Department of Energy
Carlsbad Field Office
P. O. Box 3090
Carlsbad, New Mexico 88221

June 5, 2024

Ms. Lee Ann B. Veal, Director
Radiation Protection Division
Center for Federal Regulation
Environmental Protection Agency
1200 Pennsylvania Ave. N.W.
Washington, DC 20460

Subject: Notification for Start of Experimental Activities Associated with Storage of a Nonflammable Gas Mixture Containing Hydrogen in Permian Basin Bedded Salt Formations

Dear Ms. Veal:

This correspondence serves as notification that experimental tests associated with storage of a nonflammable gas mixture containing Hydrogen (<5.5%) are planned to be conducted in accordance with test plan SDI-TP-004 for Hydrogen (Nonflammable Gas Mixture) Storage in Permian Basin Bedded Salt Formations. The enclosed test plan describes a series of tests to be conducted in the N-940 drift of the northern underground experimental area, designated for Salt Disposal Investigations, at the Waste Isolation Pilot Plant (WIPP) facility. The tests are non-WIPP related.

The goal of these tests is to understand the behavior of hydrogen in bedded salt with the objective of validating pore-scale and effective-porous medium models. The gas used for this test will be a diluted nonflammable gas mixture with hydrogen in either nitrogen or argon.

The planned tests will not result in modifications or impacts to waste disposal processes or operations, the WIPP repository footprint through new mining, the mine ventilation system, or introduce hazards/material not previously evaluated. Work implementation details, task-specific hazard analysis, and safety work requirements will be established in WIPP-approved work control documents before work release. Upon completion of the experimental activity, all activity-specific hardware and equipment will be removed from the WIPP underground.

CBFO:ERCD:MG:SV: 24-0349

If you have any questions, please contact George Basabilvazo at (575) 706-0083.

Sincerely,

MARK BOLLINGER

Digitally signed by MARK BOLLINGER
Date: 2024.06.05 17:26:34 -06'00'

Mark Bollinger
Manager
Carlsbad Field Office

Enclosure

cc:

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TEST PLAN

SDI-TP-004, REVISION 0

Hydrogen (Nonflammable Gas Mixture) Storage in Permian Basin Bedded Salt Formations

Effective Date: 4/18/2024

Prepared By: SHAWN OTTO (Affiliate) Digitally signed by SHAWN OTTO (Affiliate) Date: 2024.04.16 09:18:10 -06'00'

Shawn Otto — Date
WIPP Underground Test Coordination Office

Prepared By: Eric Guiltinan — 4/16/2024

Eric Guiltinan — Date
Los Alamos National Laboratory – Principal Investigator

Concurrence: — 4/16/2024

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Doug Weaver — Date
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HISTORY OF REVISION

Rev. No.	Approval Date	Summary of Revision
0	4/18/2024	Initial Issue

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ACRONYMS

CBFO	Carlsbad Field Office
DOE	Department of Energy
EPA	Environmental Protection Agency
H_2	Hydrogen
IPT	Integrated Project Team
JHA	Job Hazard Analysis
LANL	Los Alamos National Laboratory
LANL-CO	Los Alamos National Laboratory Carlsbad Office
M&O	Management and Operating Contractor
M&TE	Measuring and Test Equipment
PI	Principal Investigator
QA	Quality Assurance
QAPD	Quality Assurance Program Description
SDI	Salt Disposal Investigations
SN	Scientific Notebook
TCO	Test Coordination Office
WIPP	Waste Isolation Pilot Plant
WP	WIPP Procedure

