FOSSIL FUEL PROCESSING TECHNICAL/PROFESSIONAL SERVICES

COAL FEEDER SURVEY FOR ILLINOIS COAL GASIFICATION GROUP

MASTER

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A JOINT VENTURE OF
UOP INC. AND
SYSTEM DEVELOPMENT CORPORATION

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COAL FEEDER SURVEY
FOR
ILLINOIS COAL GASIFICATION GROUP

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COAL FEEDER SURVEY

1.0 INTRODUCTION AND SUMMARY

An evaluation of three coal feeder concepts (lockhopper, Fuller Kinyon screw and Foster Miller pocket feeder) for use in the ICGG first stage gasifier was made. For the sake of consistency, all feed concepts were evaluated on the same basis, that is, feeding a nominal 100 Tons per hour (TPH) against a back pressure of 50 psig. Also, all feed systems were assumed to have similar atmospheric storage hoppers and final injection systems. Accordingly, no further consideration of these support systems was made.

This survey was accomplished by reviewing the literature, interviewing vendors, contacting applicable facilities and performing necessary original analysis. The emphasis of the survey was on the test and industrial experience of each system.

The results of this survey which are summarized on Table I show that the lockhopper system still should be considered as the baseline system because it is a proven system with extensive operating experience. On the other hand, if definitive tests can prove conclusively that the Fuller Kinyon screw pump will deliver coal against 50 psig back pressure with acceptable efficiencies and coal particle attrition characteristics, it would be the preferred system because it is the lowest cost and easiest to maintain.

The Foster Miller linear pocket feeder is an excellent innovative solution to the coal feeder problem. This design, however, is more suited for use in feeding against much higher pressures than 50 psig required in this application.

TABLE I
FEEDER COMPARISON

ITEM	LOCKHOPPER	FULLER KINYON	FOSTER MILLER
<u>COST</u>			
Capital Cost	\$300-350 K	\$70-90 K	\$2,000,000 for two 50 TPH units. Operating cost not established.
Annual Operating Cost	\$150-250 K	\$75-85 K	
<u>DEVELOPMENT/TEST STATUS</u>	Batch feeders such as Lurgi well developed. Continuous feeders such as Synthane are recent development.	Well developed for conveying into low back pressures (<35 psig). Occasional use to 60 psi.	5 TPH development machine only. 250 cumulative hours. Good progress being made.
<u>COAL FEED EXPERIENCE</u>	Preferred system for most coal process plants.	Not generally used for coal feed. Considerable experience with coal dust at low (<35 psig) pressures.	5 TPH test machine only.
<u>INDUSTRIAL EXPERIENCE</u>	Used in Lurgi Gasifiers for past 30 years. Used in blast furnace feeders.	Widely used for past 50 years in granular materials conveying systems, mostly at pressure under 35 psig.	None
<u>POWER REQUIREMENTS</u>	~ 30 KW for gas re-compression for single stage hopper. ~ 20 KW for dual feed hopper.	~ 150 KW for screw drive.	~ 75 KW for pressurization, chain drive and drying.

TABLE I (Continued)

ITEM	LOCKHOPPER	FULLER KINYON	FOSTER MILLER
<u>CONTROL</u>			
Number of Feedback and Command Signals Required to Control Feeder	25 - 30	7 - 10	12 - 18
<u>MAINTENANCE</u>			
Replace/Repair	Feeder valves every 2 Mos. @ 7000 cycle life	Screw - once every 6 to 12 Mos.	<ul style="list-style-type: none"> o Piston seals - 12 Mos.(Est.) o Seal tubes - 12 Mos.(Est.) o Chain links - not yet defined
<u>POSSIBLE DESIGN OR SCALING PROBLEMS</u>	Valve cycling tests should probably be run on 10" valves (Existing test data is for 6" valves)	Validation of scale-up from tests on 6" test machine to full scale 10" machine.	Although scale-up is conceptually simple, <u>no actual scale-up experience</u> exists.
<u>MAJOR ADVANTAGES</u>	<ul style="list-style-type: none"> o Proven Design Concept o No problem with pressure level. o Heavily supported by R&D 	<ul style="list-style-type: none"> o Low cost o Rugged, simple, relatively easily maintained. o Continuous operation 	<p>Ability to feed into high ~ 500 psi back pressures at controlled rates.</p> <ul style="list-style-type: none"> o Continuous operation
<u>MAJOR DISADVANTAGES</u>	<ul style="list-style-type: none"> o Limited valve life. o Complex control o High cost. o Intermittent feed unless injection hopper used. 	<ul style="list-style-type: none"> o Upper limit on back pressure may be near 50 psi. o Possible excessive coal attrition. 	<ul style="list-style-type: none"> o 5 TPH machine only. o No industrial experience. o High cost

2.0. STATEMENT OF WORK

The ground rules for the work performed in this study are described in the overall program plan as "Sub-task (2) A - ICGG Coal Feed Method Study", which is reproduced, in part, below:

Sub-Task (2) A - ICGG Coal Feed Method Study

UOP/SDC shall provide an independent review and assessment of Coal Feeding Systems to include the following:

1. A review of vendor information on (1) lock hopper, (2) Fuller Kinyon pumps, and (3) Foster Miller feeders limited to current status to provide:
 - a. A review of test data and similar industrial experience for this equipment or comparable equipment.
 - b. Comments on testing, materials of construction and design changes that are indicated.
2. Suitability of equipment for handling the reactor feed coal size up based on COED pilot plant data.
3. Evaluation of Fuller Kinyon pumps for delivering acceptable coal product particle size distribution to the gasifiers.
4. Determination of capital and operating costs of each feeder.
5. Listing of other advantages/disadvantages of each feeder.
6. Recommendations.

3.0 SYSTEM REQUIREMENTS

The basic requirements for the feed system are:

Flow Rate Tons/Day:	Commercial	25,935
	Demo	2,330
Lock Hopper Valve Size:	Commercial	10" Dia.
	Demo	Not Sized (assume 10")
Valve Temp:	Demo	250°F
Gasifier Pressure	Nominal 50 psig	
Coal Sizing:	<u>Mesh Size</u>	<u>Total in %</u>
	14	14
	28	45
	45	63
	100	78
	250	88
	325	93
	Pan	100

For the sake of uniformity, this study has been limited to evaluation of a single feed system designed to deliver 100 TPH of 14 x 0 mesh coal against a back pressure of 50 psig. A coal bulk density of 50 Lb./Cu.Ft. has been assumed. Additional constraints, discussed only superficially in this report, should be considered if the range of variable or design conditions vary significantly from our initial assumptions. Some of these constraints are:

- o Pressure Range:

If peak pressure exceed 50 psig by a significant amount, say to 70 psig, performance of the Fuller Kinyon pump can be severely affected.

- o Feed Injection Method:

If system is to be gravity fed (from above gasifier) foundation requirements become expensive particularly for

the lockhoppers and the Foster Miller feeder. If coal is to be gas injected, an acceptable range of gas-solids ratio must be specified as well as the allowable pressure drop.

- o Temperature Range:

If feed is hot gas or steam injected, 250°F valve temperature may be too low.

- o Flow Metering and Control:

Feed control requirements may eliminate some batch-type metering systems.

"Feed System" in this context is defined as that set of equipment or machinery designed to move coal from a hopper at atmospheric pressure to the inlet of the coal injector which is at 50 psig. We have not included a review of flow metering systems or final injection systems (such as gas-solids transport). A general discussion, however, is given on the problem of interfacing the feed system to the various support equipment such as flow control and feed injection.

4.0 LOCKHOPPER SYSTEM

4.1 SUMMARY

Lockhoppers represent the baseline feed system for most current projected coal conversion plants. Lockhoppers have probably been selected primarily because of their proven ability to feed coal at relatively high pressures. Key to successful lockhopper operation are reliable, long lived valves. Accordingly, the discussion that follows emphasizes valve operational and test experience.

Figure 4.1 shows a typical lockhopper feed system sized for 100 TPH of 50 Lb./Cu.Ft. coal. The feed hopper is sized for a cycle rate of 5 per hour. Assuming a valve life of 7000 cycles, the nominal (continuous) running time before repair is about 2 months. Dual feed hoppers are not used because the savings from gas recompression at approximately \$3 K per year is small in comparison to the cost of an additional hopper and valve set, approximately \$50 K.

