UNIVERSITY OF ALBERTA

FLARE RESEARCH PROJECT

Characterization of Gases and Liquids Flared at Battery Sites in the Western Canadian Sedimentary Basin

March 4, 2004

Executive Summary

Previous experimental research into the efficiency and emissions from flares focussed on burning relatively simple gaseous fuel streams. These studies produced models to predict the combustion efficiency of flares as a function of flare gas flow rate, stack diameter, crosswind speed and gas composition as expressed by energy density. Other field work on solution gas flares suggested that the flare stream was considerably more complex because of the inclusion of liquids. That study also suggested that the performance of flares could be profoundly affected by the presence of liquid thus limiting the usefulness of the above mentioned efficiency model.

This current report presents the results of a preliminary field study to characterize the nature and relative quantities of gases and liquids being flared at battery sites in the Western Canadian Sedimentary Basin. The results of this study will be used to make recommendations on further field study to yet better characterize the materials being flared and the need to revisit the efficiency model.

The present research required the development and construction of a sampling system to collect both the gas and liquid components of the flare stream for analysis. This system was tested in the laboratory and was capable of collecting liquid droplets as small as 0.3 micrometers in diameter. Protocols were developed for the collection and analysis of gaseous and liquid samples for their composition and relative mass fractions.

In total, arrangements were made to test seven battery sites in North and Central Alberta. Operators of these sites provided special sample port access to the flare stream after the liquid knockout system and as near to the flare as possible. This sampling configuration insured the sampled materials would be representative of the actual gas and liquid mixture being flared. The samples were collected and analyzed by an independent chemical analysis company.

The most important result of this research was that no liquids were collected or observed at any of the sites tested. This result has important implications regarding the assumption that liquids are commonly found in these flaring streams. The chemical analysis performed on the gas phase collected at sites showed a wide variation in the volume fraction of fuel and inert components. No credible correlation could be made to link the appearance of smoke at a flaring site to the composition of the flare gases.

Since all the flare streams tested were free of liquids there is no compelling reason to undertake more field testing for liquids or to modify the previous model for predicting the combustion efficiency of flares in a crosswind.

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1. Introduction

The University of Alberta's Flare Research Project and Natural Resources Canada have conducted laboratory-based experimental research to quantify the efficiency and emissions from flares burning in a crosswind. This research could be considered to have adopted a rather idealized or simplistic point of view towards flaring because of the nature of the fuels burned. The research involved relatively simple fuels (e.g., sales grade natural gas, commercial grade propane, and technical grade ethane or propylene). Sometimes non-reacting diluents (e.g., nitrogen and carbon dioxide) were added to the flare stream to alter the energy density of the gases being burned. From the hundreds of tests conducted at the University of Alberta a semi-empirical, predictive model was developed for the combustion efficiency of flares (c.f., Johnson, M.R. and Kostiuk, L.W., "A Parametric Model for the Efficiency of Flares in a Crosswind", Proceedings of the Combustion Institute 29: 1943-1950, 2002). Experiments have also been conducted with liquid droplets, composed of octane, diesel or water, added to the flare stream. Like the gas phase, these droplets were of a simple composition and were only meant to simulate some expected carryover from the liquid knockout system or from condensing vapors in the flare stream. The reason for this concern about the influence of the liquid phase on the combustion of flare gas was a previous report (Strosher, M., "Investigation of Flare Gas Emissions in Alberta", Alberta Research Council Report to Environment Canada, Alberta Energy and Utilities Board, and Canadian Association of Petroleum Producers, 145 pages, 1996). This ARC report suggested that the inclusion of liquids in the flare stream had a profound effect on the combustion efficiency and thereby may limit the usefulness of any efficiency model based on gas-only flare streams.

The use of simple fuels was justifiable in the laboratory work as it allowed for a general understanding of the origins of the emissions and inefficiencies. Another reason for not trying to match field conditions in the laboratory is that little is known about nature of the materials actually being flared at battery sites. Ideally, one needs to know the gas phase composition, liquid phase composition, relative masses of gas and liquid phases, and droplet size range in order to match the field operating conditions. Some insight into actual operating conditions in the Western Canadian Sedimentary Basin can be derived from the Alberta Energy and Utilities Board (AEUB) databases which provide monthly volumes of gas being flared in the province and an unconnected listing of the gas phase composition at various battery sites (c.f., Johnson, M.R., Spangelo, J.L. and Kostiuk, L.W. Journal of the Air and Waste Management Association 51:1167-1177. 2001). Unfortunately, these databases give what appears to be only half the picture because there is no similar data on the volume and composition of the liquid phase being flared.

In an attempt to gain insight into the liquid phase associated with solution gas flares, the University of Alberta sampled knockout drums at two oil batteries in 1999. These unpublished results showed that the drum's liquid contents were stratified with a hydrocarbon-based layer residing above a brackish water layer. The analysis of these two layers was quite limited in its usefulness in determining the composition and mass fraction of the liquids being flared. The tests showed only what material was trapped in the knockout drums and not what was being flared. Hence, much remained unknown about the liquid phase of the flare stream.

This current report originates from a request for proposal (RFP) from the energy industry and regulators to better quantify the actual flare stream composition at battery sites in the Western Canadian Sedimentary Basin. The research proposed to fulfill this RFP was divided into two phases, of which this is a reporting on the first phase. Following is a description of the specific objectives of the first phase and how this work will define the future research direction. A brief description is then provided to how sites were selected for sampling in this first phase of the project. A detailed description is also presented of the system used to quantitatively collect gas and liquid phase samples. In addition, the planned chemical analysis for these samples is described. Lastly, the results of the field tests are reported along with recommendations for further work.

In summary, seven battery sites located in North and Central Alberta were sampled in both summer and winter conditions for the relative masses and compositions of the liquid and gas phases. No liquids were found at any of the sites tested. This result of finding no liquids has important implications for our perception of the nature of flared solution gas. The assumption of a continuous liquid component to the flare stream does not seem to be a likely occurrence. No correlation was found between smoke emissions from the flare and the compositional variations of the flare stream. The recommendations, based on these results, are not to embark on the second phase of research and that the existing efficiency model adequately represents known flaring conditions.

2. Project Objectives

The main objective of this first phase of research was to initiate a program to characterize the composition of the materials being flared at battery sites in the Western Canadian Sedimentary Basin. This research required the development and construction of a sampling system to collect both the gas and liquid components of the flare stream for analysis. This sampling system was then to be used at a limited number of sites. Besides providing researchers, industry and regulators with this data, these preliminary tests would represent the foundation of recommendations for future work including a larger scale sampling program and any alterations required to the predictive model for combustion efficiency.

3. Site Selection Procedure

Before discussing the technical details of the sampling system and procedures and the results it is important to consider the process of site selection. Despite the limited number of sites tested, attempts were made to involve as wide a range of sites as possible. Site selection was based on a series of progressively refined criteria. In the first instance, all battery sites in Alberta were screened for the production of solution gas flared as part of ongoing oil recovery operations. These sites were then reviewed to identify flares that handled a relatively consistent volume of solution gas in amounts near the provincial median for reported flow rates. This screening according to reported volumes allowed some notion of a typical flow rate and some assurance that that flow rate would exist for our site visit. Individual sites were then identified within various oil fields and pools in the province. This information aided in establishing the physical configuration of the liquid knock-out system and the flare as well as the suitability of the site for sampling. Information for this site selection process came from the Alberta Energy and Utilities Board, Department of Earth Sciences at the University of Alberta and direct communication with the battery operators. It was also necessary to communicate with representatives of oil and gas companies to gain site access to conduct this research. Implicit to this communication was the request for the installation of a special sampling port downstream of the liquid knock-out system. In the end, securing permission for site access from battery operators proved to be the most difficult task and, as a result, only a few sites were made available for this study.

Based on the sites available, sampling began with sites closest to Edmonton in order minimize the costs of debugging the sampling system and the associated operating procedure. This

approach was also adopted to re-evaluate the sampling sites and procedures according to each new set of chemical analysis. As will be shown in the Results Section, the flare stream at the first site was liquid free and its gas phase was dominated by propane (97 %). This finding was due to operational problem at the battery resulting in the propane pilot fuel being directed to the flare. The next three sites were also free of liquids and this provoked a re-evaluation of the strategy for site selection. To increase the likelihood of finding a site with liquid carryover (i.e., heavier hydrocarbons), the argument was made that this could correlate with smoking flares. The Alberta Energy Utilities Board was then engaged to help identify non-compliant, smoking flares that we could sample with the permission of the battery operator. This revised process lead to three more sites being sampled.

4. Description of Sampling System

The basic philosophy used in sampling the flare stream was to extract and characterize a portion of the flow as near to the flare exit as practical in order to have a representative sample of what is actually being burned. The idea being that the composition of the flare stream likely changes as a result of the processes it undergoes from the time it is separated from the oil and water until it reaches the top of the flare stack. Ideally, the flare stream should be sampled at the top of the stack but this is problematic due to height and working around the flame. Consequently, the samples taken in this research were at the bottom of the stack but after the liquid knock-out system (i.e., the last major piece of equipment used to process the flare stream prior to combustion). There may, in fact, be changes occurring to the flare stream along the length of the flare stack (e.g., droplet fallout), but samples taken at these locations should be broadly representative of the flare stream being flared.

Since there is interest in the composition of both the gas and liquid phases of the flare stream as well as their relative mass flow rates, it was important to extract samples in an iso-kinetic manner. The model applied to the stream flow is that the gas phase is homogeneously mixed and carries relatively small droplets that have a very low slip velocity occurring between the two phases. If the gas is sampled iso-kinetically so that its streamlines are minimally disturbed, the appropriate amount of droplets will then be extracted at the same time. Once the two-phase mixture is extracted from the stack it could then be separated and the relative flow rates could be calculated. In the case of the liquids, they were to be trapped in a coalescing filter capable of removing droplets of all sizes of practical importance. By measuring the total liquid volume collected for a known time interval, this would provide an estimate of the flow rate of droplets.

Additionally, the collected liquid would be analyzed for its composition. In the case of the gas phase, the total volume of gas was measured with a calibrated dry gas meter (after the liquids were removed) over the same time interval as the liquid collection. A portion of the liquid-free gas flow was shunted to a sampling vessel and was analyzed for its composition.

The remainder of this section provides a detailed description and discussion of the practicalities associated with the set-up of the sampling system at the battery site, the sampling apparatus itself, and the features of the sampling probe.

Sampling Set-up at a Battery Site

The sampling apparatus was transported to battery sites in a pick-up truck and then set up by the technician from a collaborating chemical analysis company. An independent chemical analysis technician was used to ensure that the necessary protocols of gas sampling, prior to any chemical analysis, were strictly followed. Once on site, the set-up of the system required about 90 minutes. This set-up time included the initial safety orientation by the battery operator or representative from the cooperating oil company.

Figure 1 shows a schematic of the sampling apparatus attached to a typical flare stack complete with a liquid knock-out system. The sampling apparatus was a self-contained system that was mounted on a frame with balloon tires. This frame allowed the sampling apparatus to be located close to the flare stack so its insulated flexible sample line could be connected to a previously prepared sample port. The details of the sample port are discussed below. The sample line from the flare stack was designed to create a downward flow into the sampling apparatus so that all

liquids would be collected. Power for the sampling system was provided by a portable gasoline powered electric generator.

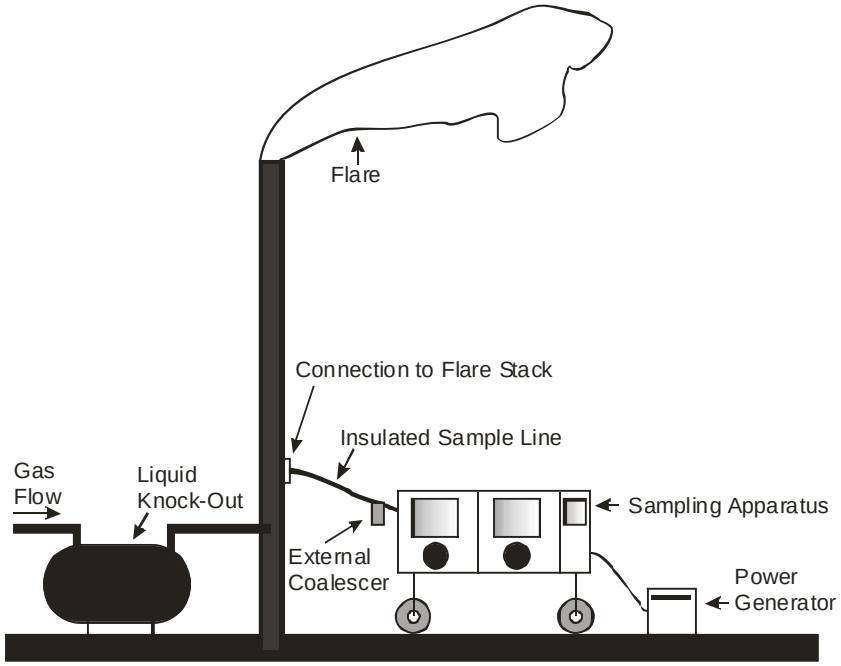


Figure 1: Sampling Apparatus in Field

Sampling Apparatus

Figure 2 shows an exterior schematic view of the sampling apparatus. The exterior of the sampling apparatus was built from an aluminum frame and plywood siding which was then painted with epoxy paint. The dimensions of the sampling system were 0.6 m x 0.6 m x 1.5 m and had an approximate mass of 75 kg. The basic layout of the apparatus is divided it into two segments such that the working section was separated from a heating system. The heating system was responsible for maintaining a constant operating temperature of 25^{O}C within the working section and allowed the system to operate effectively over a range of ambient temperature from -10^{O}C to 30^{O}C. The temperature control system consisted of a thermocouple and a control box for the heating element. The thermocouple and a thermometer were placed at the far end of the box in order to monitor the temperature.

The main working section of the sampling apparatus was fitted with a two doors that provided full access to the interior compartment. Two observation windows were cut into the doors to allow the technician to read the various meters without having to expose the system to ambient conditions. Similarly, glove holes provided access to the interior of the sampling system without requiring the technician to open the doors. The heating system also had a small access door that was used to facilitate the adjustment of the fan speed and the thermocouple control system.

The exterior line and coalescer were insulated in order to maintain them near to the temperature of the gas being sampled. The concern was that certain components of the flare stream may be in the liquid phase at ambient conditions but would become a gas phase within the interior of the sampling apparatus. This first stage of droplet removal was capable of collecting droplets to a size of 5 micrometers.

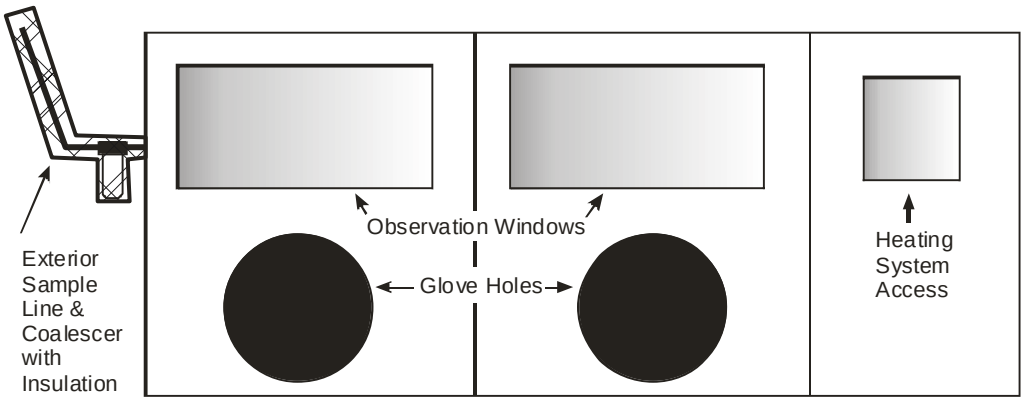


Figure 2: Exterior of Sampling Apparatus

Figure 3 is a schematic of the interior the sampling apparatus. The stream entering the interior of the sampling apparatus encountered a more sophisticated coalescing system which could capture droplets down to 0.3 μm in diameter. Any liquids collected by this or the exterior coalescing

system would be chemically analyzed and used to estimate the relative mass flow rate of the liquid phase compared to the gas phase. The now liquid-free gas stream could either be passed through the dry gas flow meter or captured in the Sulfinert sampling cylinder depending on the setting of manual valves.

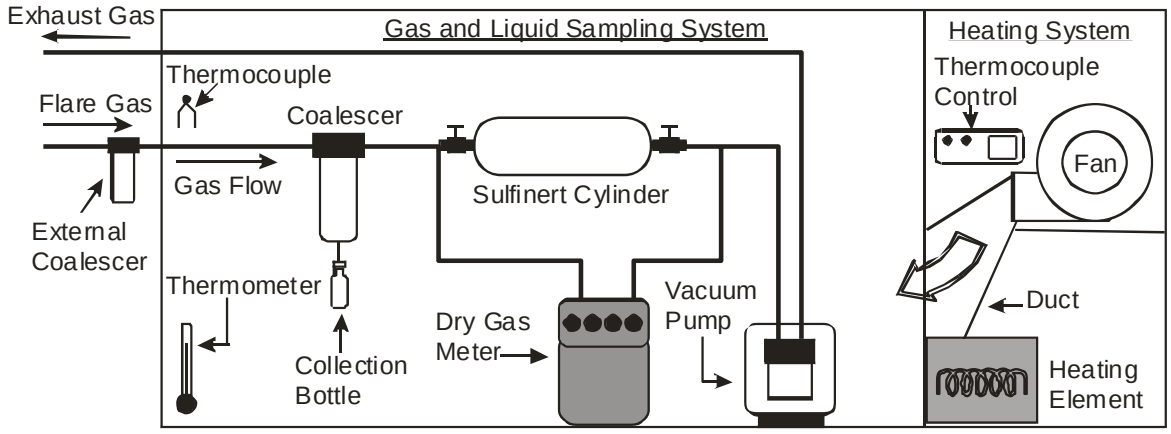


Figure 3: Interior of Sampling Apparatus

Passing the gas through the flow meter served two purposes. Its first purpose was to set the sampling flow rate so that the sample could be extracted iso-kinetically from the flare stack. This process was done using an anemometer (details discussed later) that was mounted just next to the sampling point inside the flare stack. This anemometer provided an accurate and on-line measurement of the flow velocity in the flare stack. The technician was provided with a pre-calibrated look-up chart that related the inlet velocity at the sample point to the vacuum setting within the sampling apparatus. Once the anemometer reading was taken the technician would adjust the vacuum pump to ensure iso-kinetic sampling. The second purpose of passing the liquid-free gas through the flow meter was to measure total volume flow rate over a fixed time period in order to determine volumetric flow rate within a known temperature and pressure environment.

With the manual valves in the alternate position, a sample of the gas stream could be transferred to the Sulfinert sampling cylinder. The contents of this cylinder were later chemically analyzed in laboratory conditions. Due to the critical nature of the Sulfinert cylinder, the integrity of the vessel was tested by SGS Canada Inc. During this evaluative process the container was charged with various concentrations of H_2S standards and monitored over a two-week period. At the end of this period of time, the cylinder was certified not to absorb sulphur and to protect the integrity of the sample for 15 days.

Once the sampling apparatus was completed, i.e., designed and built, a risk assessment was performed. During this process the members of the project team met to discuss the various safety hazards that could be posed by either unsafe actions or unsafe conditions. As various hazards were discussed, solutions were brought forth in order to mitigate any potentially dangerous situation. These solutions were then implemented either by modifying the design of the sampling system or the standard operating procedure.

Sampling Probe and Connection to Flare Stack

Figure 4 is a schematic of the sampling probe inserted in the flare stack. The sampling probe was made from 6 mm ID stainless steel tubing with the tip machined to a knife edge. This probe tip design minimized the disruption to the flow of the solution gas stream. This tubing was inserted into a 47.6 mm aluminum sleeve which held both the sampling probe and the vein anemometer in the 50.8 mm ball valve. This ball valve was tied into the flare stack by welding a connection to the pipe. The installation of the ball valve was completed by the operator of the battery site.

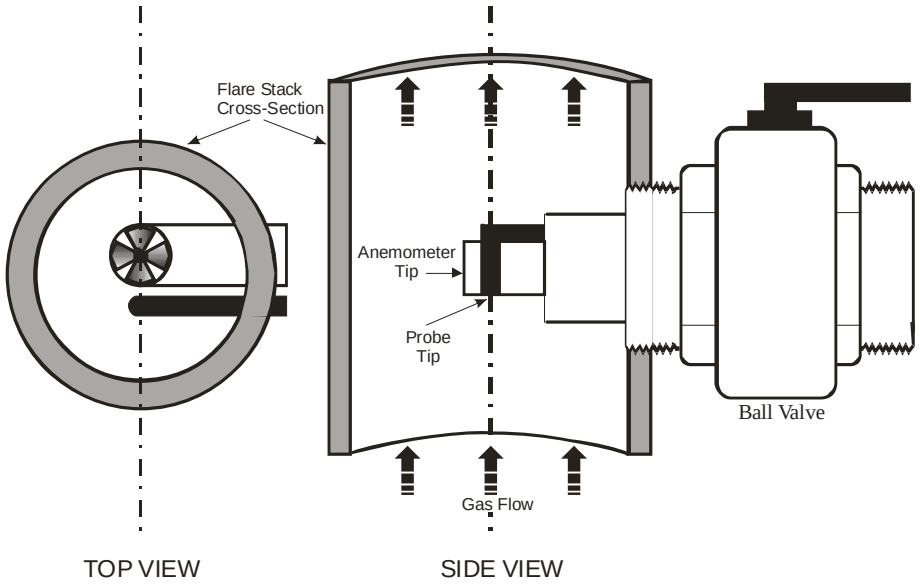


Figure 4: Sampling Probe Connection

Once the probe was in the flare-gas stream, the technician carefully positioned the probe tip in the centre of the pipe using measurements based on the outside diameter of the flare stack. This meant that both the sampling probe tip and the anemometer were essentially in the centre of the pipe. Another feature of the anemometer was that it had a thermocouple which also allowed the technician to monitor the gas temperature of the flare gas. This data could then be recorded by the technician using the data logger attached to the anemometer.

