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SURVEY OF SCREW FEEDERS

By
Gordon Sine

February 1983

Work Performed Under Contract No.: DE-AM21-81MC16050

For
U. S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By
TRW Energy and Environmental Division
Morgantown, West Virginia

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ABSTRACT

This report presents the results of a survey to determine the availability of screw feeders for use in areas related to coal feeding in the field of coal conversion.

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1.0 EXECUTIVE SUMMARY

Advanced processes for coal conversion tend toward higher temperatures and pressures. This results in a pressure boundary between the pressurized reactor and the unpressurized feedstock. Present methods of transporting the atmospheric coal feed to the pressurized reactor include lockhopper systems for dry feed and pumping systems for wet (slurry) feed. Both systems are energy consumers in that lockhoppers require pressurization media, often an inert gas mixture that can also affect product gas composition, and slurries introduce excessive moisture that must be treated. An alternate method to cross the pressure boundary directly would be to use a dry pumping technique that would inject the feed and act as a seal at the same time. Some success has been demonstrated with screw extruders during a project to develop new concepts of coal feeding. This survey was undertaken to determine the availability of screw feeding equipment that could accomplish this function, viz., the replacement of lockhopper feed systems for pressurized reactors.

A direct mail approach was selected for the survey. A letter requesting specific information relative to feeder capability in the areas of differential pressure, feed rates, feed coal size range, feeder size, temperature limitations, specific power consumption, and design details was drafted. A list of knowledgeable sources was prepared; this included manufacturers, organizations/trade associations, and individuals. The list was derived from various references including:

- a) Keystone Coal Industry Manual
- b) Thomas Register
- c) Encyclopaedia of Associations
- d) Proceedings of the Workshop on Critical Coal Conversion Equipment, October 1-3, 1980; the AIChE Annual Meeting (Coal Feed Systems Portion) June 7-10, 1982; and the Coal Feeder Development Workshop, October 13-14, 1982
- e) Buyers Guides of Technical Journals such as Chemical Engineering and Coal Age
- f) input from various individuals involved in coal projects.

The letters drafted and the compiled mailing list are included in the Appendix.

The letter was sent to fifty-five manufacturers, organizations, and individuals associated with screw feeders. Twenty-five responses were

obtained and reviewed. In addition, six individuals in various capacities in the major trade organizations were identified. Six of the more promising manufacturers were selected for follow-up contact. This information is summarized in Table I. Phone calls were made and resulted in several additional references who were also contacted by phone. One of these additional references had recently performed a study to determine the status of biomass feeders for the Canadian Forestry Service and a copy of his report "Status of Bio-Mass Feeder Technology" was obtained and reviewed.

Over seventy contacts were made and only two responses reflected off the-shelf screw type coal feeder availability. Another responder indicated that he thought he had equipment to do the job, but had no published data on it (it was used for wood chip feeding but the conversion to coal was felt feasible). And one more was going to assemble some standard components and perform feasibility tests at atmospheric pressure because so many inquiries had recently been received. However, most of those contacted were unaware of any activity in the field. The remainder were somewhat familiar with the DOE sponsored coal feeding devices but knew of no industry sponsored efforts.

One of the commercially available items, the Type M Fuller-Kinyon pump from the Fuller Company, basically feeds a pneumatic transport system and is limited to the 50 to 100 psid (psi differential pressure) range and feedstock in the $-1/4$ nominal range. Their main area of activity is in feeding atmospheric fluidized bed boilers.

The other unit, a co-rotating twin screw extruder of the ZSK type, from Werner & Pfleiderer of Stuttgart, Federal Republic of Germany, requires approximately 20% moisture to be added and is also limited in feedstock size to the $-1/4$ inch range. It does feed into high pressures having demonstrated 1500 psid operation at 860 #/hr throughputs. A unit was also supplied to VFRA Oel Ag in the Federal Republic of Germany to feed a gasifier operating near 850 psig. A copy of the report describing the results of this use was requested from VEBA.

The survey is complete. Two screw type machines were found that are used to feed coal against a differential pressure. Both are limited to the size of feed they will accept, $-1/4$ inch. One is a dry feeder that operates in the 50 to 100 psid range. The other develops high pressure (1500 psid) but requires the addition of about 20% moisture.

The Bio-Mass Feeder Technology report was reviewed and lists several additional commercial feeders that have been used to feed wood material to pressurized (approximately 150 psig) reactors: the Koppers Company, Inc. Plug Screw Feeder, the Stake Technology "Co-Axial Feeder", (mentioned earlier as having no published data available), and the C.E. Bauer Pressafiner. Sunds Defibrator Ltd. and Rise Louise Corp. are listed for lower pressure (40 psig) applications.

It is concluded that commercial screw feeders do exist that may replace lockhopper feed systems for feeding coal to pressurized reactors. However, there is little evidence (with the exception of the Type M Fuller-Kinyon pump) to support the contention that the feeders are commercially proven in the area of pressurized coal combustion or gasification and there is less evidence that they are regarded as "standard" in the industry.

Table I
Summary of Responses to Screw Feeder Survey Letter

CONTACT NAME	RESPONSE ¹				NO RESPONSE	REMARKS
	Brochure	Technical Data	Experience	Do not make feeder for this application		
1. <u>Manufacturers</u>						
Acrison Inc.					X	
Bechtel National					X	
Bloom Inc.					X	
A.E. Bogott & Sons, Inc.					X	
Buck-EI Inc.				X		
Conspray Construction Systems, Inc.	X	X	X			Not a screw feeder. Positive displacement piston.
4 Divine Engineering, Inc.					X	
Ducon Company, Inc.	X					Rotary feeder, limited differential pressure. Supplied information on Thomas & Muller.
Duplex Mill & Manufacturing Co.					X	
James Eagen & Sons Co.	X			X		Make flights & feed-screws only, not complete feeders.
Eriez Magnetics	X			X		Magnetic equipment & conveyors; vibratory feeders.
Feedmatic-Detroit, Inc.					X	
² Ferro-Tech, Inc.	X	X	X			All types of agglomeration process equipment.
Flex-Kleen Corp.					X	
FMB Systems, Inc.					X	
² FMC Corp.	X	X	X			Screw conveyors and feeders (atmospheric).

