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DEVELOPMENT OF A PILOT-SCALE KINETIC
EXTRUDER FEEDER SYSTEM AND TEST
PROGRAM

Phase 1 Report

March 1982

Work Performed Under Contract No. AC21-80MC14602

Lockheed Missiles & Space Company, Inc.
Lockheed Energy Systems
Sunnyvale, California

TECHNICAL INFORMATION CENTER
UNITED STATES DEPARTMENT OF ENERGY

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ABSTRACT

This report describes the work done under Phase I, the moisture tolerance testing of the Kinetic Extruder. The following coals were used in the test program: Western Bituminous (Utah), Eastern Bituminous (Pennsylvania), North Dakota Lignite, Sub-Bituminous (Montana), and Eastern Bituminous coal mixed with 20-percent Limestone. The coals were initially tested at the "as-received" moisture level and subsequently tested after surface moisture was added by water spray. Test results and recommendations for future research and development work are presented.

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CONCLUSIONS AND RECOMMENDATIONS

Based on the results obtained during Phase I, the moisture tolerance testing, the following conclusions are derived:

- o The Kinetic Extruder can handle any feedstock which is sufficiently free flowing to be pneumatically transferrable in the dense phase mode.
- o The "as-received" moisture level of coal does not determine the flow characteristics - lignite and sub-bituminous coals having moisture levels greater than 25 percent flow freely.
- o When surface moisture of 1 to 2 percent is added, coal becomes difficult to handle - regardless of the "as-received" moisture level.
- o To facilitate handling coals that are somewhat less than free flowing the feed hopper should be of the mass flow type - this would avoid ratholing.
- o Wear, except for the control nozzles, does not appear to pose a problem. Wear-resistant materials such as tungsten carbide, titanium carbide, and boron carbide should perform well for the control nozzles.
- o The fluidic turndown control concept, using no moving parts exposed to coal, performs reliably and has fast response.
- o Because of the pumping action of the rotor a control gas differential pressure regulator with a wider control range is required.
- o The Kinetic Extruder remote operation was demonstrated with a simple, manually operated control panel.
- o The subsystems performed well reaffirming the contention that no special requirements are imposed by the Kinetic Extruder.
- o The controlled differential-pressure, water-buffered sealing system performs well; by controlling the differential pressure across the inboard face seal the seal PV value can be kept low.

The following recommendations are made for future action:

- o Proceed with Phase II, Verification Testing.
- o For the verification test program the Kinetic Extruder should be retrofitted with the Crane gas seals. These seals can be scaled to commercial size equipment and also would permit operating at higher pressure, i.e., 400 psi.
- o Wear resistant sprue parts should be used for the test program.
- o To shorten the time required to transfer coal into the test loop a larger scalping screen should be installed.
- o To extend the throttling range and permit wider throttling at high pressure a servo controller should be installed for control of the control gas differential pressure.
- o A pilot scale Kinetic Extruder should be built and installed in an operating pilot plant. This would avoid problems associated with close loop recycling of coal and gain valuable field use experience and credibility.
- o Testing of advance housing design concepts should be accomplished. Such concepts would offer flexibility of arranging equipment in a plant, provide for use at multiple discharge lines and permit locating the Kinetic Extruder at ground level.
- o The feasibility of the derivative concept of the Kinetic Extruder, the slurry pump concept, should be demonstrated.

Section 1

OBJECTIVE AND SCOPE OF WORK

Under Phase I of this contract, Lockheed performed test and evaluation studies on an upgraded version of the 1-ton-per-hour (tph), pilot-scale Kinetic Extruder (KE) and ancillary equipment previously developed under the prior DOE contract (Contract No. EX-76-C-01-1792). Based on the generated test and evaluation data, Lockheed defined optimum operating parameters for the limitations in the extruder and ancillary equipment. Evaluation of the results of Phase I permits a determination of whether or not further DOE-funded development (Phase II) of the extruder and ancillary equipment is warranted.

To accomplish the objectives, seven tasks were performed. These tasks are described briefly below.

Task 1 - Bearing and Seal Upgrading

The bearing and seal systems of the unit required modification for reliable operation. Under this task, design modifications to the existing KE machine to accept a new bearing and a new control-gas seal were implemented. The new bearing, seal, and associated hardware was fabricated and installed in the existing housing. Checkout tests of the upgraded system were conducted.

Task 2 - Update of Test Loop

Under this task, required improvements in the test loop were designed, fabricated, installed, and tested. This included improved coal-storage and loading equipment, moisture addition apparatus, and additional instrumentation and controls.

Task 3 - Design, Specifications, and Operating Instructions

This task covers preparation of engineering drawings and design specifications for the feeder and its ancillary equipment. Also included is preparation of a detailed operating manual for the KE feeder and test loop.

Task 4 - Testing

Test runs were conducted to establish the performance of the feeder with changes in coal type, coal grind, moisture level, and additives.

Task 5 - Data Analysis

Under this task, all test data obtained were organized and analyzed. Theoretical performance calculations were made and compared with the test data. The test data were compiled.

Task 6 and 7 - Report Preparation

Monthly and quarterly progress reports and the final Phase-I summary report were prepared under these tasks.

Section 2

DESCRIPTION OF THE KINETIC EXTRUDER DRY COAL PUMP

The Kinetic Extruder takes dry pulverized coal from an atmospheric hopper, carries it across a gas pressure barrier, and feeds it into a high-pressure hopper as shown in Fig. 2-1. The transfer of coal from atmospheric pressure to the high pressure of the reactor injection system, which may range from 150 to 1,500 psia or more, is accomplished in the rotor of a high speed machine called the Kinetic Extruder.

As shown in Fig. 2-2, the Kinetic Extruder consists of a rotor, a loosely fitting casing and a receiver vessel.

Referring to Fig. 2-3, pulverized coal is fluidized and fed through the stationary coal feed tube to the center of the rotor. When the pulverized coal enters the spinning rotor, centrifugal force causes it to flow into the sprue channels and to form a compacted, moving, porous plug in each of the sprues. The moving plug forms the pressure seal. Excess gases are removed from the rotor through vent channels in the walls of the feed tube by means of a small suction system. The pressure in the center of the rotor is kept slightly subatmospheric.

The coal flow rate through the sprues is stabilized and controlled by control nozzles, located at the outlets of each sprue. The discharge rate of the control nozzle can be changed by controlling the pressure gradient across the control nozzle. This is accomplished by injecting control gas into the control nozzles from an independent outside supply. This control gas is introduced into the rotor via a set of shaft seals and then into the separate nozzles through distribution channels in the rotor. A conventional differential pressure controller is used to adjust and vary the control gas pressure differential with respect to the pressure external to the rotor, thereby "throttling" the coal flow rate. A throttling range of 3 to 1 has been demonstrated with a 30-psi nozzle pressure differential. The coal is

Fig. 2-1 Simplified Gasification Process

Fig. 2-2 Lockheed Kinetic Extruder

Fig. 2-3 Rotor

ejected from the rotor into the pressurized casing; it then flows into the receiver vessel.

The throughput of the Kinetic Extruder is controlled by the pressure differential across the control nozzles. The level of the coal in a lower injection hopper (not shown) can be used as the control signal. Throughput will decrease if the coal level rises and increase if the coal level falls.

The pressure in the casing and receiver vessel is maintained by injecting syngas or nitrogen into the upper receiver to compensate for the high-pressure gas carried with the coal from the receiver.

The coal is not highly stressed or physically changed in passing through the rotor. No agglomeration or significant change in the particle size distribution takes place.

Section 3

SUMMARY OF PROGRESS

To enhance successful operation of the Kinetic Extruder a new system of shafts, bearings and seals was designed, procured, and installed. The shaft bearings are oil lubricated rolling element bearings. The shaft inboard seals are mechanical face seals identical to those previously used. The shaft outboard seals are floating bushing type seals. The control gas seals are of the floating bushing type. The feed pipe seal and bearing was not changed. All seals were buffered with a 50-percent ethelene, glycol-water mixture. After initial problems, caused by deterioration of the face seals during storage were solved, the sealing system performed well.

The test loop was updated by installing coal loading equipment, equipment for adding surface moisture to the coal and providing remotely operated valves to permit operating the Kinetic Extruder from a central control station.

The test program was successfully performed using the five different feed stocks as planned. Test results are presented in Section 4.

Based on the work carried out previously and the obtained test results and observations, conclusions and recommendations were arrived at. (See p. xi of this report.)

The objectives of the program have been met.

Section 4

DETAILED DESCRIPTION OF TECHNICAL PROGRESS

4.1 BEARING AND SEAL UPGRADING

During the prior DOE-sponsored program, the Model No. 4 Kinetic Extruder was built and operated. This feeder, described in Ref. 1, incorporated several advanced features: water-lubricated (a 50-percent-water, 50-percent-ethylene-glycol solution was used) journal bearings were used for both the shaft bearings and the feedpipe bearings. These bearings also served as the pressure breakdown structure for the face seals, a function normally performed by floating bushing seals or labyrinth seals. The pressure difference across the face seals was maintained at 20 psi by adjusting the liquid pressure supplying the bearing to track the gas pressure inside the housing.

The rotor was designed also to permit fluidic turn-down control of the coal throughput.

The pocket-type, water-lubricated journal bearings proved to be deficient. No problems were encountered at operating speed and pressure but, eventually, bearing failures (galling and seizure) during the start-up occurred. The Model 4 feeder was then refitted with carbon-bronze plain journal bearings. Although these bearings solved the problem of galling on start-up, theoretically they exhibit instability at 3,400 rpm and normal design load irrespective of supply pressure. For this reason, the machine was operated only to 2,500 rpm at 200-psi pumping pressure.

Under the current DOE program restraints, it was deemed prudent to eliminate the risk involved in using the water-lubricated bearings by substituting rolling element bearings and a more conventional seal system.

The Model 4 control-gas injection-point floating bushing seals had unsatisfactory gas leakage at high operating pressures. The configuration has been changed to a pair of liquid-buffered double seals to eliminate this problem.

The physical arrangement of the parts fabricated for the program is shown in Fig. 4-1. The high-pressure sealing water enters through ports 1 and 1a at a pressure of about 30 psi above case pressure. The water is prevented from entering the case by the low pressure-differential face seal on the inboard side. On the outboard side, the pressure is reduced to near atmospheric by flow through the floating bushings and water drains through ports 2 and 2a. Oil for lubricating the bearings enters through ports 5 and 5a, and drains through ports 4 and 4a. The oil is sealed by shaft seals, but some seepage passes through the seals and is scavenged through ports 3, 3a, 6, and 6a.

Ports 3, 3a, 6, and 6a also scavenge water seepage past the back-up shaft seals.

Control gas for the fluidic coal flow control is admitted through port 10. Sealing water at a pressure of about 30 psi above the control gas pressure enters through ports 8 and 12. Water seepage past the shaft seals is scavenged through ports 9 and 11 by means of a pressure trap. Water pressure is reduced to near atmospheric through floating bushings and drained through ports 7 and 13.

The sealing and bearing system for the stationary coal feedpipe has not been changed. It consists of a low-pressure-differential, water-cooled face seal and a water-lubricated journal bearing which also served as a pressure breakdown structure.

The configuration shown in Fig. 4-1 defines the Model No. 5 Kinetic Extruder.

As will be shown later, once the start-up problems associated with parts carried over from the previous program which had deteriorated during storage

Fig. 4-1 Rotor Bearing Seal Assembly

were solved the new bearing and seal system performed very well. The floating bushing seals designed and manufactured by Stein Seal Company performed as predicted.

The new bearing and seal assembly was received toward the end of July 1981.

The major tasks accomplished under the installation effort include:

- o The new bearing, shaft and seal assembly was installed in the housing.
- o The seal liquid, oil lubrication, and control gas line connections were made and the systems were checked out. The back-pressure regulator, which maintains a positive pressure differential above the pressure of the Kinetic Extruder housing for the main shaft seal liquid, did not function properly. The probable cause was a deterioration of the rubber sleeve exposed to the water/Prestone mixture used as the seal liquid. A new sleeve was installed and appears to have solved the pressure control problem, but undesirable pressure oscillations were observed in the seal liquid line. To reduce these oscillations, the dual-piston water pump, rated at 6 gpm at 600 psi, was replaced with a smaller 3-gpm at 500-psi pump. This helped some but the oscillations persisted. The Flexflo regulators were eventually replaced with a different type of regulator manufactured by the Gordon Valve Company. Very smooth operation is observed except when the receiver tank pressure is atmospheric. Minor oscillations are observed when the receiver tank pressure is atmospheric.
- o The Kinetic Extruder was aligned and the torque meter was installed. The drive train was checked out and the system was run in up to the maximum operating speed of 3,600 rpm. During initial test runs, a fair amount of liquid was observed passing by the main shaft seals and through the rotor. The rotor leakage can stem from leakage of the control gas seals or from the feed pipe seal. The system was extensively checked to ensure that all lines and connections had been properly made and that the seals were properly installed. A new outboard control gas seal was installed. As the seals were run in, leakage was reduced to an acceptable level at the main shaft and no

leakage was observed through the rotor. Performance was considered satisfactory.

- o The coal supply line was connected and the coal sample extraction system was tested. It performs well.
- o The high-pressure vent gas control system was calibrated. During this step, the diaphragm in the differential pressure control valve was damaged by inadvertent overpressurization. Repairs were made and the system then operated well throughout the test program.
- o The suction system was connected to the Kinetic Extruder and the newly installed flow-measuring venturi system was checked out.
- o Coal was loaded into the test loop using the new coal loading system. To properly operate this system required adjustment and some modifications of the components to match the inputs and outputs of each. Involved are the loading hopper, the escalator, and the scalping screen. This was accomplished and the Western Bituminous Coal was loaded into the test loop.

In addition, vent lines, instrumentation, and gas purge lines were connected and the equipment was readied for testing.

Figure 4-2 shows the rotor installed in the housing and Figs. 4-3 and 4-4 show views of the Kinetic Extruder from the feed side and the drive side.

4.2 UPDATE OF TEST LOOP

The layout of the test loop for the Phase-I tests is presented in Fig. 4-5. The main changes implemented are the addition of a barrel dump and loading conveyor, centralization of controls and instrumentation, and reconfiguration for control of moisture. The new coal-loading equipment was needed for satisfactory handling of larger quantities of coal. The previous loading method was crude and only suited to bagged coal and infrequent reloading of the test loop. Coal is loaded into the outside storage hopper and then pneumatically transferred to the KE feed hopper. A water fog nozzle and associated equipment is installed in the storage hopper. Moisture is added

Fig. 4-2 Kinetic Extruder Model No. 5 Rotor in Housing

Fig. 4-3 Kinetic Extruder Model No. 5 Drive Side

Fig. 4-4 Kinetic Extruder Model No. 5 Feed Side

and mixed with the coal during repeated transfers back and forth between the coal storage and the feed hoppers. A flow sheet encompassing these two vessels is shown in Fig. 4-6.

Some improvements in instrumentation and controls have been made, but operation remains essentially manual. A few valves in the test loop have been equipped with remote actuators so the loop can be run from the control room location for the most part. These include the valves on the receiver main gas inlets and outlets, the fluidization supply, the recycle line and purges, and the transfer lines between the feed hopper and the supply hopper. The receiver-vessel pressure control was changed from purely manual to an automatic controller with a manual set point. The sprue deplugger device has also been automated.

Details of all subsystems as now configured have been incorporated in the flow diagrams, Appendix B.

Figures 4-7 and 4-8 show views of the equipment.

