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1. **Introduction and Objectives**

The U.S. Department of Energy Carlsbad Field Office (DOE/CBFO) has implemented a multi-year hydrology program (Sandia, 2003; Program Plan: WIPP Integrated Groundwater Hydrology Program, FY03-09) to determine the cause and impact of Culebra water level rises that have occurred within and near the WIPP site and to modernize and optimize the existing WIPP groundwater-monitoring well network. An important component of the hydrology program is the drilling and hydraulic testing of wells (1) to investigate various scenarios explaining the observed water level rises and (2) to replace aging monitoring wells currently scheduled to be plugged and abandoned. DOE/CBFO has tasked Sandia National Laboratories with the investigation of the Culebra water levels rises, well testing and test data interpretation, and modeling to optimize the number and locations of new wells.

Hydraulic testing and sampling focuses on acquiring data used to derive hydraulic parameter estimates for performance assessment groundwater flow and contaminant transport modeling (Chace, 2003; Sandia Test Plan TP 03-01). These data include:

- Transient head response and pumping rates acquired from single- and multi-well pumping tests to estimate such hydraulic parameters as flow dimension (n), storativity (S), and transmissivity (T);
- Indirect measurement of the rates and directions of groundwater flow through wells that can be used in model verification;
- Fluid specific gravities (or densities) used in calculation of hydraulic head gradients; and
- Water-quality analyses that provide anecdotal evidence of the presence of native waters during well development and that may be useful in inferring flow directions and fluid sources.

Interpretation of hydraulic data is achieved through use of the sophisticated well-test analysis code, nSIGHTS, under development by Sandia. nSIGHTS is a numerical code developed as part of an advanced hydrological characterization statistical methodology that provides the means to investigate and quantify uncertainties in well-test parameter estimates. A feature of the methodology is the real-time analysis of data during testing to provide feedback for test conditions, e.g., test duration, data type and logging frequency.

The DOE/CBFO well testing activities, including use of the nSIGHTS well-test analysis code, requires acquisition of high-quality data and accurate control of well test variables (e.g., pumping rate). To meet these high standards of data quality and test control, Sandia identified the need for and procured a data acquisition system (DAS) designed specifically for this hydraulic testing application. This performance test plan serves to guide the technical tasks that, when completed, will document the capabilities of the DAS and the adherence to specified acceptance criteria.

1.1 Introduction

The DAS was designed to meet the data acquisition requirements of the WIPP hydraulic testing program (Chace, 2003), while taking advantage of commercially available off-the-shelf software and compatible hardware components.

The DAS hardware was designed and built using a modular approach incorporating components directly available from SIXNET. The SIXNET hardware includes the SixTRAK IPM RTU, discrete input/output modules, and analog input/output modules. The SixTRAK IPM RTU processor is equipped with: 2 MB static RAM, 16 MB dynamic RAM, and 8 MB flash RAM; uses the LINUX operating system; and features both Ethernet and serial ports. The discrete input and output modules are both DC powered and are configured with 8 channels each, and operate over temperature ranges of -30° to 70° C. The analog input and output modules are capable of 4-20 mA signals and operate over the same temperature range as the discrete modules (i.e., -30° to 70° C). The SIXNET components are housed in a Hoffman panel enclosure, which also incorporates the 24 VDC power supplies, circuit breakers, fuses, and relays to protect and control the system.

The five software products used to operate and interface with the DAS include:

1. ISaGRAF – an RTU programming package
2. SIXNET Tool Kit – a SIXNET hardware configuration tool
3. Wonderware – a human-machine interface (HMI) tool to create custom operator interface/display screens
4. InSQL – a database product to collect and store data
5. KepWare – a data exchange tool

These five software products are described in greater detail in Section 3.

1.2 Objectives

The data acquired from hydraulic testing is used to derive parameter estimates used in WIPP compliance recertification analyses and thus the software used to operate the DAS is considered to be Compliance Decision (CD) software. Qualification of all CD DAS software must meet the requirements of NP 19-1, *Software Requirements*, unless the DAS software is an integral part of an off-the-shelf system and not subsequently modified. Under this exception, DAS software is qualified using the requirements of NP 20-1, *Test Plans*. NP 20-1 specifically states that the qualification requirements for off-the-shelf commercial software used without modification are limited to documentation of the software name, version, and hardware for which it is used.

All of the DAS software identified in Section 1.1 and described in Section 3.0 is off-the-shelf and will not be modified (cannot be modified because the source code for the software has not been provided); therefore only those parts of NP 20-1 related to identifying the software name, version, and hardware are applicable. Since the DAS software does perform simple data manipulation consisting of converting measured signals into engineering units, the requirements of NP 9-1 will apply. The conversion of the raw inputs to engineering units is performed using simple analytical operations that can be verified by hand calculations. These routine calculations are covered in Appendix C of NP 9-1, *Analyses*.

