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ENGINEERING STUDY & CONCEPTUAL DESIGN REPORT FOR PRIMARY VENTILATION DUCT FLOW MONITORING

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1	1	Cog. Mgr. RW Reed	[signature]	10/23/95	R1-51	KA White	[signature]	10/16/95	S5-13	1	2
1	1	QA J Verderber	[signature]	10/26/95	S1-57	PF Kison	[signature]	10/23/95	T4-07	2	1
1	1	Safety LS Krogsrud	[signature]	10/24/95	R3-08	KA Ealden	[signature]	10/23/95	R2-88	2	1
3		~~Env.~~ GD Feltner			R1-51	CC Scaief ~~N.A. Hertelendy~~ for Feltner	[signature]	10/23/95	S2-02	2	1

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ENGINEERING STUDY AND CONCEPTUAL DESIGN REPORT FOR PRIMARY VENTILATION DUCT FLOW MONITORING

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7. Abstract

The objective of this engineering study is to develop the preferred method and concepts for measurement of the primary exhaust ventilation flow rates in Double Shell Tanks (DSTs) on the hydrogen watch list. This includes tanks 101-AW, 103, 104, and 105-AN, and 103-SY. A systems engineering approach is utilized to weight the desired characteristics of the flow monitoring system, and then select the best alternative.

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ENGINEERING STUDY AND CONCEPTUAL DESIGN REPORT FOR PRIMARY VENTILATION DUCT FLOW MONITORING

Prepared by: B.D. Groth

Edited by: N.A. Hertelendy

Characterization Monitoring Development

TABLE OF CONTENTS

LIST OF ACRONYMS AND ABBREVIATIONS

CPA	Constant Power Anemometer
CTA	Constant Temperature Anemometer
DST	Double Shell Tank

ENGINEERING STUDY AND CONCEPTUAL DESIGN REPORT FOR PRIMARY VENTILATION DUCT FLOW MONITORING

1.0 OBJECTIVE

The objective of this engineering study is to develop the preferred method and concepts for measurement of the primary exhaust ventilation flow rates in Double Shell Tanks (DSTs) on the hydrogen watch list. This includes tanks 101-AW, 103, 104, and 105-AN, 103-SY. A systems engineering approach is utilized to weigh the desired characteristics of the flow monitoring system, and then select the best alternative.

1.1 BACKGROUND AND SCOPE

Accurate air flow measurement at the low flow rates existing in these vent ducts is quite difficult. In addition, there is a wide variety of flowmeters on the market that makes selecting an appropriate flowmeter a complex and potentially difficult task. Trade-offs in performance among the various characteristics such as accuracy, response time, range, cost, and maintainability are necessary in order to select the flowmeter that best meets the needs for a given application.

Measurement of air flow in these 30.48 cm (12 inch) diameter ducts involves instrumentation that is intrusive into the ducts. This greatly increases the cost of installing, maintaining and calibrating the instrument as these ducts are radiologically contaminated. Since these tanks are on the hydrogen watch list there are additional requirements that will also increase these costs.

1.2 PURPOSE AND NEED

The purpose of flow monitoring for these tanks is that in conjunction with hydrogen monitoring equipment already installed, it will allow for determination of the overall hydrogen generation and release rates. This information will assist in evaluating ventilation system effectiveness in resolving hydrogen safety issues. This work is to be done in order to comply with draft Systems Engineering Requirement WHC-SD-WM-OSR-16.R.0A.SEC.5.29 which states in part:

> "Administrative controls shall be established to manage flammable gas hazards related to the waste storage tanks that generate flammable gasses. The administrative controls shall include not only tanks in which waste exhibits the potential to retain flammable gasses and release them episodically but also tanks in which waste generates and releases flammable gasses chronically. The program elements shall include as a minimum:

a. Flammable gas generation rates and ventilation effectiveness, as well as tank physical parameter information (e.g. waste level, pressure, temperature), shall be evaluated and compared with established criteria to (1) assign the proper NFPA classifications and (2) identify tanks in which waste exhibits the potential to retain flammable gases and release them episodically and thus comprise the Flammable Gas Watch List."

