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COMPARISON OF TWO METHODS FOR CONVEYING KERR-McGEE ASH CONCENTRATE: FULLER-KINYON PUMPS VS. BLOWTANK PNEUMATIC TRANSPORT SYSTEM

Final Report

By
Stu Schwartz
Samir F. Moujaes

September 1983

Work Performed Under Contract No. AC05-78OR03054

International Coal Refining Company
Allentown, Pennsylvania

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ABSTRACT

The Fuller Company conducted tests to determine the feasibility of conveying Kerr-McGee ash concentrate (KMAC) by two different methods: a Fuller-Kinyon pump conveying system and a blowtank pneumatic transport system. The Fuller-Kinyon tests showed that a 1,500-ft/min conveying velocity satisfied a wide range of KMAC flow conditions. No conveying problems occurred in either system at temperatures below 550°F at this velocity. Also, no appreciable KMAC attrition was noted. Thus, technically, either system can convey KMAC satisfactorily. Additional studies conducted independently by GKT to compare the economics and on-stream reliability of both methods showed that the Fuller-Kinyon pump is more reliable and has a lower total cost than the blowtank system. Based on these results, ICRC included the Fuller-Kinyon pump conveying system in its Baseline Design for the SRC-I Demonstration Plant.

EXECUTIVE SUMMARY

Two studies performed by the Fuller Company were prompted by the need to select the best available way to transport Kerr-McGee ash concentrate (KMAC) to the gasifier feed system in the SRC-I Demonstration Plant, at a rate of 70 tons per hour (tph) at about 450°F. This report details studies on two transport methods that were considered: a Fuller-Kinyon pump system and a blowtank pneumatic transport system. Evaluation of both systems addressed two main concerns:

1. Potential problems conveying KMAC at temperatures up to 550°F, which is the highest temperature at which KMAC will be conveyed.
2. Attrition of the KMAC as it is conveyed through the system.

First, Fuller investigated the conveyability of KMAC in a Fuller-Kinyon pump at elevated temperatures. The objective was to optimize operating parameters with this conveying mode and then examine the system's effect on particle attrition.

Fuller used an available experimental system to test KMAC flow rates at ambient and elevated temperatures. Running tests at ambient temperatures narrowed the range over which parameters such as loading density, line pressure, and gas flow rates could be varied to optimize the system. High-temperature tests were then conducted to determine the effect of temperature, as well as possible KMAC conveyability problems, e.g., particle agglomeration.

The ambient-temperature tests conducted to optimize flow parameters showed that power consumed by the pump was proportional to the line pressure drop against it. The study showed that pressure drop due to the solid/gas flow decreased sharply in the region in which the solids began to settle on the pipe bottom. After solids began to settle, the pressure drop increased because flow through the pipe became increasingly restricted. Results showed that, for a given system, there is an optimum velocity that gives the lowest pressure drop; this, in turn, results in the lowest power consumed by the pump to transport the same volumetric rate of KMAC. Decreasing the volumetric flow of gas will again increase the system pressure drop.

For the two types of KMAC tested, optimum velocities ranged between 1,200 and 1,500 ft/min. The lower limit represents a higher percentage of fine KMAC materials, which provide a larger interfacial surface area and have a greater tendency to fluidize than larger KMAC particles. These results were consistent with those of other researchers. Although the material could be transported at velocities as low as 300 ft/min, no gain in power consumption would be expected. Thus, Fuller chose a conveying velocity of 1,500 ft/min, which ICRC deems adequate to ensure complete suspension.

Because higher velocities signify a greater chance of attrition, a size distribution study was conducted during which samples were taken after each pass of KMAC through the system. Breakage occurred, especially after the first pass through the pump.

To determine the extent of attrition, Fuller sifted the KMAC through mesh screens. The data indicated that attrition occurred during the first cycle of operation. However, results from independent studies, indicated that attrition did not occur. It was concluded that Fuller's tests were in error because the KMAC used as a reference sample had agglomerated during storage. Agglomeration would not occur during actual plant operation.

The two KMAC samples were also run at several high temperatures and flow rates. The motor load readings indicated no signs of material binding or sticking in either pump or conveying line up to 550°F. A fine layer of KMAC was detected inside the conveying line and in parts of the pump, but it could be easily vacuumed off. Hence, it was deduced that there should be no problem in conveying KMAC at high temperatures using the Fuller-Kinyon pump system. Purging with nitrogen was recommended at shutdown due to the combustible nature of the material.

In summary, the Fuller-Kinyon pump can convey KMAC materials without major problems at temperatures below 550°F. Particle attrition is not believed to be a problem in such a system, and hence poses no additional problems for the gasifier feeding system.

For the second study, Fuller constructed and tested a blowtank conveying system, operating under SRC-I Demonstration Plant conditions. The KMAC was heated by mixing it in a suspension preheater with hot nitrogen that had been heated indirectly to minimize the possibility of combustion. After the blowtank was filled, the KMAC was pushed pneumatically through the system to the discharge cyclone. The total conveying distance tested was 105 ft.

During the first few tests runs at high temperature, a sharp increase in line pressure signaled that the preheater was blocked. Subsequently, large chunks of KMAC were removed. The preheater blockage problems were a good indication that adhesion would be a problem at KMAC temperatures between 580 and 775°F.

The pickup velocity selected as optimal for design during the Fuller-Kinyon pump tests was also used with the blowtank system. No KMAC was deposited on the inside walls of the blowtank or the conveying line. Only a thin layer of KMAC was observed on the tank walls, which could easily be brushed off.

Attrition of the KMAC particles as they passed through the conveying system was also studied by screening different samples withdrawn from the drums and at the discharge point. Results were inconclusive; particle distributions measured for different samples varied widely. The variations may not be statistically significant, however, because the samples were random and not many were tested. Also, some of the samples were collected from drums in which the KMAC had agglomerated.

Thus, overall, no definite trend regarding attrition was observed. One observation, however, was that particles started to agglomerate as the KMAC temperature rose above 575°F. This was reflected by a drop in the percent particles passing the 325 mesh screen and a noticeable increase in bulk density.

In general, Fuller concluded that a blowtank system does not result in appreciable attrition of KMAC at temperatures below 575°F. Above this critical point, the competing processes of agglomeration and attrition make it impossible to determine the effects of attrition alone.

Overall, the advantages and disadvantages of both systems can be summarized as follows:

1. Both systems are capable of transporting KMAC at around 550°F.

2. The Fuller-Kinyon pump can deliver KMAC at a constant volumetric rate, whereas the blowtank system operates in batches, unless two are installed in parallel and used in a coordinated discharging and charging mode.

3. Because no drive is needed for the blowtank, it will require less maintenance and less power than the Fuller-Kinyon system. Both can operate at the same line pressure and gas flow rate.

4. Finding the proper space and headroom for the blowtank in a process plant environment like the SRC-I facility might be a problem. The blowtank is expected to be from 9 to 22 ft tall.

5. Heat loss from the blowtank vent as KMAC is being charged to the system is more than the minimal heat loss from the pump, because it is a continuous operation.

6. Technically, neither system is particularly superior to the other; both could convey KMAC to the gasifier adequately. However, the Fuller-Kinyon pump appears to be more reliable

Subsequent to the Fuller report, GKT performed a more detailed study to compare the operational reliability, flexibility, maintainability, and safety of both systems (see Appendix 3). The study concluded that the Fuller-Kinyon pump system was preferable to the blowtank pneumatic system for transporting KMAC from the SRC deashing area to the dust preparation area. In particular, the study noted that:

- Fuller-Kinyon pumps have been used to transport materials more abrasive than KMAC.
- Fuller-Kinyon pumps are not as high as blowtank conveying systems, so they will need less steel support.

- Fuller-Kinyon pumps are more reliable; erosion of their moving parts is a slow process, allowing regular inspection and maintenance.
- The sealing surfaces of valves in a blowtank operating at 420°F may be unreliable.

Finally, economic evaluation indicated that the total cost for the Fuller-Kinyon pump would be less than that for the blowtank system. Based on all these results, ICRC selected the Fuller-Kinyon system for the Baseline Design for the SRC-I Demonstration Plant.

CONVEYING KMAC IN FULLER-KINYON PUMPS
(PROGRAM 13.3.2)

INTRODUCTION AND THEORY

In many special applications of a product where the feasibility of its use is uncertain, a physical study must be performed to determine the limits of the product in the specific application. The investigation described in this section was designed to set operating constraints for the Fuller-Kinyon pump, being considered for conveying Kerr-McGee ash concentrate (KMAC) in the SRC-I Demonstration Plant. ICRC's design for the plant specifies that the KMAC must be conveyed approximately 1,500 ft at a rate of 70 tons per hour (tph). Of significance is the 450°F temperature at which the KMAC is to be conveyed.

Conveying a material such as KMAC that has a low bulk density of 25 lb/ft^3 requires a pump larger than the Research Department at Fuller Company could accommodate. Therefore, a scaled-down demonstration was conducted in order to effectively model full-scale conditions.

Overall objectives of the tests on the Fuller-Kinyon pump were as follows:

1. Optimize the operating parameters of a Fuller-Kinyon pump for conveying KMAC at ambient temperature
2. Determine the extent of attrition of the KMAC during conveying
3. Determine feasibility of conveying KMAC at temperatures up to 550°F

Ambient-Temperature Tests

The first series of tests to optimize the conveying parameters for KMAC was conducted at ambient temperature. Briefly, a Fuller-Kinyon Type M pump (M-150) was used to feed a 4-in.-diameter conveying line, approximately 585 ft long. During Phase I of the ambient-temperature tests, the volumetric flow rate of nitrogen was varied to alter the conveying capacity.

Generally, the volumetric flow rate is measured in terms of standard cubic feet per minute (scfm). Because the facility used in the current investigation differed from that of the customer, a parameter had to be determined that was independent of the equipment size, particularly the pipe diameter. Normally, specific materials require a certain velocity to become fully entrained in the air stream without leaving a large residue in the pipe. By the law of continuity of mass, the velocity is lowest at the start of a conveying system because of expansion and pressure loss of the conveying gas, i.e., velocity increases as pressure and density decrease. Thus, if the material can be entrained at the start of the conveying system, it will usually remain entrained throughout the entire system. This minimum velocity is called the <u>pickup velocity</u>.

The pickup velocity is related to the nitrogen flow rate as follows. Let:

PUV = pickup velocity (ft/min)
acfm = actual volumetric flow rate (ft^3/min)
scfm = volumetric flow rate at standard conditions (namely, 14.7 psia, 70°F)
A = pipe cross-sectional area (ft^2)
P_L = line pressure measured at pipe entrance (psig)
T = temperature at pipe entrance (°F)

Because volumetric flow rate is defined by:

$$Q = \int_A \vec{V} \cdot d\vec{A} \qquad (1)$$

(where Q = volumetric flow rate, V = velocity, and A = area) and there is no change in the area, equation 1 becomes:

$$Q = V \times A \qquad (2)$$

or in terms of the current investigation:

$$\text{acfm} = \text{PUV} \times A \qquad (3)$$

From basic gas laws, acfm is related to scfm by:

$$\text{scfm} = \text{acfm}\left(\frac{P_L + 14.7\text{ psi}}{14.7\text{ psia}}\right)\left(\frac{530°\text{R}}{T(°\text{F}) + 460}\right) \qquad (4)$$

One can see that by maintaining a constant line pressure and varying the volumetric flow rate, it is possible to vary the pickup velocity. The only way to maintain constant line pressure is to vary the rate of material entering the conveying system, since changing the volumetric flow rate changes the energy available for conveying.

Figure 1 offers a graphic explanation of general conveying characteristics. The pressure loss due to friction and expansion in an empty pipe is proportional to the square of the gas velocity (Figure 1). At constant pressure, the potential energy of the gas is linear with volume, since the energy input to the gas is expressed as:

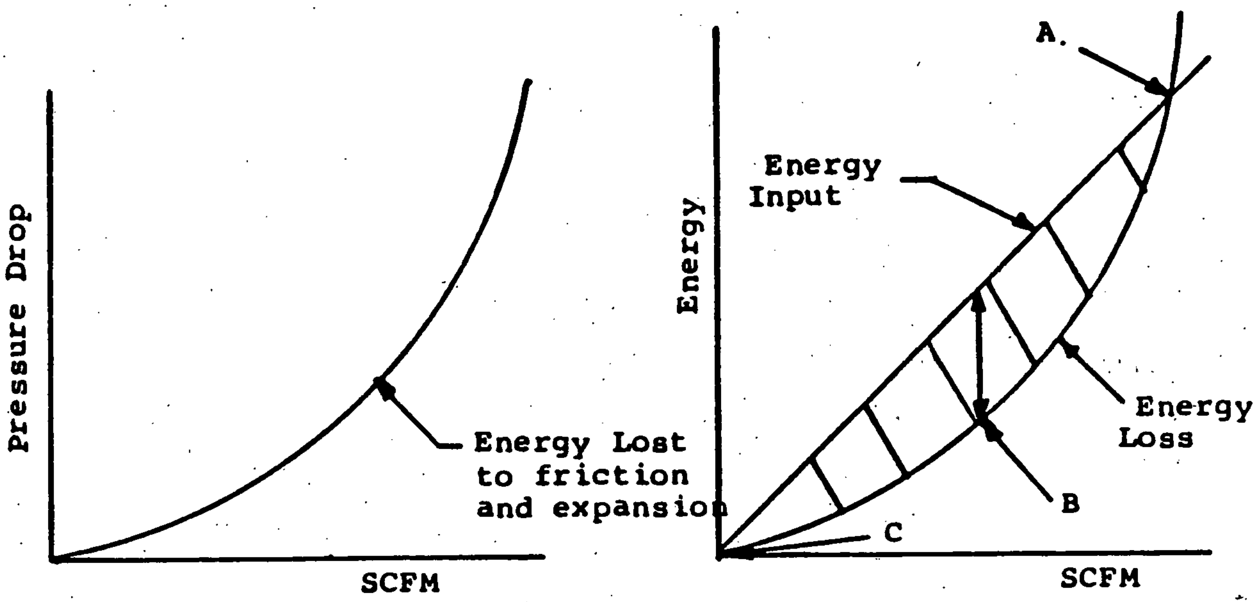
$$E = \int P \cdot dV \qquad (5)$$

Superimposing the pressure-loss curve of Figure 1a on a plot of the potential gas energy vs. volumetric flow rate (Figure 1b) shows the energy available for conveying material (the area between the two curves).

Figure 1c shows that, as the available energy is increased, the rate of conveying is increased. Remember that this explanation assumes that the pressure in the line is not changed. One can see that the maximum rate of conveying will be achieved when maximum conveying energy is available. It is this optimum point, namely point B on Figure 1, that was being searched for in the first series of ambient tests.

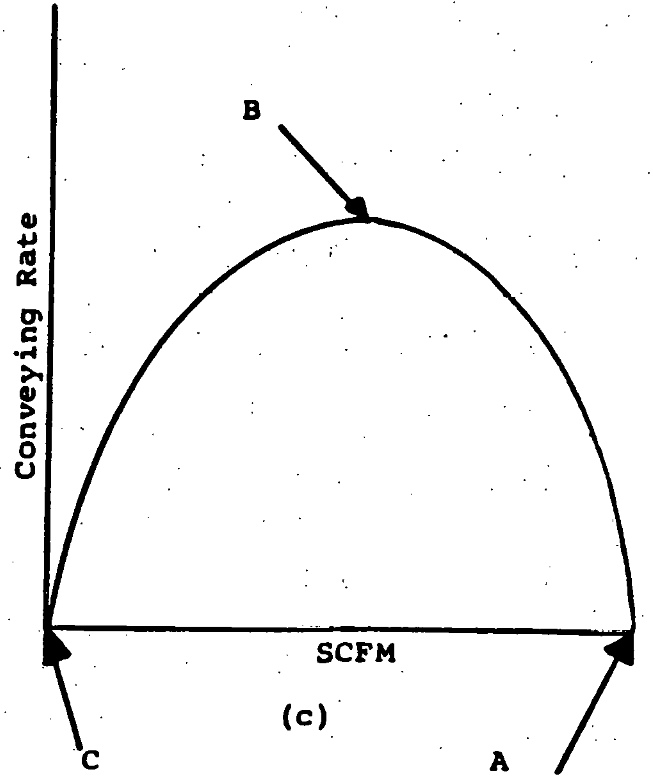
After the optimum pickup velocity was determined, the effect of the conveying rate on line pressure was studied in order to size a better conveying system. During this phase of testing, the pickup velocity (therefore, the acfm) was held constant. The scfm was varied to compensate for pressure changes.

Figure 1
Effects of Volumetric Flow Rate of Gas on Conveying Characteristics



(a) Air Only

(b) Available Conveying Energy is Area Between the Curves



(c)

Finally, material breakage, or attrition, was studied. Fresh material was run through the entire conveying system and sampled after each pass. Five passes were made at the pickup velocity determined in the first part of the ambient-temperature tests.

