SAVANNAH RIVER SITE
SUMP MEASURING SYSTEM
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The process sumps in H-Canyon at the Savannah River Site (SRS) collect leaks from process tanks and jumpers. To prevent build-up of fissile material the sumps are frequently flushed which generates liquid waste and is prone to human error. The development of inserts filled with a neutron poison will allow a reduction in the frequency of flushing. Due to concrete deterioration and deformation of the sump liners the current dimensions of the sumps are unknown. Knowledge of these dimensions is necessary for development of the inserts. To solve this problem a remote Sump Measurement System was designed, fabricated, and tested to aid development of the sump inserts.

I. INTRODUCTION

H-Canyon is a chemical separation facility at the Savannah River Site (SRS) built to support the production of nuclear materials, and its main purpose is to reprocess spent uranium fuel and other enriched uranium fuels. H-Canyon began operation in 1955. The building is a long, multilevel facility and is referred to as a canyon because of its long, rectangular shape. The radiation rates inside portions of the canyon are lethal at a close distance. The canyon contains a series of cells with concrete walls and cell covers, and all work is performed remotely from a central control room using bridge cranes. Within these cells processes are performed with nuclear material to obtain the desired product. Each cell in the canyon contains a process sump which is nominally 24" x 24" in cross section and between 24" and 30" in depth. The sumps are designed to collect leaks from process tanks and jumpers. Each sump is provided with a transfer jet to empty the sump to a waste tank.

The H-Canyon Double Contingency Analysis (DCA) identified a scenario for leaks into the sump and onto the cell floors. In particular, a slow or intermittent leak could allow liquids on a cell floor to evaporate before reaching the sump, leaving a residue of fissile material. Given sufficient time, enough fissile material could collect to allow a criticality to occur.

The facility has controlled this scenario, in the past, by flushing the cell floors and the sumps at regular frequencies, which prevents the buildup of fissile material. The frequency is determined individually for each cell based on the rate of processing within that cell and the nature of the materials stored in or transferred through the cell. Flush frequencies range from monthly to once every sixty months. Frequent cell flushing is very time consuming for H-Canyon Operations and generates liquid waste. Furthermore, the current program is prone to human error, and there is potential to miscalculate flush frequency and thereby reduce criticality safety.

The goal of the Sump Inserts program was to reduce the sump volume in an effort to eliminate the possibility of a criticality. The plan to reduce sump volume would be achieved by installing a sump insert that would displace approximately 60% of the sump volume with a neutron poison resulting in an annular space with a critically safe geometry. This would allow a reduction in flush frequency to annually for those sumps with inserts.

II. CONCEPTUAL DESIGN

The design of the sump measuring device was based upon a number of requirements in order to measure the sump three-dimensionally.

II.A. Design Requirements

The SMD also needed an accuracy of within 1/8" The SMD also had to be small enough to enter the sump without knowing the size in advance. Contact with the internal sides or bottom of the sump was not desired and needed to be minimized to reduce spread of contamination within the canyons.

Numerous obstructing pipes and supports are positioned above the sump locations increasing the difficulty of lowering the SMD and positioning the SMD within the sumps. Operation of the SMD had to be performed remotely with deployment from the in-cell bridge crane. This is even made more challenging by the locations of the sumps against the canyon wall. Power for the SMD also had to be provided by the bridge crane. Measurment data was required to be sent from the SMD to the control roomvia radio signals. The SMD needed to be robust and able to handle impacts against the canyon side walls and piping during deployment in the sump and during retrieval by the bridge crane winch. Positioning within the sumps was further made difficult by the slope of the canyon floor. Stabilizing position was also desired to eliminate the error of obtained data from a shifting measurement platform.

