	0.00241	0.92837	0.00196	0.93121	0.00247	0.92948	0.00154	45747
54	3870	0.94251	0.92857	0.94156	0.93147	0.00236	0.92838	0.00190	0.93151	0.00242	0.92958	0.00151	46704
55	3976	0.91952	0.90593	0.92321	0.93113	0.00232	0.92774	0.00195	0.93127	0.00236	0.92919	0.00154	43391
56	4001	0.92409	0.94236	0.92651	0.93093	0.00226	0.92814	0.00194	0.93114	0.00230	0.92944	0.00151	44067
57	4034	0.93487	0.92789	0.93466	0.93104	0.00220	0.92814	0.00189	0.93124	0.00224	0.92947	0.00147	45272
58	4082	0.91877	0.93644	0.91656	0.93071	0.00217	0.92835	0.00185	0.93085	0.00221	0.92941	0.00142	47072
59	3824	0.92266	0.91639	0.92606	0.93051	0.00212	0.92805	0.00183	0.93073	0.00216	0.92924	0.00140	47137
60	3975	0.92255	0.91799	0.92317	0.93031	0.00208	0.92780	0.00180	0.93054	0.00211	0.92902	0.00138	46989
61	4024	0.92316	0.93569	0.92724	0.93014	0.00203	0.92799	0.00177	0.93046	0.00206	0.92914	0.00136	47618
62	4071	0.94980	0.92836	0.95633	0.93060	0.00204	0.92800	0.00172	0.93107	0.00210	0.92928	0.00137	45534
63	3995	0.92496	0.94011	0.92625	0.93047	0.00200	0.92828	0.00171	0.93096	0.00206	0.92941	0.00134	46317
64	3875	0.92117	0.93830	0.92682	0.93026	0.00196	0.92851	0.00168	0.93087	0.00201	0.92947	0.00132	46586
65	3916	0.92930	0.92296	0.92428	0.93024	0.00192	0.92838	0.00165	0.93072	0.00197	0.92929	0.00129	48310
66	4042	0.94121	0.94642	0.94067	0.93048	0.00189	0.92878	0.00166	0.93094	0.00194	0.92965	0.00130	46367
67	4086	0.93205	0.92503	0.93065	0.93051	0.00185	0.92870	0.00163	0.93093	0.00190	0.92960	0.00127	47527
68	3976	0.94099	0.92269	0.93864	0.93073	0.00182	0.92857	0.00160	0.93109	0.00187	0.92961	0.00124	48668
69	4138	0.92823	0.93166	0.92767	0.93068	0.00179	0.92863	0.00157	0.93102	0.00183	0.92961	0.00121	49855
70	3987	0.94563	0.93298	0.94343	0.93098	0.00178	0.92872	0.00154	0.93127	0.00181	0.92978	0.00120	50018
71	4141	0.93213	0.92684	0.93322	0.93100	0.00174	0.92868	0.00151	0.93131	0.00177	0.92978	0.00118	50899
72	3967	0.93193	0.91221	0.93111	0.93102	0.00171	0.92837	0.00151	0.93131	0.00174	0.92961	0.00117	50383
73	3954	0.93674	0.90692	0.94417	0.93113	0.00168	0.92796	0.00154	0.93155	0.00172	0.92956	0.00116	49936
74	4037	0.93839	0.92287	0.93794	0.93126	0.00165	0.92787	0.00151	0.93167	0.00170	0.92956	0.00114	50705
75	4004	0.92296	0.92061	0.91912	0.93111	0.00163	0.92774	0.00149	0.93144	0.00168	0.92936	0.00113	50712
76	4046	0.92522	0.93671	0.92384	0.93100	0.00160	0.92790	0.00147	0.93130	0.00166	0.92940	0.00111	52044
77	4026	0.93997	0.92766	0.94088	0.93116	0.00158	0.92789	0.00144	0.93147	0.00163	0.92946	0.00109	52527
78	4030	0.92264	0.93769	0.92399	0.93101	0.00156	0.92806	0.00143	0.93134	0.00161	0.92950	0.00107	53710
79	3878	0.94176	0.93066	0.94065	0.93120	0.00155	0.92810	0.00141	0.93150	0.00159	0.92959	0.00106	54125
80	4214	0.93488	0.90932	0.93667	0.93126	0.00152	0.92779	0.00142	0.93159	0.00157	0.92950	0.00106	53547
81	3850	0.91805	0.93949	0.91385	0.93104	0.00151	0.92798	0.00141	0.93129	0.00157	0.92947	0.00103	55337
82	3908	0.93261	0.93620	0.93294	0.93107	0.00149	0.92812	0.00139	0.93132	0.00154	0.92956	0.00102	55995
83	4061	0.93037	0.92977	0.93066	0.93106	0.00146	0.92814	0.00137	0.93131	0.00152	0.92957	0.00100	56929
84	3956	0.93579	0.93833	0.93585	0.93113	0.00144	0.92830	0.00136	0.93138	0.00150	0.92969	0.00099	57081
85	4068	0.94567	0.92105	0.94424	0.93135	0.00144	0.92819	0.00134	0.93158	0.00149	0.92972	0.00098	57592
86	4227	0.93742	0.92645	0.93911	0.93145	0.00142	0.92816	0.00132	0.93169	0.00147	0.92975	0.00097	58146
87	4011	0.95215	0.92713	0.95133	0.93175	0.00143	0.92815	0.00130	0.93199	0.00148	0.92985	0.00096	57599
88	3915	0.93181	0.90686	0.93262	0.93176	0.00141	0.92784	0.00132	0.93200	0.00145	0.92973	0.00097	56124
89	3946	0.94357	0.93562	0.93921	0.93193	0.00140	0.92795	0.00130	0.93210	0.00144	0.92984	0.00096	56196
90	4074	0.95595	0.92908	0.95519	0.93227	0.00142	0.92796	0.00129	0.93243	0.00145	0.92994	0.00097	54932
91	3930	0.93495	0.93857	0.93388	0.93231	0.00140	0.92811	0.00128	0.93245	0.00143	0.93005	0.00095	55390

92	3922	0.92770	0.93594	0.92973	0.93224	0.00138	0.92822	0.00126	0.93241	0.00141	0.93010	0.00094	56305
93	3997	0.92184	0.94377	0.92063	0.93210	0.00137	0.92844	0.00126	0.93225	0.00140	0.93016	0.00092	57644
94	3955	0.93728	0.90967	0.93635	0.93217	0.00136	0.92818	0.00127	0.93231	0.00139	0.93008	0.00092	57055
95	4034	0.94091	0.92250	0.93895	0.93229	0.00134	0.92811	0.00126	0.93240	0.00137	0.93008	0.00091	57533
96	3941	0.94676	0.92336	0.94901	0.93248	0.00134	0.92804	0.00124	0.93261	0.00137	0.93013	0.00091	57545
97	3998	0.92597	0.91550	0.92921	0.93239	0.00132	0.92788	0.00124	0.93257	0.00135	0.93004	0.00090	57188
98	3721	0.91481	0.92697	0.91417	0.93217	0.00133	0.92787	0.00122	0.93233	0.00136	0.92989	0.00090	57351
99	3927	0.92953	0.92958	0.92948	0.93213	0.00131	0.92789	0.00121	0.93230	0.00134	0.92989	0.00088	58185
100	3972	0.89973	0.94069	0.90010	0.93173	0.00136	0.92805	0.00120	0.93190	0.00138	0.92974	0.00087	59425
101	3782	0.94210	0.93497	0.94067	0.93186	0.00134	0.92814	0.00119	0.93200	0.00137	0.92983	0.00086	59415
102	4167	0.92835	0.92207	0.92935	0.93181	0.00133	0.92806	0.00118	0.93197	0.00135	0.92978	0.00086	59781
103	3841	0.92593	0.93854	0.92675	0.93174	0.00131	0.92819	0.00117	0.93191	0.00134	0.92983	0.00084	60671
104	3962	0.91654	0.94329	0.91576	0.93156	0.00131	0.92837	0.00117	0.93172	0.00134	0.92986	0.00083	62005
105	3975	0.91923	0.93878	0.91739	0.93142	0.00130	0.92849	0.00116	0.93155	0.00133	0.92985	0.00082	63175
106	3977	0.93637	0.89784	0.93756	0.93148	0.00129	0.92813	0.00120	0.93162	0.00132	0.92974	0.00083	60810
107	4034	0.92088	0.92257	0.91984	0.93135	0.00128	0.92807	0.00119	0.93148	0.00131	0.92964	0.00082	60672
108	3963	0.90667	0.93227	0.90971	0.93107	0.00130	0.92812	0.00118	0.93124	0.00132	0.92954	0.00082	61106
109	4008	0.91508	0.91997	0.91703	0.93089	0.00129	0.92803	0.00117	0.93108	0.00131	0.92942	0.00082	60471
110	4028	0.91988	0.93019	0.92475	0.93077	0.00129	0.92805	0.00115	0.93101	0.00130	0.92941	0.00081	61130
111	4138	0.93204	0.91872	0.93302	0.93079	0.00127	0.92795	0.00115	0.93103	0.00128	0.92937	0.00080	61422
112	4138	0.91616	0.93408	0.91201	0.93063	0.00127	0.92801	0.00114	0.93082	0.00129	0.92929	0.00079	62132
113	3840	0.91989	0.92774	0.91632	0.93051	0.00126	0.92801	0.00112	0.93066	0.00128	0.92920	0.00079	62453
114	4050	0.92811	0.93045	0.93033	0.93049	0.00125	0.92804	0.00111	0.93066	0.00127	0.92921	0.00078	63101
115	4047	0.92474	0.94843	0.92143	0.93042	0.00123	0.92825	0.00112	0.93056	0.00126	0.92930	0.00077	63598
116	3868	0.91379	0.93072	0.91306	0.93025	0.00123	0.92828	0.00111	0.93038	0.00126	0.92923	0.00076	63956
117	4022	0.91355	0.93035	0.91622	0.93008	0.00123	0.92830	0.00110	0.93024	0.00125	0.92917	0.00076	64449
118	4120	0.94439	0.93169	0.94567	0.93023	0.00123	0.92833	0.00109	0.93039	0.00125	0.92926	0.00076	64037
119	4108	0.91526	0.91227	0.91796	0.93007	0.00123	0.92817	0.00109	0.93027	0.00125	0.92913	0.00076	62279
120	3841	0.92439	0.95556	0.92724	0.93002	0.00122	0.92845	0.00111	0.93024	0.00123	0.92928	0.00077	60783

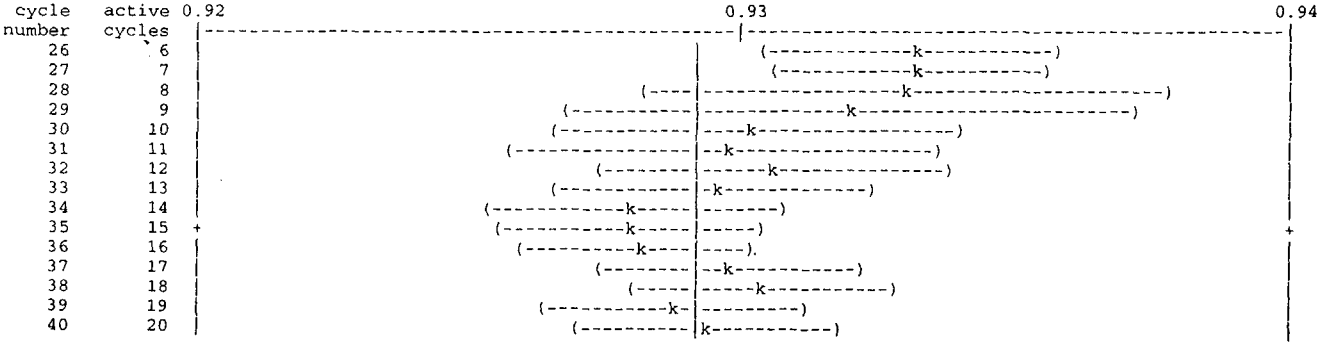
the largest active cycle keffs by estimator are:

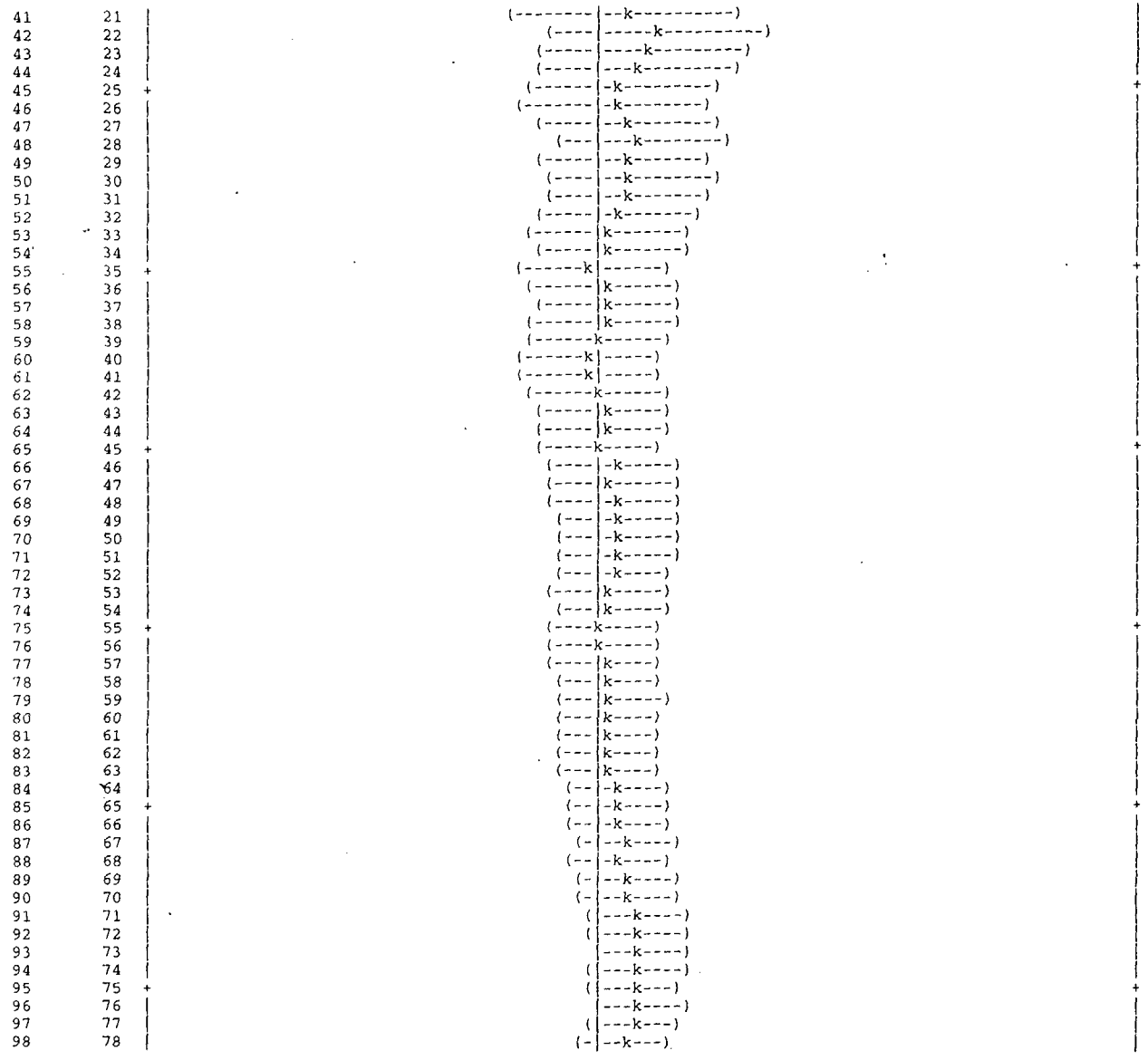
collision 0.95959 on cycle 27
absorption 0.95556 on cycle 120
track length 0.95897 on cycle 27

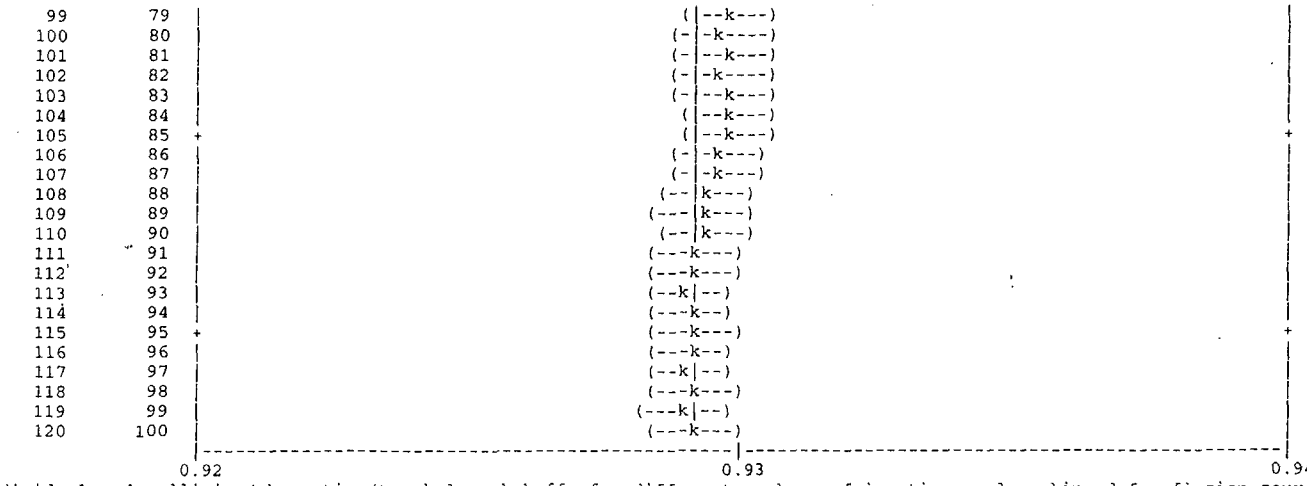
the smallest active cycle keffs by estimator are:

collision 0.89419 on cycle 39
absorption 0.89784 on cycle 106
track length 0.89380 on cycle 39

1plot of the estimated col/abs/track-length keff one standard deviation interval versus cycle number (| = final keff = 0.92928)







individual and collision/absorption/track-length keffs for different numbers of inactive cycles skipped for fission source settling

skip cycles	active cycles	active neutrons	average keff estimators and deviations k(col)	st dev	k(abs)	st dev	k(trk)	st dev	normality co/ab/tl	average k(c/a/t) k(c/a/t)	st dev	k(c/a/t) confidence intervals 95% confidence	99% confidence
0	120	478709	0.9321	0.0015	0.9288	0.0015	0.9321	0.0015	no/no/no	0.93044	0.00123	0.92800-0.93288	0.92720-0.93368
1	119	474709	0.9312	0.0011	0.9278	0.0011	0.9312	0.0012	95/95/95	0.92940	0.00075	0.92790-0.93089	0.92742-0.93138
2	118	470667	0.9310	0.0011	0.9276	0.0011	0.9310	0.0012	95/95/95	0.92922	0.00074	0.92775-0.93068	0.92728-0.93116
3	117	467003	0.9307	0.0011	0.9278	0.0011	0.9307	0.0011	95/95/95	0.92921	0.00074	0.92774-0.93068	0.92726-0.93116
4	116	462842	0.9307	0.0011	0.9278	0.0011	0.9307	0.0011	95/95/95	0.92918	0.00074	0.92769-0.93066	0.92721-0.93114
5	115	458916	0.9306	0.0011	0.9279	0.0011	0.9306	0.0012	95/95/95	0.92918	0.00075	0.92769-0.93067	0.92720-0.93116
6	114	454849	0.9306	0.0011	0.9279	0.0011	0.9307	0.0012	95/95/95	0.92920	0.00076	0.92769-0.93070	0.92720-0.93119
7	113	450874	0.9305	0.0011	0.9278	0.0011	0.9305	0.0012	95/95/95	0.92908	0.00075	0.92758-0.93057	0.92709-0.93106
8	112	446760	0.9305	0.0011	0.9278	0.0011	0.9306	0.0012	95/95/95	0.92910	0.00076	0.92759-0.93061	0.92710-0.93110
9	111	442820	0.9305	0.0012	0.9280	0.0011	0.9306	0.0012	95/95/95	0.92920	0.00075	0.92770-0.93070	0.92721-0.93119
10	110	438796	0.9304	0.0012	0.9281	0.0011	0.9305	0.0012	95/95/95	0.92921	0.00076	0.92770-0.93072	0.92720-0.93121
11	109	434772	0.9304	0.0012	0.9282	0.0011	0.9306	0.0012	95/95/95	0.92928	0.00076	0.92776-0.93080	0.92727-0.93130
12	108	430861	0.9303	0.0012	0.9281	0.0011	0.9305	0.0012	95/95/95	0.92921	0.00077	0.92768-0.93074	0.92719-0.93124
13	107	426772	0.9302	0.0012	0.9283	0.0011	0.9304	0.0012	95/95/95	0.92926	0.00077	0.92773-0.93080	0.92723-0.93130
14	106	422757	0.9300	0.0012	0.9282	0.0011	0.9301	0.0012	95/95/95	0.92910	0.00075	0.92762-0.93059	0.92713-0.93108
15	105	418772	0.9299	0.0012	0.9282	0.0011	0.9300	0.0012	95/95/95	0.92904	0.00075	0.92755-0.93054	0.92706-0.93103
16	104	414805	0.9298	0.0012	0.9284	0.0011	0.9299	0.0012	95/95/95	0.92909	0.00075	0.92759-0.93060	0.92710-0.93109
17	103	410752	0.9298	0.0012	0.9284	0.0011	0.9300	0.0012	95/95/95	0.92913	0.00076	0.92761-0.93065	0.92712-0.93114
18	102	406926	0.9299	0.0012	0.9283	0.0011	0.9300	0.0012	95/95/95	0.92913	0.00077	0.92759-0.93066	0.92709-0.93116
19	101	402957	0.9299	0.0012	0.9286	0.0011	0.9300	0.0012	95/95/95	0.92927	0.00076	0.92776-0.93078	0.92727-0.93128
20	100*	398906	0.9300	0.0012	0.9284	0.0011	0.9302	0.0012	95/95/95	0.92928	0.00077	0.92775-0.93081	0.92725-0.93131
22	98	390942	0.9300	0.0012	0.9285	0.0011	0.9302	0.0013	95/95/95	0.92930	0.00078	0.92774-0.93086	0.92723-0.93137
24	96	382992	0.9299	0.0012	0.9286	0.0012	0.9301	0.0013	95/95/95	0.92926	0.00080	0.92767-0.93084	0.92715-0.93136
26	94	375156	0.9298	0.0013	0.9284	0.0012	0.9299	0.0013	95/95/95	0.92910	0.00080	0.92750-0.93070	0.92697-0.93122
28	92	367233	0.9295	0.0013	0.9287	0.0012	0.9296	0.0013	95/95/95	0.92911	0.00080	0.92752-0.93070	0.92701-0.93122
30	90	359234	0.9295	0.0013	0.9289	0.0012	0.9296	0.0013	95/95/95	0.92921	0.00081	0.92759-0.93083	0.92707-0.93135
32	88	351370	0.9296	0.0013	0.9290	0.0012	0.9297	0.0013	95/95/95	0.92930	0.00081	0.92769-0.93091	0.92716-0.93144

34	86	343457	0.9297	0.0013	0.9291	0.0012	0.9298	0.0014	95/95/95	0.92944	0.00082	0.92780-0.93108	0.92726-0.93161
36	84	335529	0.9299	0.0013	0.9290	0.0012	0.9300	0.0014	95/95/95	0.92948	0.00084	0.92780-0.93116	0.92725-0.93170
38	82	327505	0.9295	0.0014	0.9286	0.0012	0.9297	0.0014	95/95/95	0.92910	0.00082	0.92747-0.93073	0.92694-0.93126
40	80	319686	0.9297	0.0013	0.9285	0.0013	0.9298	0.0013	95/95/95	0.92917	0.00078	0.92761-0.93073	0.92710-0.93124
42	78	311440	0.9298	0.0013	0.9281	0.0013	0.9300	0.0014	95/95/95	0.92898	0.00080	0.92739-0.93056	0.92687-0.93108
44	76	303348	0.9295	0.0013	0.9285	0.0012	0.9297	0.0014	95/95/95	0.92904	0.00081	0.92742-0.93066	0.92689-0.93119
46	74	295537	0.9301	0.0013	0.9282	0.0013	0.9303	0.0013	95/95/95	0.92921	0.00083	0.92754-0.93087	0.92700-0.93142
48	72	287507	0.9298	0.0013	0.9280	0.0013	0.9300	0.0014	95/95/95	0.92897	0.00084	0.92730-0.93065	0.92675-0.93119
50	70	279471	0.9298	0.0013	0.9280	0.0013	0.9301	0.0014	95/95/95	0.92903	0.00085	0.92734-0.93072	0.92678-0.93128
52	68	271425	0.9295	0.0014	0.9284	0.0013	0.9297	0.0014	95/95/95	0.92906	0.00087	0.92733-0.93079	0.92676-0.93136
54	66	263621	0.9293	0.0014	0.9285	0.0014	0.9296	0.0014	95/95/95	0.92905	0.00089	0.92728-0.93083	0.92669-0.93141
56	64	255644	0.9295	0.0014	0.9286	0.0014	0.9297	0.0014	95/95/95	0.92915	0.00088	0.92740-0.93091	0.92682-0.93149
58	62	247528	0.9296	0.0015	0.9285	0.0014	0.9299	0.0015	95/95/95	0.92917	0.00091	0.92735-0.93098	0.92675-0.93158
60	60	239729	0.9298	0.0015	0.9289	0.0014	0.9300	0.0015	95/95/95	0.92942	0.00091	0.92759-0.93125	0.92699-0.93186
62	58	231634	0.9296	0.0015	0.9288	0.0015	0.9296	0.0015	95/95/95	0.92920	0.00091	0.92737-0.93103	0.92676-0.93163
64	56	223764	0.9298	0.0015	0.9284	0.0015	0.9297	0.0015	95/95/95	0.92901	0.00094	0.92712-0.93089	0.92650-0.93152
66	54	215806	0.9296	0.0016	0.9282	0.0015	0.9296	0.0016	95/95/95	0.92886	0.00092	0.92701-0.93072	0.92639-0.93133
68	52	207744	0.9294	0.0016	0.9283	0.0016	0.9294	0.0016	95/95/95	0.92889	0.00096	0.92697-0.93082	0.92632-0.93146
70	50	199619	0.9291	0.0017	0.9282	0.0016	0.9292	0.0017	95/95/95	0.92872	0.00098	0.92674-0.93070	0.92607-0.93136
72	48	191511	0.9289	0.0017	0.9285	0.0017	0.9291	0.0018	95/95/95	0.92885	0.00101	0.92681-0.93089	0.92613-0.93157
74	46	183520	0.9286	0.0018	0.9291	0.0017	0.9286	0.0018	95/95/95	0.92886	0.00105	0.92674-0.93099	0.92602-0.93171
76	44	175470	0.9288	0.0019	0.9291	0.0017	0.9289	0.0019	95/95/95	0.92910	0.00107	0.92693-0.93127	0.92619-0.93200
78	42	167414	0.9286	0.0019	0.9290	0.0018	0.9287	0.0019	95/95/95	0.92890	0.00112	0.92665-0.93116	0.92588-0.93192
80	40	159322	0.9282	0.0020	0.9294	0.0018	0.9282	0.0020	95/95/95	0.92891	0.00116	0.92657-0.93126	0.92577-0.93205
82	38	151564	0.9283	0.0021	0.9290	0.0019	0.9285	0.0020	95/95/95	0.92885	0.00121	0.92641-0.93130	0.92557-0.93214
84	36	143547	0.9280	0.0022	0.9287	0.0020	0.9282	0.0021	95/95/95	0.92858	0.00125	0.92604-0.93112	0.92516-0.93200
86	34	135252	0.9272	0.0022	0.9290	0.0021	0.9274	0.0022	95/95/95	0.92837	0.00132	0.92567-0.93106	0.92474-0.93199
88	32	127326	0.9263	0.0022	0.9297	0.0021	0.9265	0.0022	95/95/95	0.92833	0.00136	0.92555-0.93111	0.92459-0.93207
90	30	119306	0.9248	0.0021	0.9296	0.0022	0.9251	0.0021	95/95/95	0.92731	0.00138	0.92448-0.93014	0.92349-0.93113
92	28	111454	0.9243	0.0022	0.9290	0.0023	0.9246	0.0022	95/95/95	0.92680	0.00141	0.92388-0.92971	0.92285-0.93074
94	26	103502	0.9239	0.0023	0.9292	0.0023	0.9243	0.0023	95/95/95	0.92686	0.00154	0.92368-0.93005	0.92254-0.93118
96	24	95527	0.9222	0.0021	0.9297	0.0025	0.9227	0.0022	95/95/95	0.92591	0.00167	0.92243-0.92938	0.92117-0.93064
98	22	87808	0.9224	0.0023	0.9305	0.0026	0.9228	0.0023	95/95/95	0.92632	0.00179	0.92257-0.93008	0.92120-0.93145
100	20	79909	0.9232	0.0022	0.9300	0.0028	0.9236	0.0022	95/95/95	0.92616	0.00187	0.92222-0.93011	0.92074-0.93158
102	18	71960	0.9218	0.0022	0.9302	0.0031	0.9223	0.0023	95/95/95	0.92496	0.00198	0.92074-0.92919	0.91913-0.93080
104	16	64157	0.9219	0.0024	0.9289	0.0034	0.9225	0.0025	95/95/95	0.92464	0.00213	0.92004-0.92923	0.91823-0.93105
106	14	56205	0.9211	0.0025	0.9304	0.0030	0.9218	0.0026	95/95/95	0.92509	0.00280	0.91893-0.93124	0.91640-0.93377
108	12	48208	0.9223	0.0026	0.9308	0.0034	0.9229	0.0028	95/95/95	0.92544	0.00312	0.91837-0.93250	0.91529-0.93558
110	10	40172	0.9232	0.0031	0.9320	0.0040	0.9233	0.0034	95/95/95	0.92636	0.00343	0.91824-0.93448	0.91435-0.93837
112	8	31896	0.9230	0.0036	0.9334	0.0047	0.9235	0.0038	95/95/95	0.92660	0.00491	0.91398-0.93922	0.90681-0.94640
114	6	24006	0.9227	0.0048	0.9348	0.0062	0.9236	0.0048	95/95/95	0.92796	0.00760	0.90376-0.95215	0.88355-0.97236
116	4	16091	0.9244	0.0071	0.9325	0.0089	0.9268	0.0067	95/95/95	0.97818	0.02077	0.71418-1.24218	0.00000-2.30046
117	3	12069	0.9280	0.0086	0.9332	0.0125	0.9303	0.0081					
118	2	7949	0.9198	0.0046	0.9339	0.0216	0.9226	0.0046					

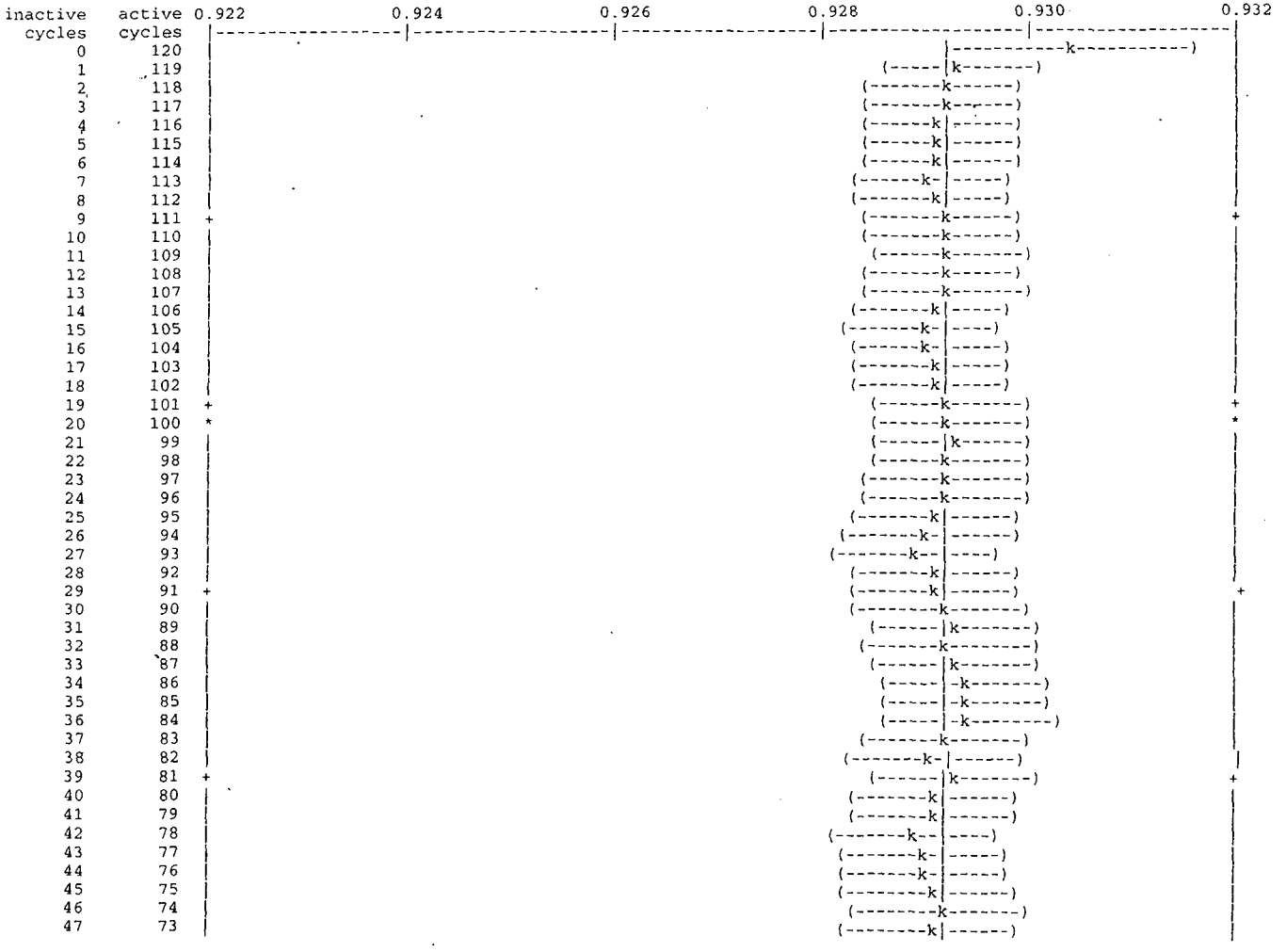
the minimum estimated standard deviation for the col/abs/tl keff estimator occurs with 2 inactive cycles and 118 active cycles.

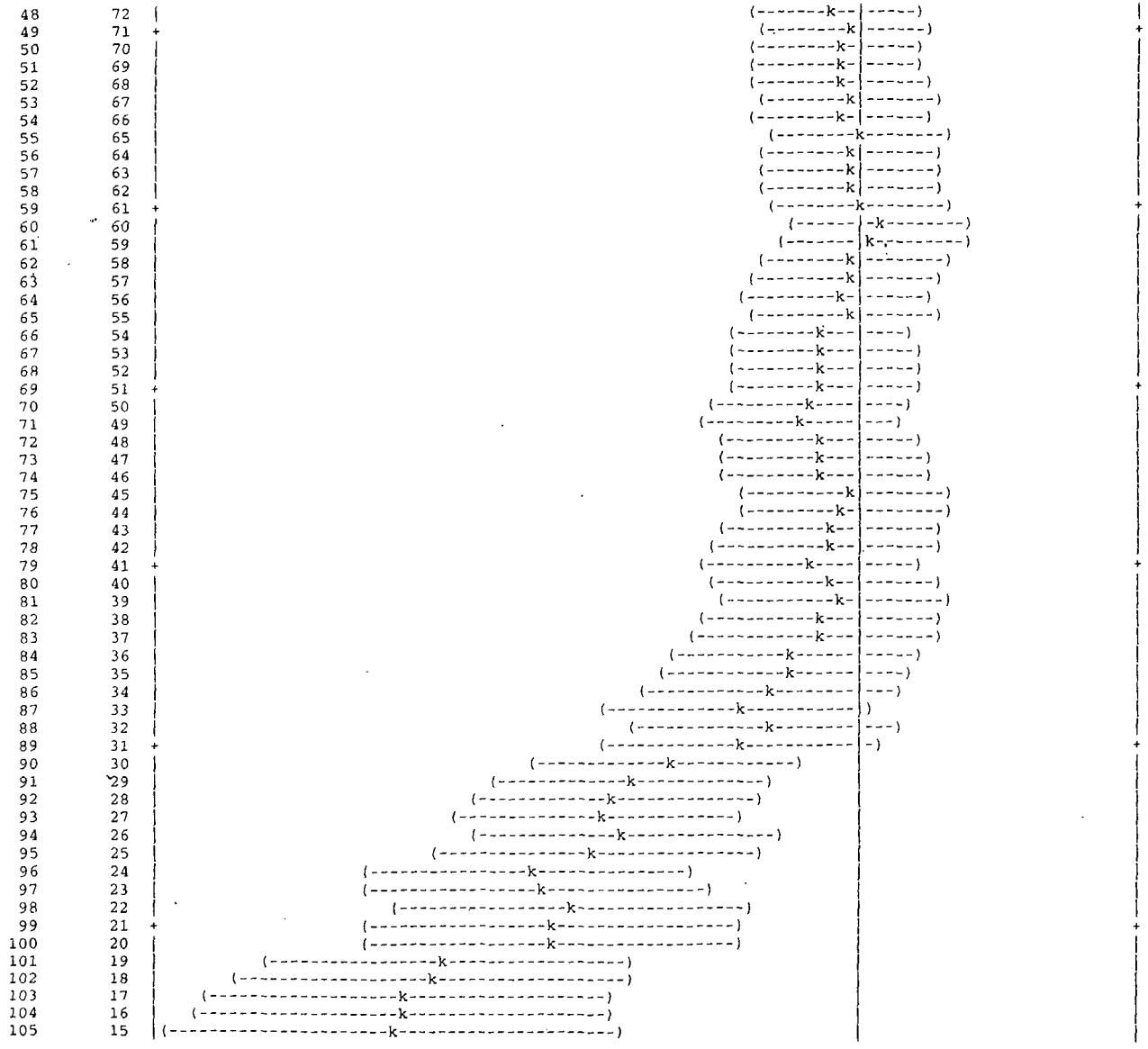
the first active half of the problem skips 20 cycles and uses 50 active cycles; the second half skips 70 and uses 50 cycles.
the col/abs/trk-len keff, one standard deviation, and 68, 95, and 99 percent intervals for each active half of the problem are:

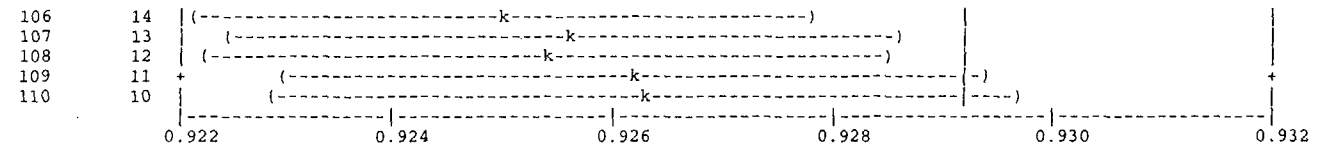
problem	keff	standard deviation	68% confidence	95% confidence	99% confidence

first half	0.92978	0.00120	0.92858 to 0.93099	0.92737 to 0.93219	0.92656 to 0.93300
second half	0.92872	0.00098	0.92773 to 0.92971	0.92674 to 0.93070	0.92607 to 0.93136
final result	0.92928	0.00077	0.92851 to 0.93005	0.92775 to 0.93081	0.92725 to 0.93131

the first and second half values of k(collision/absorption/track length) appear to be the same at the 68 percent confidence level.
lplot of the estimated col/abs/track-length keff one standard deviation interval by active cycle number (| = final keff = 0.92928)







dump no. 3 on file 4c100r nps = 478709 coll = 35918342 ctm = 28.98 nrn = 650997706

2 warning messages so far.

run terminated when 120 kcode cycles were done.

computer time = 29.00 minutes

mcnp version 4a 10/01/93 02/11/01 03:45:03 probid = 02/11/01 03:16:03

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Calculation Cover Page

3065 Southwestern Boulevard
Suite 202
Orchard Park, NY 14127
716 675 7130 Tel
716 675 7137 Fax

Job No: **30822-244-330 /6860** Calculation No: **BUF-2001-013/Rev. 1** Date: **February 25, 2001**

Problem Statement & Calculation Objectives:

To determine the Pu-239 mass sub-critical limit for ∞ × ∞ × 12 ft arrays of 2.5-cubic-foot boxes with Pu-239-cellulose spheres and pure cellulose or void outside the sphere. Every box has 1 sphere containing the same amount of Pu-239.

References and Data Available:

J. F. Briemiester, ed., MCNP - A General Purpose Monte Carlo N-Particle Transport Code, Version 4A, LA-12625, Los Alamos National Laboratory, Los Alamos NM, 1993
C. D. Harmon, II et al., Criticality Calculations with MCNP: A Primer, Manual LA-12827, Los Alamos National Laboratory, Los Alamos NM, 1993
D. R. Lide, CRC Handbook of Chemistry an Physics, CRC Press, Boston MA, 1991.
F. H. Attix, Introduction to Radiological Physics and Radiation Dosimetry. John Wiley & Sons, Inc., New York NY, 1986

Attachments:

Attachment 1: MCNP surface and cell numbers
Attachment 2: MCNP input file
Attachment 3: MCNP output file

Prepared by:

Signature Igor V. Chichkov — Date 03/14/01

Checked by:

Signature Kevin Roberts — Date 3/30/01

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Job No 30822-244-330 /6860 Job: PSR-6 By IVC Date 03/14/01
Client WVNS Subject: cellulose-Pu-239 spheres Chk'd. KR Date 3/30/01

Analysis

Assumptions

- Pu-239 inside the sphere is uniformly mixed with 0.72 g/cm^3 cellulose
- The pure cellulose (0.72 g/cm^3) fills the entire space inside the container and outside the Plutonium sphere.
- The containers stand on the 3 m thick concrete floor
- The box inside dimensions are 2.875 x 2.875 x 2.875 foot
- The box wall thickness is zero
- Every box in the array contains the same mass of Pu-239
- The boxes are arranged in the infinite square array, 12 feet heigh ($\infty \times \infty \times$ 12 ft)

MCNP Model

Neutron multiplication factors were calculated with MCNP4A code. Attachments 1 has the drawings of the models used. Examples of MCNP input and output files for both cases can also be found in the Attachments. The plutonium spheres were located in the box's corner as shown in Attachments 1.

Air, Carbon Steel, Concrete and Cellulose Composition

Table 1 shows the element weight fractions for air (Attix F.H., 1986). Table 2 shows the element composition of concrete (Harmon C. D., II et al., 1993) in the floor.

Table 1. Air composition

Element	Weight Fraction
Carbon (C)	0.000124
Nitrogen (N)	0.755267
Oxygen (O)	0.231781
Argon (Ar)	0.012827

Table 2. Concrete composition

Element	Weight Fraction
Hydrogen (H)	0.010
Oxygen (O)	0.532
Sodium (Na)	0.029
Aluminum (Al)	0.034
Silicon (Si)	0.337
Calcium (Ca)	0.044
Iron (Fe)	0.014

The weight fractions of the elements composing the cellulose were determined based on the known atomic weights of the elements (Table 3) and the cellulose chemical formula - $C_6H_{10}O_5$.

Table 3. The atomic weights of the elements

Element	Atomic Weight
Hydrogen (H)	1.00794
Carbon (C)	12.0107
Oxygen (O)	15.9994

The molecular weight of cellulose ($C_6H_{10}O_5$) was calculated as the sum of all atomic weights composing the molecule. The weight fraction of an ith element was found as a ratio of the ith element weight in the molecule to the molecular weight of this molecule.

$$(w_i)_{cel} = \frac{n_i A_i}{M_{cel}} = \frac{n_i A_i}{\sum n_i A_i} \qquad (1)$$

where

$(w_i)_{cel}$ = the weight fraction of ith element in a molecule of cellulose

n_i = the number of the ith elements in a cellulose molecule

A_i = the atomic weight of the ith element, g/mol

M_{cel} = the molecular weight a cellulose molecule, g/mol

Calculated weight fractions for cellulose are shown in Table 4.

Table 4. Cellulose Weight Fractions

Element	Weight Fraction
Hydrogen (H)	0.062
Carbon (C)	0.444
Oxygen (O)	0.493

Radii of the Plutonium containing spheres.

The spheres with several different radii were studied. The minimum size of the Plutonium containing sphere corresponded to the sphere with pure Pu-239 and the maximum size was limited by the dimensions of the container, i.e. half of the box height. The minimum radius equation (3) was derived from the volume of a sphere equation (2)

$$V_{Pu} = \frac{4\pi\left(R_{Pu}\right)^3}{3} \qquad (2)$$

$$R_{\min} = R_{Pu} = \sqrt[3]{\frac{3V_{Pu}}{4\pi}} = \sqrt[3]{\frac{3m_{Pu}}{4\pi\rho_{Pu}}} \qquad (3)$$

where:

R_{min} = the minimum possible radius of the sphere containing Pu-239, cm

R_{Pu} = the radius of the metal Plutonium sphere, cm

V_{Pu} = the volume of the sphere with Pu-239, cm^3

m_{Pu} = the mass of the Plutonium sphere, g

ρ_{Pu} = the density of the metal Plutonium, 19.78 g/cm^3

Composition of the Plutonium containing spheres

The weight fractions of the elements composing the mixture are defined as the ratio of the mass of the element in the mixture to the total mass of the mixture. Total mass of the mixture was determined using

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equation (4):

$$M_{total} = m_{Pu} + m_{cel} = m_{Pu} + V_{cel}\rho_{cel} =$$

$$= m_{Pu} + \left(V_{Total} - V_{Pu}\right)\rho_{cel} = m_{Pu} + \left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel} \qquad (4)$$

where

M_{Total} = the total mass of the mixture, g

m_{Pu} = the mass of Pu-239 in a sphere, g

m_{cel} = the mass of a cellulose in a sphere, g

V_{Total} = the total volume of a sphere, cm^3

V_{cel} = the volume of a cellulose in the sphere, cm^3

ρ_{cel} = the density of a cellulose, 0.72 g/cm^3

V_{Pu} = the volume of Pu-239 in the sphere, cm^3

ρ_{Pu} = the density of the metal Plutonium, 19.78 g/cm^3

R = the radius of a Plutonium containing sphere, cm

In the Plutonium-cellulose mixture, the weight fraction of Pu-239 was calculated using equation 5, and the weight fractions of elements composing cellulose were calculated using equation 7 as a product of the weight fraction of a cellulose in the Plutonium-cellulose mixture (equation 6) and the weight fraction of an element in a pure cellulose (equation 1).

$$w_{Pu} = \frac{m_{Pu}}{M_{total}} = \frac{m_{Pu}}{m_{Pu} + \left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel}} \qquad (5)$$

$$w_{cel} = \frac{m_{cel}}{M_{total}} = \frac{\left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel}}{m_{Pu} + \left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel}} \qquad (6)$$

$$w_i = w_{cel}(w_i)_{cel} = \frac{\left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel} n_i A_i}{\left[m_{Pu} + \left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel}\right]\sum n_i A_i} \qquad (7)$$

All variables in equations 5-7 are as described above. Table 6 shows the composition of the Plutonium containing spheres.

The cases for spheres with 150g, 200g, 250, and 350g of Pu-239 were studied and based on the calculated neutron multiplication factors, the Pu-239 sub-critical mass limit was determined. Tables 5-8 show the composition of the spheres used in the models.

Table 5. The composition of the spheres with 150g of Pu-239.

Radius of the sphere, cm	5	10	15	20	43.815
Mixture density, g/cm^3	0.99605095	0.754506369	0.730224109	0.724313296	0.720410233
Pu-239 weight fraction	0.287614702	0.047461312	0.014530237	0.00617997	0.000591
Carbon (C) weight fraction	0.316623206	0.42336058	0.437996961	0.44170828	0.444192345
Hydrogen (H)weight fraction	0.044285123	0.059214154	0.0612613	0.061780391	0.062127829
Oxygen (O) weight fraction	0.351476969	0.469963954	0.486211502	0.490331361	0.49308887

Table 6. The composition of the spheres with 200g of Pu-239.

Radius of the sphere, cm	5	10	15	20	43.815
Mixture density, g/cm^3	1.088067933	0.766008492	0.733632146	0.725751061	0.720546978
Pu-239 weight fraction	0.351055161	0.062331532	0.019283651	0.00822363	0.0007878
Carbon (C) weight fraction	0.288426777	0.416751437	0.435884283	0.440799963	0.44410486
Hydrogen (H)weight fraction	0.040341374	0.058289753	0.060965806	0.061653347	0.062115593
Oxygen (O) weight fraction	0.320176688	0.462627278	0.48386626	0.489323057	0.493

Table 7. The composition of the spheres with 250g of Pu-239.

Radius of the sphere, cm	5	10	15	20	43.815
Mixture density, g/cm^3	1.180084916	0.777510615	0.737040182	0.727188827	0.720683722
Pu-239 weight fraction	0.404602095	0.076761786	0.023993105	0.010259217	0.0009846
Carbon (C) weight fraction	0.264627575	0.410337838	0.433791142	0.439895237	0.444017409
Hydrogen (H)weight fraction	0.037012652	0.057392703	0.060673045	0.061526806	0.062103362
Oxygen (O) weight fraction	0.293757678	0.455507673	0.481542708	0.48831874	0.4928946

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Table 8. The composition of the spheres with 350g of Pu-239.

Radius of the sphere, cm	5	10	15	20	43.815
Mixture density, g/cm^3	1.364118883	0.80051486	0.743856255	0.730064358	0.720957211
Pu-239 weight fraction	0.490023831	0.104378256	0.033282553	0.014306332	0.00137785
Carbon (C) weight fraction	0.226661457	0.39806356	0.4296624	0.438096477	0.443842606
Hydrogen (H)weight fraction	0.031702447	0.055675937	0.06009557	0.061275219	0.062078912
Oxygen (O) weight fraction	0.251612265	0.441882247	0.476959476	0.486321972	0.492700633

Results

The results of the calculations performed using MCNP-4A code are shown in the following tables and graphs. Tables 9-12 provide the Monte Carlo determined neutron multiplication factor (k_{eff}) values and their standard deviations (σ), and Figures 1-4 plot the k_{eff} +2 σ values for all studied cases (150g, 200g, 250, and 350g).

Table 9. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for the boxes with 150 g of Pu-239.

R and X-, Y-, Z- coordinates for the center of the sphere, cm					cellulose outside the sphere			void outside the sphere		
R	X	Y	Z1	Z2	k_{eff}	σ	k_{eff}+ 2σ	k_{eff}	σ	k_{eff}+ 2σ
5	5	5	82.63	92.63	0.5646	0.0012	0.5671	0.0884	0.0005	0.0894
10	10	10	77.63	97.63	0.81441	0.00147	0.8174	0.30188	0.00105	0.3040
15	15	15	72.63	102.63	0.7699	0.0011	0.7721	0.4858	0.0010	0.4878
20	20	20	67.63	107.63	0.6129	0.0008	0.6144	0.5300	0.0010	0.5320
43.815	43.815	43.815	43.815	131.445	0.1723	0.0002	0.1727	0.2259	0.0002	0.2262

Table 10. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for the boxes with 200 g of Pu-239.

