TEST REPORT FOR FLOOR SAW CUTTING SYSTEM TEST, 300-296 REMOTE SOIL EXCAVATION PROJECT

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

Contractor for the U.S. Department of Energy
under Contract DE-AC06-08RL14788

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TEST REPORT FOR FLOOR SAW CUTTING SYSTEM TEST, 300-296
REMOTE SOIL EXCAVATION PROJECT

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Total pages: 44
# TABLE OF CONTENTS

1.0 EXECUTIVE SUMMARY .................................................................................................................... 3

2.0 INTRODUCTION AND SCOPE ........................................................................................................ 4

3.0 TESTING REQUIREMENTS AND OBJECTIVES ............................................................................... 4

4.0 TEST ARTICLE DESCRIPTION ........................................................................................................ 6
   4.1. General Operation of the Saw and Controller ........................................................................... 8
   4.2. Blade Cooling Nozzles Set-up .................................................................................................... 9

5.0 TEST SET-UP ................................................................................................................................... 10
   5.1. Floor Mock Up .......................................................................................................................... 10
   5.2. Water Delivery System ............................................................................................................ 11
       5.2.1. Instrument Calibration ....................................................................................................... 12
   5.3. Data Recording ........................................................................................................................... 12
       5.3.1. Yokogawa® data logger .................................................................................................... 12
       5.3.2. Computer interface with Variable Frequency Drives (VFD) .............................................. 12
       5.3.3. Blade measurements ......................................................................................................... 12
       5.3.4. Blade temperature ............................................................................................................. 12

6.0 TESTING SEQUENCE ..................................................................................................................... 14

7.0 TESTING RESULTS .......................................................................................................................... 27
   7.1. Blade Type Selection .................................................................................................................. 27
   7.2. Saw System Control Parameters ............................................................................................... 30
       7.2.1. H4-02 ............................................................................................................................... 30
       7.2.2. EPROM Chip Modification ................................................................................................. 30
       7.2.3. Sequential Operations ...................................................................................................... 31
   7.3. Blade Cooling Water .................................................................................................................. 31
       7.3.1. Flow Rate ........................................................................................................................ 31
       7.3.2. Nozzle Selection and Positioning ....................................................................................... 32
   7.4. Dust Control ............................................................................................................................... 34
   7.5. Cut Direction and Rotation ....................................................................................................... 34
   7.6. Embed Cutting ............................................................................................................................ 35
   7.7. Unstable/Canted Frame Placement ............................................................................................ 36
   7.8. Saw Positioning on the Floor ..................................................................................................... 36
   7.9. Other Topics of Interest ............................................................................................................ 37
       7.9.1. Controller and Inverter Fault Conditions ......................................................................... 37
       7.9.2. Particulate Build-up On Track ......................................................................................... 37
       7.9.3. Mud Accumulation Inside Shroud .................................................................................... 37

8.0 CONCLUSIONS AND RECOMMENDATIONS ............................................................................... 39

9.0 REFERENCES ................................................................................................................................. 41
### Table of Figures

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Saw Controller Box and Handheld Controls</td>
<td>9</td>
</tr>
<tr>
<td>2</td>
<td>Nozzle Access Hole Location (4 nozzles, both ends and both sides)</td>
<td>9</td>
</tr>
<tr>
<td>3</td>
<td>Test Floor Mock-up</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>Water Rack Configuration</td>
<td>13</td>
</tr>
<tr>
<td>5</td>
<td>Cut #5, 2” depth pass</td>
<td>15</td>
</tr>
<tr>
<td>6</td>
<td>Position (inches) vs. time for 2” deep embed Cut #7</td>
<td>16</td>
</tr>
<tr>
<td>7</td>
<td>Blade Damage After Cut #7</td>
<td>16</td>
</tr>
<tr>
<td>8</td>
<td>Cut #12, 2” pass (left) and 4” pass (right)</td>
<td>18</td>
</tr>
<tr>
<td>9</td>
<td>Embed Metal beneath Liner</td>
<td>19</td>
</tr>
<tr>
<td>10</td>
<td>Gravel under Saw Frame Foot</td>
<td>20</td>
</tr>
<tr>
<td>11</td>
<td>Canted Saw Frame</td>
<td>21</td>
</tr>
<tr>
<td>12</td>
<td>Cut #28, Displacement vs. time, 0-2” Deep cut Varying H4-02 (yellow line)</td>
<td>23</td>
</tr>
<tr>
<td>13</td>
<td>Cut #28, Displacement vs. time, 0-4” Deep cut Varying H4-02 (yellow line)</td>
<td>24</td>
</tr>
<tr>
<td>14</td>
<td>Cut #48 First 4 gph Cut</td>
<td>26</td>
</tr>
<tr>
<td>15</td>
<td>Cut #49 Second 4 gph Cut</td>
<td>26</td>
</tr>
<tr>
<td>16</td>
<td>CONCUT® WS-5K-30187 (left) WS-5M-30187 (right)</td>
<td>27</td>
</tr>
<tr>
<td>17</td>
<td>WS-5K-30187 Blade Recession Data</td>
<td>28</td>
</tr>
<tr>
<td>18</td>
<td>WS-5M-30187 Blade Recession Data</td>
<td>29</td>
</tr>
<tr>
<td>19</td>
<td>Nozzle Plumbing on Shroud</td>
<td>32</td>
</tr>
<tr>
<td>20</td>
<td>Nozzle Spray Angles – Loc-Line 5-Stream Nozzle</td>
<td>33</td>
</tr>
<tr>
<td>21</td>
<td>Loc-Line Single Stream Nozzle, 1/16”</td>
<td>33</td>
</tr>
<tr>
<td>22</td>
<td>Hago™ M3 Full Cone Nozzle</td>
<td>34</td>
</tr>
<tr>
<td>23</td>
<td>Recommended Cut Directions</td>
<td>35</td>
</tr>
<tr>
<td>24</td>
<td>Mud Accumulation during Run #26 thru #56</td>
<td>38</td>
</tr>
</tbody>
</table>

### ATTACHMENTS

<table>
<thead>
<tr>
<th>Attachment</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>WORK PACKAGE COPY – 4A-17-00489/2</td>
<td>A-1</td>
</tr>
<tr>
<td>B</td>
<td>FRAME DRAWINGS</td>
<td>B-1</td>
</tr>
<tr>
<td>C</td>
<td>CUT SUMMARY TABLE</td>
<td>C-1</td>
</tr>
<tr>
<td>D</td>
<td>TEST CUT RUN SHEETS (All cuts)</td>
<td>D-1</td>
</tr>
<tr>
<td>E</td>
<td>TEST RUN DATA PLOTS</td>
<td>E-1</td>
</tr>
<tr>
<td>F</td>
<td>PHOTO ARCHIVE</td>
<td>F-1</td>
</tr>
<tr>
<td>G</td>
<td>TEST SLAB DETAILS</td>
<td>G-1</td>
</tr>
<tr>
<td>H</td>
<td>VFD INITIAL PARAMETERS</td>
<td>H-1</td>
</tr>
</tbody>
</table>
1.0 EXECUTIVE SUMMARY

The objective of the testing covered in this report is to determine the capability of the Floor Saw System (FSS) compared to the required 300-296 Remote Soil Excavation Project need to cut the 324 Building Radiochemical Engineering Complex (REC) B-Cell floor. These tests were defined and conducted to identify critical operating parameters that are needed for normal operations of the FSS as well as those scenarios that may lead to damage or failure. The successful completion of these testing activities have paved the way for definitive criteria to be provided for the procurement contract.

This testing resulted in:

- Identifying a single blade that is predicted to last twice as long as needed in order to cut up the complete floor of the 324 B-Cell. (7.1 Blade Type Selection)
- Establishing saw system operating parameters that will cut twice as fast as the previous configuration. (Figure 12 Cut #28, Displacement vs. time, 0-2” Deep cut Varying H4-02 (yellow line) Figure 12 & 13)
- Defining fail safe conditions and recovery operations. (Table 1)
- Operating procedures and scenarios for efficient and effective use (8.0)
- Identifying customized criteria for manufactured equipment having long lead times (Secs. 7.2 & 8.0)
- Including recommended engineered controls, reducing operator fatigue and errors, and reducing risk. (Secs. 7.2.3 & 8.0)
2.0 INTRODUCTION AND SCOPE

The objective of the 300-296 Remote Soil Excavation Project is to excavate highly radioactive soil from beneath the 324 REC B-cell floor. The current plan involves multiple processes within B-Cell to segment the stainless steel lined concrete floor slab and remove it along with the contaminated soil beneath. Several pieces of specialized equipment will be utilized to accomplish these tasks including the Floor Saw System (FSS) to cut through the stainless steel liner and a portion of the concrete pad. During the project conceptual design phase a floor saw was identified as the best candidate and a proof of principle (PoP) testing was completed (KUR-1782F-RPT-014).

The purpose of the testing discussed in this report is to provide additional development testing that is required to ensure performance specifications are clearly established prior to a design-and-build procurement contract release.