4.3 DESIGN, SPECIFICATIONS, AND OPERATING INSTRUCTIONS

This work, covering preparation of engineering drawings and design specifications for the feeder and its ancillary equipment, including detailed operating instructions for the KE feeder and test loop, is described in Appendix B.

4.4 TESTING AND DATA ANALYSIS

The objective of this program is to determine the ability of the KE to handle various coal feed stock of varying moisture content by testing. To accomplish this objective, the existing equipment was modified as described in Sections 4.1 and 4.2. The equipment was installed and the unit was checked out. At the start of the test program, problems were encountered in the sealing area. The inboard face seals did not seal properly.

— PLAN —

— SIDE ELEVATION —
SCALE 1" = 40'

TEST LOOP-PHASE I

— END ELEVATION —

Fig. 4-5 Coal Feed Facility Space Requirement

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Fig. 4-6 DOE Kinetic Extruder Coal Feed Flow Sheet

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Fig. 4-7 Coal Feeder Test Loop Coal Loading and Support Equipment

Fig. 4-8 Coal Feeder Test Loop Remote Control Station

After investigating possible causes for seal leakage, it was determined that the seal surfaces had deteriorated during storage. This is discussed in greater detail in Section 4.4.7. Relapping of the seal surfaces has eliminated the sealing problem.

The sprue flow monitoring instrumentation indicated uneven flow through the sprue and poor response to control gas flow.

Plugging of some filters which were installed in the twelve branch lines inside the roter was identified as the cause of the problems. As a short-term solution, the filters have been removed. The long-term solution is to relocate the filters upstream of the manifold. This is discussed in greater detail in Section 4.4.6.

Having corrected the problems of seal leakage and uneven sprue flow the equipment performed well.

The following coals were tested:

- o Western Bituminuous (Utah)
- o North Dakota Lignite
- o Sub-bituminuous (Montana)
- o Eastern Bituminuous (Pennsylvania) + Limestone
- o Eastern Bituminuous (Pennsylvania)

The coals, except for the Western Bituminous, were procured through Resource Engineering Incorporated, Waltham, MA. The same firm would also be able to supply the other coal feeder contractors permitting all firms to work with the same feed stock.

Table 4-1 shows the moisture level and grind size requested and actually received. As indicated, the moisture level was much higher than requested. This forced a change in the test plan. Under original plans dry (less than 4-percent moisture) coal was to be loaded in the test loop. After testing with dry coal, moisture would be added to the coal to bring the moisture level

Table 4-1 PROPERTIES OF TEST COALS

Coal Feed Stock	Moisture (%)		Grind Size (% passing, 200 mesh)	
	Specified	Received*	Specified	Received*
1. Western Bituminous (Utah)	-	5.0	-	55.0
2. Lignite (North Dakota)	≤ 4	28.5	70 ± 5	33.3
3. Subbituminous (Montana)	≤ 4	24.8	70 ± 5	50.5
4. Eastern Bituminous (Pennsylvania) + 20% Limestone	≤ 4	5.5	≤ 35	43.8
5. Eastern Bituminous (Pennsylvania)	≤ 4	6.0	70 ± 5	62.9

*Test loop samples after loading and before feeding

to 7 percent and ultimately to 14 percent. Testing would continue until the machine could no longer tolerate the high moisture level.

The plan was changed and the coals were tested as the "as-received" moisture level. Moisture was then added and most coals became very difficult to handle when added moisture surpassed the 2-percent level.

The grind size also failed to meet specifications. The coals were, in general, coarser than desired. The Lignite was considerably coarser and was barely compatible with the equipment. The Eastern Bituminous coal mixed with 20 percent Limestone was finer than specified.

As will be discussed in the following sections, these discrepancies have in certain cases limited the range over which the testing could be performed.

Test results are presented in the following sections.

4.4.1 Testing with Western Bituminous Coal

Testing with Western Bituminous Coal (As Received 5-Percent Moisture). A series of tests was performed with the "as received" Western Bituminous coal having a moisture content of 5 percent. The test points are shown in Fig. 4-9 and the test data are given in Table 4-2. The data presented were obtained during the times that the seals had acceptably low leakage rates and accurate test data could be obtained.

Testing with Western Bituminous Coal (7-Percent Total Moisture). A series of tests was performed with the Western Bituminous coal after the moisture content was increased to 7 percent from the starting moisture level of 4.2 percent. Moisture was added to the coal by spraying water (0.25 percent alkyl ether of polyethelene glycol was used as a wetting agent) through a spray nozzle located in the storage hopper. The spray was turned on during transport of coal into the storage hopper from the feed hopper. Using this technique, the moisture could be increased by a little less than 1 percent per round trip between the two hoppers. The method was successful in producing a rather homogeneously wetted feedstock.

The Kinetic Extruder tolerated the higher moisture feedstock reasonably well. Some difficulties were encountered in getting the coal to flow into the coal feed pipe from the atmospheric feed hopper. Test data were obtained at the operating points shown in Fig. 4-10. These test data are summarized in Table 4-3. Coal was recycled repeatedly during testing and some drying (from 8 to 6 percent) took place over the course of the experiments. Figure 4-11 shows the variation of moisture level as a function of elapsed running time.

One problem, which was noted during operations with the higher moisture coal, was occasional brief losses of vacuum in the eye of the rotor. According to our strip chart records, this was manifested by an eyepressure pulse or a

Fig. 4-9 Test Points with Western Bituminous Coal (as received 5-percent moisture)

series of pulses with peaks approaching atmospheric pressure. The duration of the pulses was typically 1 to 5 seconds (s). On a few occasions, the pulse was longer and led to a blowback. Since the residence time of coal within the rotor is about 5 s (at 1 tph), when the coal flow into the rotor is stopped for more than 5 s the sprues drain free of coal and a blowback is inevitable.

The most likely cause of the observed loss of vacuum in the eye of the rotor was ratholing of the coal in the atmospheric feed hopper and the subsequent interruption of coal transfer into the coal feed pipe. When the coal feed pipe empties, the rotor eye suction system communicates directly with the atmosphere. Gas is admitted into the rotor eye and the vacuum is lost. If coal flow into the coal feed pipe is started before blowback occurs, the coal will stop the gas flow and the suction system will reestablish the vacuum so that normal operation is again observed.

Table 4-2 SUMMARY OF TEST DATA WESTERN BITUMINOUS COAL (AS RECEIVED
5-PERCENT MOISTURE)

Run Number	302	303	303	305	306	307	313	314	314	314	315	316
Throughput (tph)	0.56	0.71	0.99	0.63	1.04	1.06	0.84	1.14	0.82	1.01	0.84	1.33
Delivery Pressure (psig)	0	39	35	100	102	100	150	200	203	203	60	55
Control Gas Pressure Differential (psig)	11	11	15	10	23	27	12.5	20	6	18	13	30
Torque (ft-lb)	16.6	19.6	23.5	32.4	36.1	39.6	40.5	53.5	45.2	45.5	33.9	36.5
Speed (rpm)	1,824	2,087	2,643	2,930	2,960	3,313	2,760	3,233	3,014	3,020	3,027	2,965
Suction System Flow (scfm)	-	-	-	-	-	-	7.5	9.5	7.8	-	4.2	-
Rotor Eye Pressure (in. Hg)	-7	-7	-7	-5	-5	-5	-6	-5	-5	-5	-	-
Carrier Gas Pressure (in. Hg)	-3	-	-	-4	-	-	-2	-2	-2	-2	-2	-
Receiver Coal Temperature (°F)	66	66	-	70	72	78	65	69	74	75	-	64
Eye Temperature (°F)	75	77	-	82	79	85	73	82	95	105	-	68
Suction (Baghouse) Pressure (in. Hg)	-8.5	-8	-	-	-	-	-8.5	-8	-8	-	-	-

Fig. 4-10 Test Points With Western Bituminous Coal (7 Percent Moisture)

Fig. 4-11 Test Loop Coal Moisture Level During 7-Percent Moisture Tests

Table 4-3 SUMMARY OF TEST DATA (WESTERN BITUMINOUS COAL, 7-PERCENT MOISTURE)

Run Number	322	322	323	324	324	327	327	328	328	329	330	331	331	332	333	333
Throughput (tph)	0.82	1.36	0.98	1.14	1.20	1.09	1.38	0.98	0	1.49	1.46	1.21	0.89	0.84	0.85	0.91
Delivery Pressure (psig)	50	50	100	107	105	104	110	105	0	200	200	50	50	195	100	98
Control Gas Pressure Differential (psig)	7.5	17	10	14	20	10.5	17	8	7.5	11	10.5	11	1	2	6	8
Torque (ft-lb)	29.8	36.7	38.0	36.3	37.0	43.5	42.0	37.3	17.6	54.5	56.3	37.0	33.0	46.2	33.4	33.5
Speed (rpm)	2,485	2,905	2,917	2,721	2,700	2,755	2,747	2,759	2,757	3,080	3,025	3,015	3,035	3,060	2,275	2,481
Suction System Flow (scfm)	-	-	6.9	-	-	5.5	5.6	5.4	-	6.1	5.7	4.6	4.4	5.9	-	4.4
Rotor Eye Pressure (in. Hg)	-6	-5.5	-5	-6	-5	-6	-6.5	-6	-	-6	-6	-6.5	-6.5	-6.5	-6	-6
Carrier Gas Pressure (in. Hg)	-2	-	-2	-	-	-2	-2	-2	-	-2	-2	-2	-2	-2	-	-2
Receiver Coal Temperature (°F)	63	58	63	66	65	59	61	67	66	70	62	63	67	74	59	61
Eye Temperature (°F)	79	77	72	83	87	66	71	80	88	79	73	77	80	84	63	71
Suction (Baghouse)	-	-	-8.3	-	-	-3.5	-8.5	-8.0	-	-8.2	-8	-8.3	-8.2	-8.2	-	-8.2

To verify our interpretation of the observed behavior, a sight-glass-like section has been installed in the coal feed pipe and coal flow is being monitored with a photoelectric detector. As described later, this additional information has confirmed that ratholing occurs and causes the observed problem.

Based on the tests conducted with the 7-percent moisture coal, we conclude that the Kinetic Extruder can handle the moist feed stock but that modifications in the feed hopper are required to avoid ratholing.

Testing with Western Bituminous Coal (10-percent Moisture)

After completion of the 7-percent moisture tests, additional moisture was added to the coal using our spray-during-transfer technique. By the time the moisture level had been built up to 10 percent, the material became very difficult to handle. Frequent plugging of the transfer lines between the feed hopper and storage hoppers occurred even though the transfer pressure was increased from 25 to 50 psig. The transfer rate was very slow - only about one third of the rate obtainable with the coal before adding moisture.

A well-mixed batch of 10-percent moisture coal was finally prepared and tested in the Kinetic Extruder. Having encountered such difficulties with the pneumatic transfer, we were not surprised that the material flowed very poorly through the Kinetic Extruder. Based on the sprue flow signatures, all of the nozzle discharge flows became very weak within a few seconds after each deplugger cycle*. By cycling the deplugger about 20 times per minute, one test run was conducted at 50 psig. The average coal flow rate was only about 50 percent of what it should have been. Complete data for the run are presented in Table 4-4.

*The method used for sprue flow detection and sprue unplugging was described in Section 4.2.8 of the Phase-III Report (Report No. FE1792-61).

Table 4-4. TEST DATA FOR WESTERN BITUMINOUS COAL (10-PERCENT MOISTURE)

Run Number	334
Throughput (tph)	0.45
Delivery Pressure (psig)	50
Control Gas Pressure Differential (psig)	8
Torque (ft-lb)	30.4
Speed (rpm)	2,917
Suction System Flow (scfm)	5.2
Rotor Eye Pressure (in. Hg)	-6
Carrier Gas Pressure (in. Hg)	-2
Receiver Coal Temperature (°F)	61
Eye Temperature (°F)	71
Suction (Baghouse) Pressure (in. Hg)	-8.2

To conclude, this coal with 10-percent moisture (6-percent added surface moisture) cannot be handled by the Kinetic Extruder. Based on the observed behavior, we doubt that this material could be handled by any feeder or transfer system.

Retest of Western Bituminous Coal (As Received 5 Percent Moisture). Due to seal leakage problems during initial testing, some of the Western Bituminous coal test data was incomplete or uncertain. Therefore, at the end of the program this test loop was reloaded with this feedstock and some test points were repeated. The new data are presented in Tables 4-5 and 4-6 and included in Fig. 4-12, together with the original data.

No particular changes in performance can be discerned.

Resin in the Coal. One 1-ton lot of Western Bituminous coal deposited a hard lacquer on sprue surfaces nearly blocking the control nozzles' exit orifices. Tracing this lot indicates that our supplier was unable to obtain coal from his usual source in Utah because of a coal strike and had accepted a

Table 4-5 SUMMARY OF TEST DATA (RETEST OF WESTERN BITUMINOUS COAL FROM UTAH)

Run Number	370	371	371	372	372	372	371
Throughput (tph)	1.25	1.45	0.97	1.18	0.98	0.68	1.28
Delivery Pressure (psig)	205	200	198	0	125	115	120
Control Gas Pressure Differential (psig)	9	15	5	9.5	9	5	15
Torque (ft-lb)	60.5	63.2	49.8	33.4	44.0	32.2	49.5
Speed (rpm)	3,195	3,360	2,940	2,890	2,900	2,255	3,200
Suction System Flow (scfm)	6.3	3.9	4.9	3.2	3.6	-	4.4
Rotor Eye Pressure (in. Hg)	-4.3	-5.5	-5.0	-6.3	-5.9	-5.5	-6.0
Carrier Gas Pressure (in. Hg)	-3.5	-3.5	-3.5	-3.5	-3.0	-3.0	-3.0
Carrier Gas Flow (scfm)	2.5	3.1	2.8	3.2	3.6	3.2	3.5
Receiver Coal Temperature (°F)	59	64	67	51	54	56	60
Eye Temperature (°F)	62	71	79	62	65	73	76
Suction (Baghouse) Pressure (in. Hg)	-8.0	-8.7	-8.4	-8.8	-8.3	-	-8.7

Table 4-6 LOCKHEED LAB TEST DATA (RETEST OF WESTERN BITUMINOUS COAL FROM UTAH)

Sample Number	Ohaus Moisture (%)	Permeability* 10^{-12} ft^2	Location Sampled	Elapsed Run Time with Coal (h)
221	4.9	6.4	Bag	-
222	4.8	7.5	Bag	-
223	5.0	7.6	Feed Pipe (Before Running)	0
224	4.9	6.3	Feed Pipe (After Run No. 370)	0.2
225	4.4	5.0	Feed Pipe (After Run No. 371)	0.8
226	4.7	4.5	Feed Pipe (After Run No. 371)	0.8
227	4.7	5.6	Feed Pipe (After Run No. 372)	1.4

Fig. 4-12 Test Points with Western Bituminous Coal (as received 5-percent moisture)

substitute shipment. (Some Utah coals are said to have a high resin content; resin is at times separated and sold separately.)

Since this lacquer deposition was an isolated case, it was decided to switch back to the normal supply of Western Bituminous coal. The nozzles were cleaned and the coal removed from the test loop. A sample of the coal was sent to the testing laboratory to attempt to identify the cause of the problem. The test lab concluded that the nozzle deposits were mainly fine grained pyrite in an exceptionally fine matrix. They felt the cementing of the material was probably due to some additive in the coal, possibly a petroleum derivative added to raise Btu values or as a dust control substance (see Test Report, Appendix C).