1.0 INTRODUCTION

Large-scale hydrogen (H_2) geologic storage presents a viable alternative to surface storage that is both safer and more economical. One option being considered by Department of Energy (DOE) is hydrogen storage in salt formations. Currently in the United States, hydrogen storage has been conducted within salt domes/caverns. However, hydrogen storage within bedded salt has only been done in the United Kingdom. As the United States ramps up its research and development (R&D) effort in the hydrogen storage field, New Mexico has a unique advantage in that bedded salt formations are located strategically in areas where excess energy production can be harnessed for hydrogen production. The deep geologic repository at the Waste Isolation Pilot Plant (WIPP) receives defense-related transuranic (TRU) waste for permanent disposal. In addition to waste disposal, the WIPP is a unique location and environment for conducting underground research. The WIPP's underground has hosted numerous universities and research institutions across the nation for conducting scientific experiments and R&D campaigns. The open door policy for conducting experiments in the WIPP underground and the unique geology provide a testing location to further understand hydrogen storage within bedded salt. A small-scale hydrogen storage experiment using vertical and/or horizontal boreholes in the WIPP underground will be utilized for pressure testing the boreholes and measurement of hydrogen diffusion and advective transport. The core samples obtained from drilling the boreholes will be utilized in off-site experiments to further enhance and understand hydrogen storage.

This work is planned to be conducted in the N-940 drift of the northern underground experimental area at the WIPP facility. None of the planned test activities result in modifications or impacts to waste disposal processes or operations, there will be no changes to the WIPP footprint, there will be no changes to the WIPP ventilation, or no new hazards or materials not previously evaluated. The proposed hydrogen storage test is not related to WIPP facility disposal mission. There is no mining associated with this hydrogen storage test. The hydrogen storage test activities are limited in scope and complexity and will not affect the mission or operations of TRU waste disposal at the WIPP. The gas used for this test will be a diluted nonflammable gas mixture with hydrogen in either nitrogen or argon.

2.0 WORKSCOPE

2.1 PURPOSE AND SCOPE

The overall purpose and scope of this technical work is to advance technology to develop hydrogen storage caverns in Permian Basin bedded salt. The primary goal for testing in the WIPP underground is the execution of a small-scale hydrogen storage field test to validate pore-scale and effective porous medium scale observations. Data are used for modeling and model validation.

WIPP core samples are a key competent for hydrogen storage research as well. The core samples will be collected during borehole construction in accordance with SDI-SP-005, *SDI Sample Control*. Core samples will be taken offsite and used for quantification of physical properties of Salado Formation rocks used for the development of predictive models regarding hydrogen storage effectiveness and identify potential alterations.

2.2 MAJOR ACTIVITIES

The section below lists and describes each major activity associated with this workscope.

2.2.1 Borehole Array

The borehole array will consist of five boreholes (attachment 1). There will be four drilled boreholes and one cored borehole. The drilled boreholes will be ~2.1 inches in diameter and lengths will vary from 10 to 20 meters (~32.81 to 65.62 feet). The cored borehole will be ~4.75 inches in diameter with a length of ~ 20 meters (65.62 feet. The boreholes will be drilled vertically up through the back in two stages. First, the central cored borehole will be completed and instrumented. This will allow for hydrogen measurements to be completed without any communication to the satellite boreholes. Later the satellite boreholes will be drilled and instrumented in an attempt to measure the flow of hydrogen along stratigraphic beds. The length of the boreholes ensure that many geologic units, such as halite, anhydrite, polyhalitic halite, argillaceous halite, and clay seams are passed through for the purpose of testing lithological variation. If problems arise during the vertical drilling, then horizontal boreholes may need to be used for the test. Common drilling problems in the vertical orientation are core retrieval, cuttings build up in the borehole, and brine and/or clay encounters that lead to drill

bit/core barrel binding. Horizontal boreholes that are angled can also achieve lithological variation for the purpose of this test. The goal is for the boreholes to be in the vertical orientation. A nonflammable gas mixture of hydrogen in nitrogen or argon will be stored in the cored borehole and the surrounding drilled boreholes will be used for monitoring hydrogen migration.

Core samples from the cored borehole will be collected in accordance with procedure SDI-SP-005. The procedure prescribes the process for ensuring that SDI core and sample identification, collection, handling, logging, use, storage, shipping, archiving, disposition, and disposal, including those identified as nonconforming, are performed in such a manner as to prevent damage, reduction in scientific value, or loss of identity and/or traceability. The core will be transferred off-site for analysis and core transfer will be documented in the SDI-SP-005 chain-of-custody form.