Elevated-Temperature Tests

One of the major concerns addressed in the current investigation was the behavior of hot KMAC within the conveying system. During normal operation, the Fuller-Kinyon pump will be handling KMAC at temperatures above 250°F. Thus, this phase of testing exposed the pump and conveying system to KMAC that had been heated to various temperatures up to 550°F. One concern was that the hot KMAC might become somewhat elastic, or "sticky," binding the pump and/or clogging the conveying line.

Thus, KMAC was fed into the Fuller-Kinyon pump at elevated temperatures and conveyed at a pickup velocity approximately equal to the optimum found in the ambient-temperature test. Motor loads were read and used to determine whether any KMAC deposition was indeed hindering pump operation. Similarly, the line pressure was monitored to discern possible clogging of the conveying line. A line-pressure increase during testing, while the conveying rate remained constant, indicated that the KMAC was adhering to the walls of the pipe, reducing the conveying line diameter and increasing the power demand by the pump.

EXPERIMENTAL APPARATUS AND PROCEDURES

Apparatus for Ambient-Temperature Test (Figure 2)

A Fuller-Kinyon 150-mm Type M pump was used in conjunction with a 150-mm windbox and 150-mm flapper valve. The pump was belt-driven by a 150-hp (155-kW) Reliance Duty Master a-c motor. A Lebow shaft torque sensor was coupled in-line between a jackshaft (driven by the motor) and the screw shaft (Figure 3). The torque sensor measured the torque input to the pump, thus providing a way to calculate the power supplied to the pump. The output from the torque sensor was recorded on an Esterline Angus chart recorder, as well as a digital display.

Figure 2
Apparatus for Ambient-Temperature Tests

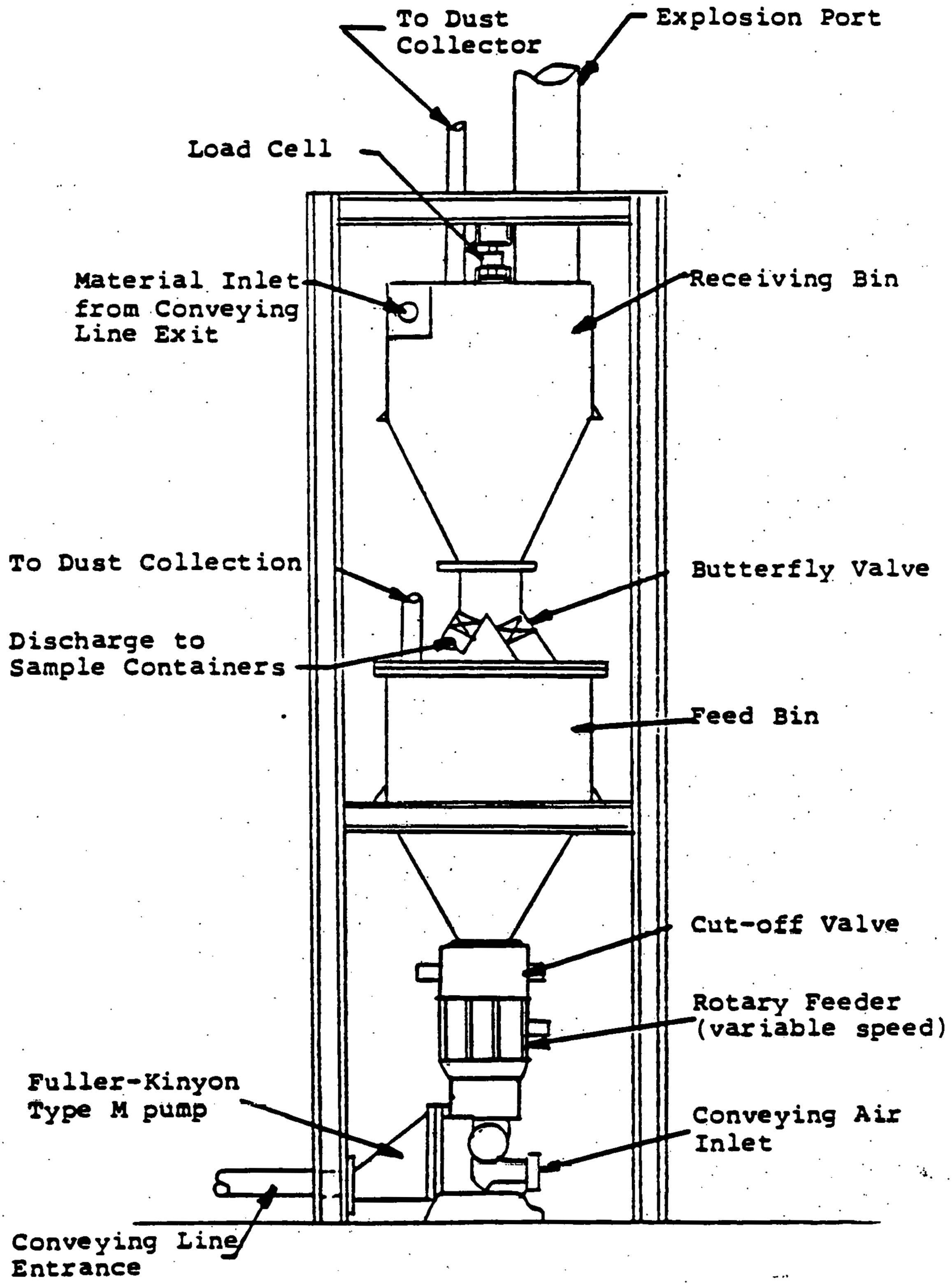
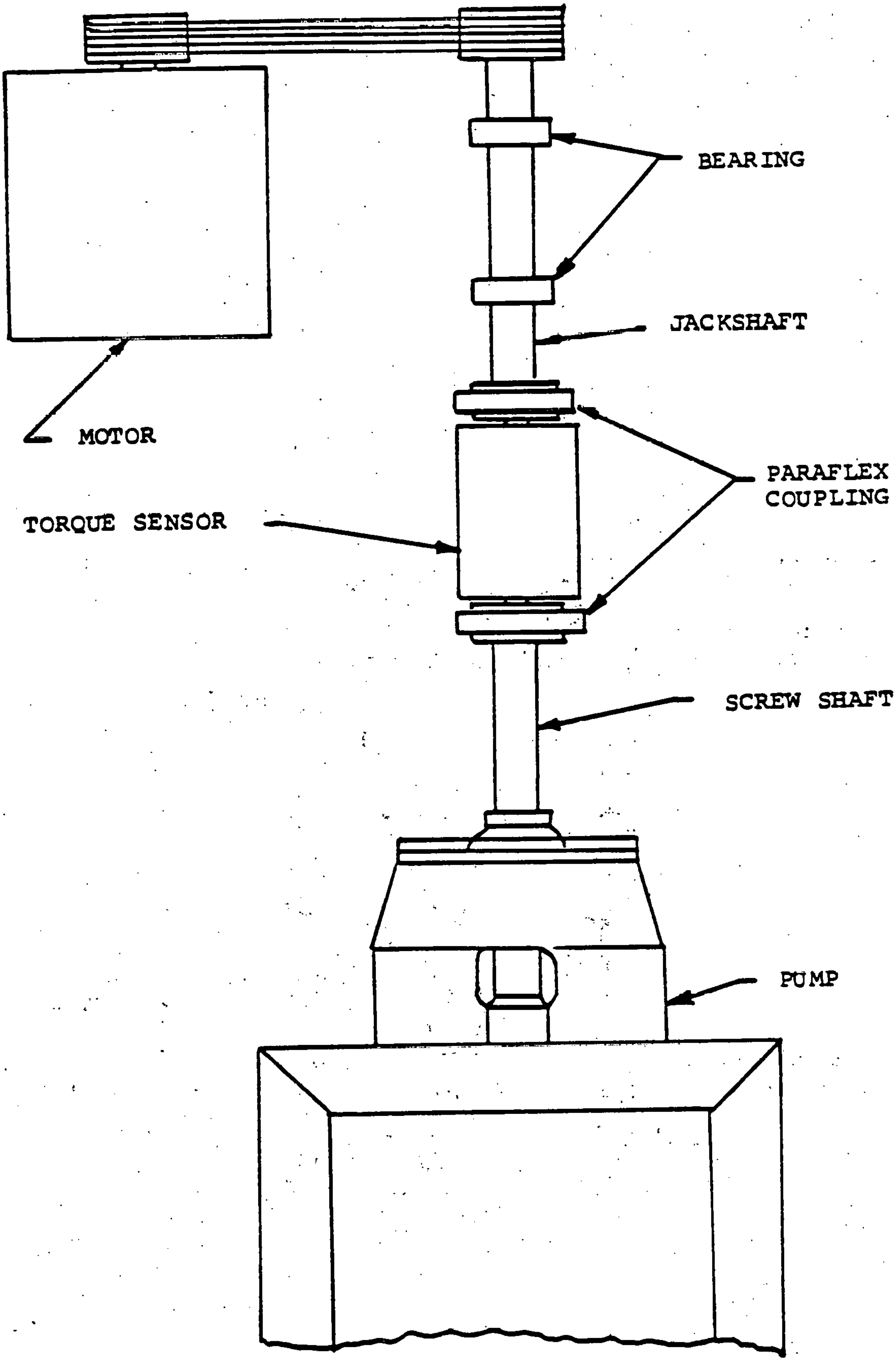


Figure 3
Torque Drive for Power Measurement
on Fuller-Kinyon Pump



To account for variance in power usage by the pump, three power readings were taken from the chart recorder: (1) the highest power used; (2) the lowest power used; and (3) a modal average power. Figure 4 shows the typical fluctuations in power observed during a test run. The modal average was determined subjectively by eye, as the reading where the pump appeared to operate most frequently. For example, in observation 826, the modal average was observed to be 29, with a high of 31 and a low of 22.

The material was fed to the pump through a rotary cutoff valve and Fuller Metric 300 rotary feeder, which controlled the feed rate. A U.S. Motor 1-hp (0.75-kW) variable-speed motor connected to a sprocket/chain drive system varied the speed of the rotary feeder.

Nitrogen flow rate provided the necessary mechanism for conveying the KMAC. Nitrogen pressure was regulated by a Fisher pressure regulator, since the incoming supply pressure was 80 to 100 psig. An orifice plate set in the pipe between the regulator and intake manifold measured the airflow rate, which was regulated by a manual globe valve downstream of the orifice. The pressure drop across the orifice was recorded on a second Esterline Angus chart recorder (see Appendix 1 for sample calculations).

The pump discharged into a 4-in.-diameter conveying line, which immediately rose 20 ft. As shown in Figure 5, total conveying distance was approximately 600 ft, including six long-radius 90° bends and four specially fabricated 30° bends, before discharge into a receiving-weigh bin. This bin, as well as the dust collector, was fitted with coded explosion ports.

The receiving bin was fitted with a strain gauge load cell, and the weight of the material in the bin was recorded on a strip chart recorder. From this measurement, conveying capacity could be determined (see Appendix 1). After the experimental run was completed, a pneumatic valve was opened and the material was emptied into the main feed bin.

The windbox (line) pressure and intake manifold pressure were also monitored via pressure taps. The output of the pressure transducers coupled to these taps was recorded on the same strip chart recorder as the orifice differential pressure. A flow control orifice regulated the

Figure 4
Typical Power Readings from Torque Sensor

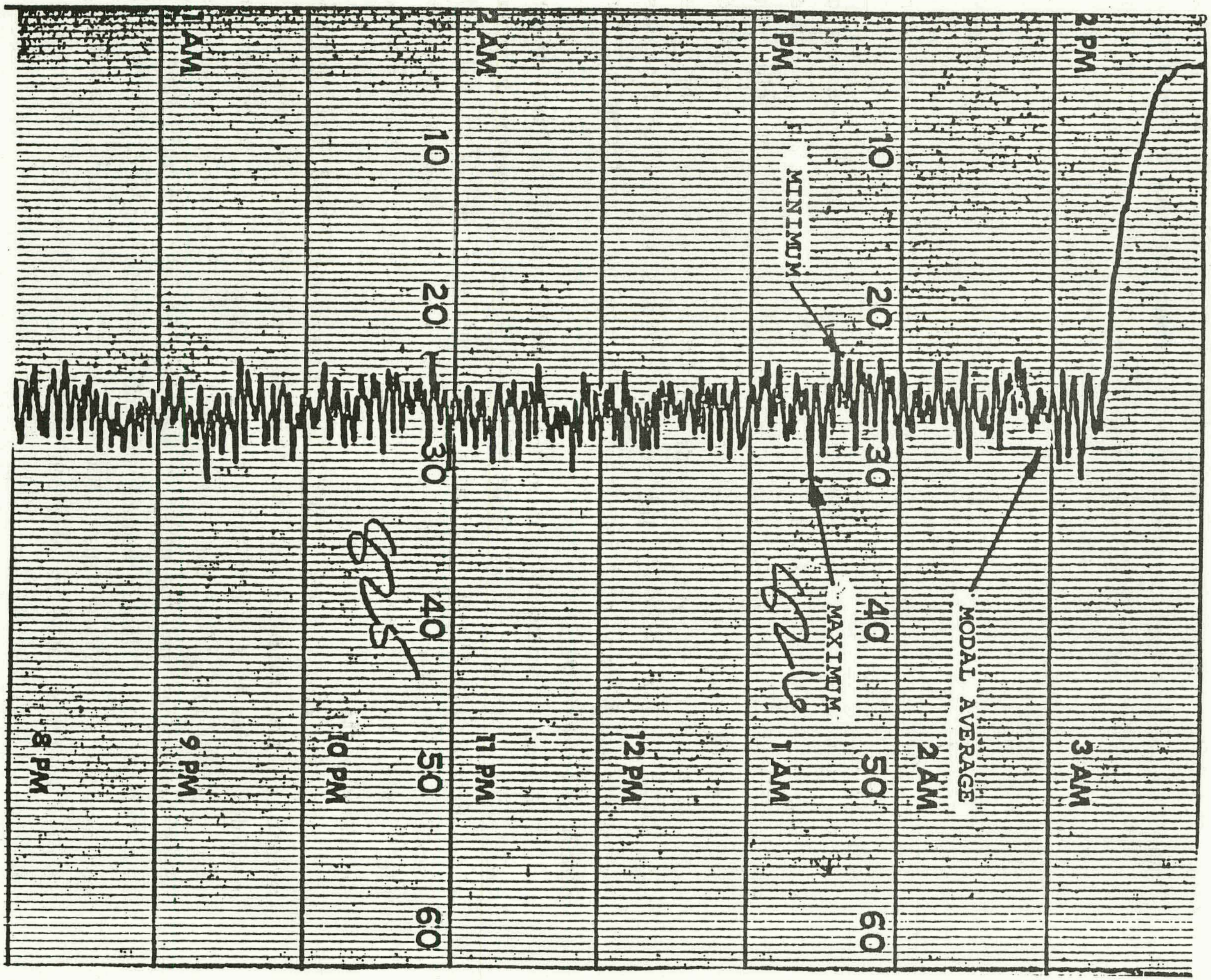
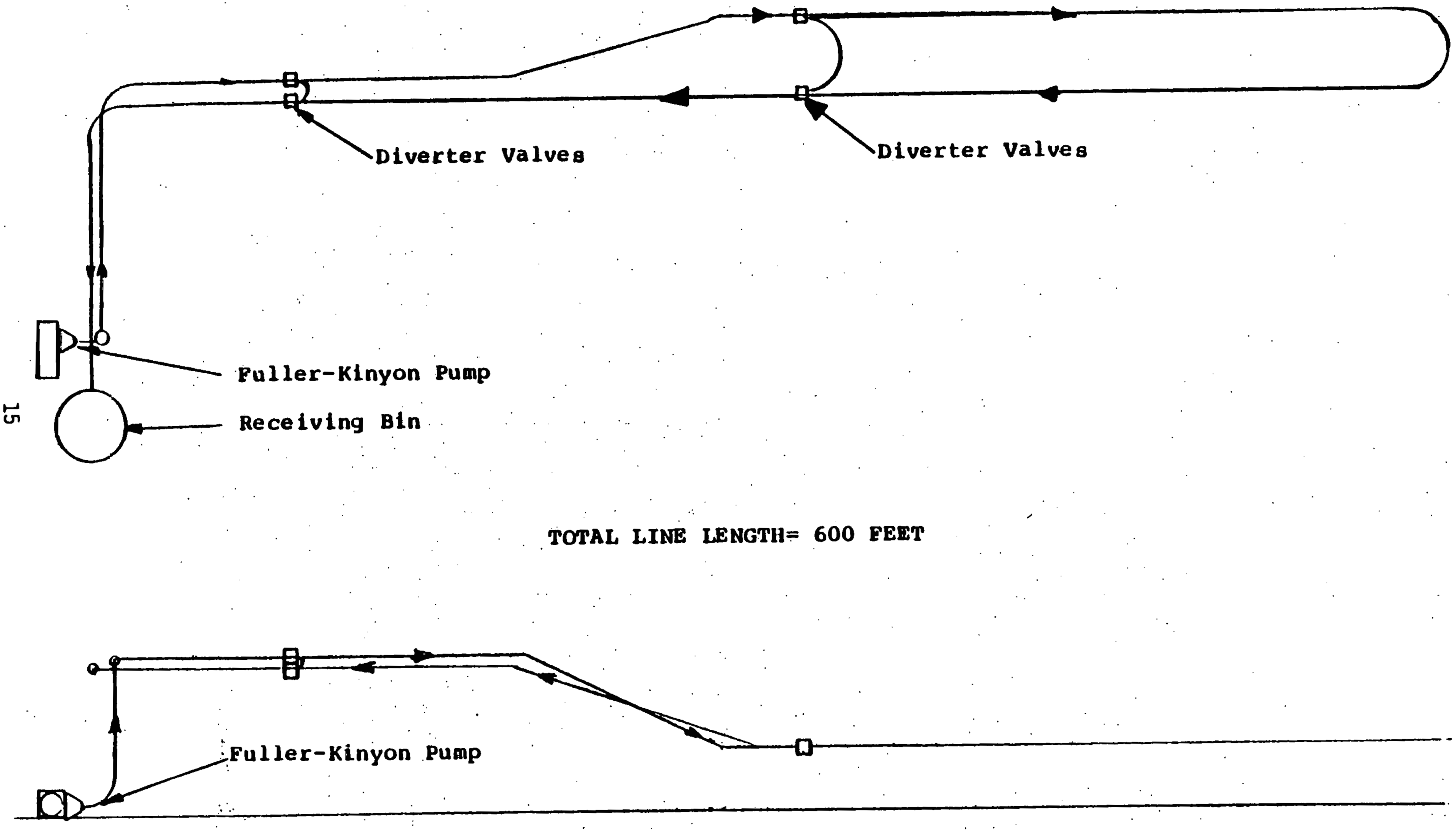


Figure 5
Conveying Line Configuration



nitrogen purge flow rate to the discharge end seals, since the correct volumetric flow rate to these seals is essential to proper operation of the pump.

