Swagelok

Sample Systems Evaluation and Advisory Services Report

ABC Company

123 Street Road

Philadelphia, PA 19145

USA

Prepared by:

Swagelok Penn

SWAGELOK® SAMPLE SYSTEM EVALUATION AND ADVISORY SERVICES

Swagelok Sample System Evaluation and Advisory Services is a service program offered by Swagelok and its global distributor network in which we use our industry expertise in analytical instrumentation system design to help improve the quality of sampling at your facilities.

Swagelok Sample System Evaluation and Advisory Services helps you troubleshoot and resolve problem areas in sampling systems that may exist at your facilities.

SWAGELOK® FIELD ENGINEERING

Swagelok employs a team of engineers throughout the world as an extension of our headquarters in Solon, Ohio. Their mission is to be the technical liaison and advocate between the customer, our distributor network, and the factory by providing an extension of Swagelok engineering resources.

Their primary focus is to provide technical expertise through a sound understanding of our customers' applications.

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Any calculations or statements of improvement are based on the industry-referenced *book, Industrial Sampling Systems—Reliable Design and Maintenance for Process Analyzers*, by Tony Waters.

Learn more at http://www.industrial-sampling-systems.com/

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Swagelok® Sample System Advisory Service Team	Swagelok Penn Local Team	ABC Company Team
SENIOR FIELD ENGINEER - AMERICAS	REGIONAL FIELD ENGINEER	

EXECUTIVE SUMMARY

Swagelok Sample System Advisory Services conducted an evaluation of 4 sample systems at ABC Company in November with the following key objectives:

1. Assess the design and performance of the sample systems
2. Verify any known problems reported on the current sample systems
3. Identify possible improvement opportunities
4. Provide cost effective manufactured solutions that will improve the system and resolve current problems

The Sample System Evaluation and Advisory Services team met with John Doe and Jane Doe from the Analyzer department and Eric Doe from the Process Control Engineering department.

Existing Systems

The sample system consists of various subsystems: process and sample extraction system, field preconditioning system, sample conditioning system, calibration system, and analyzer and sample disposal system. The information contained in this report includes photos supplied by the owner company and drawings prepared by Swagelok Field Engineering, which have been reviewed by the owner company. It also contains references from the site escort, information from DCS and observations from the Field Engineer.

Four systems were reviewed and assessed:

1	137 Crude Unit Cloud Point Analyzer	Based on data analysis, it appears that the cloud point analyzer responds to changes in draw rate on the order of several hours. Operational experience tells us that the cloud point should change roughly an hour after changes to the draw from the atmospheric tower are made. The additional lag time creates complications monitoring and controlling the HFO stream to its cloud specification, and as such should be minimized if possible.
2	137 Crude Unit Foul Gas Sampling System	Relief valve was relieving at pressures less than 10 psi. The hoses are frequently breaking and needing replacement.
3	868 FCCU DePropanizer Overhead	When process moves are made, there is an 80 – 90 minute dead time before the 868 deprop overhead analyzer sees a change, and then it takes up to 6 hours for the full change.
4	868 FCCU CEMS Unit	Ammonia is being injected in the process and this is causing plugging in the sample lines due to wax and salt formation. Analyzers are measuring O_2, CO, SO_2, and NO_x.

General Findings

- There are a substantial number of dead legs due to system modifications and design changes.
- Measuring and control devices were not functioning or present in many cases (flowmeters, gauges, etc.).
- Heat tracing / insulation was installed properly.

Recommended Improvements

This information is provided as the basis for further detailed engineering to be carried out as part of any project to adopt the suggested changes. References are made to *Industrial Sampling Systems—Reliable Design and Maintenance for Process Analyzers* by Tony Waters, published by Swagelok.

The following should help improve the sampling systems

- Re-design of the sample systems to ensure timeliness, representativeness and compatibility of the system
- Use of sample probes to extract the process sample to help reduce particles entering the sample system and to improve the overall response time of the analyzer system
- Selection of proper measuring and control devices
- Improve safety by using proper safety devices (e.g. proportional safety relief valves) and double-block-and-bleed valves for the extraction of the process sample and for the grab sample system.

Improvement Roadmap

To facilitate system improvements, each system addressed in the report includes a roadmap, a table which includes the estimated cost to implement, relative value of the change, and suggested priority based on impact to the system. Below is the scale associated with each item on a roadmap:

COST TO IMPLEMENT		RELATIVE VALUE	
$	**< $1,000**	▲	**Low**
$$	**< $5,000**	▲▲	
$$$	**< $25,000**	▲▲▲	**Medium**
$$$$	**< $50,000**	▲▲▲▲	
$$$$$	**> $50,000**	▲▲▲▲▲	**High**

INTRODUCTION

It is conservative to suggest that more than 80% of problems with online process analyzers are due to the performance of the system that delivers the sample for analysis. The intent of this report is to assess the design and performance of those systems. By surveying the four sampling system, the Swagelok Field Engineering Team will help ABC Company to recognize potential improvements to drive savings and increase overall profitability.

1. 137 Crude Unit Cloud Point Analyzer

The information contained in this section includes photographs and drawings prepared by Swagelok Field Engineering. It also contains references and observations from the Field Engineer. This system is made up of the following:

- Sample Extraction System (SXS)
- Sample Transport System (STS)
- Sample Conditioning System (SCS)

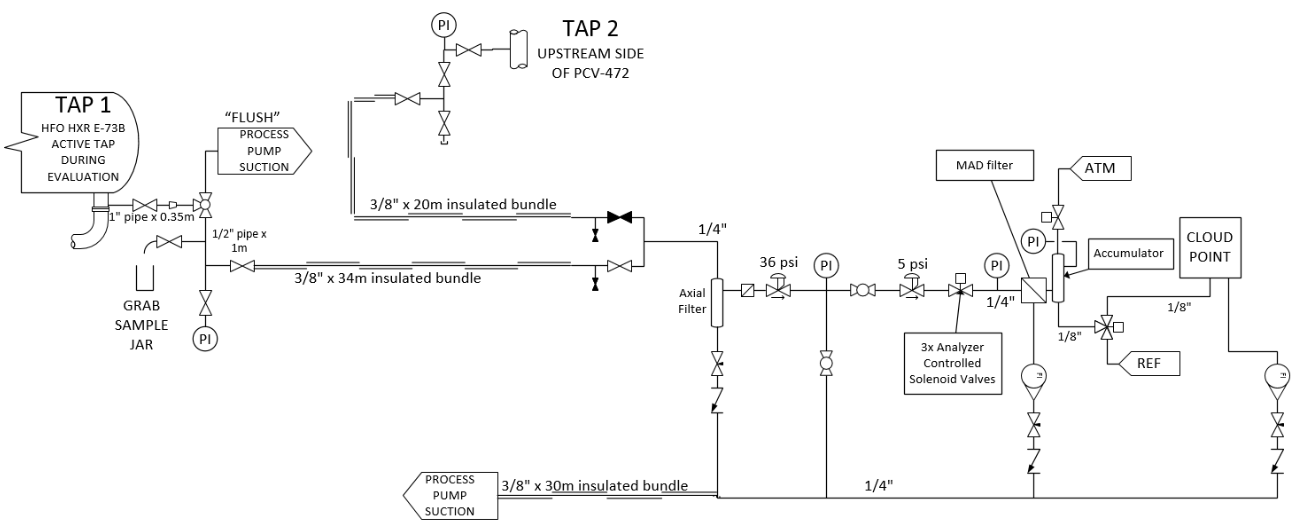

Figure 1 - 137 Crude Unit cloud point analyzer P&ID

Problem statement:

ABC Company has experienced a time delay on the order of several hours on the 137 Crude Unit cloud point analyzer. Two separate taps were identified for time delay investigation. Tap 1 beneath heat exchanger E-73B was active at the time of the evaluation.

1.1. Sample Extraction System

❖ **Subsystem Observation – Evaluation – Recommendation**

Figure 2 - Sample tap 1: HFO/LFO HXR E-73B

Figure 3 - Sample tap 2: HFO, PCV-472

Observation	Evaluation	Recommendation
▪ Two taps were identified for 137 Crude unit cloud point measurement. ABC Company communicated both taps are used and the active tap is determined by process stream composition / makeup. ▪ Tap 1 beneath heat exchanger E-73B exits a short run of vertical pipe. A pressure gauge on the heat exchanger read 40 psig. This was the tap supplying the analyzer with sample during the evaluation. ▪ The pressure at tap 2 near the PCV-472 control valve read 46 psig on the PI diagram supplied by ABC Company communicated it can be as low as 30 psig.	▪ The tap at the heat exchanger is near a downstream elbow. It is best to locate a sample tap a minimum of 2 pipe diameters from downstream elbows.	▪ Move tap 1 and tap 2 to a new location. Ensure they are 5 pipe diameters downstream of the nearest flow disturbance such as elbows, pumps, flow control valves, etc. Selecting a tap location with a higher pressure should increase flow on the bypass loop at the sample conditioning system, improving time delay. A tap location closer to the tower should also help decrease process delay.

▪ There is no probe installed at either tap.	▪ Using a probe reduces time delay, avoids sampling from the dirty area near pipe walls, and discourages particulate entry into the sample system.	▪ At the new or the existing tap locations, install a probe. The probe should protrude 25-35% into the process pipe.
▪ The pressure gauge at tap 1 beneath heat exchanger E-73B is not readable.	▪ It is not possible to determine the tap pressure using this gauge. The gauge is also a dead leg.	▪ Remove the gauge and eliminate the run to the gauge. For sample tap pressure, use the gauge at the back of the heat exchanger.
▪ At tap 2 by PCV-472, the run of piping beneath the tee where the sample enters the 3/8" sample transport tubing is unused.	▪ This run is a deadleg and is most likely contributing to increased time delay.	▪ Remove the piping run (see figure 3, yellow box).

