# DRY COAL FEEDER DEVELOPMENT PROGRAM AT INGERSOLL-RAND RESEARCH, INC.

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## ABSTRACT

Ingersoll-Rand Research, Incorporated is developing a dry coal screw feeder under contract to the Energy Research and Development Administration for feeding coal into coal gasification reactors operating at pressures up to 1500 psig. The program consists of laboratory development of 1.5" and 5.5" diameter screw feeders followed by field testing of the large feeder at a pilot plant. A description of both feeders, their associated test systems and the test results to date on the small feeder under several different modes of operation are presented. In addition, three new piston feeder concepts and their technical and economical merits are discussed.

## INTRODUCTION

With an increasing emphasis being put on the development of coal gasification systems, a number of problems have been identified which demand immediate attention. One of these is the process by which coal is delivered to the pressurized reactor; especially those operating at 300-1500 psig. Although the pilot plants are currently designed to use either a lock hopper or a slurry feed system, both have serious shortcomings and questionable long range adaptability to commercial gasification plants.

The lock hopper is particularly undesirable because it involves a cumbersome installation and requires frequent maintenance of valves. In addition to these, it tends to be expensive and inefficient because the gas must be compressed to the reactor pressure level before coal can be introduced into the reactor.

On the other hand, whereas the slurry feed concept is more economical and advantageous in performance over the lock hopper method, it tends to adversely affect the energy balance because of the thermal inefficiency due to the heat of vaporization of the carrier liquid. The slurry carrier also creates problems in pumping, condensation, subsequent separation and continual makeup.

Recognizing these difficulties in the current feeder technology for coal conversion processes, ERDA has set as one of its goals, the development of an efficient and reliable dry coal feeder. Such a system must be capable of delivering against high back pressures and be economically suitable for future commercial scale gasification plants.

To achieve this objective, the Fossil Energy Division of ERDA awarded a contract to work on a three phase program to Ingersoll-Rand Research, Inc. The now completed first phase established the feeder requirements for coal gasification plants, developed new concepts for delivering coal, and made recommendations about necessary equipment. The three new feeder concepts generated during this phase are briefly discussed in this paper with respect to general concept and operation.

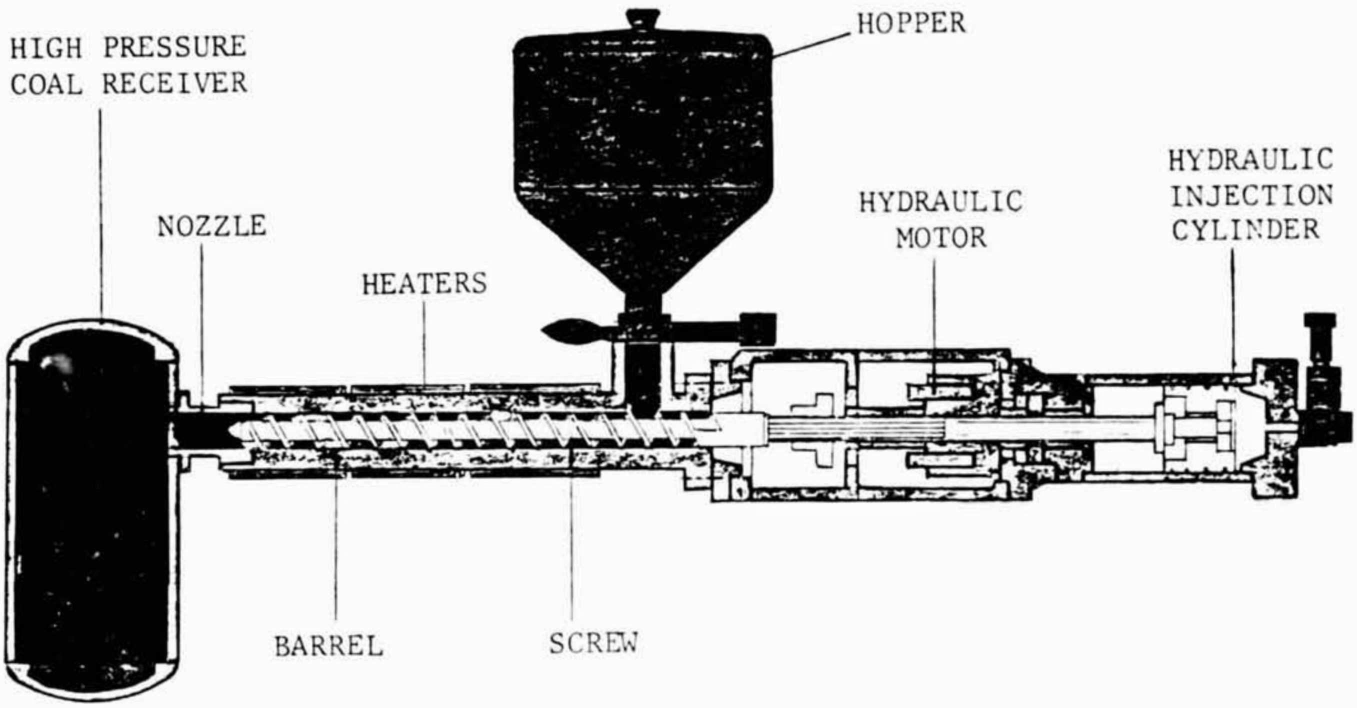
The objective of Phase II which is currently being carried forward, involves the development of 1.5 and 5.5-inch diameter coal screw feeders in the laboratory. These prototypes are establishing performance criteria and information needed for subsequent commercial scale-up. The progress made in this part of the program is the main subject of this paper. The knowledge gained during the Phase II will improve success of the Phase III field testing of the 5.5-inch screw feeder at an existing pilot plant.

## COAL SCREW FEEDER OPERATION

A general schematic of the coal screw feeder is shown in Figure 1. The feeder consists of a feed hopper, a screw, a barrel with heaters, a nozzle and a screw drive and injection system. The screw rotates in a tightly fitted barrel. The sized coal (-8 mesh) is gravity fed to the screw from the hopper. The coal particles are conveyed along the barrel and at the same time compacted to provide the necessary gas seal against back leakage. This pumping action is the result of a force balance between the coal and barrel frictional force, coal and screw frictional force and the pressure gradient in the coal along the screw.

The coal is subsequently discharged into the high pressure vessel by an extrusion or injection mode. In addition, the feeder can be operated with and without external heating of the coal through the barrel. To date, coal has been successfully pumped in the following modes: (1) Extrusion mode, with external heat and (2) Injection mode, without external heat.

During the extrusion mode, with external heat operation, coal is heated in the barrel to its semi-plasticized condition with electric heaters. As the coal particles move forward, they are compacted and agglomerated, forming a cylindrical plug in the nozzle, at the discharge end of the screw. These agglomerated coal particles provide a seal against elevated gas back pressure. The vapors generated from the heated coal are vented through an opening in the barrel near the intake area.




COAL SCREW FEEDER - GENERAL SCHEMATIC

Figure 1

In the case of injection mode without external heat, the coal particles are compacted as they move forward in the barrel forming a compacted plug in the nozzle at the discharge end of the screw. The axial thrust force on the screw causes the screw to travel backwards. The screw rotation is then stopped and the coal plug is injected by ramming the screw forward. The compaction of the particles due to both screw rotation and ramming action, provides the sealing against elevated gas back pressure.

## MAJOR AREAS OF INVESTIGATION AND TECHNICAL APPRCACH

In order to successfully develop a coal screw feeder, several areas must be carefully investigated during the laboratory and pilot plant testing. The information acquired from this work will be used in developing a reliable scale-up method which will be the basis for designing large feeders for commercial plant service. The major areas requiring investigation relate to the characteristics of the coal as well as the design and operating characteristics of the machine. Of particular importance are the physical and chemical properties of the selected coal type; e.g. size, moisture content, friction coefficient, viscosity, packing coking, volatile matter etc. Important feeder design and operating parameters are screw geometry, screw and barrel wear, coal output, power consumption etc. In addition, the sealing capability of the feeder should be investigated up to 1500 psig gas back pressure. In view of the practical difficulties in developing a large commercial size coal feeder, the present approach is to develop two sizes of screw feeders of significantly different coal delivery capacity. A small feeder, 1½" diameter screw, was selected for the initial testing effort because of its manageable size, flexibility, ease of rapid change of design and operating parameters and capability for expediting testing. This feeder is being used to experimentally study the effect of the design and operating variables on the performance.

The second and larger feeder, 5½" diameter screw, now reaching development testing status will be particularly used to study the size effect and help establish the design scale-up method necessary for designing a feeder for a commercial scale gasification plant. In addition, pre-pilot plant testing will be carried out in the laboratory prior to its installation at a pilot plant for field testing.

Theoretical analysis is being carried out in parallel with development testing and is being used to guide experimentation and to develop a scale-up method.

# 1½" DIAMETER SCREW FEEDER

## DESCRIPTION OF EQUIPMENT

The 1½ inch diameter screw feeder used in the first series of tests is a standard Negri-Bossi, V-12 model injection molding machine and was purchased from Ingersoll-Rand's IMPCO Division. As shown in Figure 2, the machine has a main control box, coal storage hopper, a barrel containing the rotating screw, a coal receiver, a hydraulic drive system and is powered by a 20 hp electrical motor.

The surfaces of the barrel and the rotating screw are nitrided to minimize potential wear from the coal. The barrel is designed to withstand 20,000 psig pressure. In addition, the barrel is equipped with five electrical heater bands which have a total heat capacity of 6 Kw and are automatically controlled according to the temperature settings at three locations along the barrel. The operating time of each heater is recorded to give the heat input.

The screw is driven by a swash plate hydraulic motor mounted co-axially with the screw. The rotational speed can be ried from 0 to 225 rpm with a maximum torque of 400 ft-lb.

At the discharge end of the barrel is a straight cylindrical nozzle, and a specially designed, high pressure coal extrudate receiver mounted on the clamp. When the

