DEMONSTRATION OF A LOW COST 2-TOWER MICRO SCALE N_2 REJECTION SYSTEM TO UPGRADE LOW-BTU GAS FROM STRIPPER WELLS

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ABSTRACT

Natural gas is marketed on the basis of its heat content (950 BTU/cu ft or higher). U.S. pipeline specifications vary but generally require nitrogen (N_2) to be less than 5% resulting in 32 tcf (17% of known reserves) to be categorized as low-BTU "sub quality". N_2 is thus a major target for removal to upgrade natural gas to pipeline quality. A significant portion of the nation's N_2-rich low-BTU gas is trapped in modest to small fields owned by stripper operators, or isolated behind pipe. These small fields are not amenable to upgrading technologies such as cryogenic separation and conventional pressure swing adsorption (PSA) because these fields cannot usually deliver the large feed volumes necessary for profitable operations of these types of technologies.

In an attempt to encourage economically viable upgrading of low-BTU gas from stripper wells, a demonstration project that encompasses the planning, design, construction, operation, and optimization of an easily built, low-cost, 2-tower micro-scale PSA (pressure swing adsorption) plant for N_2-rejection using non-patented processes and commonly available equipment was proposed as a joint project between the Kansas Geological Survey (KGS) and American Energies Corporation (AEC), Wichita, Kansas.

During the current reporting period, land for a plant site was acquired in the Elmdale field, Chase County, Kansas, and it was followed by the construction of a pad at the plant site. Different components of the plant was purchased and refitted, and then used to complete the construction of the plant. Upon completion of construction, the equipment vessels and pipelines were painted and the plant was made ready for pressure testing. Data inventory of production history, wireline logs, and geologic reports was started in order to conduct a resource evaluation of low-BTU gas potential around the

plant site. For purposes of technology transfer, a dedicated project web site was constructed and uploaded with pictures, reports, analyses, and relevant collected data.

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INTRODUCTION

Natural gas is marketed on the basis of its heat content (950 BTU/cu ft or higher). U.S. pipeline specifications vary but generally require nitrogen (N_2) to be less than 5% resulting in 32 tcf (17% of known reserves) to be categorized as low-BTU “sub quality”. N_2 is thus a major target for removal to upgrade natural gas to pipeline quality. A significant portion of the nation’s N_2-rich low-BTU gas is trapped in modest to small fields owned by stripper operators, or isolated behind pipe. These small fields are not amenable to upgrading technologies such as cryogenic separation and conventional pressure swing adsorption (PSA) because these fields cannot usually deliver the large feed volumes necessary for profitable operations of these types of technologies.

It is the objective of this project to design, construct, operate, and optimize a micro-scale N_2 rejection plant to economically upgrading of low-BTU gas from stripper wells. Our goals were to build a low-cost, 2-tower micro-scale PSA (pressure swing adsorption) plant that would adsorb methane and heavier hydrocarbons under pressure while rejecting the N_2 followed by extraction of the hydrocarbons under vacuum.

Construction of the micro-scale N_2 rejection plant has been completed. The plant is located in Elmdale field, Chase County, Kansas where many wells have encountered low-BTU gas from different horizons. At present, a majority of the low-BTU gas remains unproduced behind pipe. Figure 1 shows the location of the Elmdale field where the majority of the leases are owned/operated by our industry partner American Energies Corporation (AEC), Wichita, Kansas. The location of the plant was chosen so that it is close to the existing pipeline infrastructure (shown in broken red lines) linked to the Southern Star Central pipeline. Also, the plant is located close to Frankhauser Trust E1 well, which produces out of Lansing-Kansas City zone, but had tested significant gas production potential in Tecumseh horizon which produces low-BTU gas in a neighboring well (Palmer 1) to the south. AEC plans to recomplete the Frankhauser Trust E1 well in Tecumseh, test it, and then connect it to the plant to provide a feed stream of low-BTU gas.

EXECUTIVE SUMMARY

This project is a joint effort by the Kansas Geological Survey and American Energies Corporation (a company that primarily operates stripper wells in Kansas). Construction of the proposed micro-scale N_2 rejection plant to upgrade low-BTU gas was begun with earnest after the signing of the contract on September 7, 2007. Requisite land at the proposed plant site was acquired and prepared to build a pad with gravel.

Plant construction at the Elmdale field, Chase County, Kansas was completed during this reporting period. The constructed plant has the following characteristics:

a) Uses non-patented processes and commonly available equipment to minimize construction costs.

b) Uses easily obtained and inexpensive activated charcoal as the adsorbent bed.

c) Is designed as skid-mounted modular units so that the plant is mobile and scalable as per feed volumes.

d) Has a small environmental foot print (400 sq. ft).

e) Does not emit any volatile organic compounds (VOCs).

f) Has few moving parts outside the engine and compressor to reduce labor and maintenance costs.

g) Can operate in remote locations without being connected to the electric grid by being powered by solar panels and low-Btu feed gas.

A web-site dedicated to the project that can be publicly accessed at http://www.kgs.ku.edu/PRS/Microscale/index.html has been built and will serve as the repository to display all results, reports, presentations, pictures, and data analyses related to the project. Also, an inventory of wireline logs from Elmdale field wells and those in the vicinity of the plant has been initiated for the purpose of analyzing gas producing potential of sands above the Lansing-Kansas City – the prevalent producer.

The project along with technology transfer workshops (to be scheduled upon completion) will show that stripper gas well operators can easily build micro N_2-rejection plants for about $100,000, operate it at attractive rates of return (of at least 40%), and significantly add (~1 tcf) to the nation's reserves.

EXPERIMENTAL

PROCESS DESCRIPTION

Figures 2 to 4 are flow diagrams that explain the major steps of the PSA process employed in the operation of the N_2 rejection plant. In the first step, the low-BTU gas is fed into Tower 1 (from bottom left corner of Figure 2). The feed line pressure is expected to be in the range of 50 to 60 psia. During this adsorption stage, the outflow from Tower 1 is closed and the methane is adsorbed in the bed of activated carbon resulting in an increase in tower pressure to around 50 psia. The adsorption time will be determined through the optimization routine. During this phase, Tower 2 remains disconnected from the feed stream.