1.2. Sample transport system

❖ **Subsystem Observation – Evaluation – Recommendation**

Figure 4 - Sample Transport Line

Observation	Evaluation	Recommendation
▪ The sample transport line for both tap locations is 3/8" insulated tubing. The wall thickness could not be verified and is assumed to be .035".	▪ The insulation looked to be installed properly and is in good condition.	▪ None
▪ The transport line reduces to 1/4" just before shelter penetration. The return lines in	▪ The drop in tubing size results in a larger pressure drop for the sample during transport and	▪ Replace the 1/4" tubing on the sample transport and return / bypass lines inside the shelter with 3/8" x .035

the shelter are also 1/4". Wall thickness could not be verified and is assumed to be .035".	return / bypass. This could decrease flow and increase time delay when the pressure at tap 2: PCV-472 falls to its low point of 30 psi as communicated by ABC Company.	tubing.

1.3. Sample conditioning system

❖ Subsystem Observation – Evaluation – Recommendation

Figure 5 - Sample conditioning system

Figure 6 - Sample conditioning system

Observation	Evaluation	Recommendation
▪ The pressure gauge at the entrance to the Membrane Anti-clogging Device (MAD) filter is a dead leg.	▪ Dead legs increase time delay and decrease the representativeness of the sample.	▪ Move the pressure gauge to the bypass side of the Membrane Anti-clogging Device (MAD) filter.
▪ ABC Company stated the analyzer floods if the bypass needle valve is opened too far. The analyzer return line joins all bypass flow lines and returns to the suction side of a pump with tag number 110 A/B.	▪ Phase Technologies recommends the spent sample from the analyzer be returned to atmospheric pressure. Opening the needle valve to accommodate more bypass flow most likely creates a positive pressure downstream of the analyzer. This positive pressure may prevent the pump in the analyzer from pumping the spent sample into the return line, resulting in a backflush and flooding of the analyzer. This could also help	▪ A spent sample recovery system at atmospheric pressure with 4 alarm level switches should be installed (see P&ID on page 14). The outlet of the recovery system can be plumbed to pump tag number 110 A/B suction. Ensure 3/8" tubing is used for sample transport to axial filter and from axial filter to return. Use 3/8" tubing or larger on sample

Observation	Evaluation	Recommendation
	explain time delay concerns as the analyzer could be sampling the same fluid multiple times as it is backflushed into the analyzer.	recovery system return tubing.
▪ Needle valve on the bypass flow of axial filter is barely cracked. ABC Company said this was to ensure enough pressure went to the analyzer stream. No flowmeter was present on the bypass stream so bypass flow could not be determined.	▪ Low bypass flow is most likely leading to a large time delay. The low flow present in the existing system most likely decreases the effectiveness of the axial filter.	▪ Install spent sample recovery system as detailed above. Install a flowmeter with needle valve on the bypass line. Set the flow to 2.5 liters per minute (40 gallons per hour). This should provide a 1 minute transport time from tap 2 at 30 psi to the analyzer flow loop and provide at least 20 psi to the analyzer flow loop. 20 psi is the minimum supply pressure recommended by Phase Technologies.
▪ The flowmeter on the Membrane Anti-clogging Device (MAD) filter bypass was set to 3 gallons per hour.	▪ Phase Technologies recommends 20 gallons per hour on the bypass of the Membrane Anti-clogging Device (MAD) filter. Increasing the MAD bypass flow should further decrease time delay. The bypass flow was most likely decreased to prevent pressure build up in the return line. Pressure in the return line could prevent the analyzer from pumping the spent sample into the return line. If this flow was set higher in the past, it may help explain time delay concerns as the analyzer could be sampling the same fluid multiple times as it is unable to pump it out to the return line.	▪ Increase bypass flow on the Membrane Anti-clogging Device (MAD) device to 20 gallons per hour. Plumb the bypass line to the sample recovery system.

1.4. Performance of the existing system: 137 Crude Unit Cloud Point

While investigating the time delay concern it was determined that no flowmeter existed on the bypass line of the axial filter. The needle valve on the bypass line is typically barely cracked open. Knowing this and in order to evaluate the time delay of the existing system, a bypass flow of 20 cc/min was estimated. Next, the sample conditioning system was observed while the analyzer was cycling. Phase technologies stated the analyzer draws a sample once every 10 minutes. During this 10 minute time between cycles, no flow was present in the analyzer flow loop. An analyzer flow normalized over the 10 minute period between cycles came to 30 cc/min and a bypass flow for the Membrane Anti-clogging Device (MAD) filter in the analyzer flow loop using the same method came to 38 cc/min. These flows were used in calculating a time delay of approximately 36 minutes in the sample system (figure 7). The combined HFO/LFO delay from tap 1 beneath heat exchanger E-73B is presented as it is the longer of the two delays. The delay from the control valve PCV-472 tap is approximately 28 minutes.

Time delay calculation by section – existing system: 137 Crude Unit Cloud Point

(time delay in minutes)

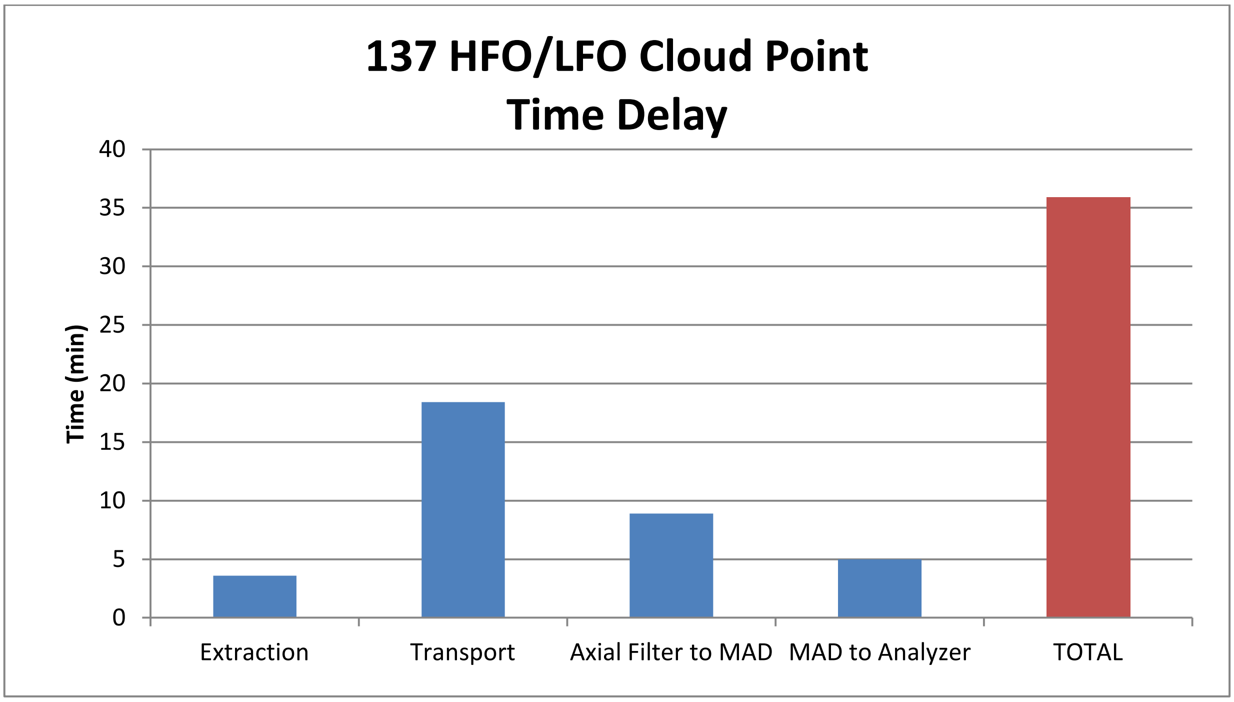

Figure 7 – existing performance, 137 Crude Unit Cloud Point sample system

To understand the total delay from the tower that is to be controlled using the cloud point analyzer, a time delay for the process was estimated. Dimensions for the dryer (20' tall by 16' dia), heat exchangers (16' long by 3' dia, 3 total), and total length of process pipe from the tower to the sample tap (165' of 12" pipe) were used to calculate process transport and process vessel volumes. The volumes in the dryer and heat exchangers were multiplied by three as they are mixing volumes and it takes three times the volume to completely purge the old fluid. The final dryer volume was halved due to control valve LC-404 showing 50% level in the dryer. The three heat exchangers' total volume was halved under the assumption each vessel is 50% cooling piping. Using these volumes and a flow rate of 1700 barrels per hour (270,000 liters per hour) taken from the PI diagram, the process delay was estimated to be 45 minutes (figure 8).

Figure 8 - 137 Crude Unit cloud point process delay

It should be noted the total delay of 81 minutes does not include the dwell time of the tower itself. It is important to remember that all time delays are cumulative so any process vessels not seen during the survey and the tower dwell time can be added to the 81 minutes the Swagelok FE team calculated based on our observations.

1.5. 137 Crude Unit Cloud Point – Improvement Roadmap

Priority		Estimated Value	Cost to Implement
Install sample recovery system for spent analyzer sample per P&ID (page 14).	1	▲▲▲▲▲	$$$
Install flowmeter with needle valve on the bypass line after the axial filter. Set flow to 2.5 L/min.	1	▲▲▲▲▲	$
Increase flow on the MAD filter bypass to 20 gallons per hour.	1	▲▲▲▲	$
Replace 1/4" tubing on transport and return / bypass lines with 3/8" x .035	2	▲▲	$
Install probe at taps.	2	▲▲▲	$$
Move tap location closer to the tower.	3	▲▲▲	$$$

1.6. Performance of the proposed improved system: 137 Crude Unit Cloud Point

To decrease the time delay in the overall sample system we propose to increase the bypass flow through the axial filter. To avoid a positive pressure downstream of the analyzer that may prevent the analyzer from pumping spent sample into the return line, a sample recovery system at atmospheric pressure should be installed. To further reduce time delay, the bypass flow on the Membrane Anti-clogging Device (MAD) filter should be increased to 20 gallons per hour per the manufacturers recommendation. In addition, a flowmeter with a needle valve should be installed after the axial filter on the bypass line. It should be set at 2.5 L/min (40 gallons per hour) to generate a time delay for sample extraction and transport of approximately 45 seconds. In order to estimate the improved total time delay (figure 9), the 2.5 L/min flow for bypass was used. This flow should be achievable even if pressure drops to 30 psig at tap 2: PCV-472. With the pressure at tap 1: Heat Exchanger E-73B being 40 psi at the time of the audit, the 2.5 L/min (40 gallons per hour) flow should be achievable regardless of which tap is in use. When the 1/4" line is replaced with

3/8" x .035, the flow should be increased to 3 L/min (50 gallons per hour) to ensure turbulent flow and a more representative sample.