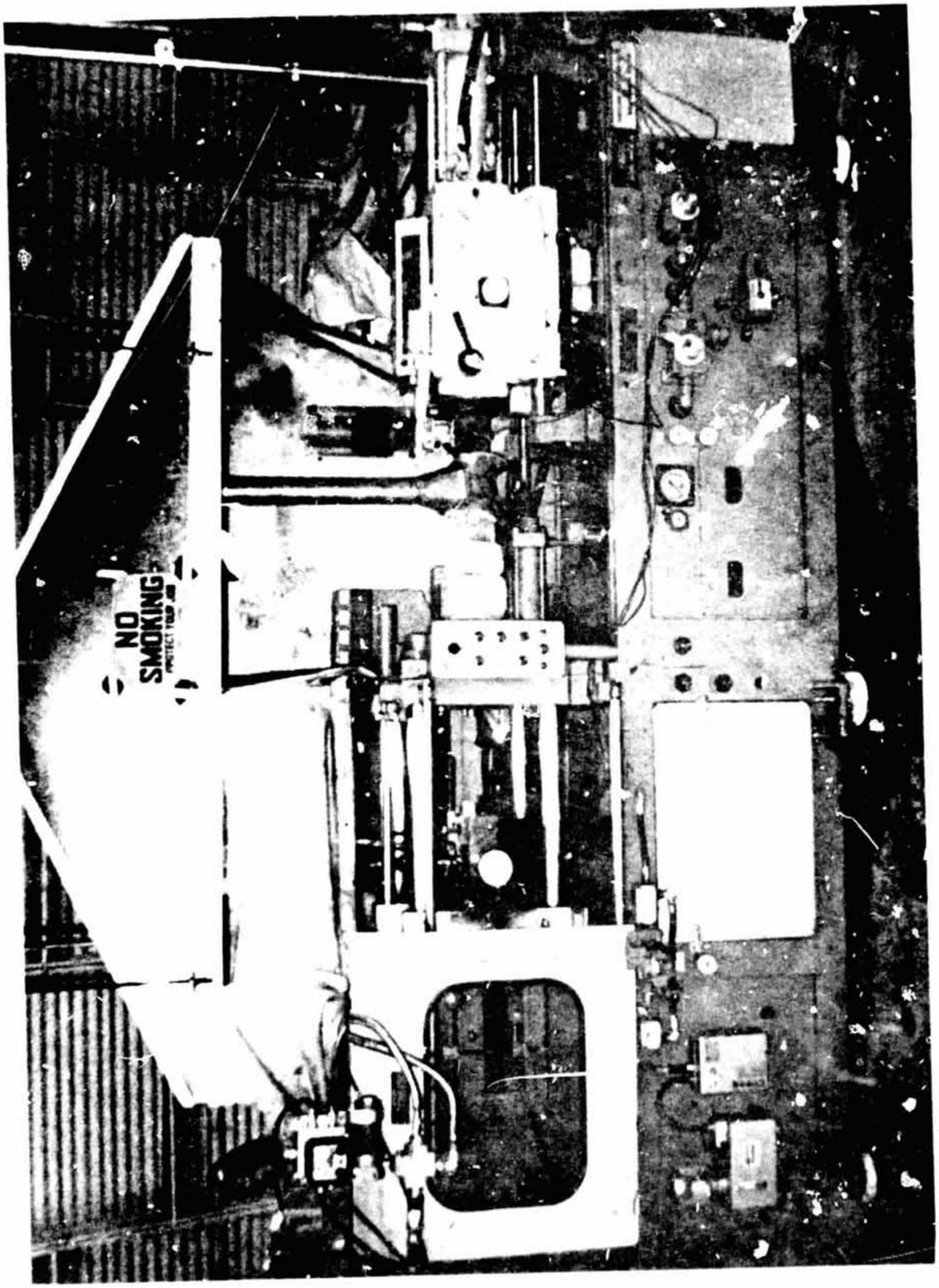



Figure 2: 1 1/2" DIAMETER SCREW FEEDER

clamp is in the open position, coal is extruded against atmospheric condition and can be observed continuously during operation. On the other hand, in order to extrude against a gas back pressure, the clamp is closed. The high pressure coal receiver engages with the nozzle and the receiver is then pressurized with nitrogen to the desired pressure level.

## TESTING

The 1½" diameter screw feeder has been tested successfully in pumping a variety of coals against elevated gas back pressures.

The coals tested have included samples from the Pittsburgh seam, the Pittsburgh #8 seam and the Illinois #6 seam. In some cases, the coal was used as received, in others it was dried and screened. In all cases, the coal particles were sized to less than 8 mesh; while in some tests 30 mesh was set as a minimum and in others as received fines were included. Gas back pressure was varied up to 1500 psig and the rotational speed of the screw was also a variable.

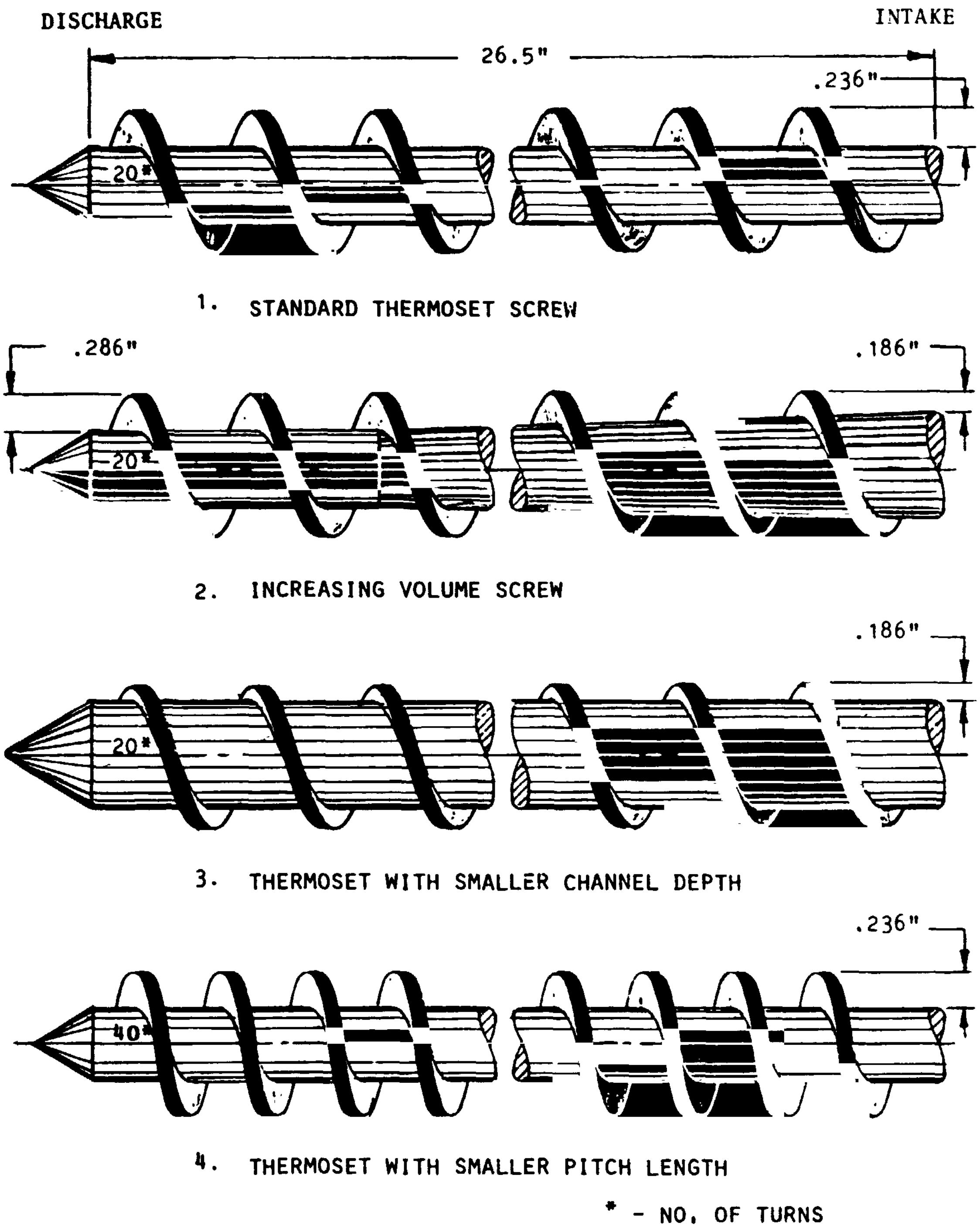
The testing was done in two modes; extrusion, with external heat and injection, and without external heat. The testing in these modes has b[illegible] extensive and critical to the continuing development of the dry coal screw feeder.

EXTRUSION MODE WITH EXTERNAL HEAT

The extrusion mode using external heat, initially presented some operational difficulties because of the volatile vapors generated from the heating of the coal. These vapors tended to form pockets within the coal moving along the barrel. Periodically the compressed vapors discharged with a loud puff; shooting hot coal from the barrel's discharge end. Additionally, some of the volatile vapors tended to escape back to the feed hopper, condense on the incoming coal, and cause bridging problems in the intake area. Proper venting of the vapors through a hole in the barrel near the intake area was found to be effective in minimizing these difficulties.

Temperature distribution along the barrel is one of the important operating parameters which affects the compaction of the coal. When coal became highly compacted in the screw, excessive frictional torque sometimes caused the screw to stall. On the other hand, insufficient compaction may have resulted in a loose coal plug that could not seal against the back pressure. Nevertheless, a steady state operation was achieved by controlling the temperature along the barrel.

Four screw configurations as shown in Figure 3 were evaluated for performance. The standard thermoset screw, #1 in Figure 3, which came with the 1½" diameter machine was initially tested for performance. It was found that this




SCREW CONFIGURATIONS
1 1/2" DIAMETER SCREW FEEDER

Figure 3

screw was extremely sensitive to barrel temperature such that a high barrel temperature resulted in poor quality extrudate and low setting caused screw stalling. Only by shortening the screw and reducing the rotation speed to 10 rpm could a plug be extruded in a steady state operation. The energy required was found to be excessive and the coal feed rate lower than desirable. No other testing was subsequently done with this screw.

Performance of the thermoset screw with smaller channel depth, #3 in Figure 3, and that of the thermoset screw with smaller pitch length, #4 in Figure 3, was also not satisfactory. Although steady state operation was possible with the smaller channel depth screw, the output was somewhat lower and the specific power consumption higher than achieved with the increasing volume screw (#2 in Figure 3). With the smaller pitch screw (#4) problems developed because of the higher rotational speeds needed for operation. Steady state operation was never truly achieved.

The most acceptable screw configuration is the increasing volume screw, #2 in Figure 3. Not only was steady state operation possible, but the output and specific power consumption were most favorable. Tests were carried out at 20 and 30 rpm and pressures from 0 to 900 psig. The results of these latter tests are discussed below.

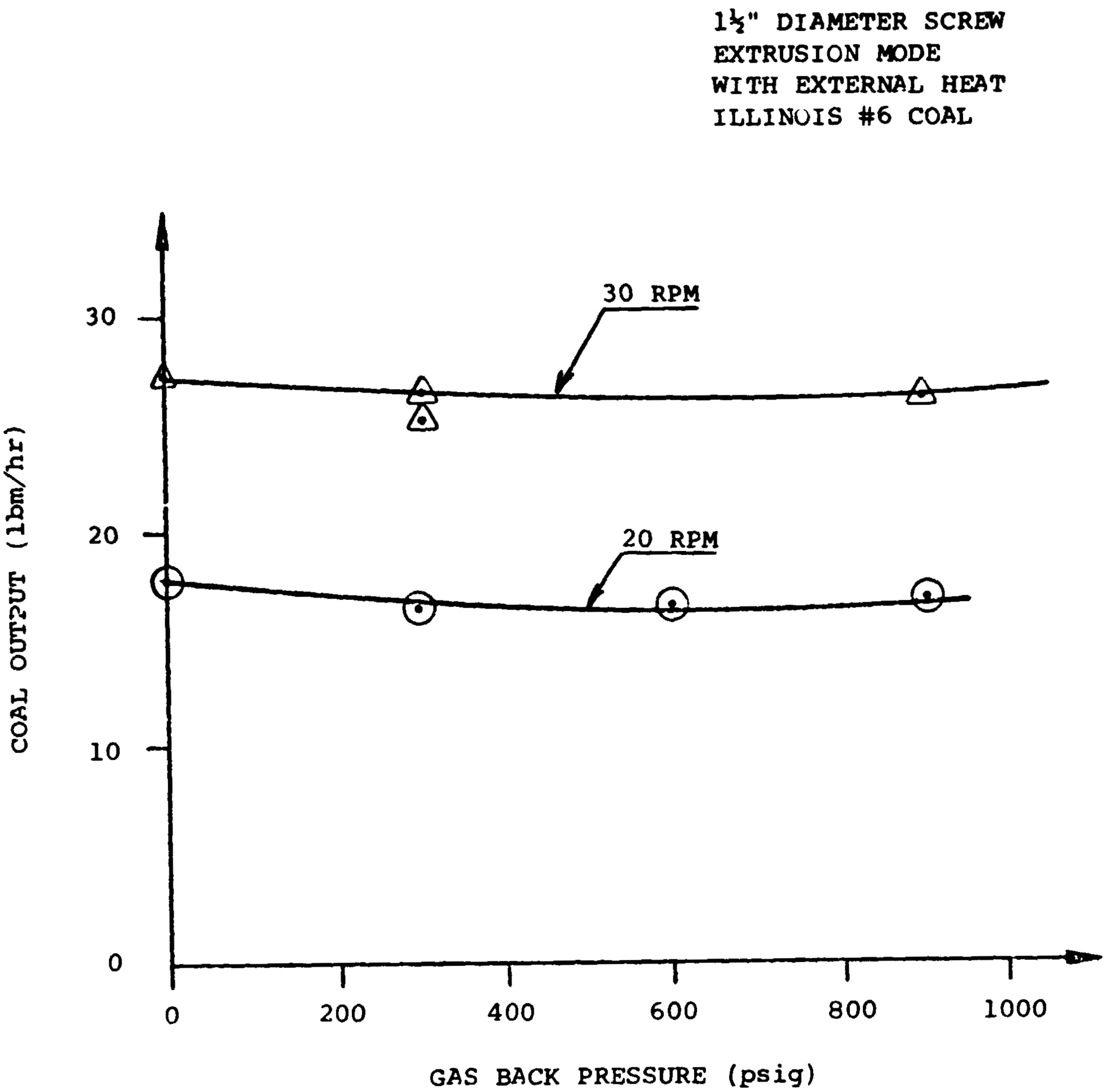
Coal Output

The steady state operation tests with increasing volume screw were carried out with Illinois #6 coal. As indicated in Figure 4, which relates coal output to gas back pressure at screw rotational speeds of 20 and 30 rpm, coal output is somewhat independent of gas back pressure and is approximately proportional to rotational speed.