A gas injection system with its injection hopper is shown in Figure 4.1 since it provides steady uniform feed rate. The injection hopper is equipped with a weighing load cell and calibrator to assure reasonably accurate weighing. (The problem with many weighing systems is that of establishing system gains in the presence of physical restraints such as bellows and system and environmental changes. A dead weight calibrator is considered necessary to assure accurate gains in the face of changes in hopper pressure and weight and external environment.) The control system required is not shown but from the number of control signals (approximately 25) it is the most complex of the three systems being considered. Since most of the signals are binary (i.e., On/Off), the feed system control is ideally suited for a micro or mini computer system.

FIGURE 4.1
TWO-STAGE LOCKHOPPER

The estimated capital cost of a 100 TPH lockhopper system is approximately \$300 K to \$350 K. Annual operating cost (based on a 7000 cycle valve life) is approximately \$150 K to \$250 K.

In summary, the lockhopper, in spite of its cost and possible operability problems, should still be considered as the baseline system. This is because it is the most widely used, most extensively supported and is the only system with extensive plant experience.

4.2 SYSTEM DESCRIPTION AND OPERATION

Concept

Conceptually a lockhopper system is a classically simple method for feeding coal into a pressure vessel. In operation, coal is dropped from a feed hopper at atmospheric pressure, into a vented lockhopper. The lockhopper is then pressurized to slightly above the coal gasifier operating pressure. The coal is discharged from the lockhopper, the hopper is isolated, and the pressurizing gas is vented in preparation for the next feeding cycle.

In theory only, two valves are required; one at both ends of the lockhopper. In actual practice, as many as 12 coal shutoff valves can be used as in the lockhopper feed system for the Synthane plant. The extra valves are used to provide redundant series shutoff as well as for parallel hoppers. The sketches on the next page illustrate various hopper-feeder schemes that can be used.

The simplest scheme, Figure 4.2, shows a single hopper with a pair of isolation valves. The feed is by gravity and is batch cycled. The obvious advantage is its simplicity. Disadvantages are high gas recompression costs and no redundancy.

FIGURE 4.2
BASIC LOCKHOPPER

FIGURE 4.3
DUAL FEED HOPPER

FIGURE 4.4
CONTINUOUS FEED WITH
INJECTION HOPPER

4-4(C)

FIGURE 4.5
DUAL FEED HOPPER WITH
CONTINUOUS FEED INJECTION HOPPER

Both redundancy and gas savings can be obtained by adding a parallel hopper as in Figure 4.3. The gas recompression savings is approximately a third. In case of a single valve failure, gasifier feed capacity could still be maintained doubling the cycle time for the remaining hopper. The feed, however, would still be by batch.

The batching problem is overcome in designs shown on Figure 4.4 and 4.5. An injection hopper is added below the main feed hopper. This injection hopper supplies coal to some low pressure loss device such as a screw, star feeder or transport gas. This system permits continuous controlled feed with the positive pressure control of lockhoppers.

Because of its basic simplicity, the lockhopper system is the most widely used system. For example, in a recent JPL report*, 14 gasifiers out of 24 investigated used lockhopper based feed systems. Gasifier pressures ranged from slightly above atmospheric to 1500 psig. Coal sizes ranged from 1-1/2 inch to minus 200 mesh. On the other hand, because of problems, mostly with valves, reliable continuous operation was reportedly difficult to achieve. The paragraphs that follow describe some of these problems and the work being done to correct this.

Operational Experience

Experience with lockhopper feed systems varies widely. The Lurgi integral lock system has been in operation for a number of years feeding coal against a reactor pressure between 350 - 450 psi. Average time between repairs is reported to be a "few" months with cycle times of 4 - 7 per hour**

*"Evaluation of ERDA sponsored Coal Feed System Development",
R. Phen, et al, Proc. Conf. Coal Feeding, Caltech, 1977.

**Personal communication, Frank Glann, JPL, February 5, 1979.

The Synthane plant experience has been reported in detail*. Extraordinary problems were encountered during start up because of contamination and corrosion induced damage during installation.

The system, designed by Petrocarb, used EBV valves. Design feed rate was 1.67 to 5 TPH against 1000 psig. The actual working pressures obtained was about 600 psig.

Various types of valve seat and ball coatings were tried in an attempt to reduce wear. Maintenance and operating procedures were developed to enhance valve life. The conclusion of the report was that "after initial testing and shakedown -- performance is considered satisfactory." About 1000 operating cycles on the unit representing a total thru-put of 750 Tons was accomplished. This represents approximately 10 days continuous operation for the 72 TDP plant.

The Hygas pilot plant valve experience is described by Hudziak, Kendron & Bair**. The first raw coal feed system consisted of a pair of 8-inch Type T Gemco valves. Cycle rates was 4 per minute for delivery of 3 to 4 TPH against 5 to 8 psig back pressure. At this cycle rate, the valves quickly wore out due mainly to hot gas erosion. The feed system was then redesigned with a larger hopper to provide a lower cycle rate (1-2 minute cycles) and 3- and 4-inch Kamyr ball valves with stellite seats and hard chromed ball surfaces. These valves were reported to have worked quite well for nearly two years with only ball seat clearance adjustments.

* R. Lewis, R.R. Santore, and D. Dubis, "Coal Pressurization & Feeding, Use of Lockhopper Systems", Proc. Conf. on Coal Feeding Technology, Caltech, July 1977.

** "Operating Experience with solids handling valves in Hygas Pilot Plant", J. Hudziak, T.J. Kendron, W.G. Bair, Proc. Inst. Gas Tech. Valve Work Shop, Nov. 1977.

The CO₂ Acceptor Plant in Rapid City, South Dakota, fed hot, 500°F, lignite. into a 150 psig back pressure at a nominal 3 TPH rate*. Floating ball valves were used. Successful operation, reportedly, was never fully achieved. The first valves failed when the metal seal ring seized. Replacement valves with reinforced teflon seats lasted 3 to 4 months.

Current Status of Valve Development

As the discussion above indicates, the key element of the hopper system is block valve for the materials. The experience so far seems to indicate that the most successful is a ball valve, preferably with an integral stem and with a minimum of extraneous parts. Valve designs which allowed fines to accumulate in their sealing mechanism would often fail. A substantial effort has been expended to date on materials research and tests to improve life and reliability. Much of this work has been performed and/or directed by the Morgantown Energy Test Center (METC). In addition, METC has developed valve test procedures and a valve test facility. The test facility is capable of simulating operating conditions for valves operating in both the feed and discharge ends of a reactor. A test program evaluating various candidate vendor valves is now underway. The present application comes under the METC defined Type I category, which has the least rigorous requirements.

The work at METC is supported in part by the Bureau of Mines Metallurgical Research Center in Albany, Oregon**. The BuMines facility is running wear and materials tests on various candidate valves and materials. A wear life of 30,000 cycles is the goal. So far, the best valves can achieve 7000 cycles. These tests are run at a temperature of 400°F and a pressure of 165 psig. The granular material cycling through the valve was bottom ash from the METC producer gas pilot plant.

* "Valve Problems at CO₂ Acceptor Pilot Plant Rapid City, S.D.", M. H. Vardaman, Proc. Inst. Gas Tech., Valve Workshop, Nov. 1977.

** J. S. Hansen, "Ball Valve Tests on Coal Gasifier Lock-hopper Simulation", paper to be presented to Intl. Conf. on Wear of Materials, 1979.

The operating conditions for the BuMines tests were more severe than this application which is 250°F and 50 psig with pulverized coal, not ash.