Time delay calculation by section – improved system: 137 Crude Unit Cloud Point

(Time delay in minutes)

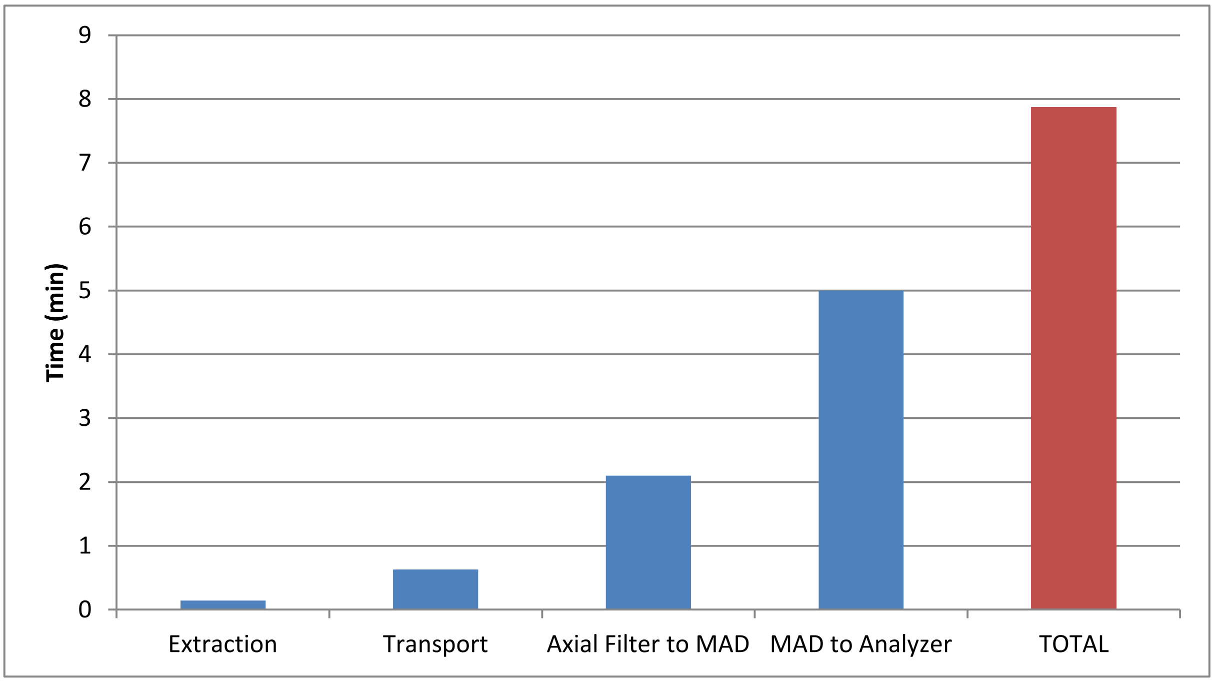

Figure 9 – improved performance, 137 Crude Unit cloud point sample system

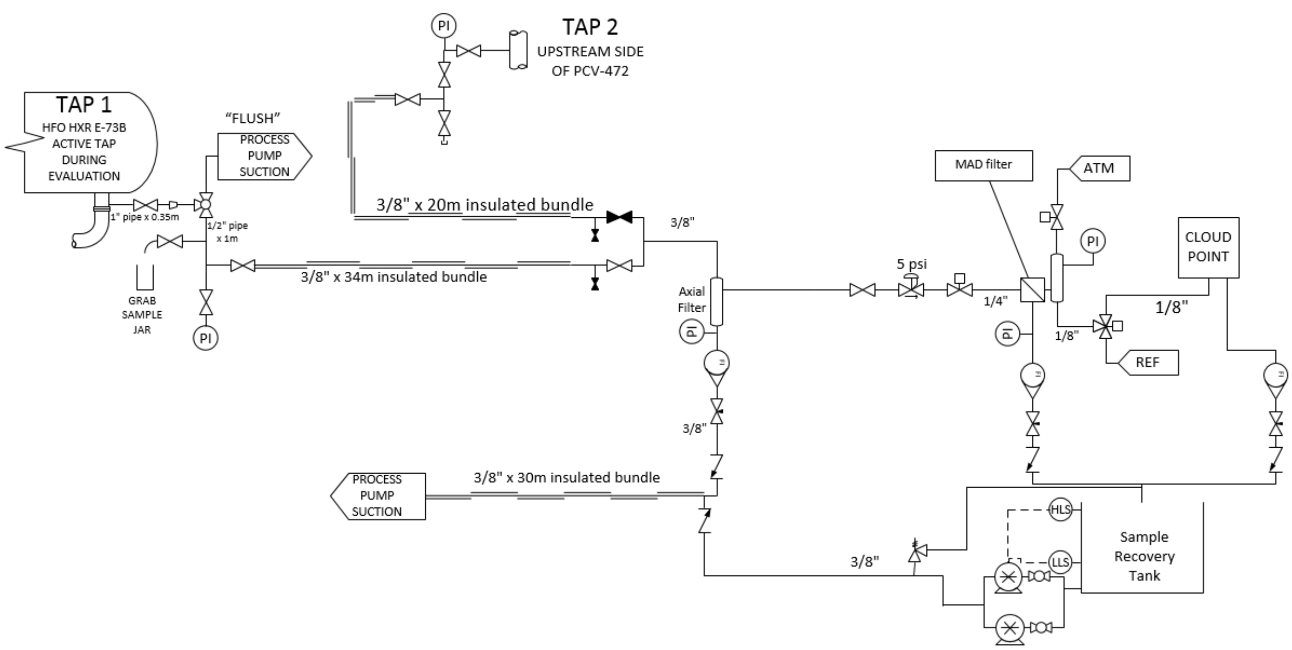

Figure 10 – 137 Crude Unit cloud point improved system P&ID

2. 137 Crude Unit Foul Gas Grab Sample System

The information contained in this section includes photographs and drawings prepared by Swagelok Field Engineering. It also contains references and observations from the Field Engineer. This system is made up of the following:

- Sample Extraction System (SXS)
- Sample Transport System (STS)
- Grab Sample System (GSM)

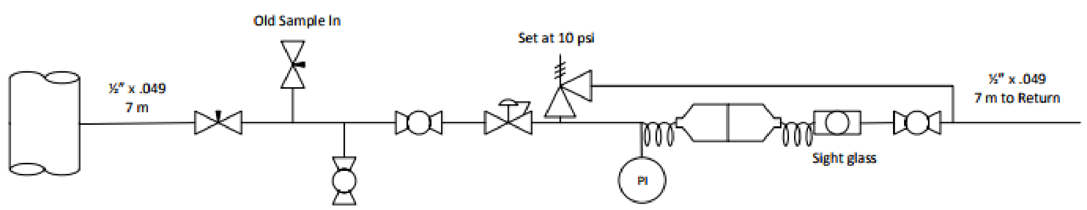

Figure 11 – 137 Crude Unit Foul Gas Grab Sample System P&ID

Problem statement:

Relief valve was set at 10 psi but relieving at pressures less than 10 psi. The hoses are frequently cracking or breaking and needing replacement.

2.1. Sample Extraction System 137 Crude Unit Foul Gas Grab Sample System

❖ Subsystem Observation – Evaluation – Recommendation

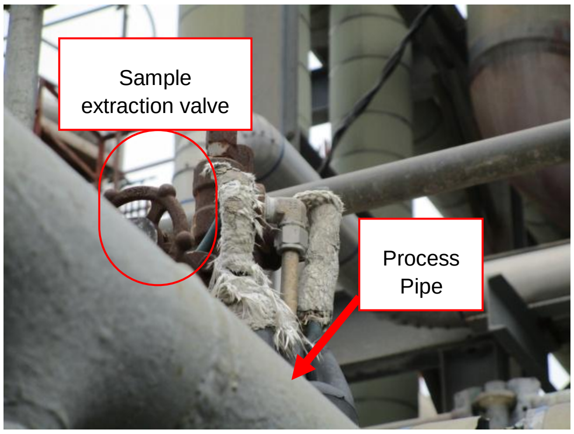

Figure 4 – Sample tap location 137 Crude Unit foul gas sample station

Observation	Evaluation	Recommendation
▪ The sample tap location is installed on a horizontal 8" process pipe. It appears to exit the top of the process pipe, however the team was unable to access the tap as it was 20' above grade with no usable scaffolding nearby.	▪ There was no probe installed in the system. Probes ensure that a sample is timely and representative of process. They also discourage particulate entry and sample from the clean fluid closer to the middle of the pipe.	▪ Install a sample probe. The probe should protrude 25-35% of the way into the process pipe. The tap should be on top of the process pipe.