Power Consumption

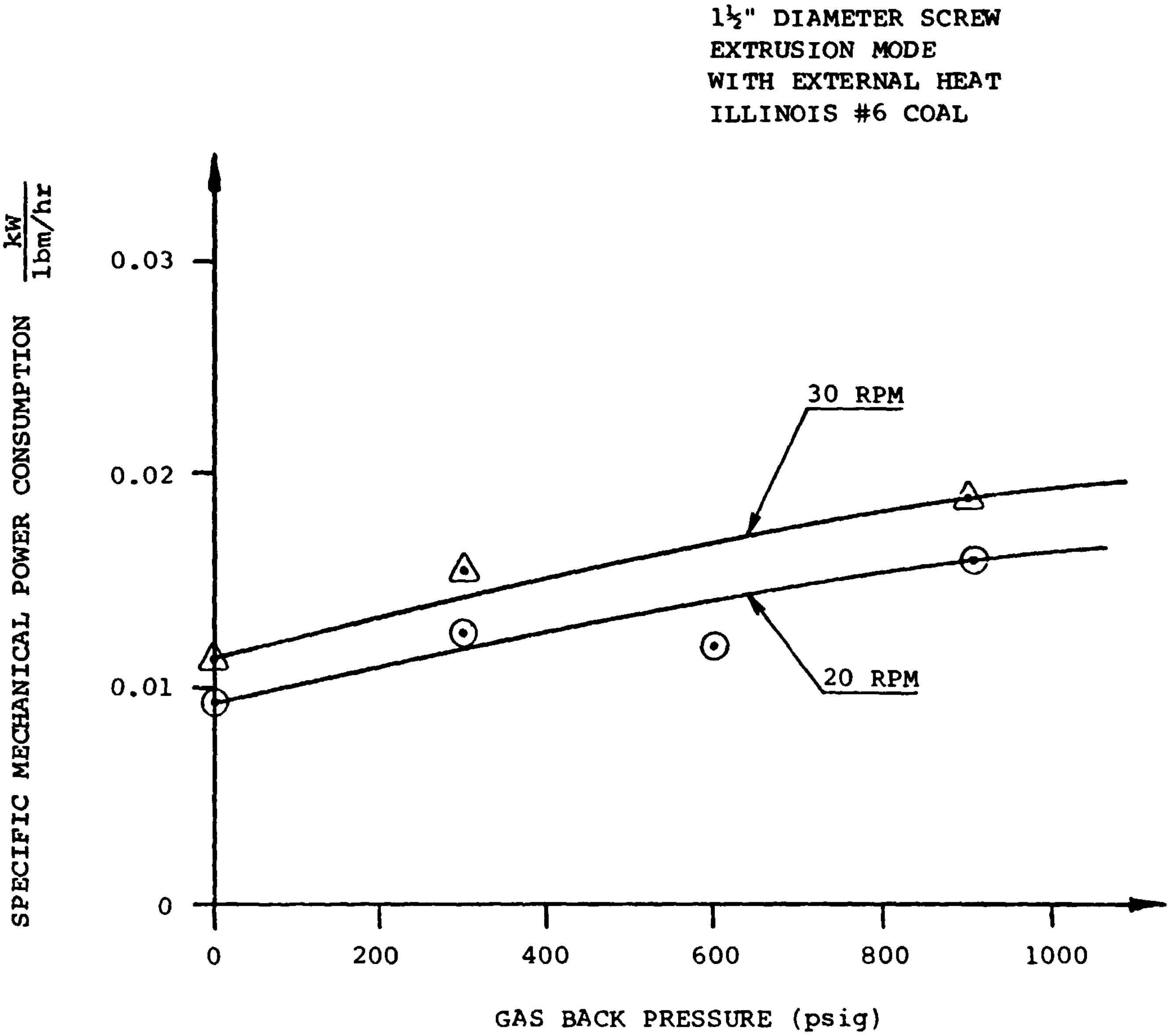
It is evident from Figure 5 that mechanical power increases with gas back pressure and the performance improves as the screw rotational speed is decreased. It should be noted that the power here includes neither the frictional power of the machine nor the electrical power used to heat the coal.

The electrical heat input to the coal was determined by recording the total time the heaters were turned on. The total energy input during the steady state operations with the Pittsburgh #8 seam coal is shown in Figure 6, where mechanical, electrical and total specific power consumption are plotted versus back pressure. The graph clearly indicates that only a minor portion of the total power is consumed mechanically in driving the screw; however, a large amount of heat energy is used to heat the coal and evaporate the r isture in the input coal. It should be pointed out that as far as the total process energy balance is concerned this energy input to heat the coal does not represent a



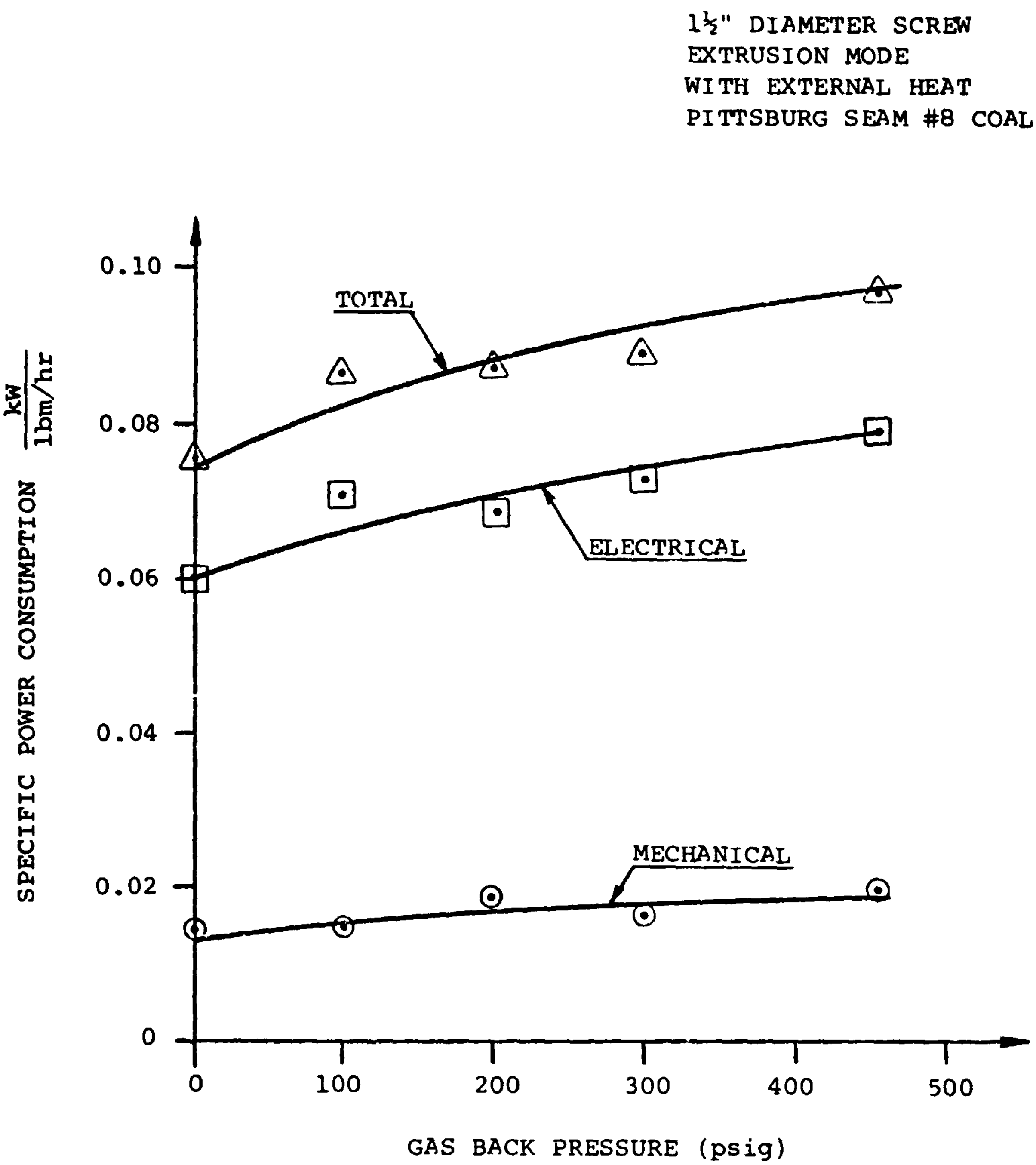

COAL OUTPUT VERSUS GAS BACK PRESSURE

Figure 4




SPECIFIC MECHANICAL POWER CONSUMPTION
VERSUS GAS BACK PRESSURE

Figure 5




SPECIFIC POWER CONSUMPTION VERSUS GAS BACK PRESSURE

Figure 6

thermal inefficiency. On the contrary, this may be viewed as a preheat process combined with the feeding. In addition, since some volatiles are driven off from the coal, it offers possibility of converting agglomerating coal to non-agglomerating coal which is desirable for certain processes.

Moisture Content

The testing to date indicates that the moisture content of the incoming coal significantly affects the feeder performance with respect to power consumption and vapor generation. The higher moisture content requires more heat for evaporation and the vapors generated is undesirable from an operational standpoint. For efficient operation in the extrusion mode, the input coal should have a low moisture content.

INJECTION MODE WITHOUT EXTERNAL HEAT

As outlined earlier, the injection mode involves the discharge of a compacted coal plug through the ramming action of the screw. Study of this operation was initially done using a standard thermoset screw with a length to diameter (L/D) ratio of 20. Preliminary tests indicated the importance of the L/D ratio with respect to the torque, power and tendency of the screw to stall. Because steady state operation could not be achieved with the L/D ratio of 20, the feeder was redesigned with a new barrel and a constant channel depth screw having an L/D ratio of approximately 6. Although with this modification feeder operation was improved, the continuous increase of barrel temperature due to heat addition from internal friction made the steady state operation impossible. It became apparent that the barrel temperature must be controlled and a water jacket was designed around the barrel. Steady state operation was achieved after this modification.