2. Approach

This plan implements a series of test cases to evaluate the operation and performance of the fully assembled DAS, including both the off-the-shelf software and the hardware components. By using this system configuration, an end-to-end assessment can be made directly without relying on inferences drawn from tests conducted on individual components and/or software packages.

Seven test cases have been develop and are summarized as follows:

1. Evaluate the system's ability to measure an analog input signal, convert the value to an engineering unit using calibration coefficients, and display the feedback at the HMI.
2. Evaluate the system's ability to measure a Resistive Temperature Device (RTD) or thermocouple input signal and convert the signal value to an engineering unit.
3. Evaluate the system's ability to measure an analog input signal, convert the value to engineering units using Min/Max ranges, and display the feedback at the (HMI).
4. Validate the system's ability to control either a valve position or motor speed using a 4-20 mA output signal.
5. Evaluate the system's ability to let the user enter High and Low alarm limits that when exceeded will notify the operator of an off-normal condition.
6. Evaluate the highest speed at which all DAS channels can be scanned and the associated data logged and stored without loss of integrity.
7. Evaluate the DAS system, instrumentation, and control hardware (valves, pump, etc) in a hydraulic well test mock-up.

Test Cases 1 through 3 focus on the ability of the DAS to log various types of raw data and convert these raw data to engineering units using simple user-supplied algorithms. Test Case 4 demonstrates the ability of the DAS to perform its control function, while Test Case 5 evaluates the HMI software by testing the DAS's ability to acknowledge user inputs correctly and display alarm limits based on the user input. Data logging speed and the degradation in speed caused by greater numbers of logged channels are evaluated in Test Case 6. Finally, Test Case 7 represents a complete system test under conditions that simulate a full-scale hydraulic test.

During the performance of the test cases, relevant information including: a list of equipment used, calibration status of instrumentation, operator name(s), date/time/conditions of the test and the data acquired during each test will be recorded on standard forms (see Attachments 1 through 6). Each form will contain the version number of the DAS software being tested and identify the analysis plan followed. As appropriate, hand calculations of simple calculations, unit conversions, and data manipulations will be performed and the results reviewed, checked, and documented on the standard forms or in the Scientific Notebooks. The DAS must achieve the acceptance criteria defined in each of the test cases in order to successfully pass this demonstration test. Subsequent to the completion of all test cases, a data report will be prepared to document all test activities related to this plan as well as the final results. This report will receive technical, management, and QA reviews before it is submitted to the Sandia Records Center.

2.1 Project Resources

The analysis plan will be conducted with the DAS installed in the Sandia Hydrology Test Trailer to simulate field operations and to provide for the necessary interface with various hydraulic measurement and test equipment mounted in the trailer. For the convenience of test personnel, the test trailer will be stationed within the secured area of Sandia’s facility located at 4100 National Parks Highway, Carlsbad, NM for all tests.

This analysis plan will be implemented by field test personnel responsible for the setup, operation and maintenance of the WIPP Hydrology DAS. The analysis plan shall be implemented whenever changes are made to the ISAGraf controller logic or the Wonderware HMI. The activities in this analysis plan are funded out of the Sandia WIPP Hydrology program which is under the direction of the Department of Energy (DOE).

2.2 Project Tasks and Milestones

N/A

3. Software List

The subsequent test cases will be run on a computer system using a Windows 2000 Server, (Service Pack 3 or higher) operating system and the software described in Table 1. The test cases developed for this plan will demonstrate the proper operation of all off-the-shelf software identified in the table. With the exception of the ISaGRAF and Wonderware software, there is no programming involved. Both ISaGRAF and Wonderware provide the capability to develop unique applications using their programming tools. For this system a separate ISaGRAF program was developed. This program performs the math functions that convert raw data to engineering values, and it also controls the pump motor speed and valve position using PID logic. The Wonderware HMI application was developed to interface with the SIXNET DAS and to allow an operator to set the parameters used by the DAS to generate alarms, scale raw values to engineering values, and display real-time feedback on the test process.

Table 1. Software Utilized in the WIPP Hydrology DAS

Software Name	Version	Function	Comment
ISaGRAF	3.47	Program SIXNET RTU (Processor)	ISaGRAF is an IEC61131 compliant off-the-shelf programming package used to develop a program in the RTU which converts the raw values to engineering units and controls pump speed and valve position
SIXNET I/O Tool Kit	2.4	Configure SIXNET Hardware	SIXNET I/O Tool Kit is an off-the-shelf software package that is used to configure the SIXNET hardware. This capability includes configuration of I/O channels, ports, addressing, etc.
Wonderware by Invensys Systems	8.0, SP1	Human Machine Interface Software	Wonderware is an off-the-shelf software package used by the system operator to create a custom set of operator-interface screens that allow the user to view and input parameters to the

Software Name	Version	Function	Comment
			program running in the SIXNET RTU.
InSQL by Invensys Systems	8.0, SP1	Database	InSQL is an off-the-shelf database product capable of interfacing with the HMI (Wonderware) to collect and store the data being collected by the DAS
KepWare	4.100.239	OPC Data Exchange	KepWare is device-driver software used during data exchange between the Wonderware HMI software and the SIXNET Universal Driver Resource (UDR) using OPC client protocol.

