SALT DISPOSAL INVESTIGATIONS

TEST PLAN
SDI-TP-002-REVISION 1

TESTING OF A PROTOTYPE CANISTER HEATER IN THE WIPP UNDERGROUND

Effective Date:

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REVISION HISTORY

Revision Number	Effective Date	Pages Revised	Description of Revision
00	12/16/2014	N/A	Initial Issue
01		All	Revised to incorporate an in-situ heated canister test in run-of-mine salt in the WIPP underground.

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FIGURES AND TABLES

ATTACHMENTS

ACRONYMS

CBFO	Carlsbad Field Office
DOE	Department of Energy
EES	Earth and Environmental Sciences
LANL	Los Alamos National Laboratory
LANL-CO	Los Alamos National Laboratory-Carlsbad Operations
M&TE	Measuring and Test Equipment
NQ	Non-Quality Assurance/Non-Quality Level 1
ROM	Run-of-Mine
SDI	Salt Disposal Investigations
TCO	Test Coordination Office
WIPP	Waste Isolation Pilot Plant

1.0 INTRODUCTION

An area of ongoing research at the Waste Isolation Pilot Plant (WIPP) is a planned test of bedded salt as a host for heat generating radioactive materials. There is a continued need for research into the potential performance of a repository for heat-generating waste in bedded salt and a need to better understand the integrated response of the salt at the field scale. In particular, it will be important to investigate the evolution of the small but non-negligible quantities of water within the salt as the heat from radioactive decay diffuses into the surrounding geologic medium.

There are several testing concepts being examined possessing scalable attributes lending themselves to transferability from the surface to the WIPP underground (SNL 2016). These concepts range from small-diameter borehole tests, to intermediate canister-scale tests, to large drift-scale tests. The larger test concepts require intermediate to full-size canister heaters to provide the heat sources necessary for the testing.

The large drift-scale concept calls for a set of five heaters in each of two test drifts. This configuration would enable study of large-scale behavior under both sub-boiling conditions and above-boiling conditions. The emphasis is on confirmation of expected behavior and validation of numerical models under both conduction-dominated and perhaps coupled thermal-hydrologic-chemical conditions. Standard measurements of temperature and drift closure will be made, along with an extensive set of measurements aimed at determining the fate and transport of mobilized water from inclusions, intergranular space, and hydrous minerals (DOE 2012).

In preparation for any of the larger field tests, a full-scale prototype heater canister was designed and fabricated in fiscal year 2014 (S.M. Stoller Corporation 2014) representing the type of heater proposed for the in-situ thermal tests planned in the WIPP. RESPEC was contracted to design the heater and control systems and Stoller was contracted to fabricate the designed canister (RESPEC 2014). The canister was subsequently tested in a Los Alamos National Laboratory – Carlsbad Operations (LANL-CO) surface facility in Carlsbad for almost two years under revision 00 of this test plan. Canister performance including internal and external temperatures, were monitored.

This test plan provides the outline for the next phase of testing of the prototype canister heater for robustness, reliability, and heating characteristics while in an in-situ salt environment. This plan describes the installation of a single full-size heated canister in the underground at WIPP (Attachment 1) to test operability and heater power supply systems in in-situ conditions. This work will use the opportunity to further the development and testing of key instrumentation suites for use in future thermal testing programs (LANL 2013). Additionally, data from this experiment may reduce uncertainty in our understanding of the behavior of a heated canister under a Run-of-Mine (ROM) salt pile and provide vital checks on numerical simulations.

2.0 WORK SCOPE

2.1 PURPOSE AND SCOPE

The purpose of this testing program is to demonstrate the ability of the canister to operate under in-situ salt conditions in the WIPP underground. The testing will also provide investigators an understanding of the reliability and thermal dynamics of the prototype canister heater. Power, temperature, and environmental data will be collected and evaluated for a better understanding of the performance of the prototype canister heater.

2.2 MAJOR ACTIVITIES

In the previous testing on the surface, the canister heater was turned on at a power of 250 watts (representing the low-wattage test planned for the underground thermal test) and heated for a period of approximately seven days or until a near steady state was achieved based upon data observation. Temperature was measured at a variety of locations both on the canister surface and on the internals (Attachment 2). The wattage was then increased in intervals until a maximum power output of 1375 watts was obtained. A maximum skin temperature of approximately 80 degrees C was obtained. A high set-point of 195 degrees C was established on the heater strips to automatically shut-down the system.

In this in-situ test, it will be important that the ROM salt be exposed to the same heating characteristics that may be experienced in the intermediate to drift-scale tests. Therefore, the canister will be started at a single level of 1000 watts and adjusted as needed through comparing the in-situ results to the surface testing results (see Appendices 1).

Whereas standard research and development methods will be deployed to ensure test data are reliable and accurate, the testing conducted through this test plan will be considered non-Quality Assurance (NQ) and best management practices will be applied where appropriate.