4.4.2 Testing with North Dakota Lignite

Testing with North Dakota Lignite (as received 28-percent Ohaus moisture) was accomplished. Generally speaking, the Lignite coal appears well suited to the Kinetic Extruder. Table 4-7 lists the data obtained in the series of tests. Operating points are shown graphically in Fig. 4-13. Problems observed related to recycling coal in our test loop. The fact that this particular batch of coal was far out of its grind specification limited the range of operation.

Out of Specification Grind. The Lignite coal was specified to be ground to 70 ± 5 percent passing 200 mesh. The lab test report from the vendor, Resource Engineering, showed 73.7 percent passing 200 mesh. However, the coal as delivered to us was much coarser than this. A sample sent to an independent test lab yielded a sieve analysis showing only 33 percent passing 200 mesh. Copies of the pertinent lab test reports are included in Appendix A.

Coal sample moisture and coal permeability tests were conducted by Lockheed. Table 4-8 gives these data for the coal samples taken during Lignite testing. It may be noted that there was considerable drum-to-drum variability in properties of the coal shipment. The coal used in testing had permeabilities

Table 4-7 SUMMARY OF TEST DATA NORTH DAKOTA LIGNITE (AS RECEIVED
28-PERCENT MOISTURE)

Run Number	336	337	338	339	339	339	340	340	340	340	341	342	342	342	343
Throughput (tph)	0.93	1.40	1.05	-	-	-	1.07	-	1.10	1.04	1.89	-	0.92	0.86	-
Delivery Pressure (psig)	100	100	105	0	100	100	100	0	155	155	50	0	100	150	55
Control Gas Pressure Differential (psig)	9.5	18	10	9	10	10	9	11	9	9	5	8	5	4	8
Torque (ft-lb)	37.4	42.5	42.2	28.3	-	-	37.6	29.3	47.8	47.5	34.0	32.3	42.2	45.2	39.2
Speed (rpm)	2696	2984	3070	2776	2824	3533	2720	2725	3106	3180	2230	3420	3215	3215	3090
Suction System Flow (scfm)	7.8	6.9	5.9	-	-	-	5.3	4.4	6.3	5.1	6.3	4.5	5.6, 5.8	7.5	4.0
Rotor Eye Pressure (in. Hg)	-4	-5.3	-6	-	-	-	-6	-5.5	-5	-5	-6	-7	-6	-5	-6.5
Carrier Gas Pressure (in. Hg)	-2	-2	-2	-	-	-	-2	-2	-2	-2	-2	-2	-2	-2	-3
Receiver Coal Temperature (°F)	54	-	58	-	-	-	-	58	60	-	-	-	61	-	-
Eye Temperature (°F)	59	-	70	-	-	-	-	67	71	-	-	-	78	-	-
Suction (Baghouse) Pressure (in. Hg)	-7.8	-8.0	-8.0	-	-	-	-7.2	-7.7	-7.5	-8.0	-8.0	-8.5	-8.2	-8.5	-8.2
Sprue Outlet Diameter (in.)	0.345	0.345	0.283	0.283	0.283	0.283	0.231	0.231	0.231	0.231	0.345	0.283	0.283	0.283	0.283

Fig. 4-13 Test Points with North Dakota Lignite Coal
(as received 28-percent moisture)

ranging from $16.9 \times 10^{-12} \text{ ft}^2$ down to $10 \times 10^{-12} \text{ ft}^2$ after about twelve recycles through the test loop. These values are about 3 times higher than optimum for the Kinetic Extruder sprues on hand. This high permeability is, of course, a consequence of the coarseness of the grind.

Because of the higher permeability, leakage back through the moving coal plug exceeds the design value for our 1-tph machine. For our existing installation, we reached the capacity of the rotor eye suction system at a delivery pressure of 150 psi. To be able to reach higher pressures with this out-of-specification grind, a larger suction system is required or the coal plug velocity in the sprue needs to be increased.

Testing with Lignite with 2-Percent Added Moisture. Although the as received moisture of the Lignite (28 percent) was far above the original plan of 14-percent maximum moisture to be tested, it was decided to briefly test at

Table 4-8 LOCKHEED LAB TEST DATA (NORTH DAKOTA LIGNITE COAL)

Sample Number	Ohaus Moisture (%)	Permeability* 10^{-12} ft^2	Location Samples	Elapsed Run Time With Coal (h)
107	32.5	33.0	Drum No. 20	
134	25.7	12.4	Drum -	-
135	28.7	19.0	Drum -	-
137	26.4	7.6	Drum No. 10	-
139	28.1	14.8	Drum No. 9	-
140	25.0	19.3	Drum No. 5	-
141	28.2	16.9	Feed Pipe (before any running)	0
142	28.7	16.0	Feed Pipe (before any runing)	0
143	28.1	11.8	Feed Pipe, Run No. 337	1.7
144	28.0	11.2	Feed Pipe, Run No. 338	2.3
145	27.7	10.9	Feed Pipe, Run No. 339	2.8
146	27.3	10.1	Feed Pipe, Run No. 340	3.8
147	27.5	10.1	Feed Pipe, Run No. 342	5.4
150	27.4	8.9	Feed Pipe, Run No. 343	6.3

*1000g compaction test

higher moisture levels. Using the spray and recycle system described earlier, sufficient water was added to the coal to increase its moisture by 3 to 4 percent. However, the moisture either evaporated or condensed and drained to the bottom of the supply hopper. In any event, only about an extra 2 percent actually showed up in coal samples taken from the KE feed pipe. This increased the moisture content from about 27 percent to 29 percent. The water spray did give the coal a wetter "look" and hence the material was tested in the KE at this moisture level.

Table 4-9 lists the data from the limited tests which were conducted. The added moisture had two significant effects: (1) the coal throughput was reduced about 25 percent in comparison to the original Lignite, and (2) rotor pressure increases and blowbacks occurred, similar to, but more severe than that seen with the wet Western Bituminous coal.

The new sight glass instrumentation described in Section 4.4.15 had been installed prior to these tests and confirmed that the rotor eye pressure disturbances and blowbacks were caused by ratholing in the feed hopper.

The tests indicate that the feed hopper discharge system is inadequate for handling the moisture-added Lignite. The system was based on the zone fluidization concept developed by the Morgantown Coal Research Center, Ref. 2, and performs very well for coals that have not been sprayed with water to increase moisture. These wetted coals require better mass-flow-type hopper discharges to avoid ratholing and the resulting stoppage of coal flow.

4.4.3 Testing with Montana Sub-Bituminous Coal

Testing of the Montana Sub-Bituminous Coal was started in late December. In general, this coal flows through the KE unit quite well and no problems were encountered in performing the test matrix. This favorable result was quite gratifying since the material were to be quite troublesome to load into the test loop. The major problem was difficulty in feeding the coal through the 18-in. diameter Sweco scalping screen (20 mesh). Flow rates through the

Table 4-9 SUMMARY OF TEST DATA NORTH DAKOTA LIGNITE
(2-PERCENT ADDED MOISTURE)

Run Number	344	344	345
Throughput (tph)	0.66	-	0.74
Delivery Pressure (psig)	105	88	0
Control Gas Pressure Differential (psig)	6.5	6.5	6
Torque (ft-lb)	43.4	-	28.6
Speed (rpm)	3,120	3,120	3,130
Suction System Flow (scfm)	7.7	6.5	-
Rotor Eye Pressure (in. Hg)	-5.5	-6	-7
Carrier Gas Pressure (in. Hg)	-3	-3	-3
Receiver Coal Temperature (°F)	54	-	-
Eye Temperature (°F)	58	-	-
Suction (Baghouse) (Pressure (in.Hg)	-8.2	-	-

screen were very low and considerable material was rejected by the screen. A significant number of oversize particles were present but the great bulk of the rejected coal consisted of wet balls or clumps of fine material. There was considerable variation of moisture content both between coal drums and from top to bottom within the individual drums. The bottom third of many of the drums consisted of much wetter lumpy material which was mostly rejected by the screen. Ohaus moisture test results on some 17 samples taken from various drums ranged from 19 to 35 percent, with most clustering around 25 percent.

A second problem was persistent ratholing of the material in the vibrating FMC feeder cone which serves as our barrel dump. The vibration level of this cone had little impact and the coal had to be manually prodded from time to time to collapse the ratholes.

Once inside the test loop vessels, however, there were no further handling problems with the material. Pneumatic transfer rates between hoppers were high, at modest pressures, and no plugging of transfer lines occurred.

The moisture content of the mixed batch of coal the test loop was 25 percent.

Testing with Montana Subbituminous Coal (25-percent moisture). Testing with the Montana Sub-Bituminous feedstock at 25-percent moisture was completed on schedule. As discussed, this material was troublesome to load into the test loop. However, once loaded in the test loop, it flowed through the Kinetic Extractor satisfactorily. Data obtained in the test series is summarized in Table 4-10, and test operating points are presented graphically in Fig. 4-14. Lab test results for various coal samples taken during the course of testing are given in Table 4-11.

Generally speaking, the sub-bituminous coal at the 25-percent moisture level is well suited to the Kinetic Extruder. This coal was not quite so far out of its grind specification as the Lignite so that its permeability was low enough to allow testing up to 300-psig discharge pressure. This represents the present upper pressure limit of our hardware due to the seal travel limit (see Section 4.4.7).

At the 300-psi level, the seal surfaces at the feed-side shaft separated and seal liquid was pumped into the receiver hopper. When pressure was reduced, the seal reseated and is again performing well. No damage was done to the equipment.

Testing with Montana Sub-bituminous Coal (moisture added). The sub-bituminous coal could not be tested at water-spray-enhanced moisture levels due to the

Table 4-10 SUMMARY OF TEST DATA (MONTANA SUB-BITUMINOUS COAL,
AS-RECEIVED MOISTURE 25 PERCENT)

Run Number	346	348	348	349	349	350	350	351	351	352	353	353	354	354	355
Throughput (tph)	0.78	0.95	1.00	1.00	0.95	0.72	1.10	0.95	0	1.15	0.68	0.46	1.17	1.12	0.96
Delivery Pressure (psig)	50	105	106	107	205	110	110	255	0	254	200	100	207	112	300
Control Gas Pressure Differential (psig)	6	8	13	13	9	6	17	7	7	14	3	2	19	19	14
Torque (ft-lb)	31.5	39.5	41.0	45.8	52.3	36.8	49.0	64.2	21.3	67.1	46.9	28.9	63.0	48.2	79.1
Speed (rpm)	2,720	2,830	2,815	3,145	3,325	2,555	3,310	3,410	3,410	3,420	2,860	2,210	3,465	3,450	3,420
Suction System Flow (scfm)	5.2	5.5	5.6	4.3	7.8	4.1	4.5	7.2	-	6.2	6.0	4.9	5.3	4.4	6.0
Rotor Eye Pressure (in. Hg)	-7	-6.5	-6.3	-7	-5.5	-7	-7	-6	-1	-5	-5	-6	-6	-6	-5.3
Carrier Gas Pressure (in. Hg)	-3	-3	-3	-3	-3	-3	-3	-3	-	-3	-3	-3	-3	-3	-4.5
Receiver Coal Temperature (°F)	-	54	-	51	56	53	56	67	67	63	58	61	63	67	-
Eye Temperature (°F)	-	62	-	58	66	62	67	77	83	72	70	78	73	81	-
Suction (Baghouse) Pressure (in. Hg)	-8.5	-8.3	-8.3	-8.5	-	-8	-8.5	-8.5	-	-8.2	-8.1	-8.3	-8.2	-8.5	-

Fig. 4-14 Test Points with Montana Sub-bituminous Coal
(as received moisture 25 percent)

fact that the seal popoff contaminated the coal load with several gallons of seal liquid. Insufficient reserve stock was on hand to reload the test loop.

4.4.4 Testing with Pennsylvania Eastern Bituminous Coal Mixed with 20-Percent Limestone (5.5-percent moisture)

Testing of the Pennsylvania Eastern Bituminous feedstock was completed. Our experience with this material was similar to that with the sub-bituminous coal in that it was very difficult to load into the loop, but flowed through the Kinetic Extruder satisfactorily. Loading problems included very slow flow out of the vibrating barrel-dump hopper and slow flow through the scalping screen. The trouble in loading correlated strongly with the moisture level of the particular drum of coal charged into the loading hopper. As before, once inside our test loop, the material could be pneumatically handled without problems.

Table 4-11 LOCKHEED LAB TEST DATA (MONTANA SUB-BITUMINOUS COAL)

Sample Number	Ohaus Moisture (%)	Permeability* 10^{-12} ft ²	Location Sampled	Elapsed Run Time With Coal (h)
157	24.3	8.9	Drum 22	-
158	26.0	14.8	Drum -	-
159	20.3	3.0	Drum 24	-
160	30.2	3.5	Drum -	-
162	27.0	16.8	Drum 6	-
163	24.5	11.7	Drum 7	-
164	24.8	10.9	Drum 18	-
165	19.1	4.9	Drum -	-
166	25.0	13.4	Drum -	-
167	24.8	13.9	Drum -	-
168	25.7	13.1	Drum -	-
169	22.3	10.4	Drum -	-
171	25.1	16.3	Drum 7	-
172	25.2	9.9	Drum -	-
173	25.0	9.1	FP** (before running)	0
174	24.5	8.7	FP (before running)	0
175	24.2	6.9	FP (Run No. 348)	0.6
176	23.2	6.1	FP (Run No. 349)	1.4
177	23.8	5.1	FP (Run No. 352)	3.8
178	23.2	4.3	FP (Run No. 354)	4.7
180	23.5	4.9	FP (Run No. 355)	5.4
181	23.6	4.6	FP (Run No. 355)	5.4

*1000-g compaction test

**Feed Pipe

Within the limitations imposed by the present equipment, the test matrix for this feedstock was completed. Test-run data are shown in Table 4-12 and Fig. 4-15 for the KE operating points. Feedstock moisture and permeability data are listed in Table 4-13 for the samples taken during the course of the tests.

Testing with Pennsylvania Eastern Bituminous Coal Mixed with 20-percent Limestone and 2-percent Added Water. After completion of the tests at the initial moisture level of 5.5 percent, the moisture was increased to 7.5 percent by water spray and testing resumed. The machine could not handle the material in this condition. The frequency of nozzle flow stoppages was very high ($\approx 1/\text{sec}$) and severe feed hopper ratholing occurred. The problem was similar to that with the wetted lignite.

Data for a single run made at 75 psig is included in Table 4-12 and Fig. 4-15. No further testing was attempted with this feedstock.

4.4.5 Testing with Eastern Bituminous Coal From Pennsylvania (as received 6 percent moisture)

The Eastern Bituminous coal proved to be the most difficult feedstock to test in its as received moisture condition (6 percent). The material ratholed in the feedhopper and only a small quantity could be fed before exhausting the central core of material in the hopper and running out of coal. Attrition of the coal in the loop was also greater than other coals, in part because the same small amount was recycled over and over, and in part because the coal is more fragile than the others. It had the rather high Hardgrove grindability index of 93.

Due to coal attrition in the loop the coal permeability had decayed to below that which the present equipment would tolerate after only some eight test points were obtained. The test data is summarized in Table 4-14 and Fig. 4-16. Laboratory test data on coal samples taken during the test series is given in Table 4-15.