2.2. Sample transport system 137 Foul Gas Grab Sample System

❖ Subsystem Observation – Evaluation – Recommendation

Observation	Evaluation	Recommendation
▪ Transport tubing was ½" stainless steel and uninsulated. The transport tubing was approximately 25'.	▪ Tubing installed properly	▪ None

2.3. Grab Sample System 137 Crude Unit Foul Gas Grab Sample System

❖ **Subsystem Observation – Evaluation – Recommendation**

Figure 13 – 137 Crude Unit Foul Gas Sample Station

Observation	Evaluation	Recommendation
▪ The Grab Sample Panel has a number of safety concerns with valves and potential gas exposure with hoses that are not suitable.	▪ Operator safety concern due to potential exposure to harmful gas.	▪ The Grab Sample requires a complete re-design to meet modern performance criteria.
▪ The sample container is in a horizontal orientation during sampling.	▪ In order to capture the most representative sample, gases should be sampled in a vertical orientation. In addition, the flow should go from top to bottom in gas grab sample applications.	▪ The Grab Sample requires a complete re-design to meet modern performance criteria.
▪ The lines in the Grab Sample panel are not fixed with appropriate tube supports.	▪ Safety concern. The tubing and components should be fixed with appropriate supports.	▪ The Grab Sample requires a complete re-design to meet modern performance criteria.
▪ The lines from the tee to the needle valve on the old sample line and from the tee to the 1 piece ball valve are dead legs.	▪ Dead legs decrease the representativeness of the sample and increase time delay	▪ Replace the tees with elbows or unions to remove the dead legs

2.4. Performance of the existing system

Given no flowrates, time delays were not calculated in this system. The major issues were safety of the operators with the existing equipment. To improve this set up a whole new system design would be recommended with a standard Grab Sample Panel found in other areas of the plant.

2.5. Improvement Roadmap for 137 Crude Unit Foul Gas Grab Sample

Priority		Estimated Value	Cost to Implement
Complete re-design of Grab Sample System	1	▲▲▲▲▲	$$
Remove dead legs on transport tubing	1	▲▲▲	$

Figure 14 - Safe grab sample station example

2.6. Improved System 137 Crude Unit Foul Gas Grab Sample Station

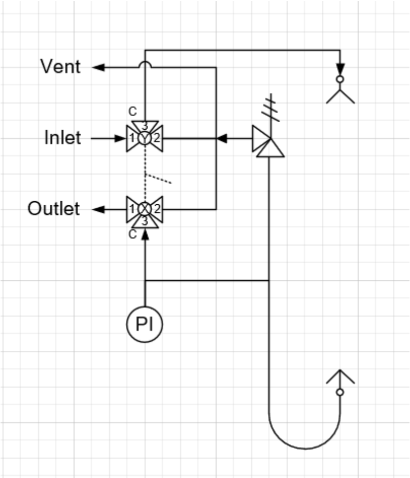

Figure 15 - 137 Crude Unit Foul Gas Grab Sample Improved P&ID

3. 868 FCCU De-propanizer Overhead

The information contained in this section includes photographs and drawings prepared by Swagelok Field Engineering. It also contains references and observations from the Field Engineer. This system is made up of the following:

- Sample Extraction System (SXS)
- Sample Transport System (STS)
- Sample Conditioning System (SCS)

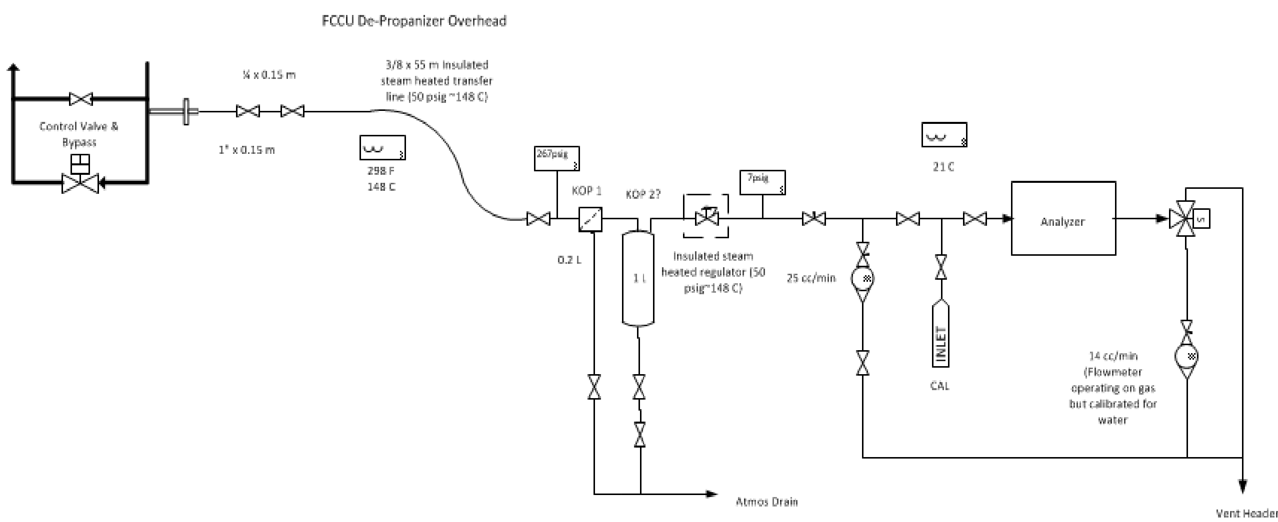

Figure 16 - 868 De-propanizer Overhead P&ID

Problem statement:

When process moves are made, there is thought to be an 80 – 90 minute time delay before the 868 deprop overhead gas chromatograph sees a change, and then it takes up to 6 hours for the full change.

Process conditions: De-propanizer overheads are a liquid at 100 degrees F and 270 psig.

3.1. Sample Extraction System

❖ **Subsystem Observation – Evaluation – Recommendation**

Figure 17 – 868 FCCU Deprop Overhead sample tap

Observation	Evaluation	Recommendation
▪ The sample tap location is on a vertical 8" process pipe. The process fluid is a liquid flowing downward. The sample nozzle is a 2" pipe	▪ Sample tap location is adequate	▪ None
▪ There is a retractable probe installed with ¼" tubing, we were shown a similar probe with a ferrule welded on the end to prevent blowout, and told the probe in use was of the same design	▪ Probe is acceptable	▪ None
▪ The tap has ¼" single shut-off isolation valve	▪ Safety concern	▪ A double block and bleed valve should be fitted as a process isolation. This would allow isolating and venting the system while doing maintenance to the attached system. A mechanical limiter should be installed in addition to the welded ferrule on the probe end.

3.2. Sample Pre-conditioning System

❖ **Subsystem Observation – Evaluation – Recommendation**

Observation	Evaluation	Recommendation
▪ There is no Pre-Conditioning system	▪ Liquid sample moves from tap to sample transport line where it is subjected to steam heat and is undergoing uncontrolled vaporization. This is most likely causing fractionation of the sample in the line, leading to excessive delay and unrepresentative sample. See figure 22 on page 27 for a demonstration on how the sample changes phase from tap to analyzer.	▪ Fluid should not be allowed to vaporize in the sample transport lines. Install an electrically traced regulator to control vaporization at sample tap – 10 psi set point.

3.3. Sample Transport System

❖ **Subsystem Observation – Evaluation – Recommendation**

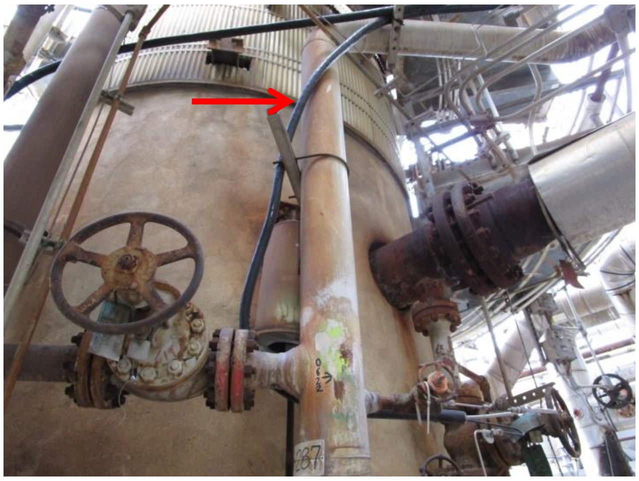

Figure 18 – 868 Deprop Overhead Steam Traced 3/8" tubing

Observation	Evaluation	Recommendation
▪ The transport line consists of 3/8" inch sample tubing and a steam trace line. These two lines are insulated together. The wall thickness of the tubing could not be verified. ▪ Insulation does not come all the way to the probe.	▪ Liquid is being vaporized in the sample transport line, leading to sample fractionation and a very long time delay. Flow rates of bypass and analyzer stream are impossible to judge due to missing flowmeters on bypass line and incorrectly specified flowmeters on analyzer stream.	▪ Heating should only be applied to sample transport line downstream from regulator. Electric heating to 70 C or 160 F should be more effective. If saturated steam must be used, steam pressure should be limited to <10 psig, or about 230-240 degrees F maximum. ▪ Re-design sample transport system with vaporizing feature, controllable bypass system design and correctly specified instruments.

3.4. Sample Conditioning System

❖ **Subsystem Observation – Evaluation – Recommendation**

Figure 19 - 868 FCCU Deprop Overhead Sample Conditioning System

Observation	Evaluation	Recommendation
▪ Lack of steam trace and insulation once sample line enters the shelter. ▪ The sample conditioning system (SCS) has 2 knock out pots.	▪ The lack of steam trace and insulation causes cold spots which can lead to condensation of the sample. ▪ Performance concern. The second knock out pot (probably a retrofit attempt at removing condensate) contributes to an enormous time delay and raises concern for the sample quality with the condensation occurring. Not necessary if sample transport and bypass systems were designed and performing correctly.	The SCS requires a complete re-design to meet modern performance criteria to transport the sample in a representative manner to avoid condensation and excessive time delays: ▪ Install a fast loop system to ensure representative sample and reduce time delay ▪ Vaporize the process liquid close to the tap using a proper vaporizer subsystem ▪ Reducing the pressure close to the tap should ensure the sample stays in the vapor phase

3.5. Performance of the existing system:

There are a number of factors contributing to an unacceptable time delay and unrepresentative analysis of this system.