Prior to field tests, the system was fully evaluated in the laboratory and was shown to be able to collect gas and liquid phases for droplets as small as 0.3 micrometers.

Sampling Procedure

Before leaving for a field test, the sampling apparatus was cleaned and purged of any impurities. The glassware and the coalescer filter were cleaned with solvents and then dried. Once dry,

these components were then weighed using a micro-balance. These weights were then recorded in order to quantify any liquids captured during sampling. In addition, the 1000cc Sulfinert sampling cylinder was purged with helium gas and then pressurized to 207 kPa with helium (helium was used since it does not interfere with the subsequent gas chromatography). This helium, stored in the Sulfinert container, was later used to purge the system in the field prior to sampling.

In the field, before inserting the probe into the flare stack, the technician inspected the probe for any traces of liquid. This inspection was completed prior to each test. Once the sampling system was connected to the flare stack, the technician allowed the system to warm up using the internal heating system. The technician waited for the temperature of the sampling system to meet or exceed that of the flare gas. The higher temperature of the sampling system assured that no liquids would be collected due to condensation. Before any flare gas entered the sampling system, the sampling line was purged with helium gas stored in the Sulfinert cylinder. Once this purge had been completed, flare gas was allowed to flow through the system. At this point, the technician adjusted the gas flow rate of the sampling pump to match that of the flare gas. Up to this point, no flare gas had been collected. When the correct sampling rate had been attained, the following procedure was used: note time, record gas meter reading and temperatures (flare gas, liquid knock-out, sampling apparatus, and gas meter), open probe shut-off valve, turn pump on, verify sampling rate and make necessary changes with pump and flow restrictor, sample for 45 minutes. For each field test, four samples of approximately 45 minutes were taken (the actual duration of sampling depended on the flow rate of flare gas). The samples were then sent out for analysis.

5. Chemical Analysis of Collected Samples

Once the samples of gas and liquid were collected, they were sent immediately to an independent chemical analysis company for processing. For the gas phase, it was initially planned that a standard C10+ analysis would be sufficient to characterize the composition of this aspect of the flare stream. The test protocol used for this analysis was the 4502-SOP-1016 which is based on GPA 2261-00. This analysis detects and quantifies the following compounds: N_2, CO_2, C1, C2, C3, iC4, nC4, iC5, nC5, C6, C7, C8, C9, and C10+. Included with these results was the determination of other useful physical gas properties such as the gross or higher heating value (HHV), the net or lower heating value (LHV), the relative molecular mass, and the density. This test was used for all the sites tested and served as a baseline by which sites were compared.

For any liquids collected it was planned that a standard C30+ analysis would be performed using test protocol 4502-SOP-1017. Since no liquids were collected at any of the sites visited, this test was only applied to some condensate drained from the bottom of one of the flare stacks tested. These results were then compared to previous results[1] concerning the condensate from this same site as well as a generic "raw condensate" sample that was representative of the liquid found in the oil and gas industry.[2]

Once it became clear that having a liquid phase in the flare gas stream was not common, the analysis of the gas phase was enhanced to provide a greater discrimination between sites. This enhanced analysis was considered in order to identify any chemical species that might be

[1] In December 1999, the University of Alberta (Flare Research Project) visited this site. Liquid samples were taken from the liquid knock-out drum and then tested by a laboratory using a test similar to the C30+ analysis.
[2] To view this comparison, refer to the Field Test Report entitled "Site #5" and the graph entitled "HC (liquid) Comparison (by Boiling Pt)" found in the Appendix.

responsible for causing a flare to emit smoke. This more detailed hydrocarbon analysis was done according to test protocol 4502-SOP-1049 which is based on GPA 2261-00. This analysis tested for 439 compounds and separated the identified compounds into the more general categories of paraffins, isoparaffins, aromatics, napthenes, olefins, and oxygenates. This test could detect compounds to an accuracy of 1ppm.

6. Results and Discussion

A generic summary of the sites visited are provided in Table 1. Details that would allow the specific site to be identified have been removed from this report as part of our agreements with the battery operators in gaining access to their sites. In total, seven battery sites were tested as part of this research. Since there was no control over the site's operating or ambient conditions, it should be pointed out that the temperature varied from -7 to 30^{O}C, the wind speed varied from 0 to 7.2 m/s, the flare stream velocity varied from 0.3 to 7.1 m/s and the LHV (a gross indicator of chemical composition varied from 35.9 to 47.0 MJ/kg.

Table 1: Compilation of Test Conditions

			Flare Gas		Ambient Conditions (Ave)	
Test	Area	Stack Diameter	Velocity	LHV	Crosswind	Temperature
		mm	m/s	MJ/kg	km/h	^{o}C
1	Fort Saskatchewan	88.9	0.3	46.2	10.0	-3.0
2	Lamont	73.0	7.1	42.6	18.5	14.6
3	Camrose	168.3	2.5	37.4	20.0	25.5
4	Grande Prairie	114.3	4.2	47.0	18.6	26.1
5	Edmonton	114.3	1.5	35.9	13.8	13.3
6	Edson	88.9	4.1	46.6	15.6	12.5
7	Grande Prairie	114.3	5.8	42.3	24.0	3.6

A detailed reporting of the battery sites tested and the results of the chemical analysis is provided in the attached appendix. These reports contain a great deal of detail and therefore a collection

of brief site-by-site synopsis of these comprehensive reports is provided below. The synopses contain the highlights of the each site visit. Following these synopses, the data is reviewed in the context of all the sites visited to draw conclusions about what can be expected at battery sites in the Western Canadian Sedimentary Basin.

Site #1:

The first test site visited was a single well battery with a 400 barrel stock tank. There was no liquid separator system in place and there was no visible smoke being emitted from the flare. The flow rate at this site was very low. No liquids were collected. When the sampling probe was removed from the flare stack it was dry and showed no signs of being exposed to any liquids. Analysis of the gas phase showed that 97% of the volume being flare was propane. The reason for this result was a plumbing and operational problem at the site which led to propane, which was normally intended as pilot fuel for the flare, to flow back into the stock tank and then later to the flare. The battery operators used this information to correct problems at the site. This site was not retested because the flow rate of the flare stream was considered too low.

Site #2:

The second site tested was an 18 well battery with a high flare stream flow rate such that the sample was drawn at a 5.5 m/s. There were also large fluctuations in the flare stream flow rate. There was a liquid knock-out system in place that the operators stated was emptied twice a year. The flare stream at this site was not flared, but was processed by one of two incinerators. Since there was no flare stack, the sample was drawn from a horizontal section of pipe leading to the incinerators. There was no visible smoke being emitted from the combustion system. No liquids

were collected and the probe was dry when removed. Analysis of the gas phase showed that the flare stream contained 93% methane.

Site #3:

The third site visited was a seven well battery that was equipped with a single buried knock-out drum that was reported to be emptied twice a year. This was the same site that the Alberta Research Council used as part of the testing of a DIAL system to measure flare efficiency. No liquids were collected at this site and the probe was dry when removed from the flare stack. Analysis of the gas phase showed that this site was sour (1.15% H_2S), contained a large concentration of CO_2 (13%), methane was present at 61% and there was relative high concentrations of C2 and C3 hydrocarbons (17%). This site was revisited later with an additional test applied to look for liquids in the flare stream. In these tests a material known as "Pig Mat" was held in the flare stream and inspected later. Pig Mat is a cloth that is especially adsorbent to oils and provided a visual confirmation that no liquids were in the flare stream.

Site #4:

The forth site visited was a single well battery and the first of the smoking flares tested. The battery site had a liquid knock-out system, but it had not needed to be emptied in the previous four years. Access to the flare stream was provided by the operators in a section of the pipe at a 45^o angle. No liquids were collected at this site and the probe was dry after the test. A detailed chemical analysis was conducted on the gas phase sample collected and showed relatively high concentrations of C2 and C3 hydrocarbons (17%). The overwhelming portion of hydrocarbons in the flare stream was paraffins and iso-parafinns (99.3%). There were only trace

concentrations of aromatics, napthenes, olefins and oxygenates, so it is not possible to attribute the appearance of smoke to any particular fuel component.

Site #5:

The fifth site tested had a reputation as a battery that handled relatively large amounts of liquids. The operator reported needing to empty approximately 20 liters of liquid from the base of the flare stack monthly. The origins of these liquids were not known to be either part of a continuous accumulation at a slow rate or a relatively few number of events over the month where larger quantities of liquid made their way to the flare. During the sampling no liquids were collected and the probe was dry on removal. The gas phase was analyzed and it was notable that there were relatively high concentrations of CO_2 (13.1%), as well as components in the C7-C9 range of hydrocarbons (1.5%). There was no smoke being emitted from this flare. Some of the liquid was extracted from the base of the flare stack and sent for analysis. It should be emphasized that this liquid was not part of the flare stream that went up the flare stack and participated in combustion. The details of this analysis are provided in the appendix along with an analysis of liquid extracted from this knockout drum in 1999. These results showed that the liquids collected at the base of the stack are consistent with typical liquid condensate found in the upstream oil and gas industry.

Site #6:

The sixth site was a single well battery that was emitting smoke from the flare. The sampling port provided by the operators was on a horizontal section of pipe leading to the flare. In this case, 99.7% of the hydrocarbons in the flare stream were paraffins and iso-parafinns. There were

only trace concentrations of aromatics, napthenes, olefins and oxygenates, so it is not possible to attribute the appearance of smoke to any particular fuel component. No liquids were collected and the probe was dry after the test.

Site #7:

The seventh site was a single well battery and the flare was emitting smoke. No liquids were collected and the probe was dry on removal. Pig Mat inserted into the flare stream was used as a visual confirmation that there were no liquids present. An analysis of the gas phase showed 10% N_2 in the flare stream with high concentrations of C2 and C3 hydrocarbons (28%). In this case, 99.8% of the hydrocarbons in the flare stream were paraffins and iso-paraffins. There were only trace concentrations of aromatics, napthenes, olefins and oxygenates, so it is not possible to attribute the appearance of smoke to any particular fuel component.

Two important results arise from the seven sites tested. The first is the observation that the occurrence of liquids in the flare stream does not appear to be as common as previously assumed. The second point is that relatively minor variations in the composition of the gas being flared and the operating conditions resulted in either smoking or non-smoking flares.

In total seven sites were tested through iso-kinetic sampling of the solution gas just prior to combustion and no liquids were collected. The system employed for this sampling was tested in laboratory simulations before going to the field situation and had no difficulty in collecting droplets as small as 0.3 micrometers. This may appear to be a negative result since one of the

objectives of this research was to characterize the composition of the liquid phase being flared. However, finding no sites with liquids challenges some basic working assumptions about solution gas flare sites. Essentially, it appears that having liquids in the flare stream is a relatively rare occurrence as opposed to being relatively common. This conclusion is based on a statistical argument because only seven of a few thousand possible sites were examined. If the occurrence of liquids were considered to exist 50% of the time then it is possible to calculate the likelihood of going to seven sites chosen randomly and finding no liquids. For that situation, it was a 1 in 128 chance that the research would visit only liquid-free sites. (If one believed that liquids existed at 90% of the sites then the choosing of seven liquid-free sites would be a 1 in ten million chance.) Another way of stating the likelihood of visiting seven liquid-free sites was a 50% chance only if 91% of the solution gas sites were liquid-free. It is impossible to comment on the question if the sites were, in fact, not random relative to liquid content or the issue of a systematic bias created through the action of the site operators prior to or during our sampling.

The chemical analyses at sites 2 through 7 (site 1 being essentially propane) showed a wide variation in the volume fractions of C1 through C9 and the amounts of inert compounds. For example, the amount of methane varied from 56 to 93% and CO_2 varied from 0.4 to 13.3%. The detailed chemical analyses conducted on the gas phase showed that between 99.3 and 99.8% of the hydrocarbon fuels in the flare stream were paraffins or iso- paraffins. Hence, there was only very small amount of more complex fuel molecules in the flare stream so no credible correlation could be made to the appearance of smoke and the fuel composition or any other measured operating parameter.

7. Conclusions

Seven battery sites located in North and Central Alberta were sampled in both summer and winter conditions for the relative masses and compositional variations in their liquid and gas phases. As part of this research a sampling apparatus and a procedure were developed to collect both the liquid and gas phases of the flare stream. These samples were drawn at the base of the flare stacks so that they would be representative of the materials being flared. No liquids were found at any of the sites tested and this negative result leads to the statistical argument that flare streams containing liquids are far less likely to exist than previously assumed. No correlation was found between smoke emissions from the flare and the compositional variations of the flare stream. Based on these results, the recommendations are not to embark on the second phase of field sampling research or to modify the previous model for predicting the combustion efficiency of flares in a crosswind.

APPENDIX A

Detailed Field Test Reports

FIELD TEST REPORT
SITE #1

PTAC Project - Solution Gas And Knockout Liquids Characterization

Site / Operator:	Personnel:	Test Date:	Lab Report Number:
XXX	Kevin Morphy, Pascal Poudenx	March 14, 2003	S-2048-UA03/18/03

EXECUTIVE SUMMARY

LIQUID PHASE IN GAS STREAM	N/A	g. / litre of gas

LIQUID PHASE COMPOSITION
N/A

GAS PHASE COMPOSITION (%)											
N2	CO2	H2S	C1	C2	**C3**	iC4	nC4	iC5	nC5	C6	C7+
0.03	0.04	0	0.02	1.49	**96.75**	0.69	0.05	0.03	0.03	0.12	0.75

- First field test ever.
- 65 litres of gas sampled in 2 hours.
- No liquid collected. The probe came out dry.
- Sample composed mostly of propane.
- Explanations: the propane came from the pilot light gas reserve most likely because the oil pump head was not working properly so no oil came up the well and no gas was sent to the flare. Therefore, the flare line and probably the stock tank were full of the pilot light propane during the sampling period.
- The well pump needs repairs before a new test is attempted.

SITE INFORMATION

OVERVIEW


OPERATOR: XXX LOCATION: XXX

DIRECTION: XXX

CONTACT: XXX

PRODUCTION RATE (EUB Data)	122	m^3 /day

EQUIPMENT: - 1 Pump jack
- 1 400 bbl. Stock Tank approximately 50% full
- No Liquid separator or knock out drum.

FLARE		GAS STREAM		
1	3 " Diameter, Portable	Velocity	< 0.3	m/s

REMARKS:

The flame was short (1-2 ft) and no smoke was visible.
XXX told us the oil pump head was not working properly and the volume of oil brought up was much lower than usual. They put chemical down the well the day before in an attempt to increase the flow but it did not succeed. The flare was shut down the day before the test to install the access port on the stack and again in the morning to install the valve on the access port.

TEST CONDITIONS

OPERATORS: - Kevin Morphy (SGS) (780) 416-5188 kevin.morphy@sgs.com
- Pascal Poudenx (U of A) (780) 492-7210 poudenx@ualberta.ca

4 samples taken over 2 hours at the base of the flare stack.

PROBE	5/16" O.D. 0.035" wall Th.

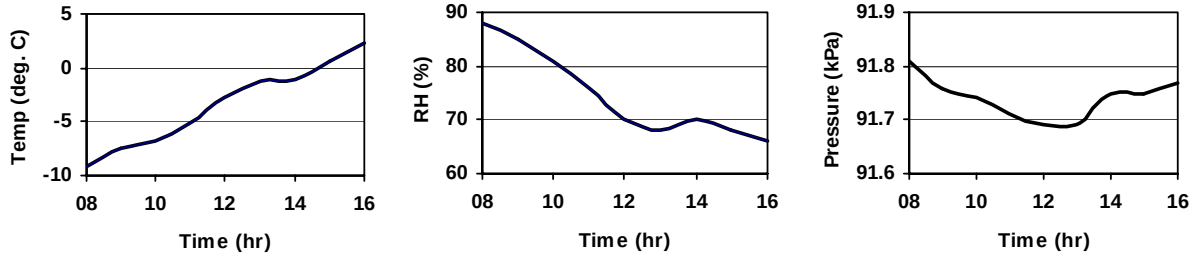
VOLUME SAMPLED*	65 litres

* Corrected at 101.3kPa & 15º C

SAMPLING RATE	0.56 l/min

Corresponding VELOCITY	0.32 m/s

WEATHER: Clear sky, light wind (<13 km/h) from North-North-West.



Source: Environment Canada, Data for XXX.

PORT DETAILS:

The probe is inserted in the gas stream at the base of the flare stack after the flame arrestor.

The valve was a 2" gate valve with 2" NPT thread.

Our sleeve was threaded on the valve and the probe inserted in the sleeve.

The sealing between the sleeve and the probe is done with two O-rings.

ACCESS PORT AND PROBE OVERVIEW

SAMPLING DETAILS:

TIME	ACTION	GAS METER (litre)	SAMPLING RATE (l/min)	CYLINDER PRESSURE
12:00	Start Test	2832.44		20" Hg
12:30	Sample #1	2847.1	0.49	up to 10" Hg
13:00	Sample #2	2858.37	0.38	up to 0" Hg
13:30	Sample #3	2879.39	0.70	up to 10 psi
14:00	Sample #4 + End Test	2900.01	0.69	up to 17 psi

TEMPERATURES:

TIME	SOURCE	GAS METER	LIQUID KNOCK/OUT	SAMPLING APPARATUS
12:00	6.6	17	14.6	26.4
14:00	12	27		37

LIQUID PHASE:

COMPONENT	START MASS (g)	END MASS (g)	MASS DIFF. (g)
Knock/out bottle	78.9094	78.9094	0
Coalescer bottle	64.2608	64.2608	0
Coalescer filter	154.13	154.1801	0.0501

Total Mass Collected:	0.0501 g

Note: the liquid collected was a contamination from a previous test done in the lab with Diesel and not actual liquid coming from the flare stream. The probe came out completely dry after two hours inside the stack.

A NALYSIS & RESULTS

The gas analysis was performed in the SGS lab in Point Tupper, Nova Scotia on 5 days after the sample.

See Gas Analysis report for details

PROBLEMS ENCOUNTERED & ACTIONS TAKEN

Several problems have been encountered during this first field test:

	PROBLEM	ACTION
MAJOR ISSUES	Generator key forgotten	Include key check in pre-test checklist
	Gas leak through the anemometer	Sealing plug installed
	Anemometer output at 0 when probe inside the stack	Investigation showed that reading goes to 0 when velocity < 0.3 m/s
SECONDARY ISSUES	Bent door hook	Frame leg shorten
	Improper sitting of the frame on top of the box.	Moved door hook and cut top of access panel
	Difficulty to remove ground rod	Modify ground rod
	Plugged exhaust	Made a stand for exhaust

FUTURE ACTIONS

- No future test on this site because of the low flow rate and absence of liquid.
- Meanwhile other sites are considered as potential test site.

FIELD TEST REPORT
SITE #2

PTAC Project - Solution Gas And Knockout Liquids Characterization

Site / Operator:	Personnel:	Test Date:	Lab Report Number:
XXX	Kevin Morphy, Pascal Poudenx	May 21, 2003	S-2048-UA05/21/03

EXECUTIVE SUMMARY

LIQUID PHASE IN GAS STREAM	N/A	g. / litre of gas

LIQUID PHASE COMPOSITION
N/A

GAS PHASE COMPOSITION (%)											
N2	CO2	H2S	**C1**	C2	C3	iC4	nC4	iC5	nC5	C6	C7+
1.03	5.28	0	**92.99**	0.3	0.06	0.07	0.06	0.02	0.02	0.03	0.14

- Sample taken downstream of liquid knock-out.
- 966.3 litres of gas sampled in 2 hours.
- No liquid collected. The probe came out dry.
- Fluctuating flow rate (from 1.7 to 17 m/s)
- Average flow rate above pump capabilities. Sampling done at 5.5 m/s
- No future tests scheduled for this location.

SITE INFORMATION

OVERVIEW


OPERATOR: XXX LOCATION: XXX

DIRECTION: XXX

CONTACTS: XXX

PRODUCTION RATE (EUB Data)	N / A	m^3 /day

EQUIPMENT:
- 18 wells
- 6 400 bbl. Stock Tank (3 for oil and 3 for water)
- 2 Treaters
- 1 Knock out drum (emptied twice a year)
- 2 Incinerators (1 small temporary one)

REMARKS:

The most part of the flow was sent to the main incinerator with approx. a 1/3 of the flow directed to the second incinerator.
Our access port was installed on the temporary line between the main line going to the main incinerator and the second incinerator.

TEST CONDITIONS

TECHNICIANS: - Kevin Morphy (SGS) (780) 416-5188 kevin.morphy@sgs.com
- Pascal Poudenx (U of A) (780) 492-7210 poudenx@ualberta.ca

4 samples taken over 2 hours.

PROBE	5/16" O.D. 0.035" wall Th.

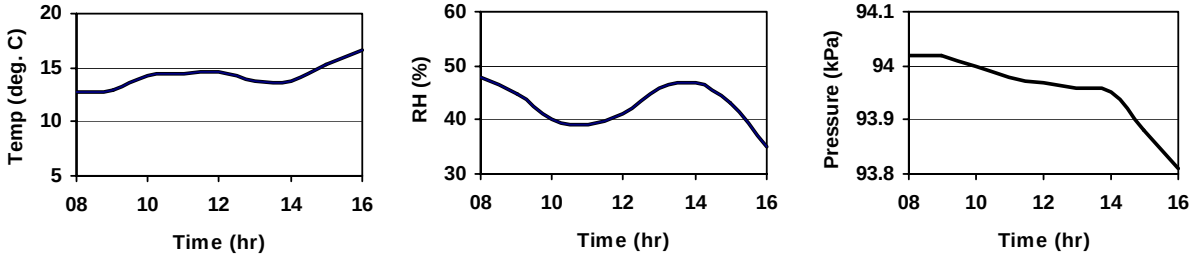
VOLUME SAMPLED*	966.3 litres

* Corrected at 101.3kPa & 15º C

SAMPLING RATE	8.45 l/min

Corresponding VELOCITY	4.73 m/s

WEATHER: Light scattered shower, moderate wind (17-20 km/h) from North-West.