2.3 INTENDED USE OF DATA AND PRODUCTS

The data collected from these tests will be used by the WIPP Test Coordination Office (TCO) in ensuring the operability and robustness of the prototype canister heater in an in-situ environment. Additionally, the data will be used by the test team to aid in the design and planning for future tests in the WIPP underground. Thirdly, the data will be used by the LANL Computational Earth Science group (EES-16) of the Earth and Environmental Sciences Division for supporting information in modeling efforts related to the proposed thermal testing program in WIPP. This modeling will be used to inform the design of the planned intermediate and large-scale thermal tests by achieving a better understanding of thermal transients associated with the heater itself, so that those transients can be distinguished from transients in the surrounding medium. Additionally, experiments performed in this configuration will provide valuable new information on ROM salt backfill in the presence of in-situ temperatures, pressures, and gas/liquid migration with a full-size heated canister.

Data will be collected and averaged every fifteen minutes and once per day with an automated data acquisition system. The fifteen minute data frequency will aid in data reduction for observing equipment failure. Questionable data will be omitted or noted as error/suspect readings. The frequency of data has also been determined to provide an adequate amount for supporting information in modeling.

2.4 ORGANIZATIONS PERFORMING THE WORK

2.4.1 Responsibilities

The WIPP Test Coordination Office (TCO) Data Collection Lead is responsible for implementing the test in the WIPP underground including a data acquisition system that measures and stores data. Additionally the TCO Data Collection Lead is responsible for the initial data reduction that entails observing the data for error and suspect readings (which will be noted as found) and data acceptance and validation. The Data Collection Lead will generate a Microsoft excel data file and test documentation in a scientific notebook.

LANL is responsible for comprehensive data reduction and will provide input for testing parameters, including wattage set points and test parameters in the systematic testing process.

Nuclear Waste Partnership LLC is responsible for providing underground access, power, lighting, communications, hoisting, and transport of equipment and the canister to the underground.

2.4.2 Interfaces

The TCO is responsible for coordinating the underground operations with the Maintenance and Operations contractor including test work control that establishes the expectations, responsibilities, and controls that ensure the safe conduct of physical scientific work that protects people, the environment, and property through implementation of the Integrated Safety Management System.

The TCO Data Collection Lead is responsible for interfacing with the TCO to meet the work control requirements. The Data Collection Lead is also responsible for coordinating with the LANL EES-16 modeling group to ensure that data collection is sufficient for modeling efforts.

All parties are responsible for interfacing with the Department of Energy Carlsbad Field Office (DOE CBFO) for test direction and to ensure that DOE CBFO expectations are fulfilled.

3.0 EXPERIMENTAL METHODS

3.1 OVERALL TEST STRATEGY AND PROCESS

3.1.1 Test Variables

The critical measurement variables for testing are actual system power, canister heater strip temperature, outer canister temperatures (both on the canister and in the ROM salt), and environmental conditions (i.e. temperature, relative humidity, and dew point).

Data quality evaluation will be conducted through qualitative graphical review of all measurements on a frequent basis. Since the measurements are redundant, frequent reviews of the data will find error and suspect readings when graphical abnormalities are observed. Quantitative reviews may be invoked when triggered by the qualitative reviews.

3.1.2 Pretest Predictions and Expected Results

As previously described, LANL EES-16 investigators will be developing more sophisticated models to predict the behavior of the canister heater in a variety of media. Environmental conditions within the WIPP underground (e.g. air flow) will affect the temperature of the canister. Appendices 1 provides data from the testing conducted on the surface for both the 750 watt and 1000 watt conditions. Appendices 2 provides pre-test predictions from a 1500 watt modeling simulation for temperatures.

3.1.3 Acceptance Criteria and Data Validation

Data acceptance and validation will be conducted through qualitative graphical reviewing of all measurements on a frequent basis. Since the measurements are redundant, frequent reviews of the data will find error and suspect readings that will be documented as such. Otherwise the frequent data reviews will determine that the instrumentation is measuring as expected within instrument accuracies and the data will be accepted and considered valid. Validated data will be distributed for supporting information in modeling and scientific analysis.

3.1.4 Test Requirements, Standards, and Regulations

The testing will be conducted as NQ, however data acquisition and instrumentation protocols, and scientific notebook documentation will be used.

There are no nationally-recognized testing standards or regulations associated with this testing.

3.1.5 Test Procedures and Implementing Documents

Test work authorization and control will be implemented through procedure SDI-SP-001, *Testing Work Authorization and Control.*

A scientific notebook will be used to document the testing in accordance with the procedure SDI-SP-003, *SDI Scientific Notebooks.*

If any other procedures are used for conducting science they will be found through the website https://lcodocs.lanl.gov.