Table 4-12 SUMMARY OF TEST DATA (PENNSYLVANIA EASTERN BITUMINOUS COAL
PLUS 20 PERCENT LIMESTONE AS RECEIVED MOISTURE (5.5%))

Run Number	357	357	358	358	359	360	360	361	361	361	362*
Throughput (tph)	0.92	0.97	1.27	0.58	1.32	0.81	0.91	0.68	1.57	1.04	0.60
Delivery Pressure (psig)	105	197	105	105	200	200	250	0	0	260	75
Control Gas Pressure Differential (psig)	10	9	20	3	20	3	10	5	20	20	8
Torque (ft-lb)	42.4	49.0	47.4	29.0	63.0	41.5	54.4	22.5	36.1	61.5	40.7
Speed (rpm)	2950	2970	3310	2320	3460	2705	3125	2200	3400	3360	3300
Suction System Flow (scfm)	4.3	5.2	4.4	4.8	5.0	5.4	5.3	4.0	4.9	5.9	-
Rotor Eye Pressure (in. Hg)	-7	-6	-7	-7	-6.5	-6.2	-6.0	-7	-7	-6	-6.5
Carrier Gas Pressure (in. Hg)	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3
Receiver Coal Temperature (°F)	-	-	58	59	55	59	64	57	60	75	48
Eye Temperature (°F)	-	-	72	81	63	74	79	73	75	85	62
Suction (Baghouse) Pressure (in.Hg)	-8.5	-8.5	-8.5	-8.7	-8.5	-8.5	-8.1	-8.6	-8.6	-8.5	-

*Added moisture, total 7.5%

Fig. 4-15 Test Points With Pennsylvania Eastern Bituminous Coal Mixed With 20-Percent Limestone

Based on these tests the feed hopper design will have to be improved as discussed in Section 4.4.12 in order to satisfactorily handle the Eastern Bituminous coal at 6-percent moisture. If this is done there will be no problem feeding the material in a once through system where attrition is not a factor.

Testing with Eastern Bituminous Coal with Added Moisture (1 percent moisture added). Testing of the Eastern Bituminous coal with the moisture increased by 1 percent by means of the water spray was also attempted. As expected, this increase in surface moisture made the feed hopper ratholing problem too severe to operate. One test point was obtained, with difficulty, and the data is included in Tables 4-14 and 4-15 and Fig. 4-16 with the other data.

Table 4-13 LOCKHEED LAB TEST DATA (PENNSYLVANIA EASTERN BITUMINOUS COAL PLUS 20-PERCENT LIMESTONE)

Sample Number	Ohaus Moisture (%)	Permeability* 10^{-12} ft ²	Location Sampled	Elapsed Run Time With Coal (h)
183	6.2	10.0	Drum 1	-
184	4.4	2.9	Drum 2	-
185	4.0	4.1	Drum 3	-
186	4.5	7.0	Drum 7	-
187	3.5	4.2	Drum 4	-
188	5.4	4.8	Drum 5	-
189	4.8	3.4	Drum 6	-
193	4.2	3.4	Drum -	-
194	3.6	1.4	Drum -	-
195	4.0	5.6	Drum -	-
196	4.8	4.1	Drum -	-
197	5.5	3.1	FP** (run 357)	0.3
198	5.4	3.2	FP (run 357)	0.3
199	5.9	2.3	FP (run 360)	1.8
200	5.9	2.4	FP (run 361)	2.4
201	6.1	2.7	FP (adding H ₂ O)	
202	7.2	3.9	FP (adding H ₂ O)	
203	7.4	3.7	FP (run 362)	-

*1000-g compaction test

**Feed Pipe

Table 4-14 SUMMARY OF TEST DATA (PENNSYLVANIA EASTERN BITUMINOUS COAL)

Run Number	364	364	366	366	366	367	368	369*
Throughput (tph)	0.62	0.66	1.00	1.10	0.92	1.47	0.71	0.63
Delivery Pressure (psig)	110	100	105	100	200	0	100	75
Control Gas Pressure Differential (psig)	10	13	9	8	4	8	4	4
Torque (ft-lb)	43.7	40.0	41.2	47.3	57.8	32.5	41.4	35.9
Speed (rpm)	3,090	3,050	2,945	3,430	3,385	2,500	2,995	3,030
Suction System Flow (scfm)	-	5.0	4.2	-	5.6	5.4	5.2	4.8
Rotor Eye Pressure (in. Hg)	-7	-6.5	-7	-	-6	-7	-7	-5.5
Carrier Gas Pressure (in. Hg)	-3	-2	-2	-	-2	-2	-2	-2
Carrier Gas Flow (scfm)	3.5	3.7	3.8	-	3.6	3.7	3.6	3.6
Receiver Coal Temperature (°F)	51	56	58	-	68	52	59	58
Eye Temperature (°F)	63	73	69	-	83	58	67	67
Suction (Baghouse) Pressure (in. Hg)	-8.6	-8.5	-8.6	-	-8.3	-8.7	-8.0	-8.2

*1-percent added surface moisture

Fig. 4-16 Test Points with Eastern Bituminous Coal (Pennsylvania)

4.4.6 Operating Problems Encountered During Initial Operation of the Model No. 5 Kinetic Extruder

Two operating problems plagued operation of the Kinetic Extruder and delayed the start-up of the test program. These were seal leakage and uneven coal flow through the twelve sprues. As indicated below in both instances, the cause has been identified and corrective action was taken. The problems have been eliminated.

Face Seals. From the beginning of the program, we have been plagued by leakage of the face seals. These seals were procured about 2 years ago under Phase III of the original coal feeder development program. They consist of a spring-loaded face seal made from silicon carbide and shrunk fit into a metallic "carpenter 42" holder. The mating ring is made of 400-series stainless steel coated with tungsten carbide.

Table 4-15 LOCKHEED LAB TEST DATA (PENNSYLVANIA EASTERN BITUMINOUS COAL)

Sample Number	Ohaus Moisture (%)	Permeability* 10^{-12} ft ²	Location Samples	Elapsed Run Time With Coal (h)
205	6.0	8.8	Drum 1	-
206	5.2	2.9	Drum 2	-
207	5.9	6.9	Drum 3	-
208	5.9	4.7	Drum 5	-
209	4.9	2.8	Drum 6	-
210	5.6	3.6	Drum	-
211	6.0	3.7	Feed Pipe (before any running)	0
212	6.0	3.9	Feed Pipe (before any runing)	0
213	5.8	4.0	Drum	-
214	6.4	5.1	Drum	-
215	5.9	5.2	Drum	-
216	5.6	3.2	Feed Pipe, Run No. 364	0.5
217	5.2	2.0	Feed Pipe, Run No. 366	1.3
218	5.1	1.4	Feed Pipe, Run No. 368	2.6
219	6.0	3.0	Feed, Pipe, Adding H ₂ O	-
220	6.2	3.0	Feed Pipe, Run No. 369	-

*1000-g compaction test

By careful installation and shimming, a set of seals was installed which had an acceptable leakage rate (about 25 cm³/min). This rate was tolerable, yet higher than attainable with well fitting face seals. After a few hours of operation, one of the seals opened and dumped a large amount of liquid into the receiver vessel. The equipment was dismantled and no cause could be detected for the observed failure. Several sets of unused seals were installed and tested for leaks; they all leaked excessively. At this point, the seals proper became suspect and inspection showed that the seal surfaces were in fact distorted and out of specification. For good sealing, the

surfaces should be flat to within 2 to 3 helium light bands. None of the sealing surfaces could qualify.

It appears that the seal had deteriorated during storage. Rework was required. The backlog at the seal vendor, however, made reworked seals unavailable to us in time to complete the program. A local shop, knowledgeable in seal rework, had just recently acquired the capability to handle the silicon-carbide and tungsten-carbide materials. Six sets of seals were submitted for rework. Three sets of reworked seals were judged acceptable by the vendor but judged marginal by us. Testing after installation indicated high leakage. A second pair of seals was submitted and good surfaces were obtained. These seals were installed in the number 2 and 3 positions and sealed well under static and dynamic conditions. The cause of the seal leakage problem has been identified and an acceptance method implemented at Lockheed which can differentiate between good and unacceptable seals. Presently there is no detectable face seal leakage in either static or dynamic tests. An unrelated seal failure occurred when during one test the silicon carbide insert separated from the metallic holder. This caused a large dump of liquid into the test loop.

Uneven Nozzle Flow Problem. Uneven coal discharge flow from the control nozzles has been observed. It was attributed to seal liquid leakage into the rotor eye. However, when a nonleaking set of seals was installed the uneven flow continued. The source of the problem has since been traced to fouling of the control gas nozzle filters which are installed near the end of each sprue. These filters ensure against any possibility of coal dust reaching the control gas seals under abnormal operating conditions.

When fouling occurs, the control gas distribution is disturbed. As a result, nozzles with fouled filters do not get adequate control gas and the coal flow is reduced. The nozzle also exhibits poor response to control gas pressure variation.

To avoid this imbalance problem, the filter should be located upstream at the manifold system which distributes control gas to the twelve nozzles. Time does not permit this change-over at this time. The uneven flow problem was solved in the interim by removing the filters.

Figures 4-17 and 4-18 illustrate the nozzle coal flow signatures with and without use of the control gas filters. As indicated by Fig. 4-18, when the control gas is evenly distributed all nozzles flow evenly.

4.4.7 Test Pressure Limitation

During the initial part of the test program, we have limited our test pressure to 200 psig to eliminate any chance of damaging our equipment. When the case is pressurized, the seals must deflect to compensate for the shift in position between shaft, housing and the coal feed tube.

As shown in Fig. 4-19, the rotor is locked to the housing on the drive shaft through the thrust bearing. Seal No. 1 does not have to compensate for any housing deflection. On the opposite side, the bearing can slide relative to the housing and the seal must accommodate the total housing deflection. That is, Seal No. 2 must expand by twice the deflection of the housing wall. The feed tube is rigidly attached to the housing and Seal No. 3 must compress the same amount as Seal No. 2 expands. The allowable seal movement is ± 0.030 in. Initial measurements by dial gage indicated a possible case deflection of around 0.015 in. per 100 psi. The exact location of the seal relative to the casing is difficult to determine to the required accuracy. Temperature readings at 200-psi case pressure of a thermocouple, located inside the coal feed tube in the rotor eye, indicated heat buildup caused by a potential bottoming out of the seal. Until more measurements could be made and we were more confident of seal location and case deflection, it is prudent to limit operating pressure to about 200 psig. Damage to the rotor hardware would make it impossible to finish the program within budget.

SPRUE NUMBER: 1 2 3 4 5 6 7 8 9 10 11 12 1,

Fig. 4-17 Nozzle Flow Signatures with Nozzle Control Gas Filters Installed

SPRUE NUMBER: 1 2 3 4 5 6 7 8 9 10 11 12

Fig. 4-18 Nozzle Flow Signatures without Filters

Fig. 4-19 Shaft Seals Axial Displacement

As more confidence was obtained maximum test pressures were gradually increased. At 300 psi, case deflection caused the drive shaft seal faces to separate. When pressure was reduced the seal resealed and no further leakage has been observed.

An upper limit of around 300 psi is also presently to be confronted because of the control-gas-differential pressure-control system. The diaphragms in the valves have an upper operating limit of 350 psi. Since control-gas pressure should vary up to 50 psi above chamber pressure, chamber pressure must be limited to about 300 psi. By the time this limitation became known to us, we were unable to take corrective action.

4.4.8 Limit on Turn-Down Ratio

A second problem encountered with our control gas differential pressure system is that we cannot operate at differential pressures greater than about 30 psi. This limits turn down to about 2 to 1.

To obtain the desired 3-to-1 ratio, differential pressures up to 60 psi could be required. At higher delivery pressures the control gas pressure is increased by 20 to 30 psi between the shaft injection point and the control nozzle because of the pumping action of the rotor, as further discussed below. The effect of this pumping action further limits the throttling range of our present equipment at the higher delivery pressures. For satisfactory operation, our system, comprised of two mechanical pressure regulators, needs to be replaced by a servo controller. Such equipment is commercially available. Schedule and budget, however, did not permit upgrading the system at this time.

4.4.9 Control Nozzle Calibration

The combined effects of speed and control nozzle gas pressure differential on coal flow rate can be theoretically approximated as follows:

$$M_c = N C_d d^{5/2} [G + A \Delta P_N]^{1/2} \quad (1)$$

where

- M_c = coal flow rate
- N = number of sprues
- C_d = nozzle discharge constant
- d = nozzle diameter
- G = G force, rw^2/g
- ΔP_N = control nozzle pressure differential (nozzle entrance pressure - casing pressure)
- A = pressure constant

In our test setup, the differential pressure ΔP_C , is measured. This is the differential pressure between the casing and the control gas introduction pressure at the rotating shaft seal assembly. At higher delivery pressures and higher rotor speeds, the gas pressure inside the rotor gas passages increases due to centrifugal forces and a correction to ΔP_C must be made before ΔP_N can be determined. The relationship between ΔP_C and ΔP_N is given by:

$$\Delta P_N = \Delta P_C + \rho_g \frac{r^2 w^2}{2} \quad (2)$$

where

- P_c = measured pressure differential
- ρ_g = control gas density
- r = radial position of nozzle entrance
- w = rotor speed

The magnitude of the centrifugal term is given in Fig. 4-20 as a function of pressure and rotor speed. As shown, the term is quite significant at higher speeds and pressures.

Fig. 4-20 Centrifugal Contribution to Control Nozzle Pressure Differential

This effect reduces the turndown range of the installation. The present control gas regulators cannot be set for $\Delta P_C < 0$. This means that the turndown range becomes more limited at higher pressures and speeds. To solve this problem the present control gas ΔP regulators will have to be replaced with ΔP servo controllers. These units are standard, commercially available items, however cost and schedule preclude their use at the present time.

Using Eqs. (1) and (2) and the test data presented in Table 4-3 the pressure constant, A , was determined to be 400 psi^{-1} . Using this value for A and a previously determined value of $0.59 \text{ tph-in.}^{5/2}$ for C_d , the test data given in Table 4-3 can be correlated as shown in Fig. 4-21.

Fig. 4-21 Comparison of Test Data with Performance Curves;
Western Bituminous Coal, 7-Percent Moisture

4.4.10 Back Leakage Flow Analysis

If terms of comparing actual to theoretical Kinetic Extruder performance, the most sensitive parameter is sprue gas leakage flow. This leakage flow is a function of discharge pressure, coal flow rate, and coal plug permeability, density, and porosity. Figure 4-22 shows theoretical predictions of the gas leakage as a function of discharge pressure and coal flow rate for a fixed value of permeability, $k = 4 \times 10^{-12} \text{ ft}^2$.

A desired test result is the relationship between the effective bed permeability of the moving coal plug in the sprues and the permeability measured in our static laboratory test. This may be determined by comparing predicted versus actual sprue leakage data. Previous test data had shown that the lab procedure underpredicted the sprue permeability by about 25 percent.

The measured suction system gas flow rate, Q_S , is related to the sprue leakage flow, Q_L , by the mass balance around the rotor eye:

$$Q_S = Q_M + Q_P + Q_C + Q_L$$

where

- Q_M = excess transport gas coming into rotor with coal
- Q_P = pressure tap purge
- Q_C = carrier gas flow

The flows Q_M and Q_P are small and can be determined by calibration or, with reasonable accuracy, by estimation. A larger component is Q_C which varies with the rotor eye and carrier gas pressure differential. Calibration constants to determine $Q_M + Q_P + Q_C$ were determined from Q_S data at low or zero pressure, where $Q_L \leq 0$. Part way through the test program a flow meter was installed to measure Q_C directly as an additional check.