R and X-, Y-, Z- coordinates for the center of the sphere, cm					cellulose outside the sphere			void outside the sphere		
R	X	Y	Z1	Z2	k_{eff}	σ	k_{eff}+ 2σ	k_{eff}	σ	k_{eff}+ 2σ
5	5	5	82.63	92.63	0.5804	0.0013	0.5829	0.1000	0.0006	0.1012
10	10	10	77.63	97.63	0.85562	0.00136	0.8583	0.32365	0.00121	0.3261
15	15	15	72.63	102.63	0.8499	0.0013	0.8524	0.5432	0.0011	0.5453
20	20	20	67.63	107.63	0.7131	0.0009	0.7149	0.6181	0.0010	0.6202
43.815	43.815	43.815	43.815	131.445	0.2221	0.0002	0.2225	0.2906	0.0002	0.2909

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Sheet No. 8/12
Calc. No. BUF-2001-014
Rev. No. 1

Job No 30822-244-330 /6860 Job: PSR-6 By IIC Date 03/14/01
Client WVNS Subject: cellulose-Pu-239 spheres Chk'd. KL Date 3/30/01

Table 11. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for the boxes with 250 g of Pu-239.

R and X-, Y-, Z- coordinates for the center of the sphere, cm					cellulose outside the sphere			void outside the sphere		
R	X	Y	Z1	Z2	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$
5	5	5	82.63	92.63	0.5903	0.0013	0.5928	0.1123	0.0006	0.1134
10	10	10	77.63	97.63	0.8791	0.0014	0.8819	0.33982	0.00116	0.3421
15	15	15	72.63	102.63	0.9070	0.0012	0.9095	0.5833	0.0013	0.5859
20	20	20	67.63	107.63	0.7886	0.0009	0.7904	0.6881	0.0010	0.6900
43.815	43.815	43.815	43.815	131.445	0.2696	0.0002	0.2700	0.3511	0.0002	0.3515

Table 12. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for the boxes with 350 g of Pu-239.

R and X-, Y-, Z- coordinates for the center of the sphere, cm					cellulose outside the sphere			void outside the sphere		
R	X	Y	Z1	Z2	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$
5	5	5	82.63	92.63	0.6135	0.0013	0.6160	0.1364	0.0005	0.1374
10	10	10	77.63	97.63	0.9121	0.00135	0.9148	0.36055	0.00132	0.36
15	15	15	72.63	102.63	0.9809	0.0013	0.9836	0.6397	0.0014	0.6425
20	20	20	67.63	107.63	0.8985	0.0012	0.9008	0.7864	0.0012	0.7889
43.815	43.815	43.815	43.815	131.445	0.3563	0.0004	0.3570	0.4594	0.0003	0.4600

Figure 1. k_{eff} +2σ for the boxes with 150 g of Pu-239 .

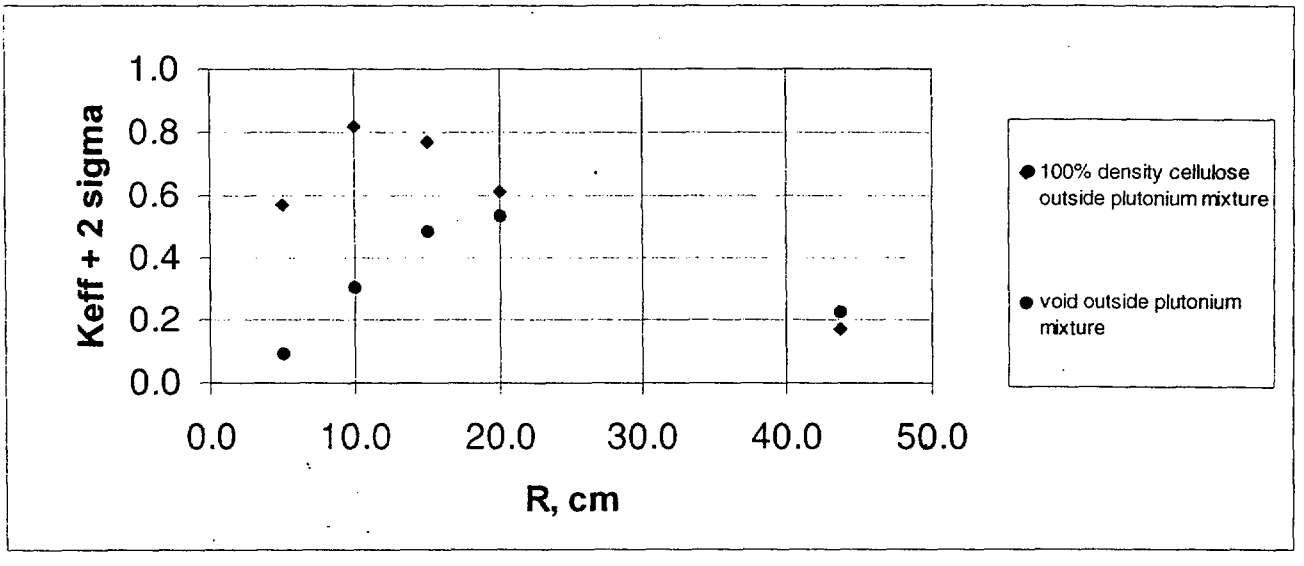

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Figure 2. k_{eff} +2σ for the boxes with 200 g of Pu-239 .

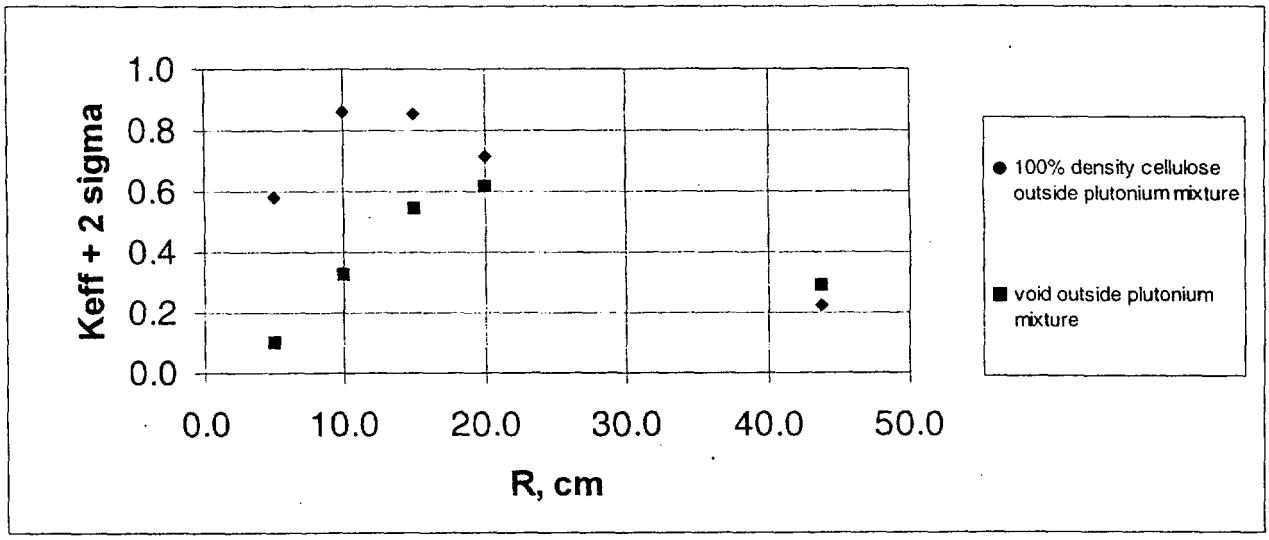

Figure 3. k_{eff} +2σ for the boxes with 250 g of Pu-239.

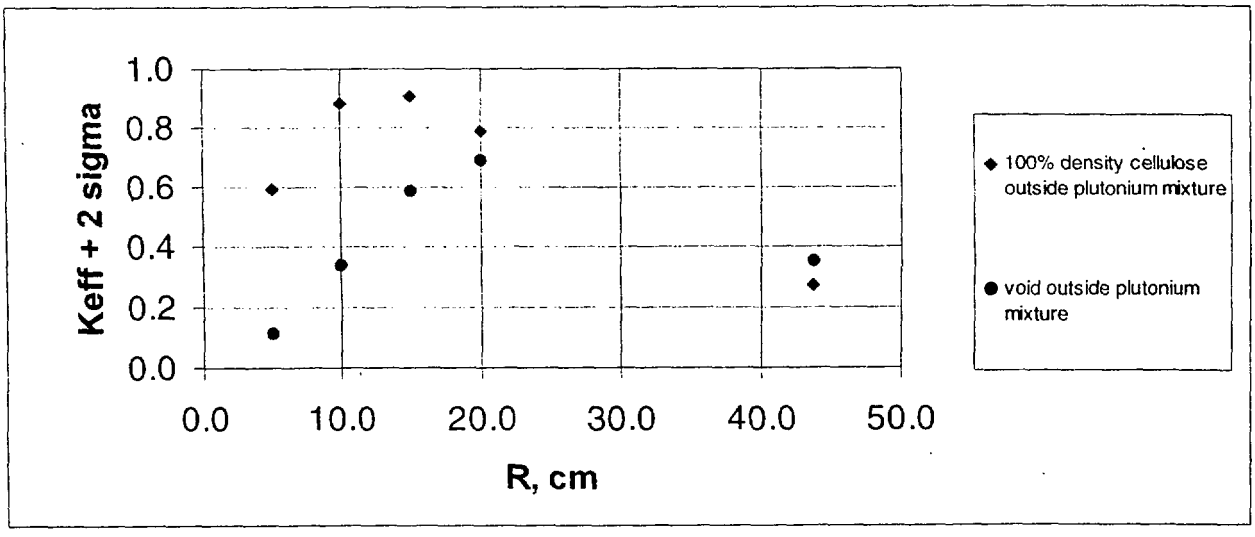

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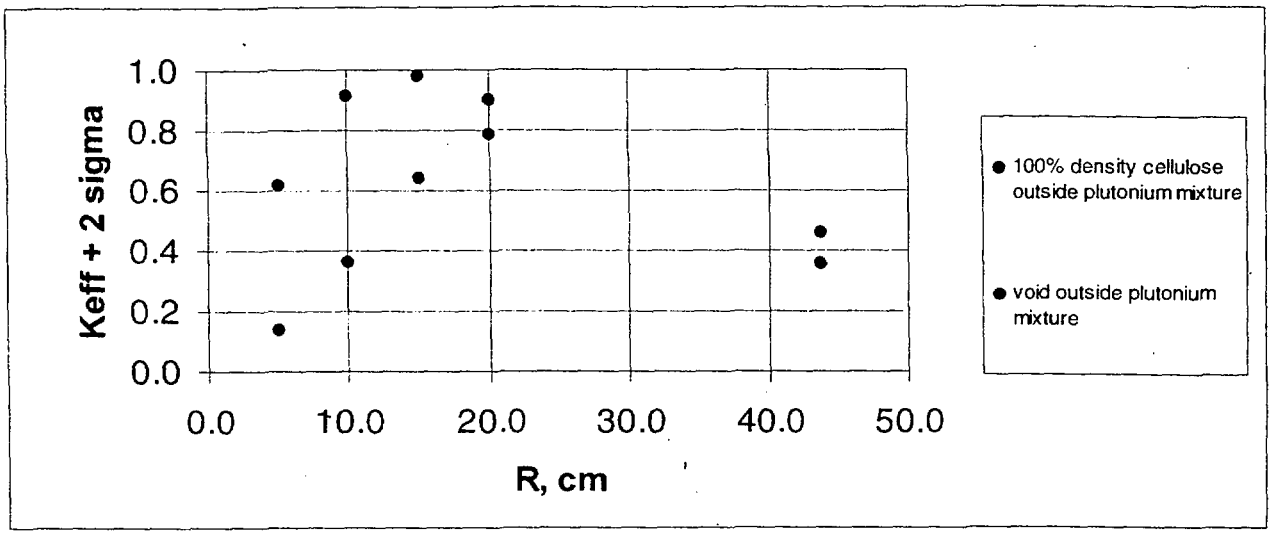
Figure 4. k_{eff} +2σ for the boxes with 350 g of Pu-239.



The criterion for the Pu-239 mass limit is:

$$k_{eff} + 2\sigma \leq k_a - \Delta k_b - \sigma_b \quad (8)$$

Where:

k_{eff} = neutron multiplication factor predicted by MCNP

σ = standard deviation of predicted k_{eff}

$k_a = 0.95$ = established allowable limiting neutron multiplication factor

Δk_b = calculation method bias

σ_b = bias uncertainty

The calculation method bias together with bias uncertainty ($\Delta k_b + \sigma_b$) is no more than 0.02. Thus the criterion (8) can be modified as:

$$k_{eff} + 2\sigma \leq 0.93 \quad (9)$$

Where:

k_{eff} = neutron multiplication factor predicted by MCNP

σ = standard deviation of predicted k_{eff}

To determine the Pu-239 mass limit, the maximum values of k_{eff} +2σ as a function of Pu-239 mass (Table 13) were approximated with a polynomial equation, which is shown on Figure 5.

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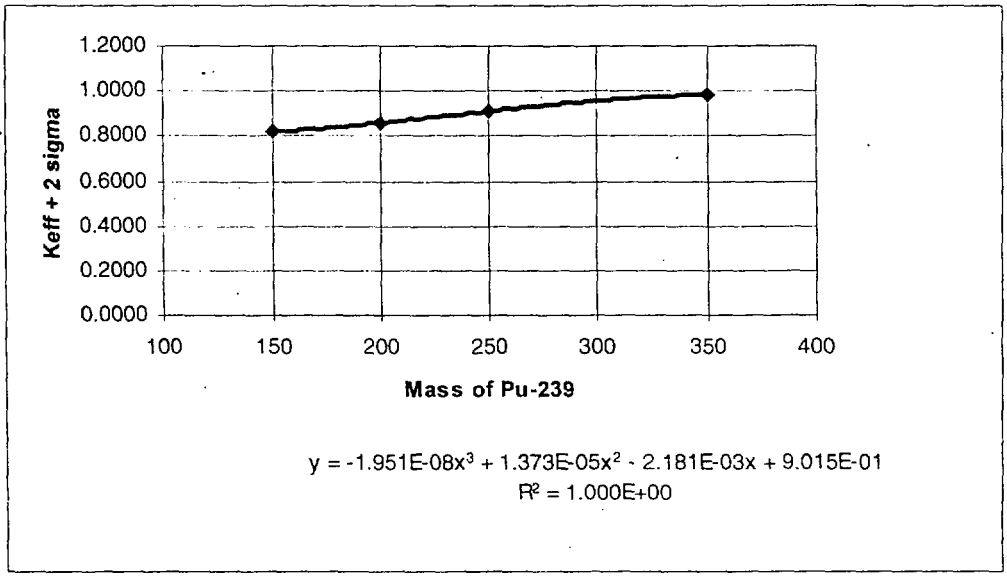
Table 13. The maximum values of k_{eff} +2σ as a function of Pu-239 mass.

Mass of Pu-239, g	k_{eff}	σ	k_{eff}+ 2σ
150	0.81441	0.00147	0.8174
200	0.85562	0.00136	0.8583
250	0.9070	0.0012	0.9095
350	0.9809	0.0013	0.9836

Figure 5. The maximum values of k_{eff} +2σ as a function of Pu-239 mass.



Solving the polynomial equation from Figure 4 determines the Pu-239 mass limit as 265g per box. To check this result, another set of MCNP runs was performed. Table 14 shows the composition of the Plutonium containing spheres, and Table 15 and Figure 6 show the calculation results for the arrays of boxes with 265g of Pu-239.

Table 14. The composition of the spheres with 265g of Pu-239

Radius of the sphere, cm	5	10	15	20	43.815
Mixture density, g/cm^3	1.207690011	0.780961251	0.738062593	0.727620156	0.720724745
Pu-239 weight fraction	0.419075023	0.081007975	0.02539746	0.010868323	0.0015863
Carbon (C) weight fraction	0.258195009	0.408450598	0.433166969	0.439624517	0.443749958
Hydrogen (H)weight fraction	0.036112949	0.05712874	0.060585744	0.061488941	0.062065954
Oxygen (O) weight fraction	0.286617019	0.453412686	0.480849826	0.488018218	0.492597787

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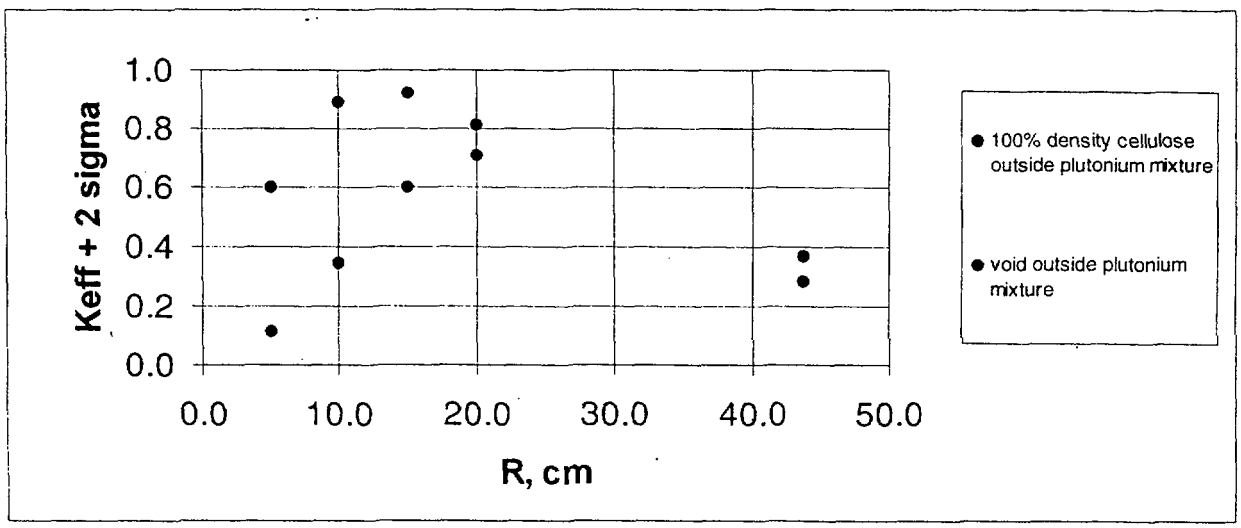
Client WVNS Subject: cellulose-Pu-239 spheres Chk'd. KR Date 3/30/07

Table 15. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for the boxes with 265 g of Pu-239.

R and X-, Y-, Z- coordinates for the center of the sphere, cm					cellulose outside the sphere			void outside the sphere		
R	X	Y	Z1	Z2	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$
5	5	5	82.63	92.63	0.5957	0.0014	0.5986	0.1162	0.0005	0.1173
10	10	10	77.63	97.63	0.88582	0.00141	0.8886	0.34223	0.00121	0.3447
15	15	15	72.63	102.63	0.9206	0.0013	0.9233	0.5947	0.0014	0.5974
20	20	20	67.63	107.63	0.8091	0.0010	0.8110	0.7049	0.0010	0.7069
43.815	43.815	43.815	43.815	131.445	0.2831	0.0003	0.2837	0.3679	0.0002	0.3683

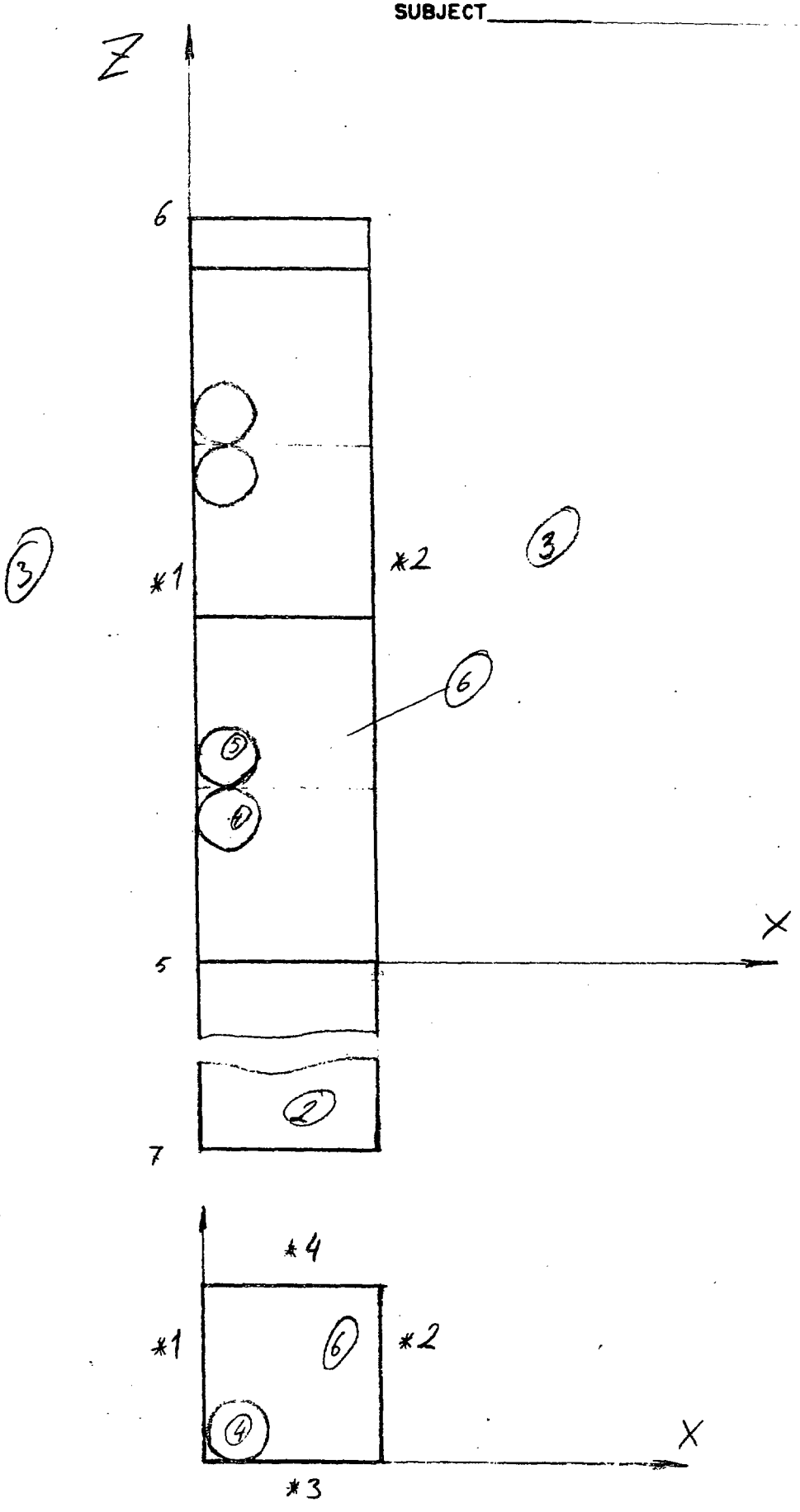
Figure 6. k_{eff} +2σ for the boxes with 265g of Pu-239.



The k_{eff} +2σ values in Table 15 confirm that 265g of Pu-239 is a sub-critical mass limit for $\infty \times \infty \times 12$ ft arrays of 2.875-cubic-foot boxes with Pu-239-cellulose spheres and pure cellulose or void outside the sphere.

Attachment 1: MCNP model with surface and cell numbers

REVISIONS
BY _____ DATE _____ TO EO ____
BY _____ DATE _____ TO EO ____



BY _____ DATE _____
CHECKED BY _____
COPY TO EO _____

Attachment 2: MCNP input file

```
                                                    3b081
k eff, 265g of Pu-239 in cellulose spheres in 2.875 c. foot of pure celulose
C
C Cell cards
C
C ---------------------------------------------------------------------------
1 0   1 -2 3 -4 5 -6 fill=2          imp:n=1 $ box with lattice
2 2  -2.3    1 -2 3 -4 -5 7          imp:n=1 $ Concrete floor
3 0        -1 : 2 : -3 : 4 : -7 : 6  imp:n=0 $ Outside world
c
c Universe 1
4 3  -0.738063 -8              u=1    imp:n=1 $ 1 Pu-239 and cellulose sphere
5 3  -0.738063 -9              u=1    imp:n=1 $ 2 Pu-239 and cellulose sphere
6 1  -0.72       8 9            u=1    imp:n=1 $ cellulose
c
c Lattice (2 spheres with Pu-239 in 2 cubes of cellulose matrix)
7 0 10 -11 12 -13 14 -15 lat=1 fill=1 u=2 imp:n=1 $ Lattice
C ---------------------------------------------------------------------------
c
c Note: next line must be completely blank

c Surface cards
C ---------------------------------------------------------------------------
*1 px 0.001
*2 px 87.631  $  box length (2.875 foot)
*3 py 0.001
*4 py 87.631  $  box width (2.875 foot)
5  pz 0.001
6  pz 365.761 $  box height (12 feet)
c                More thnan 350.52cm (11.5 feet) - 4 tiers of B-25 box height
c                (4x34.5" or 4x87.63 cm)
7  pz -300 $ concrete floor boundary
8  s 15.0 15.0  72.63 15.0 $ 1st Pu-239 containing sphere
9  s 15.0 15.0  102.63 15.0 $ 2nd Pu-239 containing sphere
c
c Lattice surfases:
10 px 0
11 px 87.63  $ 2.875 feet
12 py 0
13 py 87.63  $ 2.875 feet
14 pz 0
15 pz 175.26 $ 2 x 2.875 feet
C ---------------------------------------------------------------------------
c
c Note: next line must be completely blank

c Data cards
c
c Materials
c
c
c Celulose matrix (Elements: C, H, O)
m1     6000.50c  -0.444
       1001.50c  -0.062
       8016.50c  -0.493
c Concrete (KENO Regular Concrete Standard Mix) from Harmon at al.
c Criticality Calculation with MCNP. A Primer. p. C-4
c (Elements: H, O, Na, Si, Al, Ca, Fe)
m2     1001.50c -0.010
       8016.50c -0.532
      11023.50c -0.029
      13027.50c -0.034
      14000.50c -0.337
      20000.50c -0.044
      26000.55c -0.014
c Pu-239 and cellulose
m3    94239.55c  -0.02539746
       6000.50c  -0.433166969
       1001.50c  -0.060585744
       8016.50c  -0.480849826
c
mode n
print 40 60 80 100 110 126
kcode 4000 1. 20 120
ksrc  15.0 15.0  72.63
      15.0 15.0  102.63
```

Attachment 3: MCNP output file

```
1mcnp     version 4a     ld=10/01/93                    02/14/01 08:19:43
*************************************************************************          probid =    02/14/01 08:19:43
name=3b081

      k eff, 265g of Pu-239 in cellulose spheres in 2.875 c. foot of pure celulose
      C
      C Cell cards
      C
      C ---------------------------------------------------------------------
      1 0   1 -2 3 -4 5 -6 fill=2          imp:n=1 $ box with lattice
      2 2  -2.3    1 -2 3 -4 -5 7          imp:n=1 $ Concrete floor
      3 0         -1 : 2 : -3 : 4 : -7 : 6  imp:n=0 $ Outside world
      c
      c Universe 1
      4 3  -0.738063 -8              u=1    imp:n=1 $ 1 Pu-239 and cellulose sphere
      5 3  -0.738063 -9              u=1    imp:n=1 $ 2 Pu-239 and cellulose sphere
      6 1  -0.72       8 9            u=1    imp:n=1 $ cellulose
      c
      c Lattice (2 spheres with Pu-239 in 2 cubes of cellulose matrix)
      7 0 10 -11 12 -13 14 -15 lat=1 fill=1 u=2 imp:n=1 $ Lattice
      C ---------------------------------------------------------------------
      c
      c Note: next line must be completely blank

      c Surface cards
      C ---------------------------------------------------------------------
      *1 px 0.001
      *2 px 87.631  $  box length (2.875 foot)
      *3 py 0.001
      *4 py 87.631  $  box width (2.875 foot)
      5  pz 0.001
      6  pz 365.761 $  box height (12 feet)
      c                More thnan 350.52cm (11.5 feet) - 4 tiers of B-25 box height
      c                (4x34.5" or 4x87.63 cm)
      7  pz -300 $ concrete floor boundary
      8  s 15.0 15.0  72.63 15.0 $ 1st Pu-239 containing sphere
      9  s 15.0 15.0  102.63 15.0 $ 2nd Pu-239 containing sphere
      c
      c Lattice surfases:
      10 px 0
      11 px 87.63  $ 2.875 feet
      12 py 0
      13 py 87.63  $ 2.875 feet
      14 pz 0
      15 pz 175.26 $ 2 x 2.875 feet
      C ---------------------------------------------------------------------
      c
      c Note: next line must be completely blank

      c Data cards
      c
      c Materials
      c
      c
      c Celulose matrix (Elements: C, H, O)
      m1      6000.50c  -0.444
              1001.50c  -0.062
              8016.50c  -0.493
```

```
   55-        c Concrete (KENO Regular Concrete Standard Mix) from Harmon at al.
   56-        c Criticality Calculation with MCNP. A Primer. p. C-4
   57-        c (Elements: H, O, Na, Si, Al, Ca, Fe)
   58-        m2      1001.50c -0.010
   59-                8016.50c -0.532
   60-               11023.50c -0.029
   61-               13027.50c -0.034
   62-               14000.50c -0.337
   63-               20000.50c -0.044
   64-               26000.55c -0.014
   65-        c Pu-239 and cellulose
   66-        m3     94239.55c  -0.02539746
   67-                6000.50c  -0.433166969
   68-                1001.50c  -0.060585744
   69-                8016.50c  -0.480849826
   70-        c
   71-        mode n
   72-        print 40 60 80 100 110 126
   73-        kcode 4000 1. 20 120
   74-        ksrc  15.0 15.0  72.63
   75-              15.0 15.0  102.63
   76-
 total fission nubar data are being used.
1material composition                                                    print table 40

 the sum of the fractions of material     1 was 9.990000E-01

 material
  number      component nuclide, atom fraction

     1            6000,  0.28588       1001,  0.47576       8016,  0.23837
     2            1001,  0.16803       8016,  0.56324      11023,  0.02136      13027,  0.02134
                 14000,  0.20319      20000,  0.01859      26000,  0.00425
     3           94239,  0.00084       6000,  0.28543       1001,  0.47579       8016,  0.23793


 material
  number      component nuclide, mass fraction

     1            6000,  0.44444       1001,  0.06206       8016,  0.49349
     2            1001,  0.01000       8016,  0.53200      11023,  0.02900      13027,  0.03400
                 14000,  0.33700      20000,  0.04400      26000,  0.01400
     3           94239,  0.02540       6000,  0.43317       1001,  0.06059       8016,  0.48085

 warning.     1 of the materials had unnormalized fractions.
1cells                                                                   print table 60

                          atom          gram                                        neutron
        cell   mat      density       density       volume          mass       pieces importance

     1     1     0  0.00000E+00  0.00000E+00  2.80868E+06  0.00000E+00      0  1.0000E+00
     2     2     2  8.17913E-02  2.30000E+00  2.30371E+06  5.29854E+06      0  1.0000E+00
     3     3     0  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00      0  0.0000E+00
     4     4     3  5.61574E-02  7.38063E-01  1.41372E+04  1.04341E+04      1  1.0000E+00
     5     5     3  5.61574E-02  7.38063E-01  1.41372E+04  1.04341E+04      1  1.0000E+00
```

```
     6     6     1  5.61219E-02 7.20000E-01 0.00000E+00 0.00000E+00     0  1.0000E+00
     7     7     0  0.00000E+00 0.00000E+00 1.34582E+06 0.00000E+00     0  1.0000E+00

 total                                      6.48649E+06 5.31941E+06

          1 warning message so far.
1cross-section tables                                                                    print table 100

     table    length

                        tables from file critxs

   1001.50c    1153  njoy                                                        (  1301)      79/07/31.
   6000.50c   16126  njoy                                                        (  1306)      79/07/31.
   8016.50c   23669  njoy                                                        ( 1276)      05/14/81
  11023.50c   36270  njoy                                                        (  1311)      79/06/21.
  13027.50c   22891  njoy                                                        (  1313)      79/09/08.
  14000.50c   48275  njoy                                                        (  1314)      79/06/21.
  20000.50c   26104  njoy                                                        (  1320)      79/06/22.
  26000.55c   84136  njoy                                                        ( 260)       10/21/82
  94239.55c   67551  njoy                                          total nu      ( 1399)      02/21/85

  total      326175

 warning.  neutron energy cutoff is below some cross-section tables.



 decimal words of dynamically allocated storage

     general             111136
     tallies                  0
     bank                 12403
     cross sections      326175

     total               449714

*****************************************************************************************************************
 dump no.    1 on file 3b081r       nps =         0     coll =              0     ctm =    0.00     nrn =              0

 source distribution written to file 3b081s          cycle =     0

          2 warning messages so far.
1   starting mcrun.      field length =      0      cp0 =  0.01                                    print table 110

      k eff, 265g of Pu-239 in cellulose spheres in 2.875 c. foot of pure celulose

 nps   x          y          z        cell lattice(i,j,k)  surface    u          v          w        energy     weight      time

  1  1.500E+01  1.500E+01  7.263E+01    1                          5.085E-01  4.733E-01  7.193E-01  2.209E+00  1.000E+00  0.000E+00
     1.500E+01  1.500E+01  7.263E+01    7(   0,    0,    0)        5.085E-01  4.733E-01  7.193E-01
     1.500E+01  1.500E+01  7.263E+01    4                      0   5.085E-01  4.733E-01  7.193E-01
  2  1.500E+01  1.500E+01  7.263E+01    1                          8.952E-01 -4.447E-01 -2.944E-02  4.904E+00  1.000E+00  0.000E+00
     1.500E+01  1.500E+01  7.263E+01    7(   0,    0,    0)        8.952E-01 -4.447E-01 -2.944E-02
```

	1.500E+01	1.500E+01	7.263E+01	4				0	8.952E-01	-4.447E-01	-2.944E-02			
3	1.500E+01	1.500E+01	7.263E+01	1					-6.184E-01	-4.495E-01	6.446E-01	3.809E-01	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	7.263E+01	7(	0,	0,	0)		-6.184E-01	-4.495E-01	6.446E-01			
	1.500E+01	1.500E+01	7.263E+01	4				0	-6.184E-01	-4.495E-01	6.446E-01			
4	1.500E+01	1.500E+01	7.263E+01	1					9.710E-01	-5.665E-02	-2.323E-01	1.331E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	7.263E+01	7(	0,	0,	0)		9.710E-01	-5.665E-02	-2.323E-01			
	1.500E+01	1.500E+01	7.263E+01	4				0	9.710E-01	-5.665E-02	-2.323E-01			
5	1.500E+01	1.500E+01	7.263E+01	1					5.861E-01	1.496E-01	-7.963E-01	1.902E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	7.263E+01	7(	0,	0,	0)		5.861E-01	1.496E-01	-7.963E-01			
	1.500E+01	1.500E+01	7.263E+01	4				0	5.861E-01	1.496E-01	-7.963E-01			
6	1.500E+01	1.500E+01	7.263E+01	1					-6.489E-02	-1.626E-01	9.845E-01	4.410E-01	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	7.263E+01	7(	0,	0,	0)		-6.489E-02	-1.626E-01	9.845E-01			
	1.500E+01	1.500E+01	7.263E+01	4				0	-6.489E-02	-1.626E-01	9.845E-01			
7	1.500E+01	1.500E+01	7.263E+01	1					-7.068E-02	3.263E-02	-9.970E-01	4.750E-01	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	7.263E+01	7(	0,	0,	0)		-7.068E-02	3.263E-02	-9.970E-01			
	1.500E+01	1.500E+01	7.263E+01	4				0	-7.068E-02	3.263E-02	-9.970E-01			
8	1.500E+01	1.500E+01	7.263E+01	1					-3.915E-01	4.664E-01	-7.932E-01	4.136E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	7.263E+01	7(	0,	0,	0)		-3.915E-01	4.664E-01	-7.932E-01			
	1.500E+01	1.500E+01	7.263E+01	4				0	-3.915E-01	4.664E-01	-7.932E-01			
9	1.500E+01	1.500E+01	7.263E+01	1					-2.368E-01	9.215E-01	-3.079E-01	7.453E-02	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	7.263E+01	7(	0,	0,	0)		-2.368E-01	9.215E-01	-3.079E-01			
	1.500E+01	1.500E+01	7.263E+01	4				0	-2.368E-01	9.215E-01	-3.079E-01			
10	1.500E+01	1.500E+01	7.263E+01	1					1.946E-01	-3.204E-01	9.271E-01	3.128E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	7.263E+01	7(	0,	0,	0)		1.946E-01	-3.204E-01	9.271E-01			
	1.500E+01	1.500E+01	7.263E+01	4				0	1.946E-01	-3.204E-01	9.271E-01			
11	1.500E+01	1.500E+01	7.263E+01	1					-6.698E-01	-7.177E-01	-1.905E-01	1.014E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	7.263E+01	7(	0,	0,	0)		-6.698E-01	-7.177E-01	-1.905E-01			
	1.500E+01	1.500E+01	7.263E+01	4				0	-6.698E-01	-7.177E-01	-1.905E-01			
12	1.500E+01	1.500E+01	7.263E+01	1					-8.398E-01	-4.129E-01	3.524E-01	1.395E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	7.263E+01	7(	0,	0,	0)		-8.398E-01	-4.129E-01	3.524E-01			
	1.500E+01	1.500E+01	7.263E+01	4				0	-8.398E-01	-4.129E-01	3.524E-01			
13	1.500E+01	1.500E+01	7.263E+01	1					-1.714E-01	-8.572E-01	4.857E-01	7.748E-01	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	7.263E+01	7(	0,	0,	0)		-1.714E-01	-8.572E-01	4.857E-01			
	1.500E+01	1.500E+01	7.263E+01	4				0	-1.714E-01	-8.572E-01	4.857E-01			
14	1.500E+01	1.500E+01	7.263E+01	1					-2.489E-01	-5.118E-01	-8.222E-01	1.101E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	7.263E+01	7(	0,	0,	0)		-2.489E-01	-5.118E-01	-8.222E-01			
	1.500E+01	1.500E+01	7.263E+01	4				0	-2.489E-01	-5.118E-01	-8.222E-01			
15	1.500E+01	1.500E+01	7.263E+01	1					-2.959E-01	2.119E-01	9.314E-01	1.951E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	7.263E+01	7(	0,	0,	0)		-2.959E-01	2.119E-01	9.314E-01			
	1.500E+01	1.500E+01	7.263E+01	4				0	-2.959E-01	2.119E-01	9.314E-01			
16	1.500E+01	1.500E+01	7.263E+01	1					1.395E-01	-9.829E-01	1.202E-01	2.186E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	7.263E+01	7(	0,	0,	0)		1.395E-01	-9.829E-01	1.202E-01			
	1.500E+01	1.500E+01	7.263E+01	4				0	1.395E-01	-9.829E-01	1.202E-01			
17	1.500E+01	1.500E+01	7.263E+01	1					6.909E-01	-7.110E-01	1.307E-01	1.865E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	7.263E+01	7(	0,	0,	0)		6.909E-01	-7.110E-01	1.307E-01			
	1.500E+01	1.500E+01	7.263E+01	4				0	6.909E-01	-7.110E-01	1.307E-01			
18	1.500E+01	1.500E+01	7.263E+01	1					-6.580E-01	5.320E-01	-5.329E-01	1.229E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	7.263E+01	7(	0,	0,	0)		-6.580E-01	5.320E-01	-5.329E-01			
	1.500E+01	1.500E+01	7.263E+01	4				0	-6.580E-01	5.320E-01	-5.329E-01			
19	1.500E+01	1.500E+01	7.263E+01	1					-9.903E-01	-1.380E-01	1.353E-02	1.305E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	7.263E+01	7(	0,	0,	0)		-9.903E-01	-1.380E-01	1.353E-02			
	1.500E+01	1.500E+01	7.263E+01	4				0	-9.903E-01	-1.380E-01	1.353E-02			
20	1.500E+01	1.500E+01	7.263E+01	1					7.462E-01	4.859E-01	-4.551E-01	1.000E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	7.263E+01	7(	0,	0,	0)		7.462E-01	4.859E-01	-4.551E-01			
	1.500E+01	1.500E+01	7.263E+01	4				0	7.462E-01	4.859E-01	-4.551E-01			
21	1.500E+01	1.500E+01	7.263E+01	1					-1.977E-01	9.797E-01	3.360E-02	3.990E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	7.263E+01	7(	0,	0,	0)		-1.977E-01	9.797E-01	3.360E-02			
	1.500E+01	1.500E+01	7.263E+01	4				0	-1.977E-01	9.797E-01	3.360E-02			

```
22  1.500E+01  1.500E+01  7.263E+01  1                                  -9.117E-01 -3.647E-01 -1.891E-01  2.665E-01  1.000E+00  0.000E+00
    1.500E+01  1.500E+01  7.263E+01  7(  0,  0,  0)                     -9.117E-01 -3.647E-01 -1.891E-01
    1.500E+01  1.500E+01  7.263E+01  4                                0 -9.117E-01 -3.647E-01 -1.891E-01
23  1.500E+01  1.500E+01  7.263E+01  1                                  -4.287E-01  8.361E-01 -3.423E-01  1.156E+00  1.000E+00  0.000E+00
    1.500E+01  1.500E+01  7.263E+01  7(  0,  0,  0)                     -4.287E-01  8.361E-01 -3.423E-01
    1.500E+01  1.500E+01  7.263E+01  4                                0 -4.287E-01  8.361E-01 -3.423E-01
24  1.500E+01  1.500E+01  7.263E+01  1                                   1.080E-01  3.412E-01 -9.338E-01  2.669E+00  1.000E+00  0.000E+00
    1.500E+01  1.500E+01  7.263E+01  7(  0,  0,  0)                      1.080E-01  3.412E-01 -9.338E-01
    1.500E+01  1.500E+01  7.263E+01  4                                0  1.080E-01  3.412E-01 -9.338E-01
25  1.500E+01  1.500E+01  7.263E+01  1                                  -9.111E-01 -9.012E-03 -4.122E-01  2.185E+00  1.000E+00  0.000E+00
    1.500E+01  1.500E+01  7.263E+01  7(  0,  0,  0)                     -9.111E-01 -9.012E-03 -4.122E-01
    1.500E+01  1.500E+01  7.263E+01  4                                0 -9.111E-01 -9.012E-03 -4.122E-01
26  1.500E+01  1.500E+01  7.263E+01  1                                  -2.568E-01 -6.391E-01 -7.249E-01  4.225E+00  1.000E+00  0.000E+00
    1.500E+01  1.500E+01  7.263E+01  7(  0,  0,  0)                     -2.568E-01 -6.391E-01 -7.249E-01
    1.500E+01  1.500E+01  7.263E+01  4                                0 -2.568E-01 -6.391E-01 -7.249E-01
27  1.500E+01  1.500E+01  7.263E+01  1                                  -2.912E-01  8.086E-01  5.113E-01  1.079E+00  1.000E+00  0.000E+00
    1.500E+01  1.500E+01  7.263E+01  7(  0,  0,  0)                     -2.912E-01  8.086E-01  5.113E-01
    1.500E+01  1.500E+01  7.263E+01  4                                0 -2.912E-01  8.086E-01  5.113E-01
28  1.500E+01  1.500E+01  7.263E+01  1                                   1.472E-01 -9.514E-01  2.705E-01  3.461E+00  1.000E+00  0.000E+00
    1.500E+01  1.500E+01  7.263E+01  7(  0,  0,  0)                      1.472E-01 -9.514E-01  2.705E-01
    1.500E+01  1.500E+01  7.263E+01  4                                0  1.472E-01 -9.514E-01  2.705E-01
29  1.500E+01  1.500E+01  7.263E+01  1                                  -6.135E-01 -7.645E-01 -1.978E-01  1.836E+00  1.000E+00  0.000E+00
    1.500E+01  1.500E+01  7.263E+01  7(  0,  0,  0)                     -6.135E-01 -7.645E-01 -1.978E-01
    1.500E+01  1.500E+01  7.263E+01  4                                0 -6.135E-01 -7.645E-01 -1.978E-01
30  1.500E+01  1.500E+01  7.263E+01  1                                  -5.702E-01  5.651E-01 -5.963E-01  4.556E-01  1.000E+00  0.000E+00
    1.500E+01  1.500E+01  7.263E+01  7(  0,  0,  0)                     -5.702E-01  5.651E-01 -5.963E-01
    1.500E+01  1.500E+01  7.263E+01  4                                0 -5.702E-01  5.651E-01 -5.963E-01
31  1.500E+01  1.500E+01  7.263E+01  1                                  -6.607E-01  5.373E-01 -5.242E-01  6.415E-01  1.000E+00  0.000E+00
    1.500E+01  1.500E+01  7.263E+01  7(  0,  0,  0)                     -6.607E-01  5.373E-01 -5.242E-01
    1.500E+01  1.500E+01  7.263E+01  4                                0 -6.607E-01  5.373E-01 -5.242E-01
32  1.500E+01  1.500E+01  7.263E+01  1                                  -9.742E-02 -3.639E-01 -9.263E-01  2.764E+00  1.000E+00  0.000E+00
    1.500E+01  1.500E+01  7.263E+01  7(  0,  0,  0)                     -9.742E-02 -3.639E-01 -9.263E-01
    1.500E+01  1.500E+01  7.263E+01  4                                0 -9.742E-02 -3.639E-01 -9.263E-01
33  1.500E+01  1.500E+01  7.263E+01  1                                  -1.965E-01 -3.145E-01 -9.287E-01  2.785E-01  1.000E+00  0.000E+00
    1.500E+01  1.500E+01  7.263E+01  7(  0,  0,  0)                     -1.965E-01 -3.145E-01 -9.287E-01
    1.500E+01  1.500E+01  7.263E+01  4                                0 -1.965E-01 -3.145E-01 -9.287E-01
34  1.500E+01  1.500E+01  7.263E+01  1                                   4.097E-01  8.465E-01 -3.399E-01  9.097E-01  1.000E+00  0.000E+00
    1.500E+01  1.500E+01  7.263E+01  7(  0,  0,  0)                      4.097E-01  8.465E-01 -3.399E-01
    1.500E+01  1.500E+01  7.263E+01  4                                0  4.097E-01  8.465E-01 -3.399E-01
35  1.500E+01  1.500E+01  7.263E+01  1                                  -4.048E-02  8.831E-01  4.675E-01  3.360E-01  1.000E+00  0.000E+00
    1.500E+01  1.500E+01  7.263E+01  7(  0,  0,  0)                     -4.048E-02  8.831E-01  4.675E-01
    1.500E+01  1.500E+01  7.263E+01  4                                0 -4.048E-02  8.831E-01  4.675E-01
36  1.500E+01  1.500E+01  7.263E+01  1                                   3.371E-01 -9.269E-01 -1.652E-01  6.376E-01  1.000E+00  0.000E+00
    1.500E+01  1.500E+01  7.263E+01  7(  0,  0,  0)                      3.371E-01 -9.269E-01 -1.652E-01
    1.500E+01  1.500E+01  7.263E+01  4                                0  3.371E-01 -9.269E-01 -1.652E-01
37  1.500E+01  1.500E+01  7.263E+01  1                                  -1.867E-01  9.756E-01 -1.155E-01  2.186E+00  1.000E+00  0.000E+00
    1.500E+01  1.500E+01  7.263E+01  7(  0,  0,  0)                     -1.867E-01  9.756E-01 -1.155E-01
    1.500E+01  1.500E+01  7.263E+01  4                                0 -1.867E-01  9.756E-01 -1.155E-01
38  1.500E+01  1.500E+01  7.263E+01  1                                  -2.616E-01  2.336E-01 -9.365E-01  7.314E-01  1.000E+00  0.000E+00
    1.500E+01  1.500E+01  7.263E+01  7(  0,  0,  0)                     -2.616E-01  2.336E-01 -9.365E-01
    1.500E+01  1.500E+01  7.263E+01  4                                0 -2.616E-01  2.336E-01 -9.365E-01
39  1.500E+01  1.500E+01  7.263E+01  1                                   9.780E-01 -7.641E-02 -1.939E-01  2.997E-01  1.000E+00  0.000E+00
    1.500E+01  1.500E+01  7.263E+01  7(  0,  0,  0)                      9.780E-01 -7.641E-02 -1.939E-01
    1.500E+01  1.500E+01  7.263E+01  4                                0  9.780E-01 -7.641E-02 -1.939E-01
40  1.500E+01  1.500E+01  7.263E+01  1                                   2.580E-01 -7.076E-01  6.578E-01  1.444E+00  1.000E+00  0.000E+00
    1.500E+01  1.500E+01  7.263E+01  7(  0,  0,  0)                      2.580E-01 -7.076E-01  6.578E-01
    1.500E+01  1.500E+01  7.263E+01  4                                0  2.580E-01 -7.076E-01  6.578E-01
41  1.500E+01  1.500E+01  7.263E+01  1                                  -3.212E-01 -7.678E-01 -5.543E-01  1.914E+00  1.000E+00  0.000E+00
```

```
     1.500E+01  1.500E+01  7.263E+01    7(   0,    0,    0)        -3.212E-01 -7.678E-01 -5.543E-01
     1.500E+01  1.500E+01  7.263E+01    4                       0 -3.212E-01 -7.678E-01 -5.543E-01
 42  1.500E+01  1.500E+01  7.263E+01    1                          5.039E-01 -1.460E-01  8.513E-01  1.502E+00  1.000E+00  0.000E+00
     1.500E+01  1.500E+01  7.263E+01    7(   0,    0,    0)         5.039E-01 -1.460E-01  8.513E-01
     1.500E+01  1.500E+01  7.263E+01    4                       0  5.039E-01 -1.460E-01  8.513E-01
 43  1.500E+01  1.500E+01  7.263E+01    1                          6.080E-01  5.487E-01  5.738E-01  5.971E+00  1.000E+00  0.000E+00
     1.500E+01  1.500E+01  7.263E+01    7(   0,    0,    0)         6.080E-01  5.487E-01  5.738E-01
     1.500E+01  1.500E+01  7.263E+01    4                       0  6.080E-01  5.487E-01  5.738E-01
 44  1.500E+01  1.500E+01  7.263E+01    1                         -2.932E-01  9.304E-01 -2.199E-01  1.827E+00  1.000E+00  0.000E+00
     1.500E+01  1.500E+01  7.263E+01    7(   0,    0,    0)        -2.932E-01  9.304E-01 -2.199E-01
     1.500E+01  1.500E+01  7.263E+01    4                       0 -2.932E-01  9.304E-01 -2.199E-01
 45  1.500E+01  1.500E+01  7.263E+01    1                         -8.475E-01 -3.993E-01 -3.497E-01  1.928E+00  1.000E+00  0.000E+00
     1.500E+01  1.500E+01  7.263E+01    7(   0,    0,    0)        -8.475E-01 -3.993E-01 -3.497E-01
     1.500E+01  1.500E+01  7.263E+01    4                       0 -8.475E-01 -3.993E-01 -3.497E-01
 46  1.500E+01  1.500E+01  7.263E+01    1                          1.200E-01 -9.195E-01 -3.743E-01  1.351E+00  1.000E+00  0.000E+00
     1.500E+01  1.500E+01  7.263E+01    7(   0,    0,    0)         1.200E-01 -9.195E-01 -3.743E-01
     1.500E+01  1.500E+01  7.263E+01    4                       0  1.200E-01 -9.195E-01 -3.743E-01
 47  1.500E+01  1.500E+01  7.263E+01    1                          7.085E-01  5.879E-01  3.904E-01  2.288E+00  1.000E+00  0.000E+00
     1.500E+01  1.500E+01  7.263E+01    7(   0,    0,    0)         7.085E-01  5.879E-01  3.904E-01
     1.500E+01  1.500E+01  7.263E+01    4                       0  7.085E-01  5.879E-01  3.904E-01
 48  1.500E+01  1.500E+01  7.263E+01    1                          4.261E-01  9.046E-01  9.254E-03  1.230E+00  1.000E+00  0.000E+00
     1.500E+01  1.500E+01  7.263E+01    7(   0,    0,    0)         4.261E-01  9.046E-01  9.254E-03
     1.500E+01  1.500E+01  7.263E+01    4                       0  4.261E-01  9.046E-01  9.254E-03
 49  1.500E+01  1.500E+01  7.263E+01    1                          5.431E-01  4.270E-01 -7.230E-01  1.433E+00  1.000E+00  0.000E+00
     1.500E+01  1.500E+01  7.263E+01    7(   0,    0,    0)         5.431E-01  4.270E-01 -7.230E-01
     1.500E+01  1.500E+01  7.263E+01    4                       0  5.431E-01  4.270E-01 -7.230E-01
 50  1.500E+01  1.500E+01  7.263E+01    1                         -1.053E-01 -9.805E-01  1.658E-01  6.572E-01  1.000E+00  0.000E+00
     1.500E+01  1.500E+01  7.263E+01    7(   0,    0,    0)        -1.053E-01 -9.805E-01  1.658E-01
     1.500E+01  1.500E+01  7.263E+01    4                       0 -1.053E-01 -9.805E-01  1.658E-01
lestimated keff results by cycle                                                                    print table 175

 source distribution written to file 3b081s          cycle =    20

 source distribution written to file 3b081s          cycle =    23

 source distribution written to file 3b081s          cycle =    26

 source distribution written to file 3b081s          cycle =    29

 source distribution written to file 3b081s          cycle =    32

 source distribution written to file 3b081s          cycle =    35

 source distribution written to file 3b081s          cycle =    38

 source distribution written to file 3b081s          cycle =    41

*****************************************************************************************************************
dump no.    2 on file 3b081r       nps =    163611     coll =       22667477     ctm =   15.01     nrn =      390275270

 source distribution written to file 3b081s          cycle =    44

 source distribution written to file 3b081s          cycle =    47

 source distribution written to file 3b081s          cycle =    50

 source distribution written to file 3b081s          cycle =    53
```

source distribution written to file 3b081s cycle = 56

source distribution written to file 3b081s cycle = 59

source distribution written to file 3b081s cycle = 62

source distribution written to file 3b081s cycle = 65

source distribution written to file 3b081s cycle = 68

source distribution written to file 3b081s cycle = 71

source distribution written to file 3b081s cycle = 74

source distribution written to file 3b081s cycle = 77

source distribution written to file 3b081s cycle = 80

****

dump no. 3 on file 3b081r nps = 327952 coll = 45459761 ctm = 30.01 nrn = 782692945

source distribution written to file 3b081s cycle = 83

source distribution written to file 3b081s cycle = 86

source distribution written to file 3b081s cycle = 89

source distribution written to file 3b081s cycle = 92

source distribution written to file 3b081s cycle = 95

source distribution written to file 3b081s cycle = 98

estimator	cycle 100	ave of 80 cycles	combination	simple average	combined average	corr
k(collision)	0.924849	0.924256 0.0021	k(col/abs)	0.923020 0.0016	0.922090 0.0015	0.5639
k(absorption)	0.920291	0.921784 0.0015	k(abs/tk ln)	0.923336 0.0016	0.922258 0.0015	0.5136
k(trk length)	0.928233	0.924887 0.0021	k(tk ln/col)	0.924572 0.0021	0.924524 0.0021	0.9563
rem life(col)	2.7718E+04	2.7508E+04 0.0025	k(col/abs/tk ln)	0.923643 0.0017	0.922333 0.0015	
rem life(abs)	2.7603E+04	2.7501E+04 0.0025	life(col/abs)	2.7505E+04 0.0025	2.7502E+04 0.0025	0.9670

source points generated 4016

source distribution written to file 3b081s cycle = 101

source distribution written to file 3b081s cycle = 104

source distribution written to file 3b081s cycle = 107

source distribution written to file 3b081s cycle = 110

source distribution written to file 3b081s cycle = 113

estimator	cycle 116	ave of 96 cycles	combination	simple average	combined average	corr
k(collision)	0.958276	0.921359 0.0022	k(col/abs)	0.920907 0.0017	0.920523 0.0015	0.6066
k(absorption)	0.922611	0.920456 0.0015	k(abs/tk ln)	0.921278 0.0017	0.920639 0.0015	0.5621
k(trk length)	0.956920	0.922100 0.0022	k(tk ln/col)	0.921730 0.0022	0.921730 0.0022	0.9698
rem life(col)	2.9384E+04	2.7522E+04 0.0025	k(col/abs/tk ln)	0.921305 0.0018	0.920893 0.0015	

rem life(abs)	2.9329E+04	2.7527E+04	0.0024	life(col/abs)	2.7525E+04	0.0025	2.7528E+04	0.0024	0.9720

source points generated 4109

source distribution written to file 3b081s cycle = 116

estimator	cycle 117	ave of 97 cycles		combination	simple average		combined average		corr
k(collision)	0.924688	0.921393	0.0022	k(col/abs)	0.920913	0.0017	0.920504	0.0015	0.6061
k(absorption)	0.918105	0.920432	0.0015	k(abs/tk ln)	0.921261	0.0016	0.920617	0.0015	0.5621
k(trk length)	0.921022	0.922089	0.0022	k(tk ln/col)	0.921741	0.0022	0.921743	0.0022	0.9695
rem life(col)	2.7224E+04	2.7519E+04	0.0025	k(col/abs/tk ln)	0.921305	0.0018	0.920846	0.0015	
rem life(abs)	2.7438E+04	2.7526E+04	0.0024	life(col/abs)	2.7523E+04	0.0024	2.7527E+04	0.0024	0.9716

source points generated 3844

estimator	cycle 118	ave of 98 cycles		combination	simple average		combined average		corr
k(collision)	0.923595	0.921416	0.0022	k(col/abs)	0.920886	0.0016	0.920439	0.0015	0.6045
k(absorption)	0.913078	0.920357	0.0015	k(abs/tk ln)	0.921230	0.0016	0.920555	0.0015	0.5608
k(trk length)	0.923437	0.922103	0.0022	k(tk ln/col)	0.921759	0.0022	0.921762	0.0022	0.9695
rem life(col)	2.7870E+04	2.7523E+04	0.0025	k(col/abs/tk ln)	0.921292	0.0018	0.920775	0.0015	
rem life(abs)	2.7867E+04	2.7530E+04	0.0024	life(col/abs)	2.7526E+04	0.0024	2.7531E+04	0.0024	0.9717

source points generated 3980

estimator	cycle 119	ave of 99 cycles		combination	simple average		combined average		corr
k(collision)	0.908187	0.921282	0.0022	k(col/abs)	0.920751	0.0016	0.920302	0.0015	0.6069
k(absorption)	0.906750	0.920219	0.0015	k(abs/tk ln)	0.921113	0.0016	0.920426	0.0015	0.5622
k(trk length)	0.912640	0.922007	0.0022	k(tk ln/col)	0.921645	0.0021	0.921660	0.0022	0.9694
rem life(col)	2.7446E+04	2.7522E+04	0.0024	k(col/abs/tk ln)	0.921170	0.0018	0.920671	0.0015	
rem life(abs)	2.7424E+04	2.7529E+04	0.0024	life(col/abs)	2.7525E+04	0.0024	2.7530E+04	0.0024	0.9717

source points generated 4064

source distribution written to file 3b081s cycle = 119

estimator	cycle 120	ave of 100 cycles		combination	simple average		combined average		corr
k(collision)	0.930271	0.921372	0.0021	k(col/abs)	0.920777	0.0016	0.920276	0.0015	0.6047
k(absorption)	0.916458	0.920182	0.0015	k(abs/tk ln)	0.921134	0.0016	0.920404	0.0015	0.5604
k(trk length)	0.929810	0.922085	0.0021	k(tk ln/col)	0.921729	0.0021	0.921747	0.0022	0.9695
rem life(col)	2.7367E+04	2.7520E+04	0.0024	k(col/abs/tk ln)	0.921213	0.0017	0.920638	0.0015	
rem life(abs)	2.7371E+04	2.7527E+04	0.0023	life(col/abs)	2.7524E+04	0.0024	2.7528E+04	0.0023	0.9717

source points generated 4137

source distribution written to file 3b081s cycle = 120

1problem summary

run terminated when 120 kcode cycles were done.