Table I (Cont.)

CONTACT NAME	RESPONSE				NO RESPONSE	REMARKS
	Brochure	Technical Data	Experience	Do not make feeder for this application		
Foster-Miller Associates, Inc.					X	Developed Linear Pocket Feeder under DOE Contract
² Fuller Company	X		X			50/100 psid; up to 650°F.
General Electric Co.					X	
Henderson Industries					X	
Horst Dynamics, Inc.					X	Mail returned.
IFE Systems, Inc.	X					Not a screw feeder, plow type device, no pressure generated.
⁵ Ingersoll-Rand					X	Developed screw feeder & piston feeder under DOE Contract.
Jeffrey Manufacturing					X	
Kinergy Corporation	X	X				Supplied information on ² Screw Conveyor Corporation.
K-Tron Corporation					X	
Lively Manufacturing and Equipment Co.				X		Telephone response.
Lockheed	X	X	X			Not a screw feeder, kinetic extruder.
MMM Mars Mineral					X	
Metalfab, Inc.					X	
Mikropul Corporation					X	
Moksnes Mfg., Inc.					X	
Nash International Inc.					X	

Table I (Cont.)

CONTACT NAME	RESPONSE				NO RESPONSE	REMARKS
	Brochure	Technical Data	Experience	Do not make feeder for this application		
New Castle Industries, Inc.					X	
Nott Company					X	
Penn Bangor, Inc.	X					No coal experience.
Petrocarb, Inc.	X		X			Not a screw feeder. Pneumatic system, 600 psig, lock-hopper type.
Sprout-Waldron					X	
² Thomas & Muller Co., Inc.	X	X	X			Some experience at low pressure differential (2-5 psi).
Union Carbide					X	Mail returned.
Vibranetics, Inc.					X	
Vibra Screw, Inc.					X	
² Werner & Pfleiderer Corp.	X	X	X			Co-rotating twin-screw extrusion.
Willis & Paul Engineers, Inc.				X		
Wyssmont, Inc.	X	X				Not a screw feed, rotary type, low differential (air-lock).
2. <u>Organizations</u>						
Association of Professional Material Handling Consultants (APMHC)				X		Provided roster.
Conveyor Equipment Manufacturers Association (CEMA)		X		X		Purchased technical specifications ANSI/CEMA 550-1980, 300-1981, 350-1981, 102-1982; 1982-1983 Roster.

Table I (Cont.)

CONTACT NAME	RESPONSE				NO RESPONSE	REMARKS
	Brochure	Technical Data	Experience	Do not make feeder for this application		
Deep Foundations Institute					X	
International Material Management Society					X	
Material Handling Equipment Distributors Association				X		Management education programs for distributors.
Material Handling Institute	X			X		Industrial coal conversion processes screw feeders out of scope.
Petroleum Equipment Suppliers Association					X	Mail returned.
<u>3. Individuals</u>						
Bill Borsch ³				X		CEMA Representative - no direct experience.
Eric Carlson ³				X		CEMA Representative - no direct experience.
Bob Footlik ³				X		APMHC Representative - no direct experience.
George Gross ³				X		APMHC Representative - no direct experience.
Don W. Lewis		X	X			Jet Propulsion Laboratory researcher. Recommended additional sources.

Table I (Cont.)

CONTACT NAME	RESPONSE				NO RESPONSE	REMARKS
	Brochure	Technical Data	Experience	Do not make feeder for this application		
James L. Powell			X			DOE Headquarters. Recommended additional sources.
David Schaefer ³					X	APMHC Representative. Could not contact.
George Schultz ³				X		A. Epstein & Sons, Chicago. Referred by R. Footlik, APMHC. Recommended additional sources.
Donald H. Wilson ³				X		APMHC Representative - no direct experience.
Subtotals	<u>MFG</u>	<u>ORG</u>	<u>IND</u>			
	45	7	9			
TOTALS		61				

¹Brochure indicates a bulletin describing the feeder was submitted.
 Technical Data indicates dimensional and/or performance data were submitted.
 Experience indicates that the feeder has been used to feed or transport coal.

²Manufacturers selected for follow-up phone calls.

³Telephone contact only.

2.0 INTRODUCTION

Means to alleviate the dependency of the United States on foreign oil include the efficient and environmentally sound use of coal. Pressurized coal gasification and combustion processes promote this objective. A method of feeding coal from atmospheric pressure to the pressurized reactors is required. Present techniques include lockhopper systems for dry feed and slurry pumping systems for wet feed. Both, while successful, result in wasted energy.

Lockhopper systems require a pressurizing medium and a method for venting. If external medium, e.g., an inert gas, is used, it must be compressed to at least system pressure. Further, depending on the volumes involved, it could affect product gas quality and/or combustion efficiency. If process gas is used, it must be vented resulting in lost product and perhaps environmental problems. Germany and England are attempting to improve lockhopper operation by using a device with a piston to sweep the process gas (pressurizing medium) from the hopper back to the process prior to depressurizing the hopper for the next batch load from atmosphere¹. One such device is the Lurgi-Schlepper Feeder where a sealing piston replaces the top or atmospheric valve².

Slurry systems require considerable amounts of liquid, nominally water and typically over 50% by weight. While some of this water may be used in process reactions, the remainder tends to lower process temperatures and subsequently results in some sort of wastewater treatment, both of which are energy consuming.

What is really desired for coal feeder applications is a metering pump that handles a solid feedstock of various consistencies and requires little power while developing substantial equivalent head.

Some confusion exists relative to terms used in coal feeding. However, this confusion does not exist in the materials handling industry as represented by the Conveyor Equipment Manufacturers Association (CEMA). Their terms are well defined. A conveyor is a device that basically transports material from one place to another. The material can be heated, cooled, dewatered, etc.

¹Coal R&D, Vol. 6 No. 2, Casey Publishing Company, February 2, 1983.

