TECHNICAL REPORT

EPA Phase II Aggregate Site Report

Cost-Effective Directed Inspection and Maintenance Control Opportunities at Five Gas Processing Plants and Upstream Gathering Compressor Stations and Well Sites

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EXECUTIVE SUMMARY

A comprehensive measurement program has been conducted at five natural gas-processing plants in the United States to identify cost-effective opportunities for reducing natural gas losses due to fugitive equipment leaks and avoidable process inefficiencies or wastage. This program, referred to as Phase II, followed a Phase I program that surveyed four gas plants in 2000.

The second Phase study included upstream facilities such as well sites and gathering compressor stations in addition to the gas processing plants. The additional gas processing plants were selected to give a range of plant size, locations, throughput, plant age, and both sweet and sour gas facilities to ensure that the results represented the entire natural gas processing industry.

Raw natural gas is predominantly methane but may contain varying amounts of non-methane hydrocarbons (NMHC) and contaminants, such as hydrogen sulfide (H_2S), nitrogen (N_2), carbon dioxide (CO_2) and water vapor (H_2O). Natural gas losses to the atmosphere are direct emissions of these constituents. Natural gas losses into flare systems or excess fuel consumption result in atmospheric emissions of CO_2 and other combustion byproducts including unburned methane.

Here, cost effective opportunities to reduce natural gas losses are seen primarily as a sensible means of reducing methane and other greenhouse gas (GHG) emissions (predominantly CO_2), and to a lesser extent, NMHC emissions. All GHG emissions are expressed as CO_2-equivalent emissions (CO_2E) using a global warming potential of 21 for methane. A baseline assessment of the fugitive natural gas losses and target air pollutant emissions at each host facility is provided, and the potential savings and emission reductions from natural gas loss decreases are highlighted. Additionally, total hydrocarbon (THC) emission factors are presented for fugitive equipment leaks and the active natural gas-fueled process equipment surveyed.

All fieldwork was conducted during the first quarter 2004 and second quarter 2005. The work comprised a fugitive-emissions survey of equipment components in hydrocarbon gas service, measurement and characterization of flows into all key vent and flare systems, and limited performance testing of natural gas-fueled combustion equipment at three of the five surveyed sites. Emissions from selected pressure relief valves vented to the flare were measured at two sites. Residual flaring activities were also determined. Although not specifically targeted, any components in hydrocarbon-liquid or air service that were noticeably leaking were tagged and brought to the attention of site personnel. Complete component counts were prepared for the surveyed equipment.

The plants were also surveyed with an optical passive infrared camera designed specifically for leak detection. A comparison between leak detection methods is included in this second Phase report.

A total of 74,438 individual equipment components from five gas processing facilities, 12 well sites, and seven upstream gathering compressor stations were surveyed. Sufficient process information was collected to determine total annual emissions from the compiled measurement results. Additionally, specific emission-control opportunities were identified, and a preliminary cost-benefit analysis was performed to evaluate these opportunities. The analysis considered the estimated cost of repair and corresponding lifetime and the conserved gas value. Site personnel were solicited to provide input and assistance in identifying site-specific constraints and to help ensure that cost data were satisfactorily considered.

EMISSIONS INVENTORY OVERVIEW

Total atmospheric methane emissions from all sources at the combined sites are estimated at 8,071 tonnes per year. Corresponding GHG and NMHC emissions are estimated at 598,184 tonnes per year CO_2E and 3,625 tonnes per year, respectively. The majority of total methane emissions resulted from fugitive equipment leaks (55%). Incomplete combustion by natural gas-fuelled equipment and process venting are also noteworthy methane emissions sources (17% and 16%, respectively). The major GHG emissions sources are fuel consumption by compressor engines and process heaters (74%), fugitive equipment leaks (17%), process venting (5%), and flare/vent systems (3%). Fugitive equipment leaks are the primary NMHC emissions source (73%). In general, gathering compressor stations offered cost-effective opportunities with the majority of the methane emissions from fugitive leaks associated with leaking compressors. From the twelve wells surveyed, opportunities exist at well heads that have separators, tanks, and heater treaters.

NATURAL GAS LOSSES OVERVIEW

The value of all five sites natural gas losses - including direct atmospheric emissions, gas leakage into flare systems, and excess fuel consumption by process equipment - is estimated to be $8.4 million per year (an average of $1.7 million per year per plant). The *fugitive* emission opportunities totalled $2.9 million dollar or $580,000 per facility per year. The cost to survey and repair these leaks is approximately $ 74,200 per facility (i.e. survey cost for one site at $25,000 plus cost of repairs for leakers with positive net present value, averaged $49,200 per site).