The FSS is comprised of the Floor Saw, supporting framework, and an integrated control system. The saw system includes a Diamond Technology, Inc. (DTI) model AK-400 Wall Saw with modifications for remote floor cutting operations. A representative mockup of a SS lined B-Cell floor at MASF was used for testing the FSS.

The testing scope was a phased approach which included the following four key aspects:

1. System basic functionality demonstration
2. System off-normal functional demonstration
3. Anomaly recovery
4. Operational parameters and guidelines

For each phase the test team, comprised of the testing manager, testing coordinator (TC), and the design authority (DA), would evaluate the results of previous testing and determine scope for the next test cut(s). Parameter variations in the saw controller and variations in blade cooling flow rate are examples of the variations in system operation that were studied. Placement of the saw frame on the floor effects the interaction of the saw with the stainless steel embeds and liner. Observations associated with these interactions are important for planning the B-Cell campaign.

3.0 TESTING REQUIREMENTS AND OBJECTIVES

The requirements for this test are captured in the test specification, PRC-STP-TS-00080, Floor Saw Cutting System Test Specification, 300-296 Soil Removal Project, Rev. 0.

Table 1 repeats the test objectives defined in the test specification and provide a reference to sections of this document supporting the results against each of the test objectives.

The testing strategy was to perform a set of “baseline cuts” utilizing the best estimate of operational parameters, then to continue testing based upon the results of those baseline cuts, changing operating parameters to satisfy the objectives defined. Additionally, specific cut configurations were defined to challenge the system in off-normal situations or in recovery from problems conditions. Section 6.0 describes the sequence of testing as performed and provides insight to the decision process from run to run. Run selections were made with an eye to satisfying the prescribed test objectives.
## Table 1 Specification Test Objectives

<table>
<thead>
<tr>
<th>Item #</th>
<th>Objective</th>
<th>Description</th>
<th>Success Criteria</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Use a single blade for all of the 324 REC B-Cell floor cutting.</td>
<td>A minimum of 2500 in-feet of cutting is needed for B-cell floor removal activities. This needs to be accomplished using only one saw blade.</td>
<td>Blade wear measuring the blade regression measurements are confidently taken and correlated to inch-feet of floor cut.</td>
<td>Successful. Refer to section 7.1.</td>
</tr>
<tr>
<td>2</td>
<td>Determine acceptable operational parameters for cutting each test type.</td>
<td>Correlate saw cutting operating parameters and performance during different cutting operations and conditions.</td>
<td>Operating parameter data is correlated with cut configuration and observed saw performance and recorded data.</td>
<td>Successful. Refer to section 6.0</td>
</tr>
<tr>
<td>3</td>
<td>Position and orient the saw on the slab using the center pick point.</td>
<td>Demonstrate the ability to position the saw anywhere on the slab using the center pick point. This may include changing the balance by moving the saw head along the track allowing the saw to tilt.</td>
<td>A center-picked saw is positioned using only crane movements. Saw rotations are achieved effectively by dragging a corner of the saw on the floor and/or using walls.</td>
<td>Successful. Refer to section 7.8</td>
</tr>
<tr>
<td>4</td>
<td>Determine most effective blade cutting/cooling water application configuration.</td>
<td>Adjusting spray nozzle directions and flow rates while measuring cutting performance will provide the needed nozzle configuration basis.</td>
<td>Minimum water is used without impacting cutting performance or blade life. Operational parameters determined.</td>
<td>Successful. Refer to section 7.3</td>
</tr>
<tr>
<td>5</td>
<td>Demonstrate the saw system’s frame stability.</td>
<td>The B-Cell floor is uneven. Testing must demonstrate the saw system’s ability to transverse and cut while unevenly supported. Test for any saw frame movements after cutting begins.</td>
<td>In either of the saw-frame-twisting scenarios, the amount of twist is documented for later evaluation by others.</td>
<td>Successful. Refer to section 7.7</td>
</tr>
<tr>
<td>6</td>
<td>Recommend “normal” operating parameters.</td>
<td>During testing develop operational steps, procedures, processes, and methodologies</td>
<td>Saw performance data is collected to determine recommended operating parameters.</td>
<td>Successful. Refer to section 7.0</td>
</tr>
<tr>
<td>7</td>
<td>Develop / demonstrate recovery from off-normal situations</td>
<td>Probable off-normal situations and failure modes will be explored and recovery procedures will be determined. E.g. binding, translation/feed malfunctions, smearing, etc.</td>
<td>If off-normal conditions occur, an evaluation has been established for recovery or replacement determination.</td>
<td>Successful. Refer to section 7.2</td>
</tr>
</tbody>
</table>
4.0 TEST ARTICLE DESCRIPTION

The key test articles are as follows:

- DTI AK-400 Wall saw (Diamond Tech Incorporated)
- CONCUT® (CONCUT is a registered trademark of the Concut Inc., Kent Washington) saw blades: WS-5K-30187 and WS-5M-30187 were tested. (Concut Diamond Products)
- Fabricated Saw Frame

The DTI-AK-400 Wall Saw, along with its controller box and a number of other accessories were provided to the test by the project. The saw had been used in previous saw testing as discussed in section 2.0. However, in that previous testing, the saw was temporarily mounted to a section of track, prior to the design of the frame assembly. Refer to the manufactures manual - AK-400 Models: M/M1/M2 25HP HYCYCLE WALL SAW, Safety Operation Maintenance Troubleshooting Repair Parts, Prices & Schematics, 2005-001 - for further description of the wall saw.

In this test, the frame design drawings were complete and supplied by the project for use as a starting point for shop fabrication of a prototype frame assembly. The drawings submitted to the testing organization are included in Attachment B and include the following:

- KUR-1782F-DWG-P400 (1 sheet)*
- KUR-1782F-DWG-M-REC-3000-000 (2 sheets)
- KUR-1782F-DWG-M-REC-3000-001 (1 sheet)
- KUR-1782F-DWG-M-REC-3100-000 (7 sheets)
- KUR-1782F-DWG-M-REC-3200-000 (1 sheet)
- KUR-1782F-DWG-M-REC-3210-000 (3 sheets)
- KUR-1782F-DWG-M-REC-3300-000 (1 sheet)
- KUR-1782F-DWG-M-REC-3300-001 (1 sheet)**
- KUR-1782F-DWG-M-REC-3300-002 (1 sheet)**
- KUR-1782F-DWG-M-REC-3300-003 (1 sheet)**
- KUR-1782F-DWG-M-REC-3300-004 (1 sheet)
- KUR-1782F-DWG-M-REC-3300-005 (1 sheet)**
- KUR-1782F-DWG-M-REC-3300-006 (1 sheet)**
- KUR-1782F-DWG-M-REC-3310-000 (1 sheet)
- KUR-1782F-DWG-M-REC-3310-002 (1 sheet)**
- KUR-1782F-DWG-M-REC-3310-003 (1 sheet)**
- KUR-1782F-DWG-M-REC-3310-002 (1 sheet)**
- KUR-1782F-DWG-M-REC-3311-000 (1 sheet)**
- KUR-1782F-DWG-M-REC-3400-000 (2 sheets)**
- KUR-1782F-DWG-M-REC-3410-000 (2 sheets)**
- KUR-1782F-DWG-M-REC-3420-000 (1 sheets)**
- KUR-1782F-DWG-M-REC-3421-000 (2 sheets)**
- KUR-1782F-DWG-M-REC-3422-000 (2 sheets)**
- KUR-1782F-DWG-M-REC-3430-000 (1 sheets)**
- KUR-1782F-DWG-M-REC-3430-001 (1 sheets)**
- KUR-1782F-DWG-M-REC-3431-000 (2 sheets)**
During the fabrication process for this saw frame, a variety of redline changes were proposed and accepted to either fix a problem with the fabrication drawing, or to execute an agreed-to change to the design. The redline changes are also part of Attachment B. The following bullets discuss the major redline changes:

- **Changed frame feet.**
  The DA requested that the feet be changed from the leveling mounts called out in the previous design. Instead, 1” thick plate cut to 6”x6” squares were welded to the bottom of the frame in three places. (Refer to redline description in Attachment B).

- **Cable/hose Carrier Track Attachment**
  The DA decided to eliminate the Cable/hose Carrier Track Attachment from the test article. The design was incomplete and as plans were made to correct the issues, it was determined that a better solution would be to connect the Cable/hose Carrier directly to an arm protruding off of the saw carriage assembly. This will allow for a longer range of motion of the saw along the track and simplify the system design.

The following items are not considered redline changes to the design drawings, but they were added to the design to improve operability for testing. The DA will determine, based upon performance during testing, if any or all of these changes should be implemented in the operational system. Photos of these items have been added to Attachment B

- **Depth of Cut Indicator**
  In order to visually track the depth of a plunge, a mechanical indicator was added to the saw design. The servo VFD feedback is not designed to allow a direct reading as to blade depth. Since depth-of-cut is a critical parameter in saw operation, the final design must include some means of knowing the saw depth below the floor liner. It is recommended that both a visual indicator similar to what was used be included as well as an electronic depth indicator for when the saw is deployed on uneven surfaces.