02/14/01 09:03:50

k eff, 265g of Pu-239 in cellulose spheres in 2.875 c. foot of pure celulose probid = 02/14/01 08:19:43

0

neutron creation	tracks	weight (per source particle)	energy	neutron loss	tracks	weight (per source particle)	energy
source	480785	9.9837E-01	2.1100E+00	escape	0	0.	0.
				energy cutoff	0	0.	0.
				time cutoff	0	0.	0.
weight window	0	0.	0.	weight window	0	0.	0.
cell importance	0	0.	0.	cell importance	0	0.	0.
weight cutoff	0	1.0020E-01	4.1187E-08	weight cutoff	480787	1.0003E-01	4.0244E-08
energy importance	0	0.	0.	energy importance	0	0.	0.
dxtran	0	0.	0.	dxtran	0	0.	0.
forced collisions	0	0.	0.	forced collisions	0	0.	0.

exp. transform	0	0.	0.	exp. transform	0	0.	0.
upscattering	0	0.	7.1451E-07	downscattering	0	0.	2.0884E+00
				capture	0	6.8051E-01	1.9562E-02
(n,xn)	4	5.4593E-06	5.3806E-06	loss to (n,xn)	2	2.7297E-06	2.4931E-05
fission	0	0.	0.	loss to fission	0	3.1803E-01	2.0546E-03
total	480789	1.0986E+00	2.1100E+00	total	480789	1.0986E+00	2.1100E+00

number of neutrons banked	2	average lifetime, shakes		cutoffs
neutron tracks per source particle	1.0000E+00	escape	0.0000E+00	tco 1.0000E+34
neutron collisions per source particle	1.3862E+02	capture	2.7511E+04	eco 0.0000E+00
total neutron collisions	66648699	capture or escape	2.7511E+04	wc1 -5.0000E-01
net multiplication	1.0000E+00 0.0000	any termination	3.3792E+04	wc2 -2.5000E-01

computer time so far in this run	44.13 minutes	maximum number ever in bank	1
computer time in mcrun	44.12 minutes	bank overflows to backup file	0
source particles per minute	1.0898E+04	field length	0
random numbers generated	1147470272	most random numbers used was	26804 in history 464027

range of sampled source weights = 9.1470E-01 to 1.1283E+00

1neutron activity in each cell print table 126

	cell	tracks entering	population	collisions	collisions * weight (per history)	number weighted energy	flux weighted energy	average track weight (relative)	average track mfp (cm)
1	1	0	0	0	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2	2	2951	1228	73954	6.7115E-02	3.3398E-05	2.1451E-01	4.5689E-01	2.0037E+00
4	4	627864	286801	4973837	8.5760E+00	3.4078E-04	7.3147E-01	8.9286E-01	3.3810E+00
5	5	631689	288809	5029814	8.6760E+00	3.4164E-04	7.3285E-01	8.9304E-01	3.3854E+00
6	6	1008993	434442	56571094	6.5999E+01	4.8954E-05	2.6195E-01	6.0478E-01	1.9715E+00
7	7	0	0	0	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
total		2271497	1011280	66648699	8.3318E+01				

1keff results for: k eff, 265g of Pu-239 in cellulose spheres in 2.875 c. foot of pure celulose probid = 02/14/01 08:19:43

the initial fission neutron source distribution used the 2 source points that were input on the ksrc card.
the criticality problem was scheduled to skip 20 cycles and run a total of 120 cycles with nominally 4000 neutrons per cycle.
this problem has run 20 inactive cycles with 80098 neutron histories and 100 active cycles with 400687 neutron histories.

this calculation has completed the requested number of keff cycles using a total of 480785 fission neutron source histories.
all cells with fissionable material were sampled and had fission neutron source points.

the results of the w test for normality applied to the individual collision, absorption, and track-length keff cycle values are:

the k(collision) cycle values appear normally distributed at the 95 percent confidence level
the k(absorption) cycle values appear normally distributed at the 95 percent confidence level
the k(trk length) cycle values appear normally distributed at the 99 percent confidence level, but not at 95 percent

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the final estimated combined collision/absorption/track-length keff = 0.92064 with an estimated standard deviation of 0.00134

the estimated 68, 95, & 99 percent keff confidence intervals are 0.91930 to 0.92198, 0.91797 to 0.92331, and 0.91710 to 0.92418

| the estimated collision/absorption neutron removal lifetime = 2.75E-04 seconds with an estimated standard deviation of 6.44E-07 |

the estimated average keffs, one standard deviations, and 68, 95, and 99 percent confidence intervals are:

keff estimator	keff	standard deviation	68% confidence	95% confidence	99% confidence	corr
collision	0.92137	0.00197	0.91940 to 0.92334	0.91745 to 0.92529	0.91617 to 0.92657	
absorption	0.92018	0.00134	0.91884 to 0.92152	0.91752 to 0.92285	0.91665 to 0.92372	
track length	0.92209	0.00197	0.92012 to 0.92405	0.91817 to 0.92600	0.91689 to 0.92728	
col/absorp	0.92028	0.00134	0.91893 to 0.92162	0.91760 to 0.92295	0.91673 to 0.92382	0.6047
abs/trk len	0.92040	0.00134	0.91906 to 0.92174	0.91774 to 0.92307	0.91686 to 0.92394	0.5604
col/trk len	0.92175	0.00198	0.91976 to 0.92373	0.91780 to 0.92570	0.91651 to 0.92699	0.9695
col/abs/trk len	0.92064	0.00134	0.91930 to 0.92198	0.91797 to 0.92331	0.91710 to 0.92418	

if the largest of each keff occurred on the next cycle, the keff results and 68, 95, and 99 percent confidence intervals would be:

keff estimator	keff	standard deviation	68% confidence	95% confidence	99% confidence
collision	0.92191	0.00202	0.91989 to 0.92394	0.91788 to 0.92595	0.91657 to 0.92726
absorption	0.92048	0.00136	0.91912 to 0.92184	0.91778 to 0.92319	0.91689 to 0.92407
track length	0.92258	0.00201	0.92057 to 0.92460	0.91858 to 0.92659	0.91728 to 0.92789
col/abs/trk len	0.92093	0.00136	0.91957 to 0.92229	0.91822 to 0.92364	0.91734 to 0.92453

the estimated collision/absorption neutron lifetimes, one standard deviations, and 68, 95, and 99 percent confidence intervals are:

type	lifetime(sec)	standard deviation	68% confidence	95% confidence	99% confidence
removal	2.7528E-04	6.4423E-07	2.7464E-04 to 2.7593E-04	2.7400E-04 to 2.7657E-04	2.7358E-04 to 2.7698E-04
capture	2.7523E-04	5.6877E-07	2.7466E-04 to 2.7580E-04	2.7410E-04 to 2.7636E-04	2.7373E-04 to 2.7673E-04
fission	1.4358E-04	3.0332E-07	1.4328E-04 to 1.4388E-04	1.4298E-04 to 1.4418E-04	1.4278E-04 to 1.4438E-04
escape	0.0000E+00	0.0000E+00	0.0000E+00 to 0.0000E+00	0.0000E+00 to 0.0000E+00	0.0000E+00 to 0.0000E+00

laverage individual and combined collision/absorption/track-length keff results for 7 different batch sizes

cycles per keff batch	number of k batches	average keff estimators and deviations k(col) st dev	k(abs) st dev	k(trk) st dev	normality co/ab/trk	average k(c/a/t) k(c/a/t) st dev	k(c/a/t) confidence intervals 95% confidence	99% confidence
1	100	0.9214 0.0020	0.9202 0.0013	0.9221 0.0020	95/95/99	0.92064 0.00134	0.91797-0.92331	0.91710-0.92418
2	50	0.9214 0.0022	0.9202 0.0014	0.9221 0.0021	95/95/95	0.92053 0.00143	0.91766-0.92341	0.91669-0.92437
4	25	0.9214 0.0024	0.9202 0.0014	0.9221 0.0024	95/95/95	0.92014 0.00144	0.91715-0.92312	0.91608-0.92419
5	20	0.9214 0.0025	0.9202 0.0013	0.9221 0.0024	95/95/95	0.92012 0.00149	0.91697-0.92327	0.91580-0.92444
10	10	0.9214 0.0028	0.9202 0.0015	0.9221 0.0028	95/95/95	0.92005 0.00192	0.91550-0.92460	0.91331-0.92678
20	5	0.9214 0.0029	0.9202 0.0020	0.9221 0.0028	no/95/99	0.92843 0.00671	0.89956-0.95729	0.86184-0.99501
25	4	0.9214 0.0041	0.9202 0.0023	0.9221 0.0041	95/95/95	0.91965 0.00796	0.81850-1.02079	0.41304-1.42625

lindividual and average keff estimator results by cycle

keff cycle	neutron histories	keff estimators by cycle k(coll)	k(abs)	k(track)	average keff estimators and deviations k(coll) st dev	k(abs) st dev	k(track) st dev	average k(c/a/t) k(c/a/t) st dev	fom
1	4000	1.04029	1.03890	1.03884					
2	4233	0.91483	0.90581	0.92076					
3	3545	0.90147	0.89954	0.91046					
4	3943	0.92145	0.91281	0.91654					
5	4082	0.90414	0.93272	0.90312					

6	3806	0.94358	0.92697	0.94401							
7	4233	0.91966	0.91074	0.91767							
8	3945	0.95344	0.93359	0.95910							
9	4115	0.91864	0.89461	0.91757							
10	3926	0.88921	0.91158	0.89557							
11	3802	0.89683	0.91292	0.90063							
12	4048	0.93777	0.94452	0.93954							
13	4189	0.92299	0.93341	0.93313							
14	4034	0.91342	0.92717	0.90380							
15	3939	0.90193	0.93602	0.89944							
16	3990	0.90761	0.90023	0.89714							
17	4004	0.91437	0.93849	0.91904							
18	4082	0.90248	0.92637	0.90157							
19	4055	0.92078	0.91092	0.91900							
20	4127	0.89866	0.92946	0.89589							
		begin active keff cycles									
21	3839	0.93199	0.92604	0.92970							
22	4180	0.92407	0.92129	0.92786	0.92803	0.00396	0.92366	0.00237	0.92878	0.00092	
23	3916	0.93361	0.92553	0.92959	0.92989	0.00295	0.92429	0.00150	0.92905	0.00060	
24	4000	0.94774	0.91567	0.94483	0.93435	0.00492	0.92213	0.00240	0.93299	0.00397	0.92578 0.00060 1621495
25	3973	0.92491	0.91707	0.92846	0.93246	0.00426	0.92112	0.00212	0.93209	0.00320	0.92533 0.00098 488854
26	3925	0.91873	0.90705	0.92745	0.93018	0.00416	0.91877	0.00291	0.93131	0.00273	0.92541 0.00126 246021
27	3911	0.93707	0.93166	0.93940	0.93116	0.00365	0.92062	0.00307	0.93247	0.00258	0.92811 0.00352 27442
28	4141	0.90447	0.91331	0.90713	0.92782	0.00460	0.91970	0.00281	0.92930	0.00388	0.92339 0.00364 22035
29	3859	0.93531	0.92667	0.94351	0.92866	0.00414	0.92048	0.00260	0.93088	0.00377	0.92317 0.00416 15097
30	4096	0.92657	0.92944	0.93115	0.92845	0.00371	0.92137	0.00249	0.93091	0.00337	0.92447 0.00387 15435
31	3949	0.91916	0.90950	0.92351	0.92760	0.00346	0.92029	0.00250	0.93023	0.00312	0.92415 0.00394 13528
32	3873	0.93276	0.92152	0.92313	0.92803	0.00319	0.92040	0.00228	0.92964	0.00291	0.92315 0.00331 17646
33	4044	0.92591	0.93524	0.92852	0.92787	0.00294	0.92154	0.00239	0.92956	0.00268	0.92492 0.00297 20320
34	4018	0.92448	0.92469	0.92129	0.92763	0.00273	0.92176	0.00223	0.92897	0.00255	0.92467 0.00260 24590
35	4017	0.90226	0.90636	0.90245	0.92594	0.00305	0.92074	0.00231	0.92720	0.00296	0.92247 0.00284 19131
36	3814	0.92307	0.90374	0.92493	0.92576	0.00286	0.91967	0.00241	0.92706	0.00277	0.92242 0.00291 17027
37	4142	0.92833	0.91740	0.92938	0.92591	0.00269	0.91954	0.00227	0.92719	0.00261	0.92239 0.00278 17559
38	3985	0.94195	0.92782	0.94811	0.92680	0.00269	0.92000	0.00219	0.92836	0.00272	0.92238 0.00285 15806
39	4031	0.89775	0.92131	0.89561	0.92527	0.00297	0.92007	0.00207	0.92663	0.00310	0.92133 0.00240 21162
40	3770	0.90825	0.91667	0.89621	0.92442	0.00294	0.91990	0.00197	0.92511	0.00331	0.92067 0.00218 24367
41	4030	0.94540	0.92847	0.95177	0.92542	0.00297	0.92031	0.00192	0.92638	0.00339	0.92091 0.00218 23190
42	4189	0.94177	0.93465	0.92964	0.92616	0.00293	0.92096	0.00194	0.92653	0.00324	0.92157 0.00220 21644
43	4066	0.91441	0.89640	0.92150	0.92565	0.00284	0.91989	0.00214	0.92631	0.00310	0.92113 0.00239 17523
44	3817	0.93826	0.94155	0.93673	0.92618	0.00277	0.92079	0.00224	0.92674	0.00300	0.92222 0.00244 16220
45	4023	0.93116	0.93876	0.92886	0.92638	0.00267	0.92151	0.00227	0.92683	0.00288	0.92304 0.00237 16450
46	4057	0.89918	0.90730	0.91114	0.92533	0.00277	0.92097	0.00224	0.92623	0.00283	0.92242 0.00231 16672
47	3903	0.89518	0.89835	0.89064	0.92421	0.00289	0.92013	0.00232	0.92491	0.00303	0.92112 0.00246 14147
48	3952	0.93359	0.90473	0.94365	0.92455	0.00280	0.91958	0.00230	0.92558	0.00299	0.92110 0.00242 14049
49	4122	0.90903	0.94136	0.91201	0.92401	0.00276	0.92033	0.00234	0.92511	0.00293	0.92192 0.00230 15068
50	3844	0.95620	0.93249	0.95075	0.92509	0.00287	0.92073	0.00230	0.92596	0.00295	0.92229 0.00230 14579
51	4296	0.95134	0.93170	0.95192	0.92593	0.00290	0.92109	0.00225	0.92680	0.00298	0.92260 0.00230 14084
52	4011	0.90753	0.90415	0.90803	0.92536	0.00287	0.92056	0.00224	0.92621	0.00294	0.92203 0.00231 13559
53	3704	0.94247	0.93206	0.94378	0.92588	0.00283	0.92091	0.00220	0.92675	0.00290	0.92236 0.00229 13412
54	4113	0.92378	0.92481	0.92660	0.92581	0.00275	0.92102	0.00214	0.92674	0.00281	0.92248 0.00222 13853
55	3962	0.91978	0.92051	0.91826	0.92564	0.00267	0.92101	0.00208	0.92650	0.00274	0.92238 0.00215 14381
56	4040	0.93518	0.92311	0.93746	0.92591	0.00261	0.92107	0.00202	0.92680	0.00268	0.92248 0.00210 14581
57	4034	0.93817	0.90811	0.93393	0.92624	0.00256	0.92072	0.00199	0.92700	0.00262	0.92237 0.00209 14372
58	3986	0.88951	0.91530	0.88450	0.92527	0.00267	0.92057	0.00195	0.92588	0.00278	0.92166 0.00202 14985

59	3912	0.89186	0.90404	0.89358	0.92442	0.00274	0.92015	0.00194	0.92505	0.00283	0.92101	0.00201	14613
60	3953	0.90822	0.92455	0.90482	0.92401	0.00270	0.92026	0.00190	0.92454	0.00281	0.92101	0.00194	15368
61	4122	0.90526	0.91510	0.90939	0.92355	0.00267	0.92013	0.00185	0.92417	0.00276	0.92085	0.00189	15791
62	3954	0.92429	0.91055	0.93016	0.92357	0.00261	0.91991	0.00182	0.92432	0.00270	0.92075	0.00186	15913
63	4073	0.92469	0.92781	0.91453	0.92360	0.00255	0.92009	0.00179	0.92409	0.00265	0.92080	0.00180	16507
64	3900	0.93238	0.93526	0.93365	0.92380	0.00250	0.92043	0.00178	0.92431	0.00259	0.92117	0.00179	16348
65	4036	0.91077	0.90569	0.91777	0.92351	0.00246	0.92011	0.00177	0.92416	0.00254	0.92094	0.00178	16265
66	3966	0.92256	0.92825	0.92160	0.92349	0.00241	0.92028	0.00174	0.92411	0.00248	0.92109	0.00174	16661
67	4052	0.91498	0.90410	0.92129	0.92331	0.00236	0.91994	0.00174	0.92405	0.00243	0.92090	0.00173	16479
68	4010	0.91383	0.92762	0.91743	0.92311	0.00232	0.92010	0.00171	0.92391	0.00238	0.92106	0.00169	16871
69	4037	0.91134	0.92201	0.91505	0.92287	0.00228	0.92014	0.00168	0.92373	0.00234	0.92108	0.00165	17306
70	4009	0.89419	0.90315	0.88994	0.92229	0.00231	0.91980	0.00168	0.92305	0.00239	0.92054	0.00167	16552
71	3890	0.95980	0.94207	0.96273	0.92303	0.00238	0.92023	0.00170	0.92383	0.00247	0.92092	0.00172	15256
72	4318	0.93392	0.91738	0.92660	0.92324	0.00234	0.92018	0.00167	0.92388	0.00242	0.92083	0.00169	15468
73	3924	0.94188	0.90404	0.93961	0.92359	0.00233	0.91988	0.00167	0.92418	0.00240	0.92071	0.00169	15223
74	4024	0.93817	0.93580	0.94577	0.92386	0.00230	0.92017	0.00166	0.92458	0.00238	0.92101	0.00170	14791
75	3993	0.92715	0.93481	0.92893	0.92392	0.00226	0.92044	0.00165	0.92466	0.00234	0.92129	0.00168	14837
76	3975	0.96632	0.93189	0.96211	0.92468	0.00234	0.92064	0.00163	0.92533	0.00240	0.92144	0.00169	14524
77	4203	0.90006	0.92033	0.90406	0.92425	0.00234	0.92064	0.00161	0.92495	0.00238	0.92138	0.00165	14948
78	3820	0.94781	0.91620	0.94733	0.92465	0.00234	0.92056	0.00158	0.92534	0.00237	0.92137	0.00163	15046
79	4225	0.93362	0.92212	0.93302	0.92480	0.00230	0.92059	0.00155	0.92547	0.00234	0.92140	0.00160	15238
80	3909	0.90384	0.89902	0.90419	0.92445	0.00229	0.92023	0.00157	0.92512	0.00232	0.92105	0.00162	14618
81	3867	0.90654	0.91628	0.90862	0.92416	0.00227	0.92016	0.00154	0.92484	0.00230	0.92094	0.00159	14910
82	4050	0.94190	0.94044	0.94969	0.92445	0.00225	0.92049	0.00155	0.92525	0.00230	0.92124	0.00162	14266
83	4206	0.92933	0.93936	0.93481	0.92452	0.00222	0.92079	0.00156	0.92540	0.00227	0.92155	0.00162	14029
84	4012	0.91706	0.91675	0.91589	0.92441	0.00219	0.92072	0.00153	0.92525	0.00224	0.92147	0.00159	14257
85	3907	0.92751	0.94274	0.92516	0.92446	0.00215	0.92106	0.00155	0.92525	0.00220	0.92186	0.00159	14185
86	4078	0.93413	0.92635	0.93188	0.92460	0.00212	0.92114	0.00153	0.92535	0.00217	0.92194	0.00156	14366
87	4110	0.90073	0.91214	0.89701	0.92425	0.00212	0.92101	0.00151	0.92492	0.00218	0.92169	0.00154	14495
88	3921	0.91637	0.91579	0.92328	0.92413	0.00209	0.92093	0.00149	0.92490	0.00215	0.92163	0.00153	14632
89	4112	0.97618	0.94946	0.97249	0.92488	0.00220	0.92135	0.00152	0.92559	0.00223	0.92197	0.00158	13481
90	4260	0.93637	0.91902	0.93621	0.92505	0.00217	0.92131	0.00150	0.92574	0.00220	0.92196	0.00156	13593
91	3800	0.94076	0.93046	0.93538	0.92527	0.00215	0.92144	0.00149	0.92588	0.00217	0.92208	0.00154	13731
92	3926	0.91457	0.92648	0.91086	0.92512	0.00213	0.92151	0.00147	0.92567	0.00215	0.92211	0.00151	14079
93	3950	0.92959	0.93768	0.93309	0.92518	0.00210	0.92173	0.00147	0.92577	0.00212	0.92235	0.00151	14010
94	4032	0.91562	0.93431	0.91208	0.92505	0.00207	0.92190	0.00146	0.92559	0.00210	0.92251	0.00148	14306
95	3877	0.90229	0.91352	0.91602	0.92475	0.00207	0.92179	0.00144	0.92546	0.00208	0.92245	0.00147	14413
96	3994	0.90228	0.91673	0.90527	0.92445	0.00206	0.92172	0.00142	0.92519	0.00207	0.92235	0.00145	14609
97	3991	0.91916	0.92458	0.91790	0.92439	0.00204	0.92176	0.00140	0.92510	0.00204	0.92236	0.00142	14862
98	4072	0.91725	0.92117	0.91837	0.92429	0.00201	0.92175	0.00139	0.92501	0.00202	0.92235	0.00141	15074
99	3978	0.92075	0.92561	0.91185	0.92425	0.00199	0.92180	0.00137	0.92485	0.00200	0.92233	0.00138	15411
100	4084	0.92485	0.92029	0.92823	0.92426	0.00196	0.92178	0.00135	0.92489	0.00198	0.92233	0.00137	15571
101	4016	0.90790	0.92547	0.90698	0.92405	0.00195	0.92183	0.00134	0.92467	0.00196	0.92234	0.00134	15878
102	3969	0.90749	0.89720	0.91564	0.92385	0.00194	0.92153	0.00135	0.92456	0.00194	0.92216	0.00136	15400
103	4030	0.89179	0.91930	0.89649	0.92347	0.00195	0.92150	0.00134	0.92422	0.00195	0.92210	0.00134	15634
104	3921	0.90771	0.89097	0.91274	0.92328	0.00194	0.92114	0.00137	0.92408	0.00193	0.92187	0.00136	14832
105	4128	0.85442	0.89471	0.85702	0.92247	0.00208	0.92083	0.00139	0.92329	0.00206	0.92140	0.00139	14039
106	3736	0.91466	0.90664	0.91661	0.92238	0.00206	0.92066	0.00138	0.92321	0.00204	0.92126	0.00139	13996
107	4373	0.88097	0.91003	0.87902	0.92190	0.00209	0.92054	0.00137	0.92271	0.00208	0.92105	0.00138	14022
108	3965	0.92208	0.92437	0.92112	0.92190	0.00206	0.92058	0.00136	0.92269	0.00206	0.92108	0.00136	14201
109	4203	0.92609	0.93375	0.92823	0.92195	0.00204	0.92073	0.00135	0.92275	0.00203	0.92123	0.00135	14176
110	4022	0.91730	0.91362	0.91781	0.92190	0.00202	0.92065	0.00134	0.92270	0.00201	0.92115	0.00134	14279

111	3976	0.87172	0.89155	0.86874	0.92135	0.00207	0.92033	0.00136	0.92210	0.00208	0.92072	0.00137	13487
112	3825	0.88130	0.88968	0.88260	0.92091	0.00209	0.92000	0.00139	0.92167	0.00210	0.92038	0.00140	12810
113	4040	0.92244	0.91142	0.92508	0.92093	0.00207	0.91991	0.00137	0.92171	0.00208	0.92031	0.00139	12861
114	4185	0.92710	0.95052	0.92317	0.92099	0.00205	0.92023	0.00140	0.92173	0.00205	0.92066	0.00140	12499
115	4082	0.91872	0.93921	0.92246	0.92097	0.00203	0.92043	0.00140	0.92173	0.00203	0.92085	0.00140	12361
116	4055	0.95828	0.92261	0.95692	0.92136	0.00204	0.92046	0.00138	0.92210	0.00204	0.92089	0.00139	12465
117	4109	0.92469	0.91811	0.92102	0.92139	0.00202	0.92043	0.00137	0.92209	0.00202	0.92085	0.00137	12602
118	3844	0.92359	0.91308	0.92344	0.92142	0.00200	0.92036	0.00136	0.92210	0.00200	0.92078	0.00136	12690
119	3980	0.90819	0.90675	0.91264	0.92128	0.00199	0.92022	0.00135	0.92201	0.00198	0.92067	0.00135	12688
120	4064	0.93027	0.91646	0.92981	0.92137	0.00197	0.92018	0.00134	0.92209	0.00197	0.92064	0.00134	12801

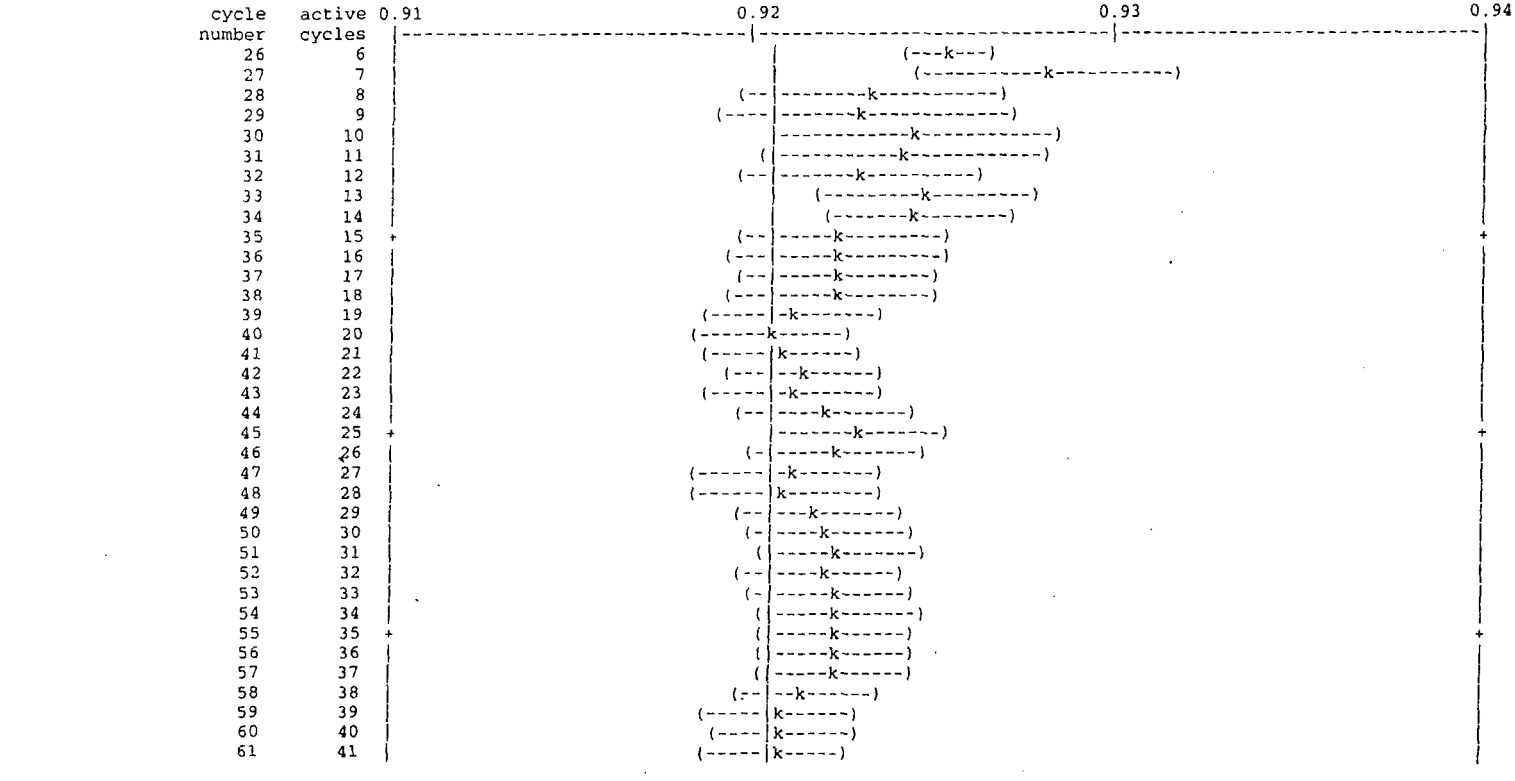
the largest active cycle keffs by estimator are:

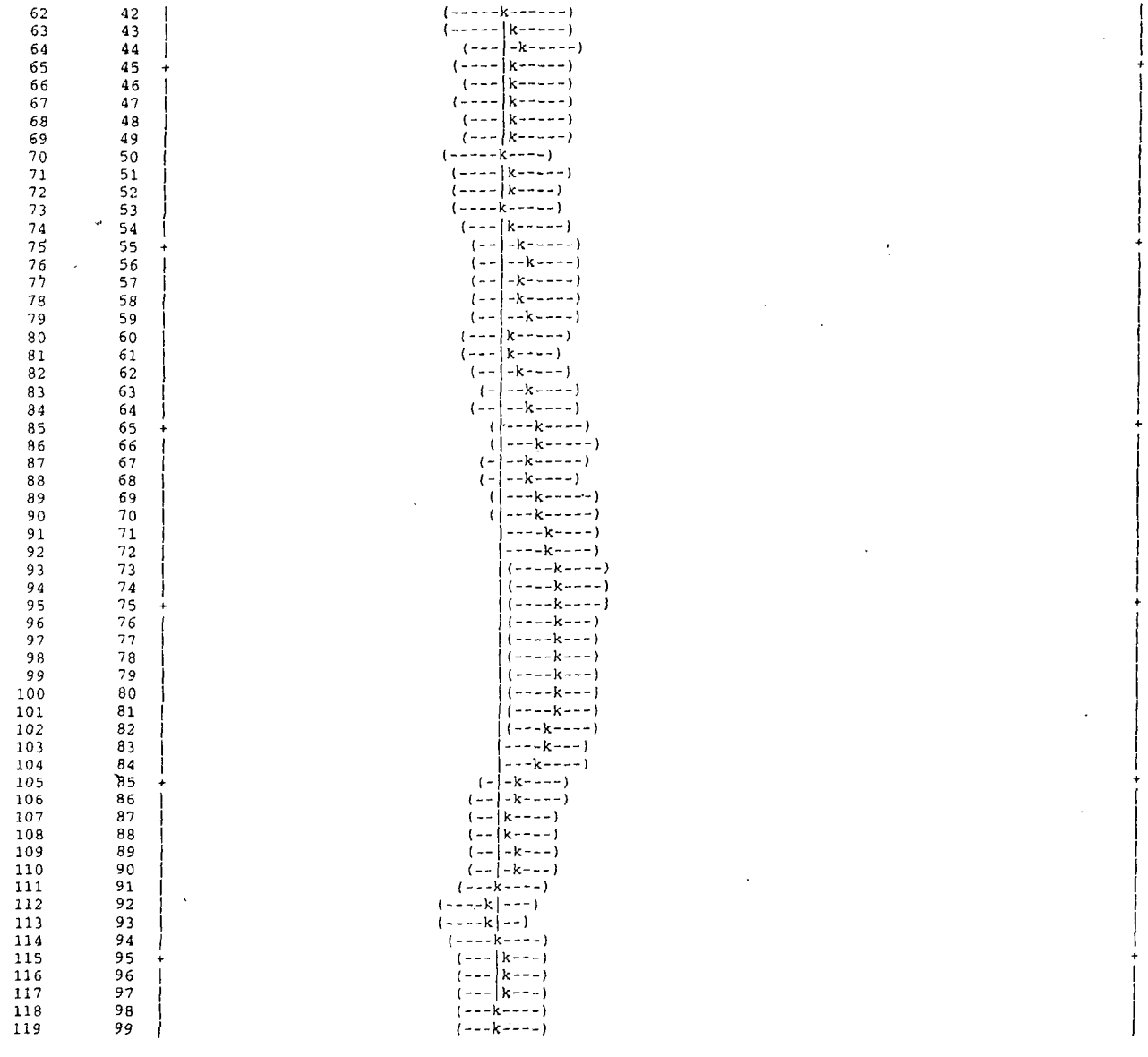
collision 0.97618 on cycle 89
absorption 0.95052 on cycle 114
track length 0.97249 on cycle 89

the smallest active cycle keffs by estimator are:

collision 0.85442 on cycle 105
absorption 0.88968 on cycle 112
track length 0.85702 on cycle 105

iplot of the estimated col/abs/track-length keff one standard deviation interval versus cycle number (| = final keff = 0.92064)





120 100 |(----k---)|
0.91 0.92 0.93 0.94

lindividual and collision/absorption/track-length keffs for different numbers of inactive cycles skipped for fission source settling

skip cycles	active cycles	active neutrons	average keff estimators and deviations k(col)	st dev	k(abs)	st dev	k(trk)	st dev	normality co/ab/tl	average k(c/a/t) k(c/a/t)	st dev	k(c/a/t) confidence intervals 95% confidence	99% confidence
0	120	480785	0.9213	0.0020	0.9212	0.0016	0.9220	0.0020	no/no/no	0.92152	0.00158	0.91838-0.92467	0.91735-0.92570
1	119	476785	0.9203	0.0018	0.9202	0.0012	0.9210	0.0018	95/95/95	0.92048	0.00123	0.91802-0.92294	0.91722-0.92374
2	118	472552	0.9204	0.0018	0.9203	0.0012	0.9210	0.0018	95/95/95	0.92057	0.00124	0.91810-0.92303	0.91729-0.92384
3	117	469007	0.9205	0.0018	0.9205	0.0012	0.9211	0.0018	95/95/95	0.92069	0.00124	0.91822-0.92315	0.91741-0.92396
4	116	465064	0.9205	0.0018	0.9206	0.0013	0.9212	0.0018	95/95/95	0.92077	0.00125	0.91828-0.92325	0.91747-0.92406
5	115	460982	0.9207	0.0018	0.9205	0.0013	0.9213	0.0018	95/95/95	0.92069	0.00126	0.91819-0.92320	0.91737-0.92402
6	114	457176	0.9205	0.0018	0.9204	0.0013	0.9211	0.0018	95/95/95	0.92062	0.00127	0.91810-0.92314	0.91727-0.92397
7	113	452943	0.9205	0.0018	0.9205	0.0013	0.9212	0.0019	95/95/95	0.92071	0.00128	0.91816-0.92325	0.91734-0.92408
8	112	448998	0.9202	0.0018	0.9204	0.0013	0.9208	0.0018	95/95/95	0.92057	0.00128	0.91803-0.92311	0.91720-0.92394
9	111	444883	0.9202	0.0018	0.9206	0.0013	0.9208	0.0019	95/95/95	0.92079	0.00127	0.91826-0.92332	0.91743-0.92415
10	110	440957	0.9205	0.0018	0.9207	0.0013	0.9211	0.0019	95/95/95	0.92087	0.00128	0.91832-0.92341	0.91749-0.92424
11	109	437155	0.9207	0.0018	0.9208	0.0013	0.9213	0.0019	95/95/95	0.92094	0.00129	0.91838-0.92350	0.91755-0.92434
12	108	433107	0.9206	0.0019	0.9206	0.0013	0.9211	0.0019	95/95/95	0.92073	0.00128	0.91819-0.92328	0.91736-0.92411
13	107	428918	0.9205	0.0019	0.9204	0.0013	0.9210	0.0019	95/95/95	0.92062	0.00128	0.91807-0.92317	0.91724-0.92400
14	106	424884	0.9206	0.0019	0.9204	0.0013	0.9211	0.0019	95/95/95	0.92061	0.00130	0.91803-0.92319	0.91719-0.92403
15	105	420945	0.9208	0.0019	0.9202	0.0013	0.9213	0.0019	95/95/95	0.92050	0.00131	0.91790-0.92310	0.91705-0.92395
16	104	416955	0.9209	0.0019	0.9204	0.0013	0.9216	0.0019	95/95/99	0.92079	0.00130	0.91820-0.92338	0.91736-0.92423
17	103	412951	0.9210	0.0019	0.9202	0.0013	0.9216	0.0019	95/95/95	0.92063	0.00130	0.91804-0.92322	0.91719-0.92407
18	102	408869	0.9211	0.0019	0.9202	0.0013	0.9218	0.0019	95/95/99	0.92060	0.00132	0.91798-0.92322	0.91712-0.92407
19	101	404814	0.9211	0.0020	0.9203	0.0013	0.9218	0.0020	95/95/95	0.92070	0.00132	0.91806-0.92334	0.91720-0.92420
20	100*	400687	0.9214	0.0020	0.9202	0.0013	0.9221	0.0020	95/95/99	0.92064	0.00134	0.91797-0.92331	0.91710-0.92418
22	98	392668	0.9212	0.0020	0.9201	0.0014	0.9219	0.0020	95/95/95	0.92056	0.00137	0.91784-0.92328	0.91695-0.92417
24	96	384752	0.9208	0.0020	0.9201	0.0014	0.9216	0.0020	95/95/95	0.92056	0.00140	0.91778-0.92334	0.91687-0.92425
26	94	376854	0.9208	0.0021	0.9203	0.0014	0.9215	0.0021	95/95/95	0.92063	0.00142	0.91781-0.92346	0.91689-0.92438
28	92	368802	0.9208	0.0021	0.9202	0.0014	0.9215	0.0021	95/95/95	0.92058	0.00144	0.91771-0.92344	0.91678-0.92438
30	90	360847	0.9206	0.0021	0.9200	0.0015	0.9211	0.0021	95/95/95	0.92037	0.00146	0.91747-0.92327	0.91652-0.92422
32	88	353025	0.9205	0.0022	0.9202	0.0015	0.9211	0.0022	95/95/95	0.92049	0.00149	0.91753-0.92346	0.91656-0.92442
34	86	344963	0.9204	0.0022	0.9199	0.0015	0.9210	0.0022	95/95/95	0.92029	0.00151	0.91727-0.92330	0.91629-0.92428
36	84	337132	0.9205	0.0023	0.9203	0.0015	0.9211	0.0023	95/95/95	0.92062	0.00153	0.91757-0.92366	0.91658-0.92466
38	82	329005	0.9202	0.0023	0.9202	0.0016	0.9207	0.0023	95/95/95	0.92052	0.00156	0.91742-0.92362	0.91641-0.92463
40	80	321204	0.9206	0.0023	0.9203	0.0016	0.9213	0.0023	95/95/95	0.92075	0.00160	0.91757-0.92393	0.91653-0.92497
42	78	312985	0.9200	0.0024	0.9200	0.0016	0.9208	0.0023	95/95/95	0.92050	0.00163	0.91724-0.92375	0.91617-0.92482
44	76	305102	0.9199	0.0024	0.9200	0.0016	0.9206	0.0024	95/95/95	0.92039	0.00163	0.91714-0.92365	0.91607-0.92472
46	74	297022	0.9200	0.0025	0.9199	0.0016	0.9206	0.0025	95/95/95	0.92020	0.00165	0.91690-0.92350	0.91582-0.92458
48	72	289167	0.9201	0.0025	0.9204	0.0016	0.9207	0.0025	95/95/99	0.92068	0.00166	0.91738-0.92399	0.91629-0.92507
50	70	281201	0.9198	0.0025	0.9199	0.0016	0.9204	0.0025	95/95/99	0.92023	0.00167	0.91689-0.92358	0.91580-0.92467
52	68	272894	0.9195	0.0025	0.9200	0.0017	0.9201	0.0025	99/95/99	0.92028	0.00170	0.91689-0.92367	0.91578-0.92478
54	66	265077	0.9191	0.0026	0.9197	0.0017	0.9197	0.0026	99/95/99	0.92001	0.00173	0.91654-0.92347	0.91540-0.92461
56	64	257075	0.9188	0.0027	0.9197	0.0018	0.9194	0.0026	95/95/99	0.91994	0.00179	0.91636-0.92351	0.91519-0.92469
58	62	249055	0.9190	0.0027	0.9199	0.0018	0.9198	0.0026	99/95/99	0.92035	0.00184	0.91667-0.92403	0.91545-0.92525
60	60	241190	0.9196	0.0027	0.9201	0.0018	0.9204	0.0027	99/95/no	0.92057	0.00188	0.91680-0.92434	0.91555-0.92559
62	58	233114	0.9198	0.0028	0.9204	0.0019	0.9205	0.0028	99/95/99	0.92071	0.00194	0.91683-0.92459	0.91555-0.92588
64	56	225141	0.9195	0.0029	0.9200	0.0019	0.9203	0.0029	99/95/99	0.92041	0.00200	0.91639-0.92442	0.91505-0.92576
66	54	217139	0.9196	0.0030	0.9201	0.0020	0.9204	0.0030	95/95/99	0.92041	0.00206	0.91628-0.92454	0.91491-0.92591
68	52	209077	0.9198	0.0031	0.9203	0.0020	0.9204	0.0031	95/95/95	0.92048	0.00210	0.91625-0.92470	0.91485-0.92610
70	50	201031	0.9205	0.0032	0.9206	0.0021	0.9211	0.0031	95/95/95	0.92088	0.00215	0.91655-0.92521	0.91511-0.92666

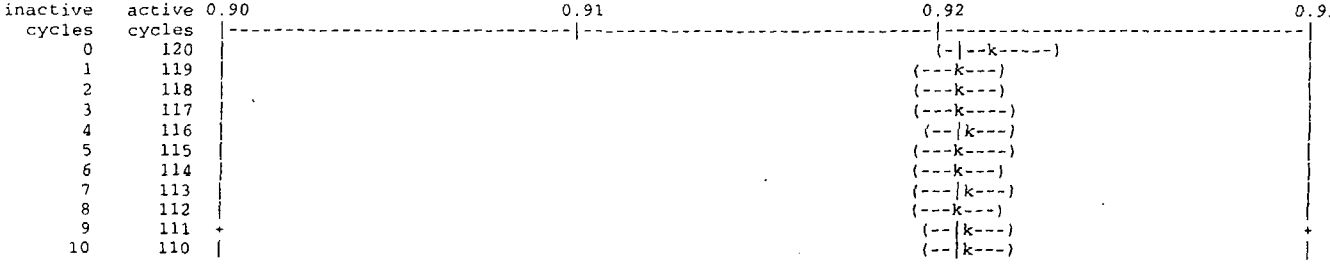
72	48	192823	0.9193	0.0032	0.9202	0.0021	0.9201	0.0031	95/95/95	0.92062	0.00219	0.91621-0.92504	0.91473-0.92652
74	46	184875	0.9185	0.0033	0.9202	0.0022	0.9192	0.0032	95/95/95	0.92075	0.00221	0.91630-0.92520	0.91480-0.92670
76	44	176907	0.9172	0.0033	0.9196	0.0022	0.9180	0.0032	95/95/95	0.92014	0.00229	0.91551-0.92477	0.91395-0.92633
78	42	168884	0.9168	0.0033	0.9197	0.0023	0.9176	0.0033	95/95/95	0.92020	0.00241	0.91533-0.92508	0.91368-0.92673
80	40	160750	0.9167	0.0034	0.9201	0.0024	0.9175	0.0034	95/95/95	0.92074	0.00249	0.91569-0.92578	0.91397-0.92750
82	38	152833	0.9164	0.0035	0.9197	0.0025	0.9169	0.0034	95/95/99	0.92022	0.00248	0.91517-0.92526	0.91345-0.92699
84	36	144615	0.9160	0.0037	0.9192	0.0025	0.9165	0.0036	95/95/99	0.91982	0.00250	0.91473-0.92490	0.91298-0.92665
86	34	136630	0.9151	0.0039	0.9183	0.0026	0.9158	0.0038	95/95/99	0.91913	0.00258	0.91386-0.92439	0.91204-0.92621
88	32	128599	0.9155	0.0041	0.9186	0.0027	0.9161	0.0040	95/95/99	0.91937	0.00270	0.91384-0.92490	0.91191-0.92682
90	30	120227	0.9128	0.0038	0.9175	0.0027	0.9136	0.0037	99/95/no	0.91790	0.00281	0.91213-0.92366	0.91012-0.92568
92	28	112501	0.9117	0.0039	0.9168	0.0029	0.9129	0.0039	99/95/no	0.91729	0.00307	0.91096-0.92362	0.90872-0.92586
94	26	104519	0.9109	0.0042	0.9153	0.0029	0.9121	0.0041	99/95/no	0.91613	0.00308	0.90975-0.92250	0.90747-0.92478
96	24	96648	0.9116	0.0045	0.9153	0.0031	0.9122	0.0044	99/95/no	0.91599	0.00319	0.90935-0.92264	0.90695-0.92504
98	22	88585	0.9110	0.0049	0.9146	0.0034	0.9117	0.0048	99/95/99	0.91539	0.00347	0.90812-0.92265	0.90546-0.92531
100	20	80523	0.9098	0.0053	0.9138	0.0037	0.9109	0.0052	95/95/99	0.91526	0.00394	0.90695-0.92358	0.90384-0.92669
102	18	72538	0.9101	0.0059	0.9140	0.0039	0.9108	0.0058	95/95/99	0.91493	0.00428	0.90581-0.92405	0.90233-0.92754
104	16	64587	0.9114	0.0066	0.9152	0.0042	0.9116	0.0065	99/95/99	0.91563	0.00450	0.90591-0.92535	0.90208-0.92918
106	14	56723	0.9152	0.0061	0.9172	0.0044	0.9151	0.0062	95/95/99	0.91703	0.00483	0.90640-0.92767	0.90203-0.93204
108	12	48385	0.9175	0.0065	0.9172	0.0051	0.9177	0.0065	95/95/99	0.91737	0.00560	0.90471-0.93003	0.89918-0.93556
110	10	40160	0.9166	0.0078	0.9159	0.0059	0.9166	0.0078	95/95/95	0.91599	0.00661	0.90035-0.93163	0.89284-0.93914
112	8	32359	0.9267	0.0051	0.9223	0.0053	0.9268	0.0046	95/95/99	0.92502	0.00392	0.91494-0.93511	0.90920-0.94085
114	6	24134	0.9273	0.0069	0.9194	0.0045	0.9277	0.0063	95/95/95	0.92232	0.00643	0.90184-0.94280	0.88474-0.95990
116	4	15997	0.9217	0.0047	0.9136	0.0025	0.9217	0.0036	95/95/95	0.91176	0.00186	0.88807-0.93544	0.79312-1.03039
117	3	11888	0.9207	0.0065	0.9121	0.0028	0.9220	0.0050					
118	2	8044	0.9192	0.0110	0.9116	0.0049	0.9212	0.0086					