2.0 SUMMARY

Several types of flow monitors were investigated and determined whether they useful for this application. Based on their performance, some were selected for further evaluation, and were evaluated against each other to find the one which offered the best performance at the lowest initial and operating cost. The selected, i.e. the preferred, unit was found to be the Sierra[1] Series 640 Steel-Trak™. This unit is capable of measuring air velocities from 1.5 to 107 m/min (5-350 fpm) or air flow rates of 0.1 to 7.8 m^3 (4-275 ft^3) per minute direct without any conversion, and it is approved for Class I, Division I, Group B, C, and D, service. The other possible selection is the traverse type differential pressure element coupled with a high accuracy pressure transmitter (PDT) to monitor the flow velocity. This unit was found to be marginal if not incapable to measure the 12.2 m/min (40 fpm) air velocity, i.e. the 2.5E-3 Pa ($1x10^{-5}$ inches of water) differential pressure. It further required the temperature of the vapor stream, and computations from the data, to calculate the air flow. To execute these calculations, (to derive the air mass flow from the temperature and the differential pressure data), would require an additional programmable controller or some other compatible device.

3.0 RECOMMENDATION AND CONCLUSIONS

3.1 RECOMMENDATIONS

The preferred, unit was determined to be the Sierra Series 640 Steel-Trak™. This unit is capable in measuring air velocities from 5 fpm to 350 fpm, or air flow rates of 0.1 to 7.8 m^3 (4-275 ft^3) per minute direct without any conversion, in single range or up to 3.3E m (10,000 ft) per minute, in multiple ranges. It can be calibrated to read and display either mass flow or air velocity direct, without additional data or hardware. It can operate between 7.2 and 35 °C (45-95°F) without any degradation of accuracy, or 4.4 and 65 °C (40-150°F) with minimal loss of accuracy. It is approved for Class I, Division I, Group B, C, and D, service. It has a 4 ma to 20 ma output which is directly compatible with the Tank Monitoring and Control System, (TMACS), and it is supplied with 15.2 m (50 ft) of cable, as a plus it can have a local digital Liquid Crystal Display, LCD. It is reasonably priced at

[1] A trademark of Sierra Instruments Inc, Monterey, California

approximately $2,000 per sensor, (09/95). The sensor will receive it's power from a source near the farm and connect to the TMACS data link or the Standard Hydrogen Monitoring System (SHMS) where TMACS is not available.

3.2 CONCLUSIONS

The main source of error in trying to measure the flow in some of these vent ducts is the velocity distribution. In some tanks, the location where the sensor can be installed is close to elbows, valves, or other devices that causes the flow to be distorted to one side, creating an error in the flow measurement. Flow distribution due to normally turbulent flow can be accounted for during calibration, minimizing if not eliminating the radial flow distribution caused error. It may be desirable in some cases to use multiple sensors, (up to six sensors are feasible), and average these readings to obtain higher accuracy. The additional cost versus the added accuracy is questionable at best, thus multiple sensor probes are not recommended.

4.0 UNCERTAINTIES

Following is a list of uncertainties identified and the potential impacts of each:

1. The required accuracy of the mass flow rate is not clearly defined. The stated purpose of this project is to provide information on the total amount of hydrogen off-gassed by the monitored tanks. Since the required accuracy is not defined, specifications of commercially available monitoring devices were reviewed to determine what was reasonable. However, installation location probably plays an even larger role in the overall accuracy of the flow measurement. Some manufacturers estimated that without flow straighteners, the location constraints in AN and AW farms could cause up to a 6% error. The location is limited in these farms due to the ventilation ducts being below grade and only accessible at the ventilation instrument pits.

