Appendix H: Air Quality (Task 5.3.6)
H.7 Flaring Mitigation Field Test - ORC Generator

HARC-EFD
Final Report

Subcontract #: EFDTIP2-TIP220
EFD Field Trial Project Overview:

Flare Gas Reduction Trial Using an Organic Rankine Cycle Generator

January 11, 2016

Final Report
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"Flare Gas Reduction Trial Using an Organic Rankine Cycle Generator"

HARC subcontract number: EFDTIP2-TIP220

Offeror: Gulf Coast Green Energy


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ABSTRACT
As part of the EFD-TIP effort, the Environmentally Friendly (EFD) Team identified technology from
**RPSEA Contract 08123-10 - Electrical Power Generation from Produced Water: Field Demonstration of Ways to Reduce Operating Costs of Small Producers, - April 2012**, that is applicable to a field trial. RPSEA 08123-10 successfully demonstrated produced water-to-power and the ability of Gulf Coast Green Energy (GCGE) to produce electricity from the waste heat in the produced water using the ElectraTherm Green Machine organic rankine cycle (ORC) waste heat generator.

Because of the successful GCGE produced water-to-power project, EFD as part of the EFD-TIP effort allocated funds for the Trial to Gulf Coast Green Energy (GCGE) to use the technology in a new application. The application uses flare gas to fuel a low emission hot water boiler which then supplied the ORC with the necessary thermal units to generate power for on-site operations.

The goals of this project were to reduce Oil and Gas operators’ flaring, generate power for on-site operations, maintain/increase productivity, increase energy efficiency, reduce environmental impacts of flaring, and create a more favorable public perception.

The overall objective was to identify and demonstrate a technology that uses gas for a beneficial use (electricity production) that would otherwise be flared. The electricity would reduce field operating costs and minimize the environmental impact by converting the flare gas to low emissions electricity.

Introduction
Gulf Coast Green Energy (GCGE), located southwest of Houston, Texas in Bay City, specializes in selling and installing waste heat-to-power technologies for internal combustion engine, O&G flare gas reduction, geothermal, and industrial applications. GCGE is a distributor for the ElectraTherm, Inc. small scale on-site Power+ Generator waste heat to power generator which uses wasted heat to create fuel free and emission free electricity which can be used on site or for transmission off site for field operations. GCGE also researches new and innovative applications for the ElectraTherm technology and has completed successful demonstration projects that have lead the way to practical and mainstream applications that provide economical fuel and emission free power.
Hess Corporation is a leading producer with a premier acreage position in North Dakota’s Bakken shale formation with a commitment to increasing productivity through its use of lean manufacturing processes. Because of Hess’ commitment to reducing energy use and limiting emissions, GCGE requested that Hess participate in this flare and emission reduction Trial. Hess agreed to host the Trial on a Hess well pad in North Dakota. The U.S. EPA and the State of North Dakota have strict regulations which require reduced flaring. Additionally, North Dakota regulations require that flare gas must be used for a “beneficial use” (see N.D. flare reduction mandates in Attachment 1, P.24-27) The Trial System demonstrated specific positive results by providing a beneficial use (power production) for gas that would otherwise have been flared.

The field trial successfully integrated into the well production process a “System” which included the combination of the ElectraTherm Power+™ Generator Series 4400 FL Organic Rankine Cycle (ORC) and a Cleaver-Brooks 150 H.P. low emission (30 ppm NOx) hot water boiler (the System) to accomplish the goal of reducing NOx, VOC, and CO emissions at existing flares while concurrently using the thermal energy contained in the natural gas flare for a beneficial use to create distributed, operator-free electricity within an economically viable, mobile, and repeatable package. The System provides attractive economics for the owner of the flare while providing definitive on-site and local environmental benefits associated with the reduced emissions from the System compared to traditional gas flaring (See Attachment 3 for the Texas A&M emissions comparison study results). Additionally, the System provides the benefit of distributed electrical production.

GCGE contracted with the Houston Advanced Research Center (HARC) and HARC’s Environmentally Friendly Drilling Systems (EFD) for the demonstration. Funding for the project was provided to HARC via a grant from the Research Partnership to Secure Energy for America (RPSEA) and GCGE.

Mr. Satish Ravendran, P.E. with, HARC was the principal investigator for HARC and GCGE’s Loy Sneary, CEO was the Contractor and Project Manager for this 90 day Trial. The industry partners are: Hess Corporation and ElectraTherm, Inc. Texas A&M University’s Institute of Renewable Natural Resources (IRNR) provided third party verification and conducted on-site research as part of an emissions research study for comparing emissions from Gulf Coast Green Energy’s (GCGE) ElectraTherm Power+™ Generator (Power+) System boiler with the emissions from open flaring. This field Trial required collaborative efforts by Gulf Coast Green Energy, ElectraTherm, and Hess Corp.
to identify and select the optimum oil and gas flare location. Gulf Coast Green Energy installed operated, and maintained all equipment in partnership with ElectraTherm’s engineering Team and assistance from Hess engineering and field personnel.

An oil well pad located in the Bakken shale play in North Dakota and owned by Hess Corp. was the site of the field Trial. Final selection was based on a site with access to the power grid and the appropriate amount of flared gas for the flare reduction System. The power generated by the System was base load (24/7) and was contributed to Hess Corp. for use to power on-site operations during the Trial.

Background

Statement of the Problem
In several states in the U.S. the exploration and production of oil and gas has led to increased production of natural gas which is flared where there are no existing pipelines and other infrastructure in place to deliver the gas for processing and distribution. In North Dakota wells flare up to 30% of the gas produced. The North Dakota Industrial Commission, Department of Mineral Resources, Oil and Gas Division is charged by the Legislature with regulating the amount of flared gas (see Attachment A, P.24-27). Currently state flaring caps requires companies to capture 77% of total gas and use it for a beneficial use by April, 2016; then 85% by November 2016; and 91% within five years. To meet these requirements gas companies are actively seeking viable/economical alternative solutions to reduce flaring.

The Challenge
There is a significant challenge in using flare gas for a beneficial use where current infrastructure does not allow for the gas to be transported for processing and distributed for sale. This project was designed to demonstrate that generating low emission power for on-site operations is a valuable, untapped resource that can be used to make O&G producers more efficient, competitive and profitable. Gulf Coast Green Energy (GCGE) installed the ElectraTherm, Inc. Power+ Generator together with a low emission hot water boiler (30 ppm NOx) on a producing Hess Inc. well pad which is flaring gas due to lack of pipe line infrastructure.
Current Technologies
Organic Rankine Cycle (ORC) generators create pressure by boiling various refrigerants/chemical working fluids into a high pressure gas. The gas then expands in a one way system and turns an expander or high speed turbine, which then drives a generator that generates electricity.

This trial used hot water from a hot water boiler which burns the flare gas to deliver the necessary thermal units to operate the ORC. Typically gas that is flared in the O&G industry declines relatively quickly. Historically, ORC’s incorporating turbo-expanders or turbines have not been commercially viable in sizes less than 1MW. These ORC systems are in the 250 KWh-1 MW range and require large hot water flow rates of approximately 1,000 gpm +.

As the flare gas volume declines it becomes increasingly difficult for these large ORC’s to produce maximum power. However, one technology uses a patented, robust, low-cost twin screw expander which requires much less water volume than the larger ORC’s. The ElectraTherm Power+™ Generator is capable of generating between 35 kWh and 110 kWh with hot water flows of 350 GPM and less. Because flare gas volume typically declines and because many wells only flare small amounts of gas, a smaller scale ORC which is easily transported and installed is a preferable solution when ORC’s are considered. Smaller scale ORC’s have the advantage of using multiple ORC’s when the well is flaring its maximum volume of gas. Then as the wells gas declines, these ORC’s can be moved to new locations while the remaining ORC’s are left to make a beneficial use of the gas. This solution is particularly attractive when the ORC is easily installed and transported.

Internal combustion engines and turbines connected to generators can also be fueled by the flare gas and can deliver power for on-site operations. However, both of these solutions create emissions which when added to existing well pad emissions may cause emissions permitting complications. These two solutions also require additional equipment to treat raw flare gas prior to combustion and require a strict maintenance schedule.

Because there is such a wide variation in the volume of gas flared and because a scalable ORC which can quickly be moved from well to well is preferable, the ElectraTherm Power+ Generator flare gas system was selected for this Trial. Additionally the Power+ Generator system does not require treating raw flare gas and requires approximately 1-2 man hours/week to maintain.

Another reason GCGE demonstrated the Power+ Generator System was its size and portability. It is skid mounted and can be moved with a forklift or small crane, making it easy and quick to install. It has a minimal footprint of 400 sq’ for the Power+ Generator and 400 Sq’ for the boiler equipment. This was important because of the speed and efficiency at which the O&G industry operates. Future deployments will require even less installation time and costs when the units are mounted and left on the trailers which transport them. This was a key “Lessons Learned” issue because in the future the cost and
coordination of lifting equipment will not be necessary. The trailer mounted configuration is currently being designed.

**How It Works**
Gas which was previously being flared is delivered from GTUIT gas treating equipment (see [www.gtuit.com](http://www.gtuit.com)) by means of a slip stream and directed to the low emissions boiler burner (30 ppm NOx) using safety approved hose. The boiler is a hot water boiler and not a steam boiler so no licensed operator or special operations training is necessary.

![Figure 2 & 3: GTUIT gas treating equipment](image)

The hot water is then delivered to the Power+ Generator and enters a heat exchanger where the hot water is heated and pressurizes the working fluid. The working fluid for this Trial is Honeywell’s R-245 FA, which is an EPA-approved, non-hazardous, non-toxic and non-flammable fluid. The high pressure vapor drives the twin-screw expander which is connected to an Induction Generator (the power block) to create electricity.

The patented twin-screw expander is unique in its configuration, lubrication, and specifications; but is based on reliable, proven compressor technology. The robust screw allows the admittance of wet vapor through the expander, therefore allowing access to lower temperature resources. A patented process and lubrication scheme simplifies and eliminates lubrication reservoirs, oil coolers, pumps, lines and filters; creating a simple, robust, efficient system with fewer parasitic loads.

After the working fluid expands across the twin screw expander to spin the generator, the low pressure vapor must be condensed to a liquid to begin the cycle again. Various methods of condensing can be utilized; a cooling tower, a direct air cooled condenser, or even ground water has been used. The condensing side of the ORC for this demonstration utilized a closed liquid loop radiator eliminating the extensive amount of fresh water usage and maintenance expenses associated with operating a cooling
tower. The Power + Generator is a relatively small unit at 8 X 40 X 10 feet, which allows for easy transport to remote locations.

Additional benefits of the Power + Generator include its simple design and low maintenance, with no gearbox, and no oil pump or oil changes necessary. The Power + Generator control system is fully automated, allowing remote control, remote monitoring, and off site diagnostics and trending.

The Organic Rankine Cycle (ORC) technology used in the Power+ Generator is demonstrated in the visual graph below:

**Refrigerant** - Honeywell R245FA  
**Basic Cycle** - Organic Rankine Cycle (ORC) Twin Screw

![Figure 4. Schematic of ORC with Twin Screw Expander](image)

**Goals and Objectives**

The objective of the field trial was to demonstrate an Organic Rankine Cycle (ORC) generator and to validate the viability the ORC to economically convert flared gas into electricity using flare gas to fuel a hot water boiler to supply hot water to the ORC (ORC system).

Goals:
- Demonstrate the ability of the ORC system to produce electricity from the flare gas.
- Demonstrate that electricity production does not interfere with well operation.
- Determine environmental impacts of flare gas reduction.
- Reduce Operating Costs

The project had several subsidiary goals. Chief among these were:
- Demonstrate that producing electricity from flared gas can be accomplished while reducing emissions from the site.
- Install and operate the equipment with minimal interference to normal operations of an oil/gas well.
- Address the requirements of oil and gas producers to use flared gas for a beneficial use.
• Increase the profitability of producing oil and gas wells by adding offsetting costs during production.

It was important to use an actual field trial to determine the “unknowns” that existed, but which could not be identified in lab and bench scale runs. A field trial was also needed to identify the areas for corrective action that could be incorporated in newly designed equipment and flare gas reduction applications. The overall purpose of this study was to identify and demonstrate a technology that will use flare gas for a beneficial use and increase energy efficiency and that will also reduce the field operating cost of producing oil and gas wells by producing “on-site power” (distributed generation) to offset the cost of purchased power.

**Project Organization and Management**
Management of the project consisted of a work structure breakdown plan that addressed the overall project, a technology status assessment report, and a technology transfer plan. There were seven major project tasks, described below. These Project Tasks were:

- Partners Planning Meeting
- Field Equipment Design and Refitting:
- Field Installation
- Field Operations and Monitoring
- Data Analysis and Equipment maintenance
- Technology Transfer
- Economic Analysis

**Project Tasks**

- **Partners Planning Meeting**
A site selection and project-planning meeting was held with the Partners at the Hess offices in Houston, Texas on April 14, 2014 to discuss a possible field Trial on a Hess well pad. The meeting included Hess engineering Team, HARC, EFD, and GCGE.

