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SANDIA NATIONAL LABORATORIES
WASTE ISOLATION PILOT PLANT

Analysis Plan for Demonstration Test Process: WIPP MFGCS SIXNET Data Acquisition System

1.4.2.2
Task GeoChemistry

Effective Date: 01/30/08

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1. Introduction and Objectives

The U.S. Department of Energy Carlsbad Field Office (DOE/CBFO) has directed Sandia National Laboratories to develop an experimental program that will assess the corrosion behavior of carbon steel and lead (Pb) alloys used to contain contact handled and remote handled waste under WIPP-relevant conditions.

This experimental program will focus on acquiring data used to derive corrosion parameter estimates that provide insight into the extent to which metals used at the WIPP (specifically carbon steel and lead) might augment the actions of the engineered barriers through the consumption of carbon dioxide (CO2) (Wall, 2006). The test objectives include:

- Determine to what extend iron and lead materials consume Carbon Dioxide (CO2) through the formation of carbonates
- The role these carbonates may potentially have in supporting the magnesium oxide in its role of CO2 sequestration, and;
- Indirect assessment of the rate at which the waste-container materials will consume other microbially-produced gases,

To achieve the test objectives for this research, a mixed flow gas corrosion system (MFGCS) has been developed to simulate several of the in-room atmospheres anticipated at WIPP. A number of material samples will be exposed to these atmospheres over various time periods and their surfaces analyzed using an array of analytical instruments to assess the corrosion. The MFGCS is comprised of a data acquisition system (DAS) and instrumentation that will provide a continuous flow of gas over these material samples. The MFGCS will provide atmospheres that have a 70% relative humidity, < 5 ppm of oxygen and established CO2 levels that are consistent with the test objectives (Wall, 2006).

1.1 Introduction

The MFGCS was designed to meet the data acquisition and control requirements of the WIPP iron and lead corrosion testing program (Wall, 2006), 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 VT mIPM RTU, discrete output modules, and analog input/output modules. The SixTRAK VT mIPM RTU processor is equipped with: 512 KB static RAM, 16 MB dynamic RAM, and 16 MB flash RAM; uses the LINUX operating system; and features both Ethernet and serial communication ports. The 16 channel discrete output module is DC powered and the analog input and output modules are capable of measuring or outputing signals of up to +/- 10.00 VDC and/or 4-20 mA. All modules have an operating temperature range of –30° to 70° C. The SIXNET components are mounted within a rack mounted enclosure, which also incorporates the +/- 15VDC and 24 VDC power supplies, circuit breakers, fuses, and relays to protect and control the system.

The four software products used to operate and interface with the MFGCS 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. KepWare – a data exchange tool

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

1.2 Objectives

The data acquired from iron and lead corrosion testing is used to derive parameter estimates which can be 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 calculation requirements 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 MFGCS, 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.

Six 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 an analog input signal, convert the value to engineering units using Min/Max ranges, and display the feedback at the HMI.
3. Validate the system's ability to control flow control valve positions using a 0-5 VDC output signal to maintain desired relative humidity levels in the test chambers.
4. Validate the system's ability to control a flow control valve position using a 0-5 VDC output signal to maintain desired CO2 concentrations in the test chambers.
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 MFGCS's control of solenoid valves that route the selected process gas to the CO2 Analyzer. This final test case also serves as a readiness exercise for the iron and lead corrosion test by testing a minimum of four fully functioning systems.

Test Cases 1 through 2 focus on the ability of the MFGCS to measure various types of raw data and convert these raw data to engineering units using simple user-supplied algorithms. Test Cases 3 and 4 demonstrate the ability of the MFGCS to perform its Proportional, Integral & Derivative (PID) control function, while Test Case 5 evaluates the HMI software by testing the MFGCS's ability to acknowledge user inputs correctly and display alarm limits based on the user input. Finally, Test Case 6 represents a complete system test under conditions that simulate a full-scale iron and lead corrosion test. This test case verifies the control of the soleniod valves that route sample gas to the CO2 analyzer and the ability of the MFGCS to store the data to a file.