- **Travel Distance Transducer**
  Test data and success of each test run was enhanced by having the position of the saw along the track electronically tracked and recorded. Translation speed is a good indicator of saw health and performance. Visual observation of saw speed is deceptive and not a good way to know if the saw is progressing in all cases. A laser distance transducer was attached to the end of the frame and reflected off of the moving saw. The data was collected on a data logger.
• **RJ45 pass-through Plugs on Controller Box**
  Data associated with the performance of the Variable Frequency Drives for the saw motor and the servos was collected during the test by interfacing with the VFDs using a laptop computer. The interface cable must penetrate the controller box, which houses 480 VAC power. Previous users ran the cables through the door and closed the door on the cables, subjecting them to damage and reducing the effectiveness of the door seals. Two RJ45 pass-through plugs were incorporated into the control box to alleviate this problem. The installation was reviewed by the Hanford site Electrical SME and approved, not invalidating the UL rating of the control box.

• **Dust/Water Skirt between Floor and Shroud**
  Although not included in the saw design drawings, the previous testing photographs show that a skirt was attached around the base of the shroud to confine the water inside the shroud and to reduce dust generation. Testing personnel and the DA agreed that this skirt is a good idea, so another one was fabricated and included onto the shroud for this testing. It is recommended that a skirt be added to the operational design.

4.1. **General Operation of the Saw and Controller**

The DTI AK-400 saw includes three motors; a 25 HP saw motor and two smaller drive motors, one for carriage translation and another for raising and lowering the blade into the work. Control of these motors is performed by a supplied control box which houses 2 Variable Frequency Drives (VFD). The large drive is dedicated to the saw motor. The smaller drive is switched between the ‘plunging’ action and the ‘translation’ action.

Note that control box water cooling is not controlled by the control box directly. For this test, the water flows for cooling were controlled procedurally.

A hand held controller interfaces with the control box. Figure 1 shows the control box and the handheld controls. There are no controls for the operator to directly affect the speed of plunging, translating or cutting. These parameters are handled internally by the control box electronics and are designed to make real-time adjustments to the drive and plunge speed based upon feedback from the saw motor VFD with respect to the current and/or torque on the saw motor. These controls and parameters are set (or changed) based upon the saw manufacturer design.

After placing the saw frame in the desired location on the floor for a cut, with the blade above the work surface, the saw motor is started by switching the “MOTOR” toggle switch to either the CW or CCW position, depending on the desired cut direction (e.g. for a down-cut when moving right, the saw would be switched to the CW position). (Note that the “MOTOR” switch is a three position toggle switch, the center position is ‘off’). Once up to speed, the center toggle switch is placed in the “ARM” position and then the “FEED” toggle switch is moved to “DOWN”. (Note that the ‘FEED’ switch is also a three position toggle switch, the center position is ‘neutral’). The operator would watch the saw depth gauge and stop plunging by moving the “FEED” switch to the center ‘off’ position when the desired depth was reached.

Then the center switch is moved to the “TRACK” position and the “FEED” switch is moved to the desired direction (Left or Right). Here, the automatic servo control takes over to control the carriage speed rate based on the saw motor load. There were no limit switches on this test unit and the operator had to stop the carriage travel feed before the end of travel was reached.
When the end of cutting position was reached, the “FEED” switch is moved into the center ‘off’ position to stop translation. Then the center switch is moved to “ARM” and then the “FEED” switch is placed in “UP” to raise the blade out of the work. The “MOTOR” switch can be then placed in its center ‘off’ position. Note that later in testing, at the end of the first pass at 2” depth, the saw was then stopped (without raising), reversed rotation direction, restarted, then plunged down to the 4” depth for the ‘return cut’.

![Saw Controller Box and Handheld Controls](image1)

Figure 1  Saw Controller Box and Handheld Controls

4.2. Blade Cooling Nozzles Set-up

Nozzles for blade cooling were plumbed with stainless steel tubing along the outside of the shroud assembly, distributed to each of 4 holes drilled into the shroud. The nozzles themselves were attached to short segments of adjustable plastic Loc-Line tubing so that angles could be adjusted if desired. Nozzles were aimed toward the blade surface and at a downward angle to ensure the water would be pulled along the side of the blade into the cut. Figure 2 shows the general arrangement of one of the 4 nozzles initially used.

For details of nozzles types utilized and associated flow rates and controls, refer to section 7.3.

![Nozzle Access Hole Location](image2)

Figure 2  Nozzle Access Hole Location (4 nozzles, both ends and both sides)
5.0 TEST SET-UP

Testing was performed at the Maintenance and Storage Facility (MASF) in the 400 Area of the Hanford Site. The test was performed indoors.

The MASF facility provided 480 VAC power for the saw operation. The facility is equipped with an overhead bridge crane to allow for demonstration of saw frame movement considerations. Facility water supply and drains were used as needed. All other necessary utilities were available as needed by the testing.

5.1. Floor Mock Up

A mock-up of the B-cell floor system was designed to accommodate limitations associated with the MASF facility. The final floor mock-up was 22'-2" x 22'-2", instead of the B-cell footprint of 22’ x 25’ (wall to wall).

Ecology blocks were used to create low ‘walls’ on two sides to simulate the B-cell wall, assisting in the demonstration of saw frame handling considerations during testing.

The floor mock-up was constructed by CHPRC Project Technical Service (PTS) organization under the work package CS-16-07662. The floor drawing used for construction is repeated in Attachment G of this document for reference. Figure 3 shows the completed floor mock-up with the saw and saw frame, ready to begin testing.

Figure 3  Test Floor Mock-up
Limitations with respect to testing for the floor mock-up are listed below:

- The mock-up floor is slightly smaller than the B-Cell floor.
- During construction the embeds were supplied in three sections. Due to complications, the three pieces were not connected using field welds as originally planned. Instead, they were bolted together using an angle bracket. This was determined to be adequate to hold the embeds in position to allow for the concrete to be poured.
- The floor design utilized fewer embeds running North/South (one every 48 inches, instead of every 16”). Therefore, cuts running east/west would encounter fewer embeds than cuts running north/south.
- Non-availability of the required Steel welded wire (Item #12 on the sketch) resulted in a substitution of a smaller wire gauge being installed. This mesh is below the embeds and not considered to be significant to the saw performance while cutting.

5.2. Water Delivery System

Supply water to the saw system was provided using a rack of instruments and valves as shown in Figure 4. Water supply was generally patterned after the designations provided on KUR-1782F-DWG-P400, however some changes were made due to limitations and simplifications of the test unique configuration. The plant water was filtered to 1 micron to avoid any potential for plugging of nozzles.

Blade cooling water was supplied through a pressure regulator set initially at 40 psig. However, flow was controlled using a rotometer, instead of relying on the nozzle orifice to control flow at a fixed pressure. This allowed the testing to adjust flow rate if desired.

At later stages of testing, the nozzle configuration was changed such that the regulator pressure was increased to 60 psig so that the nozzles available could achieve higher total flow than available at the lower pressure. In a final design solution, all components of the piping system shall be addressed so that the desired flow and pressure is achievable.

The Motor cooling water and the Control Box cooling water were supplied with a pressure regulator set at 40 psig.

For the Motor cooling water loop, a 3/8 inch Parker hose (model 801) was used. The length of hose from the valve rack out to the motor was 60 feet. The return hose was also 60 feet. The quick disconnects that came with the saw were retained. Note, this hose is a size upgrade from the ¼” hose shown on the supplied system drawing, KUR-1782F-DWG-P400. The larger hose allowed the flow rate through the motor to exceed the desired minimum of 1 gallon/minute. The resulting flow through the motor cooling loop was 1.1 gpm and this value was retained for all cuts.

The Control Box cooling hoses were only required to be 15 feet each way. Parker hose (model 801) in size 1/4 inch was used for this loop and achieved 1.2 gpm. This value was also retained for all cuts.

An additional water line to the saw was added for dust-controlling misting nozzle during the initial set of test runs. The flow was not metered on these nozzles. Flow was measured using
time and weight while operating at 40 psig and the results recorded in the applicable run sheets. Inlet water temperature was measured with TE-TEST-1. The return cooling water from the saw motor and the control box were also measured with TE-TEST-2 and TE-Test-3 to allow for differential temperature observations.

5.2.1. Instrument Calibration

The instruments (pressure gauges and flow meters) were field-checked against a calibrated source for adequacy. Those calibrations are documented in the test log (found in Attachment A).

5.3. Data Recording

5.3.1. Yokogawa® data logger

Four instruments were recorded in the Yokogawa® (Yokogawa is a registered trademark of the Yokogawa Electric Corp., Tokyo, Japan) data logger: Saw position (inches), Cooling Inlet Water temperature, Control Box Cooling Water discharge temperature, Saw Motor Cooling Water discharge temperature.

In addition, the data logger computes Delta T for the Saw Motor and the Control Box.