3.1.6 Scientific Notebooks and Data Packages

Scientific notebook SDI-SN-0001, *Salt Defense Disposal Investigations General Scientific Notebook* will be used to document experiment design, record information associated with data collection, develop new methodologies, record performance check information, prototyping, and/or research associated with field testing in such detail that the entire process could be replicated.

The data will be documented in the scientific notebook (i.e. error or suspect data) in such a fashion that end-users will understand the data set. Any error or suspect data will be clearly identified as to avoid assumptions regarding this data.

Since the test is NQ, the electronic data and scientific notebook can be used to develop a data package and/or report that provide supporting data for modeling or scientific analysis if necessary. Otherwise an informal process (such as emailing of electronic data and any relevant scientific notebook entries) will be used to share data that will clearly identify error and suspect data.

3.1.7 Prerequisites and Special Controls

The data acquisition system will be controlled via lock and key access in a facility where only trained and authorized personnel have access. All reduced data will be accompanied by the original, non-manipulated data set to show traceability. Only trained and qualified personnel will distribute the data.

3.2 SAMPLE CONTROL

3.2.1 Sample Collection, Preservation, and Control

No physical samples are expected for this testing. If any samples of the ROM salt or intact salt are collected they will be collected in accordance with procedure *SDI-SP-005 Sample Control* and documented in the scientific notebook.

3.3 DATA ACQUISITION AND QUALITY CONTROL

3.3.1 Measuring and Test Equipment

Table 1-1 contains the planned measuring and test equipment (M&TE) that will be used to collect the NQ data.

Table 1-1: Test Measuring and Test Equipment (M&TE)

Manufacturer	Description	Model	Measurement Range	Measurement Accuracy	Operating Range
Campbell Scientific, Inc.	Barometric Pressure Sensor	CS106	500 to 1100 mb	+/-1.5 mb	-40 to 60 deg C
Campbell Scientific, Inc.	Measurement and Control Datalogger	CR1000	+/- 5000 mV	+/- 0.12 % reading + offset	-25 to 50 deg C
Campbell Scientific, Inc.	Soil Water Content Reflectometer	CS655	5 to 50 % Volumetric Water Content	+/-5% Volumetric Water Content	-10 to 70 deg C
Campbell Scientific, Inc.	Temperature and Relative Humidity Probe	HC2S3-L	Temperature - (-)40 to 60 deg C, Relative Humidity - 0 to 100% RH	Temperature - (+/-) 0.1 deg C, Relative Humidity - (+/-) 0.8% RH	-40 to 100 deg C

Manufacturer	Description	Model	Measurement Range	Measurement Accuracy	Operating Range
Michell Instruments	Chilled-Mirror Hygrometer	OPTSC02D IS02ACEST DLP232CM STD	-40 to 90 deg C Dew Point, Relative Humidity 2.0 to 100% RH	+/- 0.2 deg C Dew Point	-20 to 50 deg C
Omega	Type K Thermocouple	K	-200 to 1250 deg C	+/- 2.2 deg C	-200 to 1250 deg C

3.3.2 Calibration and Data Quality

All instrumentation and equipment will consist of "off-the-shelf" items ordered directly from qualified suppliers and will be evaluated prior to use for proper functionality. No specially designed equipment is anticipated. All equipment will be used according to the supplier's operation specifications. Redundancy in instrumentation will help ensure data quality. Quality Level 1 pre and post calibration will not be performed on the instruments.

3.3.3 Known Sources of Experimental Error and Uncertainty

There are no known sources of experimental error and uncertainty. Frequent data reduction and review will reveal any measurement errors, which will be reported as such, that surface as a result of the conditions during testing.

3.3.4 Data Acquisition

Data acquisition will be accomplished electronically with Campbell Scientific, Inc. Measurement and Control Dataloggers and supporting information (e.g. datalogger configuration) will be documented in the scientific notebook, SDI-SN-0001, *Salt Defense Disposal Investigations General Scientific Notebook.*

Frequent data reduction will ensure that data are recorded as expected in accordance with the datalogger configuration. The datalogger will be configured for scheduled data collections every 15 minutes and once per 24 hour period where the 3 second data intervals will be averaged for the M&TE listed in section 3.3.1.

Electronic data will be stored in the datalogger internal memory (~1 year capacity), on a computer connected to the datalogger, and on a second computer used for data reduction. The data will be stored on these sources.

Data transfers will be conducted by skilled personnel familiar with the data acquisition systems to minimize data transfer/conversion errors.

Data transfers to end users will be accomplished via email and/or by compact or digital video disk.

3.3.5 Software

LoggerNet Version 4.4.2 Datalogger Support Software will be used with Campbell Scientific, Inc. Measurement and Control Dataloggers in the data acquisition system. The software is commercial software used for datalogger configuration and data transfers to a computer.

In-use tests are not applicable to the software.