1. The sample transport line is steam-heated. Liquid propane is boiling in the line resulting in a combination of extremely slow liquid flow plus slow movement of the vapor because it is at high pressure. It is likely that this combination of slow movements is contributing many hours of delay in the sample transport system.
2. The liquid sample should be vaporized at the process tap and transported as a low-pressure vapor.
3. Previous attempts to knock out moisture create large mixing volumes that also contribute to the unacceptable time delay. This coupled with the heated regulator in the analyzer shelter increase the chances of the sample being unrepresentative.
4. The flow measurement devices in the stream switching cabinet are calibrated to liquid rather than gas.
5. There is no double block and bleed in the stream switching enclosure which leads to cross contamination of samples.
6. Process delays in the accumulator and 2 heat exchangers are calculated below using the same method as 137 Crude Unit process delay calculations. The flow rate used is the sum of the flows downstream of pump P-203 as both flow rates act on the fluid in the accumulator and heat exchangers. This flow came to 22 MBPD + 3000 BPD = 25,000 BPD = 4,000,000 liters per day = 167,000 liters per hour

$$\boldsymbol{Delay_{process}} = \frac{\boldsymbol{Delay_{Accumulator} + Delay_{heat\ exchangers} + Delay_{process\ pipe}}}{\boldsymbol{Flow\ rate}}$$

$$\boldsymbol{Delay_{process}} = \frac{\boldsymbol{\frac{100,000L}{2} X\ 3 + \frac{8,000L}{2} X\ 2\ X\ 3 + 5,000L}}{\boldsymbol{167,000\ \frac{L}{hr}}}$$

$$\boldsymbol{Delay_{process}} = \boldsymbol{1\ hour}$$

The time delay is partly due to the volume of the knock out pots installed to contain condensation and mostly due to the high pressure and vaporization occurring in the sample transport line. An additional delay to consider is the 1 hour process delay.

Improvement Roadmap for 868 De-Propanizer Overhead

Priority		Estimated Value	Cost to Implement
Install a heated regulator at the tap as near as possible to the probe and set to 10 psi. This should result in a much faster response time and position the gas well within the vapor phase of the propane/propene mixture. Use an electrically-heated vaporizer to avoid potential fractionation or reaction of the sample; steam is too hot.	**1**	▲▲▲▲▲	$$
Re-design fast loop/bypass system using electric heated sample transport line, controllable flowmeter, review bypass filter design.	**2**	▲▲▲▲▲	$$$
Replace flowmeters with models that are calibrated for gas to get an accurate flow reading. Both the analyzer flowmeter and bypass flowmeter are calibrated for water. This makes it difficult to measure the flowrate of the gas going into the analyzer.	**3**	▲▲▲▲	$
Consider replacing the stream selection and calibration switching system under the analyzer to a double block and bleed system to avoid contamination of the sample.	**4**	▲▲▲	$

Improved Schematic with Re-Design

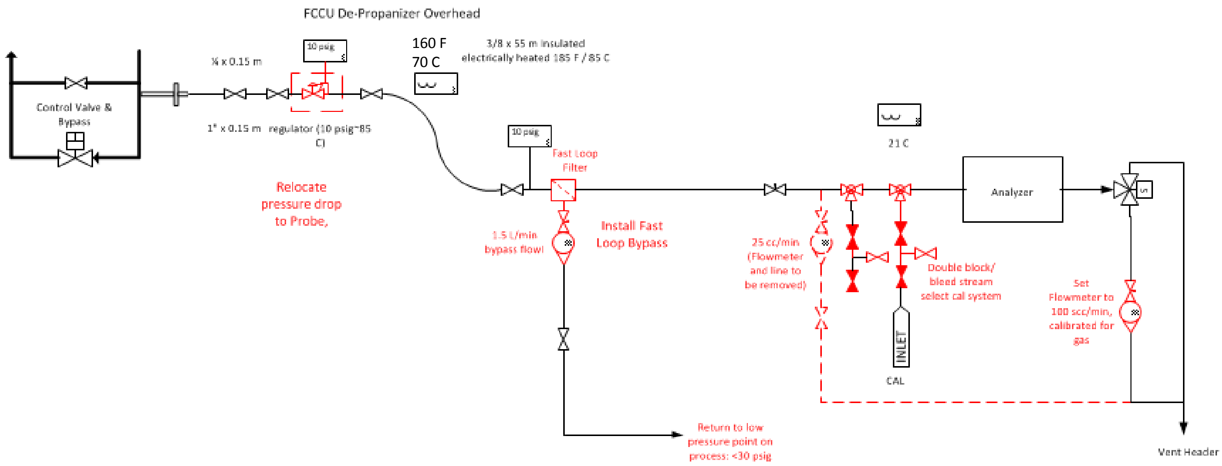

Figure 20 - 868 FCCU De-prop Overhead improved system P&ID

Time delay calculation by section – improved system: 868 De-propanizer Overhead

Overall delay: about 2 minutes

(Time delay in seconds)