These estimates do not include the cost of identifying and evaluating natural gas loss reduction opportunities; however, such costs are typically small compared to the net benefit obtained. For example, the current five site survey costs, when expressed in terms of the total number of components in gas service, were approximately $1.5 per component, which is more than the cost of conventional VOC LDAR programs. This per component cost may be reduced if a routine survey were to be implemented and maybe artificially high as a result of the R&D activities. Actual per-component costs vary between facilities and tend to increase with the operation complexity, facility remoteness, work condition severity, and the relative number of vents, combustion sources and control opportunities identified. The current study identified more than $3,200 in annual gross savings, or $3,000 in net savings (including after repair or control costs), per component for control opportunities having a less than a 1-year payback based on a gas value of $7.15/Mscf ($6.78/GJ). Considering opportunity identification costs reduces the net savings by only about 4%. If a value is assigned to the resulting GHG credits, work is done as a routine commercial service rather than as a study, and efforts are focused on the plant areas most likely to offer meaningful control opportunities, improved economics would be realized.

Overall, it is estimated that up to 96.6% of total fugitive natural gas losses are cost-effective to reduce with no net financial burden to surveyed sites. If the cost of natural gas increases, the number of components that are cost effective to repair will not increase significantly however, the saving realized will scale commensurate with the price increase. These reductions would result in emission reductions of 61% for methane, 17% for GHG CO_2E, and 67% for NMHC considering emissions from all sources. The relatively low impact on GHG CO_2E emissions is due to the significant contribution of CO_2 emissions from fuel consumption to total GHG emissions.

The main cost-effective control opportunities identified at the sites are:

- **Fugitive Equipment Leaks**:
  Approximately 2.2% of the equipment components (approximately 1,629 out of 74,438) in hydrocarbon service were determined to be leaking (i.e., had a screening value of 10,000 ppm or more) at the combined sites. Commensurate with the findings from the initial gas plant surveys, components in vibrational, high-use, and thermal-cycle gas services were the most leak prone. The majority of the identified natural gas losses from fugitive equipment leaks were attributed to a relatively small number of leaking components. Open-ended lines emissions were the greatest contributor to this source category, accounting for 32% of the total, followed by connectors (30%), compressor seals (20%), and block valves (15%). The remaining 3% were from pressure relief valves, regulators, orifice meters, control valves, and crank case vents.

  It is estimated that implementing all cost-effective equipment-repair or replacement opportunities identified would reduce natural gas losses from ***fugitive*** equipment leaks by 96.6% and result in gross annual cost savings of approximately $2.9 million (based on a gas value $7.15/Mscf or $6.78/GJ). This equates to an average gross annual savings of approximately $580,000 per site. Site-specific values ranged from $75,646 to $1.2 million. Lower losses and fewer loss-reduction opportunities would be expected at newer plants. Conversely, higher losses and more loss-reduction opportunities would likely be found at older and/or poorly maintained plants.

  Repairs to the 10 largest emitting cost-effective-to-repair components at each site (refer to Appendix I for a components list ranked by emission rate) would reduce natural gas losses by approximately 521 Mscfd, or 58%.

- **Flaring**:
  The five sites flare or main vent systems residual gas flows (i.e., flows excluding blowdown and emergency relief events) totalled 496 Mscfd. In several cases, the system flows were sufficient to potentially justify installing a vent– or flare-gas recovery unit. Alternatively, the residual gas flow source or sources (e.g., excess purge gas consumption and leaking pressure-relief devices, drains, and blowdown valves connected to the flare header) could be repaired. However, these sources are often difficult to isolate, usually require a major plant shutdown to fix, and are likely to reoccur. Installing economically feasible flare-gas recovery units would reduce surveyed plants GHG emission by approximately 16,609 tonnes CO_2E per year, and take less than a year to pay out.

- **Natural Gas-Fueled Process Equipment**:
  While several of the compressor engines tested would have benefited from tuning, most units proved to be operating efficiently (i.e., air-to-fuel ratios and flue gas combustibles concentrations were at or near manufacturers recommended values). This likely reflects the high attention level typically given to combustion equipment at continuously manned facilities such as those surveyed. Greater combustion efficiency improvement opportunities are believed to exist for tuning heaters and engines at unmanned field facilities. Total avoidable fuel consumption from servicing all economic-to-tune engines and heaters at the five sites is estimated to be 446 Mscfd, which equals GHG emission reductions of 13,100 tonnes CO_2E per year.

  The natural gas-fueled engines surveyed were all properly matched with the current process load requirements (i.e., the units were operating within the optimum portion of their performance curve). Notwithstanding this, situations may arise where engines are operated outside their performance curve optimum area (e.g., due to changes in original load requirements caused by production changes or initial equipment mismatching with process applications) causing significant excessive operating costs.

