

77-55

COAL PRESSURIZATION AND FEEDING--
USE OF A LOCK HOPPER SYSTEM

R. Lewis

R. R. Santore

D. Dubis

U. S. Energy Research and Development
Administration, Synthane Pilot Plant
Pittsburgh, Pennsylvania

COAL PRESSURIZATION AND FEEDINGUSE OF A LOCK HOPPER SYSTEMINTRODUCTION

The SYNTHANE process is a high pressure coal gasification system developed by the Pittsburgh Energy Research Center of the U. S. Energy Research and Development Administration (E.R.D.A.), formerly a part of the U. S. Bureau of Mines. It was designed to convert bituminous coal, subbituminous coal and lignite into a satisfactory substitute for natural gas with a heating value of 950 BTU's per cubic foot. A 72 ton per day SYNTHANE Pilot Plant has been constructed in South Park Township near Pittsburgh, Pennsylvania.

A necessary preliminary step in high pressure coal gasification processes is to take ground coal at atmospheric pressure and feed it to the gasification system at operating pressure. For reasons that are not pertinent to this report a decision was made to use lock hoppers at SYNTHANE. Accordingly, a proprietary system was purchased from Petrocarb, Incorporated. This system was designed to feed coal at pressures up to 1000 psig at rates of 1.67 to 5.0 tons per hour.

This report will discuss some of the specific problems experienced with the operation of the Petrocarb system at the SYNTHANE Pilot Plant. It will also review the modifications made to improve its performance.

SUMMARY

The SYNTHANE gasifier has been operated periodically from July, 1976 to the present time (January 31, 1977). During this period more than 750 tons of coal have been fed to it through the Petrocarb system. Including functional tests, this represents approximately 1000 cycles on the single train and 500 cycles on the dual train portions of the system.

After an initial testing and shakedown period the performance of the Petrocarb unit is considered satisfactory. With certain limitations it can be depended upon to feed coal to the gasifier within the design feed range. For a system of this degree of mechanical complexity, maintenance is reasonable.

Major problems encountered during the initial testing and operation have been eliminated. Brief interruptions of coal feed will probably continue to occur occasionally due to the difficulty of completely eliminating minor breakdowns.

DESCRIPTION OF SYSTEM

The system consists of a weigh hopper, two lock hoppers (storage injectors), a feed hopper (primary injector), interconnecting piping, valves, instruments and controls, all furnished by Petrocarb, Incorporated (see Appendix A-1, Drawing E438-A-007 Rev. 6). It is designed for automatic operation and operates on a demand basis triggered by a low level probe in the primary injector. The system may also be operated in a manual mode.

Coal enters the system at atmospheric pressure from the pulverized coal storage bin (FE-103). Batches of up to 2500 pounds drop by gravity to the weigh hopper (FE-106). The weigh hopper is mounted on load cells and weighs each batch and then allows it to fall through open valves into an empty lock hopper (FE-104A or B). The lock hopper is then isolated by closing the inlet valves. Pressurizing gas (SYNTHANE uses CO₂) is introduced into the lock hopper to raise its pressure to equal that of the pressurized feed hopper (FE-105). Valves below the full lock hopper then open to allow the batch to fall by gravity into the pressurized feed hopper. The empty lock hopper is again isolated by closing the outlet valves. The gas is cross-vented to the second lock hopper which is at atmospheric pressure and has now been charged with coal. When the pressures of the two lock hoppers have essentially equalized the cross-pressurization valves are closed and the remaining gas in the empty lock hopper is vented. Additional gas is then pumped into the full lock hopper to raise it to system pressure and the cycle is repeated using alternate lock hoppers. The cross-pressurization procedure reduces the total amount of gas needed to pressurize a lock hopper but some gas is unavoidably wasted.

When coal feed to the gasifier is required, the primary injector discharge valve (XCV-26) is opened and coal flows continuously from the primary injector into the coal conveying line to the gasifier. Carbon dioxide is used as the conveying medium. The coal feed rate for any given transport line velocity is controlled by varying the pressure differential between the primary injector and the gasifier. Carbon dioxide required to maintain the system pressure enters the primary injector through nozzles located just above the discharge valve. These gas inlet nozzles are designed to keep the coal partially fluidized and continuously flowing. Coal flow may be stopped at any time by closing the primary injector discharge valve.

