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VALUE-ADDED PRODUCTS FROM REMOTE NATURAL GAS

Topical Report

By
Lyle A. Johnson Jr.

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For
Carl D. Underwood Oil and Gas
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And
U.S. Department of Energy
National Energy Technology Laboratory
Morgantown, West Virginia

By
Western Research Institute
Laramie, Wyoming

DISCLAIMER

ABSTRACT

In Wyoming and throughout the United States, there are natural gas fields that are not producing because of their remoteness from gas pipelines. Some of these fields are ideal candidates for a cogeneration scheme where components suitable for chemical feedstock or direct use, such as propane and butane, are separated. Resulting low- to medium-Btu gas is fired in a gas turbine system to provide power for the separation plant. Excess power is sold to the utility, making the integrated plant a true cogeneration facility.

This project seeks to identify the appropriate technologies for various subsystems of an integrated plant to recover value-added products from wet gas and/or retrograde condensate reservoirs. Various vendors and equipment manufacturers will be contacted and a data base consisting of feedstock constraints and output specifications for various subsystems and components will be developed. Based on vendor specifications, gas reservoirs suited for value-added product recovery will be identified. A candidate reservoir will then be selected, and an optimum plant layout will be developed. A facility will then be constructed and operated.

The project consists of eight subtasks: Compilation of Reservoir Data; Review of Treatment and Conditioning Technologies; Review of Product Recovery and Separation Technologies; Development of Power Generation System; Integrated Plant Design for Candidate Field; System Fabrication; System Operation and Monitoring; and Economic Evaluation and Reporting. The first five tasks have been completed and the sixth is nearly complete. Systems Operations and Monitoring will start next year. The Economic Evaluation and Reporting task will be a continuous effort for the entire project.

The reservoir selected for the initial demonstration of the process is the Burnt Wagon Field, Natrona County, Wyoming. The field is in a remote location with no electric power to the area and no gas transmission line. The design for the gas processing train to produce the liquefied gas products includes three gas compressors, a cryogenic separation unit, and a natural gas powered generator. Based on the equipment specifications, air quality permits for the well field and the gas processing unit were developed and the permits were issued by the Wyoming Department of Environmental Quality. Also, to make state and federal reporting easier, three of the four leases that made up the Burnt Wagon were combined.

All major equipment has been installed and individual component operability is being conducted. During the next project year, operability testing and the shakedown of the entire system will be completed. Once shakedown is complete, the system will be turned over to the cosponsor for day-to-day operations. During operations, data will be collected through remote linkage to the data acquisition system or analysis of the system performance to develop an economic evaluation of the process.

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EXECUTIVE SUMMARY

In Wyoming and throughout the United States there are natural gas fields that are not producing because of their remoteness from gas pipelines. Some of these fields are ideal candidates for a cogeneration scheme where components suitable for chemical feedstock or direct use, such as propane and butane, are separated. Resulting low- to medium-Btu gas is fired in a gas turbine system to provide power for the separation plant. Excess power is sold to the utility, making the integrated plant a true cogeneration facility.

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INTRODUCTION

Many gas fields in the United States are not producing because of their remoteness from the gas transmission infrastructure. A cursory examination of such reserves in Wyoming shows that nearly one-third of these fields can be utilized for recovering and producing chemical feedstock such as propane, butane, and pentanes.

Gas reservoirs are categorized as dry gas reservoirs, wet gas reservoirs, and retrograde condensate reservoirs. Dry gas reservoirs are composed largely of methane and ethane, with a small percentage of heavier components. Wet gas reservoirs are composed mainly of light hydrocarbons and contain a higher concentration of heavier components than the dry gas reservoirs. In wet gas reservoirs, the temperature and pressure conditions prevalent in the reservoir are in the gas phase region of the phase stability. However, under surface production conditions, condensate that can be separated develops. Retrograde condensate reservoirs are characterized by an even larger concentration of heavy components than present in wet gas reservoirs. In these reservoirs, gas condenses to liquid as the reservoir pressure and temperature decrease during production. Development of condensate is undesirable because the liquid becomes trapped in the reservoir and blocks pores, thus reducing the overall gas recovery and production rate.