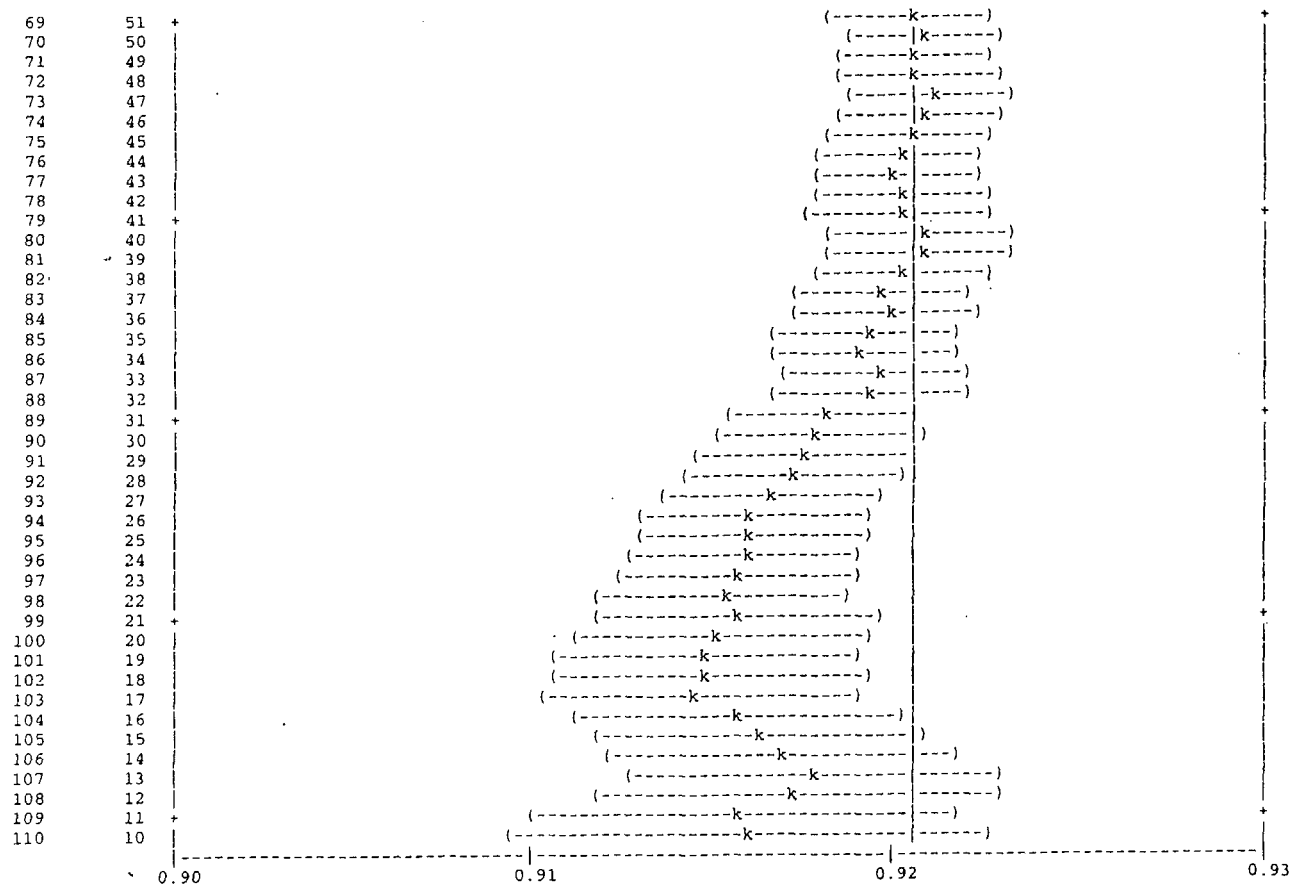
the minimum estimated standard deviation for the col/abs/tl keff estimator occurs with 115 inactive cycles and 5 active cycles.

the first active half of the problem skips 20 cycles and uses 50 active cycles; the second half skips 70 and uses 50 cycles.
the col/abs/trk-len keff, one standard deviation, and 68, 95, and 99 percent intervals for each active half of the problem are:

problem	keff	standard deviation	68% confidence	95% confidence	99% confidence
first half	0.92054	0.00167	0.91886 to 0.92222	0.91718 to 0.92390	0.91605 to 0.92502
second half	0.92088	0.00215	0.91872 to 0.92305	0.91655 to 0.92521	0.91511 to 0.92666
final result	0.92064	0.00134	0.91930 to 0.92198	0.91797 to 0.92331	0.91710 to 0.92418

the first and second half values of k(collision/absorption/track length) appear to be the same at the 68 percent confidence level.
1plot of the estimated col/abs/track-length keff one standard deviation interval by active cycle number (| = final keff = 0.92064)





dump no. 4 on file 3b081r nps = 480785 coll = 66648699 ctm = 44.12 nrn = 1147470272

2 warning messages so far.

run terminated when 120 kcode cycles were done.

computer time = 44.13 minutes

mcnp version 4a 10/01/93 02/14/01 09:03:50 probid = 02/14/01 08:19:43

URS

Calculation Cover Page

3065 Southwestern Boulevard
Suite 202
Orchard Park, NY 14127
716 675 7130 Tel
716 675 7137 Fax

Job No: **30822-244-330 /6860** Calculation No: **BUF-2001-014/Rev. 1** Date: **February 25, 2001**

Problem Statement & Calculation Objectives:

To determine the Pu-239 mass sub-critical limit for $\infty \times \infty \times 12$ ft arrays of 2.875-cubic-foot boxes with Pu-239-cellulose spheres and pure cellulose or void outside the sphere. Every box has 1 sphere containing the same amount of Pu-239.

References and Data Available:

J. F. Briemiester, ed., MCNP - A General Purpose Monte Carlo N-Particle Transport Code, Version 4A, LA-12625, Los Alamos National Laboratory, Los Alamos NM, 1993
C. D. Harmon, II et al., Criticality Calculations with MCNP: A Primer, Manual LA-12827, Los Alamos National Laboratory, Los Alamos NM, 1993
D. R. Lide, CRC Handbook of Chemistry an Physics, CRC Press, Boston MA, 1991.
F. H. Attix, Introduction to Radiological Physics and Radiation Dosimetry. John Wiley & Sons, Inc., New York NY, 1986

Attachments:

Attachment 1: MCNP surface and cell numbers
Attachment 2: MCNP input file
Attachment 3: MCNP output file

Prepared by:

Signature Igor V. Chichkov — Date 03/14/01

Checked by:

Signature Kevin Roberts — Date 3/30/01

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Analysis

Assumptions

- Pu-239 inside the sphere is uniformly mixed with 0.72 g/cm^3 cellulose
- The pure cellulose (0.72 g/cm^3) fills the entire space inside the container and outside the Plutonium sphere.
- The containers stand on the 3 m thick concrete floor
- The box inside dimensions are 2.5 x 2.5 x 2.5 foot
- The box wall thickness is zero
- Every box in the array contains the same mass of Pu-239
- The boxes are arranged in the infinite square array, 12 feet heigh ($\infty \times \infty \times$ 12 ft)

MCNP Model

Neutron multiplication factors were calculated with MCNP4A code. Attachments 1 has the drawings of the models used. Examples of MCNP input and output files for both cases can also be found in the Attachments. The plutonium spheres were located in the box's corner as shown in Attachments 1.

Air, Carbon Steel, Concrete and Cellulose Composition

Table 1 shows the element weight fractions for air (Attix F.H., 1986). Table 2 shows the element composition of concrete (Harmon C. D., II et al., 1993) in the floor.

Table 1. Air composition

Element	Weight Fraction
Carbon (C)	0.000124
Nitrogen (N)	0.755267
Oxygen (O)	0.231781
Argon (Ar)	0.012827

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Table 2. Concrete composition

Element	Weight Fraction
Hydrogen (H)	0.010
Oxygen (O)	0.532
Sodium (Na)	0.029
Aluminum (Al)	0.034
Silicon (Si)	0.337
Calcium (Ca)	0.044
Iron (Fe)	0.014

The weight fractions of the elements composing the cellulose were determined based on the known atomic weights of the elements (Table 3) and the cellulose chemical formula - $C_6H_{10}O_5$.

Table 3. The atomic weights of the elements

Element	Atomic Weight
Hydrogen (H)	1.00794
Carbon (C)	12.0107
Oxygen (O)	15.9994

The molecular weight of cellulose ($C_6H_{10}O_5$) was calculated as the sum of all atomic weights composing the molecule. The weight fraction of an ith element was found as a ratio of the ith element weight in the molecule to the molecular weight of this molecule.

$$(w_i)_{cel} = \frac{n_i A_i}{M_{cel}} = \frac{n_i A_i}{\sum n_i A_i} \qquad (1)$$

where

$(w_i)_{cel}$ = the weight fraction of ith element in a molecule of cellulose

n_i = the number of the ith elements in a cellulose molecule

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A_i = the atomic weight of the ith element, g/mol

M_{cel} = the molecular weight a cellulose molecule, g/mol

Calculated weight fractions for cellulose are shown in Table 4.

Table 4. Cellulose Weight Fractions

Element	Weight Fraction
Hydrogen (H)	0.062
Carbon (C)	0.444
Oxygen (O)	0.493

Radii of the Plutonium containing spheres.

The spheres with several different radii were studied. The minimum size of the Plutonium containing sphere corresponded to the sphere with pure Pu-239 and the maximum size was limited by the dimensions of the container, i.e. half of the box height. The minimum radius equation (3) was derived from the volume of a sphere equation (2)

$$V_{Pu} = \frac{4\pi\left(R_{Pu}\right)^3}{3} \qquad (2)$$

$$R_{\min} = R_{Pu} = \sqrt[3]{\frac{3V_{Pu}}{4\pi}} = \sqrt[3]{\frac{3m_{Pu}}{4\pi\rho_{Pu}}} \qquad (3)$$

where:

R_{min} = the minimum possible radius of the sphere containing Pu-239, cm

R_{Pu} = the radius of the metal Plutonium sphere, cm

V_{Pu} = the volume of the sphere with Pu-239, cm^3

m_{Pu} = the mass of the Plutonium sphere, g

ρ_{Pu} = the density of the metal Plutonium, 19.78 g/cm^3

Composition of the Plutonium containing spheres

The weight fractions of the elements composing the mixture are defined as the ratio of the mass of the element in the mixture to the total mass of the mixture. Total mass of the mixture was determined using

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equation (4):

$$M_{total} = m_{Pu} + m_{cel} = m_{Pu} + V_{cel}\rho_{cel} =$$
$$= m_{Pu} + \left(V_{Total} - V_{Pu}\right)\rho_{cel} = m_{Pu} + \left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel} \qquad (4)$$

where

M_{Total} = the total mass of the mixture, g

m_{Pu} = the mass of Pu-239 in a sphere, g

m_{cel} = the mass of a cellulose in a sphere, g

V_{Total} = the total volume of a sphere, cm^3

V_{cel} = the volume of a cellulose in the sphere, cm^3

ρ_{cel} = the density of a cellulose, 0.72 g/cm^3

V_{Pu} = the volume of Pu-239 in the sphere, cm^3

ρ_{Pu} = the density of the metal Plutonium, 19.78 g/cm^3

R = the radius of a Plutonium containing sphere, cm

In the Plutonium-cellulose mixture, the weight fraction of Pu-239 was calculated using equation 5, and the weight fractions of elements composing cellulose were calculated using equation 7 as a product of the weight fraction of a cellulose in the Plutonium-cellulose mixture (equation 6) and the weight fraction of an element in a pure cellulose (equation 1).

$$w_{Pu} = \frac{m_{Pu}}{M_{total}} = \frac{m_{Pu}}{m_{Pu} + \left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel}} \qquad (5)$$

$$w_{cel} = \frac{m_{cel}}{M_{total}} = \frac{\left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel}}{m_{Pu} + \left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel}} \qquad (6)$$

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$$w_i = w_{cel}(w_i)_{cel} = \frac{\left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel} n_i A_i}{\left[m_{Pu} + \left(\frac{4\pi R^3}{3} - \frac{m_{Pu}}{\rho_{Pu}}\right)\rho_{cel}\right]\sum n_i A_i} \qquad (7)$$

All variables in equations 5-7 are as described above. Table 6 shows the composition of the Plutonium containing spheres.

The cases for spheres with 150g, 200g, 250, and 350g of Pu-239 were studied and based on the calculated neutron multiplication factors, the Pu-239 sub-critical mass limit was determined. Tables 5-8 show the composition of the spheres used in the models.

Table 5. The composition of the spheres with 150g of Pu-239.

Radius of the sphere, cm	5	10	15	20	38.1
Mixture density, g/cm^3	0.99605095	0.754506369	0.730224109	0.724313296	0.720623913
Pu-239 weight fraction	0.287614702	0.047461312	0.014530237	0.00617997	0.0008985
Carbon (C) weight fraction	0.316623206	0.42336058	0.437996961	0.44170828	0.444055654
Hydrogen (H)weight fraction	0.044285123	0.059214154	0.0612613	0.061780391	0.062108711
Oxygen (O) weight fraction	0.351476969	0.469963954	0.486211502	0.490331361	0.492937133

Table 6. The composition of the spheres with 200g of Pu-239.

Radius of the sphere, cm	5	10	15	20	38.1
Mixture density, g/cm^3	1.088067933	0.766008492	0.733632146	0.725751061	0.720831885
Pu-239 weight fraction	0.351055161	0.062331532	0.019283651	0.00822363	0.00119766
Carbon (C) weight fraction	0.288426777	0.416751437	0.435884283	0.440799963	0.443922693
Hydrogen (H)weight fraction	0.040341374	0.058289753	0.060965806	0.061653347	0.062090114
Oxygen (O) weight fraction	0.320176688	0.462627278	0.48386626	0.489323057	0.492789536

Table 7. The composition of the spheres with 250g of Pu-239.

Radius of the sphere, cm	5	10	15	20	38.1
Mixture density, g/cm^3	1.180084916	0.777510615	0.737040182	0.727188827	0.721039856
Pu-239 weight fraction	0.404602095	0.076761786	0.023993105	0.010259217	0.001496639
Carbon (C) weight fraction	0.264627575	0.410337838	0.433791142	0.439895237	0.443789809
Hydrogen (H)weight fraction	0.037012652	0.057392703	0.060673045	0.061526806	0.062071528
Oxygen (O) weight fraction	0.293757678	0.455507673	0.481542708	0.48831874	0.4926420

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Table 8. The composition of the spheres with 350g of Pu-239.

Radius of the sphere, cm	5	10	15	20	38.1
Mixture density, g/cm^3	1.364118883	0.80051486	0.743856255	0.730064358	0.721455798
Pu-239 weight fraction	0.490023831	0.104378256	0.033282553	0.014306332	0.002094087
Carbon (C) weight fraction	0.226661457	0.39806356	0.4296624	0.438096477	0.44352427
Hydrogen (H)weight fraction	0.031702447	0.055675937	0.06009557	0.061275219	0.062034388
Oxygen (O) weight fraction	0.251612265	0.441882247	0.476959476	0.486321972	0.492

Results

The results of the calculations performed using MCNP-4A code are shown in the following tables and graphs. Tables 9-12 provide the Monte Carlo determined neutron multiplication factor (k_{eff}) values and their standard deviations (σ), and Figures 1-4 plot the k_{eff} +2 σ values for all studied cases (150g, 200g, 250, and 350g).

Table 9. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for the boxes with 150 g of Pu-239.

R and X-, Y-, Z- coordinates for the center of the sphere, cm					cellulose outside the sphere			void outside the sphere		
R	X	Y	Z1	Z2	k_{eff}	σ	k_{eff}+ 2σ	k_{eff}	σ	k_{eff}+ 2σ
5	5	5	71.2	81.2	0.5652	0.0013	0.5678	0.0925	0.0005	0.0935
10	10	10	66.2	86.2	0.81542	0.00122	0.8179	0.33355	0.0011	0.3358
15	15	15	61.2	91.2	0.7683	0.0010	0.7703	0.5654	0.0012	0.5679
20	20	20	56.2	96.2	0.6139	0.0008	0.6155	0.6370	0.0009	0.6388
38.1	38.1	38.1	38.1	114.3	0.1637	0.0001	0.1639	0.2283	0.0001	0.2286

Table 10. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for the boxes with 200 g of Pu-239.

R and X-, Y-, Z- coordinates for the center of the sphere, cm					cellulose outside the sphere			void outside the sphere		
R	X	Y	Z1	Z2	k_{eff}	σ	k_{eff}+ 2σ	k_{eff}	σ	k_{eff}+ 2σ
5	5	5	71.2	81.2	0.5798	0.0015	0.5828	0.1060	0.0005	0.1070
10	10	10	66.2	86.2	0.8554	0.0013	0.8580	0.3576	0.0013	0.3601
15	15	15	61.2	91.2	0.8516	0.0012	0.8540	0.6277	0.0014	0.6304
20	20	20	56.2	96.2	0.7134	0.0009	0.7153	0.7380	0.0010	0.7401
38.1	38.1	38.1	38.1	114.3	0.2119	0.0002	0.2123	0.2933	0.0002	0.2936

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Table 11. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for the boxes with 250 g of Pu-239.

R and X-, Y-, Z- coordinates for the center of the sphere, cm					cellulose outside the sphere			void outside the sphere		
R	X	Y	Z1	Z2	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$
5	5	5	71.2	81.2	0.5890	0.0013	0.5916	0.1192	0.0006	0.1204
10	10	10	66.2	86.2	0.8805	0.0014	0.8833	0.37156	0.00112	0.3738
15	15	15	61.2	91.2	0.9075	0.0013	0.9101	0.6743	0.0014	0.6771
20	20	20	56.2	96.2	0.7914	0.0010	0.7933	0.8151	0.0010	0.8171
38.1	38.1	38.1	38.1	114.3	0.3629	0.0003	0.3636	0.4940	0.0003	0.4946

Table 12. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for the boxes with 350 g of Pu-239.

R and X-, Y-, Z- coordinates for the center of the sphere, cm					cellulose outside the sphere			void outside the sphere		
R	X	Y	Z1	Z2	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$
5	5	5	71.2	81.2	0.6136	0.0013	0.6161	0.1414	0.0007	0.14
10	10	10	66.2	86.2	0.91582	0.0014	0.9186	0.39407	0.00118	0.39
15	15	15	61.2	91.2	0.9802	0.0013	0.9828	0.7336	0.0014	0.7364
20	20	20	56.2	96.2	0.9001	0.0012	0.9024	0.9262	0.0011	0.9284
38.1	38.1	38.1	38.1	114.3	0.4691	0.0004	0.4700	0.6295	0.0003	0.6302

Figure 1. k_{eff} +2σ for the boxes with 150 g of Pu-239 .

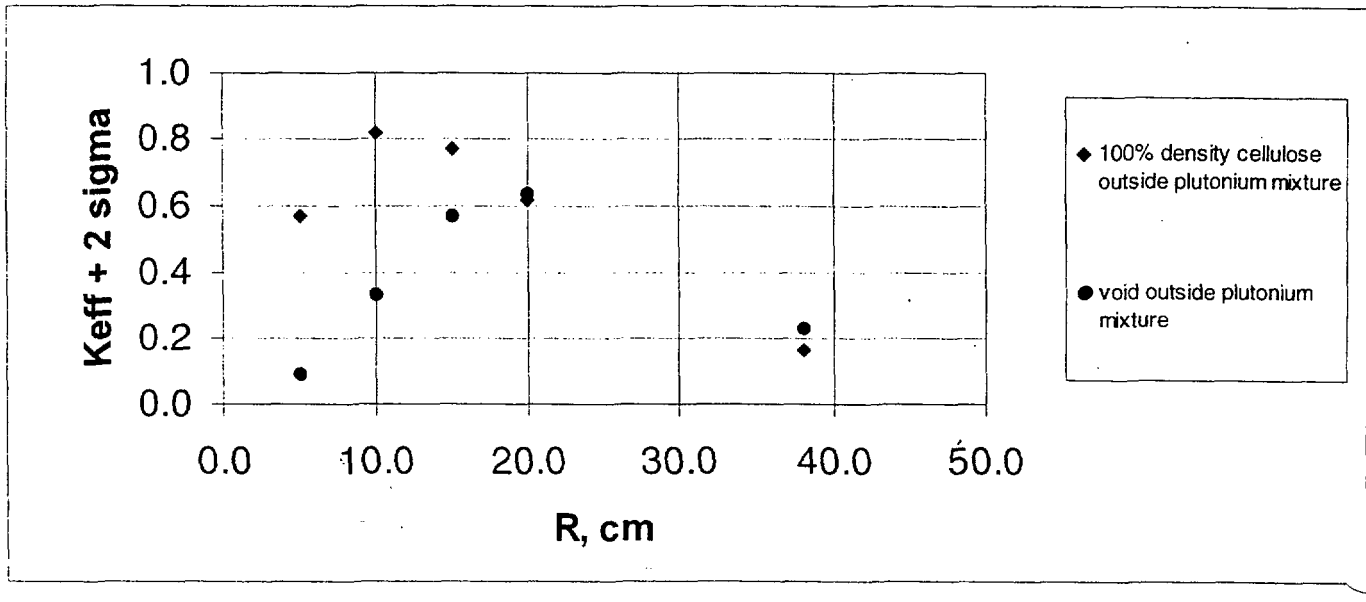

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Figure 2. k_{eff} +2σ for the boxes with 200 g of Pu-239 .

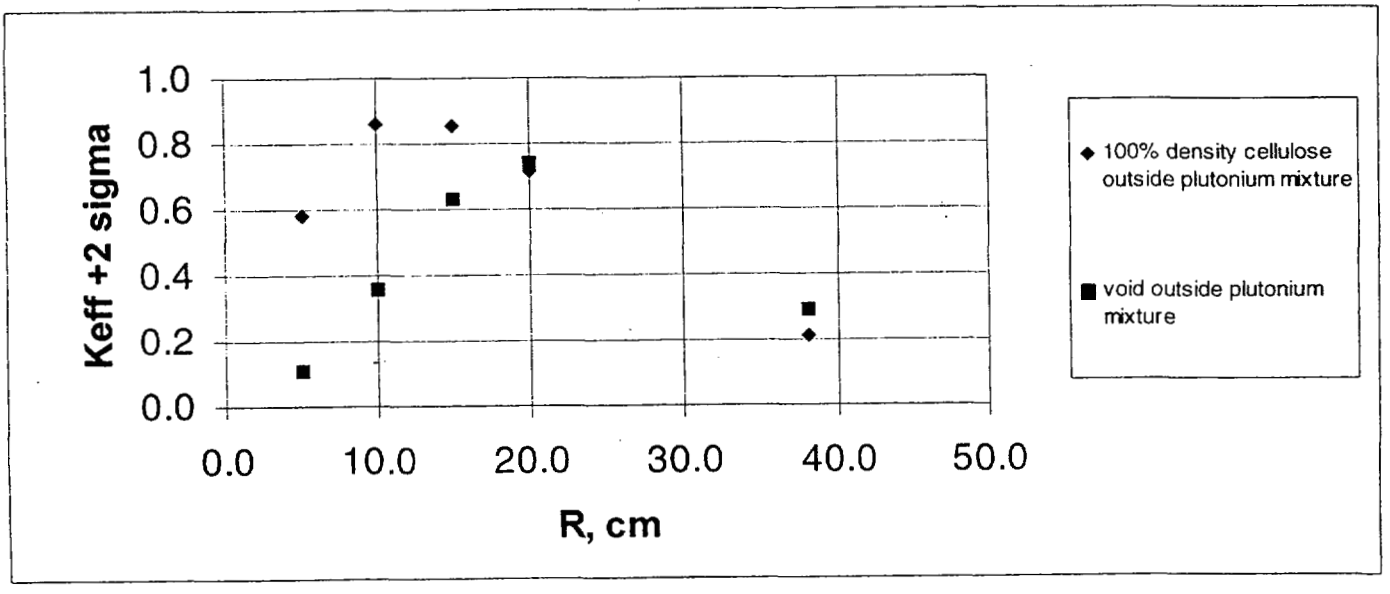

Figure 3. k_{eff} +2σ for the boxes with 250 g of Pu-239.

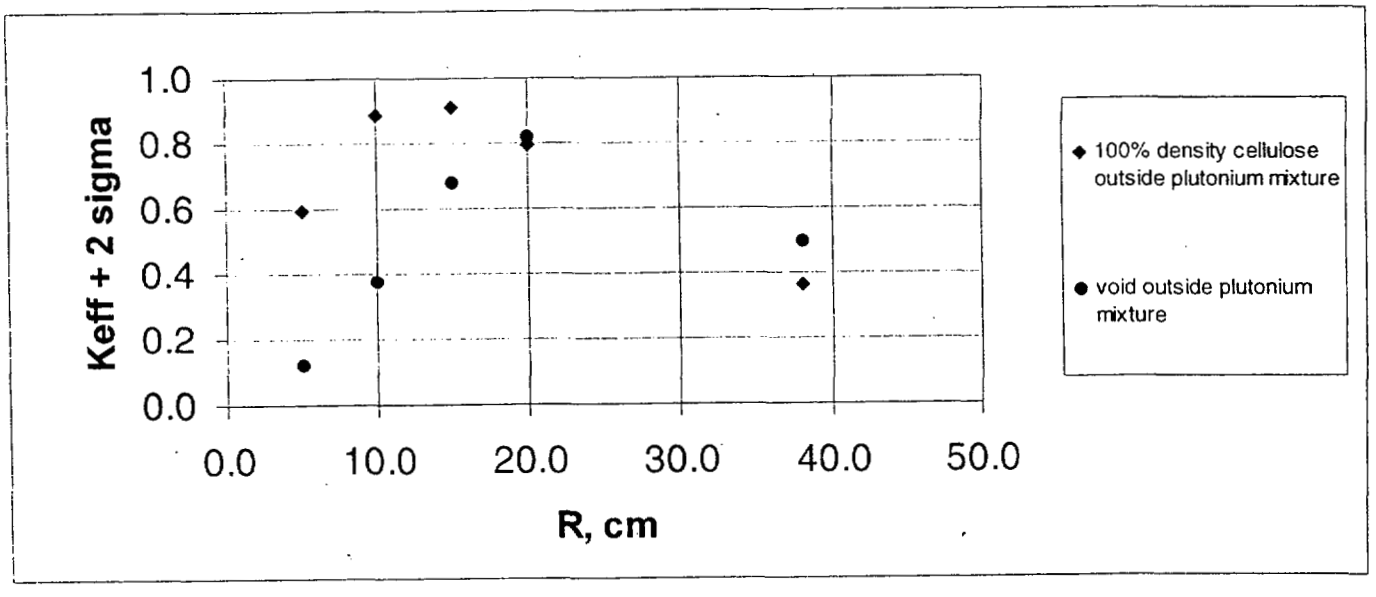

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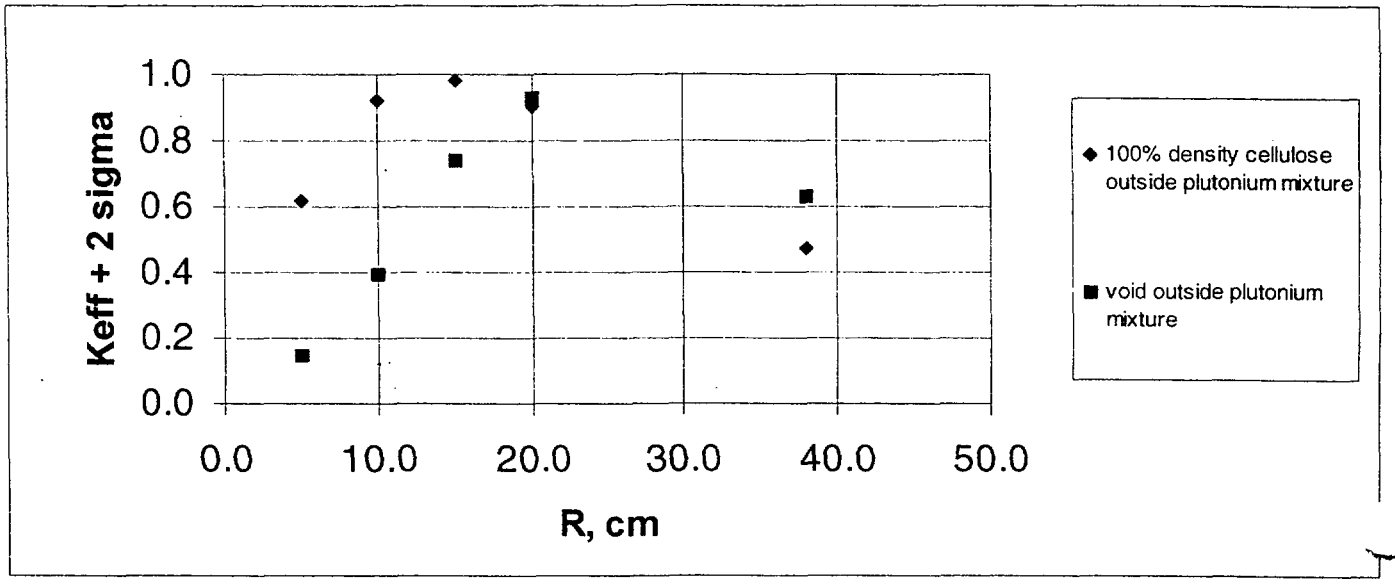
Figure 4. k_{eff} +2σ for the boxes with 350 g of Pu-239.



The criterion for the Pu-239 mass limit is:

$$k_{eff} + 2\sigma \leq k_a - \Delta k_b - \sigma_b \quad (8)$$

Where:

k_{eff} = neutron multiplication factor predicted by MCNP

σ = standard deviation of predicted k_{eff}

$k_a = 0.95$ = established allowable limiting neutron multiplication factor

Δk_b = calculation method bias

σ_b = bias uncertainty

The calculation method bias together with bias uncertainty ($\Delta k_b + \sigma_b$) is no more than 0.02. Thus the criterion (8) can be modified as:

$$k_{eff} + 2\sigma \leq 0.93 \quad (9)$$

Where:

k_{eff} = neutron multiplication factor predicted by MCNP

σ = standard deviation of predicted k_{eff}

To determine the Pu-239 mass limit, the maximum values of k_{eff} +2σ as a function of Pu-239 mass (Table 13) were approximated with a polynomial equation, which is shown on Figure 5.

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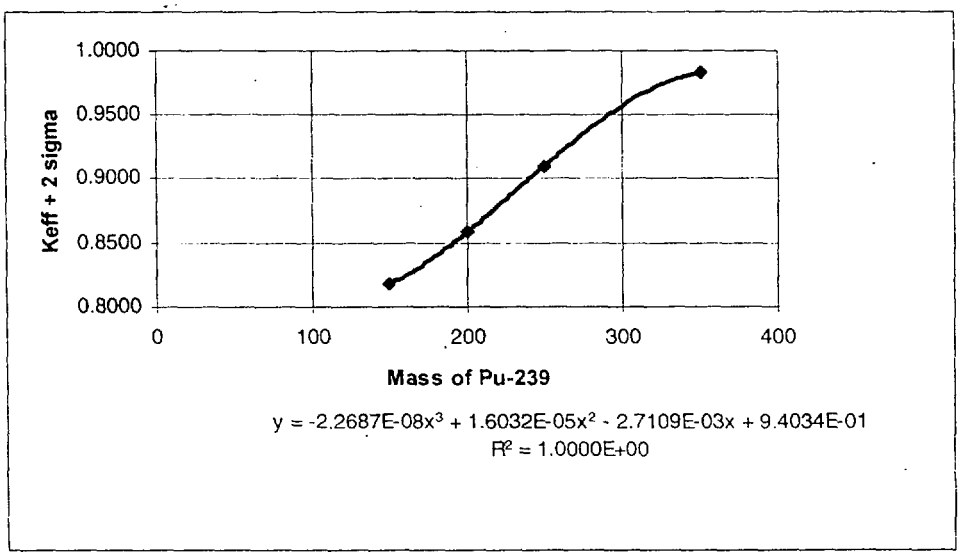
Table 13. The maximum values of k_{eff} +2σ as a function of Pu-239 mass.

Mass of Pu-239, g	k_{eff}	σ	k_{eff} + 2σ
150	0.81542	0.00122	0.8179
200	0.8554	0.0013	0.8580
250	0.9075	0.0013	0.9101
350	0.9802	0.0013	0.9828

Figure 5. The maximum values of k_{eff} +2σ as a function of Pu-239 mass.



Solving the polynomial equation from Figure 4 determines the Pu-239 mass limit as 265g per box. To check this result, another set of MCNP runs was performed. Table 14 shows the composition of the Plutonium-containing spheres, and Table 15 and Figure 6 show the calculation results for the arrays of boxes with 265g of Pu-239.

Table 14. The composition of the spheres with 265g of Pu-239

Radius of the sphere, cm	5	10	15	20	38.1
Mixture density, g/cm³	1.207690011	0.780961251	0.738062593	0.727620156	0.721102247
Pu-239 weight fraction	0.419075023	0.081007975	0.02539746	0.010868323	0.0015863
Carbon (C) weight fraction	0.258195009	0.408450598	0.433166969	0.439624517	0.443749958
Hydrogen (H)weight fraction	0.036112949	0.05712874	0.060585744	0.061488941	0.062065954
Oxygen (O) weight fraction	0.286617019	0.453412686	0.480849826	0.488018218	0.492597787

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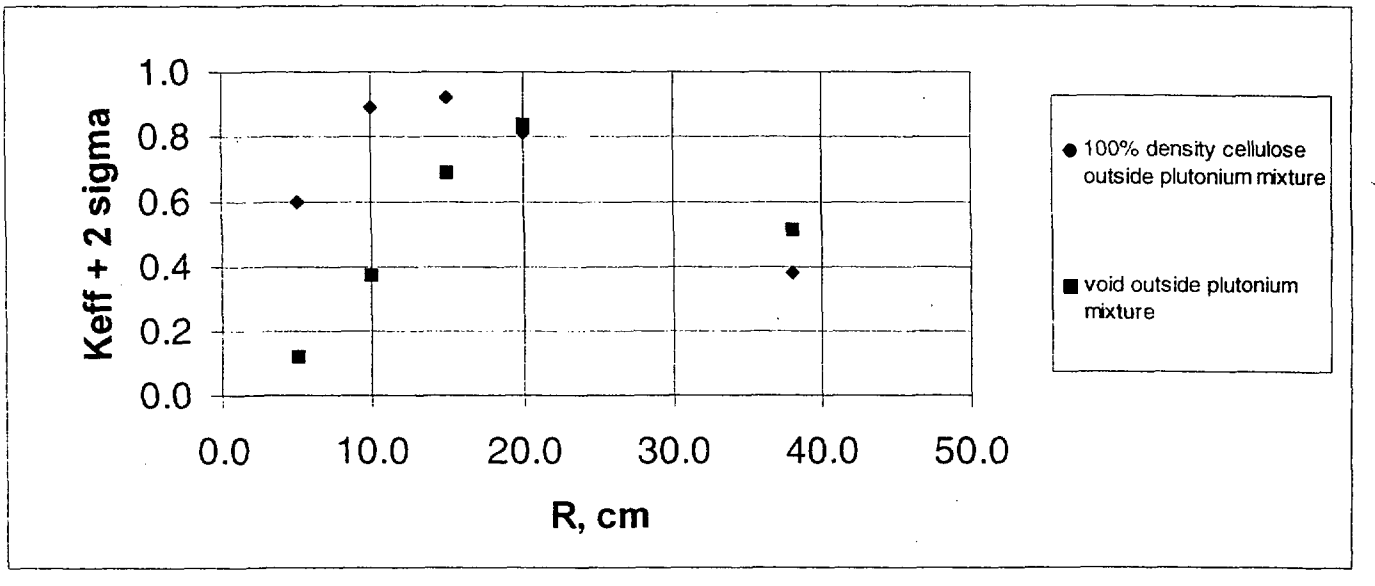
Table 15. The neutron multiplication factor (k_{eff}) values and their standard deviations (σ) for the boxes with 265 g of Pu-239.

R and X-, Y-, Z- coordinates for the center of the sphere, cm					cellulose outside the sphere			void outside the sphere		
R	X	Y	Z1	Z2	k_{eff}	σ	$k_{eff}+2\sigma$	k_{eff}	σ	$k_{eff}+2\sigma$
5	5	5	71.2	81.2	0.5975	0.0014	0.6003	0.1229	0.0007	0.1242
10	10	10	66.2	86.2	0.88914	0.00148	0.8921	0.37609	0.00104	0.3782
15	15	15	61.2	91.2	0.9215	0.0012	0.9239	0.6866	0.0014	0.6894
20	20	20	56.2	96.2	0.8097	0.0010	0.8117	0.8336	0.0010	0.8356
38.1	38.1	38.1	38.1	114.3	0.3799	0.0003	0.3806	0.5157	0.0003	0.5163

Figure 6. $k_{eff}+2\sigma$ for the boxes with 265g of Pu-239.



The $k_{eff}+2\sigma$ values in Table 15 confirm that 265g of Pu-239 is a sub-critical mass limit for $\infty \times \infty \times 12$ ft arrays of 2.5-cubic-foot boxes with Pu-239-cellulose spheres and pure cellulose or void outside the sphere.

Attachment 1: MCNP model with surface and cell numbers

REVISIONS
BY _____ DATE _____ TO EO ____
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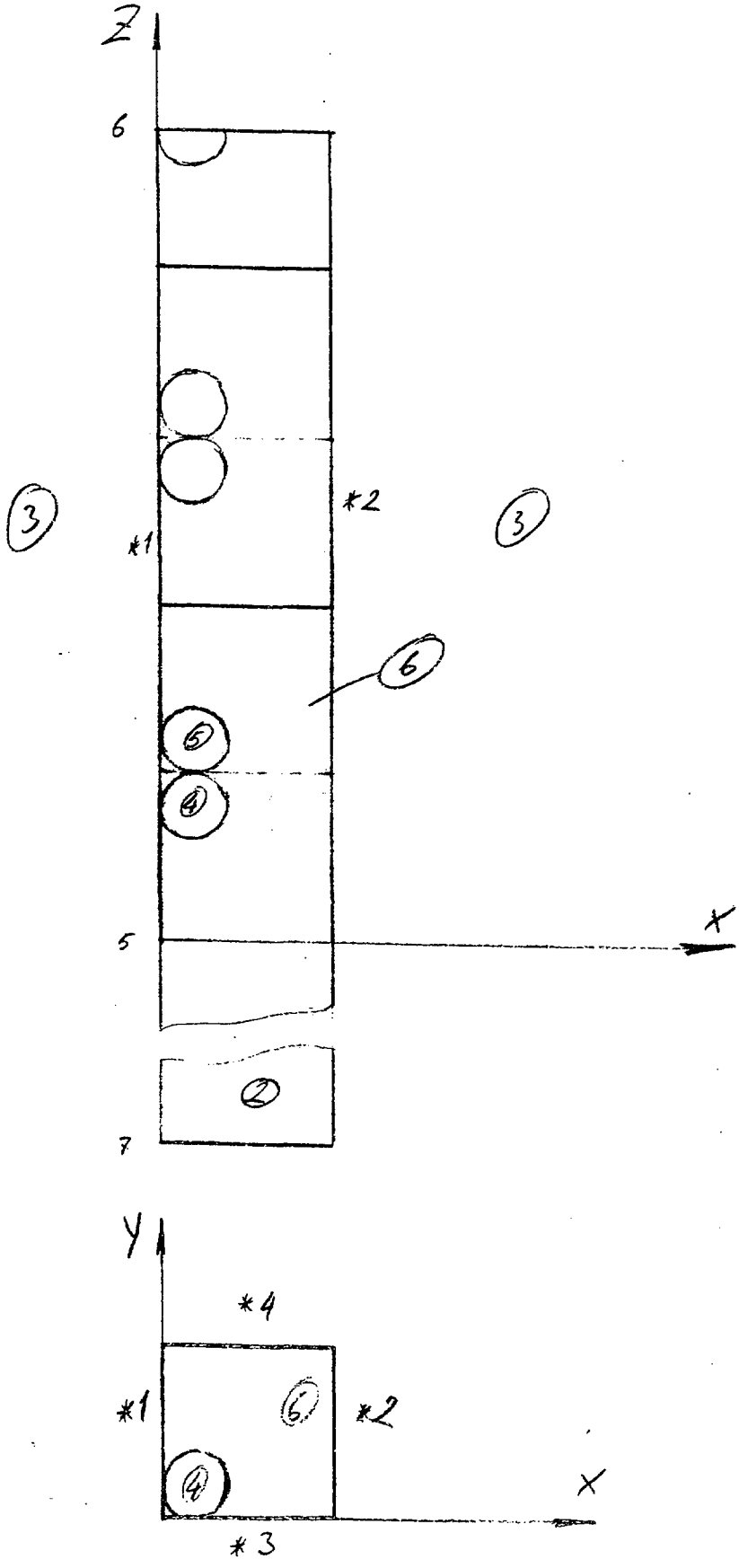

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Dames & Moore

Attachment 2: MCNP input file

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```
k eff, 265g of Pu-239 in cellulose spheres in 2.5 c. foot of pure celulose
C
C Cell cards
C
C ------------------------------------------------------------------------
1 0   1 -2 3 -4 5 -6 fill=2          imp:n=1 $ box with lattice
2 2  -2.3    1 -2 3 -4 -5 7         imp:n=1 $ Concrete floor
3 0         -1 : 2 : -3 : 4 : -7 : 6  imp:n=0 $ Outside world
c
c Universe 1
4 3  -0.738063 -8              u=1    imp:n=1 $ 1 Pu-239 and cellulose sphere
5 3  -0.738063 -9              u=1    imp:n=1 $ 2 Pu-239 and cellulose sphere
6 1  -0.72       8 9            u=1    imp:n=1 $ Pure Cellulose
c
c Lattice (2 spheres with Pu-239 in 2 cubes of cellulose matrix)
7 0 10 -11 12 -13 14 -15 lat=1 fill=1 u=2 imp:n=1 $ Lattice
C ------------------------------------------------------------------------
c
c Note: next line must be completely blank

c Surface cards
C ------------------------------------------------------------------------
*1 px 0.001
*2 px 76.201  $  box length (2.5 foot)
*3 py 0.001
*4 py 76.201  $  box width (2.5 foot)
5  pz 0.001
6  pz 365.761 $  box height (12 feet)
c                More thnan 350.52cm (11.5 feet) - 4 tiers of B-25 box height
c                (4x34.5" or 4x87.63 cm)
7  pz -300 $ concrete floor boundary
8  s 15.0 15.0  61.2 15.0 $ 1st Pu-239 containing sphere
9  s 15.0 15.0  91.2 15.0 $ 2nd Pu-239 containing sphere
c
c Lattice surfases:
10 px 0
11 px 76.20  $ 2.5 feet
12 py 0
13 py 76.20  $ 2.5 feet
14 pz 0
15 pz 152.40 $ 2 x 2.5 feet
C ------------------------------------------------------------------------
c
c Note: next line must be completely blank

c Data cards
c
c Materials
c
c
c Celulose matrix (Elements: C, H, O)
m1      6000.50c  -0.444
        1001.50c  -0.062
        8016.50c  -0.493
c Concrete (KENO Regular Concrete Standard Mix) from Harmon at al.
c Criticality Calculation with MCNP. A Primer. p. C-4
c (Elements: H, O, Na, Si, Al, Ca, Fe)
m2      1001.50c -0.010
        8016.50c -0.532
       11023.50c -0.029
       13027.50c -0.034
       14000.50c -0.337
       20000.50c -0.044
       26000.55c -0.014
c Pu-239 and cellulose
m3     94239.55c  -0.02539746
        6000.50c  -0.433166969
        1001.50c  -0.060585744
        8016.50c  -0.480849826
c
mode n
print 40 60 80 100 110 126
kcode 4000 1. 20 120
ksrc  15.0 15.0  61.2
      15.0 15.0  91.2
```

Attachment 3: MCNP output file

```
lmcnp     version 4a    ld=10/01/93                    03/06/01 13:31:59
*************************************************************************          probid =   03/06/01 13:31:59
name=3b141

      k eff, 265g of Pu-239 in cellulose spheres in 2.5 c. foot of pure celulose
      C
      C Cell cards
      C
      C ---------------------------------------------------------------------
      1 0   1 -2 3 -4 5 -6 fill=2           imp:n=1 $ box with lattice
      2 2  -2.3    1 -2 3 -4 -5 7           imp:n=1 $ Concrete floor
      3 0         -1 : 2 : -3 : 4 : -7 : 6  imp:n=0 $ Outside world
      c
      c Universe 1
      4 3  -0.738063 -8              u=1    imp:n=1 $ 1 Pu-239 and cellulose sphere
      5 3  -0.738063 -9              u=1    imp:n=1 $ 2 Pu-239 and cellulose sphere
      6 1  -0.72       8 9            u=1    imp:n=1 $ Pure Cellulose
      c
      c Lattice (2 spheres with Pu-239 in 2 cubes of cellulose matrix)
      7 0 10 -11 12 -13 14 -15 lat=1 fill=1 u=2 imp:n=1 $ Lattice
      C ---------------------------------------------------------------------
      c
      c Note: next line must be completely blank

      c Surface cards
      C ---------------------------------------------------------------------
      *1 px 0.001
      *2 px 76.201  $  box length (2.5 foot)
      *3 py 0.001
      *4 py 76.201  $  box width (2.5 foot)
      5  pz 0.001
      6  pz 365.761 $  box height (12 feet)
      c                More thnan 350.52cm (11.5 feet) - 4 tiers of B-25 box height
      c                (4x34.5" or 4x87.63 cm)
      7  pz -300 $ concrete floor boundary
      8  s 15.0 15.0  61.2 15.0 $ 1st Pu-239 containing sphere
      9  s 15.0 15.0  91.2 15.0 $ 2nd Pu-239 containing sphere
      c
      c Lattice surfases:
      10 px 0
      11 px 76.20  $ 2.5 feet
      12 py 0
      13 py 76.20  $ 2.5 feet
      14 pz 0
      15 pz 152.40 $ 2 x 2.5 feet
      C ---------------------------------------------------------------------
      c
      c Note: next line must be completely blank

      c Data cards
      c
      c Materials
      c
      c
      c Celulose matrix (Elements: C, H, O)
      m1      6000.50c  -0.444
              1001.50c  -0.062
              8016.50c  -0.493
```

```
   55-       c Concrete (KENO Regular Concrete Standard Mix) from Harmon at al.
   56-       c Criticality Calculation with MCNP. A Primer. p. C-4
   57-       c (Elements: H, O, Na, Si, Al, Ca, Fe)
   58-       m2      1001.50c -0.010
   59-               8016.50c -0.532
   60-              11023.50c -0.029
   61-              13027.50c -0.034
   62-              14000.50c -0.337
   63-              20000.50c -0.044
   64-              26000.55c -0.014
   65-       c Pu-239 and cellulose
   66-       m3     94239.55c  -0.02539746
   67-               6000.50c  -0.433166969
   68-               1001.50c  -0.060585744
   69-               8016.50c  -0.480849826
   70-       c
   71-       mode n
   72-       print 40 60 80 100 110 126
   73-       kcode 4000 1. 20 120
   74-       ksrc  15.0 15.0  61.2
   75-             15.0 15.0  91.2
   76-
 total fission nubar data are being used.
1material composition                                                    print table 40

 the sum of the fractions of material    1 was 9.990000E-01

 material
  number     component nuclide, atom fraction

     1            6000,  0.28588       1001,  0.47576       8016,  0.23837
     2            1001,  0.16803       8016,  0.56324      11023,  0.02136      13027,  0.02134
                 14000,  0.20319      20000,  0.01859      26000,  0.00425
     3           94239,  0.00084       6000,  0.28543       1001,  0.47579       8016,  0.23793



 material
  number     component nuclide, mass fraction

     1            6000,  0.44444       1001,  0.06206       8016,  0.49349
     2            1001,  0.01000       8016,  0.53200      11023,  0.02900      13027,  0.03400
                 14000,  0.33700      20000,  0.04400      26000,  0.01400
     3           94239,  0.02540       6000,  0.43317       1001,  0.06059       8016,  0.48085

 warning.    1 of the materials had unnormalized fractions.
1cells                                                                   print table 60

                          atom          gram                                        neutron
       cell  mat        density       density        volume          mass        pieces importance

     1     1    0  0.00000E+00  0.00000E+00  2.12376E+06  0.00000E+00       0  1.0000E+00
     2     2    2  8.17913E-02  2.30000E+00  1.74194E+06  4.00646E+06       0  1.0000E+00
     3     3    0  0.00000E+00  0.00000E+00  0.00000E+00  0.00000E+00       0  0.0000E+00
     4     4    3  5.61574E-02  7.38063E-01  1.41372E+04  1.04341E+04       1  1.0000E+00
     5     5    3  5.61574E-02  7.38063E-01  1.41372E+04  1.04341E+04       1  1.0000E+00
```

```
     6     6    1  5.61219E-02 7.20000E-01 0.00000E+00 0.00000E+00      0  1.0000E+00
     7     7    0  0.00000E+00 0.00000E+00 8.84901E+05 0.00000E+00      0  1.0000E+00

 total                                     4.77888E+06 4.02733E+06

         1 warning message so far.
 1cross-section tables                                                              print table 100

     table    length

                        tables from file critxs

   1001.50c     1153  njoy                                                  (  1301)      79/07/31.
   6000.50c    16126  njoy                                                  (  1306)      79/07/31.
   8016.50c    23669  njoy                                                   ( 1276)      05/14/81
  11023.50c    36270  njoy                                                  (  1311)      79/06/21.
  13027.50c    22891  njoy                                                  (  1313)      79/09/08.
  14000.50c    48275  njoy                                                  (  1314)      79/06/21.
  20000.50c    26104  njoy                                                  (  1320)      79/06/22.
  26000.55c    84136  njoy                                                  ( 260)        10/21/82
  94239.55c    67551  njoy                                 total nu          ( 1399)      02/21/85

 total       326175

 warning.  neutron energy cutoff is below some cross-section tables.



 decimal words of dynamically allocated storage

     general              111136
     tallies                   0
     bank                  12403
     cross sections       326175

     total                449714

 ********************************************************************************************************************************
 dump no.     1 on file 3b141r       nps =          0      coll =              0      ctm =     0.00      nrn =               0

 source distribution written to file 3b141s          cycle =      0

         2 warning messages so far.
 1   starting mcrun.       field length =       0      cp0 =  0.01                                        print table 110

      k eff, 265g of Pu-239 in cellulose spheres in 2.5 c. foot of pure celulose

 nps   x          y          z        cell lattice(i,j,k)  surface    u          v          w          energy     weight      time.