Subsequent Partner meetings and teleconferences were held to determine Trial feasibility and potential locations. After study and review by Hess, approval for the Trial was given and a location was selected in North Dakota’s Bakken on the Hess HA-Rolfsrud well pad.
- Equipment Design and Refitting
The ElectraTherm Power+ Generator was tested at the ElectraTherm factory and mounted on a flat rack skid and made ready for transport by truck to the site. After much research by ElectraTherm engineering and GCGE, R.F. MacDonald Boilers in Modesto California was selected to provide the boiler and associated equipment as a self-contained unit which was sent to the ElectraTherm factory for controls and hot water interfacing with the Power+ Generator. Then both units were shipped to the Hess well pad by a commercial trucking company.

- Field Installation
The equipment arrived onsite and was unloaded. Installation began on July 27, 2015. The installation and final System commissioning was completed on July 29, 2015. Testing was performed from July 29 through August 5, 2015 with 24/7 operation beginning on August 7.
- **Field Operations and Monitoring**

After installation and commissioning were successfully completed the GCGE/ET Team departed and left the System in full unmanned operation with monitoring and controls operated remotely from Reno and Texas. Hess operators were trained by the GCGE/ET Team in the design and operation of the System. Because of the simplicity of the System and the ability to monitor and control remotely, the training was completed in less than an hour.
There were a few issues with the boiler over the first week. GCGE contracted with PBBS Boilers in Minot, N.D. for boiler commissioning and service. The PBBS Technician quickly identified and corrected all issues. There were also shut downs in the System caused by what was presumed to be power bumps or flickers on the McKenzie Electric Coop power lines. Because of the positive relationship developed between McKenzie and GCGE, McKenzie installed monitoring equipment on their line. With the information gathered by the equipment, McKenzie and ElectraTherm engineers quickly identified that the outages were cause by minor under voltage events which caused the Power+ Generator to shut down. The Power+ Generator controls were modified to allow for the under voltage and no subsequent outages occurred.
On a few occasions the System required a manual restart. Because the Hess operators had been trained they performed the manual restart in a matter of minutes while performing their routine duties at the site. The Hess operators were extremely cooperative and helpful throughout the entire Trial.

Cumulative runtime was 1937 Hr. with 103,486 total cumulative kWh generated with an average of output of 53.4 kWe from the Power + Generator flare reduction System.

The System achieved 89% runtime over the Trial period. This was better than anticipated because this was a first for integrating a boiler with the Power+ generator using flare gas. With the lessons learned from the Trial it is anticipated that a 98% runtime can be anticipated which parallels the ElectraTherm fleet average.

![Figure 15: The System](image)

**- Data Analysis and Equipment Maintenance**
(See Attachment 2 for the weekly runtime data)

**Lessons Learned**

The three month Trial successfully concluded on November 7, 2015 with Cumulative runtime of 1937 Hr. and 103,486 total cumulative kWh generated with an average of output of 53.4 kWe from the Power + 65 kWe generator.

The Trial proved that emissions can be reduced and a beneficial use (electricity) can be made from raw or treated gas that would otherwise be flared.
- Equipment Transport
Transportation of the Power+ Generator and the Boiler skids will be permanently mounted on trailers, one for each of the two skids. This will negate the need for unloading equipment and associated costs. It will also allow for hard piping of the water lines between the two units.

- Boiler Selection
The boiler selected for this project could have supplied the necessary hot water to generate twice the power output from the Series 4400 65 kWe Power+ Generator which would consume twice the gas. Or it was capable of supplying enough hot water for a Series 6500 110 kWe Power+ Generator. Future projects will more closely match the boiler with the Power+ generator selected. The Trial boiler was selected because it was available and waiting on a more appropriately sized unit would have added to the installation date.

![Figure 16 & 17: Boiler and associated equipment](image)

Additionally we learned that the boiler was a 30 psi design which would not allow the hot water temperature to go above 220 F. To maximize the output of the Power+ Generator water temperature of 240 F was required. Therefore future installations will include a 60 psi boiler rather than the current 30 psi boiler to allow for max kWe output from Power+ Generator.

- Installation and Operation at Remote Locations
The Power+ Generator flare reduction System's modularity proved extremely helpful in both installation and removal. The installation/commissioning was completed in two days. By permanently trailer mounting the system, that time can be cut to one day.

The local crane, electrical, boiler, and water delivery contractors were interviewed in person and secured two weeks prior to equipment arrival. This paid great dividends because a good business and working relationship was built before any work was started. This allowed for seamless operations when their services were required.

There was also an in person meeting between GCGE and the CEO and lead engineer with McKenzie Electric Coop two weeks prior to equipment arrival. The meeting was to introduce GCGC and the Power+ Generator to the Coop and to answer any questions they had and, as well as assure them that the
System would not cause the Coop any safety issues, additional work, or power grid issues. The meeting led to a very beneficial working relationship with the Coop.

GCGE also later met in person with Basin Electric Coop which generates the power that McKenzie distributes and sells to its customers. Just as with the Coop, Basin and GCGE have a good relationship now that Basin is familiar with the Power+ Generator and GCGE.

- **System Winterization**
  Because the Trial would conclude prior to freezing weather and the harsh winter conditions of North Dakota, the System was not winterized. Future Systems will be winterized which includes adding glycol to the Power + radiator and heat exchanges and the boiler. Additionally the boiler containers will include a thermostatically controlled gas heater inside the container as well as louvered air vents.

- **Raw Gas Applications**
  Because the gas used for the Trial was treated by GTUIT’s technology, the boiler system did not require any additional equipment to allow the boilers burner to operate. However, untreated gas applications will include a vaporizer to remove liquids which are typically associated with raw gas.

- **Locations with Large Flare Gas Volumes**
  The site selected had an abundance of flared gas which was much greater than the Trial Power+ Generator System required. For sites such as this, the larger 110 kWe Series 6500 Power+ Generator System should be considers. If the desire is to reduce the maximum amount of flare gas, additional Power + Generator Systems can easily be connected in a series because of the “plug and play” ease of installation of the System.

  The flare gas available during the Trial was great enough to generate approx. 500 kWe, which would supply the power needs for the site once electric artificial lifts are brought on line.

  The Trial System is well suited for smaller flare gas locations which have smaller power requirements which can be provided by the Power+ Generator System.

**Economics**
Review of the demonstration and cost analysis speaks to the economic benefits of the application. A post project analysis concluded that the Power+ Generator System provided all of the sites power needs since the electric artificial lifts had not been connected to the power grid.

Based on the information gained by the Trial a Series 4400 Power+ Generator System would generate power for approx. $.045/kWe. Using a value of $30/bbl, the System would payout in less than twelve months when mandated oil production curtailment is avoided.

The extremely low cost of power makes engine gensets and turbine power generation solutions less attractive due to capital intensive heavy maintenance.
Environmental Impact

By addressing the needs of the Local, Federal, and State governments to reduce flaring, this project is a success.

The Texas A&M Emissions Report (Attachment 3) concludes that the Power+ Generator flare reduction System “has the distinct advantage of reducing emissions of key air pollutants by factors ranging from half to less than 10% when compared to open flaring. Scaling up the boiler sizing and/or using the latest generation of boiler technology, such as low NOx burners, would reduce emissions further.”

It goes on to say “The real benefit is the power generated by raw gas or fuel gas which would otherwise be wasted by open flaring. Furthermore, this new technology would meet the goals of the US EPA and North Dakota Department of Health – Air Quality by reducing emissions and providing energy by reuse of the produced raw gas or fuel gas.”

CO avg% reduction: 89.1
NOx avg% reduction: 48.1
VOC avg % reduction: 92.8

Conclusion
The Trial at the Hess well pad in North Dakota provides insight into feasibility of future applications from lessons learned to reduce installation time, increase efficiency, and generate additional power. The Trial
was a success and proved that the Power+ Generator flare reduction solution is an effective and economical alternative to flaring. The System uses gas for a beneficial use that would otherwise be flared.

Additionally, emissions from the site can be greatly reduced as determined by the Texas A&M emissions study.

**Other Power+ Generator Efficiency Opportunities**
When considering the Power+ Generator System for flare gas reduction, companies should consider utilizing the “Plug and Play” ease of connecting multiple Systems for sites with large volumes of flare gas. They should also consider using a single system for sites that flare the volume of gas needed for a single System (approx. 2200 SQFD).

Because the System requires a boiler and associated equipment, this System is not required for other waste heat sources. Waste heat from internal combustion engine jacket water and exhaust gas as well as compressed gas cooling do not require the CapX of the boiler system and can provide very cost effective on-site power. For these applications a single skid mounted Power+ Generator can be deployed.

Cumulative runtime was 1937 Hr. with 103,486 total cumulative kWh generated with an average of output of 53.4 kWe from the Power + Generator flare reduction System.

The System achieved 89% runtime over the Trial period. This was better than anticipated because this was a first for integrating a boiler with the Power+ Generator using flare gas. With the lessons learned from the Trial it is anticipated that an ElectraTherm fleet average of 98% can be achieved.
North Dakota Flare Reduction Order

BEFORE THE INDUSTRIAL COMMISSION
OF THE STATE OF NORTH DAKOTA

CASE NO. 22058 (CONTINUED) ORDER NO. 24665

IN THE MATTER OF A HEARING CALLED ON A MOTION OF THE COMMISSION TO CONSIDER AMENDING THE CURRENT BAKKEN, BAKKEN/THREE FORKS, AND/OR THREE FORKS POOL FIELD RULES TO RESTRICT OIL PRODUCTION AND/OR IMPOSE SUCH PROVISIONS AS DEEMED APPROPRIATE TO REDUCE THE AMOUNT OF FLARED GAS.

ORDER OF THE COMMISSION

THE COMMISSION FINDS:

(1) This cause originally came on for hearing at 9:00 a.m. on the 22nd day of April, 2014.

(2) North Dakota Industrial Commission (Commission) Order No. 24392, signed May 14, 2014 continued the decision in this matter for an additional ninety days.

(3) This hearing was called on a motion of the Commission to consider amending the current Bakken, Bakken/Three Forks, and/or Three Forks Pool field rules to restrict oil production and/or impose such provisions as deemed appropriate to reduce the amount of flared gas.

This special hearing was scheduled to address the Commission’s newly-adopted policy on reducing gas flaring. The policy goals were to reduce the flared volume of gas, reduce the number of wells flaring, and reduce the duration of flaring from wells.

Action items to reach the policy goals included requiring Gas Capture Plans for increased density, temporary spacing, and proper spacing cases; requiring Gas Capture Plans for all applications for a permit to drill; schedule semi-annual meetings with midstream gas gathering companies to gauge the effect of Gas Capture Plans, production curtailments, contracts, and
service interruptions; dedicate information technology resources to develop a web-based pipeline incident report form to better assess right-of-way issues; direct the Pipeline Authority to track flaring on/off the Fort Berthold Indian Reservation and report capture status versus goals; and docket this hearing to review and revise Bakken, Bakken/Three Forks, and/or Three Forks Pool rules governing production curtailment.

Case No. 22058 (Continued) Order No. 24665

(2)

(4) Prior to the hearing, the Commission indicated it was seeking testimony of technical nature for input on the following:

a. Length of time wells should be allowed to produce at maximum while flaring? b. What production rate restrictions are appropriate for wells connected to gas gathering or beneficial uses? c. What types of administrative approval of exemptions from production restrictions are appropriate? d. What consideration should be given to ambient air quality regarding production rates or restrictions? e. Should production rates and restrictions be adjusted for well economics and percentage of gas captured by well site, field-pool, region or operator? f. Should production rates for wells not connected to gas gathering or beneficial uses be reduced in stages or set at a low rate after payout?

Written comments were allowed no later than 5:00 p.m., Monday, April 21, 2014.

The following concerned land/royalty owners also submitted written comments: Tim Stroh and Eugene Bardal.

The following concerned citizens also submitted written comments: Wally Stephens, Peggy Klein, Al Coen, Susan and Paul Bultsma, Carol Nelson, Lyle and Susan Best, Pete and Vawnita Best, Galen Grote, Norma Stenslie, Joletta Bird Bear, James Stewart, Corinne L., Shelly Ventsch, Candance Kraft, Rose Veeder, Cedar Gillette, and Curtis Bardal.


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(3)


(7) Having allowed all interested persons an opportunity to be heard and having heard, reviewed, and considered all testimony and evidence presented, the Commission makes the following conclusions. Much of the testimony was relevant, but did not address the six topics on which the Commission sought testimony.

(8) The typical Bakken, Bakken/Three Forks, and/or Three Forks Pool is defined as that accumulation of oil and gas found in the interval from 50 feet above the Bakken Formation to above the top of the Birdbear Formation within the limits of any given field. To ease confusion, the Pool will collectively be hereinafter referred to as the Bakken Pool.

(9) Development of Bakken Pools in North Dakota is currently ongoing and encompasses over 15,000 square miles of land. Total gas plant capacity in North Dakota exceeds total gas production in the state although many bottlenecks exist in the current gas gathering
infrastructure due to the high liquid content of the gas, the prolific volumes of oil and gas during initial production, increasing pipeline pressure that requires installation of additional compressors, and in some cases undersized pipe. Most operators are prudently attempting to connect their wells to a gas gathering system, but due to many aforementioned constraints in the gas gathering systems, much of the gas is not processed.

(10) Bakken Pools producing in North Dakota are oil reservoirs and gas is produced in association with the oil at the wellhead as a by-product of oil production. The value of the oil produced far exceeds the value of any gas produced in association with the oil.