2.2.2 Test Infrastructure and Instrumentation

The cored borehole will act as the hydrogen storage borehole. The hydrogen used in the test will be a less than 5.5% hydrogen in argon or nitrogen gas mixture to ensure that the gas mixture is classified as non-flammable. An inflatable packer will be used in the cored borehole, and the hydrogen gas mixture will be injected into the borehole behind the packer and when the desired pressure, typically 20 psi, is achieved, a valve will be closed to store the hydrogen gas mixture behind the packer. For a 20-meter borehole, with a 4.75-inch diameter, gas flowed at 20-psi will produce 322 liters of gas. The estimated working area near the boreholes is 42,475 liters. Note, this working area is not confined and there is air flow from the ventilation system. If the working area is treated as a confined space and there was a sudden release of the 322 liters of gas from the borehole, then the oxygen level would be reduced from 20.95 % to 20.76 to 20.80% per confined space calculations. 20.76% is well above 19.5%, which is the confined space minimum acceptable % oxygen level. If the desired pressure cannot be achieved, due to the high permeability of the formation, then gas flow will be maintained and the monitoring boreholes should see the hydrogen migration and the formation can be characterized. For this scenario, 2,942 liters of gas are needed to displace oxygen levels below 19.5%. A flow controller will be used for monitoring the total volume of gas flowed to the formation and the volume will not exceed 2,942 liters. Again, this is a conservative calculation for a confined space. The

working area is not a confined space and there is air flow from the ventilation system.

Three of the drilled monitoring boreholes (15m, 15m, and 10m long boreholes) will use either mechanical or inflatable packers with one inflow and one outflow pass thru to circulate air behind the packer. The circulation line will have monitoring instrumentation in the air stream to monitor for hydrogen.

The remaining 20-meter drilled borehole will have a dual inflatable packer system with a ~24-inch test interval between the two packers. The front packer will have one inflow and one outflow pass thru to circulate air between the two packers in the test interval. The circulation line will have the hydrogen monitoring instrumentation in the air stream to monitor for hydrogen. The dual packer system can be moved within the borehole to test varying portions of the borehole for hydrogen migration.

Hydrogen monitoring instrumentation will be a residual gas analyzer and potentially a SPEC Sensors hydrogen electrochemical sensor in the event that the residual gas analyzer malfunctions.

Pumps will be used to re-circulate the air between the boreholes with the instrumentation located at the rib. Mass flow controllers will control the re-circulation flow rate to satisfy the instrumentation flow requirements.

The boreholes will be isolated from the drift environment using mechanical and/or inflatable packers. All inflatable packers' inflation pressures will be controlled with regulators. The inflation pressure of the packers will be equal to or below the manufacture's recommendation for the inflation pressure. The regulators will have pressure relief valves that ensure the pressure cannot be greater than the tolerance of the instruments downstream from the regulators. All inflatable packers will have pressure transducers to monitor the inflation pressure. All packers will use pressure transducers to monitor the air pressure and the hydrogen borehole will use a pressure transducer to monitor the pressure of the injected hydrogen gas mixture behind the packer.

2.2.3 Testing Schedule

Testing will be conducted in two phases. First, the central borehole will be cored and instrumented. Prior to drilling the remaining satellite boreholes, the central borehole will be pressurized with the non-flammable hydrogen mixture and the pressure in the borehole will be monitored. We foresee this testing period lasting as long as two to three months but the length will depend on the rate at which the pressure drops. By conducting the test in phases, we mitigate the risk of large cross communication between the boreholes from preventing the measurement of hydrogen loss to the formation. Also during this stage, the core samples will be collected and shipped to Los Alamos and the University of Texas at Austin for laboratory hydrogen exposure tests.