Data is saved as a proprietary .dds file that can be opened and plotted from the supplied software. Plots of saw position, and delta temperature for every run is provided in Attachment E. [Note, an unsolved quirk in the software shifts the time axis on the plots by 1 hour. Care should be taken when correlating data with other data sources in this report.]

5.3.2. Computer interface with Variable Frequency Drives (VFD)

For each of the two Control Box VFDs, a laptop computer, running proprietary software from the VFD manufacturer (Yaskawa America, Inc.) was used to extract information about the motor performance through the VFD controller, such as current, torque, fin temperature, etc. This data is output and saved as CSV files that are readable by Microsoft Excel® (Excel is a registered trademark of the Microsoft Corporation, Redmond, Washington).

5.3.3. Blade measurements

Shop calipers and micrometers were used to measure the blade diameter and thickness at various stages of testing. The measurements are recorded on the Cut Run Sheets that are compiled in Attachment D. The results of the blade measurements are discussed further in section 7.1.

5.3.4. Blade temperature

As soon as possible at the end of each test cut, an access window on the shroud was opened and an infrared thermometer was used to record the blade surface temperature.
Figure 4 Water Rack Configuration

* Increased to ~60 psi at test run 5.3-34 and for remainder of testing.
6.0 TESTING SEQUENCE

The strategy for this testing was to perform a set of ‘baseline’ cuts from which to compare the subsequent cuts, allowing for evaluation of the success/failure of various changes in configuration and cut type. After these baseline cuts, variation in cut location, operating parameters, cut direction, water flow rates, and cut depths were attempted to gain a complete understanding of the saw performance in multiple situations so that saw operations could be better defined as the project moves forward. Some cuts were specifically required by the test procedure (contained in the work package, Attachment A) and others were allowable excursion from the minimum set defined.

The following subsections are a narrative of the testing in chronologic order, and provide insight into the real-time evaluation of the saw performance and the decisions for making changes to parameters and configurations. Refer to Attachment C for a table of each cut made in order.

Cuts #1 through #6: Blade 1/Baseline Cuts: The following represents the configuration used in the initial baseline cuts. These 12 passes created six 4” deep cuts approximately 12 feet long:

- Blade 1: CONCUT® WS-5K-30187
- Blade cooling water flow rate: 20 gallons per hour (gph)
- Nozzle configuration: flow only on the ‘leading edge’ of the blade, both sides of blade (the edge where the blade cuts down into the material. Nozzles used were the Lok-Line 5-hole flat stream. (See section 7.3).
- 0-2” plunge and cut, down-cutting into the material.
- 2-4” plunge and cut, also down-cutting into the material (reversing both the blade and travel directions.)

The first cut (cut #1, in the north-south direction) was made while Industrial Safety representative monitored sound levels and dust generation to evaluate need for special Personnel Protective Equipment. This cut was inadvertently made with the controller set to the “Core Drill Wire saw” setting. This switch setting is a less aggressive saw setting and resulted in increased cutting time. However, the saw performed without issue. The switch was changed to the “Wall Floor Push” setting after cut #1.

Since the first pass of cut 1 generated dust that concerned facility personnel, the second pass made use of a hand held misting wand to see if dust could be reduced with external misting. Since that seemed successful, cuts #2 through #6, traveling east-west, included a mounted set of misting nozzles (7.5 gph each) located at each end of the shroud. These nozzles were retained through cut #24, however subsequently determined to be unnecessary.

It was noted that as cutting progressed from cut #2 through #6, the translation speed slowed and travel times increased (from 11.77 minutes for the 2” pass in cut #2 up to 26.47 minutes for the 2” pass in cut #6) without making any other changes to the testing configuration. Concern for the blade health was noted. Refer to section 7.1 for a discussion of blade wear rates associated with Blade 1.

Figure 5 shows a typical baseline cut at the 2” depth. Close examination of the curve shows small ‘plateaus’ where the embeds were crossed, increasing motor current, and slowing the travel speed slightly. For this cut, as shown in Figure 5, nine embeds were crossed.
Cut #7: Blade 1/“Embed Cut”: It was decided to move to a required cut that plunges through the liner and directly into an embed and cuts through that embed along the entire length of the cut. The same blade configuration and pass depths were used as cuts #1 through #6 above.

Time to plunge the initial 2” took approximately 5 minutes, roughly twice the previous plunge times. Then during the cut, the saw would clearly struggle to progress, experiencing large periods of time with no progress. Figure 6 below shows the position of the saw as it progressed through the cut. Subsequent observations and consideration of this cut led to a conclusion that the saw was ‘binding’ in locations where the cut embed, or other loose part of the liner or embed, would bear against the side of the saw blade, adding drag that would be read by the controller as over current on the saw motor. This would cause the carriage drive motor to slow down the translation of the saw. Total time to cut the first 2” depth was 51 minutes, much longer than previous baseline cuts.

After the return cut at 4” depth, which was completed without significant problems, the blade was photographed and significant damage was observed to the blade teeth (see Figure 7).
Figure 6  Position (inches) vs. time for 2” deep embed Cut #7

Figure 7  Blade Damage After Cut #7
At this point, after the observed blade damage along with the wear rate experienced thus far (see section 7.1), discussions with the saw blade manufacturer led to a decision to abandon the WS-5K-30187 (80-segment) blade type and move on to testing of the WS-5M-30187 (40-segment) blade.

Cuts #8 through #13: Blade 2/Baseline Cuts: The following represents the configuration used in the next set of baseline cuts. It was our intent to perform these six cuts with identical settings to cuts #1 through #6 to allow direct comparison between the two blade models. These 12 passes created six 4” deep cuts approximately 12 feet long:

- **Blade 2:** CONCUT® WS-5M-30187
- Blade cooling water flow rate: 20 gallons per hour
- Nozzle configuration: flow only on the ‘leading edge’ of the blade, both sides of blade (the edge where the blade cut down into the material. Nozzles used were the Lok-Line 5-hole flat stream. (See section 7.3).
- 0-2” plunge and cut, down-cutting into the material.
- 2-4” plunge and cut, also down-cutting into the material (reversing both translation and rotation.)

The first of these cuts (cut #8) was again made with the controller set to the “Core Drill Wire saw” setting. The switch was changed to the “Wall Floor Push” setting after cut #8.

All six cuts went well, without any notable problems. The 2” cuts took approximately 15 minutes to travel 12’. The 4” return cuts took approximately 6 minutes.

It was noticed that dust generation was minimal. It was believed that this was partly due to the fact that the excess water from previous cuts migrates under the liner and has saturated the concrete enough that any free dust from the concrete pour is wet. Note that at this point we were still operating the external misting nozzles.

Figure 8 shows a typical baseline cut, saw operating well, no binding while making cuts perpendicular to embeds.
Cut #14: Blade 2/ “Embed Cut”: The next cut was a repeat of Cut #7 cutting along the entire length of the embed. Same blade configuration and pass depths were used as cuts #8 through #13 above.

Time to plunge the initial 2” took approximately 6 minutes, but was accomplished without issue. The translation went fine, although slow, for the first 77 inches of travel (~16 minutes). At this point, the saw went into an overcurrent condition and the saw visibly and audibly began to shudder, and finally stopped cutting. A current spike of 60 amps was recorded, shutting down the VFD to the saw.

The Test Coordinator (TC) and Design Authority (DA) attempted to raise the non-rotating blade up out of the cut with plunging servo motor was unsuccessfully due to the floor liner binding to the side of the blade in the kerf. The saw had to be translated about 1 foot back toward the start before the blade was able to be extracted from the kerf. Visual inspection of the blade resulted in no concerns about the blade health.

Following up on the observations and conclusions from the previous Cut #7, in this case we also inspected the cut for impinging metal. Figure 9 is a photo that shows a cut end of an embed, not welded to the frame, that is impinging into the cut area. It was concluded that “free piece” was rubbing on the side of the saw blade causing the saw blade motor to overload (also causing the translation to stop).

The saw was plunged down to 4” at the present location and the return pass was made without issue. Post cut blade inspection revealed no damage to the blade.
Figure 9  Embed Metal beneath Liner

Cut #15: Blade 2/ “Embed Cut continued”: The saw was moved to a point beyond the binding zone found during cut #14 and another cut along the same embed was attempted. Results of this cut mimicked the results of cut #14 in that after about another 25 inches of travel, the saw bound up and stopped progressing during the 2” initial pass.

On the 4” deep pass, the blade rotation was changed from down-cut to up-cut for portions of the cut to evaluate if up-cutting would be more effective to get past binding areas. Whereas the 4” deep pass was successfully completed, there was insufficient evidence to conclude that up-cutting was better than down-cutting on the deeper pass.

At this point, discussions between the DA and TC focused on the observation that the ability of the control system to ‘fight-through’ binding situations seemed to be weak. It was our opinion from watching that a more aggressive setting, one that would allow the saw current to reach higher values before directing the translation drive to slow. The DA began discussions with the saw manufacturer to consider a more aggressive cutting approach. See Cut #28: “H4-02 Parameter Variation”.