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 5). Each form will contain the version number of the MFGCS software being tested and identify the analysis plan followed. As appropriate, hand 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 MFGCS 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 MFGCS assembled in the analytical laboratory and to provide for the necessary interface with various iron and lead corrosion measurement and test equipment mounted in the laboratory.

This analysis plan will be implemented by laboratory test personnel responsible for the setup, operation and maintenance of the WIPP Iron and Lead Corrosion MFGCS. 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 Geochemistry 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 XP (Service Pack 2 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 controls the flow controller 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 MFGCS 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 humidity and CO2 concentrations
SIXNET I/O Tool Kit	3.1 or higher	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	9.0 or higher	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 program running in the SIXNET RTU.
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 MFGCS software is to acquire/measure the raw signal levels from the laboratory instrumentation, convert these signals to an engineering unit, and store these data to a file. This function is accomplished using a SIXNET DAS as detailed in SNL Drawing package #DWG 06-02-1, sheets 0-18. The SIXNET input/output (I/O) modules read the voltage or current outputs from calibrated laboratory instrumentation. For voltage or current input signals, the SIXNET I/O reads these values as digital bytes. 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. 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 Common Separated Variable (CSV) file.

The other function of the MFGCS is to allow the user to select desired relative humidity levels and CO2 gas concentration levels and to have the MFGCS automatically control and maintain these values using flow controller valves to adjust the mixture of humid/dry nitrogen and CO2 gas mixed in the test chambers. This plan will verify the HMI's ability to operate the MFGCS at the desired relative humidity and CO2 concentration set points and the MFGCS's ability to maintain these values. 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 (m = slope, b = intercept, X = 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 a spreadsheet. This spreadsheet will 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 the coefficients listed in Attachment 1 for each channel being verified.
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 laboratory 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 spreadsheet.

4.2 TEST CASE #2: Signal Value Conversion using y = [(Max- Min) * (x / 32768)]

The second 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:

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

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 2 spreadsheet. 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 2 spreadsheet. It may be necessary to disconnect any laboratory 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 2 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 2 spreadsheet for specific channel configuration.
4) From the main HMI operator interface screen, note and record in the Attachment 2 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 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 value and the hand-calculated value is less than +/- 0.5% of reading.

See Attachment 2 for sample template of the spreadsheet.

4.3 TEST CASE #3: Validation of Relative Humidity Control Using Flow Control Valves & PID Loop

The third test case validates the system's ability to operate flow controller valves using a 0-5VDC output signal. A PID loop will control these outputs in either an automatic or a manual mode. In automatic mode, the PID controller will resolve the output signal based on changes in the process variable (Relative Humidity). 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.

4.3.1 Manual Mode Validation

1) With all systems powered up and the operator interface computer running the HMI application, select Manual Mode control for the specified process gas stream dry nitrogen flow control valve PID function from the HMI.
2) Connect the Martel current signal measurement ports to the valve command channel identified on the Attachment 3 spreadsheet. It may be necessary to disconnect any laboratory 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 3 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 3 spreadsheet for the specified process gas stream signal and record all results on the spreadsheet.
5) The system must perform as commanded (i.e., increase in setpoint results in an increase in voltage output, etc) to successfully pass this test sequence.

4.3.2 Automatic Mode Validation

1) From the HMI, place the specified Process Gas Stream PID Loop Controller in the Automatic Mode and enter the PID parameter values contained on the Attachment 3 spreadsheet.
2) With relative humidity (R.H.) as the process variable, connect the Martel unit 0-5 VDC source to the dry nitrogen flow controller valve position command pins.
3) Connect the Martel voltage measurement leads to the dry nitrogen flow controller valve signal output pins identified on the Attachment 3 spreadsheet.
4) Enter an automatic set point of 75% R.H for the PID loop. Set the Martel source output to a value of approximately 50.0 % R.H. (approximately 2.5VDC). The PID loop should drive the flow control valve output signal from 0-5 VDC in progressive increments of 5% using a 5 second (approximate) interval.
5) When the flow control valve output signal nears +5.0 VDC, change the automatic mode set point to 25% R.H.. The PID loop should decrease the valve output signal in 5% increments using a 5 second (approximate) interval.
6) Repeat Sections 4.3.1 and 4.3.2, steps 1 through 5 for each of the six process gas streams.
7) Document all results on the Attachment 3 spreadsheet. The software is considered to be operating correctly if the output signal increments approximately 5% at the set interval through the 0 to 5 VDC output range.