²"Status of Biomass Feeder Technology" by B.H. Levelton & Associates Ltd. Contractor's Final Report, DSS Contract 43SS.KN107-1-4420, ENFOR Project C-259, December 1982.

en route but this is incidental to the basic function of transport. A feeder is a device that meters or controls the flow rate of a material. It is often used in conjunction with a conveyor. Extruders are not addressed by CEMA but are customarily thought of as processing equipment as opposed to transporting equipment. The function of an extruder is to change the state of the feedstock, e.g., plasticize pellets to some formed shape. That is, a solid material is plasticized or melted and then forced through a die and solidified. Normally high internal pressures are associated with extruders while conveyors operate at one atmosphere.

The United States DOE has and is sponsoring the development of coal feeders, particularly to supply coal to pressurized reactors. This development has been proceeding since 1975. An ideal feeder would take run-of-mine coal as delivered and without beneficiation or additives deposit it at a prescribed rate in a pressurized reactor for processing. This entails three steps: (1) transporting, (2) metering, and (3) sealing.

Several techniques to accomplish this were/are being pursued in the DOE program. Primary among them are: a Linear-Pocket Feeder by Foster-Miller Associates, Inc.; a Coal Screw Feeder by Ingersoll-Rand Research, Inc.; a Kinetic-Extruder Feeder by Lockheed Missiles and Space Company; a Coal Piston Feeder by Ingersoll-Rand Research, Inc.; and a Dynamic Sleeve Piston Feeder by Conspray Construction Systems, Inc. All of these devices have demonstrated proof of concept and are now ready for qualification or long term testing to determine reliability and performance under commercial environments. This will entail considerable expense since installation on a pilot scale gasifier or combustor is required. Seven years have past since the inception of the DOE sponsored coal feeder development program. In this time frame considerable activity has occurred in the energy arena. Screw feeders and conveyors are one of the most popular materials handling system and the one most likely to be adaptable to differential pressure application (without the use of isolation or lockhopper type devices). It was therefore deemed appropriate to ascertain if commercial screw feeder equipment had been independently developed over this time frame. If there was commercial equipment available with some operation history it would lessen or negate the need for government (DOE) to perform long term reliability testing.

3.0 SURVEY METHOD

A direct mail approach was selected for the survey. A letter requesting specific information relative to feeder capability in the areas of differential pressure, feed rates, feed coal size range, feeder size, temperature limitations, specific power consumption, and design details was drafted.

Contacts for the screw feeder survey were obtained from various sources within the coal and synfuels industry. Trade journals, material buyers guides, newsletters, and individuals were gleaned to obtain a list of initial contacts for off-the-shelf equipment and state-of-the-art or developed technology. These contacts included manufacturers, organizations/trade associations, and individuals. The list was derived from various items including:

- a) Keystone Coal Industry Manual
- b) Thomas Register
- c) Encyclopaedia of Associations
- d) Proceedings of the Workshop on Critical Coal Conversion Equipment, October 1-3, 1980; the AIChE Annual Meeting (Coal Feed Systems Portion) June 7-10, 1982; and the Coal Feeder Development Workshop, October 13-14, 1982
- e) Buyers Guides of Technical Journals such as Chemical Engineering and Coal Age
- f) input from various individuals involved in coal projects.

Each source was reviewed with special emphasis on coal and screw feeders. The names appearing most often throughout the entire range of documentation were selected for the survey. The letters drafted and the compiled mailing list are included as Appendix A.

A direct mail canvass was made and the responses were screened for follow-up telephone contact. The criterion for follow-up was basically that the responder made a screw feeder/conveyor that had been used in a coal application. These follow-up contacts in turn led to additional leads who were also contacted by phone. Requests for documentation relative to performance and screw feeder design were made of each contact.

4.0 SURVEY RESULTS

The letters requesting information were sent to 45 manufacturers, 7 organizations, and 2 individuals. No response was received from 27 manufacturers and 3 organizations. Five manufacturers indicated they did not make a feeder for this application, i.e., to feed across a pressure boundary and provide a seal. Six made feeders that were other than screw feeders, e.g., rotary feeders. One had no experience with coal and one had experience but used components made by a separate manufacturer. Five indicated screw feeders with coal experience. Four organizations indicated they were not aware of feeders for this application; one supplied a roster of members, one provided extensive technical standards, and two were generally not involved with feeders per se. The two individuals contacted provided information from their experience and supplied additional contacts. However, the experience was primarily with the DOE sponsored feeder work. Four individuals were selected from the roster supplied by the Association of Professional Material Handling Consultants (APMHC) and were contacted by phone. None were able to supply any direct information but one did supply an additional contact. Two individuals were selected from the Standards supplied by the Conveyor Equipment Manufacturers Association (CEMA). They were contacted by phone but were unable to provide information relative to this application. Results of the initial contacts are summarized in Table I.

Based on the above, six manufacturers were selected for follow-up. They were:

- Ferro-Tech
- FMC Corporation
- Fuller Company
- Screw Conveyor Corporation
- Thomas & Muller Co., Inc.
- Werner & Pfleiderer Corporation

Telephone conversations were held with these six manufacturers selected from screening the initial responses to the survey questions. The results of these conversations follow.

Ferro-Tech³

Ferro-Tech is located at 467 Eureka Road, Wyandotte, Michigan 48192, telephone (313) 282-7300. Discussions were held with Carl A. Holley, President, on several occasions during January and February 1983. Ferro-Tech is primarily involved in agglomeration process development and equipment manufacture. Feeders are incidental to their primary function of agglomerating materials. Ferro-Tech is presently involved in bio-mass activities but they have extensive experience with numerous materials including coal and have used screw type extrusion machines to produce coal logs. They have also used pelletizers and briquetters to agglomerate coal dust, filter cake, and fines. However, Ferro-Tech indicated they did not feel their equipment would be appropriate for differential pressure applications at this time. They knew of no off-the-shelf equipment on the market that would perform the function desired. The name of a consultant, Tom Miles, who was knowledgeable in the feeding of bio-mass, particularly wood products was supplied. Ferro-Tech also suggested talking to J.C. Steele & Sons, Inc. relative to extruders.