Source: Environment Canada, Data for XXX Station.

PORT DETAILS:

The probe was inserted in a 2" horizontal line.

The valve was a 2" ball valve with 2" NPT thread.

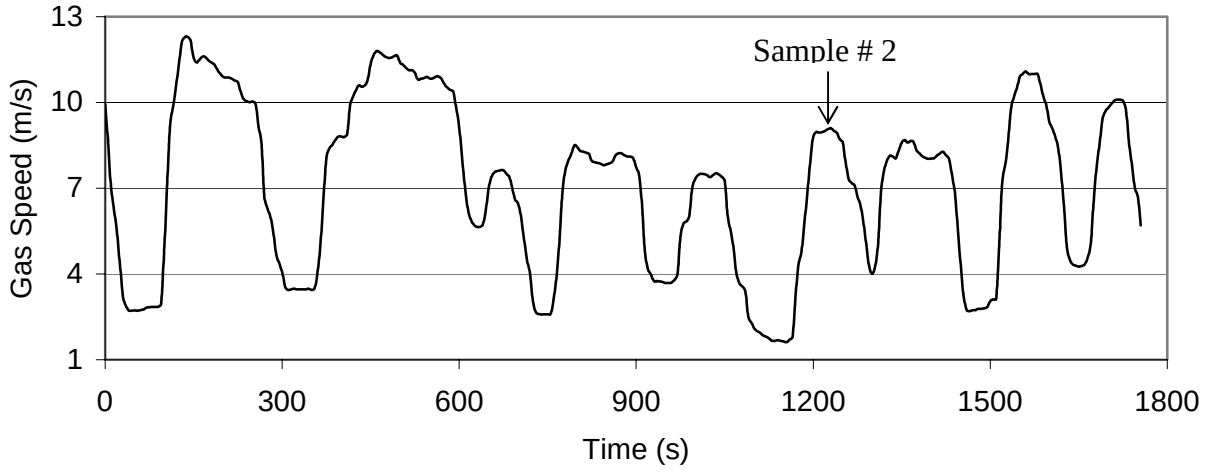
Our sleeve was threaded on the valve and the probe inserted in the sleeve.

The sealing between the sleeve and the probe is done with two O-rings.

ACCESS PORT AND PROBE OVERVIEW

FLOW VELOCITY:

The gas stream velocity was continuously fluctuating between 2 and 12 m/s with spikes as low as 1.7 m/s and as high as 17 m/s.
The average flow velocity was estimated around 7.1 m/s but the maximum sampling velocity was 5.5 m/s.
The following figure shows an example of flow velocity as measured during the sampling. Data logging was done every 5 seconds by hand.



SAMPLING DETAILS:

TIME	ACTION	GAS METER (litre)	SAMPLING RATE (l/min)	CYLINDER PRESSURE
12:05	Start Test	3102.95		20" Hg
12:40	Sample #1	3494.0	11.17	up to 10" Hg
13:05	Sample #2	3600.0	4.24	up to 0" Hg
13:35	Sample #3	3849.0	8.30	up to 10 psi
14:05	Sample #4 + End Test	4116.67	8.92	up to 17 psi

TEMPERATURES: All in Deg. C

TIME	SOURCE	GAS METER	LIQUID KNOCK/OUT	SAMPLING APPARATUS
12:00	22.8	27	26.4	30.4
14:00	24.4	33.5	33.5	37

LIQUID PHASE:

No liquid was collected.
Note: Water dripped out of the valve when the probe was pulled out. Since the valve was horizontal, the water collected at the bottom. We suspect the water was there before the probe was inserted.

ANALYSIS & RESULTS

The gas analysis was performed in the SGS lab in Point Tupper, Nova Scotia on 5 days after the sample.

See Gas Analysis report for details.

PROBLEM ENCOUNTERED & ACTION TAKEN

Several problems have been encountered during this second field test:

	PROBLEM	ACTION
MAJOR ISSUES	Back pressure in exhaust line (1.5 PSI)	Replace 1/4" line with garden hose
	Limited flow rate.	Make sure flow rate of future tests are within specs
	Concern of the operator regarding the way the probe is secured	Replace sleeve with a compression fitting

FUTURE ACTIONS

- No future test on this site because of the absence of water.
- Meanwhile other sites are considered as potential test site.

FIELD TEST REPORT
SITE #3

PTAC Project - Solution Gas And Knockout Liquids Characterization

Site / Operator:	Personnel:	Test Date:	Lab Report Number:
XXX	Kevin Morphy, Pascal Poudenx	June 18, 2003	S-2048-UA 06/18/03

EXECUTIVE SUMMARY

LIQUID PHASE IN GAS STREAM	N/A	g. / litre of gas

LIQUID PHASE COMPOSITION
N/A

GAS PHASE COMPOSITION (%) (Air Free)											
N2	CO2	H2S	**C1**	C2	C3	iC4	nC4	iC5	nC5	C6	C7+
0	13.29	1.15	**60.67**	10.19	7.25	1.34	3.01	0.82	0.78	0.45	0.88

- First test performed on a sour site (1% H_2S).
- Test performed while ARC was testing DIAL laser technique. We provided flow rate information to the laser team.
- 667.2 litres of gas sampled in 2 hours 25 minutes through a 6" vertical pipe leading to the flare stack. Sampling done at an average of 4.86 l/min (2.7 m/s). Flow rate: 2.2 to 2.7 m/s, average @ 2.46 m/s.
- No liquid collected. The probe came out dry.
- Large amount of air in the sample (50-60%). Sampling system tests did not show any leakage. Issue under investigation at the site.
- Test was normalized by numerically removing the air from the test sample.
- No future tests at this location.

SITE INFORMATION

OVERVIEW


OPERATOR: XXX LOCATION: XXX

DIRECTION: XXX

CONTACTS: XXX

PRODUCTION RATE (EUB Data)	1,500	m^3 /day

EQUIPMENT:
- 7 wells
- 1 Treater (current oil production: 12 m3/day, 250 m3/day of water)
- 1 underground knock out drum (emptied once a year, approx 2 m^3 removed)
- 1 Flare stack, 6" diameter

REMARKS:

This is a very old site with a very low production rate.
All the solution gas is flared through a 6" stack.
The access port was installed on the vertical line downstream of the underground knock-out drum.

Sour site. Kevin measured 1.15 % H_2S

TEST CONDITIONS

TECHNICIANS: - Kevin Morphy (SGS) (780) 416-5188 kevin.morphy@sgs.com
- Pascal Poudenx (U of A) (780) 492-7210 poudenx@ualberta.ca

4 samples taken over 2 hours 25 minutes.

PROBE	5/16" O.D. 0.035" wall Th.

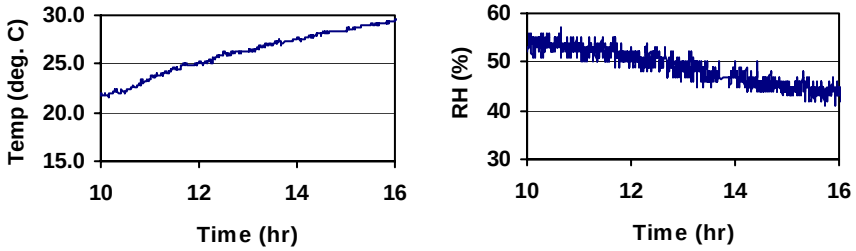
VOLUME SAMPLED*	667.2 litres

* Corrected at 101.3kPa & 15º C

SAMPLING RATE	4.86 l/min

Corresponding VELOCITY	2.4 m/s

WEATHER: sunny and hot, strong wind (>20 km/h).



Weather data provided by the DIAL Laser team on site weather station

PORT DETAILS:

The probe was inserted in a 6" vertical line.

The valve was a 2 1/2" ball valve with 2" NPT thread reducing bushing.

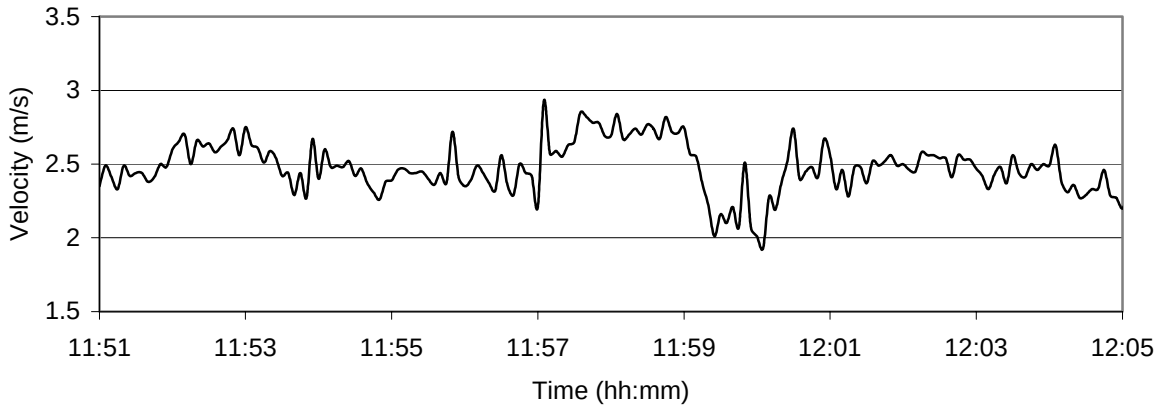
The probe was inserted in our 2" sleeve threaded onto the reducing bushing.

Probe-Sleeve sealing was ensured with 2 O-rings.

ACCESS PORT AND PROBE OVERVIEW

FLOW VELOCITY:

The gas stream velocity was fluctuating between 2.2 and 2.7 m/s.
The average flow velocity was estimated around 2.46 m/s.
The following figure shows an example of flow velocity as measured during the sampling. Data were saved on the data logger every 5 seconds



SAMPLING DETAILS:

TIME	ACTION	GAS METER (litre)	SAMPLING RATE (l/min)	CYLINDER PRESSURE
10:35	Start Test	4255		20" Hg
11:05	Sample #1	4470	7.17	up to 10" Hg
11:35	Sample #2	4595	4.17	up to 0" Hg
12:07	Sample #3	4710	3.59	up to 10 psi
13:00	Sample #4 + End Test	4959	4.70	up to 17 psi

Average Sampling rate: 4.86 l/min (2.7 m/s)

TEMPERATURES: All in Deg. C

TIME	SOURCE	GAS METER	LIQUID KNOCK/OUT	SAMPLING APPARATUS
12:00	24	24	29	24
14:00		34	35.8	36.2

Average Temperature: 29 Deg. C

The temperature sensor on the anemometer did not work. The source temperature was estimated based on the pipe temperature and the gas meter temperature.

LIQUID PHASE:

No liquid was collected.

ANALYSIS & RESULTS

The gas analysis was performed in the SGS lab in Point Tupper, Nova Scotia on 5 days after the sample.

See Gas Analysis report for details.

PROBLEM ENCOUNTERED & ACTION TAKEN

Few problems have been encountered during this third field test:

	PROBLEM	ACTION
	Sample contained 50-60% Air	Problem under investigation *
ON SITE ISSUES	No temperature reading from anemometer	Anemometer Sent back to Omega
	No stop watch	Add stop watch to check list
	Small leak from the acetone bottle	Replace cleaning fluid bottles

* XXX, from XXX was contacted and asked to see if there would be an explanation on site for such a large amount of air in the stream.
Kevin said he had seen streams containing air due to leakage from the vapour recovery system but never in such large quantity.
The pump of the sampling device was disassembled and the diaphragm inspected by Pascal. No crack was found.
The sampling line was tested under 20" Hg vacuum from the probe to the pump by Larry and Pascal. No leak was found. The line between the pump and the vessel is under positive pressure and therefore could not have been a location for air contamination.

FUTURE ACTIONS

- Understand reason of air contamination.
- No future test on this site because of the absence of water.
- Meanwhile other sites are considered as potential test site.

FIELD TEST REPORT
SITE #4

PTAC Project - Solution Gas And Knockout Liquids Characterization

Site / Operator:	Field Personnel:	Test Date:	SGS Lab Report Number:
XXX	Kevin Morphy	July 30, 2003	S-2048-UA 07/30/03

EXECUTIVE SUMMARY

LIQUID PHASE IN GAS STREAM	N/A	g. / litre of gas

LIQUID PHASE COMPOSITION
N/A

Gas Phase Composition (Air Free)

Comp.	H2S	N2	CO2	C1	C2	C3	iC4	nC4	iC5	nC5	C6	C7	C8	C9	C10+		Total
%	-	0.87	1.06	**74.29**	9.90	7.38	1.02	2.68	0.65	0.85	0.62	0.46	0.15	0.05	0.02		100.00

Peak Codes
P-Paraffins
I-Isoparaffins
A-Aromatics
N-Napthenes
O-Olefins

Detailed Hydrocarbon Analysis

Compound	Mole Fraction	Peak Type
C11-Aromatic	0.000002	A
C11-Aromatic	0.000063	A
sec-Butylcyclohexane	0.000012	N
1-Ethyl-2-isopropylbenzene	0.000002	A
C11-Isoparaffin	0.000120	I
2,3-Dimethylheptane	0.000027	I
2-Methyloctane	0.000029	I
3-Methyloctane	0.000041	I
o-Xylene	0.000039	A
n-Nonane	0.000063	P
n-Octane	0.000170	P
2,6-Dimethylheptane	0.000089	I
C9-Olefin	0.000049	O

2,5&3,5-Dimethylheptane	0.000025	I
Ethylbenzene	0.000078	A
m-Xylene	0.000060	A
t,c-1,2,4-TMcyclopentane	0.000049	N
t,c-1,2,3-TMcyclopentane	0.000057	N
Toluene	0.000300	A
2-Methyl-Heptane	0.000096	I
4-Methyl-Heptane	0.000024	I
trans-1,4-Dimethylcyclohexane	0.000047	N
3-Methylheptane	0.000053	I
3-Ethylhexane	0.000008	I
C8-Diolefin	0.000031	O
C8-Olefin	0.000012	O
2,2,5-Trimethylhexane	0.000014	I
trans-1-Ethyl-3-methyl-cyclopentane	0.000015	N
trans-1-Ethyl-2-methyl-cyclopentane	0.000024	N
C8-Olefins	0.000020	O
2-Methylhexane	0.000325	I
2,3-Dimethylpentane	0.000065	I
3-Methylhexane	0.000307	I
trans-1,3-Dmcyclopentane	0.000162	N
cis,1-3,Dmcyclopentane	0.000140	N
trans,1-2-Dmcyclopentane	0.000297	N
n-Heptane	0.000614	P
Methylcyclohexane	0.000397	N
1,1,3-Trimethylcyclopentane	0.000045	N
Ethylcyclopentane	0.000070	N
2,5-Dimethylhexane + C8-Olefin	0.000039	I
2,4-Dimethylhexane	0.000029	I
3-Methylpentane	0.000922	I
n-Hexane	0.002470	P
Methylcyclopentane	0.001107	N
2,4-Dimethylpentane	0.000059	I
Benzene	0.000822	A
Cyclohexane	0.000702	N
Methane	0.742900	P
Ethane	0.099000	P
Propane	0.073800	P
Isobutane	0.010200	I
n-Butane	0.026800	P
Isopentane	0.006500	I
n-Pentane	0.008500	P
2,2-Dimethylbutane	0.000053	I
Cyclopentane	0.000818	N
2,3-Dimethylbutane	0.000173	I
2-Methylpentane	0.001764	I
Total	0.980699	

Peak Codes
P-Paraffins
I-Isoparaffins
A-Aromatics
N-Napthenes
O-Olefins
X-Oxygenates

Group Summary	
Group	**Mole Frac.**
Aromatics	0.0014
Olefins	0.0001
Paraffins	0.9543
Oxygenates	0.0000
Isoparaffins	0.0210
Napthenes	0.0039
Total**	**0.9807**

**Bal. is N2 and CO2

Notes on Site:

- First sample from a smokey flare. Kevin noted that the flare was smoking continuously during the entire test.
- Detailed hydrocarbon analysis completed for smokey flare.
- This is a single well battery site.
- No liquid collected. Flare KO hasn't been emptied in 4 years.
- 1631.2 litres of gas sampled in 3 hours 51 minutes through a 3" 45^{o}-pipe leading to the flare stack. Sampling done at an average of 7.45 l/min (4.15 m/s). Flow rate: 3.9 to 4.1 m/s.

SITE INFORMATION

OVERVIEW

OPERATOR: XXX LOCATION: XXX

LOCATION: XXX

CONTACTS: XXX

PRODUCTION RATE (EUB Data; 10^3 m^3 /month)	30.8	May 2003

EQUIPMENT: - 1 Well
- 1 Treater (oil/gas separation with “pop” tank)
- 1 Knock-out drum (not emptied in 4 years)
- 1 Flare stack, 4" diameter

REMARKS:

This site was located by XXX of XXX as a smokey flare.
All the solution gas is flared through a 4" stack (see Kevin’s report for schematic).
The access port was installed on a 45^o-line between the knock-out drum and the flare stack.
The gas flared at this site is sweet.

TEST CONDITIONS

TECHNICIAN: - Kevin Morphy (SGS) (780) 416-5188 kevin.morphy@sgs.com

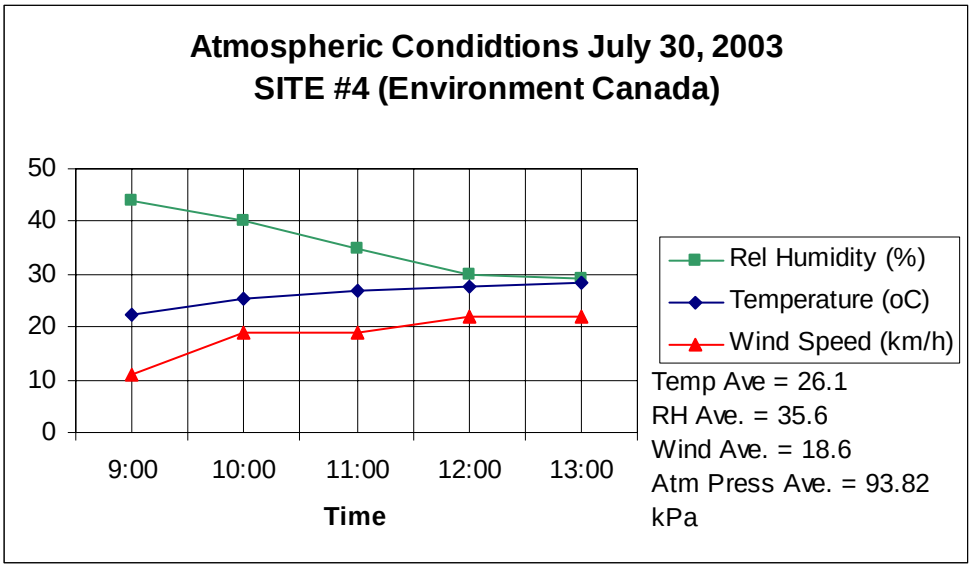
4 samples taken over 3 hours 51 minutes.

PROBE	5/16" O.D. 0.035" wall Th.	VOLUME SAMPLED*	1631.2 litres

* Corrected at 101.3kPa & 15º C

SAMPLING RATE	7.45 l/min (4.15 m/s)	FLARE GAS VELOCITY	3.9-4.1 m/s

WEATHER: sunny and hot (26.1°C), wind (~ 19 km/h): data from Environment Canada (http://www.climate.weatheroffice.ec.gc.ca/advanceSearch/searchHistoricDataStations_e.html).



PORT DETAILS:

The probe was inserted in a 3" 45°- line, which led to the 4" flare stack.

The valve was a 2 1/2" ball valve with 2" NPT thread reducing bushing.

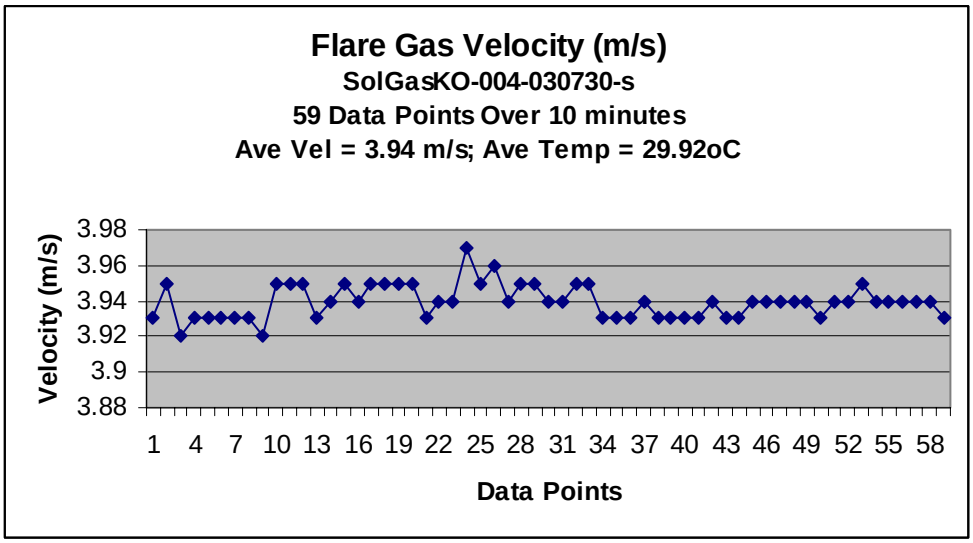
The probe was inserted in our 2" sleeve threaded onto the reducing bushing.

