FLUE GAS GENERATION PROBLEMS, SOLUTIONS AND COST - BLOCK 31 FIELD

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INTRODUCTION

The world's largest flue gas operation is being conducted in the Block 31 Field, Crane County, Texas. This multipay field was discovered by The Atlantic Refining Co., now Atlantic Richfield Co, in Nov. 1945. Early in the field's life, the industry's first miscible displacement program was started in the Devonian reservoir. The 54 MMCF/D flue gas plant started operations on March 8, 1966. The miscible program had been conducted for approximately 17 yrs. Prior to construction of the flue gas plant, a conventional gasoline plant and injection facilities were in operation. By burning a portion of the absorber residue gas in a controlled atmosphere, the volume can be increased 9-11 times. Operation of this flue gas plant resulted in not having to purchase 30-40 MMCF/D of natural gas, permitting the sale of 20-30 MMCF/D of produced gas and assuring a good supply of displacement gas for the reservoir. The flue gas plant will extend the economic life of the injection program.

PROCESS DISCUSSION

A diagram of the processing scheme of the Block 31 facilities is shown in Fig. 1. Feed stock for the flue gas plant is absorber residue gas and air.

Incorporated in the flue gas plant is a treating system for the residue gas prior to its combustion in the flue gas generators. The objective of the treating plant is to reduce sulfur content. Experience and laboratory tests indicate fouling and corrosion problems occur unless the sulfur content is kept low. The process consists of amine sweetening, glycol dehydration and molecular sieve adsorption of sulfur. The spent regeneration gas from the molecular sieve unit is fed to 100,000 lb/hr steam boiler for steam generation.

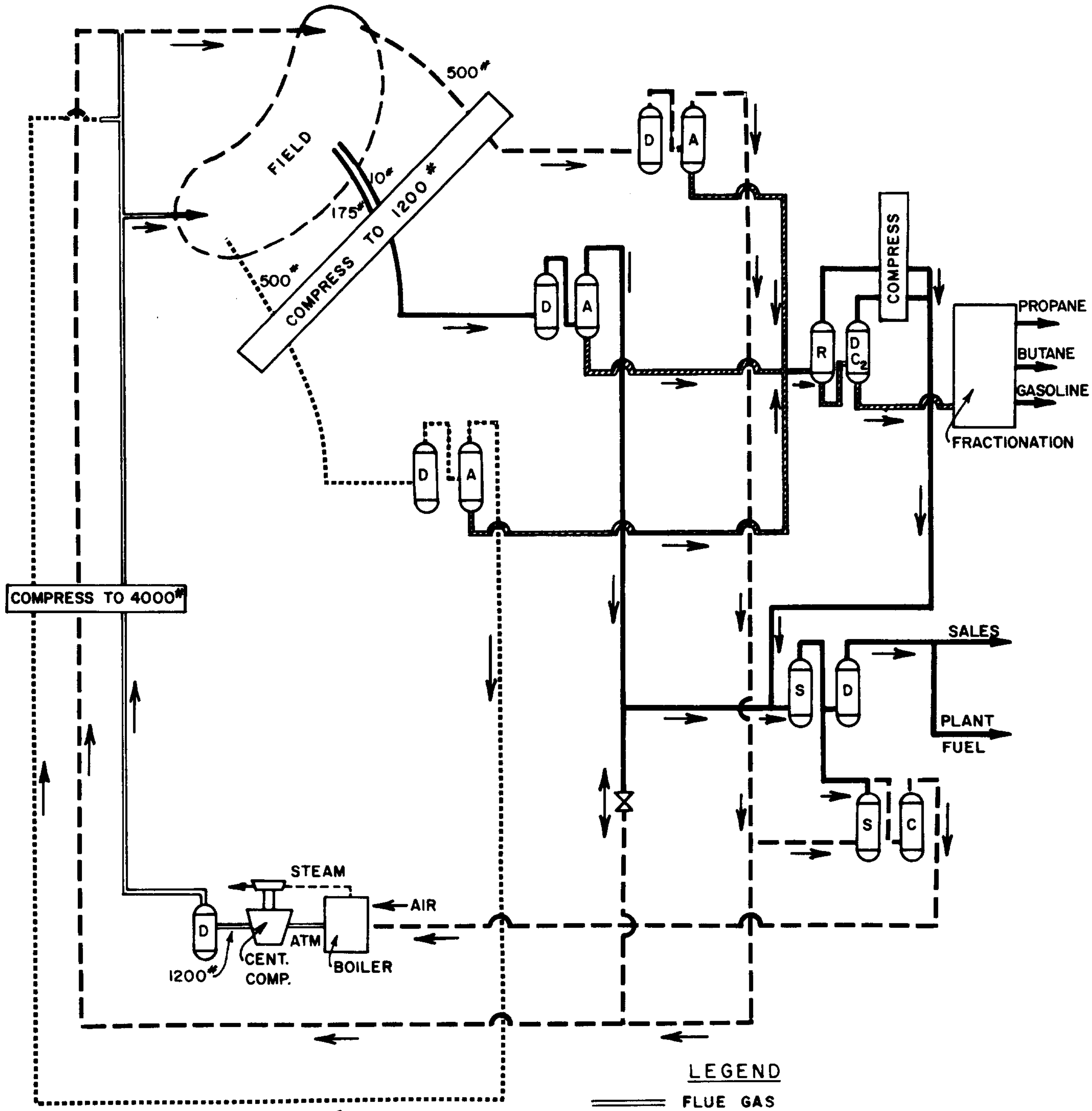
The flue gas generators are 100,000 lb/hr steam packaged boilers derated to 77,000#/hr for flue gas generation. The combustion chamber operates at approximately 17 in. of water pressure. As a boiler, these units would contain two gas burners, but when utilized as a flue gas generator only one burner is employed. Incorporated in the burner design are provisions for recirculating the stack gas around the periphery of the burner to control flame temperature. At elevated burner temperatures, highly corrosive oxides of nitrogen are formed. By this recirculation method, it has been possible to produce flue gas of sufficient purity that a catalyst is not required to convert oxygen and nitrogen compounds.