3.3.6 Provisions for Handling Unexpected Results, Unanticipated Test Conditions, or Off-Normal Events during Testing

If there are unexpected high temperatures or high wattages (beyond the wattage set point) the data acquisition system will power down the power supply. The TCO staff will coordinate and investigate the problem at the testing location and ensure that the prototype canister heater is powered down and placed in a cold stand by state.

The data collection system will automatically shut the system down if certain set-points are reached (e.g. if the heater strips approach 195 degrees C). This may be a possibility in tests at 1000 watts or above.

Any unexpected results will be investigated and rectified prior to resuming testing.

Nonconforming data will be identified and documented in the scientific notebook, data package, data report, or a combination of these. Users will be notified of data nonconformance's as necessary.

3.3.7 Deviations from Test Standards or the Test Plan

Deviations from the test standards or this Test Plan will be documented in the scientific notebook.

Since M&TE will not be calibrated there will be no deviations from test standards and no specially prepared test procedures are required.

3.3.8 Records

Records generated from this test plan (scientific notebook SDI-SN-0001 documentation, data or reports) will be considered NQ records and submitted to the LANL-CO Record Center using SDI-QP-007, *SDI Record Management*.

4.0 QUALIFICATION AND TRAINING

Participants performing work under this test plan are required to read this test plan and associated work control documents as applicable to the work. Required training is defined in the associated work control documents.

5.0 HEALTH AND SAFETY

The health and safety hazards associated with this work are chemical, electrical, environmental, and thermal. The health and safety hazards are controlled and mitigated through TCO Work Control Documents and associated Job Hazard Analyses. Currently, TCO Work Control Document TCO-WA-0007R04, *Instrumented Study Sites in WIPP* authorizes and releases the work in the underground.

6.0 PERMITS AND AUTHORIZATIONS

No special permits, licensing requirements, or special authorizations are required to conduct the scientific activity.

7.0 REFERENCES AND ATTACHMENTS

References

DOE (U.S. Department of Energy), *A Conceptual Plan for Salt Defense Disposal Investigations for the Disposal of DOE-EM Managed Wastes.* DOE/CBFO-12-3485. Carlsbad: Department of Energy Carlsbad Field Office. June 2012.

Letter, Krantz (RESPEC) to Weaver, *Salt Defense Disposal Investigation Heater System Design and Specifications Submission* (Portage Subcontract Number 5028S29), dated June 4, 2014.

Letter, George (S.M. Stoller Corporation) to Schwarz (Los Alamos National Laboratory), *Transmittal of the Comprehensive Final Report - Independent Design Analysis and Verification of "Heater Canister" as Part of the Salt Defense Disposal Investigation* (Subcontract Number 253219), dated October 29, 2014

SNL (Sandia National Laboratory), F. Hansen, R. MacKinnon, S. Sobolik, and P. Stauffer. *Intermediate Scale Testing Recommendation Report.* FCRD-UFD-2016-000030 Rev 0. Albuquerque. September 2016.

LANL (Los Alamos National Laboratory), S. Otto and A. Miller. *Salt Instrumentation Research and Development Status Report.* FCRD-UFD-2013-000203. Carlsbad: Department of Energy Carlsbad Field Office. September 2013.

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ATTACHMENT 1

Proposed Underground Location of the Prototype Canister Heater

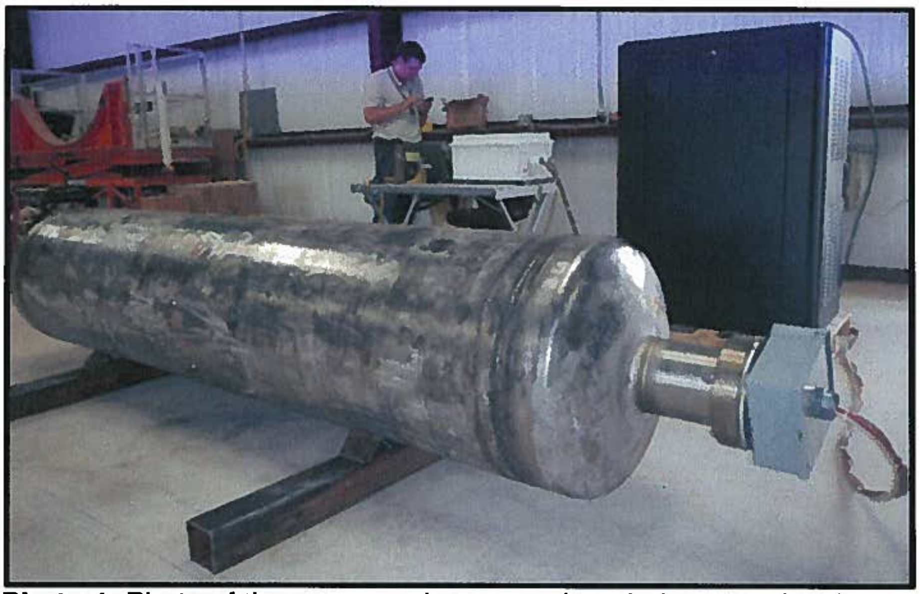


Photo 1: Photo of the prototype heater canister being tested at the LANL Mobile Loading Facility in Carlsbad.