Apparatus for Elevated-Temperature Test (Figure 6)

Pump and Conveying Line. A Fuller-Kinyon 4-in. Type H2 pump equipped with a water-cooled seal assembly conveyed the hot KMAC into a 2-in.-diameter conveying line. The pump was belt-driven by a 40-hp U.S. electric a-c motor. Power consumption by the pump was measured at the starter by reading amperage on each of the three leads of the three-phase supply.

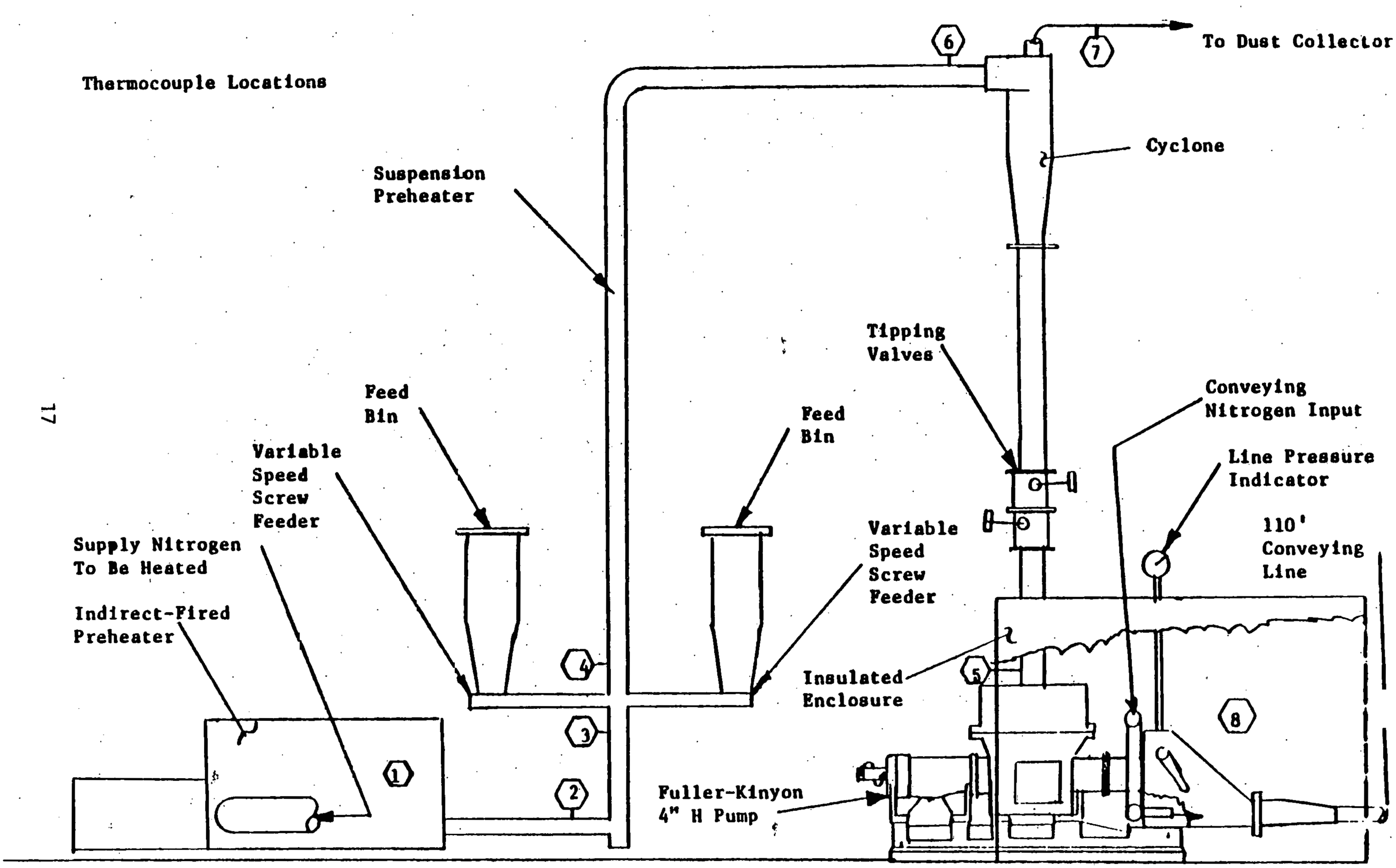
The pump discharged into a 2-in.-diameter conveying line, which rose 9 ft through two bends before moving horizontally. The material was then conveyed about 100 ft before being discharged into the discharge cyclone. The KMAC was conveyed from the cyclone after being separated from the nitrogen and was placed in drums. Total conveying distance was approximately 110 ft. The volumetric nitrogen flow rate was controlled by a critical flow orifice in the same manner as in the ambient-temperature tests.

Feed System to the Pump. As mentioned previously, material temperatures up to 550°F are of interest. The following method was used to heat the KMAC.

Nitrogen from the supply tank passed through a steam vaporizer to maintain a temperature of nearly 100°F. Next, an indirectly fired preheater raised the temperature of the nitrogen up to 850°F. The hot nitrogen entered an 8-in.-diameter suspension preheater (shown in Figure 6). Two variable-speed screw feeders injected the ambient-temperature KMAC into the suspension preheater approximately 3 ft above the nitrogen entrance. The cocurrent flow of hot nitrogen and KMAC provided for enough heat transfer to raise the material to the desired temperature.

After reaching thermal equilibrium, the mixture entered a refractory-lined cyclone, which separated the nitrogen from the heated KMAC. The nitrogen was conveyed to a Plenum Pulse dust collector (baghouse), while the KMAC was passed through dual tipping valves into the

Figure 6
Apparatus for Elevated-Temperature Tests



pump. The drop leg to the pump was insulated with 2-in. calcium silicate insulation, and the pump was enclosed in an insulated box in order to minimize heat loss. The box was heated internally using a portable space heater.

Thermocouples were installed (see locations in Figure 6) to monitor the following temperatures, which were displayed on a digital readout: preheater enclosure at preheater exit; nitrogen temperature; nitrogen temperature before contacting KMAC; temperature of nitrogen/KMAC mixture just after contact; KMAC temperature entering the pump; temperature of nitrogen/KMAC mixture entering cyclone; nitrogen temperature after being separated by cyclone; temperature inside box surrounding the pump.

Procedures for Ambient-Temperature Test

Phase I--Pickup Velocity Tests:

1. Nitrogen flow rate was set at 700 scfm by adjusting regulator and globe valve.
2. Pump was turned on.
3. Rotary feeder was turned on.
4. After steady-state conditions were achieved, pressures, motor load data, and conveying rate were recorded.
5. Nitrogen flow rate was decreased to 600 scfm.
6. Rotary feeder speed was adjusted to alter the feed to the pump until the same line pressure was achieved as in step 4.
7. Steps 5 and 6 were repeated until difficulty in conveying was observed. Increments in nitrogen flow rate were changed if deemed necessary.

Phases II and III:

1. Nitrogen flow rate was set high enough to avoid plugging the pipes; this involved using results of Phase I.
2. Pump and rotary feeder were turned on.
3. Globe valve was adjusted until the nitrogen flow rate yielded the optimum pickup velocity (found in Phase I) for the current line pressure.
4. Pressures, motor load data, and conveying rates were recorded.

5. Samples were obtained for breakage analysis.
6. Feed to pump was adjusted.
7. Steps 3 to 6 were repeated until several data points were generated.

Procedures for Elevated-Temperature Tests

1. Nitrogen flow rate to the preheater and pump was set.
2. Fuel to preheater was turned on in order to raise nitrogen temperature.
3. When the nitrogen temperature approached 500°F, the pump was turned on.
4. Hoppers feeding the suspension preheater were loaded.
5. Screw conveyors were turned on.
6. Speed of feeders was adjusted until desired material temperature entering the pump was reached.
7. The system was allowed to run for several minutes at this condition to ensure equilibrium.
8. Conveying rates, motor load readings, and temperatures were measured.

RESULTS AND DISCUSSION

Ambient-Temperature Tests

Two types of KMAC were tested in a Type M Fuller-Kinyon pump at ambient temperature. The two types, varying slightly in chemical composition, are designated by run numbers (Run 211 and Run 225).

Tables 1-3 present results of the conveying tests. Observations regarding the effects of the nitrogen volumetric flow rate will be discussed first, followed by a discussion of material attrition observed during conveying.

Conveyability of KMAC. As discussed, the ambient-temperature tests were designed to optimize the operating parameters of the Fuller-Kinyon pump by studying the effects of volumetric flow rate (in terms of pickup velocity) and of conveying rate (capacity). As the data in Table 1 show, the program deviated somewhat from the original objective of

Table 1

Results of Conveying Tests at Ambient Temperature[a]

Line length (ft)	Flow rate		Supply pressure (psig)	Line pressure (psig)	Pickup velocity (ft/min)	Conveying capacity (lb/min)	Shaft power (hp)			Motor input power (hp)	Observation
	scfm	acfm					High	Avg	Low		
					Run 225 KMAC						
600	628.6	359.6	23	11	4,123.28	180	20	19	13	31.4	1
600	628.6	359.6	23	11	4,123.28	180	20	19	13	35.5	2
600	505.7	313.6	15	9	3,596.84	160	12	11	10	30.9	3
600	416.4	269.7	14	8	3,092.50	160	10	10	8	29.7	4
600	309.8	209.9	11	7	2,406.62	160	8	8	8	27.1	5
600	199.6	135.2	8	7	1,550.47	180	8	8	8	26.5	6
600	162.0	104.9	9	8	1,203.21	160	9	9	9	26.5	7
600	136.4	88.3	9	8	1,012.75	180	10	10	9	28.1	8
600	113.7	70.5	10	9	808.95	160	13	12	10	29.5	9
					Run 211 KMAC						
600	350.6	227.1	12	8	2,604.04	200	14	14	11	31.4	15
600	272.5	184.6	10	7	2,117.07	200	12	12	10	29.5	16
600	200.4	142.3	8	6	1,631.78	200	9	9	8	27.7	17
600	165.0	117.2	7	6	1,343.66	200	8	8	8	27.7	18
600	113.7	80.8	6	6	926.19	180	9	9	8	27.4	19
600	85.6	58.0	7	7	664.81	200	10	9	8	27.9	20
600	165.0	117.2	7	6	1,343.66	200	8	8	7	26.7	21

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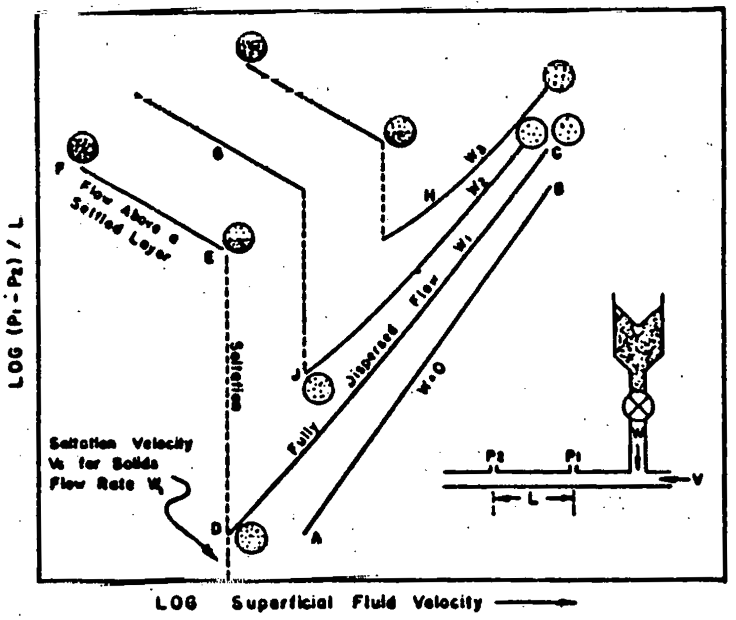
[a] Discharge housing, standard right; screw number, 116-81-4-1126; number of weights, 0; number of spacers, 0; number of nozzles, 7; nozzle size, 0.63 in.; line diameter, 4.0 in.

maintaining a constant line pressure and varying the pickup velocity. Instead, Fuller allowed the line pressure to vary and operated the pump at its maximum volumetric capacity (i.e., the highest volume of material that the pump can pass in a given time) with adjustable pickup velocity. This approach was taken in order to study the effects of gas flow rate on pump power usage by observing the change in line pressure. Previous testing has shown that the power consumption of the pump is proportional to the line pressure drop against it. Furthermore, Zenz and Othmer (1960) have shown that, for a constant material loading (termed "capacity" in this report), it is possible to determine when material is beginning to saltate in the pipe. Figure 7 shows that as the pickup velocity is decreased, the pressure drop in the conveying system will also decrease until material begins to settle in the pipe. As explained in the introductory section, once this settling commences, the effective cross-sectional area of the pipe is reduced, resulting in an increase in pressure drop.

Table 1 and Figures 8 and 9 show that, as the velocity decreased, the line pressure decreased correspondingly, until slug flow was visually observed in observations 7 and 18. This trend was observed for both Runs 211 and 225. Observation 1 showed that the highest line pressure occurred with the highest volumetric flow rate. For Run 225 KMAC, slug flow was observed below a velocity of approximately 1,500 ft/min. As velocities were decreased below this point, increases in line pressure and power consumption were observed. Similarly, for Run 211 KMAC, slug flow was observed at and below a velocity of 1,200 ft/min. The slight difference between these two observed "settling" velocities can be explained by the fact that Run 211 KMAC had a larger proportion of fine particles, which generally require less energy for conveying. These results are consistent with those of Zenz and Othmer.