KEY FINDINGS

- The value of natural gas losses from all five facilities in the Phase II DI&M survey - including direct atmospheric emissions, gas leakage into flare systems, and excess fuel consumption by process equipment - is estimated to be $8.4 million per year (an average of $1.7 million per year per plant). The findings from these additional 5 plant surveys solidify the economic benefits of voluntarily adopting and initiating DI&M.

The table below summarizes the finding from the Phase II DI&M site surveys.

Table I - Summary of Phase II Plants Surveyed							
Site #	Type	Age	Component Count	*Fugitive* Gas Losses (Mscfd)	Annual Value of Lost Gas ($)	Gas Throughput (mMscfd)	% of Throughput
1	Sweet	6	22,290	271	$757,259	500	0.05
2	Sweet	28	12,330	23	$75,646	206	0.01
3	Sweet	39	18,353	117	$612,593	130	0.09
4	Sour	27	16,687	69	$193,978	45	0.15
5	Sour	57	4,778	423	$1,296,510	87	0.48
Average		31.4	14,887	903	$587,197[A]	193.6	0.16

[A] This value excludes sources from combustion, flare activities, well sites and storage tanks.

- The results show that facilities surveyed with more than 30 years of service have significantly higher methane emissions per volume gas throughput, and higher overall leak frequencies than facilities with less than 30 years of service. The facilities survey during this Phase of the program ranged from 6 to 57 years with an average of 30.4 years. Facilities processing sour gas have higher methane emissions per volume gas throughout and leak frequencies than facilities processing sweet gas streams. Statistical comparisons for surveyed sites on the effects of gas plant service years and process stream type were not attempted due to the limited number of sites surveyed. It is recommended that additional analyses, including results from the Phase I and other surveys, be conducted to develop statistically significant correlations of fugitive equipment leak rates with service years and process gas type.

- A targeted DI&M program aimed at proven opportunities can significantly reduce the time and resources required to identify and repair those leaks that represent the "low hanging fruit" within the facility. Components associated with vibration (i.e. compressors) and heat-cycle (i.e. mole sieve) services contributed 97% of the total fugitive equipment leaks. These results again emphasize that employing a targeted DI&M program would significantly reduce the cost of initiating a DI&M program. However, significant additional opportunities were discovered at each site that would have been overlooked if the scope was narrowed to only include these targeted sources.

- A Phase I test site was selected for retest in Phase II to determine changes in fugitive leaks characteristics. Process changes at this site resulted in thirty percent of the Phase I components being decommissioned. These process units were replaced prior to the Phase II survey. While fugitive emissions from the new process units components tested in Phase II were only 20% of the fugitive emissions from the decommissioned components tested in Phase I, the overall Phase II site level fugitive emissions were still 50% higher than in Phase I. This indicates higher Phase II fugitive emission leaks from 70% of components that were not replaced between Phases, and suggests that the facility DI&M program has not been effective at controlling fugitive equipment leaks at this site. In addition, a comparison of the average Phase I and Phase II emission factors by component type shows a very different distribution between Phase I and II sites.

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GLOSSARY

Blow-By	Gas from a piston cylinder that leaks past the piston rings into the crankcase.
Carbon Dioxide Equivalent (CO_2E) -	Carbon dioxide equivalent is an expression of the total emissions from all the greenhouse gases, based on the gases relative ability to trap heat in the atmosphere. Greenhouse gases (GHGs) are atmospheric compounds that trap heat in the atmosphere by absorbing long-wave radiation from the earth's surface while allowing the sun's energy to pass through. The most relevant GHGs for natural gas systems are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Global warming potentials (GWPs) were developed as a simple measure of the global warming effects of various greenhouse gases emissions relative to carbon dioxide emissions. The current practice (IPCC, 1996) is to use a 100-year time horizon for global warming potentials. Therefore, the GWPs used in this document are: $CO_2 = 1.0$, $CH_4 = 21.0$ and $N_2O = 310$. Greenhouse gases emissions are converted to carbon dioxide equivalent (CO_2E) emissions by multiplying the mass emissions of each gas by the appropriate global warming potential and summing the CO_2E emissions. CO_2E emissions are expressed in metric tonnes.
Centrifugal Compressor Seal Systems -	Centrifugal compressors generally require shaft-end seals between the compressor and bearing housings. Either face-contact oil-lubricated mechanical seals or oil-ring shaft seals, or dry-gas shaft seals are used. Seal leakage will tend to increase with wear between the seal and compressor shaft, operating pressure, and shaft rotational speed.
Combustion Efficiency -	The extent to which all input combustible material has been completely oxidized (i.e., to produce H_2O, CO_2 and SO_2). Complete combustion is often approached but is never actually achieved. The main factors that contribute to incomplete combustion are thermodynamic, kinetic, mass transfer and heat transfer limitations. In fuel rich systems, oxygen deficiency is also a factor.