EXPERIENCES

Prestartup

The system was installed at SYNTHANE during 1974 but testing was not started until July, 1975. Poor storage practices during construction and the amount of time the system remained idle before use caused many problems during the initial pressure testing.

Valves

Valves have been more troublesome than any other single component. Correction of valve malfunctions in the Petrocarb system has required more time and effort than any other problem.

With one or two exceptions all valves in the Petrocarb system are ball valves. Due to the experimental nature of the plant various materials were specified for the balls used in the Petrocarb valves. The most prevalent material used is 440C stainless steel but some balls were coated with tungsten carbide (LW-IN40) or ceramic (LC-4). The larger 6 inch and 8 inch valves were all hard face coated and have not been a problem. The smaller 2 inch through 4 inch gas handling valves have balls of all three materials. For valves of this size we have obtained no better service with the hard face coated balls and have therefore standardized on the cheaper 440C stainless steel for the ball material. All valve seats are stellite on 316 stainless steel and show little or no wear (see Appendix A-2, Cutaway Valve Sketch).

During the first pressure test numerous valves leaked and several would not rotate. Inspection showed that these valves were obstructed with construction debris or the balls and seats were frozen in place due to corrosion of the steel bodies caused by moisture. All these valves were removed and made serviceable by cleaning, relapping of balls and seats or replacing badly corroded balls and seats.

Methods of reducing the corrosion of the carbon steel valve bodies have been investigated. In conjunction with the valve manufacturer three methods have been suggested and are being considered: (1) valve bodies can be produced of a material less susceptible to corrosion, such as stainless steel, (2) bodies can be electroless nickel coated or (3) an internal body sleeve can be installed in a critical area.

It has been determined that high gas velocities and rapid valve actuation in venting and cross-pressurization service caused many valve malfunctions. Phenomena such as spring retainer wear and deformation, axial ball and stem movement, retraction and cocking of seats, all of which contribute to valve leakage, can be attributed to the above factors.

Actuator speeds were appreciably reduced. The valves were initially opening or closing in less than two seconds. This time factor has now been increased to 10 to 15 seconds for all the valves in question. Vent orifice diameters have been reduced and orifices have been relocated down stream of the vent valves. After these two changes were made most problems with these valves have been eliminated.

Two separate failures of shafts twisting off the balls have occurred. Initial investigation indicated a crack started at the root of a sharp corner and may have been deepened by corrosive attack. Subsequent additional torsional loads applied by the actuator in rotating the ball ultimately caused failure.

At the time the Petrocarb system was purchased it was felt that valve failures due to erosion might be frequent, causing delays in plant operation. An investigation was conducted into state-of-the-art valves and new and novel valve designs^{1/}. However, after seven months of operation and a system throughput of over 750 tons of coal there have been no valve failures due to erosion. The performance of the 6 inch and 3 inch coal handling valves has been particularly satisfactory. This can probably be attributed to: (1) the fact that these valves are purged with CO₂ before opening and closing and (2) the valves open and close against no differential pressure.

Other system modifications have been made in an effort to improve operation. Piping configurations have been changed to eliminate areas where moisture can condense and be trapped. Isolation valves were installed in the vent lines to separate the two lock hoppers. If one lock hopper system fails, it can now be isolated and repaired while the other lock hopper is still operating.

Electro-Mechanical Components

The Petrocarb system requires numerous pressure switches, relays and micro-switches to function, particularly in an automatic sequencing mode. We have been unable to operate this system consistently in an automatic sequencing mode because of frequent malfunctions of the mechanical or electrical components. On occasion, only one train of lock hoppers has been used. The fact that the system is capable of continued service in spite of component malfunctions is considered an advantage.

Initially, individual batch weights of coal in the weigh hopper were inaccurate and inconsistent because the load cells were very sensitive and were affected by many physical factors. Adjustments to the load cells and revision to supports of piping and vessels corrected the problem. Accurate and repetitive weights are now regularly obtained.