Upon completion of the adsorption phase, the inlet solenoid valves to both the towers are shut, and the pressure equalization valves at the top of the towers are momentarily opened (Figure 3) so that the pressure equilibrates to around 20 to 25 psia in both the towers. This pressure equalization stage is crucial to reduce the pressure shock on the adsorbent beds as Tower 1 will be put under vacuum to desorb the adsorbed methane (hydrocarbons) after equalizing the pressures. Without this step, the adsorbent bed in the tower would swing from 50 psia to -5 psia instantaneously resulting in bed degradation, dust foul up, and bed compaction. The intermediate step of pressure equalization helps to reduce the pressure shock on the beds as they switch from one mode to the other.

Figure 4 shows the third step of the process where Tower 2 gets connected to the feed stream while Tower 1 is put under vacuum. The pressure in Tower 2 now rises to the line pressure between 50 to 60 psia while Tower 1 goes to -5 psia to extract the adsorbed methane.

SITE PREPARATION

The site selected for locating the plant is shown in Figure 1. Requisite area near the Woods A1 well was acquisitioned from the landowner. This site is adjacent to previously existing water well and also has access to electric supply. The site was leveled and prepared as a pad with gravel to build the plant.

PLANT DESCRIPTION

Figure 5 shows the general layout of the plant. The compact layout minimizes its environmental foot print particularly because it is located in the middle of farming land. Figure 6 shows the (2 inch) feed gas line entering the plant passing through a scrubber for removal of entrained moisture. The dehydrated feed gas then passes through a flow meter that records the rate and pressure. Figure 7 shows the pipe carrying the feed gas into the adsorption/desorption towers. Each of these towers, made of carbon steel, has a 48 inch diameter and is 8 feet tall (seam to seam). Electronically controlled solenoid valves (colored in red) allow feed gas to flow into one tower for adsorption while isolating the other tower for desorption under vacuum. Atop the towers, solenoid valves enable pressure equalization between towers before the adsorption tower switches to desorption mode and vice-versa. A small fraction of the (N_2 rich) waste gas is utilized as instrument gas and is cleaned by the instrument gas scrubber. Figure 7 also shows manholes located at the base of the towers for removal of spent bed materials and cleanup. Commercially available granulated carbon (Figure 8A) was used to charge the towers (Figures 8B and 8C). The activated carbon was purchased in 1100 lb bags. Each tower was charged with about 2200 lbs of activated carbon costing around 7 cents/lb. Figures 9A and 9B show the front and the rear views of the towers. Adsorbed methane is desorbed from the bed under vacuum and flows to the compressor through the upgraded gas line visible in Figure 9B. The lines carrying N_2-rich effluent gas from the towers are visible in Figure 9B and they connect through a (2 inch line) to the methane detector and then onto the flare tower (Figure 10A). The on-line methane detector sets an alarm when methane breakthrough occurs in the effluent stream prompting a change in cycle time. The bull nipple and the hopper used to load the towers with activated carbon are shown in Figure 10B.

Figure 11 shows a 6-cyclinder 50 HP VGG-330 gas-fired engine that operates on the low-BTU feed gas and drives the compressor which pulls the vacuum on the tower under desorption. The upgraded gas is cleaned by the gas scrubber before entering the compressor via a 3 inch line. The compressor used is Ingersoll-Rand unit that is designed for vacuum service. This compressor was modified to run a strong vacuum. The compressed gas passes through a condensate removal tower (Figure 12) before flowing into a surge tank that is designed to have a 1 hour holding capacity for maximum flow rates of 150 mcf/d. Upgraded gas is held in the surge tank (5 feet diameter and 25 feet long) for about an hour so that output from the tank achieves a uniform composition with a heat value greater than 950 BTU/cu ft and a nitrogen content around 5 to 6% or less. The upgraded gas from the surge tank passes through the sales gas meter before connecting to the nearby pipeline.

The construction of the plant was completed during this reporting period. Upon completion of the plant building, all exterior surfaces were painted.

DATA INVENTORY

One of the deliverables for this project is to complete a local resource evaluation of low-BTU reserves around the plant. There are a number of wells producing from the Lansing-Kansas City formation in the area around the Elmdale field. Many of these wells have modern logs and it is our intent to inventory and collect available logs to analyze gas production potential of sands located above the Lansing-Kansas City. AEC has provided the well-level production data for all Elmdale wells that they own/operate. Inventory of wireline logs is under progress.

TECHNOLOGY TRANSFER

A web site dedicated to project has been built and can be publicly accessed at http://www.kgs.ku.edu/PRS/Microscale/index.html. It is our intent to keep this web site regularly updated with pictures, results, cross-sections, log analyses etc. All reports and presentations will also be posted on this web site.

RESULTS & DISCUSSIONS

The N_2 rejection plant is yet to be connected to a low BTU source. The process of optimization to maximize methane recovery at lowest operating costs will commence after the plant is connected to the low-BTU gas well. It is during this process of optimization that data will be collected and analyzed.

FUTURE TASKS

It is expected that during the next reporting period, the following tasks will be undertaken:

a) Test pressure and vacuum integrity of the plant.

b) Recomplete a low-BTU zone at the nearby Frankhauser Trust E1 well.

c) Connect the plant to a low-BTU gas source.

d) Operate plant and optimize it to upgrade low-BTU gas to pipeline quality.