Thomas R. Miles, Consulting Design Engineer, 5475 S.W. Arrow Wood Lane, Portland, Oregon 97225, telephone (503) 292-0107 was contacted. He has had 35 years' experience as a materials handling consultant primarily in the wood products industry and is presently involved with biomass (woodchip) feeders for gasifiers. Tom says he knows of no device that will do what we want. He has been working on several projects involving feeding biomass to pressurized reactors (1000 #/hr @ 300 psig; 600 #/hr @ 150 psig). However, no differential pressures are involved. The feeders are downstream of a lockhopper type system that isolates the reactors from the atmosphere. He hypothesized that the feeders

³ See Bibliography for references.

he was using could possibly seal up to 50 psid (psi differential pressure) but that the plug integrity was absolutely unreliable, at least with woodchips. He suggested talking to Wayne Edwards who had just completed a survey similar to ours relative to biomass feeders.

Jim Pickett was contacted by phone at J.C. Steele & Sons, Inc., 710 South Mulberry St., Statesville, NC 28677, telephone (704) 872-3681. Jim indicated that they made extruders to reclaim coal fines by forming them into coal logs. This was not done at a differential pressure but he felt that it was feasible. However, some development work would be required to determine feedstock limitations, sealing capabilities, etc. So while he envisions his equipment being able to do the function we want, it would require a development effort to verify it.

Wayne Edwards, B.H. Levelton and Associates Ltd., 8805 Osler Street, Vancouver, British Columbia, Canada V6P 4G1, telephone (604) 266-1411, was telephoned. He indicated that he had recently completed a study for the Canadian Forestry Service on the Status of Biomass Feeder Technology and suggested obtaining a copy of the report. This was done. He also suggested calling Stake Technology Corp. in Oakville, Ontario as they might have a feeder that would work in the 250 psid range.

The Canadian report, "ENFOR Project C-259, Status of Biomass Feeder Technology" is comprehensive and is recommended to all who desire an overview of feeder technology. It points out that feeders available for use on pressurized systems include: lockhopper, linear pocket, piston, rotary, and screw types. Many of the designs for higher differential pressures have not been used for wood residues but originated from a development program funded by the U.S. Department of Energy for feeding pressurized coal gasifiers. The findings of the report state that, at differential pressures up to 145 psid, several well-proven feeders are available for feeding wood chips and sawdust. These include lockhopper, rotary, and screw feeders. Some examples of lockhopper systems are Lurgi Coal Luck, Petrocarb Pneumatic, and Miles Biomass; rotary feeders are Bauer, Kamyr, and Beaumont; screw feeders include Sunds Defibrator Ltd. (40 psid), Rise Louise Corp. (7 psid), Fuller-Kinyon, Type M (50 psid), and Koppers Company, Inc., Sprout Waldron Div. (150 psid). The screw feeders listed as potential high-pressure feeders for wood residues are: C. E. Bauer Pressafiner, General Electric Screw Feeder, Ingersoll-Rand Screw Feeder, Koppers Screw Feeder, Stake Technology Screw Feeder and the Werner & Pfleiderer Screw Feeder. Of these, the Bauer, Koppers, and Stake units have proven operation with wood residues. The Werner & Pfleiderer

unit has demonstrated it can operate with wood residues.

The Koppers Plug Screw Feeder is commercially available. Wood chips form a plug in a tapered spool prior to injection into a pressurized steaming vessel. Typical differential pressure is 150 psid. Calls were made to several areas within the Sprout-Waldron Division. They do make plug screw feeders for various applications. One is used to feed pet food to steam cookers and operates at 15 to 20 psid with no blowback problems (Glenn Falk). Another is used in the pulp and paper area at about 150 psid and seals against steam. It has only been used on wood products to date. There has been no experience using coal. Design and test effort would be required before a coal application could be considered because of the considerable difference in the materials (coal vs. wood chips) properties. In short, to use the biomass plug screw feeder for coal applications would take some development work; it could probably not be used "off-the-shelf" (Jim Foresman).

The Stake Technology unit is a "Co-Axial Feeder" in which a feed material is metered to a single compression screw and the precompacted "plug" is moved forward against a choke by a reciprocating piston. Most service has been at a differential pressure of 350 psid. A call was made to Igor Fridrich at Stake Technology Limited, 220 Wyecroft Road, Oakville, Ontario, Canada, L6K 3V1, telephone (416) 842-4560. Igor stated they have built ten machines to custom requirements for biomass feeding; one unit fed 18,000 ft³/hr (approximately 180 tons/hr) at 500 psid. They have no experience with coal but feel very confident their machine would work and are very interested in working on development in this area.

The Bauer Pressafiner was designed for high pressure (1000 psid) de-watering of pulps but may be considered a feeder. A truncated conical feed screw provides initial compression and eliminates voids. The material is compressed about 4 to 1 as it moves along the screw. Liquid is "squeezed" out through a unique screen device. The long feed screw forms a plug to seal against back pressure from the pressurized reactor. Telephone conversation with Larry Tantello at C. E. Bauer, P.O. Box 968, Springfield, Ohio 45501, telephone (513) 390-3400,

indicated that Bauer deals in wood products and has little or no experience with coal. He felt the abrasiveness of coal would be a problem. The Pressafiner is in fact a screw press and the item more appropriate for our use would be a plug screw feeder. They do make one but it is limited to about 100 psid and has not been used for coal.

This concludes the results obtained from the Ferro-Tech₃ contact.

FMC Corporation⁴

FMC Corporation, Material Handling Equipment Division is located in Tupelo, Mississippi 38801 (Box 1370), telephone (601) 869-5711. FMC manufactures Link-Belt Screw Conveyors and Screw Feeders and their equipment is backed by extensive field experience. They have pioneered in the development of screw conveyor components and accessories and their production facilities have kept pace with advancements in design. They have handled a variety of materials including coal in sizes ranging from fines to a combination of fines and lumps. Their catalog provided information to enable selection of off-the-shelf equipment and provided dimensional data also. In addition they suggested contacting the Conveyor Equipment Manufacturers Association (CEMA) at 1000 Vermont Ave. N.W., Washington, D. C. 20005, telephone (202) 628-4634 to obtain design specifications and standards for off-the-shelf equipment. This was done.