2. Even though a fairly large error could result, it is assumed that the addition of flow straighteners or any other device that will require removing a section or the duct and then rewelding a new spool piece in place is undesirable. Such work is difficult and expensive in a radiological environment with the potential for flammable gases to be present.

3. The required response time is not clearly defined. Specifications of commercially available monitoring devices were reviewed to determine what is reasonable. Comparison to the data logging frequency was also made. This should have minimal impact as long as the response times are less than about 30 seconds as the data logging frequency is one minute.

5.0 DESCRIPTION OF ALTERNATIVES AND SOLUTIONS

5.1 CRITERIA

The design criteria for the vent flow monitoring system is documented by WHC-SD-WM-DRD-003, *Design Requirements Document - Primary Ventilation Flow Monitoring for DSTs on the Hydrogen Watch List*. A list of the main criteria is shown in Table 1.

FLOW MONITORING SPECIFICATION INFORMATION

TABLE 1

CRITERIA	PERFORMANCE
Velocity Range	0.15 to 2.03 m/s (30 to 400 ft/min) Nominal: AN - 0.56 m/s (110 ft/min) AW - 1.07 m/s (210 ft/min) SY - 0.91 m/s (180 ft/min)
Accuracy	±0.08 m/s (±15 ft/min)
Response time	Less than 10 seconds for a 50% step increase or decrease from the nominal flow rate.
Hazardous location	Must be factory mutual (FM) approved for use in a Class I, Division 1, Group B environment.
Process Temperature	15 to 65°C (60 to 150°F) Nominal - 90°F
Ambient Temperature	-30 to 50°C (-20 to 120°F)
Radiation	< 0.3 mSV (30 mrem)/hr
Process Media	Air - with occasional hydrogen to 4% of volume
Chemicals	pH: 5-14 from ammonia vapors (rarely will the vapor be acidic, but the possibility exists) H_2: Up to 4% by volume
Pressure	0 to 1.49E3 Pa (0 to -6 inches of water), nominal 4.98E2 Pa (-2 inches of water)

Application is in a 30.5 cm (12") diameter round pipe (standard schedule).

Ideal installation location can not be met. Have approximately 3.66 m (12 ft) to work with between a 45 degree elbow upstream and a butterfly damper downstream.

5.2 ASSUMPTIONS

Selections of the instrument to be used, is made by this Engineering Study and Conceptual Design document.

5.3 ALTERNATIVES

There is a wide array of flow monitoring technologies that might be applicable to use in these vent ducts. The approach that was taken to identify alternatives and then narrow down the field was: 1) A list of commercially available flow monitoring technologies developed. 2) The list was then narrowed down to those technologies that were applicable, based on use in low flow velocity air. 3) A list of various models was developed for comparison to the design requirements. 4) Two or three models from the list that most closely meet the design requirements were compared by developing a conceptual installation design, and discussing the pros and cons of each model.

5.3.1 Selection of Flow Monitoring Technologies

The following flow monitoring technologies were investigated as to whether they would be viable for this application.

- Magnetic Flow Meters
- Vortex Shedding Flow Meters
- Coriolis Mass Flow Meters
- Thermal Mass Flow Meters
- Turbine Flow Meters
- Differential Pressure Flow Elements (e.g. flow orifice, pitot tube, flow traverse probe, venturi nozzle, etc.)
- Ultrasonic Time of Flight Flow Meters
- Ultrasonic Doppler Flow Meters

From this list, two technologies were quickly identified as having the best potential for use in this application. The two technologies are the Thermal Mass Flow Meters (also known as thermal anemometers), and the flow traverse probe with a pressure transducer and square root extractor. The others were dismissed for the following reasons.

<u>Magnetic Flow Meters</u>

Magnetic flow meters are not designed for use in gases or vapors.

<u>Vortex Shedding Flow Meters</u>

Require a Reynolds number of >10,000 for linear operation, which is not met in this application under all conditions. No models were identified that were capable of monitoring at this low a flow rate.