Connectors - A connector is any flanged or threaded connection, or mechanical coupling, but excludes all welded or back-welded connections. If properly installed and maintained, a connector can provide essentially leak-free service for extended time periods. However, there are many factors that can cause leakage problems. Common leak causes include vibration, thermal stress and cycles, dirty or damaged contact surfaces, incorrect sealing material, improper tightening, misalignment, and external abuse.

Crank Case - The crank case on reciprocating engines and compressors houses the crank shaft and associated parts, and typically an oil supply to lubricate the crank shaft. Integral compressors have a single crank case because the engine and compressor share a common crank shaft. Non-integral compressors typically have two crank cases, one on the engine side and another on the compression side.

Destruction Efficiency - The extent to which a target substance present in the input combustibles has been destroyed (i.e., converted to intermediate, partially-oxidized, and fully-oxidized products of combustion). DE is typically expresses as a percentage: 100 * (in – out)/in.

Flare and vent systems - Venting and flaring are common disposal methods for gas processing plants waste gas. The stacks are designed to provide safe effluent dispersion. Flares are normally used where the waste gas contains odorous or toxic components (e.g., hydrogen sulfide). Otherwise, the gas is usually vented. Typically, separate flare/vent systems are used for high- and low-pressure waste gas streams.

Fugitive Emissions - Unintentional leaks from equipment components including, but not limited to, valves, flanges and other connections, pumps and compressors, pressure relief devices, process drains, open-ended valves, pump and compressor seals, system degassing vents, accumulator vessel vents, agitator seals, and access door seals. Fugitive sources tend to be continuous emitters and have low to moderate emission rates.

Gas Plant - A gas processing plant is a facility for extracting condensable hydrocarbons from natural gas and for upgrading the gas quality to market specifications (i.e., removing contaminants such as H_2O, H_2S and CO_2 and possibly adjusting the heating value).

Heat Rate -	The heat energy (based on the fuel net or lower heating value) which must be input to a combustion device to produce the rated power output. Heat rate is usually expressed in terms of net J/kW·h.
Integral Compressor	A reciprocating compressor that shares a common crankshaft and crankcase with the engine.
Methane Leak	Greater than 10,000 parts per million as measured by a dual-element hydrocarbon detector (i.e., catalytic-oxidation/thermal-conductivity).
Molecular Sieve	Absorbers composed of zeolites (aluminosilicate crystalline polymers) used to remove water vapor from natural gas. Zeolites are regenerated periodically by heating.
Long-Term Natural Gas Contract Price -	Historically, long-term contracts have been used by buyers to secure a natural gas supply and by sellers to reduce large reserve development risk. During the 1960s and 70s, these contracts were established for terms of up to 20 to 25 years and the gas price was determined by periodic negotiations. The recent trend is towards shorter contract durations, and most new long-term contracts index the gas price to spot market rates. Today, a typical long-term contract with a cogeneration plant is about 15 years. Given the sellers and buyers interest in risk management, there is also a trend towards greater standardization of long-term contracts to facilitate hedging activity in the financial or the over-the-counter markets.
Open-ended Valves and Lines -	An open-ended valve is any valve that releases process fluids directly to the atmosphere from valve seat leakage. The leakage may be caused by improper seating due to an obstruction or sludge accumulation, or a damaged or worn seat. An open-ended line is a pipe or tube segment attached to a leaking valve and that opens to the atmosphere. Few open-ended valves and lines are designed into process systems. However, actual numbers can be quite significant at some sites due to poor operating practices and various process modifications that may occur over time. Some common examples of open ended valves and lines are:

- scrubber, compressor-unit, station, and mainline blowdown valves;
- supply-gas valve for a gas-operated engine starter (i.e., where natural gas is the supply medium);
- instrument block valves where the instrument has been removed for repair or other reasons; and
- purge or sampling points.

Power Output - The net shaft power available from an engine after all losses and power take-offs (e.g., ignition-system power generators, cooling fans, turbo chargers and pumps for fuel, lubricating oil, and liquid coolant) have been subtracted. For heaters and boilers, it is the net heat transferred to a target process fluid or system.