  1  1.500E+01  1.500E+01  6.120E+01     1                          5.085E-01  4.733E-01  7.193E-01  2.209E+00  1.000E+00  0.000E+00
     1.500E+01  1.500E+01  6.120E+01     7(   0,    0,    0)        5.085E-01  4.733E-01  7.193E-01
     1.500E+01  1.500E+01  6.120E+01     4                    0     5.085E-01  4.733E-01  7.193E-01
  2  1.500E+01  1.500E+01  6.120E+01     1                          8.952E-01 -4.447E-01 -2.944E-02  4.904E+00  1.000E+00  0.000E+00
     1.500E+01  1.500E+01  6.120E+01     7(   0,    0,    0)        8.952E-01 -4.447E-01 -2.944E-02
```

```
    1.500E+01   1.500E+01   6.120E+01   4
3   1.500E+01   1.500E+01   6.120E+01   1
    1.500E+01   1.500E+01   6.120E+01   7(   0,   0,   0)
    1.500E+01   1.500E+01   6.120E+01   4
4   1.500E+01   1.500E+01   6.120E+01   1
    1.500E+01   1.500E+01   6.120E+01   7(   0,   0,   0)
    1.500E+01   1.500E+01   6.120E+01   4
5   1.500E+01   1.500E+01   6.120E+01   1
    1.500E+01   1.500E+01   6.120E+01   7(   0,   0,   0)
    1.500E+01   1.500E+01   6.120E+01   4
6   1.500E+01   1.500E+01   6.120E+01   1
    1.500E+01   1.500E+01   6.120E+01   7(   0,   0,   0)
    1.500E+01   1.500E+01   6.120E+01   4
7   1.500E+01   1.500E+01   6.120E+01   1
    1.500E+01   1.500E+01   6.120E+01   7(   0,   0,   0)
    1.500E+01   1.500E+01   6.120E+01   4
8   1.500E+01   1.500E+01   6.120E+01   1
    1.500E+01   1.500E+01   6.120E+01   7(   0,   0,   0)
    1.500E+01   1.500E+01   6.120E+01   4
9   1.500E+01   1.500E+01   6.120E+01   1
    1.500E+01   1.500E+01   6.120E+01   7(   0,   0,   0)
    1.500E+01   1.500E+01   6.120E+01   4
10  1.500E+01   1.500E+01   6.120E+01   1
    1.500E+01   1.500E+01   6.120E+01   7(   0,   0,   0)
    1.500E+01   1.500E+01   6.120E+01   4
11  1.500E+01   1.500E+01   6.120E+01   1
    1.500E+01   1.500E+01   6.120E+01   7(   0,   0,   0)
    1.500E+01   1.500E+01   6.120E+01   4
12  1.500E+01   1.500E+01   6.120E+01   1
    1.500E+01   1.500E+01   6.120E+01   7(   0,   0,   0)
    1.500E+01   1.500E+01   6.120E+01   4
13  1.500E+01   1.500E+01   6.120E+01   1
    1.500E+01   1.500E+01   6.120E+01   7(   0,   0,   0)
    1.500E+01   1.500E+01   6.120E+01   4
14  1.500E+01   1.500E+01   6.120E+01   1
    1.500E+01   1.500E+01   6.120E+01   7(   0,   0,   0)
    1.500E+01   1.500E+01   6.120E+01   4
15  1.500E+01   1.500E+01   6.120E+01   1
    1.500E+01   1.500E+01   6.120E+01   7(   0,   0,   0)
    1.500E+01   1.500E+01   6.120E+01   4
16  1.500E+01   1.500E+01   6.120E+01   1
    1.500E+01   1.500E+01   6.120E+01   7(   0,   0,   0)
    1.500E+01   1.500E+01   6.120E+01   4
17  1.500E+01   1.500E+01   6.120E+01   1
    1.500E+01   1.500E+01   6.120E+01   7(   0,   0,   0)
    1.500E+01   1.500E+01   6.120E+01   4
18  1.500E+01   1.500E+01   6.120E+01   1
    1.500E+01   1.500E+01   6.120E+01   7(   0,   0,   0)
    1.500E+01   1.500E+01   6.120E+01   4
19  1.500E+01   1.500E+01   6.120E+01   1
    1.500E+01   1.500E+01   6.120E+01   7(   0,   0,   0)
    1.500E+01   1.500E+01   6.120E+01   4
20  1.500E+01   1.500E+01   6.120E+01   1
    1.500E+01   1.500E+01   6.120E+01   7(   0,   0,   0)
    1.500E+01   1.500E+01   6.120E+01   4
21  1.500E+01   1.500E+01   6.120E+01   1
    1.500E+01   1.500E+01   6.120E+01   7(   0,   0,   0)
    1.500E+01   1.500E+01   6.120E+01   4
```

```
0  8.952E-01 -4.447E-01 -2.944E-02
  -6.184E-01 -4.495E-01  6.446E-01  3.809E-01  1.000E+00  0.000E+00
  -6.184E-01 -4.495E-01  6.446E-01
0 -6.184E-01 -4.495E-01  6.446E-01
   9.710E-01 -5.665E-02 -2.323E-01  1.331E+00  1.000E+00  0.000E+00
   9.710E-01 -5.665E-02 -2.323E-01
0  9.710E-01 -5.665E-02 -2.323E-01
   5.861E-01  1.496E-01 -7.963E-01  1.902E+00  1.000E+00  0.000E+00
   5.861E-01  1.496E-01 -7.963E-01
0  5.861E-01  1.496E-01 -7.963E-01
  -6.489E-02 -1.626E-01  9.845E-01  4.410E-01  1.000E+00  0.000E+00
  -6.489E-02 -1.626E-01  9.845E-01
0 -6.489E-02 -1.626E-01  9.845E-01
  -7.068E-02  3.263E-02 -9.970E-01  4.750E-01  1.000E+00  0.000E+00
  -7.068E-02  3.263E-02 -9.970E-01
0 -7.068E-02  3.263E-02 -9.970E-01
  -3.915E-01  4.664E-01 -7.932E-01  4.136E+00  1.000E+00  0.000E+00
  -3.915E-01  4.664E-01 -7.932E-01
0 -3.915E-01  4.664E-01 -7.932E-01
  -2.368E-01  9.215E-01 -3.079E-01  7.453E-02  1.000E+00  0.000E+00
  -2.368E-01  9.215E-01 -3.079E-01
0 -2.368E-01  9.215E-01 -3.079E-01
   1.946E-01 -3.204E-01  9.271E-01  3.128E+00  1.000E+00  0.000E+00
   1.946E-01 -3.204E-01  9.271E-01
0  1.946E-01 -3.204E-01  9.271E-01
  -6.698E-01 -7.177E-01 -1.905E-01  1.014E+00  1.000E+00  0.000E+00
  -6.698E-01 -7.177E-01 -1.905E-01
0 -6.698E-01 -7.177E-01 -1.905E-01
  -8.398E-01 -4.129E-01  3.524E-01  1.395E+00  1.000E+00  0.000E+00
  -8.398E-01 -4.129E-01  3.524E-01
0 -8.398E-01 -4.129E-01  3.524E-01
  -1.714E-01 -8.572E-01  4.857E-01  7.748E-01  1.000E+00  0.000E+00
  -1.714E-01 -8.572E-01  4.857E-01
0 -1.714E-01 -8.572E-01  4.857E-01
  -2.489E-01 -5.118E-01 -8.222E-01  1.101E+00  1.000E+00  0.000E+00
  -2.489E-01 -5.118E-01 -8.222E-01
0 -2.489E-01 -5.118E-01 -8.222E-01
  -2.959E-01  2.119E-01  9.314E-01  1.951E+00  1.000E+00  0.000E+00
  -2.959E-01  2.119E-01  9.314E-01
0 -2.959E-01  2.119E-01  9.314E-01
   1.395E-01 -9.829E-01  1.202E-01  2.186E+00  1.000E+00  0.000E+00
   1.395E-01 -9.829E-01  1.202E-01
0  1.395E-01 -9.829E-01  1.202E-01
   6.909E-01 -7.110E-01  1.307E-01  1.865E+00  1.000E+00  0.000E+00
   6.909E-01 -7.110E-01  1.307E-01
0  6.909E-01 -7.110E-01  1.307E-01
  -6.580E-01  5.320E-01 -5.329E-01  1.229E+00  1.000E+00  0.000E+00
  -6.580E-01  5.320E-01 -5.329E-01
0 -6.580E-01  5.320E-01 -5.329E-01
  -9.903E-01 -1.380E-01  1.353E-02  1.305E+00  1.000E+00  0.000E+00
  -9.903E-01 -1.380E-01  1.353E-02
0 -9.903E-01 -1.380E-01  1.353E-02
   7.462E-01  4.859E-01 -4.551E-01  1.000E+00  1.000E+00  0.000E+00
   7.462E-01  4.859E-01 -4.551E-01
0  7.462E-01  4.859E-01 -4.551E-01
  -1.977E-01  9.797E-01  3.360E-02  3.990E+00  1.000E+00  0.000E+00
  -1.977E-01  9.797E-01  3.360E-02
0 -1.977E-01  9.797E-01  3.360E-02
```

22	1.500E+01	1.500E+01	6.120E+01	1					-9.117E-01	-3.647E-01	-1.891E-01	2.665E-01	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	6.120E+01	7(	0,	0,	0)		-9.117E-01	-3.647E-01	-1.891E-01			
	1.500E+01	1.500E+01	6.120E+01	4				0	-9.117E-01	-3.647E-01	-1.891E-01			
23	1.500E+01	1.500E+01	6.120E+01	1					-4.287E-01	8.361E-01	-3.423E-01	1.156E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	6.120E+01	7(	0,	0,	0)		-4.287E-01	8.361E-01	-3.423E-01			
	1.500E+01	1.500E+01	6.120E+01	4				0	-4.287E-01	8.361E-01	-3.423E-01			
24	1.500E+01	1.500E+01	6.120E+01	1					1.080E-01	3.412E-01	-9.338E-01	2.669E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	6.120E+01	7(	0,	0,	0)		1.080E-01	3.412E-01	-9.338E-01			
	1.500E+01	1.500E+01	6.120E+01	4				0	1.080E-01	3.412E-01	-9.338E-01			
25	1.500E+01	1.500E+01	6.120E+01	1					-9.111E-01	-9.012E-03	-4.122E-01	2.185E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	6.120E+01	7(	0,	0,	0)		-9.111E-01	-9.012E-03	-4.122E-01			
	1.500E+01	1.500E+01	6.120E+01	4				0	-9.111E-01	-9.012E-03	-4.122E-01			
26	1.500E+01	1.500E+01	6.120E+01	1					-2.568E-01	-6.391E-01	-7.249E-01	4.225E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	6.120E+01	7(	0,	0,	0)		-2.568E-01	-6.391E-01	-7.249E-01			
	1.500E+01	1.500E+01	6.120E+01	4				0	-2.568E-01	-6.391E-01	-7.249E-01			
27	1.500E+01	1.500E+01	6.120E+01	1					-2.912E-01	8.086E-01	5.113E-01	1.079E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	6.120E+01	7(	0,	0,	0)		-2.912E-01	8.086E-01	5.113E-01			
	1.500E+01	1.500E+01	6.120E+01	4				0	-2.912E-01	8.086E-01	5.113E-01			
28	1.500E+01	1.500E+01	6.120E+01	1					1.472E-01	-9.514E-01	2.705E-01	3.461E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	6.120E+01	7(	0,	0,	0)		1.472E-01	-9.514E-01	2.705E-01			
	1.500E+01	1.500E+01	6.120E+01	4				0	1.472E-01	-9.514E-01	2.705E-01			
29	1.500E+01	1.500E+01	6.120E+01	1					-6.135E-01	-7.645E-01	-1.978E-01	1.836E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	6.120E+01	7(	0,	0,	0)		-6.135E-01	-7.645E-01	-1.978E-01			
	1.500E+01	1.500E+01	6.120E+01	4				0	-6.135E-01	-7.645E-01	-1.978E-01			
30	1.500E+01	1.500E+01	6.120E+01	1					-5.702E-01	5.651E-01	-5.963E-01	4.556E-01	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	6.120E+01	7(	0,	0,	0)		-5.702E-01	5.651E-01	-5.963E-01			
	1.500E+01	1.500E+01	6.120E+01	4				0	-5.702E-01	5.651E-01	-5.963E-01			
31	1.500E+01	1.500E+01	6.120E+01	1					-6.607E-01	5.373E-01	-5.242E-01	6.415E-01	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	6.120E+01	7(	0,	0,	0)		-6.607E-01	5.373E-01	-5.242E-01			
	1.500E+01	1.500E+01	6.120E+01	4				0	-6.607E-01	5.373E-01	-5.242E-01			
32	1.500E+01	1.500E+01	6.120E+01	1					-9.742E-02	-3.639E-01	-9.263E-01	2.764E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	6.120E+01	7(	0,	0,	0)		-9.742E-02	-3.639E-01	-9.263E-01			
	1.500E+01	1.500E+01	6.120E+01	4				0	-9.742E-02	-3.639E-01	-9.263E-01			
33	1.500E+01	1.500E+01	6.120E+01	1					-1.965E-01	-3.145E-01	-9.287E-01	2.785E-01	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	6.120E+01	7(	0,	0,	0)		-1.965E-01	-3.145E-01	-9.287E-01			
	1.500E+01	1.500E+01	6.120E+01	4				0	-1.965E-01	-3.145E-01	-9.287E-01			
34	1.500E+01	1.500E+01	6.120E+01	1					4.097E-01	8.465E-01	-3.399E-01	9.097E-01	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	6.120E+01	7(	0,	0,	0)		4.097E-01	8.465E-01	-3.399E-01			
	1.500E+01	1.500E+01	6.120E+01	4				0	4.097E-01	8.465E-01	-3.399E-01			
35	1.500E+01	1.500E+01	6.120E+01	1					-4.048E-02	8.831E-01	4.675E-01	3.360E-01	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	6.120E+01	7(	0,	0,	0)		-4.048E-02	8.831E-01	4.675E-01			
	1.500E+01	1.500E+01	6.120E+01	4				0	-4.048E-02	8.831E-01	4.675E-01			
36	1.500E+01	1.500E+01	6.120E+01	1					3.371E-01	-9.269E-01	-1.652E-01	6.376E-01	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	6.120E+01	7(	0,	0,	0)		3.371E-01	-9.269E-01	-1.652E-01			
	1.500E+01	1.500E+01	6.120E+01	4				0	3.371E-01	-9.269E-01	-1.652E-01			
37	1.500E+01	1.500E+01	6.120E+01	1					-1.867E-01	9.756E-01	-1.155E-01	2.186E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	6.120E+01	7(	0,	0,	0)		-1.867E-01	9.756E-01	-1.155E-01			
	1.500E+01	1.500E+01	6.120E+01	4				0	-1.867E-01	9.756E-01	-1.155E-01			
38	1.500E+01	1.500E+01	6.120E+01	1					-2.616E-01	2.336E-01	-9.365E-01	7.314E-01	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	6.120E+01	7(	0,	0,	0)		-2.616E-01	2.336E-01	-9.365E-01			
	1.500E+01	1.500E+01	6.120E+01	4				0	-2.616E-01	2.336E-01	-9.365E-01			
39	1.500E+01	1.500E+01	6.120E+01	1					9.780E-01	-7.641E-02	-1.939E-01	2.997E-01	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	6.120E+01	7(	0,	0,	0)		9.780E-01	-7.641E-02	-1.939E-01			
	1.500E+01	1.500E+01	6.120E+01	4				0	9.780E-01	-7.641E-02	-1.939E-01			
40	1.500E+01	1.500E+01	6.120E+01	1					2.580E-01	-7.076E-01	6.578E-01	1.444E+00	1.000E+00	0.000E+00
	1.500E+01	1.500E+01	6.120E+01	7(	0,	0,	0)		2.580E-01	-7.076E-01	6.578E-01			
	1.500E+01	1.500E+01	6.120E+01	4				0	2.580E-01	-7.076E-01	6.578E-01			
41	1.500E+01	1.500E+01	6.120E+01	1					-3.212E-01	-7.678E-01	-5.543E-01	1.914E+00	1.000E+00	0.000E+00

```
     1.500E+01   1.500E+01   6.120E+01    7(    0,    0,    0)        -3.212E-01 -7.678E-01 -5.543E-01
     1.500E+01   1.500E+01   6.120E+01    4                          0 -3.212E-01 -7.678E-01 -5.543E-01
 42  1.500E+01   1.500E+01   6.120E+01    1                            5.039E-01 -1.460E-01  8.513E-01  1.502E+00  1.000E+00  0.000E+00
     1.500E+01   1.500E+01   6.120E+01    7(    0,    0,    0)        5.039E-01 -1.460E-01  8.513E-01
     1.500E+01   1.500E+01   6.120E+01    4                          0  5.039E-01 -1.460E-01  8.513E-01
 43  1.500E+01   1.500E+01   6.120E+01    1                            6.080E-01  5.487E-01  5.738E-01  5.971E+00  1.000E+00  0.000E+00
     1.500E+01   1.500E+01   6.120E+01    7(    0,    0,    0)        6.080E-01  5.487E-01  5.738E-01
     1.500E+01   1.500E+01   6.120E+01    4                          0  6.080E-01  5.487E-01  5.738E-01
 44  1.500E+01   1.500E+01   6.120E+01    1                           -2.932E-01  9.304E-01 -2.199E-01  1.827E+00  1.000E+00  0.000E+00
     1.500E+01   1.500E+01   6.120E+01    7(    0,    0,    0)       -2.932E-01  9.304E-01 -2.199E-01
     1.500E+01   1.500E+01   6.120E+01    4                          0 -2.932E-01  9.304E-01 -2.199E-01
 45  1.500E+01   1.500E+01   6.120E+01    1                           -8.475E-01 -3.993E-01 -3.497E-01  1.928E+00  1.000E+00  0.000E+00
     1.500E+01   1.500E+01   6.120E+01    7(    0,    0,    0)       -8.475E-01 -3.993E-01 -3.497E-01
     1.500E+01   1.500E+01   6.120E+01    4                          0 -8.475E-01 -3.993E-01 -3.497E-01
 46  1.500E+01   1.500E+01   6.120E+01    1                            1.200E-01 -9.195E-01 -3.743E-01  1.351E+00  1.000E+00  0.000E+00
     1.500E+01   1.500E+01   6.120E+01    7(    0,    0,    0)        1.200E-01 -9.195E-01 -3.743E-01
     1.500E+01   1.500E+01   6.120E+01    4                          0  1.200E-01 -9.195E-01 -3.743E-01
 47  1.500E+01   1.500E+01   6.120E+01    1                            7.085E-01  5.879E-01  3.904E-01  2.288E+00  1.000E+00  0.000E+00
     1.500E+01   1.500E+01   6.120E+01    7(    0,    0,    0)        7.085E-01  5.879E-01  3.904E-01
     1.500E+01   1.500E+01   6.120E+01    4                          0  7.085E-01  5.879E-01  3.904E-01
 48  1.500E+01   1.500E+01   6.120E+01    1                            4.261E-01  9.046E-01  9.254E-03  1.230E+00  1.000E+00  0.000E+00
     1.500E+01   1.500E+01   6.120E+01    7(    0,    0,    0)        4.261E-01  9.046E-01  9.254E-03
     1.500E+01   1.500E+01   6.120E+01    4                          0  4.261E-01  9.046E-01  9.254E-03
 49  1.500E+01   1.500E+01   6.120E+01    1                            5.431E-01  4.270E-01 -7.230E-01  1.433E+00  1.000E+00  0.000E+00
     1.500E+01   1.500E+01   6.120E+01    7(    0,    0,    0)        5.431E-01  4.270E-01 -7.230E-01
     1.500E+01   1.500E+01   6.120E+01    4                          0  5.431E-01  4.270E-01 -7.230E-01
 50  1.500E+01   1.500E+01   6.120E+01    1                           -1.053E-01 -9.805E-01  1.658E-01  6.572E-01  1.000E+00  0.000E+00
     1.500E+01   1.500E+01   6.120E+01    7(    0,    0,    0)       -1.053E-01 -9.805E-01  1.658E-01
     1.500E+01   1.500E+01   6.120E+01    4                          0 -1.053E-01 -9.805E-01  1.658E-01
lestimated keff results by cycle                                                                    print table 175

 source distribution written to file 3b141s          cycle =    20

 source distribution written to file 3b141s          cycle =    23

 source distribution written to file 3b141s          cycle =    26

 source distribution written to file 3b141s          cycle =    29

 source distribution written to file 3b141s          cycle =    32

 source distribution written to file 3b141s          cycle =    35

 source distribution written to file 3b141s          cycle =    38

 source distribution written to file 3b141s          cycle =    41

 ************************************************************************************************************************
dump no.     2 on file 3b141r        nps =     168125      coll =       23254452      ctm =    15.31      nrn =       400432399

 source distribution written to file 3b141s          cycle =    44

 source distribution written to file 3b141s          cycle =    47

 source distribution written to file 3b141s          cycle =    50

 source distribution written to file 3b141s          cycle =    53
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source distribution written to file 3b141s cycle = 56

source distribution written to file 3b141s cycle = 59

source distribution written to file 3b141s cycle = 62

source distribution written to file 3b141s cycle = 65

source distribution written to file 3b141s cycle = 68

source distribution written to file 3b141s cycle = 71

source distribution written to file 3b141s cycle = 74

source distribution written to file 3b141s cycle = 77

source distribution written to file 3b141s cycle = 80

source distribution written to file 3b141s cycle = 83

****

dump no. 3 on file 3b141r nps = 336243 coll = 46476473 ctm = 30.60 nrn = 800204011

source distribution written to file 3b141s cycle = 86

source distribution written to file 3b141s cycle = 89

source distribution written to file 3b141s cycle = 92

source distribution written to file 3b141s cycle = 95

source distribution written to file 3b141s cycle = 98

estimator	cycle 100	ave of 80 cycles	combination	simple average	combined average	corr
k(collision)	0.911142	0.920675 0.0022	k(col/abs)	0.921119 0.0015	0.921325 0.0014	0.3135
k(absorption)	0.906522	0.921562 0.0015	k(abs/tk ln)	0.920859 0.0015	0.921185 0.0014	0.2454
k(trk length)	0.908281	0.920155 0.0023	k(tk ln/col)	0.920415 0.0022	0.920678 0.0022	0.9657
rem life(col)	2.8103E+04	2.7505E+04 0.0028	k(col/abs/tk ln)	0.920797 0.0017	0.921114 0.0014	
rem life(abs)	2.7951E+04	2.7491E+04 0.0026	life(col/abs)	2.7498E+04 0.0027	2.7488E+04 0.0027	0.9666

source points generated 3817

source distribution written to file 3b141s cycle = 101

source distribution written to file 3b141s cycle = 104

source distribution written to file 3b141s cycle = 107

source distribution written to file 3b141s cycle = 110

source distribution written to file 3b141s cycle = 113

estimator	cycle 116	ave of 96 cycles	combination	simple average	combined average	corr
k(collision)	0.928203	0.920912 0.0019	k(col/abs)	0.921302 0.0013	0.921434 0.0013	0.2524
k(absorption)	0.916327	0.921692 0.0015	k(abs/tk ln)	0.921080 0.0014	0.921309 0.0013	0.1962
k(trk length)	0.928079	0.920469 0.0020	k(tk ln/col)	0.920691 0.0019	0.920984 0.0019	0.9621
rem life(col)	2.7704E+04	2.7468E+04 0.0027	k(col/abs/tk ln)	0.921024 0.0015	0.921337 0.0013	

```
 rem life(abs)   2.7456E+04     2.7451E+04 0.0025     life(col/abs)     2.7460E+04 0.0026   2.7444E+04 0.0025   0.9710
 source points generated   4062

 source distribution written to file 3b141s          cycle =   116

  estimator     cycle   117   ave of    97 cycles      combination         simple average    combined average     corr
 k(collision)      0.909196       0.920791 0.0019     k(col/abs)          0.921173 0.0013     0.921302 0.0013   0.2575
 k(absorption)     0.908377       0.921554 0.0015     k(abs/tk ln)        0.920934 0.0014     0.921167 0.0013   0.2031
 k(trk length)     0.905371       0.920314 0.0020     k(tk ln/col)        0.920552 0.0019     0.920877 0.0019   0.9622
 rem life(col)   2.7520E+04     2.7469E+04 0.0026     k(col/abs/tk ln)    0.920886 0.0015     0.921205 0.0013
 rem life(abs)   2.7457E+04     2.7452E+04 0.0025     life(col/abs)     2.7460E+04 0.0025   2.7444E+04 0.0025   0.9710
 source points generated   3864

  estimator     cycle   118   ave of    98 cycles      combination         simple average    combined average     corr
 k(collision)      0.929376       0.920879 0.0019     k(col/abs)          0.921318 0.0013     0.921462 0.0013   0.2619
 k(absorption)     0.941416       0.921757 0.0015     k(abs/tk ln)        0.921116 0.0014     0.921354 0.0013   0.2133
 k(trk length)     0.936169       0.920475 0.0020     k(tk ln/col)        0.920677 0.0019     0.920960 0.0019   0.9617
 rem life(col)   2.6241E+04     2.7456E+04 0.0026     k(col/abs/tk ln)    0.921037 0.0015     0.921403 0.0013
 rem life(abs)   2.6442E+04     2.7441E+04 0.0025     life(col/abs)     2.7449E+04 0.0025   2.7434E+04 0.0025   0.9715
 source points generated   4116

  estimator     cycle   119   ave of    99 cycles      combination         simple average    combined average     corr
 k(collision)      0.928809       0.920959 0.0019     k(col/abs)          0.921482 0.0013     0.921643 0.0013   0.2657
 k(absorption)     0.946222       0.922004 0.0015     k(abs/tk ln)        0.921286 0.0014     0.921542 0.0013   0.2186
 k(trk length)     0.929556       0.920567 0.0020     k(tk ln/col)        0.920763 0.0019     0.921039 0.0019   0.9618
 rem life(col)   2.7052E+04     2.7452E+04 0.0026     k(col/abs/tk ln)    0.921177 0.0015     0.921592 0.0013
 rem life(abs)   2.7167E+04     2.7438E+04 0.0025     life(col/abs)     2.7445E+04 0.0025   2.7432E+04 0.0025   0.9715
 source points generated   4040

 source distribution written to file 3b141s          cycle =   119

  estimator     cycle   120   ave of   100 cycles      combination         simple average    combined average     corr
 k(collision)      0.909018       0.920840 0.0019     k(col/abs)          0.921415 0.0013     0.921595 0.0013   0.2657
 k(absorption)     0.920665       0.921991 0.0015     k(abs/tk ln)        0.921196 0.0013     0.921483 0.0013   0.2186
 k(trk length)     0.903955       0.920401 0.0020     k(tk ln/col)        0.920620 0.0019     0.920938 0.0019   0.9618
 rem life(col)   2.6157E+04     2.7439E+04 0.0026     k(col/abs/tk ln)    0.921077 0.0015     0.921542 0.0013
 rem life(abs)   2.6573E+04     2.7430E+04 0.0025     life(col/abs)     2.7434E+04 0.0025   2.7424E+04 0.0024   0.9708
 source points generated   3843

 source distribution written to file 3b141s          cycle =   120
1problem summary

      run terminated when   120 kcode cycles were done.
+                                                                                                  03/06/01 14:15:45
      k eff, 265g of Pu-239 in cellulose spheres in 2.5 c. foot of pure celulose          probid =   03/06/01 13:31:59
0
 neutron creation    tracks      weight        energy          neutron loss        tracks      weight        energy
                                 (per source particle)                                           (per source particle)

 source              480568    9.9882E-01    2.1112E+00        escape                   0    0.            0.
                                                               energy cutoff            0    0.            0.
                                                               time cutoff              0    0.            0.
 weight window            0    0.            0.                weight window            0    0.            0.
 cell importance          0    0.            0.                cell importance          0    0.            0.
 weight cutoff            0    9.9774E-02    3.8780E-08        weight cutoff       480569    9.9979E-02    3.7981E-08
 energy importance        0    0.            0.                energy importance        0    0.            0.
 dxtran                   0    0.            0.                dxtran                   0    0.            0.
 forced collisions        0    0.            0.                forced collisions        0    0.            0.
```

exp. transform	0	0.	0.	exp. transform	0	0.	0.
upscattering	0	0.	7.1246E-07	downscattering	0	0.	2.0893E+00
				capture	0	6.7993E-01	1.9863E-02
(n,xn)	2	2.9618E-06	1.5444E-06	loss to (n,xn)	1	1.4809E-06	9.7671E-06
fission	0	0.	0.	loss to fission	0	3.1869E-01	2.0000E-03
total	480570	1.0986E+00	2.1112E+00	total	480570	1.0986E+00	2.1112E+00

number of neutrons banked	1	average lifetime, shakes		cutoffs	
neutron tracks per source particle	1.0000E+00	escape	0.0000E+00	tco	1.0000E+34
neutron collisions per source particle	1.3829E+02	capture	2.7397E+04	eco	0.0000E+00
total neutron collisions	66457411	capture or escape	2.7397E+04	wc1	-5.0000E-01
net multiplication	1.0000E+00 0.0000	any termination	3.3674E+04	wc2	-2.5000E-01

computer time so far in this run	43.77 minutes	maximum number ever in bank	1
computer time in mcrun	43.76 minutes	bank overflows to backup file	0
source particles per minute	1.0982E+04	field length	0
random numbers generated	1144246788	most random numbers used was	24077 in history 107419

range of sampled source weights = 9.4429E-01 to 1.1357E+00

1neutron activity in each cell print table 126

	cell	tracks entering	population	collisions	collisions * weight (per history)	number weighted energy	flux weighted energy	average track weight (relative)	average track mfp (cm)
1	1	0	0	0	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
2	2	7466	3064	188076	1.7350E-01	3.1138E-05	2.0729E-01	4.6395E-01	1.9929E+00
4	4	636203	289632	5048980	8.7270E+00	3.4232E-04	7.3321E-01	8.9420E-01	3.3870E+00
5	5	624963	285804	4949566	8.5470E+00	3.4282E-04	7.3256E-01	8.9369E-01	3.3839E+00
6	6	1092431	434628	56270789	6.5748E+01	4.9340E-05	2.6423E-01	6.0563E-01	1.9767E+00
7	7	0	0	0	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00	0.0000E+00
total		2361063	1013128	66457411	8.3196E+01				

1keff results for: k eff, 265g of Pu-239 in cellulose spheres in 2.5 c. foot of pure celulose probid = 03/06/01 13:31:59

the initial fission neutron source distribution used the 2 source points that were input on the ksrc card.
the criticality problem was scheduled to skip 20 cycles and run a total of 120 cycles with nominally 4000 neutrons per cycle.
this problem has run 20 inactive cycles with 80165 neutron histories and 100 active cycles with 400403 neutron histories.

this calculation has completed the requested number of keff cycles using a total of 480568 fission neutron source histories.
all cells with fissionable material were sampled and had fission neutron source points.

the results of the w test for normality applied to the individual collision, absorption, and track-length keff cycle values are:

the k(collision) cycle values appear normally distributed at the 95 percent confidence level
the k(absorption) cycle values appear normally distributed at the 95 percent confidence level
the k(trk length) cycle values appear normally distributed at the 95 percent confidence level

---

the final estimated combined collision/absorption/track-length keff = 0.92154 with an estimated standard deviation of 0.00120

the estimated 68, 95, & 99 percent keff confidence intervals are 0.92034 to 0.92274, 0.91915 to 0.92393, and 0.91837 to 0.92471

the estimated collision/absorption neutron removal lifetime = 2.74E-04 seconds with an estimated standard deviation of 6.71E-07

the estimated average keffs, one standard deviations, and 68, 95, and 99 percent confidence intervals are:

keff estimator	keff	standard deviation	68% confidence	95% confidence	99% confidence	corr
collision	0.92084	0.00170	0.91913 to 0.92255	0.91744 to 0.92423	0.91634 to 0.92534	
absorption	0.92199	0.00135	0.92064 to 0.92334	0.91931 to 0.92467	0.91843 to 0.92555	
track length	0.92040	0.00181	0.91859 to 0.92221	0.91680 to 0.92400	0.91563 to 0.92517	
col/absorp	0.92159	0.00119	0.92040 to 0.92279	0.91922 to 0.92397	0.91845 to 0.92474	0.2657
abs/trk len	0.92148	0.00119	0.92029 to 0.92268	0.91910 to 0.92386	0.91833 to 0.92464	0.2186
col/trk len	0.92094	0.00172	0.91922 to 0.92266	0.91752 to 0.92436	0.91640 to 0.92547	0.9618
col/abs/trk len	0.92154	0.00120	0.92034 to 0.92274	0.91915 to 0.92393	0.91837 to 0.92471	

if the largest of each keff occurred on the next cycle, the keff results and 68, 95, and 99 percent confidence intervals would be:

keff estimator	keff	standard deviation	68% confidence	95% confidence	99% confidence
collision	0.92125	0.00174	0.91951 to 0.92298	0.91779 to 0.92470	0.91666 to 0.92583
absorption	0.92229	0.00137	0.92092 to 0.92366	0.91957 to 0.92501	0.91868 to 0.92590
track length	0.92084	0.00184	0.91899 to 0.92268	0.91717 to 0.92450	0.91597 to 0.92570
col/abs/trk len	0.92191	0.00124	0.92067 to 0.92314	0.91945 to 0.92437	0.91864 to 0.92517

the estimated collision/absorption neutron lifetimes, one standard deviations, and 68, 95, and 99 percent confidence intervals are:

type	lifetime(sec)	standard deviation	68% confidence	95% confidence	99% confidence
removal	2.7424E-04	6.7131E-07	2.7357E-04 to 2.7491E-04	2.7291E-04 to 2.7558E-04	2.7247E-04 to 2.7602E-04
capture	2.7441E-04	5.9772E-07	2.7381E-04 to 2.7500E-04	2.7322E-04 to 2.7560E-04	2.7283E-04 to 2.7599E-04
fission	1.4328E-04	3.1968E-07	1.4296E-04 to 1.4360E-04	1.4264E-04 to 1.4391E-04	1.4243E-04 to 1.4412E-04
escape	0.0000E+00	0.0000E+00	0.0000E+00 to 0.0000E+00	0.0000E+00 to 0.0000E+00	0.0000E+00 to 0.0000E+00

laverage individual and combined collision/absorption/track-length keff results for 7 different batch sizes

cycles per keff batch	number of k batches	average keff estimators and deviations k(col)	st dev	k(abs)	st dev	k(trk)	st dev	normality co/ab/trk	average k(c/a/t) k(c/a/t)	st dev	k(c/a/t) confidence intervals 95% confidence	99% confidence
1	100	0.9208	0.0017	0.9220	0.0013	0.9204	0.0018	95/95/95	0.92154	0.00120	0.91915-0.92393	0.91837-0.92471
2	50	0.9208	0.0016	0.9220	0.0014	0.9204	0.0017	95/95/95	0.92132	0.00119	0.91894-0.92371	0.91814-0.92451
4	25	0.9208	0.0015	0.9220	0.0014	0.9204	0.0016	95/95/95	0.92119	0.00124	0.91862-0.92376	0.91770-0.92468
5	20	0.9208	0.0019	0.9220	0.0015	0.9204	0.0021	95/95/95	0.92148	0.00127	0.91880-0.92415	0.91780-0.92515
10	10	0.9208	0.0018	0.9220	0.0013	0.9204	0.0020	95/95/95	0.92168	0.00146	0.91822-0.92513	0.91656-0.92679
20	5	0.9208	0.0008	0.9220	0.0013	0.9204	0.0010	95/95/95	0.92112	0.00107	0.91649-0.92574	0.91046-0.93178
25	4	0.9208	0.0008	0.9220	0.0011	0.9204	0.0006	95/99/95	0.91994	0.00074	0.91059-0.92929	0.87312-0.96676

lindividual and average keff estimator results by cycle

keff cycle	neutron histories	keff estimators by cycle k(coll)	k(abs)	k(track)	average keff estimators and deviations k(coll)	st dev	k(abs)	st dev	k(track)	st dev	average k(c/a/t) k(c/a/t)	st dev	fom
1	4000	1.04068	1.03928	1.03914									
2	4236	0.91650	0.91520	0.92119									
3	3522	0.87161	0.91832	0.86809									
4	3780	0.91922	0.92697	0.92795									
5	4191	0.90471	0.92419	0.89859									

6	4045	0.92919	0.93238	0.92837									
7	4085	0.91998	0.92818	0.91188									
8	4026	0.91353	0.91909	0.91372									
9	3985	0.91056	0.89436	0.90517									
10	3900	0.89666	0.92223	0.90660									
11	4089	0.91047	0.93026	0.90491									
12	4030	0.90402	0.91263	0.91386									
13	3971	0.91958	0.91246	0.93097									
14	4125	0.89942	0.90423	0.90194									
15	4019	0.90430	0.91037	0.90099									
16	3956	0.91382	0.93672	0.91823									
17	4100	0.94130	0.93306	0.94252									
18	4113	0.92792	0.91742	0.93168									
19	4047	0.93126	0.93644	0.92567									
20	3945	0.90144	0.91068	0.90636									
		begin active keff cycles											
21	3916	0.91692	0.92046	0.91481									
22	4045	0.91274	0.91613	0.91252	0.91483	0.00209	0.91830	0.00217	0.91366	0.00114			
23	3972	0.90329	0.90999	0.90590	0.91098	0.00403	0.91553	0.00304	0.91108	0.00267			
24	4039	0.95442	0.92136	0.96426	0.92184	0.01123	0.91699	0.00260	0.92437	0.01343	0.91848	0.00051	2245650
25	4207	0.91981	0.93341	0.91062	0.92144	0.00871	0.92027	0.00385	0.92162	0.01076	0.91985	0.00106	411394
26	3955	0.94971	0.94922	0.95184	0.92615	0.00853	0.92510	0.00576	0.92666	0.01013	0.92536	0.00714	7677
27	4193	0.93563	0.91210	0.93594	0.92750	0.00733	0.92324	0.00521	0.92798	0.00866	0.92398	0.00650	7872
28	3945	0.92220	0.90892	0.93175	0.92684	0.00639	0.92145	0.00485	0.92846	0.00752	0.92282	0.00573	8862
29	3898	0.94457	0.90189	0.94256	0.92881	0.00597	0.91928	0.00480	0.93002	0.00681	0.92264	0.00547	8660
30	4130	0.92981	0.92570	0.93198	0.92891	0.00534	0.91992	0.00434	0.93022	0.00609	0.92315	0.00483	9985
31	3946	0.92445	0.91739	0.92803	0.92850	0.00484	0.91969	0.00393	0.93002	0.00552	0.92285	0.00436	11137
32	3935	0.91782	0.91211	0.91688	0.92761	0.00451	0.91906	0.00365	0.92892	0.00515	0.92204	0.00404	11894
33	3865	0.91879	0.89855	0.92192	0.92693	0.00421	0.91748	0.00371	0.92839	0.00477	0.92130	0.00411	10602
34	4041	0.91380	0.89749	0.91608	0.92600	0.00400	0.91605	0.00372	0.92751	0.00450	0.92040	0.00417	9498
35	3879	0.92277	0.92885	0.91290	0.92578	0.00373	0.91690	0.00356	0.92653	0.00430	0.92093	0.00379	10766
36	4030	0.90187	0.90537	0.89685	0.92429	0.00380	0.91618	0.00341	0.92468	0.00443	0.91956	0.00374	10321
37	3876	0.90452	0.91770	0.90886	0.92312	0.00375	0.91627	0.00320	0.92375	0.00427	0.91881	0.00335	12141
38	3958	0.92108	0.92422	0.91975	0.92301	0.00354	0.91671	0.00305	0.92352	0.00403	0.91910	0.00312	13185
39	4128	0.93383	0.91759	0.93756	0.92358	0.00340	0.91676	0.00289	0.92426	0.00388	0.91928	0.00300	13521
40	4056	0.90812	0.92768	0.90479	0.92281	0.00331	0.91731	0.00279	0.92329	0.00381	0.91937	0.00274	15410
41	3897	0.93260	0.92555	0.93370	0.92327	0.00319	0.91770	0.00269	0.92379	0.00366	0.91978	0.00265	15704
42	4049	0.89259	0.92891	0.88624	0.92188	0.00334	0.91821	0.00261	0.92208	0.00388	0.91947	0.00243	17786
43	3878	0.89400	0.91205	0.89790	0.92067	0.00342	0.91794	0.00251	0.92103	0.00386	0.91878	0.00236	18096
44	4026	0.91986	0.92717	0.91408	0.92063	0.00327	0.91833	0.00243	0.92074	0.00370	0.91900	0.00226	18922
45	4068	0.88615	0.92818	0.88950	0.91925	0.00343	0.91872	0.00237	0.91949	0.00377	0.91893	0.00214	20142
46	3855	0.90482	0.90802	0.90986	0.91870	0.00334	0.91831	0.00231	0.91912	0.00364	0.91858	0.00210	20185
47	4086	0.91335	0.90295	0.90898	0.91850	0.00322	0.91774	0.00230	0.91874	0.00352	0.91802	0.00209	19638
48	4017	0.96184	0.93232	0.96361	0.92005	0.00347	0.91826	0.00227	0.92034	0.00375	0.91873	0.00218	17413
49	4150	0.91540	0.91717	0.91718	0.91989	0.00335	0.91822	0.00219	0.92024	0.00362	0.91868	0.00210	18082
50	3790	0.94581	0.92941	0.93368	0.92075	0.00335	0.91860	0.00215	0.92068	0.00353	0.91897	0.00205	18259
51	4169	0.92732	0.93359	0.93002	0.92096	0.00325	0.91908	0.00214	0.92098	0.00342	0.91947	0.00204	17930
52	3859	0.94365	0.94002	0.93335	0.92167	0.00322	0.91973	0.00217	0.92137	0.00334	0.91992	0.00205	17293
53	3923	0.89591	0.92652	0.88866	0.92089	0.00322	0.91994	0.00211	0.92038	0.00338	0.91981	0.00198	17888
54	3844	0.94334	0.92741	0.94317	0.92155	0.00319	0.92016	0.00206	0.92105	0.00335	0.92009	0.00195	17950
55	4193	0.91930	0.90072	0.92488	0.92149	0.00310	0.91960	0.00208	0.92116	0.00326	0.91972	0.00193	17802
56	3973	0.94234	0.93498	0.94088	0.92207	0.00307	0.92003	0.00206	0.92171	0.00321	0.92013	0.00193	17313
57	4171	0.93927	0.93861	0.93975	0.92253	0.00302	0.92053	0.00207	0.92220	0.00316	0.92066	0.00195	16538
58	3985	0.91484	0.93456	0.90971	0.92233	0.00295	0.92090	0.00205	0.92187	0.00309	0.92084	0.00190	16910

59	3875	0.94273	0.92447	0.93942	0.92285	0.00292	0.92099	0.00200	0.92232	0.00305	0.92094	0.00186	17169
60	4191	0.89151	0.92760	0.89222	0.92207	0.00295	0.92116	0.00195	0.92156	0.00306	0.92096	0.00180	17881
61	3818	0.87578	0.90898	0.87965	0.92094	0.00309	0.92086	0.00193	0.92054	0.00316	0.92055	0.00179	17774
62	3909	0.93092	0.89587	0.92277	0.92118	0.00302	0.92027	0.00197	0.92060	0.00308	0.92010	0.00185	16157
63	4229	0.92851	0.91458	0.93636	0.92135	0.00296	0.92013	0.00193	0.92096	0.00303	0.92015	0.00180	16634
64	3938	0.94051	0.92322	0.94128	0.92178	0.00292	0.92020	0.00189	0.92142	0.00300	0.92030	0.00177	16875
65	4183	0.90666	0.91327	0.89829	0.92145	0.00288	0.92005	0.00185	0.92091	0.00298	0.92005	0.00176	16695
66	3836	0.91208	0.92674	0.91304	0.92124	0.00282	0.92020	0.00182	0.92074	0.00291	0.92015	0.00172	17121
67	4043	0.92967	0.92907	0.93615	0.92142	0.00277	0.92038	0.00179	0.92107	0.00287	0.92044	0.00169	17202
68	4006	0.92364	0.93216	0.91969	0.92147	0.00271	0.92063	0.00177	0.92104	0.00281	0.92061	0.00167	17378
69	3882	0.90408	0.93477	0.90207	0.92111	0.00268	0.92092	0.00175	0.92065	0.00278	0.92075	0.00164	17669
70	3970	0.91042	0.92620	0.91054	0.92090	0.00263	0.92102	0.00172	0.92045	0.00273	0.92080	0.00160	18063
71	4001	0.90996	0.93890	0.90597	0.92069	0.00259	0.92137	0.00172	0.92016	0.00269	0.92097	0.00159	18125
72	4071	0.92504	0.91982	0.92285	0.92077	0.00254	0.92134	0.00169	0.92022	0.00264	0.92096	0.00156	18463
73	4027	0.91546	0.91387	0.91542	0.92067	0.00249	0.92120	0.00166	0.92013	0.00259	0.92083	0.00153	18697
74	4049	0.93268	0.93413	0.93216	0.92089	0.00246	0.92144	0.00165	0.92035	0.00255	0.92106	0.00152	18596
75	4121	0.90782	0.94437	0.90843	0.92065	0.00242	0.92186	0.00167	0.92013	0.00252	0.92132	0.00152	18345
76	3878	0.94173	0.92215	0.94364	0.92103	0.00241	0.92187	0.00164	0.92055	0.00251	0.92145	0.00149	18639
77	4073	0.93892	0.93014	0.93622	0.92135	0.00239	0.92201	0.00162	0.92083	0.00248	0.92161	0.00148	18709
78	3915	0.92981	0.92514	0.92863	0.92149	0.00235	0.92206	0.00159	0.92096	0.00244	0.92169	0.00145	19004
79	3980	0.92706	0.90256	0.93043	0.92159	0.00231	0.92173	0.00160	0.92112	0.00240	0.92148	0.00144	19035
80	4031	0.91940	0.92314	0.92068	0.92155	0.00227	0.92176	0.00157	0.92111	0.00236	0.92150	0.00141	19393
81	3985	0.93483	0.95184	0.93116	0.92177	0.00225	0.92225	0.00162	0.92128	0.00233	0.92187	0.00145	18194
82	4101	0.89633	0.91566	0.90731	0.92136	0.00225	0.92214	0.00160	0.92105	0.00230	0.92176	0.00142	18524
83	3906	0.90679	0.93489	0.90467	0.92113	0.00222	0.92235	0.00159	0.92079	0.00228	0.92182	0.00140	18754
84	4113	0.91477	0.90659	0.91744	0.92103	0.00219	0.92210	0.00158	0.92074	0.00224	0.92163	0.00139	18757
85	3966	0.93560	0.94736	0.93327	0.92125	0.00217	0.92249	0.00161	0.92093	0.00222	0.92194	0.00141	18011
86	4140	0.96176	0.92575	0.96003	0.92186	0.00222	0.92254	0.00158	0.92153	0.00226	0.92214	0.00140	17979
87	4035	0.91780	0.92042	0.91450	0.92180	0.00219	0.92251	0.00156	0.92142	0.00223	0.92208	0.00138	18185
88	3803	0.92843	0.91875	0.93166	0.92190	0.00216	0.92245	0.00154	0.92157	0.00220	0.92210	0.00136	18515
89	4070	0.89429	0.90245	0.88809	0.92150	0.00216	0.92216	0.00154	0.92109	0.00222	0.92177	0.00139	17375
90	3837	0.92652	0.90886	0.93017	0.92157	0.00213	0.92197	0.00153	0.92122	0.00220	0.92167	0.00138	17603
91	4175	0.89546	0.91602	0.89511	0.92120	0.00214	0.92189	0.00151	0.92085	0.00220	0.92152	0.00137	17587
92	3854	0.92464	0.92764	0.92908	0.92125	0.00211	0.92197	0.00149	0.92096	0.00217	0.92163	0.00135	17770
93	4175	0.91720	0.92897	0.92030	0.92120	0.00208	0.92206	0.00148	0.92095	0.00214	0.92171	0.00133	17963
94	3994	0.89044	0.90554	0.88387	0.92078	0.00209	0.92184	0.00147	0.92045	0.00217	0.92143	0.00135	17152
95	3920	0.89758	0.90172	0.89175	0.92047	0.00209	0.92157	0.00148	0.92007	0.00217	0.92115	0.00137	16438
96	4042	0.93867	0.91180	0.94075	0.92071	0.00207	0.92144	0.00146	0.92034	0.00216	0.92113	0.00135	16696
97	4147	0.89978	0.91737	0.90300	0.92044	0.00206	0.92139	0.00145	0.92012	0.00214	0.92103	0.00134	16843
98	3856	0.93669	0.93174	0.93505	0.92065	0.00205	0.92152	0.00143	0.92031	0.00213	0.92118	0.00133	16871
99	4162	0.93235	0.93962	0.92009	0.92080	0.00203	0.92175	0.00143	0.92031	0.00210	0.92129	0.00132	16794
100	3978	0.91114	0.90652	0.90828	0.92068	0.00201	0.92156	0.00143	0.92016	0.00208	0.92111	0.00132	16636
101	3817	0.91708	0.95244	0.91334	0.92063	0.00198	0.92194	0.00146	0.92007	0.00205	0.92133	0.00133	16186
102	4027	0.92751	0.93700	0.92316	0.92071	0.00196	0.92213	0.00145	0.92011	0.00203	0.92145	0.00132	16178
103	3983	0.91519	0.91962	0.90670	0.92065	0.00194	0.92210	0.00144	0.91995	0.00201	0.92138	0.00131	16233
104	3961	0.93312	0.92239	0.93428	0.92080	0.00192	0.92210	0.00142	0.92012	0.00199	0.92144	0.00130	16440
105	4083	0.91578	0.92499	0.90831	0.92074	0.00190	0.92213	0.00140	0.91998	0.00198	0.92142	0.00129	16555
106	4040	0.92772	0.93322	0.93052	0.92082	0.00188	0.92226	0.00139	0.92010	0.00196	0.92156	0.00128	16603
107	3996	0.91629	0.88866	0.90907	0.92077	0.00186	0.92188	0.00143	0.91997	0.00194	0.92129	0.00130	15711
108	3971	0.90924	0.93128	0.91165	0.92064	0.00184	0.92198	0.00142	0.91988	0.00192	0.92134	0.00129	15896
109	3982	0.89758	0.91503	0.90723	0.92038	0.00184	0.92191	0.00140	0.91974	0.00190	0.92122	0.00128	16072
110	3990	0.89477	0.93107	0.89108	0.92009	0.00184	0.92201	0.00139	0.91942	0.00191	0.92119	0.00126	16176