The weight totalizer^{2/} has not functioned properly. This may be due to electrical interferences because of the unit's location. Arc suppressors have been installed in an effort to eliminate this problem^{3/}. In addition, batch weights are now being totalized by the data acquisition computer.

^{1/} A considerable amount of information was obtained and several valves were purchased and are on hand. A separate report on this subject will be issued in the near future.

^{2/} Totalizes and indicates the total weight of individual weigh hopper batches.

^{3/} At the time of this writing these revisions have not been tested.

Operations

This system was designed to feed dry ground coal to the gasifier. Operation has been interrupted frequently by two recurring problems, both of which cause plugging of the discharge venturi below the primary injector.

- (a) Foreign Material. Although the vessels were originally cleaned during start-up operations, construction and maintenance debris has continued to come through, lodging in the venturi and interrupting coal flow. A screen was installed in the weigh hopper in an effort to correct this problem.
- (b) Wet Coal. This problem has been eliminated by disconnecting the Petrocarb vent from a common vent line to the thermal oxidizer. This vent was originally shared by Petrocarb and the fluidizing steam discharge from the char cooler. It was found that steam from the char cooler entered the lock hoppers and the dry coal storage bin through the vent valves and condensed in these vessels, wetting the coal. A separate line from the Petrocarb system to the thermal oxidizer is being installed.

This system was designed to feed coal at a maximum rate of five tons per hour with a turn down ratio of 3 to 1. To date, we have been unable to achieve turn down rates below 2-1/2 to 1, or approximately two tons per hour. Rates in the 2 to 5 tons per hour range have generally been found to be reproducible and reliable. Rates below two tons per hour have been erratic. The current range is adequate for Montana subbituminous coal. However, when operating with caking coals requiring pretreatment, lower feed rates such as 1-1/2 tons per hour may be required. Discussions were undertaken with Petrocarb, Inc. to determine what changes might be necessary to achieve lower rates. Petrocarb's position is that a feed rate of 1.67 tons per hour should be attainable with the present system. At feed rates below two tons per hour wide fluctuations in the fluidizing gas to the primary injector have been noted. Petrocarb feels this may be limiting the turn down ratio. They have suggested improving the control of this fluidizing gas and recommended fine tuning of the various control instruments involved.

FEATURES OF THE SYSTEM

The Petrocarb system feeds dry ground coal by entraining it in a pressurized transport gas stream. In the gasification unit the coal can be separated from the transport gas without any additional energy input.

When the system is operating in an automatic mode it requires little operator attention. When operating in a manual mode, some additional operator attention is required. The fact that it can be run in a manual mode is considered an advantage.

Parallel lock hopper trains conserve on pressurizing gas and also provide some redundancy allowing for continued operation when one train is inoperable.

The Petrocarb unit contains many electrical and mechanical components necessitating a continual maintenance effort. When in the stand-by mode, normally between runs, daily cycling of valves and pressure testing of the system before start-up is required. If kept idle for longer periods of time additional rechecking of the instrumentation is also necessary to assure reliable performance.

For the Petrocarb unit installed at SYNTHANE we have been unable to find a means of instantaneously measuring the coal flow rate. Therefore, feed rates are obtained by averaging batch weights over a period of time.

Coal flow rates are not absolutely constant and are estimated to fluctuate approximately $\pm 5\%$.

As previously discussed, coal feed rates can be controlled within a given range. The feed rate range is primarily a function of the pressure differential between the primary injector and the gasification unit. The rate is controlled within the design limits by varying this pressure differential. Petrocarb has stated that the best way to lower the operating range and still retain high solids to gas ratios, with a reasonable line velocity, is to change the line size in preference to introducing point restrictions or increasing gas flow. It is therefore inconvenient to change the range because a new diameter feed line would have to be installed.

This type of feeding system consumes considerable energy, mostly in the compression of gas, a significant portion of which is lost through venting, leakage and passage of gas out with the coal.

Capability of scale-up is inherent in this type of system. Larger size components are commercially available.

