



REPORT AND RECOMMENDATIONS

Stanford CIS Gas Monitoring Systems Evaluation

Executive Summary

Stanford requested HPM Systems to perform an evaluation of its current gas monitoring system. The evaluation included a review of existing documentation, system components, and overall operation. As part of this evaluation, specific recommendations were to be made to enhance system effectiveness, reliability, and serviceability. This report and additional drawings have been prepared as a result of this evaluation.

Documents reviewed during this evaluation included the following:

- System drawings, floor plans and calculations prepared for the original facility construction, the expansion phase, and subsequent upgrades
- Matrixes of sensor data, most recent service reports, most recent annual test
- Program matrix
- PLC and Wonderware programs

The specific titles and issue dates are included in the appendix.

In addition to the review of documentation a site visit was made on July 8, 2008 with a follow up on August 4, 2008. The purposes of site visits were to verify actual field conditions as compared to the documentation. Also during these visits observations were made as to the type quantity and installation of equipment.

GENERAL OBSERVATIONS

Much of the equipment is original vintage design. The PLC and I/O modules are currently commercially available and appear to be serviceable. Approximately one-half of the gas detectors are models that are no longer produced and are not available. Replacement sensor cells and tapes are still available for these detectors, but the manufacturer will slowly phase these units out as replacement parts become unavailable. Unfortunately the upgraded models the manufacturer has available are not directly compatible with the existing system.

Audible and visual indicators do not meet current code requirements for visibility or audibility, but have been demonstrated to work during the last system test. The Emergency Manual Off (EMO) stations have not been tested from the records reviewed here, but they appear to be serviceable. The same situation exists with the seismic detector and fire alarm input - there is no record of recent tests.

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The available system documentation is significantly deficient. The most current program matrix includes points that have been disconnected. It also appears that the shutdown logic it shows is not consistent. This could be indicative of an error in the document or an error in the application of functional logic.

There is no comprehensive drawing set showing all devices, interconnection, or I/O connection points. The original drawings do have most of this information but they have not been updated as changes have occurred. Tool names are inconsistent between various documents such as drawings, matrix, and HMI screens.

As noted earlier, test data from the last system test does not show that any system inputs have been tested (e.g. fire alarm input, seismic, EMO, etc.) nor has the System 16 detector been tested.

Sensor distribution is deficient. During the walk through several deficiencies were noted. There are Toxic Gas Ordinance (TGO) Class I and TGO Class II gases in use without monitoring. Gases listed on the System 16 as being monitored are not being monitored due to programming discrepancies. There are flammable and pyrophoric gases that are not monitored.

RECOMMENDATIONS

1. Define the gases used at each tool, the source and any other point such as exhausted enclosures involved.
2. Develop a consistent naming scheme for all tools, cabinets, sensors, and HMI screens.
3. Develop or adopt a consistent functional logic schema for shutdown and annunciation. Update the program and program matrix with this data.
4. Update drawings and create system drawings to provide future serviceability. All drawings should be CAD based for easy modification.
5. Upgrade system infrastructure to accommodate additional current and future requirements.
6. Install new gas detectors as required to meet TGO code.
7. Perform and document a complete system test.

Review and Recommendations

Stanford has requested a review of its gas monitoring system. This review is limited to a walk through inspection as well as the available documentation as provided by Stanford and is enumerated in the appendix. This is the report of that review and the recommendations generated as a result.

It should be noted that this was not a skeptical review in that all documents are taken at face value to be correct. We have not sought to verify or validate any of the data contained therein, and have accepted them as accurate. However we have pointed out any inconsistency we have discovered as a result of this review. Further action will be required to determine the root cause for those inconsistencies.

GENERAL SYSTEM DESCRIPTION

The gas monitoring system at the Stanford CIS / CISX facility is a Programmable Logic Controller (PLC) based system. The PLC is monitored and controlled by a computer running software to provide a Supervisory Control and Data Acquisition (SCADA) functionality.