Fig. 4-22 Variation of Calculated Sprue Gas Leakage Flow with Pressure and Throughput. (Coal Permeability = $4 \times 10^{-12} \text{ ft}^2$, Coal Density 42 lb/ft^3 , Coal Porosity 0.50, 0.283-in. Sprue Outlet)

In order to make theoretical predictions for each feedstock and test condition, the bulk density and porosity of the coal plug must be specified in addition to the permeability. The bulk density data are measured for test samples in conjunction with the permeability laboratory measurement. Porosity, ϵ , was calculated from true particle density (ρ_T) and the bulk density (ρ_B) according to $\epsilon = (\rho_T - \rho_B) / \xi_T$. True density of the samples was measured by means of water slurry mixing procedure. The pertinent density data for the five feedstocks tested is given in Table 4-16.

Using the appropriate values of the parameters, theoretical predictions have been made and are compared with experimental sprue gas leakage data for four of the feedstocks in Figs. 4-23, 4-24, 4-25, and 4-26. Each of the figures shows sprue leakage vs pressure data for one feedstock, a fairly narrow range

Table 4-16 COAL PROPERTY MEASUREMENTS USED FOR THEORETICAL PREDICTIONS

Coal	Sample No.	True Density (lb/ft ³)	1000 g Bulk Density (lb/ft ³)	1000 g Porosity
Western Bituminous	124	81.7	44.3	0.458
Lignite	147	73.0	48.7	0.333
Sub-Bituminous	181	73.6	49.3	0.330
Eastern Bituminous + 20% Limestone	198	83.0	59.0	0.286
Eastern Bituminous	217	74.2	49.9	0.328

of coal flows, and also a narrow range of static sample permeabilities. The static permeability having been determined from test samples taken during the course of the testing. The plotted data points may be compared with the theoretical curves which have been generated for a range of values of permeability.

Inspection of these figures shows the effective sprue plug permeability, that is the value which produces general agreement between theoretical predictions and the experimental data, varies between about $14 \times 10^{-12} \text{ ft}^2$ (for Lignite) and about 3.5×10^{-12} (for the Eastern Bituminous + 20 percent Limestone). More significantly, the relationship between this effective permeability and the static laboratory measurement of permeability is reasonably fixed for all the feedstocks. The static laboratory procedure appears to underpredict the sprue permeability by 10 to 40 percent. This is in general agreement with previous test data.

4.4.11 Kinetic Extruder Torque Data Analysis

Torque required at the Kinetic Extruder rotor shaft is made up of three contributions: (1) "internal work" torque (T_I) due to coal flow through the rotor, (2) parasitic rotor skin drag torque (T_E), and (3) bearing and seal friction (T_B). Total shaft torque requirements may be calculated from:

Fig. 4-23 Comparison of Theoretical and Experimental Sprue Gas Leakage Flows for Lignite Coal Tests. Theoretical curves for coal flow = 0.99 tph, bulk density = 49 lb/ft³, porosity = 0.33

Fig. 4-24 Comparison of Theoretical and Experimental Sprue Gas Leakage Flows for Subbituminous Coal Tests. Theoretical curves for coal flow = 0.99 tph, bulk density = 49 lb/ft³, porosity = 0.33

Fig. 4-25 Comparison of Theoretical and Experimental Sprue Gas Leakage Flows for Eastern Bituminous + 20% Limestone Tests. Theoretical curves for coal flow = 0.99 tph, bulk density = 59 lb/ft³, porosity = 0.29

Fig. 4-26 Comparison of Theoretical and Experimental Sprue Gas Leakage Flows for Western Coal Tests. Theoretical curves for coal flow = 1.32 tph, bulk density = 44 lb/ft³, porosity = 0.46

$$T = T_B + T_I + T_E$$

$$T = T_B + r^2 w m_c + C_m \frac{1}{2} \rho w^2 r^5 \left[1 + \frac{5}{2} \frac{h}{r} \right] \quad (1)$$

where, in compatible Units:

- m_c = coal flow rate
- w = rotor speed
- ρ = external gas density
- r = rotor radius
- C_m = dimensionless torque coefficient
- h = rotor rim thickness

Bearing and seal friction was determined from unpressurized tests with no coal flow. Typical data are included in Fig. 4-27. Variation of this term with seal fluid temperature (viscosity) was noted, as would be expected.

Table 4-17 gives a compilation of all the torque data obtained in the test program. Listed there, for each run, is the pressure, coal flow, temperature, speed, shaft torque, T , the bearing and seal torque, T_B , based on Fig. 4-27 and the run temperature, and the net torque, $T - T_B$. By comparing predictions based on Eq. (1) with the experimental data one may deduce by trial and error that the torque coefficient for the rotor is approximately $C_m = 0.005$. Figure 4-28 shows a comparison of predictions for 205 psig, $m_c = 1$ tph and 105 psig, $m_c = 1$ tph with experimental data at similar pressures and throughputs.

A torque coefficient of $C_m = 0.005$ for the KE No. 5 rotor represents a significant improvement over earlier configurations (see Ref. 1).

4.4.12 Feed Hopper Flow Problems

Feed hopper flow problems have been encountered for some of the feed stocks tested. These problems become quite severe when the coal is sprayed with water. Two specific problems have been encountered: (1) inability to

Fig. 2-27 Seal/Bearing Parasitic Drag (0 psig, No Coal Flow)

maintain a dense phase flow to the KE from the feed hopper due to "ratholing," and (2) formation of immobile moist cakes of material at the bottom of the feed hopper, which mechanically interfere with a fluidized coal discharge.

The present feed hopper configuration is illustrated in Fig. 4-29. As shown, the hopper is rather squat, with a coal bed height/diameter ratio of only about 1.2 even when completely full. The hopper could hold a total of about 1500 lb of coal. Zone fluidization is used to produce a dense phase discharge of fluidized coal to the KE inlet. The fluidizing gas is independently fed to three separate manifolds at the bottom of the hopper. These are (1) a fluidizing plate containing drilled holes immediately around the coal outlet, (2) an inner ring manifold containing four concentric 1/2-in. tubing rings with drilled holes, and (3) an outer ring manifold with 2 concentric rings of 1/2-in. tubing with drilled holes. To minimize gas consumption, the coal is well fluidized only in the central zone of the hopper. At maximum flow, the outer ring manifold produces a fluidizing velocity of only about 5 mm/sec.

Table 4-17 TORQUE DATA

Run No.	Pressure (psig)	Coal Flow (tph)	Temperature ($^{\circ}$ F)	Speed (rpm)	T Gross Torque (ft-lb)	T _B Bearing and Seal Torque (ft-lb)	T - T _B Net Rotor Torque (ft-lb)
301	0	0.57	80	1,875	15.5	17	-1.5
302	0	0.56	75	1,824	16.6	18	1.4
302	0	0.57	-	2,198	17.3	18	-0.7
303	39	0.71	77	2,087	19.6	18	1.6
303	35	0.99	-	2,643	23.5	21	2.5
305	100	0.63	82	2,930	32.4	20	12.4
306	102	1.04	79	2,960	36.1	21	15.1
307	100	1.06	85	3,310	39.6	22	17.6
310	50	0.51	-	1,991	21.5	19	2.5
313	150	0.84	73	2,760	40.5	22	18.5
314	200	1.14	82	3,233	53.5	21	32.5
314	203	0.82	95	3,014	45.2	18	27.2
314	203	1.01	105	3,020	45.5	17	28.5
315	60	0.84	-	3,027	33.9	23	10.9
316	55	1.33	68	2,965	36.5	23	13.5
322	50	0.82	79	2,485	29.8	20	9.8
322	50	1.36	77	2,905	20.3	21	-0.7
323	100	0.98	72	2,720	38.0	22	16.0
324	107	1.14	83	2,721	36.3	20	16.3
324	105	1.20	87	2,700	37.0	19	18.0
327	104	1.09	66	2,755	43.5	22	21.5
327	110	1.38	71	2,747	42.0	21.5	20.5
328	105	0.98	80	2,759	37.3	20	17.3
329	200	1.49	79	3,080	54.5	22	32.5
330	200	1.46	73	3,025	56.3	23	33.3
331	50	1.21	77	3,015	37.0	22	15.0
331	50	0.89	80	3,035	33.0	22	11.0

Table 4-17 (Cont.)

Run No.	Pressure (psig)	Coal Flow (tph)	Temperature (°F)	Speed (rpm)	T Gross Torque (ft-lb)	T _B Bearing and Seal Torque (ft-lb)	T - T _B Net Rotor Torque (ft-lb)
332	195	0.74	84	3,060	46.2	20.5	25.7
333	100	0.85	63	2,275	33.4	22	11.4
333	98	0.91	71	2,481	33.5	21.5	12.0
334	50	0.45	71	2,917	30.4	22	8.4
336	100	0.93	59	2,696	37.4	24	13.4
337	100	1.40	-	2,984	42.5	23	19.5
338	105	1.05	58	3,070	42.2	25.5	16.7
340	100	1.07	-	2,720	37.6	22	15.6
340	155	1.10	71	3,106	47.8	23	24.8
340	155	1.04	-	3,180	47.5	23	24.5
341	50	1.89	-	2,230	34	20	14
342	100	0.92	78	3,215	42.2	22	20.2
342	150	0.86	-	3,215	45.2	22	23.2
344	105	0.66	58	3,120	43.4	25	18.4
346	50	0.78	-	2,720	31.5	24	15.5
348	105	0.95	62	2,830	39.5	23	16.5
348	106	1.00	-	2,815	41.0	23	18
349	107	1.00	58	3,145	45.8	25	20.8
349	205	0.95	66	3,025	52.3	24	28.3
350	110	0.72	62	2,555	36.8	22	14.8
350	110	1.10	67	3,307	49.0	24	25.0
351	255	0.95	77	3,408	64.2	23	41.2
352	254	1.15	72	3,420	67.1	24	43.1
353	200	0.68	70	2,860	46.9	22.5	24.4
353	100	0.46	78	2,210	28.9	19	9.9
354	207	1.17	73	3,465	63.0	24	39.0
354	112	1.12	81	3,450	48.2	23	25.2

Table 4-17 (Cont.)

Run No.	Pressure (psig)	Coal Flow (tph)	Temperature (°F)	Speed (rpm)	T Gross Torque (ft-lb)	T _B Bearing and Seal Torque (ft-lb)	T - T _B Net Rotor Torque (ft-lb)
355	300	0.96	-	3,420	79.1	23	56.1
357	105	0.92	-	2,953	42.4	22	20.4
357	197	0.97	-	2,966	49.0	22	27.0
358	105	1.27	72	3,312	47.4	24	23.4
358	105	0.58	81	2,317	29.0	18	11.0
359	200	1.32	63	3,458	63.0	26	37.0
360	200	0.81	74	2,704	41.5	22	19.5
360	250	0.91	79	3,125	54.4	22	32.4
361	260	1.04	85	3,360	61.5	21	40.5
362	75	0.60	62	3,300	40.7	25	15.7
364	110	0.61	63	3,090	43.7	24	19.7
364	100	0.66	73	3,048	40.0	23	17.0
366	105	1.00	69	2,945	41.2	23	18.2
366	100	1.10	-	3,430	47.3	24	23.3
366	200	0.92	83	3,385	57.8	22	35.8
	0	1.47	58	2,500	32.5	23	9.5
368	100	0.71	67	2,995	41.4	24	17.4
369	75	0.63	67	3,030	35.9	24	11.9
370	205	1.25	62	3,195	60.5	25	35.5
371	200	1.45	71	3,360	63.2	24	39.2
371	198	0.97	79	2,940	49.8	21	28.9
372	0	1.18	62	2,898	33.4	24.5	9.1
372	125	0.98	64	2,900	44.0	24.5	20.5
372	115	0.68	73	2,255	32.2	20	12.2
372	120	1.28	76	3,200	49.5	22.5	27.0

Fig. 4-28 Experimental Torque Data Compared to Predictions From Eq. (1) With $C_m = 0.005$

Fig. 4-29 Fluidizing Manifold Arrangement in Feed Hopper

This feed hopper configuration using zone fluidization worked satisfactorily for most of the feedstocks at the as-received moisture level. However, for the Eastern Bituminous coal, and for all of the coals when sprayed with the water, there were problems. First of all was an inability to remove all of the coal from the hoppers pneumatically, as shown in Fig. 4-30. If the material was reasonably free flowing, this quantity of residual coal only amounted to between 100 and 200 lb. However, with the wet material, up to 600 lb was left in the hopper. This meant that the hopper had to be opened up and manually cleaned when feedstocks were changed. Furthermore, the residual feed hopper material was found on one occasion (Montana sub-bituminous coal, unwetted) to have congealed into large cakes which physically partly blocked the coal outlet and also interfered with fluidization.

Fig. 4-30 Typical Residual Coal not Removable from Feed Hopper

The second problem was due to an intermittent rat-holing problem as illustrated in Fig. 4-31. This problem is discussed in more detail in Section 4.4.15. The precise mechanism is somewhat conjectural, but the manifestation was an absence of coal flow from the KE feed pipe followed by a loss of rotor-eye vacuum.

Usually, these upsets were brief and flow resumed within a couple of seconds. It appears that the coal is only well fluidized in the central core of the hopper and when this zone is exhausted the feed is more or less by coal sloughing off the walls of a central "rathole." From time to time, the rathole extends all the way to the outlet pipe causing the observed loss of rotor-eye vacuum. As would be expected, this problem worsened as the feed hopper coal bed became shallower.

Fig. 4-31 Feed Hopper "Rathole" Problem Encountered with Moist Coal

Based on experience to date, the following is recommended for a more reliable KE feed hopper design.

- o Increase the bed height/diameter ratio of the feed hopper
- o Fluidize the entire cross section of the hopper
- o To prevent material hangup and possible cake formation, the hopper bottom should be sloped to the outlet point to obtain "mass flow."

4.4.13 Problems Caused by Recycling of Lignite Feedstock

On the first pass or two, the Lignite coal fed quite well through the Kinetic Extruder. However, after the coal had been recycled a couple of times a very frequent flow-stoppage problem developed in the control nozzle. The missing nozzle flows would restart immediately upon activation of the deplugger jet; however, the frequency of the stoppages was enough to cause much inconvenience.

The problem was traced to the Lignite's formation of a coating resembling old peeling paint inside the rotor casing. Flakes of this coating spalled off due to erosion and/or pressure fluctuation. As a result, the coal feed stock became heavily contaminated with flakes. Sieving some of the coal samples taken from the coal inlet pipe showed lots of these flakes of a size larger than the control nozzle outlets. The flakes had little structural strength but were solid enough to temporarily plug the control nozzles until broken up and dislodged by the action of the deplugger.

The feed pipe and the inside of the rotor were inspected with a borescope and it was verified that no coating or deposits formed in these locations. Therefore, the flow stoppage problem is strictly associated with the use of recycled coal and would not be encountered in once-through feeding in an operating plant.

We suspect that even the infrequent nozzle flow stoppages encountered with other types of coal are associated with manufacture of oversize coal flakes or lumps in the casing or receiver vessel. A scheme to sieve the recycled coal stream was devised to address this problem but not implemented.

Coupon Test. In an effort to establish means to eliminate or reduce the Lignite coating problem inside the casing, a brief material coupon test was conducted. In this test, approximately 6-in.-square sheets of various materials were attached inside the casing lid to determine if the coating would also form on alternate substrates. Three new materials were tried: (1) teflon, (2) stainless steel sheet, and (3) insulated stainless steel sheet. A cleaned off area of the existing casing material was also left on the lid as a control.