4. Tasks

The primary function of the DAS software is to acquire/measure the raw signal levels from the field instrumentation, convert these signals to an engineering unit, and store these data in a database. This function is accomplished using a SIXNET DAS as detailed in SNL Drawing package #DWG 03-01-1, sheets 1-20. The SIXNET input/output (I/O) modules read the voltage, resistance or current outputs from calibrated field instrumentation. For voltage or current input signals, the SIXNET I/O reads these values as digital bytes. For resistive temperature devices or thermocouples, the SIXNET DAS reads these signals and internally converts them to a temperature value. For temperature devices, there is no raw signal level available to the user. The SIXNET hardware provides 16-bit resolution; therefore, the raw voltage or current signal from the instrumentation is typically read as -32768 to +32768 bits. These raw signal levels are stored as bit values in the database. The DAS converts these raw signals to an engineering unit using calibration coefficients entered via the (HMI) by the operator of the system. This HMI software was developed using the Wonderware product series. This plan details the verification of the HMI's interface with the DAS, the accuracy of the DAS in measuring the instrumentation signal levels, the accuracy of the equations used to convert these raw signal values to engineering units, and the storage of these data to a database.

The other function of the DAS is to allow the user to select a desired flow rate or well water level and to have the DAS automatically control and maintain these values using either a modulating valve or the variable speed control capability of the pump motor. This plan will verify the HMI's ability to allow the user to select the mode of operation, the desired set point and the DAS's ability to maintain this set point. The DAS and HMI utilize Proportional, Integral & Derivative (PID) Loop logic for the automatic control of these system variables.

4.1 TEST CASE #1: Signal Conversion using $y = mx + b$ Equation

The first test case has been developed to validate the system's ability to measure an analog input signal, convert the value to an engineering unit (y) using the equation:

$$Y = mX + b \text{ (} m = \text{slope, } b = \text{intercept, } X = \text{raw signal value)}$$

and to display the value at the HMI. To accomplish this test case, the operator will use the HMI to input calibration coefficients (i.e., m and b) for each operational channel of the DAS. Then, the operator will

supply an input voltage or current to the I/O module for each channel using a calibrated source (e.g., Martel signal calibrator) and will record the feedback data in engineering units as displayed at the HMI. All of these data will be recorded into an Excel spreadsheet. This spreadsheet will also calculate the engineering units based on the input voltage/current and summarize the error between the measured and calculated values. Each of the following steps will be performed for all channels identified in the Attachment 1 spreadsheet.

- 1) With all systems powered up and the operator interface computer running the HMI application, enter a set of calibration coefficients for the first channel identified in the attached spreadsheet. After entering the coefficients, be sure to check the channel as active and to save the results. Also enter the calibration coefficients into the Excel spreadsheet.
- 2) Connect the Martel signal calibrator to the channel I/O module identified on the Attachment 1 spreadsheet. It may be necessary to disconnect any field instrumentation wiring that is already connected to that channel module. Record the calibration due date for the Martel in the “Calibrated Source” section of the spreadsheet.
- 3) Set the Martel calibrator to ‘On’ and enter the first signal source value identified on the Attachment 1 spreadsheet for the applicable channel. The signal input will either be a voltage or current value as determined by the configuration of the channel. Please refer to the Attachment 1 spreadsheet for specific channel configuration.
- 4) Note and record in the Attachment 1 spreadsheet the value being displayed at the HMI for this applicable channel.
- 5) Using either the spreadsheet or a calculator, use the same calibration coefficients entered via the HMI to calculate the engineering units. Record this value in the ‘Hand Calc Value’ column on the Attachment 1 spreadsheet. The difference between the HMI value and the hand-calculated value represents the error introduced by the analog-to-digital converter and the linear transformation to engineering units.
- 6) Repeat the previous steps until all applicable channels have been validated/tested.
- 7) Document all results on the Attachment 1 spreadsheet. The system is considered to be operating correctly if the errors are less than +/- 0.5 % of reading.

See Attachment 1 for a sample template of the Excel spreadsheet.

4.2 TEST CASE #2: Signal Value Conversion for Temperature Instrumentation

The second test case has been developed to validate the system’s ability to measure a Resistive Temperature Device (RTD) or Thermocouple input signal and convert these signal values to engineering units using standard (e.g., ASTM, manufacturer-recommended, etc) coefficients and a calculation contained in the firmware of the SIXNET DAS.