This project will identify the appropriate technologies for an integrated plant to recover value-added products, liquified natural gas, and/or alcohol from wet gas and/or retrograde condensate reservoirs. Vendors and equipment manufacturers will be utilized to provide equipment specifications and feedstock constraints for various subsystems and components. Concomitantly, remote and/or inactive gas reservoirs in Wyoming will be evaluated for potential use. Based on vendor specifications, an initial gas reservoir suited for the value-added product recovery system will be identified, and an optimum plant layout developed. A facility will then be constructed and operated.

The project has the potential to open a new way to utilize the gas reserves of the United States that, because of a lack of transmission infrastructure, might otherwise remain underutilized. This type of project also offers a way to test some of the recent developments in low- to medium-Btu gas turbine technology, as well as enhanced gas and oil recovery schemes based on steam and/or gas injection.

OBJECTIVES

The objective of this task is to demonstrate the commercial viability of recovering value-added products from remote wet gas and retrograde condensate gas reservoirs in a cogeneration scheme. Realizing that selection of technologies for various subsystems is dictated by the specifics of upstream and downstream components, the specific objectives of the project are those of plant/systems integration. Objectives of the work are:

- Identify gas reservoirs suitable for such a scheme and select a candidate reservoir based on the available gas field data.

- Identify suitable treatment and conditioning steps and available technologies for the candidate reservoir.

- Develop a range of expected gas composition for power generation. Both conventional and gas turbine technologies will be evaluated.

- Develop an integrated plant layout for the candidate reservoir.

- Construct a pilot plant for the candidate reservoir.

- Operate, monitor, and evaluate the process system.

- Develop plant economics.

PROJECT TASKS

Following is a brief description of the activities to be completed as part of this project.

Compilation of Reservoir Data

Available reservoir data from public and private sources such as the United States and Wyoming Geological Surveys, the Wyoming Oil and Gas Commission, and oil company files will be reviewed. For this project, special attention will be paid to detailed chemistry, contaminants, and reservoir conditions. Equipment selection for gas conditioning and separation technologies is not dictated by the pipeline specifications, but by the salable product quality and the power generation equipment. Based on the review of treatment and conditioning technologies and gas separation technologies, ranges of compatible gas chemistries will be established and used to identify candidate gas fields.

Underwood Oil and Gas Inc., the cosponsor for the project, has several properties that are potential candidates for such a value-added product recovery scheme. Detailed reservoir data will be developed with the intention of identifying one of them as a candidate reservoir for implementation of the process. Activities that may be needed for proper analysis of the reservoirs include: well conditioning for representative sampling, laboratory analyses to identify the composition and properties of the reservoir fluids, and well productivity.

This task has been completed.

Review of Treatment and Conditioning Technologies

Gas produced at any field can contain any number of impurities at the wellhead and in the formation. As in the case of conventional gas field operations for pipeline production, some of these can be detrimental to the operation of a value-added product recovery scheme. The major contaminant of concern from the standpoint of power generation equipment is expected to be sulfur compounds that can cause serious corrosion in the hot-section components of equipment. From the standpoint of gas separation equipment, contaminant tolerance levels are dictated by the separation technology(s) employed. Therefore, special emphasis will be placed on the contaminant removal/suppression efficacy of the specific technologies. If warranted, vendors will be contacted to determine the lowest achievable contaminant levels and associated costs.

This task has been completed.

Review of Product Recovery and Separation Technologies

Depending on the reservoir conditions and wellhead chemistry, several options exist for product recovery and subsequent separation of salable components. Recovery systems such as absorption/stripper and fractionation, membrane separation, cryogenic recovery, and other separation techniques will be evaluated. Pertinent information for various combinations of recovery and separation schemes will be developed to identify the optimum configuration as dictated by the product quality specifications and gas well chemistry.

This task has been completed.