According to John Kelly*, a major wear mechanism is that caused by erosion from high velocity particulate laden gas. Wear is reported to vary somewhere between the 2.4 and 6th power of velocity. Since velocity varies at the square root of pressure, the net wear index exponent is $(1/2) \times 2.4$ or 1.2. The wear decrease factor is therefore equal to the pressure ratio raised to the 1.2 power, or 3.4 times less wear at 50 psig (65 psia) than at 165 (180 psia).

$$\text{Wear} \propto (V)^{2.4} \text{ to } (V)^6; (\text{use } V^{2.4})$$

$$V \propto p^{1/2}$$

$$\therefore \text{Wear} \propto (p^{1/2})^{2.4} \text{ or } p^{1.2}$$

$$P = 180/65 \text{ or } 2.77$$

$$\text{Wear reduction} \sim 2.77^{1.2} \text{ or } 3.4$$

Assuming, 1) erosion is the primary wear mechanism and, 2) that coal is as abrasive as ash, a maximum cycle life based on the best valves available today is of the order of 7000×3.4 or 23,800. At a cycle rate of 5 per hour, this represents 6-1/2 months operation before repair/replacement.

However, since the above analysis is based on somewhat tenuous assumptions, life in excess of the current 7000+ cycles cannot be well justified.

It does, however, indicate that longer life at the lower operating pressures is a strong possibility.

*Telcon, 6 February 1979, Bureau of Mines, Albany, Oregon.

System Configuration

A typical lockhopper system suitable for use in a 100 TPH, 50 psig gasifier is shown schematically on Figure 4.1 Page 4-2. An injection hopper is shown in order to make the hopper feed system comparable to the Foster Miller or the Fuller Kinyon system in providing uniform flow. Parallel feed hoppers are not used since the savings possible from reduced gas recompression at 50 psi is small.

The vertical height from foundation to the inlet hopper flange is approximately 70 feet. The estimated weight filled with coal is 50 Tons.

Three solids control ball valves are shown. The hoppers are sized for a nominal 5 cycles per hour. Valves V_1 and V_2 are the primary solids cycling valves. Valve V_3 is normally open. Five gas control valves to pressurize and vent the hoppers are used. The injection hopper is shown with a load cell weighing system to permit continuous flow control. A mechanically actuated dead weight load cell calibration is shown to assure valid weight readings in the face of varying environmental and internal pressurization changes.

Control System

The controls for a lockhopper require sensing, logical sequencing and command. In the simple system described above, 25 to 30 command or feedback signals are required for control. As a minimum, this would require an elaborate hard wired logic system or a micro computer based control system. The valves require hydraulic or pneumatic power supplies.

The feed back and control signals required for the simple (non-redundant) hopper system are listed below:

Feedback Signals

- o Valve Position Status - 8 places
- o Load Cell Reading
- o Load Cell Calibrator Position
- o Hopper Gas Pressure - 2 places
- o Hopper Fill Status - 2 places

If gas transport is used:

- o Gasifier pressure
- o Transport Gas Flow Rate
- o Transport Gas Pressure

Control Signals

- o Valve Drive - 8 places
- o Load Cell Calibrate Command

If gas transport is used:

- o Transport Gas Flow Control

Maintenance

According to the discussion on hopper experience, continuous trouble-free operation was rarely achieved. Even with the best test data, namely, 7000 cycles, maximum expected valve operating time would be about 2 months.

$$7000 \text{ cycles} / (5 \text{ cycles/hour}) = 2 \text{ months}$$

Using this assumption, it can be expected that 12 changeouts of the main feed hopper valves and an unknown amount for the normally open injection hopper block valve would be required. The downtime can be minimized by using the experience of the various pilot plants. From these plants, it has been found that the following operating rules are helpful:

- o Solids valves should be open or closed only when pressures are equalized.
- o An automatic purge system should be included to blow the valve seats clean before closure.
- o Valve actuation times should be slowed to perhaps 30 seconds.

4.3 SURVEY RESULTS

A survey of the solids handling valve industry was made to determine their current state of the art, as well as costs and use history. The results of the survey shows slow but steady progress in the last several years. However, no breakthroughs have been noted that will assure, for example, a 30,000 cycle life.

No hard data was found on valve cycle life in actual plant use. However, based on a review of the current literature it appears that valve life in U.S. pilot plants is in the "low to mid thousands" of cycles. In controlled tests at BuMines and METC, it appears that 7000+ cycles may be the current maximum. To our knowledge no cycling tests at conditions simulating this application (which is less severe than BuMines or METC) have been run.

Valve life data from actual tests vary widely from vendor claims. Valve manufacturers have quoted valve lives in the range of 50,000 to 100,000 cycles.

Probably the potentially most definitive and valuable data on valve life are the state of the art (SOA) tests now being performed by METC. These tests, whose results should be available this year (1979), will provide both relative and absolute life cycle capability on various valves. Until these test results are published, definitive statements on coal handling valve life should be withheld.

A list of valve manufacturers and hopper systems engineers contacted and a description of potentially useful valves follow.

Description of Typical Solids Control Valves

A description of five (5) typical solids control valves that have been used in handling coal follows. These valves are considered representative of various designs of commercial units and are not intended as an industry survey but rather an indication of the experience that has been gained to date on some units. Coal handling and industrial solids flow control experience are cited where data is available. Costs for 10 inch (I.D.) X ANSI 150 Class valve with and/or without operator tended to be in the range from \$7000 to \$10,000.

EBV - Ball Valve

Configuration

Trunnion mounted ball - see cutaway next page.

Key Features

- o Spring loaded seal rings maintain seal in the presence of wear.
- o Trunnion mount permits low torque operation.
- o Hard surface seats, usually stellite, and chromed ball.

Coal Service Experience

- o See attached list.

Industrial Experience

- o See page 4-14.

ALL PARTS INTERCHANGEABLE
FOR LIKE VALVES OF THE SAME
SIZE AND PRESSURE CLASS.

END CONNECTIONS-AVAILABLE
IN A VARIETY OF UNION NUT
CONNECTIONS, INTEGRAL WELD
AND FLANGED ENDS.

BALL STEM. ONE PIECE BALL
AND STEM PROVIDES MAXIMUM
STRENGTH & EASE OF OPERATION

BALL. CHROME, NICKEL, OR
STELLITE SURFACE LAPPED
AGAINST THE SUITABLE SEATING
MATERIAL.

SEATS-METAL OR ELASTOMER
ENCASED IN THE RIGID SPOOL
EXCEPTIONAL SEALING UNDER
THE MOST ADVERSE CONDITIONS.

TRUNNION BEARINGS. PERMIT
LOW OPERATING TORQUE AND
EXACT BALL ALIGNMENT.

SPRING RETAINER-SPRINGS
PROVIDE PRE-LOAD TO SEAL
TIGHTLY FROM VACUUM TO
10,800 PSI. COMPENSATE FOR
SEAT WEAR.

BODY AND BALL-IN VARIOUS
MATERIALS SUITABLE FOR UP
TO 10,800 PSI AND 1200°F.

FULL PORT. MAXIMUM FLOW
AT MINIMUM PRESSURE DROP.

EBV VALVE

INDUSTRIAL APPLICATION OF EBV (EPG) VALVES

MATERIALS	NO. OF APPLCS.	VALVE SIZE RANGE	TEMPERATURE RANGE	PRESSURE RANGE	REMARKS
FREON SLURRY	2	1½"	N/A	3000 PSI	EBV SO# EH-1167 EH-1168
ABRASIVE SLURRY	1	2"	800 F.	1051 PSI	EBV SO# EH-1630
WOOD CHIPS	1	2"	520 F.	800 PSI	EBV SO# EH-1779
CHARCOAL	2	6"	825 F.	825 PSI	EBV SO# EH-1518 EH-1519
BITUMINOUS COAL	1	10"	120 F.	100 PSI	EBV SO# EH-2080
COAL	655	¾" - 10"	100 F. to 800 F.	0 PSI to 1150 PSI	MOSTLY SYNTHANE & H.R.I.

Rockwell Swing Gate Check Valve

Configuration

Swing Gate Check - See schematic below

Rockwell conceptual approach to Lock Hopper valving.

Key Features

- o Gas purged seat.
- o Quick opening so that falling coal does not erode valve face.

Coal Service (or test) Experience

- o Institute of Gas Technology test, approximately 5000 cycles on 3-inch development valve.

Industrial Experience

- o No production so far on swing gate check valves.
- o Rockwell manufactures a line of ball and plug valves for industrial use.