See Attachment 3 for a sample template of the spreadsheet.

4.4 TEST CASE #4: Validation of CO2 Gas Concentration using Flow Control Valve PID Loop

The fourth test case validates the system's ability to operate flow controller valves using a 0-5VDC 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 (CO2 levels). 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 the specified process gas stream flow control valve PID function from the HMI.
2) Connect the Martel current signal measurement ports to the flow control valve command channel identified on the Attachment 4 spreadsheet. It may be necessary to disconnect any laboratory 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 specified process gas stream signal and record all results on the spreadsheet.
5) The system must perform as commanded (i.e., increase in setpoint results in an increase in voltage output, etc) to successfully pass this test sequence.

4.4.2 Automatic Mode Validation

1) From the HMI, place the Specified Process Gas Stream PID Loop Controller in the Automatic Mode and enter the PID parameter values contained on the Attachment 4 spreadsheet.
2) With CO2 as the process variable, connect the Martel unit 0-5 VDC source to the CO2 flow controller valve position command pins.
3) Connect the Martel voltage measurement leads to the CO2 flow controller valve signal output pins identified on the Attachment 4 spreadsheet.
4) Enter an automatic set point of 4000 PPM CO2 for the PID loop. Set the Martel source output to a value of approximately 2000.0 PPM CO2 (approximately 2.5VDC). The PID loop should drive the CO2 flow control valve output signal from 0-5 VDC in progressive increments of 5% using a 5 second (approximate) interval.
5) When the CO2 flow control valve output signal nears +5.0 VDC, change the automatic mode set point to 1000 PPM CO2. The PID loop should decrease the valve output signal in 5% increments using a 5 second (approximate) interval.
6) Repeat Steps 1 through 5 for each of the six process gas streams CO2 flow control valves.

7) 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 0 to 5 VDC output range.

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

4.6 TEST CASE #6: Validation of Control Functions for Gas Stream Solenoid Valve to The CO2 Analyzer

Test #6 will be an end-to-end demonstration test of the MFGCS system, instrumentation, and control hardware (solenoid valves and flow controllers). This test may be completed using iron and lead corrosion process gas stream test mock-up (using a standard mixing and test chambers to simulate a typical iron or lead corrosion experiment configuration. The following general steps will be performed, but specific actions may be adjusted during the test:

1) Make the appropriate iron and lead corrosion, power, and instrumentation lead connections to the test equipment.
2) By operating the flow controllers and using pure nitrogen gas, purge the oxygen 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. Select each MFGCS system that will be active as part of this test case. A minimum of four systems should be in operation to adequately test the performance of the system.

4) Activate the data acquisition data storage function via HMI computer by initiating the routing of the various process gases to the CO2 analyzer. The system should initial start with MFGCS#1 system gas (if selected as active) and approximately ever 15 minutes or when the reading is stabile (within 5% for 1 minute) then switch to the next soleniod valve.

5) When the CO2 level (as measured by the CO2 analyzer) has stabilized the value should also be recorded and stored for the selected gas process stream. When the data is stored, the data record should include the oxygen level and relative humidity value for each process gas stream active for this test.

6) After letting the test operate a minimum of 2 hours, deactivate the data acquisition and control software routine and examine the data from all gages/instrumentation to evaluate the performance of the DAS.

7) Document all results from the test on printout of the data file that was created as part of this test case. This should be a *.csv. that displays the data collected throughout this process. The software is considered to be operating correctly if the DAS Controls route the process gases correctly to the CO2 analyzer and the correct data is measured and recorded to the data file in a *.csv file format.