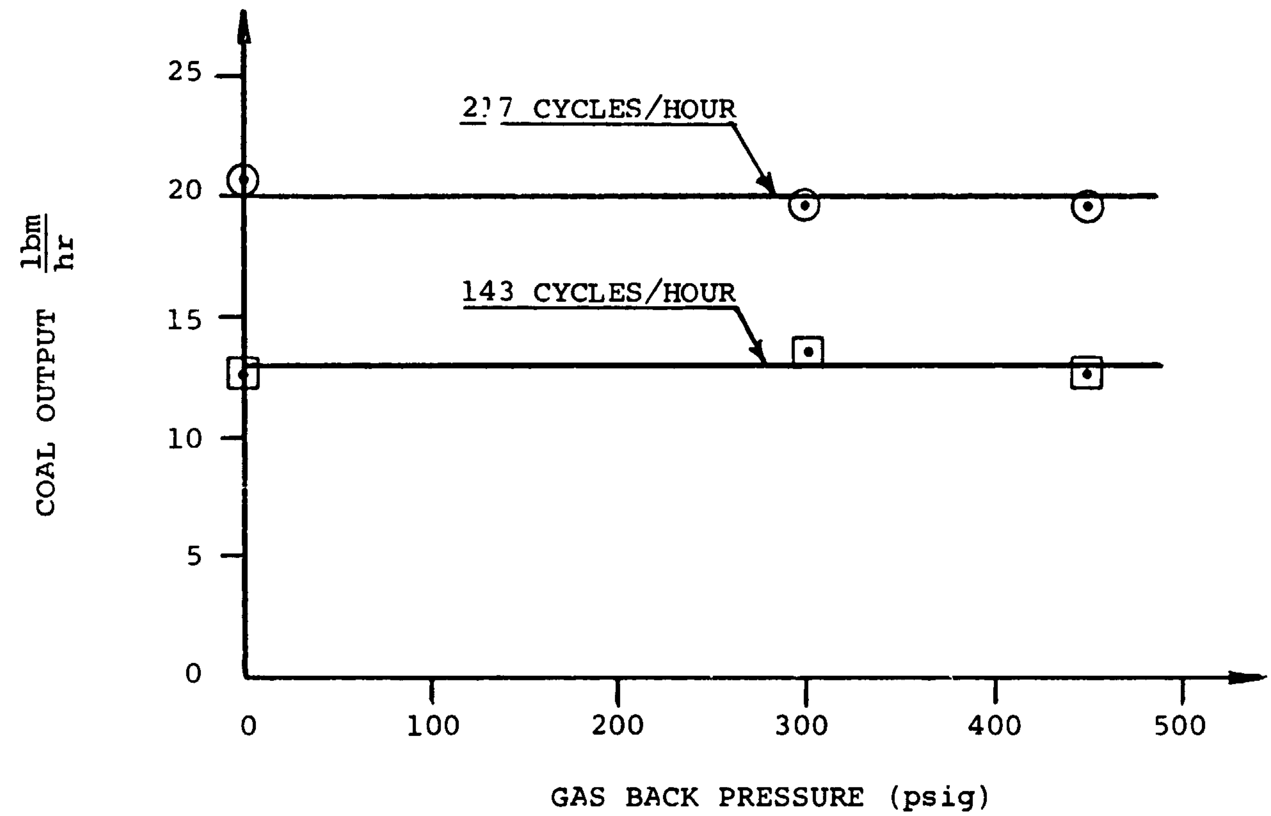
Coal Output

A cycle in the injection mode includes all the operations from filling the screw and forming the coal plug to injecting the plug into the receiver. Although the screw can be operated at higher rotational speeds to improve filling time of the cycle, the limiting factor for the cycle is the injection portion. It was found that if the number of cycles per unit time is increased beyond a certain level, the coal will not be sufficiently compacted to provide an effective seal against gas back pressure. An upper limit of coal feed rate, therefore, may exist. The coal output versus back pressure is shown in Figure 7 for 217 and 143 cycles/hour. This test, run on the Illinois #6 seam coal, clearly shows that output is independent of gas back pressure and is directly proportional to the cycle rate.

Power Consumption

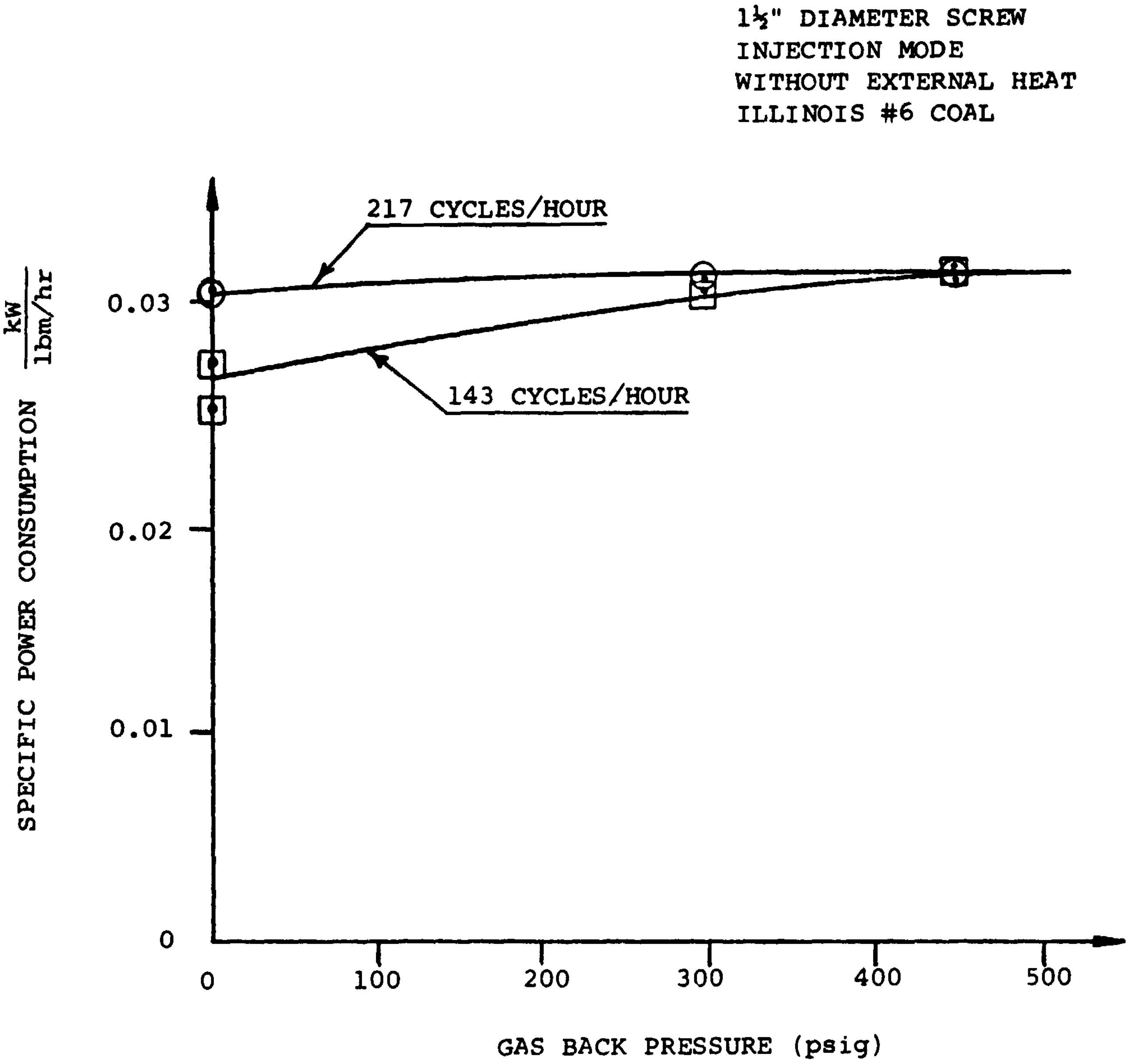
The plot of the specific power consumption versus gas back pressure is shown in Figure 8. Whereas specific power

1½" DIAMETER SCREW
INJECTION MODE
WITHOUT EXTERNAL HEAT
ILLINOIS #6 COAL




COAL OUTPUT VERSUS GAS BACK PRESSURE

Figure 7




SPECII 'C POWER CONSUMPTION VERSUS
GAS BACK PRESSURE

Figure 8

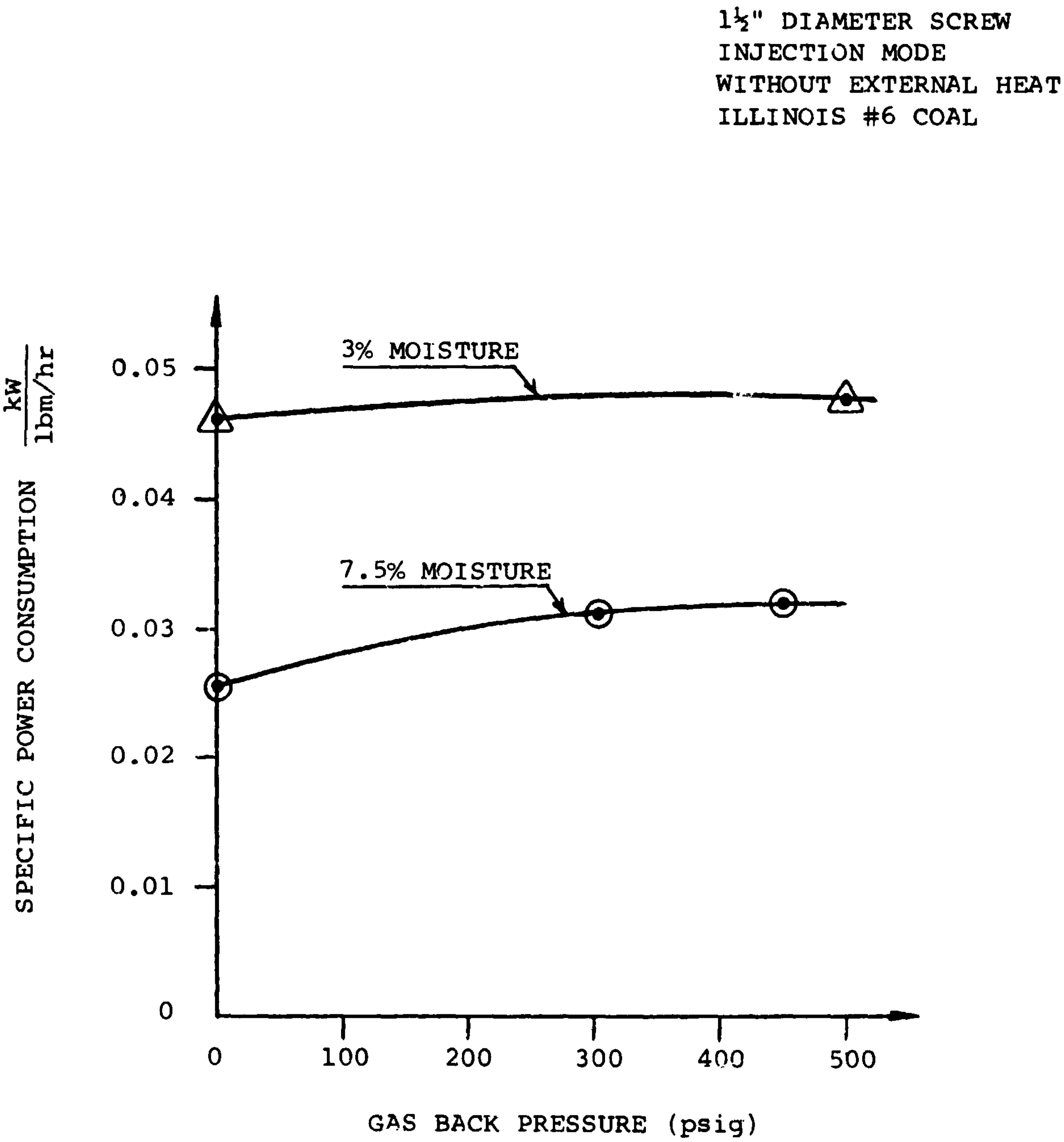
increases with higher gas pressure in the case of the 143 cycle/hour tests, there is no significant increase observable for the 217 cycle/hour rate. It is believed that the variation in the moisture content of the input coals used during this series of tests was the cause for the difference in the general behavior.