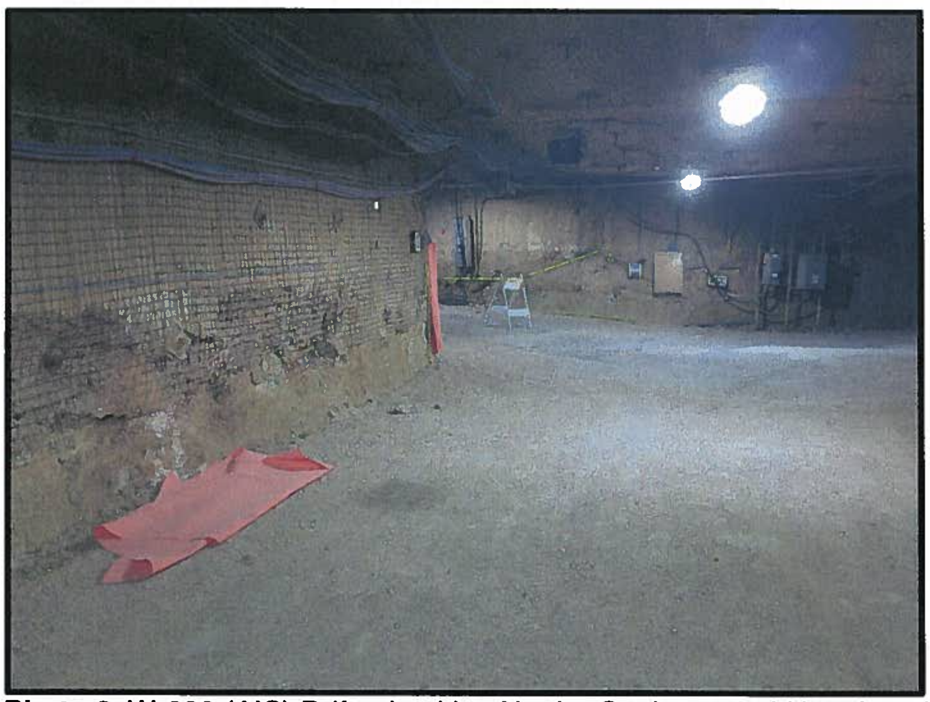
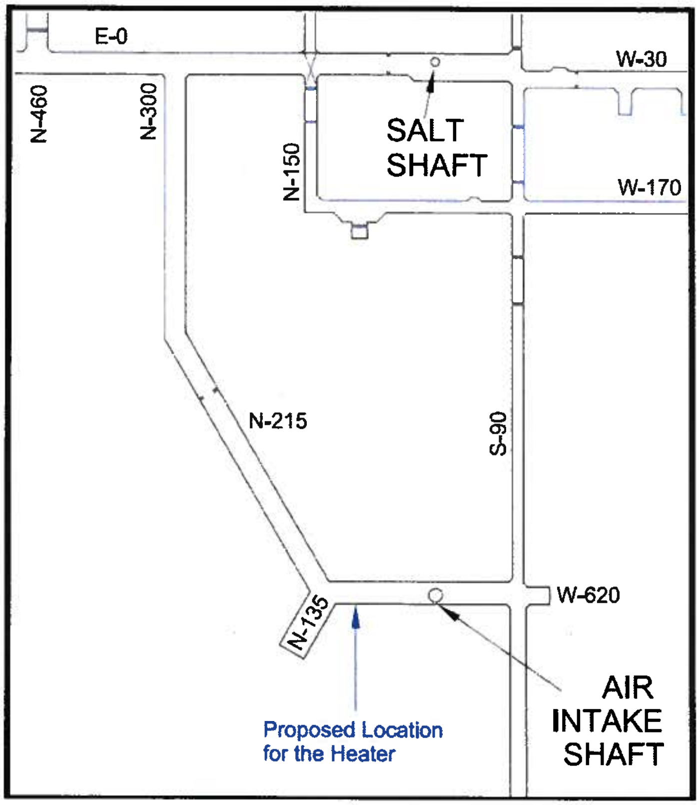