Coriolis Mass Flow Meters

Not typically used for gases and vapors. Typically available for ducts up to 15 cm (6 inches) in diameter only.

Turbine Flow Meters

Typically unable to measure flow at this low of a velocity.

Differential Pressure Elements

With the exception of the flow traverse probe and the pitot tube, installation of other types of flow elements in the duct (which is made of standard schedule carbon steel pipe) is thought to be too difficult and costly. Installation of an orifice or nozzle would require removal of a section of the duct and welding in flanges for a new spool piece.

Ultrasonic Time of Flight

Applicable for this application, but clearly offers no further benefits over thermal mass flow or the flow traverse probe. Installation in the vent duct is considerably more difficult and requires twice the number of penetrations.

Ultrasonic Doppler

Not designed for use in gases and vapors.

5.3.2 Description of Applicable Technologies

5.3.2.1 Thermal Mass Flow Meters There are two basic types of thermal convection mass flow sensors in general use today:

a) Constant Power Anemometer (CPA)
b) Constant Temperature Anemometer (CTA)

Both operate on the same premise that a heated element inserted into the fluid stream will develop a temperature differential between it and the fluid stream due to convective losses. These convective losses are proportional to the square root of the flow velocity. A means of measuring the ambient temperature of the fluid and the heated element is incorporated into the design of the sensor.

A CPA provides a fixed electrical power to a resistance element. The difference between the temperature of the heated element and the ambient fluid temperature is measured. The temperature difference is large at low flow velocities and decreases with increasing flow velocities. The temperature difference is conditioned to be linear with the mass velocity.

A CTA maintains a constant temperature differential between the heated element and the ambient fluid by means of a feedback loop controlling the current to the heater element. The amount of electrical power needed to maintain this temperature differential is proportional to the flow velocity. At low flow velocities, a small amount of power is needed; and at high flow velocities, a larger amount of power. The power signal is also conditioned to be linear with the mass velocity. The only meaningful advantage a CTA has over a CPA in this application is that is has a much faster response time to changes in flow because only the outer surface of the heated element is dependent on its thermal inertia. The center is already at a constant temperature.

Thermal anemometers are capable of measuring flows over a very wide range and at low flows. Several manufacturers claim the ability to monitor flows down to the 0.08-0.10 m/s (15-20 ft/min) range.

5.3.2.2 Flow Traverse Probe with Differential Pressure Transmitter A flow traverse probe operates on the same principle as a pitot tube in that the difference between the static and dynamic pressure is measured. The flow traverse probe is able to perform this in several duct locations at once and provide an equal-weighted average flow which is much more accurate in most applications. The flow rate is related to the differential pressure (at standard conditions) by the following equation:

$$V=4005\sqrt{d.p.}$$

Where: V is velocity in feet per minute
d.p. is differential pressure in inches of water

Because of this relationship it can be seen how difficult it is to accurately measure the low flow rates required for this application. For flow rates at the bottom of the range, the differential pressure would be approximately 1.49E-2 Pa ($6E^{-5}$ inches of water), a very difficult pressure to measure. One manufacturer claims to be able to accurately measure from 0.2 to 2.0 m/s (40-400 ft/min). This is outside the design criteria range, but only by a small margin, so it was still thought to be a viable technology for further investigation.

5.3.2.3 Comparison of Instruments to Requirements Table 2 provides a comparison of the published specifications of several different flow meters against the requirements.