Cut #16: “Oblique cut”: The oblique cut was made at 5 degrees from parallel of an embed, plunging only through the liner and concrete before crossing that embed at that steep angle. All other saw parameters were kept the same as cuts #8 through #15 with respect to water nozzles, flow rates, controller settings etc.

This cut plunged to 2” without issue, but at about 65”, after crossing the embed at 5 degrees the saw stopped translating and would not progress. The run was stopped. Again, we postulated another binding conditions due to the oblique triangular cuts in the embed below the liner likely bearing on the saw blade.
Cutting was restarted by backing up to a point in the previous kerf where we were away from the binding area. Again we plunged to 2”, but this time we operated using an up-cut action. The cut again bogged down when it reached the trouble area. A series of moves, including reducing depth of cut and reversing to a down-cut produced no appreciable help to keep the saw moving through the binding.

Conclusions are the same as for the embed cut (Cuts #14 and #15), namely that these are difficult cuts for the saw configuration, most likely due to the binding induced by the stainless steel embeds and liner. Either these cuts need to be avoided completely in B-cell, and/or the saw needs to be made more aggressive to ‘fight’ through these binding conditions. See Cut #28: “H4-02 Parameter Variation” and Section 7.6 for further discussion.

Cut #17: “Debris (Gravel) Cut”: This was a required cut to evaluate the cutting performance impacted by a ‘loose’ base under the saw feet. In particular, we were looking to see if the saw moved such that the saw would get off its line and possibly bind up. This condition is a possible condition for cutting in the B-cell due to the existing grout on the floor.

Parameters again remain unchanged from baseline runs.

The frame was lifted and a small mound of 5/8” minus gravel was placed under each of the three (6” square) feet. The frame was set down onto the gravel, raised and set back down 3 times to settle the saw in place. See Figure 10.

Figure 10  Gravel under Saw Frame Foot

The resulting cut went without issue, except for a slightly longer run time. Indexing marks on the floor for the saw position indicated that the frame may have shifted about 1/16” inch at one end. This could have been responsible for slight binding and increased cut time at the end of the return cut. Otherwise, a full 4 inch cut (in two passes) was made without a problem.

Cut #18: “Canted Cut”: This was a required cut to evaluate the impact of setting one saw foot up onto a piece of debris, causing the blade to be ‘canted’ as it plunged and cut.

There were no issues with this cut, other than the observation that the passes were made slightly
faster than similar cuts. This is due to the fact that the ‘canting’ causes the cut to be reducing depth of cut as the saw translates. No evidence of additional binding.

![Figure 11  Canted Saw Frame](image)

**Cut #19: “Baseline cut”**: This cut was performed just to see how the saw would perform compared to previous baseline cuts after having been subjected to the difficulties of the off-normal cuts from #14 through #18. Cutting was perpendicular to the embeds using two passes of 2” to accomplish the 4” deep cut. Again, operating parameters were not changed from the previous baseline cuts (#9 through #13).

Although cutting was slightly slower than previous cuts (18 minutes for 0-2” cut instead of 15; 10 minutes for 2-4” cut instead of 6), the cut was smooth and had no issues.

**Cuts #20 and #21: “4 inch deep, single pass”**: These cuts were performed to evaluate if there is a benefit to cutting all 4 inches deep in a single pass. Cut #20 was performed as a down-cut and was completed without any issues. The cut took 5 minutes to plunge and approximately 34 minutes to traverse the 12 feet. This rate was not any significant improvement over making two passes, one at 15 minutes and the second at 6 minutes as demonstrated in the baseline cuts.

In Cut #21, while up-cutting, the saw bogged down to a stop after traveling only 29 inches, and taking almost 30 minutes. At this point, the saw was stopped, the blade reversed to a down-cut again and the cut progressed, finishing the 144 inch cut in an additional 39 minutes. It is believed that up-cutting with the stainless liner causes undue drag on the blade as the liner material bends upward when the teeth exit the cut.

*For these reasons, up-cutting and 4” deep cuts are not advisable for the operational system.*

**Cuts #22 through #24: “Baseline Cross-Cuts”**: These cuts were performed to evaluate any effects of making cuts that cross existing cuts at 90 degrees. In general these cuts were executed without any problems with the exception of elevated cutting times. In some cases the liner is completely cut in a rectangle and, if not welded to an embed, would come free. There were no instances of the plates becoming projectiles or interfering with the blade to the extent of binding or stopping the rotations. However, it is believed that the loose and/or free steel may contribute to the elevated cutting times.
Cuts #25 through #27:  “Cooling Water Variations”:  All cuts thus far were made with 20 gph of water being applied to the blade for lubrication and cooling.  On top of that, an additional 14 gph of external misting water for dust mitigation have been used.

The purpose of these cuts is to investigate reduction in cooling water and nozzle numbers and positions so that less water could be used in the B-cell during cutting.

The first two of these cuts (cut #25 and #26) replaced the 5-stream Loc-line nozzle with a single stream Loc-Line nozzle and reduced the total flow rate to 10 gph.  As before, only two of the nozzles operated at a time, one on either side of the blade at the ‘leading edge’ where the blade plunges down into the work.  For cut #25, the saw was set up on 1.5” blocks so that the skirt was not touching the floor and the external misting nozzles were turned off.  During this 2” deep cut, there was not any more significant dust generated than observed in previous runs.  Cycling on and off the external misting nozzles did not help or hinder dust mitigation.  A plume of water mist and possibly smoke is formed around the blade, but it dissipates rapidly and does not rise more that a few feet before disappearing.  Lowering the skirt in cut #26 did not change these results.

An observation was made that one of the 5-stream nozzles removed was plugged.  This is likely due to the fact that the previous configuration used a selection ball valve to only supply water to the down-cutting nozzles, without any flow going through other two nozzles. This allowed the cutting “mud” to get slung up into the other nozzle holes. Without flow, nozzle plugging is a real concern.

Because of this, Cut #27 changed all 4 nozzles to utilize a cone mist nozzle rated at 1.8 gph @ 40 psi and the valve that was used to swap water direction was removed from the design so that all four nozzles operated at the same time. The total water flow rate for all 4 nozzles was controlled from the valve skid at between 9 and 10 gph.

In this configuration, half the water (~5 gph) is sprayed on the ‘leading edge’ of the blade to lubricate the cutting and the other half of the water is misted onto the blade as it exits the cut, creating a cooling mist throughout the shroud and perhaps helps with dust mitigation.

This configuration reduces the total water usage from ~34 gph down to about 9 gph. Cutting went well and no significant dust generation was noticed.

Some slowing of the saw cut was observed in these three cuts, but it is attributed to the unwelded liner in the area of the cutting and the still good condition of the blade itself.

Cut #28:  “H4-02 Parameter Variation”:  Discussions with the DTI, the saw manufacturer, resulted in changing this parameter setting that determines the aggressiveness of the saw to overcome binding and other slowing situations. This saw VFD parameter is identified as H4-02, and called the “Multi-Function Analog Output.” All previous cuts (1-27) used the setting for H4-02 at 66% (see section 7.2 for further discussion about parameters). The saw manufacturer indicated that the setting could be as low as 50% to increase aggressiveness (this is the normal default setting for this parameter.) The lower setting of this parameter allows a greater increase in the saw motor current before the “servo” starts to reduce the speed of plunging or carriage translation rates.
This cutting test allowed variations in the H4-02 parameter at three levels (66%, 60% and 55%) both for the 0-2” deep pass and for the 2-4” deep pass. (Note that the water cooling flow rates for all subsequent runs (after cut #27) remained at about 9 gph.) Cutting results for the 0-2” depth is shown in Figure 12 and for the return 2-4” depth in Figure 13. In these charts, time is on the X-axis (5 minute increments) and carriage position is on the Y-axis (20” marks), thus the slope of the yellow line is the cut rate = distance / time. (The red line is the VFD controller fin temperature, and the green line is the water delta temp, not discussed in this section.) Significant improvement in saw performance was realized without overheating the blade or creating more dust. In subsequent testing, it was noted that changing this parameter reduced the wear rates and extended the blade life.

The end of the run in Figure 13, shows a 0-4” depth cut in one pass. It was thought that with the more aggressive cutting operating parameter of 55%, that the single, full 4” depth, cutting rate might be faster overall than the two sequential 2” depth cuts out and back. The resulting 2.2” per minute for this part of the cut was NOT faster than the two sequential cuts. Single 4” deep cutting was not considered as an option after this test.
Cuts #29 and #30: “Baseline Cuts with New Settings”: It was decided to perform a new set of baseline cuts that utilized the water nozzle set-up from cut #27 and the H4-02 setting of 55% from cut #28 to allow for direct comparison with the baseline cuts made in cuts #9 through #13. In fact, cut #30 ventured to an H4-02 setting of 50%.