Pressure-Relief or Safety Valves - Pressure relief or safety valves are used to protect process piping and vessels from being accidentally over-pressured. They are spring loaded so that they are fully closed when the upstream pressure is below the set point, and only open when the set point is exceeded. Relief valves open in proportion to the overpressure to provide modulated venting. Safety valves pop to a full-open position on activation.

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Gas that leaks from a pressure-relief valve may be detected at the vent pipe (or horn) end. Additionally, there normally is a monitoring port located on the bottom of the horn near the valve.

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Pump Seals - Positive displacement pumps are normally used for pumping hydrocarbon liquids at oil and gas facilities. Positive displacement pumps have a reciprocating piston, diaphragm or plunger, or else a rotary screw or gear.

Packing, with or without a sealant, is the simplest means of controlling leakage around the pump shaft. It may be used on both rotating and reciprocating pumps. Specially designed packing materials are available for different service types. The selected material is placed in a stuffing box and the packing gland is tightened to compress the packing around the shaft. All packings leak and generally require frequent gland tightening and periodic packing replacement.

Particulate contamination, overheating, seal wear, sliding seal leakage, and vibration will contribute to increased leakage rates over time.

Reciprocating Compressor Packing Systems - Packings are used on reciprocating compressors to control leakage around the piston rod on each cylinder. Conventional packing systems have always been prone to leaking a certain amount, even under the best of conditions. According to one manufacturer, leakage from within the cylinder or through any of the various vents will be on the order of 1.7 to 3.4 m^3/h under normal conditions and for most gases. However, these rates may increase rapidly with normal system wear and degradation.

Standard Reference Conditions - Most equipment manufacturers reference flow, concentration, and equipment performance data to ISO standard conditions of 15°C, 101.325 kPa, sea level and 0.0 % relative humidity.

Thermal Efficiency - The percentage or portion of input energy converted to useful work or heat output. For combustion equipment, typical convention is to express the input energy in terms of the net (lower) heating value of the fuel. This results in the following relation for thermal efficiency:

$$\eta = Thermal\ Efficiency = \frac{Useful\ Work/Heat\ Output}{Net\ Heat/Energy\ Input}\ x\ 100\%$$

Alternatively, thermal efficiency may be expressed in terms of energy losses as follows:

$$\eta = \left(1 - \frac{\Sigma Energy\ Losses}{Net\ Heat/Energy\ Input} \right) x\ 100\%$$

Thermal efficiency losses can occur due to the following factors:

- combustion exhaust heat losses (i.e., residual heat value in the exhaust gases);
- heat rejected to cooling jacket water and lubrication oil;
- radiation from equipment hot surfaces;
- air infiltration;
- incomplete combustion; and
- mechanical losses (e.g., friction losses and energy needed to run cooling fans and lubricating-oil pumps).

Total Hydrocarbons - All compounds containing at least one hydrogen atom and one carbon atom, with the exception of carbonates and bicarbonates.

Total Organic Compounds (TOC) - TOC comprises all VOCs plus all non-reactive organic compounds (i.e., methane, ethane, methylene chloride, methyl chloroform, many fluorocarbons, and certain classes of per fluorocarbons).

Valves - There are three main locations on a typical valve where leakage may occur: (1) from the valve body and around the valve stem, (2) around the end connections, or (3) past the valve seat. Leaks of the first type are referred to as valve leaks. Emissions from the end connections are classified as connector leaks. Leakage past the valve seat is only a potential emissions source if the valve, or any downstream piping, is open to the atmosphere. This is referred to as an open-ended valve or line.

The potential leak points on the different valve types are, as applicable: around the valve stem, body seals (e.g., where the bonnet bolts to the valve body, retainer connections), body fittings (e.g., grease nipples, bleed ports), packing guide, and any stem packing system monitoring ports. Typically, the most likely part to leak is the valve-stem packing.

The different valve types include gate, globe, butterfly, ball, and plug. The first two types are a rising-stem design and the rest are quarter-turn valves. Valves may either be equipped with a hand-wheel or lever for manual operations, or an actuator or motor for automated operation.

Vented Emissions -	Vented emissions are releases to the atmosphere by design or operational practice, and may occur on either a continuous or intermittent basis. The most common vented emissions causes or sources are gas-operated devices that use natural gas as the supply medium (e.g., compressor start motors, chemical injection and odorization pumps, instrument control loops, valve actuators, and some types of glycol circulation pumps), equipment blowdowns and purging activities, and glycol dehydrators still-column off-gas venting.
Volatile Organic Compounds (VOC) -	Any compound of carbon, excluding carbon monoxide, and carbon dioxide, which participates in atmospheric chemical reactions. This excludes methane, ethane, methylene chloride, methyl chloroform, many fluorocarbons, and certain classes of per fluorocarbons.