Subsequent phone calls to FMC indicated that FMC is not involved with feeders that produce any sort of plugging action. They have not done work of this sort in the past and it is not their product line at this time. Such an item would certainly not be off-the-shelf and would have to be an "engineered order". It (the sealing requirement) is considered to be out of the field of expertise for materials handling people. They would be willing to fabricate equipment to order (i.e., to customer supplied drawings) but doubted they would be able to warrant performance.

⁴See Bibliography for references.

CEMA was contacted and the following items were purchased:

<u>Standard No.</u>	<u>Title</u>	<u>Content</u>
CEMA No. 102-1982	Conveyor Terms and Definitions	Presents the accepted terminology for the industry.
ANSI/CEMA 300-1981	Screw Conveyor Dimensional Standards	Presents dimensional data used throughout the industry.
ANSI/CEMA 350-1981	Screw Conveyors	Presents technical data used to select (design) off-the-shelf (i.e., standard) equipment. Much of the data is empirical having been developed over years of experience in the industry.
ANSI/CEMA 550-1980	Classification and Definition of Bulk Materials	Defines materials and assigns material codes used throughout the industry for equipment design and selection. Much of the data is empirical having been developed over years of experience.

These publications are standards for the industry and several have been adopted by the American National Standards Institute. Therefore, when talking about off-the-shelf "commercial" equipment, these standards apply "since most all reputable major manufacturers subscribe to their standards" (FMC).

Fuller Company⁵

Fuller Company is located at 2040 Avenue C, P.O. Box 2040, Bethlehem, PA 18001, telephone (215) 264-6011. Fuller has over 50 years' experience in coal handling systems. Initial activities with the Fuller-Kinyon pump were related to eliminating

⁵See Bibliography for references.

the explosion hazard involved in conveying pulverized coal. They have seen extensive use on atmospheric fluidized bed combustion facilities including the demonstration unit (30 megawatt) at Rivesville, WV. The Type M Fuller-Kinyon pump has successfully fed solids at a differential pressure of 50 psi and development of 100 psid capability is progressing. Coal size of 1/2" X 1/4" has been conveyed; 650°F is the upper temperature limit for the pump. A telephone conversation with Fuller revealed the basic use of the Type M Fuller-Kinyon pump is to introduce atmospheric coal into a 50 to 100 psig pneumatic conveying system while maintaining a continuous material (coal) seal. A flapper type check valve provides a safety feature. A plug is not formed, however, and this more or less limits the basic Type M pump to the 50 to 100 psid range. The largest pump made to date has a capacity of 150 tons/hour; most of the pumps in use are in the 10 to 20 tons/hour range and are used on atmospheric fluid bed boiler applications. The Biomass Feeder Technology report stated a 100 mm (approximately 4 inches) Fuller-Kinyon pump had been modified to a plug screw feeder to feed a pressurized vessel. No blowback was observed when feeding minus 6 mm (about 1/4 inch) coal at 8 tonnes/hour (about 17,650 #/hr) against a differential of 620 kPa (about 90 psi). 25 kW power was required resulting in a specific power consumption of $3.8 \frac{\text{hp}}{\text{ton/hour}}$.

Kinergy Corporation/Screw Conveyor Corporation⁶

Kinergy Corporation is located at 4821 Jennings Lane, Louisville, Kentucky 40218, telephone (502) 964-5901 and are designers and manufacturers of bulk materials handling equipment. Screw Conveyor Corporation is located at 700 Hoffman Street, Hammond, Indiana 46327, telephone (219) 931-1450 and are manufacturers of a full line of screw conveyors and other bulk handling equipment.

Kinergy Corporation responded to the survey and presented information relative to their knowledge of screw feeder designs. They indicated that most screw feeders (commercial, off-the-shelf) are manufactured to a "standard" format and enclosed a Screw Conveyor Corporation catalog as an example. (These follow closely the CEMA documents.) They were not aware of any user

⁶See Bibliography for references.

where a screw feeder or conveyor could develop and seal a differential pressure. The suggestion was made that an airlock type device be used to maintain the entire feeder at pressure or be on the downstream side of the feeder. A subsequent call to Kinergy revealed that screw feeders were treated as an accessory at Kinergy and that our application would require a very special design. Kinergy had no experience in this area and, to their knowledge, there was no off-the-shelf equipment that would do the job. Screw Conveyor Corporation makes standard screw feeders and components for all types of applications and Kinergy suggested calling them as they would likely know if a "commercial" feeder for our application was available. Screw Conveyor Corporation was contacted by phone. They know of no application where screw conveyors/feeders are used to generate a differential pressure. They have made a lot of screw feeders but none to do this sort of application. They have done a lot of work with coal but none at differential pressure. They have made feeders for pressurized service but have had "locks" on one or both ends. From their experience, the design would take a lot of engineering. They doubt if coal above 1/8" maximum could be made to seal without a binder, paste, or something to fill in the voids. The forces required would probably stall the screw, bend the flights, strip the flights, or result in some other damage. They would be glad to fabricate to customer supplied prints but could not be responsible for the design. They know of no standard "off-the-shelf" hardware that could perform this function.

Ducon Company, Inc./Dravo Doyle/Thomas & Muller Co., Inc.⁷

Dravo Doyle, 995 Manor Oak Two, 1910 Cochran Road, Pittsburgh, PA 15220, telephone (412) 343-9850 responded to the survey as representatives of Ducon Fluid Transport Division, Ducon Company, Inc. They pointed out that Ducon does not make screw feeders. However, they also represent Thomas & Muller who do and they enclosed a bulletin from them. Thomas & Muller is located at Box 1930, Camden, New Jersey 08101, telephone (609) 963-3500. They make custom designed, custom built, feeders as well as standard feeders. Folger Thomas was contacted by phone and indicated they had extensive experience in coal handling and feeding.