The PLC monitors remote inputs and outputs (I/O) through three panels located in various areas. These remote I/O panels monitor analog inputs and discrete inputs. Analog inputs monitor the majority of gas detectors, giving a reading of gas values. There are some gas detector points that are monitored as digital inputs which only yield alarm on – off status. Other points with on – off status include fire alarm status, seismic detection, EMO stations, and EMCS Fans.

System outputs are also controlled by the PLC. The outputs include gas cabinet shutdowns, audible visual indicators, bulk gas Hydrogen and Oxygen shutdown, and fire alarm signals.

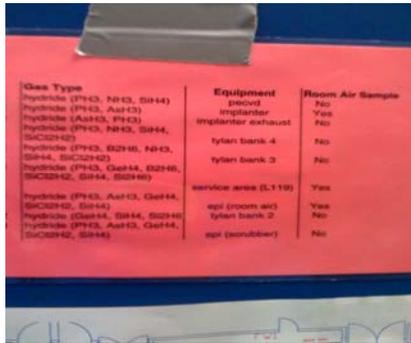
GAS DETECTION

SYSTEM 16

There are three types of gas detector in use. The first is a paper tape type monitor. This monitor the System 16 draws samples from various locations to a central analyzer. If the sample contains target gas it will react with the treated paper tape. The reaction is relational to the concentration of the gas, allowing the instrument to quantify the gas in the ppm or ppb range. The System 16 will detect gases in the hydrides family including Silane, Phosphine, Arsine, Diborane, and Germane. Currently this instrument monitors thirteen points.

There are several issues with this detector:

1. The detector is used to sense for Germane. This requires programming to allow for the instrument to resolve Germane in the proper range. To resolve in the correct range the sample time per point is 240 seconds. This is documented in the appendix.



Gas Type	Equipment	Room Air Sample
Hydroide (PF43, NF43, SH44)	panel	Yes
Hydroide (PF43, Au43)	implanter	Yes
Hydroide (Au43, PF43)	implanter default	No
Hydroide (PF43, NF43, SH44, SHC2242)	tylan bank 4	No
Hydroide (PF43, SH46, NF43, SH44, SHC2242)	tylan bank 3	No
Hydroide (PF43, Gaf44, SH46, SHC2242, SH44, SH46)	service area (L110)	Yes
Hydroide (PF43, Au43, Gaf44, SHC2242, SH44)	api (room air)	Yes
Hydroide (Gaf44, SH44, SH46)	tylan bank 2	No
Hydroide (PF43, Au43, Gaf44, SHC2242, SH44)	api (scrubber)	No

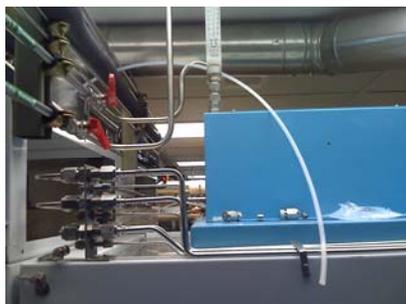
2. The unit does not detect ammonia. The list on the side of the System 16 indicates that it is expected to detect ammonia on two points- PECVD and Tylan 4. See the photo at left. It should be noted that TGO does not require monitoring for Ammonia as it is classified as a Class III gas.

3. The unit does not detect Dichlorosilane. The same list indicates it is expected to detect it in two operator breathing zone and one tool. Dichlorosilane is a Class II gas which is required to be monitored.

4. The System 16 is reliant upon sample lines to draw an air sample from each monitored location. Several changes have been made and there are sample lines that have been disconnected. In the photo to the right note the sample lines that have been disconnected. This is near the location where the ion implanter was previously installed.



5. In addition to disconnected sample lines in at least one location the sample line has been cut and attached to another location. The photo below shows the back and top of the Thermco 2. The sample line to the gas jungle was cut and reconnected to the adjoining gas box. This has left the furnace unprotected. This furnace has Silane, Dichlorosilane, Diborane, and Phosphine which all need monitoring by TGO code.