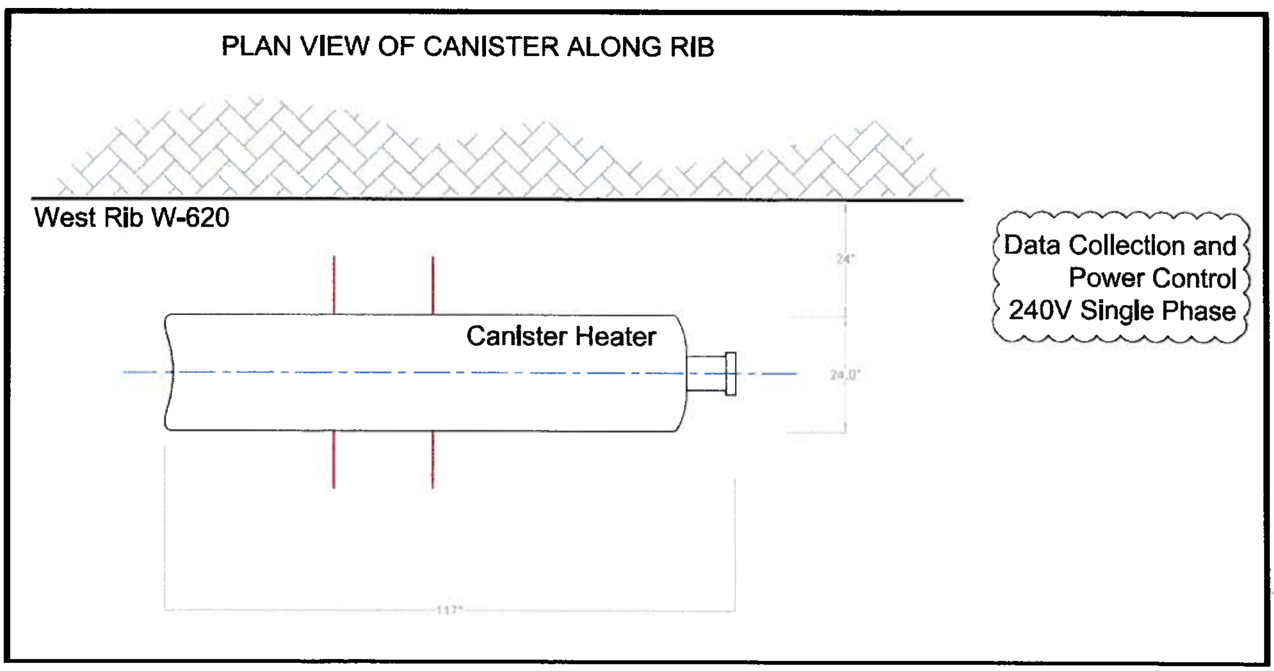
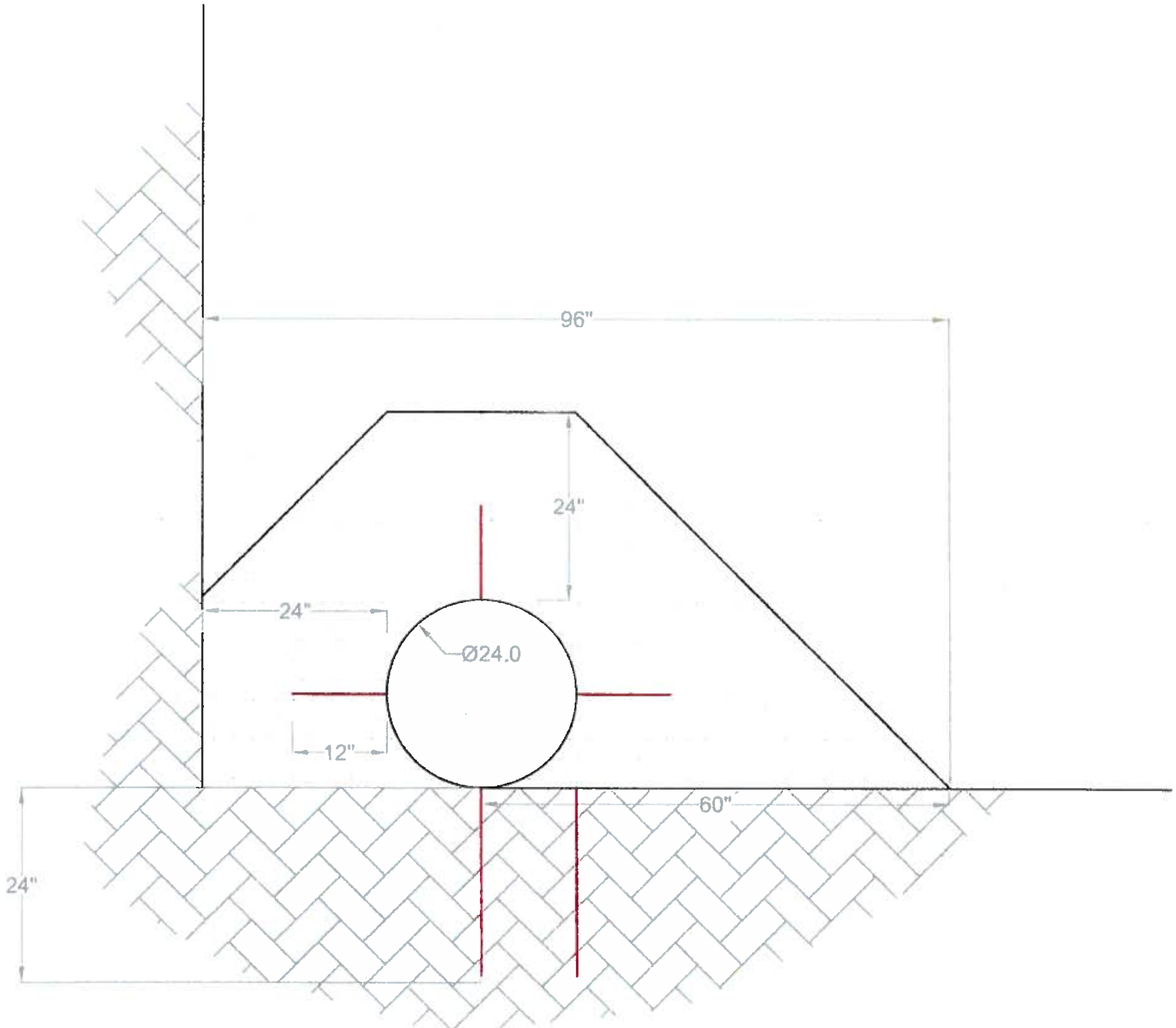