II.B. Concept Development

Concepts for the SMD were developed. An electromechanical design was conceived that actuated multiple potentiometer-like devices. The potentiometers were planned to obtain multiple point measurements from the sump floor depth and the sump opening. A number of challenges were discovered with this concept. Contact of the measuring sensors with the sump provided a source of contamination. Multiple actuators and multiple sensors were needed to fix the SMD position and obtain measurement data. The use of multiple actuators and sensors increases the chance of potential failure and the complexity of the system. This concept also had the detractor of only providing a limited number of data locations within the sump.

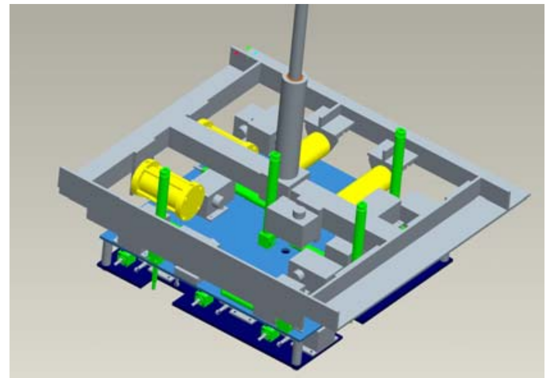

Fig. 1 – Electromechanical Concept

A second concept was then evaluated using a single actuator and laser sensor with a limited number of actuators for positioning the SMD. This design concept had the advantage of not physically contacting the inner sump, a reduced number of actuators lowering the probability of system failure, providing an unlimited number of possible dimensional data points, and providing the capability of changing the measurement locations as needed remotely without physical changes to the SMD structure.

III. SYSTEM DESCRIPTION

The Sump Measuring System (SMS), consists of the Sump Measuring Device (see Fig. 1) which is lowered and positioned in the canyon sumps for making measurements, the associated cabling through the canyon, the radio frequency (RF) link from the canyon to the Crane Operator Control (COC), a laptop computer and software used to control the SMD components and record / analyze data.

III.A. Sump Measuring Device

When deployed, the SMD frame rests on the cell floor, and the measuring components extend into the sump. Two linear actuators are included on the frame and mounted perpendicular to each other. These actuators extend to "fix" the SMD within the sump so that the SMD does not change position in the sump during measurements. The SMD incorporates a laser distance meter mounted on a motorized positioning device. The positioning device uses a stepper motor to pan the laser 360 degrees to obtain horizontal measurements around the sump and then another stepper motor indexes (tilts) the laser downward to begin another series of horizontal measurements. Both stepper motors use encoders to verify their position. The laser measures the distance to the sump wall at specific positions. Because the SMD will not always rest on a level surface, an inclinometer, mounted to the same positioning device, measures the tilt angle of the laser distance meter to ensure measurement accuracy. Two self-illuminated cameras are mounted on the SMD. The Camera #1 view is in the direction of the laser which permits the operator to view and record the condition of the sump walls during measurement. Camera #2 provides a top view of the equipment, this camera provides the ability to check SMD component function and also assists in alignment of the SMD during deployment within the canyon sump. On-board electronics and power supplies are contained in a Control Box mounted on top of the SMD frame. A side view of the SMD is provided in Figure 2.

