A NOVEL DRY COAL FEEDING CONCEPT FOR HIGH-PRESSURE GASIFIERS

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ABSTRACT

A novel dry coal feeding concept has been developed for injecting ground coal into high-pressure gasifiers. Significant power savings are projected because the coal is injected directly with a ram and there is no requirement for pumping large volumes of gas or fluid against pressure.

A novel feature of the concept is that a new seal zone is formed between the ram and injection tube each cycle. The seal zone comprises a mixture of a small quantity of finely ground coal and a fluid. To demonstrate the feasibility of the concept, coal was injected into a 1000-psi chamber with an experimental device having a 7-1/2-inch-diameter ram and a 28-inch-long stroke.

A NOVEL DRY COAL FEEDING CONCEPT FOR HIGH-PRESSURE GASIFIERS*

by

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BACKGROUND

The development of a dependable system for feeding dry coal into vessels operating at pressures up to 1200 psig is a key element in the development of the second-generation gasification processes. A critical problem confronting any approach for dry-coal feeding is excessive wear and abrasion. In most systems, virtually no abrasion can be tolerated because of the resulting gas leakage, which is especially critical at the pressures contemplated for these second-generation gasification processes.

Battelle initiated a program whose objectives were to conceive and develop a system for dry-coal feeding that would avoid or minimize wear and abrasion and that could be used to feed coal into vessels operating at pressures of 1000 psig or higher. After evaluation of numerous approaches on a small scale (3.5-inch-diameter tube), the concept described in this paper was developed.**

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** Two U.S. patent applications on the concept have been allowed and are expected to issue in 1977.

THE BATTELLE CONCEPT

A new concept of injecting dry coal was conceived and investigated by Battelle under the internally funded Battelle Energy Program. The concept involves filling an inlet tube with coal and pushing the charge of coal into a pressurized gasifier storage chamber with a ram. A seal plug between the ram and tube is formed for each injection cycle by a mixture of graded fine coal and a fluid, e.g., oil. The seal plug may be pre-formed outside the injection tube and placed within the tube after a charge of bulk coal has been loaded. The seal plug accounts for less than 0.5 percent of the total coal volume charged in each injection and the quantity of fluid used to form the plug is less than 0.05 percent of the total volume of coal.

The idea of sealed piston feeding of coal is not new and has been proposed many times before. However, it was not considered feasible because problems of wear and abrasion in such piston feeders become evident long before any practical operating times are accumulated. Wear and abrasion result from the abrasiveness of the coal and the force required to push the coal against the high-pressure differential. The high-pressure differential causes high leak rates to develop where sealing surfaces are abraded.

The Battelle concept minimizes wear and abrasion, while still maintaining sealing effectiveness, by providing a localized seal layer of a coal-fluid mixture. During the exploratory phase of this work, it was found that adding a small amount of fluid to a thin layer of a particulate coal charge in a feed tube resulted in several very important advantages:

(1) Pressure leakage is prevented.

(2) The compression required to prevent leakage with wetted coal is less than that required with unwetted coal.

(3) The thin layer of wetted coal acts as a very effective sealing piston that is movable at far lower pressures than are required for the movement of unwetted coal. The piston moving the coal does not do any sealing when operating with the thin wetted layer of coal.

(4) Wear on the tube wall is greatly reduced because the fluid in the wetted layer of coal acts as a lubricant and coal does not need to be nearly as compressed (which contributes to wear) as when operating without a seal zone. For example, 1-inch chunks of coal were fed between the seal zones.

(5) Wear that occurs does not result in leakage because the wetted coal and fluid contained therein flow into surface irregularities and thus prevent leakage.

On the basis of preliminary estimates, it is believed that this coal-feeding concept would allow a reduction in installed capital costs and also savings in power when compared to either lock-hopper or slurry feeders.

Battelle's experimental work has established the feasibility of this concept. We believe that it is sufficiently promising to warrant further development.

EXPERIMENTAL PROGRAM

The primary objective of the experimental program was to demonstrate the feasibility of the Battelle dry-coal feeding concept. A secondary objective was to assess the applicability of the concept to a commercially sized gasification system.