In general, the operator will enter a known resistance or thermocouple signal from a calibrated source into the applicable I/O channel. The operator will then record the feedback data in engineering units as displayed at the HMI. All of these data will be recorded into Excel spreadsheet as displayed in attachment 2. This spreadsheet will calculate the error between the signal applied to the I/O input and

the calculated value displayed at the HMI. The following steps will be performed for all channels identified in the Attachment 2 spreadsheet.

- 1) With all systems powered up and the operator interface computer running the HMI application, check the channel as active at the HMI.
- 2) Connect the Martel signal calibrator to the channel identified on the Attachment 2 spreadsheet. It may be necessary to disconnect any field instrumentation wiring that is already connected to the channel. Record the calibration due date for the Martel in the “Calibrated Source” section of the spreadsheet.
- 3) Set the Martel calibrator to ‘On’ and enter the first signal source value identified on the Attachment 2 spreadsheet for the applicable channel. This input will either be a resistance value or thermocouple signal value as defined on the Attachment 2 spreadsheet for a specific channel configuration.
- 4) From the main HMI operator interface screen, note and record in the spreadsheet the value being displayed at the HMI for this channel.
- 5) Record the supplied value from the Martel calibrator in the ‘Source Value’ column on the Attachment 2 spreadsheet.
- 6) Repeat the previous steps until all applicable channels have been validated/tested.
- 7) Document all results on the Attachment 2 spreadsheet. The system is considered to be operating correctly if the difference between the HMI displayed value and the Source Value is less than +/- 0.5 ° C.

See Attachment 2 for a sample template of the Excel spreadsheet.

4.3 TEST CASE #3: Signal Value Conversion using $y = [(Max- Min) * (x / 32768)]$

The third test case has been developed to validate the system’s ability to measure analog input signals, convert the values to engineering units (y) using the equation:

$$Y = [(Range Max-Range Min) * (x / 32768)] \quad (x = \text{raw signal value})$$

and display the feedback at the HMI. To accomplish this test case, the operator will use the HMI software to input both the maximum and minimum ranges for the channel. Then, the operator will use a calibrated source to supply an input voltage or current to the channel I/O module and will record the feedback data in engineering units as displayed at the HMI. All of these data will be recorded into an Excel spreadsheet. This spreadsheet will also calculate the engineering units based on the input voltage/current and summarize the error between the measured and calculated values. The following steps will be performed for all channels that use this equation:

- 1) With all systems powered up and the operator interface computer running the HMI application, enter a maximum and minimum range for the first channel identified in Attachment 3 spreadsheet. After entering the ranges for the channel be sure to check the channel as active and to save the results. Also enter the maximum and minimum range values into the Excel spreadsheet.

- 2) Connect the Martel signal calibrator to the channel identified on the Attachment 3 spreadsheet. It may be necessary to disconnect any field instrumentation wiring that is already connected to that channel. Record the calibration due date for the Martel in the “Calibrated Source” section of the spreadsheet.
- 3) Set the Martel calibrator to ‘On’ and enter the first signal source value identified on the Attachment 3 spreadsheet for the applicable channel. The input will either be a voltage or current signal as determined by the configuration of the channel. Refer to the Attachment 3 spreadsheet for specific channel configuration.
- 4) From the main HMI operator interface screen, note and record in the Attachment 3 spreadsheet the value being displayed at the HMI for this applicable channel.
- 5) Using either the spreadsheet or a calculator, derive the engineering units for the applied input signal. Record this value in the ‘Hand Calc Value’ column on the Attachment 3 spreadsheet.
- 6) Repeat the previous steps until all applicable channels have been validated/tested.
- 7) Document all results on the Attachment 3 spreadsheet. The system is considered to be operating correctly if the difference between the HMI value and the hand-calculated value is less than +/- 0.5% of reading.

See Attachment 3 for sample template of the Excel spreadsheet.

4.4 TEST CASE #4: Validation of Control Output Signals

The fourth test case validates the system’s ability to control either a valve position or motor speed using a 4-20ma output signal. A PID loop will control these outputs in either an automatic mode or a manual mode. In automatic mode, the PID controller will resolve the output signal based on changes in the process variable. In manual mode, the user, via a command from the HMI software, will control the output signals. This test case will validate the operator’s ability to control and tune the PID loop variables by entering values at the HMI and watching the corresponding changes in the automatic or manual mode PID loop output.

4.4.1 Manual Mode Validation

- 1) With all systems powered up and the operator interface computer running the HMI application, select Manual Mode control for both the Valve and Variable Frequency Drive (VFD) PID functions from the HMI.
- 2) Connect the Martel current signal measurement ports to the valve command channel identified on the Attachment 4 spreadsheet. It may be necessary to disconnect any field instrumentation wiring that is already connected to that channel. Record the calibration due date for the Martel in the “Calibrated Source” section of the spreadsheet.
- 3) From the HMI, select the various set points identified in the Attachment 4 spreadsheet. Record the measured value as indicated on the Martel unit and continue on to the next set point.
- 4) Repeat this process for the channels identified on the Attachment 4 spreadsheet for the VFD Speed Command signal and record all results on the spreadsheet.