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1 INTRODUCTION

An intensive fugitive emissions screening and measurement program was conducted during the first quarter 2004 and second quarter 2005 at five gas processing facilities in the USA. The selected facilities were of various ages, types, and throughputs and were evaluated with a strong emphasis on identifying and quantifying natural gas losses from leaking equipment components in heat-cycle and vibration services. The facilities included sweet and sour gas processing, and a variety of processes including compression, separation, storage, and flare systems.

The study's primary objective was to demonstrate the cost-effectiveness of conducting a comprehensive leak detection and repair (LDAR) program at domestic gas production and processing facilities using HiFlow™ Sampler technology. Field measurements also included an assessment of emissions from continuous vents, combustion equipment, and flare systems and natural gas-fuelled equipment diagnostic checks. Such efforts are employed to achieve sensible and verifiable reductions in methane, GHG, and NMHC emissions, while providing industry with potentially noteworthy emissions reduction opportunities with commensurate financial incentives. These opportunities were presented to surveyed plants in the plant level reports. Based on the compiled test results, the greatest opportunities for cost-effective reduction of natural gas losses are from the control of leaking equipment components and leakage of process gas into vent and flare systems. Therefore, the report emphasizes fugitive leak opportunities.

Background information, on key differences between the conventional EPA Method 21 approach to leak detection and repair and the approach used here, is provided in Section 2. A more detailed description of the current approach and other measurement techniques employed plus an overview of the basic assessment methodology are presented in Section 3. Section 3 also delineates the economic criteria used to evaluate the identified emission control opportunities.

The measurement program results are presented in Section 4. These results include an overview of the identified control opportunities, measured emissions and natural gas loss inventories, average emission factors, and leak statistics. The study conclusions and recommendations are presented in Section 5, and cited references are listed in Section 6. Detailed listings of all the identified equipment leaks are provided in Appendices I and II, ranked by emission rate and payout period, respectively. The following information is provided for each component: Site No., Tag No., Process Unit, Component Description, Emission Rate (10^3 m^3/yr), Estimated Repair Costs ($), Net Present Value of Repair ($), CO_2E Emissions (tonne/yr), and Repair Payback Period (yr).

Appendix III presents detailed accounts of the combustion analysis and efficiency testing results for each tested unit. Average equipment component schedules by process unit type are provided in Appendix IV. The financial considerations and assumptions applied are summarized in Appendix V while the assumed component repair costs and mean repair lives are provided in Appendix VI. Physical Acoustics V-Pac measurements are detailed in Appendix VII.

2 BACKGROUND

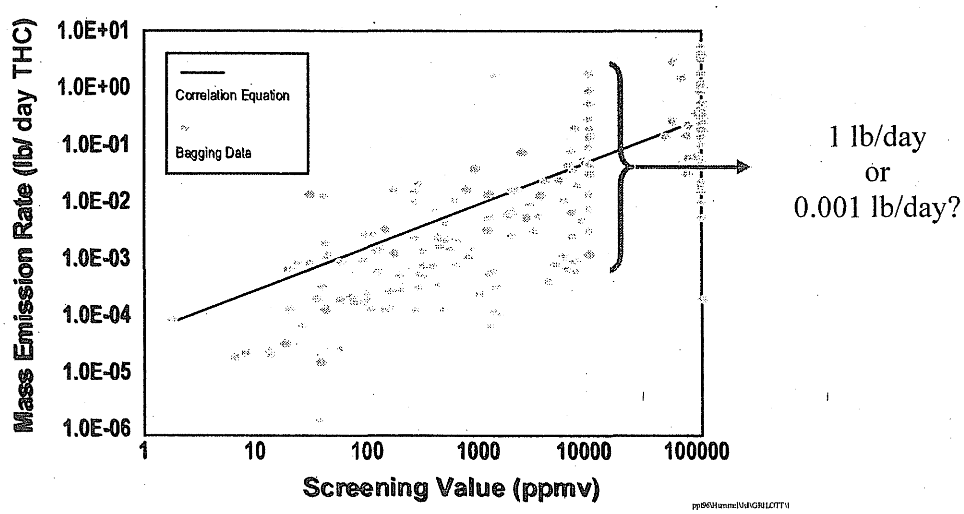
Under the settlement terms of a recent Consent Decree, deadlines are established for EPA to review and, if appropriate, revise the NSPS standards for Subparts J, VV and GGG, 40 CFR 60.100–109, 60.480–498, 60.590–593. The New Source Performance Standards in 40 CFR Part 60 KKK (back reference VV) provides the regulatory requirements for conducting a leak detection and repair (LDAR) program for the onshore natural gas processing industry. This standard is directed at controlling/reducing volatile organic compound (VOC) emissions and specifically excludes methane and ethane. Therefore, gas-processing facilities have typically only included the light liquid and refrigeration areas in leak detection programs. Subsequently, very little information pertaining to potential leakage from the remainder of the facility (i.e. non-regulated) was available. The primary project objectives were to evaluate leak potentials and the cost-effectiveness of implementing LDAR programs at natural gas processing facilities.