111	3981	0.93413	0.89330	0.93534	0.92025	0.00182	0.92169	0.00141	0.91959	0.00189	0.92100	0.00126	16150
112	4202	0.94108	0.91539	0.95079	0.92047	0.00182	0.92162	0.00140	0.91993	0.00190	0.92108	0.00124	16407
113	4070	0.93273	0.91851	0.93243	0.92060	0.00180	0.92159	0.00138	0.92007	0.00189	0.92110	0.00123	16595
114	4046	0.94199	0.94028	0.95025	0.92083	0.00180	0.92179	0.00138	0.92039	0.00189	0.92138	0.00123	16232
115	4059	0.92114	0.91793	0.92041	0.92084	0.00178	0.92175	0.00137	0.92039	0.00187	0.92135	0.00122	16398
116	3881	0.92820	0.91633	0.92808	0.92091	0.00176	0.92169	0.00136	0.92047	0.00186	0.92134	0.00121	16585
117	4062	0.90920	0.90838	0.90537	0.92079	0.00175	0.92155	0.00135	0.92031	0.00184	0.92120	0.00120	16501
118	3864	0.92938	0.94142	0.93617	0.92088	0.00173	0.92176	0.00135	0.92048	0.00183	0.92140	0.00120	16348
119	4116	0.92881	0.94622	0.92956	0.92096	0.00172	0.92200	0.00136	0.92057	0.00182	0.92159	0.00121	16087
120	4040	0.90902	0.92066	0.90396	0.92084	0.00170	0.92199	0.00135	0.92040	0.00181	0.92154	0.00120	16185

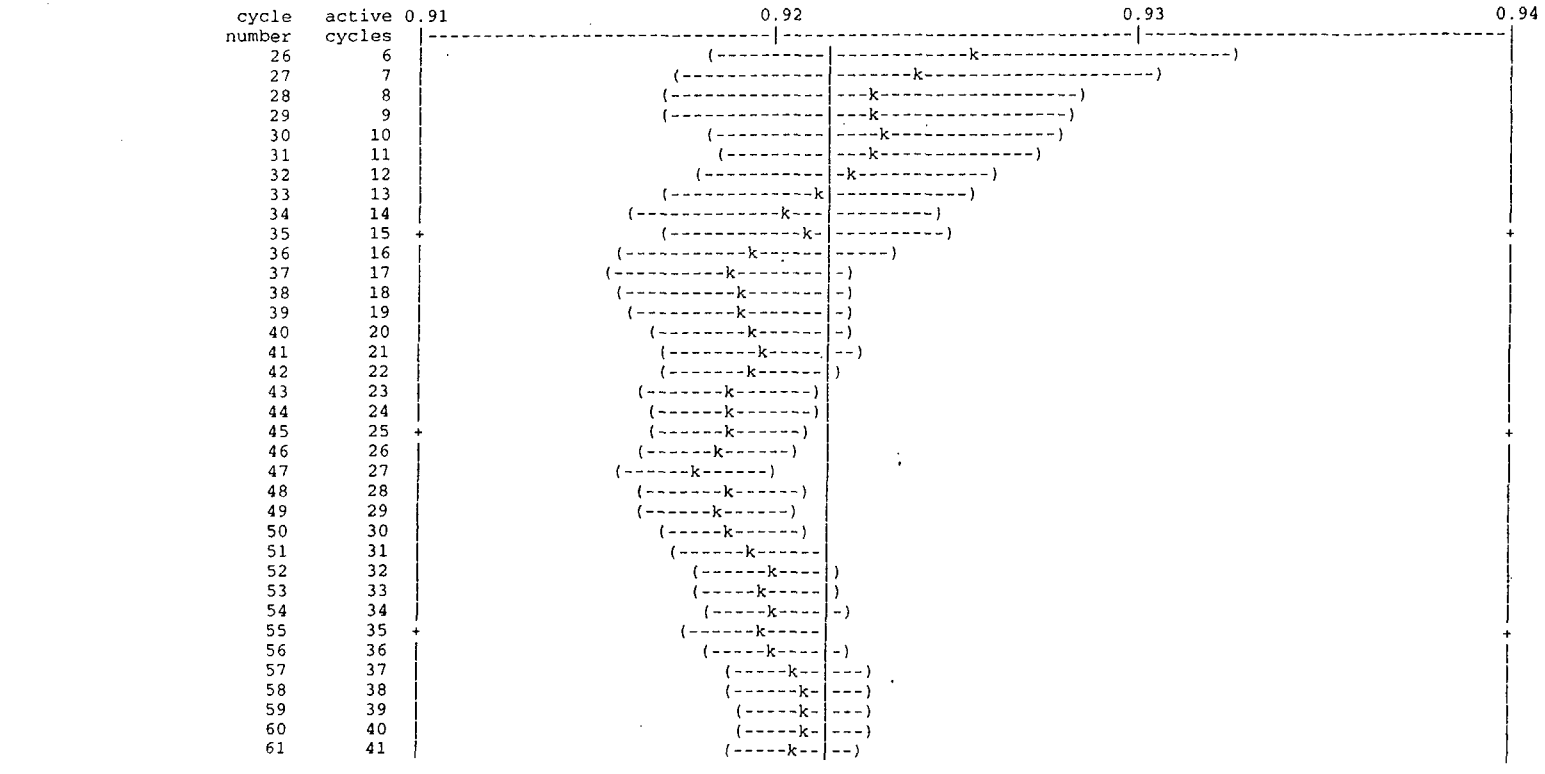
the largest active cycle keffs by estimator are:

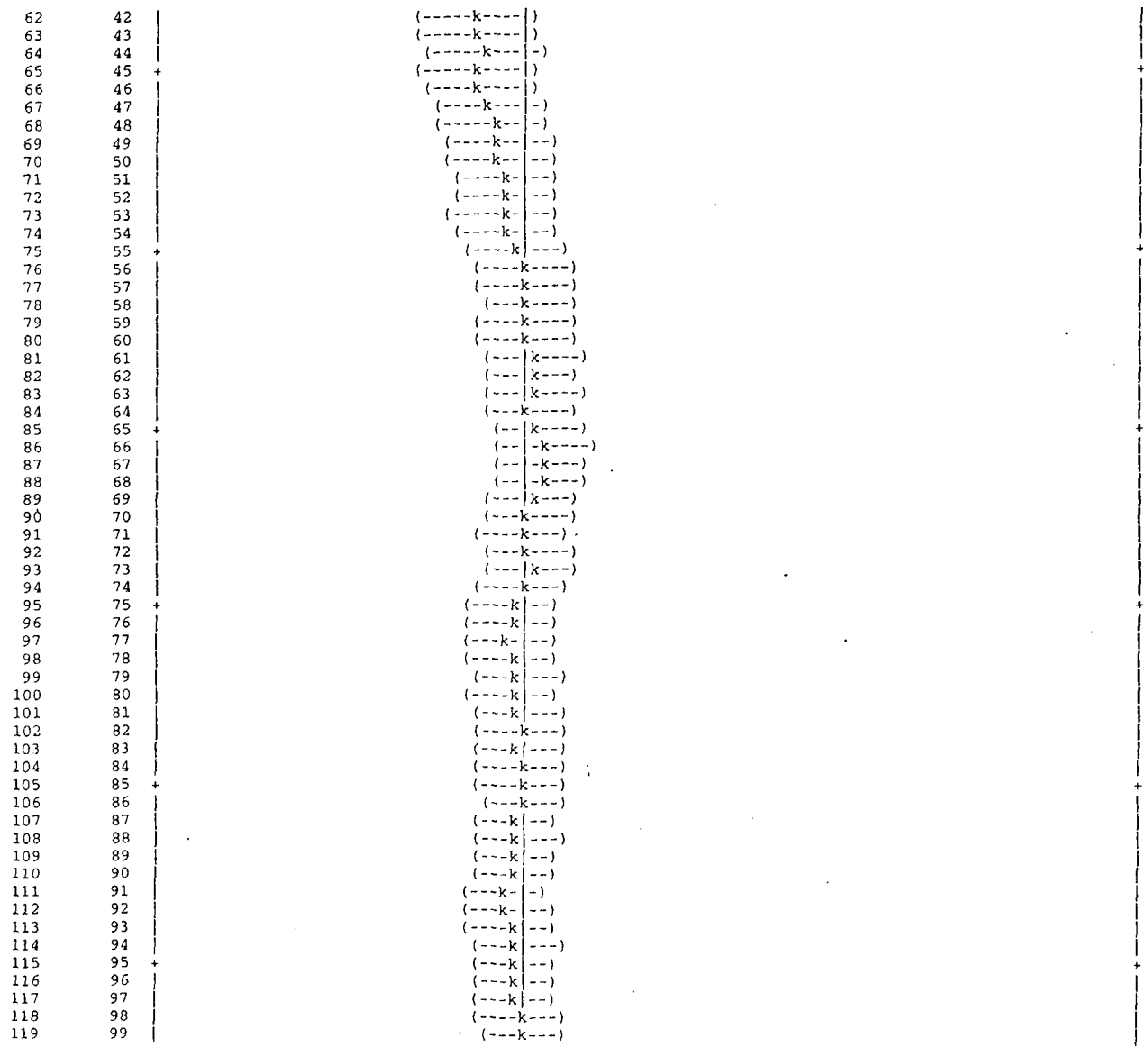
collision 0.96184 on cycle 48
absorption 0.95244 on cycle 101
track length 0.96426 on cycle 24

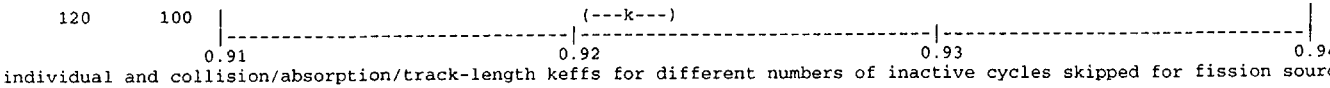
the smallest active cycle keffs by estimator are:

collision 0.87578 on cycle 61
absorption 0.88866 on cycle 107
track length 0.87965 on cycle 61

1plot of the estimated col/abs/track-length keff one standard deviation interval versus cycle number (| = final keff = 0.92154)







lindividual and collision/absorption/track-length keffs for different numbers of inactive cycles skipped for fission source settling

skip cycles	active cycles	active neutrons	average keff estimators and deviations k(col)	st dev	k(abs)	st dev	k(trk)	st dev	normality co/ab/tl	average k(c/a/t) k(c/a/t)	st dev	k(c/a/t) confidence intervals 95% confidence	99% confidence
0	120	480568	0.9205	0.0018	0.9227	0.0015	0.9203	0.0019	no/no/no	0.92198	0.00147	0.91905-0.92492	0.91809-0.92588
1	119	476568	0.9195	0.0016	0.9217	0.0012	0.9193	0.0016	95/95/95	0.92098	0.00109	0.91881-0.92315	0.91810-0.92386
2	118	472332	0.9195	0.0016	0.9218	0.0012	0.9193	0.0017	95/95/95	0.92102	0.00110	0.91883-0.92321	0.91812-0.92392
3	117	468810	0.9199	0.0015	0.9218	0.0012	0.9197	0.0016	95/95/95	0.92113	0.00109	0.91895-0.92331	0.91824-0.92402
4	116	465030	0.9199	0.0015	0.9218	0.0012	0.9197	0.0016	95/95/95	0.92109	0.00110	0.91889-0.92328	0.91818-0.92400
5	115	460839	0.9201	0.0016	0.9217	0.0012	0.9199	0.0016	95/95/95	0.92112	0.00111	0.91891-0.92333	0.91819-0.92406
6	114	456794	0.9200	0.0016	0.9216	0.0013	0.9198	0.0016	95/95/95	0.92104	0.00112	0.91881-0.92326	0.91809-0.92398
7	113	452709	0.9200	0.0016	0.9216	0.0013	0.9198	0.0017	95/95/95	0.92101	0.00112	0.91877-0.92326	0.91804-0.92399
8	112	448683	0.9200	0.0016	0.9216	0.0013	0.9199	0.0017	95/95/95	0.92105	0.00113	0.91879-0.92331	0.91805-0.92404
9	111	444698	0.9201	0.0016	0.9219	0.0013	0.9200	0.0017	95/95/95	0.92127	0.00113	0.91902-0.92351	0.91829-0.92424
10	110	440798	0.9203	0.0016	0.9218	0.0013	0.9202	0.0017	95/95/95	0.92131	0.00113	0.91905-0.92357	0.91831-0.92431
11	109	436709	0.9204	0.0016	0.9218	0.0013	0.9203	0.0017	95/95/95	0.92130	0.00114	0.91902-0.92358	0.91827-0.92432
12	108	432679	0.9206	0.0016	0.9219	0.0013	0.9204	0.0017	95/95/95	0.92139	0.00115	0.91909-0.92368	0.91834-0.92443
13	107	428708	0.9206	0.0016	0.9219	0.0013	0.9203	0.0017	95/95/95	0.92144	0.00116	0.91912-0.92375	0.91836-0.92451
14	106	424583	0.9208	0.0016	0.9221	0.0013	0.9204	0.0017	95/95/95	0.92161	0.00116	0.91930-0.92393	0.91855-0.92468
15	105	420564	0.9209	0.0017	0.9222	0.0013	0.9206	0.0017	95/95/95	0.92174	0.00116	0.91942-0.92406	0.91866-0.92481
16	104	416608	0.9210	0.0017	0.9221	0.0013	0.9206	0.0018	95/95/95	0.92166	0.00117	0.91932-0.92400	0.91856-0.92476
17	103	412508	0.9208	0.0017	0.9220	0.0013	0.9204	0.0018	95/95/95	0.92151	0.00118	0.91917-0.92386	0.91841-0.92462
18	102	408395	0.9208	0.0017	0.9220	0.0013	0.9203	0.0018	95/95/95	0.92151	0.00119	0.91914-0.92388	0.91837-0.92465
19	101	404348	0.9206	0.0017	0.9219	0.0013	0.9203	0.0018	95/95/95	0.92140	0.00119	0.91903-0.92378	0.91825-0.92456
20	100*	400403	0.9208	0.0017	0.9220	0.0013	0.9204	0.0018	95/95/95	0.92154	0.00120	0.91915-0.92393	0.91837-0.92471
22	98	392442	0.9210	0.0017	0.9221	0.0014	0.9205	0.0018	95/95/95	0.92163	0.00122	0.91920-0.92407	0.91841-0.92486
24	96	384431	0.9208	0.0017	0.9222	0.0014	0.9202	0.0018	95/95/95	0.92161	0.00124	0.91915-0.92407	0.91835-0.92488
26	94	376269	0.9205	0.0017	0.9218	0.0014	0.9200	0.0018	95/95/95	0.92125	0.00122	0.91882-0.92368	0.91802-0.92447
28	92	368131	0.9203	0.0018	0.9220	0.0014	0.9197	0.0018	95/95/95	0.92134	0.00125	0.91885-0.92384	0.91804-0.92465
30	90	360103	0.9199	0.0018	0.9222	0.0014	0.9193	0.0019	95/95/95	0.92133	0.00128	0.91878-0.92389	0.91795-0.92472
32	88	352222	0.9199	0.0018	0.9224	0.0014	0.9192	0.0019	95/95/95	0.92144	0.00131	0.91883-0.92405	0.91797-0.92490
34	86	344316	0.9200	0.0019	0.9230	0.0014	0.9192	0.0019	95/95/95	0.92193	0.00132	0.91931-0.92455	0.91845-0.92541
36	84	336407	0.9202	0.0019	0.9231	0.0014	0.9196	0.0020	95/95/95	0.92209	0.00132	0.91946-0.92472	0.91860-0.92558
38	82	328573	0.9204	0.0019	0.9231	0.0015	0.9197	0.0020	95/95/95	0.92218	0.00135	0.91949-0.92487	0.91861-0.92575
40	80	320389	0.9203	0.0020	0.9232	0.0015	0.9197	0.0020	95/95/95	0.92218	0.00139	0.91941-0.92494	0.91851-0.92584
42	78	312443	0.9205	0.0020	0.9231	0.0015	0.9199	0.0020	95/95/95	0.92214	0.00141	0.91932-0.92496	0.91840-0.92588
44	76	304539	0.9209	0.0020	0.9231	0.0016	0.9203	0.0021	95/95/95	0.92233	0.00143	0.91947-0.92518	0.91854-0.92612
46	74	296616	0.9216	0.0020	0.9233	0.0016	0.9209	0.0021	95/95/95	0.92266	0.00145	0.91977-0.92556	0.91882-0.92651
48	72	288513	0.9211	0.0020	0.9234	0.0016	0.9204	0.0021	95/95/95	0.92253	0.00145	0.91964-0.92542	0.91869-0.92637
50	70	280573	0.9209	0.0020	0.9234	0.0017	0.9203	0.0021	95/95/95	0.92247	0.00147	0.91952-0.92541	0.91856-0.92638
52	68	272545	0.9204	0.0020	0.9231	0.0017	0.9199	0.0022	95/95/95	0.92210	0.00148	0.91914-0.92505	0.91817-0.92602
54	66	264778	0.9205	0.0020	0.9229	0.0017	0.9201	0.0021	95/95/95	0.92197	0.00151	0.91896-0.92498	0.91796-0.92597
56	64	256612	0.9201	0.0020	0.9231	0.0018	0.9197	0.0022	95/95/95	0.92199	0.00152	0.91894-0.92503	0.91794-0.92604
58	62	248456	0.9199	0.0021	0.9227	0.0018	0.9195	0.0022	95/95/95	0.92163	0.00154	0.91855-0.92472	0.91753-0.92573
60	60	240390	0.9200	0.0021	0.9225	0.0018	0.9196	0.0022	95/95/95	0.92155	0.00157	0.91840-0.92469	0.91736-0.92573
62	58	232663	0.9206	0.0020	0.9232	0.0018	0.9203	0.0022	95/95/95	0.92212	0.00154	0.91903-0.92520	0.91801-0.92622
64	56	224496	0.9201	0.0020	0.9234	0.0019	0.9196	0.0022	95/95/95	0.92200	0.00160	0.91879-0.92520	0.91773-0.92627
66	54	216477	0.9205	0.0021	0.9235	0.0019	0.9201	0.0023	95/95/95	0.92219	0.00164	0.91890-0.92548	0.91781-0.92658
68	52	208428	0.9203	0.0021	0.9232	0.0020	0.9198	0.0023	95/95/95	0.92195	0.00169	0.91854-0.92535	0.91741-0.92649
70	50	200576	0.9208	0.0022	0.9230	0.0021	0.9204	0.0024	95/95/95	0.92202	0.00175	0.91850-0.92555	0.91732-0.92673

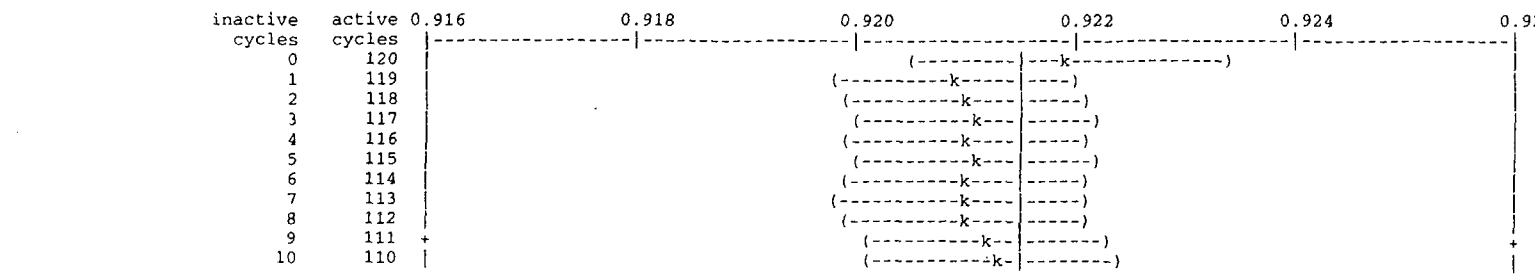
72	48	192504	0.9209	0.0023	0.9227	0.0021	0.9206	0.0025	95/95/95	0.92194	0.00182	0.91827-0.92560	0.91704-0.92683
74	46	184428	0.9208	0.0024	0.9226	0.0022	0.9205	0.0026	95/95/95	0.92185	0.00187	0.91806-0.92563	0.91679-0.92690
76	44	176429	0.9206	0.0024	0.9222	0.0023	0.9202	0.0026	95/95/95	0.92151	0.00195	0.91758-0.92544	0.91625-0.92677
78	42	168441	0.9199	0.0025	0.9219	0.0024	0.9196	0.0027	95/95/95	0.92104	0.00201	0.91697-0.92510	0.91559-0.92648
80	40	160430	0.9198	0.0026	0.9223	0.0024	0.9193	0.0028	95/95/95	0.92127	0.00212	0.91699-0.92556	0.91553-0.92702
82	38	152344	0.9200	0.0026	0.9217	0.0024	0.9193	0.0029	95/95/95	0.92129	0.00206	0.91710-0.92547	0.91567-0.92690
84	36	144325	0.9205	0.0027	0.9218	0.0025	0.9198	0.0031	95/95/95	0.92163	0.00215	0.91726-0.92600	0.91576-0.92750
86	34	136219	0.9189	0.0026	0.9209	0.0025	0.9182	0.0030	95/95/95	0.92028	0.00205	0.91610-0.92446	0.91466-0.92591
88	32	128381	0.9186	0.0027	0.9210	0.0027	0.9179	0.0032	95/95/95	0.92020	0.00219	0.91572-0.92468	0.91417-0.92624
90	30	120474	0.9191	0.0028	0.9220	0.0028	0.9185	0.0032	95/95/95	0.92090	0.00225	0.91628-0.92551	0.91466-0.92713
92	28	112445	0.9198	0.0028	0.9221	0.0029	0.9190	0.0033	95/95/95	0.92129	0.00234	0.91648-0.92611	0.91478-0.92781
94	26	104276	0.9210	0.0028	0.9224	0.0031	0.9203	0.0033	95/95/95	0.92195	0.00236	0.91708-0.92683	0.91533-0.92857
96	24	96314	0.9212	0.0028	0.9237	0.0032	0.9206	0.0032	95/95/95	0.92246	0.00239	0.91748-0.92744	0.91568-0.92924
98	22	88311	0.9215	0.0028	0.9236	0.0035	0.9207	0.0033	95/95/95	0.92263	0.00240	0.91760-0.92765	0.91576-0.92949
100	20	80171	0.9215	0.0030	0.9237	0.0036	0.9214	0.0036	95/95/95	0.92239	0.00233	0.91747-0.92731	0.91564-0.92915
102	18	72327	0.9214	0.0033	0.9214	0.0036	0.9217	0.0040	95/95/95	0.92109	0.00236	0.91607-0.92612	0.91415-0.92803
104	16	64383	0.9211	0.0036	0.9214	0.0040	0.9219	0.0043	95/95/95	0.92040	0.00265	0.91467-0.92613	0.91241-0.92839
106	14	56260	0.9210	0.0041	0.9203	0.0045	0.9222	0.0048	95/95/95	0.91925	0.00301	0.91263-0.92587	0.90991-0.92859
108	12	48293	0.9223	0.0046	0.9220	0.0044	0.9242	0.0055	95/95/95	0.92053	0.00359	0.91240-0.92865	0.90885-0.93220
110	10	40321	0.9276	0.0036	0.9218	0.0052	0.9292	0.0050	95/95/95	0.92347	0.00199	0.91877-0.92816	0.91652-0.93042
112	8	32138	0.9251	0.0040	0.9262	0.0050	0.9258	0.0055	95/95/95	0.92387	0.00217	0.91830-0.92945	0.91513-0.93262
114	6	24022	0.9210	0.0039	0.9252	0.0062	0.9206	0.0054	95/95/95	0.92224	0.00298	0.91277-0.93171	0.90486-0.93962
116	4	16082	0.9191	0.0058	0.9292	0.0089	0.9188	0.0083	99/95/95	0.91397	0.00579	0.84032-0.98761	0.54510-1.28284
117	3	12020	0.9224	0.0067	0.9361	0.0078	0.9232	0.0098					
118	2	8156	0.9189	0.0099	0.9334	0.0128	0.9168	0.0128					

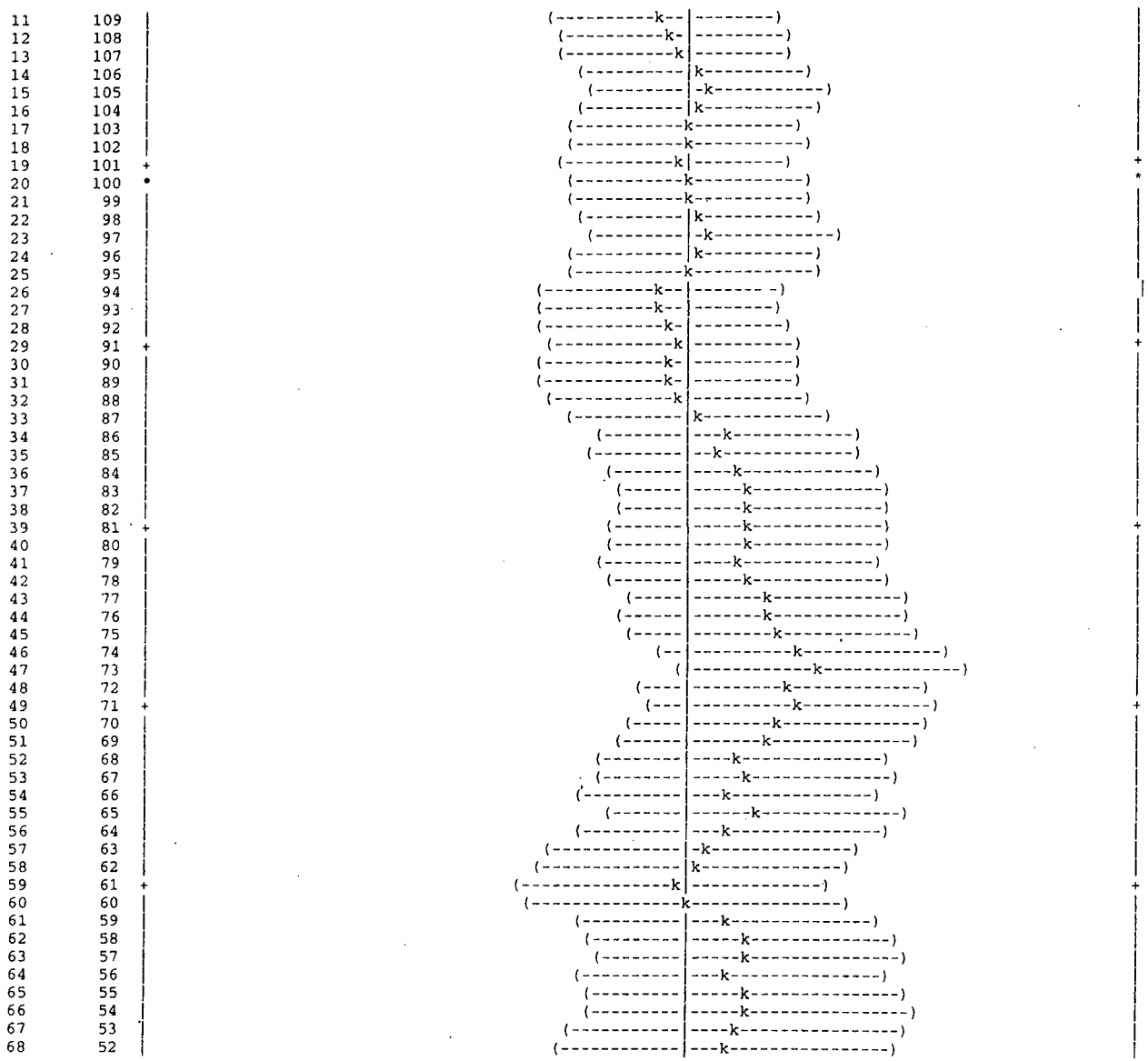
the minimum estimated standard deviation for the col/abs/tl keff estimator occurs with 1 inactive cycles and 119 active cycles.

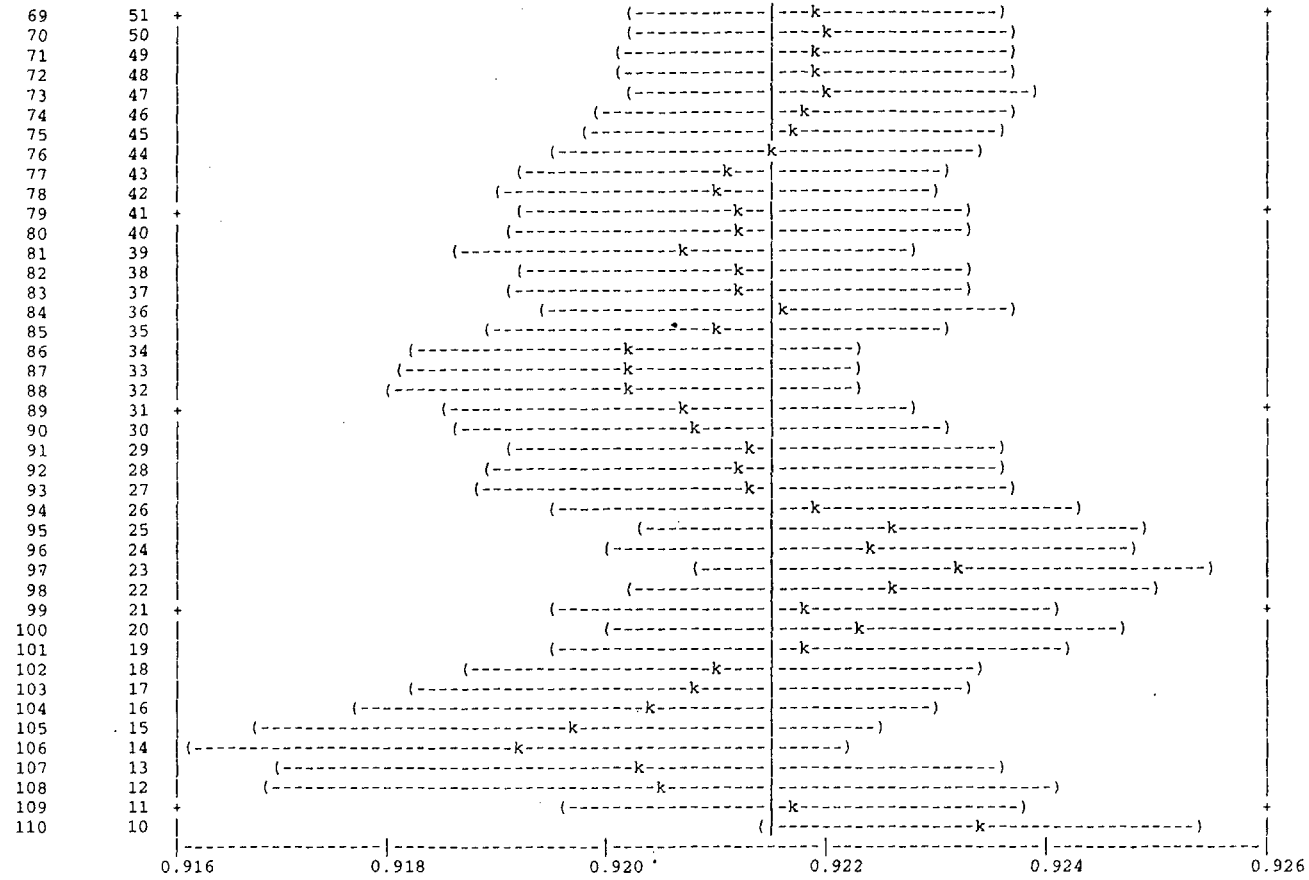
the first active half of the problem skips 20 cycles and uses 50 active cycles; the second half skips 70 and uses 50 cycles.
the col/abs/trk-len keff, one standard deviation, and 68, 95, and 99 percent intervals for each active half of the problem are:

problem	keff	standard deviation	68% confidence	95% confidence	99% confidence
first half	0.92080	0.00160	0.91918 to 0.92241	0.91757 to 0.92402	0.91649 to 0.92510
second half	0.92202	0.00175	0.92026 to 0.92378	0.91850 to 0.92555	0.91732 to 0.92673
final result	0.92154	0.00120	0.92034 to 0.92274	0.91915 to 0.92393	0.91837 to 0.92471

the first and second half values of k(collision/absorption/track length) appear to be the same at the 68 percent confidence level.
1plot of the estimated col/abs/track-length keff one standard deviation interval by active cycle number (| = final keff = 0.92154)







dump no. 4 on file 3b141r nps = 480568 coll = 66457411 ctm = 43.76 nrn = 1144246788

2 warning messages so far.

run terminated when 120 kcode cycles were done.

computer time = 43.77 minutes

mcnp version 4a 10/01/93 03/06/01 14:15:45 probid = 03/06/01 13:31:59

APPENDIX B

MCNP 4A SOFTWARE VALIDATION PLAN AND REPORT FOR CRITICALITY CALCULATIONS

MCNP 4A SOFTWARE VALIDATION PLAN AND REPORT FOR CRITICALITY CALCULATIONS

Prepared by URS

APPROVAL

Prepared by:

Igor Chichkov 06/22/2000

MCNP 4A User/Validation Plan Developer — Date

Reviewed by:

Joseph C. Wolniewicz / JOSEPH C. WOLNIEWICZ 06/22/2000

Independent Reviewer — Date

Approved by:

Joseph C. Wolniewicz / JOSEPH C. WOLNIEWICZ 06/22/2000

Cognizant Manager — Date

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Test Personnel	5
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Appendix 1 - File comparison report generated by test problems for verification included in the MCNP 4A package

Appendix 2 - MCNP input file for calculation of effective neutron multiplication factor for a 69 L sphere of $U(4.89)O_2F_2$ solution without reflection.

Appendix 3 - MCNP output file for calculation of effective neutron multiplication factor for a 69 L sphere $U(4.89)O_2F_2$ solution without reflection.

Appendix 4 - MCNP4A Calculation Method Bias and Bias uncertainty of criticality calculations for low enriched uranium systems

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Appendix 4 - MCNP4A Calculation Method Bias and Bias uncertainty of criticality calculations for low enriched uranium systems

MCNP 4A SOFTWARE VALIDATION PLAN

Software and Hardware Identification

The software being tested for validation purposes is MCNP 4A Monte Carlo N-Particle Transport Code System. MCNP 4A was developed by the Radiation Transport Group (X-6) of the Applied Theoretical Physics Division (X Division) at Los Alamos National Laboratory, Los Alamos, New Mexico. The software is distributed by the Radiation Safety Information Computational Center (RSICC), Oak Ridge, Tennessee.

MCNP 4A is a general-purpose, continuos-energy, generalized geometry, time dependent, coupled neutron-photon-electron Monte Carlo transport code system. MCNP 4A treats an arbitrary three-dimensional configuration of materials in geometric cells bounded by first- and second-degree surfaces and some special fourth-degree surfaces. Pointwise or continuous-energy cross section data are used, although multigroup data may also be used. Fixed-source adjoint calculations may be made with the multigroup data option. For neutrons, all reactions in a particular cross-section evaluation are accounted for. Both free gas and S(alpha, beta) thermal treatments are used. Criticality sources as well as fixed and surface sources are available.

MCNP 4A is operable on Cray computers, IBM mainframes, UNIX workstations, VAX computers and all computers in general with at least 150 megabytes of hard disk. Executable files for the PC version are proved for running on 8MB memory on 80486, 80386 or higher computer with a coprocessor.

Compilation of MCNP requires both FORTRAN 77 and ANSI C standard compilers. The PC version requires DOS Version 4 or higher. The PC executables included in the package were created with Lahey Fortran F77L-EM/32 version 5.10 compiler under DOS 6.0.

Validation testing is to be performed on a 550-megahertz Pentium III PC with 64 MB of random access memory and sufficient hard disk space to perform a complete installation, operating in a Windows NT environment.

Purpose and Scope of Testing

Testing is being performed to validate MCNP 4A for the purpose of estimating neutron multiplication factors for systems with low-enriched uranium fuel.

Specific Tests to be Performed

The test problems for verification included in the MCNP 4A package are to be run. The test problems are neither good nor typical examples of MCNP problems. Rather, they are highly irregular test configurations designed to exercise as many features as possible. The INPnn files are the same for all systems, but the answers, MCTL?? (?? = 01, 02, etc.), differ slightly from system to system because of differences in arithmetic processors. The test set works on the basis of "particle tracking" in which the random walks must be identical.

MCNP 4A comes with 25 test problems (TESTINP.TAR) and other files shown in Table 1.

Table 1. Verification files in MCNP 4A package.

File	Description
RUNPROB	Script file for MCNP verification. Named RUNPROB.SYS for non-UNIX systems
TESTINP.TAR	Compressed input files for MCNP verification. Named TESTINP.SYS for non-UNIX systems
TESTMCTL.SYS	Compressed tally output files for MCNP verification
TESTOUTP.SYS	Compressed MCNP output files for MCNP verification
XSDIR	Cross-section directory for MCNP verification
TESTLIB1	Cross-section data for MCNP verification

The system identifier "DOS" for PCs operating in WindowsNT environment is to be substituted for the "SYS" suffix. The following commands will uncompress the input/output files and execute the test problem scrip:

```
PKARC TESTINP.DOS
PKARC TESTMCTL.DOS
PKXARC TESTOUP.DOS
COPY RUNPROB.DOS RUNPROB.BAT
RUNPROB
```

MCNP 4A is to be further validated by calculating the effective neutron multiplication factor for U(4.89)O_2F_2 solution in a 69 L aluminum sphere without reflection. The H/^{235}U atomic ratio is 524 and ^{235}U density is 0.0425 g/cm^3.

Evaluation Methods to be Used

The script of the test problem for verification included in MCNP 4A package performs the following steps for the test problems:

1. Execute MCNP for the 1st test problem
2. Compare the tally output file (inp01m) with the standard (mctl01)
3. Compare the output file (inp01o) with the standard (outp01)
4. Remove the RUNTPE file (inp01r)
5. Repeat steps 1-4 for each of the rest of 25 test problems

File comparison results are to be printed out for documentation purposes.

The calculated effective neutron multiplication factor for $U(4.89)O_2F_2$ solution in a 69 L aluminum sphere without a reflector outside is to be compared to the value $k_{eff} = 1$ published in H.C. Paxton, N.L. Provost. *Critical Dimensions of Systems Containing ^{235}U, ^{239}Pu, and ^{233}U*, LA-10860-MS, 1986 Revision, LANL Los Alamos NM. The critical dimension for this sphere is based on the Oak Ridge critical experiments.

Acceptance Criteria to be Used

Upon completion of the test problems for verification included into MCNP 4A package, there should be 25 inp??m and inp??o files (?? = 01, 02, etc.). If any of these are missing, test ?? failed. Differences between these runs and the standard shown up in the DIF?? files. Exact tracking is required for MCNP 4A verification, thus significant differences (i.e., other than round-off in the last digit) may prove to be serious (e.g., compiler bugs, etc.). In such cases, the cause of the difference should be fully understood.

In the case of calculating the effective neutron multiplication factor for $U(4.89)O_2F_2$ solution in 69 L aluminum sphere without reflection, the MCNP calculated result should fall into the range:

$$k_{eff} = 1 \pm (2\sigma + \Delta k_b + \sigma_b)$$

Where:
k_{eff} = neutron multiplication factor predicted by MCNP
σ = standard deviation of MCNP predicted k_{eff}
Δk_b = calculation method bias
σ_b = bias uncertainty

For the case of low enriched uranium fuel, calculation method bias together with bias uncertainty ($\Delta k_b + \sigma_b$) is chosen to be 0.02 based on criticality experiments published in *International Handbook of Evaluated Criticality Safety Benchmark Experiments, Volume IV Low Enriched Uranium Systems*, NEA Nuclear Science Committee, OECD Paris 1995. The derivation of calculation method bias and bias uncertainty values can be found in Appendix 4. Thus, the acceptance criterion can be modified as:

$$k_{eff} = 1 \pm (2\sigma + 0.02)$$

Where:

k_{eff} = neutron multiplication factor predicted by MCNP
σ = standard deviation of MCNP predicted k_{eff}

Based on the above discussion, and using 0.95 as the established "safe" threshold neutron multiplication factor, the results of MCNP 4A calculations should be compared to a subcritical limit of 0.93 (i.e. calculated $k_\infty + 2\sigma \leq 0.93$ and $k_{eff} + 2\sigma \leq 0.93$)

If applicable published results of criticality experiment(s) involving low enriched uranium systems without moderation or reflection are found, MCNP4A validation is to be performed against one of these experiments also.

Documentation Required

The file comparison report generated by test problems for verification included in the MCNP 4A package is to be printed out and attached to this document.

The MCNP input and output files for the calculation of the effective neutron multiplication factor for $U(4.89)O_2F_2$ solution in a 69 L aluminum sphere without reflector outside are also to be printed out and attached to this document.

If applicable published results of criticality experiments(s) involving low enriched uranium systems without moderation or reflection are found, the MCNP input and output files for the calculation of the effective neutron multiplication factor associated with one such experiment are to be printed out and attached to this document.

MCNP 4A SOFTWARE VALIDATION TEST REPORT

Test Personnel

The test plan was implemented by Igor V. Chichkov of URS.

Description of Test Performance

The MCNP 4A software operated/executed well. No difficulties were encountered in this regard. The MCNP 4A documentation was adequate for developing input decks and provided adequate discussions on those parameters that can significantly impact the calculated outputs. No difficulties or problems arose that were not satisfactorily resolved by a close examination of the MCNP 4A documentation. The MCNP 4A documentation and sample problems were of sufficient quality to provide a high degree of confidence that the input deck was properly developed and the modeling satisfactory in regard to the problem on calculation of an effective neutron multiplication factor for $U(4.89)O_2F_2$ solution in a 69 L aluminum sphere without reflection.

Evaluation of Results

Part of the Validation Plan for MCNP 4A was to compare the generated output (i.e., the output generated by the hardware and software being validated) from the execution of input decks provided with the MCNP 4A software with output provided with the MCNP 4A software. The software provided by the Radiation Safety Information Computational Center (RSICC) to URS contains both the input decks to be run, and the outputs. The acceptance criterion for this part of the Validation Plan is that generated output files must be identical to the output files provided with the MCNP 4A software. The byte size of the files must be the same, and all the lines in the output files must be the same too. These criteria were met. Appendix 1 contain the required documentation for this part of the Validation Plan.

The other part of the Validation Plan was to compare the calculated effective neutron multiplication factor for $U(4.89)O_2F_2$ solution in a 69 L aluminum sphere without reflection with criterion $1 \pm (2\sigma + 0.02)$ where σ is the standard deviation of the MCNP predicted k_{eff} value. The input file for the model is attached to Appendix 2, and the output file is attached to Appendix 3. The neutron multiplication factor calculation results are shown in Table 2.

Table 2 The MCNP 4A calculation results for the effective neutron multiplication factor for $U(4.89)O_2F_2$ solution in 69 L aluminum sphere without reflection.

k_{eff}	σ	$1 + (2\sigma + 0.02)$	$1 - (2\sigma + 0.02)$
0.99174	0.00099	1.02198	0.97802

As can be seen from Table 2, the criterion $k_{eff} = 1 \pm (2\sigma + 0.02)$ was met.

An extensive literature search was performed, but no published results of criticality experiments involving low enriched uranium systems without moderation or reflection were found. Additionally, consultation with criticality experts (e.g., the primary author of the KENO criticality code) did not prove beneficial. However, the October 22, 1993 edition of the RSICC newsletter states the following regarding MCNP4A:

> The last version of MCNP released to RSICC, MCNP4.2, was so robust that in over two years of use by over a thousand users at hundreds of institutions around the world, no important errors were found. MCNP4A raises the standard of quality even higher. The code can be made to track MCNP4.2 identically (except for MCNP4.2 bugs), indicating that no new bugs have been added. The test set has been upgraded, and the installation procedure has been tightened further and includes a new data library specifically for test problems using internationally unrestricted ENDF/B-VI and ENDL data. There has been more testing and benchmarking of MCNP4A than any prerelease MCNP version in history. The code has undergone eight months of testing with preliminary versions at Los Alamos. Many significant changes from MCNP4.2 have been documented and can be traced. Most Software Quality Assurance guidelines of the IEEE and European ISO-9000 have been applied, including for the first time multiple review of all coding.

This statement, coupled with the established sound performance of MCNP 4A for low enriched moderated systems, provides a large measure of assurance that the code produces reliable results for various systems with fissile materials including low enriched uranium systems without moderation or reflection.

Conclusions

The modules of MCNP 4A that are being considered for use in criticality calculations met all acceptance criteria during validation testing. Furthermore, there was good agreement between the MCNP 4A calculated effective neutron multiplication factor for $U(4.89)O_2F_2$ solution in a 69 L aluminum sphere without reflection and the reference value $k_{eff} = 1$. It is concluded that the MCNP 4A modules under consideration are suitable for the desired application, i.e., criticality calculations.