The experimental work was undertaken to investigate the influence of the following variables on the seal time and force required to push the coal through the injection tube:

(1) Compaction pressure
(2) Viscosity of the sealing fluid
(3) Coal-to-fluid ratios in the seal zone
(4) Seal zone coal mesh sizes
(5) Operating gas pressure levels.

Experimental Equipment

Initial experiments utilizing 2-inch-ID and 3-1/2-inch-ID injection tubes established the feasibility of forming a coal-fluid moving seal against 1000 psig of gas pressure for a time sufficient to reload the tube. Additional larger scale experiments were then performed on a single-cycle basis to analyze the effects of scale-up on the formation of the seal plugs. In this scale-up phase, apparatus with a 7-1/2-inch-ID injection tube equipped with a gate mechanism was fabricated.

A vessel designed to accept a 36-lb charge of coal from the feed tube while pressurized to a maximum 1000 psig was provided. A removable end plate was installed on one end of the vessel to allow removal of the coal after each injection cycle. A sliding gate assembly was provided in the pressure vessel to close off the bottom of the feed tube during the charging and compaction steps of the coal injection cycle. The gate was moved to its position under the injection tube by the action of a sliding wedge on which it rested. The wedge was actuated by a hydraulic cylinder mounted on the outside o the pressure vessel. This experimental apparatus is shown diagrammatically in Figure 1. A ram with 0.01-inch radial clearance was used to compact the coal used in the injection tube and to push the coal charge into the pressure vessel.

Experimental Procedures

The feeding cycle is shown in Figure 2. In the first step, the ram is withdrawn and the injection tube is filled with bulk coal. In the second step, a new seal zone in a carrier ring is placed above the bulk coal. In the third step, the ram advances to compact the coal. This compaction of the new seal zone forms the seal between the ram and tube. Finally, in the fourth step (1) the gate is opened, (2) the ram injects the lower seal zone and bulk coal, and (3) the gate is closed. The seal zone remaining in the end of the tube and backed up by the ram provides the necessary sealing against pressure until closing of the gate.

Average seal time of all experiments was approximately 40 seconds against 1000 psig, which is more than 10 seconds above the maximum expected pressure exposure time of an operating syst