CONCLUSIONS

The following items have been completed during this reporting period:

1. Site preparation and building a pad at the location of the plant.

2. Completed construction of the plant.

3. Data inventory of wireline logs and well-level production has been initiated.

4. A project-specific web site has been constructed to display results about various aspects of the project.

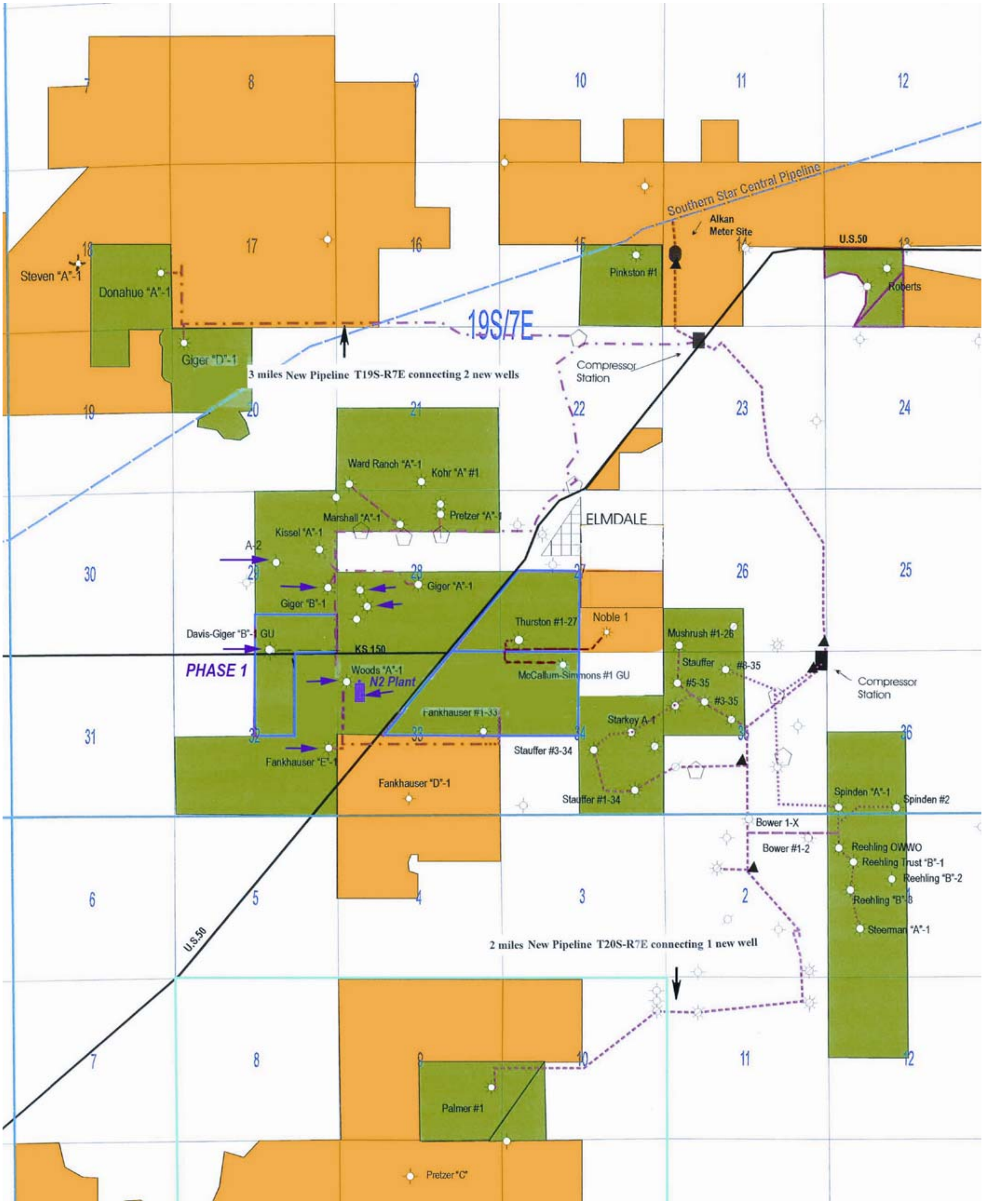


Figure 1. Map showing the location of the Elmdale field, Chase County, Kansas along with the location of the N_2 rejection plant.