(11) Leasehold interests in some Bakken Pool spacing units are not yet held by production. The initial horizontal well drilled in such spacing units should be allowed to produce at its maximum efficient rate, regardless if the well is connected to a gas gathering system. Allowing such wells to produce at a maximum efficient rate will allow valuable information to be obtained in order to make decisions with regard to future wells and infrastructure requirements in the spacing unit.

(12) Some Bakken Pool spacing units are being developed where the operator is aware that the existing gas gathering infrastructure is insufficient to allow surplus gas to be processed through the gas gathering system. In instances where significant amounts of surplus gas is flared due to the insufficient collection system, production should be restricted unless significant amounts of surplus gas is captured for beneficial consumption, or utilized in a value-added process.

(13) Some Bakken Pools could have up to five separate horizontal targets, resulting in as many as twenty-eight wells within the same spacing unit.

(14) Various time frames for maximum efficient rates were suggested. North Dakota’s production of Bakken Pool associated gas is typically associated with an unusually high temperature, pressure, and liquid content. Initial production decline is also very rapid, due to the highly fractured nature of the completion interval.

(15) The Commission believes the North Dakota Petroleum Council’s Flaring Task Force’s targets of capturing 74% of the gas by October 1, 2014; 77% by January 1, 2015; 85% by January 1, 2016; and 90% by October 1, 2020 with potential for 95% capture are attainable and should
be adopted as gas capture goals by the Commission. The restrictions imposed by this order will strive to meet such goals.

(16) Production restrictions imposed by the Commission will constitute force majeure in most producer/gas gatherer contracts and excuse parties from performing certain parts of the contract while production restrictions are imposed.

(17) Delineation drilling activity versus multi-well development requires separate and unique solutions.

(18) Pipeline construction across rough topography or around surface waters causes delays in connecting wells to a gas gathering system.

(19) Flexibility is required due to surface landowner, tribal, and federal government right-of-way delays; temporary midstream down-time for system upgrades and maintenance; federal regulatory restrictions or delays; safety issues; delayed access to electrical power; and possible reservoir damage.

(20) Well payout and economics should not be used to determine production restrictions.

(21) Some well site value-added processes that utilize the surplus gas in a beneficial manner are economic.

(22) Commission production records indicate the majority of gas flared in North Dakota is from wells already connected to a gas gathering system. Such wells should not be excluded from gas capture goals adopted by the Commission.

(23) Some flared gas contains components that if improperly combusted could cause air quality degradation and health issues.

(24) On the Fort Berthold Indian Reservation, many Bakken Pools are also within the jurisdiction of the Mandan Hidatsa and Arikara (MHA) Nation and Bureau of Land Management (BLM). In some cases, companies must comply with MHA Nation, BLM, and Commission rules. The Commission should work with federal and tribal authorities to ensure that restrictions imposed herein provide clarity and protection of correlative rights for the oil and gas companies operating in the respective jurisdictions.

(25) The production allowances and restrictions imposed herein will provide for the effective and efficient recovery of oil from the Bakken Pool, encourage rapid development, avoid the drilling of unnecessary wells, and prevent waste in a manner that will protect correlative rights.
(5)  

IT IS THEREFORE ORDERED:

(1) All Commission orders allowing wells completed in a Bakken, Bakken/Three Forks, and/or Three Forks Pool to produce at a maximum efficient rate shall remain in full force and effect through September 30, 2014. All wells completed in a Bakken, Bakken/Three Forks, and/or Three Forks Pool are hereafter allowed to produce at a maximum efficient rate through September 30, 2014. After September 30, 2014, the gas capture from all existing wells shall be evaluated and oil production from all existing and future wells shall not exceed the production allowances herein.

(2) The first horizontal well completed in a Bakken, Bakken/Three Forks, and/or Three Forks Pool non-overlapping spacing unit shall be allowed to produce at a maximum efficient rate.

(3) All wells completed in a Bakken, Bakken/Three Forks, and/or Three Forks Pool that have received an exemption to North Dakota Century Code Section 38-08-06.4 shall be allowed to produce at a maximum efficient rate.

(4) All infill horizontal wells, including overlapping spacing units, completed in a Bakken, Bakken/Three Forks, and/or Three Forks Pool, shall be allowed to produce at a maximum efficient rate for a period of 90 days commencing on the first day oil is produced through wellhead equipment into tanks from the ultimate producing interval after casing has been run; after that, such wells shall be allowed to continue to produce at a maximum efficient rate if the well or operator meets or exceeds the Commission approved gas capture goals. The gas capture percentage shall be calculated by summing monthly gas sold plus monthly gas used on lease plus monthly gas processed in a Commission approved beneficial manner, divided by the total monthly volume of associated gas produced by the operator. The operator is allowed to remove the initial 14 days of flowback gas in the total monthly volume calculation. The Commission will accept compliance with the gas capture goals by well, field, county, or statewide by operator. If such gas capture percentage is not attained at maximum efficient rate, the well(s) shall be restricted to 200 barrels of oil per day if at least 60% of the monthly volume of associated gas produced from the well is captured, otherwise oil production from such wells shall not exceed 100 barrels of oil per day.

The Commission will recognize the following as surplus gas being utilized in a beneficial manner:
a. Equipped with an electrical generator that consumes surplus gas from the well; b. Equipped with a system that intakes the surplus gas and natural gas liquids volume from the well for beneficial consumption by means of compression to liquid for use as fuel, transport to a processing facility, production of petrochemicals or fertilizer, conversion to liquid fuels, separating and collecting the propane and heavier hydrocarbons; and c. Equipped with other value-added processes as approved by the Director which reduce the volume or intensity of the flare by more than 60%.

(5) If the flaring of gas produced with crude oil from a Bakken, Bakken/Three Forks, and/or Three Forks Pool is determined by the North Dakota Department of Health as causing a violation of the North Dakota Air Pollution Control Rules (North Dakota Administrative Code Article 33-15), production from the respective pool may be further restricted.

(6) This order shall remain in full force and effect until further order of the Commission.

Dated this 1st day of July, 2014.

INDUSTRIAL COMMISSION  STATE OF NORTH DAKOTA

/s/ Jack Dalrymple, Governor

/s/ Wayne Stenehjem, Attorney General

/s/ Doug Goehring, Agriculture Commissioner
Attachment B.

Flare Reduction Trial Weekly Runtime Data
Run Data Summary for 7/30 – 8/6.
Series 4400 65 kWe ElectraTherm Power+ Generator and 150 H.P. 30 psi Clever Brooks boiler
Average Hot Water In = 232 F
Average Cold Water In = 90 F
Cumulative runtime: 114 Hr.
Total kWh generated: 3,957
Average Gross kW: 51.47
(As noted in Lessons Learned, future installations will include a 60 psi boiler rather than the current 30 psi boiler to allow for max kW output from Power+ Generator)

Run Data Summary for 8/7/15 - 8/14/15
Series 4400 65 kWe ElectraTherm Power+ Generator and 150 H.P. 30 psi Clever Brooks boiler
Cumulative runtime: 219 Hr.
Total cumulative kWh generated: 9,429
Average Gross kW: 52.15
(As noted in Lessons Learned, future installations will include a 60 psi boiler rather than the current 30 psi boiler to allow for max kW output from Power+ Generator)
Run Data Summary for 8/14/15 - 8/21/15
*Series 4400 65 kWe ElectraTherm Power+ Generator and 150 H.P. 30 psi Clever Brooks boiler*
Cumulative runtime: 384 Hr.
Total cumulative kWh generated: 15,890
Average Gross kWe: 49.55
(As noted in Lessons Learned, future installations will include a 60 psi boiler rather than the current 30 psi boiler to allow for max kWe output from Power+ Generator)

Run Data Summary for 8/21/15 - 8/28/15
*Series 4400 65 kWe ElectraTherm Power+ Generator and 150 H.P. 30 psi Clever Brooks boiler*
Cumulative runtime: 452 Hr.
Total cumulative kWh generated: 21,456
Average Gross kWe: 53.11
(As noted in Lessons Learned, future installations will include a 60 psi boiler rather than the current 30 psi boiler to allow for max kWe output from Power+ Generator)
Run Data Summary for 8/28/15 – 9/4/15
Series 4400 65 kWe ElectraTherm Power+ Generator and 150 H.P. 30 psi Clever Brooks boiler
Cumulative runtime: 584 Hr.
Total cumulative kWh generated: 28,075
Average Gross kWe: 50.13
(As noted in Lessons Learned, future installations will include a 60 psi boiler rather than the current 30 psi boiler to allow for max kWe output from Power+ Generator)

Run Data Summary for 9/4/15 – 9/10/15
Series 4400 65 kWe ElectraTherm Power+ Generator and 150 H.P. 30 psi Clever Brooks boiler
Cumulative runtime: 696 Hr.
Total cumulative kWh generated: 34,144
Average Gross kWe: 53.77
(As noted in Lessons Learned, future installations will include a 60 psi boiler rather than the current 30 psi boiler to allow for max kWe output from Power+ Generator)
Run Data Summary for 9/12/15 – 9/18/15
Series 4400 65 kWe ElectraTherm Power+ Generator and 150 H.P. 30 psi Clever Brooks boiler
Cumulative runtime: 855 Hr.
Total cumulative kWh generated: 42,891
Average Gross kWe: 54.43
(As noted in Lessons Learned, future installations will include a 60 psi boiler rather than the current 30 psi boiler to allow for max we output from Power+ Generator)

Run Data Summary for 9/18/15 – 9/25/15
Series 4400 65 kWe ElectraTherm Power+ Generator and 150 H.P. 30 psi Clever Brooks boiler
Cumulative runtime: 1043 Hr.
Total cumulative kWh generated: 53,296
Average Gross kWe: 56.16
(As noted in Lessons Learned, future installations will include a 60 psi boiler rather than the current 30 psi boiler to allow for max we output from Power+ Generator)
Run Data Summary for 9/25/15 – 10/2/15
Series 4400 65 kWe ElectraTherm Power+ Generator and 150 H.P. 30 psi Clever Brooks boiler
Cumulative runtime: 1161 Hr.
Total cumulative kWh generated: 59,700
Average Gross kWe: 54
(As noted in Lessons Learned, future installations will include a 60 psi boiler rather than the current 30 psi boiler to allow for max we output from Power+ Generator)

Run Data Summary for 10/1/15 – 10/8/15
Series 4400 65 kWe ElectraTherm Power+ Generator and 150 H.P. 30 psi Clever Brooks boiler
Cumulative runtime: 1319 Hr.
Total cumulative kWh generated: 69,961
Average Gross kWe: 58.4
(As noted in Lessons Learned, future installations will include a 60 psi boiler rather than the current 30 psi boiler to allow for max we output from Power+ Generator)

Run Data Summary for 10/8/15 – 10/15/15
Series 4400 65 kWe ElectraTherm Power+ Generator and 150 H.P. 30 psi Clever Brooks boiler
Cumulative runtime: 1436 Hr.
Total cumulative kWh generated: 75,228
Average Gross kW: 53.51
(As noted in Lessons Learned, future installations will include a 60 psi boiler rather than the current 30 psi boiler to allow for max kW output from Power+ Generator)

Run Data Summary for 10/15/15 – 10/22/15
Series 4400 65 kW ElectraTherm Power+ Generator and 150 H.P. 30 psi Clever Brooks boiler
Cumulative runtime: 1577 Hr.
Total cumulative kWh generated: 83,207
Average Gross kW: 56.38
(As noted in Lessons Learned, future installations will include a 60 psi boiler rather than the current 30 psi boiler to allow for max kW output from Power+ Generator)
Run Data Summary for 10/22/15 – 10/30/15
Series 4400 65 kWe ElectraTherm Power+ Generator and 150 H.P. 30 psi Clever Brooks boiler
Cumulative runtime: 1702 Hr.
Total cumulative kWh generated: 90,335
Average Gross kWe: 57
(As noted in Lessons Learned, future installations will include a 60 psi boiler rather than the current 30 psi boiler to allow for max kWe output from Power+ Generator)

Run Data Summary for 10/30-11/6/15
Series 4400 65 kWe ElectraTherm Power+ Generator and 150 H.P. 30 psi Clever Brooks boiler
Cumulative runtime: 1848 Hr.
Total cumulative kWh generated: 98,524
Average Gross kWe: 56
(As noted in Lessons Learned, future installations will include a 60 psi boiler rather than the current 30 psi boiler to allow for max kWe output from Power+ Generator)
Run Data Summary for 11/7-13/15
Series 4400 65 kWe ElectraTherm Power+ Generator and 150 H.P. 30 psi Clever Brooks boiler
Cumulative runtime: 1937 Hr.
Total cumulative kWh generated: 103,486
Average Gross kWe: 53.4
(As noted in Lessons Learned, future installations will include a 60 psi boiler rather than the current 30 psi boiler to allow for max kWe output from Power+ Generator)
Attachment C.