Photo 2: W-620 (AIS) Drift – Looking North. Canister would be placed on left rib (west). Power distribution panel is shown on the north rib toward the upper right of the photograph.


E-0
W-30
N-460
N-300
SALT
SHAFT
N-150
W-170
N-215
S-90
W-620
N-135
AIR
INTAKE
SHAFT
Proposed Location
for the Heater


PLAN VIEW OF CANISTER ALONG RIB
West Rib W-620
Canister Heater
Data Collection and
Power Control
240V Single Phase

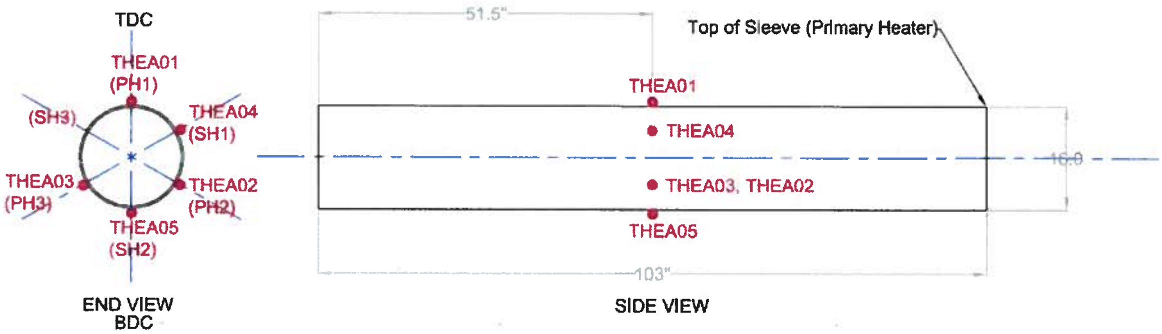
END VIEW OF CANISTER UNDER ROM SALT



ATTACHMENT 2

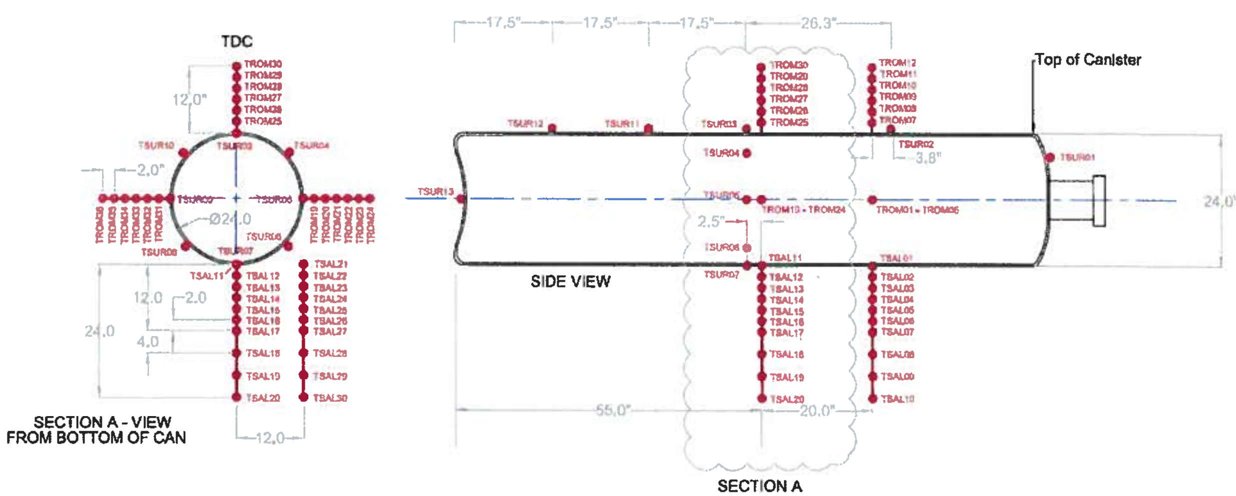
Thermocouple Layout on the Prototype Canister Heater