Probe-Sleeve sealing was ensured with 2 O-rings.

ACCESS PORT AND PROBE OVERVIEW

FLOW VELOCITY:

The gas stream velocity was steady throughout the test at 3.9 - 4.1 m/s.
The average sampling flow velocity was estimated around 4.15 m/s.
The following figure shows an example of flow velocity as measured during sampling. Data were saved on the data logger every 10 seconds for 10 minutes for a total of 59 data points.



SAMPLING DETAILS:

TIME (end)	Subsample	GAS METER (litre)	SAMPLING RATE (l/min)	Sample Duration (min.)
10:12	#1	5818	5.73	58
11:08	#2	6266	8.00	56
12:10	#3	6884	9.97	62
13:05	#4	7206.62	5.87	55

Average Sampling rate: 7.45 l/min (4.15 m/s)

TEMPERATURES (start and end times): All in Deg. C

TIME	SOURCE	GAS METER	LIQUID KNOCK/OUT	SAMPLING APPARATUS
09:14	22.8	20.0	30.7	24.1
13:05	30.8	38.0	39.40	40.2

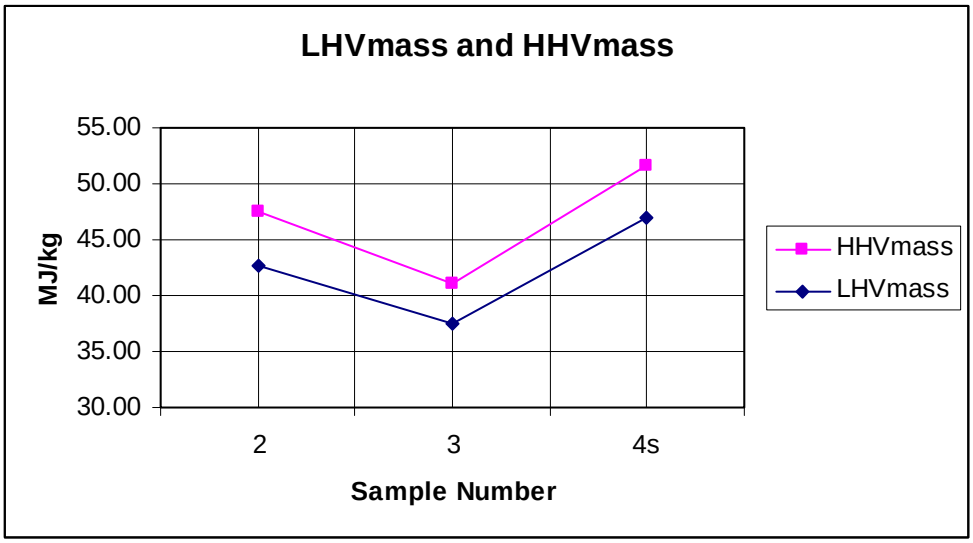
Average Gas Meter Temperature: 29 Deg. C

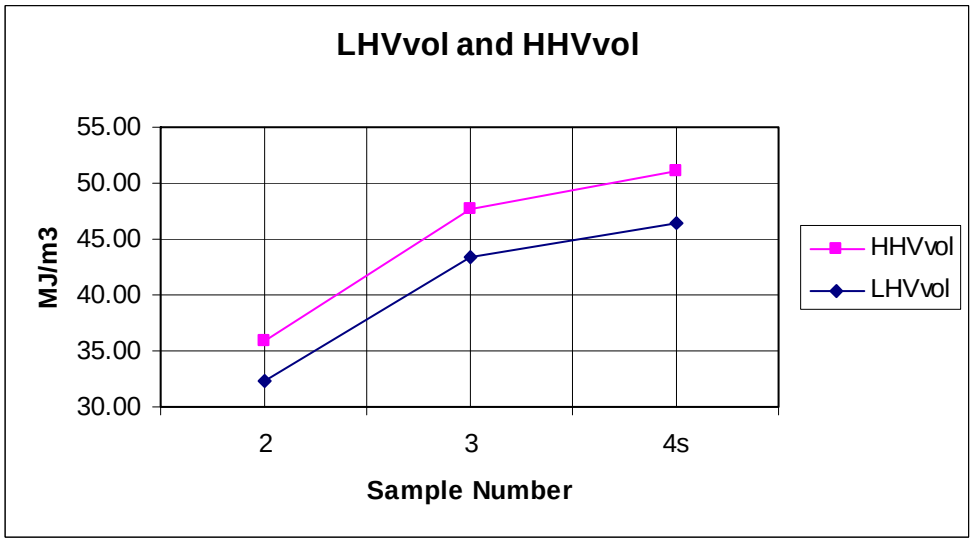
LIQUID PHASE:

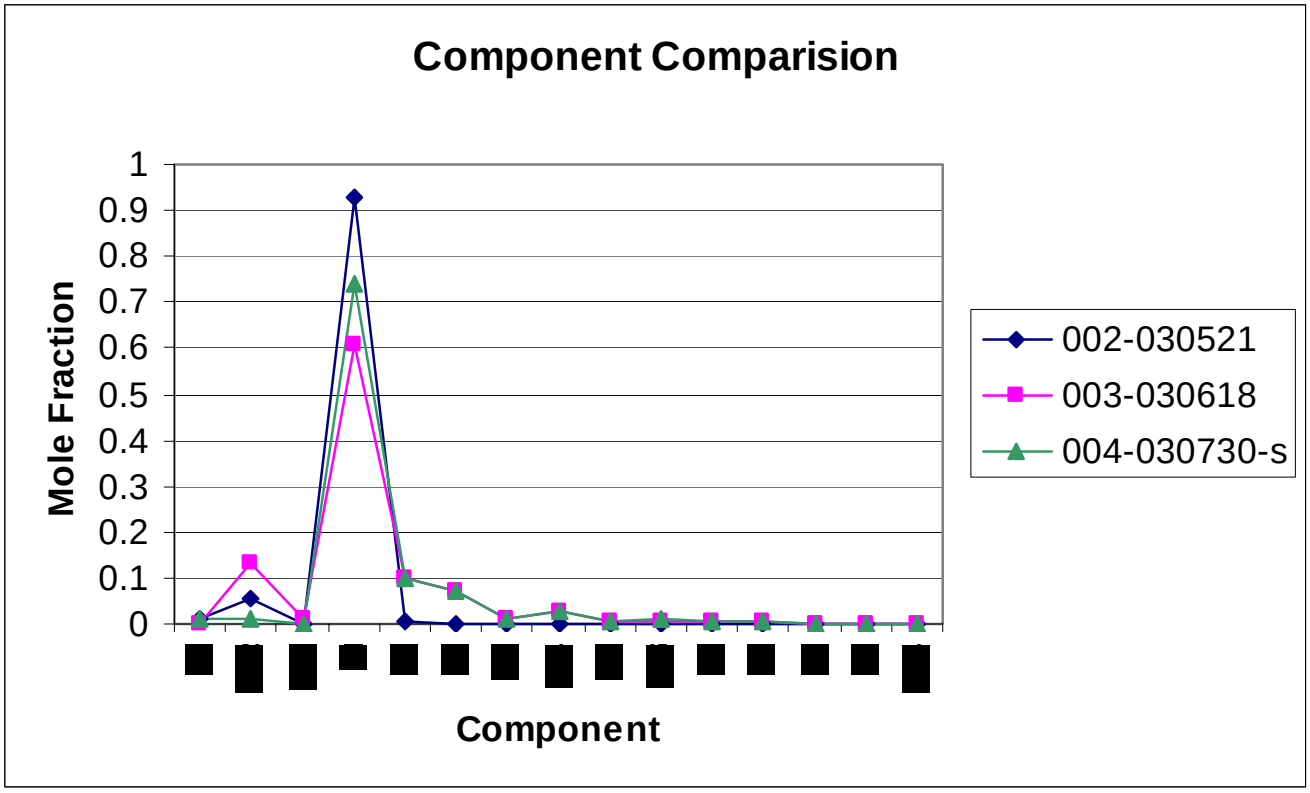
No liquid was collected.

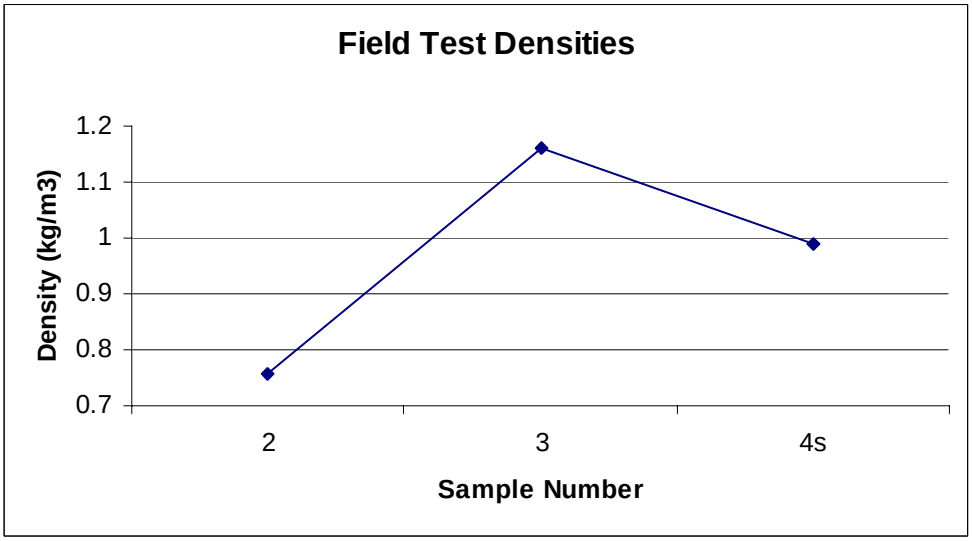
COMPARISON OF BATTERY SITE RESULTS

These graphs compare various results between battery sites.






Component Comparision
Mole Fraction
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Component
002-030521
003-030618
004-030730-s


Field Test Densities
Density (kg/m3)
1.2
1.1
1
0.9
0.8
0.7
2
3
4s
Sample Number

ANALYSIS & RESULTS

The gas analysis was performed in the SGS lab in Point Tupper, Nova Scotia 4 days after the sample.

See Gas Analysis report for details.

PROBLEMS ENCOUNTERED & ACTION TAKEN

Few problems have been encountered during this fourth field test:

	PROBLEM	ACTION
	Sample contained ~20% Air	Problem under investigation
ON SITE ISSUES		

FUTURE ACTIONS

- Understand reason of air contamination.
- The air contamination issue was solved by installing better o-ring seals for the first stage coalescer that sits outside the sampling box. In addition, all of the fittings were checked for leaks. Some Swagelok fittings were leaking due to over-tightening and were replaced.

FIELD TEST REPORT
SITE #5

PTAC Project - Solution Gas And Knockout Liquids Characterization

Site / Operator:	Field Personnel:	Test Date:	SGS Lab Report Number:
XXX*	Kevin Morphy	August 27, 2003	S-2048-UA 08/27/03

EXECUTIVE SUMMARY

LIQUID PHASE IN GAS STREAM	N/A	g. / litre of gas

LIQUID PHASE COMPOSITION
N/A

Gas Phase Composition (Air Free) S-2048-UA 08/27/03																	
Comp.	**H2S**	**N2**	**CO2**	**C1**	**C2**	**C3**	**iC4**	**nC4**	**iC5**	**nC5**	**C6**	**C7**	**C8**	**C9**	**C10+**		**Total**
%	-	1.26	13.08	**79.52**	2.89	0.59	0.27	0.22	0.14	0.09	0.25	0.71	0.56	0.36	0.06		100.00

Notes on Site:

- *EUB data uses the LSD of XXX while the LSD of XXX is posted by the gate at the entrance of the lease. The information that I received from the EUB is that this well is directional or horizontal. The surface (wellhead/facilities) location is XXX while the bottomhole location is in XXX. The posted signage always indicates the wellhead physical location of the site.

- Kevin, with the operator, collected a sample of condensate from the base of the flare stack. This sample was taken from a drain plug at the base of the flare and stored in a glass sampling bottle (approximately 100 ml). This sample was sent to Point Tupper, N.S. for C30+ anaylsis (see below for results). THIS SAMPLE WAS NOT COLLECTED FROM THE GAS STREAM. The most likely cause of this accumulation of liquid at the bottom of the stack is condensation. The considerable temperature drop

from the treater to the flare stack results in liquid formation. This is NOT an indication of droplets suspended in the gas stream, i.e., the presence of an aerosol.

- No liquid was collected using our sampling apparatus. It's interesting to the note that the base of the flare stack needs to be emptied about once a month (yield ~ 5 gallon pail). The operator drained about this amount when Kevin showed up for the test.

- 485.48 litres of gas sampled in 3 hours 16 minutes from a 4" flare stack (sampling port was installed about 8' off the ground). The sampling was done at an average of 2.48 l/min (1.45 m/s). The flow rate of the gas in the stack varied from 1.3 to 1.7 m/s.

SITE INFORMATION

OVERVIEW

OPERATOR: XXX LOCATION: XXX

LOCATION: XXX

CONTACTS: XXX

PRODUCTION RATE (EUB Data; 10^3 m^3 /month)	30.8	May 2003

EQUIPMENT: - 5 Wells (6 wells on EUB data)
- 1 Treater (oil/gas separation)
- 1 Knock-out drum (housed in a shack)
- 1 Flare stack, 4" diameter (3” insulated line up to flare stack)

REMARKS:

This site access was arranged through XXX.
All the solution gas is flared through a 4" stack (see Kevin's report for schematic).
The access port was installed on the flare stack (after the knock-out drum).
The gas flared at this site was sweet.
The collection of rather large volumes of condensate is a result of cooling the gas stream. Kevin said the separator was at about 60^{o}C, while the KO was kept in a shack at about 20^{o}C, and the exposed flare stack was at about 14^{o}C during the day we tested. The successive cooling of the gas results in the dew point being reached and liquid condensing.

TEST CONDITIONS

TECHNICIAN: - Kevin Morphy (SGS) (780) 416-5188 kevin.morphy@sgs.com

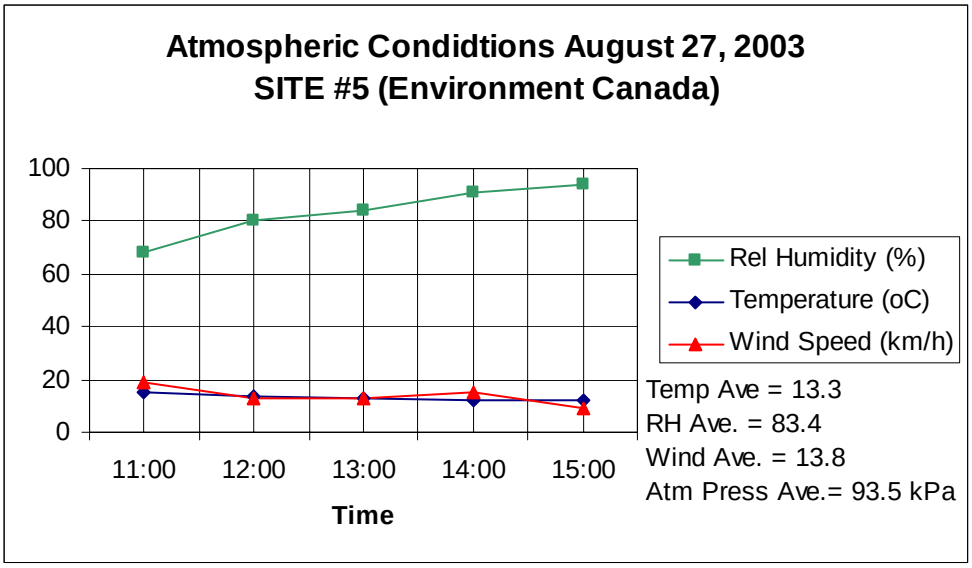
4 samples taken over 3 hours 16 minutes.

PROBE	5/16" O.D. 0.035" wall Th.	VOLUME SAMPLED*	467.9 litres

* Corrected at 101.3kPa & 15º C

SAMPLING RATE	2.48 l/min (1.45 m/s)	FLARE GAS VELOCITY	1.3–1.7 m/s

WEATHER: overcast (13.3ºC), wind (13.8 km/h): data from Environment Canada (http://www.climate.weatheroffice.ec.gc.ca/advanceSearch/searchHistoricDataStations_e.html).



PORT DETAILS:

The probe was inserted directly into 4" flare stack.

The valve was a 2 1/2" ball valve with 2" NPT thread reducing bushing.

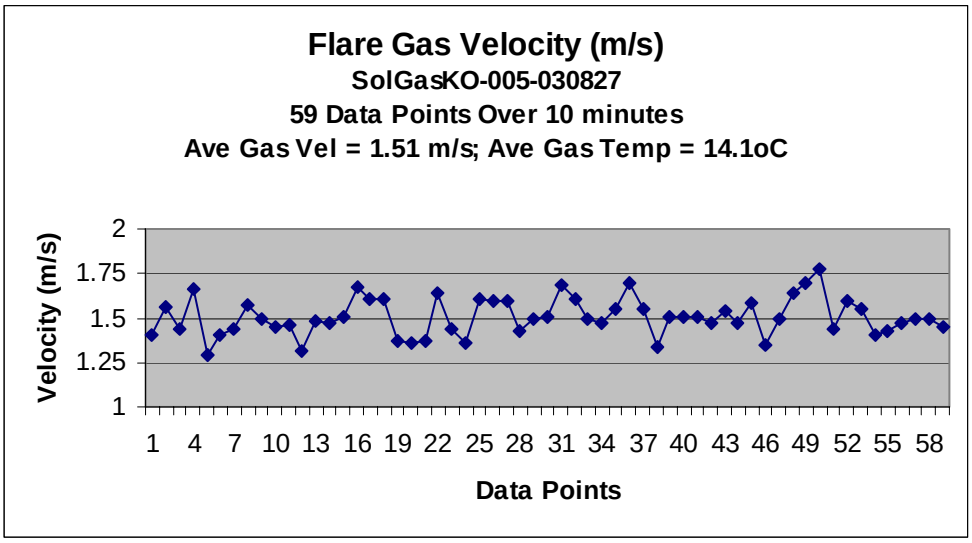
The probe was inserted in our 2" sleeve threaded onto the reducing bushing.

Probe-Sleeve sealing was ensured with 2 O-rings.

ACCESS PORT AND PROBE OVERVIEW

FLOW VELOCITY:

The gas stream velocity was steady throughout the test at 1.3 – 1.7 m/s.
The average sampling flow velocity was estimated around 2.48 m/s.
The following figure shows an example of flow velocity as measured during sampling. Data were saved on the data logger every 10 seconds for 10 minutes for a total of 59 data points.



SAMPLING DETAILS:

TIME (end)	Subsample	GAS METER (litre)	SAMPLING RATE (l/min)	Sample Duration (min.)
12:07	#1	7488	3.23	33
12:55	#2	7596	2.25	48
13:40	#3	7717	2.69	45
14:50	#4	7867	2.14	70

Average Sampling rate: 2.48 l/min (1.45 m/s)

TEMPERATURES (start and end times): All in Deg. C

TIME	SOURCE	GAS METER	LIQUID KNOCK/OUT	SAMPLING APPARATUS
11:34	18.10	20.0	17.1	20.2
14:50	14.2	28.0	21.3	29.6

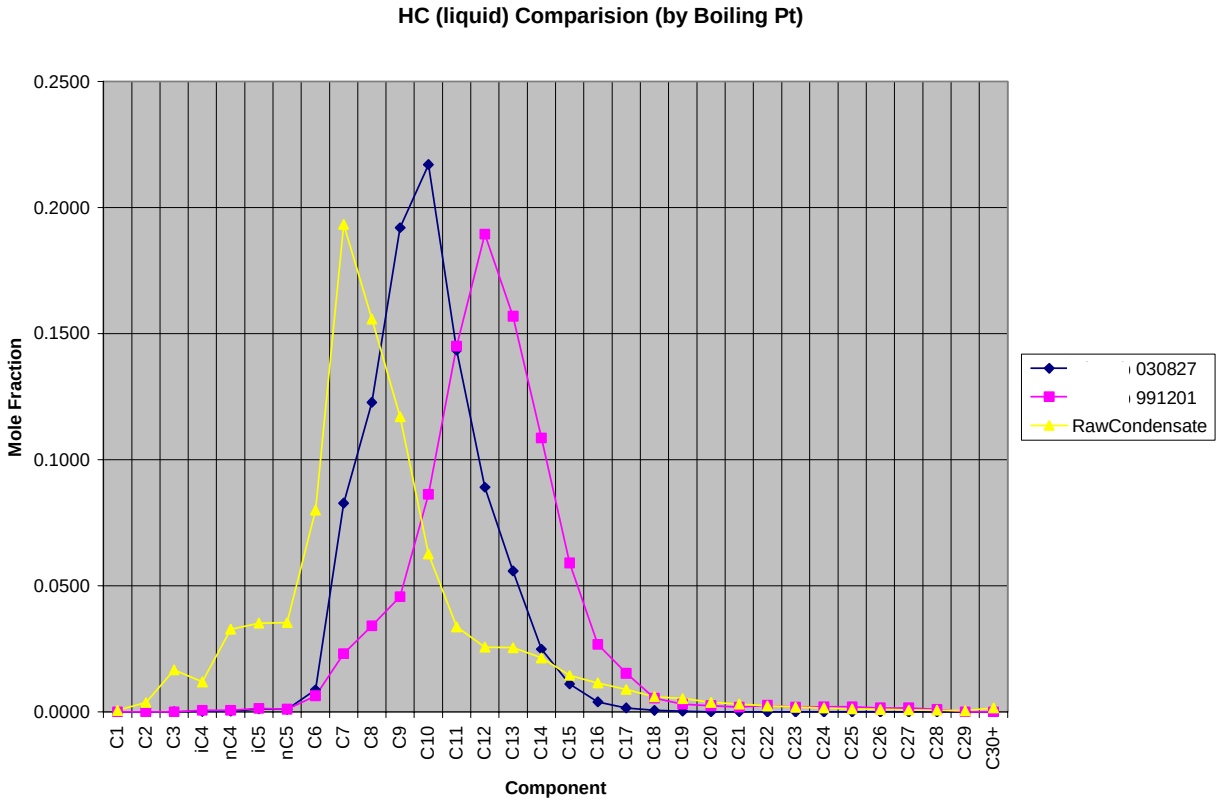
Average Gas Meter Temperature: 24.0 Deg. C

LIQUID PHASE:

No liquid was collected using our sampling apparatus. However, the following liquid analysis (C30+) was performed on a sample drained from the base of the flare stack.