Texas A&M
Institute of Renewable Natural Resources
Final Report
Emissions Study:
ElectraTherm Power+ Generator
Compared to
Open Flaring

Prepared by
Texas A&M/Institute of Renewable Natural Resources
Under the
Houston Advanced Research Center/ Environmentally Friendly Drilling Program

October 2015
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   B. Flaring Emissions
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1. Introduction

The State of North Dakota Department of Health and the U.S. Environmental Protection Agency (US EPA) have recently begun to regulate open flaring of raw gas (untreated) and fuel gas (treated). Texas A&M/Institute of Renewal Natural Resources (IRNR) visited a Hess site in the Bakken Shale Play in North Dakota during September 8-10, 2015 to collect research data as part of an emissions research study for comparing emissions from the Gulf Coast Green Energy’s (GCGE) ElectraTherm Power+ generator (Power+) system’s boiler with the emissions from open flaring. The actual process includes both raw gas and fuel gas used for other functions at the site. For this study, it was assumed that all the available gas would either be sent to the treater flare or utilized to generate auxiliary power with the Power+ generator.

A meter, which reads in units of standard cubic feet per hour (scfh), was added in-line to measure the actual gas flow rate to the Power+ boiler. Gas flowrate data\(^1\) was recorded at 30-minute intervals for use in determining emissions from both sources (see photographs - Attachment C). Emissions for both the flare and boiler were estimated using standard US EPA approved emission factors and methods. Both emissions from flaring and the Power+ boiler are considered external combustion emission sources and therefore emit most of the same criteria pollutants\(^2\) - Nitrous Oxides (NO\(_x\)), Carbon Monoxide (CO), Volatile Organic Compounds (VOC).

\(^1\)From the heater treater unit’s data acquisition systems and the Power+ boiler’s flow meter.
\(^2\)Pollutants for which the federal government has set National Ambient Air Quality Standards (NAAQS) or that contribute to the formation of those pollutants (e.g., VOCs in the formation of ozone).

2. Research Plan

This report is not intended to detail the operations of any of the process units but to evaluate emissions and other benefits of a technology alternative to open flaring. Innovations such as the ElectraTherm Power+ generator are necessary to replace flaring as these regulations go into effect. The Power+ generator system utilizes a patented technology to produce organic Rankine cycle power with minimum water flow (e.g., 200 gallons per minute (gpm) versus conventional 1,000 gpm) and simple design (i.e., no gear box or oil pump) to produce power from raw gas or fuel gas which would otherwise be sent to an open treater flare.

**Site:** The site selected for this research study was Hess Corporation site HA-ROLFSUD 152-96-1720H in the North Dakota Bakken shale play. This site has five free-flowing oil and gas wells (1720H2 through 1720H6). The liquids are flowed directly to a 14-tank battery (for oil and brine). These products are loaded onto tanker trucks daily. The wet gas is sent to a series of five dedicated heater treaters (one for each well) for processing prior to flowing out to the treater flare or other units such as the ElectraTherm Power+ boiler.
Process: The oil and gas are free from a tight shale formation that is sent to various upstream units for initial processing and use. This research is focused on emissions from the entire process and does not attempt to describe the processing in detailed technical terms. Figure 1 diagrams the basic process.
FIGURE 1. Process Diagram

- O&G Wells
- Heater Treaters
- Tank Battery
- Treater Flare
- Raw Gas & Oil
- Raw Liquid Products
- Gas to Flare
- Gas to Generator
- Power Output
- ElectraTherm Power + w/Boiler

Final Report
Houston Advanced Research Center/Environmentally Friendly Drilling Systems
3. Data Collection/Post Processing

Data collection consisted of readings for each of the five heater treater units (thousands of cubic feet per day or MCF/day) off the data acquisition system display and gas meter usage readings for Power+ boiler (standard cubic feet per hour or scfh). Readings were taken at approximate 30-minute intervals. The heater treater production flowrates were converted to scfh to match the boiler consumption rate units as shown in the example below:

**Run 1 - Heater Treater #4 10:35 AM:**

\[
331.81 \text{ MCF/day} \times 24 \text{ hr/d} \times 1000/\text{M} = 13,825.4 \text{ scfh}
\]

The five individual production values (in scfh) were then summed to determine the overall production rate value for each of the first five runs as shown in the example for Run 1 below:

**Run 1 – Heater Treater #2 - #6:**

\[
\text{SUM (16,750.8, 29,851.3, 13,825.4, 13,824.6, and 23,567.9) = 122,520.0 scfh}
\]

The percentage of the total available gas used by the boiler was also calculated for each run as shown in the example for Run 1 below:

**Run 1 – Boiler Hourly Flowrate (scfh): 1,951 scfh**

\[
1,951 / 122,520 \times 100 = 1.6\%
\]

In addition, a raw gas and fuel gas analyses were provided by Hess (dated 8/27/2015) for this site. The dry basis heating value of 1655.93 Btu/scf was utilized to calculate emissions using CleaverBrooks® emissions data for the 30 ppm NOx 150 Hp boiler and US EPA AP-42 emission factors document (for comparison).

Boiler plate specifications and process information was also collected during the site survey.

4. Emissions Calculation Methods

NO\textsubscript{x}, CO, and VOC were the contaminants of concern for this study. Emissions from sulfur compounds such as SO\textsubscript{2} (sulfur dioxide), H\textsubscript{2}S (hydrogen sulfide) and PM (particulate matter) were not evaluated since the sulfur content of the treated fuel is minimal and particulate matter emissions cannot be compared due to the fact that flaring emission factors are considered soot/smoke versus actual sized particulate matter (represented by the boiler emission factors). Furthermore, sized particulate would be required for comparison to the standard (e.g., National Ambient Air Quality Standard for particulate matter less than 10 micron or PM\textsubscript{10}). Emissions of NO\textsubscript{x}, CO, and VOC were calculated for both sources and both fuel types (raw gas and fuel gas).
A. Boiler Emissions

Model specific factors for the 30 PPM natural gas Power+ 150 Hp CleaverBrooks® boiler were from the operators manual (Table A10-8).

Table A10-8. Model CBR Boiler Emission Data

<table>
<thead>
<tr>
<th>POLLUTANT</th>
<th>ESTIMATED LEVELS - UNCONTROLLED</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>60 PPM System</td>
</tr>
<tr>
<td>CO</td>
<td>ppm(^a)</td>
</tr>
<tr>
<td></td>
<td>Lb/MMBtu</td>
</tr>
<tr>
<td>NOx</td>
<td>ppm(^a)</td>
</tr>
<tr>
<td></td>
<td>Lb/MMBtu</td>
</tr>
<tr>
<td>SOx</td>
<td>ppm(^a)</td>
</tr>
<tr>
<td></td>
<td>Lb/MMBtu</td>
</tr>
<tr>
<td>HC/VOCs</td>
<td>ppm(^a)</td>
</tr>
<tr>
<td></td>
<td>Lb/MMBtu</td>
</tr>
<tr>
<td>PM</td>
<td>ppm(^a)</td>
</tr>
<tr>
<td></td>
<td>Lb/MMBtu</td>
</tr>
</tbody>
</table>

NOTES:
- Refer to Section E for detailed emission information.
- ppm levels are given on a dry volume basis and corrected to 3% oxygen (15% excess air)
- CO emission is 50 ppm when boiler is operating above 50% of rated capacity. CO emission is 150 ppm when boiler is operating below 50% of rated capacity.
- Based on fuel constituent levels of:
  - Fuel-bound nitrogen content = 0.05% by weight
  - Sulfur content = 0.5% by weight
  - Ash content = 0.01% by weight
  - Conradson carbon residue = 16% by weight

**TABLE 1. Cleaver Brooks Emission Factors**

These values were converted from the values reported (lb pollutant/MMBtu) to lb pollutant/MMscf using the dry basis heating value of both the raw and fuel gas for direct comparison the US EPA emission factors (AP-42, Table 1.4-1 and Table 1.4-2) for boilers in this size range (less than 100 MMBtu/hr). For the most part, the CleaverBrooks® emission factor values were comparable or lower except for VOC which was more than twice the EPA value. See boiler emissions factor tables below.

<table>
<thead>
<tr>
<th>EMISSION FACTORS</th>
<th>AP-42 Table 1-4.2</th>
<th>CleaverBrooks(^b) Fuel Gas</th>
<th>CleaverBrooks(^b) Raw Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO</td>
<td>lb/MMscf</td>
<td>lb/MMscf(^1)</td>
<td>lb/MMscf(^1)</td>
</tr>
<tr>
<td>NOx</td>
<td>84.00</td>
<td>58.17</td>
<td>66.24</td>
</tr>
<tr>
<td>VOC</td>
<td>50.00</td>
<td>50.89</td>
<td>57.96</td>
</tr>
<tr>
<td></td>
<td>5.50</td>
<td>14.54</td>
<td>16.96</td>
</tr>
</tbody>
</table>

\(^1\)Conversion to lb/MMscf based on dry basis heating values

**TABLE 2. Boiler Emission Factors**
Boiler emissions were calculated as follows:

\[ \text{Flowrate (____ scf/hr or scfh) x MM/1,000,000 x Emission Factor (lb pollutant/MMscf)} = \text{lb pollutant/hr} \]

B. Flaring Emissions

Flare emissions were calculated based on the assumption that all raw gas or fuel gas was available for flaring and producing emissions from flaring. Emission factors from US EPA Emissions Factor document (AP-42) were used to determine emission of NO\(_x\), CO, and VOC.

<table>
<thead>
<tr>
<th>Total HC/VOC</th>
<th>CO</th>
<th>NOx</th>
</tr>
</thead>
<tbody>
<tr>
<td>lb/MMBtu</td>
<td>lb/MMBtu</td>
<td>lb/MMBtu</td>
</tr>
<tr>
<td>0.140</td>
<td>0.370</td>
<td>0.068</td>
</tr>
</tbody>
</table>

US EPA AP-42, Table 13.5-1

**TABLE 3. Flare Emission Factors**

Emissions from flaring were calculated as follows:

\[ \text{Gas dry basis heating value (____ Btu/scf) x Flowrate (____ scfh) x MM/1,000,000 x Emission Factor (lb pollutant/MMBtu)} \]

5. Results

A. Boiler Emissions

Emissions from the boiler for each of the five (5) runs are reported in the table below for both raw gas and fuel gas. Note: Emission values are shown for hourly emission rates based on the CleaverBrooks\textsuperscript{®} emissions test factors.

<table>
<thead>
<tr>
<th>BOILER EMISSIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Run #</td>
</tr>
<tr>
<td>RUN 1</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>RUN 2</td>
</tr>
<tr>
<td></td>
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<tr>
<td></td>
</tr>
<tr>
<td>RUN 3</td>
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<tr>
<td></td>
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<td></td>
</tr>
<tr>
<td>RUN 4</td>
</tr>
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<tr>
<td></td>
</tr>
<tr>
<td>RUN 5</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
TABLE 4. Boiler Emissions

B. Flaring Emissions

Emissions from both raw gas and fuel gas based on the total available for flaring for each of the five (5) runs are reported in the table below. Note: Emissions were based on the higher flowrate which was the first five data collection runs (RUNs 1 - 5) which was 150,674 scfh or 3.6 MMscfd. This was also corresponds to the timeframe for which the Power+ boiler was in operation.

<table>
<thead>
<tr>
<th>Run #</th>
<th>Pollutant</th>
<th>Fuel Gas lb/hr</th>
<th>Raw Gas lb/hr</th>
</tr>
</thead>
<tbody>
<tr>
<td>RUN 1</td>
<td>CO</td>
<td>65.92</td>
<td>75.07</td>
</tr>
<tr>
<td></td>
<td>NOx</td>
<td>12.11</td>
<td>13.80</td>
</tr>
<tr>
<td></td>
<td>VOC</td>
<td>24.94</td>
<td>28.40</td>
</tr>
<tr>
<td>RUN 2</td>
<td>CO</td>
<td>79.11</td>
<td>90.09</td>
</tr>
<tr>
<td></td>
<td>NOx</td>
<td>14.54</td>
<td>16.56</td>
</tr>
<tr>
<td></td>
<td>VOC</td>
<td>29.93</td>
<td>34.09</td>
</tr>
<tr>
<td>RUN 3</td>
<td>CO</td>
<td>95.62</td>
<td>108.89</td>
</tr>
<tr>
<td></td>
<td>NOx</td>
<td>17.57</td>
<td>20.01</td>
</tr>
<tr>
<td></td>
<td>VOC</td>
<td>36.18</td>
<td>41.20</td>
</tr>
<tr>
<td>RUN 4</td>
<td>CO</td>
<td>66.70</td>
<td>75.95</td>
</tr>
<tr>
<td></td>
<td>NOx</td>
<td>12.26</td>
<td>13.96</td>
</tr>
<tr>
<td></td>
<td>VOC</td>
<td>25.24</td>
<td>28.74</td>
</tr>
<tr>
<td>RUN 5</td>
<td>CO</td>
<td>98.00</td>
<td>111.60</td>
</tr>
<tr>
<td></td>
<td>NOx</td>
<td>18.01</td>
<td>20.51</td>
</tr>
<tr>
<td></td>
<td>VOC</td>
<td>37.08</td>
<td>42.23</td>
</tr>
</tbody>
</table>

TABLE 5. Flare Emissions

Emissions are typically reported on an annual basis in addition to the short-term hourly values. Annual emissions are not included since the annual operating hours for the boiler and the flare would need to be tracked in order calculate annual emission for any given year. Potential to emit (which is usually a gross overestimate) can be calculated by simply multiplying by an assumed fulltime operating schedule of 8760 hours per year.