TABLE 2

Instrument	Type*	Range (ft/min)	Accuracy	Process Temp. (°F)	Environ. Temp. (°F)	Response Time (seconds)	FM Approval for Class I, Div. 1, Group B
Design Criteria	N/A	30-400	±15 ft/min	60 to 150	-20 to 120	≤ 10	Required
AMC Veltron 7200AZ with a Volu-Probe 4SS	FTP	40-400	±0.45% FS	-50 to 350 no icing	40 to 120	0.5	No
FCI LT81A	CPA	15-custom	±1% FS or ±3% reading	-50 to 350	0 to 150	For 63.3% change: 9 sec. decreasing 15 sec. increasing	Yes
FCI MT86	CPA - multipoint	15-custom	±1% FS or ±3% reading	-50 to 350	-50 to 150 0 to 150 W/LCD	For 63.3% change: 9 sec. decreasing 15 sec. increasing	Yes
Kurz series 450Ex	CTA	20-400	±[1% reading + 20 SFPM]	-40 to 392	-40 to 140	1	Pending (2 months?)
Sierra series 640 STEEL-TRAK™	CTA	5-350	±1% FS <10% ±2% reading 10% - 100%	45 to 145	-4 to 122	1	Yes
Eldridge Model 8831-SSS-AIR	CTA	15-400	±[2% reading + 1% FS]	-52 to 392	32 to 122	1	Transmitter is. Probe unknown.
Thermal Instrument Co. model 59 or 62	CTA	?	± 1% FS	-20 to 350	?	1.5	No
Worth Instruments	CPA	30-400	±2% reading	?	?	?	?

* Type CTA - Constant Temperature Anemometer
CPA - Constant Power Anemometer
FTP - Flow Traverse Probe

From the table it can be seen that the three instruments that most nearly meet the design specification are the FCI constant power anemometer, the Sierra constant temperature anemometer, and the Air Monitor Corp. traverse probe and differential pressure transmitter. The Sierra CTM offers the most compatibility with the design requirements in all areas of performance: safety, ease of installations, simplicity of calibration and data retrieval, as well as reasonably low cost.

5.3.3 Conceptual Design

In order to carefully evaluate the three technologies it is necessary to develop a conceptual installation design in order to compare costs, ease or use, and ease of maintenance. The constant pressure and constant temperature anemometers will have the same installation design even though the minimum temperature listed for the Sierra instrument is -20 °C (-4°F). Consultation with the sales representative have indicated the instrument has been tested down to -2.3 °C (-10°F) with no adverse effects, and the company feels -29 °C (-20°F) should not be a problem.

5.3.3.1 Thermal Anemometers Since both thermal anemometers include weather tight instrumentation that can meet the ambient temperature criteria no weather enclosure is needed. The transmitter can be mounted either right at the vent header with the probe, or remotely within 30 m (100 feet) of the probe. The probe itself requires a 2.54 cm (1 inch) diameter opening with 1 inch MNPT threading. Saddle clamps with a gasket will be used to provide this fitting as was done with the SHMS. This will prevent having to weld on the vent duct. Both of these instruments can be powered by 24 VDC which is available at the associated SHMS cabinet.

Essentially, all that is required is to drill a 2.54 cm (1 inch) diameter hole in the vent duct and then install the saddle clamp and the probe/transmitter assembly on the duct. Power and signal wires are then routed from the transmitter to the associated SHMS cabinet. The transmitter output signal (4-20 mAdc) will be connected to the strip chart recorder in the SHMS and to the TMACs cabinet associated with that SHMS. In the AN and AW farms the duct work is located in a ventilation pit below grade, while in SY farm the duct work is above grade. In the ventilation pits a small diameter hole will need to be drilled through the concrete in order to route wiring into the pit.

5.3.3.2 Traverse Probe and Differential Pressure Transmitter The main difference in installation of the this option is that the differential pressure transmitter will need to be installed in an environmentally controlled cabinet as the electronics are only rated from 4 to 49 °C (40 to 120°F), and are not weatherproof. This entails installing a nearby cabinet with heating and air conditioning which preliminary calculations show requires 3-5 amps of 240 VAC power. This cabinet will require that a concrete pad be poured.

The probe installation will require a 4.45 cm (1 3/4 inch) diameter hole be cut in the vent duct, and then four to eight 0.64 cm (1/4 inch) diameter holes drilled and tapped for the mounting plate. Tubing from this probe to the transmitter will then be routed to transmit the pneumatic signal. The output from the transmitter (4-20 mAdc) will then be routed to the SHMS cabinet strip chart recorder and to the associated TMACs.