Liquid Hydrocarbon Analysis			
4502-SOP-1017			
Northrock Chamberlain			
Component	**Mole Frac.**	**Mass Frac.**	**Volume Frac.**
N2	0.0000	0.0000	0.0000
CO2	0.0000	0.0000	0.0000
H2S	0.0000	0.0000	0.0000
C1	0.0000	0.0000	0.0000
C2	0.0001	0.0000	0.0000
C3	0.0001	0.0000	0.0001
iC4	0.0002	0.0001	0.0001
nC4	0.0003	0.0001	0.0002
iC5	0.0012	0.0006	0.0008
nC5	0.0010	0.0005	0.0007
C6+	0.9971	0.9987	0.9981
Total	1.0000	1.0000	1.0000

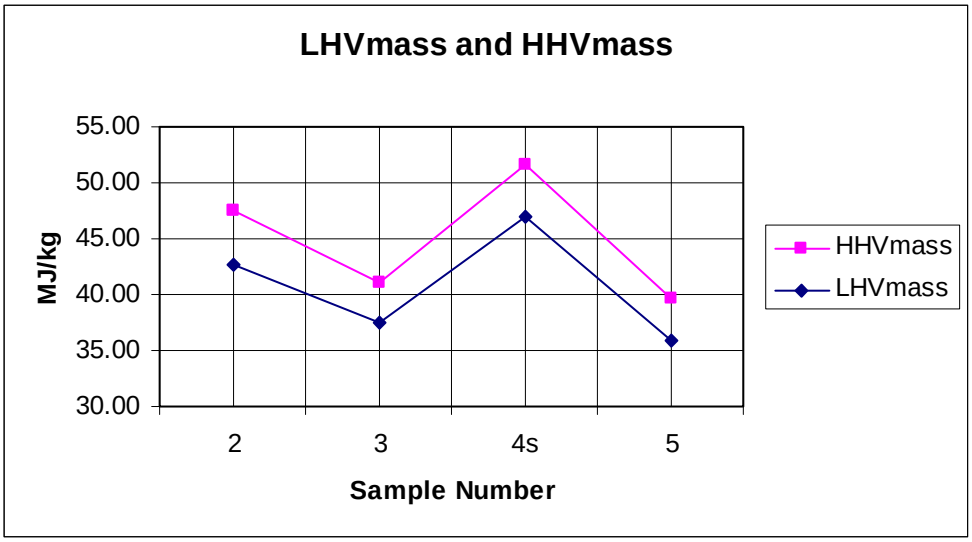
Liquid Hydrocarbon Analysis			
4502-SOP-1017			
Northrock Chamberlain			
Component	**Mole Frac.**	**Mass Frac.**	**Volume Frac.**
C6	0.0068	0.0043	0.0052
C7	0.0513	0.0374	0.0400
C8	0.1181	0.0981	0.1022
C9	0.1464	0.1365	0.1396
C10	0.1905	0.1976	0.1982
C11	0.1434	0.1630	0.1614
C12	0.0891	0.1104	0.1081
C13	0.0559	0.0749	0.0727
C14	0.0249	0.0359	0.0345
C15	0.0111	0.0171	0.0163
C16	0.0040	0.0066	0.0062
C17	0.0016	0.0028	0.0026
C18	0.0006	0.0012	0.0011
C19	0.0003	0.0005	0.0005
C20	0.0001	0.0002	0.0002
C21	0.0001	0.0001	0.0001
C22	0.0000	0.0001	0.0001
C23	0.0000	0.0000	0.0000
C24	0.0000	0.0000	0.0000
C25	0.0000	0.0000	0.0000
C26	0.0000	0.0000	0.0000
C27	0.0000	0.0000	0.0000
C28	0.0000	0.0000	0.0000
C29	0.0000	0.0000	0.0000
C30+	0.0000	0.0000	0.0000

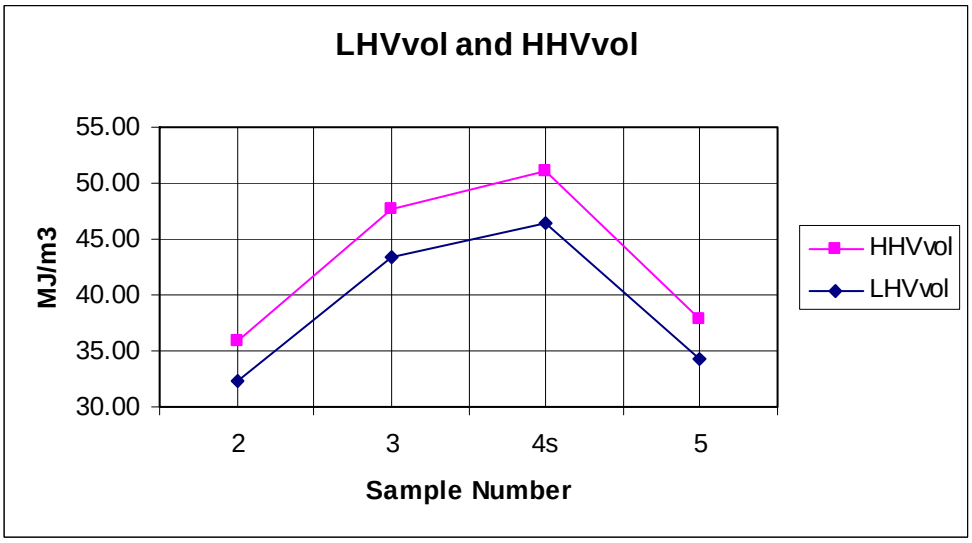


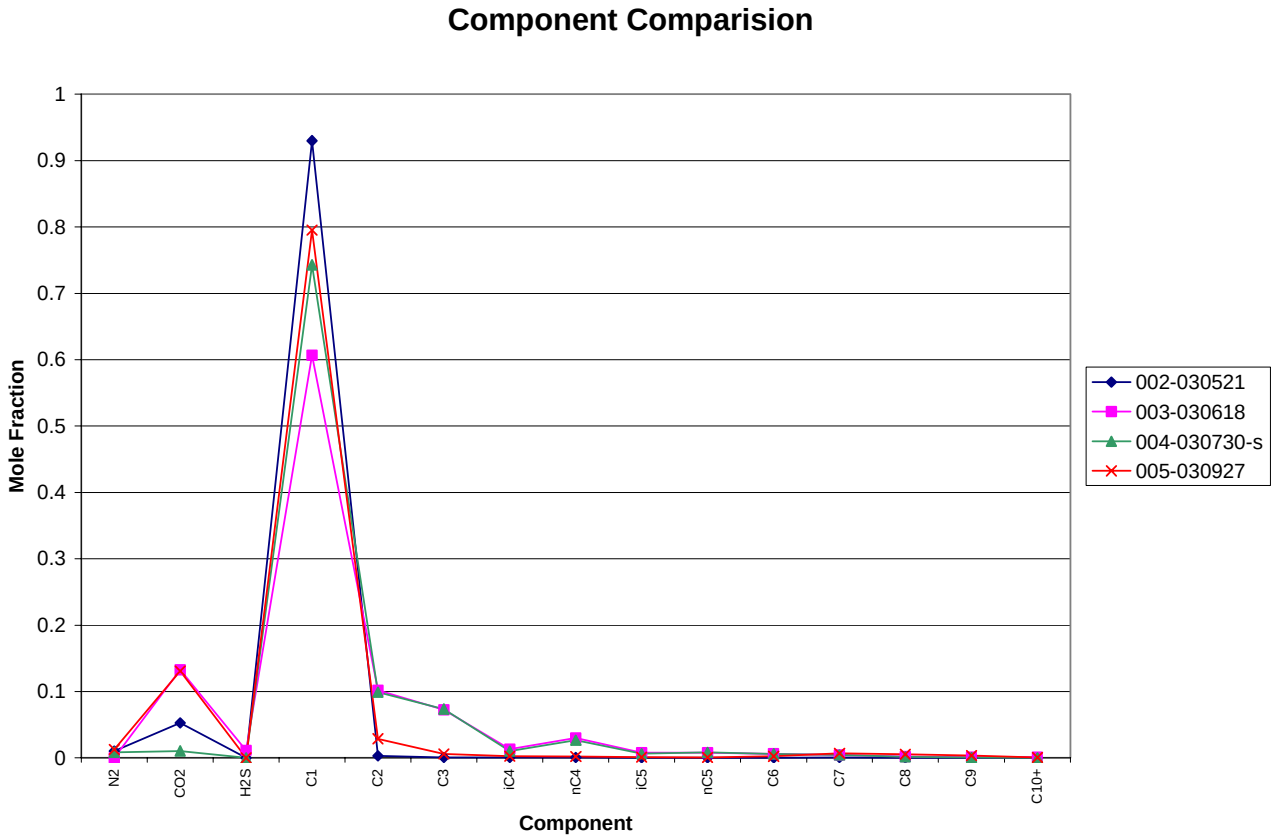
The above graph compares two liquid condensate results from this site taken by the University of Alberta Flare Research Project. The first sample, "991201," was taken in December 1999 and the second sample, "030827," was taken in August 2003 (as a part of this current project). These two results were then compared with a typical raw condensate sample, "RawCondensate," from the oil and gas industry. The comparison serves to show that the current sample contains a high concentration of hydrocarbons with a narrow band of boiling points which is typical of raw condensate found in the field.

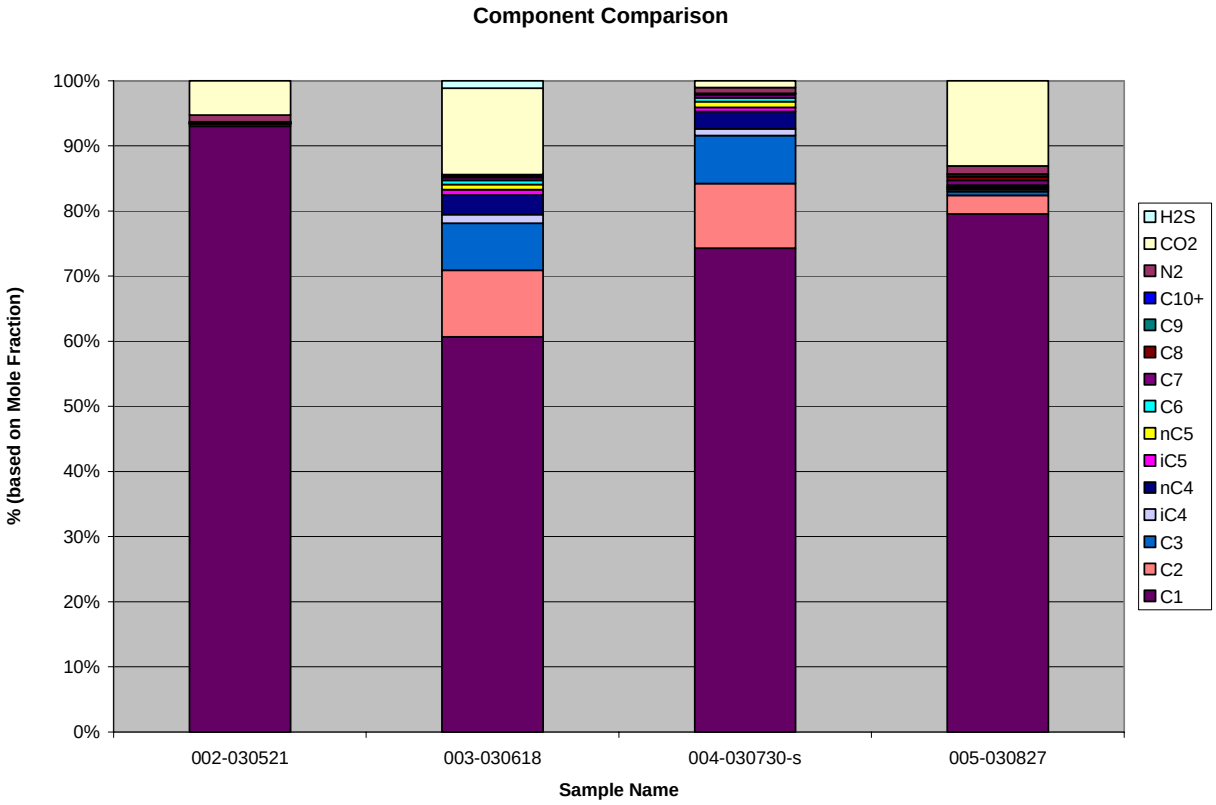
COMPARISON OF BATTERY SITE RESULTS

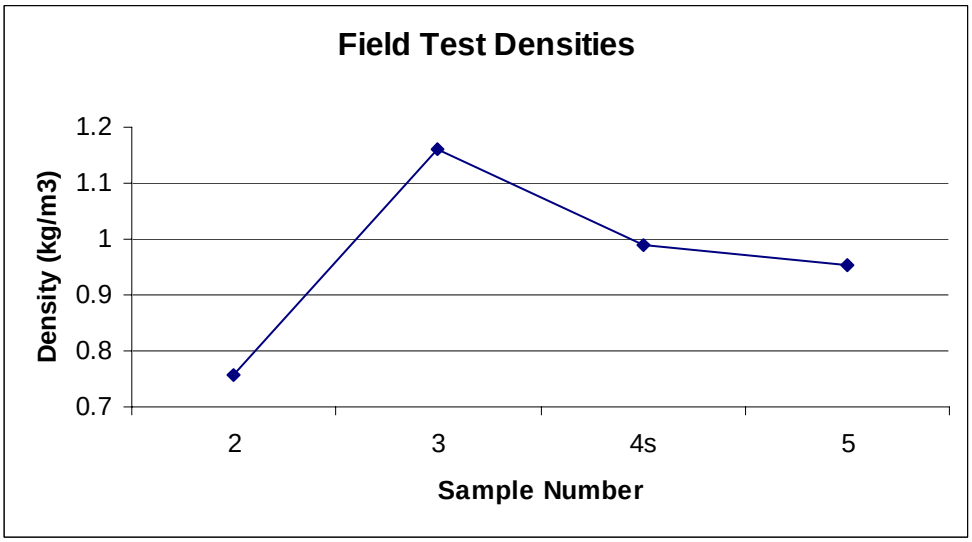
These graphs compare various results between battery sites sampled thus far.






Component Comparision
Mole Fraction
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
N2
CO2
H2S
C1
C2
C3
iC4
nC4
iC5
nC5
C6
C7
C8
C9
C10+
Component
002-030521
003-030618
004-030730-s
005-030927


Component Comparison
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
% (based on Mole Fraction)
002-030521
003-030618
004-030730-s
005-030827
Sample Name
H2S
CO2
N2
C10+
C9
C8
C7
C6
nC5
iC5
nC4
iC4
C3
C2
C1


Field Test Densities
1.2
1.1
1
0.9
0.8
0.7
Density (kg/m3)
2
3
4s
5
Sample Number

ANALYSIS & RESULTS

The gas analysis was performed in the SGS lab in Point Tupper, Nova Scotia 7 days after the sample was taken at the battery site.

See Gas Analysis report for details.

The liquid analysis was received September 16, 2003 from SGS. This analysis was difficult to perform since the boiling points of the hydrocarbons were in a very tight range. This makes analysis by gas chromatograph more challenging since the peaks on the chromatograph are very close together making their delineation more difficult.

PROBLEMS ENCOUNTERED & ACTIONS TAKEN

Few problems have been encountered during this fifth field test:

	PROBLEM	ACTION
ON SITE ISSUES	LEL monitor failed	Phoned Fisher and rectified situation. There's a problem with the outlet into which the charger was plugged.
	Anemometer Reading Fluctuated	Phoned Omega and tested anemometer in UofA wind tunnel. The anemometer reading matched well with Pitot tube reading. See graph for results.

FUTURE ACTIONS

- Select proper electrical outlet for battery charger.

FIELD TEST REPORT
SITE #6

PTAC Project - Solution Gas And Knockout Liquids Characterization

Site / Operator:	Field Personnel:	Test Date:	SGS Lab Report Number:
XXX	Kevin Morphy	Sept. 9, 2003	S-2048-UA 09/09/03

EXECUTIVE SUMMARY

LIQUID PHASE IN GAS STREAM	N/A	g. / litre of gas

LIQUID PHASE COMPOSITION
N/A

Gas Phase Composition (Air Free)

Comp.	H2S	N2	CO2	C1	C2	C3	iC4	nC4	iC5	nC5	C6	C7	C8	C9	C10+		Total
%	-	0.38	1.99	**79.54**	9.88	5.10	0.63	1.31	0.30	0.34	0.22	0.17	0.09	0.03	0.02		100.00

Detailed Hydrocarbon Analysis 030909

Compound	Mole Fraction	Peak Type
Methane	0.795400	P
Ethane	0.098800	P
Propane	0.051000	P
n-Butane	0.013100	P
Isobutane	0.006300	I
n-Pentane	0.003400	P
Isopentane	0.003000	I
n-Hexane	0.000853	P
2-Methylpentane	0.000623	I
Benzene	0.000444	A
Toluene	0.000382	A
Cyclohexane	0.000375	N

Peak Codes
P-Paraffins
I-Isoparaffins
A-Aromatics
N-Napthenes
O-Olefins
X-Oxygenates

Methylcyclopentane	0.000334	N
3-Methylpentane	0.000332	I
Methylcyclohexane	0.000269	N
Cyclopentane	0.000250	N
n-Heptane	0.000192	P
2-Methylhexane	0.000138	I
2,3-Dimethylbutane	0.000105	I
3-Methylhexane	0.000091	I
m-Xylene	0.000073	A
n-Octane	0.000058	P
C11-Isoparaffin	0.000056	I
trans,1-2-Dmcyclopentane	0.000051	N
Propylcyclopentane	0.000043	N
2,2-Dimethylbutane	0.000037	I
2-Methyl-Heptane	0.000033	I
trans-1,3-Dmcyclopentane	0.000029	N
1,3,5-Trimethylbenzene	0.000028	A
Ethylbenzene	0.000027	A
cis,1-3,Dmcyclopentane	0.000026	N
p-Xylene	0.000024	A
o-Xylene	0.000024	A
n-Nonane	0.000022	P
2,4-Dimethylpentane	0.000021	I
3-Methylheptane	0.000021	I
trans-1,4-Dimethylcyclohexane	0.000019	N
1,2,4-Trimethylbenzene	0.000019	A
Ethylcyclopentane	0.000018	N
2,6-Dimethylheptane	0.000018	I
1-Ethyl-3-methylbenzene	0.000014	A
1-Ethyl-2-methylbenzene	0.000014	A
C8-Diolefin	0.000012	O
C9-Olefin	0.000012	O
4-Methyl-Heptane	0.000011	I
C8-Olefins	0.000010	O
2,4-Dimethylhexane	0.000009	I
Isopropylbenzene	0.000009	A
Propylbenzene	0.000009	A
3,3-Dimethyloctane	0.000009	I
1-Ethyl-4-methylbenzene	0.000009	A
n-Decane	0.000009	P
t,c-1,2,4-TMcyclopentane	0.000008	N
2,5&3,5-Dimethylheptane	0.000008	I
2-Methyloctane	0.000008	I
3-Methyloctane	0.000008	I
1,1,3-Trimethylcyclopentane	0.000007	N
2,5-Dimethylhexane + C8-Olefin	0.000007	I
t,c-1,2,3-TMcyclopentane	0.000007	N
trans-1-Ethyl-2-methyl-cyclopentane	0.000007	N

Peak Codes
P-Paraffins
I-Isoparaffins
A-Aromatics
N-Napthenes
O-Olefins

2,3-Dimethylheptane	0.000006	I
4-Methyloctane + C9-Olefin	0.000006	I
trans-2-Nonene	0.000005	O
2,6-Dimethyloctane	0.000005	I
4-Methylnonane	0.000005	I
2-Methylnonane	0.000005	I
C10-Naphthene	0.000005	N
2,3-Dimethylhexane	0.000004	I
C8-Olefin	0.000004	O
trans-1-Ethyl-4-Methyl-cyclohexane	0.000004	N
cis-1-Ethyl-4-Methyl-cyclohexane	0.000004	N
2,2,5-Trimethylhexane	0.000003	I
trans-1-Ethyl-3-methyl-cyclopentane	0.000003	N
2,2-Dimethylhexane	0.000002	I
3,3-DMIhexane + C8-Olefin	0.000002	I
2,3,4-Trimethylpentane	0.000002	I
C8-Diolefin + C8-Olefin	0.000002	O
trans-1,2,4-Trimethylcyclohexane	0.000002	N
C9-Olefin	0.000002	O
C9-Olefin	0.000002	O
3-Methyl-3-ethylhexane	0.000002	I
3-Ethylheptane	0.000002	I
Total	**0.976299**	

Peak Codes
P-Paraffins
I-Isoparaffins
A-Aromatics
N-Napthenes
O-Olefins
X-Oxygenates

Group Summary	
Group	**Mole Frac.**
Aromatics	0.001076
Olefins	0.000049
Paraffins	0.962834
Oxygenates	0.000000
Isoparaffins	0.010879
Napthenes	0.001461
Total**	**0.9763**

**Bal. is N2 and CO2

Notes on Site:

- Second sample from a smokey flare. Kevin noted that the flare was smoking continuously during the entire test.
- Detailed hydrocarbon analysis completed for smokey flare.
- This is a single well battery site.