6. Conclusion

A direct comparison of emissions based on the amounts of raw gas and fuel gas consumed by the boiler compared to the total available for flaring (1.57%) is provided in the table below. It is important to note that the emissions from the Power+ boiler are lower (comparatively less harmful to the environment) and would provide the added utility of power generated for use from the raw gas or fuel gas which would otherwise be wasted.
<table>
<thead>
<tr>
<th>Run #</th>
<th>Pollutant</th>
<th>Flare</th>
<th>Boiler</th>
<th>% of Flare</th>
</tr>
</thead>
<tbody>
<tr>
<td>RUN 1</td>
<td>CO</td>
<td>1.18</td>
<td>0.13</td>
<td>10.9</td>
</tr>
<tr>
<td></td>
<td>NOx</td>
<td>0.22</td>
<td>0.11</td>
<td>52.2</td>
</tr>
<tr>
<td></td>
<td>VOC</td>
<td>0.45</td>
<td>0.03</td>
<td>7.2</td>
</tr>
<tr>
<td>RUN 2</td>
<td>CO</td>
<td>1.41</td>
<td>0.17</td>
<td>12.1</td>
</tr>
<tr>
<td></td>
<td>NOx</td>
<td>0.26</td>
<td>0.15</td>
<td>57.3</td>
</tr>
<tr>
<td></td>
<td>VOC</td>
<td>0.54</td>
<td>0.04</td>
<td>8.0</td>
</tr>
<tr>
<td>RUN 3</td>
<td>CO</td>
<td>1.71</td>
<td>0.18</td>
<td>10.5</td>
</tr>
<tr>
<td></td>
<td>NOx</td>
<td>0.31</td>
<td>0.16</td>
<td>49.7</td>
</tr>
<tr>
<td></td>
<td>VOC</td>
<td>0.65</td>
<td>0.05</td>
<td>7.0</td>
</tr>
<tr>
<td>RUN 4</td>
<td>CO</td>
<td>1.19</td>
<td>0.14</td>
<td>12.0</td>
</tr>
<tr>
<td></td>
<td>NOx</td>
<td>0.22</td>
<td>0.13</td>
<td>57.0</td>
</tr>
<tr>
<td></td>
<td>VOC</td>
<td>0.45</td>
<td>0.04</td>
<td>8.0</td>
</tr>
<tr>
<td>RUN 5</td>
<td>CO</td>
<td>1.75</td>
<td>0.16</td>
<td>9.1</td>
</tr>
<tr>
<td></td>
<td>NOx</td>
<td>0.32</td>
<td>0.14</td>
<td>43.5</td>
</tr>
<tr>
<td></td>
<td>VOC</td>
<td>0.66</td>
<td>0.04</td>
<td>6.0</td>
</tr>
</tbody>
</table>

**TABLE 6. Emissions Comparison – Raw Gas**

The average percent of the emissions from the boiler compare to the flare for either fuel is presented in the table below. In terms of emission reductions: CO would be 10.9% of flaring – 89.1% reduction, NOx would be 51.9% of flaring – 48.1% reduction, and VOC would be 7.2% of flaring – 92.8% reduction.

<table>
<thead>
<tr>
<th>Run #</th>
<th>Pollutant</th>
<th>Flare</th>
<th>Boiler</th>
<th>% of Flare</th>
</tr>
</thead>
<tbody>
<tr>
<td>RUN 1</td>
<td>CO</td>
<td>1.03</td>
<td>0.11</td>
<td>10.9</td>
</tr>
<tr>
<td></td>
<td>NOx</td>
<td>0.19</td>
<td>0.10</td>
<td>52.2</td>
</tr>
<tr>
<td></td>
<td>VOC</td>
<td>0.39</td>
<td>0.03</td>
<td>7.2</td>
</tr>
<tr>
<td>RUN 2</td>
<td>CO</td>
<td>1.24</td>
<td>0.15</td>
<td>12.1</td>
</tr>
<tr>
<td></td>
<td>NOx</td>
<td>0.23</td>
<td>0.13</td>
<td>57.3</td>
</tr>
<tr>
<td></td>
<td>VOC</td>
<td>0.47</td>
<td>0.04</td>
<td>8.0</td>
</tr>
<tr>
<td>RUN 3</td>
<td>CO</td>
<td>1.50</td>
<td>0.16</td>
<td>10.5</td>
</tr>
<tr>
<td></td>
<td>NOx</td>
<td>0.28</td>
<td>0.14</td>
<td>49.7</td>
</tr>
<tr>
<td></td>
<td>VOC</td>
<td>0.57</td>
<td>0.04</td>
<td>7.0</td>
</tr>
<tr>
<td>RUN 4</td>
<td>CO</td>
<td>1.05</td>
<td>0.13</td>
<td>12.0</td>
</tr>
<tr>
<td></td>
<td>NOx</td>
<td>0.19</td>
<td>0.11</td>
<td>57.0</td>
</tr>
<tr>
<td></td>
<td>VOC</td>
<td>0.40</td>
<td>0.03</td>
<td>8.0</td>
</tr>
<tr>
<td>RUN 5</td>
<td>CO</td>
<td>1.54</td>
<td>0.14</td>
<td>9.1</td>
</tr>
<tr>
<td></td>
<td>NOx</td>
<td>0.28</td>
<td>0.12</td>
<td>43.5</td>
</tr>
<tr>
<td></td>
<td>VOC</td>
<td>0.58</td>
<td>0.03</td>
<td>6.0</td>
</tr>
</tbody>
</table>

**TABLE 7. Emissions Comparison – Fuel Gas**
<table>
<thead>
<tr>
<th>NOx avg%</th>
<th>48.1</th>
</tr>
</thead>
<tbody>
<tr>
<td>VOC avg%</td>
<td>92.8</td>
</tr>
</tbody>
</table>

**TABLE 8. Percent Reduction**

Combustion of gas in boilers powering organic Rankine cycle generators has the distinct advantage of reducing emissions of key air pollutants by factors ranging from half to less than 10% when compared to open flaring. Scaling up the boiler sizing and/or using the latest generation of boiler technology, such as low NO\textsubscript{x} burners, would reduce emissions further.

The real benefit is the power generated by raw gas or fuel gas which would otherwise be wasted by open flaring. Furthermore, this new technology would meet the goals of the US EPA and North Dakota Department of Health – Air Quality by reducing emissions and providing energy by reuse of the produced raw gas or fuel gas.

**7. References**

c. HESS Corporation, Fuel Analyses, Raw Gas and Fuel Gas, 8/27/2015
e. On-site Data Collection – Texas A&M/IRNR (J. Alonzo), 9/8/15 through 9/10/15.
APPENDIX A

RAW DATA
HESS CORP. SITE - HA-ROLFSUD 152-96-1720H (H2-H6)
10-Oct-15

**POWER+ BOILER ON**

### RUN 1

<table>
<thead>
<tr>
<th>Unit</th>
<th>Daily Flowrate (mcf/d)</th>
<th>Current Day (mcf)</th>
<th>Previous Day (mcf)</th>
<th>Hourly Flowrate (scf/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H2</td>
<td>402.02</td>
<td>160.53</td>
<td>585.45</td>
<td>16,750.8</td>
</tr>
<tr>
<td>H3</td>
<td>716.43</td>
<td>265.47</td>
<td>971.81</td>
<td>29,851.3</td>
</tr>
<tr>
<td>H4</td>
<td>331.81</td>
<td>113.45</td>
<td>417.14</td>
<td>13,825.4</td>
</tr>
<tr>
<td>H5</td>
<td>924.59</td>
<td>263.39</td>
<td>959.84</td>
<td>38,524.6</td>
</tr>
<tr>
<td>H6</td>
<td>565.63</td>
<td>210.55</td>
<td>764.56</td>
<td>23,567.9</td>
</tr>
<tr>
<td>Boiler</td>
<td>1,951.0</td>
<td>1,951.0</td>
<td>1,951.0</td>
<td>1.6%</td>
</tr>
</tbody>
</table>

### RUN 2

<table>
<thead>
<tr>
<th>Unit</th>
<th>Flowrate (mcf/d)</th>
<th>Current Day (mcf)</th>
<th>Previous Day (mcf)</th>
<th>Flowrate (scf/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H2</td>
<td>640.02</td>
<td>169.69</td>
<td>585.45</td>
<td>26,667.5</td>
</tr>
<tr>
<td>H3</td>
<td>916.63</td>
<td>281.25</td>
<td>971.81</td>
<td>38,192.9</td>
</tr>
<tr>
<td>H4</td>
<td>452.9</td>
<td>120.67</td>
<td>417.14</td>
<td>18,870.8</td>
</tr>
<tr>
<td>H5</td>
<td>870.82</td>
<td>278.11</td>
<td>959.84</td>
<td>36,284.2</td>
</tr>
<tr>
<td>H6</td>
<td>648.39</td>
<td>222.39</td>
<td>764.56</td>
<td>27,016.3</td>
</tr>
<tr>
<td>Boiler</td>
<td>2,578.0</td>
<td>2,578.0</td>
<td>2,578.0</td>
<td>1.75%</td>
</tr>
</tbody>
</table>

### RUN 3

<table>
<thead>
<tr>
<th>Unit</th>
<th>Flowrate (mcf/d)</th>
<th>Current Day (mcf)</th>
<th>Previous Day (mcf)</th>
<th>Flowrate (scf/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H2</td>
<td>1157.56</td>
<td>181.25</td>
<td>585.45</td>
<td>48,231.7</td>
</tr>
<tr>
<td>H3</td>
<td>1459.68</td>
<td>299.75</td>
<td>971.81</td>
<td>60,820.0</td>
</tr>
<tr>
<td>H4</td>
<td>310.71</td>
<td>128.3</td>
<td>417.14</td>
<td>12,946.3</td>
</tr>
<tr>
<td>H5</td>
<td>770.6</td>
<td>296.86</td>
<td>959.84</td>
<td>32,108.3</td>
</tr>
<tr>
<td>H6</td>
<td>566.67</td>
<td>237.36</td>
<td>764.56</td>
<td>23,611.3</td>
</tr>
<tr>
<td>Boiler</td>
<td>2,699.0</td>
<td>2,699.0</td>
<td>2,699.0</td>
<td>1.52%</td>
</tr>
</tbody>
</table>

### RUN 4

<table>
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<tr>
<th>Unit</th>
<th>Flowrate (mcf/d)</th>
<th>Current Day (mcf)</th>
<th>Previous Day (mcf)</th>
<th>Flowrate (scf/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H2</td>
<td>565.66</td>
<td>188.906</td>
<td>585.45</td>
<td>23,569.2</td>
</tr>
<tr>
<td>H3</td>
<td>871.77</td>
<td>314.781</td>
<td>971.81</td>
<td>36,323.8</td>
</tr>
<tr>
<td>H4</td>
<td>322.01</td>
<td>134.19</td>
<td>417.14</td>
<td>13,417.1</td>
</tr>
<tr>
<td>H5</td>
<td>412.189</td>
<td>310.375</td>
<td>959.84</td>
<td>17,174.5</td>
</tr>
<tr>
<td>H6</td>
<td>803.458</td>
<td>248.797</td>
<td>764.56</td>
<td>33,477.4</td>
</tr>
<tr>
<td>Boiler</td>
<td>2,157.0</td>
<td>2,157.0</td>
<td>2,157.0</td>
<td>1.74%</td>
</tr>
</tbody>
</table>

### RUN 5

<table>
<thead>
<tr>
<th>Unit</th>
<th>Flowrate (mcf/d)</th>
<th>Current Day (mcf)</th>
<th>Previous Day (mcf)</th>
<th>Flowrate (scf/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H2</td>
<td>1093.12</td>
<td>203.2</td>
<td>585.45</td>
<td>45,546.7</td>
</tr>
<tr>
<td>H3</td>
<td>1110.52</td>
<td>331.72</td>
<td>971.81</td>
<td>46,271.7</td>
</tr>
<tr>
<td>H4</td>
<td>595.21</td>
<td>143.61</td>
<td>417.14</td>
<td>24,800.4</td>
</tr>
<tr>
<td>H5</td>
<td>915.41</td>
<td>332.91</td>
<td>959.84</td>
<td>38,142.1</td>
</tr>
<tr>
<td>H6</td>
<td>657.07</td>
<td>265.94</td>
<td>764.56</td>
<td>27,377.9</td>
</tr>
<tr>
<td>Boiler</td>
<td>2,421.0</td>
<td>2,421.0</td>
<td>2,421.0</td>
<td>1.33%</td>
</tr>
</tbody>
</table>

**Average Fuel Gas Production** 150,674.0 scfh
**Average Fuel Consumption (boiler)** 2,361.2 scfh
**Average Percentage of Fuel Consumed** 1.57%
## HESS CORP. SITE - HA-ROLFSUD 152-96-1720H (H2-H6)

### 10-Oct-15

#### POWER+ BOILER OFF

**9/10/2015 13:20** RUN 6

<table>
<thead>
<tr>
<th>Unit</th>
<th>Daily Flowrate (mcf/d)</th>
<th>Current Day (mcf)</th>
<th>Previous Day (mcf)</th>
<th>Flowrate (scf/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H2</td>
<td>630.14</td>
<td>225.672</td>
<td>585.45</td>
<td>26,255.8</td>
</tr>
<tr>
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<td>1233.13</td>
<td>376.09</td>
<td>971.81</td>
<td>51,380.4</td>
</tr>
<tr>
<td>H4</td>
<td>402.72</td>
<td>160.02</td>
<td>417.14</td>
<td>16,780.0</td>
</tr>
<tr>
<td>H5</td>
<td>1207.89</td>
<td>371.69</td>
<td>959.84</td>
<td>50,328.8</td>
</tr>
<tr>
<td>Boiler</td>
<td>0.0</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