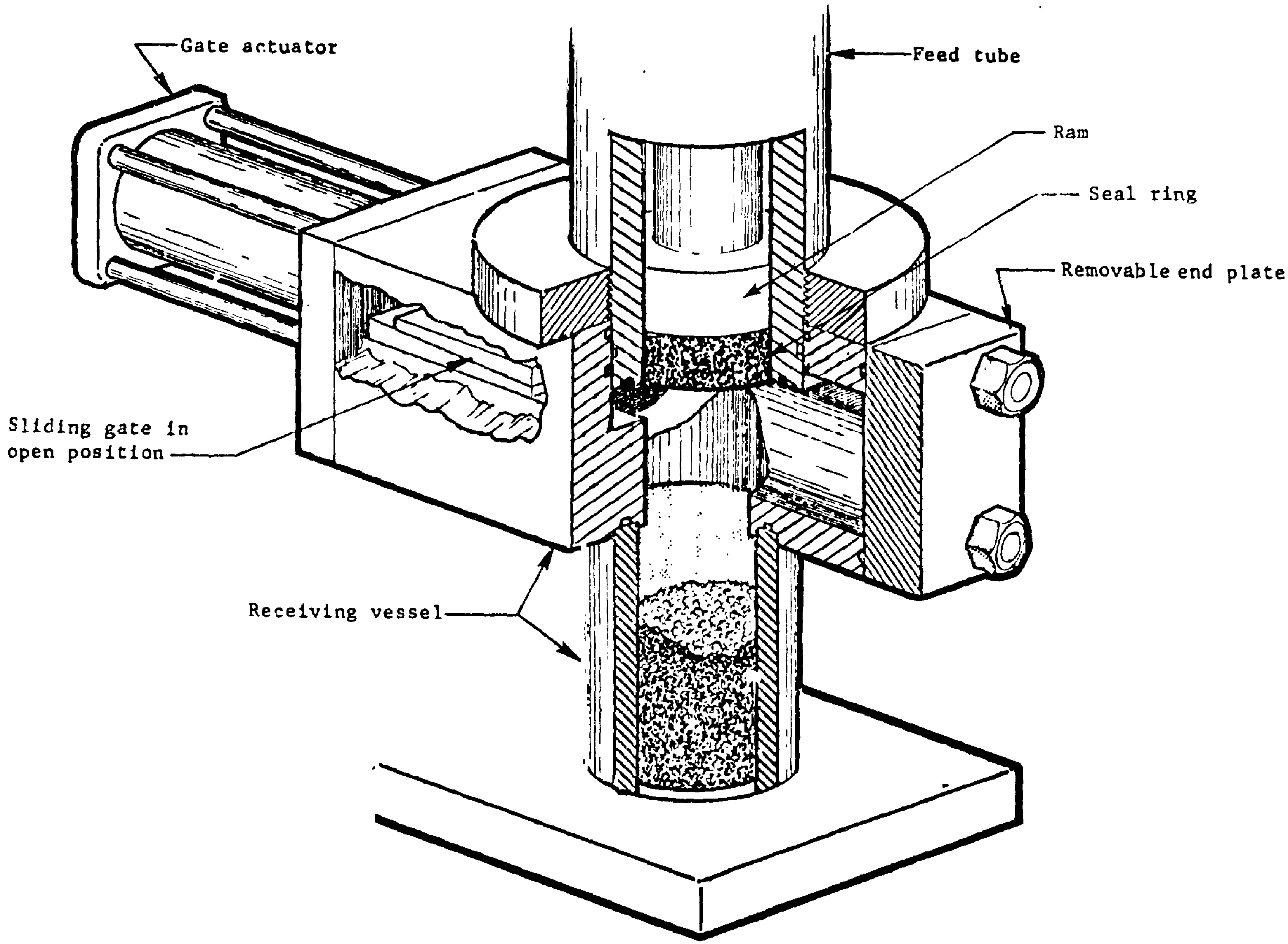

FIGURE 1. EXPERIMENTAL DRY-COAL-FEEDER MECHANISM

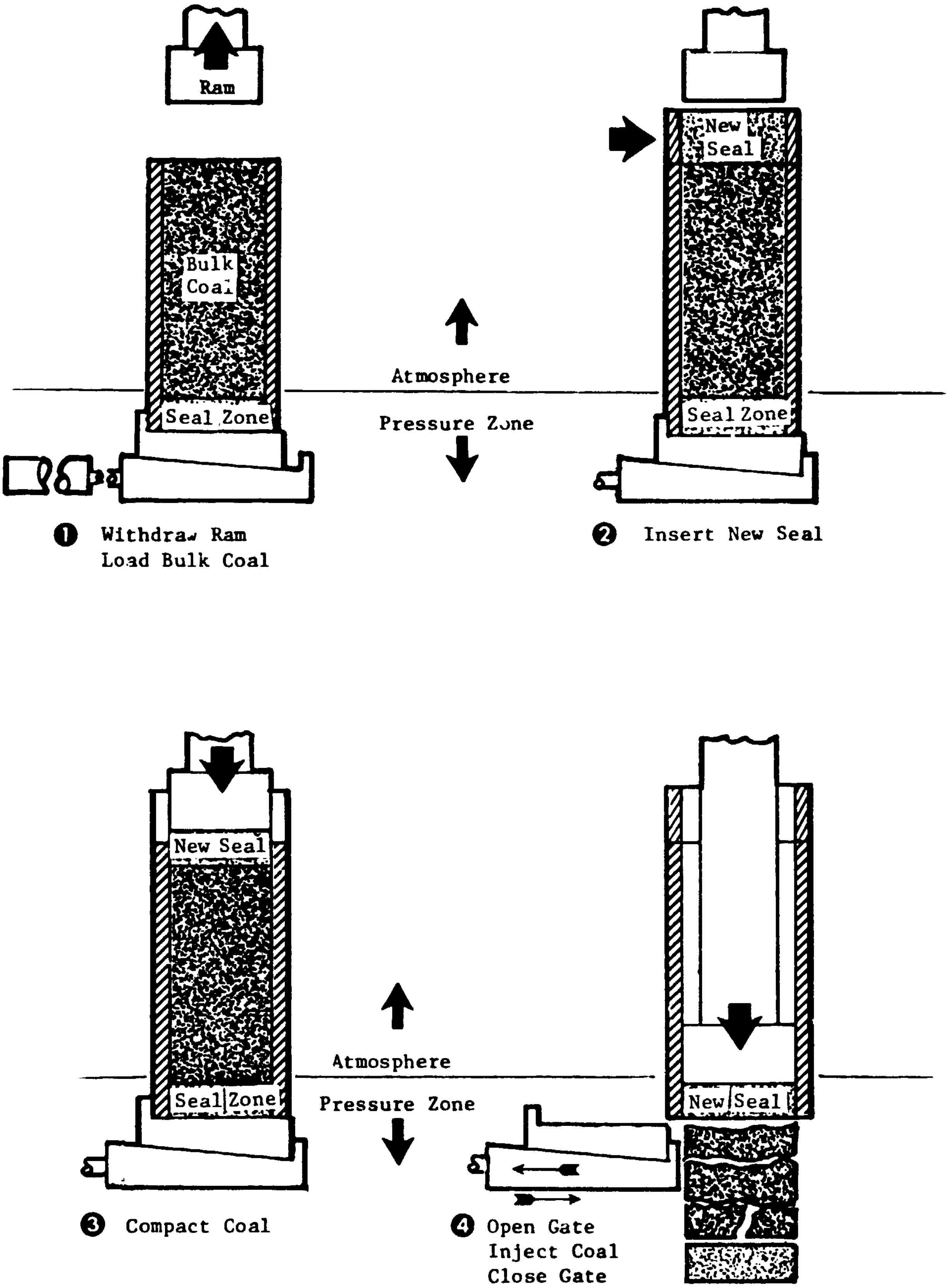

FIGURE 2. COAL FEED CYCLE

Compaction pressures of 2000 psig were required to form seal rings which averaged 36 seconds of seal time. Adequate packing of the fine coal particles occurs at this pressure. Higher pressures tend to distort and crush the coal and increase the injection forces.

A 50-weight motor oil and a 42-ssu-viscosity crude oil were used in the coal paste of the seal ring to determine the influence of viscosity on the seal time. The higher viscosity oil produced seal times that averaged approximately 20 seconds longer than seals produced by crude oil. However, the crude oil produced seals that averaged 27 seconds, which would provide a seal for the length of time required in the proposed full-scale system.

The use of various coal/fluid mixtures for the seal rings was investigated. It was found that an average improvement in seal time of 12 seconds was obtained when using 200-mesh and 20-mesh coal in equal parts rather than 200-mesh coal alone. This suggests a better packing ability, and consequently fewer voids, when using a well-graded mixture of coal rather than a mixture of uniform size. A drier paste mixture also improved the performance of the coal seal by reducing the extrusion of the seal ring around the ram.