During the second phase of the test, the four satellite boreholes will be drilled and instrumented. Communication between these boreholes will be measured during tests where the central borehole is pressurized. The design of these boreholes will allow for experiments measuring hydrogen communication with depth into the formation as well as distance from the central borehole. The distance between the boreholes is approximate and may be expanded or reduced slightly depending on the findings from the first phase of the experiment. We will use numerical simulations as well as our field experience to guide any adjustments.

2.3 INTENDED USE OF DATA AND PRODUCTS

The intended use of the data are to test, evaluate, and characterize hydrogen storage applications and to explore the feasibility of hydrogen storage in bedded rock salt of the Permian Basin.

Data acquisition systems will log and store pressure transducer, and mass flow controller data. The data collection intervals for these instruments will be defined by the principal investigators (PI's) and the data collection intervals will be less than or equal to 10-minute intervals. The gas analyzer, used for monitoring hydrogen migration, will also collect data in intervals less than or equal to 10-minutes.

All stored data can be downloaded and stored electronically in spreadsheets and/or databases where data can be reduced and analyzed to better understand hydrogen migration.

Data will be shared electronically with the collaboration and data may be used for modeling, publications, and to determine the feasibility of hydrogen storage in bedded rock salt.

2.4 ORGANIZATIONS PERFORMING THE WORK

2.4.1 Responsibilities

WIPP Management and Operating Contractor (M&O)

The M&O is responsible for drilling the boreholes for this test. The M&O will also be responsible for utility requirements to support the proposed investigations including electrical power, compressed air, lighting, communications, and ventilation. This work will be formally requested and scheduled through the M&O Management and Control Procedure WP 10-WC3015, *Scheduling and Work Authorization*.

Test Coordination Office (TCO)

The TCO is responsible for ensuring tests are planned and executed in compliance with procedures, processes, directives, and orders related to quality, environmental compliance, measurement & test equipment control, safety and health, integrated safety management, work control, underground access, sample control, data and software management, and other requirements related to scientific investigations. TCO responsibilities will be performed in accordance with M&O's processes for conducting physical work in the WIPP underground (WP 02-EC.12, *Site Users and Tenants Guide for Organizations, Personnel, or Companies That Perform Work on U.S. Department of Energy Property or Rights-of-Way on or Around the Waste Isolation Pilot Plant* and WP 12-IS.01-6, *Industrial Safety Program – Visitor, Vendor, User, Tenant, and Subcontractor Safety Controls*). The TCO helps to ensure that DOE-Carlsbad Field Office (CBFO) sponsored science and testing activities in the WIPP underground generate test-related information and data that are of high quality, and that all testing activities are well coordinated, focused, and safe, particularly when multiple organizations are involved in the investigations.

The TCO will provide trained and qualified staff for the collection, logging, and control of cores and samples in the underground under procedure SDI-SP-005, *SDI Sample Control*.

The TCO will provide trained and qualified staff for installing and maintaining test infrastructure, measuring and test equipment, and data acquisition systems. The TCO will provide the downloaded data to LANL PIs for analysis.

Los Alamos National Laboratory and University of Texas at Austin

The PIs from Los Alamos National Laboratory and the University of Texas at Austin will provide the scientists and experimental personnel necessary to execute the task as a team effort, plan and execute the experimental activities described herein. The PIs will request core and samples as appropriate and will provide any unique scientific equipment, instrumentation, and resources necessary for the implementation of the program.

2.4.2 Interfaces

The TCO is responsible for coordinating the test work authorization and 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 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 PIs to ensure that data collection is sufficient for data analysis and modeling efforts.

The M&O will ensure important information related to issues affecting the science program (e.g., power outages, access restrictions) is provided to the TCO in a timely manner so that adjustments can be made.

All parties are responsible for interfacing with the CBFO to ensure that expectations are fulfilled.