Effect of Moisture

Tests were also carried out to determine the effect of input coal (-8 mesh) moisture content on the feeder performance. The data is presented in Figure 9 which compares the results of 3.0% and 7.5% moisture in the input coal. It is clear that the higher moisture coal (7.5%) requires a specific power consumption of approximately 33% less than for a lower (3.0%) moisture coal. Other tests using fine coal (-30 mesh) indicate the same general trend, but for slightly different moisture contents: 5.8% and 10.7%.

## EXTRUDATE CHARACTERISTICS

Figure 10 shows the typical extrudate from the 1½" diameter feeder operating in the extrusion mode with external heat and the injection mode without heat. The external heating with extrusion mode tends to form plasticized skin surrounding a compacted and slightly agglomerated core (see A in Figure 10).




SPECIFIC POWER CONSUMPTION VERSUS
GAS BACK PRESSURE

Figure 9

[illegible]. Injection Mode
without External Heat

A. Extrusion Mode
with External Heat

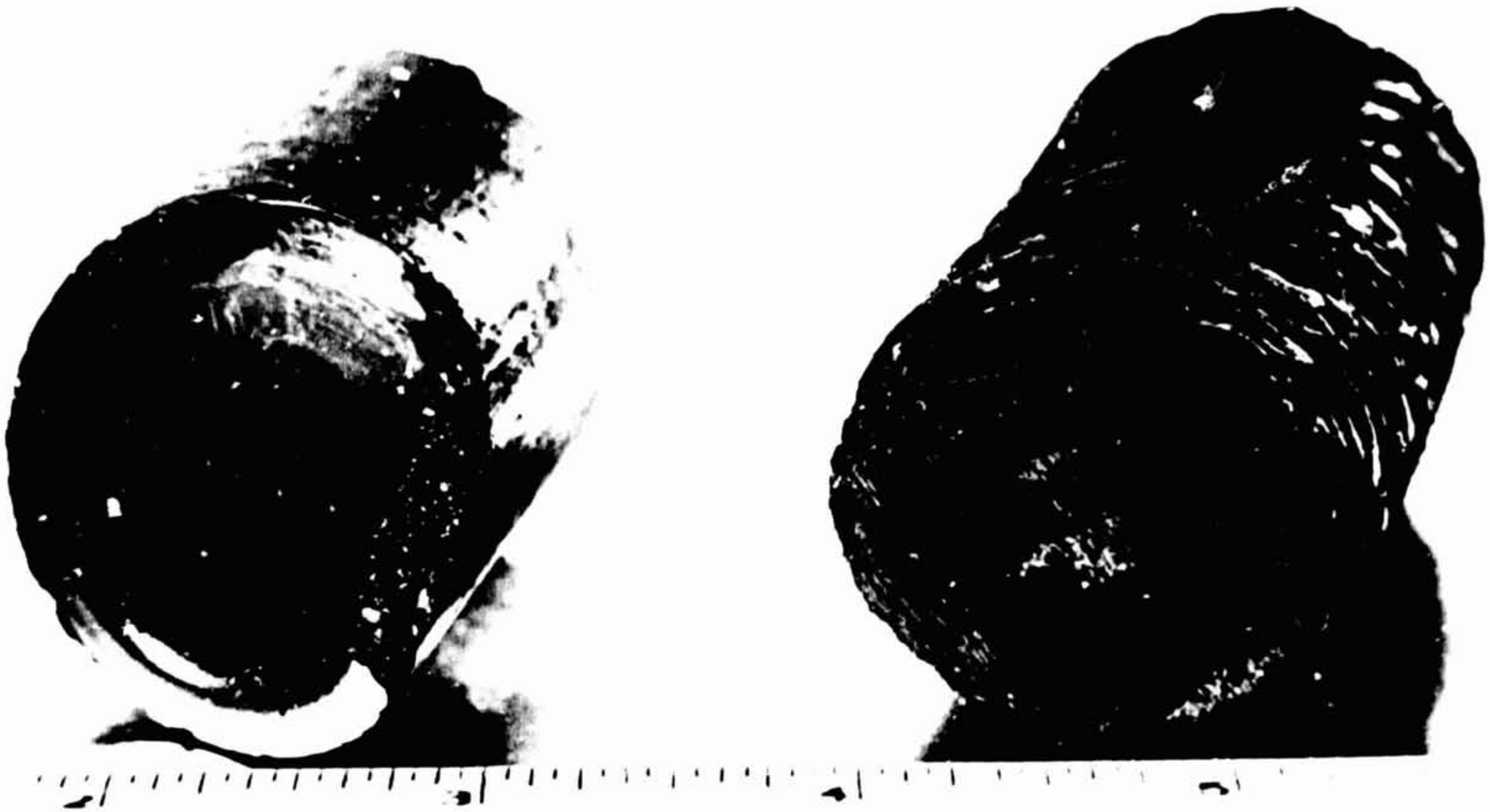


Figure 10: TYPICAL EXTRUDATE

In contrast, the extrudate plug (see B in Figure 10) from the injection mode, which did not involve external heating, tends to be glazed on the outside cylindrical surface and is of a highly compacted, granular structure in cross section.

Tests on the extrudates are being currently carried out at the Coal Research facility at Pennsylvania State University to determine the Proximate and Ultimate Analysis, the Free Swelling Index and the Hardgrove Grindability Index. The samples will also be subjected to a 1000$^{o}$F, 300 psig pressure environment to determine their ability to retain their integrity.

## CONCLUSIONS

Several conclusions have been drawn from the development testing to date with the 1½" diameter screw feeder.

### General

Various types and sizes of coal can be successfully pumped on a continuous basis to elevated gas back pressure with screw feeding. The sealing capability can be achieved either by taking advantage of coal plasticizing properties (extrusion mode with external heat) or by compacting coal particles (injection mode without external heat). The screw geometry, coal properties, input coal moisture content etc.

all have significant effect on the feeder performance. Coal output is essentially independent of back pressure and is nearly proportional to screw speed or cycle rate.

Extrusion Mode with External Heat

- Coal properties with respect to temperature, pressure and time are extremely important to proper operation of the screw feeder.
- Proper barrel venting is required to maintain consistent coal flow.
- Temperature distribution along the barrel is important.
- Input coal moisture content strongly affects performance and must be kept to a minimum.
- Increasing volume screw configuration with length to diameter ratio of 20 yields best performance.

Injection Mode without External Heat

- Increase in input coal moisture content significantly reduces power consumption.
- The screw length to diameter ratio should be approximately 6 for successful operation.
- Barrel temperature should be maintained below 200$^{o}$F.

# 5½ INCH DIAMETER SCREW FEEDER

## DESCRIPTION OF EQUIPMENT

Concurrently with the testing program of the 1½ inch diameter screw feeder, work has been progressing with the installation and preparations for tests with the 5½ inch diameter feeder. It is a specially modified, standard IMPCO 1500 injection molding machine fabricated by the IMPCO Division of the Ingersoll-Rand Company (Figure 11).

To meet the requirements necessary to feed coal at elevated gas back pressure, the machine has been extensively redesigned in the electrical and hydraulic systems. The screw flights are surface hardened with colmonoy and the surfaces are protected from corrosion with flash chrome plate. The Xaloy liner is shrunk into the barrel to protect the surface from wear. The barrel is heated in a similar manner as the 1½" diameter screw feeder with total heat input capability of 70 kw. The screw is internally heated with a specially designed 20 kw cartridge heater. The screw is driven by a vane-type hydraulic motor mounted coaxially with the screw. The screw speed can be varied from 0 - 60 rpm. The total rated feeder power is 200 hp.

The schematic of the feeder test system is shown in Figure 12. Two major system components are a high pressure coal receiver (vessel) and an extrudate break-up device. The system is designed for a coal feed rate of 1.0 ton/hour