Experiments were performed to obtain data concerning the feeding of lump coal, and the effect of different varieties of coal on forming the seal. Illinois Montour No. 4 coal in the size range of 1-inch to 1/4-inch diameter and North Dakota lignite in lumps up to 3 inches in diameter were run at a compaction pressure of 2000 psig. Both lump-coal feeding experiments used seal rings made from the same coal variety as the coal being fed. No differences in the performance of these seal rings could be detected.

Experiments were performed to assess the effect of operating pressure on seal times. The operating pressure in the receiver was increased from 500 to 1000 psig. This resulted in an increase in average seal time from 33 seconds to 44 seconds and is attributed to the increased radial pressure exerted by the seal ring at the higher receiver pressure.

Experimental Findings

From these experiments, we have concluded that

(1) The bulk coal being injected can range in size from 200-mesh to 3-inch lumps (maximum size investigated). With the 2-inch lump coal a moderate amount of crushing occurred (8-1/2 percent passing 1/8-inch mesh).

(2) The type of coal (bituminous and lignite) comprising the seal ring has no apparent effect on forming the seal.

(3) The concept is suited for high-pressure systems of up to 1000 psig and possibly higher.

(4) Seal plugs could be formed separately and transferred into the injection tube after it has been filled with coal.

(5) After feeding to a pressurized reservoir, the compacted bulk coal can be easily restored to its original condition by minimal agitation (such as from a mixing-type mechanism, screw feeder, or even gravity fall).