⁷See Bibliography for references

However, much of their work is custom designed, custom built, and somewhat proprietary to their clients' restricting the amount of information that could be divulged. He had worked on some plug feed extrusion devices that operated to 1600°F at low pressure, 5 to 15 psig. They did not operate at a differential pressure but he felt that a plug could be formed that would seal at modest differential pressure, in the range of 30 psi. He indicated that while they had no off-the-shelf equipment to perform the function we desired, they would be very willing to do some development work in this area. In fact, his associate, Al Glover, had been approached several times recently on an application similar to ours and as a result they were planning to run a few demonstration tests using standard components. How far they would proceed would depend on the results obtained and continued demonstrated market interest. Apparently there was presently no off-the-shelf equipment to perform this feeding function and a development project would be required to provide one.

Werner & Pfleiderer Corporation⁸

Werner & Pfleiderer are located in Stuttgart, Federal Republic of Germany with a United States Office at 663 E. Crescent Ave., Ramsey, New Jersey 07446, telephone (201) 327-6300. They are primarily involved in plastics technology, polymer processing, and twin screw extrusion systems. They have been involved in trying to transfer the plastics technology to the feeding of coal using twin-screw extruders since 1971. John Stewart supplied numerous technical documents and brochures. He also indicated a 120 mm (approximately 4 3/4") twin screw ZSK type extruder had been feeding coal to a pressurized reactor in the Federal Republic of Germany for about a year. The company (VEBA Oel Ag) was contacted by letter but no response has been received.

The Werner & Pfleiderer ZSK type extruder employs co-rotating intermeshing screws where one screw "wipes" the other screw as they revolve and effects a positive displacement pumping action. This technique has demonstrated feeding of a high solids content (80% by weight) coal slurry at 800°F and a differential pressure of 3000 psid. Feedstocks to -1/2 inch maximum have been accommodated.

⁸See Bibliography for references

Screw extruder technology as applied to pumping plastics at several thousand psi is a mature science but plastics industry technology generally does not work with coal. Bench scale single screw testing with coal slurries demonstrated 1000 psid operation. However, larger scale testing resulted in numerous problems with caking, wear, blowback, etc. Twin-screw Werner & Pfleiderer type extruders have overcome many of the single-screw problems; 1500 psid operation has been demonstrated. Sized coal is required; -1/4 inch maximum is indicated. Double screening may be required. Werner & Pfleiderer claim they are ready to supply twin-screw pumps (commercial units) for long term service on high pressure gasification or liquefaction equipment.

In addition to the above contacts, the book Coal Gasifiers by E. J. Hoffman (1981) was reviewed and the two feed systems mentioned therein were researched. Acrison Inc. of 20-T Empire Blvd., Moonachie, N.J. 07074, telephone (201) 440-8300 and Bloomer-Fiske, Inc. of 4016 S. Princeton St., Chicago, IL 60609, telephone (312) 523-2300 were contacted by phone. Neither was aware of any off-the-shelf equipment to perform to our requirements. Acrison, Inc. provides precision feeding/metering of coal, normally pulverized, using gravimetric methods such as weight belts. They are not involved in any sort of pressurized feeding which they implied was done with "locks". Bloomer-Fiske, Inc. are a contract manufacturer. They have no product per se but make custom equipment to clients' drawings and specifications. They do not have the expertise to engineer a feeder and suggested contacting Screw Conveyor Corporation which was reported on above.

Don Lewis at JPL suggested talking to Welex, Inc., 850 Jolly Rd., Blue Bell, PA 19422, telephone (215) 542-8000, who had participated in the early work in coal extrusion. Frank Nissel was contacted and indicated that the numerous problems with coal properties, e.g., going from "rocks" to a highly viscous liquid within the extruder, make the single screw extruder a poor candidate for feeder service. Part of the problem is that the single screw extruder, commonly thought of as a positive feed device is really not. Propulsion of the material through the extruder is related to friction between the material being transported and the screw and barrel surfaces. If adequate friction is not developed the material tends to stay in one place, simply tumbling over on itself as the screw turns. There is no positive displacement feature such as a piston moving in a cylinder since the screw does not normally translate relative to the barrel. Detailed design

information can be found in Section 3.0 Existing Literature and Design Information of DOE Document EY-77-C-21-8085-004-1⁹. Welex thought that a twin screw extruder or a combination single screw/gear pump arrangement would be appropriate. While both these techniques are commercial in the plastics industry, Welex knew of no commercial applications feeding coal. It was inferred from the discussion with Welex that coal feeding with a screw type device at differential pressure of any magnitude was still in the development or even research stage.

The Institute of Gas Technology (IGT), 3424 State St., Chicago, IL 60616, telephone (312) 567-3650, was mentioned as having done a lot of feeder development work by one of the sources contacted (George Schultz, A. Epstein and Sons, Chicago, IL). IGT was contacted (Dr. Ted Knowlton) and they indicated that they had done some proprietary feeder work in the oil shale area but that the differential pressures involved were minimal, certainly less than 5 psid. They mentioned the equipment they used came from Screw Conveyor Corporation and Thomas & Muller Company, both of which were reported on above. It was inferred from the discussion held with IGT that screw conveyor/feeder equipment was not suitable for our intended application, at least not at this time. Trying to form a high pressure (500 to 1000 psid) gas seal using run of mine coal as a feedstock is just not state-of-the-art. Larger coal particles (greater than 1/8 - 1/4 inch), even when compressed by existing screw feeder type devices, afford too large a void (flow path) area to effect a gas seal of any magnitude. Feedstock size reduction and the use of binders would help. However, it was suggested that the Kamyr feeder device might meet the requirements¹⁰. Since this device was not a screw type, it was not pursued as part of this survey. The information loop appeared to be closing (source references being repeated) and the survey was terminated at this time.