- 5) The system must perform as commanded (i.e., increase in setpoint results in increase in current output, etc) to successfully pass this test sequence.

4.4.2 Automatic Mode Validation

- 1) From the HMI, place the Valve PID Loop Controller in the Automatic Mode and enter the PID parameter values contained on the Attachment 4 spreadsheet.
- 2) Select Flow Rate as the process variable and connect the Martel unit 4-20 mA source to the flow meter input channel.
- 3) Connect the Martel current measurement leads to the valve output channel identified on the Attachment 4 spreadsheet.
- 4) Enter an automatic set point of 5.0 GPM for the valve PID loop. Set the Martel source output to a value of approximately 4.0 GPM (approximately 10 mA). The PID loop should drive the Valve output signal from 4-20 mA in progressive increments of 5% using a 5 second (approximate) interval.
- 5) When the Valve output signal nears 20 mA, change the automatic mode set point to 3.0 GPM. The PID loop should decrease the valve output signal in 5% increments using a 5 second (approximate) interval.
- 6) From the HMI, change the control variable for this PID loop from the Valve to the VFD Speed Command, connect the Martel measurement leads to the VFD command output channel, and repeat steps 1 through 5.
- 7) From the HMI, place the Valve PID loop in Manual Mode and put the VFD PID loop in Automatic Mode. Repeat steps 1 through 7 for the VFD PID loop controller.
- 8) Document all results on the Attachment 4 spreadsheet. The software is considered to be operating correctly if the output signals increment approximately 5% at the set interval through the 4 to 20 mA output range.

See Attachment 4 for a sample template of the Excel spreadsheet.

4.5 TEST CASE #5: Validation of ALARMS

Test Case #5 has been developed to validate the system's ability to let the user enter High and Low alarm limits that when exceeded will notify the operator of an off-normal condition. This validation is accomplished by connecting a calibrated source to the analog input channel, varying the supplied source value until the simulated gage signal exceeds the alarm thresholds, and having the HMI display this alarm condition. The following steps should be implemented for all analog channels and for various discrete inputs used for generating alarms.

- 1) From the HMI, enter calibration coefficients and High/Low alarm limits for all analog channels.
- 2) Connect the Martel signal source to the applicable channel. Record the calibration due date for the Martel in the "Calibrated Source" section of the spreadsheet.

- 3) Adjust the Martel output to a value that exceeds the high alarm limit for that analog channel. The HMI should display an alarm annunciation for the applicable channel.
- 4) Adjust the Martel output to a value less than the low alarm limit for that analog channel. The HMI should display an alarm annunciation for the applicable channel.
- 5) Repeat Steps 2 through 4 for all analog channels identified in Attachment 5.
- 6) Connect a 24 VDC signal to the specific discrete input channels identified in the Attachment 5 spreadsheet. When this signal is applied the applicable alarm annunciation should be displayed at the HMI.
- 7) Repeat Step 6 for all discrete input channels listed in Attachment 5.
- 8) Document all results on the Attachment 5 spreadsheet. The software is considered to be operating correctly if the HMI properly displays and annunciates the alarm being tested.

See Attachment 5 for a sample template of the Excel spreadsheet.

4.6 TEST CASE #6: EVALUATION OF DATA LOGGING RATES

Logging data at high frequencies (e.g., all channels every second) is an important feature of a hydrology DAS, particularly when data are acquired during hydraulic testing. Therefore, Test Case #6 has been designed to evaluate the highest speed at which all DAS channels can be scanned and the associated data logged and stored without loss of integrity. The test may be conducted as a stand-alone activity or in parallel with Test Case #7 (described below). The following steps will be performed to evaluate data logging rates:

- 1) With all systems powered up and the operator interface computer running the HMI application, enter a set of calibration coefficients for all channels configured on the DAS. After entering the coefficients, be sure to check the channels as active and to save the results.
- 2) Connect the appropriate instruments/gages to their respective channel I/O modules. Update and print the Instrumentation Configuration screen, to capture the information regarding the instruments being used and their calibration status. Submit this information with the analysis report.
- 3) In sequence, set the data logging frequency for each analog channel to 1 second. Then activate data acquisition for a monitoring period not shorter than 50 times the logging frequency (e.g., if the logging frequency is set at one set of readings per minute, then the monitoring period should be 50 minutes).
- 4) Examine the logged data and determine if data were recorded appropriately for each channel (i.e., data values are accurate and were recorded at the specified frequency). If the logging frequency and data integrity were maintained, record this frequency along with the number of channels scanned and other relevant DAS parameters/characteristics.