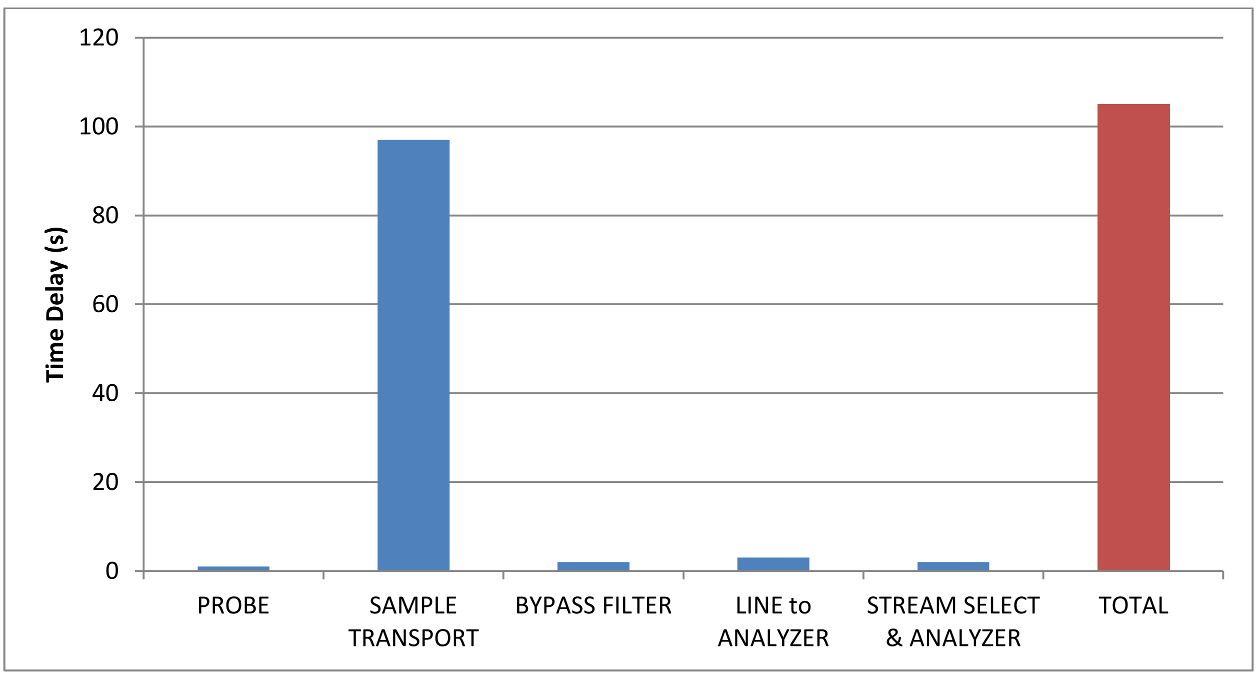

Figure 21 - 868 FCCU De-propanizer Overhead improved time delay

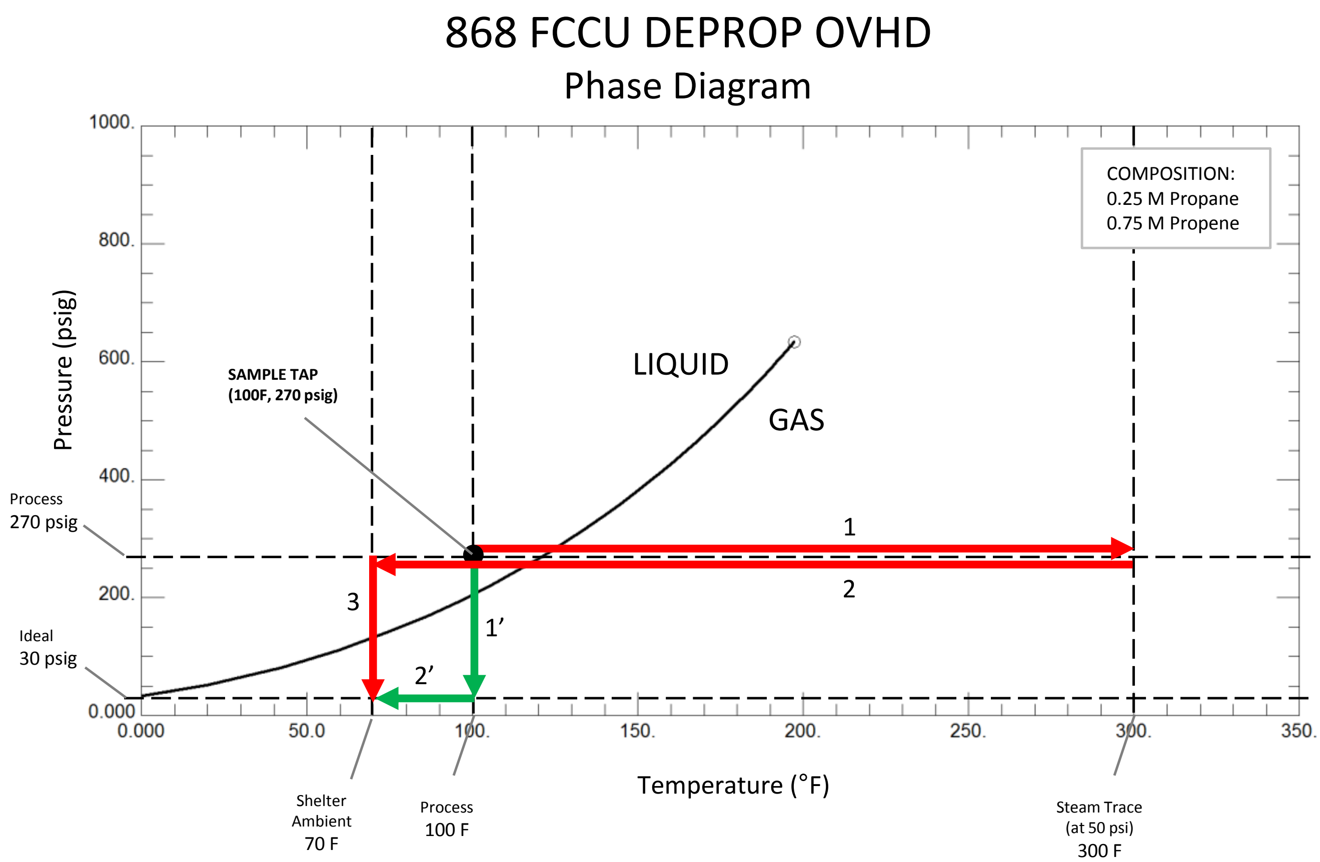

Figure 22 – Phase change in current Sample Transport System (red) and proposed system (green).

There appears to be unintended phase change multiple times as the sample moves from the process to the analyzer. Starting with a liquid at the process and considering that the analyzer requires a gas sample there needs to be at least one phase change. Additional phase changes may contribute to uncontrolled fractionation of the sample which can result in a sample that is not representative of the process. Figure 22 shows the phase changes in the current system in red and the phases changes in the proposed system in green. The black dot represents the starting conditions of the process at the sample tap.

Current Sample Transport System (red):

1) **Sample changes from liquid to gas** as the temperature increases from 100 °F at the sample tap to 300 °F in the transport line traced with 50 psi, 300 °F steam.
2) **Sample changes from gas to liquid** as the line temperature drops to 70 °F in the shelter where the transport line is exposed to ambient temperature.
3) **Sample changes from liquid to gas** as pressure drops from 270 psig to about 30 psig across a traced and insulated pressure reducing regulator.

Proposed Sample Transport System (green):

1') **Sample changes from liquid to gas** as pressure drops from 270 psig to 10 psi at a vaporizing regulator located near the sample tap.

2') **No phase change** as temperature drops to ambient inside of the shelter.

Proposed system calculations spreadsheet

COMPLETE SAMPLE TRANSPORT SYSTEM DESIGN SPREADSHEET

SAMPLE CONDITIONS	UNITS	SAMPLE SUPPLY SYSTEM: PROBE	LINE #1	FILTER / POT	LINE #2	SAMPLE STATE	SLOW LOOP THROUGH ANALYZER: FILTER / POT	LINE IN	TOTAL	LINE OUT		RETURN LINE TO DISPOSAL
SAMPLE STATE	info	Select "LIQUID" OR "GAS" >>				GAS						
SAMPLE DENSITY	kg/m³	600	2		2	Enter P & T @ FLOWMETER ↓		2		2		2
SAMPLE VISCOSITY	cP	0.0	0.0		0.0			0.0		0.0		0.0
SAMPLE PRESSURE	barg	19	1	1	1	1		0.5		0		0
SAMPLE TEMPERATURE	°c	30	85	85	85	85		85		21		21
SAMPLE PRESSURE	bara	20	2	2	1.5	2	0	1.5		1		1
SAMPLE TEMPERATURE	K	303	358	358	358	358	0	358		294		294
	TRANSPORT LINE DATA AND SAMPLE VOLUME IN LINE SEGMENTS											
LINE LENGTH	m	0.3	55	3	4		3	1		2		2
NUMBER OF ELBOWS	#			Describe ↓	4		Describe ↓					
MATERIAL CODE	spec	1/4" x 0.049	3/8" x 0.035	swirl or sim.	1/4" x 0.035			1/8" x 0.020		1/8" x 0.020		3/8" x 0.035
PIPE OR TUBE	info	TUBE	TUBE	Enter Physical Volume of device ↓	TUBE		Enter Physical Volume of device in mL ↓	TUBE		TUBE		TUBE
EXTERNAL DIAMETER OF LINE	mm	6.35	9.53		6.35			3.18		3.18		9.53
INTERNAL DIAMETER OF LINE	mm	3.86	7.75		4.57			2.16		2.16		7.75
UNIT VOLUME	mL/m	11.7	47.1	25	16.4	SUPPLY LINES		3.7	TO ANALYZER	3.7		47.1
PHYSICAL LINE VOLUME	mL	4	2593	75	66	2737	0	4	4	7		94
EXPANDED VOLUME (IF GAS)	mL	41	2593	75	49	2758	0	3	3	4		57
	FLOW RATE AND VELOCITY IN TRANSPORT LINES											
TRANSPORT TIME	s	Enter maximum acceptable time in supply line >>				50	Enter max time to analyzer >>		10	s		60
MINIMUM LINE FLOW	L/min	This is the minimum flow rate for desired transport time				3.31	Minimum flow to analyzer		0.02	L/min		TOTAL DELAY REQUESTED
SLOW LOOP FLOW RATE	L/min	This portion of the flow diverts to the analyzer				>>	Enter flow to analyzer >>		0.1	L/min		105
MINIMUM FAST LOOP FLOW	L/min	This is the minimum flow that must bypass the analyzer				3.3	Does the flow leaving the analyzer join the return line? Select "YES" or "NO"					TOTAL DELAY ACHIEVED
FAST LOOP FLOW RATE	L/min	Enter preferred flow rate to bypass the analyzer >>				1.5			>>	>>	>>	NO
ACTUAL LINE FLOW	L/min	This is the sum of the analyzer and bypass flow rates				1.60			0.10	L/min		1.50
SEGMENT LAG TIME	s	1.6	97.2	2.8	1.8	103.4	0.0	1.6	1.6	2.7		2.2
SEGMENT VELOCITY	m/s	0.19	0.6		2.2	DELAY IN SUPPLY SIDE		0.6	DELAY TO ANALYZER	0.7		0.9
	TURBULENCE AND PRESSURE DROP IN TRANSPORT LINES											
REYNOLDS NUMBER	none	53810	930		2110			280		340		1530
FLOW REGIME	n/a	TURBULENT	LAMINAR		CRITICAL			LAMINAR		LAMINAR		LAMINAR
RELATIVE ROUGHNESS	ε/d	0.00039	n/a		n/a			n/a		n/a		n/a
FRICTION FACTOR*	none	0.022	0.069		0.030			0.229		0.188		0.042
EFFECTIVE LENGTH	m	0	55		6	FAST LOOP TOTAL ΔP		1	SLOW LOOP TOTAL ΔP	2		2
PRESSURE DROP	bar	0.00	0.00		0.00	0.00		0	0.0	0		0

*assumed turbulent if Re>=2300

PROBE RESONANCE CALCULATION

STANDARD REFERENCE METHOD	STD	EEMUA 138	IEC/TR 61831
CONCLUSION: SELECTED PROBE IS...	OK?	NO DATA	NO DATA
ACTUAL PROCESS VELOCITY	m/s		
PIPING DESIGN VELOCITY	m/s		
PROBE MATERIAL MODULUS *	GPa	198.0	316 SS
PROBE MATERIAL DENSITY *	kg/m³	7960	316 SS
MAXIMUM PROBE LENGTH	m	NO DATA	NO DATA

this calculation requires entries for process velocity, and probe temperature and length

* default values are for 316 stainless steel overwrite new values for other material

COLOR KEY	
ENTER USER DECISION	CALCULATED VALUE
ENTER APPLICATION DATA	DO NOT ENTER
LOOKUP VALUE	WARNING

Figure 23 - Improved system time delay

4. 868 FCCU CEMS

The information contained in this section includes photographs and drawings prepared by Swagelok Field Engineering. It also contains references and observations from the Field Engineer. This system is made up of the following:

- Sample Extraction System (SXS)
- Pre-conditioning System (PCS)
- Sample Transport System (STS)
- Sample Conditioning System (SCS)