TCs ON THE MIDPOINT OF THE STRIP HEATERS



THEA = Thermocouples on the heater strips inside the canister (1-5)

TCs OUTSIDE THE CANISTER

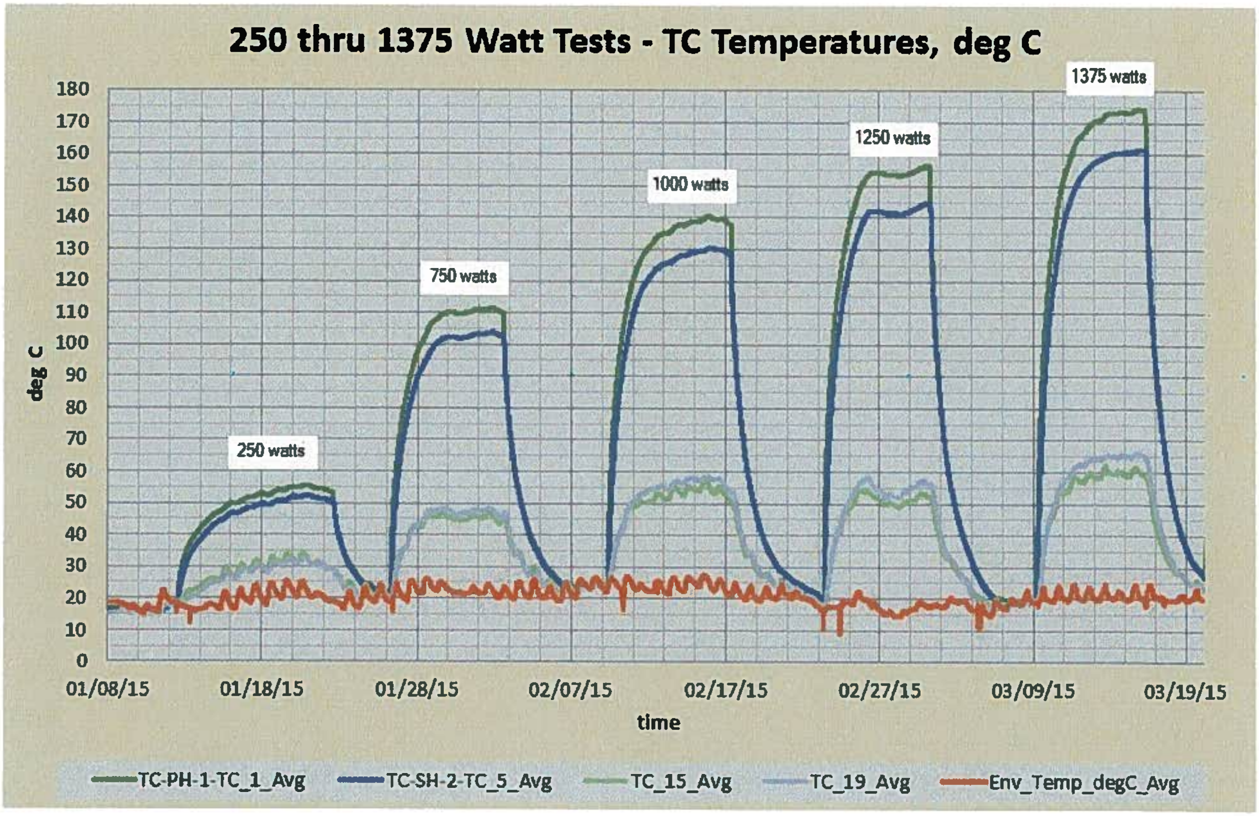


All dimensions in inches

THEA = Thermocouples on the heater strips inside the canister (1-5)
TSUR = Thermocouples on the surface of the canister (1-13)
TROM = Thermocouples in the ROM salt above and to the sides of the canister (1-36)
TSAL = Thermocouples in the intact salt underneath the canister (1-30)

APPENDIX 1

Graphical Representation of Actual Data for the Prototype Canister Heater



APPENDIX 2

Pre-Test Predictions (Provided by P. Johnson, Dept. of Geology, University at Buffalo)