Appendix 1

File comparison report generated by test problems for verification included in the MCNP 4A package

```
Comparing files INP01M and MCTL01
FC: no differences encountered

Comparing files INP02M and MCTL02
FC: no differences encountered

Comparing files INP03M and MCTL03
FC: no differences encountered

Comparing files INP04M and MCTL04
FC: no differences encountered

Comparing files INP05M and MCTL05
FC: no differences encountered

Comparing files INP06M and MCTL06
FC: no differences encountered

Comparing files INP07M and MCTL07
FC: no differences encountered

Comparing files INP08M and MCTL08
FC: no differences encountered

Comparing files INP09M and MCTL09
FC: no differences encountered

Comparing files INP10M and MCTL10
FC: no differences encountered

Comparing files INP11M and MCTL11
FC: no differences encountered

Comparing files INP12M and MCTL12
FC: no differences encountered

Comparing files INP13M and MCTL13
FC: no differences encountered

Comparing files INP14M and MCTL14
FC: no differences encountered

Comparing files INP15M and MCTL15
FC: no differences encountered

Comparing files INP16M and MCTL16
FC: no differences encountered

Comparing files INP17M and MCTL17
FC: no differences encountered

Comparing files INP18M and MCTL18
FC: no differences encountered

Comparing files INP19M and MCTL19
FC: no differences encountered

Comparing files INP20M and MCTL20
FC: no differences encountered

Comparing files INP21M and MCTL21
FC: no differences encountered

Comparing files INP22M and MCTL22
FC: no differences encountered

Comparing files INP23M and MCTL23
FC: no differences encountered

Comparing files INP24M and MCTL24
FC: no differences encountered

Comparing files INP25M and MCTL25
FC: no differences encountered
```

Appendix 2

MCNP input file for calculation of effective neutron multiplication factor for a 69 L sphere of $U(4.89)O_2F_2$ solution without reflection.

```
                                                                    S69a2
Al Sphere with UO2F2 water solut. V=69L, unrefl., fwU235=4.89, H/U235 = 524
c
c Cell cards
c
c ---------------------------------------------------------------------------
1 1 9.6588e-2  -1    imp:n=1 $ sphere with solution
2 2 -2.70      1 -2 imp:n=1 $ Al shpere
3 0            2    imp:n=0 $ Outside world
c ---------------------------------------------------------------------------
c
c Note: next line must be completely blank

c Surface cards
c ---------------------------------------------------------------------------
1 so 25.44408    $ 69 L sphere
2 so 25.60283    $ Al sphere (1/16 inch thickness)
c ---------------------------------------------------------------------------
c
c Note: next line must be completely blank

c Data cards
c
c Materials
c
c
c 4.89% enrichment UO2F2 water solution H/U235 = 524
c (H-1, O-16, F-19, U-235, U-238)
m1      1001.50c  5.7058e-2
        8016.50c  3.2929e-2
        9019.50c  4.3996e-3
       92235.50c  1.0889e-4
       92238.50c  2.0911e-3
mt1 lwtr.01t
c Al
m2     13027.50c  1.0
c
mode n
print 40 60 80 100 110 126
kcode 4000 1. 20 200
ksrc  0 0 0
```

Appendix 3

MCNP output file for calculation of effective neutron multiplication factor for a 69 L sphere of $U(4.89)O_2F_2$ solution without reflection.

```
lmcnp    version 4a    ld=10/01 93                    06/19/00 16:04:53
*****************************************************************************          probid =   06/19/00 16:04:53
name=s69a2

      Al Sphere with UO2F2 water solut. V=69L, unrefl., fwU235=4.89, H/U235 = 524
      c
      c Cell cards
      c
      c ---------------------------------------------------------------------
      1 1 9.6588e-2  -1     imp:n=1 $ sphere with solution
      2 2  2.70       1 -2 imp:n=1 $ Al shpere
      3 0             2    imp:n=0 $ Outside world
      c ---------------------------------------------------------------------
      c
      c Note: next line must be completely blank

      c Surface cards
      c ---------------------------------------------------------------------
      1 so 25.44408    $ 69 L sphere
      2 so 25.60283    $ Al sphere (1/16 inch thickness)
      c ---------------------------------------------------------------------
      c
      c Note: next line must be completely blank

      c Data cards
      c
      c Materials
      c
      c
      c 4.89% enrichment UO2F2 water solution H/U235 = 524
      c (H-1, O-16, F-19, U-235, U-238)
      m1      1001.50c  5.7058e-2
              8016.50c  3.2929e-2
              9019.50c  4.3996e-3
             92235.50c  1.0889e-4
             92238.50c  2.0911e-3
      mt1 lwtr.01t
      c Al
      m2     13027.50c  1.0
      c
      mode n
      print 40 60 80 100 110 126
      kcode 4000 1. 20 200
      ksrc  0 0 0

total fission nubar data are being used.
lmaterial composition                                                                    print table 40

the sum of the fractions of material    1 was 9.658659E-02

material
 number     component nuclide, atom fraction

   1            1001,  0.59074       8016,  0.34093       9019,  0.04555       92235,  0.00113
               92238,  0.02165
associated thermal s(a,b) data sets:    lwtr.01t
   2           13027,  1.00000
```

```
material
 number      component nuclide, mass fraction

    1            1001,  0.04828       8016,  0.44217       9019,  0.07017       92235,  0.02149
                92238,  0.41790
    2           13027,  1.00000

warning.    1 of the materials had unnormalized fractions.
lcells                                                                                    print table 60

                     atom        gram                                          neutron
      cell  mat    density     density     volume       mass     pieces importance

    1     1    1s 9.65880E-02 1.97804E+00 6.90000E+04 1.36485E+05     1  1.0000E+00
    2     2    2  6.02616E-02 2.70000E+00 1.29958E+03 3.50887E+03     1  1.0000E+00
    3     3    0  0.00000E+00 0.00000E+00 0.00000E+00 0.00000E+00     0  0.0000E+00

total                                     7.02995E+04 1.39994E+05

         1 warning message so far.
lcross-section tables                                                                     print table 100

    table    length

                     tables from file critxs

  1001.50c    1153  njoy                                                          (  1301)      79/07/31.
  8016.50c   23669  njoy                                                          ( 1276)      05/14/81
  9019.50c   20657  njoy                                                          (  1309)      79/06/22.
 13027.50c   22891  njoy                                                          (  1313)      79/09/08.
 92235.50c   44188  njoy                                      total nu             (  1395)      79/09/12.
 92238.50c   66440  njoy                                      total nu             (  1398)      79/09/13.
  lwtr.01t   10193  hydrogen in light water at 300 degrees kelvin                1001     0     010/22/85

 total      189191

warning.  neutron energy cutoff is below some cross-section tables.



decimal words of dynamically allocated storage

    general              113988
    tallies                   0
    bank                   6403
    cross sections       189191

    total                309582

.................................................................................................................
dump no.    1 on file s69a2r       nps =        0     coll =              0     ctm =    0.00     nrn =              0
```

escape 6.3758E-05 6.0255E-07 6.3154E-05 to 6.4361E-05 , 6.2557E-05 to 6.4958E-05 6.2166E-05 to 6.5350E-05

laverage individual and combined collision/absorption/track-length keff results for 7 different batch sizes

cycles per keff batch	number of k batches	average keff estimators and deviations k(col)	st dev	k(abs)	st dev	k(trk)	st dev	normality co/ab/trk	average k(c/a/t) k(c/a/t)	st dev	k(c/a/t) confidence intervals 95% confidence	99% confidence
1	100	0.9448	0.0015	0.9444	0.0014	0.9448	0.0016	95/95/95	0.94460	0.00130	0.94201-0.94719	0.94117-0.94803
2	50	0.9448	0.0013	0.9444	0.0013	0.9448	0.0016	95/95/95	0.94462	0.00119	0.94222-0.94702	0.94141-0.94782
4	25	0.9448	0.0013	0.9444	0.0014	0.9448	0.0015	95/95/99	0.94466	0.00126	0.94205-0.94728	0.94111-0.94822
5	20	0.9448	0.0012	0.9444	0.0013	0.9448	0.0015	95/95/95	0.94466	0.00126	0.94200-0.94732	0.94101-0.94831
10	10	0.9448	0.0012	0.9444	0.0013	0.9448	0.0013	95/95/95	0.94467	0.00122	0.94178-0.94755	0.94040-0.94894
20	5	0.9448	0.0014	0.9444	0.0015	0.9448	0.0019	95/95/95	0.94501	0.00177	0.93739-0.95263	0.92743-0.96259
25	4	0.9448	0.0017	0.9444	0.0018	0.9448	0.0014	95/95/95	0.94443	0.00235	0.91454-0.97433	0.79471-1.09416

lindividual and average keff estimator results by cycle

keff cycle	neutron histories	keff estimators by cycle k(coll)	k(abs)	k(track)	average keff estimators and deviations k(coll)	st dev	k(abs)	st dev	k(track)	st dev	average k(c/a/t) k(c/a/t)	st dev	fom
1	4000	0.92018	0.90561	0.91812									
2	3663	0.90982	0.90622	0.92375									
3	3901	*0.92952*	*0.91404*	0.92148									
4	4160	0.92869	0.93307	0.93513									
5	3999	0.90947	0.93027	0.90266									
6	3975	0.94145	0.92231	0.94579									
7	4112	*0.91214*	*0.91664*	0.92057									
8	3871	0.93508	0.96572	0.92667									
9	4095	0.95234	0.95346	0.93934									
10	4058	0.92532	0.94327	0.92870									
11	3915	0.96075	0.96056	0.95162									
12	4104	0.93173	0.92924	0.92301									
13	3875	0.94191	0.93120	0.94157									
14	4124	0.93591	0.94347	0.93214									
15	4015	0.93484	0.94916	0.92607									
16	3987	0.96131	0.97064	0.96418									
17	4088	0.94880	0.94500	0.94542									
18	3954	0.96055	0.93922	*0.96906*									
19	4103	*0.91967*	0.93435	0.89922									
20	3824	0.94304	0.94694	0.92161									
		begin active keff cycles											
21	4113	0.94172	0.95714	0.93071									
22	3964	0.94408	0.94352	0.96638	0.94290	0.00118	0.95033	0.00681	0.94855	0.01783			
23	4011	0.90696	0.91577	0.92542	0.93092	0.01200	0.93881	0.01217	0.94084	0.01286			
24	*3900*	*0.98705*	0.97092	0.98241	0.94495	0.01640	0.94684	0.01177	0.95123	0.01381	0.95510	0.00961	10946
25	4319	0.95537	0.95268	0.96518	0.94704	0.01287	0.94800	0.00919	0.95402	0.01105	0.95611	0.00653	18712
26	3865	0.93323	0.92977	0.93326	*0.94474*	*0.01076*	0.94497	0.00810	0.95056	0.00967	0.95004	0.00828	9657
27	3897	0.98086	0.96494	0.97548	0.94990	0.01045	0.94782	0.00741	0.95412	0.00891	0.94985	0.00654	13254
28	4228	0.90501	0.90561	0.92548	0.94429	0.01065	0.94254	0.00831	0.95054	0.00851	0.94848	0.00711	9775
29	3678	0.92279	0.93067	0.91922	0.94190	0.00969	0.94122	0.00745	0.94706	0.00827	0.94590	0.00615	11661
30	4048	0.95027	0.94713	0.95332	0.94274	0.00871	0.94181	0.00669	0.94769	0.00742	0.94606	0.00543	13441
31	4143	0.96427	0.96280	0.95106	0.94469	0.00812	0.94372	0.00634	0.94799	0.00672	0.94631	0.00461	16935
32	4059	0.93033	0.91959	0.94416	0.94350	0.00751	0.94171	0.00613	0.94767	0.00614	0.94539	0.00473	14672
33	3812	0.94657	0.93688	0.94156	0.94373	0.00691	0.94134	0.00565	0.94720	0.00567	0.94378	0.00470	13763
34	4127	0.95380	0.96063	0.94145	0.94445	0.00644	0.94272	0.00541	0.94679	*0.00527*	*0.94452*	*0.00416*	16269
35	4028	0.94260	0.94702	0.96029	0.94433	0.00599	0.94301	0.00504	0.94769	0.00499	0.94579	0.00427	14436
36	4039	0.95649	0.95575	0.97269	0.94509	0.00566	0.94380	0.00478	0.94925	0.00492	0.94686	0.00442	12668
37	4119	0.96106	0.94929	0.95781	0.94603	0.00540	0.94413	0. 00451	0.94976	0.00465	0.94660	0.00417	13379

38	3983	0.93150	0.93295	0.93460	0.94522	0.00515	0.94350	0.00429	0.94892	0.00446	0.94595	0.00397	13971
39	3858	0.94580	0.92646	0.93726	0.94525	0.00487	0.94261	0.00416	0.94830	0.00426	0.94473	0.00420	11789
40	4027	0.92955	0.93527	0.92216	0.94446	0.00469	0.94224	0.00396	0.94700	0.00425	0.94366	0.00395	12661
41	3931	0.93993	0.95647	0.94313	0.94425	0.00447	0.94292	0.00383	0.94681	0.00405	0.94470	0.00375	13367
42	4090	0.94203	0.93664	0.94196	0.94415	0.00426	0.94263	0.00366	0.94659	0.00387	0.94435	0.00360	13846
43	3929	0.93820	0.94131	0.95480	0.94389	0.00408	0.94258	0.00350	0.94695	0.00371	0.94460	0.00349	14129
44	3991	0.92843	0.93803	0.94454	0.94325	0.00396	0.94239	0.00336	0.94685	0.00355	0.94470	0.00336	14571
45	3969	0.96811	0.96337	0.95301	0.94424	0.00392	0.94322	0.00333	0.94709	0.00342	0.94523	0.00319	15583
46	4108	0.94780	0.94998	0.95288	0.94438	0.00377	0.94348	0.00321	0.94732	0.00329	0.94553	0.00308	15975
47	3908	0.94280	0.94442	0.94850	0.94432	0.00363	0.94352	0.00309	0.94736	0.00317	0.94563	0.00297	16544
48	3973	0.93783	0.94242	0.94161	0.94409	0.00351	0.94348	0.00297	0.94716	0.00306	0.94559	0.00285	17251
49	3978	0.95010	0.95972	0.94910	0.94429	0.00339	0.94404	0.00292	0.94722	0.00295	0.94611	0.00277	17695
50	4001	0.96291	0.97120	0.96907	0.94491	0.00333	0.94495	0.00297	0.94795	0.00294	0.94702	0.00286	16099
51	4138	0.95649	0.97077	0.97306	0.94529	0.00324	0.94578	0.00299	0.94876	0.00296	0.94767	0.00298	14332
52	3999	0.92688	0.92739	0.92969	0.94471	0.00319	0.94520	0.00295	0.94816	0.00293	0.94707	0.00295	14103
53	3832	0.92587	0.93926	0.91462	0.94414	0.00315	0.94502	0.00286	0.94715	0.00301	0.94630	0.00289	14305
54	4085	0.93292	0.94255	0.92847	0.94381	0.00307	0.94495	0.00278	0.94660	0.00298	0.94603	0.00281	14689
55	4031	0.98239	0.94339	0.97374	0.94491	0.00318	0.94491	0.00270	0.94737	0.00299	0.94611	0.00270	15432
56	4199	0.94239	0.94222	0.92892	0.94484	0.00309	0.94483	0.00262	0.94686	0.00295	0.94574	0.00261	15975
57	3800	0.96437	0.94403	0.97998	0.94537	0.00305	0.94481	0.00255	0.94776	0.00301	0.94589	0.00257	16040
58	4055	0.94908	0.96958	0.93994	0.94547	0.00297	0.94546	0.00257	0.94755	0.00293	0.94642	0.00252	16321
59	3906	0.96559	0.97181	0.96415	0.94599	0.00294	0.94614	0.00259	0.94798	0.00289	0.94705	0.00252	15839
60	4042	0.95718	0.94456	0.93759	0.94626	0.00288	0.94610	0.00253	0.94772	0.00283	0.94679	0.00245	16401
61	4038	0.93743	0.93678	0.93241	0.94605	0.00282	0.94587	0.00247	0.94734	0.00278	0.94648	0.00240	16615
62	3887	0.95474	0.93294	0.94480	0.94626	0.00276	0.94556	0.00243	0.94728	0.00272	0.94621	0.00236	16817
63	4150	0.95891	0.94173	0.94973	0.94655	0.00271	0.94547	0.00238	0.94734	0.00265	0.94615	0.00230	17175
64	3977	0.94290	0.94230	0.93649	0.94647	0.00265	0.94540	0.00232	0.94709	0.00260	0.94600	0.00225	17564
65	3914	0.95370	0.97674	0.93214	0.94663	0.00259	0.94610	0.00238	0.94676	0.00257	0.94636	0.00221	17888
66	4085	0.93012	0.94039	0.93044	0.94627	0.00256	0.94597	0.00233	0.94641	0.00254	0.94614	0.00217	18149
67	3851	0.94296	0.95023	0.95234	0.94620	0.00251	0.94606	0.00228	0.94653	0.00249	0.94626	0.00212	18511
68	4074	0.95000	0.95530	0.93271	0.94628	0.00246	0.94626	0.00224	0.94624	0.00245	0.94625	0.00208	18946
69	4007	0.94375	0.94731	0.95567	0.94623	0.00241	0.94628	0.00219	0.94644	0.00241	0.94635	0.00204	19309
70	3974	0.96506	0.95824	0.95338	0.94660	0.00239	0.94652	0.00216	0.94658	0.00236	0.94654	0.00200	19577
71	4111	0.94637	0.93139	0.93812	0.94660	0.00234	0.94622	0.00214	0.94641	0.00232	0.94628	0.00198	19591
72	3957	0.93884	0.92468	0.94405	0.94645	0.00230	0.94581	0.00214	0.94636	0.00228	0.94604	0.00196	19593
73	3980	0.93779	0.93336	0.95239	0.94629	0.00226	0.94557	0.00211	0.94648	0.00224	0.94596	0.00193	19941
74	3996	0.93574	0.95070	0.92702	0.94609	0.00223	0.94567	0.00207	0.94612	0.00222	0.94585	0.00189	20335
75	3948	0.95832	0.95655	0.96862	0.94631	0.00220	0.94586	0.00205	0.94653	0.00222	0.94614	0.00188	20214
76	4054	0.94276	0.93602	0.95795	0.94625	0.00216	0.94569	0.00202	0.94673	0.00219	0.94613	0.00185	20549
77	3995	0.92232	0.92836	0.90980	0.94583	0.00216	0.94538	0.00200	0.94608	0.00225	0.94565	0.00187	19736
78	3922	0.94284	0.95308	0.95599	0.94578	0.00212	0.94552	0.00197	0.94625	0.00221	0.94580	0.00184	19977
79	4158	0.93862	0.94597	0.93026	0.94566	0.00209	0.94553	0.00194	0.94598	0.00219	0.94570	0.00181	20289
80	3955	0.94131	0.93883	0.94787	0.94558	0.00206	0.94541	0.00191	0.94601	0.00216	0.94564	0.00178	20610
81	4011	0.94673	0.96285	0.93770	0.94560	0.00202	0.94570	0.00190	0.94588	0.00213	0.94577	0.00175	20884
82	3997	0.94253	0.93932	0.96151	0.94555	0.00199	0.94560	0.00187	0.94613	0.00211	0.94580	0.00173	21194
83	3949	0.94704	0.95634	0.93395	0.94558	0.00196	0.94577	0.00185	0.94594	0.00208	0.94583	0.00170	21582
84	4026	0.94825	0.94742	0.94205	0.94562	0.00193	0.94579	0.00182	0.94588	0.00205	0.94582	0.00167	21949
85	4019	0.93320	0.94455	0.92451	0.94543	0.00191	0.94577	0.00179	0.94555	0.00204	0.94568	0.00165	22134
86	3917	0.95162	0.95430	0.94819	0.94552	0.00188	0.94590	0.00177	0.94559	0.00201	0.94578	0.00163	22418
87	4073	0.93792	0.94819	0.92512	0.94541	0.00186	0.94594	0.00174	0.94528	0.00201	0.94569	0.00161	22662
88	3933	0.93171	0.91938	0.93975	0.94521	0.00184	0.94555	0.00176	0.94520	0.00198	0.94540	0.00160	22368
89	3968	0.92631	0.92959	0.92052	0.94493	0.00184	0.94532	0.00175	0.94484	0.00198	0.94513	0.00161	21990
90	3911	0.92640	0.93004	0.92718	0.94467	0.00183	0.94510	0.00174	0.94459	0.00197	0.94490	0.00160	21828

source distribution written to file s09a2s cycle = 0

2 warning messages so far.

1 starting mcnp. field length = 0 cp0 = 0.01 print table 110

Al sphere with U02F2 water solut. V=69L, unrefl., kwU235=4.89, H/U235 = 524

nps	x	y	z	cell	surf	u	v	w	energy	weight	time
1	0.000E+00	0.000E+00	0.000E+00	1	0	5.085E-01	4.733E-01	7.193E-01	2.209E+00	1.000E+00	0.000E+00
2	0.000E+00	0.000E+00	0.000E+00	1	0	8.952E-01	-4.447E-01	-2.944E-02	4.904E+00	1.000E+00	0.000E+00
3	0.000E+00	0.000E+00	0.000E+00	1	0	-6.184E-01	-4.495E-01	6.446E-01	3.809E-01	1.000E+00	0.000E+00
4	0.000E+00	0.000E+00	0.000E+00	1	0	9.710E-01	-5.665E-02	-2.323E-01	1.331E+00	1.000E+00	0.000E+00
5	0.000E+00	0.000E+00	0.000E+00	1	0	5.861E-01	1.496E-01	-7.963E-01	1.902E+00	1.000E+00	0.000E+00
6	0.000E+00	0.000E+00	0.000E+00	1	0	-6.489E-02	-1.626E-01	9.845E-01	4.410E-01	1.000E+00	0.000E+00
7	0.000E+00	0.000E+00	0.000E+00	1	0	-7.068E-02	3.263E-02	-9.970E-01	4.750E-01	1.000E+00	0.000E+00
8	0.000E+00	0.000E+00	0.000E+00	1	0	-3.915E-01	4.664E-01	-7.932E-01	4.136E+00	1.000E+00	0.000E+00
9	0.000E+00	0.000E+00	0.000E+00	1	0	-2.368E-01	9.215E-01	-3.079E-01	7.453E-02	1.000E+00	0.000E+00
10	0.000E+00	0.000E+00	0.000E+00	1	0	1.946E-01	-3.204E-01	9.271E-01	3.128E+00	1.000E+00	0.000E+00
11	0.000E+00	0.000E+00	0.000E+00	1	0	-6.698E-01	-7.177E-01	-1.905E-01	1.014E+00	1.000E+00	0.000E+00
12	0.000E+00	0.000E+00	0.000E+00	1	0	-8.398E-01	-4.129E-01	3.524E-01	1.395E+00	1.000E+00	0.000E+00
13	0.000E+00	0.000E+00	0.000E+00	1	0	-1.714E-01	-8.572E-01	4.857E-01	7.748E-01	1.000E+00	0.000E+00
14	0.000E+00	0.000E+00	0.000E+00	1	0	-2.489E-01	-5.118E-01	-8.222E-01	1.101E+00	1.000E+00	0.000E+00
15	0.000E+00	0.000E+00	0.000E+00	1	0	-2.959E-01	2.119E-01	9.314E-01	1.951E+00	1.000E+00	0.000E+00
16	0.000E+00	0.000E+00	0.000E+00	1	0	1.395E-01	-9.829E-01	1.202E-01	2.186E+00	1.000E+00	0.000E+00
17	0.000E+00	0.000E+00	0.000E+00	1	0	6.909E-01	-7.110E-01	1.307E-01	1.865E+00	1.000E+00	0.000E+00
18	0.000E+00	0.000E+00	0.000E+00	1	0	-6.580E-01	5.320E-01	-5.329E-01	1.229E+00	1.000E+00	0.000E+00
19	0.000E+00	0.000E+00	0.000E+00	1	0	-9.903E-01	-1.380E-01	1.353E-02	1.305E+00	1.000E+00	0.000E+00
20	0.000E+00	0.000E+00	0.000E+00	1	0	7.462E-01	4.859E-01	-4.551E-01	1.000E+00	1.000E+00	0.000E+00
21	0.000E+00	0.000E+00	0.000E+00	1	0	-1.977E-01	9.797E-01	3.360E-02	3.990E+00	1.000E+00	0.000E+00
22	0.000E+00	0.000E+00	0.000E+00	1	0	-9.117E-01	-3.647E-01	-1.891E-01	2.665E-01	1.000E+00	0.000E+00
23	0.000E+00	0.000E+00	0.000E+00	1	0	-4.287E-01	8.361E-01	-3.423E-01	1.156E+00	1.000E+00	0.000E+00
24	0.000E+00	0.000E+00	0.000E+00	1	0	1.080E-01	3.412E-01	-9.338E-01	2.669E+00	1.000E+00	0.000E+00
25	0.000E+00	0.000E+00	0.000E+00	1	0	-9.111E-01	-9.012E-03	-4.122E-01	2.185E+00	1.000E+00	0.000E+00
26	0.000E+00	0.000E+00	0.000E+00	1	0	-2.568E-01	-6.391E-01	-7.249E-01	4.225E+00	1.000E+00	0.000E+00
27	0.000E+00	0.000E+00	0.000E+00	1	0	-2.912E-01	8.086E-01	5.113E-01	1.079E+00	1.000E+00	0.000E+00
28	0.000E+00	0.000E+00	0.000E+00	1	0	1.472E-01	-9.514E-01	2.705E-01	3.461E+00	1.000E+00	0.000E+00
29	0.000E+00	0.000E+00	0.000E+00	1	0	-6.135E-01	-7.645E-01	-1.978E-01	1.836E+00	1.000E+00	0.000E+00
30	0.000E+00	0.000E+00	0.000E+00	1	0	-5.702E-01	5.651E-01	-5.963E-01	4.556E-01	1.000E+00	0.000E+00
31	0.000E+00	0.000E+00	0.000E+00	1	0	-6.607E-01	5.373E-01	-5.242E-01	6.415E-01	1.000E+00	0.000E+00
32	0.000E+00	0.000E+00	0.000E+00	1	0	-9.742E-02	-3.639E-01	-9.263E-01	2.764E+00	1.000E+00	0.000E+00
33	0.000E+00	0.000E+00	0.000E+00	1	0	-1.965E-01	-3.145E-01	-9.287E-01	2.785E+00	1.000E+00	0.000E+00
34	0.000E+00	0.000E+00	0.000E+00	1	0	4.097E-01	8.465E-01	-3.399E-01	9.097E-01	1.000E+00	0.000E+00
35	0.000E+00	0.000E+00	0.000E+00	1	0	-4.048E-02	8.831E-01	4.675E-01	3.360E-01	1.000E+00	0.000E+00
36	0.000E+00	0.000E+00	0.000E+00	1	0	3.371E-01	-9.269E-01	-1.652E-01	6.376E-01	1.000E+00	0.000E+00
37	0.000E+00	0.000E+00	0.000E+00	1	0	-1.867E-01	9.756E-01	-1.155E-01	2.186E+00	1.000E+00	0.000E+00
38	0.000E+00	0.000E+00	0.000E+00	1	0	-2.616E-01	2.336E-01	-9.365E-01	7.314E-01	1.000E+00	0.000E+00
39	0.000E+00	0.000E+00	0.000E+00	1	0	9.780E-01	-7.641E-02	-1.939E-01	2.997E-01	1.000E+00	0.000E+00
40	0.000E+00	0.000E+00	0.000E+00	1	0	2.580E-01	-7.076E-01	6.578E-01	1.444E+00	1.000E+00	0.000E+00
41	0.000E+00	0.000E+00	0.000E+00	1	0	-3.212E-01	-7.678E-01	-5.543E-01	1.914E+00	1.000E+00	0.000E+00
42	0.000E+00	0.000E+00	0.000E+00	1	0	5.039E-01	-1.460E-01	8.513E-01	1.502E+00	1.000E+00	0.000E+00
43	0.000E+00	0.000E+00	0.000E+00	1	0	6.080E-01	5.487E-01	5.738E-01	5.971E+00	1.000E+00	0.000E+00
44	0.000E+00	0.000E+00	0.000E+00	1	0	-2.932E-01	9.304E-01	-2.199E-01	1.827E+00	1.000E+00	0.000E+00
45	0.000E+00	0.000E+00	0.000E+00	1	0	-8.475E-01	-3.993E-01	-3.497E-01	1.928E+00	1.000E+00	0.000E+00
46	0.000E+00	0.000E+00	0.000E+00	1	0	1.200E-01	-9.195E-01	-3.743E-01	1.351E+00	1.000E+00	0.000E+00
47	0.000E+00	0.000E+00	0.000E+00	1	0	7.085E-01	5.879E-01	3.904E-01	2.288E+00	1.000E+00	0.000E+00

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   48  0.000E+00  0.000E+00  0.000E+00     1      0  4.261E-01  9.046E-01  9.254E-03  1.230E+00  1.000E+00  0.000E+00
   49  0.000E+00  0.000E+00  0.000E+00     1      0  5.431E-01  4.270E-01 -7.230E-01  1.433E+00  1.000E+00  0.000E+00
   50  0.000E+00  0.000E+00  0.000E+00     1      0  1.053E-01 -9.805E-01  1.658E-01  6.572E-01  1.000E+00  0.000E+00
festimated keff results by cycle                                                                        print table 175

source distribution written to file s69a2s          cycle =    20

source distribution written to file s69a2s          cycle =    31

source distribution written to file s69a2s          cycle =    42

source distribution written to file s69a2s          cycle =    53

source distribution written to file s69a2s          cycle =    64

source distribution written to file s69a2s          cycle =    75

source distribution written to file s69a2s          cycle =    86

source distribution written to file s69a2s          cycle =    97

 estimator      cycle   100   ave of    80 cycles      combination          simple average    combined average     corr
k(collision)      0.994024        0.992724 0.0019     k(col/abs)           0.992363 0.0015     0.992237 0.0014   0.3974
k(absorption)     0.971549        0.992001 0.0016     k(abs/tk ln)         0.992318 0.0015     0.992198 0.0014   0.3833
k(trk length)     0.992832        0.992635 0.0020     k(tk ln/col)         0.992679 0.0020     0.992781 0.0019   0.9887
rem life(col)   2.9966E+03      2.9562E+03 0.0034     k(col/abs/tk ln)     0.992453 0.0016     0.992250 0.0014
rem life(abs)   2.9481E+03      2.9556E+03 0.0021     life(col/abs)      2.9559E+03 0.0027   2.9552E+03 0.0018   0.8765
source points generated   4048

source distribution written to file s69a2s          cycle =   108

source distribution written to file s69a2s          cycle =   119

source distribution written to file s69a2s          cycle =   131

source distribution written to file s69a2s          cycle =   142

source distribution written to file s69a2s          cycle =   153

*****************************************************************************************************************
dump no.    2 on file s69a2r       nps =    652206     coll =      30134559     ctm =   15.02     nrn =     346513229

source distribution written to file s69a2s          cycle =   164

source distribution written to file s69a2s          cycle =   175

source distribution written to file s69a2s          cycle =   186

 estimator      cycle   196   ave of   176 cycles      combination          simple average    combined average     corr
k(collision)      0.974402        0.991922 0.0014     k(col/abs)           0.991930 0.0011     0.991933 0.0010   0.4307
k(absorption)     0.968458        0.991937 0.0011     k(abs/tk ln)         0.991855 0.0011     0.991898 0.0010   0.4176
k(trk length)     0.972152        0.991773 0.0015     k(tk ln/col)         0.991848 0.0014     0.992022 0.0014   0.9883
rem life(col)   2.9523E+03      2.9536E+03 0.0024     k(col/abs/tk ln)     0.991878 0.0012     0.991955 0.0010
rem life(abs)   2.8789E+03      2.9538E+03 0.0015     life(col/abs)      2.9537E+03 0.0019   2.9539E+03 0.0013   0.8899
source points generated   3966