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6. The system is not labeled as to where the detection points are currently installed. The map on the unit only defines 9 points as monitored. The system is monitoring 13. If the unit should go into alarm it would not be possible to define the origin of an alarm.
7. The system is wired to only monitor alarm status. When a gas is detected there is no indication of the actual level displayed on the SCADA system.
8. The System 16 is no longer in production. The manufacturer has promised to support the system through 2008 and longer as long as parts are available.

FMK DETECTORS

The second type of detectors in use is an electrochemical point of use detector, the FMK. Each FMK is connected directly to the I/O points which monitor its analog value. This gives a true reading of concentration, not just alarm status. Most of these detectors are functional and the sensors are changed biannually. There are a few issues found with the FMK detectors.

1. The FMK detectors have apparently been relocated. In the last service March 2008 Sensor the MST14 sensor was changed from Chlorine to Hydrogen Chloride. This creates two problems. FMK detectors are gas specific. This means that the whole unit needs to be changed when changing gas type. Secondly the PLC is scaled for a Chlorine sensor which has a maximum 10 ppm range. A Hydrogen Chloride sensor has a maximum range of 50 ppm. Thus there is now a 5 x scaling error on the display and the alarm set point is set at 5 ppm. This translates in an alarm being triggered at a 25 ppm detection of HCl, but a display of 5 ppm on the screen. This could potentially lead to a significant issue for responders.
2. Several sensors were found installed but have been removed from the system. Sensor D21 which was used to monitor the Ion Implanter is an example of this.
3. Some sensors are bypassed on the SCADA system and the reason is not clear. Sensor D26 (Fluorine) in Room 106 and Sensor 29 (Arsine) in Room 110X are examples of this.
4. When sensors are replaced at FMK detectors, an adjustment is performed to set the "CE" value. This matches the sensor output to the transmitter, There are several units that indicate that they were not adjusted correctly in the last sensor service since the adjustment is broken. MST12 and MST60 are examples of this. Without this adjustment the displayed values will deviate from true readings.

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5. The FMK detector is no longer in production. The manufacturer has not announced when it will stop production of sensors for this unit, but spares or replacements for the transmitter are no longer available.
6. There is no direct replacement available for the FMK detector. The Satellite is functionally able to replace the FMK, but extra wiring (a three wire connection) is required to change from one to another. The I/O panels are designed to support two- wire detectors like the FMK, not three-wire like the Satellite. When changing a point the I/O cabinet wiring needs to be changed.
7. FMK detectors are sensor specific. They cannot be easily changed to monitor another gas than the original one specified.

SATELLITE DETECTORS

The third type of detector used in this system is the Satellite. The Satellite is the current production model of electrochemical sensor available from Honeywell. There are two different types of Satellites, one is analog and is connected directly to the I/O monitor points to read analog values. The second version is digital, or LON Works. This unit is wired to a network. The network has an output interface that then connects to the I/O input module. Up to 16 detectors can be connected on the network. The Satellite is a universal detector; it can be changed to monitor different gases through programming on the front panel. Since the Satellites are the most recently installed, there are few issues with them.

PLC AND ASSOCIATED EQUIPMENT

The PLC is a GE Fanuc Series 90-70. It is provided with two bus modules. These buses are connected to the remote I/O panels and the modules in them. Each bus can address up to 32 modules. System capacity is defined as the total number of modules installed. The system capacity is as follows:

	Max	Used	Available
Bus 1	32	26	6
Bus 2	32	2	30
Analog Input Points	108	103	5
Discrete I/O	192	130	32

TABLE 1 - PLC CAPACITY

System capabilities are defined as the maximums that the equipment will support. Currently capabilities far exceed system capacity. The system capabilities are defined in Table 2. It should be noted that capabilities will vary as software is developed. For instance some routines will require several buffers, others none.