Remarks

- o Swing gate check valves are developmental, no production exists so far.

Gemco - T-Ball Valve

Configuration

Spherical segment rotates 1/4 turn to seal. See catalog sketch below:

THE PRECISE SPHERICAL SURFACE
OF A GEMCO VALVE DISC MATES
WITH A PRECISE SPHERICAL SEAT

Key Features

- o Spherical segment does not contact seat.
- o Valve swing hinge designed with eccentric collar which permits close adjustment of the seat clearance.

Coal Plant and Test Experience

- o See list next page

Industrial Experience

- o See list next page

INDUSTRIAL APPLICATION OF "GEMCO" VALVES

MATERIALS	NUMBER OF APPLICATION	VALVE SIZE RANGE	TEMPERATURE RANGE	PRESSURE RANGE	REMARKS
Metal Powders	328	3" to 14"	Ambient To 1500°F	N/A	Types T, B, D & Airlocks
Abrasives	353	3" to 16"	Ambient	N/A	Types T, AL, D, RS, B, TLD, GMC
Cement	7	12"	Ambient	N/A	Types TLD, Sq S/C
Ceramics	8	8"	Ambient	N/A	Type D-2
Carbon	52	8" to 16"	Ambient	N/A	Types T, TLD
Coal Gas	24	3" to 16"	N/A	N/A	Types T, AL
Coal Gasification	22	3" to 16"	N/A	N/A	Types T, D, AL, VTAL

TOTAL 794

KAMYR

**tight closing
hard metal-seated
ball valves**

CONFIGURATION

INTEGRAL STEM BALL VALVE.

KEY FEATURES

**SEAT/SEAL ADJUSTMENT FACTORY SET, I.E., NO SPRING LOADED
SEAL FOLLOWER.**

HIGH TEMPERATURE UNITS MADE WITH ALL STAINLESS STEEL.

COAL PLANT AND TEST EXPERIENCE

USED IN COAL PROCESS PLANTS. (SEE ATTACHED LIST).

KAMYR BALL VALVES

INDUSTRIAL APPLICATION OF "KAMYR" VALVES

MATERIALS	NUMBER OF APPLICATION	VALVE SIZE RANGE	TEMPERATURE RANGE	PRESSURE RANGE	REMARKS
Iron Ore	150	1" to 6"	600 ⁰ to 1500 ⁰ F	N/A	Ball Va.
Powdered Metal	6	1/2" and 6"	680 ⁰ to 1200 ⁰ F	N/A	Ball Va.
Gravel	2	2" and 3"	1000 ⁰ to 1600 ⁰ F	N/A	Ball Va.
Ashes	34	1" to 4"	600 ⁰ to 1000 ⁰ F	N/A	Ball Va.
Charcoal	33	1/2" to 6"	600 ⁰ to 1500 ⁰ F	N/A	Ball Va.
Coal	102	1/2" to 6"	600 ⁰ to 1200 ⁰ F	N/A	Ball Va.

TOTAL 327

Everlasting

Configuration

Rotating disk over a flat lapped surface. Contact is continuous and prevents material from being trapped between seal.

PARTS SPECIFICATION		
B-1	INLET BONNET	CAST IRON, ASTM A 278 CL 30
B-2R	OUTLET BONNET	CAST IRON, ASTM A 278 CL 30
G-3	OUTLET SEAT	S.S. 440-C (700 BHN)
G-18	OUTLET DISC	S.S. 440-C (700 BHN)
LEVER ARM		STEEL
G-4R	POST	S.S. 17-4PH
G-5	POST GASKET	HARD ASBESTOS
G-9	DISC SPRING	S.S. 17-7PH
G-6	POST SPRING	S.S. 17-7PH
G-5A	POST PACKING (INNER)	ASBESTOS-GRAPHITE
G-5B	POST PACKING (OUTER)	ASBESTOS-INCONEL WIRE
G-22	GLAND	STEEL
G-10	BODY GASKET	S.S. 304 CORRUGATED
G-83	WRENCH (HANDLE)	STEEL
G-84	MACHINE SCREW	NYLOK® SELF LOCKING

1" FIG. B 1200-A-R (Right Hand)

Key Features

- o Flat surfaces permits flat lapping which produces an effective seal.
- o Square edged valve disc and seat surfaces shear away trapped debris.
- o Hardened wear resistant seal surfaces.

Industrial Experience

- o Coke oven feed and vent valves with steam and coal fines or dry coal fines alone. Sizes from 1/2- to 24-inch.

4.4 DATA SOURCES

LITERATURE REFERENCES

1. "Proceeding of the Conference on Coal Feeding Systems", Cal. Inst. Tech., June 1977.

Contains papers on Synthane Plant experience, Morgantown Energy Technology Center R&D on feed systems, Lurgi Gasifier feeders, Foster Miller pocket feeder, Fuller Kinyon screw, and JPL's coal feeder monitoring activities.

2. "Proceedings of the Workshop on Valves for Solids Handling Service in Coal Conversion", Co-sponsored by METC, Valve Manufacturers Association, TRW and W.Va. University, November 1977.

Contains papers on valve experience at Hygas, Synthane and CO₂ Acceptor Plants.

3. "Survey of Valve Industry Capability to Furnish 6-Inch Valves for Coal Conversion Processes", John F. Gardner, Morgantown Energy Technology Center, METC 78/10, February 1977.

Describes results of a survey to determine vendor capability to supply coal process control valves. Replies from 34 vendors received and processed.

4. "Survey of Industrial Coal Conversion Equipment Capabilities: Valves", W. A. Bush, E. C. Slade, Oak Ridge National Laboratory, ONRL/TM-6071, June 1978.

This report is a follow-up to METC's survey (ref. 3 above). Contains one-page summaries of 77 valve manufacturers.

5. "Ball Valve Wear Tests in Coal Gasifier Lock-Hopper Simulator", J. S. Hansen, BuMines, ALB 78-25, Pre-print, (Paper to be presented at International Conference on Wear of Materials, April 1979).

Describes results of life tests on 6-inch ball valves, under simulated (hot, pressurized) conditions.

6. "Update on Lockhopper Valve Development", J. F. Gardner, F. D. Freeburn, METC, Pre-print, (paper to be presented at AIChE, Houston Meeting, April, 1979).

TRIP REPORTS

1. D. H. Jaeger
January 3, 1979

Summary of meetings with DOE, (Germantown) during week of 3 January 1979. Information on various sources for lockhopper data obtained.

2. J. Fukuzawa, R. Figel
February 5, 1979

Summary of meeting with JPL on their experience with lockhopper and coal feeder systems.

3. A. Rezos
February 6, 1979

Summary of trip made to East Coast. Includes visits to METC, Synthane, Petrocarb, Gemco, Foster Miller and Kamyr.

TELEPHONE SUMMARIES

1. Babcock & Wilcox/Rezos
March 2, 1979

Describes Babcock & Wilcox's experience with lockhopper systems,
including 10,000 cycle valve life test.

2. John Kelly - BuMines, Albany Oregon/Fukuzawa
February 6, 1979

Discusses BuMines abrasion test program on valves.

5.0 FULLER KINYON SCREW PUMP REVIEW

5.1 SUMMARY

The industrial and test experience of the Fuller Kinyon (F-K) screw pump for feeding coal at a rate of 100 TPH into a 50 psig back pressure, has been reviewed. The review, to date, shows that the F-K screws are widely used in conveying systems operating in the 100 TPH flow range but mostly at pressures below 35 psig.

Recent tests with small screws (3 - 4 inch diameter) with coal against back pressure up to 70 psig, showed results which do not correlate well with the usual F-K rating tables. A strong possibility exists that the F-K screws in these tests were penalized by operation at conditions well off design optimums.

Under proper conditions, cement and other granular materials have been satisfactorily conveyed at pressures up to 70 psig. To our knowledge, however, no totally satisfactory tests have been run on coal under conditions simulating the present application requirements.

If a Fuller Kinyon pump is to be used for this coal feed application, further definitive tests should be run. These tests should be run at conditions which closely simulate the design operating conditions as to pressure, pump exit conditions and coal characteristics.