These cuts performed as expected, where cut #29 took 10 minutes for the 2” pass and returned in 6 minutes for the 2-4” pass. Dust was minimal. Cut #30, with the more aggressive setting of H4-02 at 50% took 8 minutes for the 2” pass and returned in 6 minutes.

The only slight improvement for cut #30 was at the expense of added heat and steam observed. Pushing past embeds seemed a bit more difficult in that the saw would visibly struggle before driving on. It was also observed that the real-time logging data indicated that this aggressive cutting was “bouncing” the blade against the work by overreacting to the motor current load.

For this reason, our observations would recommend 55% for the H4-02 setting for the B-cell application.

Cuts #31 through 38: “Perimeter Cuts”: These cuts were made 3” outside of the expansion joint in the mock-up floor slab. These cuts were outside of the central slab area and actually into what
would be the B-Cell wall footing which extends 20” from the wall into the floor area. This “clean cut” perimeter is intended to give a defining edge for floor and soil removal activities later. The intention is to cut the entire perimeter to allow removal of the expansion joint when rubblizing the floor. At the direction of the DA, the East perimeter and half of the North perimeter was cut at a depth of 6” to evaluate rubblizing differences in a later scope of work. The South perimeter and the remaining portion of the North and West perimeters were cut to a depth of 2”. The intent was to allow for future evaluation of the effectiveness of the arm mounted jack-hammer to break this joint. Cuts were completed without any issues.

It should be noted that originally the deep cuts were planned at 7”, but due to a physical limitation of the saw frame, the blade cannot be plunged deeper than 6”. A simple modification to the frame angle just below the saw rotating arm would allow an additional 4” of depth of cut in case this is desired in the operation. Should a layer of grout or other debris be left in B-Cell, this added depth capability would be essential.

Cuts #39 through #47 and Cuts #50 through #56: “Final Cuts”: These cuts are the final ~50 inches in line with the previous 12’ long cuts, continuing completely across to the far end of the floor. This created removable blocks of floor of various sizes.

All of these cuts were completed without issue. The only thing worth noting is that the ‘overlap’ to a previous cut did not seem to give the saw any trouble with respect to binding or fouling. It is still recommended that the overlapping cut should be performed to an overlap length of greater than the distance between the cross cuts. This will ensure that the block will be free for removal due to an uncut portion of liner.

Cuts #48 and #49: “4 gph Cuts”: The purpose of these cuts was to try to find a minimum water flow rate for blade cooling. With the H4-02 setting at 55%, the cuts were performed as two pass, 2” each cuts with down-cutting. Nozzle configuration did not change from the 4 misting nozzles, all running, but with a reduced total flow rate down to 4 gph, controlled from the rotometer needle valve at the valve rack.

On cut #48 (refer to Figure 14), the initial plunge seemed somewhat violent and noisy. The Plunge was completed in 2 minutes (approximately twice as long as expected). There were 3 controller faults during this plunge.

With the flow at 4 gph, translation was going very slow, but steady, averaging about 13 inches/minute which is half of what was expected. After 17 inches of cutting at this reduced rate, the TC increased the water flow up to the 9 gph established previously.

The saw almost immediately responded with improved cutting speed.

On cut #49 (refer to Figure 15), flow was returned to the 4 gph to give it another attempt. However on this cut, after about 1 inch of plunging, the saw seemed to stop progressing and becoming violent. The TC increased water flow back to 9 gph and again the saw began to perform normally, finishing the plunge and continuing with the translation at a normal rate.

After 100 inches, the TC again lowered the flow back to 4 gph. Seconds later, the saw began to struggle again, confirming that this flow rate is insufficient for saw performance. The rate was brought back to 9 gph and the cut was completed. Based on these tests, it is recommended a minimum 9 gph water flow rate be set to the saw blade using cone spray misting nozzles.
Figure 14  Cut #48 First 4 gph Cut

4 gph. Plunging was again violent and noisy. Changed to 9 gph after plunging the first inch. At about 100 inches, lowered the water flow down to 4 gph again. At 90 inches, set the flow rate back to 9 gph, where it stayed for the duration of the cut.

Figure 15 Cut #49 Second 4 gph Cut
7.0 TESTING RESULTS

7.1. Blade Type Selection

Blade 1:
The first 7 cuts were made using a CONCUT® WS-5K-30187, an 80-segment saw blade (Figure 16, left). This blade was provided from Concut Inc. errantly and was used for these cuts before the error was discovered. However, after discussions with Concut Inc., their representative expressed confidence in the use of this blade with the 25 HP motor on the saw. Blade wear measurements taken during the first 7 cuts are shown in Figure 17 for the WS-5K-30187 blade. The blade diameter was measured every time at three evenly spaced locations labeled A, B, & C at 120° apart. This chart shows the in-ft. of material cut along the X-axis and the blade diameter along the Y-axis. The allowed recession wear on this blade was 0.354 inches (radially) allowing a reduced diameter of twice that amount. The data is recorded on the Cut Run sheets accumulated in Attachment D. The thickness of each of 6 teeth were also measured along with the diameter, however there was little change in tooth thickness over the entire testing.

![Figure 16](image1.png)

A linear extrapolation of the data shows that the wear rate would render the blade completely spent close to the initial minimum target of cutting 2500 in-ft. of floor (inches depth x length of feet cut). Even though the embed cut was the most damaging to the blade physically (test run#7), the wear rate from the baseline cuts also suggests that the blade will wear out too quickly to assume it will successfully cut the B-cell floor without needing replacement.

Blade 2:
All remaining cuts (cut#8 through cut #56) were made using a CONCUT® WS-5M-30187, 40-segment saw blade (Figure 16, right). Because of the lack of damage or excessive wear, the blade was used throughout the remaining tests.

Blade wear, or recession results, are shown on Figure 18. From this chart, it is clear that the wear rate for the blade #2 is approximately 50% spent at the 3300 in-ft. of extrapolated cutting. By cutting 1600 in-ft. this extrapolation has a high level of confidence. This supports the prediction to last twice as long as the first blade and is deemed superior to for this application. There is a high probability that this blade will survive to cut the entire B-cell floor. Again, the tooth thickness was measured and found to be insignificant with respect to wear over the entire testing, however, rounding of the corners was observed, but didn’t seem to impact the effectiveness.
Figure 17  WS-5K-30187 Blade Recession Data
Figure 18 WS-5M-30187 Blade Recession Data
7.2. Saw System Control Parameters

7.2.1. H4-02

The two variable frequency drives (VFD) for the three motors (saw blade, plunging swing arm, and carriage travel) have a myriad of control parameters, mostly at their default settings but may also be easily changed by a qualified technician. Diamond Technologies Incorporated (DTI), the manufacturer of this sawing system uses the Yaskawa VFDs controller/drivers with some of settings modified from the VFD manufacturer’s default configuration. Those changed parameters are highlighted with a “[M]” in Attachment H. These settings were used in previous testing by Kurion and were also used as the starting baseline for the testing covered in this document.

The H4-02 parameter is identified as the “Multi-Function Analog 1 (Analog Terminal/Analog Monitor Gain)” setting that provides an output signal (0-10 VDC) proportional to the saw motor current. The default manufacturer’s setting for this parameter is 50%. This signal feeds into a DTI controller interface affecting the servo VFD which drives either the swing-arm (plunge cutting) motor, or the carriage track drive motor. One VFD is switched from one motor to the other during normal operations. Previous testing used the baseline, conservative setting for this parameter of 66%. The lower % setting produces a more aggressive cutting operation.

The objective of this testing activity was to evaluate the blade wear rate and the floor cutting rate based on using a more aggressive cutting approach. The first 27 cuts were operated at the 66% setting, establishing a solid baseline for the initial cutting performance. The next several cuts were specifically designed to compare the effects and performance of changing just this parameter. The H4-02 was changed during a single cut for comparison. This is shown in Figure 12, Cut #28. The additional values targeted to be tested were 60%, 55%, and 50%.

7.2.2. EPROM Chip Modification

In the DTI control system enclosure, the two VFD’s communicate with each other and also through a custom DTI control box to integrate the signals and provide the I/O for the user interface. An EPROM chip in that controller is programmed (among other things) to control how quickly and aggressively the servo VFD responds to the saw VFD current.

An observation was provided to DTI, that the servo VFD was reacting too quickly to the saw motor current VFD. This was observed by the saw current spiking every second or two, then dropping back down to no-load current. The feedback control loop was literally slamming the blade against the cutting surface, instantly overloading the saw, the servo would back off the blade, the saw current would drop off then the servo would slam the blade back into the cutting surface.

The DA asked DTI to change the control loop to keep the same response for backing off the blade (servo controlled), but after the saw current dropped off, the servo would re-engage the blade much slower and softer. DTI sent an updated EPROM that was installed and used for all cuts after #46. The results from this change were phenomenal by taking out this huge oscillation in the control loop to a smooth and steady cutting operation.
7.2.3. Sequential Operations

Throughout the testing activities many different parameters were varied to establish optimal operating settings. All of this testing was performed by one operator who had to pay very close attention continuously to the cutting operations. These testing activities have recommended several operations-assisted sensors, limit switches, controller changes, etc. that will greatly reduce the risk from operator fatigue and inattention. During the final test cuts to finish cutting the slab into specified sizes, the same sequence was repeated. This is the sequence this test report is recommending. Therefore, in order to maintain operational consistency, reduce operator fatigue, and reduce operational risks, it would be very beneficial to have this same simple sequence run without the need for operational control, just operator monitoring.