- 5) Maintain the DAS logging frequency at the value verified in Step 4, and instruct the PID Loop controller to change set points thereby modulating the flow valve or varying the pump motor speed. Repeat this action at least five times. Examine the logged data to evaluate the effect of set point changes on the data logging frequency.
- 6) After confirming that the DAS logging frequency was maintained during Step 5, initiate communication with the DAS to extract/download data while maintaining data acquisition. Examine the data logged during data extraction to evaluate the effect of data extraction on the data logging frequency.
- 7) Document all results on the Attachment 6 spreadsheet. The software is considered to be operating correctly if the DAS logging frequency is maintained without any data drops (no data recorded) during all of the preceding steps.

See Attachment 6 for a sample template of the Excel spreadsheet.

4.7 TEST CASE #7: EVALUATION OF PID LOOP CONTROL SETPOINTS

During operation, PID loop control requires that the operator input setpoint values (e.g., signal deadband and integral, derivative, and proportional constants) to prevent control-variable overshoot/undershoot, oscillation, etc. These values will be treated as variables during field operations because they depend on factors such as pump back-pressure, flow rate, physical position of control units within the hydraulic system, etc. Test #7 will be an end-to-end demonstration test of the DAS system, instrumentation, and control hardware (valves, pump etc). This test may be completed using a hydraulic well test mock-up (using a standard submersible well pump installed into a water reservoir to simulate a typical WIPP well installation), or it may be conducted in parallel with a field activity such as water-quality sampling or a pump test (providing it does not interfere with the test). The following general steps will be performed, but specific actions may be adjusted during the test, particularly if the test is completed during a field test activity:

- 1) Make the appropriate hydraulic, power, and instrumentation lead connections to the test well pump and downhole pressure transducer(s).
- 2) Run the pump to fill the hydraulic lines with water and purge air from the system.
- 3) Input initial PID loop control setpoints (based on operator experience), control parameters (e.g., desired flow rate), and appropriate calibration coefficients for active gages.
- 4) Activate the data acquisition and control software routines from the command computer to begin pumping and observe the transient response of the test well by monitoring the flow meter and down-hole pressure gages. If necessary adjust the PID loop setpoints to reduce control signal overshoot/undershoot, oscillations, etc.
- 5) When the well water level (as measured by down-hole pressure transducers) has stabilized at the specified flow rate, fine tune the PID control loop by iteratively adjusting the setpoints until the controlled-variable signal remains relatively stable without excessive overshoot/undershoot,

oscillation, etc. Record the values of the PID loop setpoints, the flow rate, and down-hole pressure.

- 6) Deactivate the data acquisition and control software routine and examine the data from all gages/instrumentation to evaluate the performance of the DAS.
- 7) Repeat Steps 3 through 6 at least twice using different flow rates.
- 8) Document all results from the test in the Scientific Notebook. The software is considered to be operating correctly if the DAS Control functions can be adjusted and maintained at stable levels during all of the preceding steps.

5. Special Considerations

During the performance of each test case, relevant data, including a list of equipment used, operator name(s), date/time/conditions of the test, etc, will be documented in a Scientific Notebook. In addition, data acquired during each test will be recorded on standard forms (examples: Attachments 1 through 6). As appropriate, hand calculations of simple calculations, unit conversions, and data manipulations will be performed and the results reviewed, checked, and documented on the standard forms or in the Scientific Notebook.

The following documents will be generated during the completion of this testing process:

- Test Case Documents: TEST-001, TEST-002, TEST-003, TEST-004, TEST-005, and TEST-006
- DAS Instrumentation Configuration Screen Printout

Subsequent to the completion of all test cases, a data report will be prepared to document all activities and final results related to this plan, and to incorporate the documents generated during the testing process. This report will receive technical, management, and QA reviews before it is submitted to the Sandia Records Center.

6. Applicable Procedures

The following procedures relate to or govern the work described in this analysis plan. The most current version effective at the time of the analysis plan implementation shall be utilized.

NP 6-1, "*Document Review Process*"

NP 6-2, "*Document Control Process*"

NP 9-1, "*Analysis*"

NP 12-1, "*Control of Measuring and Test Equipment*"

NP 17-1, "*Records*"

NP 20-1, "*Test Plans*"

NP 20-2, "*Scientific Notebooks*"

TP 03-01, Rev. 0, "*Testing of Wells at the WIPP Site*"

ATTACHMENT 1 – Analog Conversion Sample Spreadsheet

Analog Signal Inputs for 0-10VDC or 4-20ma and Using Equation $y = mx + b$

Test Case #:	TEST-001 – Analog Signal Conversion using equation $Y = mX + b$		
Platform/OS:	Windows 2000 Server		
Module I.D.:	Analog Input Module #1 & #2	Date:	
Wonderware Ver:	Version 2.0		
ISAGRAF Ver:	Version 2.0		
Description:	Validate analog signal conversion to engineering units using a known calibrated source		
Acceptance Criteria:	The value displayed by the HMI must be with in +/- 0.5% of the Hand Calculated Value		
Calibrated Source SN:	10641	Cal Due Date:	Tested By:
		Reviewed By:	