3.0 EXPERIMENTAL METHODS

3.1 OVERALL TEST STATEGY AND PROCESS

3.1.1 Test Variables

The test variables include the gas composition, gas pressure and variability of the salt texture. Hydrogen migration will be monitored as a function of pressure, gas concentration and salt compositions.

3.1.2 Pretest Predictions and Expected Results

Pre-test predictions are the hydrogen will migrate via the Lithological variations to the monitoring boreholes and the hydrogen monitoring instrumentation will validate and characterize the ability of the hydrogen to migrate. Since the hydrogen atom is small, the migration pathway could be through the bedded salt. The dual packer system that will be used in the drilled boreholes can be moved throughout the monitoring boreholes to test specific borehole intervals to define the migration pathway.

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 errors and suspect readings that will be documented as such. The frequent data reviews will determine if 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 under 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 lcodocs.lanl.gov.

3.1.6 SDI 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 electronic data and scientific notebook will be used to develop a data package and/or report that provide supporting data for modeling or scientific analysis. The data will be documented (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.

3.1.7 Prerequisites and Special Controls

Following the approval of this test plan and prior to work release, Section 5.4 of management and control procedure WP 02-PC3003, *EPA Compliance Programs Screening and Evaluation* will be followed to ensure the Environmental Protection Agency (EPA) is notified of the planned experimental work activity.

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

3.2 SAMPLE CONTROL

3.2.1 Sample Collection, Preservation, and Control

SDI-SP-005, *SDI Sample Control,* establishes the process, responsibilities, and controls used for all aspects of sampling and core collection for the SDI and other activities in the WIPP SDI research area as directed by the DOE CBFO. This procedure

provides a process that ultimately ensures that SDI samples comply with the SDI Quality Assurance Program Description (QAPD) (DOE. June 2011a) requirements.

The predominant number of samples from this program will come from core generated from the drilling program.

The objectives of this procedure are to define the responsibilities, including organizational interfaces, to maintain the integrity of SDI samples and core during the life of the sample.

The M&O will provide underground core drilling and sample support. This work will be requested through WP 10-3011, *Work Control Process.*

3.3 DATA ACQUISTION AND QUALITY CONTROL

3.3.1 Measuring and Test Equipment

Table 1 – M&TE and Instrumentation, shows the M&TE and instrumentation that will be used to collect the non-quality assurance (QA) data.

3.3.2 Calibration and Data Quality

All instrumentation and equipment will consist of "off-the-shelf" items ordered directly from qualified suppliers. All instrumentation will be evaluated prior to use for proper functionality. All equipment will be used according to the supplier's operation specifications. Redundancy in instrumentation will help ensure data quality. QA 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.

Electronic data will be stored in the datalogger internal memory (~1 year capacity), 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 electronic transfer.

3.3.5 Software

LoggerNet Version 4.7 (or newer if an update to the software is released during the test) 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

In the event that unexpected results or conditions are identified, work shall be paused to assess if the task can be continued safely. If adjustments can be made, that are within the scope and mitigations in the Job Hazard Analysis (JHA), then work can continue. If the condition identified is outside of the JHA scope then work shall be stopped and the work control document will be revised, reviewed, and approved before restating work.

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 or report.

Since Measuring and Test Equipment (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) will be considered non-QA 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 for fieldwork will be defined in the associated work control document TCO-WA-0026.

The PIs and the LANL research team consist of experts in conducting borehole experiments with pressurized gas both underground at WIPP and at the Nevada National Security Site.

5.0 HEALTH AND SAFETY

The health and safety hazards associated with this work are primarily electrical, environmental, and pressure related in addition to underground work hazards. The health and safety hazards are controlled and mitigated through SDI Work Authorizations and Hazard Control Plans.

The M&O will develop job hazard analyses and associated work control products necessary to safely conduct the survey and coring activities, as well as any ancillary construction or test support functions (e.g. establishment of utilities).