The combustion section of the plant consists of four flue gas generators and one power boiler totaling a steam-generating capacity of 408,000 lb/hr. Because the flue gas generators require steady load conditions, the power boiler steam load is varied to provide swing in steam requirements. Rotating machinery is powered by steam to recover the heat dissipated in the manufacturing of flue gas.

The flue gas is collected in a 54-in. duct from the four gas generators and scrubbed in a quench tower by water-wash. The wash water is in a closed system circulating through a combineair cooling unit. As the gas is cooled, combustion water is condensed for treatment and usage as boiler feed water.

Here, the flue gas begins its journey through the compressor section of the plant, from the quench tower into the reservoir at 4200 psig.

Compression to 1220 psig is accomplished by a centrifugal gas compressor powered by a 22,000 BHP steam turbine. The steam turbine and compressor is in a balcony-type building with piping connected through the floor of the building.



LEGEND

═══	FLUE GAS
▬▬▬	HYDROCARBON GAS
▨▨▨	RICH ABSORBER OIL
A	ABSORBER
C	CAUSTIC UNIT (MERCAPTAN REMOVAL)
D	DEHYDRATOR
R	REABSORBER
DC_2	DEETHANIZER
S	SWEETENING.

FIG. 1—SCHEMATIC DIAGRAM OF BLOCK 31 FLUE GAS FACILITIES

Lube oil cooling, circulation pumps, etc. are located directly below, at ground level.

The turbine shaft is coupled through a flexible coupling to the first compressor. Both units operate at 4200 to 4600 RPM. The first compressor is connected to a speed increaser, with 2.547 ratio, driving the last two compressors in excess of 11,000 RPM. As the gas is compressed and reaches a temperature of 300 to 320°F, it is removed from the compressor train and cooled by aerial fans.

Due to inherent critical characteristics, the rotating compressor train must be brought from a no-load condition to 80% load very rapidly. During startup, precise control cannot be maintained, so specification flue gas is not produced. The compressor and boiler plant are artificially loaded by compressing air from atmospheric pressure to 1100 psig. As the plant stabilizes, the flue gas generators are adjusted to make specification inert gas. The compressed air in the centrifugal train is changed from air to flue gas. During this period, oxygen and combustible content are closely controlled.

OPERATION

The plant, except for placing on stream, is successfully operated by one operator. During a startup there are five to six people present. The operator can, in most instances, make changes to vary the operating conditions without leaving the control room.

The critical operating information is displayed on a central control board for the gas treating, boilers, cooling and turbine areas. Incorporated in the design and subsequent additions is a series of sophisticated instrumentation to monitor and control critical points of operation. The monitored items are oxygen content, combustibles in gas, continuous vibrational analyses and bearing temperatures of the turbine train.

CORROSION CONTROL

Two of the keys to successful operation with inert gas injection are (1) the control of corrosion, and (2) control of fouling of plant and field equipment. Corrosion due to oxygen, carbon dioxide and nitrous oxide would be severe, if not controlled.