- No liquid collected. Flare KO was emptied recently.

- 1327.04 litres of gas sampled (1293.2 litres corrected gas volume at 101.325 kPa and 15^{o}C) in 3 hours through a 3"-pipe leading to the flare stack. Sampling done at an average of 7.37 l/min (4.19 m/s). The flow rate of the solution gas going to flare was measured to be 4.13 m/s.

Smokey Flare

SITE INFORMATION

OVERVIEW

(The above picture was enhanced using software.)

OPERATOR: XXX LOCATION: XXX

LOCATION: XXX

CONTACTS: XXX

PRODUCTION RATE (EUB Data; 10^3 m^3 /month)	42.4	July 2003

EQUIPMENT: - 1 Well
- 1 Knock-out drum (recently emptied)
- 1 Flare stack, 3" diameter

REMARKS:
This site was located by XXX of XXX as a smokey flare.
All the solution gas is flared through a 3" stack (see Kevin's schematic below).
The access port was installed on a 3"-line between the knock-out drum and the flare stack (before the flame arrestor).
The gas flared at this site is sweet.

TEST CONDITIONS

TECHNICIAN: - Kevin Morphy (SGS) (780) 416-5188 kevin.morphy@sgs.com

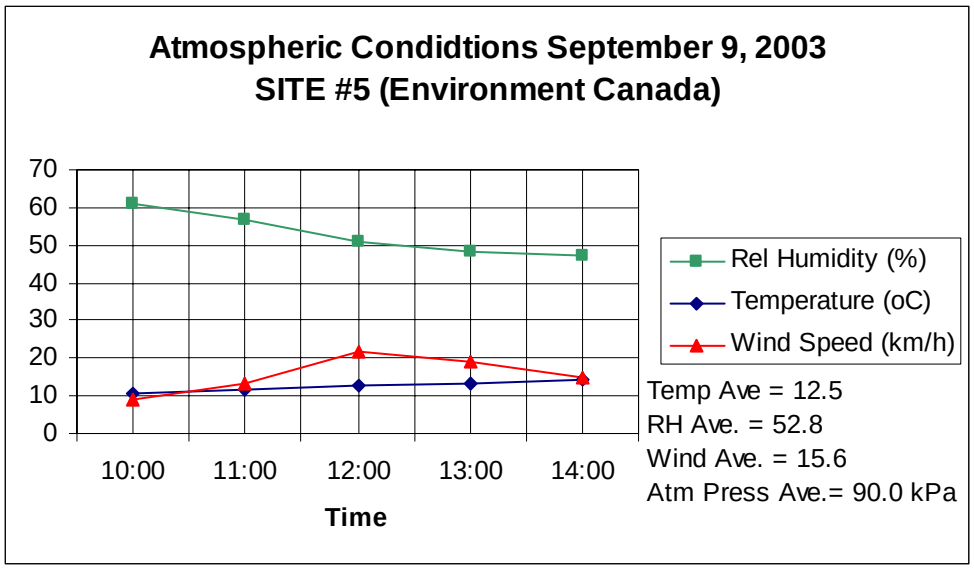
4 samples taken over 3 hours 0 minutes.

PROBE	5/16" O.D. 0.035" wall Th.	VOLUME SAMPLED*	1293.2 litres

* Corrected at 101.3kPa & 15º C

SAMPLING RATE	7.37 l/min (4.19 m/s)	FLARE GAS VELOCITY	4.13 m/s

WEATHER: overcast (~ 12.5 ^{o}C), wind (~ 15.6 km/h): data from Environment Canada (http://www.climate.weatheroffice.ec.gc.ca/advanceSearch/searchHistoricDataStations_e.html).



PORT DETAILS:

The probe was inserted in a 3"- line, which led to the 3" flare stack.

The valve was a 2 1/2" ball valve with 2" NPT thread reducing bushing.

The probe was inserted in our 2" sleeve threaded onto the reducing bushing.

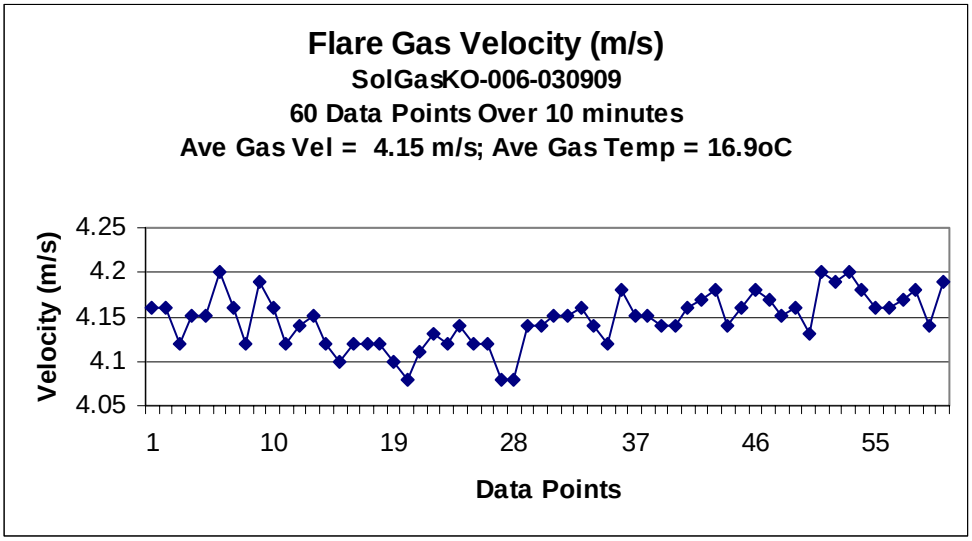
Probe-Sleeve sealing was ensured with 2 O-rings.

ACCESS PORT AND PROBE OVERVIEW

This picture has been enhanced using software.

FLOW VELOCITY:

The gas stream velocity was steady throughout the test at 4.13 m/s.
The average sampling flow velocity was estimated around 4.15 m/s.
The following figure shows an example of flow velocity as measured during sampling. Data were saved on the data logger every 10 seconds for 10 minutes for a total of 60 data points.



SAMPLING DETAILS:

TIME (end)	Subsample	Gas Sampled (l)	Sampling Rate (l/min)	Sample Duration (min.)
11:05	#1	347.11	7.71	45
11:50	#2	326.0	7.24	45
12:35	#3	327.0	7.27	45
13:20	#4	326.93	7.27	45

Average Sampling rate: 7.37 l/min (4.19 m/s)

TEMPERATURES (start and end times): All in Deg. C

TIME	SOURCE	GAS METER	LIQUID KNOCK/OUT	SAMPLING APPARATUS
10:20	14.5	15.0	16.1	15.0
13:20	20.8	27.0	25.1	29.3

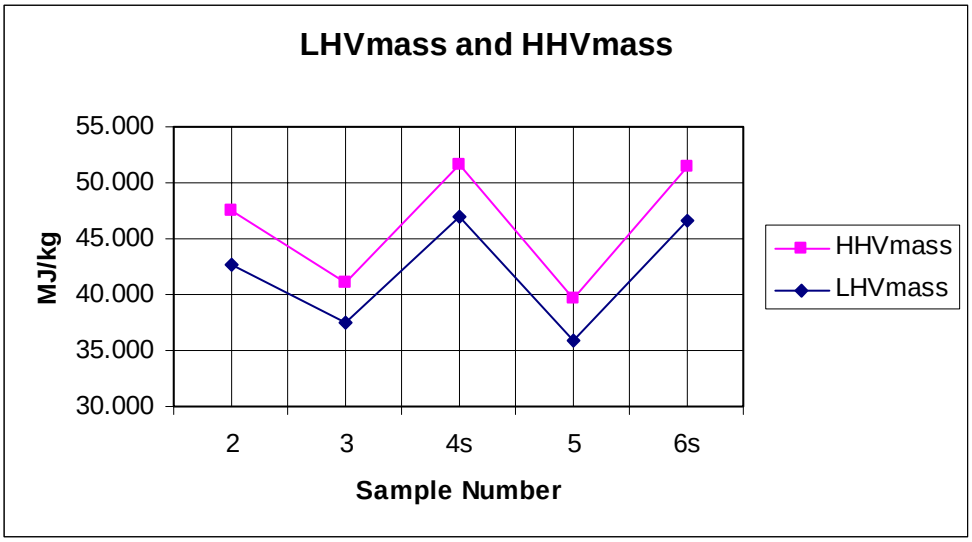
Average Gas Meter Temperature: 21 Deg. C

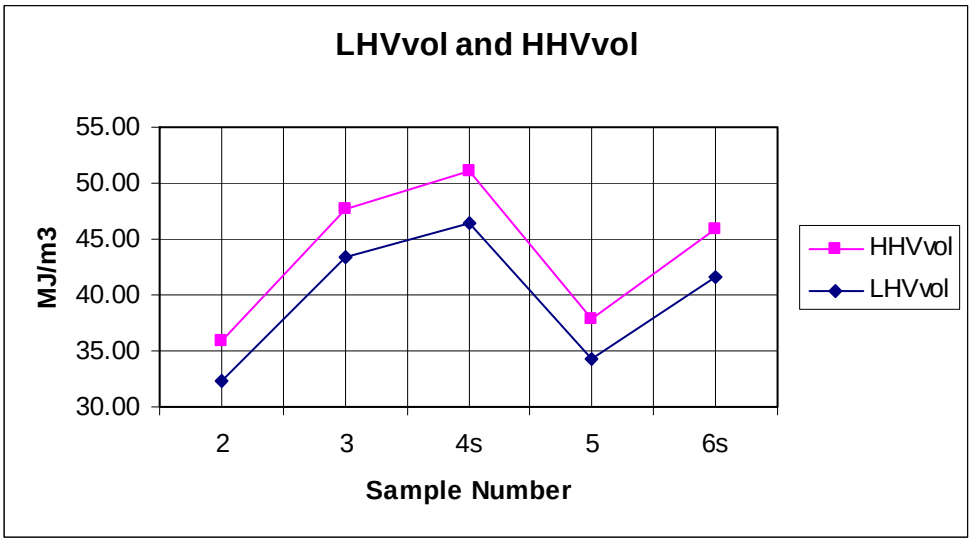
LIQUID PHASE:

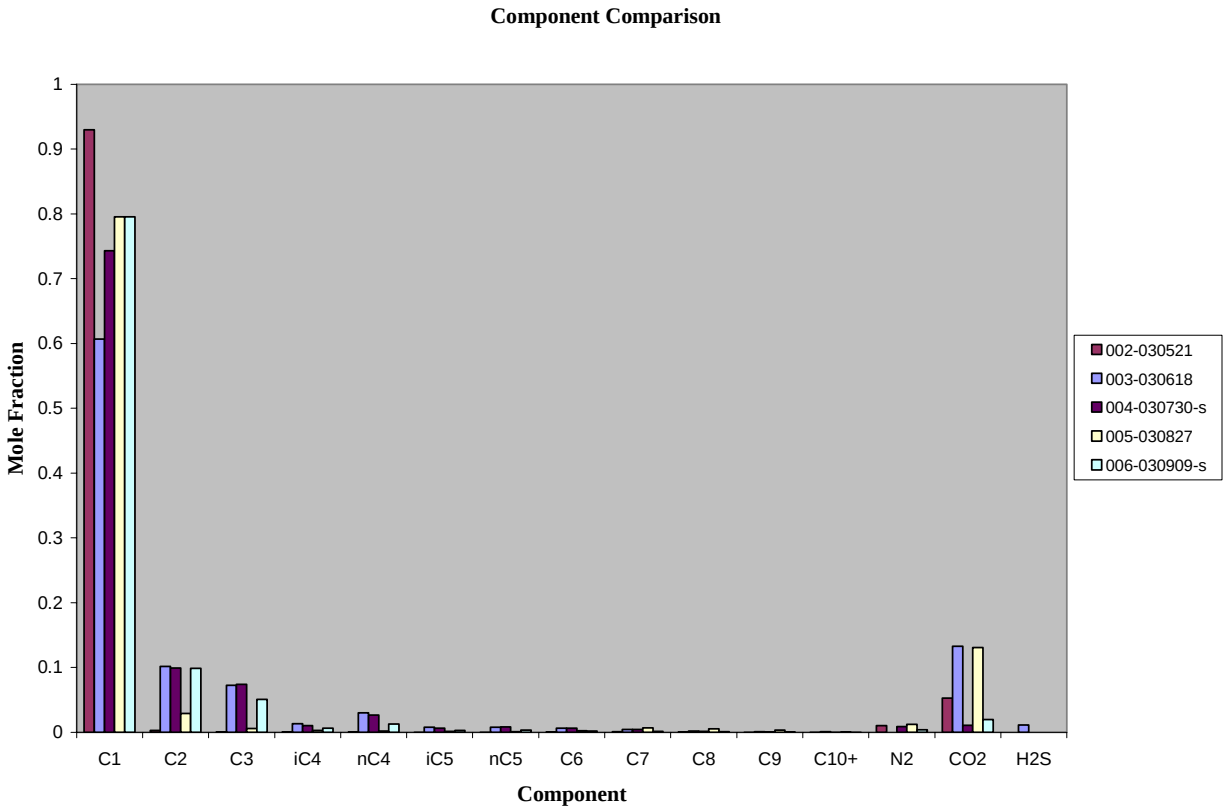
No liquid was collected.

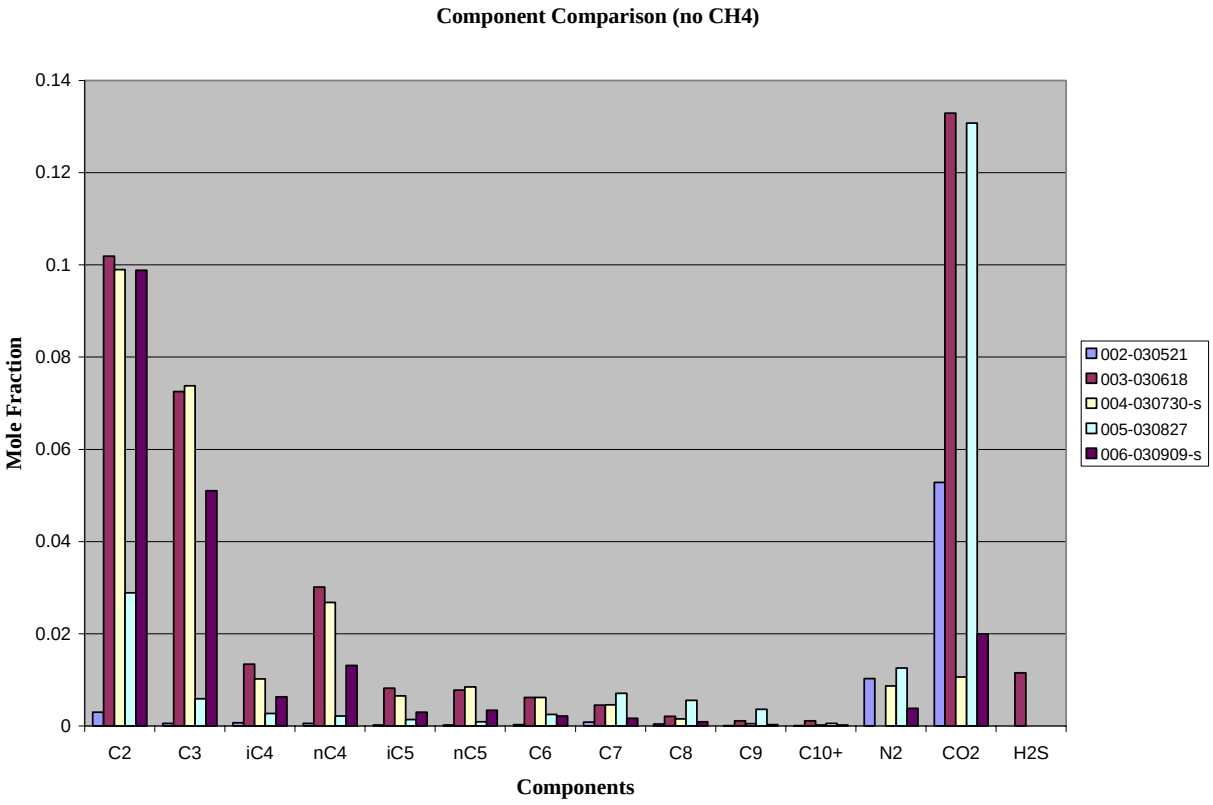
COMPARISON OF BATTERY SITE RESULTS

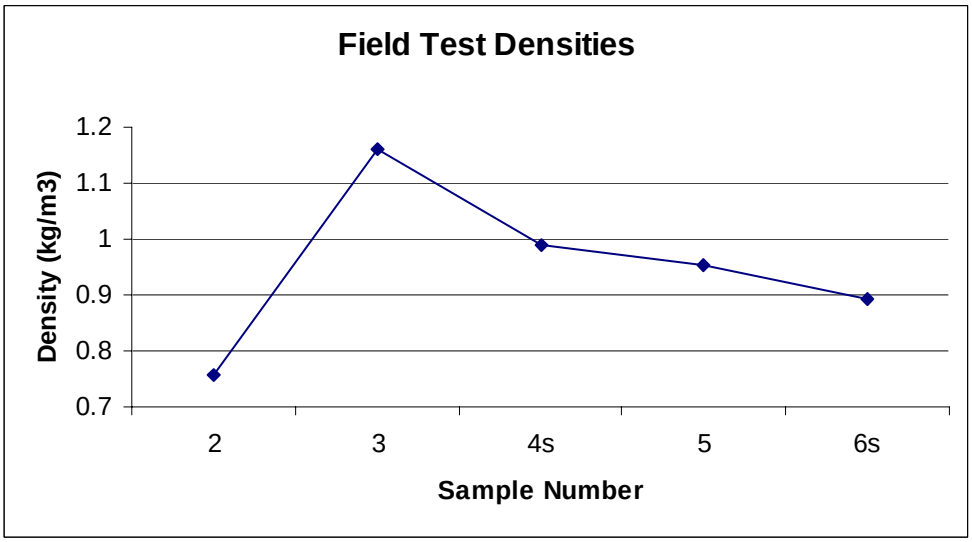
These graphs compare various results between battery sites sampled thus far.






Component Comparison
Mole Fraction
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
C1
C2
C3
iC4
nC4
iC5
nC5
C6
C7
C8
C9
C10+
N2
CO2
H2S
Component
002-030521
003-030618
004-030730-s
005-030827
006-030909-s


Component Comparison (no CH4)
Mole Fraction
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
C2
C3
iC4
nC4
iC5
nC5
C6
C7
C8
C9
C10+
N2
CO2
H2S
Components
002-030521
003-030618
004-030730-s
005-030827
006-030909-s


Field Test Densities
Density (kg/m3)
1.2
1.1
1
0.9
0.8
0.7
2
3
4s
5
6s
Sample Number

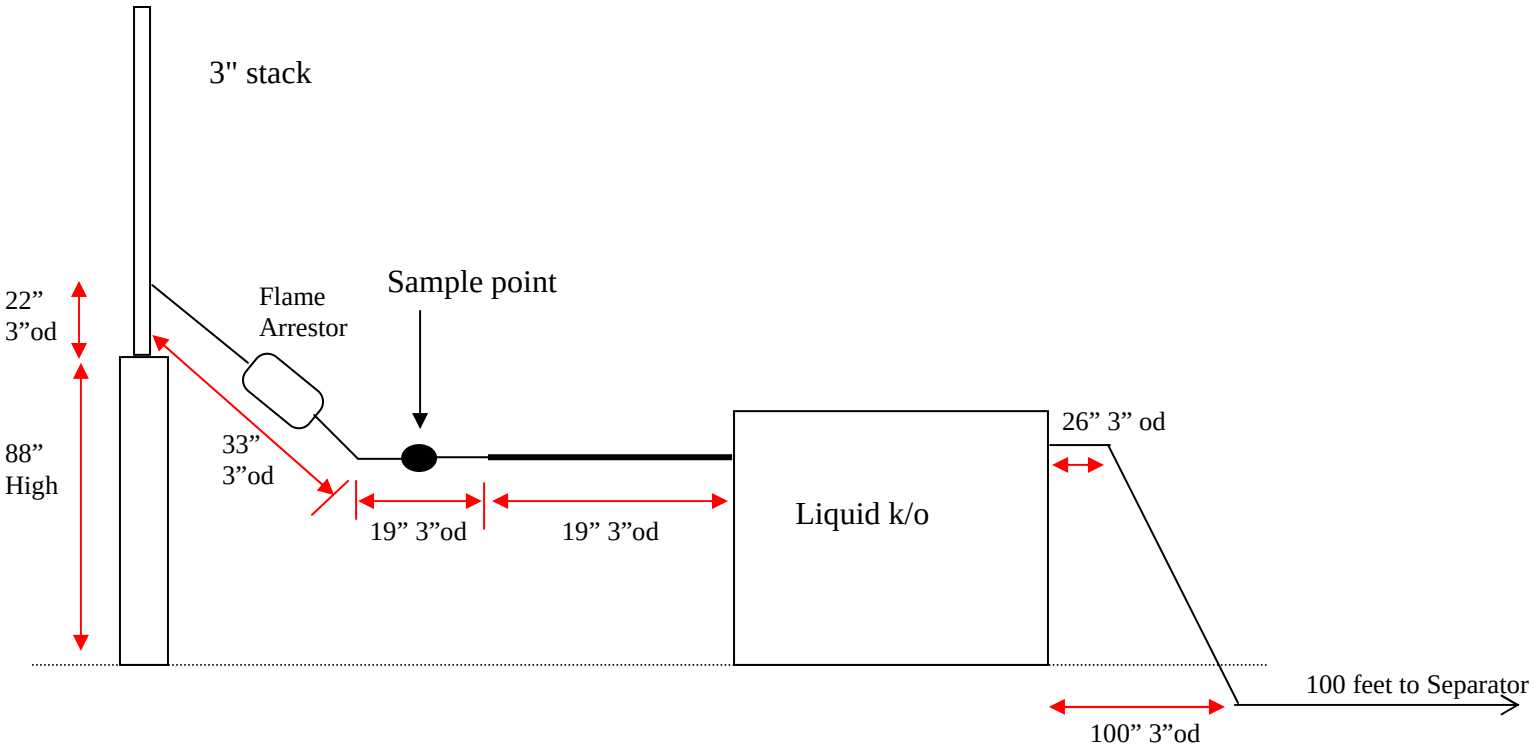
SGS ANALYSIS

The gas analysis was performed in the SGS lab in Point Tupper, Nova Scotia xxx days after the sample.