KMAC can be conveyed at velocities as low as 665 ft/min (see observation 20), if not lower. Presumably, this material can be conveyed at velocities in the range of 300 ft/min; however, this offers no advantage regarding power consumption by the pump. Figures 10 and 11 show that in terms of the pump's power usage, it is most advantageous to design the conveying system with just enough velocity to maintain the

Figure 7
Schematic Representation of Fluid/Solids Flow Characteristics in Horizontal Transport
(Zenz and Othmer, 1960)



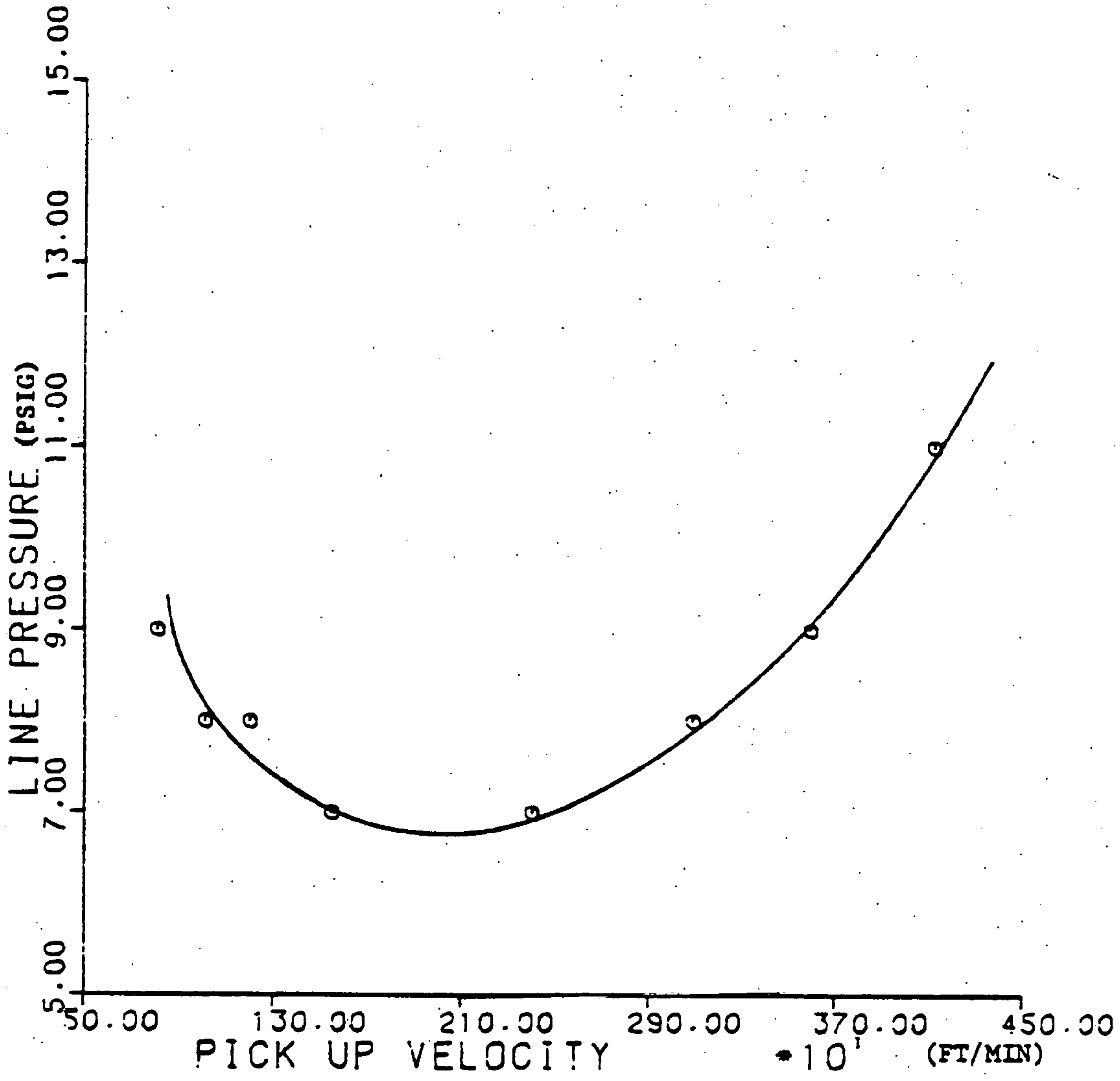


Figure 8
Line Pressure at Various Velocities at
Constant Material Loading
(Run 225 KMAC)

STD. RIGHT

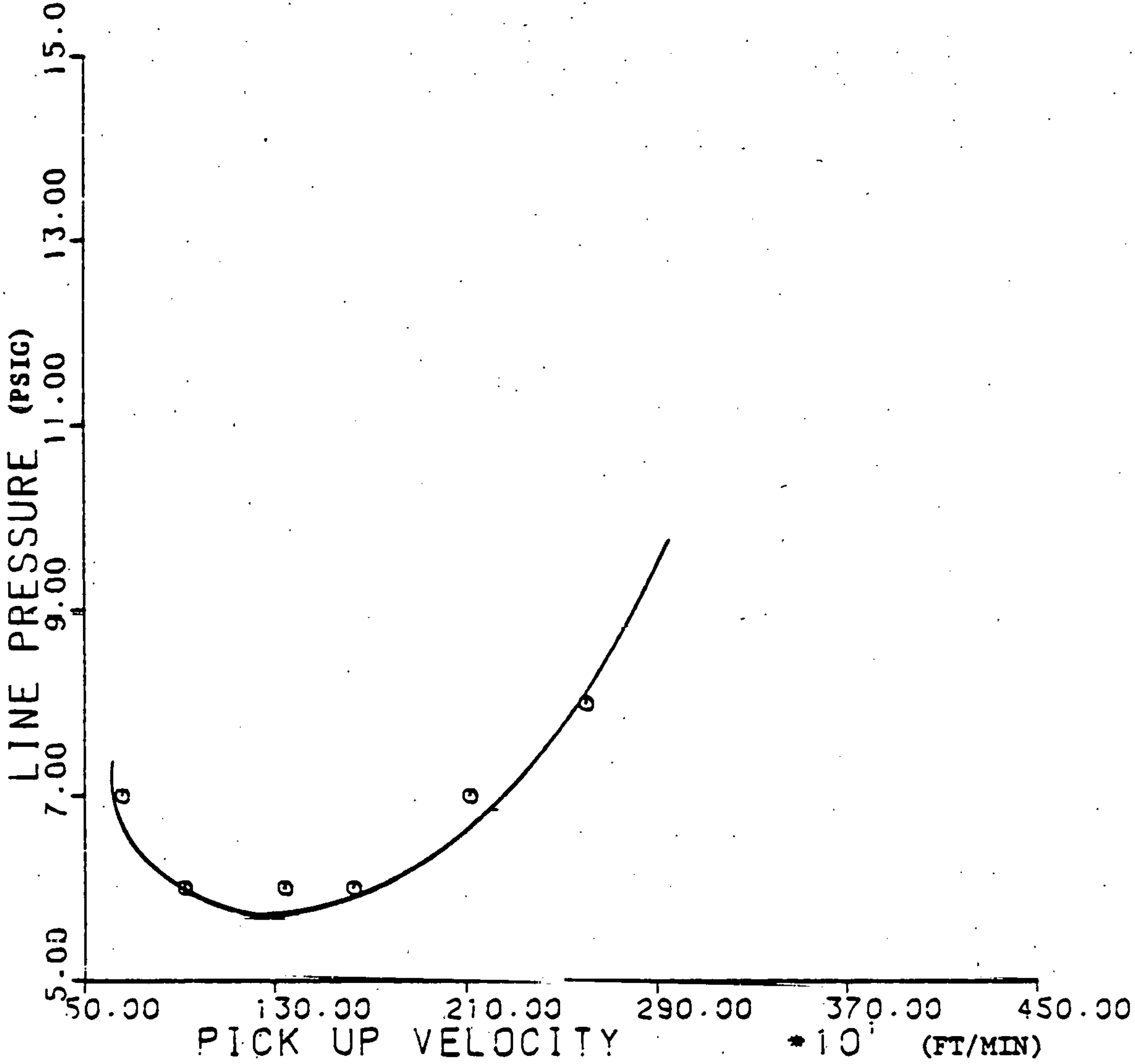
SCREW NUMBER 1126 RPM 1236

0 WEIGHTS 0 SPACERS 7 NOZZLES

LINE DIAMETER 4.00 LINE LENGTH 600

NOZZLE SIZE 0.6250 CONVEYING RATE = 180 LB./MIN

Figure 9
Line Pressure at Various Velocities
for a Constant Material Loading
(Run 211 KMAC)



STANDARD RIGHT

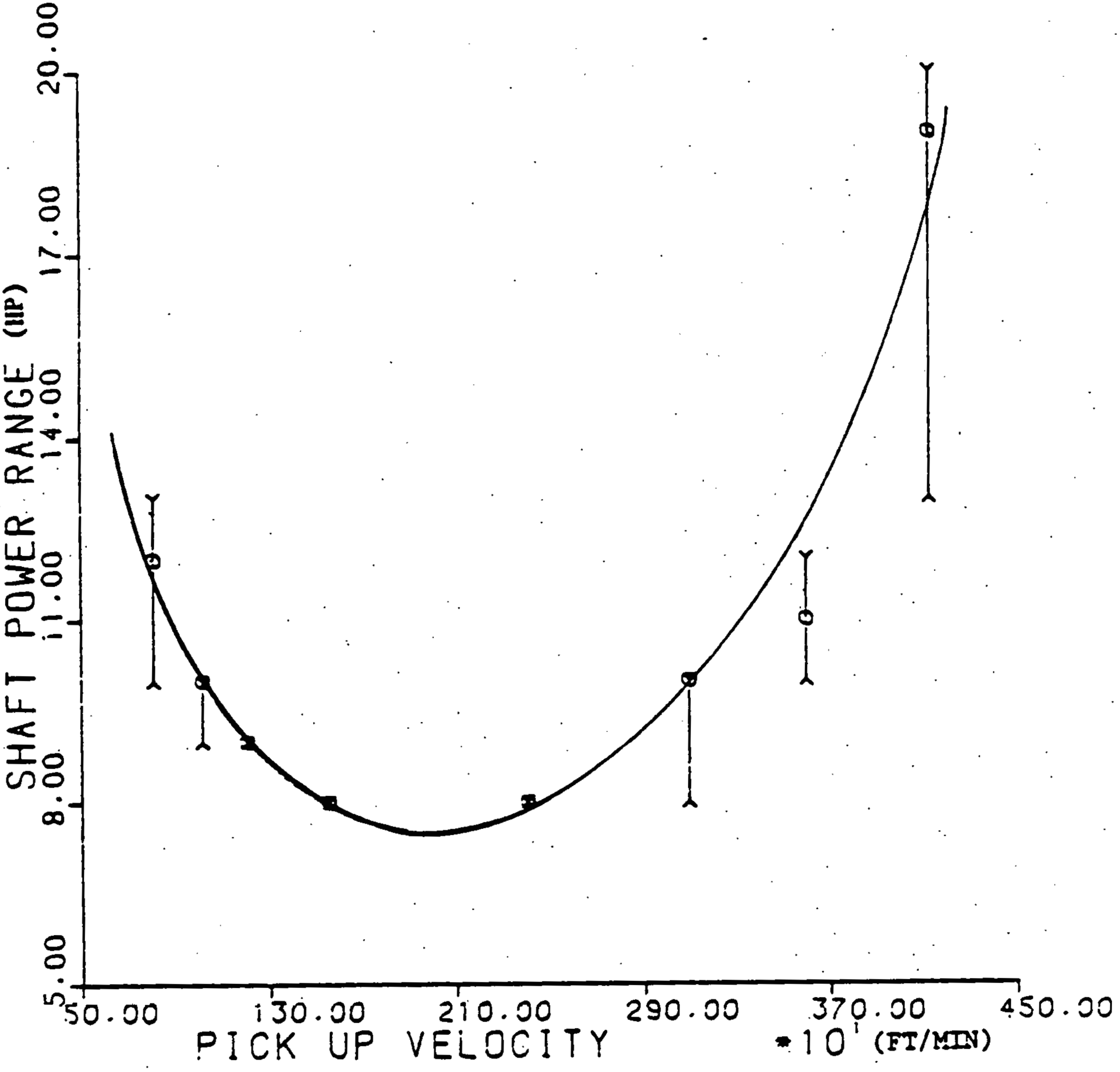
SCREW NUMBER 1126 RPM 1237

0 WEIGHTS 0 SPACERS 7 NOZZLES

LINE DIAMETER 4.00 LINE LENGTH 600

NOZZLE SIZE 0.6250 CONVEYING RATE= 200 LB./MIN

Figure 10
Effect of Pickup Velocity on Power Consumption (Run 225 KMAC)



STD. RIGHT

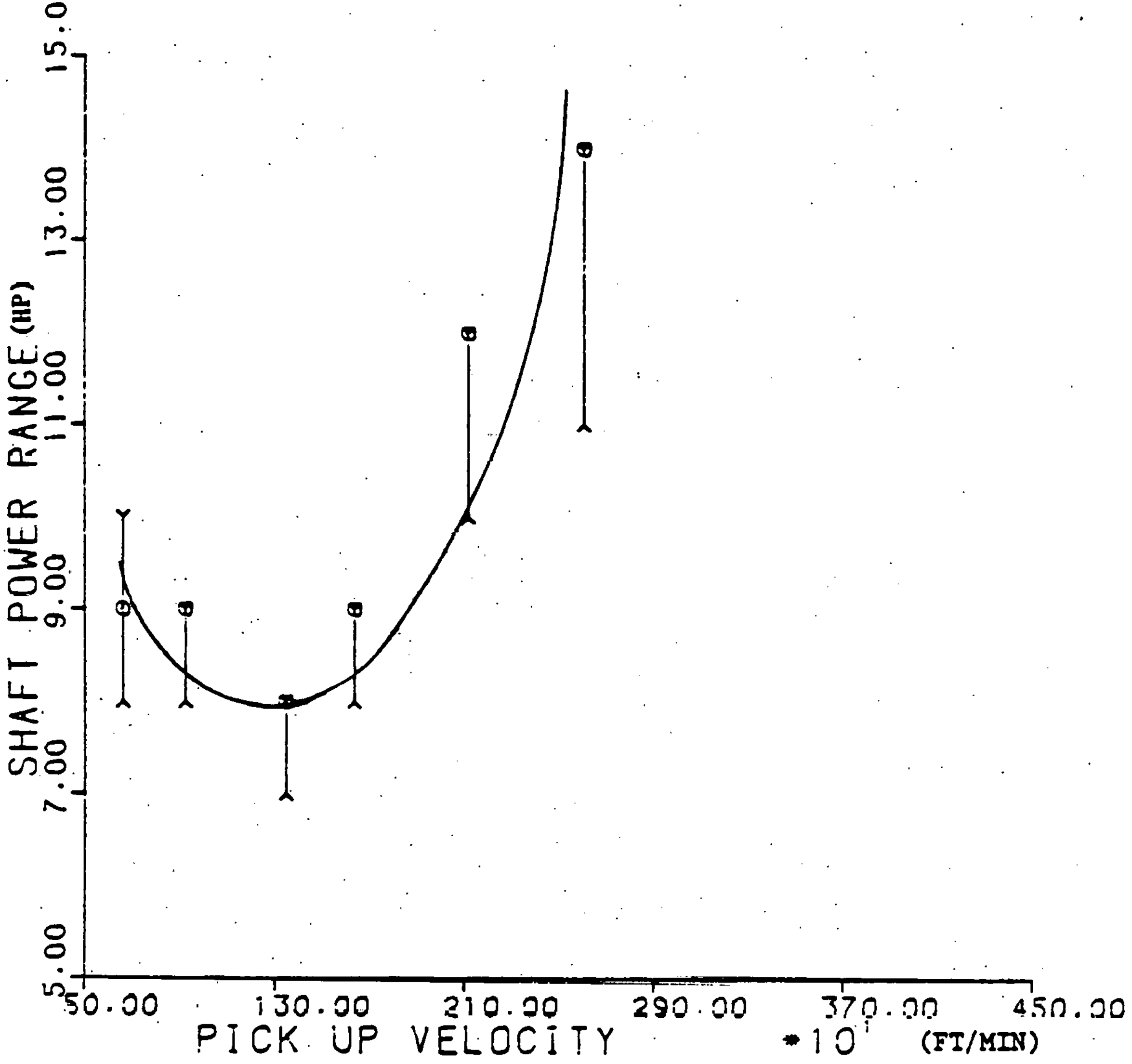
SCREW NUMBER 1126 RPM 1236

0 WEIGHTS 0 SPACERS 7 NOZZLES

LINE DIAMETER 4.00 LINE LENGTH 600

NOZZLE SIZE 0.6250 CONVEYING RATE = 180 LB/MIN

Figure 11
Effect of Pickup Velocity on
Power Consumption (Run 211 KMAC)



STANDARD RIGHT DISCHARGE

SCREW NUMBER 1126 RPM 1237

0 WEIGHTS 0 SPACERS 7 NOZZLES

LINE DIAMETER 4.00 LINE LENGTH 600

NOZZLE SIZE 0.6250 CONVEYING RATE = 200 LB/MIN material particles in suspension, without creating the excessive pressure drop associated with high velocity. The optimum pickup velocity for Run 225 KMAC is believed to be approximately 1,500 ft/min, since minimum power was consumed at this point (see Figure 10). Below this velocity, slug flow and increased pressure drop were observed. Similar observations suggested that the pickup velocity for Run 211 KMAC can be optimized at approximately 1,300 ft/min. However, if one system is being used to convey both types of KMAC, then conveying both types (either individually or together) at 1,500 ft/min would not be a detriment. Having one flow rate would be more convenient when changing materials.