Development of Power Generation System

The use of conventional, natural-gas powered, electrical generators and commercially available, low- to medium-Btu, gas-fired turbines will be reviewed. The availability and suitability of these systems for each scheme will be evaluated by contacting the major equipment manufacturers. Recent developments in the turbine technology for coal gasification systems have led to the design of high-efficiency engines in the low-Btu gas range. Based on the information provided by the manufacturers, a conventional or gas turbine generator system will be selected.

This task has been completed.

Integrated Plant Design for Candidate Field

Based on the data developed in previous tasks, preliminary specifications for the gas conditioning equipment, the recovery and separation, and the power generation systems will be developed for the candidate field. An integrated data acquisition and control system will also be designed. Vendors for the system components and costs will be determined.

This task has been completed.

System Construction

Based on the specifications developed in the plant design task, the system components will be either leased or purchased. The system will be installed at the candidate field. Each component will be checked for operability prior to a complete system shakedown.

The major construction element has been completed. The task involving the operability of the individual components remains to be completed. Some equipment problems and inclement weather slowed this task from the original estimate.

System Operation and Monitoring

Following shakedown, the system will be operated to analyze processing variables and to establish scale-up and economic criteria for larger scale units. During this period, any system or equipment modifications will be done. Operations will be on a round-the-clock basis for whatever periods are required to establish steady-state operating conditions and provide equipment dependability data.

This task will commence when the previous task is complete.

Economic Evaluation and Reporting

An estimate of the capital investment required for a commercial-size facility will be developed. Economic evaluation of the process will include operating and maintenance costs and a projected revenue base. A preliminary market analysis for various possible products will be undertaken early in the project and factored into the selection of recovery and separation technologies.

This task will also include preparation of information for necessary permits, preparation and submission of required technical reports, and the preparation and submission of technical papers to technical meetings and symposia, leading to transfer of the technology to the general petroleum industry on a timely basis.

This is an ongoing task throughout the entire project.

RESULTS AND CONCLUSIONS

Available reservoir data from public and private sources such as the United States and Wyoming Geological Surveys, the Wyoming Oil and Gas Commission, and oil companies were reviewed. Special attention was paid to gas chemistry, contaminants, and reservoir conditions. Also used to select a candidate reservoir was gas conditioning and separation technology requirements, the salable product quality, and requirements of the power generation equipment.

Underwood Oil and Gas Inc. had several properties that were potential candidates for such a value-added product recovery scheme. Detailed reservoir data was developed with the hope of identifying one of them as a candidate reservoir for implementation of the process. The reservoir selected for the initial demonstration of the process is the Burnt Wagon Field, Natrona County, Wyoming. The field is in a remote location with no electric power to the area and no active gas transmission line. The field is also close enough to an equipment and materials supply area, such that this initial development phase will not be penalized by long-term delays in replacement or repair equipment and materials.

Following selection of the field, the cosponsor tested the wells to produce a current gas analysis and flow data. This data was used to specify equipment size. The field consists of five active wells, three wells that produce oil and gas, one well that produces only oil, and one well that has watered out. The three oil and gas producers have the oil separated from the gas and stored in tanks at the well site. The gas from the three wells is piped to a single location at which the gas processing system is placed. The watered-out well will be used for gas reinjection. To make operations simpler and to make state and federal reporting easier, three of the four leases that made up the Burnt Wagon field were combined through work with the U.S. Bureau of Land Management.

The initial, integrated-plant flow diagram is shown in Figure 1. The design includes natural gas compression, cryogenic separation, electric power from a natural gas powered generator, and gas reinjection. The operation pressure of the cryogenic system is 500 to 600 psig and the reinjection of the nonconverted gas is designed for 1,500 to 2,000 psig. To start the project, gas reinjection was selected for the nonconverted gas. The prospects of a gas turbine generator system for excess electrical power and/or a system for producing a clean liquid fuel from the dry methane-ethane gas will continue to be evaluated. If either system has potential to increase the project economics and budgetary constraints are not a problem, they will be incorporated in the future.