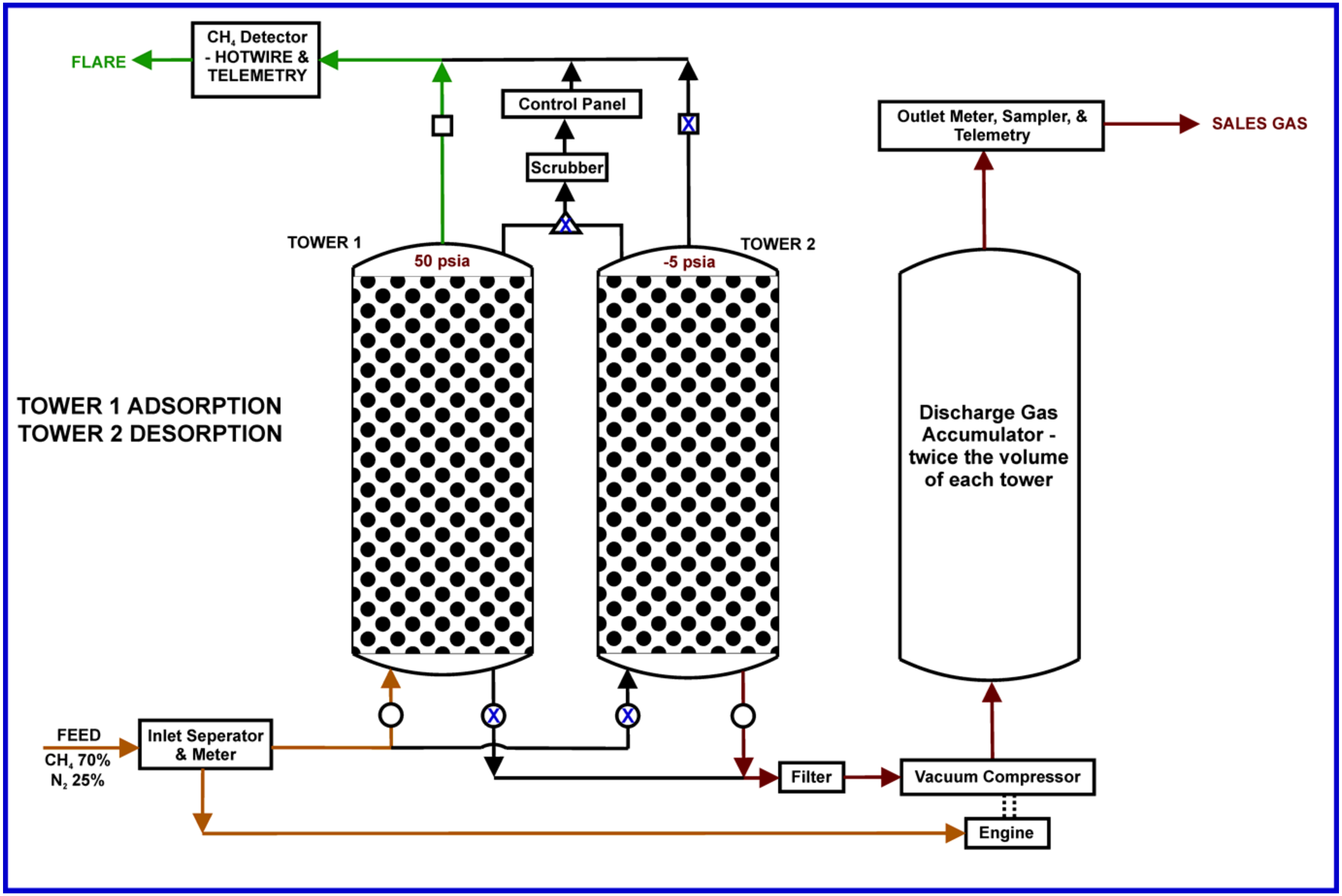


Figure 2: Step 1 of the plant process showing adsroption of methane in Tower 1.

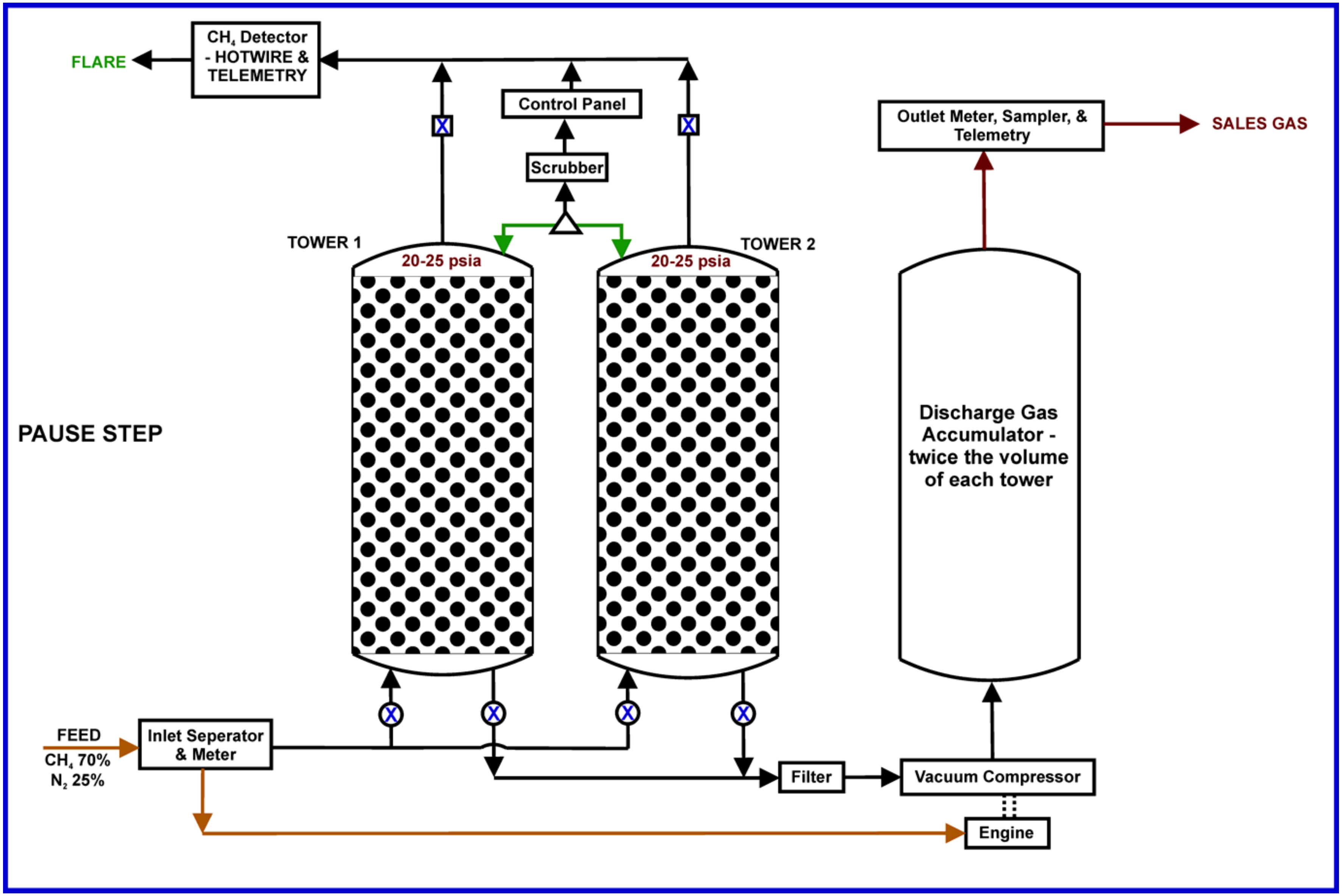


Figure 3: Step 2 of the plant process showing pressure equalization between Towers 1 and 2..