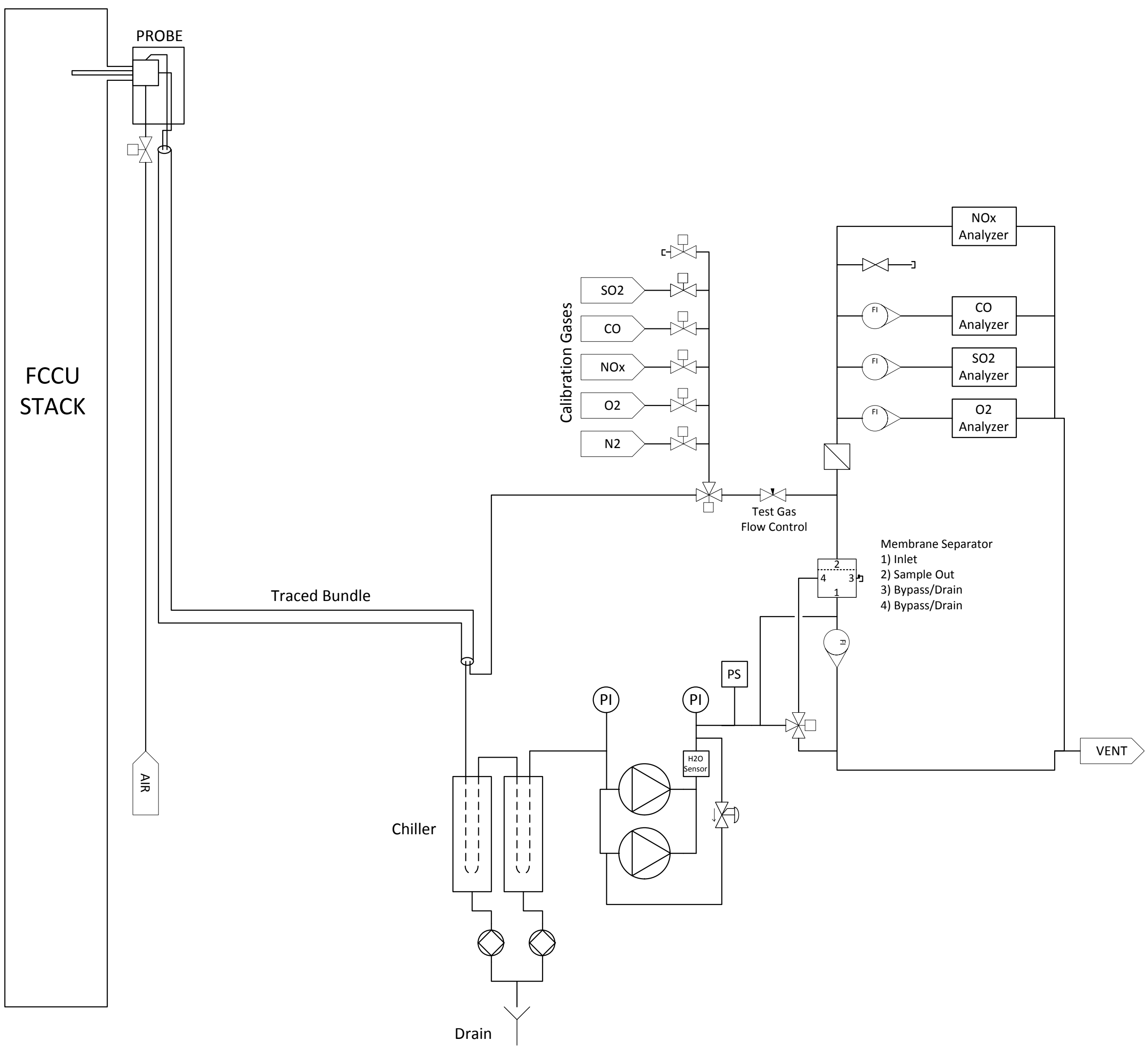

Figure 24 – 868 FCCU CEMS P&ID

Problem statement:

ABC Company has reported that they're cleaning out the section of sample line just prior to the chiller as frequently as monthly due to the formation of light brown crystalline substance. ABC Company reports that this problem is likely due to them injecting ammonia into the stack to reduce NO_x.

4.1. FCCU CEMS – Sample Extraction System and Sample Preconditioning System

❖ **Subsystem Observation – Evaluation – Recommendation**

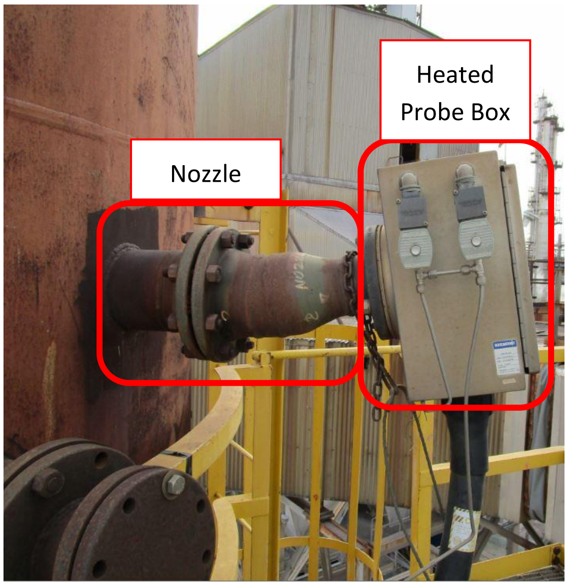

Figure 25 – 868 FCCU CEMS nozzle and heated probe box.

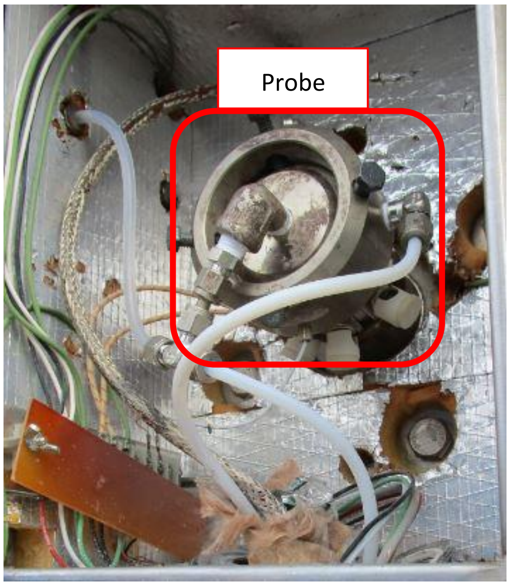

Figure 26 – 868 FCCU CEMS Probe inside heated box

Observation	Evaluation	Recommendation
▪ Tap is located approximately 50 ft up the FCCU stack.	This is the typical location for CEMS tap	
▪ The CEMS enclosure includes air purge and accumulator, sample and calibration line connections, a heater (set to 300F), and a filtered probe.	This is the typical equipment for CEMS and there is no indication that it is malfunctioning.	

4.2. Sample transport system 868 FCCU CEMS

❖ **Subsystem Observation – Evaluation – Recommendation**

Figure 27 – CEMS traced sample bundle at probe box

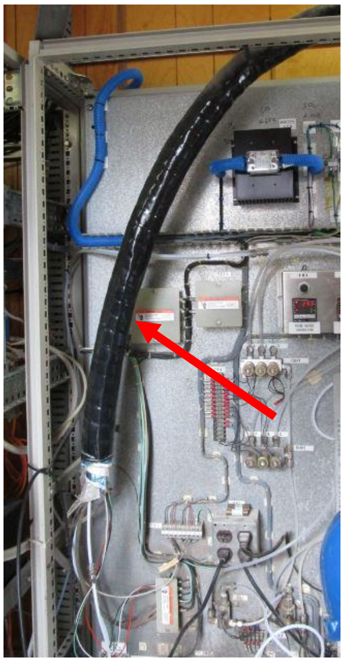

Figure 28 – CEMS bundle at conditioning panel in shelter

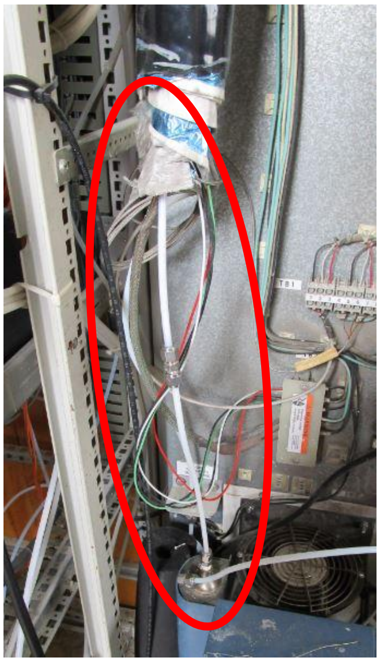

Figure 29 – Bare section of CEMS sample line prior to the chiller

Observation	Evaluation	Recommendation
▪ Transport line is electrically traced at 300F	This is a typical configuration and temperature set point for CEMS	
▪ The traced portion of the transport line stops about 18” prior to the chiller leaving this section exposed to atmospheric temperature. The sample pump fan is blowing air on the sample line.	Leaving this section untraced and uninsulated allows the sample line to cool to atmospheric conditions. Ammonia reacts with SOx at this lower temperature and deposits solids on the inside walls of the sample line leading to plugging.	Install a heated ammonia scrubber just after the trace stops, prior to the chiller. Inspect and clean the chiller to clear any solid deposits. Install insulation to any untraced sample line prior to the chiller.