**9/10/2015 14:00** RUN 7

<table>
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<th>Daily Flowrate (mcf/d)</th>
<th>Current Day (mcf)</th>
<th>Previous Day (mcf)</th>
<th>Flowrate (scf/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H2</td>
<td>590.25</td>
<td>239.45</td>
<td>585.45</td>
<td>24,593.8</td>
</tr>
<tr>
<td>H3</td>
<td>1067.96</td>
<td>399.03</td>
<td>971.81</td>
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</tr>
<tr>
<td>H4</td>
<td>391.29</td>
<td>169.64</td>
<td>417.14</td>
<td>16,303.8</td>
</tr>
<tr>
<td>H5</td>
<td>447.75</td>
<td>393.64</td>
<td>959.84</td>
<td>18,656.3</td>
</tr>
<tr>
<td>H6</td>
<td>1006.97</td>
<td>315.42</td>
<td>764.56</td>
<td>41,957.1</td>
</tr>
<tr>
<td>Boiler</td>
<td>0.0</td>
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<td></td>
<td></td>
</tr>
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</table>

**9/10/2015 14:25** RUN 8

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<th>Daily Flowrate (mcf/d)</th>
<th>Current Day (mcf)</th>
<th>Previous Day (mcf)</th>
<th>Flowrate (scf/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H2</td>
<td>839.74</td>
<td>251.94</td>
<td>585.45</td>
<td>34,989.2</td>
</tr>
<tr>
<td>H3</td>
<td>841.52</td>
<td>420.13</td>
<td>971.81</td>
<td>35,063.3</td>
</tr>
<tr>
<td>H4</td>
<td>365.24</td>
<td>178.48</td>
<td>417.14</td>
<td>15,218.3</td>
</tr>
<tr>
<td>H5</td>
<td>939.97</td>
<td>415.16</td>
<td>959.84</td>
<td>39,165.4</td>
</tr>
<tr>
<td>H6</td>
<td>668.61</td>
<td>331.73</td>
<td>764.56</td>
<td>27,858.8</td>
</tr>
<tr>
<td>Boiler</td>
<td>0.0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**9/10/2015 14:55** RUN 9

<table>
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<th>Current Day (mcf)</th>
<th>Previous Day (mcf)</th>
<th>Flowrate (scf/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H2</td>
<td>614.63</td>
<td>262.77</td>
<td>585.45</td>
<td>25,609.6</td>
</tr>
<tr>
<td>H3</td>
<td>1084.75</td>
<td>437.56</td>
<td>971.81</td>
<td>45,197.9</td>
</tr>
<tr>
<td>H4</td>
<td>300.96</td>
<td>185.8</td>
<td>417.14</td>
<td>12,540.0</td>
</tr>
<tr>
<td>H5</td>
<td>685.05</td>
<td>431.58</td>
<td>959.84</td>
<td>28,543.8</td>
</tr>
<tr>
<td>H6</td>
<td>664.36</td>
<td>345.73</td>
<td>764.56</td>
<td>27,681.7</td>
</tr>
<tr>
<td>Boiler</td>
<td>0.0</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**9/10/2015 15:20** RUN 10

<table>
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<th>Daily Flowrate (mcf/d)</th>
<th>Current Day (mcf)</th>
<th>Previous Day (mcf)</th>
<th>Flowrate (scf/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>H2</td>
<td>528.31</td>
<td>274.77</td>
<td>585.45</td>
<td>22,012.9</td>
</tr>
<tr>
<td>H3</td>
<td>954.11</td>
<td>457.19</td>
<td>971.81</td>
<td>39,754.6</td>
</tr>
<tr>
<td>H4</td>
<td>439.06</td>
<td>194.41</td>
<td>417.14</td>
<td>18,294.2</td>
</tr>
<tr>
<td>H5</td>
<td>471.49</td>
<td>450.63</td>
<td>959.84</td>
<td>19,645.4</td>
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<tr>
<td>H6</td>
<td>586.33</td>
<td>360.95</td>
<td>764.56</td>
<td>24,430.4</td>
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<tr>
<td>Boiler</td>
<td>0.0</td>
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</table>

**scfh (total production)**

- RUN 6: 144,745.0
- RUN 7: 146,009.2
- RUN 8: 152,295.0
- RUN 9: 139,572.9
- RUN 10: 124,137.5
APPENDIX B
GAS ANALYSES
# Fuel (Treated) Gas

## Hess Corporation
Tioga Gas Plant
Settlement

- **Inject Date/Time:** 8/27/2015 10:15
- **Sample Name:** HA ROLFSRUD 152-96-1702 H-2-6 #1
- **Well Number:** HA ROLFSRUD 152-96-1702 H-2-6 #1
- **Producer:** HESS CORP
- **Secured By:** ZP
- **Sample Pressure:** 8
- **Sample Cylinder Number:** 337
- **Analysis Date:** 8/27/2015 10:15
- **Date Sample Taken:** 8/25/2015 0:00
- **Effective Date:** 8/27/2015 0:00
- **Sample Temperature:** 0
- **Meter:** 1
- **H2S:** 0

## Component Analysis

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<thead>
<tr>
<th>Component Name</th>
<th>Mole %</th>
<th>GPM</th>
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<tbody>
<tr>
<td>Carbon dioxide</td>
<td>0.8560</td>
<td>0</td>
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<tr>
<td>Ethane</td>
<td>18.9281</td>
<td>0</td>
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<tr>
<td>Hexanes plus</td>
<td>1.1164</td>
<td>0.4579</td>
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<tr>
<td>Isobutane</td>
<td>1.0991</td>
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<tr>
<td>Isopentane</td>
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<td>Methane</td>
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<tr>
<td>n-Butane</td>
<td>3.1861</td>
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<td>Nitrogen</td>
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<td>n-Pentane</td>
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<td>Propane</td>
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### Totals

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<tr>
<td>GPM For Pentanes†</td>
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<tr>
<td>GPM For Butanes†</td>
<td>2.37477</td>
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<tr>
<td>GPM For Propanes†</td>
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<td>Calculated BTUs (Dry Basis):</td>
<td>1454.13</td>
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<td>Calculated BTUs (Wet Basis):</td>
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<td>Specific Gravity (Calculated w/H2S - Ideal):</td>
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<tr>
<td>Specific Gravity (Calculated w/H2S - Real):</td>
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<tr>
<td>Pressure:</td>
<td>14.73</td>
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</table>
RAW (UNTREATED) GAS

8/27/2015 10:55

Hess Corporation
Tioga Gas Plant
Settlement

Inject Datetime: 8/27/2015 10:38
Sample Name: HA ROLFSRUD 152-96-1702 H-2-6 #2
Well Number: HA ROLFSRUD 152-96-1702 H-2-6 #2
Producer: HESS CORP
Secured By: ZF
Sample Pressure: 39
Sample Cylinder Number: 258

<table>
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<tr>
<th>Component Name</th>
<th>Mole %</th>
<th>GPM</th>
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</thead>
<tbody>
<tr>
<td>Carbon dioxide</td>
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<tr>
<td>Ethane</td>
<td>15.7246</td>
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<td>Hexanes plus</td>
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<td>Isobutane</td>
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<td>Isopentane</td>
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<td>Nitrogen</td>
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<td>n-Pentane</td>
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<td>Oxygen</td>
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<tr>
<td>Propane</td>
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</table>

Total GPM: 100

GPM For Pentanes+: 2.62935
GPM For Butanes+: 5.92023
GPM For Propane+: 9.20121
Calculated BTUs (Dry Basis): 1685.26
Calculated BTUs (Wet Basis): 1685.93
Specific Gravity (Calculated w/H2S - Ideal): 1.07399
Specific Gravity (Calculated w/H2S - Real): 1.07423
Pressure Base: 14.73

Sample Temperature: 0
Meter: 2
H2S: 0.00025
APPENDIX C

PHOTOS
Heater Treater Data Acquisition System Flow Totals

CURRENT (reading)
MCF/Day converted to scf/hr (scfh)

Power+ Boiler Gas Meter
Attachment D.

Weekly Project Reports
HARC/EFD Flare-to-Power Trial Project

Weekly Report November 7 -13, 2015

The following is a summary of activities for the week:

This is the last weekly report as the Trial has concluded.

Nov 5: The final run day was Nov. 5 and the chart is below.

Nov.7: Decommissioning plans made

Nov. 11: PBBS Boilers and Nuverra Environmental turned off gas and vacuumed out water from system.

Nov.15: GCGE will make all equipment ready for loading and shipping

Nov. 16: All equipment will be loaded and transported by Rossco Crane.

Lessons learned this reporting period:
1. The trial has been very successful and has demonstrated that a beneficial use of flare gas is possible by using the Power+ generator system to make low emission power for on-site use.
2. The system requires very little maintenance with approx. 1 man hour/week
3. The Power+ system is an economical alternative to curtailing oil production due to flaring regulations
4. The system provides a beneficial use for gas that would otherwise be flared.
5. A more detailed report and lessons learned is forthcoming

[Run Data on Next Page]
Run Data Summary for 11/7-13/15
Series 4400 65 kWe ElectraTherm Power+ Generator and 150 H.P. 30 psi Clever Brooks boiler
Cumulative runtime: 1937 Hr.
Total cumulative kWh generated: 103,486
Average Gross kW: 53.4
(As noted in Lessons Learned, future installations will include a 60 psi boiler rather than the current 30 psi boiler to allow for max kW output from Power+ Generator)
Weekly Report October 30 – November 6, 2015

The following is a summary of activities for the week:

October 30-Nov. 3: All systems nominal. Monitoring and controlling remotely.

Nov 3: Lost boiler due to gas pressure loss. Unable to contact GTUIT to determine if they also lost gas. Tyson with Hess brought boiler back on line while performing his routine duties.

Nov. 3-5: All systems nominal. Monitoring and controlling remotely.

Nov. 5: Lost boiler due to low water. Nolan with Hess, tightened two water hose clamps, added water and restarted boiler, all in approx. 30 min total.

Nov. 5-6: All systems nominal. Monitoring and controlling remotely.

Lessons learned this reporting period:
1. This week’s operation was fairly uneventful with only two shut downs caused by what is assumed was flare gas adjustments.
2. There have been no Grid Protection or phase imbalance shut downs since the settings were changed. Again, a big thanks to McKenzie Electric for their assistance in determining a solution.
3. GCGE will change the two water hose clamps. All future units will be fitted with the new style clamps.

[Run Data on Next Page]
Run Data Summary for 10/30-11/6/15
Series 4400 65 kWe ElectraTherm Power+ Generator and 150 H.P. 30 psi Clever Brooks boiler
Cumulative runtime: 1848 Hr.
Total cumulative kWh generated: 98,524
Average Gross kWe: 56
(As noted in Lessons Learned, future installations will include a 60 psi boiler rather than the current 30 psi boiler to allow for max kWe output from Power+ Generator)

All prior weekly reports found below
Weekly Report October 22-30, 2015

The following is a summary of activities for the week:

October 22-26: All systems nominal. Monitoring and controlling remotely.

October 26: Lost boiler due to lose ground wire in flame controller. PBBS boiler tech was dispatched to the site and quickly identified the problem, tightened the wire and brought the boiler on line.

October 26-27: All systems nominal. Monitoring and controlling remotely.

October 27: Boiler went down due to lost gas from gas treater units. It is assumed that a flare gas modification from the wells caused the gas treater units to go down. Gas treaters were brought back on line and boiler gas supply was restored. Power+ system was brought back on line.

October 27-30: All systems nominal. Monitoring and controlling remotely.

Lessons learned this reporting period:
1. This week’s operation was fairly uneventful with only two shut downs caused by what is assumed was change in flare gas adjustments going to the gas treaters. See Lessons Learned below. There have been no such issues since.
2. There have been no Grid Protection or phase imbalance shut downs since the settings were changed. Again, a big thanks to McKenzie Electric for their assistance in determining a solution.
3. There was no boiler or boiler related down time during this period.

[Run Data on Next Page]
Run Data Summary for 10/22/15 – 10/30/15
Series 4400 65 kWe ElectraTherm Power+ Generator and 150 H.P. 30 psi Clever Brooks boiler
Cumulative runtime: 1702 Hr.
Total cumulative kWh generated: 90,335
Average Gross kWe: 57
(As noted in Lessons Learned, future installations will include a 60 psi boiler rather than the current 30 psi boiler to allow for max kWe output from Power+ Generator)

All prior weekly reports found below
October 15 - 22, 2015

The following is a summary of activities for the week:

October 15-19: All systems nominal. Monitoring and controlling remotely.

October 19: Boiler shut down for unexplained reasons. *see Lessons Learned #1


Lessons learned this reporting period:
1. This week’s operation was fairly uneventful with only one shut down caused by an unexplained boiler shut down. PBBS Boiler tech was dispatched and found lose ground wire in flame control system. He tightened wire and restarted boiler. There have been no such issues since.
2. There have been no Grid Protection or phase imbalance shut downs since the settings were changed. Again, a big thanks to McKenzie Electric for their assistance in determining a solution.
3. There was no boiler or boiler related down time during this period.