The incentives for having a proven screw type pump are its low capital and operating costs. In addition it has an extensive history of industrial use.

5.2 SYSTEM DESCRIPTION AND OPERATION

Screw Pump Design Concept

The F-K screw pump is a rugged, mechanically simple machine designed for harsh environments. For almost fifty (50) years, a single design was used. It came in seven standard sizes with capacities ranging from 8 to 200 Tons per hour. The nominal speed of the screw is 1170 RPM. One key feature of the machine is the decreasing pitch of the screw flights near the discharge end. This decreasing pitch is designed to compress the material and thus effect a better seal. A schematic of a standard F-K "H-style" pump is shown below:

Fuller-Kinyon H-Pump Schematic

Figure 5.1

In about 1974, F-K came out with a newer design called the "M-pump". It differs from the H-pump in that the screw is bearing supported on both ends as opposed to the cantilever supported H-pump screw. Because of this improved support, the M-pumps are less sensitive to off-load conditions and to other disturbances that cause screw vibration. The general trend on the M-pumps appears to show that the screws will have longer life.

A schematic of the new M-pump is shown below:

Fuller-Kinyon M-Pump Schematic

Figure 5.2

The primary operation/maintenance problem is screw life. In cement plant operation, screw life runs from a "few months" to over a year. The screws and seal liners are replaceable and repairable. Repairing consists mainly of applying a hard surface coating to the worn parts on usually the last one or two screw flights.

Mr. Solt* of F-K feels that the screws should "last forever" pumping coal since coal is considered by them to be far less abrasive than cement.

*Telcon Jan. 31, 1979, with Paul Solt of Fuller Kinyon.

Performance

At design operating conditions the F-K pump is essentially a fixed displacement machine. That is, a constant volume per screw revolution is produced. Thus weight flow, in terms of tons per hour (TPH), is proportional to screw speed and product bulk density. A screw rated at 100 TPH of cement at a bulk density of 85 Lb./Cu.Ft. will produce only about 50 TPH of coal which is roughly half the density of cement.

Screws which operate at or near design conditions have volumetric efficiencies in the 10-20% range. These values are based on an analysis of F-K ratings shown graphically on Figure 5.4, for four (4) screw sizes ranging from 150mm to 300mm in diameter. Variations within a single diameter (D) are obtained by changing the screw pitch (P) over a small range. The pitch is varied from $P = D$ to $P = 2/3D$. The smaller pitch, of course, produces smaller flow since flow is proportional to $P \times D^2$.

At constant back pressure, flow will not be produced until a minimum screw speed is attained. This minimum speed, which has been seen to vary between 300 to 1200 RPM, is a function of back pressure, material properties and screw exit conditions. It is generally determined experimentally.

Power required per TPH delivered varies strongly with back pressure and weakly with speed and material density. Typically, cement transport requires 1 to 2 HP per TPH against 35 psi back pressure. Again, more precise values, for other materials such as coal, must be determined experimentally.

Flow control is accomplished by metering the flow into the screw inlet hopper usually by a variable speed star wheel feeder. The new M-pumps are capable of operating at turndown ratios as high as 8:1. The older H-pumps were limited to turndowns closer to 2:1.

Operation of a F-K screw at off-design conditions such as the EPRI-Gard tests or the 1978 Morgantown tests result in very high HP/TPH values. (See discussion on "Test History with Coal", next paragraph.)

Test History with Coal

Only two test references could be found on Fuller Kinyon screws pumping against back pressure in the 50 psig range with coal. They are the Gard-EPRI tests and tests at Morgantown (METC) last summer (1978). The discussion on higher pressure operation is of concern since there appears to be no question that the F-K pumps can deliver coal at pressure under 35 psig. The early (1964) test at METC were run at 15 psig back pressure. The original F-K pump application was designed for coal dust. These pumps are reputed to have run for "years" without problems.

The Gard/EPRI tests showed a pronounced drop off in delivery at pressures above 60 psi. This, inspite of various attempts at modifying the exit seal and seal liner. Screw performances in the range of 4 to 7 HP/Ton per hour were obtained at 50 psig.

On the F-K screws in the Gard/EPRI tests, it should be noted that the drive motor was underpowered to the extent that at full load, speeds above 570 RPM could not be obtained. Based on later tests at F-K, screw speed was found to be an important parameter in effective sealing. It appears that at higher speeds, centrifugal force provides an extra component of sealing.

Tests were run at METC in July 1978, on a modified H-pump equipped with a 4-inch screw. The results of these tests show that coal can be pumped against back pressures up to 50 psi but at very low efficiency.

Taking one typical test point:

Back Pressure = 50 psig
 Delivered Flow = 20.3 Lb./Min.
 Input Power = 42.5 HP

Assuming a 4 x 2 screw (diameter X pitch) with a 30% solidity, and 1170 RPM, the volumetric efficiency is about 10%.

The specific power, HP/TPH, is:

$$\begin{aligned} \text{HP/Ton per Hr.} &= \frac{42.5}{20.3} \times 33.3 \quad (33.3 \text{ Lb./Min.} = 1 \text{ TPH}) \\ \text{HP/TPH} &= \underline{70} \end{aligned}$$

The mechanical efficiency = Power Out/Power In

$$\begin{aligned} \text{Power Out} &= \text{CFM} \times \Delta P / 33000 \text{ Ft.Lb./HP} \\ &= \frac{(20.3 \text{ Lb./Min.}) / (50 \text{ Lb./Ft.}^3) \times (50 \text{ psi} \times 144)}{33000} \end{aligned}$$

$$\text{Power Out} = 0.1 \text{ HP}$$

$$\begin{aligned} \text{Efficiency} &= .1/42.5 = \\ &= 1/4\% \end{aligned}$$

This latter value appears to be in order of magnitude less than normal for a F-K screw. A possibility exists, therefore, that screw was operating at off-design condition. In this regard, Mr. Solt of F-K said that the modified screw lacked the desired exit seal length as well as having a restricted exit conveying pipe.

F-K Pump Coal Attrition

Sieve analyses were made at various intervals during the GARD-EPRI tests. These data have been cross-plotted to obtain an estimate of the degree of attrition per passage through the screw. This cross-plot is shown on Figure 5.3. It shows an increase from 2-½ of 9% passing a 25 mesh screen for 16 cycles, or an average of 0.4% per cycle.

The attrition appears to vary with coal size. Larger size particles suffer more attrition than the smaller particles. This fact is encouraging. F-K pumps do cause attrition but more in the larger size particles than in the unwanted smaller (< 200 mesh) sizes.

The coal used in these tests was reported to be "Pennsylvania bituminous". Pennsylvania coals usually have a Hargrove grindability index of about 90. Assuming attrition is directly proportional to the grindability index, Illinois #6 coal with an index of 60 should suffer 50% less attrition passing through an F-K pump than Pennsylvania coal.

Operational Experience with Other Materials at 50 psig

F-K pumps routinely feed granular materials at pressures up to 35 psi. Experience with higher back pressures are rare but some notable cases are cited below.

A pair of 5-inch (size 125mm) F-K H-style pumps have been used for "years" feeding raw materials into a Gruder preheater at a nominal back pressure of 55 psi.

Recently, F-K ran performance test on a high density granular material in a size 150 M-pump at back pressures up to 70 psi.

(CROSS-PLOTTED FROM FIGURE 10, GARD-EPRI TEST REPORT)

FIGURE 5.3

**ATTRITION OF PENNSYLVANIA BITUMINOUS
COAL THROUGH FULLER KINYON SCREW PUMP**

Tests were conducted over a range of speeds and pressures. A definite speed related flow efficiency was found. For example, no flow could be produced at 300 RPM. "Satisfactory flow" could be produced at 600 RPM and full flow could be produced at 1170 RPM. Two data points from this calibration obtained from Mr. Solt* indicate how well the machine performed.

Case 1. 1500 Lb./Min. @ 20 psi - 28 HP required

Case 2. 1500 Lb./Min. @ 40 psi - 42 HP required

The HP/TPH for Case 1 is .93 and 1.73 for Case 2.