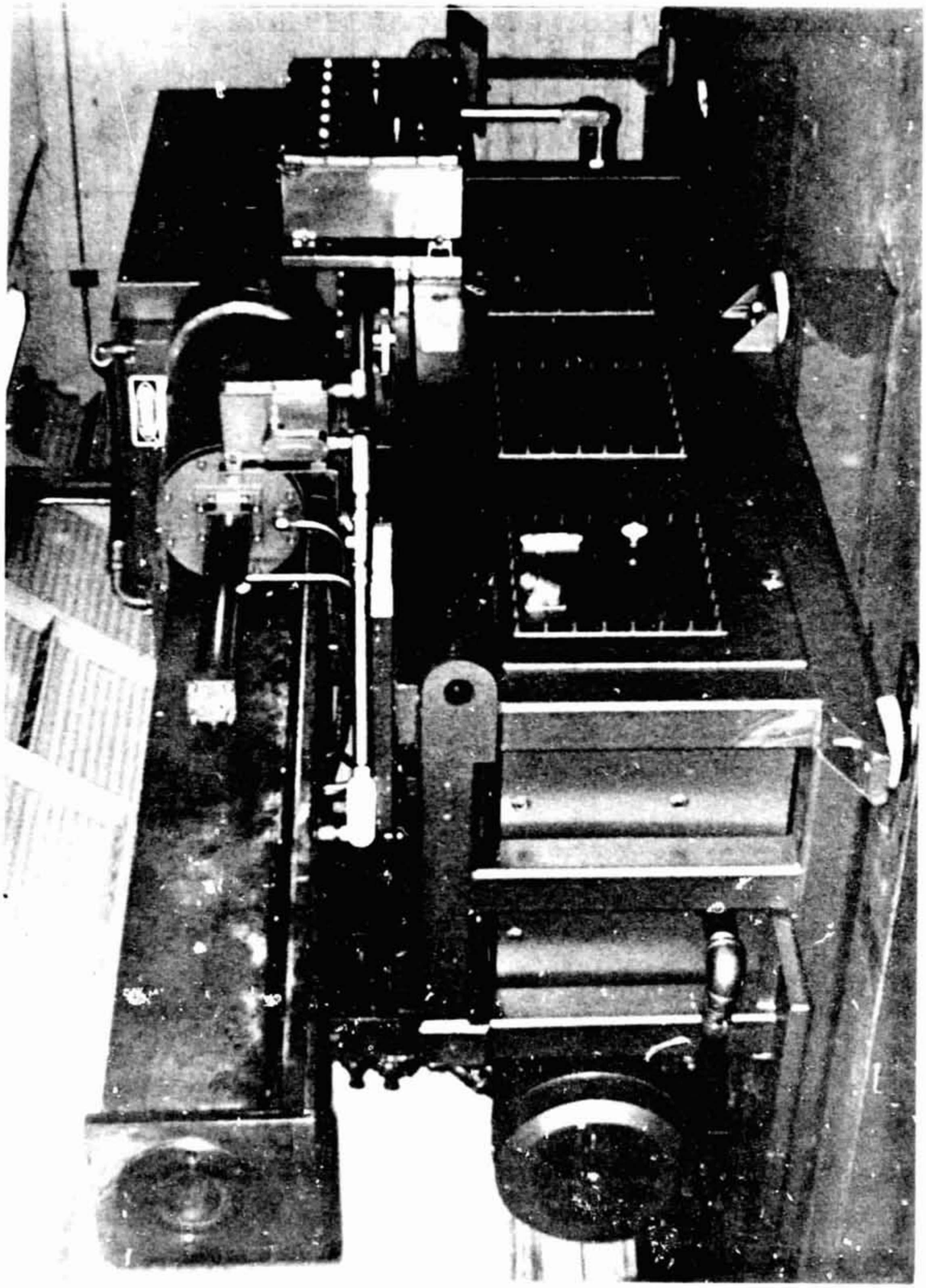
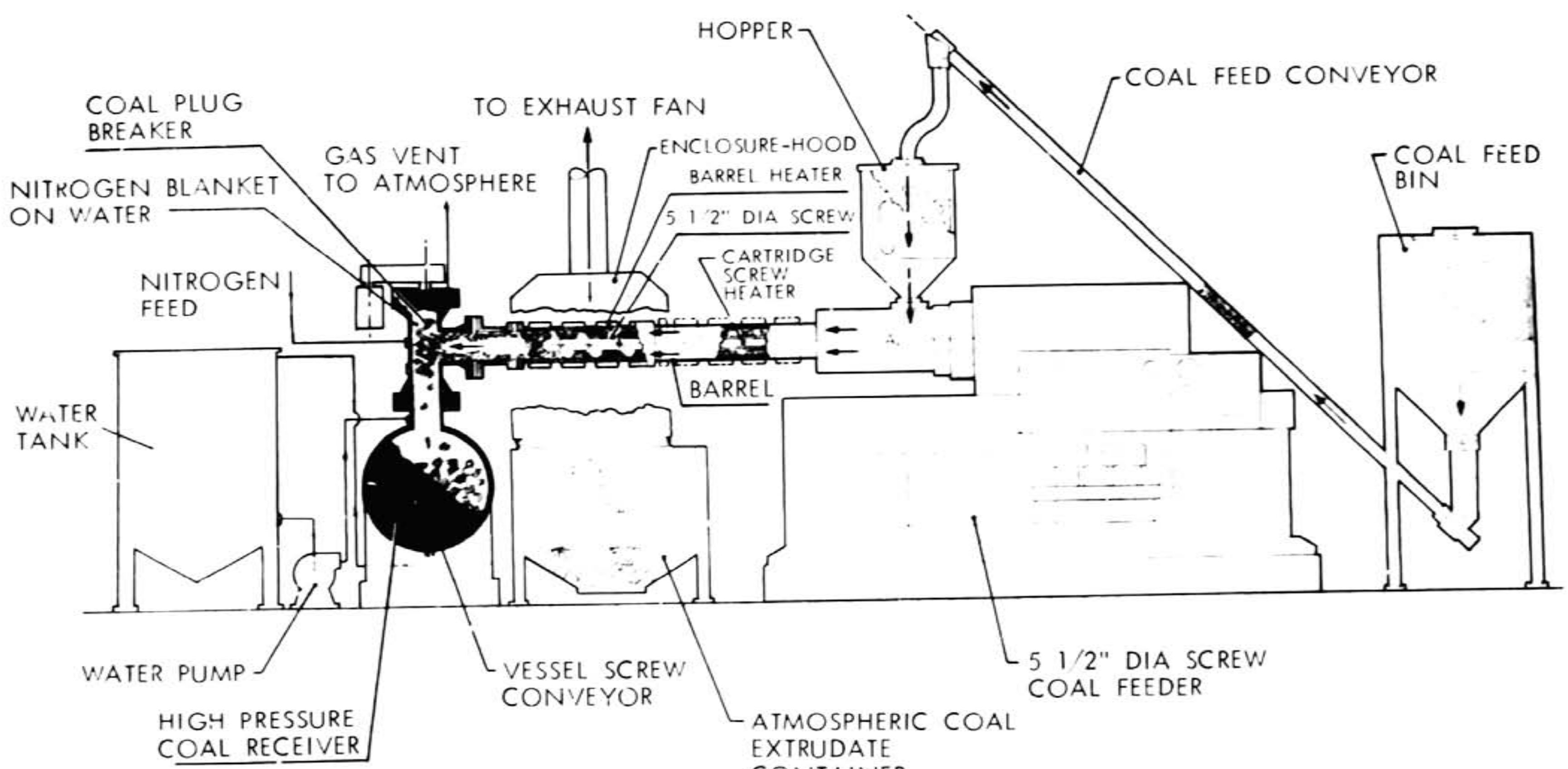


Figure 11: 5 1/2" DIAMETER SCREW FEEDER




TEST SYSTEM SCHEMATIC
FOR 5 1/2" DIA SCREW COAL FEEDER

Figure 12

with the capability for operation up to 5 tons/hour and back pressures of 1500 psig. The extruded coal from the feeder is conveyed to the high pressure coal receiver through a transition piece and the coal breaker. The breaker has a continuous, helical flight type cutter with sharp cutting edges and is mounted on a vertical shaft which can be rotated at varying speeds. The coal plug is fragmented by the breaker into small pieces (1" - 2") so that it can be readily removed from the vessel.

In operation, the high pressure coal receiver is filled with water and pressurized to the desired level with nitrogen gas in the space between the feeder and the receiver. The water is used to minimize the volume of high pressure gas for safety and economy. Moreover, the water level is maintained constant within the vessel as the coal extrudate fills the vessel. When the vessel is filled to the desired level with coal extrudate, the remaining water is drained and the gas in the vessel is vented to atmosphere. The coal is discharged from the vessel to the outside of the laboratory with a screw conveyor located at the bottom of the vessel.

The feeder and its test system are shown in Figure 13 as installed in the laboratory.

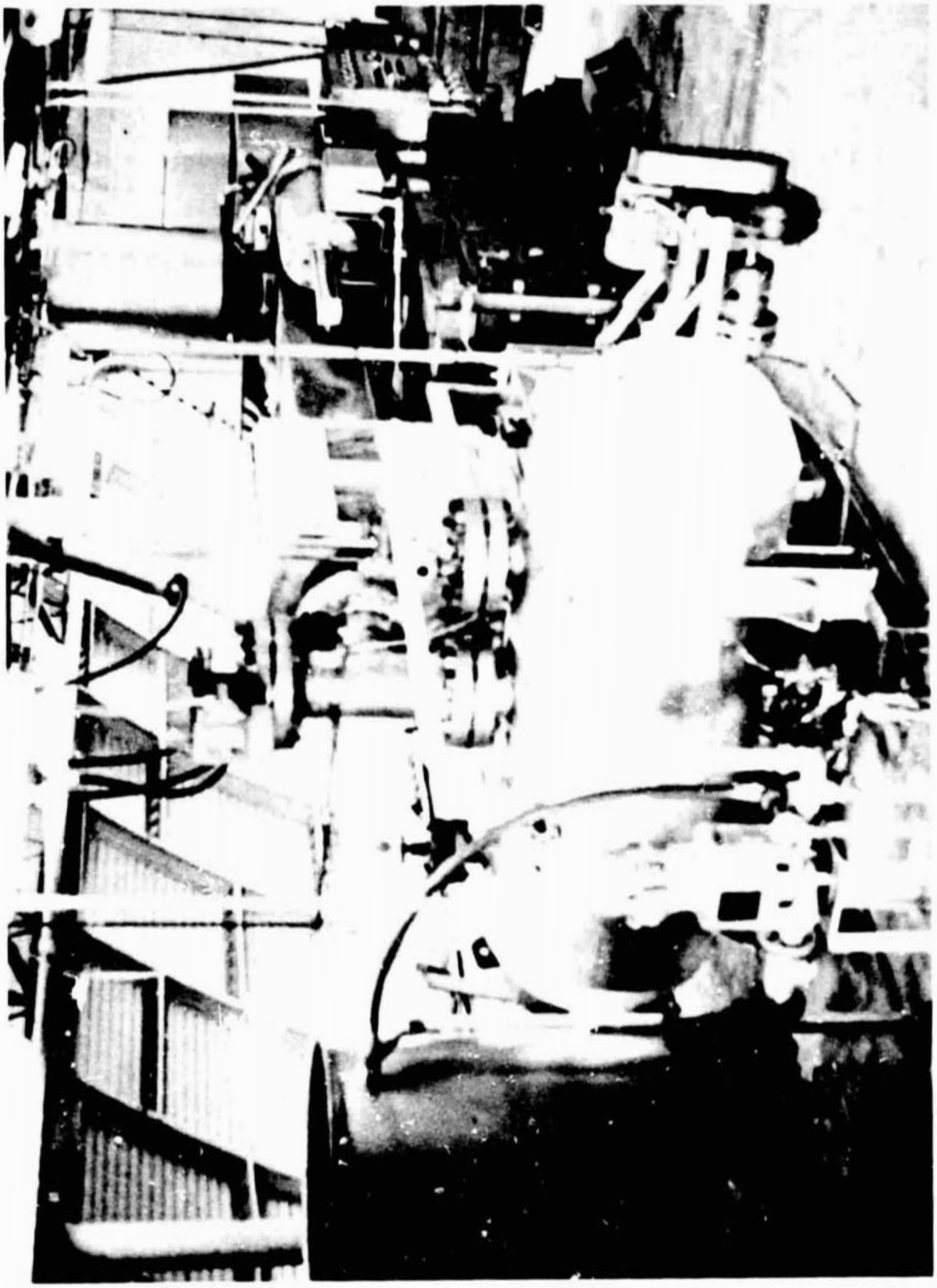


Figure 13: 5 1/2" DIAMETER SCREW FEEDER AND TEST SYSTEM

## PRESENT STATUS AND FUTURE PLAN

Testing with the 5½" diameter screw feeder, which began in March 1977, has been limited thus far largely to the "shaking down" of the feeder's subsystems. These tests have already provided valuable information for certain design alterations to the feeder and system which should greatly improve overall operation.