Attrition of the Material. Apparent particle attrition was observed during the ambient tests. Table 2 summarizes the results of the conveying characteristics observed during the study of material breakage. Following each pass of the material through the conveying system, approximately one-half of the material was returned to the feed bin. One-quart samples were then withdrawn from the bin for particle-size analyses. Results of the size analyses are listed in Table 3.

Fuller measured the particle size of the samples by using the dry mesh screen method. The data in Table 3 show that there was apparent attrition during the first cycle of operation. However, results from previous studies of KMAC particle-size distribution performed by Air Products and Chemicals, Inc.,[1] using the wet Microtrac technique, indicate that attrition did not occur (Table 4). The data for Runs 225BC, 225F, 225G, and 225I indicate that the median particle-size distribution falls within a reasonably narrow range, i.e., 25-45 µm. The median particle-size distribution cited in O'Leary's report[1] agrees well with the mean particle sizes measured for a run 225 KMAC sample at a later date.[2] The sample studied was obtained after it had passed through five cycles in the Fuller-Kinyon pump system. Table 5 presents the results: sample 3 and its repeat had almost the same mean diameters in all five

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[1] J. R. O'Leary, "Particle Size and Bulk Density of KMAC," Internal ICRC Memorandum, January 6, 1981.

[2] "Particle Size Analysis of KMAC Samples." Memorandum from W. W. Stawasz (Air Products) to Y. K. Bhide (ICRC), November 24, 1982.

Table 2

Conveying Characteristics Observed during Study of Material Breakage[a]

Line length (ft)	Flow rate		Supply pressure (psig)	Line pressure (psig)	Pickup velocity (ft/min)	Conveying capacity (lb/min)	Shaft power (hp)			Motor input power (hp)	Observation
	scfm	acfm					High	Avg	Low		
					Run 225 KMAC						
600	162.0	115.1	7	6	1,319.46	200	12	11	10	29.7	10
600	147.4	110.0	6	5	1,261.00	160	8	8	8	27.7	11
600	133.4	99.6	6	5	1,141.81	140	8	8	7	27.5	12
600	120.7	94.9	5	4	1,087.90	100	7	7	6	27.0	13
600	109.8	86.3	4	4	989.47	100	7	7	7	27.1	14
					Run 211 KMAC						
600	177.1	125.8	7	6	1,442.47	200	10	10	9	28.3	22
600	168.7	125.9	6	5	1,443.75	160	8	8	8	27.7	23
600	152.5	119.8	5	4	1,374.40	120	7	7	7	26.3	24
600	136.4	107.2	4	4	1,229.38	100	7	7	6	25.2	25
699	127.3	105.7	4	3	1,212.16	80	7	6	6	26.3	26

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[a] Discharge housing, standard right; screw number, 116-81-4-1126; number of weights, 0; number of spacers, 0; number of nozzles, 7; nozzle size, 0.63 in.; line diameter, 4.0 in.

Table 3

Attrition Results--Percentage Passing Various Mesh Sizes

Condition	Mesh size							Bulk density (lb/ft^3)
	325	200	150	100	65	48	35	
Run 225 KMAC								
Fresh	49.5	65.4	75.5	85.6	92.8	97.1	100.0	24.6
After 1st pass	77.6	83.6	88.0	94.0	97.0	100.0		20.7
After 2nd pass	82.3	87.0	94.0	96.4	97.6	98.8	100.0	20.7
After 3rd pass	84.0	82.0	93.3	96.0	98.7	100.0		20.7
After 4th pass	87.5	91.6	94.4	96.5	98.6	99.3	100.0	21.6
After 5th pass	80.0	85.7	91.4	94.3	97.2	98.6	100.0	22.2
Run 211 KMAC								
Fresh	51.9	77.2	86.8	94.0	97.6	98.8	100.0	23.8
After 1st pass	84.0	87.7	92.6	95.1	97.6	98.8	100.0	21.2
After 2nd pass	75.3	85.7	89.6	95.8	97.4	98.7	100.0	21.2
After 3rd pass	85.6	90.4	93.6	96.8	98.4	98.4	100.0	20.9
After 4th pass	81.8	90.3	92.7	96.4	98.8	98.8	100.0	20.8
After 5th pass	73.9	87.0	91.9	96.8	98.4	98.4	100.0	21.3

Table 4

Summary of Material-Balance Results for KMAC[c]

Sample no.	Run no.	Particle size 50% (μm)	Particle size % <88 μm	KMAC[a] (% cresol insoluble)
61638	219AB	56	72	69.1
71525-B	220AB	59[b]	68	69.2
62534-B	220DE	49[b]	75	70.4
63315	221ABC	32	87	67.5
63550	221G	37	89	64.3
64106	222ABC	27	93	63.2
64985	225BC	34	84	68.3
65601	225F	45	84	67.0
65931	225G	28	88	64.0
65783	225I	36	81	66.2
67245	227A	49	69	69.8
61519-B	227CD	52[b]	74	66.1
68346	227E	48	74	65.2
69661	228AB	35	81	67.4
71526-F	229AB	28[b]	91	65.0
71521-B	230	18[b]	98	63.3

[a] Deashing solvent free.
[b] Average of three or more samples.
[c] From O'Leary; see footnote 1 to the text.

Table 5

Particle-Size Distribution of Run 225 KMAC Using a Microtrac Analyzer[a,b]

	Calculated surface area	Volume mean diameter	Particle size by distribution (μm)			% at 22 μm
			10% smaller than	50% smaller than	90% smaller than	
Sample 3						
Cycle 1	0.480	35.5	4.5	23.0	95.9	47.9
Cycle 2	0.485	33.6	4.6	22.3	83.3	49.2
Cycle 3	0.479	33.6	4.7	22.7	81.5	48.4
Cycle 4	0.481	34.4	4.6	23.0	89.4	47.8
Cycle 5	0.479	34.0	4.6	22.9	87.5	47.9
Average	0.481	34.2	4.6	22.8	87.5	48.3
Sample 3 (repeat)						
Cycle 1	0.524	36.5	4.3	20.0	98.0	52.5
Cycle 2	0.506	37.4	4.4	20.8	99.6	51.6
Cycle 3	0.478	39.3	4.5	24.2	101.0	46.8
Cycle 4	0.467	39.7	4.6	25.0	100.0	45.9
Cycle 5	0.457	40.9	4.7	25.8	103.0	45.2
Average	0.467	38.8	4.5	23.2	100.0	48.4
Sample 4						
Cycle 1	0.640	17.4	3.8	14.4	35.2	68.9
Cycle 2	0.639	17.3	3.8	14.5	35.0	69.2
Cycle 3	0.646	17.1	3.8	14.3	34.6	69.9
Average	0.642	17.3	3.8	14.4	34.9	69.3
Sample 5						
Cycle 1	0.650	17.5	3.7	14.4	35.2	69.3
Cycle 2	0.651	17.2	3.8	14.3	34.8	69.2
Cycle 3	0.633	18.9	3.8	14.8	37.4	67.3
Average	0.645	17.9	3.8	14.5	35.8	68.6

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[a] 10-min sonification, 400-sec sample time.
[b] From Stawasz memorandum; see footnote 2 to the text.

cycles. The average mean diameter was 34.2-38.8 μm, almost midway in the range reported by O'Leary.

These conflicting results suggest that the particle sizes measured during the Fuller tests were incorrect and that no major attrition occurred. One explanation for the difference between the size of the reference KMAC particles and that of samples from the next five passes is that the reference sample had been stored before being measured. KMAC agglomerates when stored for a long time. Thus, the KMAC that was recycled in the Fuller-Kinyon system was actually close to its original particle size (compare Tables 4 and 5), and had not broken down.

Accounting for Material Losses. Table 6 summarizes the distribution of material in the conveying system. This tabulation was made in order to approximate the quantity of material lost from dust collection, from being left in the conveying line, or from other losses.

After observation 1, approximately 100 lb of KMAC remained in the receiving bin throughout the test. During observations 1 through 9, 9 lb of KMAC was lost to dust collection. When the pickup velocities are lowered, material is expected to drop from the nitrogen stream and lay in the pipe. As seen in Table 6 for Runs 225 and 211 KMAC, some material remained in the conveying line.

Following observation 26, the conveying line was dismantled approximately 40 ft from the pickup point and inspected for material buildup. A residue approximately 1/4-in. thick was observed. A similar test was performed 30 ft from the end of the conveying system; the residue varied from 1/8 to 3/4 in. thick. It is speculated that the material was moving in waves through the conveying line.

Elevated-Temperature Tests

The objective of this phase of testing was to determine if KMAC could be conveyed at elevated temperatures. Results are listed in Table 7.

Runs 225 and 211 KMAC were tested at several temperatures and feed rates. Results and observations for each material were similar, and the discussion of each has been combined here to avoid repetition. Note that once the temperature of nitrogen entering the suspension preheater

Table 6

Distribution of Runs 211 and 225 KMAC in the Fuller-Kinyon Pump Conveying System

	Weight (lb) at observation number			
	1-9	10-14	15-21	22-26
Start	1,047	1,308	965	800
Reading on load cell at conclusion	960	1,290	980	800
Tare weight of receiving bin as indicated on load cell	0	100	140	140
Actual weight at conclusion	960	1,190	840	660
Loss to dust collection	9	16	11	7
Spillover to sample drums	0	78	0	116
Left in conveying line	78	4	114	17

Table 7

Results of Elevated-Temperature Tests

Material temperature entering pump (°F)	Nitrogen flow rate to preheater (scfm)	Nitrogen flow rate for conveying (scfm)	Line pressure (psig)	Conveying rate (lb/hr)	Motor amperage		
					1	2	3
		Run 225 KMAC					
189	575	41	2	2,310	17	14	15
264	575	41	1	1,584	16	12	14
357	575	41	1	1,540	16	12	14
419	575	41	<1	570	15	11	13
455	575	41	<1	396	15	11	13
		Run 211 KMAC					
431	620	41	1	1,740	15	12	16
446	620	41	1	1,080	15	12	16
467	620	41	<1	531	15	12	16
480	620	41	<1	531	15	12	16
500	620	41	<1	410	13	10	15
551	620	41	<1	350	13	10	15

reached approximately 850°F, the only way to raise the material temperature further was to lower the feed rate into the preheater, i.e., reduce the material-to-gas mass ratio.

At each pump inlet temperature, motor loads (amperages) were read. At all temperatures, no signs of material sticking were observed. The motor load never increased, which would have indicated binding or sticking in the pump and/or conveying line. The line pressure never increased during testing, leading to the deduction that material did not build up on the conveying line walls. This deduction was verified upon equipment disassembly. Both the pump and conveying line were inspected for material buildup. No measurable accumulation (less than 1/32 in.) was observed in the conveying line. Within the pump, there was approximately a 1/32- to 1/16-in. buildup on the inlet hopper walls and screw flights. However, this buildup is typical of most pump applications, and was merely a buildup of fine powder, rather than sticky material. Thus, buildup in the pump could be easily brushed or vacuumed off, leaving no residue. Overall, then, measurable material buildup did not result during conveying of KMAC up to temperatures of approximately 550°F. Thus, a Fuller-Kinyon conveying system should not be hindered by conveying KMAC at such temperatures.

An important point to note is that KMAC is combustible, which was demonstrated dramatically during these tests. At the conclusion of the elevated-temperature runs, the nitrogen supply was shut off; however, the baghouse fan continued to pull ambient air into the dust collector. Sufficient heat remained in the baghouse to ignite the KMAC in the presence of oxygen. Subsequently, all of the bags were lost.

Therefore, caution must be exercised during shutdown of the conveying system. Since all the components, such as the pump, cyclones, and baghouse, have been heated substantially during operation, they become a source of ignition for any KMAC remaining in or around the system. Therefore, the nitrogen should be flowed continuously after the feed is stopped, until the temperature of the equipment and remaining material has reached safe levels.

CONCLUSIONS

The results of the Fuller-Kinyon pump tests lead to the following conclusions:

1. The Fuller-Kinyon pump is a feasible means of conveying KMAC at temperatures up to 550°F.
2. KMAC can be conveyed satisfactorily at a pickup velocity of 1,500 ft/min.
3. Particle attrition is not believed to be a problem.
4. Measurable material buildup was not observed in either the pump or conveying line while KMAC was conveyed at temperatures up to 550°F.

CONVEYING KMAC IN A BLOWTANK CONVEYING SYSTEM

(PROGRAM 13.3.3)

INTRODUCTION

The Fuller-Kinyon pump tests described in the preceding section showed that KMAC is relatively easy to convey, in the sense that relatively low conveying velocities are possible. Lowering the velocity reduces system power consumption. During the pump tests, an air velocity at the conveying line entrance (the pickup velocity) of 1,500 ft/min yielded the least pressure drop in the conveying line and least power consumption. Although this velocity is not the best for all KMAC conveying systems, it serves as a reference point for sizing other methods, including blowtank conveying. Unless the system designed for the demonstration plant varies drastically from that tested, the 1,500-ft/min velocity will yield satisfactory results. It should be noted that this velocity is not critical; operating at ±20% of that rate will not drastically alter conveying characteristics.

Although the Fuller-Kinyon pump tests showed that elevated temperatures would not impede conveyance after the KMAC was in the conveying line, Fuller speculated that problems might be encountered in the blowtank system. Operating at high temperatures might enhance the tendency of the KMAC particles to stick to themselves, which could cause blockage of the blowtank. Normally, once blockage has occurred, it is difficult to quickly break up the solid particles and continue conveying.

Thus, the design of the blowtank tests was based on results from the Fuller-Kinyon pump test. KMAC was conveyed at temperatures up to 550°F at pickup velocities ranging from 1,000 to 1,500 ft/min. Any blockage in the blowtank was detected by monitoring the line pressure. During conveying, a drop in the line pressure indicated that material was not being fed into the conveying line. Then, if the amount of material received differed from the amount loaded into the tank, the system was checked for blockage. Discharge blockage was monitored by checking for a steady rise in tank pressure while there was no line-pressure drop, indicating that no flow of solids was occurring in the system.

The study's objectives were the same as those of the Fuller-Kinyon pump test:

1. Study problems that might be encountered when conveying KMAC from a blowtank at temperatures up to 550°F.
2. Determine the amount of material attrition (or particle breakage) during conveyance through the blowtank system.

APPARATUS AND PROCEDURE

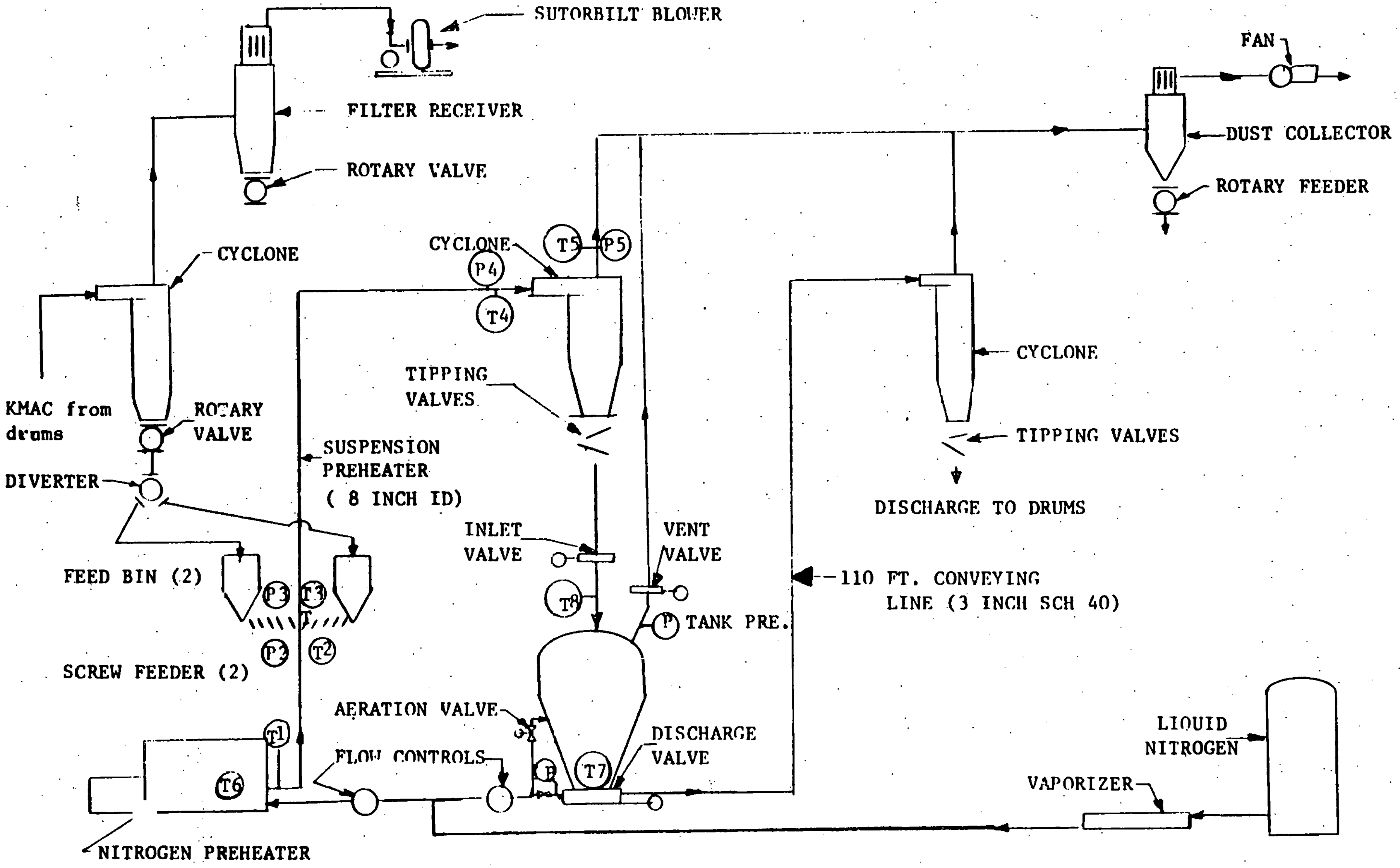
Feed System to the Blowtank

The system used to heat KMAC was basically the same as that used for the Fuller-Kinyon pump tests. In the blowtank tests, KMAC was withdrawn by vacuum from the drums and dropped through a rotary feeder into the screw feeder bins (Figure 12). The screw feeders injected the ambient-temperature KMAC into a suspension preheater, through which hot nitrogen flowed. The nitrogen was heated to as high as 850°F in an indirectly fired preheater. Regulation of the nitrogen flow rate is described in the following section.