In summary, Battelle's experimental work has established the feasibility of forming a renewable seal of coal and fluid between a ram and a tube for injecting coal into a high-pressure chamber. Also, it has indicated that this concept has potential application in large scale gasification systems.

COMMERCIAL CONCEPT FOR DRY FEEDING OF COAL INTO A GASIFIER

Several combinations of injection tube diameter, ram stroke, and cycle time can be used to achieve an 80-ton-per-hour feed rate for a full-scale system. Engineering judgments of tradeoffs have led to consideration of a system utilizing two 24-inch-diameter by 10-foot-long injection tubes with the injection ram cycling at a total rate of two injections per minute.

The full-scale feeding apparatus will inject coal into a pressurized storage reservoir unit that would be remote from the gasifier unit. Thus, appears that the coal-feeding unit can be operated at ambient temperature. Also, it is assumed that a satisfactory seal could be obtained in a coal-feeding apparatus with a large diameter injection tube because better seal performance was experienced with the 7-1/2-inch-ID injection tube as compared with the seals obtained with the 3-1/2-inch-ID tube.

The main functional components of the coal-feeding system are:

(1) A press unit to compact the coal and inject it into a receiving chamber having a pressure of 1000 psig. The ram and its cylinder are mounted on a carriage so that the ram can be u ed to inject coal alternately through two injection tubes.

(2) A pair of injection tubes each equipped with a gate to close the bottom end of the tube against the 1000 psig gas pressure in the receiving chamber.

(3) A pair of receiving chambers to receive the coal charge injected by the ram.

(4) A screw conveyor to empty the receiving chambers of the coal charges.

(5) Two bulk coal-loading systems to fill the injection tubes with coal charges.

(6) A seal-ring-assembly system to form the seal ring and convey it to the inlets of the injection tubes.

Figure 3 shows a side and front view of the press feeding unit design which has a height of 33 feet. The unit is approximately 12 feet square and extends . . 10 feet below ground level. The press design shown is based on a laminated assembly of steel plates. The total weight of the press and other components is estimated to be 250 tons. A special feature of the press is the hydraulic cylinder which is mounted on a carriage. The carriage moves the cylinder with ram and bulk-coal-loading devices alternately over the two injection tubes so that while the coal is being injected in one tube, the other tube is being loaded. The movable ram also provides the clearance above the tube for the loading of the coal into the tube by the loading unit.