Most natural gas industry LDAR programs rely on U.S. EPA Method 21. Depending upon the leak screening instrument detector, the concentration of either total hydrocarbons (THC) or VOCs in the air from a leaking component is measured, and then the leak rate is estimated using a correlation equation or measured using the bag and sample procedure. In a conventional LDAR program for fugitive emissions control, U.S. EPA's Method 21 is utilized to screen the facility for leaks at a prescribed frequency (e.g. quarterly, bi-annually or annually). All components that screen above a given threshold (typically 10,000 parts per million) are to be repaired.

There are a numerous shortcomings with the Method 21 approach. The uncertainties in emissions estimates calculated using the correlation equation are very high. Additionally, the correlation equations only go to screening concentrations of 10,000 or 100,000 parts per million – any leak above these screening concentrations has the same estimated leak rate (known as a "pegged source" emission factor). Figure 1 shows the correlation equation and screening concentration values measured using Method 21 plotted against the leak rate measured with the bag and sample procedure. The data scatter is about ± two orders of magnitude. The bag and sample procedure directly measures leak rates; however, is very time intensive and expensive and the correlation equation approach is therefore used for most large scale LDAR programs. Data collected in Phase 1 showed that 65% of the natural gas facilities fugitive components that screened above 10,000 parts per million are cost-effective to repair. Consequently, by repairing all components that screen above 10,000 parts per million per Method 21, resources are wasted by repairing components – 35% of the total based on the Phase I results – whose repair costs exceed the value of gas saved. Another shortcoming of the conventional Method 21 approach is that it does not accurately measure either the facility baseline emissions or the emissions reduction (error is ± 300%). Because the emissions reduction cannot be accurately determined, the benefits of implementing an LDAR program cannot be evaluated.

The HiFlow™ Sampler, described in Section 3.1.2, quickly and accurately quantifies fugitive emissions leak rates and has significantly reduced natural gas plants LDAR programs costs. Cost-effective repairs, those with repair costs less than the saved gas value, can be identified and completed while non cost-effective repairs are not performed and maintenance resources are optimized. The Phase 1 data showed that 80 to 90 % of facility emissions are often emitted from a small fraction of the leaks; thus, significant emissions reductions can be achieved by repairing a few big leakers. In addition, a HiFlow™ Sampler LDAR program accurately measures the facility baseline emissions and the emissions reduction can be accurately determined. Therefore, the LDAR program implementation benefits can be evaluated.

Figure 1 Leak Rate versus Concentration



The primary objective of the overall study is to assess baseline methane (CH_4) emissions at natural gas processing and production facilities, and delineate and quantify the extent of cost-effective opportunities for reducing these emissions. A secondary objective is to evaluate the potential for cost-effective reduction of other GHG emissions (primarily CO_2) through process efficiency gains, and to establish a Best Management Practice for conducting DI&M programs.

Primary sources of methane emissions include, leakage, venting, storage losses, incomplete combustion (fuel use and flaring). Other methane losses includes, increased fuel use due to avoidable inefficiencies, thermal efficiency of fired equipment, compression efficiency, tail gas incinerators, electric power generation, and horsepower mismatch to required work.

Phase II addressed data gaps identified during the Phase I study and improved the overall statistical significance of the Phase I study for system wide extrapolation of results and serves as the basis for developing an industry specific best management practices guidance document.

Phase II provided the following:

- An increased number and type of gas processing facilities and components within the current database giving an improved statistical basis for extrapolation of the results system-wide.
- An indication of the effectiveness of repairs to the major leakers at a Phase I facility and the increases in leakage over time at gas plants.
- An initial indication of CH_4 and GHG emission reduction opportunities at gas production facilities upstream of the gas processing plant (e.g., gas-gathering systems including compression and well-site facilities).

Although the primary goal of Phase II was to expand the results of the prior Phase I DI&M study through broader industry participation and an increased emissions database, a secondary goal was to assess and integrate a suite of tools for improving survey efficiency. The scope of work and project approach for the second Phase was consistent with the Phase I study and allows for direct comparison with the previous results.

3 METHODOLOGY

This section describes the methodology used by the study team to identify and evaluate cost-effective emission-reduction opportunities at the gas processing facilities. The different measurement techniques considered for each primary source type are delineated.