	Defined	Used
Discrete Inputs (I)	2048	411
Discrete Outputs (Q)	2048	416
Buffers (M)	4096	629
Timers (T)	256	0
Relays (R)	1024	678
Analog Inputs (AI)	108	103
Analog Outputs (AQ)	64	0

TABLE 2 - PLC CAPABILITY

SCADA SOFTWARE

The primary system monitoring point is in the Emergency Response Room. The system runs on Wonderware version 9.5 software. This system has been upgraded recently and this version of software, while not the very latest, is a recent version. As such it is a currently supported version. The system can be remotely viewed and controlled as well.

SYSTEM ARCHITECTURE

The architecture is defined as the physical interconnections that the system uses to acquire data and control outputs. The system currently is a hybrid using both PLC and Lonworks architectures married together. Both of these architectures have advantages when used independently. Once combined, they create a more complex architecture to program and maintain.

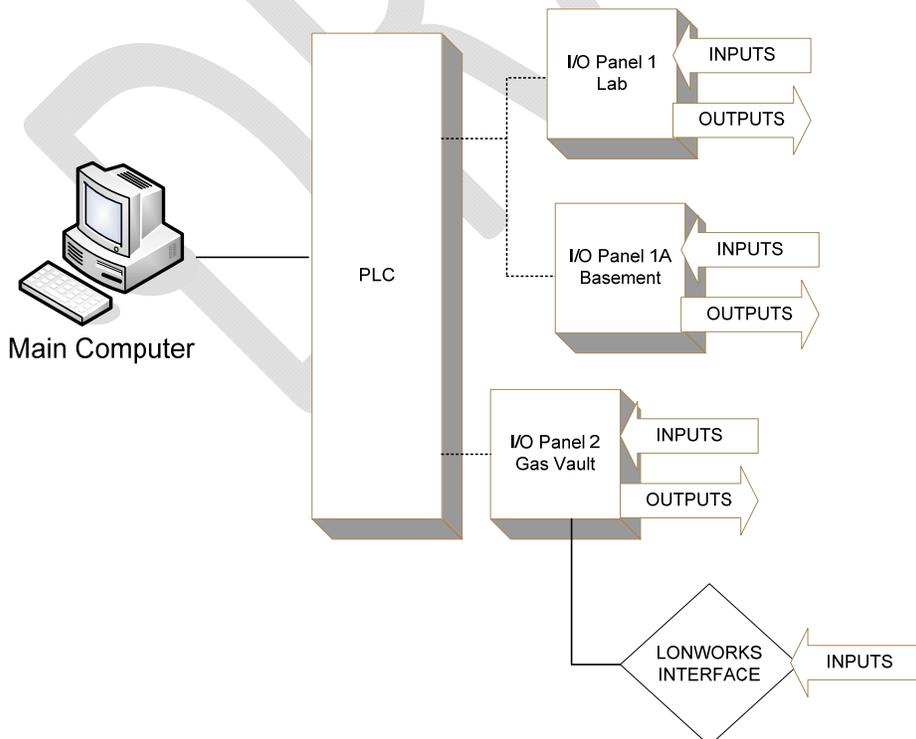


FIGURE 1 - SYSTEM ARCHITECTURE

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Referencing Figure 1 there are three separate programs

- SCADA program in the main computer
- PLC Program in the PLC
- Lonworks Program in the Lonworks interface

Each of these programs must pass information in a structured format to and from all of the devices it is connected to. It should be noted that all three are different programming languages as well. This is the complexity introduced in the hybrid arrangement. It can lead to difficulty in coordination of all programs. Furthermore a change in any one must be propagated to all of the others.

While all of the equipment is normally reliable, there is a proliferation of components. The more components used in a system the greater potential for failure exists. For example there are separate power supplies for each of the subsystems shown.