A 15% solution of aqua ammonia (NH_4OH) is used to neutralize these acid gases. Portable pH meters and pH paper are used to monitor its injection rate. The iron counts have been in the 1-2 ppm range, at the lower pressure, and 0.5 to 0.8 ppm at 1200 psig. These rates have been checked by coupons and visual inspection. The problem area has been the lower pressure level where large volumes of condensed water are present. Several tubes in the quench tower Combineair cooler and one in the fifth stage inner cooler have been plugged because of leaks. If overinjection of ammonia occurs, ammonium carbonate precipitates and has to be removed with warm water. Ammonium carbonate formation has proven critical at pressures above 600 lb.

CENTRIFUGAL COMPRESSOR

Alignment of the compressor train is critical. All piping stresses must be resolved against structural members rather than compressor or turbine nozzles. Distortions of rotating bodies as they heat and expand have been established with optical alignment tools so they can be misaligned cold to place them in hot alignment.

DEHYDRATION

Initially, dehydration was performed at the 600 psig level with glycol, but multiple problems developed. Fouling occurred in both the centrifugal and reciprocating compressors from glycol carryover; therefore, dehydration at the 600 lb level was discontinued. Presently a combination of dew point depression by refrigeration and glycol is used to dehydrate the flue gas at 1200 psig.

RECIPROCATING COMPRESSORS

Reciprocating compressors are used to compress the gas from 1200 psig to 4200 psig. Single-stage compression at this level caused a multitide of problems due to excessive heat generation in the cylinders. Compression ratios should be kept low enough to prevent excessive temperatures.

Lubrication must be closely controlled and special oil used to minimize fouling with carbonaceous material. A balance is made between compressor maintenance and wellbore damage. Compressor cylinders and packing life are increased with overlubrication, but lines and well bores are fouled.

SYSTEM OBSERVATIONS

The recovery of flue gas expressed as a ratio of fuel gas has proven to be 5.7 to 1, not as high as anticipated. There are several reasons for this. The plant is highly automated to protect equipment, minimize operating labor requirements and insure that explosive mixtures do not occur. Controllers are cascaded to sense varying conditions to assure control.

Quality flue gas is manufactured safely only as a result of this sophisticated instrumentation. Instruments and control valves must operate in split seconds. It has been found that they must not be allowed to reach a point where the inertial characteristic of the pneumatic system is too great. At times, this requires recycling of gases and at others, flaring flue gas. The vented flue gas has not been an economical burden because excess flue gas is generated producing the required steam for operating.

The instrumentation has been responsible for a number of unscheduled shutdowns. Both corrosion and boiler problems are aggravated by startups.

The corrosion results from moist air being compressed for approximately 1-1/2 hrs per startup.

In the generators, frequent purging has resulted in wide variations of fire box pressures and caused damage to refractory material. When the turbine is placed on line, rapid acceleration of steam loads occur. This has contributed to boiler problems.

Flue gas is hard to handle. Small leaks between gasketed or sealed surfaces must be quickly stopped as flue gas will erode the metal.

INJECTION WELL PERFORMANCE.

Injection well plugging was encountered during a period of excessive compressor maintenance. It continued to a lesser extent after this period. The plugging was attributed to several factors; compressor lubricants and compounds which were formed when switching from flue gas to sour injection hydrocarbon gas. Two practices have helped this problem: (1) limiting the switching of flue gas and hydrocarbon gas through the same well and (2) reducing compressor lubrication. During this period, cartridge-type filters were placed at the compressor discharge and well head.

Injection of flue gas is limited to the southern portion of the field to reduce contamination of the produced gas in other areas. Segregation of high nitrogen content gas (see Fig. 1) is maintained in the plant and injection facilities.

COST

The cost of a flue gas plant such as Block 31 or for any size plant can be estimated by a process engineer. The plant is built with components commonly used in the processing and refining industry. To take shock loads, flue gas generator casements should be greater in structural strength than a normal boiler. This adds 10% to a package boiler. No exotic or alloy metals were used in any of the equipment. Instead, corrosion has been controlled by means of NH_4OH. Controls used on the flue gas generators to control combustion and fuel air ratios, are common to the power industry. The flame temperatures are controlled by recycling exhaust gas; and the use of catalyst for conversion of contaminates is not required.

CONCLUSIONS

More than eight years of flue gas operations have indicated certain conclusions:

1. Flue gas of acceptable purity can be developed in generators without catalysts.
2. For a Block 31 type plant, the manufacture of flue gas is approximately 30% less than theoretical.
3. Corrosion can be controlled by ammonia, but requires close control of injection rates.
4. Where reciprocating compressors are used, compression ratios should be kept low and special lubricants used.
5. Flue gas has proven to be incompatible with sour hydrocarbon gas. However, it can be mixed with sweet hydrocarbon gas.
6. Special attention should be devoted to instrumentation and boiler structures.
7. Dehydration of flue gas can be accomplished by refrigeration and injection of glycol.