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 5). 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, *“Analyses”*

NP 12-1, *"Control of Measuring and Test Equipment"*
NP 17-1, *"Records"*
NP 20-1, *"Test Plans"*
NP 20-2, *"Scientific Notebooks"*
TP 06-02, *"Iron and Lead Corrosion in WIPP-Relevant Conditions"*

7. References

Wall, 2006. "Iron and Lead Corrosion in WIPP-Relevant Conditions" Sandia Test Plan TP 06-02, Rev 1. Carlsbad, NM: Sandia National Laboratories.

ATTACHMENT 1 – Analog Conversion Using y=mX+b 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 XP		
Module I.D.		Date:	
Wonderware Ver:			
ISAGRAF Ver:			
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 +/- .5% of the Excel Calculated Value		
Calibrated Source SN:	Cal Due Date:	Tested By:	
		Reviewed By:	

Analog Input Channel	Slope (m)	Intercept (b)	Source Sig (vdc or ma)	HMI Feedback	Hand Calc Value	% Delta	Comments
VT mIPM - Ch 1 Nitrogen Cylinder Pressure (4-20ma = 0-3000 psig)	187.5	-750	4.50				Analog Inputs on the Vt mIPM
			8.00				
			12.00				
			16.00				
			19.50				
VT mIPM - Ch 2 CO2 Cylinder Pressure (4-20ma = 0-3000 psig)	187.5	-750	4.50				Analog Inputs on the Vt mIPM
			8.00				
			12.00				
			16.00				
			19.50				
VT mIPM - Ch 3 Dry Nitrogen Flow Meter Pressure Transducer (0-10VDC = 0-100 psig)	6.246	-25	1.00				Analog Inputs on the Vt mIPM
			2.50				
			5.00				
			7.50				
			9.75				
VT mIPM - Ch 4 Humid Nitrogen Flow Meter Pressure Transducer (0-10VDC = 0-100 psig)	6.246	-25	1.00				Analog Inputs on the Vt mIPM
			2.50				
			5.00				
			7.50				
			9.75				
VT mIPM - Ch 5 CO2 Flow Meter Pressure Transducer (0-10VDC = 0-100 psig)	6.246	-25	1.00				Analog Inputs on the Vt mIPM
			2.50				
			5.00				
			7.50				
			9.75				
Analog Input #1 - Ch 1 MFGCS #1 Relative Humidity (0-10VDC = 0-100% RH)	12	-45	1.00				Analog Input Module #1
			2.50				
			5.00				
			7.50				
			9.75				
Analog Input #1 - Ch 2 MFGCS #2 Relative Humidity (0-10VDC = 0-100% RH)	7.53	-75	1.00				Analog Input Module #1
			2.50				
			5.00				
			7.50				
			9.75				
Analog Input #1 - Ch 3 MFGCS #3 Relative Humidity (0-10VDC = 0-100% RH)	12	-45	1.00				Analog Input Module #1
			2.50				
			5.00				
			7.50				
			9.75				
Analog Input #1 - Ch 4 MFGCS #4 Relative Humidity (0-10VDC = 0-100% RH)	12	-45	1.00				Analog Input Module #1
			2.50				
			5.00				
			7.50				
			9.75				
Analog Input #1 - Ch 5 CO2 Analyzer Channel 1 (0-10VDC = 0-5000 ppm CO2)	500	2	1.00				Analog Input Module #1
			2.50				
			5.00				
			7.50				
			9.75				

ATTACHMENT 1 – Analog Conversion y=mX+b Spreadsheet (continued)