A 45-min. test run was made with these coupons installed. Inspection after the run showed considerable coating buildup on the existing casing material but none on either the teflon or the smooth stainless steel surfaces. The casing material is ASTM A36 and has a fairly rough and corroded surface. Evidently, just the better surface finish mitigates the coating problem.

Based on these results, we have lined the inside surface of the casing with stainless steel sheet material. The formation of flakes has not been observed in subsequent testing with other coals.

4.4.14 Effect of Feeder on Particle Size

The coal particles are not subject to large forces in passing through the sprue. No high stress compaction takes place as for instance is observed in screw type extruders. During pneumatic transfer of the coal from the supply hopper to the feed hopper and recycling from the receiver hopper to the feed hopper the coal travels in 3/4 pipes at high velocities (≈ 50 ft/sec) and makes four 90 deg turns. Most of the observed minor attrition probably occurs during these transfer operations.

Test data shown in Table 4-18 give before-and-after sieve analyses which clearly show that only minor changes are observed for most coals. The Eastern Bituminous coal has a high grindability index and this is reflected in somewhat higher attrition.

Table 4-18: EFFECT OF KE FEEDER ON GRIND SIZE

Feedstock	Sample No.	Approximate No. of Passes Through KE	Sieve Analysis (% Passing 200 Mesh)	Grindability Index
Western Bituminous (Utah)	223	0	55.0	-
Western Bituminous (Utah)	226	2	57.8	-
Lignite (North Dakota)	142	0	33.3	29.3
Lignite (North Dakota)	146	3	30.0	29.3
Sub-bituminous (Montana)	173	0	50.5	48.5
Sub-bituminous (Montana)	181	4	52.8	48.5
Eastern Bituminous +20% Limestone	198	0	43.8	92.9
Eastern Bituminous +20% Limestone	199	3	48.0	92.9
Eastern Bituminous (Pennsylvania)	211	0	62.9	92.9
Eastern Bituminous (Pennsylvania)	218	6	70.5	92.9

No significant change in particle size should occur in the normal "once through" mode of operation.

4.4.15 Coal Feed Pipe Flow Detector

The new instrumentation installed in the coal feed pipe to detect coal flow consists of a photo detector and a light beam which traverses the 3/4-in. feed pipe through a pair of small windows. The device is located in the vertical

pipe section about 3 ft from the KE inlet. This set-up immediately detects any loss of coal feed into the KE.

Figure 4-32 shows a strip chart record illustrating the sequence of events caused by feed hopper ratholing. From top to bottom, this chart contains traces of the light transmission from the new detector, the control gas pressure differential (ΔP_c), the rotor shaft torque, and the rotor eye pressure (P_e). The chart speed was 0.1 in./sec.

The Fig. 4-32 record contains 3 eye pressure upsets, the last of which precedes the sprues emptying and a "blowback." Each of the rotor eye pressure rises follows by about 1 sec the loss of coal at the photodetector location in the feed pipe. One second is the time period it takes the length of feed pipe between the detector and the rotor eye to be drained free of coal. Once this occurs, the eye pressure rises immediately to the pressure in the feed hopper (ambient pressure). As shown in Fig. 4-32, the feed pipe flow restarted and the KE was able to continue feeding and recover from the first two events. This is due to the fact that the rotor contains about a 5-sec coal inventory and therefore the coal feed can be interrupted for shorter times without the sprues draining completely free of coal and the seal being lost. The actual loss of the sprue plugs is signaled on the record by the drop off in ΔP_c .

The above described sequence of events is only consistent with a loss of the coal feed to the KE due to feed hopper ratholing.

4.4.16 Observations Noted During Coal Loading Into Test Loop

Loading coal into the test loop was a separate and distinct operation from actual testing of the Kinetic Extruder, and as such does not directly bear on the feeder tests. However, various problems were encountered in loading some of the coals which should be documented.

The equipment for loading coal (purchased mostly in drums) into the test loop consisted of the following: a barrel dump equipped with an FMC vibrating cone

Fig. 4-32 Strip Chart Record Illustrating Sequence of Events in Blowback due to Feed Hopper Ratholing. Lignite Coal with Added Moisture: Chart Speed 0.1 in./sec.

and trough feeder which metered the coal onto a cleated elevator belt. The elevator belt then discharged through an 18-in. Sweco scalping screen (20 mesh) into the test loop storage hopper. Once inside the storage hopper the coal could be transferred pneumatically to the KE feed hopper after the loading operation was completed.

Montana sub-bituminous coal was the first material found to be troublesome to load into the test loop. The major problem was difficulty in feeding the coal through the scalping screen. Flow rates through the screen were very low and considerable material was rejected by the screen. A significant number of oversize particles were present but the great bulk of the rejected coal consisted of wet balls or clumps of fine material. There was considerable variation of moisture content both between coal drums and from top to bottom within the individual drums. The bottom third of many of the drums consisted of much wetter lumpy material which was mostly rejected by the screen. Ohaus moisture test results on some 17 samples taken from various drums ranged from 19 to 35 percent, with most clustering around 25 percent.

A second problem was persistent ratholing of the material in the vibrating FMC feeder cone which serves the barrel dump bottom. The vibration level of this cone had little impact and the coal had to be manually prodded from time to time to collapse the rat holes.

Loading of the Pennsylvania Eastern Bituminous + 20 percent limestone feedstock also gave difficulties. Loading problems included both slow flow out of the vibrating barrel-dump hopper and slow flow through the scalping screen. The trouble in loading correlated strongly with the moisture level of the particular drum of coal charged into the loading hopper. Rather than ratholing, as with the subbituminous, vibration appeared to compact the material in the loading hopper and belt feed trough resulting in very slow outflow onto the belt. Experience with Eastern Bituminous without limestone was similar but with the additional tendency for the vibrating scalping screen to fill up with large (hen's egg size) balls of material.

Once inside the test loop vessels, however, there were no further handling problems with any of the material. Pneumatic transfer rates between hoppers were high, at modest pressures, and no plugging of transfer lines occurred.

4.4.17 Flowability Test Results

Table 4-19 lists laboratory flowability test results for a selection of samples of the feedstocks tested in the program. The flowability test is a Lockheed designed material test performed in a laboratory centrifuge. It involves determining the g-force required to induce flow (G_f) through a test orifice after compacting the material at 1000 g. A flow inducing g-force of < 1000 g should guarantee no problems with flow stoppage in the KE nozzles due to any cohesive doming phenomena. The test method was documented previously in Ref. 1.

As shown in Table 4-19, all of the test loop samples of the coal passed this test ($G_f < 1000$ g). However, some of the samples taken directly from the shipping drums did not. This we attribute to a caking of the material in long term storage. No nozzle flow stoppages associated with cohesive doming were observed in the test program with the nonwetted coals. With the more heavily water-spray-moistened materials, we began to see some of these phenomena.

Generally, the flowability test results correlate fairly well with ease of handling the material in the loading system. Those with lower values of G_f (Western Bituminous and Lignite) being easier to load and feed through the scalping screen.

4.5 SUMMARY OF TEST RESULTS

The test points reported separately for each test series are shown as a group in Fig. 4-33. This graph delineates the operating envelope of the Kinetic Extruder Model No. 5 and its subsystems.

Table 4-19 LABORATORY FLOWABILITY TEST RESULTS

Sample No.	Coal	Location Sampled	Ohaus Moisture (%)	G-Force* to Induce Flow (g)
101	Subbituminous	Drum	22.2	>1,000
103	Eastern Bituminous	Drum	6.4	>1,000
105	Eastern Bituminous + Limestone	Drum	4.6	>1,000
107	Lignite	Drum	32.5	190
117	Western Bituminous (type that caked on nozzles)	Feed Pipe (Run 311)	-	550
121	Western Bituminous	Feed Pipe (before running)	-	170
141	Lignite	Feed Pipe (before running)	28.2	180
142	Lignite	Feed Pipe (before running)	-	170
143	Lignite	Feed Pipe (Run 337)	28.1	200
144	Lignite	Feed Pipe (Run 338)	-	170
145	Lignite	Feed Pipe (Run 339)	-	170
150	Lignite	Feed Pipe (Run 340)	27.3	180
152	Lignite + 2% H ₂ O	Feed Pipe (before running)	28.6	370
162	Subbituminous	Drum	27.0	>1,000
173	Subbituminous	Feed Pipe (before running)	25.0	250
178	Subbituminous	Feed Pipe (Run 354)	23.2	250
198	Eastern Bituminous + Limestone	Feed Pipe (Run 357)	5.4	290
199	Eastern Bituminous + Limestone	Feed Pipe (Run 360)	5.9	290
203	Eastern Bituminous + Limestone + 2% H ₂ O	Feed Pipe (Run 362)	7.4	520
212	Eastern Bituminous	Feed Pipe (before running)	6.0	550
218	Eastern Bituminous	Feed Pipe (Run 368)	5.1	350
220	Eastern Bituminous + 1% H ₂ O	Feed Pipe (Run 369)	6.2	520

*After compaction at 1,000 g

Fig. 4-33 Summary of All Kinetic Extruder Test Points Obtained in the Phase I Program

The operating range could be extended as shown in Fig. 4-33 by removing the test pressure limitation. This can be accomplished by substituting seals having greater working deflection capability or using a stiffer housing having less sidewall deflection. The throttling capability at higher pressure can be increased by use of a more compatible differential pressure controller.

Conclusions for the as received coal tests are shown in Table 4-20 and for the surface moisture added tests in Table 4-21.

As indicated earlier the Kinetic Extruder is able to handle the moisture level in the as received levels. When the surface moisture reaches the 1 to 2 percent level the limit is reached for pneumatic transport and the coals become very difficult to handle. One lot of Western Bituminous coal coated the sprue bodies and the control nozzles with a residue and this lot was not suitable for feeding to the Kinetic Extruder.

Table 4-20 FEEDSTOCK SUITABILITY TO KE AS RECEIVED MOISTURE LEVEL

Feedstock	Moisture (%)	Feedstock Related Problems	Assessment of Suitability of Feedstock to KE in Once Through System*
Western Bituminous (Utah)	5	None	Good
Lignite (North Dakota)	28	Grind too coarse - high permeability, flakes in recycled coal	Good
Subbituminous (Montana)	25	None	Good
Eastern Bituminous +20% Limestone	6	None	Good
Eastern Bituminous	6	Some feed hopper ratholing, attrition of recycled coal	Good
Western Bituminous (Odd 1 ton lot)	4	Left resinous coating on sprues and nozzles	Unsuitable

*Assumes improved feed hopper

Table 4-21 FEEDSTOCK SUITABILITY TO KE - COAL SPRAYED WITH WATER

Feedstock	Original Moisture (%)	Added Surface Moisture (%)	Feedstock Related Problems	Assessment of Suitability of Feedstock to KE in Once Through System*
Western Bituminous (Utah)	4	3	Some feedhopper ratholing	OK
Western Bituminous (Utah)	4	6	Severe feed hopper ratholing, frequent nozzle flow stoppage	Unsuitable
Lignite (North Dakota)	27	2	Grind too coarse - high permeability, flakes in recycled coal, feed hopper ratholing	Marginal
Subbituminous (Montana)	-	-	Not tested wet	-
Eastern Bituminous + 20% Limestone	6	1-1/2	Severe feed hopper ratholing, frequent nozzle flow stoppage	Marginal
Eastern Bituminous	5	1	Severe feed hopper ratholing	OK

*Assumes improved feed hopper

4.6 REFERENCES

1. _____, Coal Feeder Development Program, Phase III Report, FE-1792-61, Dist. Category UC-90b, Lockheed Missiles & Space Company, Inc., Sunnyvale, CA, Sep 1979
2. W. R. Huff, et al., "A Pilot-Scale Fluidized-Coal Feeder Utilizing Zone Fluidization," U.S. Bureau of Mines, Report of Investigations 6488

Section 5

EVALUATION OF THE KINETIC EXTRUDER

At the beginning of the test program, 12 evaluation criteria had been established. In this section we review pertinent information and test data against these criteria.

5.1 DIFFERENTIAL PRESSURE CAPABILITY

Under the present Phase I of the program, the Model 5 Kinetic Extruder has been operated up to 300 psi delivery pressure. This limit was imposed by case deflection and subsystem limitations. The delivery pressure and throughput relationship limits the obtainable steady state delivery pressure for uncooled equipment as follows:

Size (tph)	Delivery Pressure (psi)
1	400 - 500
7	600 - 800
50	900 - 1100

Higher pressure can be obtained if the rotor operates in hydrogen gas.

5.2 THROUGHPUT CAPABILITY

The Model 5 Kinetic Extruder has a nominal capacity of 1 tph. During this phase of the program, flow rates ranging from about 0.6 tph to 1.8 tph have been demonstrated.

5.3 INSTALLED AND OPERATIONAL COSTS

The cost and designing fabricating and operating the Kinetic Extruder is greatly influenced by site-specific requirements. These include local codes,

and customer requirements and interface definitions. It is therefore not possible to generalize.

To duplicate the Kinetic Extruder presently operated by us, in wear-resistant materials, having a maximum delivery rate of 1.5 tph at 400 psi would cost about \$200,000 in 1982 dollars (subsystems not included).

5.4 TOTAL HORSEPOWER REQUIREMENTS

The total horsepower required by the Model 5 Kinetic Extruder delivering 1 tph at 200 psig in our test loop is as follows:

Rotor	14 hp
Bearings/Seals	12 hp
Suction System	2 hp
Oil System	0.25 hp
Seal Liquid Systems	<u>0.75 hp</u>
Total Power	29 hp

Based on test data, the projected power requirements for commercial units using oil lubricated journal bearings, Crane gas seals, and recycled gas are as follows:

Delivery Pressure (psig)	200	450	700	1,000
Size (tph)	(hp)	(hp)	(hp)	(hp)
1	20	45	*	*
7	60	160	370	*
50	300	850	1,800	3,000

* This pressure/size combination can not be operated under steady state conditions without making provision for cooling.

5.5 RELIABILITY AND FAILURE MODES

During initial start-up of the test program, the seals and the back pressure regulator for the seal liquid system did not perform well. Deterioration, during storage was the identified cause. The seals were relapped and the pressure regulators replaced. The control gas filters were removed because contamination caused uneven sprue flow.

The only observed failure during the test program was of an electric motor driving a seal liquid pump. The motor was damaged by moisture, was repaired but failed again. It was then replaced and no further problem has been encountered.

When surface moisture above 1 to 2 percent was added to any of the feed stock, the feed hopper would "rathole" from time to time and coal would not enter the coal feed pipe. The feed pipe coal flow detector would signal flow interruption and within about 5 seconds the rotor would empty of coal and a "blowback" would occur. In a commercial plant "blowback" would be contained by closing the coal feed valve.

5.6 OPERATIONAL SAFETY

No hazardous conditions were observed. Provision must be made to ensure oil flow to the bearings and seal fluid flow to the seals. The normal indicators of bearing performance (temperature and/or vibration monitoring) should be used.

5.7 CONTROL FLEXIBILITY AND RESPONSE

All controllers performed well and no operational problems were observed. The use of spring-loaded pressure regulators restricted the range of control gas differential pressure regulation to 0 to +30 psi. To obtain a more desirable -30 to +30 psi different equipment is required.

5.8 STABILITY OF OPERATION

During normal operation, that is when the Kinetic Extruder is not driven past the operating capability, the coal flow rate is steady. No oscillations are evident.