The heated nitrogen entered an 8-in.-diameter suspension preheater, where it contacted the ambient-temperature KMAC. After reaching equilibrium temperature, the KMAC/nitrogen mixture entered a refractory-lined cyclone, which separated the nitrogen from the heated KMAC. The nitrogen was vented through a Plenum Pulse dust collector, and the KMAC was dropped through dual tipping valves into the blowtank. The drop leg to the tank was insulated with 2-in. calcium silicate insulation.

Thermocouples, installed at the locations shown in Figure 12, monitored the following temperatures, which were displayed on a digital readout: nitrogen temperature at preheater exit; nitrogen temperature before contacting KMAC; temperature of nitrogen/KMAC mixture just after contact; temperature of nitrogen/KMAC mixture entering cyclone; nitrogen temperature after being separated by cyclone; preheater enclosure at

Figure 12
Apparatus for Blowtank Test



preheater exit; KMAC temperature in bottom of blowtank; temperature of KMAC entering blowtank.

Blowtank and Conveying Line

After the blowtank had been filled, the KMAC was conveyed horizontally for approximately 50 ft in 3-in. Schedule 40 pipe. The KMAC then passed through two long radius (R/D = 12)[3] bends and was conveyed approximately 50 ft to a discharge cyclone. Total conveying distance was about 105 ft.

Gaseous nitrogen was used to convey the KMAC. Because the nitrogen was stored in a liquid state, it was first passed through a steam vaporizer. The steam vaporizer was used in lieu of a standard convection-type heat exchanger because the standard exchanger could not properly vaporize the nitrogen at the flow rates tested. The nitrogen used to heat the KMAC was regulated and measured as follows (see Figure 13). Nitrogen gas entered the system at 90-100 psig and immediately passed through a Fisher series 99 gas regulator, which lowered the supply pressure of the conveying system to 50 psig. Downstream of the series 99 regulator was a metering flow orifice used to both regulate and measure the air-flow volume. The gas regulator regulated only pressure, not volume, thus necessitating the use of some other volume-control device. Pressure taps strategically placed on each side of the orifice were connected to a mercury manometer, thus indicating the pressure drop, ΔP, across the orifice. The gas flow rate was calculated as shown in the sample calculations in Appendix 2.

Downstream of the orifice was a Fisher type 657ED diaphragm actuator, used to regulate the pressure drop across the orifice and thus the flow volume. Opening the actuator, which is similar to a control valve, increased the volume of flow to the system. This increase was measured by the ΔP across the orifice. The actuator received a signal from the pressure tap downstream of the orifice. The nitrogen flow was first fed through a Fisher type 67 volume regulator, to reduce the load pressure to that of the actuator's operating range (usually 5-40 psig). A Fisher series 98LD pressure relief valve, located upstream of the

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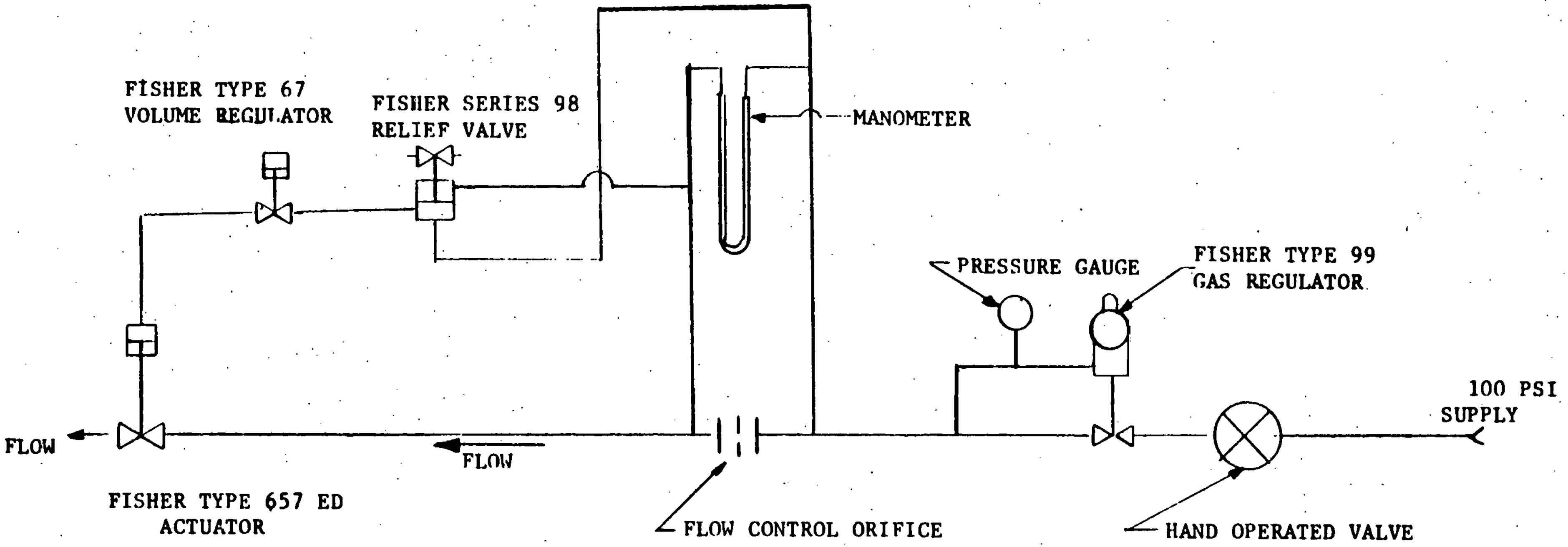
[3] R = radius of curvature of bend; D = diameter of tube.

Figure 13
Flow Control and Measurement System



actuator (see Figure 13), sensed the pressure differential across the orifice and opened or closed, allowing the proper pressure to be applied to the actuator. Thus, the actuator was not affected by changes in back pressure and accurately controlled the pressure differential of the orifice. The nitrogen supply was now completely regulated and was injected into the preheater.

The nitrogen used to convey KMAC was regulated and measured similarly. However, the diaphragm actuator and its controlling devices were replaced by a manually operated globe valve.

Both the line and tank pressures were monitored on a Bailey chart recorder. The pressure taps for these readings are also shown in Figure 12.

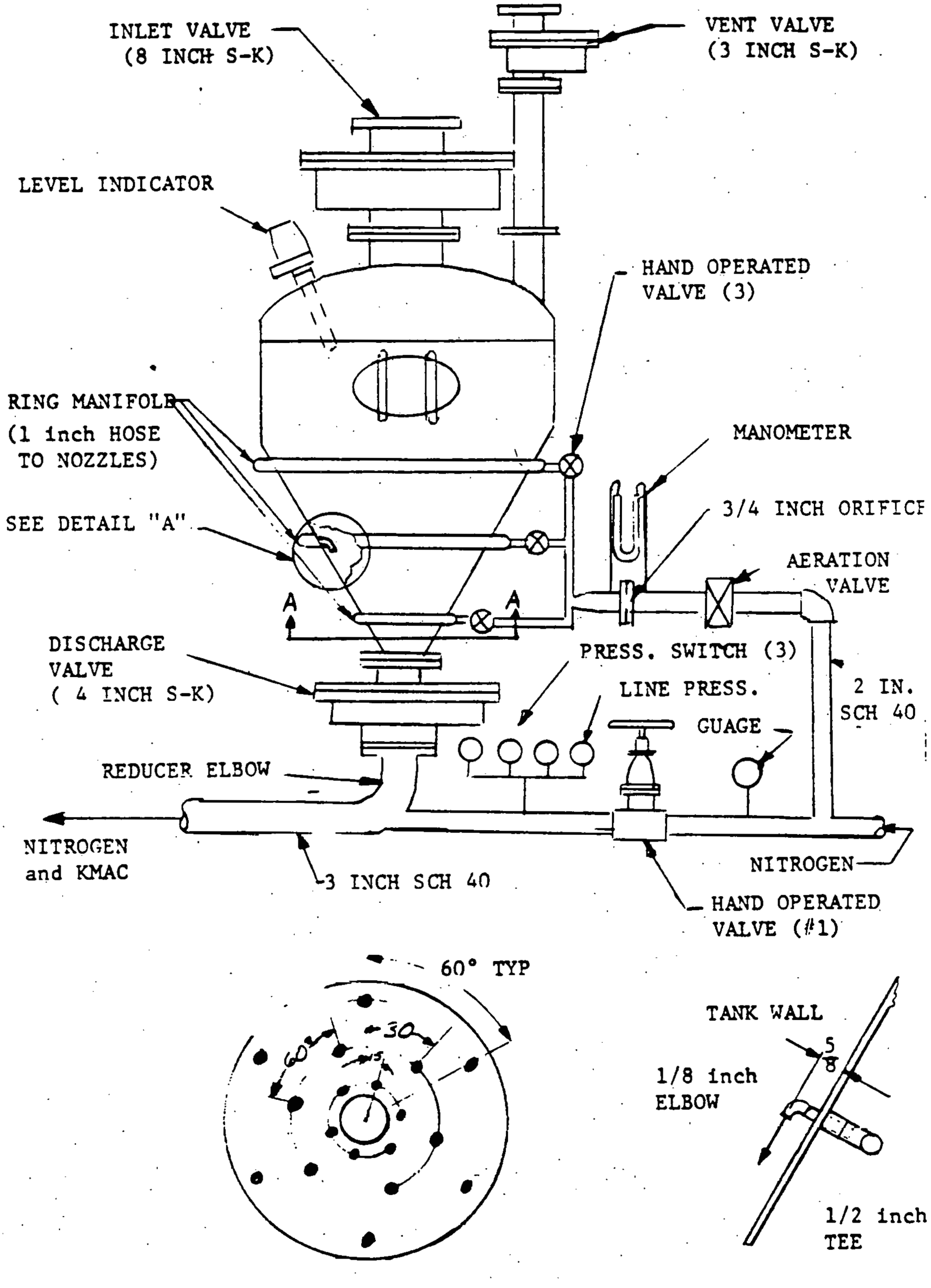
The conveying rate was determined by dividing the quantity of material conveyed by the run time. The run time started when the discharge valve was opened, initiating conveying, and continued until the line pressure returned to the "no-load" line pressure (i.e., the pressure observed from the flow of nitrogen only).

The blowtank (shown in Figure 14) is 48 in. in diameter, and has an approximate volume of 25 ft^3. The tank was designed to withstand 100-psig internal pressure at 500°F, and was hydrostatically tested to 150 psig according to ASME Code VIII design criteria.

As Figure 14 illustrates, the nitrogen was conveyed to the blowtank system in a 2-in. pipe; the flow was then split between the tank and the conveying line. A hand-operated valve (#1) adjusted the proportion of nitrogen added into the tank. Normally, this valve was adjusted during conveying until the pressure gauge upstream of the valve read 2-3 psig higher than the line pressure. In a field installation, once this adjustment is performed, this hand valve should never require readjustment.

Nitrogen entered the tank through three 1-in. internal diameter (i.d.) ring manifolds. Each manifold was fitted with a valve that could stop the flow if necessary. From each manifold, the nitrogen flowed through six 1/4-in. pipe nozzles. The nozzles were directed toward the blowtank discharge, and provided partial aeration of the material in the tank, facilitating discharge. The volume of nitrogen entering the tank was measured with a 3/4-in. flow orifice.

Figure 14
Blowtank for KMAC Conveying



A-A NOZZLE CONFIGURATION

DETAIL "A"

The blowtank was equipped with several valves. As indicated in Figure 14, Fuller one-way S-K valves were used as discharge, inlet, and vent valves. These air-operated valves, identical except for their size, have discs that slide perpendicularly to the flow of material and are positioned on beveled seats when closed (see Figure 15). They differ from butterfly valves in that they do not obstruct the flow of material. These S-K valves are either on or off and do not regulate flow. The aeration valve was a 2-in. Demco air-operated butterfly valve.

Both the discharge valve and aeration valve were connected to Mercoid pressure switches. The switch connected to the aeration valve controlled the discharge of material from the tank by closing the valve at a set pressure. As the line pressure dropped to a second set point on the switch, the valve was reopened and material was again forced into the conveying line. By changing the settings of the pressure switch, the system could be operated at different line pressures and, therefore, capacities. For this test, the valve closed at 7 psig and reopened at 5 psig.

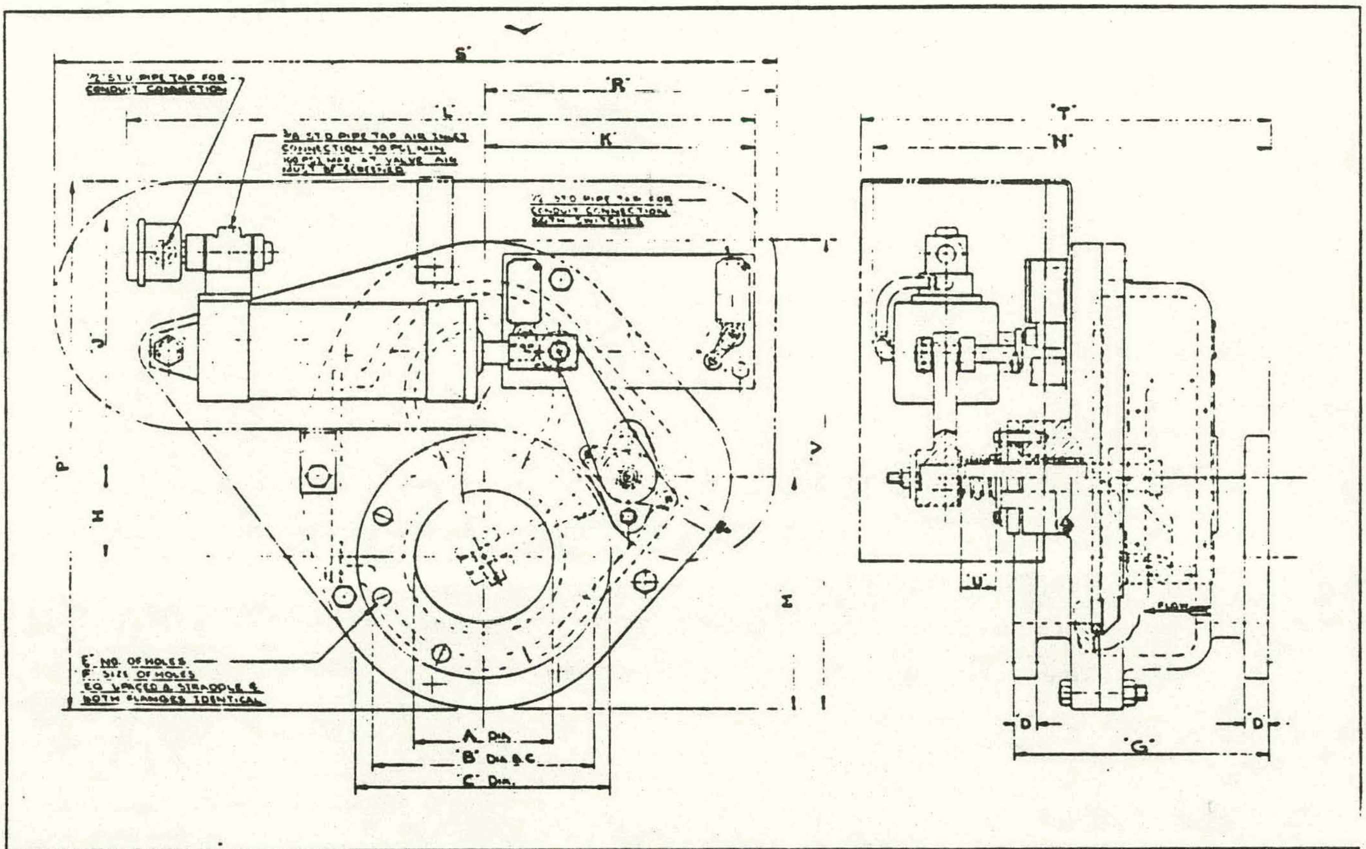
Another Mercoid switch was connected to the discharge valve. This switch was set at a slightly higher pressure than that controlling the aeration valve. If the line pressure continued to increase after the aeration valve was closed, this switch closed the discharge valve. Normally, the discharge valve will not close during conveying; however, should it happen, the valve will close at 8 psig and reopen at 6 psig.