90° operation — ¼ turn with manual lever. Gear operator, Pneumatic, Electric, or Hydraulic Actuators.

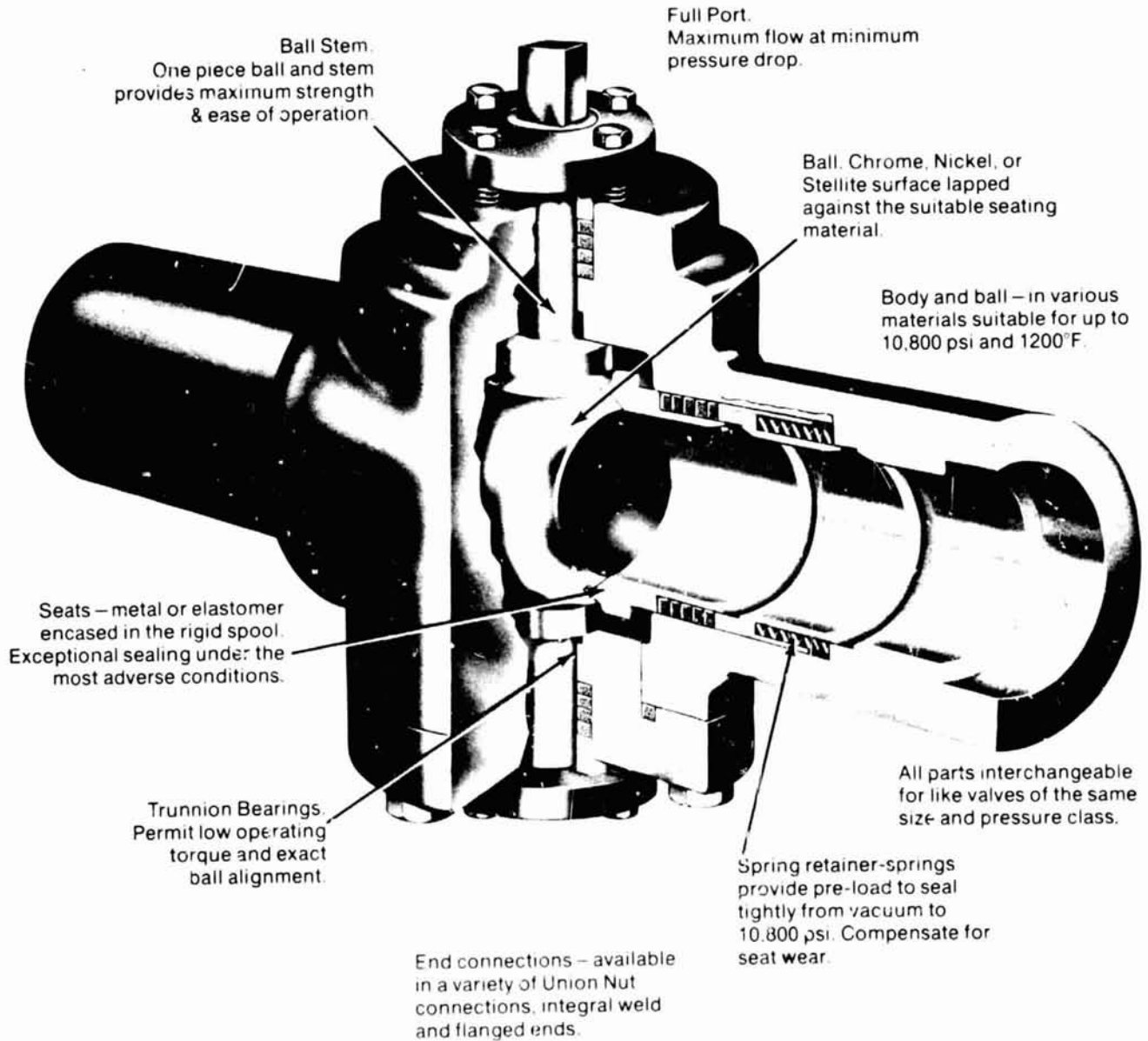