System Rating and Interface Considerations

The delivery in CFH (cubic feet per hour) of M-pumps is shown on the graph on Figure 5.4. Since the F-K pumps are essentially constant volume machines, the size required for our application is 250mm. Some variation in output within the 250mm diameter can be obtained by changes in the screw pitch. Based upon the results of our industry survey, these ratings appear to be reasonably accurate for cement. No hard data is available for other granular materials such as coal. Fuller informs us that they can predict output to at least within a screw diameter. At any rate, it would appear prudent to run flow tests on coal at conditions closely simulating the design conditions to verify screw performance.

The F-K pumps are usually installed on concrete foundations with room allowed to remove the screw. This foundation would have to be approximately 3 feet wide X 15 feet long, sized to hold a static load of 6000 Lbs. Approximately 10 feet of clear space along the pump axis must be allowed to permit removal and/or replacement of the screw. Lifting gear capable

* Telecon Feb. 7, 1979

FIGURE 5.4
DELIVERY RATINGS
FULLER KINYON M-PUMPS

of handling up to one ton load is also required to perform normal screw maintenance.

In the event that conveying gas or air is not permissible, the F-K screw pump must either be installed above the reactor feed inlet so that gravity feed is possible or an auxiliary pressurized lift system must be provided.

F-K recommends inlet hopper feed metering to control flow. Star wheel feed valves driven by a variable speed motor should provide reasonably effective volumetric flow control.

F-K pumps are normally used in conjunction with pneumatic conveying systems. These pumps are usually equipped with a check valve and a "wind-box" so that they can be directly connected to a pneumatic conveying system. Conveying velocities are in the 3000-4000 fpm range with solids-to-air ratios (by weight) near 20:1. This system would therefore seem to be suited for a gasifier using a gas injected coal feed system.

Care, however, would have to be exercised in applying the gas injection system:

- 1) If the injection system imposes a back pressure significantly higher than 50 psig, severely reduced delivery may result.
- 2) If the injection gas is hot, say 1000°F., a special and separate wind-box would have to be supplied with block valves between the injector and the F-K-pump.

Other than inlet feed control and the feed injector, very little additional equipment is required to support the F-K installation. Figure 5.5, Fuller Kinyon Feeder, shows the basic functional elements of a F-K system.

System Control

Control requirements for the F-K feed system are minimal. Feed back and/or control signals include:

- o Pump Status (On/Off)
- o Motor Power/Speed
- o Atmospheric Hopper Level
- o Star Feeder Speed
- o Wind Box Pressure
- o Block Valve Status (Open/Closed)

If gas injection is used:

- o Transport Gas Pressure and Flow
- o Gasifier Back Pressure

Maintenance

The primary maintenance item is the screw. Under load usually the last two flights of the screw wear. The screws can be repaired by reinforcing the worn areas with a hard surface coating. F-K also has a service whereby worn screws can be exchanged for refurbished units.

FIGURE 5.5
FULLER-KINYON COAL FEEDING SYSTEM

Based on interviews with cement plant operators, screws can be replaced in 4 to 6 hours by their maintenance crews. Screw life varies widely, from a few weeks to over a year, depending on the amount of use and/or abuse. In normal operation, the F-K pumps are not required to be continuously manned with either operators or maintenance personnel.

Again, the amount of maintenance required varies widely with plant operators. One plant reported an average of less than 8 hours per month per pump. Another reported 65 hours per month per screw. This was based on data collected on 6 pumps for an entire year.

As noted earlier in this report, Fuller indicates screws operating in coal should have a much longer life than in cement. This statement appears to be based on experience with installations where coal is conveyed, usually at pressures below 30 psig. However, based on data in the literature on abrasive and erosive wear, substantial increases in life cannot be expected. For example, Perry* reports tests run by Allis Chalmers showing coke to be eight times as abrasive as cement raw material. No data on abrasiveness is shown for coal, but coke is about twice as hard to grind as coal.

Another wear index called the Miller number (which measures the relative wear due to flowing slurries) indicates that coal is about 2/3 as erosive as limestone, the main constituent of raw cement. Coal has a Miller number between 10 and 26 while limestone is 27 to 30.

The conclusion from this discussion is that one cannot categorically state that screw life with coal will be substantially longer than with cement.

*Chemical Engineer Handbook, page 8 - 10, Perry & Chilton, 5th Ed., McGraw Hill Book Co. 1973.

One additional note on maintenance should be included. A plant operator reported that on frequent occasions, a pump would "go out" catastrophically by ingesting a contaminant such as a piece of tramp iron. Accordingly, great care should be taken to insure clean feed. This statement is true for all feed systems.

5.3 INDUSTRIAL EXPERIENCE

Pre 1963 - Non-Cement

The industrial experience of the F-K screw pumps is extensive. Over 650 installations have been reported for non-cement application in a Fuller supplied document dated March 1963. Since approximately 1/2 of the F-K screw applications are for cement, the total number of F-K pumps up to 1963 must be of the order of 1000 to 2000.

The list, on the next page, shows the number of applications for various widely conveyed materials together with the minimum average and maximum throughputs. It is interesting to note that the index, HP/TPH, ranges between 1.5 and 3.

INSTALLATION LIST OF F-K CONVEYING
SYSTEMS HANDLING MATERIALS OTHER THAN CEMENT
(Revised 3/1/63)

	Number of Instln.	Capacity (TPH)			Average Pump HP (Installed)
		Minimum	Maximum	Average	
Alumina	8	1/4	100	32	67
Barite	21	20	90	50	51
Bauxite	5	6	15	10	21
Bentonite	29	8	65	27	48
Carbon	3	.6	12	4.5	-
Catalyst	50	2	25	8	8
Clay or Kaolin	64	2	55	13	23
Coal	30	1/4	70	17	21
Coke	5	1	4	2	9
Dust-Cottrell or Flue	39	1/2	40	11	33
Feldspar	5	10	25	16	24
Filler - Dolomite	13	5	50	22	31
Fluorspar	19	4	70	17	36
Fly Ash	37	4	60	21	42
Gypsum	9	3.5	20	11	23
Ilmenite	10	5	30	16	33
Limestone	87	1/2	60	18	27
Lime Hydrated	29	2	40	14	25
Magnesite	11	2	70	20	37

Note: This table derived from data supplied courtesy of Fuller Company.

	Number of Instln.	Capacity (TPH)			Average Pump HP Installed
		Minimum	Maximum	Average	
Manganese Dioxide	8	2	15	8	26
Oyster Shells	5	20	30	24	38
Phosphate Rock	60	2.5	150	26	44
Silica	53	2.3	45	18	36
Soda Ash	18	5.5	45	19	53
Sodium Tripolyphosphate	5	3	10	7	16
Starch	30	1/2	17	5	15

M-Pump Installation Record

As noted earlier, the new M-style pumps were first put in operation in 1974. There are more than 223 M-pumps installed worldwide. Over 200 of these are installed in cement plants. A breakdown of the applications are shown on the accompanying table provided by Fuller Kinyon. It should be noted that distribution between "cement plants" and "non-cement plants" is distorted (in favor of cement) because the first M-pumps were applied mostly to cement plants. Current production trends indicate a distribution closer to the traditional 50:50 split.

TYPE M PUMPS SOLD (USA SUPPLY)

GENERAL INDUSTRY									NON-CEMENT					
Cement			Raw Meal			Dust	Lime	Coal	Lime Slag Kaolin Misc. R&D					TOTAL
Mill	Transfer	Marine	Mill	Feed	Transfer									
			Kiln											
	2		30	18	3		4						57	
31	5	29	15	16	3		3			1			103	
17	2		2	1		11		4	2	1	3	1	44	
						5		5	1		5	2	1	19
48	9	29	47	35	6	16	7	9	3	1	9	3	1	233
86			88			32			17					233
206									17					233

INSTALLED LOCATION

USA	31	18	7	15	71
FOREIGN	55	70	25	2	152

Note: This table supplied courtesy of Fuller Company.