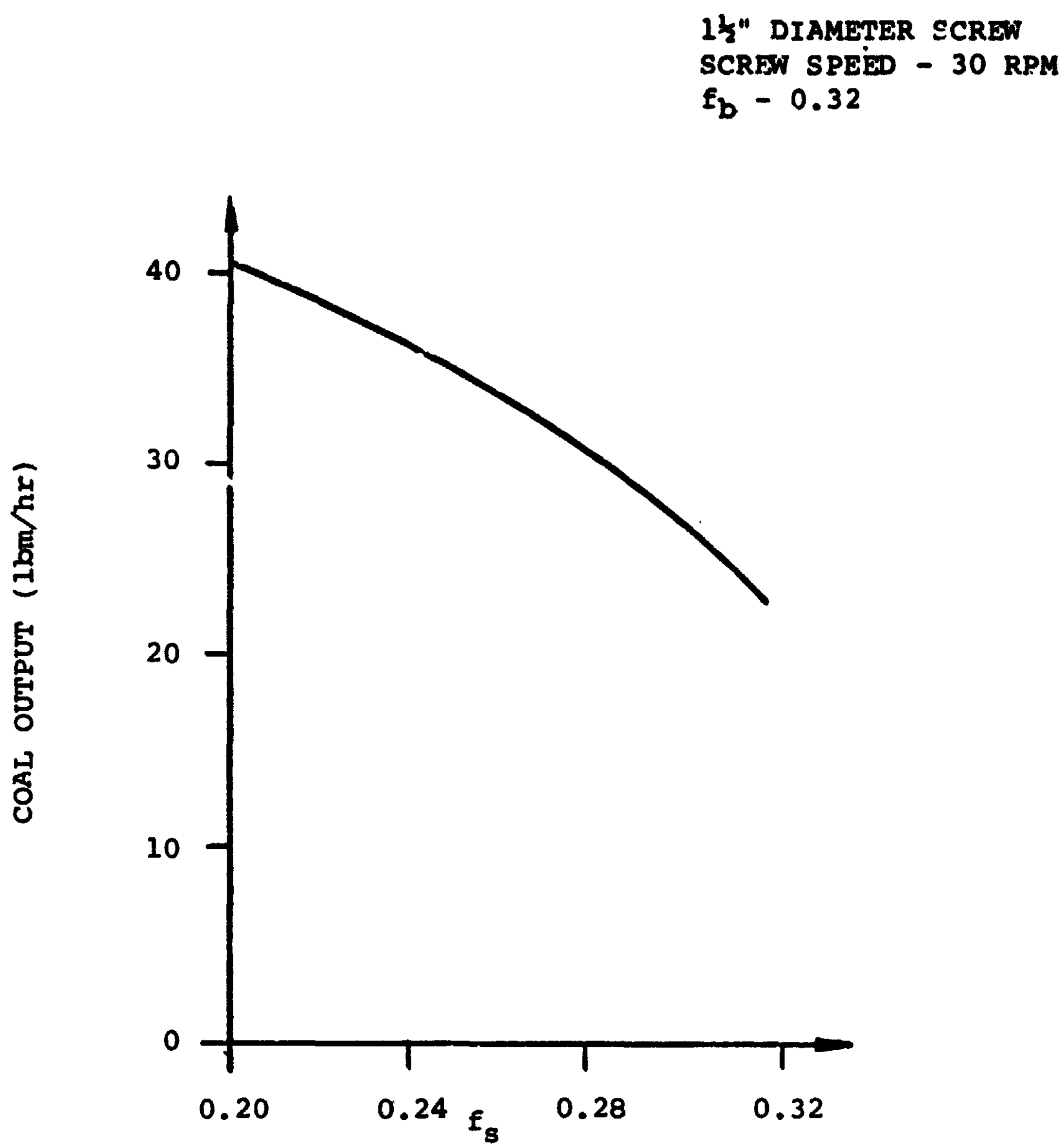
In addition, the feeder has been operated against atmospheric pressure in the extrusion mode (with and without external heat) and injection mode (without external heat). A coal plug has been successfully formed and extruded against atmospheric conditions (see Figure 14).

It is expected that a full development series of tests will be carried out with this feeder over the next several months. These tests will measure the coal output, power consumption and extrudate quality at elevated gas back pressure levels to simulate anticipated field conditions. The performance in different modes of operation will be compared. In addition, pre-pilot plant tests will be carried out in the laboratory. Following these tests, the feeder will be installed at a pilot plant for field testing. The experimental, stirred bed reactor at ERDA's Morgantown Energy Research Center appears at this time to be the most suitable installation for the pilot plant demonstration.

Figure 14: EXTRUDATE ISSUING FROM 5 1/2" DIAMETER SCREW FEEDER

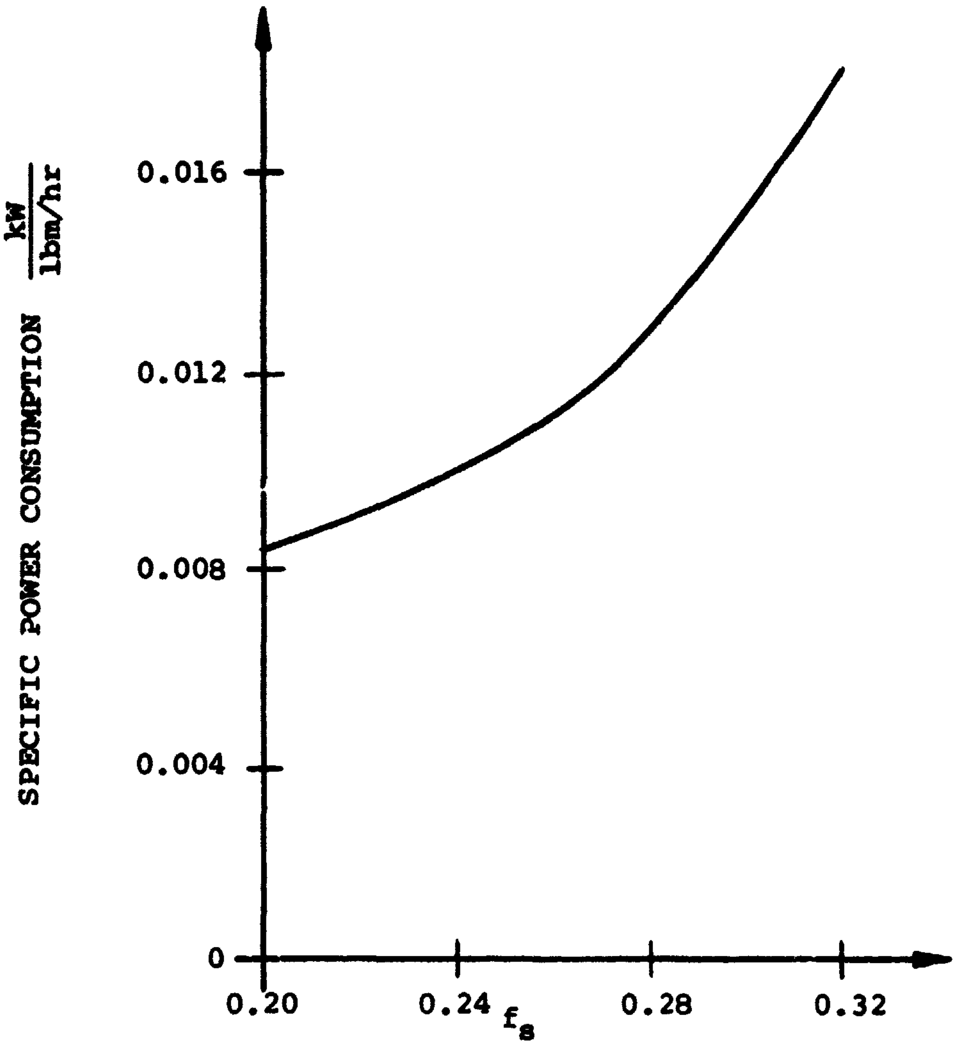
## PERFORMANCE IMPROVEMENT

A mathematical model was developed and a parameter study was carried out to relate the feeder performance to the design and operating parameters. The purpose of the study was to obtain an in depth understanding of the feeding process. Analytical results have indicated that, for a given screw geometry, reducing the friction between the coal and the screw is the most effective way to increase the pumping rate and decrease the power consumption. Figures 15 and 16 show that reducing the screw friction coefficient from .32 to .2 almost doubled the coal output rate and decreased the specific power by 50%. Accordingly, methods for providing surface lubrication for the screw are being investigated. The heating of the 5½" diameter screw also tends to decrease the friction between the screw and coal.




COAL OUTPUT VERSUS FRICTION COEFFICIENT BETWEEN COAL AND SCREW ($f_s$)

Figure 15




SPECIFIC POWER CONSUMPTION VERSUS FRICTION COEFFICIENT BETWEEN COAL AND SCREW ($f_s$)

Figure 16

## OTHER FEEDER CONCEPTS DEVELOPED

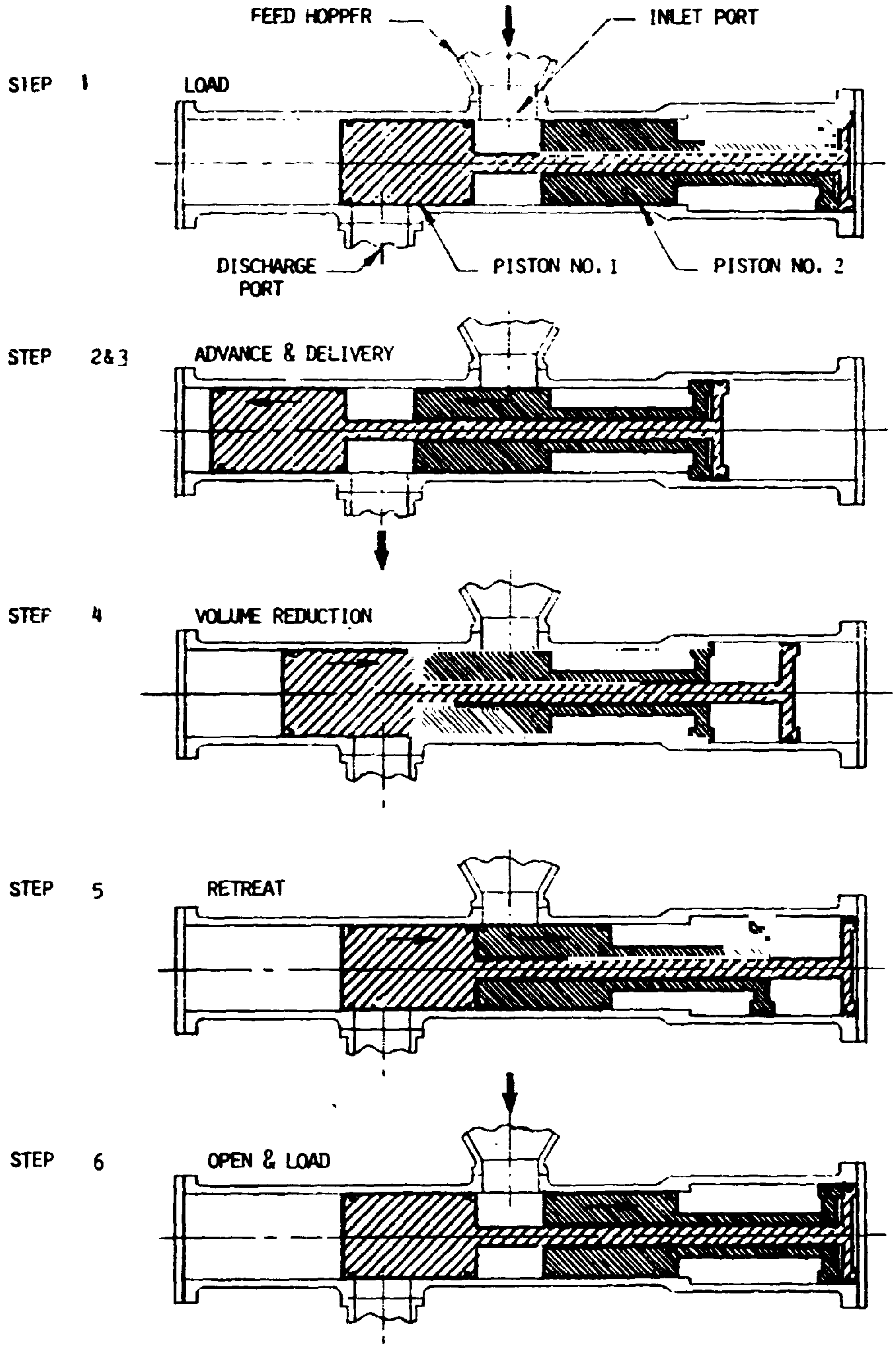
As a part of the Phase I study some effort was directed to the development of new feeder concepts. Three new concepts were generated and are briefly presented here for completeness.

Classified as piston feeders, each uses gravity to charge and unload the coal. However, they differ in their design and operation. A description of each concept is included below.

### Piston Feeder - Single Acting

The single acting piston feeder utilizes two co-axial delivery pistons which are in turn actuated by drive pistons activated by a pneumatic or hydraulic power supply. The sequence of events in a working cycle is as follows: load, advance, delivery, volume reduction, retreat and open for reloading.