Analog Input #1 - Ch 6 CO2 Analyzer Channel 2 (0-10VDC = 0-5000 ppm CO2)	500	2	1.00				Analog Input Module #1
			2.50				
			5.00				
			7.50				
			9.75				
Analog Input #1 - Ch 7 MFGCS #5 Relative Humidity (0-10VDC)	12	-45	1.00				Analog Input Module #1
			2.50				
			5.00				
			7.50				
			9.75				
Analog Input #1 - Ch 8 MFGCS #3 Relative Humidity (0-10VDC)	12	-45	1.00				Analog Input Module #1
			2.50				
			5.00				
			7.50				
			9.75				
Analog Input #3 - Ch 1 MFGCS #1 Dry Nitrogen Flow Controller (0-5VDC = 0-2000 sccm)	399.592	1.995	1.00				Analog Input Module #3
			2.00				
			3.00				
			4.00				
			4.95				
Analog Input #3 - Ch 2 MFGCS #2 Dry Nitrogen Flow Controller (0-5VDC = 0-2000 sccm)	399.88	0.765	1.00				Analog Input Module #3
			2.00				
			3.00				
			4.00				
			4.95				
Analog Input #3 - Ch 3 MFGCS #3 Dry Nitrogen Flow Controller (0-5VDC = 0-2000 sccm)	399.365	1.8124	1.00				Analog Input Module #3
			2.00				
			3.00				
			4.00				
			4.95				
Analog Input #3 - Ch 4 MFGCS #4 Dry Nitrogen Flow Controller (0-5VDC = 0-2000 sccm)	398.707	7.8728	1.00				Analog Input Module #3
			2.00				
			3.00				
			4.00				
			4.95				
Analog Input #3 - Ch 5 MFGCS #5 Dry Nitrogen Flow Controller (0-5VDC = 0-1000 sccm)	399.251	9.4661	1.00				Analog Input Module #3
			2.00				
			3.00				
			4.00				
			4.95				
Analog Input #3 - Ch 6 MFGCS #6 Dry Nitrogen Flow Controller (0-5VDC = 0-1000 sccm)	399.609	4.6946	1.00				Analog Input Module #3
			2.00				
			3.00				
			4.00				
			4.95				
Analog Input #4 - Ch 1 MFGCS #1 Humid Nitrogen Flow Controller (0-5VDC = 0-1000 sccm)	199.608	3.8767	1.00				Analog Input Module #4
			2.00				
			3.00				
			4.00				
			4.95				
Analog Input #4 - Ch 2 MFGCS #2 Humid Nitrogen Flow Controller (0-5VDC = 0-1000 sccm)	198.295	7.2249	1.00				Analog Input Module #4
			2.00				
			3.00				
			4.00				
			4.95				
Analog Input #4 - Ch 3 MFGCS #3 Humid Nitrogen Flow Controller (0-5VDC = 0-1000 sccm)	199.879	3.1103	1.00				Analog Input Module #4
			2.00				
			3.00				
			4.00				
			4.95				

ATTACHMENT 1 – Analog Conversion y=mX+b Spreadsheet (continued)

Analog Input #4 - Ch 4 MFGCS #4 Humid Nitrogen Flow Controller (0-5VDC = 0-1000 sccm)	200.039	-0.1811	1.00				Analog Input Module #4
			2.00				
			3.00				
			4.00				
			4.95				
Analog Input #4 - Ch 5 MFGCS #5 Humid Nitrogen Flow Controller (0-5VDC = 0-500 sccm)	400.195	0.0604	1.00				Analog Input Module #4
			2.00				
			3.00				
			4.00				
			4.95				
Analog Input #4 - Ch 6 MFGCS #6 Humid Nitrogen Flow Controller (0-5VDC = 0-500 sccm)	397.74	-1.601	1.00				Analog Input Module #4
			2.00				
			3.00				
			4.00				
			4.95				
Analog Input #5 - Ch 1 MFGCS #1 CO2 Flow Controller (0-5VDC = 0-1000 sccm)	19.958	-0.0805	1.00				Analog Input Module #5
			2.00				
			3.00				
			4.00				
			4.95				
Analog Input #5 - Ch 2 MFGCS #2 CO2 Flow Controller (0-5VDC = 0-1000 sccm)	20.1217	-0.4851	1.00				Analog Input Module #5
			2.00				
			3.00				
			4.00				
			4.95				
Analog Input #5 - Ch 3 MFGCS #3 CO2 Flow Controller (0-5VDC = 0-1000 sccm)	19.983	0.0181	1.00				Analog Input Module #5
			2.00				
			3.00				
			4.00				
			4.95				
Analog Input #5 - Ch 4 MFGCS #4 CO2 Flow Controller (0-5VDC = 0-1000 sccm)	20.0983	0.0208	1.00				Analog Input Module #5
			2.00				
			3.00				
			4.00				
			4.95				
Analog Input #5 - Ch 5 MFGCS #5 CO2 Flow Controller (0-5VDC = 0-500 sccm)	99.3538	0.7995	1.00				Analog Input Module #5
			2.00				
			3.00				
			4.00				
			4.95				