5.9 TURN-DOWN CAPABILITY

The demonstrated turn-down capability varied from 2.3 to 1 at low pressure 1 to 1 at 300 psi. Our differential pressure regulation equipment did not have sufficient range nor the capability to overcome the self-pressurization action of the rotor (by controlling a negative ΔP) to achieve the desired 3 to 1 turn down capability over the total delivery pressure range tested.

Commercial equipment is available to permit a 3 to 1 or higher turn down ratio over the total operating pressure range.

5.10 START/STOP CAPABILITY

Because the moving coal plug forms the pressure seal, the Kinetic Extruder can only be started when no differential pressure exists across the sprue. As soon as the coal flow has been established, a pressure differential can be maintained. By proper equipment arrangement and start-up sequence these conditions can be met and the Kinetic Extruder can be started and begin feeding coal to an already pressurized system.

Stopping under all operating conditions can be accomplished.

5.11 ABILITY TO HANDLE VARIATIONS IN FEED STOCK

The present test program has demonstrated that the Model 5 Kinetic Extruder can handle any feed stock that can be pneumatically transferred, has particles no larger than can pass a 20-mesh screen and a bed permeability between 2 and $12 \times 10^{-12} \text{ ft}^2$. Based on our knowledge to date, we believe that equipment

can be designed to handle feed stock having permeabilities ranging from 1 to 30×10^{-12} ft². Experience gained in previous work indicated that commercial grinding equipment and procedures will maintain feed stock grinding consistency well within the requirement of the Kinetic Extruder.

5.12 SCALABILITY

Design studies indicate that the critical item for large commercial equipment are the seals. Scalability of the Crane gas seals up to the sizes required for 100-tph machines has been verified. All other components for the Kinetic Extruder such as forgings for the rotor, castings for the housing, bearings, and shafts pose no scale-up problems. Subsystems are readily available.

Appendix A
TEST LABORATORY REPORTS

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Resource Engineering Incorporated

80 Bacon Street, Waltham, Massachusetts 02154 (617) 894-6720

DATE 6/30/81

COAL ANALYSIS REPORT

ULTIMATE AND PROXIMATE ANALYSIS

YOUR PURCHASE ORDER # YMV 6D0380A ANALYSIS REPORT: RA 215-1
SAMPLE RECEIVED: _____ SAMPLE: Sub-Bituminous (Montana)
RECEIVED FOR: Larkheed Missiles & Space Co.

	<u>AS RECEIVED</u>	<u>DRY BASIS</u>
% MOISTURE	20.21	----
% ASH	9.25	11.59
% VOLATILE MATTER	32.17	40.32
% FIXED CARBON	38.37	48.09
% SULFUR	.85	1.07
% CHLORINE	.07	.09
% CARBON	52.78	66.15
% HYDROGEN	3.42	4.29
% NITROGEN	0.82	1.03
% OXYGEN (By Difference)	12.60	15.78
BTU/Lb	9,267	11,613
MAF - BTU/Lb.	----	13,136
GRINDABILITY	48.46	----
SIVE ANALYSIS	74.0% - 200	----

RESPECTFULLY SUBMITTED BY

Thomas Schuler
Thomas Schuler
Laboratory Manager

Resource Engineering Incorporated

80 Bacon Street, Waltham, Massachusetts 02154 (617) 894-6720

DATE 6/30/81

COAL ANALYSIS REPORT

ULTIMATE AND PROXIMATE ANALYSIS

YOUR PURCHASE ORDER # YMV 6D0380A ANALYSIS REPORT: RA 215-3
SAMPLE RECEIVED: _____ SAMPLE: Eastern Bituminous (Penn.)
RECEIVED FOR: Larkheed Missiles & Space Co.

	<u>AS RECEIVED</u>	<u>DRY BASIS</u>
% MOISTURE	1.41	----
% ASH	11.69	11.86
% VOLATILE MATTER	27.70	28.10
% FIXED CARBON	59.20	60.04
% SULFUR	3.22	3.27
% CHLORINE	.14	.14
% CARBON	75.56	76.64
% HYDROGEN	4.34	4.40
% NITROGEN	1.32	1.34
% OXYGEN (By Difference)	2.32	2.35
BTU/Lb	13.215	13,405
MAF - BTU/Lb.	----	15,208
GRINDABILITY	92.94	----
SIVE ANALYSIS	73.1% - 200	----

RESPECTFULLY SUBMITTED BY

Thomas Schuler
Thomas Schuler
Laboratory Manager *in*

Resource Engineering Incorporated

80 Bacon Street, Waltham, Massachusetts 02154 (617) 894-6720

DATE 6/30/81

COAL ANALYSIS REPORT

ULTIMATE AND PROXIMATE ANALYSIS

YOUR PURCHASE ORDER # YMV 6D0380A ANALYSIS REPORT: RA 215-3
SAMPLE RECEIVED: _____ SAMPLE: Eastern Bituminous (Penn)
RECEIVED FOR: Larkheed Missiles & Space Co.

NOTE: Containing 20% Limestone by WT

	<u>AS RECEIVED</u>	<u>DRY BASIS</u>
% MOISTURE	1.41	----
% ASH	11.69	11.86
% VOLATILE MATTER	27.70	28.10
% FIXED CARBON	59.20	60.04
% SULFUR	3.22	3.27
% CHLORINE	.14	.14
% CARBON	75.56	76.64
% HYDROGEN	4.34	4.40
% NITROGEN	1.32	1.34
% OXYGEN (By Difference)	2.32	2.35
BTU/Lb	13,215	13,405
MAF - BTU/Lb.	----	15,208
GRINDABILITY	92.94	----
SIVE ANALYSIS	73.1% - 200	----

RESPECTFULLY SUBMITTED BY

Thomas Schuler
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Laboratory Manager *JS*

Resource Engineering Incorporated

80 Bacon Street, Waltham, Massachusetts 02154 (617) 894-6720

DATE 6/30/81

COAL ANALYSIS REPORT

ULTIMATE AND PROXIMATE ANALYSIS

YOUR PURCHASE ORDER # YMV 6D0380A ANALYSIS REPORT: RA 215-7

SAMPLE RECEIVED: _____ SAMPLE: Lignite (North Dakota)

RECEIVED FOR: Larkheed Missiles & Space Co.

	<u>AS RECEIVED</u>	<u>DRY BASIS</u>
% MOISTURE	13.73	----
% ASH	13.33	15.45
% VOLATILE MATTER	36.32	42.10
% FIXED CARBON	36.62	42.45
% SULFUR	1.16	1.34
% CHLORINE	.03	.03
% CARBON	49.46	57.33
% HYDROGEN	3.39	3.93
% NITROGEN	.78	.90
% OXYGEN (By Difference)	18.12	21.02
BTU/Lb	9,269	10,743
MAF - BTU/Lb.	----	12,707
GRINDABILITY	29.30	----
SIVE ANALYSIS	73.7 % - 200	----

RESPECTFULLY SUBMITTED BY

Thomas Schuler
Thomas Schuler
Laboratory Manager

COMMERCIAL TESTING & ENGINEERING CO.

GENERAL OFFICES: 228 NORTH LA SALLE STREET, CHICAGO, ILLINOIS 60601

AREA CODE 312 726-8434

WESTERN DIVISION MANAGER
GAIL D. PALMER PLEASE ADDRESS ALL CORRESPONDENCE TO:
10775 EAST 51st AVE., DENVER, CO 80239
OFFICE TEL. (303) 373-4772LOCKHEED MISSILES & SPACE
COMPANY, INC.
P.O. Box 504
Sunnyvale, California 94086

September 14, 1981

Sample identification
by

Kind of sample reported to us Coal

Sample taken at XXXXX

Sample taken by Lockheed Missiles & Space Company, Inc.

Date sampled XXXXX

Date received 8-24-81

Lockheed Missiles & Space Company, Inc.

P.O. # YCV6F5230A

Sample No. 102

*Sub-Bituminous (Montana)**Drum sample*

Analysis report no. 72-112046

SCREEN ANALYSIS (*UNDRIED*)

	<u>PERCENT</u>	<u>ACCUMULATIVE PERCENT</u>
RETAINED ON 20 MESH, PASSING - - -	0.0	0.0
RETAINED ON 48 MESH, PASSING 20 MESH	3.3	3.3
RETAINED ON 100 MESH, PASSING 48 MESH	26.7	30.0
RETAINED ON 200 MESH, PASSING 100 MESH	46.8	76.8
RETAINED ON 325 MESH, PASSING 200 MESH	17.7	94.5
RETAINED ON - - -, PASSING 325 MESH	5.5	100.0

JLK/lm

Respectfully submitted
COMMERCIAL TESTING & ENGINEERING CO.

JAMES L. KENDRICK, Manager, Denver Laboratory

Charter Member

A-7

OVER 40 BRANCH LABORATORIES STRATEGICALLY LOCATED IN PRINCIPAL COAL MINING AREAS,
TIDEWATER AND GREAT LAKES PORTS, AND RIVER LOADING FACILITIES

LOCKHEED MISSILES & SPACE COMPANY, INC.

LAB NO. 72-112046 Page 2

IDENTIFICATION Sample No. 102 Sub-bituminous (Montana)

TOTAL WEIGHT OF SAMPLE 628.25

SCREEN ANALYSIS CURVE

NOTE: SCREEN OPENINGS ON LOGARITHMIC SCALE WITH IN. RD. = 1.25 IN. SQ. =

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AREA CODE 312 726-8434

WESTERN DIVISION MANAGER
GAIL D. PALMER PLEASE ADDRESS ALL CORRESPONDENCE TO:
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OFFICE TEL. (303) 373-4772

LOCKHEED MISSILES & SPACE
COMPANY, INC.
P.O. Box 504
Sunnyvale, California 94086

September 14, 1981

Sample identification
by

Kind of sample reported to us	Coal	Lockheed Missiles & Space Company, Inc.
Sample taken at	xxxxx	P.O. # YCV6F5231A
Sample taken by	Lockheed Missiles & Space Company, Inc.	Sample No. 104
Date sampled	xxxxx	<i>Eastern Bituminous (Penn) drum sample</i>
Date received	8-24-81	

Analysis report no. 72-112047

SCREEN ANALYSIS (UNDRIED)

	<u>PERCENT</u>	<u>ACCUMULATIVE PERCENT</u>
RETAINED ON 20 MESH, PASSING - - -	0.4	0.4
RETAINED ON 48 MESH, PASSING 20 MESH	0.2	0.6
RETAINED ON 100 MESH, PASSING 48 MESH	15.6	16.2
RETAINED ON 200 MESH, PASSING 100 MESH	50.9	67.1
RETAINED ON 325 MESH, PASSING 200 MESH	27.2	94.3
RETAINED ON - - -, PASSING 325 MESH	5.7	100.0

JLK/lm

Respectfully submitted,
COMMERCIAL TESTING & ENGINEERING CO.

JAMES L. KENDRICK, Manager, Denver Laboratory

Charter Member

OVER 40 BRANCH LABORATORIES STRATEGICALLY LOCATED IN PRINCIPAL COAL MINING AREAS,
TIDEWATER AND GREAT LAKES PORTS, AND RIVER LOADING FACILITIES

LOCKHEED MISSILES & SPACE COMPANY, INC.

LAB NO. 72-112047 Page 2

IDENTIFICATION Sample No. 104 *Eastern Bituminous (Penn)*

TOTAL WEIGHT OF SAMPLE 470.5

SCREEN ANALYSIS CURVE

NOTE: SCREEN OPENINGS ON LOGARITHMIC SCALE WITH $\frac{\text{IN. RD.}}{\text{IN. SQ.}} = 1.25$

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COMMERCIAL TESTING & ENGINEERING CO.

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AREA CODE 312 726-8434

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OFFICE TEL. (303) 373-4772

LOCKHEED MISSILES & SPACE
COMPANY, INC.
P.O. Box 504
Sunnyvale, California 94086

September 14, 1981

Sample Identification
by

Kind of sample reported to us Coal
Sample taken at xxxxx
Sample taken by Lockheed Missiles & Space Company, Inc.
Date sampled xxxxxx
Date received 8-24-81

Lockheed Missiles & Space Company, Inc.

P.O. # YCV6F5232A
Sample No. 106

*Eastern Bituminous + 20%
Limestone
(drum sample)*

Analysis report no. 72-112048

SCREEN ANALYSIS (Undried)

	PERCENT	ACCUMULATIVE PERCENT
RETAINED ON 20 MESH, PASSING - - -	1.2	1.2
RETAINED ON 48 MESH, PASSING 20 MESH	0.8	2.0
RETAINED ON 100 MESH, PASSING 48 MESH	25.5	27.5
RETAINED ON 200 MESH, PASSING 100 MESH	45.1	72.6
RETAINED ON 325 MESH, PASSING 200 MESH	22.4	95.0
RETAINED ON - - -, PASSING 325 MESH	5.0	100.0

JIK/lm

Respectfully submitted

 JAMES L. KENDRICK, Manager, Denver Laboratory

A-11

Charter Member

OVER 40 BRANCH LABORATORIES STRATEGICALLY LOCATED IN PRINCIPAL COAL MINING AREAS,
TIDEWATER AND GREAT LAKES PORTS, AND RIVER LOADING FACILITIES

LOCKHEED MISSILES & SPACE COMPANY, INC.

LAB NO. 72-112048 Page 2

IDENTIFICATION Sample No. 106 *Eastern Bituminous + 20% Limestone*

TOTAL WEIGHT OF SAMPLE 614.0

SCREEN ANALYSIS CURVE

NOTE: SCREEN OPENINGS ON LOGARITHMIC SCALE WITH IN. RD. 1.25
IN. SQ. 1.25

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OFFICE TEL. (303) 373-4772

LOCKHEED MISSILES & SPACE
COMPANY, INC.
P.O. Box 504
Sunnyvale, California 94086

September 14, 1981

Sample Identification
by

Kind of sample reported to us	Coal	Lockheed Missiles & Space Company, Inc.
Sample taken at	xxxxx	P.O. # YCV6F5233A
Sample taken by	Lockheed Missiles & Space Company, Inc.	Sample No. 108
Date sampled	xxxxx	Lignite (North Dakota)
Date received	8-24-81	drum sample

Analysis report no. 72-112049

SCREEN ANALYSIS (UNDRIED)

	<u>PERCENT</u>	<u>ACCUMULATIVE PERCENT</u>
RETAINED ON 20 MESH, PASSING - - -	0.0	0.0
RETAINED ON 48 MESH, PASSING 20 MESH	15.0	15.0
RETAINED ON 100 MESH, PASSING 48 MESH	43.1	58.1
RETAINED ON 200 MESH, PASSING 100 MESH	28.1	86.2
RETAINED ON 325 MESH, PASSING 200 MESH	11.0	97.2
RETAINED ON - - -, PASSING 325 MESH	2.8	100.0

JLK/lm

Respectfully submitted,
James L. Kendrick
JAMES L. KENDRICK, Manager, Denver Laboratory

Charter Member

OVER 40 BRANCH LABORATORIES STRATEGICALLY LOCATED IN PRINCIPAL COAL MINING AREAS,
TIDEWATER AND GREAT LAKES PORTS, AND RIVER LOADING FACILITIES

LOCKHEED MISSILES & SPACE COMPANY, INC.

LAB NO. 72-112049 Page 2

IDENTIFICATION Sample No. 108 *Lignite, undried*

TOTAL WEIGHT OF SAMPLE 539.0

SCREEN ANALYSIS CURVE

NOTE: SCREEN OPENINGS ON LOGARITHMIC SCALE WITH $\frac{\text{IN. NO.}}{\text{IN. SQ.}} = 1.25$

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COMMERCIAL TESTING & ENGINEERING CO.