Cement Plant Experience

As noted earlier, the bulk of the F-K pump experience has been in the cement industry. The cement industry, therefore, represents a most important source of information. This data source was developed in field trips to three local (Southern California) cement plants and over a dozen telephone interviews with plant operators throughout the continental U.S.. Some preliminary statistics of the survey (tabulated below) indicate that user satisfaction is high, and that the principal maintenance item, the screw, has an average life between three and six months. It should be noted that the majority of the problems cited by the plant operators relate to the light load condition which is particularly damaging to the widely used H-pumps. The new M-pumps can tolerate this condition much better.

In general, the results of the survey show the following pattern:

No. of Plants Replying

Degree of User Satisfaction:

Reasonably Satisfied	<u>8</u>
Prefer Alternate System	<u>2</u>

Principal Maintenance Item:

Screw	<u>10</u>
Bearings and Seals	<u>2</u>
Other	<u> </u>

Screw Life:

0 - 1 Month	<u> </u>
1 - 3 Months	<u>2</u>
3 - 6 Months	<u>2</u>
> - 6	<u>6</u>

Main Reason for Premature Screw Life:

Partial or Empty Screw	<u>6</u>
Foreign Material	<u>1</u>

This summary covers 12 plants having approximately 100 Fuller Kinyon pumps. Plant size in terms of number of pumps range from 2 to 40. Cement plants have typically 4 to 8 pumps each.

INDUSTRIAL USERS SURVEY

1. Cement Plant - Mid-West

Plant Manager stated that they have a dozen or so H-pumps with sizes of 6 inch to 10 inch and one 250 mm M-pump which he called the "side discharge" pump. He said that the M-pump meets its design capacity at 250 tons per hour. The material being pumped is raw feed with 80% passing a 200 mesh screen, pumping pressure is 35 psig. This pump has not been in service long enough to determine the long term maintenance problems, such as wear and tear. But, from all indications doesn't expect any problems. He prefers this pump over the H-Design because unlike the H-Design he can run the M-pump at lower capacity than on the H-pumps. They work satisfactorily provided that they are loaded properly. Normal screw life of the H-Design is 6 months.

2. Cement Plant - Mid-West

The Plant Manager said that he has not received the M-pump they have purchased yet, so he went on and talked about the H-pumps. The plant has five or six 10 inch, two 8 inch and two 6 inch pumps that are used to pump raw feed and cement 24 hours a day, several days a week against pressure of approximately 30 psig. Normal life of screw is about eight months. Normal wear is at the last 6" to a foot of the screw. The Plant Manager said that he will be happier when he gets his new M-pump. The reason is that the pump has bearing and support at both ends of the screw and this will help the screw last a longer period under any capacity of material being pumped.

3. Cement Plant - East Coast

The Plant Manager said that they have a 300 mm M-pump that has been pumping raw feed for about 2 years. 94% of material passes through 200 mesh occasionally with particles sized 2"x3"x1/4". Pumping pressure is 30 psig. This pump operates 16 hours a day. Pump screw was changed after 18 months of operation. There was operational problems after the changing of the screw because of wrong size screw replacement. The problem was corrected and there were no other problems. He also indicated that bearings and seals are normally replaced when screw is replaced. They like the M-pump much better than the H-pump.

4. Cement Plant - South

This inquiry was with the Assistant Operations Manager. He could not talk about the M-pump because he received his 300 mm pump on that very day. So we talked about the H-pumps. He said that they have 10 H-pumps with sizes ranging from 6 to 10 inches and they work satisfactorily provided that they be set, aligned, grouted and installed perfectly. He will not recommend the 10 inch H-2 pump because it has a very long overhung screw and is subject to excessive vibration. The cement plant runs 24 hours a day. When asked about the screw life, he indicated that the shortest screw life was two months and the longest was six months. He indicated that he was looking forward to operating his new M-pump and said that he expected it to be better than the H-Design.

5. Cement Plant - Mid-West

According to the Plant Supervisor, this plant has one 200 M-pump operating at 15 psig over a period of one year handling kiln feed at a rate of 260 TPH.

He stated that he was satisfied with the pump, and screw life initially was 6 months. The reason for that was improper installation which caused the motor to come apart, but he expected the screw life to be longer than one year. He also said that bearings and seals are usually changed at the same time with the screw.

This cement plant operates 24 hours a day, seven days a week. Material handled is raw feed with 80% passing a 200 mesh screen. About a dozen or so "H" design pumps are also operating which they are satisfied with. He said that they have to be properly loaded in order to perform satisfactorily. The six (6) H-pumps at this plant vary in size from 4 inch to 10 inch. He said that he liked the M-pump over the H-Design because of flexibility in pumping capacity.

6. Cement Plant - Mid-West

The Plant Manager related the following experience with F-K pumps.

- o New M-pumps on order, not yet installed.
- o Existing pump list:
 - 2 - 8" H)
 - 1 - 10" H) Operates between 15-25 psi
 - 1 - 6" H)
 - 2 - 10" B Operates at 60-70 psi (300 HP)
- o Operation and maintenance considered good. Cannot cite average life.
- o They do their own screw repair.
- o Occasional problem when screws run lightly loaded.
- o 10" B-pumps are "ancient". They do not remember when first obtained. Still delivers cement against 60-70 psi back pressure. B-pump has double support bearings similar to the "M" pump.

7. Cement Plant - Gulf Coast

The Plant Manager indicated his experience with F-K pumps, particularly the recently installed 200mm M-pump, as follows.

- o The new 200 mm M-pump is 2 months old. So far, no problems with it. It meets performance: 50 TPH @ 20 psi back pressure, 125 HP motor.
- o The remainder of the conveying systems are equipped with "H style" pumps. Their maintenance and operation record is good. Some bearing and seal problems; life 6 months to a year. Screw swap-out takes 4 - 6 hours. The plant had a total of eight (8) pumps.

8. Alkali Processor - Southern California

Results of telecon with Plant Manager:

- o There are 3 F-K pumps at this facility.
- o They convey nominally 50 TPH of 35 Lb/Cu.Ft. alkali.
- o The drive motors are approximately 150 HP.
- o No special maintenance work was done on the screws since September 1978 (when they were installed).
- o The pumps are used only intermittently, "more off than on".
- o F-K installation is generally considered satisfactory.

9. Cement Plant - Southern California

This plant does not have an extensive Fuller Kinyon screw pump system. Only one (1) 9-1/2" H-pump and two (2) 6" machines are used.

The 9-1/2" machines deliver 600-750 BBL/Hr. (110-140 TPH) cement against nominally 20 psi and has a 250 HP motor.

12. Steel Mill - California

Telecon summary with Foreman of precipitator serving open hearths.

This facility has forty (40) 6-inch F-K H-pumps removing accumulated dust from precipitators serving the open hearth furnaces (now shutdown).

The dust is largely Fe_3O_4 .

The pumps have a duty cycle of about 1/3. Screw life was about 8 months. Actual running time with a 1/3 duty cycle is, therefore, approximately 3 months.

Main problem was not the screw but seals. Fe_3O_4 dust would plug up seal assembly and harden into a cement-like material making screw removal impossible.

5.4 DATA SOURCES

LITERATURE REFERENCES

1. "Development of Coal-feeding Systems at the Morgantown Energy Research Center", J. Mark Hobday, MERC, Proceedings of the Conference of Coal Feeding Systems, California Institute of Technology, June 1977.

This paper describes work at MERC on a 4-inch Fuller Kinyon screw pump used to feed pulverized coal to a gas turbine. Satisfactory operation, without repairs or major shutdowns, was obtained for the 2000 hour test with a delivery of 3500 Lb./Hr.

2. "Continuous High Pressure Lump Coal Feeder Design Study", S. F. Fields, Gard Inc., Process Conference of Coal Feeding Systems, Caltech, June 1977.

This paper describes work performed by Gard and Fuller Kinyon on modified 4- and 3-inch Fuller Kinyon screws feeding lump coal mixed with limestone against back pressure up to 75 psig. The work was sponsored by the Electric Power Research Institute (EPRI). The results of these tests were somewhat inconclusive because of limitations in the test set up. The limitation was lack of sufficient drive power which limited the screw speed to 570 RPM. (Based on recent data at Fuller Kinyon, higher screw speeds enhance sealing.)

Although quantitative data is lacking (in this paper), flow was produced up to a back pressure of 60 psi.