Gas produced at Burnt Wagon passes through a heater treater at each well site and then through a secondary gas-liquid separator before it goes to the gas processing system. The field gas does not contain any impurities of any significance, so the selection of a treatment scheme was simplified and no contaminant removal is required. Recovery systems such as absorption/stripper and fractionation, membrane technology, cryogenic recovery, and separation techniques were reviewed. Based on the gas composition and vendor information, a cryogenic system was selected because of the experience of trouble-free operation that has been developed for the process.

The layout of the equipment selected for the gas processing system is shown in Figure 2. Field gas from the three wells is collected at a gas-liquid separator from which gas passes to the gas processing system. The gas is then compressed to 500 to 600 psig with compressors C1 and C2. The pressurized gas then goes to the cryogenic processing unit where it is chilled to -15 to -20 °F (-26.1 to -28.9 °C). The chilled mixture is then separated with the liquified gas going to storage tanks and the dry gas going to compressor C3. C3 pressurizes the gas to 1,500 to 2,000 psig for injection into the watered-out well. The dry gas is also used to fuel the electric generator, compressor C2, and the ethylene glycol dehydrator.

An electric generator was selected as the power generation scheme for this project because it was felt that the technology of small-scale turbines was not simplified enough for deployment in a remote, dirty environment. The turbine technology will continue to be evaluated for future use. The electric generator is powered by a Waukesha 1197 natural gas engine. The system provides all the power for system motors, compressors, instrumentation, and lighting.

The first compressor, C1, is an electric-powered Joy compressor that takes the field gas from approximately 50 psig to 125 psig (Figure 3). The 125-psig gas is required to start compressor C2, which is a natural-gas fueled AJAX DPC 60 with a gas starter (Figure 4). C2 raises the gas pressure to 500 to 600 psig for processing.

The cryogenic gas processing system (Figure 5) chills the pressurized gas to drop out the propane plus components. The system has, in the order of gas flow, two single-pass, tube-and-shell heat exchangers to cool the incoming gas by using the dry, chilled gas on the shell. At the inlet to the first exchanger, 20% water, 80% technical-grade ethylene glycol is added to the gas to entrain any moisture. The gas then passes through the tubes of a double-pass, tube-and-shell heat exchanger where the temperature is reduced to -15 to -20 °F (-26.1 to -28.9 °C) by pressurized propane on the shell side. The chilled mixture is then separated in a three-phase separator into dry gas, liquefied natural gas (LNG), and glycol streams. The LNG passes through a 225-psig reboiler where methane and ethane are removed before the LNG goes to storage tanks. The glycol is dumped to a reboiler where excess water is removed before reuse. The dry gas then is split into two streams, one for equipment fuel and the other to compressor C3. C3 is an electric-powered, single-stroke, Clark compressor where the dry gas is compressed to 1,500 to 2,000 psig for reinjection (Figure 3).

Also included in the equipment is a methanol injection system (Figure 6) to provide methanol at the secondary gas-liquid separator and several points on C2. No methanol injection is required downstream of the cryogenic plant since all water has been removed.

To provide monitoring of the system, a data acquisition system was designed and installed to collect pressures, temperatures, and flows from several locations. The collected data can be accessed from WRI's main office by a remote telephone connection. The data acquisition system only collects data and does not control any equipment. System control is provided by pressure control valves and internal safety controls on each individual piece of equipment.

The fugitive emissions from the gas-fueled process equipment, especially the electric generator and compressor C2, and the fugitive emissions from the oil storage tanks were determined for procuring project air emissions permits from the Wyoming Department of Environmental Quality (WYDEQ). The emissions from the wells, the heater treaters, and the oil storage tanks were determined to be below emission standards, so a waver was granted. The emissions from the gas processing equipment were also below the limits, but because of the potential for the equipment to be used at rates higher than stated, the WYDEQ requested that some type of emission control be used on the electric generator and that the emissions from the electric generator and C2 be tested on a quarterly basis. The emission control system that WYDEQ accepted for the electric generator is a catalytic converter with an air-fuel ratio control system.

All equipment has been received and installed. Because of delays in receiving some of the equipment and the early onset of inclement weather, testing of the individual system components has been delayed.