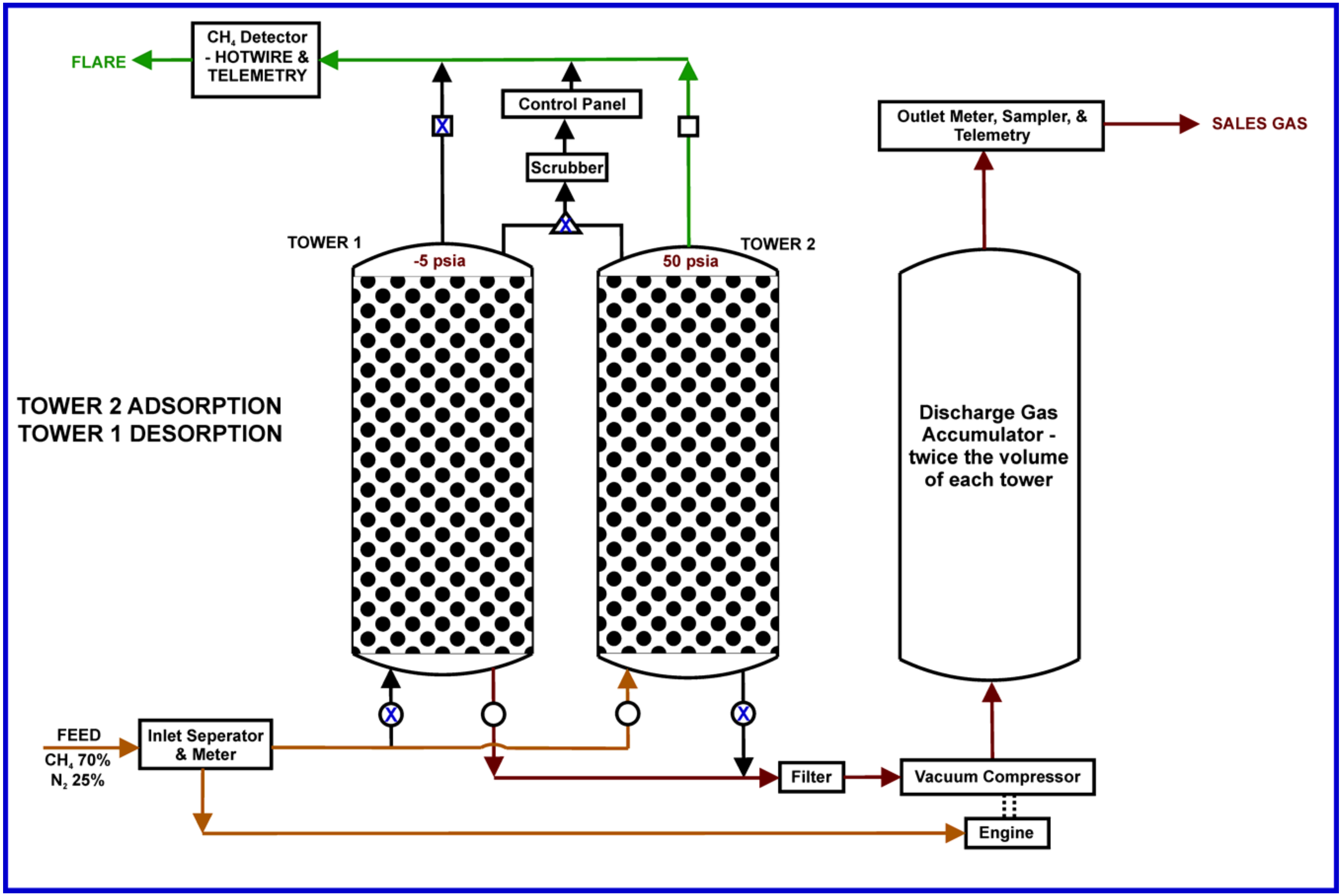


Figure 4: Step 3 of the plant process showing adsroption of methane in Tower 2 and desorption in Tower 1.

Figure 5: Picture showing the general layout of the plant.

Figure 6: Picture showing the feed gas line connecting to the scrubber to remove moisture and onwards to the flow meter.