3. "Continuous High Pressure Lump Coal Feeder Design Study", S. F. Fields, EPRI AF 410 (Research Project 526, 1977).

This reference describes work in more detail on the Gard - Fuller Kinyon tests discussed by Fields at the Caltech 1977 Conference.

VISITS AND FIELD TRIPS

1. Fuller Kinyon, Technical Representative Visit, January 19, 1979.
Visit made by Mr. Jan Bendis of Fuller Kinyon. Arrangements made for field trip to local cement plant.
2. Southwest Portland Cement - Field Trip, A. Alfi, J. Fukuzawa, and J. Kennedy, January 29, 1979.
Describes visit to cement plant. This plant was first in Southern California area to have new M-pumps.
3. Riverside Cement Plant - Field Trip, A. Alfi, J. Fukuzawa, and D. Jaeger, March 7, 1979.
Visit to cement plant which reported maintenance problems with H-pumps.
4. Kaiser Cement Plant - Field Trip, A. Alfi, J. Fukuzawa, and D. Jaeger, March 7, 1979.
Visit to cement plant who reported satisfactory operation of Fuller Kinyon H-pumps.
5. Fuller Kinyon - Visit by D. Jaeger, February 28, 1979.
Discussion with plant personnel on general status of screw pump development tests. Obtained data on recent M-pump tests as well as data on recent M-pump installations.

TELEPHONE SUMMARIES

1. Paul Solt - Fuller Kinyon/J. Fukuzawa, January 31, 1979

Discussion of status of M-pump development tests and operating characteristics.

2. Paul Solt - Fuller Kinyon/A. Alfi, J. Fukuzawa, D. Jaeger, February 7, 1979.

Follow-up of January 31 telecon. Discussed in more detail M-pump tests at high (~50 psi) pressure.

6.0 FOSTER MILLER LINEAR POCKET FEEDER (LPF)

6.1 SUMMARY

The Foster-Miller LPF is a positive displacement coal feeder that has been in development for the past four years. The work has been sponsored by the government. A 5 TPH development model now in operation has fed coal routinely up to 500 psig back pressures. After slightly more than 200 hours of cumulative running, wear on the piston seal rings and the seal tube appear minimal and seems to corroborate their estimates of 8000 hours of life. Chain link life, however, is still short of 100 hours. Work is now underway to correct this.

Operation at the 50 psig design pressure may represent an overkill for the LPF since it was originally designed for a pressure range of 100 to 1500 psig. This is not to say it will not work satisfactorily at 50 psig. (It should run quite well.) The basic problem is that its present projected cost (\$1,300,000 for one 50 TPH unit; \$2,000,000 for two), is much greater than competing systems capable of feeding into 50 psig.

In addition to the cost problem, the LPF has no industrial use history. Only engineering designs capable of supporting the 100 TPH feed requirement exists today. Delivery of hardware for this application is estimated at 18 to 24 months.

In summary, the advantages of the LPF are: 1) Positive feeding to 500 psig; 2) Relatively insensitive to coal size.

The major disadvantages are: 1) High initial cost; 2) No industrial use experience; 3) No existing physical hardware for 100 TPH requirement and, therefore, no scale up experience.

6.2 SYSTEM DESCRIPTION AND OPERATION

Concept

The LPF can be described as a partially enclosed chain conveyor with piston-like seal elements which move through a tube carrying coal from a hopper at atmospheric pressure to the high pressure feed area. High pressure water is fed into the seal tube after the coal is dumped. This high pressure water is used to displace the compressed air between the pistons in the seal tube and serves to balance the pressure on the coal side. The system could be operated without the water displacement but it would take more power to operate since (incompressible) water is easier to pump than air. The work required to operate the system is equal to the chain friction (including coal shearing transients) plus the PV work equivalent to the water pumping. The PV work (the product of pressure and volume flow) represents roughly 2/3 of the work required.

The specific power required for a 50 TPH machine feeding into 50 psig is nominally 1 HP/TPH.

A schematic of the LPF is shown on the next page.

Key features of the machine include a piston assembly with tungsten carbide or titanium carbide wear rings, and sealing tubes lined with Nye-Carb*, and Exalloy*.

Coal flow rate is controlled by the feed rate into the inlet hopper. The conveyor chain operates at constant speed, between 1 and 2 fps.

*Trade names for a hard nickel based material in which silicon carbide particles are imbedded.

LINEAR POCKET FEEDER SCHEMATIC

Current Status

A 5 TPH test machine capable of feeding coal up to 500 psig has been constructed and tested. Tests appear to have been quite successful. Over 200 hours of cumulative running have been accomplished. Wear observed on the pistons so far seem to corroborate their life estimate of 8000 hours.

There still appears to be a problem with chain link life. Present life is approximately 100 hours. A materials study is now underway to improve link life.

Designs exist for larger (50 TPH and 15000 TPD) feeders for pressures up to 1500 psi. The existing hardware, however, is limited to the 5 TPH test machine.

Delivery for a 50 TPH machine is estimated at 18 to 24 months.

System Interface Requirements

Foster Miller recommends three (3) feeders, each sized for 50 TPH, for this application. Each feeder will require:

1. Feeder chain drive and motor
2. A water pump and pressurizing system
3. Hopper and weigh belt to permit flow control

Approximate installed power for all three feeders is 150 HP based on a specific power of 1 HP/TPH. Maximum running power at the 100 TPH design value would be 100 HP.

Approximately 2/3 of this power would be consumed by the pressurization system, the balance would be consumed by the chain drive and the gas drying system.

Each feeder requires an installation area of 8 Ft. X 50 Ft. The feed inlet is 8 feet above the base flange. The feed discharge flange is 8-inch I.D. and is assumed to be 4 feet above the base flange. The total weight of the feeder including motor and water system is approximately 18 Tons.

No special provisions are provided for final injection into the gasifier. (Only an 8-inch flange is provided.) To complete the system, additional hardware would be required. For a gravity fed or an enclosed screw conveyor fed system, a pair of (series) block valves between the feeder outlet and the feeder are desired for maintenance and/or shutdown.

If the final injection is by a gas transport system, a metering hopper with a pair of isolation valves would be desirable.

System Control

Flow control is accomplished by varying the inlet feed rate. The chain is designed to run at constant speeds nominally 2 fps. Since sealing is accomplished by the piston rings, not by coal, it is possible to operate the LPF down to zero capacity. Also, since Foster Miller proposes three (two operating, one standby) 50 TPH machines incremental turndowns by 1/2 can be made by shutting one machine down.

Gasifier feed control requires the following feed-back signals from the feeder system:

- o Feeder status
- o Block valve status
- o Atmospheric hopper coal level
- o Flow rate from weigh belt
- o Chain drive power
- o Water pump discharge pressure

If gas injection is used:

- o Gasifier feed injection pressure
- o Gasifier feed transport gas flow
- o Gasifier feed transport gas pressure

The following control signals are required:

- o Block valve - open/close
- o Feeder - on/off
- o Atmospheric hopper fill
- o Feed hopper speed control
- o Water pressure control

If gas injection is used:

- o Transport gas flow/pressure

Maintenance

No maintenance history has been obtained on the LPF because no LPF has been operated continuously in an industrial environment. It can be stated, however, that the LPF has significantly more parts (eight subsystems) subject to wear-out than either the Fuller Kinyon pump (two subsystems) or the Lockhopper (three subsystems).

6.3 DATA SOURCES

LITERATURE REFERENCES

1. "Coal Feeder Development, Phase II Report", Foster Miller Assoc. Inc., FE-1793-4, September 1978.

Report describes Foster Miller's activities on coal feeder program.

Includes linear pocket, centrifugal and fluidized piston feeders.

2. "Evaluation of ERDA-Sponsored Coal Feed System Development", R. L. Phen, W. K. Luckow, L. Mattson, D. Otth, P. Tsou, JPL, 1977.

Contains comparative estimates of 625 TPH feeder system including

linear pocket and lockhoppers.

TELEPHONE SUMMARY

1. Dr. J. Harding - Foster Miller/J. Fukuzawa, February 13, 1979.

Discussed recent developments on pocket feeder and its applicability to a 50 psig coal feed system.