LANL and University of Texas at Austin staff members are responsible for providing the necessary input and products such that the TCO can develop appropriate work authorization and work control documentation, including job hazard analyses, for the testing activities for M&O review/acceptance, compliant with both laboratory and M&O requirements. This ensures the consistent and safe conduct of physical scientific work activities in the WIPP underground. This process is outlined in section 2.3 of the Integrated Project Team (IPT) Charter (CBFO. March 2013) and the products conducted under SDI-SP-001, *Testing Work Authorization and Control*. Scientists and experimental personnel

associated with this defined underground program are not only responsible for their own health and safety but are also responsible for the safety of fellow employees, and for the safe operation of the experimental activities, not precluding M&O and CBFO oversight of the scientific work.

6.0 PERMITS AND AUTHORIZATIONS

No special permits or licensing requirements are required to conduct the scientific activity. Following the approval of this test plan and prior to work release, Section 5.4 of management and control procedure WP 02-PC3003, *EPA Compliance Programs Screening and Evaluation*, will be followed to ensure the EPA is notified of the planned experimental work activity.

7.0 ATTACHMENTS

Attachment 1 – Planned Borehole Array

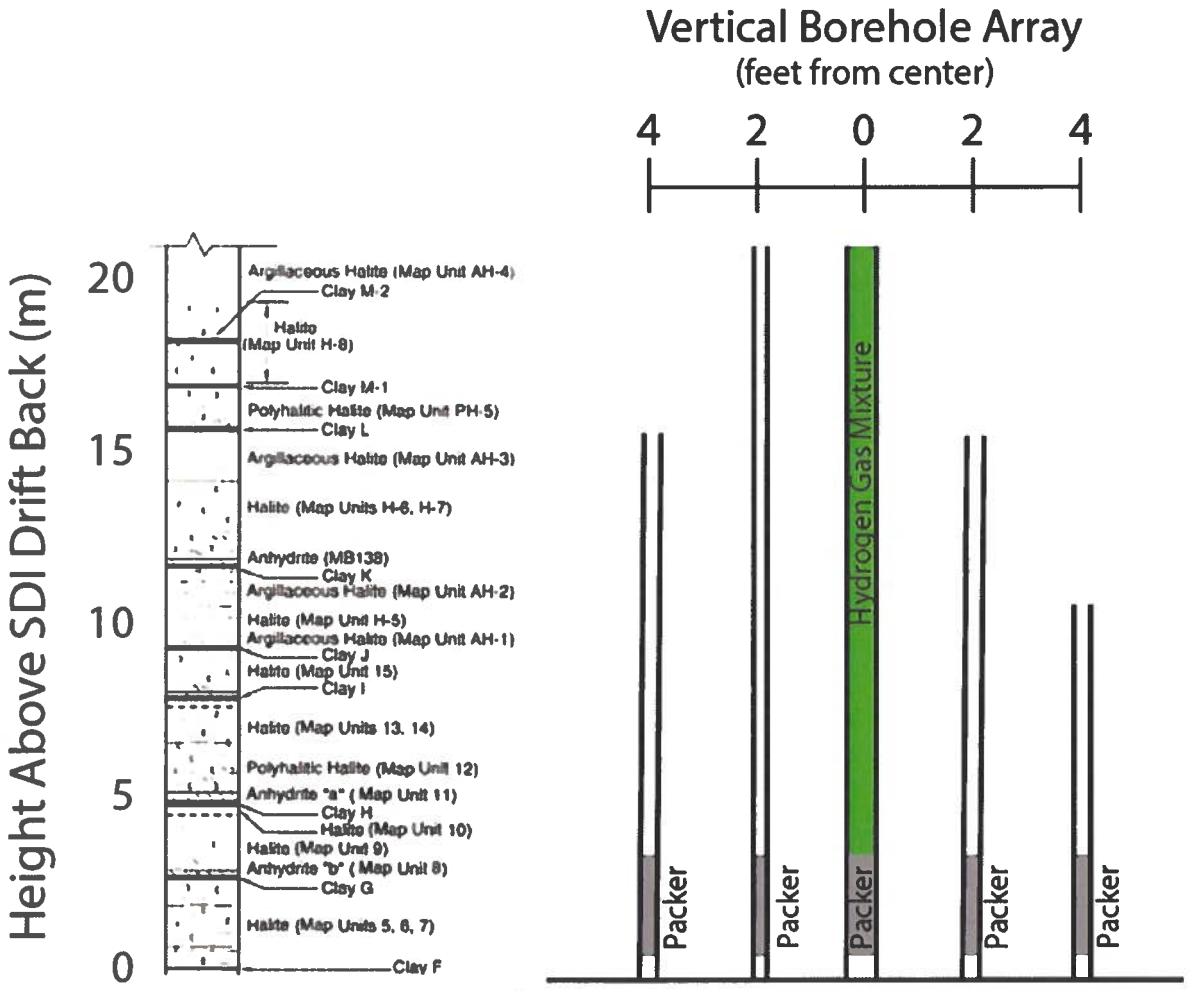

Table 1 – M&TE and Instrumentation

Description	Model	Measurement Range	Measurement Accuracy	Operating Temperature Range	Instrument Response Time	Power Requirements	Comments
Campbell Scientific CR1000X Datalogger	CR1000X	0 to 5000 mV	+/-0.06% of measurement + offset	-40 to 70 deg C	1 second	10 to 18 Vdc, 1 mA @ 1 Hz scan rate	none