As can be seen in Figure 17, there are six steps in this single acting, piston feeder cycle. In the first, the coal from the feed hopper fills the cavity between pistons 1 and 2. This is followed by the simultaneous advance of both pistons which first closes the inlet port and then brings the cavity to the delivery position. In step 4, piston 1 is driven to engage piston 2 and complete the volume reduction. This displaces the pressurized gas back



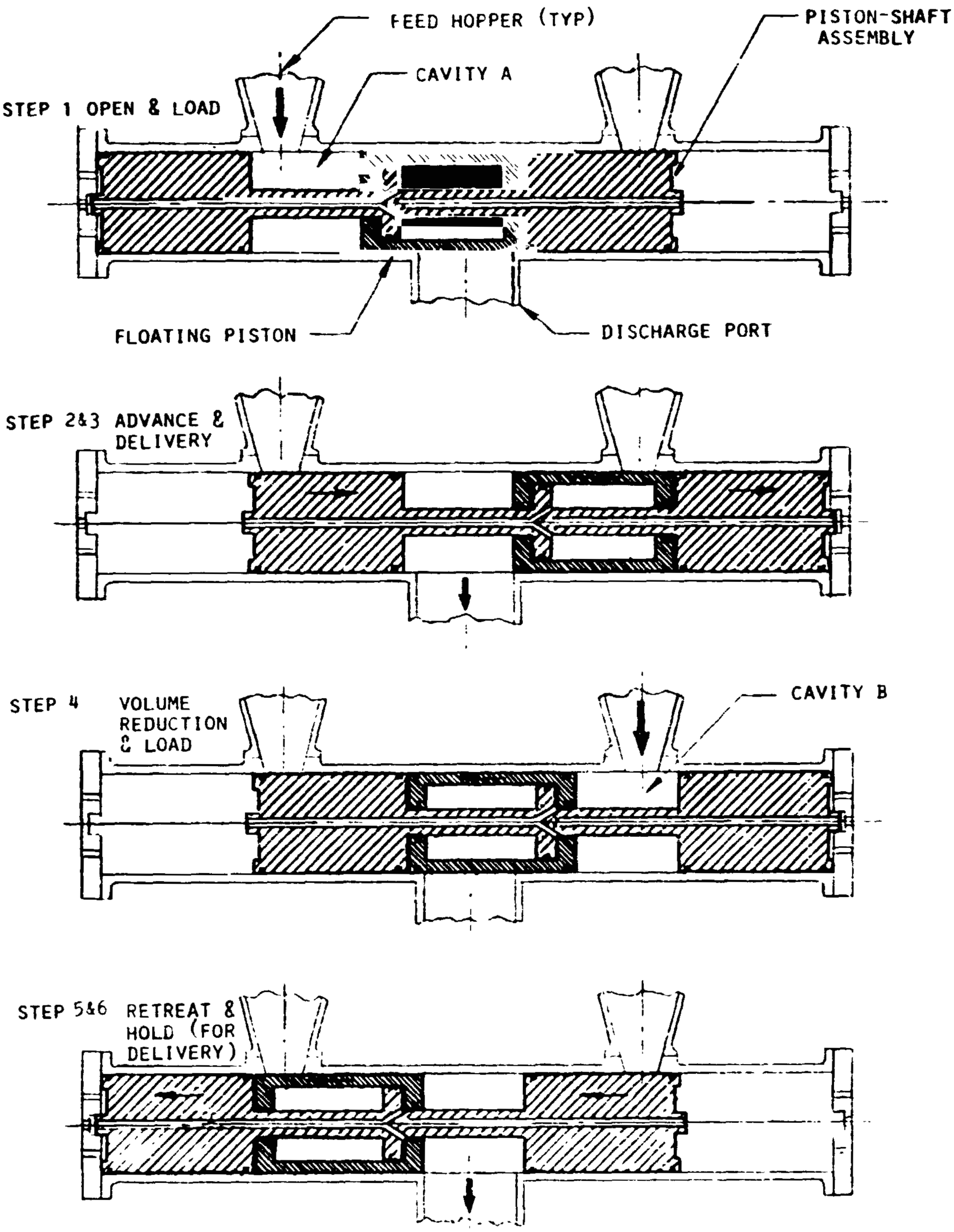

OPERATING SEQUENCE
PISTON FEEDER, SINGLE ACTING
Figure 17

into the system. In the fifth step both pistons translate back, restoring piston 1 to its original position. Finally, piston 2 is returned to its original position and the cycle starts again.

Piston Feeder - Double Acting

In the second piston feeder concept, the cylinder body contains two pistons at a fixed distance from each other joined by a common shaft. As shown in Figure 18, a floating piston lies inbetween, which, on its positioning in the cycle allows for alternate loading from the two feed hoppers. Again a power supply motivates and sequences the cycle. A summary of the operation is: open and load cavity A, advance and delivery, vclume reduction and load cavity B, advance in the opposite direction and delivery.

This cycle is broken into the following steps as shown in Figure 18. Beginning with the charging of cavity A, the second step shows the floating piston and the fixed piston - shaft assembly advancing to expose cavity A in step 3. Following this action, the floating piston is driven to the left and this returns pressurized gas back into the system and allows cavity B to be filled. In the next two operations, the fixed and floating pistons are both advanced to the left and bring cavity B to the discharge part. The cycle is ready again when the floating piston returns to the right side, and cavity A opens.




OPERATING SEQUENCE
PISTON FEEDER, DOUBLE ACTING
Figure 18

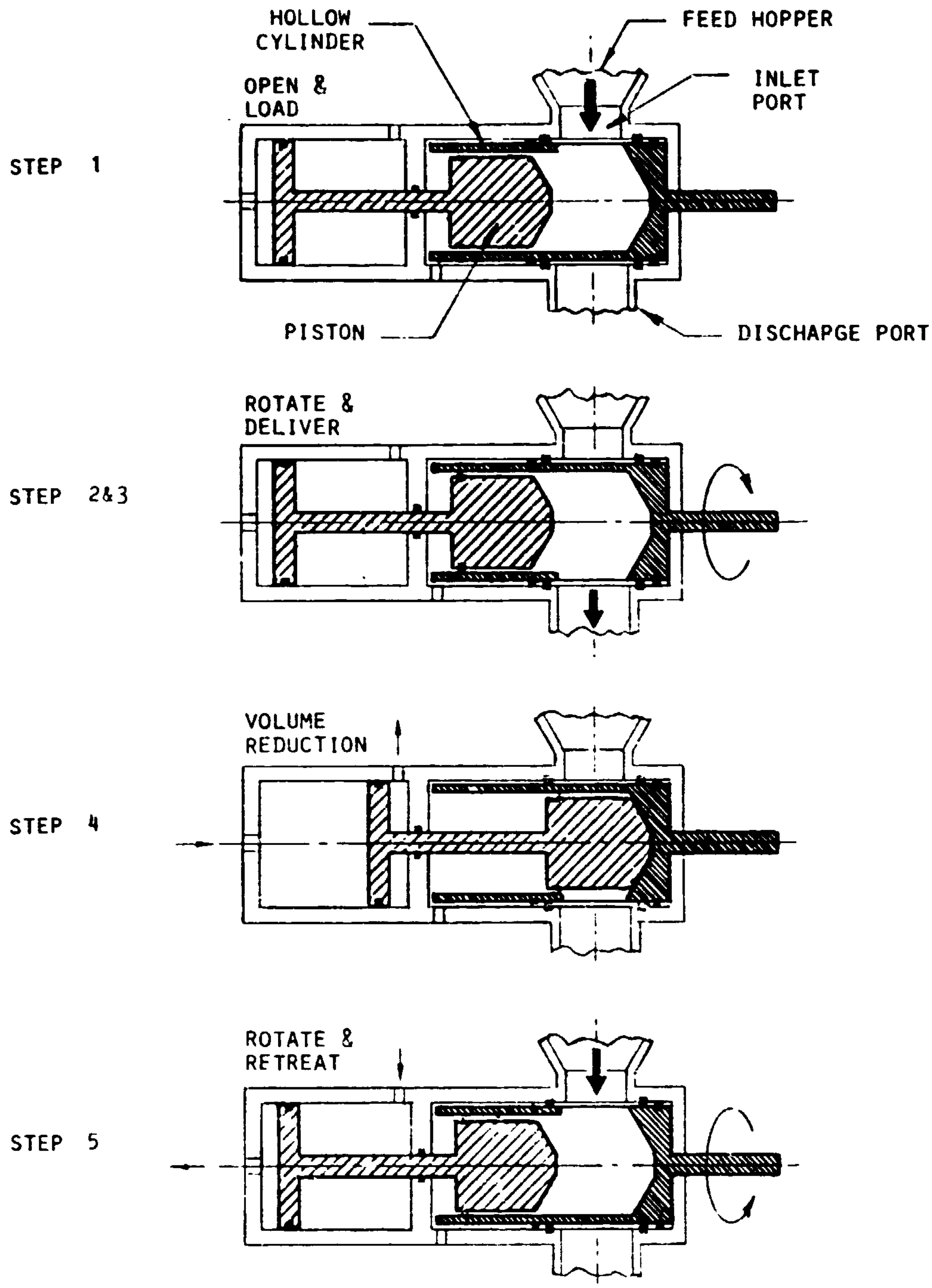
Rotary Valve Piston Feeder

The third piston feeder, shown in Figure 19, involves a single piston located within a rotating inner cylinder which is perforated on one side at its far end. This turns within the main housing which has an inlet hopper on top and a coal discharge port on the bottom. The process is sequenced and powered as in the other concepts. The delivery cycle involves the following sequence of events: open and load, rotate, delivery, volume reduction, rotate and retreat.

As Figure 19 indicates, step 1 involves the filling of the chamber with coal from the storage hopper. The cylinder then is rotated by a rotary actuator to a position where its opening corresponds to the discharge port. This action delivers the coal. The piston simultaneously moves forward to complete the volume reduction step. The hollow cylinder is then rotated back to the inlet port followed by piston withdrawal within the inner cylinder. The feeder is then ready to receive a new charge of coal.

Advantages of New Piston Feeders

An overall comparison was made of the piston feeder concepts against lockhoppers, slurry pumps and screw feeders to establish their relative merit. From this comparison, it became apparent that the piston feeder approach as a class offers significant benefits to developers of coal conversion systems.




OPERATING SEQUENCE
ROTARY VALVE PISTON FEEDER
Figure 19

While not at the development stage of lockhoppers and slurry pump systems at this time, the piston feeder concepts should provide improvements in overall process operation because of the need for fewer auxiliary subsystems and simpler control systems. For example, no pressurization gas loss from the system will be incurred to degrade process efficiency (as occurs with lockhopper systems). Accordingly, there will be no requirement to collect, scrub, clean, and recompress such gas, thus eliminating much auxiliary equipment. Similarly, the need for substantial coal preparation and slurry mixing equipment necessary with any slurry system is obviated. The heat of vaporization penalty to the process is not present.

Next, the coal will not be physically or chemically changed (i.e., crushed, compacted, agglomerated, devolatilized, etc) during the delivery process. Furthermore, the concepts will accept all coal types (i.e., caking, non-caking, bituminous, non-bituminous, etc.) as well as a wide range of coal feed particle sizes.

A very unique benefit is the inherent safety in a condition of system malfunction. If a power failure or system component failure is encountered at any stage in the delivery cycle, there can be no "blow back" from the reactor of pressurization gas through the feeder. Finally, the piston-type feeders may be easily scaled up to future commercial scale feeders.

A preliminary economic evaluation has been made on the projected commercial use of piston feeders. Taking the concept of the piston feeder and scaling it up for installation at a conversion plant with a capacity of 15,000 tons/day and reactors operating at 1500 psig has indicated that considerably lower costs are expected as compared to existing equipment operating in similar situations.

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