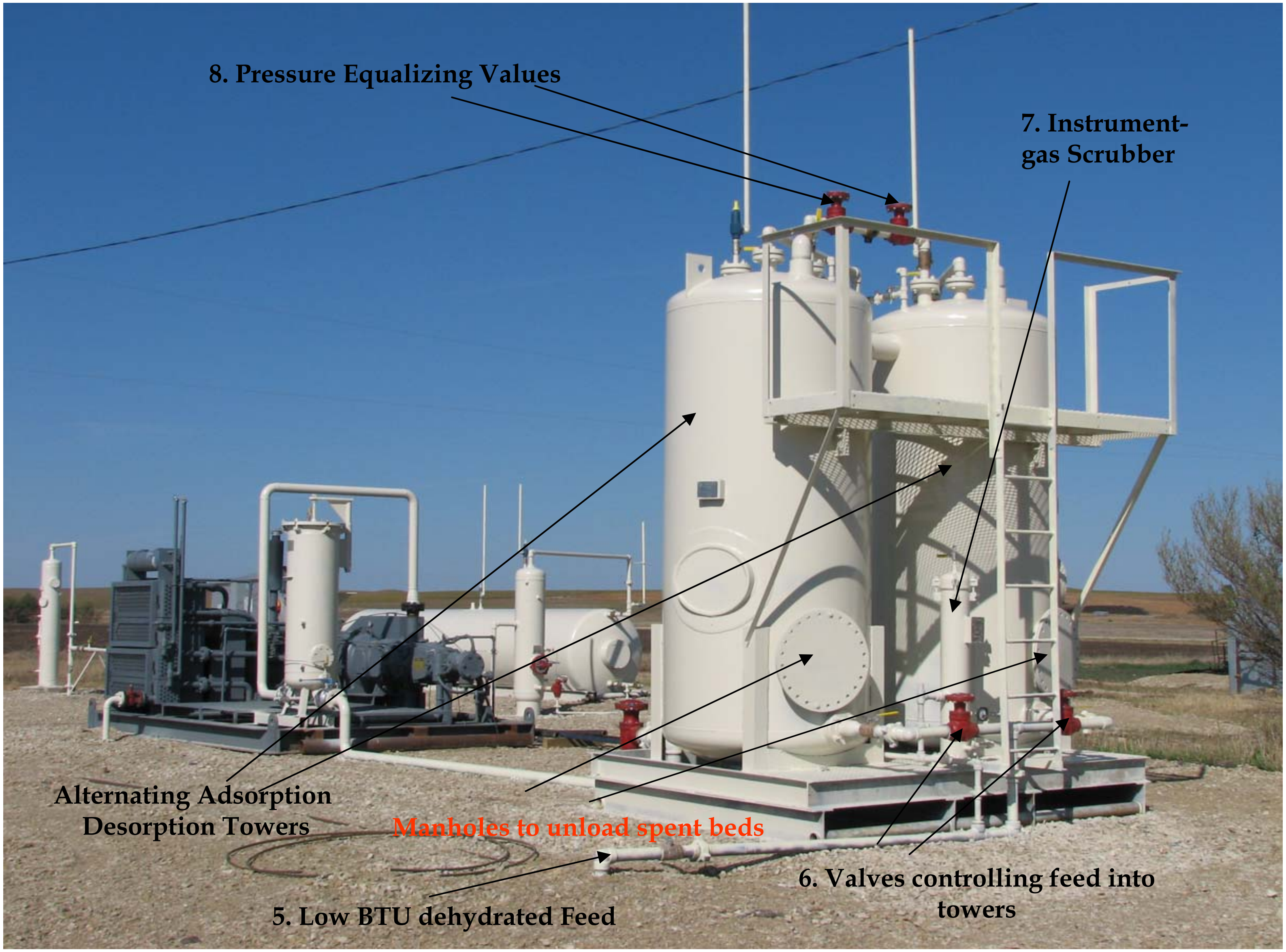


Figure 7: Picture showing the feed gas line connecting to the two towers and the valves controlling flow of gas into the towers.

Figure 8: Pictures showing the charging of the towers with activated carbon and a close up of the activated carbon granules.

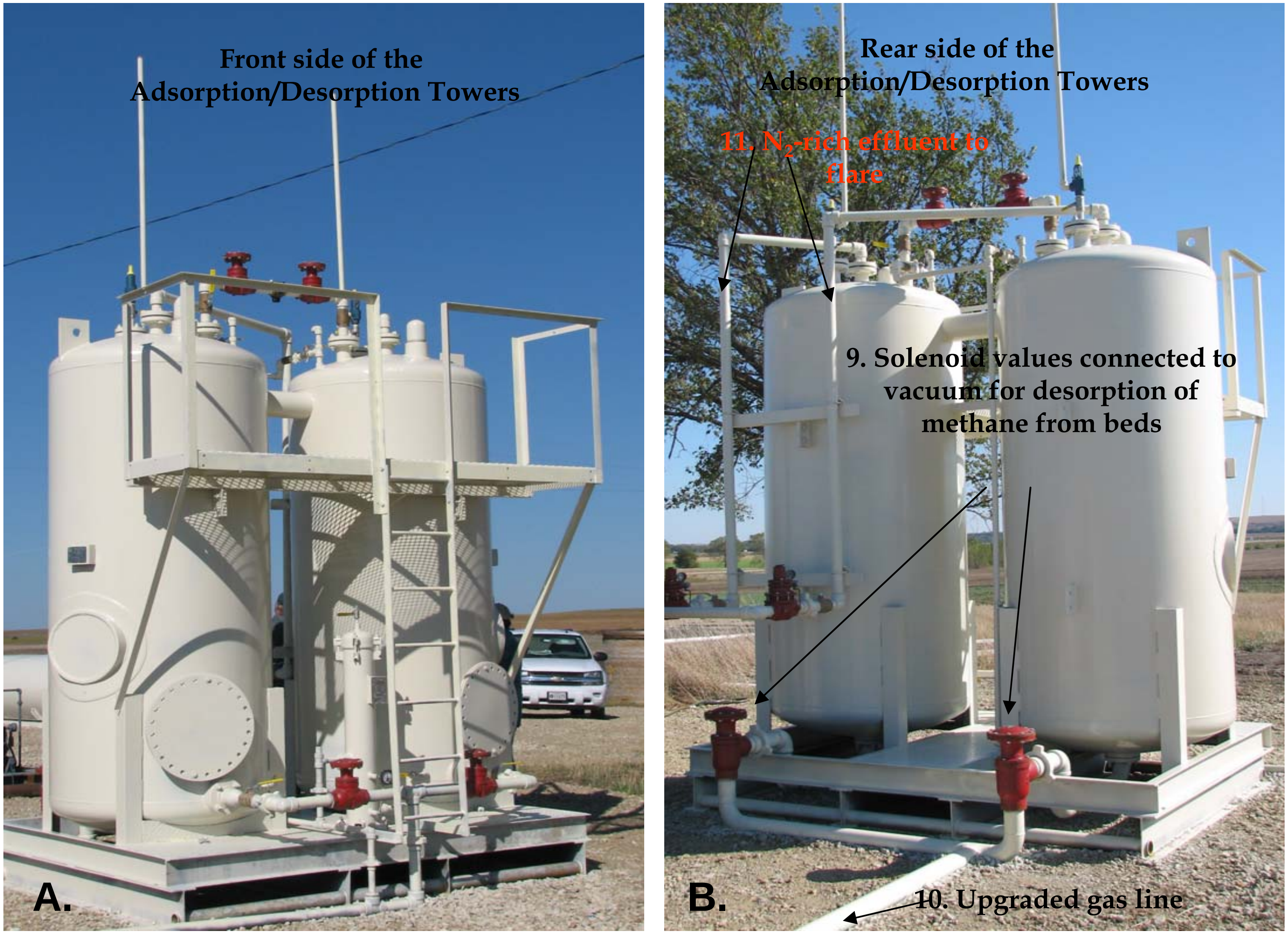
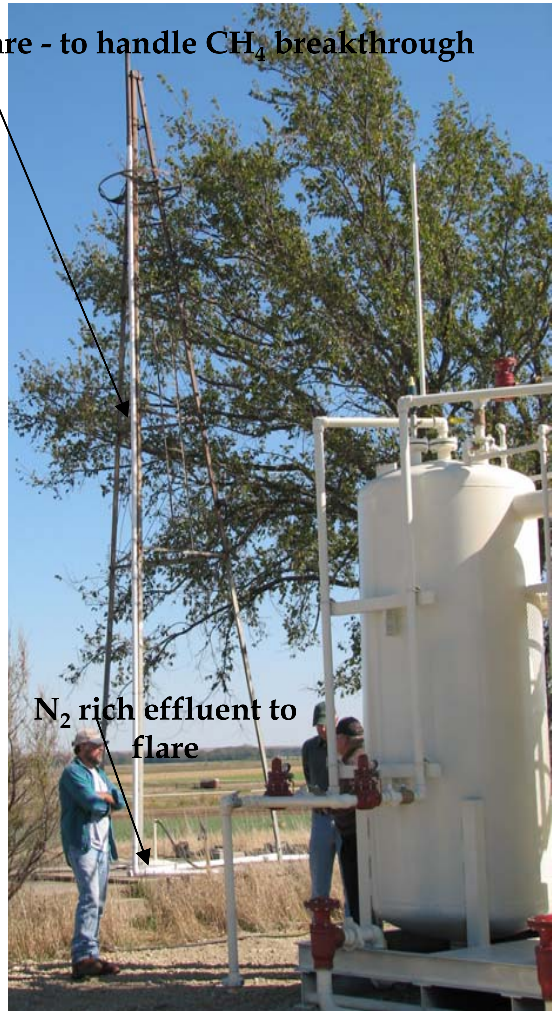