Run Data Summary for 10/15/15 – 10/22/15
Series 4400 65 kWe ElectraTherm Power+ Generator and 150 H.P. 30 psi Clever Brooks boiler
Cumulative runtime: 1577 Hr.
Total cumulative kWh generated: 83,207
Average Gross kWe: 56.38
(As noted in Lessons Learned, future installations will include a 60 psi boiler rather than the current 30 psi boiler to allow for max kWe output from Power+ Generator)
October 9 - 15, 2015

The following is a summary of activities for the week:

October 9: All systems nominal. Monitoring and controlling remotely.

October 9: Phase imbalance shut down Power+, boiler not affected.

October 9-10: All systems nominal. Monitoring and controlling remotely.

October 10: Phase imbalance shut down Power+, boiler not affected.

October 10-11: All systems nominal. Monitoring and controlling remotely.

October 11: Grid protection relay shut down Power+.

October 11-14: All systems nominal. Monitoring and controlling remotely.

Lessons learned this reporting period:
1. This week’s operation was again uninterrupted but for a few hours due to a phase imbalance and a grid protection relay shutdown on three occasions.
2. On October 14 GCGE and ElectraTherm conferenced with McKenzie Electric Coop’s engineering Team to determine if there were events on the grid that have taken the Power+ offline. It was determined that there were possible overvoltage events on the grid that may have caused the Power+ to shut down as measured by McKenzie’s recording equipment. It was agreed by all that future events may be prevented by adjusting the controls on the Power+ to allow more tolerance for overvoltage events on the grid. However, after further review of the Coops data from the recorder along with the Power+ historical scans, it was clear that the nominal site voltage fluctuates between 490V and 500V. Voltage near the correct time suggests that the shutdown events have been under voltage rather than overvoltage. The set point on the Power+ is set at less than 450V. Therefore, the likely solution is to decrease the under voltage set point to 400V. This should reduce shutdowns from the momentary spikes as seen in the Coop’s data. Because there are several other systems that will shut the Power+ in the case of a prolonged under voltage event, we asked Mark Deaver with Hess if he could assist. Mark sent one of his electricians to the site to change the set point. With ElectraTherm’s Tom Brokeau on the phone, the electrician made the change in less than three minutes. We will continue to monitor the system to determine if this change eliminates the GPR shutdowns.
3. There was no boiler or boiler related down time during this period.

One another note...
Please mark your calendar for Tuesday October 20, 2015 at 2:00-3:00 PM CDT for Environmentally Friendly Drilling Program’s web-based review of this EFD demonstration in the Bakken. Please join our meeting from your computer, tablet or smartphone. https://global.gotomeeting.com/join/541325725
You can also dial in using your phone.
United States: +1 (571) 317-3122  Access Code: 541-325-725

[Run Data on Next Page]
Run Data Summary for 10/8/15 – 10/15/15
Series 4400 65 kWe ElectraTherm Power+ Generator and 150 H.P. 30 psi Clever Brooks boiler
Cumulative runtime: 1436 Hr.
Total cumulative kWh generated: 75,228
Average Gross kW: 53.51
(As noted in Lessons Learned, future installations will include a 60 psi boiler rather than the current 30 psi boiler to allow for max kW output from Power+ Generator)

All prior weekly reports found below
Weekly Report

October 3 - 9, 2015

The following is a summary of activities for the week:

October 3-4: All systems nominal. Monitoring and controlling remotely.

October 4: Phase imbalance shut down Power+, boiler not affected.

October 4-6: All systems nominal. Monitoring and controlling remotely.

October 6: Phase imbalance shut down Power+, boiler not affected.

October 6-8: All systems nominal. Monitoring and controlling remotely.

October 8: Boiler shut down due to low water alarm. Nolan Rangel with Hess tightened hose clamp between boiler container and Power+ and added water. Boiler came back on line. All systems nominal. Monitoring and controlling remotely.

Lessons learned this reporting period:

1. This week’s operation was again uninterrupted but for a few hours due to a phase imbalance.
2. Last week McKenzie Electric Coop’s engineering Team installed recording equipment on their power line at the site and began monitoring to see if future phase imbalance events which shut down the Power+ coincide with any event on the Coop’s grid. The equipment will be left monitoring for an unspecified time or until another phase imbalance or other event causes a Power+ shut down. This week there have been two events which shut down the Power+. We will be conferencing with McKenzie next week to identify any possible causes.
3. There was no boiler or boiler related down time during this period until October 8 when the boiler shut down for low water. Nolan Rangel with Hess identified a small and slow leak from one of the hot water hoses outside the container. He tightened the clamps and added water to the boiler which allowed it to come on line. Shortly after the Power+ Generator was back on line.

One another note....

Mark your calendar for Tuesday October 20, 2015 at 2:00-3:00 PM CDT for Environmentally Friendly Drilling Program’s web-based review of this EFD demonstration in the Bakken

Please join our meeting from your computer, tablet or smartphone.

https://global.gotomeeting.com/join/541325725
You can also dial in using your phone.
United States: +1 (571) 317-3122
Access Code: 541-325-725

[Run Data on Next Page]
Run Data Summary for 10/1/15 – 10/8/15
Series 4400 65 kWe ElectraTherm Power+ Generator and 150 H.P. 30 psi Clever Brooks boiler
Cumulative runtime: 1319 Hr.
Total cumulative kWh generated: 69,961
Average Gross kWe: 58.4
(As noted in Lessons Learned, future installations will include a 60 psi boiler rather than the current 30 psi boiler to allow for max we output from Power+ Generator)
September 25 – October 2, 2015

The following is a summary of activities for the week:

September 25-26: All systems nominal. Monitoring and controlling remotely.

September 26: Phase imbalance shut down Power+, boiler not affected.

September 26 -October 2: All systems nominal. Monitoring and controlling remotely.

Lessons learned this reporting period:

1. This week’s operation was uninterrupted but for a few hours do to a phase imbalance.
2. McKenzie Electric Coop’s engineering Team installed recording equipment on their power line at the site and began monitoring to see if future phase imbalance events which shut down the Power+ coincide with any event on the Coop’s grid. The equipment will be left monitoring for an unspecified time or until another phase imbalance or other event causes a Power+ shut down.
3. There was no boiler or boiler related down time during this period.

[Run Data on Next Page]
Run Data Summary for 9/25/15 – 10/2/159/25/15
Series 4400 65 kWe ElectraTherm Power+ Generator and 150 H.P. 30 psi Clever Brooks boiler
Cumulative runtime: 1161 Hr.
Total cumulative kWh generated: 59,700
Average Gross kW: 54
(As noted in Lessons Learned, future installations will include a 60 psi boiler rather than the current 30 psi boiler to allow for max we output from Power+ Generator)

All prior weekly reports found below
Weekly Report

September 18 – September 25, 2015

The following is a summary of activities for the week:

September 18 -20: All systems nominal. Monitoring and controlling remotely.

September 20: Emergency Belt Break Shutdown sensor shut all equipment down.

September 13 – 18: All systems nominal. September 21: With input from ET engineering, Tyson Mingo with Hess performed visual inspection of drive belt and its sensor and determined that the drive belt was in place. Engineering determined that the cause of the shutdown was due to a faulty sensor and restarted all equipment. Time to restart, minimal. ET engineering is working with the sensor Mfg. to determine the cause. The purpose of the sensor is to shut the equipment off should the belt break and to aid remote operators to determine the cause of the shutdown. Other safeties in the system would also shut down, so the sensor is nonessential to the operation.

September 21-23: All systems nominal. Monitoring and controlling remotely.

September 23: Phase imbalance shut down Power+, boiler not affected. Caused by unexplained power bump. Equipment brought on line. Time to restart, minimal.

September 23-25: All systems nominal. Monitoring and controlling remotely.

Lessons learned this reporting period:

1. This week’s operation took the trial over 1000 hours of operation with over 50,000kW of power generated. It also leads us into the last weeks of the Trial.
2. But for the few hours that the Power+ was offline on Sept. 20 due to a faulty belt break sensor and a phase imbalance due to a grid power spike, the entire system has operated as designed.
3. There were no boiler or boiler related down time during this period.
4. GCGE and ET engineering conferenced with McKenzie Coop’s electrical engineers on Sept. 25 to look for reasons and solutions to grid caused power spikes. The result of the call is that the Coop will place recording equipment on their power line at the site and monitor the operation for 2-3 days. Then all parties will conference on Oct. 1 to compare any Power+ alarms with possible events found with the Coops recording equipment.

[Run Data on Next Page]
Run Data Summary for 9/18/15 – 9/25/15
Series 4400 65 kWe ElectraTherm Power+ Generator and 150 H.P. 30 psi Clever Brooks boiler
Cumulative runtime: 1043 Hr.
Total cumulative kWh generated: 53,296
Average Gross kW: 56.16
(As noted in Lessons Learned, future installations will include a 60 psi boiler rather than the current 30 psi boiler to allow for max we output from Power+ Generator)

All prior weekly reports found below
Weekly Report

September 12 – September 18, 2015

The following is a summary of activities for the week:

September 12 -13: All systems nominal. Monitoring and controlling remotely.

September 13: Phase imbalance shut down Power+, boiler not affected. Caused by unexplained power bump. Hess’s Nolan Rangel restarted while on site. Time to restart, minimal.

September 13 – 18: All systems nominal. Monitoring and controlling remotely.

Lessons learned this reporting period:

1. But for the few hours that the Power+ was offline on Sept. 13 due to a power bump, the entire system has operated as designed.
2. There was no boiler or boiler related down time during this period.
3. While we lost power only once due to a suspected power bump, we continue to narrow down the cause of the Power+ outages and will be conferencing early next week with McKenzie Power Coop to get their input and suggestions for a remedy.
4. This week’s power generation was only interrupted once for just a few hours. This week demonstrated the best power generation so far.
5. We are approaching 1000 hours of operation and the Power+ has been offline a small percentage of that time due to technical difficulties with the unit. We will provide a summary of run time as we approach the end of the Trial.

[Run Data on Next Page]
Run Data September 12 - 18, 2015

Run Data Summary for 9/12/15 – 9/18/15
Series 4400 65 kWe ElectraTherm Power+ Generator and 150 H.P. 30 psi Clever Brooks boiler
Cumulative runtime: 855 Hr.
Total cumulative kWh generated: 42,891
Average Gross kWe: 54.43
(As noted in Lessons Learned, future installations will include a 60 psi boiler rather than the current 30 psi boiler to allow for max we output from Power+ Generator)

All prior weekly reports found below
HARC/EFD Flare-to-Power Trial Project

Weekly Report

September 4 – September 11, 2015

The following is a summary of activities for the week:

September 4 - 5: All systems nominal. Monitoring and controlling remotely.

September 5: Phase imbalance shut down Power+, boiler not affected. Caused by unexplained power bump. Restarted remotely two hours later.

September 5 – 8: All equipment running 24/7. All systems nominal. Monitoring and controlling remotely.

September 7: Boiler tech, Mike Cleveland, installed boiler gas flow meter.

September 8 – 10: Program Manager, Jesse Alonzo, Texas A&M Agrilife Research | Institute of Renewable Natural Resources conducts emissions monitoring from flare and Power+ system boiler. His report is forthcoming.

September 8: Boiler shut down for unexplained reason. Tyson from Hess restarted. All systems nominal. Monitoring and controlling remotely.

September 9: RPM sensor on Power+ shut down Power+ generator. Determined that the sensor failed and was giving false readings. Troy from Delta Contractors dispatched electrician who, with guidance from ElectraTherm engineering, replaced sensor with a replacement from the spare parts inventory left on site in boiler room. Time to replace: approx. 30 minutes. Power+ brought back on line at 1900. All systems nominal. Monitoring and controlling remotely.

September 9-11: All equipment running 24/7. All systems nominal. Monitoring and controlling remotely.

Lessons learned this reporting period:

1. Boiler tech, Mike Cleveland, determined that the boiler shut downs have been caused by the low gas pressure switch setting. He reset and no new boiler shut downs have been experienced and no new shutdowns are anticipated.

2. Program Manager, Jesse Alonzo, Texas A&M Agrilife Research | Institute of Renewable Natural Resources who was on site to conduct emissions monitoring from flare and Power+ system boiler, was very helpful by assisting in determining cause of RPM sensor failure. We greatly appreciate his professionalism and his willingness to assist.

3. Hess and GTUIT were very accessible and provided the information needed for Jesse Alonzo to conduct his emissions testing.

[Run Data on Next Page]
Run Data September 4 - 10, 2015

Run Data Summary for 9/4/15 – 9/10/15
Series 4400 65 kWe ElectraTherm Power+ Generator and 150 H.P. 30 psi Clever Brooks boiler
Cumulative runtime: 696 Hr.
Total cumulative kWh generated: 34,144
Average Gross kWe: 53.77
(As noted in Lessons Learned, future installations will include a 60 psi boiler rather than the current 30 psi boiler to allow for max we output from Power+ Generator)

All prior weekly reports found below
HARC/EFD Flare-to-Power Trial Project

Weekly Report

August 28 – September 4, 2015

The following is a summary of activities for the week:

[NOTE: This report marks the beginning of the second month of the three month Trial]

August 28: All systems nominal. Monitoring and controlling remotely.