APPLICATION OF DETECTORS

The system as installed and programmed does not meet code. Stanford is under the jurisdiction of the Toxic Gas Ordinance of Santa Clara County. The code describes the requirements for monitoring and control of toxic gases. In addition the current California Fire Code (CFC) provides guidance for monitoring and control of flammable and pyrophoric gasses.

- a) All Class I and Class II toxic gases need to be monitored. Monitoring is required at each source, each exhausted enclosure with mechanical fittings (e.g. valve box) and point of use. Examples of gases not being monitored include Dichlorosilane, Germane, Phosphorous Oxychloride, and Chlorine.
- b) Area monitors and Operator breathing monitoring is required for Class I gases. Examples include Germane, Phosphine and Arsine.
- c) In some areas there appear to be excess detectors that are not required. For instance there are several Oxygen deficiency monitors where there is no hazard readily apparent. Some of these points may be deleted and the detectors reused.
- d) Shutdowns are required for flammables and pyrophoric gases. As best as can be determined from the matrix, not all of the correct shutdowns are programmed for Hydrogen and EMO stations.
- e) There are numerous inconsistencies in the program matrix logic. For instance not all H2 detectors shutdown the bulk Hydrogen or transmit the signal to the FACP.

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It is beyond the scope of this study to do a complete and comprehensive evaluation of the coverage of the system. At this time this would require the generation of documents that do not exist such as the gas usage matrix and drawings.

RECOMMENDATIONS

The following are our recommendations based upon this evaluation:

1. Audit all gases used in the Lab	<ul style="list-style-type: none">• Generate a gas usage matrix
2. Develop a common naming scheme for all tools, gas boxes, and cabinets	<ul style="list-style-type: none">• This is required for design document consistency, installation accuracy, and for quick response in an emergency
3. Define monitoring deficiencies	<ul style="list-style-type: none">• This report has identified several gases that are not being monitored and should be in accordance with TGO and CFC
4. Document the complete system	<ul style="list-style-type: none">• The system documentation where it exists is scattered across several spreadsheets drawings and files. It is impossible to work on the system confidently without the correct documentation.
5. Define a control sequence	<ul style="list-style-type: none">• Generate a functional matrix
6. Define what type of system architecture will be best	<ul style="list-style-type: none">• Three different options are offered for your consideration• Several points will need to be added for compliance with TGO
7. Replace the System 16	<ul style="list-style-type: none">• The unit is out of production• The unit has a high cost of maintenance• It does not cover all of the gases that need to be monitored• It uses lab floor space
8. Replace FMK Detectors	<ul style="list-style-type: none">• These detectors are out of production and spare parts are no longer available• Detectors are subject to incorrect sensor installation
9. Install new sensors and equipment	<ul style="list-style-type: none">• Manage installation for quality control
10. Perform a complete system test	<ul style="list-style-type: none">• 100% of all sensors and inputs need to be tested• Gas sensors need to be tested with gas

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SYSTEM ARCHITECTURE UPGRADE

There are four potential system architectures that can be implemented to increase the capacity for new detectors. These are:

- Increase the PLC with new I/O that matches the existing;
- Expand the system using Ethernet;
- Expand the system using Lonworks
- Replace the system with an all Lonworks system

Each option has its benefits and drawbacks. The factors that govern this decision will be in part based upon the development of the needs assessment as described above. As an example if only a few detectors are needed, then the expansion of the existing system may be the most cost effective solution. Even so if these detectors are spread over a great area, the expansion of the Lonworks may be the most cost effective solution.

	Match Existing	Add Ethernet	Add Lonwork	New Lonwork
Preserves initial investment in hardware and software	✓	✓	✓	
Easy to program	✓	✓		✓
Easy to add wiring			✓	✓
Requires new I/O Cabinets	✓	✓	✓	✓
Easy to modify programming	✓	✓		✓
Requires upgrade of existing involving downtime	✓	✓		
Provides two way communication				✓
Sensors visible via web browser		✓		

TABLE 3 - FEATURE COMPARISON