The inlet valve was opened after the blowtank had been relieved of pressure. The vent valve, connected to a dust collector, was opened prior to opening the inlet valve. The venting system also provided a passage for the air being displaced by the material entering the tank.

The normal sequence of operation consisted of the following steps:

1. Vent valve opened.
2. Inlet valve opened.
3. Material filled blowtank until the level indicator was actuated.

Figure 15
Fuller Co. One-Way S-K Valve



DIMENSIONS

AIR CYLINDER OPERATED

SIZE	A	B	C	D	E	F	G	H	J	K	L	M	N	P	R	S	T	U	V
3"	3"	6"	7½"	1"	4	¼"	10"	2"	9⅝"	8⅝"	20½"	6⅛"	15¼"	17¼"	9½"	2'-0"	15¾"	1½"	13¼"
4"	4"	7½"	9"	1"	8	¾"	10½"	2½"	10⅝"	10¾"	22½"	7⅝"	15⅝"	19½"	11⅝"	2'-2⅜"	16¼"	1½"	15¼"
5"	5"	8½"	10"	1"	8	⅞"	10½"	3"	10½"	10½"	23⅞"	9⅛"	16¼"	21⅜"	11½"	2'-3¼"	16¾"	1½"	18¼"
6"	6"	9½"	11"	1"	8	⅞"	11"	3⅝"	11⅝"	11¾"	2'-3"	10½"	16⅞"	23⅝"	12½"	2'-7"	17½"	1½"	21"
8"	8"	11¾"	13½"	1"	8	⅞"	14"	4⅝"	11⅝"	13⅜"	2'-2⅞"	13⅛"	19¼"	2'-2¼"	14¼"	2'-6"	19¾"	1½"	2'-2¼"
10"	10"	14¼"	16"	1⅛"	12	1"	17¾"	5⅝"	13⅞"	16⅛"	2'-4⅞"	15⅜"	23½"	2'-7½"	18"	2'-9¼"	2'-0"	2"	2'-6¾"

4. Inlet valve closed.
5. Vent valve closed.
6. For continuous operation: aeration and discharge valves opened, blower was running. For intermittent operation: blower began running.
7. Line pressure increased as material was being conveyed.
8. Line pressure decreased as blowtank was emptied.
9. Low-pressure switch activated.
10. Discharge valve closed.
11. Aeration valve closed.
12. Vent valve opened, allowing the remaining pressure in the tank to escape (refer to step 1).
13. Inlet valve opened and the entire cycle was repeated (refer to step 2).

This sequence is typical of automatic blowtank operation. However, any or all of the valves could be operated manually in order to deviate from the above sequence.

Note that a third Mercoid switch was set at or near the no-load line pressure in order to close the discharge and vent valves (see steps 10 and 11).

Procedure

The test procedure comprised 12 steps:

1. Nitrogen flow rate to the preheater was set.
2. Fuel to the preheater was turned on.
3. While the preheater was reaching the desired temperature, the KMAC was vacuum-conveyed into feed bins.
4. Inlet and vent valves to the blowtank were opened.
5. After the nitrogen reached the desired temperature, the screw feeders were turned on.
6. The feeder speed was adjusted until the KMAC entering the blowtank (at point #8) had reached the desired temperature.

7. KMAC was fed until the blowtank level indicator actuated the closing of the inlet valve or until the observer felt there was enough material in the tank for a conveying run.
8. Inlet and vent valves were closed, if the system was operated manually.
9. Nitrogen was turned on for conveying.
10. Aeration and discharge valves were opened. Conveying was now in progress.
11. Readings on the pressure gauges and manometer (across orifice measuring the flow to the tank) were recorded.
12. When the tank and line pressure returned to a no-load condition, steps 3-11 were repeated at a new KMAC temperature.

RESULTS AND DISCUSSION

Results are summarized in Tables 8 and 9. The temperatures in Table 8 were corrected following calibration of the thermocouples.

Problems Encountered

Preheater. A very interesting observation was accidentally discovered during the first few test runs. When the blowtank for run 4 was being loaded, a sharp pressure rise was noted in the suspension preheater. The pressure increase was enough to force the hoses and fluid from the water manometers that were measuring the pressure below and above the feed point in the preheater. As discussed in the section on the Fuller-Kinyon pump, a rise in pressure indicates a restriction in the pipe, provided the flow rate has not been altered. Therefore, when the pressure rise was noted, simple deduction led to the conclusion that the flow through the preheater was becoming restricted. Disassembly showed that the KMAC had adhered to the preheater walls, building up a layer that eventually filled the entire cross-sectional area of the preheater. Large, brittle chunks of KMAC were subsequently removed. Nearly the entire length of the preheater had some buildup of KMAC on the walls, with most located near the feed point.

Table 8

Flow Rate Conditions for Runs 1-8

Run no.	KMAC no.	Nitrogen flow rate (scfm)	Line pressure (psig)	Pickup velocity (ft/min)	Flow rate to tank (scfm)	Conveying rate (tph) (approx.)	KMAC temp. into tank (°F)
1	225	89	3.0	1,600	N/A	7.3	127[a]
2	225	89	3.0	1,600	30	8.5	337[a]
3	225	89	4.0	1,505	29	8.5	337[a]
4	225	86	3.5	1,495	29	6.8	395[a]
5	225	86	3.0	1,530	37	8.0	428
6	225	86	3.0	1,530	37	7.2	470
7	211	79	4.0	1,330	32	9.6	470
8	211	79	3.5	1,375	32	12.5	550+

[a] Temperature at bottom of blowtank.

When this plugging was observed, the temperature below the feed point was approximately 1,100°F, whereas that above the feed point was 915°F. Because the KMAC feed rate could not be precisely measured in these experiments, determining the exact KMAC temperature was impossible. During the testing of KMAC sample 211, the temperature below the feed point reached approximately 1,020°F. At this temperature, KMAC also built up on the walls, although not to the extent noted earlier. A 3/8-in.-thick buildup, extending from 8 in. below the feed point to 6 in. above the feed point, i.e., the hottest area occupied by the KMAC, was removed from the preheater walls at the conclusion of the test. The KMAC entering the blowtank was estimated at 580°F. The rest of the preheater was free of buildup. Therefore, it is believed that the critical point where the KMAC becomes adhesive is between 580°F (the temperature of the KMAC entering the blowtank) and 775°F (the temperature above the preheater feed point). Note that the temperature above the feed point is that of the nitrogen/KMAC mixture; the exact KMAC temperature is unknown.

Blowtank and Conveying Line. In addition to the chunks of KMAC found plugging the suspension preheater, large (approximately 4 to 5 in.) agglomerations of KMAC were subsequently found in the blowtank. These solid pieces completely stopped the discharge of material from the tank. Chart recordings of line and tank pressure show that the tank pressure rose rapidly when the conveying cycle started, while the line pressure remained at a no-load condition, thus indicating a blockage of the tank discharge. The KMAC agglomerations were discovered after the tank was allowed to set overnight following the plugging of the suspension preheater. Conceivably, the KMAC could have ignited while it was held in the tank; however, no evidence of burning (smoke stains or burnt paint) was noticed. Since the same thing could happen in a field installation, necessary precautions should be taken. Unfortunately, whether the KMAC agglomerated because of high temperatures, as it did in the preheater, or whether it ignited and adhered is unknown. In either case, this was the only incidence of problems occurring in the tank or during conveying.

Run 225 KMAC was successfully conveyed, in Run #6, at temperatures (going into the tank) of 470°F. During the first four runs, the temperature of the KMAC entering the tank was not measured.

During Run 6, the line pressure was 3 psig, and 85 scfm of nitrogen was used, resulting in a superficial velocity at the conveying line entrance of approximately 1,455 ft/min. No conveying problems were observed nor was any KMAC buildup noted in the conveying line or discharge cyclone. Approximately 7.2 tph was conveyed during this run.

Run 211 KMAC was successfully conveyed at tank inlet temperatures up to 580°F. During Run 8, the inlet temperature varied from 550 to 580°F. At these temperatures, no agglomeration problems were observed either in the material discharge from the blowtank or in the conveying line. When the blowtank was disassembled, a thin (less than 1/32 in.) coating of KMAC was found on the inner tank walls. This was not the burnt-on buildup seen in the preheater, but was a powder that could be easily brushed from the walls. Examination of the conveying line also did not reveal any buildup of KMAC. The screen analyses described in the next section show that some particle-to-particle adhesion was probably present during Run 8. However, no large agglomerations of KMAC were observed.

Attrition

Investigation of KMAC attrition during this test did not truly indicate what would occur in a standard field installation. During the current test, the KMAC was exposed to two potential sources of attrition that would not be present in a field system. First, the KMAC was vacuumed from drums. Because the KMAC was conveyed only a short distance from the drums, no appreciable attrition should result from this operation; however, the fact that the vacuuming was done should be kept in mind.

Second, the most severe source of attrition not directly related to the blowtank system is believed to be the screw feeders used to charge the suspension preheater. The screw feeder's operation creates a centrifugal force that causes the particles to grind against each other. However, attrition from this source should not be nearly as great as that from the screw of a Fuller-Kinyon pump. The pump operates at 1,200 rpm, whereas the screw feeders in this test operate at speeds from 80 to 400 rpm. At such slower speeds, the centrifugal forces creating friction are not as severe and attrition is expected to be lower.

Negligible attrition is expected in the suspension preheater, due to a combination of the short conveying distance (18 ft) and the reduced wall-to-particle friction in vertical conveying.

KMAC samples were collected from the drums before each test run and twice during the run at the discharge point. The results are tabulated in Table 9. Keep in mind that these were random samples, and absolute agreement from sample to sample may not be present. Of course, the more samples, the greater the level of confidence (statistical) in the results.

The first interesting observation is the large variation in the particle size of the feed from run to run. This does not particularly apply to Run 211 KMAC, but an extremely large variance can be seen in Run 225 KMAC. For example, in Run 31, only 43% of the sample passed a 325 mesh screen, but in Run 2, nearly 80% passed 325 mesh. The reason for this variance is uncertain. Many drums contained agglomerations resembling cement clinker; perhaps the drum sample in Run 1 was unusually laden. Such agglomerations or chunks of material will be eliminated at the SRC-I Demonstration Plant.

As the data in Table 9 show, drawing a definitive conclusion regarding KMAC attrition is very difficult. In some cases, for example, Runs 2, 3, and 7, the attrition is small: in general, only an 8% increase in the quantity of material passing 325 mesh was observed, with the increases being less for larger mesh sizes. The results of other runs such as Run 1 lead one to believe that attrition is appreciable--a 43% increase in the amount of material passing 325 mesh was noted. This increase is not believed to be typical of the system's operation, but rather a result of the lack of agglomerations in the samples taken at the product discharge. This does not mean that the agglomerations were broken up; it means that they were not present in the random samples taken. In Runs 4 and 8, an actual decrease in the quantity of material passing the various mesh sizes was evident. Note that these two runs

Table 9

Attrition Test Results for Blowtank System

Run		Bulk density (lb/ft^3)	% material passing various mesh sizes									
			28	Change	65	Change	150	Change	200	Change	325	Change
1	Feed	24.8	97.2		80.5		62.4		54.1		43.0	
	Product	21.2	100.0	+2.8	N/A	N/A	N/A	N/A	92.0	+37.9	86.0	+43.0
2	Feed	24.4	98.1		92.3		84.6		80.8		71.2	
	Product	19.9	100.0	+1.9	93.2	+0.9	86.4	+1.8	81.9	+1.1	79.6	+8.4
3	Feed	21.6	99.1		96.5		89.6		81.0		67.2	
	Product	22.2	98.1	-1.0	96.2	-0.3	88.8	-0.8	82.3	+1.3	75.8	+8.6
4	Feed	20.0	100.0		97.3		87.8		81.0		71.5	
	Product	29.1	95.2	-4.8	92.0	-5.3	83.3	-4.5	75	-5.6	58.7	-12.8
5	Feed	25.4	98.9		97.8		95.5		83.8		66.6	
	Product	23.8	99.4	+0.5	98.1	+0.3	96.2	+0.6	85.9	+2.1	73.1	+6.5
6	Feed	24.9	98.5		94.9		85.4		71.5		51.8	
	Product	25.9	100.0	+1.5	97.2	+2.3	87.8	+2.4	78.4	+6.9	60.5	+8.7
7	Feed	23.7	100.0		98.7		90.7		81.4		64.1	
	Product	26.4	100.0	0.0	100.0	+1.3	96.9	+6.2	90.0	+8.6	71.9	+7.9
8	Feed	22.7	100.0		100.0		93.3		83.7		65.4	
	Product	28.5	100.0	0.0	100.0	0.0	92.9	-0.4	82.7	-1.0	63.3	-2.1

were conducted at the highest temperatures tested, which could have caused KMAC adhesion, as previously discussed. These results lead one to believe that the KMAC particles did begin to adhere to each other. Note that in both Runs 4 and 8, the bulk density of the material increased significantly, indicating that the particles may have joined, thus eliminating voids between them. The material appeared brittle even after particle-to-particle adhesion.

In general, the use of a blowtank system apparently does not result in appreciable material attrition at temperatures below that of KMAC adhesion, approximately 575-775°F. Above the adhesion temperature, attrition of individual particles is impossible to determine because of the larger sizes of the KMAC joint particles (more than one particle joined).

CONCLUSIONS

From the results and discussion, it can be concluded that:

1. A blowtank can be used to convey Kerr-McGee ash concentrate at temperatures up to 550°F.

2. The KMAC becomes adhesive at some temperature between 580 and 775°F, was observed to be brittle after adhesion, and could be broken easily.

3. Directly measuring material attrition was difficult because the feed composition varied and the sample was small (statistically speaking). In addition, at temperatures above 550°F, the attrition of individual particles was impossible to determine due to interparticle adhesion.

COMPARISON OF FULLER-KINYON PUMP AND BLOWTANK

The Fuller-Kinyon pump and blowtank can be compared in terms of operational advantages and disadvantages. Test results show that both pieces of equipment can be used to convey KMAC up to 550°F. The determining factor is which unit will offer better long-run performance.

Both systems have several advantages. When fed from a constant height of material, the Fuller-Kinyon pump is capable of essentially constant-volume delivery. Should large chunks of nonsticky material make their way into the pump, the screw is normally capable of pulverizing and conveying them. In contrast, the tests showed that the same large chunks could cause blockage of the discharge in the blowtank, actually stopping the conveying process.

The Fuller-Kinyon pump operates continuously, and can be fed at any rate up to its maximum without shutdown. On the other hand, the blowtank is a batch process, with discrete fill and discharge cycles. During filling of the blowtanks, no conveying occurs; during conveying, no filling occurs. However, two parallel blowtanks can be used, providing a fairly continuous conveying process.

The Fuller-Kinyon pump and dual blowtank systems would operate at essentially the same conveying line pressure and gas rate. The Fuller-Kinyon pump would require a motor to drive the pump screw (~125 hp) and a rotary feeder (~3 hp).

In the design of the SRC-I Demonstration Plant, as in many other designs, the amount of headroom a piece of equipment requires may be a major consideration. Unless special foundations and a pit are built to lower the blowtank below ground level, the Fuller-Kinyon pump offers a distinct headroom advantage. The pump, equipped with a rotary feeder and cutoff valve, is approximately 9 ft high; the blowtank specified by ICRC is approximately 22 ft high.

Another factor to be considered is the heat loss from the KMAC. In the blowtank system, the material will probably lose heat through the vent during the filling cycle. Since the material sits in the tank during filling, there is more time during which heat can be lost. In the pump, the KMAC is held for a very short time.