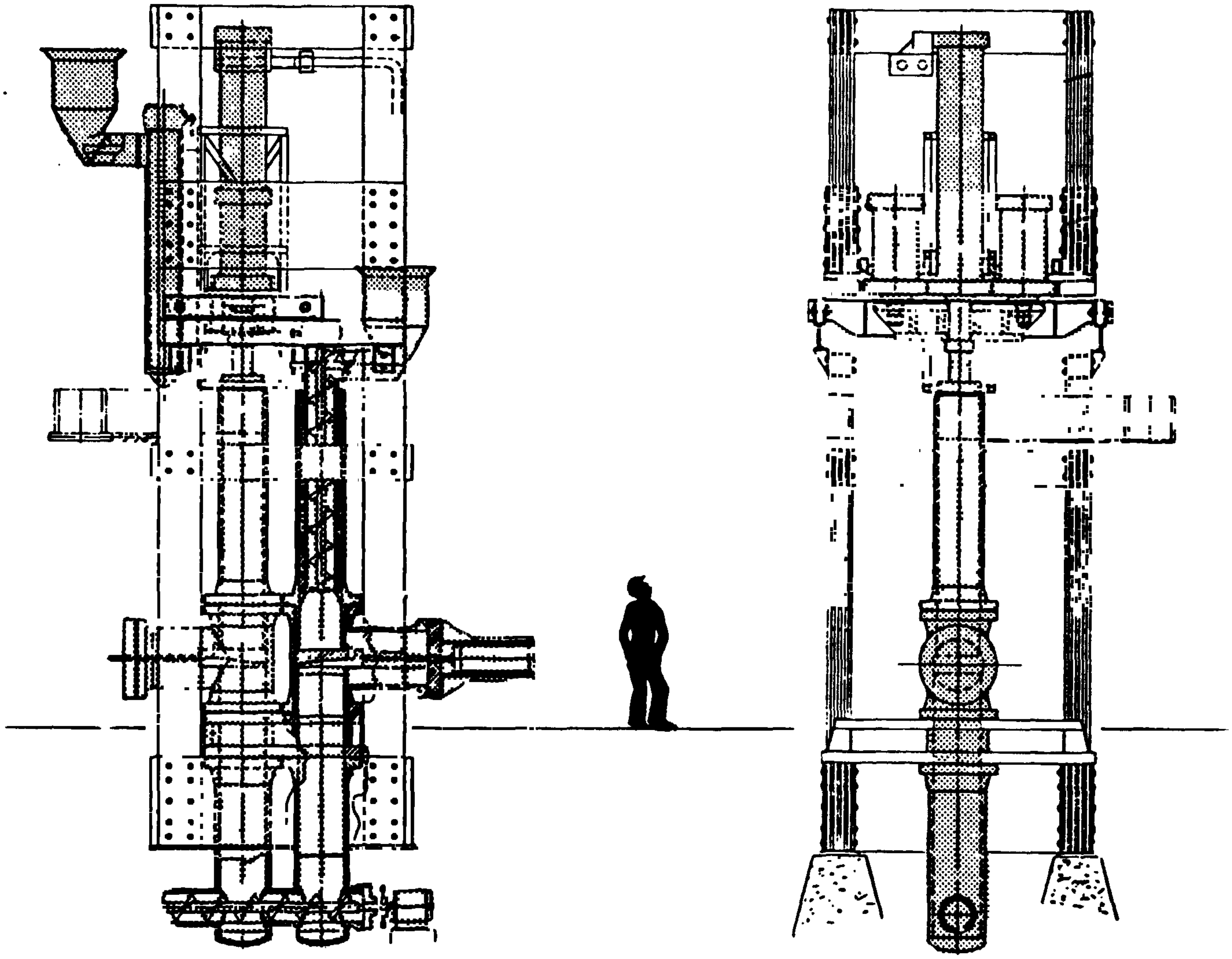

FIGURE 3. CONCEPT FOR AN 80 TON/HOUR COAL FEEDER

The gate design shown is based on the design used in the experimental apparatus and shows one method of accomplishing the required gating function between the injection tube and the receiving chamber. The gate is opened by withdrawing the lower wedge element partially from under the upper gate element so that it is moved downward and out of contact with the elastomeric seal. Continued movement of the lower wedge carries the upper element away so that the tube is fully open to the receiving chamber. As the gate opens, the top surface is swept clean by rotating brushes. The debris from this cleaning action is picked up by a small screw to convey the coal particles back into the receiving chamber.

Because of the abrasive action of the coal, a hard wear-resistant surface may be needed on the interior wall of the injection tube. A hardened steel (R_c 42) tube was used in the experimental apparatus. A surface finish of about 4 to 7 microinches is recommended to reduce the force required to push the coal from the tube.

RECOMMENDATIONS FOR DEVELOPMENT

Two additional program phases are envisioned to advance the dry-coal-feed concept from its present experimental position to operation on a gasification pilot plant:

Phase II - Continuous Operation, Systems Analysis, and Experimental Confirmation of Design Parameters

Phase III - Feeder System Design, Construction, and Operation at a Specific Pilot Plant.

The basic task for the proposed Phase II effort would be to convert the present single-cycle coal feeder to continuous operation with a design feed rate between 1 and 2 tons of coal per hour.

Complementary tasks would include:

- Additional experimental work on forming seals. Further reduction in compaction pressures and use of fluids other than oil would be directed toward obtaining data for lowering operating costs of the system.

- Laboratory studies of wear on system components to provide some means of assessing the maintenance requirements for an operating system.
- Evaluation of mechanical processing of the coal after injection so that it is suitable for feeding into a gasifier.
- Adaptation of the experimental feeder (or design of a scaled-up feeder) for further evaluation of the coal feeding concept at a specific pilot plant.

The Phase III effort would be detailed selection of a pilot plant. Operations under Phase III would use the data from Phase II to design and construct a feeder system integrated with an existing gasification pilot plant. Operation of the feeder system should extend over a period sufficient to gain experience and permit a thorough evaluation of the concept.