⁹"Coal Extruder Test Program, Coal Extrusion Present Technology" by TRW Energy Systems Planning Division, DOE Contract No. EY-77-C-21-8085, Document No. EY-77-C-21-8085-004-1, March 1978.

¹⁰"Continuous Injection of Coal to Pressurized Pipelines and Processes by Rotary Lock Chamber Exchange of Macro-Volumes of Low Pressure Slurry for Equal Volumes High Pressure Liquid", Erwin D. Funk, Kamyr, Inc., Glens Falls, NY.

5.0 CONCLUSIONS

The basic conclusion from the survey is that screw type devices to replace lockhopper systems for feeding coal to pressurized reactors do not exist as off-the-shelf equipment. Two screw type devices were found that have been used to feed coal across a pressure boundary. One has extensive service and is a commercial item — the Type M Fuller-Kinyon pump. The other, purportedly commercial but with much less service experience, is the Werner & Pfleiderer twin-screw extruder. The former is limited to the 50 to 100 psi differential pressure range and is primarily used to supply atmospheric coal to pressurized pneumatic transfer systems for fluid bed boilers. The latter develops much higher pressure — in the several thousand psi range — but requires the addition (or inherent) of 20% moisture. Both require sized coal, nominally less than 1/2 inch. The Type M pump has the advantage of design maturity and a reliable service record. However, extension of the differential capability above a few hundred psi is questionable even with major modifications. The Werner & Pfleiderer unit has the very distinct advantage of being a positive displacement type device. Cost is inferred to be a disadvantage. In addition, a service record must be developed.

Equipment in use in the biomass field, particularly wood products, conceivably can be modified or converted for coal application. These commercial devices were found to perform satisfactorily with wood products (chips, pulp, sawdust, etc.) in the 150 psid range. The consensus is that development work would be required before coal service could be realized.

Devices other than screw type feeders are available to feed coal. These include commercial systems such as Petrocarb, Lurgi, and other lockhopper systems including the Kamyr rotary lock feeder, and DOE sponsored feeders being developed by Conspray, Lockheed, Ingersoll-Rand, and Foster-Miller, Inc.

Few companies are presently involved in developing coal applications for their existing commercial equipment. Fuller Company did not indicate that they were trying to extend greatly their differential pressure range to the 100+ psi level. Werner & Pfleiderer are actively engaged in coal applications/developments. Thomas & Muller proposed performing some "demonstration" tests at their own expense. Many expressed a willingness to co-operate in developments if funding was available. A few were not interested in coal research or development efforts sponsored by government. Several were quite satisfied to act as fabricator to client prints but lacked the expertise to engineer a coal feeder product.

In short, commercial, standard, off-the-shelf screw type feeders do not exist that will take run of mine coal at atmospheric conditions and transport it across a pressure barrier above 150 psid and afford a positive seal. This is still basically the domain of lockhopper and slurry pump type systems.

6.0 RECOMMENDATIONS

Specific recommendations resulting from the survey are difficult to formulate. One is to monitor the progress of the Werner & Pfleiderer twin-screw extruder feeder. Efforts to increase the size of the feedstock and decrease the amount of added moisture should be encouraged.

The probability of commercial biomass feeders to operate with coal should be assessed by demonstration tests using existing equipment. An arrangement for doing this needs to be fashioned with the manufacturers. Candidate equipment includes the Stake Technology "Co-Axial Feeder", the Koppers Plug Screw Feeder, and the C.E. Bauer Plug Screw Feeder; emphasis should be placed on the Stake unit.

Although the bulk of the manufacturers/users of screw feeding equipment are doubtful of pressure sealing applications, some interest was expressed. Therefore, the capability to feed coal to a pressurized reactor using a commercial, off-the-shelf, screw conveyor/feeder to CEMA standards should be determined. An integrated/cost sharing effort with selected manufacturers could accomplish this. Results of the tests should be sufficient to ascertain the applicability of that equipment for this application. Thomas and Muller Co., Inc., Fuller Company, and Ferro-Tech are suggested for initial contacts.

The requirements for coal feeders need to be definitized. A specification, or series of specifications, should be developed that address particular criteria, e.g., the characteristics of the feedstock and the output product. Temperature, pressure, and leakage rate ranges should be stated. The specification(s) may need to be process specific, e.g., fixed-bed, fluidized-bed, etc. These specifications would benefit manufacturers by presenting specific values as opposed to generalized statements and could serve as a connecting link to an end item use to which the manufacturers could relate.

7.0 BIBLIOGRAPHY

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8.0 APPENDIX

Screw Feeder Survey Letters and Mailing List

Manufacturer of Screw Feeder Equipment

The Department of Energy (DOE) and the Morgantown Energy Technology Center (METC) have been involved in evaluating and developing solids feeders for application in advanced coal conversion processes. TRW is currently assisting METC to determine and document the current status of coal feeders.

In order to provide the broadest base, it is necessary to survey manufacturers of screw feeders to obtain the latest available data on screw feeders that are capable of feeding solids against a differential pressure. Therefore, the following information on your screw feeders is desired:

- Differential pressure against which solids can be fed
- Feed rates
- Coal size range and any other limitations on coal properties (moisture content, volatile level, etc.)
- Feeder size limitations
- Temperature limitations
- Specific power consumption

Higher differential pressure applications are of special interest for the advanced processes that are using higher pressures for improved conversion efficiencies.

Catalogs, drawings, specifications, etc. that you have would be most helpful in our survey and assessment of the current state of the art in screw feeders.

Should you have any questions or require clarification, please contact Gordon Sine or me at (304) 599-8622. Your assistance is sincerely appreciated.

Very truly yours,

David A. Maxfield
Task Engineer

DAM:va

Organizations/Trade Associations

The Department of Energy (DOE) and the Morgantown Energy Technology Center (METC) have been involved in evaluating and developing solids feeders for application in advanced coal conversion processes. TRW is currently assisting METC to determine and document the current status of coal feeders.