There is approximately 15-18 amps of 240 VAC power available for use at the SHMS cabinet. The SHMS cabinet is fed by 30 amp/240 VAC service of which only 12 amps is required for the SHMS under full load conditions. An exception to this is that the 103-SY SHMS is fed by 50 amp/240 VAC service.

5.3.3.3 Flow Velocity Profile Calculation of the Reynolds numbers over the desired range of operation of the flow meters show that the flow regime is in the low turbulent flow region the a majority of the time. There was an attempt by the vent and balance personnel to measure the radial flow distribution but the collected data indicated the flow was below the capability of the instrument and no useful data was obtained. Turbulent flow does give a variation of the radial flow velocities, i.e. a non uniform mass flow distribution. Under normal conditions where the sensor is at least ten diameters downstream of a disturbance or irregularity (e.g, elbow, orifice, "T"), the normal calibration will be accurate. If the disturbance is close to the meter the normal calibration will not prevail. In these cases the meter has to be calibrated inplace or in a simulated environment.

6.0 DISCUSSION OF PREFERRED ALTERNATIVE/SOLUTION

The Sierra Series 640 Steel-Trak™.

This unit is capable in measuring air velocities from 1.5 to 107 m per minute, (5-350 ft per minute), or air flow rates of 0.1 t0 7.8 m^3 (4-275 ft^3) per minute direct without any conversion in single range or up to 3,048 m

(10,000 ft) per minute, in multiple ranges. It can be calibrated to read and display either mass flow or air velocity direct, without additional data or hardware. It can operate between 7.2 and 35 °C (45-95°F) without any degradation of accuracy or 4.4 and 66 °C (40-150°F) with minimal loss of accuracy. It is approved for Class I, Division I, Group B, C, and D, service. It has a 4 ma to 20 ma output, which is directly compatible with the Tank Monitoring and Control System (TMACS), which may be located up to 15 m (50 ft) away, or recorded on a chart recorder in the Standard Hydrogen Monitoring System (SHMS) where TMACS is not available. As a plus, it has a local digital Liquid Cristal Display, LCD. It is reasonably priced at approximately $2,000 per sensor, (09/95). The sensor will receive it's power from, and connect to, the TMACS data link, or from the SHMS.

The alternate is the traverse type differential pressure element coupled with a high accuracy pressure transmitter, PDT. This unit was found to be marginal if not incapable to measure the 40 fpm air velocity, i.e. the $1x10^{-5}$ inches of water differential pressure. Further, it required the temperature of the vapor stream, and computations from the data, to calculate the air flow. To derive the air mass flow from the temperature and the differential pressure data would require an additional programmable controller, or some other compatible device to compute and present useable data. Therefore, the concept of using this device has been abandoned.

7.0 NO ACTION ALTERNATIVE

The no action alternative would mean that information to perhaps take the tank off the hydrogen watch list would not be available. Periodic data might be of some use, but to remove a tank from the hydrogen watch list based on periodic data would not stand up to the close scrutiny of outside reviewers. Certainly, the difference in the cost of operation of a tank on the hydrogen watch list versus a tank not on the hydrogen watch list is more than the cost of installation and operation of the flow monitoring system.

8.0 BIBLIOGRAPHY

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Miller, R.W., *Flow Measurement Engineering Handbook*, McGraw-Hill, 1983.