From the standpoint of mechanical reliability, the blowtank offers the advantage of having few moving parts. A typical problem of the blowtank system involves wear of the S-K discharge valve seat and disc. This type of valve, as discussed previously, differs from a butterfly valve. The flow of material is not obstructed except during opening or closing; therefore, it normally takes several years before any significant wear is evident. The S-K valve is quite simple to repair; if the parts are on hand, most repairs take less than 1-2 hr. If the valve cannot be repaired by the customer, an exchange program can be arranged with Fuller. In this program, the customer returns the valve and Fuller will immediately send an already refurbished valve at a cost much lower than that of a new valve. Other problems that are occasionally experienced are clogged pressure taps (despite purging), which lead to erroneous triggering of the pressure switches.

The Fuller-Kinyon pump may be subjected to screw wear. Friction between the screw and material can wear the screw flights, causing a subsequent reduction in the conveying rate. The screw's wear rate is a direct function of the coarseness and abrasiveness of the material being conveyed. If required, a special hard-surface coating can be applied to the screw flights to reduce the wear rate. In the case of KMAC conveyance, no special problems are expected with the screw wear rate. For materials such as KMAC, the useful life of a screw will vary from 1 year to several years, depending on the frequency of use. As was the case with S-K valves, Fuller also has a pump screw exchange program.

From an operational viewpoint, the Fuller-Kinyon pump will be less susceptible to blockage due to oversize material. Should large particles of KMAC enter or agglomerate within the tank, the blowtank discharge will become clogged. Therefore, the pump is believed to offer the advantage that it can operate under more severe variances of material feed, in terms of temperature and particle size. This point must be carefully considered for a manufacturing process that operates continuously.

Overall, comparison of both tests leads to the following conclusions:

1. Either the Fuller-Kinyon pump or a blowtank is capable of conveying hot KMAC (up to 550°F).

2. The Fuller-Kinyon pump is not very susceptible to blockage. In contrast, the blowtank system, even if fed with screened material, could be blocked by material that agglomerated within the tank.

3. The blowtank system will require more headroom than the Fuller-Kinyon pump system.

4. The Fuller-Kinyon pump will require more power than a dual blowtank system (assuming that each uses the same pipe internal diameter and line pressure).

5. Material attrition is expected to be lower in the blowtank system.

6. Heat loss from the KMAC may be greater in the blowtank system.

Technically, no clear-cut advantage seems to exist for either system; both can convey KMAC to the gasifier satisfactorily However, the results do indicate that the Fuller-Kinyon pump system is more reliable than the blowtank system. This was substantiated by a study recently completed by the German company GKT, which compared both systems technically and economically (see Appendix 3). In addition to confirming Fuller's conclusions, GKT pointed out the following additional advantages to Fuller-Kinyon pumps:

- Fuller-Kinyon pumps have been used to transport materials more abrasive than KMAC.
- Fuller-Kinyon pumps are not as high as blowtank conveying systems, so they will need less steel support. Also, because of their shorter height, large intermediate bunkers that feed

the conveying system can be installed, which will allow operating personnel to switch over to a standby unit if any repairs are needed.

- Fuller-Kinyon pumps are more reliable because they have fewer moving parts to erode; regular inspection and maintenance are easily performed.
- The sealing surfaces of valves in a blowtank operating at 420°F may be unreliable.

GKT also suggested designing the transport of KMAC with nitrogen using a ratio of 0.8-0.9 lb of KMAC/scfm of nitrogen. This ratio is based on their industrial experience in moving bulk materials.

Finally, comparison of capital and operating costs shows that the estimated equipment and annual capital costs seem to be higher for the blowtank system, while the utilities costs for the Fuller-Kinyon pump are higher. The overall difference in costs, including operating and capital costs, favors the pump system by only $10,000/year (see Appendix 3, p. 8). Thus, the economics of the two conveying systems do not differ dramatically.

Based on Fuller's study and GKT's work, ICRC favors including the Fuller-Kinyon pump in the Baseline Design for the SRC-I Demonstration Plant.

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Appendix 1

Sample Calculations for Fuller-Kinyon Pump Tests

Determination of Volumetric Flow Rate

$$\text{scfm} = K[P_u \times (\Delta P)^{0.85}]^{\frac{1}{2}}$$

where K = empirical constant determined through orifice calibration (K = 5.71 for 3/4-in. orifice)

P_u = absolute pressure upstream of orifice (psia)

ΔP = pressure drop (percent from chart recorder)

If P_u = 30 psia and ΔP = 30, then the flow rate is:

$$\text{scfm} = 5.71[(30 + 14.7) \times (30)^{0.85}]^{\frac{1}{2}} = 162$$

Determination of Pickup Velocity

If the line pressure (P_L) = 10 psig and 162 scfm is used at 100°F:

$$\text{acfm} = \text{scfm} \times [P_{std}/(P_L + 14.7)] \times (T_{line}/T_{std})$$

$$= 162 \times [14.7 \text{ psia}/(10 + 14.7 \text{ psia})] \times (560°R/530°R)$$

$$= 102 \text{ cfm}$$

Then:

$$\text{pickup velocity} = \text{acfm/pipe area}$$

$$= \text{acfm}/(\pi D^2/4)$$

$$= \frac{102/[\pi(4 \text{ in.})^2/4]}{144 \text{ in.}^2/\text{ft}^2}$$

$$= 1{,}169 \text{ ft/min}$$

Power Input to Motor

At 490 V, 60 amps, and a power factor of 40:

$$\text{horsepower used} = \text{volts} \times \text{amps} \times \frac{\text{power factor}}{100} \times 3 \times 0.00134 \text{ hp/W}$$

$$= 490 \times 60 \times 40 \times 3 \times 0.00134$$

$$= 27.29 \text{ hp}$$

Appendix 2

Sample Calculations for Blowtank Conveying System

Flow Rate to Conveying System

$$\text{scfm} = K(P_u \times \Delta P)^{\frac{1}{2}}$$

where K = empirical constant determined through calibration
(= 4.98 for ½-in. orifice)
P_u = upstream pressure (psig)
ΔP = pressure drop across orifice (psi)

If P_u = 45 psig and ΔP = 5 psi as in Run 6, then the flow rate is:

$$\text{scfm} = 4.98[(45 + 14.7) \times 5]^{\frac{1}{2}} = 86$$

Pickup Velocity

Given a line pressure (P_L) of 3 psig and a temperature of 100°F:

$$\text{acfm} = \text{scfm} \times [P_{std}/(P_L + 14.7)] \times (\text{temp}/T_{std})$$

$$= 86 \times [14.7 \text{ psia}/(3 + 14.7 \text{ psia})] \times [(100 + 460)°\text{R}/530°\text{R}]$$

$$= 75 \text{ acfm}$$

Then:

$$\text{pickup velocity} = \text{acfm}/\text{area of pipe}$$

$$= \text{acfm}/(\pi D^2/4)$$

$$= \frac{75/[\pi(3 \text{ in.})^2/4]}{144 \text{ in.}^2/\text{ft}^2}$$

$$= 1{,}528 \text{ ft/min}$$

Flow Rate to Tank

The orifice used was designed and calibrated by Bethlehem Steel Corp.

$$\text{scfm} = 0.3659YD_p^{\,2}(P_u \Delta P/T)^{1/2}$$

where Y = empirical constant based on ratio of orifice diameter to pipe diameter

D_p = pipe diameter

P_u = upstream pressure (psig)

ΔP = pressure drop (inches H_2O)

T = upstream temperature (°R)

For Run 6, P_u = 5 psig and ΔP = 22 in. H_2O:

$$\text{scfm} = 0.3659(29.1)(2.06)^2\{[(5 + 14.7)(22)]/560°R\}^{1/2} = 37.5$$

Conveying Rate

This rate is only approximate, because some KMAC will be left in the feed bin between runs. For Run 6, 458 lb of KMAC was loaded. From the chart recorder, 1.9 min elapsed from the start of the conveying cycle until the line pressure returned to a no-load condition. Therefore:

$$\begin{aligned} \text{capacity} &= 458 \text{ lb}/1.9 \text{ min} \\ &= 241 \text{ lb/min} \times 60 \text{ min/hr} \times \text{ton}/2{,}000 \text{ lb} \\ &\doteq 7.2 \text{ tons/hr} \end{aligned}$$

Appendix 3

GKT's Engineering Review of Fuller Reports

GKT
Gesellschaft für Kohle-Technologie mbH

Report

SHEET 1 OF
PROJ. NO. 4709 A
PROJECT SRC-I Demopl.

Subject: Engineering Review of Fuller Reports
on - Conveying KMAC in Fuller-Kinyon pumps dated April 82

- Fuller Report about conveying of KMAC in a blow tank dated June 82.

Prepared for International Coal Refining Company,
Allentown, PA. USA
ICRC Subcontract No.: 01 11 002
Amendment No. 12

GKT Project No.: 4709 A

Project-Manager: H.J. Heck

Reported by : W. Wacker

REV.	DEP.	BY	CHECKED	DEP.	BY	CHECKED	REV. a	REV. b	REV. c	REV d	REV. e
NAME	VZ-V										
DATE		11.5.83									

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GKT
Gesellschaft für Kohle-Technologie mbH

Report

SHEET 2 OF
PROJ NO 4709 A
PROJECT SRC-I Demopl.

FORM 55/E 1.81

Contents:

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4. Cost estimate details 9 - 11

— REV.	DEP	BY	CHECKED	DEP.	BY	CHECKED	REV. a	REV b	REV c	REV. d	REV. e
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Sch

1. Introduction

The Fuller Company has conducted studies for ICRC with respect to the feasibility of pneumatic conveying of Kerr-McGee Ash Concentrate. The results of these studies are presented by Fuller in two reports dated April and June 82. GKT reviewed these documents under the following aspects:

(i) Operational reliability, flexibility and safety

(ii) System selection recommendation

(iii) Capital and operating cost comparison between system alternatives.

The following report presents the results of GKT's review incorporating GKT's experiences from many operating plants using both types of system, pneum. pumps and blow tanks, for conveying coal dust from the coal dust preparation unit to the coal gasification unit.

The detailed results of the Fuller Reports have been reviewed by GKT. GKT did not find deviations of the details in these reports which could lead to a change of the general conclusions and recommendations given by GKT.

REV.	DEP.	BY	CHECKED	DEP	BY	CHECKED	REV. a	REV. b	REV. c	REV. d	REV. e
NAME	VZ-V	Wadé									
DATE		11.5.83									

GKT-Comments

Principly it can be stated that both systems, pneum. pump and blow tank, represent a proven technology for the purpose of conveying dry bulk materials over a horizontal and/or vertical distance of several hundred feet. The general application of these systems for conveying Kerr McGee Ash Concentrate at elevated temperatures 500°F (260°C) has been proven by Fuller Company during the test performed.

Depending on the individual application both systems have special references which have to be considered when deciding which one is to be adopted. Operational reliability, flexibility, maintenability and safety are in particular the major criteria for the system recommendation.

GKT comes to the conclusion that, for the purpose of transporting KMAC from the SRC Deashing Area to the Dust Preparation Area a system using pneumatic pumps should be prefered without wishing to say that the blow tank system would be an unaceptable alternative, especially where the conveying system has to transport the KMAC material into a bunker working at elevated pressure, for instance 30 psig.
The aspects which led to GKT's recommendation are discussed in this report. The main ones are as follows:

- GKT's pneum. pump experiences with different types of coal dust, which was in several cases more abrasive than can be expected for the KMAC material

- Pneum. pumps need less overall height, resulting in a lower steel structure

- Pneumatic pump operational reliability is high because errosion of moving parts is a long term reaction and can be observed during regular inspections, thus allowing planned maintenance.

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- Sealing surfaces of the valves in a blow tank system operating at 420°F are to be metal ones. Metal sealing surfaces are more problematic in solids service than plastic seals and should be avoided if possible, by using another system.

When attempting simulate and test the behavior of KMAC material in conveying systems at elevated temperatures, one main difference which cannot be avoided between the original hot material from the plant and the material to be tested is the necessary heating-up by hot nitrogen.

This heat-up procedure willprobably alter the physical transport behavior of the KMAC material.

In particular, the content of the deashing solvent will be greatly reduced during heating-up with hot nitrogen. To what extent this solvent removal will change the physical transport properties of the KMAC, cannot be predicted. The original KMAC from the operating Demoplant could possibly have a higher tendency to form bridges and agglomerates in the bunkers. This interrelation must be considered in the selection of the KMAC transport system.

Therefore a system less sensitive to agglomerates and bridging should be selected. Because the Fuller Report, too, classifies the pneum. pump system as less sensitive to agglomeration and bridging, this is one additional point in favor of this system.

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It is only due to the lower construction height of the pump system in relation to the blow tank system, that it is possible to install sufficiently large intermediate bunkers, in view of the design height of the steel structure.

It is GKT's opinion that sufficiently large intermediate bunkers are necessary in order to allow time for the operating staff to react by switching over to the stand-by unit, or to repair failed equipment.

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A specific aspect of the results of the Fuller reports, the conveying nitrogen consumption or solid/nitrogen ratio is discussed in the following sections.

Tests with a Fuller-Kinyon Pump

It is noticed from the reported results that the test pump capacity was not high enough to detect the max. possible solid/nitrogen ratio, when unstable conveying conditions or blockage of conveying occurs.

Knowledge of the max. solid/nitrogen ratio would have allowed application of the test results to the commercial-size system. It is GKT's opinion that a solid to nitrogen ratio of about 0.8 to 0.9 pounds/Scf is required for the commercial size pump, equivalent to the first line of test results as per table 5 Run 225.

Blow tank tests

The blow tank tests have been performed with a convying line distance of about 111 ft., resulting in a solid/nitrogen ratio representing high dense flow conditions as per table 1 Run 1 to 8.
It is GKT's opinion that for a conveying distance of about 800 ft. including several elbows and diverter valves, relevant for the commercial plant, high dense flow conditions are not recommendable because stable transport conditions are required for a wide range of physical properties of the KMAC material such as bulk density, temperature, fluidizing behaviour.
The system must be capable of compensating for exceptional conditions in case of disturbance to the upstream unit.
GKT would also recommend the use of a low density flow for the case of blow tank conveying.

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Capital and operating cost comparison

The following cost estimate can be taken for the comparision between the pneum. pump and the blow tank for a 145,465 Lb/Hr Kerr-McGee conveying system.

	Pneum. pump (4 pumps)	Blow tank (4 tanks)
Estimated costs for equipment	453 700,-- DM	835 600,-- DM
Annual capital related costs	90 740,-- DM	167 120,-- DM
Annual operating costs a) for electr. power	51 200,-- DM	-
b) for recirculating cooling water	4 040,-- DM	-
Total annual costs	145 980,-- DM	167 120,-- DM
Difference in annual costs	21 140,-- (app. $10,000, if 1$=2.1DM)	

In this cost comparison the higher costs for the structural building if a blow tank will be installed are not considered. The required height between bunker outlet and the ground level is about 43 ft for the blow tank system compared to the 15 ft for the pneum. pump system.

The required energy for pressurizing the conveying nitrogen is nearly the same for both systems, the higher nitrogen pressure for the blow tank system will be equalized by the higher nitrogen quantity for the pneum. pump, therefore it is not considered in this cost comparison.

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Cost estimate details

1) Pneum. Pumps

Estimated equipment costs 453 700,-- DM

including:

2 flat shut-off gates
2 feeding boxes with 2 outlets
4 pneumatic feeder
4 discharge spout
4 surge bins
4 pneum. pumps, water cooled
power = 27 kW, speed = 730 min^{-1}
4 motors 30 kW; speed = 1485 min^{-1}

Annual capital related costs

20 % of the equipment costs

453 700 · 0,20 = 90 740,-- DM

Annual operating costs

a) Electr. power

required power at the shaft
of the pneum. pump = 27 kWh/h
η motor = 85 %

Annual power consumption for 2 pumps

$2 \cdot 27 \cdot \frac{1}{0,85} \cdot 8000 = 512\,000$ kWh

Annual power costs for 2 pumps
512 000 kWh · 0,04 $/kWh · 2,5 DM/$ = 51 200,-- DM

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b) for recirculating cooling water

C.W. consumption for 2 pumps = $9,6\ m^3/h$

Annual costs for recirculating cooling water

$$8000\ h/a \cdot 9,6\ m^3/h \cdot \frac{0,08\ \$}{1000\ gallons} : \frac{2,50 DM}{1\ \$} \cdot \frac{1000\ l/m^3}{3,8\ l/gallon}$$
$$= 4040,\text{--}\ DM$$

The specific costs are taken of the Process Design Criteria page 43.

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2) Blow tank

Estimated equipment costs 835 600,-- DM

including:

- 4 blow tanks
- 4 inlet valves
- 4 outlet valves
- 8 intermediate valves
- 4 mixing nozzles

complete piping at the blow tanks (with the exception of conveying piping), electric control cabinet

Annual capital related costs

20 % of the equipment costs

835 600 · 0,20 = 167 120,-- DM

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