In order to provide the broadest base, TRW is surveying manufacturers of screw feeders to obtain the latest available data. Our particular interest at this time is screw feeders that are capable of supplying solids to a pressurized vessel. In addition, we are interested in keeping abreast of the state of the art and potential new developments through contact and familiarization with the industry in general. It is in this latter thrust that I am writing your association for further enlightenment.

A number of questions have developed in our search for data. It would be very helpful if you could respond to the following:

- Does your association include within its scope of operations equipment for screw feeders for industrial coal conversion processes?
- Does your association hold annual conventions? If so, does it include displays by exhibitors? What is your schedule of meetings?
- Do you know of other associations or sources that would provide opportunities for technology transfer and interaction with industry representatives?
- Does your association publish equipment information in papers or proceedings? If so, do you have a library or listings for review?

Should you have any questions or require clarification, please contact Gordon Sine or me at (304) 599-8622. Your assistance is sincerely appreciated.

Very truly yours,

David A. Maxfield
Task Engineer

DAM:va

Knowledgeable Individual

Our company is conducting a survey of screw feeder manufacturers as part of a task being performed for the Department of Energy. The specific task manager is Dave Dubis of the Morgantown Energy Technology Center. Because of your past involvement in solids feeding, we hope that you will be able to review the list of manufacturers to whom the initial information request is being sent and suggest additional contacts. A sample letter and the list of addressees for the first mailing is enclosed.

Thank you very much for your assistance in this matter.

Very truly yours,

DAM:va
Enc. as noted

David A. Maxfield
Task Engineer

MAILING LIST

Manufacturers

Acrison Inc.
20-T Empire Blvd.
Moonachie, NJ 07074

Bloom Inc.
U.S. Highway W
Independence, IA 50644

Buck-El, Inc.
24-T Commerce Street
Chatham, NJ 07928

Divine Engineering, Inc.
P.O. Box 1345
Cedar Rapids, IA 52406

Duplex Mill & Manufacturing Co.
The 400 Sigler Street
Springfield, OH 45501

Eriez Magnetics
1386 Old Freeport Road
Pittsburgh, PA 15238

Ferro-Tech, Inc.
467 Eureka Road
Wyandotte, MI 48192

FMB Systems, Inc.
151-T Main Street
Lodi, NJ 07644

Foster-Miller Associates, Inc.
350 Second Avenue
Waltham, MA 02154
Adi R. Guzdar

General Electric Co.
P.O. Box 8, River Road
Schenectady, NY 12301
A. H. Furman
Dr. Ralph R. Boericke

Bechtel National
P.O. Box 3965
San Francisco, CA 94119
M. K. V. Chari

A. E. Bogott & Sons, Inc.
110 Third Avenue
Sterling, IL 41081

Conspray Construction Systems, Inc.
111 W. Dyer Road, Suite B
Santa Ana, CA 92707
Douglas D. Peterson

Ducon Company, Inc.
Ducon Fluid Transport Division
842 First Avenue
King of Prussia, PA 19406

James Eagen & Sons Co.
204 W. 8th Street
Wyoming, PA 18644

Feedmatic-Detroit, Inc.
4660 E. 355th Street
Cleveland, OH 44094

Flex-Kleen Corp.
Attn: Marketing Department
One Northwestern Center
165 N Canal Street
Chicago, IL 60606

FMC Corp.
Material Handling Equipment Div.
Homestead City, PA 15748

Fuller Company
Box 2040
Bethlehem, PA 18001

Henderson Industries
45-T Fairfield Place
West Caldwell, NJ 07006

Horst Dynamics, Inc.
Denver, CO 80236

Ingersoll-Rand
Box 301
Princeton, NJ 08540
Dilip Mistry

Kinergy Corporation
4821 Jennings Lane
Louisville, KY 40218

Lively Manufacturing
and Equipment Co.
P.O. Box 339
Glen White, WV 25849

MMM Mars Mineral
P.O. Box 128
Valencia, PA 16059

Mikropul Corporation
Pulverizing Machinery Division
26 Chatham Road
Summit, NJ 07901

Nash International Inc.
6548 Carmel Road
P.O. Drawer 221301
Charlotte, NC 28222

Nott Company
Engineered Material Handling Division
1722 New Brighton Blvd.
Minneapolis, MN 55413

Petrocarb, Inc.
200 Broadacres Drive
Bloomfield, NJ 07003
Harold Reintjes

Thomas & Muller Co., Inc.
Box 1930
Camden, New Jersey 08101

IFE Systems, Inc.
370-B Franklin Turnpike
Mahawah, NJ 07430

Jeffrey Manufacturing
Division Dresser Industries, Inc.
41 Fisher Avenue
Bradford, PA 16701

K-Tron Corporation
20 Warrick Avenue
Glassboro, NJ 08028

Lockheed Dept. 52-33
P.O. Box 504 Building 131T
Sunnyvale, CA 94086
John H. Bonin
Dr. John W. Meyer

Metalfab, Inc.
140 Woodland Avenue
Rochelle Park, NJ 07662

Moksnes Mfg., Inc.
Accu-Rate Division
746 E. Milwaukee Street
Whitewater, WI 53190

New Castle Industries, Inc.
Feed Screws Division
925 Industrial Street
New Castle, PA 16102

Penn Bangor, Inc.
R.D. 2 (Jacktown Industrial Park)
Bangor, PA 18013

Sprout-Waldron
Koppers Co., Inc.
Muncy, PA 17756

Union Carbide/Nuclear Division
Oak Ridge National Laboratory
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P.O. Box X
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P.O. Box 21219
Louisville, KY 40221

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663 E. Crescent Avenue
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Fort Lee, NJ 07024

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1548 Tower Road
Winnetka, IL 60093

Deep Foundations Institute
P.O. Box 1043
Clifton, NJ 07014

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Distributors Association
201 Route 45
Vernon Hills, IL 60061

Petroleum Equipment
Suppliers Association
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Houston, TX 77002

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4800 Oak Grove Drive
Pasadena, CA 91103

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755 Union Blvd.
Totowa, NJ 07511

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400 Morris Avenue
Denville, NJ 07834

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1000 Vermont Ave., N.W., Suite 1200
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