9.0 APPENDICES

COST ESTIMATE FOR USING SIERRA SERIES 640 FLOW SENSORS

WBS	DESCRIPTION	ESTIMATE SUBTOTAL	CONTINGENCY		TOTAL DOLLARS
			%	Total	
1000	Subtotal-Project Mgmt	16000	20	3200	19200
2000	Subtotal-Detailed Design	47000	20	9400	56400
2100	Subtotal-Drawings	27000	20	5400	32400
2110	Installation Drawings	15000	20	3000	18000
2120	TMACS Drawings	8000	20	1600	9600
2130	Checking and Reviews	4000	20	800	4800
2200	Subtotal-Supporting Documentation	20000	20	4000	24000
2210	SDD	5000	20	1000	6000
2220	Software Documentation	2000	20	400	2400
2230	ATP/OTP	2000	20	400	2400
2240	POP	3600	20	720	4320
2250	Calibration Procedure	2400	20	480	2880
2260	USQ Screening	5000	20	1000	6000
3000	Subtotal-Installation	74000	23.65	17500	91500
3100	Subtotal-Prepare installation package	20000	20	4000	24000
3200	Subtotal-Instrumentation	54000	25.00	13500	67500
3210	Flow meters (5)	15000	20	3000	18000
3220	Conduit and wiring	2000	25	500	2500
3230	Drill vent header and install probe	15000	30	4500	19500
3240	Electrical	10000	25	2500	12500

WBS	DESCRIPTION	ESTIMATE SUBTOTAL	CONTINGENCY		TOTAL DOLLARS
3250	Excavation	10000	25	2500	12500
3260	Drill ventilation pit	2000	25	500	2500
4000	Subtotal-startup	15000	20	3000	18000
4100	Conduct ATP/OTP	8000	20	1600	9600
4200	Spare parts	5000	20	1000	6000
4300	Calibration equipment	2000	20	400	2400
TOTAL		152000	21.78	33100	185100

COST ESTIMATE FOR USING TRAVERSE TYPE DIFFERENTIAL PRESSURE SENSORS					
WBS	DESCRIPTION	ESTIMATE SUBTOTAL	CONTINGENCY		TOTAL DOLLARS
			%	TOTAL	
1000	Subtotal-Project Mgmt	20000	20	4000	24000
2000	Subtotal-Detailed Design	60600	20	12120	72720
2100	Subtotal-Drawings	39000	20	7800	46800
2110	Installation Drawings	15000	20	3000	18000
2120	TMACS Drawings	8000	20	1600	9600
2130	Inst. Cabinet drawings	12000	20	2400	14400
2140	Checking and reviews	4000	20	800	4800
2200	Subtotal-Supporting Documentation	21600	20	4320	25920
2210	SDD	6000	20	1200	7200
2220	Software Documentation	2000	20	400	2400
2230	ATP/OTP	2000	20	400	2400
2240	POP	4200	20	840	5040
2250	Calibration Procedure	2400	20	480	2880
2260	USQ screening	5000	20	1000	6000
3000	Subtotal-Installation	148500	22.32	33150	181650
3100	Subtotal-Prepare installation package	20000	20	4000	24000
3200	Subtotal-Instr Cabinet	49500	20	9900	59400
3210	Cabinet (5)	2500	20	500	3000
3220	A/C (5)	7500	20	1500	9000
3230	Heater (5)	500	20	100	600

3240	Cabinet-Shop Fab (5)	25000	20	5000	30000
3250	Excavation (5)	4000	20	800	4800
3260	Concrete pad (5)	10000	20	2000	12000
3300	Subtotal-Instrumentation	79000	24.37	19250	98250
3310	Flow meters (5)	15000	20	3000	18000
3320	Temperature transmitters (5)	15000	20	3000	18000
3320	Conduit and wiring	2000	25	500	2500
3330	Drill vent header and install probe	20000	30	6000	26000
3340	Electrical	15000	25	3750	18750
3350	Excavation	10000	25	2500	12500
3360	Drill ventilation pit	2000	25	500	2500
4000	Subtotal-Startup	18000	20	3600	21600
4100	Conduct ATP/OTP	10000	20	2000	12000
4200	Spare parts	6000	20	1200	7200
4300	Calibration equipment	2000	20	400	2400
TOTAL		247100	21.40	52870	299970