Figure 9: Close up of front and rear side of the two towers.



A.

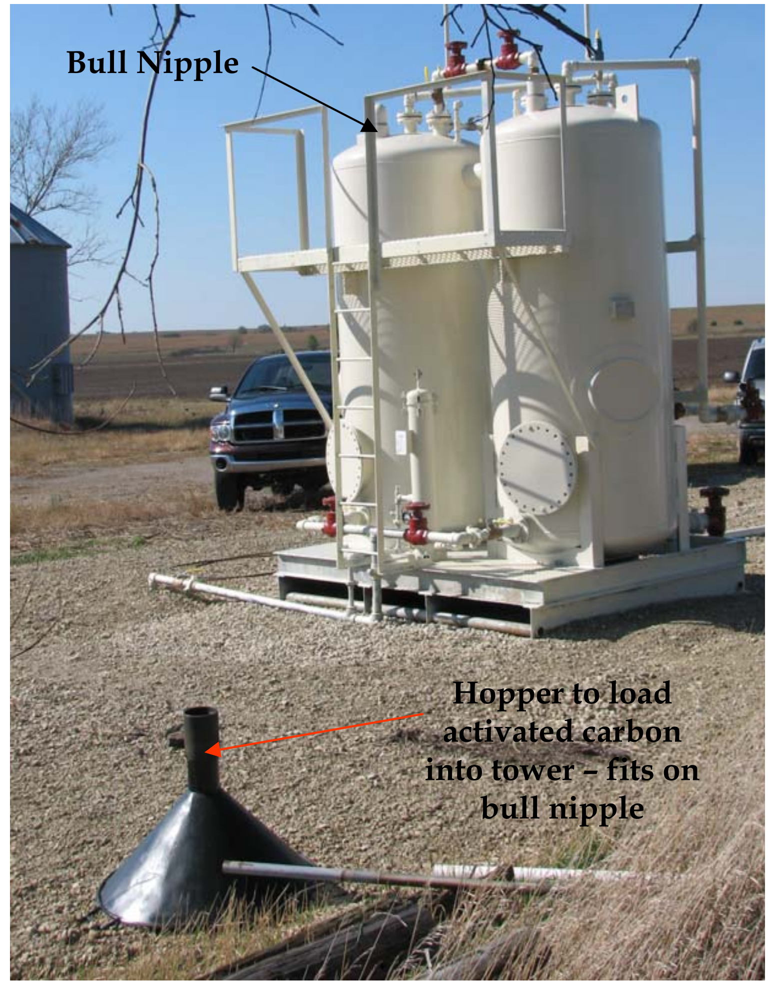


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Figure 10: A) Picture showing the vent line connecting to the flare. B) Picture showing the bull nipple and the hopper used to load the towers with activated carbon.