7.3. Blade Cooling Water

A key parameter for saw operation is the necessary flow of water onto the blade for cooling and lubrication during cutting operation. Normally concrete cutting uses generous amounts of cooling water for blade health and ease of cutting. However, in the B-cell application, excessive water addition for cutting is to be avoided to minimize migration of radionuclides downward in the soil toward the water table.

For this reason, the testing investigated minimizing water flow rates. Various nozzles types were considered and three types were tested.

7.3.1. Flow Rate

Previous testing of the saw was reported to have achieved satisfactory results with 4 gph (total) sprayed in a mist at 4 locations inside of the shroud. For this test, during the initial baseline cutting, 20 gph was selected and applied to the blade at the leading edge, where the blade enters the work. See the following section for nozzle selection and positioning.

In addition, during cuts number 2 through 24, two additional misting nozzles mounted outside of the shroud were operated to mitigate dust generation. Each of these nozzles operated at ~7.5 gph, or a total of 15 gph additional water. Refer to section 7.4 for additional discussion of dust mitigation considerations.

The 20 gph for blade cooling was excessive and water was flowing in a thin sheet across the floor liner, down the liner slope. This would indicate that a lower rate may be possible.

Runs #25-27, lower flow rates were tried, along with different nozzle types (also without the external dust misting nozzles operating). These lower flow rates, along with the elimination of the 15 gph of external misting eliminated the flowing water across the floor. Following these runs, baseline testing cuts continued using ~9 gph cooling water applied by 4 small cone spray misting nozzles to the inside of the shroud with no external misting spray. This amount of water seemed to provide adequate cooling to the blade based upon blade temperature readings taken at the end of each cut as well as general observations during cutting. The pooling/flow of free water was eliminated, and the water was forming a mud inside the shroud and on the floor.

These 4 nozzles were operated simultaneously, two at the blade entrance into the work and two at the exit end. By doing this, it eliminates a potential failure mechanism that was observed, where mud could possibly plug-up a nozzle that was not operating during cutting.

The following section provides more details on nozzle selection and positioning.
7.3.2. **Nozzle Selection and Positioning**

Figure 19 shows how nozzles were placed onto the shroud using stainless steel tubing and terminating with a short section of Loc-Line plastic tubing. The plastic tubing was for ease of adjustment during testing, but should be eliminated from the final design, taking the stainless steel tubing down to the nozzles. The valve was used to change the water flow from the left to the right so that the leading edge of the blade was sprayed, changing when the blade rotation direction was changed. (Later testing, from cut #28 and on, the valve was removed because all nozzles ran all the time. This is the recommended configuration).

![Figure 19 Nozzle Plumbing on Shroud](image)
For Cuts #1-#24, Loc-Line 5 flat stream nozzle was used to provide the 20 gph flow. Only two of the 4 nozzles were running, spraying on the leading edge of blade where blade ‘enters’ the work. See Figure 20 for nozzle orientation.

For cuts #25 and #26, a single stream spray, 1/16”, Loc-Line nozzle was used (see Figure 21. Also, only spraying on the leading edge of the blade. Total flow for both operating nozzles was 10 gph. Nozzle positioning and locations were the same as for the previous cuts.
Finally, beginning with cut #27, and for all remaining cut, Hago™ (Hago is a registered trademark of the Hago Manufacturing Company, Mountainside New Jersey) M3 cone spray nozzles were fitted into the 4 nozzle locations and the selection valve was removed from the design such that all nozzles were spraying at all times. By raising the pressure to 60 psi, 9 gph was achieve out of all 4 nozzles together. These nozzles are Stainless steel and should be satisfactory for the operational design.

![Figure 22 Hago™ M3 Full Cone Nozzle](image)

7.4. Dust Control

Initial test runs generated noticeable dust, motivating the facility supervision to require exhaust fans to pull the dust away from the saw and discharge outside. However, as testing progressed, dust became less of an issue, and finally it became completely unnecessary to operate any exhaust fans.

It is believed that the addition of the external misting nozzles helped mitigate dust generation in early test runs.

It was also observed and assumed that because of the excess water used up through cut #24 (20 gph on the blade and another 14 gph through external misting), water was migrating between the liner and the concrete beneath, through the cut kerfs, resulting in a water saturated concrete bed.

It is likely that much of the early dust was from surface drying in the zone under the liner. Once saturated, that dust ceased to be an issue.

Later testing when the water flow to the blade was reduced to 9 gph through 4 mist cone sprays under the shroud, dust also did not present any significant problem. It is postulated that the confinement created with the shroud and the skirt, and the fine misting, causes the dust generated by the cut to become wet. Observations at the lower flow rate is that ‘mud’ is formed and there is little free water or dust. For additional discussion about the mud, see section 7.9.3.

7.5. Cut Direction and Rotation

Conclusions drawn from the test runs are that ‘down-cutting’, where the blade enters the work
downward on the leading edge of the translation, is the superior method for cutting the lined concrete floor. The test cuts where up-cutting was used resulted in problems, most likely due to binding caused by the liner as it gets pulled away from the concrete surface as it cuts.

Previous testing concluded that changing the rotation direction on alternating cuts helps to keep the blade teeth from ‘coating’ or ‘galling’ with stainless steel. The reverse action, particularly through concrete, seemed to keep the blade ‘clean’. Whereas this condition was never experienced during this testing, there is no reason to deviate from this recommendation.

Based upon this consideration and the testing performed, the recommended method of cutting should be (see Figure 23):

- Plunge to 2” depth and make a 2” deep cut for the full length desired, rotating the saw for a down-cut.
- Stop the saw carriage translation and reverse the blade direction of rotation.
- Plunge from the current 2” depth to 4” deep and translate in the opposite direction, also achieving a down cut.

![Figure 23 Recommended Cut Directions](image)

### 7.6. Embed Cutting

Many of the significant problems during this testing occurred when attempting to cut along the length of an embed. The added load on the saw drives blade temperatures up and takes longer. Binding was the worse as the embed stainless steel angle is severed and bears against the blade.

For this reason, it is recommended that operational planning should attempt to avoid cutting along the length or even at a slight angle through an embed. Cutting perpendicular through the embeds slows the advance somewhat, but was not found to be any problem for the saw system.

Operations observing the change in translation rate (speed) should be used to clearly identify where each of the embeds are being cross-cut. Making notes of those locations can assure that cutting between the embeds in the other direction can be achieved with confidence. If cutting along an embed is detected, it is recommend that the cut be stopped and the saw moved aside a few inches to avoid this cutting condition. This conservative approach will improve the likelihood that a single blade/saw can make all needed cuts in B-cell.

A very careful observation of the first cuts in each direction at both the mockup location and the 324 REC should be able to determine exactly where the embeds are located. In most of the cutting rate data that was collected, it was fairly obvious where the embeds were located. Once locations have been identified, cutting on 16” centers between the embeds should easily avoid
ever cutting along the length of any embed.

7.7. Unstable/Canted Frame Placement

The test that examined these conditions (cut #17 and #18) were both successful. The saw frame as designed seems to be stable enough to accommodate an un-even floor condition. Care should be taken because when the frame is elevated above the liner, the ‘start’ of the 2” deep plunge is now no longer at the ‘zero’ point on the depth indicator, but rather when and where the blade touches the liner.

Also, if the debris is ‘tall’ (or if a cut deeper than 6” is desired), the current saw frame limits the maximum plunge to 6 inches. This limitation may prevent adequate cut depth if the frame is on debris unless a modification to the frame is made so that the saw can plunge deeper. A simple modification to the frame angle just below the saw rotating arm could allow an additional 4” of depth of cut.

7.8. Saw Positioning on the Floor

Prior to cut #36 it was decided to practice and demonstrate saw frame movement techniques.

The preferred method for placement of the saw frame using only the overhead crane was to lift at the single center pick point and use the positioning of the carriage as ballast on the track as a way to tip one end or the other to the floor. This will allow the crane to ‘pivot’ the saw around that foot and make the final alignment.

The frame is well balanced, such that when the saw is positioned at the center of the track, in alignment with the center pick-point, it hangs virtually level. Moving the saw between 1 and 2 feet from center would put the frame at a slight angle. In the movement demonstration, the operator would lift the frame until both ends came above the floor, with the frame hanging at an angle along its length. The operator would move the saw to the designated position (in the test bed the position was defined by a pen mark on the floor). He would then lower the frame so that the low end would engage the floor at the desired mark.

At this point, it was sometimes desirable to move the saw toward the low end so that end would be more highly weighted. The operator would continue lowering the frame, moving side-to-side as needed, to align the elevated end with the desired mark before lowering to the floor.