See Gas Analysis report for details.

SCHEMATIC OF BATTERY SITE

(Supplied by Kevin Morphy)



PROBLEMS ENCOUNTERED & ACTIONS TAKEN

Few problems have been encountered during this fourth field test:

	PROBLEM	ACTION
ON-SITE ISSUES	Not enough of the gray flexible tubing	Ordered one 10’ length
	Fittings for knock-out container loose	Check fittings before each test
	Spare batteries for anemometer and clock.	

FUTURE ACTIONS

- All connections must be sufficiently long to enable sampling from ports approximately 8’ from the ground.
- Need another 9 V battery for the anemometer and at least two AAA batteries for the clock that also serves as a temperature measurement device. These batteries will be spares.

FIELD TEST REPORT
SITE #7

PTAC Project - Solution Gas And Knockout Liquids Characterization

Site / Operator:	Field Personnel:	Test Date:	SGS Lab Report Number:
XXX	Kevin Morphy	Sept. 23, 2003	S-2048-UA 09/23/03

EXECUTIVE SUMMARY

LIQUID PHASE IN GAS STREAM	N/A	g. / litre of gas

LIQUID PHASE COMPOSITION
N/A

Gas Phase Composition (Air Free)

Comp.	H2S	N2	CO2	C1	C2	C3	iC4	nC4	iC5	nC5	C6	C7	C8	C9	C10+		Total
%	-	10.40	0.44	**56.31**	16.07	11.76	1.34	2.53	0.46	0.36	0.18	0.11	0.04	-	-		100.00

Detailed Hydrocarbon Analysis

Component	Mole Fraction	Peak Type
Methane	0.563100	P
Ethane	0.160700	P
Propane	0.117600	P
n-Butane	0.025300	P
Isobutane	0.013400	I
Isopentane	0.004600	I
n-Pentane	0.003600	P
2-Methylpentane	0.000618	I
n-Hexane	0.000540	P
3-Methylpentane	0.000342	I
Methylcyclopentane	0.000297	N
Benzene	0.000232	A

Peak Codes
P-Paraffins
I-Isoparaffins
A-Aromatics
N-Napthenes
O-Olefins

Cyclopentane	0.000165	N
Toluene	0.000152	A
Cyclohexane	0.000128	N
Methylcyclohexane	0.000115	N
2,3-Dimethylbutane	0.000087	I
n-Heptane	0.000084	P
trans,1-2-DMcyclopentane	0.000072	N
2-Methylhexane	0.000070	I
3-Methylhexane	0.000062	I
trans-1,3-DMcyclopentane	0.000052	N
2,2-Dimethylbutane	0.000046	I
cis,1-3,DMcyclopentane	0.000046	N
2,3-Dimethylpentane	0.000034	I
1,1,3-Trimethylcyclopentane	0.000017	N
2-Methyl-Heptane	0.000014	I
2,4-Dimethylpentane	0.000013	I
trans-1,4-Dimethylcyclohexane	0.000013	N
n-Octane	0.000013	P
t,c-1,2,4-TMcyclopentane	0.000012	N
t,c-1,2,3-TMcyclopentane	0.000011	N
3-Methylheptane	0.000008	I
m-Xylene	0.000008	A
C8-Diolefin	0.000007	O
3-Ethylpentane	0.000005	I
Ethylcyclopentane	0.000005	N
trans-1,2-Dimethylcyclohexane	0.000005	N
Ethylcycohexane	0.000005	N
4-Methyl-Heptane	0.000004	I
3,3-Dimethylpentane, 5-Methyl-1-hexene	0.000003	I
2,5-Dimethylhexane + C8-Olefin	0.000003	I
2,4-Dimethylhexane	0.000003	I
C8-Diolefin + C8-Olefin	0.000003	O
cis-1,4-Dimethylcyclohexane	0.000003	N
1,1,4-Trimethylcyclohexane	0.000003	N
2,2,3-Trimethylbutane	0.000002	I
2,3-Dimethylhexane	0.000002	I
3-Ethylhexane	0.000002	I
C8-Olefin	0.000002	O
trans-1-Ethyl-2-methyl-cyclopentane	0.000002	N
2-methyl-40Ethylhexane	0.000002	I
Ethylbenzene	0.000002	A
p-Xylene	0.000002	A
o-Xylene	0.000002	A
n-Nonane	0.000002	P
cis-2-Pentene	0.000001	O
2,2-Dimethylhexane	0.000001	I
3,3-DMIhexane + C8-Olefin	0.000001	I
C8-Olefin + C7-Diolefin	0.000001	O

Peak Codes
P-Paraffins
I-Isoparaffins
A-Aromatics
N-Napthenes
O-Olefins
X-Oxygenates

C8-Olefin	0.000001	O
2,2,5-Trimethylhexane	0.000001	I
trans-1-Ethyl-3-methyl-cyclopentane	0.000001	N
C9-Olefin	0.000001	O
cis-1,2-Dimethylcyclohexane	0.000001	N
2,6-Dimethylheptane	0.000001	I
1,1,3-Trimethylcyclohexane	0.000001	N
C9-Olefin	0.000001	O
2,3-Dimethylheptane	0.000001	I
4-Methyloctane + C9-Olefin	0.000001	I
2-Methyloctane	0.000001	I
3-Methyloctane	0.000001	I
cis-1-Ethyl-4-Methyl-cyclohexane	0.000001	N
trans-2-Nonene	0.000001	O
C9-Olefin	0.000001	O
2,6-Dimethyloctane	0.000001	I
1-Ethyl-3-methylbenzene	0.000001	A
1,3,5-Trimethylbenzene	0.000001	A
1,2,4-Trimethylbenzene	0.000001	A
sec-Butylbenzene	0.000001	A
n-Decane	0.000001	P
1,2-Dimethyl-3-ethylbenzene	0.000001	A
C11-Aromatic	0.000001	A
Total (balance is N2)	**0.891647**	

Peak Codes
P-Paraffins
I-Isoparaffins
A-Aromatics
N-Napthenes
O-Olefins
X-Oxygenates

Group Summary	
Group	**Mole Frac.**
Aromatics	0.000404
Olefins	0.000019
Paraffins	0.870940
Oxygenates	0.000000
Isoparaffins	0.019329
Napthenes	0.000955
Total**	**0.8916**

**Bal. is N2 and CO2

Notes on Site:

- Third sample from a smokey flare. Kevin noted that the flare was smoking intermittently during the entire test.
- Detailed hydrocarbon analysis completed for this smokey flare.
- This is a single well battery site.

- No liquid collected. The company recently (days before our test) installed a “gas boot” to prevent any liquid build-up from occurring in the gas line.

- 1552.93 litres of gas sampled (1532.7 litres corrected gas volume at 101.325 kPa and 15^{o}C) in 3 hours. The sampling point was located on the flare stack (4” diameter flare stack). Sampling was done at an average of 8.63 l/min (5.98 m/s). The flow rate of the solution gas going to flare was measured to be 5.8 m/s (based on 10-minute data logged with anemometer; Kevin, in his field report, quotes 6.4 m/s).

Smokey Flare

SITE INFORMATION

OVERVIEW

(The above picture was enhanced using software.)

OPERATOR: XXX LOCATION: XXX

LOCATION: XXX

CONTACTS: XXX

PRODUCTION RATE (EUB Data; 10^3 m^3 /month)	91.2	July 2003

EQUIPMENT: - 1 Well
- 1 Gas Boot (installed days before our test).
- 1 Separator
- 1 Flare stack, 4" diameter

REMARKS:

This site was located by XXX of XXX as a smokey flare.

All the solution gas is flared through a 4" stack (see Kevin's schematic below).
The access port was installed directly on the flare stack (after the flame arrestor).
The gas flared at this site is sweet.

We added a small strip of "Pig Mat" material (4 in 1 Pig Mat; Phone: 1-800-HOT-HOGS)to the underside of the sampling probe. The strip measured about 2.5cm by 2 cm. This material only absorbs oil products and not water. Kevin inspected the strip immediately after removing it from the gas stream. The strip was dry but stained a very light yellow. This sample strip has been saved. Kevin also tried to put a larger piece of this material in the gas stream once the test was over, however it was not possible to introduce this into the flare stack.

TEST CONDITIONS

TECHNICIAN: - Kevin Morphy (SGS) (780) 416-5188 kevin.morphy@sgs.com

4 samples taken over 3 hours 0 minutes.

PROBE	5/16" O.D. 0.035" wall Th.

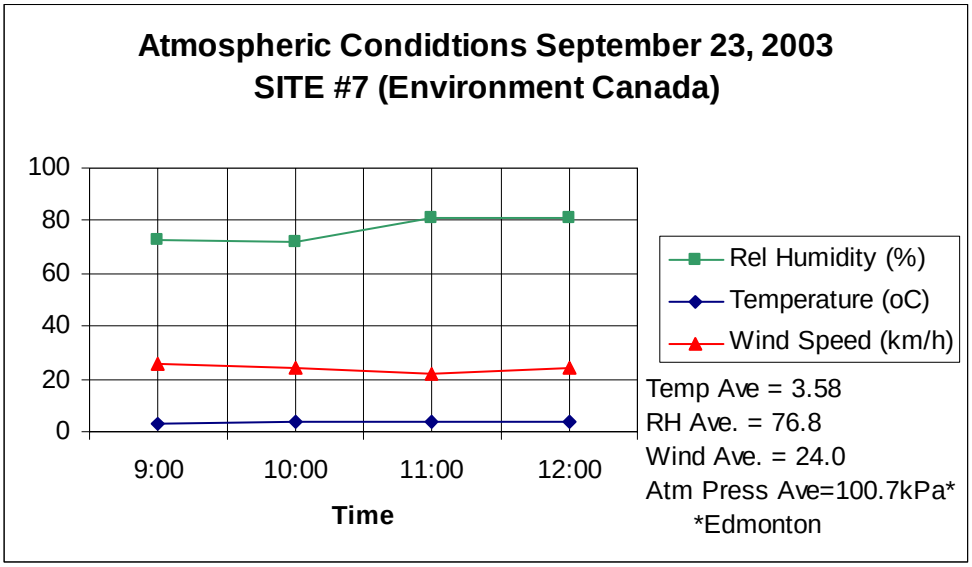
VOLUME SAMPLED*	1532.7 litres

* Corrected at 101.3kPa & 15º C

SAMPLING RATE	8.63 l/min (5.98 m/s)

FLARE GAS VELOCITY	6.4 m/s

WEATHER: overcast (~ 12.5 °C), wind (~ 15.6 km/h): data from Environment Canada (http://www.climate.weatheroffice.ec.gc.ca/advanceSearch/searchHistoricDataStations_e.html).



PORT DETAILS:

The probe was inserted directly on the 4” flare stack.

The valve was a 2 1/2" ball valve with 2" NPT thread reducing bushing.

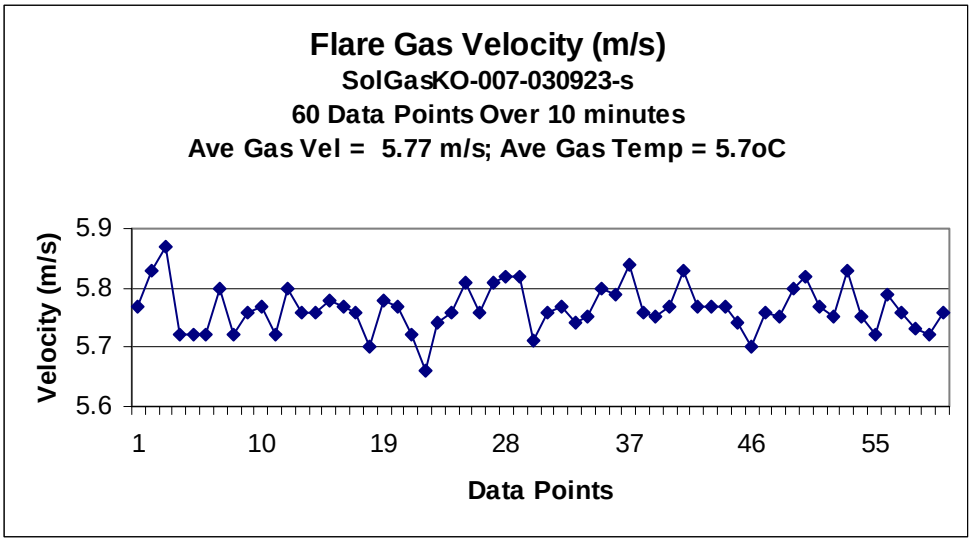
The probe was inserted in our 2" sleeve threaded onto the reducing bushing.

Probe-Sleeve sealing was ensured with 2 O-rings.

ACCESS PORT AND PROBE OVERVIEW

FLOW VELOCITY:

The gas stream velocity was steady throughout the test at 6.4 m/s.
The average sampling flow velocity was estimated around 5.77 m/s.
The following figure shows an example of flow velocity as measured during sampling. Data were saved on the data logger every 10 seconds for 10 minutes for a total of 60 data points.



SAMPLING DETAILS:

TIME (end)	Subsample	Gas Sampled (l)	Sampling Rate (l/min)	Sample Duration (min.)
10:13	#1	402.07	8.93	45
10:58	#2	338.00	7.51	45
11:43	#3	417.00	9.27	45
12:28	#4	395.86	8.80	45

Average Sampling rate: 8.63 l/min (5.98 m/s)

TEMPERATURES (start and end times): All in Deg. C

TIME	SOURCE	GAS METER	LIQUID KNOCK/OUT	SAMPLING APPARATUS
9:28	6.20	12.0	9.90	14.8
12:28	9.00	22.0	13.90	24.9

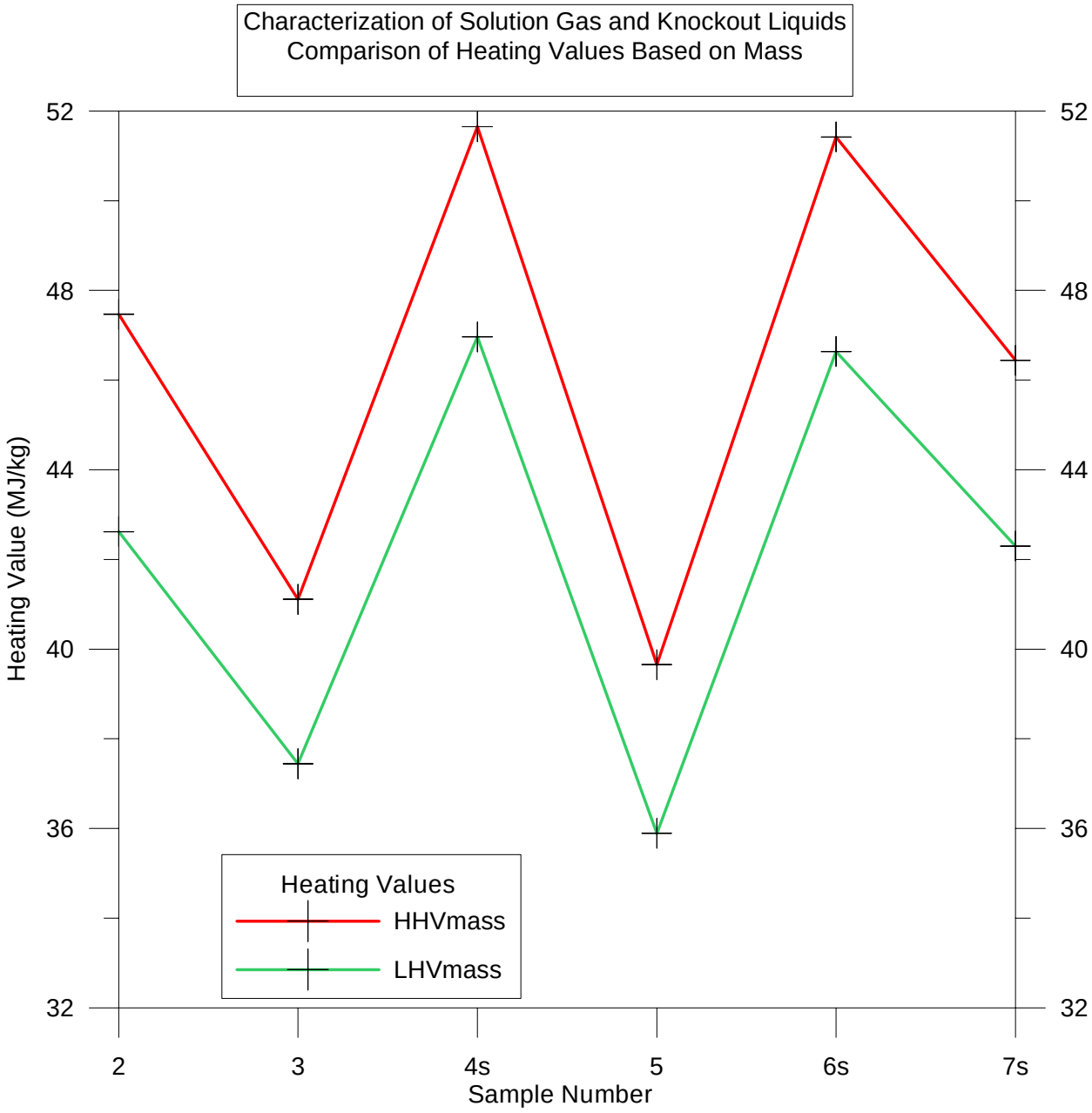
Average Gas Meter Temperature: 17 Deg. C

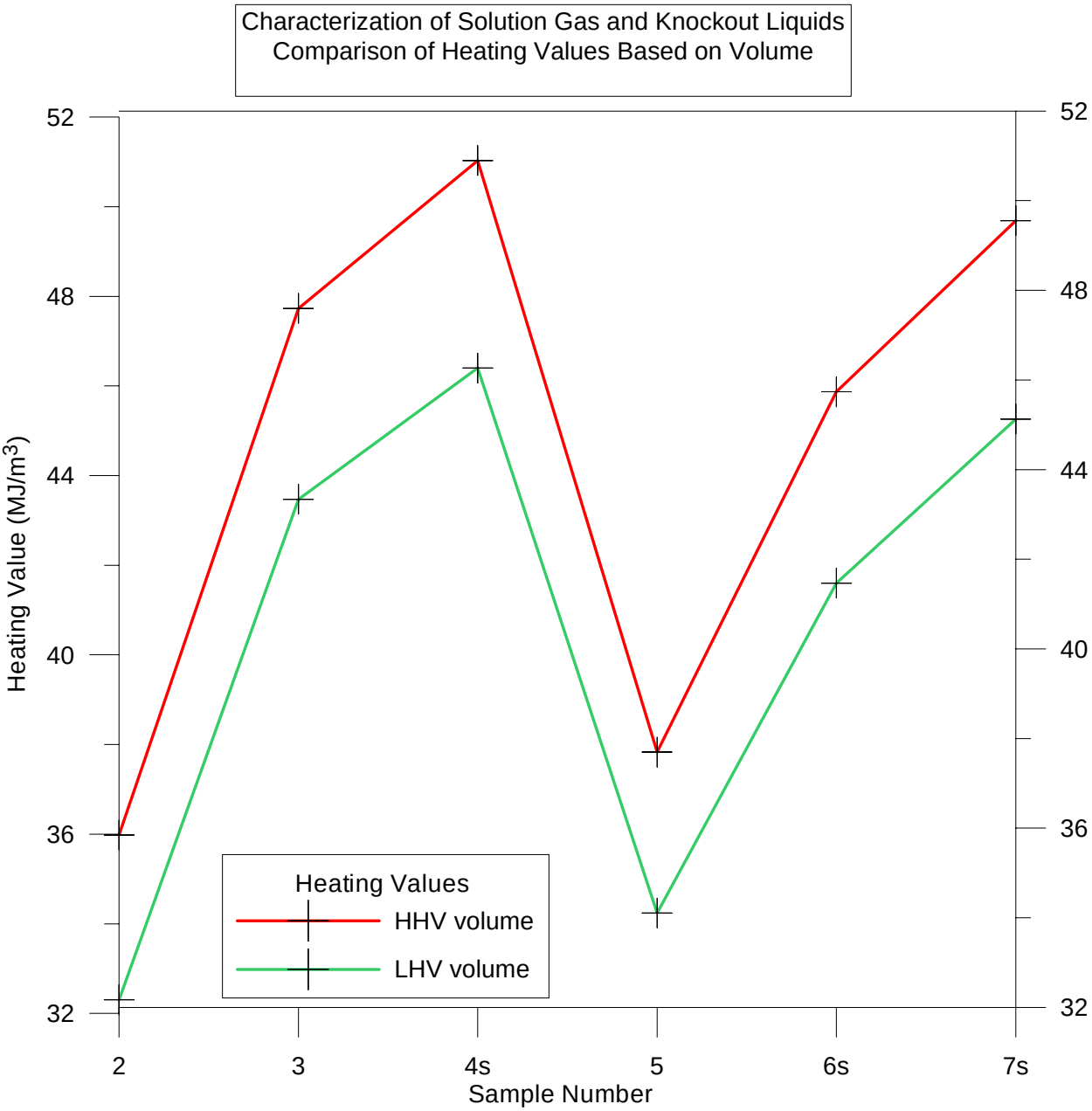
LIQUID PHASE:

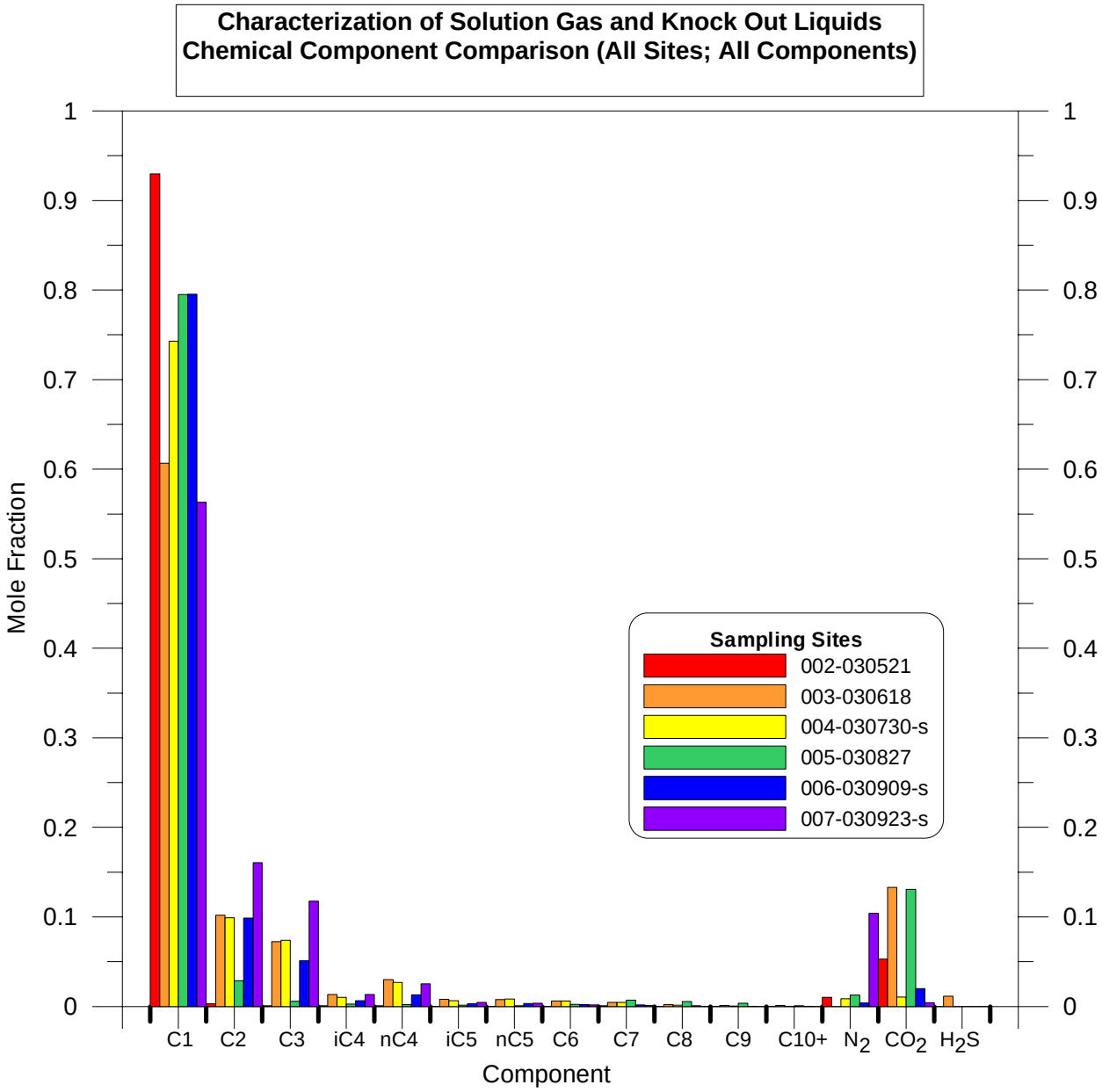
No liquid was collected.

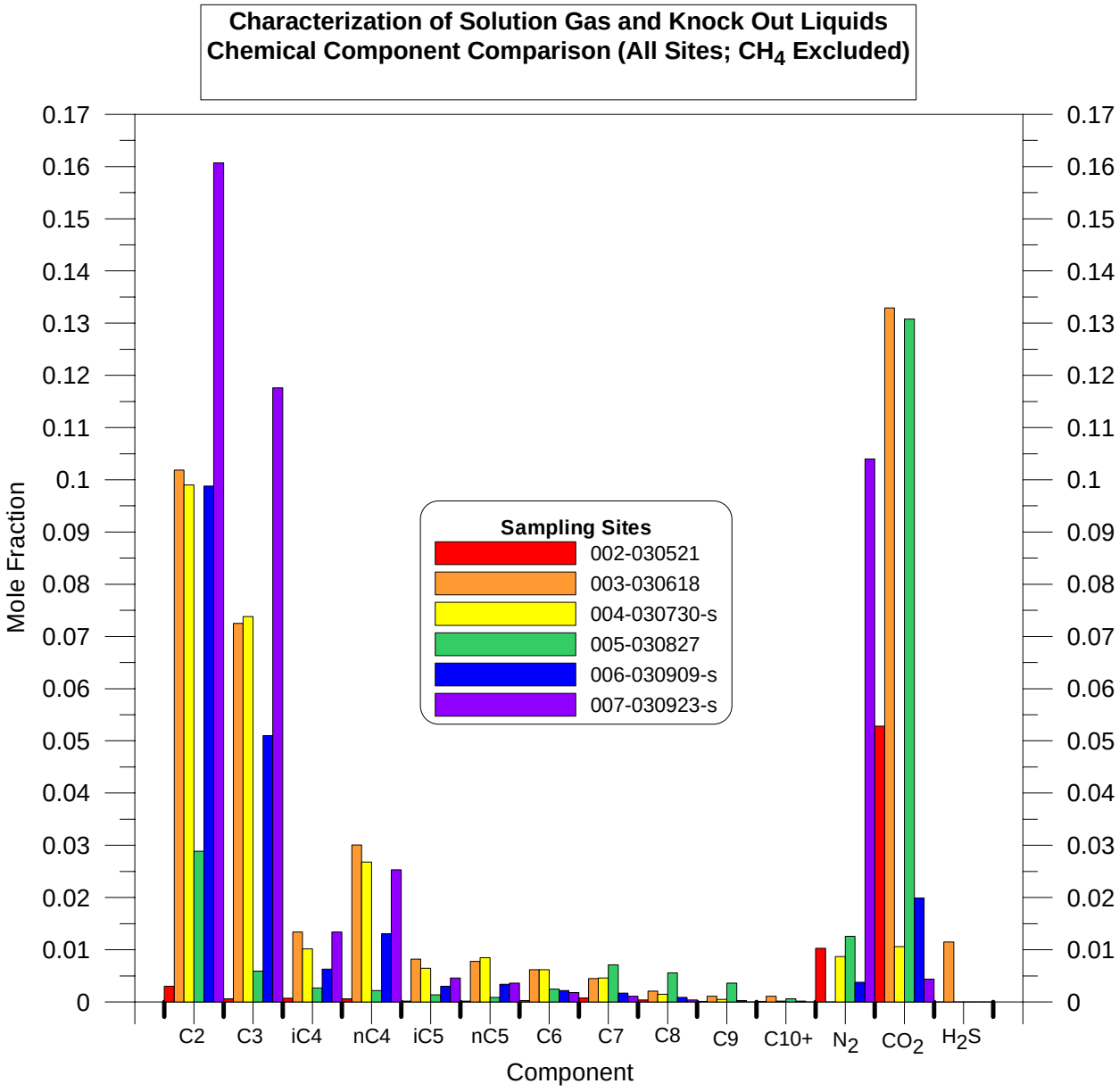
COMPARISON OF BATTERY SITE RESULTS

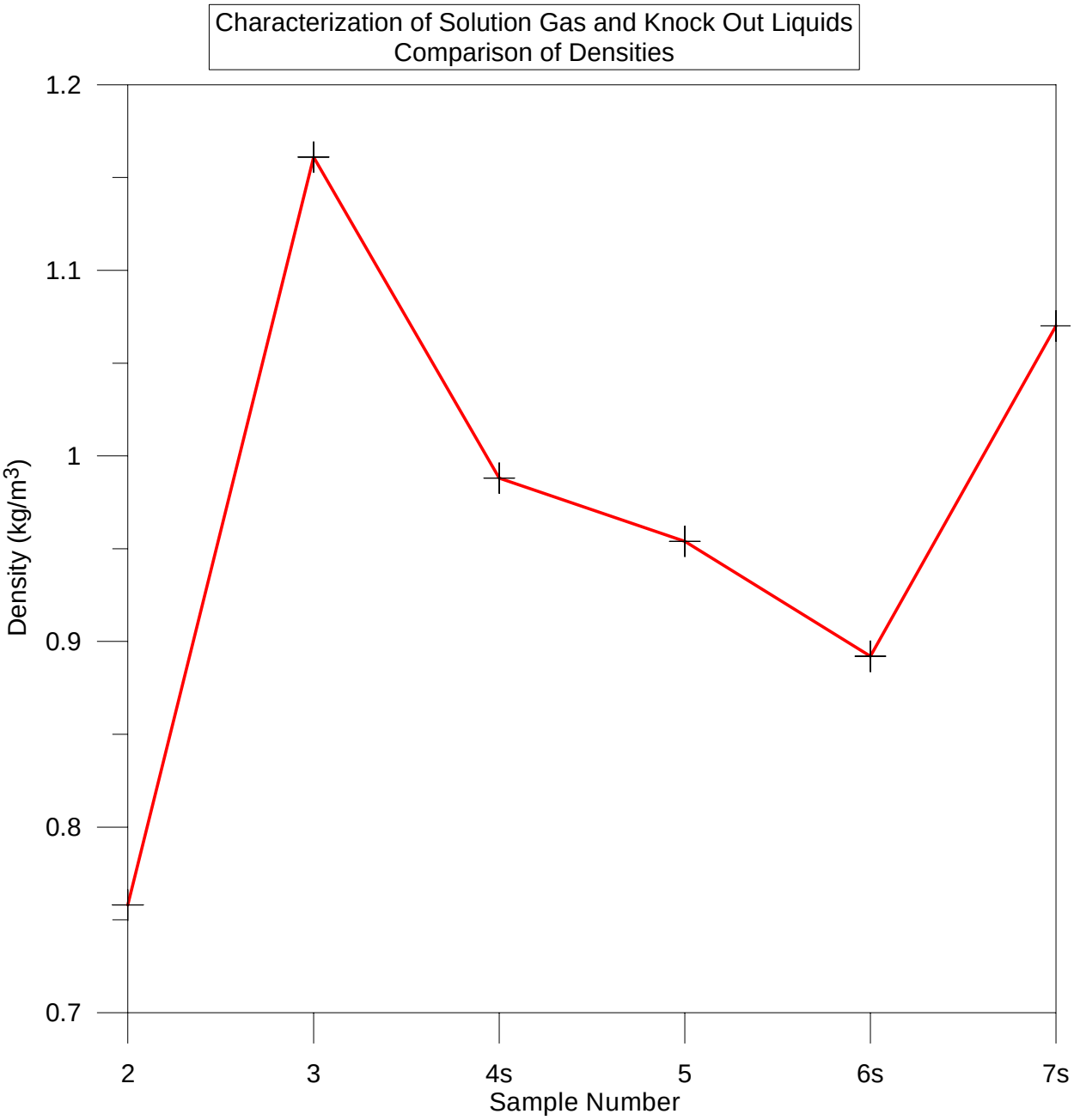
These graphs compare various results between battery sites sampled thus far.

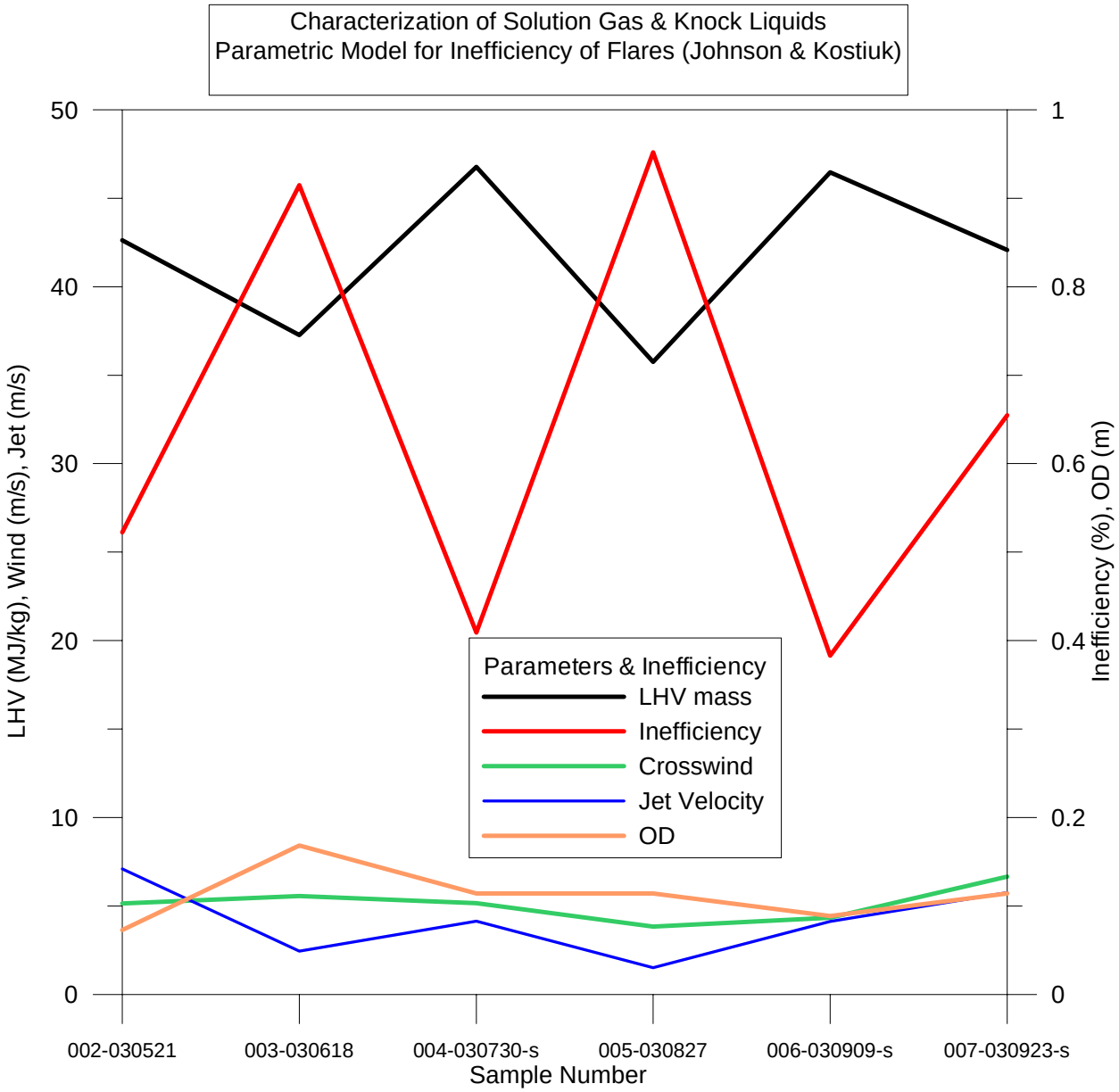


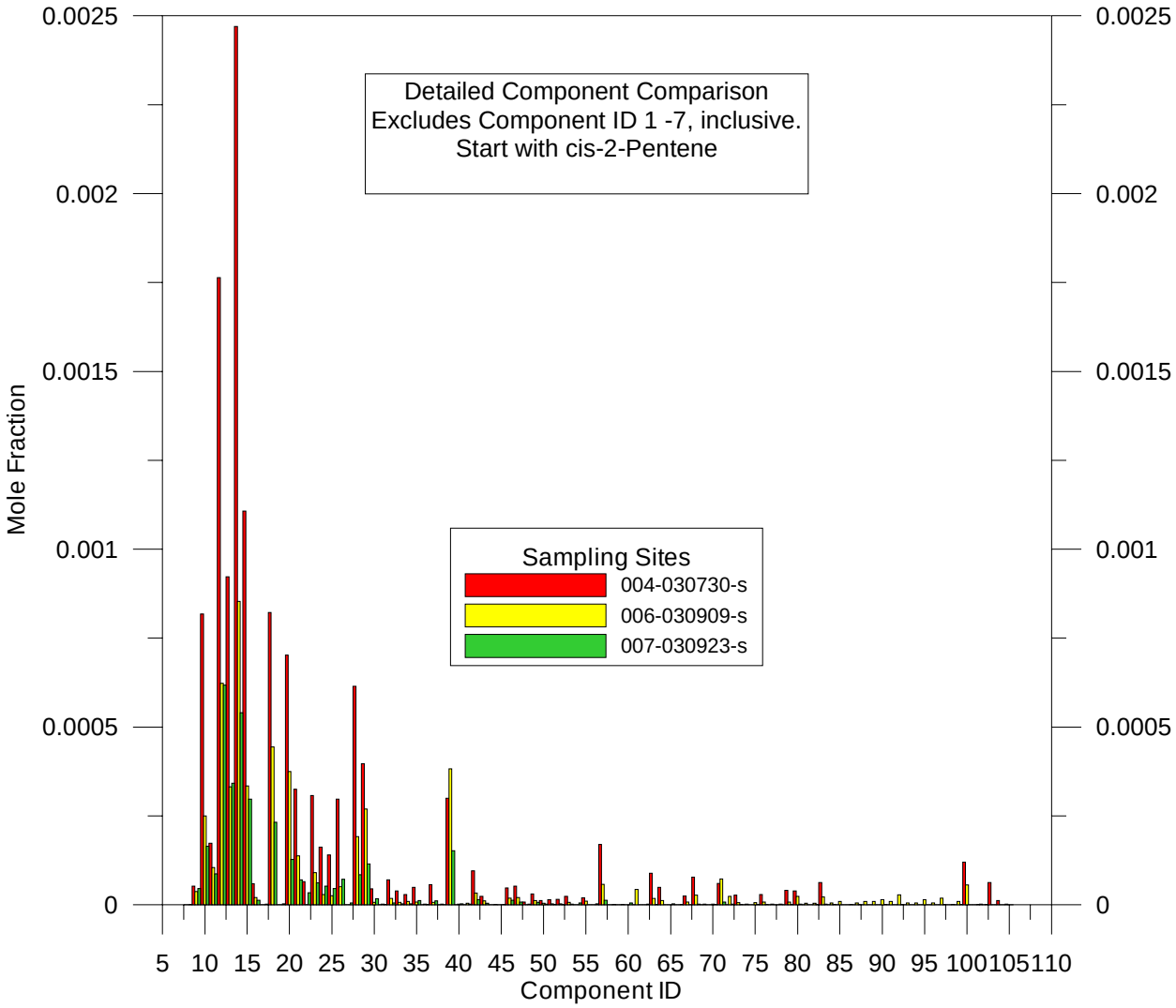

Characterization of Solution Gas and Knockout Liquids
Comparison of Heating Values Based on Volume
Heating Value (MJ/m3)
52
48
44
40
36
32
2
3
4s
5
6s
7s
Sample Number
Heating Values
HHV volume
LHV volume


Characterization of Solution Gas and Knock Out Liquids
Chemical Component Comparison (All Sites; All Components)
Mole Fraction
Component
C1
C2
C3
iC4
nC4
iC5
nC5
C6
C7
C8
C9
C10+
N2
CO2
H2S
Sampling Sites
002-030521
003-030618
004-030730-s
005-030827
006-030909-s
007-030923-s


Characterization of Solution Gas and Knock Out Liquids
Chemical Component Comparison (All Sites; CH_4 Excluded)
Mole Fraction
0.17
0.16
0.15
0.14
0.13
0.12
0.11
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Sampling Sites
002-030521
003-030618
004-030730-s
005-030827
006-030909-s
007-030923-s
C2
C3
iC4
nC4
iC5
nC5
C6
C7
C8
C9
C10+
N_2
CO_2
H_2S
Component


Characterization of Solution Gas and Knock Out Liquids
Comparison of Densities
1.2
1.1
1
0.9
0.8
0.7
Density (kg/m3)
2
3
4s
5
6s
7s
Sample Number


Characterization of Solution Gas & Knock Liquids
Parametric Model for Inefficiency of Flares (Johnson & Kostiuk)
LHV (MJ/kg), Wind (m/s), Jet (m/s)
Inefficiency (%), OD (m)
50
40
30
20
10
0
1
0.8
0.6
0.4
0.2
0
Parameters & Inefficiency
LHV mass
Inefficiency
Crosswind
Jet Velocity
OD
002-030521
003-030618
004-030730-s
005-030827
006-030909-s
007-030923-s
Sample Number


Detailed Component Comparison
Excludes Component ID 1 -7, inclusive.
Start with cis-2-Pentene
Sampling Sites
004-030730-s
006-030909-s
007-030923-s
Mole Fraction
0.0025
0.002
0.0015
0.001
0.0005
0
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100105110
Component ID

SGS ANALYSIS

The gas analysis was performed in the SGS lab in Point Tupper, Nova Scotia 3 days after the sample.

See Gas Analysis report for details.

SCHEMATIC OF BATTERY SITE

(Supplied by Kevin Morphy)