 estimator      cycle   197   ave of   177 cycles      combination          simple average    combined average     corr
```

k(collision)	0.971119	0.991805	0.0014	k(col/abs)	0.991815	0.0011	0.991819 0.0010	0.4357
k(absorption)	0.972012	0.991824	0.0011	k(abs/tk ln)	0.991750	0.0011	0.991789 0.0010	0.4215
k(tk length)	0.974424	0.991675	0.0015	k(tk ln/col)	0.991740	0.0014	0.991885 0.0014	0.9882
rem life(col)	2.9214E+03	2.9534E+03	0.0024	k(col/abs/tk ln)	0.991768	0.0012	0.991833 0.0010	
rem life(abs)	2.8951E+03	2.9534E+03	0.0015	life(col/abs)	2.9534E+03	0.0019	2.9534E+03 0.0013	0.8889

source points generated 4011

estimator	cycle 198	ave of 178 cycles		combination	simple average		combined average		corr
k(collision)	0.985082	0.991767	0.0014	k(col/abs)	0.991765	0.0010	0.991765	0.0010	0.4363
k(absorption)	0.981019	0.991764	0.0011	k(abs/tk ln)	0.991708	0.0011	0.991737	0.0010	0.4217
k(tk length)	0.987553	0.991652	0.0015	k(tk ln/col)	0.991710	0.0014	0.991837	0.0014	0.9882
rem life(col)	2.9951E+03	2.9534E+03	0.0024	k(col/abs/tk ln)	0.991728	0.0011	0.991775	0.0010	
rem life(abs)	2.9429E+03	2.9533E+03	0.0015	life(col/abs)	2.9534E+03	0.0019	2.9533E+03	0.0013	0.8888

source points generated 4110

source distribution written to file s69a2s cycle = 198

estimator	cycle 199	ave of 179 cycles		combination	simple average		combined average		corr
k(collision)	0.975905	0.991678	0.0014	k(col/abs)	0.991701	0.0010	0.991712	0.0010	0.4376
k(absorption)	0.984497	0.991723	0.0010	k(abs/tk ln)	0.991639	0.0011	0.991683	0.0010	0.4231
k(tk length)	0.974101	0.991554	0.0014	k(tk ln/col)	0.991616	0.0014	0.991756	0.0014	0.9882
rem life(col)	2.8760E+03	2.9530E+03	0.0024	k(col/abs/tk ln)	0.991652	0.0011	0.991724	0.0010	
rem life(abs)	2.8940E+03	2.9530E+03	0.0015	life(col/abs)	2.9530E+03	0.0019	2.9530E+03	0.0013	0.8892

source points generated 3926

estimator	cycle 200	ave of 180 cycles		combination	simple average		combined average		corr
k(collision)	1.021640	0.991845	0.0014	k(col/abs)	0.991766	0.0010	0.991727	0.0010	0.4301
k(absorption)	0.985213	0.991687	0.0010	k(abs/tk ln)	0.991687	0.0011	0.991687	0.0010	0.4178
k(tk length)	1.015437	0.991687	0.0014	k(tk ln/col)	0.991766	0.0014	0.991923	0.0014	0.9880
rem life(col)	3.1309E+03	2.9540E+03	0.0024	k(col/abs/tk ln)	0.991740	0.0011	0.991740	0.0010	
rem life(abs)	3.0284E+03	2.9534E+03	0.0015	life(col/abs)	2.9537E+03	0.0019	2.9531E+03	0.0013	0.8898

source points generated 4108

source distribution written to file s69a2s cycle = 200

1problem summary

run terminated when 200 kcode cycles were done.

06/19/00 16:23:18

Al Sphere with UO2F2 water solut. V=69L, unrefl., fwU235=4.89, H/U235 = 524 probid = 06/19/00 16:04:53

0

neutron creation	tracks	weight (per source particle)	energy (per source particle)	neutron loss	tracks	weight (per source particle)	energy (per source particle)
source	800202	9.9975E-01	2.0311E+00	escape	231462	2.7371E-01	3.2750E-01
				energy cutoff	0	0.	0.
				time cutoff	0	0.	0.
weight window	0	0.	0.	weight window	0	0.	0.
cell importance	0	0.	0.	cell importance	0	0.	0.
weight cutoff	0	2.2431E-02	1.4178E-07	weight cutoff	569056	2.2190E-02	1.4252E-07
energy importance	0	0.	0.	energy importance	0	0.	0.
dxtran	0	0.	0.	dxtran	0	0.	0.
forced collisions	0	0.	0.	forced collisions	0	0.	0.
exp. transform	0	0.	0.	exp. transform	0	0.	0.
upscattering	0	0.	1.4280E-07	downscattering	0	0.	1.6628E+00
				capture	0	3.1916E-01	1.9123E-02
(n,xn)	629	6.3928E-04	4.5534E-04	loss to (n,xn)	313	3.1813E-04	2.6603E-03
fission	0	0.	0.	loss to fission	0	4.0744E-01	1.9493E-02
total	800831	1.0228E+00	2.0315E+00	total	800831	1.0228E+00	2.0315E+00

number of neutrons banked	316	average lifetime, shakes	cutoffs
neutron tracks per source particle	1.0008E+00	escape 4.0145E+02	tco 1.0000E+34
neutron collisions per source particle	4.6143E+01	capture 1.9251E+03	eco 0.0000E+00
total neutron collisions	36923422	capture or escape 2.9610E+03	wc1 -5.0000E-01
net multiplication	1.0003E+00 0.0000	any termination 3.0061E+03	wc2 -2.5000E-01
computer time so far in this run	18.41 minutes	maximum number ever in bank	2
computer time in mcrun	18.41 minutes	bank overflows to backup file	0
source particles per minute	4.3476E+04	field length	0
random numbers generated	424627399	most random numbers used was	4993 in history 305359

range of sampled source weights = 7.7610E-01 to 1.1287E+00

1neutron activity in each cell print table 126

cell		tracks entering	population	collisions	collisions * weight (per history)	number weighted energy	flux weighted energy	average track weight (relative)	average track mfp (cm)
1	1	801728	800518	36913527	3.6623E+01	3.1108E-04	6.7098E-01	8.8028E-01	1.6107E+00
2	2	234990	232650	9895	1.1909E-02	1.3340E-03	1.1043E+00	9.4470E-01	8.0700E+00
total		1036718	1033168	36923422	3.6635E+01				

1keff results for: Al Sphere with UO2F2 water solut. V=69L, unrefl., fwU235=4.89, H/U235 = 524 probid = 06/19/00 16:04:53

the initial fission neutron source distribution used the 1 source points that were input on the ksrc card.
the criticality problem was scheduled to skip 20 cycles and run a total of 200 cycles with nominally 4000 neutrons per cycle.
this problem has run 20 inactive cycles with 80394 neutron histories and 180 active cycles with 719808 neutron histories.

this calculation has completed the requested number of keff cycles using a total of 800202 fission neutron source histories.
all cells with fissionable material were sampled and had fission neutron source points.

the results of the w test for normality applied to the individual collision, absorption, and track-length keff cycle values are:

the k(collision) cycle values appear normally distributed at the 99 percent confidence level, but not at 95 percent
the k(absorption) cycle values appear normally distributed at the 95 percent confidence level
warning. the k(trk length) cycle values do not appear normally distributed at the 99 percent confidence level

the final estimated combined collision/absorption/track-length keff = 0.99174 with an estimated standard deviation of 0.00099

the estimated 68, 95, & 99 percent keff confidence intervals are 0.99075 to 0.99273, 0.98978 to 0.99370, and 0.98913 to 0.99434

the estimated collision/absorption neutron removal lifetime = 2.95E-05 seconds with an estimated standard deviation of 3.87E-08

the estimated average keffs, one standard deviations, and 68, 95, and 99 percent confidence intervals are:

keff estimator	keff	standard deviation	68% confidence	95% confidence	99% confidence	corr
collision	0.99184	0.00140	0.99044 to 0.99325	0.98906 to 0.99463	0.98815 to 0.99554	

absorption	0.99169	0.00104	0.99065 to 0.99272	0.98962 to 0.99375	0.98895 to 0.99442	
track length	0.99169	0.00143	0.99025 to 0.99312	0.98883 to 0.99454	0.98790 to 0.99547	
col/absorp	0.99173	0.00098	0.99074 to 0.99271	0.98977 to 0.99368	0.98913 to 0.99432	0.4301
abs trk len	0.99169	0.00098	0.99070 to 0.99267	0.98973 to 0.99365	0.98909 to 0.99429	0.4178
col.trk len	0.99192	0.00140	0.99052 to 0.99332	0.98913 to 0.99471	0.98822 to 0.99562	0.9880
col/abs/trk len	0.99174	0.00099	0.99075 to 0.99273	0.98978 to 0.99370	0.98913 to 0.99434	

If the largest of each keff occurred on the next cycle, the keff results and 68, 95, and 99 percent confidence intervals would be:

keff estimator	keff	standard deviation	68% confidence	95% confidence	99% confidence
collision	0.99205	0.00141	0.99065 to 0.99346	0.98925 to 0.99486	0.98834 to 0.99577
absorption	0.99190	0.00105	0.99085 to 0.99295	0.98981 to 0.99399	0.98912 to 0.99468
track length	0.99189	0.00144	0.99044 to 0.99333	0.98902 to 0.99475	0.98808 to 0.99569
col/abs/trk len	0.99194	0.00100	0.99094 to 0.99295	0.98994 to 0.99394	0.98929 to 0.99460

The estimated collision/absorption neutron lifetimes, one standard deviations, and 68, 95, and 99 percent confidence intervals are:

type	lifetime(sec)	standard deviation	68% confidence	95% confidence	99% confidence
removal	2.9531E-05	3.8743E-08	2.9492E-05 to 2.9570E-05	2.9454E-05 to 2.9608E-05	2.9429E-05 to 2.9634E-05
capture	1.9244E-05	4.6249E-08	1.9198E-05 to 1.9291E-05	1.9152E-05 to 1.9336E-05	1.9122E-05 to 1.9367E-05
fission	4.4574E-05	4.6982E-08	4.4527E-05 to 4.4621E-05	4.4480E-05 to 4.4668E-05	4.4450E-05 to 4.4698E-05
escape	4.0246E-06	2.8682E-08	3.9959E-06 to 4.0533E-06	3.9675E-06 to 4.0817E-06	3.9488E-06 to 4.1004E-06

Average individual and combined collision/absorption/track-length keff results for 15 different batch sizes

cycles per keff batch	number of k batches	average keff estimators and deviations k(coll)	st dev	k(abs)	st dev	k(trk)	st dev	normality co/ab/trk	average k(c/a/t)	k(c/a/t) st dev	k(c/a/t) confidence intervals 95% confidence	99% confidence
1	180	0.9918	0.0014	0.9917	0.0010	0.9917	0.0014	99/95/no	0.99174	0.00099	0.98978-0.99370	0.98913-0.99434
2	90	0.9918	0.0016	0.9917	0.0011	0.9917	0.0017	95/95/95	0.99175	0.00112	0.98951-0.99399	0.98878-0.99472
3	60	0.9918	0.0015	0.9917	0.0012	0.9917	0.0016	95/95/95	0.99179	0.00116	0.98948-0.99411	0.98871-0.99487
4	45	0.9918	0.0017	0.9917	0.0011	0.9917	0.0017	95/95/95	0.99192	0.00110	0.98970-0.99414	0.98895-0.99489
5	36	0.9918	0.0015	0.9917	0.0011	0.9917	0.0016	95/95/95	0.99195	0.00108	0.98976-0.99415	0.98901-0.99490
6	30	0.9918	0.0016	0.9917	0.0012	0.9917	0.0017	95/95/95	0.99183	0.00120	0.98937-0.99429	0.98851-0.99515
9	20	0.9918	0.0015	0.9917	0.0010	0.9917	0.0016	95/95/95	0.99191	0.00111	0.98957-0.99426	0.98869-0.99514
10	18	0.9918	0.0013	0.9917	0.0010	0.9917	0.0013	95/95/95	0.99208	0.00101	0.98993-0.99423	0.98911-0.99505
12	15	0.9918	0.0013	0.9917	0.0010	0.9917	0.0014	95/95/95	0.99220	0.00092	0.99020-0.99421	0.98939-0.99502
15	12	0.9918	0.0010	0.9917	0.0009	0.9917	0.0011	95/95/95	0.99207	0.00090	0.99003-0.99411	0.98914-0.99500
18	10	0.9918	0.0012	0.9917	0.0008	0.9917	0.0013	95/95/95	0.99235	0.00077	0.99052-0.99418	0.98964-0.99506
20	9	0.9918	0.0011	0.9917	0.0012	0.9917	0.0012	95/95/95	0.99300	0.00085	0.99091-0.99509	0.98984-0.99616
30	6	0.9918	0.0009	0.9917	0.0007	0.9917	0.0009	95/95/95	0.99268	0.00056	0.99090-0.99447	0.98941-0.99596
36	5	0.9918	0.0014	0.9917	0.0007	0.9917	0.0015	95/95/95	0.99275	0.00099	0.98850-0.99700	0.98296 1.00255
45	4	0.9918	0.0007	0.9917	0.0007	0.9917	0.0009	95/95/95	0.99234	0.00046	0.98652-0.99815	0.96322-1.02145

Individual and average keff estimator results by cycle

keff cycle	neutron histories	keff estimators by cycle k(coll)	k(abs)	k(track)	average keff estimators and deviations k(coll)	st dev	k(abs)	st dev	k(track)	st dev	average k(c/a/t) k(c/a/t)	st dev	fom
1	4000	1.31684	1.31555	1.31284									
2	5154	1.19080	1.17579	1.19163									
3	3544	1.07936	1.07233	1.08157									
4	3588	1.05022	1.04039	1.04842									
5	3806	1.02653	1.01003	1.02561									
6	3901	0.96708	0.99249	0.96440									

7	3736	1.00533	1.00121	1.00746								
8	4180	0.97895	0.99175	0.97592								
9	3880	0.96767	0.99637	0.96679								
10	3983	1.00495	0.98642	1.00812								
11	4081	0.98721	1.02286	0.98609								
12	4095	0.98070	0.99217	0.98474								
13	3968	0.95897	0.99200	0.95683								
14	3994	1.01244	1.03231	1.01132								
15	4259	0.98142	1.00019	0.98173								
16	3945	0.99761	0.99423	1.00288								
17	3996	0.96113	0.95484	0.95418								
18	3915	0.99207	0.98577	0.99508								
19	4167	1.01048	1.01187	1.01020								
20	4122	0.97042	0.98169	0.96549								
		begin active keff cycles										
21	3856	1.02197	1.02279	1.02002								
22	4144	0.98883	1.00474	0.98689	1.00540	0.01657	1.01377	0.00902	1.00346	0.01657		
23	3777	0.99799	0.98353	0.99681	1.00293	0.00988	1.00369	0.01135	1.00124	0.00982		
24	4095	0.97268	0.99028	0.97297	0.99537	0.01030	1.00033	0.00870	0.99417	0.00991	0.98298	0.01795 8208
25	3818	1.02071	0.97949	1.02273	1.00044	0.00945	0.99616	0.00792	0.99988	0.00957	0.99267	0.00897 26893
26	4089	0.99706	1.01843	1.00442	0.99987	0.00774	0.99988	0.00746	1.00064	0.00785	0.99954	0.00761 31477
27	3853	1.00776	0.98584	1.00833	1.00100	0.00663	0.99787	0.00661	1.00174	0.00672	0.99909	0.00624 40243
28	3977	1.01835	0.99710	1.02272	1.00317	0.00614	0.99777	0.00573	1.00436	0.00638	0.99942	0.00559 43770
29	4092	0.97547	0.97392	0.97958	1.00009	0.00623	0.99512	0.00571	1.00161	0.00627	0.99754	0.00634 30086
30	3930	0.97646	0.99248	0.97654	0.99773	0.00605	0.99486	0.00511	0.99910	0.00614	0.99592	0.00558 34832
31	4033	0.99916	1.00677	0.99897	0.99786	0.00548	0.99594	0.00475	0.99909	0.00556	0.99683	0.00497 39983
32	4160	1.00364	0.99880	1.00417	0.99834	0.00502	0.99618	0.00434	0.99951	0.00509	0.99719	0.00450 44454
33	3975	1.02524	1.00292	1.02168	1.00041	0.00506	0.99670	0.00403	1.00122	0.00498	0.99853	0.00413 48752
34	4096	0.99826	0.99286	0.99961	1.00026	0.00469	0.99642	0.00374	1.00110	0.00461	0.99834	0.00384 52302
35	3875	0.98933	0.98058	0.98889	0.99953	0.00443	0.99537	0.00364	1.00029	0.00437	0.99727	0.00373 51677
36	3910	1.00502	0.98657	1.00828	0.99987	0.00415	0.99482	0.00345	1.00079	0.00412	0.99721	0.00357 53019
37	4076	0.97894	0.99759	0.97671	0.99864	0.00409	0.99498	0.00324	0.99937	0.00412	0.99651	0.00323 60895
38	3893	0.97589	0.97995	0.97535	0.99738	0.00406	0.99415	0.00317	0.99804	0.00411	0.99531	0.00320 58381
39	3995	0.97988	0.98223	0.97370	0.99646	0.00395	0.99352	0.00306	0.99676	0.00409	0.99432	0.00304 61513
40	4039	0.96936	0.97255	0.97009	0.99510	0.00398	0.99247	0.00309	0.99542	0.00410	0.99312	0.00312 55250
41	3968	0.98350	0.96168	0.98114	0.99455	0.00383	0.99100	0.00328	0.99474	0.00396	0.99216	0.00321 49540
42	4179	1.01196	1.00366	1.01217	0.99534	0.00374	0.99158	0.00318	0.99554	0.00386	0.99277	0.00315 49218
43	4154	0.98247	0.99914	0.98319	0.99478	0.00361	0.99191	0.00306	0.99500	0.00373	0.99277	0.00297 52797
44	3924	0.97867	0.96896	0.97681	0.99411	0.00352	0.99095	0.00308	0.99424	0.00365	0.99201	0.00297 50728
45	3972	1.01989	1.00945	1.02060	0.99514	0.00353	0.99169	0.00305	0.99529	0.00365	0.99275	0.00299 48089
46	4051	0.99300	1.00379	0.99489	0.99506	0.00340	0.99216	0.00296	0.99528	0.00351	0.99298	0.00286 50431
47	3869	0.99670	0.98609	0.99920	0.99512	0.00327	0.99193	0.00286	0.99542	0.00338	0.99282	0.00277 51644
48	3881	0.97656	1.00586	0.97085	0.99446	0.00322	0.99243	0.00280	0.99455	0.00338	0.99316	0.00263 55544
49	4000	0.99266	0.99490	0.99030	0.99439	0.00311	0.99251	0.00270	0.99440	0.00326	0.99325	0.00253 52798
50	4057	1.01946	1.00015	1.02021	0.99523	0.00312	0.99277	0.00262	0.99526	0.00326	0.99364	0.00250 57246
51	4179	1.00927	0.97815	1.01492	0.99568	0.00305	0.99230	0.00258	0.99589	0.00322	0.99347	0.00245 57573
52	3937	0.99859	1.00284	0.99676	0.99577	0.00295	0.99263	0.00252	0.99592	0.00312	0.99377	0.00238 59111
53	4041	1.02461	1.00805	1.02502	0.99665	0.00299	0.99309	0.00249	0.99680	0.00315	0.99429	0.00241 56139
54	4113	0.98860	0.99344	0.99011	0.99641	0.00291	0.99310	0.00241	0.99661	0.00306	0.99418	0.00233 58121
55	3901	1.00506	0.99671	1.00708	0.99666	0.00284	0.99321	0.00235	0.99691	0.00299	0.99430	0.00227 59492
56	4097	0.98856	0.99201	0.99211	0.99643	0.00277	0.99317	0.00228	0.99677	0.00291	0.99415	0.00221 60998
57	3827	0.97035	0.99648	0.96760	0.99573	0.00278	0.99326	0.00222	0.99598	0.00293	0.99396	0.00213 63986
58	3984	0.96315	0.98240	0.96076	0.99487	0.00284	0.99298	0.00218	0.99506	0.00300	0.99344	0.00211 63606
59	3995	1.00292	0.99156	1.00299	0.99508	0.00277	0.99294	0.00212	0.99526	0.00293	0.99348	0.00205 65167

60	4235	1.01701	1.00132	1.01646	0.99562	0.00276	0.99315	0.00208	0.99579	0.00291	0.99376	0.00203	64801
61	4060	1.01442	1.01335	1.01523	0.99608	0.00273	0.99364	0.00209	0.99626	0.00287	0.99424	0.00204	62671
62	3986	0.99097	1.00654	0.99415	0.99596	0.00267	0.99395	0.00206	0.99621	0.00281	0.99439	0.00199	64251
63	3941	0.96970	0.98081	0.96697	0.99535	0.00267	0.99383	0.00201	0.99553	0.00282	0.99414	0.00195	65646
64	3927	0.97621	0.96273	0.98004	0.99492	0.00265	0.99312	0.00209	0.99518	0.00278	0.99356	0.00203	59051
65	4085	0.94458	0.99684	0.94391	0.99380	0.00282	0.99321	0.00205	0.99404	0.00295	0.99327	0.00199	60062
66	3906	0.99675	0.97908	0.99695	0.99386	0.00276	0.99290	0.00202	0.99411	0.00288	0.99307	0.00196	60693
67	4261	1.00815	1.00241	1.00520	0.99417	0.00272	0.99310	0.00199	0.99434	0.00283	0.99333	0.00193	61144
68	4017	0.98688	0.98423	0.98991	0.99401	0.00266	0.99292	0.00196	0.99425	0.00277	0.99316	0.00190	61686
69	3781	0.98913	0.99318	0.98972	0.99391	0.00261	0.99292	0.00192	0.99416	0.00272	0.99314	0.00186	63106
70	3936	0.98976	0.98388	0.98805	0.99383	0.00256	0.99274	0.00189	0.99404	0.00266	0.99298	0.00183	64127
71	3998	0.96822	1.00138	0.96410	0.99333	0.00256	0.99291	0.00186	0.99345	0.00268	0.99300	0.00179	65921
72	3958	0.97219	0.96233	0.96986	0.99292	0.00254	0.99232	0.00191	0.99299	0.00266	0.99246	0.00183	61548
73	4056	0.98083	0.99560	0.97634	0.99269	0.00250	0.99239	0.00188	0.99268	0.00263	0.99248	0.00179	62872
74	4195	0.98263	0.99273	0.98474	0.99251	0.00246	0.99239	0.00184	0.99253	0.00259	0.99241	0.00176	64011
75	3993	0.99219	0.98631	0.99350	0.99250	0.00242	0.99228	0.00181	0.99255	0.00254	0.99233	0.00173	65069
76	4028	0.97428	0.96231	0.97336	0.99218	0.00240	0.99175	0.00186	0.99221	0.00252	0.99186	0.00176	61450
77	3912	1.00588	0.98791	1.00207	0.99242	0.00237	0.99168	0.00183	0.99238	0.00248	0.99192	0.00173	62446
78	4161	1.01054	1.01064	1.01400	0.99273	0.00235	0.99201	0.00183	0.99275	0.00246	0.99221	0.00173	61753
79	4016	0.98350	1.00311	0.97877	0.99257	0.00231	0.99219	0.00180	0.99252	0.00243	0.99234	0.00170	62578
80	3711	1.00214	0.98767	1.00409	0.99273	0.00228	0.99212	0.00178	0.99271	0.00240	0.99232	0.00167	63726
81	4145	1.01610	0.98661	1.01403	0.99312	0.00227	0.99203	0.00175	0.99306	0.00239	0.99239	0.00165	64419
82	4028	1.01238	1.00787	1.01272	0.99343	0.00226	0.99228	0.00174	0.99338	0.00237	0.99265	0.00165	63704
83	3894	0.96985	0.99917	0.97155	0.99305	0.00225	0.99239	0.00171	0.99303	0.00236	0.99260	0.00162	65021
84	3865	0.95469	0.98523	0.95883	0.99245	0.00230	0.99228	0.00169	0.99250	0.00238	0.99231	0.00162	64274
85	3872	1.00126	1.00258	0.99983	0.99259	0.00227	0.99244	0.00167	0.99261	0.00235	0.99247	0.00160	64720
86	4199	1.01193	0.97296	1.00762	0.99288	0.00225	0.99214	0.00167	0.99284	0.00232	0.99237	0.00158	65194
87	3972	0.99678	1.01060	0.99583	0.99294	0.00222	0.99242	0.00167	0.99288	0.00229	0.99259	0.00157	64977
88	3951	0.97512	0.97264	0.97324	0.99268	0.00220	0.99213	0.00167	0.99259	0.00227	0.99232	0.00157	63891
89	3934	0.97520	0.99258	0.97662	0.99242	0.00218	0.99214	0.00165	0.99236	0.00225	0.99224	0.00155	64803
90	4036	1.00028	1.00670	0.99619	0.99254	0.00215	0.99234	0.00164	0.99242	0.00222	0.99243	0.00154	64589
91	3980	0.99757	1.00120	0.99710	0.99261	0.00213	0.99247	0.00162	0.99248	0.00219	0.99254	0.00152	65217
92	3955	1.01041	1.01595	1.01052	0.99285	0.00211	0.99279	0.00163	0.99273	0.00217	0.99284	0.00153	63566
93	4156	0.99231	0.98778	0.99169	0.99285	0.00208	0.99273	0.00161	0.99272	0.00214	0.99280	0.00151	64365
94	3940	1.00113	0.97970	0.99991	0.99296	0.00206	0.99255	0.00160	0.99281	0.00212	0.99271	0.00149	64983
95	4075	0.99866	0.98137	0.99988	0.99303	0.00203	0.99240	0.00158	0.99291	0.00209	0.99263	0.00148	65629
96	3965	0.98489	0.97980	0.98911	0.99293	0.00201	0.99223	0.00157	0.99286	0.00206	0.99246	0.00146	65806
97	3955	0.97078	0.97335	0.97109	0.99264	0.00200	0.99199	0.00157	0.99258	0.00205	0.99220	0.00147	64574
98	3928	0.99371	0.99383	0.99561	0.99265	0.00197	0.99201	0.00155	0.99261	0.00203	0.99222	0.00145	65473
99	4133	0.99690	1.01156	0.99401	0.99271	0.00195	0.99226	0.00155	0.99263	0.00200	0.99241	0.00144	65149
100	4097	0.99402	0.97155	0.99283	0.99272	0.00193	0.99200	0.00155	0.99264	0.00198	0.99225	0.00144	64915
101	4048	0.99886	0.99099	1.00584	0.99280	0.00190	0.99199	0.00153	0.99280	0.00196	0.99226	0.00142	65809
102	4138	1.01605	1.00026	1.01476	0.99308	0.00190	0.99209	0.00152	0.99307	0.00195	0.99241	0.00141	65649
103	4034	0.98570	1.00719	0.98430	0.99299	0.00188	0.99227	0.00151	0.99296	0.00193	0.99251	0.00140	66271
104	3842	1.01499	0.99846	1.01510	0.99326	0.00188	0.99235	0.00149	0.99322	0.00193	0.99264	0.00139	66418
105	4111	0.98638	1.00198	0.99020	0.99318	0.00186	0.99246	0.00148	0.99319	0.00191	0.99269	0.00137	67239
106	3943	1.01858	0.98458	1.01414	0.99347	0.00186	0.99237	0.00146	0.99343	0.00190	0.99272	0.00136	67837
107	4159	0.95457	0.98634	0.95036	0.99302	0.00189	0.99230	0.00145	0.99294	0.00194	0.99253	0.00135	67481
108	3571	0.95943	0.97465	0.95608	0.99264	0.00191	0.99210	0.00145	0.99252	0.00196	0.99229	0.00136	66028
109	3948	0.98631	0.98829	0.98903	0.99257	0.00189	0.99205	0.00143	0.99248	0.00194	0.99223	0.00134	66745
110	4006	0.97962	0.99257	0.97595	0.99243	0.00187	0.99206	0.00141	0.99230	0.00193	0.99220	0.00133	67447
111	3918	1.00140	0.98324	1.00048	0.99253	0.00185	0.99196	0.00140	0.99239	0.00191	0.99216	0.00132	68094

112	4093	0.99058	0.99422	0.99729	0.99250	0.00183	0.99198	0.00139	0.99244	0.00189	0.99215	0.00130	69015
113	4094	1.01551	1.00436	1.01528	0.99275	0.00183	0.99211	0.00138	0.99268	0.00189	0.99231	0.00130	68565
114	4017	1.00292	0.99972	1.00809	0.99286	0.00181	0.99187	0.00138	0.99285	0.00187	0.99217	0.00129	68279
115	4041	1.01297	0.99881	1.01029	0.99307	0.00181	0.99194	0.00137	0.99303	0.00186	0.99228	0.00129	68340
116	4126	1.02582	1.02250	1.02659	0.99341	0.00182	0.99226	0.00139	0.99338	0.00188	0.99260	0.00131	64770
117	4051	1.00527	1.01759	1.00145	0.99353	0.00181	0.99252	0.00140	0.99346	0.00186	0.99283	0.00132	61555
118	3992	1.01909	1.01225	1.01966	0.99380	0.00181	0.99273	0.00140	0.99373	0.00186	0.99304	0.00132	62453
119	4009	0.97614	1.00012	0.97733	0.99362	0.00180	0.99280	0.00139	0.99357	0.00185	0.99304	0.00131	63238
120	3760	0.97443	1.01620	0.97465	0.99343	0.00179	0.99303	0.00140	0.99338	0.00184	0.99316	0.00130	63641
121	4018	0.95838	0.97498	0.95185	0.99308	0.00180	0.99286	0.00140	0.99297	0.00187	0.99295	0.00131	62368
122	3844	1.00041	0.95410	1.00350	0.99315	0.00179	0.99248	0.00143	0.99307	0.00185	0.99271	0.00132	60745
123	4076	0.95612	0.98054	0.95895	0.99279	0.00181	0.99236	0.00142	0.99274	0.00186	0.99250	0.00132	60000
124	3872	0.97896	0.98779	0.97830	0.99266	0.00179	0.99232	0.00141	0.99260	0.00185	0.99243	0.00131	60438
125	4048	1.00649	0.98333	1.00527	0.99279	0.00178	0.99223	0.00140	0.99272	0.00184	0.99241	0.00129	60962
126	4041	0.97169	1.00203	0.96963	0.99259	0.00178	0.99232	0.00139	0.99250	0.00183	0.99242	0.00128	61593
127	3909	0.99351	0.99984	0.99682	0.99260	0.00176	0.99239	0.00138	0.99254	0.00181	0.99247	0.00127	62169
128	4079	1.01567	1.00649	1.01925	0.99281	0.00176	0.99252	0.00137	0.99279	0.00181	0.99262	0.00127	61860
129	3995	0.98632	0.98650	0.98730	0.99275	0.00174	0.99247	0.00136	0.99274	0.00180	0.99256	0.00126	62311
130	3856	1.00694	0.99550	1.00648	0.99288	0.00173	0.99250	0.00135	0.99286	0.00179	0.99262	0.00125	62760
131	4030	0.97268	0.99285	0.97162	0.99270	0.00172	0.99250	0.00134	0.99267	0.00178	0.99257	0.00124	63249
132	3920	0.99538	0.98854	0.99469	0.99272	0.00171	0.99246	0.00132	0.99269	0.00176	0.99255	0.00123	63812
133	4106	0.96126	0.97897	0.96155	0.99245	0.00172	0.99234	0.00132	0.99241	0.00177	0.99238	0.00123	63157
134	3766	1.00257	0.99419	1.00086	0.99253	0.00170	0.99236	0.00131	0.99249	0.00176	0.99242	0.00122	63679
135	4129	0.97728	0.99099	0.97258	0.99240	0.00169	0.99235	0.00130	0.99232	0.00175	0.99238	0.00121	64124
136	3877	0.99697	0.97186	1.00100	0.99244	0.00168	0.99217	0.00130	0.99239	0.00174	0.99226	0.00120	64096
137	4169	0.99824	0.98690	0.99851	0.99249	0.00167	0.99213	0.00129	0.99244	0.00172	0.99224	0.00119	64615
138	4042	0.99467	0.99277	0.98783	0.99251	0.00165	0.99213	0.00127	0.99240	0.00171	0.99226	0.00118	65085
139	3997	0.98927	1.01105	0.99113	0.99248	0.00164	0.99229	0.00127	0.99239	0.00169	0.99236	0.00118	65245
140	3913	1.01781	1.01282	1.02037	0.99269	0.00164	0.99246	0.00127	0.99263	0.00170	0.99255	0.00118	64297
141	4103	0.98357	0.99476	0.97659	0.99262	0.00163	0.99248	0.00126	0.99249	0.00169	0.99255	0.00117	64760
142	3873	0.97311	0.98760	0.97381	0.99246	0.00162	0.99244	0.00125	0.99234	0.00168	0.99247	0.00116	65041
143	3966	1.01086	0.99832	1.01514	0.99261	0.00161	0.99249	0.00125	0.99253	0.00168	0.99254	0.00116	65382
144	4073	0.98391	0.98274	0.98538	0.99254	0.00160	0.99241	0.00124	0.99247	0.00166	0.99246	0.00115	65611
145	3912	1.02136	0.99391	1.02010	0.99277	0.00161	0.99242	0.00123	0.99269	0.00166	0.99254	0.00114	65796
146	4173	0.99207	1.00361	0.99074	0.99276	0.00159	0.99251	0.00122	0.99267	0.00165	0.99260	0.00114	66114
147	3860	0.99966	0.97782	1.00124	0.99282	0.00158	0.99240	0.00122	0.99274	0.00164	0.99254	0.00113	66411
148	4020	1.02493	0.98300	1.02283	0.99307	0.00159	0.99232	0.00121	0.99298	0.00164	0.99256	0.00112	66784
149	4112	1.00100	1.00344	1.00045	0.99313	0.00158	0.99241	0.00120	0.99303	0.00163	0.99264	0.00111	66962
150	3887	1.00064	0.98767	1.00185	0.99319	0.00157	0.99237	0.00119	0.99310	0.00162	0.99263	0.00111	67482
151	4057	0.97566	0.96708	0.97420	0.99305	0.00156	0.99218	0.00120	0.99296	0.00162	0.99247	0.00111	66267
152	3855	0.97922	0.98350	0.97882	0.99295	0.00155	0.99211	0.00119	0.99285	0.00161	0.99239	0.00111	66472
153	4111	0.97849	1.01454	0.98234	0.99284	0.00154	0.99228	0.00120	0.99277	0.00160	0.99247	0.00110	66809
154	4086	0.95237	0.99392	0.95239	0.99254	0.00156	0.99229	0.00119	0.99247	0.00161	0.99238	0.00109	66958
155	3932	0.95027	0.98277	0.94849	0.99222	0.00158	0.99222	0.00118	0.99214	0.00163	0.99224	0.00109	66366
156	3932	0.95559	0.96631	0.95472	0.99195	0.00159	0.99203	0.00119	0.99187	0.00164	0.99203	0.00111	64370
157	3959	0.98663	0.98111	0.99021	0.99192	0.00158	0.99195	0.00118	0.99186	0.00163	0.99196	0.00110	64578
158	4217	0.99335	0.96954	0.99241	0.99193	0.00157	0.99179	0.00118	0.99186	0.00162	0.99185	0.00110	64337
159	4017	1.02932	1.01232	1.02758	0.99220	0.00158	0.99194	0.00119	0.99212	0.00163	0.99203	0.00111	62952
160	4118	1.01019	0.99126	1.00939	0.99232	0.00158	0.99193	0.00118	0.99224	0.00162	0.99206	0.00110	63310
161	3944	1.02429	1.03016	1.02295	0.99255	0.00158	0.99220	0.00120	0.99246	0.00163	0.99232	0.00112	60319
162	4009	1.02970	1.01109	1.02269	0.99281	0.00159	0.99234	0.00120	0.99267	0.00163	0.99247	0.00113	59206
163	4080	0.98848	1.00889	0.99449	0.99278	0.00158	0.99245	0.00120	0.99269	0.00162	0.99255	0.00112	59483
164	3850	0.96746	0.97784	0.96999	0.99261	0.00158	0.99235	0.00119	0.99253	0.00161	0.99242	0.00112	59214

165	3962	0.97852	0.98782	0.97802	0.99251	0.00157	0.99232	0.00118	0.99243	0.00161	0.99237	0.00112	59518
166	4045	0.98904	0.97173	0.98724	0.99249	0.00156	0.99218	0.00118	0.99239	0.00159	0.99227	0.00111	59318
167	4048	0.98686	1.00553	0.98396	0.99245	0.00155	0.99227	0.00118	0.99233	0.00158	0.99232	0.00111	59565
168	3994	0.97400	0.99085	0.97455	0.99232	0.00155	0.99226	0.00117	0.99221	0.00158	0.99228	0.00110	59903
169	3861	0.96574	0.98469	0.96611	0.99214	0.00155	0.99221	0.00116	0.99204	0.00158	0.99219	0.00110	59955
170	3870	1.00407	1.00100	1.00529	0.99222	0.00154	0.99227	0.00116	0.99213	0.00157	0.99226	0.00109	60183
171	4182	1.02040	1.01347	1.01406	0.99241	0.00154	0.99241	0.00116	0.99227	0.00157	0.99240	0.00109	59333
172	4165	0.98412	0.98763	0.98467	0.99236	0.00153	0.99238	0.00115	0.99222	0.00156	0.99236	0.00109	59655
173	3849	0.96863	0.98317	0.96837	0.99220	0.00153	0.99232	0.00115	0.99207	0.00155	0.99227	0.00108	59683
174	4018	0.97574	0.99541	0.97546	0.99209	0.00152	0.99234	0.00114	0.99196	0.00155	0.99226	0.00108	60062
175	4031	0.97544	1.00485	0.96985	0.99199	0.00152	0.99242	0.00113	0.99182	0.00154	0.99228	0.00107	60335
176	3981	0.99416	0.99970	0.99792	0.99200	0.00151	0.99246	0.00113	0.99186	0.00153	0.99233	0.00106	60701
177	4137	1.01999	1.01105	1.02722	0.99218	0.00151	0.99258	0.00113	0.99208	0.00154	0.99248	0.00107	60175
178	4139	1.02068	0.99067	1.02462	0.99236	0.00151	0.99257	0.00112	0.99229	0.00155	0.99252	0.00106	60517
179	3956	0.96890	0.96977	0.96640	0.99221	0.00151	0.99243	0.00112	0.99212	0.00154	0.99238	0.00106	59756
180	3827	0.98905	0.98469	0.99031	0.99219	0.00150	0.99238	0.00112	0.99211	0.00153	0.99234	0.00106	60070
181	4138	0.98155	0.97390	0.97660	0.99213	0.00149	0.99226	0.00111	0.99202	0.00153	0.99224	0.00106	59862
182	3968	1.02588	0.99283	1.02693	0.99233	0.00149	0.99227	0.00111	0.99223	0.00153	0.99230	0.00105	60075
183	4203	1.01151	0.99531	1.01021	0.99245	0.00149	0.99229	0.00110	0.99234	0.00153	0.99234	0.00104	60303
184	4004	1.00207	0.99510	0.99460	0.99251	0.00148	0.99231	0.00109	0.99236	0.00152	0.99237	0.00104	60536
185	3950	0.97327	0.99625	0.97219	0.99239	0.00148	0.99233	0.00109	0.99223	0.00151	0.99236	0.00103	60910
186	3891	0.98452	0.99252	0.98141	0.99235	0.00147	0.99233	0.00108	0.99217	0.00151	0.99235	0.00103	61247
187	4093	0.98064	0.98533	0.97628	0.99228	0.00146	0.99229	0.00108	0.99207	0.00150	0.99231	0.00102	61419
188	3955	1.00041	0.99342	1.00345	0.99232	0.00145	0.99230	0.00107	0.99214	0.00149	0.99233	0.00102	61837
189	4136	0.98632	0.98295	0.98784	0.99229	0.00145	0.99224	0.00106	0.99212	0.00149	0.99227	0.00101	62055
190	3908	0.99864	0.98236	1.00305	0.99233	0.00144	0.99218	0.00106	0.99218	0.00148	0.99223	0.00101	62403
191	4015	1.01059	1.00814	1.01284	0.99243	0.00143	0.99228	0.00106	0.99230	0.00147	0.99233	0.00100	62237
192	4041	0.97771	0.99074	0.97481	0.99235	0.00143	0.99227	0.00105	0.99220	0.00147	0.99231	0.00100	62534
193	3880	0.98150	0.99807	0.98183	0.99228	0.00142	0.99230	0.00105	0.99214	0.00146	0.99232	0.00099	62923
194	4062	0.97559	0.97355	0.97686	0.99219	0.00142	0.99219	0.00105	0.99205	0.00146	0.99221	0.00099	62567
195	3921	0.96313	0.97105	0.96301	0.99202	0.00142	0.99207	0.00105	0.99189	0.00146	0.99207	0.00100	61808
196	3911	0.97440	0.96846	0.97215	0.99192	0.00141	0.99194	0.00105	0.99177	0.00145	0.99196	0.00100	61164
197	3966	0.97112	0.97203	0.97442	0.99180	0.00141	0.99182	0.00105	0.99168	0.00145	0.99183	0.00100	60705
198	4011	0.98508	0.98102	0.98755	0.99177	0.00140	0.99176	0.00105	0.99165	0.00144	0.99177	0.00099	60875
199	4110	0.97590	0.98450	0.97410	0.99168	0.00140	0.99172	0.00104	0.99155	0.00144	0.99172	0.00099	61020
200	3926	1.02164	0.98521	1.01544	0.99184	0.00140	0.99169	0.00104	0.99169	0.00143	0.99174	0.00099	61273

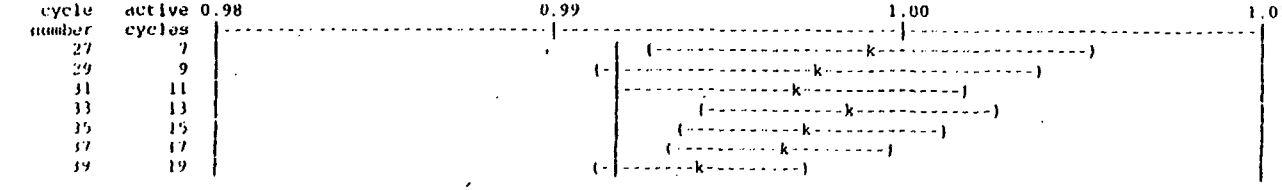
the largest active cycle keffs by estimator are:

collision 1.02970 on cycle 162
absorption 1.03016 on cycle 161
track length 1.02758 on cycle 159

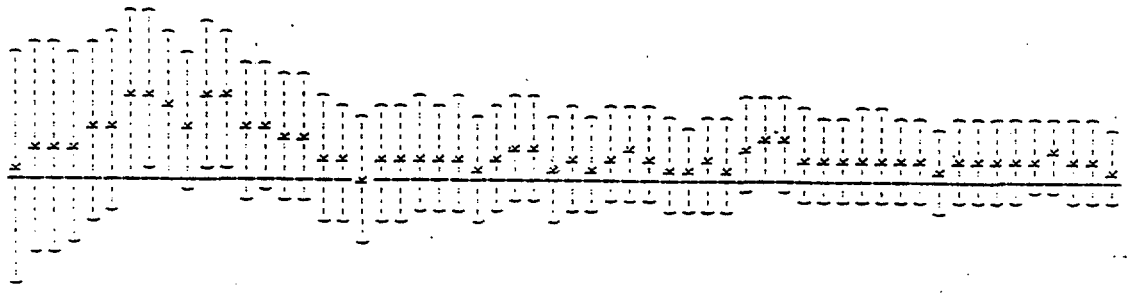
the smallest active cycle keffs by estimator are:

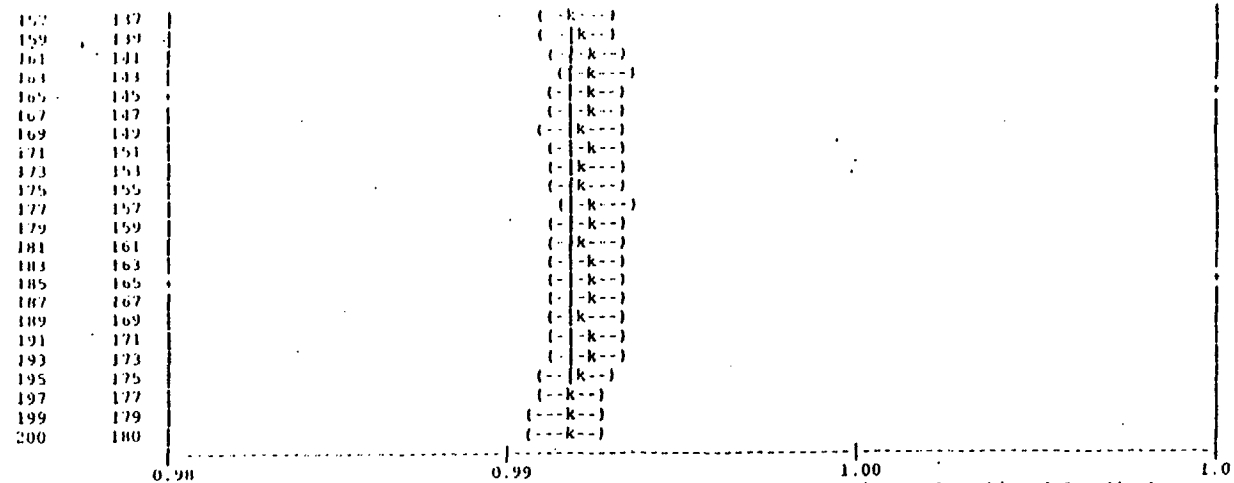
collision 0.94458 on cycle 65
absorption 0.95410 on cycle 122
track length 0.94391 on cycle 65

Iplot of the estimated col/abs/track-length keff one standard deviation interval versus cycle number (| = final keff = 0.99174)



WVNS-NCSE-001
REV. 0





Individual and collision/absorption/track-length keffs for different numbers of inactive cycles skipped for fission source settling

skip cycles	active cycles	active neutrons	average keff estimators and deviations k(col)	st dev	k(abs)	st dev	k(trk)	st dev	normality co/ab/tl	average k(c/a/t) k(c/a/t)	st dev	k(c/a/t) confidence intervals 95% confidence	99% confidence
0	200	800203	0.9949	0.0024	0.9954	0.0022	0.9947	0.0024	no/no/no	0.99521	0.00216	0.99091-0.99951	0.98950-1.00092
1	199	796202	0.9942	0.0017	0.9938	0.0014	0.9931	0.0018	no/no/no	0.99371	0.00143	0.99086-0.99657	0.98993-0.99750
2	198	791048	0.9922	0.0014	0.9928	0.0011	0.9921	0.0015	95/no/95	0.99274	0.00108	0.99058-0.99490	0.98987-0.99560
3	197	787504	0.9918	0.0014	0.9924	0.0011	0.9916	0.0014	95/95/99	0.99230	0.00101	0.99030-0.99431	0.98964-0.99497
4	196	783916	0.9915	0.0013	0.9922	0.0010	0.9913	0.0014	no/95/no	0.99205	0.00098	0.99010-0.99399	0.98946-0.99463
5	195	780030	0.9913	0.0013	0.9920	0.0010	0.9912	0.0014	no/95/no	0.99186	0.00096	0.98994-0.99378	0.98931-0.99440
6	194	776129	0.9915	0.0013	0.9920	0.0010	0.9913	0.0014	no/95/no	0.99189	0.00097	0.98996-0.99381	0.98933-0.99444
7	193	772393	0.9914	0.0013	0.9919	0.0010	0.9912	0.0014	99/95/no	0.99183	0.00097	0.98990-0.99377	0.98927-0.99440
8	192	768213	0.9914	0.0014	0.9919	0.0010	0.9913	0.0014	no/95/no	0.99185	0.00098	0.98990-0.99379	0.98927-0.99442
9	191	764333	0.9916	0.0014	0.9919	0.0010	0.9914	0.0014	99/95/no	0.99186	0.00098	0.98991-0.99382	0.98927-0.99445
10	190	760350	0.9915	0.0014	0.9920	0.0010	0.9913	0.0014	99/95/no	0.99187	0.00099	0.98990-0.99383	0.98926-0.99447
11	189	756269	0.9915	0.0014	0.9918	0.0010	0.9914	0.0014	99/95/no	0.99176	0.00098	0.98980-0.99372	0.98916-0.99436
12	188	752174	0.9916	0.0014	0.9918	0.0010	0.9914	0.0014	99/95/no	0.99178	0.00099	0.98981-0.99375	0.98917-0.99440
13	187	748206	0.9918	0.0014	0.9918	0.0010	0.9916	0.0014	99/95/no	0.99182	0.00099	0.98984-0.99380	0.98920-0.99445
14	186	744212	0.9916	0.0014	0.9916	0.0010	0.9915	0.0014	99/95/no	0.99163	0.00098	0.98968-0.99359	0.98904-0.99422
15	185	739953	0.9917	0.0014	0.9915	0.0010	0.9915	0.0014	99/95/no	0.99161	0.00099	0.98965-0.99358	0.98901-0.99422
16	184	736008	0.9917	0.0014	0.9915	0.0010	0.9915	0.0014	99/95/no	0.99160	0.00099	0.98963-0.99358	0.98898-0.99422
17	183	732012	0.9918	0.0014	0.9917	0.0010	0.9917	0.0014	99/95/no	0.99176	0.00098	0.98981-0.99371	0.98917-0.99434
18	182	728097	0.9918	0.0014	0.9917	0.0010	0.9916	0.0014	99/95/no	0.99179	0.00098	0.98983-0.99375	0.98919-0.99439
19	181	723930	0.9917	0.0014	0.9916	0.0010	0.9915	0.0014	99/95/no	0.99168	0.00098	0.98972-0.99364	0.98908-0.99428
20	180*	719808	0.9918	0.0014	0.9917	0.0010	0.9917	0.0014	99/95/no	0.99174	0.00099	0.98978-0.99370	0.98913-0.99434
22	178	711808	0.9917	0.0014	0.9914	0.0010	0.9916	0.0014	99/95/99	0.99152	0.00098	0.98957-0.99347	0.98893-0.99411
24	176	703936	0.9918	0.0014	0.9915	0.0010	0.9916	0.0015	99/95/no	0.99158	0.00099	0.98960-0.99355	0.98896-0.99419
26	174	696029	0.9916	0.0014	0.9914	0.0010	0.9914	0.0015	99/95/99	0.99145	0.00099	0.98947-0.99343	0.98882-0.99408
28	172	688199	0.9913	0.0014	0.9914	0.0010	0.9911	0.0015	99/95/99	0.99138	0.00101	0.98938-0.99338	0.98872-0.99404
30	170	680177	0.9915	0.0014	0.9915	0.0011	0.9913	0.0015	99/95/99	0.99151	0.00101	0.98949-0.99353	0.98883-0.99419

32	168	671984	0.9914	0.0015	0.9914	0.0011	0.9911	0.0015	99/95/99	0.99138	0.00102	0.98935-0.99341	0.98868-0.99407
34	166	663913	0.9911	0.0015	0.9913	0.0011	0.9909	0.0015	99/95/99	0.99127	0.00103	0.98922-0.99331	0.98855-0.99398
36	164	656638	0.9911	0.0015	0.9914	0.0011	0.9908	0.0015	99/95/99	0.99132	0.00104	0.98925-0.99339	0.98858-0.99407
38	162	648159	0.9912	0.0015	0.9914	0.0011	0.9910	0.0015	99/95/99	0.99139	0.00105	0.98930-0.99347	0.98862-0.99416
40	160	640125	0.9914	0.0015	0.9916	0.0011	0.9912	0.0015	99/95/99	0.99156	0.00105	0.98947-0.99366	0.98878-0.99434
42	158	631978	0.9914	0.0015	0.9917	0.0011	0.9912	0.0015	99/95/99	0.99162	0.00105	0.98953-0.99371	0.98885-0.99439
44	156	623900	0.9915	0.0015	0.9918	0.0011	0.9913	0.0016	99/95/99	0.99172	0.00105	0.98962-0.99382	0.98894-0.99451
46	154	615877	0.9913	0.0015	0.9916	0.0011	0.9911	0.0016	99/95/99	0.99152	0.00106	0.98941-0.99363	0.98873-0.99432
48	152	608127	0.9914	0.0015	0.9916	0.0011	0.9912	0.0016	99/95/99	0.99150	0.00107	0.98937-0.99363	0.98867-0.99433
50	150	600070	0.9912	0.0016	0.9915	0.0011	0.9910	0.0016	99/95/99	0.99139	0.00108	0.98924-0.99355	0.98854-0.99425
52	148	591954	0.9910	0.0016	0.9915	0.0011	0.9908	0.0016	99/95/99	0.99137	0.00109	0.98919-0.99355	0.98848-0.99426
54	146	583800	0.9908	0.0016	0.9914	0.0011	0.9905	0.0016	99/95/99	0.99122	0.00110	0.98903-0.99341	0.98831-0.99412
56	144	575802	0.9907	0.0016	0.9913	0.0012	0.9904	0.0016	99/95/99	0.99116	0.00112	0.98894-0.99338	0.98821-0.99411
58	142	567991	0.9910	0.0016	0.9913	0.0012	0.9908	0.0016	99/95/99	0.99126	0.00113	0.98901-0.99350	0.98828-0.99423
60	140	559761	0.9908	0.0016	0.9913	0.0012	0.9905	0.0016	95/95/99	0.99113	0.00114	0.98887-0.99340	0.98813-0.99414
62	138	551715	0.9906	0.0016	0.9910	0.0012	0.9903	0.0017	95/95/99	0.99087	0.00114	0.98860-0.99314	0.98786-0.99388
64	136	543857	0.9909	0.0016	0.9912	0.0012	0.9906	0.0017	95/95/95	0.99113	0.00114	0.98885-0.99340	0.98811-0.99414
66	134	535866	0.9912	0.0016	0.9913	0.0012	0.9909	0.0017	99/95/99	0.99124	0.00116	0.98894-0.99354	0.98819-0.99429
68	132	527586	0.9911	0.0016	0.9912	0.0012	0.9908	0.0017	99/95/99	0.99120	0.00117	0.98888-0.99353	0.98812-0.99429
70	130	519869	0.9911	0.0017	0.9913	0.0012	0.9908	0.0017	99/95/99	0.99124	0.00118	0.98888-0.99360	0.98811-0.99437
72	128	511913	0.9914	0.0017	0.9914	0.0012	0.9912	0.0017	99/95/99	0.99142	0.00118	0.98906-0.99378	0.98829-0.99455
74	126	503662	0.9916	0.0017	0.9914	0.0013	0.9913	0.0017	99/95/99	0.99143	0.00120	0.98903-0.99382	0.98825-0.99460
76	124	495641	0.9917	0.0017	0.9917	0.0013	0.9915	0.0017	99/95/99	0.99166	0.00120	0.98927-0.99406	0.98849-0.99484
78	122	487568	0.9914	0.0017	0.9915	0.0013	0.9912	0.0018	99/95/99	0.99149	0.00121	0.98907-0.99390	0.98829-0.99469
80	120	479841	0.9914	0.0018	0.9915	0.0013	0.9912	0.0018	99/95/99	0.99144	0.00123	0.98899-0.99389	0.98819-0.99469
82	118	471668	0.9910	0.0018	0.9914	0.0013	0.9908	0.0018	99/95/99	0.99127	0.00124	0.98880-0.99375	0.98799-0.99456
84	116	463910	0.9915	0.0018	0.9914	0.0013	0.9912	0.0018	95/95/99	0.99139	0.00126	0.98888-0.99390	0.98807-0.99472
86	114	455839	0.9912	0.0018	0.9914	0.0013	0.9910	0.0018	95/95/99	0.99137	0.00127	0.98883-0.99391	0.98801-0.99474
88	112	447916	0.9913	0.0018	0.9914	0.0013	0.9911	0.0019	95/95/99	0.99139	0.00128	0.98884-0.99394	0.98801-0.99477
90	110	439946	0.9914	0.0018	0.9913	0.0013	0.9912	0.0019	95/95/99	0.99130	0.00129	0.98872-0.99388	0.98788-0.99472
92	108	432011	0.9912	0.0019	0.9909	0.0013	0.9910	0.0019	95/95/99	0.99100	0.00130	0.98841-0.99358	0.98757-0.99443
94	106	423915	0.9911	0.0019	0.9911	0.0014	0.9909	0.0019	95/95/99	0.99108	0.00132	0.98845-0.99371	0.98759-0.99457
96	104	415875	0.9911	0.0019	0.9913	0.0014	0.9908	0.0020	99/95/99	0.99124	0.00134	0.98857-0.99392	0.98770-0.99479
98	102	407992	0.9912	0.0020	0.9914	0.0014	0.9910	0.0020	99/95/99	0.99140	0.00136	0.98870-0.99410	0.98782-0.99499
100	100	399762	0.9911	0.0020	0.9914	0.0014	0.9909	0.0020	99/95/99	0.99139	0.00136	0.98867-0.99411	0.98779-0.99499
102	98	391576	0.9908	0.0020	0.9913	0.0014	0.9905	0.0021	95/95/99	0.99126	0.00139	0.98849-0.99402	0.98759-0.99493
104	96	383700	0.9906	0.0020	0.9911	0.0014	0.9903	0.0021	95/95/99	0.99103	0.00141	0.98822-0.99383	0.98731-0.99475
106	94	375646	0.9904	0.0021	0.9911	0.0015	0.9901	0.0021	95/95/99	0.99093	0.00144	0.98807-0.99379	0.98714-0.99473
108	92	367914	0.9911	0.0020	0.9913	0.0015	0.9909	0.0021	95/95/99	0.99124	0.00144	0.98836-0.99411	0.98743-0.99505
110	90	359960	0.9913	0.0021	0.9913	0.0015	0.9911	0.0021	95/95/99	0.99129	0.00147	0.98836-0.99423	0.98740-0.99519
112	88	351949	0.9912	0.0021	0.9914	0.0016	0.9909	0.0022	95/95/99	0.99132	0.00151	0.98831-0.99432	0.98733-0.99530
114	86	343838	0.9907	0.0022	0.9915	0.0016	0.9904	0.0022	95/95/95	0.99133	0.00153	0.98829-0.99438	0.98729-0.99537
116	84	335671	0.9901	0.0022	0.9910	0.0015	0.9898	0.0022	95/95/95	0.99082	0.00151	0.98781-0.99382	0.98682-0.99481
118	82	327728	0.9895	0.0022	0.9904	0.0015	0.9892	0.0022	95/95/95	0.99027	0.00149	0.98730-0.99323	0.98633-0.99420
120	80	319959	0.9899	0.0022	0.9900	0.0015	0.9896	0.0023	95/95/95	0.99000	0.00151	0.98699-0.99300	0.98601-0.99398
122	78	312097	0.9901	0.0022	0.9907	0.0015	0.9899	0.0023	95/95/95	0.99059	0.00148	0.98764-0.99354	0.98667-0.99451
124	76	304149	0.9907	0.0022	0.9908	0.0015	0.9904	0.0023	95/95/95	0.99084	0.00151	0.98783-0.99385	0.98685-0.99483
126	74	296060	0.9908	0.0023	0.9908	0.0015	0.9905	0.0023	95/95/95	0.99080	0.00155	0.98772-0.99389	0.98671-0.99490
128	72	288072	0.9904	0.0023	0.9904	0.0016	0.9900	0.0023	95/95/95	0.99042	0.00157	0.98728-0.99355	0.98625-0.99458
130	70	280221	0.9902	0.0024	0.9904	0.0016	0.9898	0.0024	95/95/95	0.99038	0.00161	0.98715-0.99360	0.98610-0.99466
132	68	272271	0.9904	0.0024	0.9904	0.0017	0.9900	0.0024	95/95/95	0.99040	0.00166	0.98708-0.99372	0.98599-0.99481
134	66	264399	0.9907	0.0024	0.9905	0.0017	0.9903	0.0025	95/95/95	0.99055	0.00170	0.98716-0.99394	0.98604-0.99505
136	64	256393	0.9908	0.0025	0.9908	0.0017	0.9904	0.0025	95/95/95	0.99083	0.00173	0.98737-0.99430	0.98623-0.99544

138	62	248202	0.9906	0.0026	0.9908	0.0018	0.9903	0.0026	95/95/95	0.99083	0.00178	0.98726-0.99440	0.98608-0.99558
140	60	240292	0.9901	0.0026	0.9901	0.0018	0.9898	0.0027	95/95/95	0.99012	0.00178	0.98655-0.99369	0.98537-0.99487
142	58	232316	0.9906	0.0027	0.9901	0.0018	0.9903	0.0027	95/95/95	0.99016	0.00184	0.98648-0.99385	0.98526-0.99507
144	56	224277	0.9903	0.0028	0.9901	0.0019	0.9900	0.0028	95/95/95	0.99010	0.00190	0.98629-0.99390	0.98502-0.99517
146	54	216192	0.9897	0.0028	0.9898	0.0019	0.9894	0.0028	95/95/95	0.98974	0.00195	0.98583-0.99366	0.98453-0.99496
148	52	208312	0.9898	0.0028	0.9901	0.0020	0.9895	0.0029	95/95/95	0.98995	0.00203	0.98588-0.99402	0.98452-0.99538
150	50	200313	0.9894	0.0029	0.9899	0.0021	0.9890	0.0029	99/95/99	0.98970	0.00210	0.98548-0.99391	0.98407-0.99532
152	48	192401	0.9888	0.0030	0.9905	0.0021	0.9885	0.0030	99/95/99	0.99030	0.00213	0.98601-0.99458	0.98457-0.99602
154	46	184204	0.9898	0.0031	0.9899	0.0021	0.9894	0.0031	99/95/99	0.98983	0.00216	0.98546-0.99419	0.98399-0.99566
156	44	176340	0.9915	0.0029	0.9906	0.0021	0.9911	0.0030	no/95/no	0.99063	0.00217	0.98625-0.99501	0.98477-0.99649
158	42	168164	0.9916	0.0031	0.9913	0.0022	0.9911	0.0031	no/95/no	0.99127	0.00222	0.98678-0.99576	0.98526-0.99728
160	40	160029	0.9902	0.0031	0.9908	0.0022	0.9897	0.0031	no/95/no	0.99068	0.00226	0.98611-0.99526	0.98456-0.99681
162	38	152076	0.9882	0.0029	0.9893	0.0020	0.9880	0.0030	no/95/no	0.98917	0.00200	0.98511-0.99323	0.98372-0.99461
164	36	144146	0.9888	0.0030	0.9890	0.0020	0.9883	0.0031	no/95/no	0.98906	0.00204	0.98491-0.99322	0.98348-0.99464
166	34	136139	0.9891	0.0031	0.9896	0.0020	0.9887	0.0033	no/95/no	0.98955	0.00211	0.98526-0.99385	0.98377-0.99534
168	32	128097	0.9896	0.0033	0.9890	0.0021	0.9892	0.0034	99/95/99	0.98912	0.00219	0.98465-0.99360	0.98309-0.99515
170	30	120366	0.9900	0.0034	0.9888	0.0022	0.9895	0.0036	no/95/99	0.98892	0.00231	0.98419-0.99365	0.98253-0.99531
172	28	112019	0.9891	0.0035	0.9879	0.0022	0.9888	0.0037	99/95/no	0.98825	0.00223	0.98366-0.99284	0.98204-0.99447
174	26	104152	0.9904	0.0036	0.9878	0.0023	0.9901	0.0039	99/95/99	0.98832	0.00242	0.98332-0.99332	0.98154-0.99511
176	24	96138	0.9908	0.0039	0.9866	0.0024	0.9906	0.0041	99/95/99	0.98680	0.00252	0.98157-0.99203	0.97967-0.99392
178	22	87862	0.9882	0.0037	0.9853	0.0023	0.9874	0.0038	95/95/95	0.98544	0.00252	0.98016-0.99071	0.97823-0.99264
180	20	80079	0.9891	0.0040	0.9861	0.0024	0.9883	0.0040	95/95/99	0.98620	0.00263	0.98064-0.99175	0.97857-0.99382
182	18	71983	0.9874	0.0038	0.9865	0.0025	0.9868	0.0038	95/95/95	0.98624	0.00270	0.98049-0.99199	0.97829-0.99418
184	16	63776	0.9850	0.0039	0.9853	0.0027	0.9848	0.0039	95/95/99	0.98527	0.00285	0.97911-0.99143	0.97668-0.99386
186	14	55935	0.9859	0.0044	0.9841	0.0030	0.9860	0.0044	95/95/95	0.98421	0.00323	0.97710-0.99132	0.97418-0.99425
188	12	47887	0.9851	0.0049	0.9832	0.0034	0.9853	0.0048	95/95/95	0.98342	0.00374	0.97496-0.99189	0.97127-0.99558
190	10	39843	0.9837	0.0058	0.9833	0.0041	0.9833	0.0055	99/95/99	0.98324	0.00461	0.97233-0.99415	0.96710-0.99938
192	8	31787	0.9810	0.0062	0.9792	0.0035	0.9807	0.0056	99/95/95	0.97914	0.00388	0.96916-0.98912	0.96349-0.99480
194	6	23845	0.9819	0.0085	0.9770	0.0030	0.9811	0.0076	95/95/95	0.97612	0.00367	0.96444-0.98781	0.95468-0.99757
196	4	16011	0.9884	0.0114	0.9807	0.0030	0.9879	0.0097	95/95/95	0.98072	0.00333	0.93840-1.02304	0.76874-1.19270
197	3	12047	0.9942	0.0140	0.9836	0.0013	0.9924	0.0122					
198	2	8036	0.9988	0.0229	0.9849	0.0004	0.9948	0.0207					

the minimum estimated standard deviation for the col/abs/tl keff estimator occurs with 5 inactive cycles and 195 active cycles.

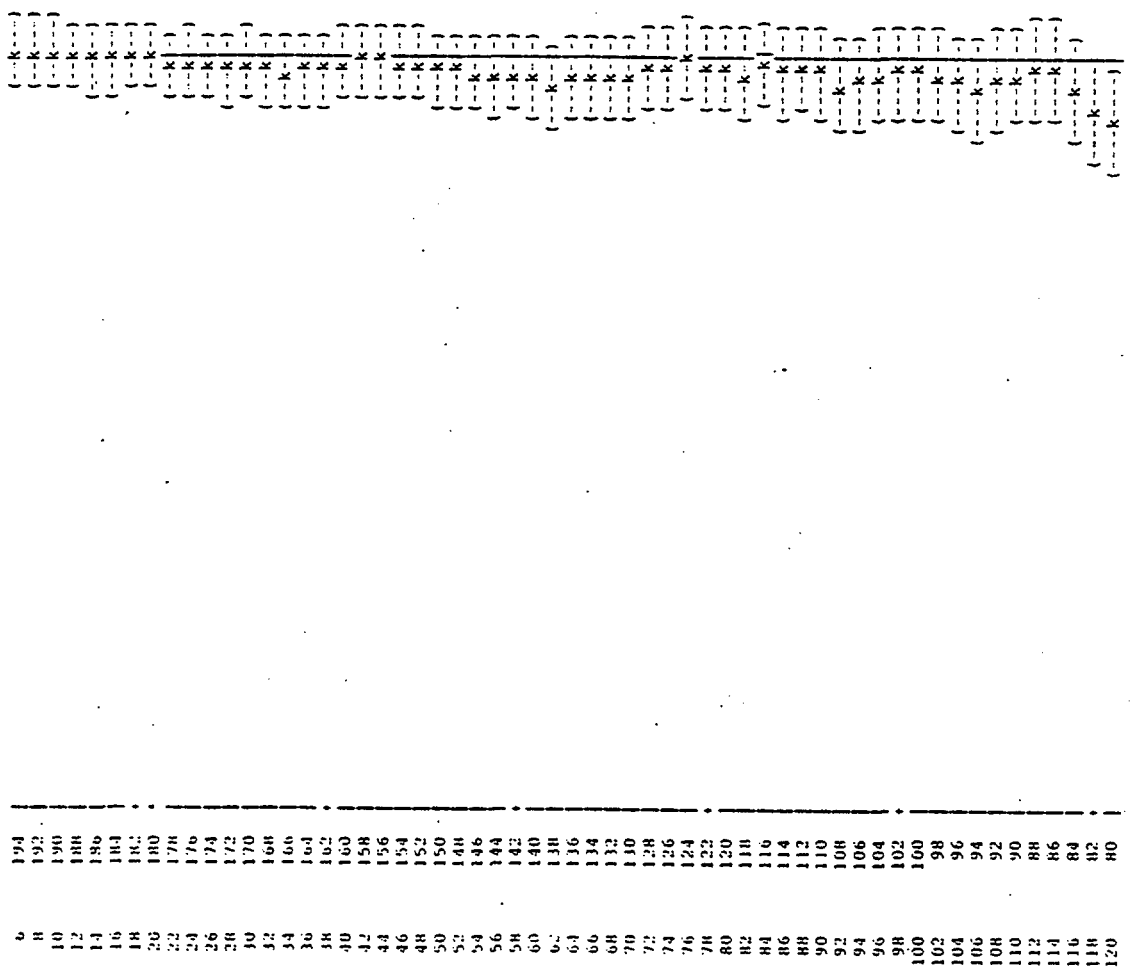
the first active half of the problem skips 20 cycles and uses 90 active cycles; the second half skips 110 and uses 90 cycles.
the col/abs/trk-len keff, one standard deviation, and 68, 95, and 99 percent intervals for each active half of the problem are:

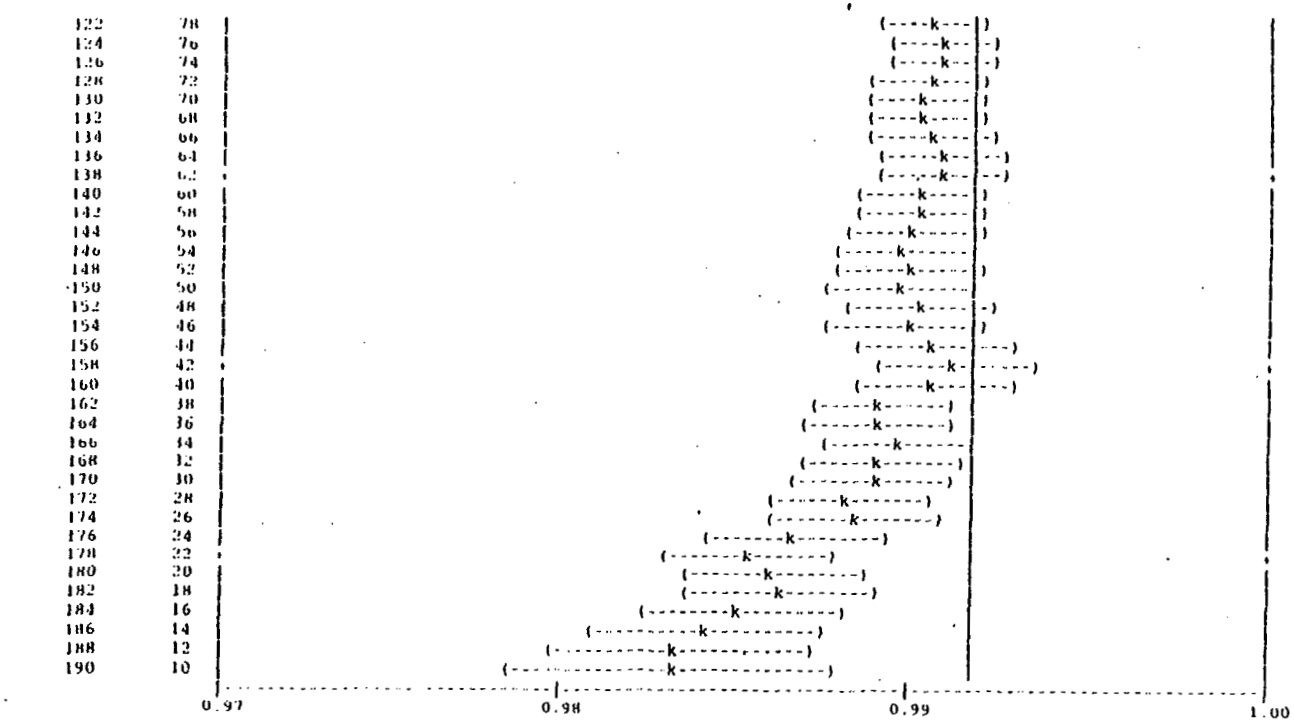
problem	keff	standard deviation	68% confidence	95% confidence	99% confidence
first half	0.99220	0.00133	0.99087 to 0.99353	0.98955 to 0.99485	0.98869 to 0.99571
second half	0.99129	0.00147	0.98982 to 0.99277	0.98836 to 0.99423	0.98740 to 0.99519
final result	0.99174	0.00099	0.99075 to 0.99273	0.98978 to 0.99370	0.98913 to 0.99434

the first and second half values of k(collision/absorption/track length) appear to be the same at the 68 percent confidence level.
Iplot of the estimated col/abs/track-length keff one standard deviation interval by active cycle number (| = final keff = 0.99174)

```
inactive   active 0.97                0.98                0.99                1.00
  cycles   cycles |-------------------|-------------------|-------------------|
       0      200 |                                                 (-------k------)
       2      198 |                                             (---k---)
       4      196 |                                         (-----k---)
```

WMNS-NCSE-001
REV. 0





dump no. 3 on file s69a2r nps = 800202 coll = 36923422 ctm = 18.41 nrn = 424627399

3 warning messages so far.

run terminated when 200 kcode cycles were done.

computer time = 18.42 minutes

mcnp version 4a 10/01/93 06/19/00 16:23:18 probid = 06/19/00 16:04:53

Appendix 4

MCNP4A Calculation Method Bias and Bias uncertainty for criticality calculations for low enriched uranium systems

MCNP 4A calculation bias and bias uncertainty for criticality calculations for low enriched uranium systems

MCNP 4A calculation bias and bias uncertainty for criticality calculations for low enriched uranium systems were determined based on the data published in *International Handbook of Evaluated Criticality Safety Benchmark Experiments, Volume IV Low Enriched Uranium Systems*, NEA Nuclear Science Committee, OECD Paris 1995. The publication contains the results of the neutron multiplication factor experimental measurements and associated calculations with Monte Carlo computer codes including MCNP 4A. For every experiment several computer runs were performed. The mean MCNP 4A calculation bias and bias uncertainty for each experiment were defined as in equation 1 and 2 respectively.

$$\Delta k_b = \frac{\sum_{i=1}^{N} (\Delta k_b)_i}{N} = \frac{\sum_{i=1}^{N} ((k_{eff})_{exp} - (k_{eff})_{MCNPi})}{N} \qquad (1)$$

$$\sigma_b = 2\sqrt{\frac{\sum_{i=1}^{N} (\Delta k_b - (\Delta k_b)_i)^2}{N}} \qquad (2)$$

where
Δk_b = the MCNP 4A calculation method bias for a given experiment
$(\Delta k_b)_i = (k_{eff})_{exp} - (k_{eff})_{MCNP\,i}$ = the MCNP 4A calculation method bias for *i*-calculation
$(k_{eff})_{exp}$ = the effective neutron multiplication factor measured in experiment
$(k_{eff})_{MCNP\,i}$ = the effective neutron multiplication factor predicted by MCNP 4A *i*-calculation
N = total number of MCNP 4A calculations
σ_b = the calculation method bias uncertainty

The positive bias only ($(k_{eff})_{exp} > (k_{eff})_{MCNP\,i}$) was considered. In case $(k_{eff})_{exp} < (k_{eff})_{MCNP\,i}$, the calculation method bias ($(\Delta k_b)_i$) was assumed to be equal to zero.

Tables 1 through 3 show the data necessary for MCNP 4A calculation method bias and bias uncertainty determination. The data in Table 1 is based on report LEU-COMP-THERM-001 *Water-moderated U(2.35)O_2 Fuel Rods in 2.032-cm Square-pitched Arrays*, Table 2 - LEU-COMP-THERM-002 *Water-moderated U(4.31)O_2 Fuel Rods in 2.54-cm Square-pitched Arrays*, and Table 3 - LEU-COMP-THERM-001 *Critical Arrays of Low-Enriched U O_2 Fuel Rods with Water-to-fuel Volume Ratios Ranging from 1.5 to 3.0.* The values of the calculation method bias and bias uncertainty can be found in Table 4.

Table 1 The data necessary for MCNP 4A calculation method bias and bias uncertainty determination based on report LEU-COMP-THERM-001 *Water-moderated U(2.35)O_2 Fuel Rods in 2.032-cm Square-pitched Arrays*

Case number, *i*	$(k_{eff})_{exp}$	$(k_{eff})_{MCNP\,i}$	$(\Delta k_b)_i$
1	0.9998	0.9921	0.0077
2	0.9998	0.996	0.0038
3	0.9998	0.9958	0.004
4	0.9998	0.9943	0.0055
5	0.9998	0.9974	0.0024
6	0.9998	0.9921	0.0077
7	0.9998	0.993	0.0068
8	0.9998	0.9922	0.0076

Table 2 The data necessary for MCNP 4A calculation method bias and bias uncertainty determination based on report LEU-COMP-THERM-002 *Water-moderated U(4.31)O_2 Fuel Rods in 2.54-cm Square-pitched Arrays*

Case number, *i*	$(k_{eff})_{exp}$	$(k_{eff})_{MCNP\,i}$	$(\Delta k_b)_i$
1	0.9997	0.997	0.0027
2	0.9997	1.0016	0
3	0.9997	0.9951	0.0046
4	0.9997	0.9975	0.0022
5	0.9997	0.9975	0.0022

Table 3 The data necessary for MCNP 4A calculation method bias and bias uncertainty determination based on report LEU-COMP-THERM-001 *Critical Arrays of Low-Enriched U O_2 Fuel Rods with Water-to-fuel Volume Ratios Ranging from 1.5 to 3.0*

Case number, *i*	$(k_{eff})_{exp}$	$(k_{eff})_{MCNP\,i}$	$(\Delta k_b)_i$
1	1	1.0017	0
2	1	1.0014	0
3	1	1.0024	0
4	1	1.0026	0
5	1	0.9998	0.0002
6	1	1.0024	0
7	1	1.0025	0
8	1	1.0021	0
9	1	1.0018	0
10	1	1.0011	0
11	1	1.0024	0
12	1	1.0025	0
13	1	1.0017	0
14	1	1.0022	0
15	1	1.0015	0
16	1	1.0028	0
17	1	1.0023	0
18	1	1.0037	0

Table 4 The MCNP 4A calculation method bias (Δk_b) and bias uncertainty (σ_b)

Report number	Δk_b	σ_b	$\Delta k_b + \sigma_b$
LEU-COMP-THERM-001	0.00569	0.00389	0.00958
LEU-COMP-THERM-002	0.00234	0.00293	0.00527
LEU-COMP-THERM-006	0.00001	0.00009	0.00010

As can be seen from Table 4, $\Delta k_b + \sigma_b$ value never exceeded 0.02. In fact it even did not exceed 0.01, and choosing 0.02 as a sum of the MCNP 4A calculation method bias and bias uncertainty gives additional safety margin to the performed MCNP 4A calculations.