ATTACHMENT 2 – Analog Conversion [Max.-Min.* (x/32767)] Spreadsheet

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

Test Case #:	TEST-002 – Analog Signal Conversion using y = [Max Range - Min Range * (x / 32768)]						
Platform/OS:							
Module I.D.							Date:
Wonderware Ver:							
ISAGRAF Ver:							
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 +/- .5% of the Excel Calculated Value						
Calibrated Source SN:			Cal Due Date:			Tested By:	
						Reviewed By:	
Analog Input Channel	**Maximum Range**	**Minimum Range**	**Source Signal (VDC)**	**HMI Feedback**	**Hand Calc Value**	**% Delta**	**Comments**
Analog Input #2 - Ch 1 MFGCS #1 Oxygen Sensor (0-10VDC = 0-100 ppm)	100	0	1.00				
			2.50				
			5.00				
			7.50				
			9.75				
Analog Input #2 - Ch 2 MFGCS #2 Oxygen Sensor (0-10VDC = 0-100 ppm)	100	0	1.00				
			2.50				
			5.00				
			7.50				
			9.75				
Analog Input #2 - Ch 3 MFGCS #3 Oxygen Sensor (0-10VDC = 0-100 ppm)	100	0	1.00				
			2.50				
			5.00				
			7.50				
			9.75				
Analog Input #2 - Ch 4 MFGCS #4 Oxygen Sensor (0-10VDC = 0-100 ppm)	100	0	1.00				
			2.50				
			5.00				
			7.50				
			9.75				

ATTACHMENT 3 – R.H. PID LOOP Validation Sample Spreadsheet

Analog Signal Output 0-5 VDC as Controlled by a PID Loop for Relative Humidity

Test Case #:	TEST-003 – Analog Signal Output Control via PID Loop Calculation for Control of Relative Humidity		
Platform/OS:			
Module I.D.		Date:	
Wonderware Ver:			
ISAGRAF Ver:			
Description:			
Acceptance Criteria:	Check or 'OK' text demonstrates acceptance of all values		
Calibrated Source SN:	Cal Due Date:	Tested By:	
		Reviewed By:	

Output Channel	Parameter	Setpoint	Measured Output (0-5 VDC)	Results Accepted	Comments
MFGCS#1 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 - % RH Variable	75.0			
		25.0			
	Manual Setpoint (Flow Controller Position)	5%			
		25%			
		50%			
		75%			
		95%			
MFGCS#2 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 - % RH Variable	75.0			
		25.0			
	Manual Setpoint (Flow Controller Position)	5%			
		25%			
		50%			
		75%			
		95%			
MFGCS#3 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 - % RH Variable	75.0			
		25.0			
	Manual Setpoint (Flow Controller Position)	5%			
		25%			
		50%			
		75%			
		95%			

ATTACHMENT 3 – R.H. PID LOOP Validation Sample Spreadsheet (continued)

MFGCS#4 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 - % RH Variable	75.0			
		25.0			
	Manual Setpoint (Flow Controller Position)	5%			
		25%			
		50%			
		75%			
		95%			
MFGCS#5 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 - % RH Variable	75.0			
		25.0			
	Manual Setpoint (Flow Controller Position)	5%			
		25%			
		50%			
		75%			
		95%			
MFGCS#6 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 - % RH Variable	75.0			
		25.0			
	Manual Setpoint (Flow Controller Position)	5%			
		25%			
		50%			
		75%			
		95%			