This method was shown to be a viable method for positioning the frame. Practice would enhance the operator’s ability to make these movements more efficiently. Difficulty was demonstrated when the saw needed to be rotated 90 degrees. (However, in the cell, the use of the side walls may make this easier.) Again, practice will also make this move more efficient.

The operational design will need to consider how it is going to determine the ‘target’ for placement of the saw. During testing, the floor was clean and the embed locations marked so that avoiding embeds and aligning parallel to them was a simple matter. That won’t be possible in the B-cell.

Also it should be noted that the cable bundle that hangs from the saw has a significant effect on the movements of the frame. In testing, an operator held the cables in an attempt to keep forces as neutral as possible. Some consideration in the final design for the cable management during movement is necessary.
7.9. Other Topics of Interest

7.9.1. Controller and Inverter Fault Conditions

Occasionally during saw operations the saw controller would fault out. In these instances, one of two failures were visually observed by an operator stationed at the computers attached to the VFDs. The failures were either an “Inverter Fault” or a “Controller Fault”.

These faults would self-clear almost immediately and the saw would normally automatically restart. When this occurred the operator turned off the saw until directed by the TC to restart.

Most often, the faults occurred when the saw was experiencing stress, or in a ‘transition mode’ (such as the start of a plunge, or the switching from plunging to translation). But not always could the fault be correlated to a specific event. Assumptions about VFD fin temperature or other high current conditions were made, however, a detailed autopsy of the causes and/or cures were never clearly determined. The saw VFD ‘fin temperature’ was quite high, upwards of 85°C, however, the controller enclosure never felt very hot. It is recommended that DTI, the manufacturer of this controller enclosure, revisit the internal heat transfer effectiveness to utilize the excellent water jacket cooling properties.

7.9.2. Particulate Build-up On Track

During cutting operations, small noises could never be heard above the 100+dB sound level cutting operations. However, while traversing the carriage from one end to the other when not cutting, excessive ‘popping’ sounds were heard as the carriage drive pinion rolled over particulate accumulated in the upward facing gear rack. Simply spraying off the rack eliminated these sounds. This debris did not seem to create any obvious interference to the function of the saw.

However, because of the loud noise made between cuttings as the saw was re-positioned, concerns about accumulation of the debris causing ongoing problems arose between test personnel and the design authority.

During the testing evolutions, test personnel frequently sprayed the track down with water, which immediately eliminated the noise and the interference. Because of this frequent ‘cleaning’, it is unknown if long term accumulations could be problematic for saw operation in the B-cell.

The design authority and test personnel agree that consideration of a protective cover is recommended to ensure trouble-free operation.

7.9.3. Mud Accumulation Inside Shroud

When the blade cooling flows were reduced from the 20 gph streaming nozzles to 9 gph cone nozzles, the internal surfaces of the shroud were found to have accumulated significant amounts of caked-on ‘mud’, leaving a narrow area for the blade, but still not touching the blade. Figure 24 shows the condition as observed after not removing the shroud between run #26 to the last run #56. It should be noted that this condition was created in about ¼ of the total cutting requirement of the B-cell cutting. It is unknown if this condition would get worse or would interfere with cutting as the mission continued.
Another consideration regarding the mud accumulation would be protection of the nozzles. Since the test design cut a hole (approx. 1” diameter) in the sides of the shrouds to pass the nozzle through, the hole contributed in keeping the nozzles clear of the accumulated mud because the mud had no shroud surface to build up upon and the mud didn’t seem to accumulate onto the nozzles or the tubing.

Operational design might consider a short duration, higher flow ‘flush’ of the shroud at the conclusion of each cut to manage this build up. However, any addition of water must be balanced by the need to minimize water addition to the soil beneath the B-Cell to mitigate the potential for radionuclide migration.

Figure 24 Mud Accumulation during Run #26 thru #56
8.0 CONCLUSIONS AND RECOMMENDATIONS

Testing was completed on schedule and all test objectives were met. The testing provided significant information to assist the project to move into acquisition of the final saw design and to begin considerations for operational parameters and procedure development.

Key recommendations for the FSS are summarized below:

Frame and Saw Design:

- Address all redline changes identified in Attachment B. These changes includes, but are not limited to:
  - Modification of the frame feet.
  - Addition of the shroud ‘skirt’ brush assembly
  - RJ45 pass-through connectors on the Controller box to retain UL rating of box
  - Use laser distance sensor (or similar distance measuring device) for tracking saw carriage position. This information is valuable to diagnose saw performance in real time. This includes a means to log and display the information which operators can view.
  - Consider laser distance sensor (or similar distance measuring device) for determining blade vertical position (depth of plunge). It would be prudent to also include mechanical means for positioning such as feelers/flags in case of failure to sensors.
  - Revision of Cable/hose carrier support such that the end of the carrier is attached to a new device that mounts directly onto the saw carriage assembly. This eliminates the separate trolley device that limits saw travel and simplifies the design.
- Consider addition of multiple laser distance sensors (or similar remote distance measuring device) for positioning and aligning the saw within the cell. It would be prudent to also include mechanical means for positioning such as feelers/flags in case of failure to sensors.
- Consider the addition of limit switches for both the carriage position on the track and for the blade plunge movement limits. The saw manufacturer indicates that hard-stops of the motors will damage the motors.
- Ensure that the Saw unit purchased includes the modification that allow for motor cooling water to be returned/recirculated as needed. This modification is not the standard design from DTI.
- Consider modification of the steel angle that runs beneath the saw such that it will not interfere with the depth of plunge. The saw and frame as given in the test design limits depth of cut to 6 inches below the bottom of the feet. There could be instances where deeper cuts are needed, in particular in cases when the saw is set on top of some debris.
- Consider a means of keeping the carriage track and drive rack clean from cutting debris, such as a flexible boot.
- Discussions about ‘fin heat’ noticed inside of the VFDs should be conducted with the DTI representatives. While the heat buildup inside the control box is low, the fin temperatures in the VFDs seemed high. (see section 7.9.1 for further discussion)
Water Flows:

- Saw motor cooling water should be ~1 gpm at all times when the saw is running, and for at least 2 minutes after the saw stops.
- Control Box cooling water should be ~1 gpm when powered. (It is likely that this could be the same cooled/recirculated water through the saw motor.)
- Blade cooling water should be ~9 gph combined from 4 cone misting nozzles (Hago™ M3 nozzles) positioned on the leading and trailing sides of the saw blade and on both faces of the saw blade. Pressure settings as necessary after considering all hoses, fittings, etc. to achieve target flow rate. Refer to section 7.3 for further discussion.
- With the lower water flow rates on the blade, mud accumulation under the shroud became noticeable and somewhat significant. Further design consideration for the impact of the accumulation and possibilities of additional features to mitigate would be prudent. Special attention to keeping mud from fouling cooling nozzles.

Saw Control:

- Set the H4-02 parameter at 55%. Consider including the ability to make changes to this parameter during operations. Keeping a computer connected to the VFD will allow for changes and also allow for monitoring of operational information in real time.
- DTI should provide the saw controller with the modified EPROM device as discussed in section 7.2.2.
- Because these custom parameters settings need to be incorporated along with the sequential operations controller, this is likely to be a long lead item and may want to be initiated early in the procurement process.

Operation Procedure:

- Saw positioning can be performed by combining crane operation with center pick-point and moving the saw carriage to ‘off-balance’ the frame to allow rotation by dragging one end on the floor. Perform this positioning activity in combination with remote distance measuring sensors / readouts (discussed above).
  - It should be noted that the influence of the cable/hose bundle coming off of the saw frame has a significant effect on the ability of the operator to position the frame. Management of this cable bundle should be a priority in upcoming design efforts.
- Recommend the following as the baseline cutting procedure (see section 7.5 for further discussion):
  - Assuming a standard cut of 4” depth is desired, make the cut in TWO passes of 2” cut.
  - Both passes are made as ‘DOWN-CUT’ (defined as the blade turning into the work at the leading edge).
  - The first pass is made by plunging to the 2” depth as measured from first contact with the floor liner. Once at depth, start carriage translation.
  - At the end of the first pass stop both the translation and the blade. Reverse the blade rotation, plunge an additional 2 inches (to the 4” depth), and then translate in the opposite direction stopping at the first pass starting point.
  - Raise the blade 2” above the work surface. Stop the blade.
  - Consider having the saw system controller provider incorporate a sequence of
operations initiated by the operator that does a full cut while self-monitoring. This will both reduce operator fatigue and greatly reduce operator errors and risks.

- When extending the length of a cut, position the saw frame as close as possible to align the new cut with the kerf of the previous cut. When cutting, ‘overlap’ the two cuts by at least 24” to assure a continuous 4” deep cut.

- Avoid cutting along the length of an embed, or at oblique angles, as these conditions create drag conditions on the saw blade. Monitoring saw performance should allow for detection of this condition. If so, recommend lifting the saw frame and moving a few inches away from the embed.

9.0 REFERENCES


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