FUTURE PLANS

The work scheduled for the next project year will commence with the testing of the operability of each component of the gas processing system. Following operability testing, shakedown of the entire system will be initiated. During this period, operational procedures, including shutdown and startup routines for the system, will be developed and tested.

Once shakedown is complete, the system will be turned over to the cosponsor for day-to-day operations. During operations, routine samples of the field gas, the LNG, and the dry gas will be taken. Periodically, testing of the emissions from the electric generator and C3 will be performed to satisfy WYDEQ requirements.

During operations, data will be collected through remote linkage to the data acquisition system. The data will be compiled and analyzed to determine the performance of the system and develop an economic evaluation of the process.

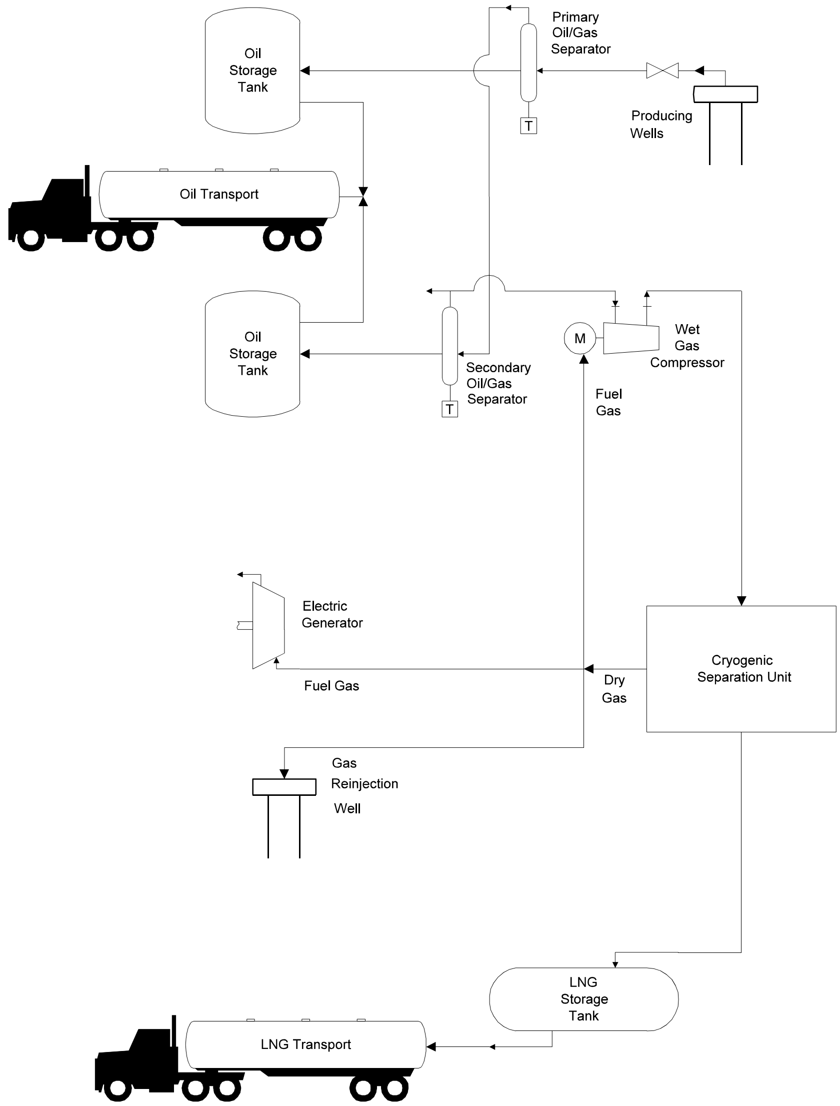

Figure 1. Value-Added Flow Sheet

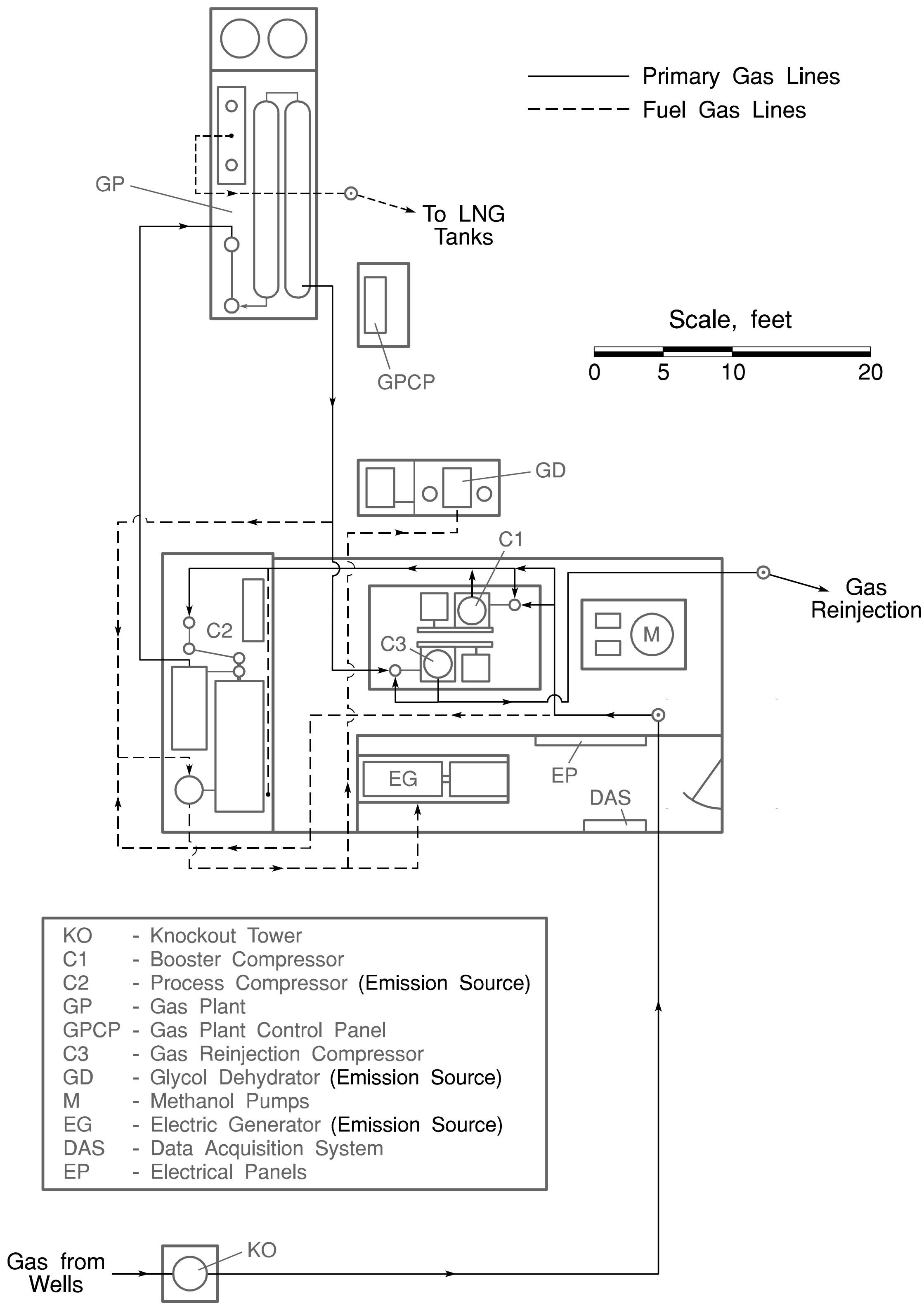

Figure 2. Equipment Layout, Value-Added Project

Figure 3. Electric Compressors C1 and C3, Burnt Wagon Field

Figure 4. Natural Gas Fueled Compressor C2, Burnt Wagon Field

Figure 5. Cryogenic Gas Processing Unit, Burnt Wagon Field

Figure 6. Methanol Injection Unit, Burnt Wagon Field