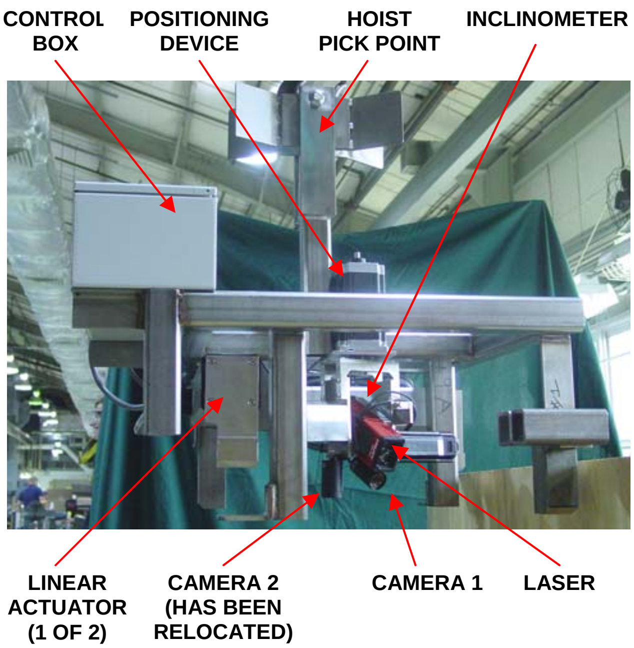

Fig. 2 – Sump Measuring Device (Side View)

III.B. Storage Box / Test Stand

A storage box/test stand was fabricated by construction personnel per direction of H-Canyon Engineering. The test stand included a simulated sump. The test stand is shown in Figure 3, and the simulated sump within the test stand is shown in Figure 4. A precision insert, referred to as the Sump Standard, was fabricated by the Savannah River National Laboratory (SRNL), Engineered Equipment and Systems department (EES) to fit within the simulated sump on the test stand. The Sump Standard was measured by the Savannah River Standards Laboratory (SRSL), and its dimensions were documented under Measurement & Test Equipment record, M&TE# 3-5166. The calibrated instrument used to measure the Sump Standard was a Mitutoyo Bright 707 Coordinate Measuring Machine (CMM). An accurate and documented measurement of the Sump Standard was required to (1) ensure that the SMS operated properly and could deliver the required measurement accuracy and (2) to allow pre- and post-measurement verification once deployed in the field.

Fig. 3 – Test Stand Exterior

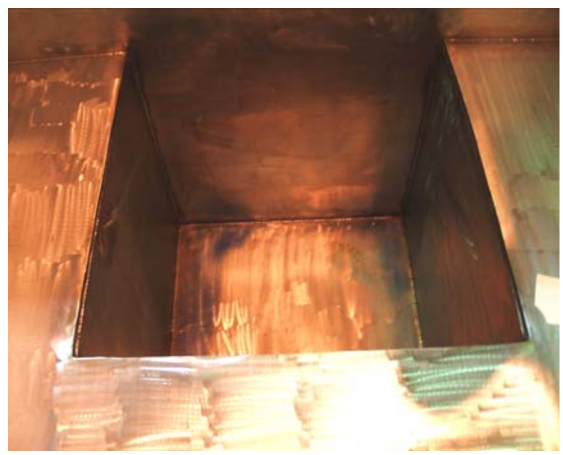

Fig. 4 – Simulated Sump Inside Test Stand

Pre- and post- verification measurements in the field would be performed by lowering the SMD into the SMD Storage Box fitted with the Sump Standard , see Figure 5.

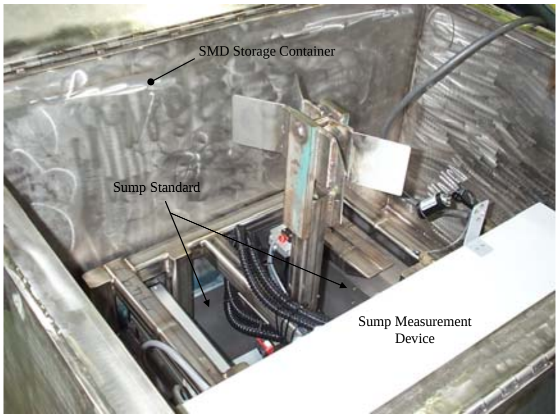

Fig. 5 – Simulated Sump Inside Test Stand

Note that the linear actuators are not used to “fix” the SMD inside the SMD Storage Box, to do so could result in distortion of the Sump Standard. Care must be taken not to disturb the SMD once pre- or post- verification measurements have been started. Once positioned, measurement of the Sump Standard would be performed. The measurements taken are compared to the measurement results from the SRNL Standards Lab. If the pre- and post – verification measurements are consistent with the results from the SRNL Standards Lab, then the measurements of the facility sump would be considered valid.