FIG. 1 CUTAWAY OF TYPICAL VALVE

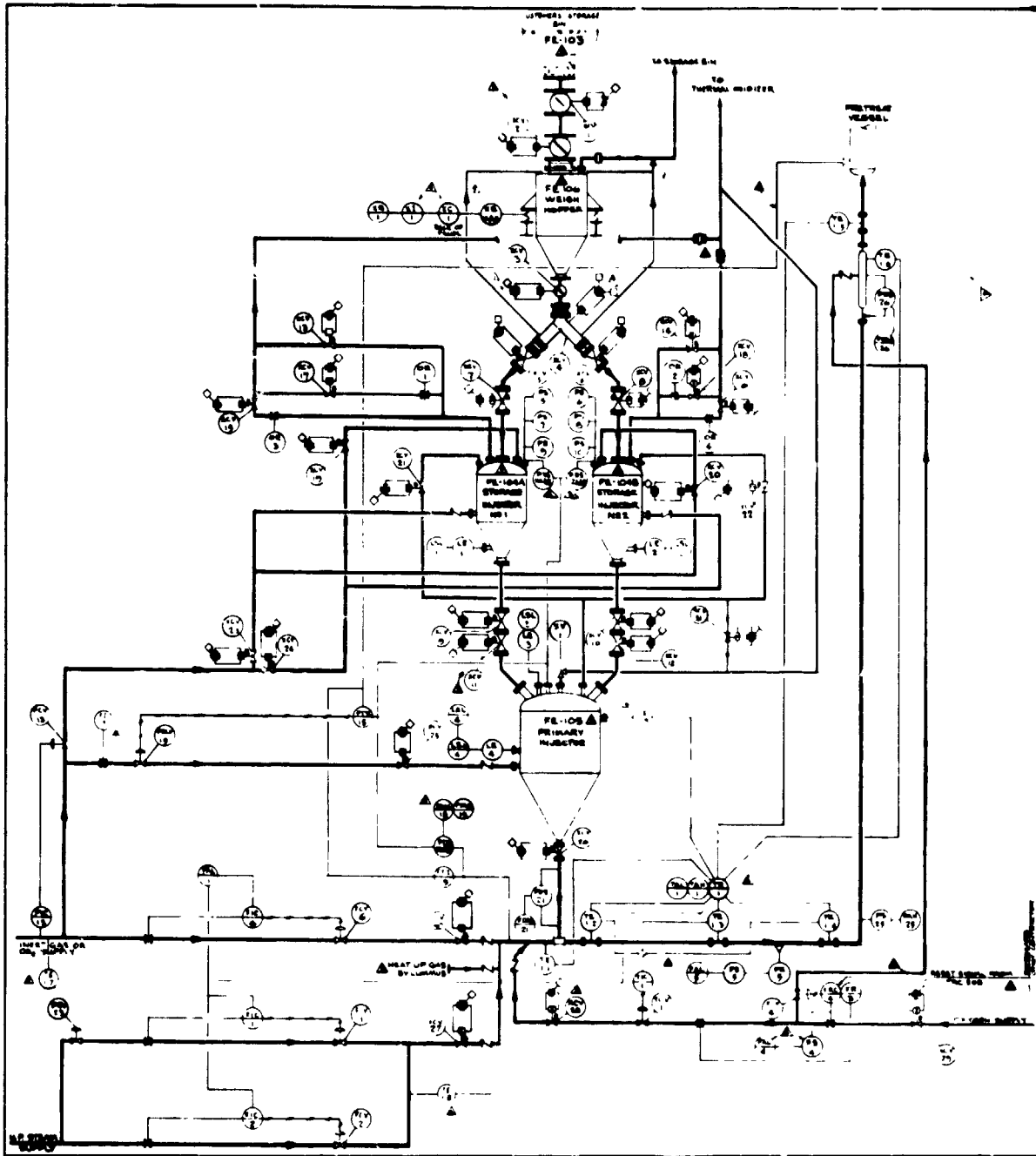


FIG. 2 SCHEMATIC FLOW DIAGRAM
FOR HIGH PRESSURE
COAL FEED SYSTEM