ATTACHMENT 4 – CO2 PID LOOP Validation Sample Spreadsheet

Analog Signal Output 0-5 VDC as Controlled by a PID Loop for CO2 Level

Test Case #:	TEST-004 – Analog Signal Output Control via PID Loop Calculation for CO2 Concentrations				
Platform/OS:					
Module I.D.					Date:
Wonderware Ver:					
ISAGRAF Ver:					
Description:					
Acceptance Criteria:	Check or 'OK' text demonstrates acceptance of all values				
Calibrated Source SN:			Cal Due Date:		Tested By:
					Reviewed By:
Output Channel	**Parameter**	**Setpoint**	**Measured Output (0-5 VDC)**	**Results Accepted**	**Comments**
MFGCS#1 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 - CO2 Level Variable	4000.0			
		1000.0			
	Manual Setpoint (Flow Controller Position)	5%			
		25%			
		50%			
		75%			
		95%			
MFGCS#2 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 - CO2 Level Variable	4000.0			
		1000.0			
	Manual Setpoint (Flow Controller Position)	5%			
		25%			
		50%			
		75%			
		95%			
MFGCS#3 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 - CO2 Level Variable	4000.0			
		1000.0			
	Manual Setpoint (Flow Controller Position)	5%			
		25%			
		50%			
		75%			
		95%			

ATTACHMENT 4 – CO2 PID LOOP Validation Sample Spreadsheet (continued)

MFGCS#4 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 - CO2 Level Variable	4000.0			
		1000.0			
	Manual Setpoint (Flow Controller Position)	5%			
		25%			
		50%			
		75%			
		95%			
MFGCS#5 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 - CO2 Level Variable	4000.0			
		1000.0			
	Manual Setpoint (Flow Controller Position)	5%			
		25%			
		50%			
		75%			
		95%			
MFGCS#6 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 - CO2 Level Variable	4000.0			
		1000.0			
	Manual Setpoint (Flow Controller Position)	5%			
		25%			
		50%			
		75%			
		95%			

ATTACHMENT 5 – Alarm Notification Sample Spreadsheet

Alarm Notification Validation

Test Case #:	TEST-005 – Alarm Verification			
Platform/OS:				
Module I.D.			Date:	
Wonderware Ver:				
ISAGRAF Ver:				
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:		Cal Due Date:		Tested By:
				Reviewed By:

Analog Input Channel	High Alarm Limit	Low Alarm Limit	High Alarm Displayed	Low Alarm Displayed	Comments
High Nitrogen Gas Pressure @ Flow Controllers	14.0				
High CO2 Pressure @ Flow Controllers	14.0				
Low Nitrogen Cylinder Pressure		200.0			
Low CO2 Cylinder Pressure		200.0			
MFGCS#1 Flow Alarm		100.0			
MFGCS#2 Flow Alarm		100.0			
MFGCS#3 Flow Alarm		100.0			
MFGCS#4 Flow Alarm		100.0			
MFGCS#5 Flow Alarm		100.0			
MFGCS#6 Flow Alarm		100.0			
MFGCS#1 RH Alarm	90.0	35.0			
MFGCS#2 RH Alarm	90.0	35.0			
MFGCS#3 RH Alarm	90.0	35.0			
MFGCS#4 RH Alarm	90.0	35.0			
MFGCS#5 RH Alarm	90.0	35.0			
MFGCS#6 RH Alarm	90.0	35.0			
MFGCS#1 Oxygen Alarm	10.0				
MFGCS#2 Oxygen Alarm	10.0				
MFGCS#3 Oxygen Alarm	10.0				
MFGCS#4 Oxygen Alarm	10.0				
MFGCS#5 Oxygen Alarm	10.0				
MFGCS#6 Oxygen Alarm	10.0				