Omega Pressure Transducer	PX319-100G5V	0 to 100 PSIG	+/-1.0%	-20 to 85 deg C	<1 millisecond	9 to 30 Vdc, <10 mA	**Pressure Overload**: 0 to 100 psig: 3 times rated pressure or 20 psi whichever is greater. **Burst Pressure**: 0 to 100 psig: 4 times rated pressure or 25 psi whichever is greater.
Omega Pressure Transducer	PX319-050G5V	0 to 50 PSIG	+/-1.0%	-20 to 85 deg C	<1 millisecond	9 to 30 Vdc, <10 mA	**Pressure Overload**: 0 to 50 psig: 3 times rated pressure or 20 psi whichever is greater. **Burst Pressure**: 0 to 50 psig: 4 times rated pressure or 25 psi whichever is greater.
Omega Flow Controller 0-2 SLPM	FMA-2605A	0 to 2 L/minute	+/-(0.8% of reading + 0.2% of Full Scale)	-10 to 50 deg C	100 milliseconds	10 to 30 Vdc, 0.250 A	**Max. Operating Pressure**: 145 psi.
Omega Flow Controller 0-20 SLPM	FMA-2608A	0 to 20 L/minute	+/-(0.8% of reading + 0.2% of Full Scale)	-10 to 50 deg C	100 milliseconds	10 to 30 Vdc, 0.250 A	**Max. Operating Pressure**: 145 psi.
Valco Valve Selector	EUTB-ST4MWE	N/A	N/A	0 to 200 deg C	<1 second	24 Vdc, 60W	**Max. Pressure:** 200 psi Gear Box T
KNF Swing Piston Compressors	NPK03KVDC-B4 PR	N/A	N/A	5 to 40 deg C	<1 second	12Vdc, 1.2A Uctrl = 0 to 5 VDC	**Max. Operating Pressure:** +550kPa (5.5 bar) **Max. Flow Rate (atm):** 2.7 L/min **Ultimate Vacuum:** 250 mbar
Pump Controller	CC5MD	N/A	N/A	?	<1 second	6V-30V DC, 6A, 16kHz	**Max. Current:** 8A
Spec Sensors Hydrogen Electrochemical Sensor	110004	0 to 1000 ppm	sensitivity nA/ppm at 10 ppm = 6 +/- 4	-10 to 40 deg C	<300 sec	not listed by manufacturer	none
SRS Residual Gas Analyzer	RGA200	Mass Range - 1 to 200 amu	better than 1 amu	maximum = 70 deg C	not listed	14 VDC @ 2.5 amps	none