III.C. Measurement Requirements

The customer requested measurement accuracy was +/- 1/16” of actual. The first set of measurements were taken near the top of the sump with the laser pointed nearly horizontally. The pan stepper motor was indexed by designated increments to take a minimum of 50 measurement data points at this level. After the pan stepper motor had completed measurements around a full 360°, the tilt stepper motor was indexed so that the next set measurements would be taken less than 2” below the initial set of measurement. The preceding steps were repeated until the entire sump was measured. At each of the data points an inclinometer reading was taken to account for fact that the SMD may not be mounted on a level surface and to provide independent verification of the measurement tilt angle (Nick/Dale please verify that this statement is true).

III.D. Software

The software for SMD control and sump measurement was developed using LabView 7.0. The software provides an operator interface for control of the SMD functions as illustrated in Figure 6. The SMD graphics interface allows the operator to test the equipment components prior to deployment for measurement of a canyon sump. Component functions that can be tested include the laser distance meter, the pan and tilt controls which provide horizontal and vertical rotation of the laser distance meter, the inclinometer, the extension and retraction of the linear actuators, and the cameras.

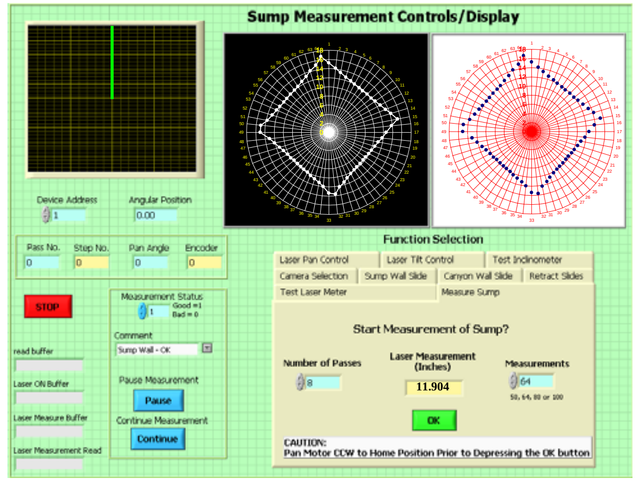

Fig. 6 – SMS Operator Interface

As shown in Figure 6, the control and measurement software interface graphically displays the inclinometer measured angle (upper left), the polar plot of the sump measurements (upper right), the most recent sump measurement and additional information such as the number of passes that have been made, the pan angle, the angular position, etc. Also, a measurement status section of the operator interface allows the individual to insert comments in the data file. In addition, the SMD can be paused at any time to allow the operator to perform other tasks such as starting a video recording of the sump, selecting one of two camera views, etc.

The SMD calibration software also allows the operator to run a series of pre and post verification measurements using the Sump Standard. The results of the analyzed data are compared to results from the SRSL for the Sump Standard. If verification results are not consistent with the results from the Standards Lab, then the software alerts the operator.

Data collected during the sump measurement is downloaded to an Excel calculation file. The transfer of data between the control and measuring software and the Excel calculation file are verified using sampling techniques per ANSI/ASQ Z1.4-2003.

The Excel calculation file uses Visual Basic macros to analyze the data obtained from the LabView software. The data analysis is accomplished through the use of a few simple key strokes. Three independent versions of the Excel/Visual Basic software are required for use with (1) the Sump Standard, (2) the 24” deep sumps, and (3) the 36” deep sumps.

III.E. Analytical Method

The analytical method was developed using Excel and Visual Basic. Visual Basic acted as the logic portion of the program using macros to manipulate the Excel spreadsheets. The program worked to find the component of the distance to the wall of the sump that is normal to the wall. This information was then collected for each pass and compared to find the minimum and maximum distance to each wall.