4.3. Sample conditioning system 868 FCCU CEMS

❖ **Subsystem Observation – Evaluation – Recommendation**

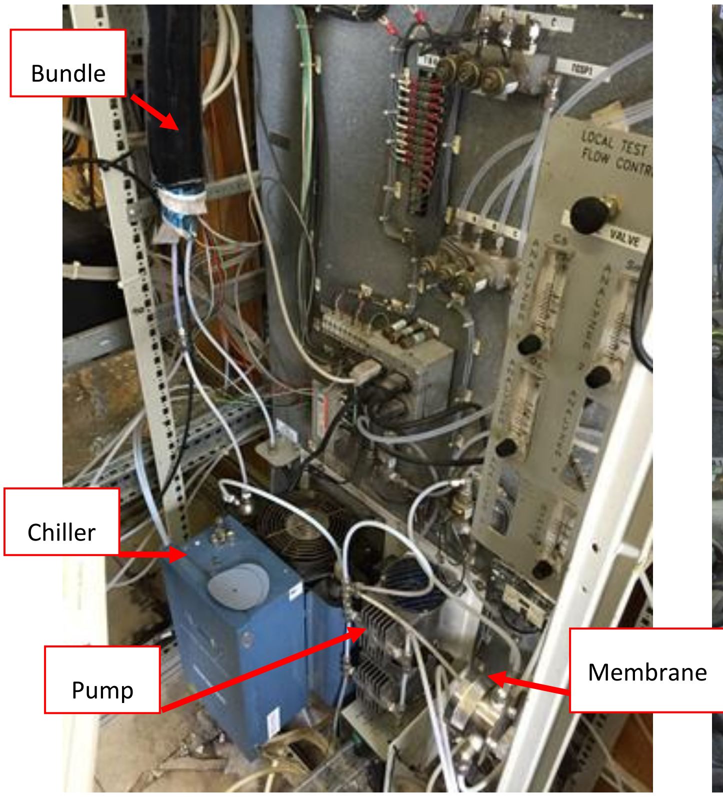

Figure 30 - Sample conditioning system FCCU CEMS

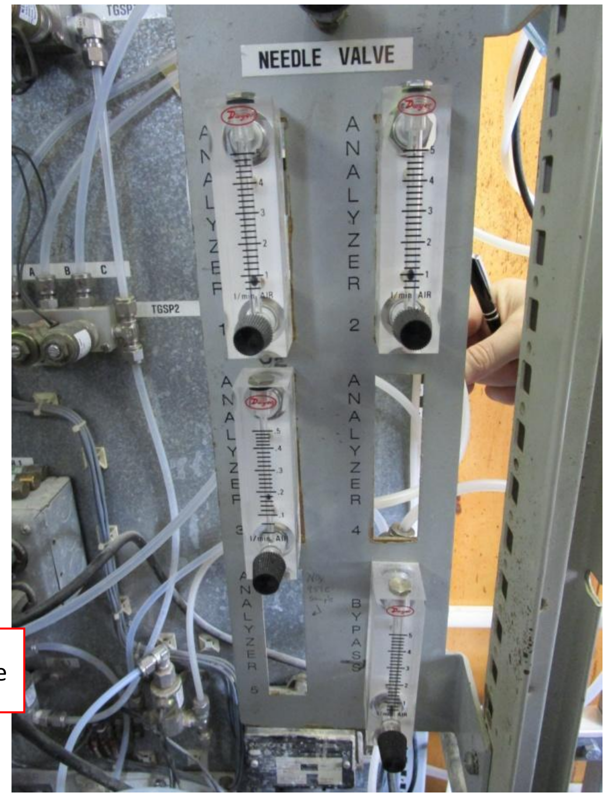

Figure 31 – Analyzer and bypass flowmeters.

Observation	Evaluation	Recommendation
▪ Chiller was set to 4 C. IR temperature taken from the exit tube was 10-12 C.	▪ The chiller may not be able to bring temperature down to set point due to a buildup of solids similar to the buildup in the tubing prior to the chiller.	▪ Install ammonia scrubber prior to the chiller. Perform maintenance on the chiller to clean out solids.
▪ Pump inlet was at 5" Hg and the outlet was at 7 psi. Following the pump is a moisture sensor and a pressure switch. A backpressure regulator tee's off to provide overpressure protection.	▪ All components appear to be functional.	
▪ Sample bypass flow meter indicated 0 L/min flow	▪ There is minimal to no flow through the bypass	▪ Verify flow path is functional. Set bypass to appropriate flow rate.

Observation	Evaluation	Recommendation
▪ A membrane separator (UFS GMS105) is used to remove moisture and provide bypass flow. Port 1 is the sample inlet. Port 2 is the sample outlet. Port 3 and 4 are bypass/drains. Port 3 was capped.	▪ Filter is oriented properly per manufacturer recommendation with inlet to the bottom and outlet to the top. The bypass/drain is connected to a 3 way valve that appears to block flow to the drain.	▪ Verify proper connection of bypass/drain
▪ Sample continues through a gas filter and then branches off through separate flow meters to the analyzers. All flows are to the low end of the flow meter scales	▪ This appears to be a functional design with everything in working condition. There may be a low flow condition or the flow meters may be oversized.	Verify proper flow to the analyzers. Consider replacing the flowmeters with appropriately sized ranges.
▪ Calibration gas is controlled to the probe or tee's into sample line prior to the analyzers by a 3 way solenoid valve.	▪ This appears to be a functional design with everything in working condition.	

4.4. Performance of the existing system: FCCU CEMS

The only reported issue with this system is the line plugging prior to the chiller. When the sample line temperature drops below the dew point of the sample, ammonia reacts with SO2 to form solids. The solids are most likely also forming in the chiller and affecting flow as well as heat transfer. Time delay was not determined for this system.

4.5. Improvement Roadmap for FCCU CEMS

Priority		Estimated Value	Cost to Implement
Add a heated ammonia scrubber prior to the chiller	**1**	▲▲▲▲▲	**$$$**
Inspect the chiller and perform maintenance/cleaning as required	**1**	▲▲▲	**$**
Add insulation to the sample line anywhere it is left bare.	**2**	▲▲▲	**$**
Verify flow rates to analyzers and replace flow meters with appropriate sizes, in applicable	**3**	▲	**$$**
Verify functional flow paths through the sample conditioning system	**3**	▲	**$**

4.6. Performance of the improved system: FCCU CEMS

With the addition of a heated ammonia scrubber as well as insulation on the sample line prior to the chiller you should eliminate the plugging issue. If solids are forming in the line prior to the chiller they are most likely also being deposited on the surfaces inside the chiller. Cleaning the chiller may improve heat transfer which can help to lower the sample temperature. A lower sample temperature should result in the removal of more condensate and reduce the chance for condensate to form later in the system. Verifying functional flow in the system and proper flow rates to the analyzers ensure that the CEMS measurements are accurate and timely.

APPENDIX

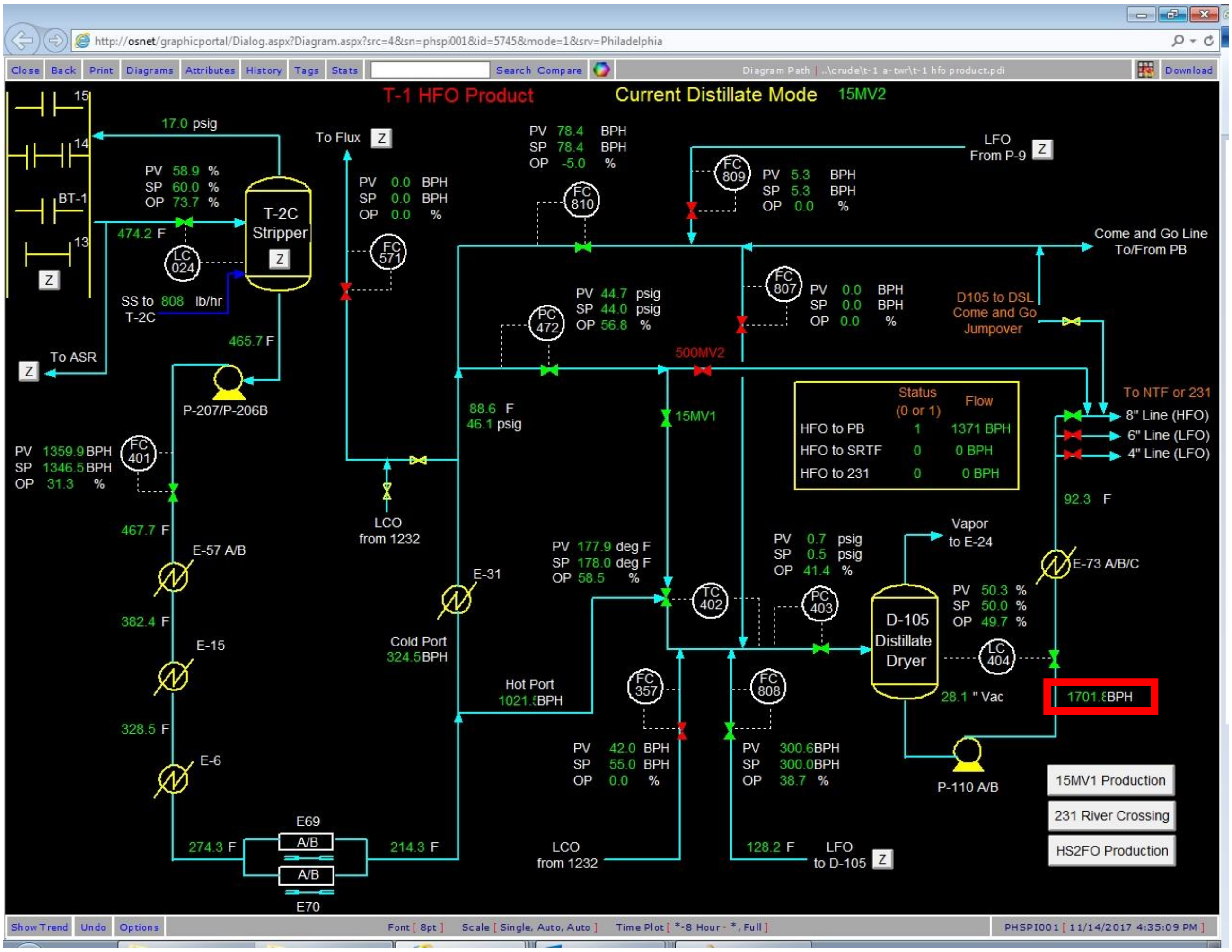

Figure 32 - 137 Crude Unit PI Diagram

GLOSSARY

This section contains terms commonly used in sample system analysis and their definitions.

Function Blocks

Symbol	**Function Block Name**
ASB	Automatic Switching Block
CFB	Calibration Fluid Block
CIB	Cool Impinger Block
CSB	Calibration Sample Block
DFB	Dual Filter Block
ECB	Enclosure Control Block
FBB	Fall Back Block
FCB	Flow Control Block
FLB	Fast Loop Block
GCB	Grab Cylinder Block

Sampling System

SXS	Sample Extraction System
PCS	Sample Preconditioning System
STS	Sample Transport System
SCS	Sample Conditioning System

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When selecting a product, the total system design must be considered to ensure safe, trouble-free performance. Function, material compatibility, adequate ratings, proper installation, operation, and maintenance are the responsibilities of the system designer and user.

Swagelok Penn
1663 Republic Road
Huntingdon Valley, PA 19006
Phone: 267-989-0300

Swagelok