Analog Input Channel	Slope (m)	Intercept (b)	Source Sig (vdc or ma)	HMI Feedback	Hand Calc Value	% Error of Reading	Comments
Ch 1 - Water Level #1 (4-20ma)			4.50				
			8.00				
			12.00				
			16.00				
			19.50				
Ch 2 - Water Level #2 (4-20ma)			4.50				
			8.00				
			12.00				
			16.00				
			19.50				
Ch 3 - Water Level #3 (4-20ma)			4.50				
			8.00				
			12.00				
			16.00				
			19.50				
Ch 4 - Water Level #4 (4-20ma)			4.50				
			8.00				
			12.00				
			16.00				
			19.50				
Ch 7 - Flow Meter Signal Manifold 1-A (4-20ma)			4.50				
			8.00				
			12.00				
			16.00				
			19.50				
Ch 8 - Barometric Pressure (DC Voltage)			1.00				
			2.50				
			5.00				
			7.50				
			9.75				
Ch 3 - Flow Meter Manifold 1-B (4-20ma)			4.50				
			8.00				
			12.00				
			16.00				
			19.50				
Ch 4 - Flow Meter Manifold 2-A (4-20ma)			4.50				
			8.00				
			12.00				
			16.00				
			19.50				
Ch 5 - Flow Meter Manifold 2-B (4-20ma)			4.50				
			8.00				
			12.00				
			16.00				
			19.50				
Ch 6 - Water Quality Manifold Pressure Transducer (4-20ma)			4.50				
			8.00				
			12.00				
			16.00				
			19.50				
Ch 7 - Flow Meter Manifold Pressure Transducer (4-20ma)			4.50				
			8.00				
			12.00				
			16.00				
			19.50				
Ch 8 - Well Head Pressure Transducer (4-20ma)			4.50				
			8.00				
			12.00				
			16.00				
			19.50				

ATTACHMENT 2 – Analog Temperature Conversion Sample Spreadsheet

Analog Signal Inputs for RTDs using Callendar VanDusen Conversion

Test Case #:	TEST-002 – Analog RTD or TC Signal Measurement				
Platform/OS:	Windows 2000 Server				
I/O Module I.D.	RTD Input Module #1 / Analog Input #3				Date:
Wonderware Ver:	Version 2.0				
ISAGRAF Ver:	Version 2.0				
Description:	Validate analog signal conversion to engineering units using a known calibrated source				
Acceptance Criteria:	The value displayed by the HMI must be within +/- 0.5° C of the Applied Value				
Calibrated Source SN: 10641	Cal Due Date:			Tested By:	
				Reviewed By:	
Analog Input Channel	Source Signal (Ohms or TC)	HMI Feedback	Source Value	Delta C	Comments
Ch 1 - Ambient Outside Temperature (RTD)	10.0° C				
	20.0° C				
	30.0° C				
	40.0° C				
	50.0° C				
Ch 2 - Well Water Temperature #1 (RTD)	10.0° C				
	20.0° C				
	30.0° C				
	40.0° C				
	50.0° C				
Ch 3 - Well Water Temperature #2 (RTD)	10.0° C				
	20.0° C				
	30.0° C				
	40.0° C				
	50.0° C				
Ch 4 - Water Quality Temperature Manifold 1-A (RTD)	10.0° C				
	20.0° C				
	30.0° C				
	40.0° C				
	50.0° C				
Ch 5 - Water Quality Temperature Manifold 2-A (RTD)	10.0° C				
	20.0° C				
	30.0° C				
	40.0° C				
	50.0° C				
Ch 6 - Ambient Temperature of DAS Trailer (RTD)	10.0° C				
	20.0° C				
	30.0° C				
	40.0° C				
	50.0° C				

ATTACHMENT 3 – Analog Conversion Sample Spreadsheet

Analog Signal Inputs for 0-10VDC or 4-20ma and Using Equation $y = [(\text{Max Range} - \text{Min Range}) * (x / 32768)]$