The following provides a step-by-step procedure that the program follows to analyze the data:

1. Parallel & Normal Distance Determination – The calculated distance returned from the LabView software (obtained using distance from laser and tilt angle from inclinometer) was broken down into its components parallel and normal to the main axes using the pan angle.
2. SMD Leg Removal – During operation of the SMD, some of the measurements taken correlated to measurements of its own structure, specifically the legs. Through measurement of the as-built SMD, the pan angles and maximum tilt angle that correspond to the laser hitting a leg were recorded and stored in the Visual Basic software. This was compared to the data returned from the LabView software to determine whether the given pan angle corresponded to a leg. If so, that data point was thrown out.
3. Outlier Determination – The data for the raw normal distance was run through two filters to ‘clean-up’ the data. The first filter used a +/- 3% (slightly larger interval than 2-sigma) to get rid of any bad measurements. The resultant data is run through a second filter using a 2-sigma range (two standard deviations) as a rule for removing bad measurements.
4. Skew Determinations – The parallel and normal distances determined from step 1 excluding the data removed from steps 2 and 3 were used to find the average slope of the data. This slope was then used to determine the angle that the SMD is skewed relative to the centerline of the sump.
5. Skew Compensation – The angle returned from step 4 is added to the value of the pan angle returned from the LabView software. This provides a corrected angle for determining the normal distance to each wall.
6. Compensated Analysis – Step1 and step 3 are repeated with the compensated data to find the minimum and maximum distances to each wall
7. Data Centering – In order for the data to be compared to the data from the standards lab it was necessary to define an origin. The point selected is the center of the sump. The coordinates of this point are found by averaging the normal distances to opposite walls.

The results of the analysis were presented on a separate sheet. The values were reported as a ‘half-width’ with the average, minimum, and maximum values. The half-width is the measurement from the sump centerline to the wall for each wall and will be equal for walls opposite each other due to the averaging technique used to obtain it.

III.E. Cabling / RF Link

A single channel RS-232 interface via the H-Canyon RF link is used to provide SMD component control. Since the interconnecting cable between the canyon crane and the SMD is approximately 175 feet in length, the RS-232 is converted to RS-485 within the crane cab and then converted from RS-485 to RS-232 at the SMD Control Box. Cable management would be provided by a cable reel (attachment point provided on the SMD frame). Addressable converters at the SMD permit unique selection of the device for control and/or measurement.

IV. RESULTS

A preliminary interface test was performed using the 705-5H simulator. The simulator in 705-5H is a duplicate of the RF technology used in the canyons. The SMS laptop computer COM port with RS-232 connection was connected directly to the simulator input RF link. The simulator output RF link was connected to an RS-485 module located in the cab interface enclosure which provided the hard–wire communications link required for the control and measurement devices located on the SMD. All control and measurement functions were successfully tested at baud rates of 9.6K, 19.2K and 38.4K. The different baud rates were checked because the motor controllers, laser meters and inclinometer use baud rate of 38.4K, 19.2K and 9.6K respectively.

A demonstration of the SMD equipment operation, the operator software, control interface and the sump measurement / analysis software was provided to H-

Canyon Quality Engineering, Process Engineering and Program Management. Operation and control of all SMD components was demonstrated. A set of measurements (8 passes, 64 data points per pass) of the Sump Standard was collected. The data was analyzed to illustrate the SMS software capability. The overall demonstration was considered successful; however, due to a faulty mounting bracket, the laser wandered from the design position as it was rotated around the sump. The required measurement accuracy (+/- 1/16”) could not be obtained.

ACRONYMNS

EES – Engineered Equipment & Systems
DCA – Double Contingency Analysis
CMM – Coordinate Measuring Machine
COC – Crane Operator Control
RF – Radio Frequency
SMD – Sump Measurement Device
SMS – Sump Measurement System
SRNL – Savannah River National Laboratory
SRS – Savannah River Site
SRSL – Savannah River Standards Laboratory