The five selected test facilities were chosen to provide a representative cross section of gas plant ages with significant on-site compression since these types of facilities were expected to offer the greatest opportunities for cost-effective reduction of natural gas losses. As shown in Table 1, three sweet and two sour gas processing plants were selected. These plants ranged from 6 to 57 years in age, for an average age of 31, and all of them have compression facilities and mole sieve dehydration units. In comparison, the average age of gas processing facilities in the United States is estimated at 26 years.

Table 1. Summary of Surveyed Plants

Site #	Type	Age	Component Count	Gas Throughput (MMscfd)
1	Sweet	6	22,290	500
2	Sweet	28	12,330	206
3	Sweet	39	18,353	130
4	Sour	27	16,687	45
5	Sour	57	4,778	87
Average		31.4	14,887	193.6

The component counts presented in Table 1 above include components less than 0.5" nominal pipe size. Overall, 14.5% of these component counts are components less than 0.5" nominal pipe size.

3.1 Emissions Survey

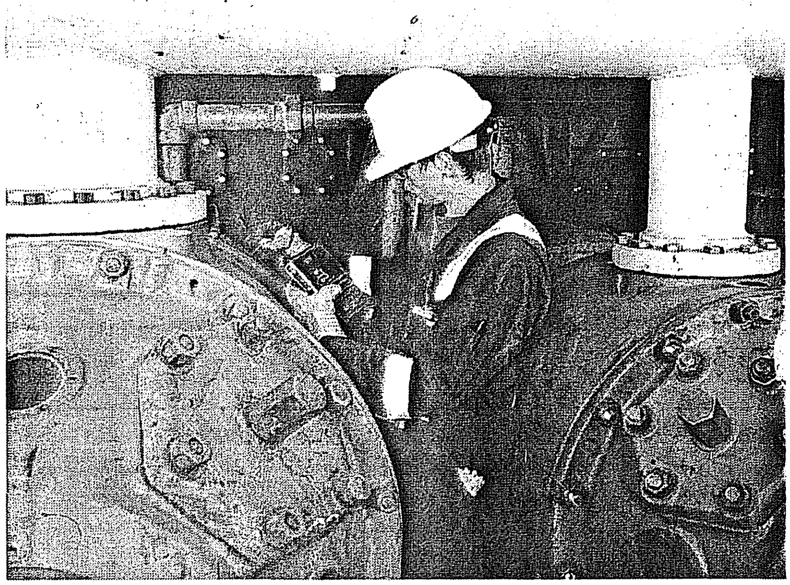
The site surveys included all or some of the following elements, as applicable:

- screening equipment components to detect leaks;
- measuring leaking equipment components (i.e., leakers) emission rates;
- measuring continuous vents emissions and emergency vents residual flows during passive periods;
- counting the surveyed equipment components;
- measuring residual flare-gas rates;
- performance testing natural gas-fueled combustion equipment;
- performance testing of compressors (newly added for Phase II);
- sampling process and waste streams;
- determining site-specific average emission factors for fugitive equipment leaks; and
- conducting an identified control opportunities cost-benefit analysis.

3.1.1 Component Screening

Equipment components on most process-, fuel- and waste-gas systems were screened for leaks. Components types surveyed included flanged and threaded connections (i.e., connectors), valves, pressure-relief devices, open-ended lines, blowdown vents (i.e., during passive periods), instrument fittings, regulator and actuator diaphragms, compressor seals, engine and compressor crankcase vents (see Figure 2), sewer drains, sump, drain tank vents and tank hatch seals.

Figure 2 Survey Team Using Gas Detector to Quantify Concentration and Screen Compressor Leaks



Components in light-liquid service generally were not screened since the program focus was natural gas losses. Furthermore, light-liquid service components do not contribute significantly to total hydrocarbon losses at gas processing plants due to their low average leak rates (U.S. EPA, 1995) and relative numbers. Leak detection (or screening) was conducted using bubble tests with soap solution, portable hydrocarbon gas detectors (Bascom-Turner Gas Sentry CGI-201 and CGI-211 and a GMI Gas Surveyor3) and an acoustic leak detector (SDT International, SDT-120).

Bubble tests, shown in Figure 3, were performed on the majority of components (including pipe threads, tubing connections, and valves) because it is usually the fastest screening technique. Components that could not be screened using bubble tests included any in high-temperature service, certain flanged connections and open-ended lines. These were screened using the gas detectors. Component determined to be leaking by the bubble tests were then screened using a hydrocarbon vapor analyzer. Hydrocarbon analyzer screening values of 10,000 parts per million or greater defined components as leaking or "leakers."