Test Case #:	TEST-003 – Analog Signal Conversion using $Y = [(\text{Max Range} - \text{Min Range}) * (x / 32768)]$						
Platform/OS:	Windows 2000 Server						
Module I.D.	Analog Input Module #1, Ch 5 & 6 and Analog Input Module #2, Ch 1 & 2					Date:	
Wonderware Ver:	Version 2.0						
ISAGRAF Ver:	Version 2.0						
Description:	Validate analog signal conversion to engineering units using a known calibrated source						
Acceptance Criteria:	The value displayed by the HMI must be with in +/- 0.5% of the Hand Calculated Value						
Calibrated Source SN: 10641				Cal Due Date:			Tested By:
							Reviewed By:
Analog Input Channel	Maximum Range	Minimum Range	Source Signal (ma)	HMI Feedback	Hand Calc Value	% Error of Reading	Comments
Ch 5 - pH Level Manifold 1-A (4-20ma)	0	14	4.500				
			8.000				
			12.000				
			16.000				
			19.500				
Ch 6 - Conductivity Level Manifold 1-A (4-20ma)	0	200	4.500				
			8.000				
			12.000				
			16.000				
			19.500				
Ch 1 - pH Level Manifold 2-A (4-20ma)	0	14	4.500				
			8.000				
			12.000				
			16.000				
			19.500				
Ch 2 - Conductivity Level Manifold 2-A (4-20ma)	0	200	4.500				
			8.000				
			12.000				
			16.000				
			19.500				

ATTACHMENT 4 – PID LOOP Validation Sample Spreadsheet

Analog Signal Output 4-20ma as Controlled by a PID Loop

Test Case #:		TEST-004 – Analog Signal Output Control via PID Loop Calculation			
Platform/OS:		Windows 2000 Server			
Module I.D.:		Analog Output Module #1		Date:	
Wonderware Ver:		Version 2.0			
ISAGRAF Ver:		Version 2.0			
Description:		Validate analog signal output with independent current measurements			
Acceptance Criteria:		Check or 'OK' text indicates system performed as commanded and demonstrates acceptance of all values			
Calibrated Source SN: 10641		Cal Due Date:		Tested By:	
				Reviewed By:	
Output Channel	Parameter	Setpoint	Measured Output (4-20ma)	Results Accepted	Comments
VFD PID Loop	Integral	1.0			
	Derivative	1.0			
	Proportional	1.0			
	Deadband	1.0			
	Loop Solve Time	5.0			
	Max. Limit	96.0			
	Min Limit	4.0			
	Max Change per loop	5.0			
	Bias	1.0			
	Automatic Setpoint - Valve Control Variable	5.0		Value increased from 4 to 20ma	
		3.0	Value decreased from 4 to 20ma		
	Automatic Setpoint - VFD Speed Control Variable	5.0	Value increased from 4 to 20ma		
		3.0	Value decreased from 4 to 20ma		
	Manual Setpoint	5%			
		25%			
50%					
75%					
95%					
VALVE PID Loop	Integral	1.0			
	Derivative	1.0			
	Proportional	1.0			
	Deadband	1.0			
	Loop Solve Time	5.0			
	Max. Limit	96.0			
	Min Limit	4.0			
	Max Change per loop	5.0			
	Bias	1.0			
	Automatic Setpoint - Valve Control Variable	5.0		Value increased from 4 to 20ma	
		3.0	Value decreased from 4 to 20ma		
	Automatic Setpoint - VFD Speed Control Variable	5.0	Value increased from 4 to 20ma		
		3.0	Value decreased from 4 to 20ma		
	Manual Setpoint	5%			
		25%			
50%					
75%					
95%					

ATTACHMENT 5 – Alarm Notification Sample Spreadsheet

Alarm Notification Validation

Test Case #:	TEST-005 – Alarm Verification		
Platform/OS:	Windows 2000 Server		
Module I.D.:	Discrete Input Module & Analog Input Modules #1 & #2	Date:	
Wonderware Ver:	Version 2.0		
ISAGRAF Ver:	Version 2.0		
Description:	Validate that High and Low Alarm Limit Logic is functioning properly and the HMI displays the correct alarm messages		
Acceptance Criteria:	The HMI displays an alarm when the alarm threshold values are exceeded		
Calibrated Source SN: 10641	Cal Due Date:	Tested By:	
		Reviewed By:	

Analog Input Channel	High Alarm Limit	Low Alarm Limit	High Alarm Displayed	Low Alarm Displayed	Comments
Well Level #1					
Well Level #2					
Well Level #3					
Well Level #4					
pH Level Manifold 1-A					
Conductivity Level Manifold 1-A					
pH Level Manifold 2-A					
Conductivity Level Manifold 2-A					
Flow Meter Manifold 1-A					
Flow Meter Manifold 1-B					
Flow Meter Manifold 2-A					
Flow Meter Manifold 2-B					
Barometric Pressure					
Ambient Outside Temperature					
Ambient Trailer Temperature					
Well Temperature #1					
Well Temperature #2					
W.Q. Temperature Manifold 1-A					
W.Q. Temperature Manifold 2-A					
W.Q. Manifold Pressure					
Flow Meter Manifold Pressure					
Well Head Pressure					
Discrete Input Channel				Alarm Displayed	Comments
E-Stop Active					
VFD Alarm					
Motor Overload					

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