August 28: Phase imbalance shut down Power+, boiler not affected. Caused by power company power bump. Restarted remotely two hours later

August 28-29: All equipment running 24/7. All systems nominal. Monitoring and controlling remotely.

August 29: Phase imbalance from power company shut down Power+ only, boiler not affected. Restarted remotely two hours later

August 29-31: All equipment running 24/7. All systems nominal. Monitoring and controlling remotely.

August 31: Phase imbalance from power company shut down Power+ only, boiler not affected. Restarted remotely two hours later

August 31-Sept. 2: All equipment running 24/7. All systems nominal. Monitoring and controlling remotely.

Sept. 2: Lost power to boiler at 1651 for unexplained reason. Power still available to and energizing Power+.

Sept 3, 0800: While on site, Nolan with Hess restarted boiler. Power+ came online automatically after hot water temp set point was achieved.

September 3-4: All equipment running 24/7. All systems nominal. Monitoring and controlling remotely.

Lessons learned this reporting period:

1. Unexplained power outages to the Power+ occurred on three occasions. We continue to collect data on the times that they occur to determine if there is a pattern. On cause could be a load which comes online routinely. We will be reviewing the data and once we have enough occurrences to indicate a pattern, or not, we will be conferencing with McKenzie Elec. Coop to explore possible causes/solutions.

[Just as mentioned last week, small power surges are normal and not unusual with any power provider. However the Power+ has a very high level of safety engineered into the system which tells the equipment that there could be a very real threat when a power spike happens. Therefore “power spikes” or “bumps” that typically do not cause issues for the vast majority of power users do cause the Power+ to shut down. There were two such spikes or bumps this week which shut down the Power+ but not the boiler system. The Power+ was easily restarted remotely which took only a matter of seconds.]

2. Although replacing the regulator appears to have solved unexplained shut down of the boiler, the LEL monitor/gas shut off valve role in shut downs is still in questions and being studied. There was one such occasion which caused the boiler to lose
power but not the Power+. Mike Cleveland will be on site on Labor Day to install boiler inlet gas flow meter and while there will install a Cat5 cable from the LEL monitor PLC to the modem contained within the Power+ which will allow internet connectivity for the PLC. ElectraTherm Chief Engineer, Tom Brokeau, should be able to then determine if the power outages are being caused by the LEL monitor/gas shut off valve.

(look to last week’s Lessons learned for information on multiple LEL monitors for future projects and remote boiler start up.)

3. Unseasonably high ambient temperatures over 100F. have occurred during this period and approaching 110F on two days. Temperatures for the coming week are forecast to be more seasonable which should allow for a higher average kW output.

4. Look to last week’s Lessons learned for information on multiple LEL monitors for future projects and remote boiler start up.

5. Unseasonably high ambient temperatures over 100F. have occurred during this period and approaching 110F on two days. Temperatures for the coming weeks are forecast to be more seasonable which should allow for a higher average kW output.

Run Data August 28 – September 4, 2015

Run Data Summary for 8/28/15 – 9/4/15
Series 4400 65 kW ElectraTherm Power+ Generator and 150 H.P. 30 psi Clever Brooks boiler
Cumulative runtime: 584 Hr.
Total cumulative kWh generated: 28,075
Average Gross kW: 50.13
(As noted in Lessons Learned, future installations will include a 60 psi boiler rather than the current 30 psi boiler to allow for max kW output from Power+ Generator)
HARC/EFD Flare-to-Power Trial Project

Weekly Report

August 21 -28, 2015

The following is a summary of activities for the week:

August 22: Boiler tech, Mike Cleveland installs new and larger diaphragm gas regulator. Boiler and Power+ restarted. All equipment running 24/7. All systems nominal. Monitoring and controlling remotely.


August 23 – 25: All equipment running 24/7. All systems nominal. Monitoring and controlling remotely.

August 25: Phase imbalance from power company shut down Power+ only, boiler not affected. Restarted remotely two hours later.

August 25 – 28: All equipment running 24/7. All systems nominal. Monitoring and controlling remotely.

Lessons learned this reporting period:

1. Small power surges are normal and not unusual with any power provider. However the Power+ has a very high level of safety engineered into the system which tells the equipment that there could be a very real threat when a power spike happens. Therefore “power spikes” or “bumps” that typically do not cause issues for the vast majority of power users do cause the Power+ to shut down. There were two such spikes or bumps this week which shut down the Power+ but not the boiler system. The Power+ was easily restarted remotely which took only a matter of seconds.

2. Replacing the regulator appears to have solved unexplained shut down of the boiler, however, the LEL monitor/gas shut off valve role in shut downs is still in questions and being studied.

3. Future boiler packages should include a minimum of two LEL monitors with three being a consideration. This will allow for multiple “voting” which will reduce the possibility of false readings by a single LEL monitor which the current boiler package has in place.

4. Remote restarts for the Power+ after a power outage have been successful and only take seconds. This does not infer that should the boiler go down that it can be restarted remotely. The current boiler package will require a manual restart which takes less than five minutes on average.

5. ElectraTherm engineering Team is studying the effects that a greater pressure boiler will have on electrical output from the Power+. The current system has a 30 PSI rating and it is assumed that a 60 PSI boiler will deliver more BTU’s to the Power+ and thus allow for greater power generation. Preliminary results indicate a fairly significant increase. Final results will be included in a future report.

6. We are also studying the effects of the close proximity of the flare to this Trail and how the significant increased ambient temperature, sometimes as much as 20+ degrees, affects the efficiency of the liquid loop radiator and thus the power output. Final results will be included in a future report.

[See run data on next page]
Below is an interesting screen from our remote monitoring equipment. It is included to demonstrate the level of sophistication that the Trial is being monitored.
Run Data August 21 – 28, 2015

Run Data Summary for 8/21/15 - 8/28/15
Series 4400 65 kWe ElectraTherm Power+ Generator and 150 H.P. 30 psi Clever Brooks boiler
Cumulative runtime: 452 Hr.
Total cumulative kWh generated: 21,456
Average Gross kWe: 53.11
(As noted in Lessons Learned, future installations will include a 60 psi boiler rather than the current 30 psi boiler to allow for max kWe output from Power+ Generator)

All prior weekly reports found below
HARC/EFD Flare-to-Power Trial Project

Weekly Report

August 14 – 21, 2015

The following is a summary of activities for the week:

August 14-17: All equipment running 24/7. All systems nominal. Monitoring and controlling remotely.

August 17: Boiler shut down at 1620 due to grid power outage which shut down the wells as well.

August 18: Hess field operators restarted boiler and Power+ after power was restored to the wells and all wells were brought back on line.

August 18-20: All systems nominal. Monitoring and controlling remotely. Lost boiler at 1500 due to no gas flow. Hess field operator restarted boiler and Power+. It appears that a power surge may have disabled the PLC which controls the LEL gas solenoids and thus shut off the flow of gas. In discussions with the power Coop we learned that the power line which supplies power to the site has had a history of power surges and in some cases outages. We are looking for a solution for intermittent and short power surges.

August 21: Boiler shut down and 0830. Will wait for boiler tech, Mike Cleveland to install new regulator on 8/22. He will assess the situation and provide feedback on the cause of the boiler going down. He, PBBS Boilers, and R.F. MacDonald Boilers agree that the new larger diaphragm gas regulator will add more reliability to the gas flow. If we continue to have occasional boiler shut downs we will evaluate the cause with a power bump from the power company being the first possible cause.

Lessons learned this reporting period:

1. Small power surges from the power company can interrupt the LEL shut off valves. A solution is being researched.
2. The Hess field operators have been very willing to assist with boiler re-start for which we want to give them a big thanks.

[Run Data on Next Page]
Run Data Summary for 8/14/15 - 8/21/15
Series 4400 65 kWe ElectraTherm Power+ Generator and 150 H.P. 30 psi Clever Brooks boiler
Cumulative runtime: 384 Hr.
Total cumulative kWh generated: 15,890
Average Gross kW: 49.55
(As noted in Lessons Learned, future installations will include a 60 psi boiler rather than the current 30 psi boiler to allow for max kW output from Power+ Generator)

All prior weekly reports found below
August 7 - 14, 2015

The following is a summary of activities for the week:

August 7-10: All equipment running 24/7. All systems nominal. Monitoring and controlling remotely.

August 11: Boiler shut down at 1430 for unknown reasons. Power+ went offline shortly after. Contacted boiler tech, Mike Cleveland to go to site and assess.

August 11-13: All systems down waiting Mike’s scheduled service call. Because of the Trial nature of the project, Mike was asked to schedule his trip as routine and non-emergency.

August 13: Mike arrives at site at 2000 and determines that the issue which shut down the boiler was low gas flow to the boiler. He checked all systems and did not find the cause. He restarted the boiler at 2045 and Power+, which was in automatic standby mode, came online as per procedure. All systems nominal. Monitoring and controlling remotely.

August 14: GCGE/ET/Mike Cleveland conference to determine cause of low gas flow to the boiler and agreed that the gas regulator between the surge tank and boiler was the cause of the low and intermittent flow. All agreed to replace the regulator with a larger capacity one which Mike is sourcing and will install when he receives it. It was agreed to continue to run the boiler to assess if the same problem occurs. Boiler and Power+ were still running at 1500. GTUIT is currently checking to see if the gas supply may have been interrupted which would have cause the shutdown. All systems nominal. Monitoring and controlling remotely.

Lessons learned this reporting period:

1. Future projects should be the greatest distance from the flare as practical. Heat from the flare increases the ambient temperature near the Power+ which decreases efficiency. (See ambient temperature line on chart below which was well above the actual ambient in Keene, N.D.) Also, locate as far away as practical from GTUIT equipment due to the high noise associated with the GTUIT process.

2. Install a larger diaphragm regulator between the gas supply and the boiler. Once the proper regulator has been identified and proven, it will be specified in all future applications. (see earlier reports for other lessons learned)

[Run Data Chart on Next Page]
Run Data Summary for 8/7/15 - 8/14/15
Series 4400 65 kWe ElectraTherm Power+ Generator and 150 H.P. 30 psi Clever Brooks boiler
Cumulative runtime: 219 Hr.
Total cumulative kWh generated: 9,429
Average Gross kWe: 52.15
(As noted in Lessons Learned, future installations will include a 60 psi boiler rather than the current 30 psi boiler to allow for max kWe output from Power+ Generator)
HARC/EFD Flare-to-Power Trial Project

Weekly Report
July 28-August 7, 2015

The following is a summary of activities for the week:

July 28: Team completes Hess on-site training in Tioga then goes to HA-Rothsurd Well site to assess site

July 29: All equipment landed and set, re-set, connected and ready for final commissioning to be completed after power is delivered to equipment. Boiler pre-commissioned by PBBS certified boiler Tech Mike Cleveland

July 30: Power delivered to equipment and final commissioning of P+ and boiler completed.

July 31: Initiated testing of all equipment. Addressed LEL monitor/emergency shut off/strobe light issue

August 1: Tested and ran all equipment during daytime. Shut down while unattended until LEL monitoring equipment installed

August 2: Ran all equipment during day but for one hour for Mike Cleveland to address and replace malfunctioning boiler high-pressure switch. LEL monitor equipment installed/tested at 1950 Hr. All LEL equipment passed all tests. Began running all equipment 24/7.

August 3: All equipment ran successfully all night. Hess Operations and Facilities completed walk around. All systems nominal. Final GCGE/ET Team members departed site and begin remote monitoring and operations.

August 4-6: All equipment running 24/7. All systems nominal. Monitoring and controlling remotely

August 7: Mike Cleveland on site at 0830 and observed the boiler shut down due to malfunctioning pressure switch. 0859: Switch replaced and boiler brought back on line and Power + restarted. All equipment is currently running and being monitored and controlled remotely. All systems nominal at 1410.

Lessons learned to date:

1. Avoid Crane – leave both Power + Generator and Boiler container on tractor trailer to provide mobility/modularity and avoid crane expense.
2. Install steps so the screens are accessible and make monitor movable to aid viewing
3. Place flex hose in troughs between the 2 trailers to raise hot water inlet and return to the appropriate height
4. Design boiler for 60 psi so there is more margin so operating conditions are not constrained by boiler pressure. Current boiler is a 30 psi design which does not allow maximum hot water temperature and Power+ Generator maximum output. Future installations will include a 60 psi boiler rather than the current 30 psi boiler which will allow for max kWe output from Power+ Generator
5. Add gas flow meter inside boiler container as part of package
6. Add boiler LEL monitor/electric shut off/strobe as part of the boiler package
7. Winterize container with HESS input for next installation

NOTE:
1. Mike Cleveland, certified boiler Tech with PBBS, will be making weekly inspections of boiler and Power+ Generator and be on call for length of Trial.
2. Additional Lessons Learned will be added throughout the Trial

[See run data on next page]
Run Data Summary for 7/30 – 8/6.
Series 4400 65 kWe ElectraTherm Power+ Generator and 150 H.P. 30 psi Clever Brooks boiler
Average Hot Water In = 232 F
Average Cold Water In = 90 F
Cumulative runtime: 114 Hr.
Total kWh generated: 3,957
Average Gross kWe: 51.47
(As noted in Lessons Learned, future installations will include a 60 psi boiler rather than the current 30 psi boiler to allow for max kWe output from Power+ Generator)