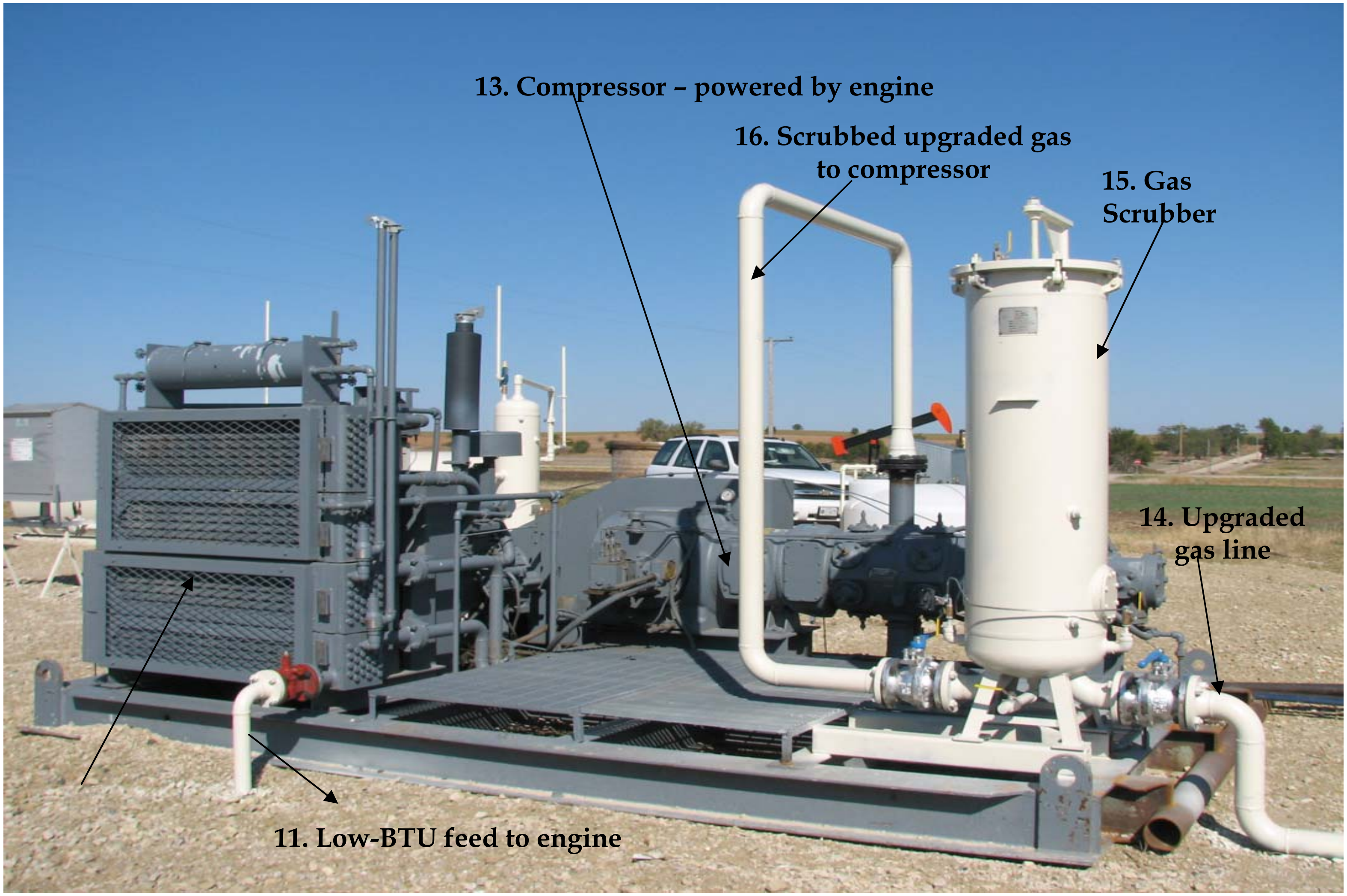

Figure 11: Picture showing the compressor that pulls a vacuum on the desorption tower along with the engine that powers it.

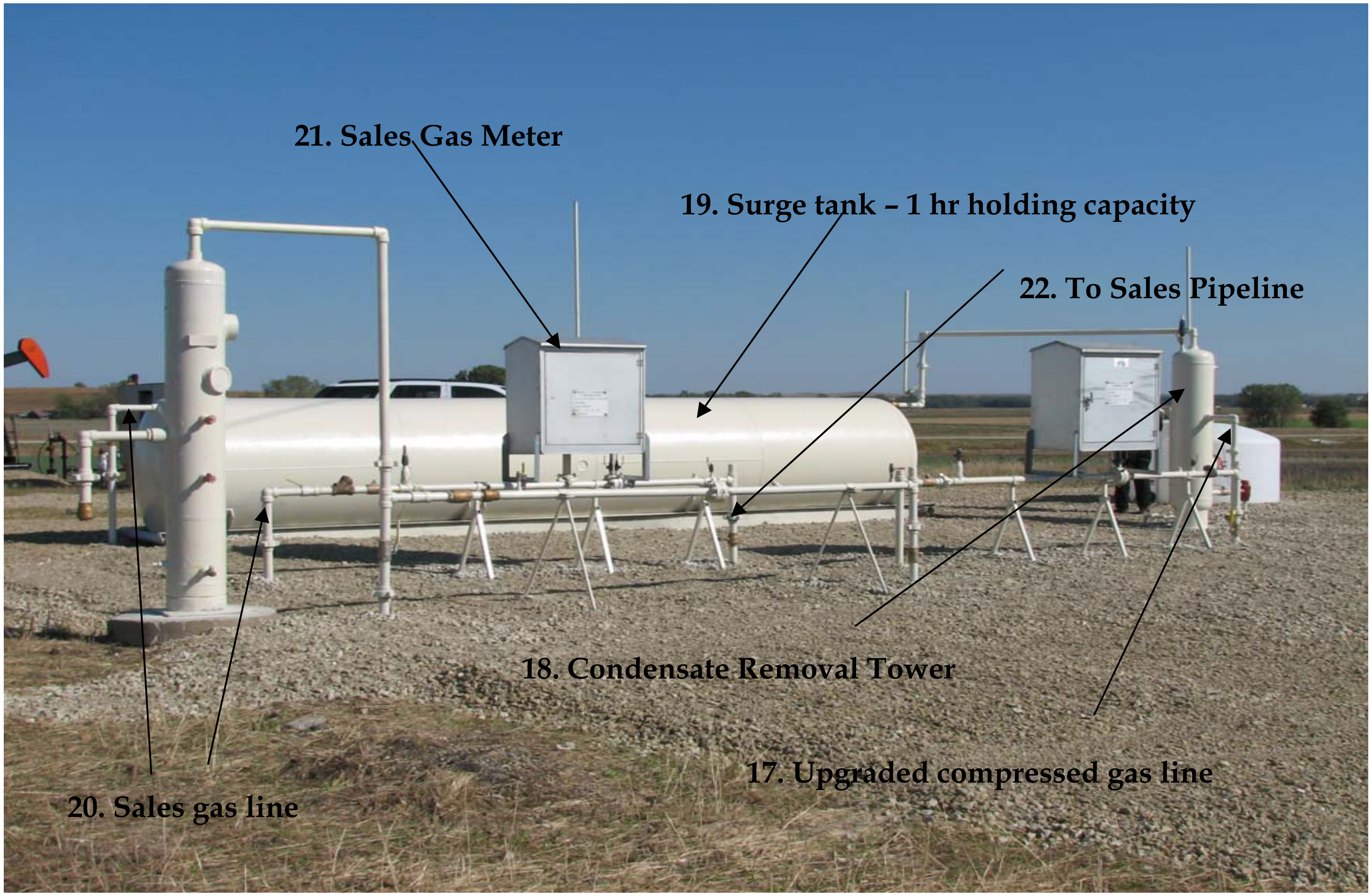

Figure 12: Picture showing the surge tank and the flow lines transferring the upgraded gas.