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AREA CODE 312 726-8434

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OFFICE TEL. (303) 373-4772

LOCKHEED MISSILES & SPACE
COMPANY, INC.
P.O. Box 504
Sunnyvale, California 94086

September 21, 1981

**Sample Identification
by**

Kind of sample reported to us Coal

Sample taken at xxxxxx

Sample taken by Lockheed Missiles & Space
 Company, Inc.

Date sampled xxxxxx

Date received 8-24-81

Lockheed Missiles & Space
Company, Inc.
P.O. # YCV6F5230A

*Moisture Analysis
(drum samples)*

Analysis report no. See Below

	<u>CT & E LAB NO.</u>	<u>SAMPLE NO.</u>	<u>% TOTAL MOISTURE</u>
<i>Sub-Bituminous</i>	72-112046	102	20.89
<i>E. Bituminous</i>	72-112047	104	6.03
<i>E. Bit. (+Limestone)</i>	72-112048	106	29.57 2.98
<i>Lignite</i>	72-112049	108	2.98 29.57

JLK/lm

Respectfully submitted,
COMMERCIAL TESTING & ENGINEERING CO.

JAMES L. KENDRICK, Manager, Denver Laboratory

Charter Member

A-15

OVER 40 BRANCH LABORATORIES STRATEGICALLY LOCATED IN PRINCIPAL COAL MINING AREAS,
TIDEWATER AND GREAT LAKES PORTS, AND RIVER LOADING FACILITIES

COMMERCIAL TESTING & ENGINEERING CO.

GENERAL OFFICES: 228 NORTH LA SALLE STREET, CHICAGO, ILLINOIS 60601

AREA CODE 312 726-8434

WESTERN DIVISION MANAGER
GAIL D. PALMER PLEASE ADDRESS ALL CORRESPONDENCE TO:
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OFFICE TEL. (303) 373-4772

September 25, 1981

LOCKHEED MISSILES & SPACE CO., INC.
P.O. Box 504
Sunnyvale, California 94086

Sample identification
by

Kind of sample reported to us Coal
Sample taken at xxxxx
Sample taken by Lockheed Missiles & Space Co., Inc.
Date sampled xxxxx
Date received 8-24-81

Lockheed Missiles & Space Co., Inc.

P.O. No. YCV6F5234A
Sample No. 110

Western Bituminous (Utah)
drum sample

Analysis report no. 72-112045 Page 1

PROXIMATE ANALYSIS
As Received Dry Basis

% Moisture	4.62	xxxxx
% Ash	7.17	7.52
% Volatile	42.37	44.42
% Fixed Carbon	45.84	48.06
	<u>100.00</u>	<u>100.00</u>
Btu/lb.	12654	13267
% Sulfur	0.61	0.64

ULTIMATE ANALYSIS
As Received Dry Basis

% Moisture	4.62	xxxxx
% Carbon	70.46	73.87
% Hydrogen	5.23	5.48
% Nitrogen	1.40	1.47
% Chlorine	0.00	0.00
% Sulfur	0.61	0.64
% Ash	7.17	7.52
% Oxygen	10.51	11.02
(diff)	<u>100.00</u>	<u>100.00</u>

% Moisture, Ash, free Volatile = 48.03
% Moisture, Ash, free Fixed Carbon = 51.97
Moisture, Ash, free Btu/lb. = 14346
Pounds of SO₂ per 10⁶ Btu = 0.965

% Dry, Mineral matter free Volatile = 47.60
% Dry, Mineral matter free Fixed Carbon = 52.40
Moist, Mineral matter free Btu/lb.* = 14346
(Based on As Received Moisture)*

Respectfully submitted
COMMERCIAL TESTING & ENGINEERING CO.
James L. Kendrick
A-16 JAMES L. KENDRICK, Manager, Denver Laboratory

Charter Member

OVER 40 BRANCH LABORATORIES STRATEGICALLY LOCATED IN PRINCIPAL COAL MINING AREAS,
TIDEWATER AND GREAT LAKES PORTS, AND RIVER LOADING FACILITIES

COMMERCIAL TESTING & ENGINEERING CO.

GENERAL OFFICES: 228 NORTH LA SALLE STREET, CHICAGO, ILLINOIS 60601

AREA CODE 312 726-8434

WESTERN DIVISION MANAGER
GAIL D. PALMERPLEASE ADDRESS ALL CORRESPONDENCE TO:
10775 EAST 51st AVE., DENVER, CO 80239
OFFICE TEL. (303) 373-4772 LOCKHEED MISSILES & SPACE CO., INC.
P.O. Box 504
Sunnyvale, California 94086

September 25, 1981

Sample identification
by

Kind of sample reported to us Coal

Sample taken at XXXXX

Sample taken by Lockheed Missiles & Space Co., Inc.

Date sampled XXXXX

Date received 8-24-81

LOCKHEED Missiles & Space Co., Inc.

P.O. No. YCV6F5234A
Sample No. 110Western Bituminous (Utah)
drum sample

Analysis report no. 72-112045 Page 2

SCREEN ANALYSIS (UNDRIED)

	<u>PERCENT</u>	<u>ACCUMULATIVE PERCENT</u>
RETAINED ON 20 MESH, PASSING - - -	0.1	0.1
RETAINED ON 48 MESH, PASSING 20 MESH	0.1	0.2
RETAINED ON 100 MESH, PASSING 48 MESH	0.9	1.1
RETAINED ON 200 MESH, PASSING 100 MESH	59.6	60.7
RETAINED ON 325 MESH, PASSING 200 MESH	39.1	99.8
RETAINED ON - - -, PASSING 325 MESH	0.2	100.0

Respectfully submitted,
COMMERCIAL TESTING & ENGINEERING CO.

JAMES L. KENDRICK, Manager, Denver Laboratory

Charter Member

A-17

OVER 40 BRANCH LABORATORIES STRATEGICALLY LOCATED IN PRINCIPAL COAL MINING AREAS,
TIDEWATER AND GREAT LAKES PORTS, AND RIVER LOADING FACILITIES

LOCKHEED MISSILES & SPACE CO., INC.

LAB NO. 72-112045 Page 3

IDENTIFICATION Coal Sample No. 110

Western Bituminous (drum sample)
Undried

TOTAL WEIGHT OF SAMPLE 496.25g

SCREEN ANALYSIS CURVE

NOTE: SCREEN OPENINGS ON LOGARITHMIC SCALE WITH $\frac{\text{IN. RD.}}{\text{IN. SQ.}} = 1.25$

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WESTERN DIVISION MANAGER
GAIL D. PALMER

PLEASE ADDRESS ALL CORRESPONDENCE TO:
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OFFICE TEL. (303) 373-4772

LOCKHEED MISSILES & SPACE CO., INC.
P.O. Box 504
Sunnyvale, California 94086

February 2, 1982

Sample identification
by

Kind of sample reported to us Coal
Sample taken at xxxxxx
Sample taken by Lockheed Missiles & Space Co., Inc.
Date sampled 12-2-81
Date received 12-30-81

Lockheed Missiles & Space Co., Inc.

P.O. # YTV6G7240A
Sample No. 142

Lignite

Test Loop Sample

Analysis report no. 72-116764-R Page 1

SCREEN ANALYSIS (DRIED)

	<u>PERCENT</u>	<u>ACCUMULATIVE PERCENT</u>
RETAINED ON 48 MESH, PASSING 20 MESH	4.5	4.5
RETAINED ON 100 MESH, PASSING 48 MESH	30.2	34.7
RETAINED ON 200 MESH, PASSING 100 MESH	32.0	66.7
RETAINED ON 325 MESH, PASSING 200 MESH	13.6	80.3
RETAINED ON - - -, PASSING 325 MESH	19.7	100.0

JLK/lm

Respectfully submitted
COMMERCIAL TESTING & ENGINEERING CO.
James L. Kendrick
JAMES L. KENDRICK, Manager, Denver Laboratory

A-19

Charter Member

OVER 40 BRANCH LABORATORIES STRATEGICALLY LOCATED IN PRINCIPAL COAL MINING AREAS,
TIDEWATER AND GREAT LAKES PORTS, AND RIVER LOADING FACILITIES

LOCKHEED MISSILES & SPACE CO., INC.
LAB NO. 72-116764-R Page 2

IDENTIFICATION Sample No. 142

Lignite Test Loop Sample
(dried)

TOTAL WEIGHT OF SAMPLE 454g

SCREEN ANALYSIS CURVE

NOTE: SCREEN OPENINGS ON LOGARITHMIC SCALE WITH IN. RD. IN. SQ. 1.25

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OFFICE TEL. (303) 373-4772

LOCKHEED MISSILES & SPACE CO., INC.
P.O. Box 504
Sunnyvale, California 94086

February 2, 1982

Sample identification
byKind of sample
reported to us Coal

Lockheed Missiles & Space Co., Inc.

Sample taken at xxxxx

P.O. # YTV6G7240A

Sample No. 146

Sample taken by Lockheed Missiles & Space Co., Inc.

Date sampled 12-8-81

Lignite

Date received 12-30-81

Test Loop Sample

Analysis report no. 72-116765-R Page 1

SCREEN ANALYSIS (dried)

	<u>PERCENT</u>	<u>ACCUMULATIVE PERCENT</u>
RETAINED ON 48 MESH, PASSING 20 MESH	4.9	4.9
RETAINED ON 100 MESH, PASSING 48 MESH	28.6	33.5
RETAINED ON 200 MESH, PASSING 100 MESH	36.5	70.0
RETAINED ON 325 MESH, PASSING 200 MESH	11.2	81.2
RETAINED ON - - -, PASSING 325 MESH	18.8	100.0

JLK/lm

Respectfully submitted
COMMERCIAL TESTING & ENGINEERING CO.
James L. Kendrick
JAMES L. KENDRICK, Manager, Denver Laboratory

A-21

Charter Member

OVER 40 BRANCH LABORATORIES STRATEGICALLY LOCATED IN PRINCIPAL COAL MINING AREAS,
, TIDEWATER AND GREAT LAKES PORTS, AND RIVER LOADING FACILITIES

LOCKHEED MISSILES & SPACE CO., INC.
LAB NO. 72-116765-R Page 2

IDENTIFICATION Sample No. 146 *Lignite, Test Loop Sample, dried*

TOTAL WEIGHT OF SAMPLE 440g

SCREEN ANALYSIS CURVE

NOTE: SCREEN OPENINGS ON LOGARITHMIC SCALE WITH $\frac{\text{IN. RD.}}{\text{IN. SQ.}} = 1.25$

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COMMERCIAL TESTING & ENGINEERING CO.

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WESTERN DIVISION MANAGER
GAIL D. PALMER PLEASE ADDRESS ALL CORRESPONDENCE TO:
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OFFICE TEL. (303) 373-4772

LOCKHEED OCEAN SYSTEMS
P.O. Box 504
Sunnyvale, California 94086

February 23, 1982

Sample identification
by

Kind of sample reported to us Coal
Sample taken at xxxxx
Sample taken by Lockheed Ocean Systems
Date sampled xxxxx
Date received 2-9-82

Lockheed Ocean Systems

Sample No. 174 Sub-Bituminous Coal

Analysis report no. 72-117304 Page 1

SCREEN ANALYSIS (Dried)

	<u>PERCENT</u>	<u>ACCUMULATIVE PERCENT</u>
RETAINED ON 20 MESH, PASSING - - -	0.4	0.4
RETAINED ON 48 MESH, PASSING 20 MESH	5.5	5.9
RETAINED ON 100 MESH, PASSING 48 MESH	12.9	18.8
RETAINED ON 200 MESH, PASSING 100 MESH	32.9	51.7
RETAINED ON 325 MESH, PASSING 200 MESH	26.9	78.6
RETAINED ON - - -, PASSING 325 MESH	21.4	100.0

JLK/lm

Respectfully submitted,
James L. Kendrick
COMMERCIAL TESTING & ENGINEERING CO.

JAMES L. KENDRICK, Manager, Denver Laboratory

Charter Member

A-23

OVER 40 BRANCH LABORATORIES STRATEGICALLY LOCATED IN PRINCIPAL COAL MINING AREAS,
TIDEWATER AND GREAT LAKES PORTS, AND RIVER LOADING FACILITIES

LOCKHEED OCEAN SYSTEMS

LAB NO. 72-117304 Page 2

IDENTIFICATION Sample No. 174 Sub-Bituminous Coal

TOTAL WEIGHT OF SAMPLE 492g

SCREEN ANALYSIS CURVE

NOTE: SCREEN OPENINGS ON LOGARITHMIC SCALE WITH $\frac{\text{IN. RD.}}{\text{IN. SQ.}} = 1.25$

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COMMERCIAL TESTING & ENGINEERING CO.

GENERAL OFFICES: 228 NORTH LA SALLE STREET, CHICAGO, ILLINOIS 60601

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WESTERN DIVISION MANAGER
GAIL D. PALMER PLEASE ADDRESS ALL CORRESPONDENCE TO:
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OFFICE TEL. (303) 373-4772

▶ LOCKHEED OCEAN SYSTEMS
P.O. Box 504
Sunnyvale, California 94086

February 24, 1982

Sample identification
byKind of sample
reported to us Coal

Lockheed Ocean Systems

Sample taken at xxxxx

Sample No. 180

Sample taken by Lockheed Ocean Systems

Sample I.D. Sub-Bituminous Coal

Date sampled 1-8-82

Date received 2-9-82

Analysis report no. 72-117306 Page 1

SCREEN ANALYSIS (dried)

	<u>PERCENT</u>	<u>ACCUMULATIVE PERCENT</u>
RETAINED ON 48 MESH, PASSING 20 MESH	4.7	4.7
RETAINED ON 100 MESH, PASSING 48 MESH	13.7	18.4
RETAINED ON 200 MESH, PASSING 100 MESH	33.6	52.0
RETAINED ON 325 MESH, PASSING 200 MESH	24.1	76.1
RETAINED ON - - -, PASSING 325 MESH	23.9	100.0

JLK/lm

Respectfully submitted,
COMMERCIAL TESTING & ENGINEERING CO.
James L. Kendrick

JAMES L. KENDRICK, Manager, Denver Laboratory

A-25

Charter Member

OVER 40 BRANCH LABORATORIES STRATEGICALLY LOCATED IN PRINCIPAL COAL MINING AREAS,
TIDEWATER AND GREAT LAKES PORTS, AND RIVER LOADING FACILITIES

LOCKHEED OCEAN SYSTEMS

LAB NO. 72-117306 Page 2

IDENTIFICATION Sample No. 180

Sample I.D. Sub-Bituminous Coal

TOTAL WEIGHT OF SAMPLE 523g

SCREEN ANALYSIS CURVE

NOTE: SCREEN OPENINGS ON LOGARITHMIC SCALE WITH $\frac{\text{IN. RD.}}{\text{IN. SQ.}} = 1.25$

COMMERCIAL TESTING & ENGINEERING CO.

COMMERCIAL TESTING & ENGINEERING CO.

GENERAL OFFICES: 228 NORTH LA SALLE STREET, CHICAGO, ILLINOIS 60601

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WESTERN DIVISION MANAGER
GAIL D. PALMER PLEASE ADDRESS ALL CORRESPONDENCE TO:
10775 EAST 51st AVE., DENVER, CO 80239
OFFICE TEL. (303) 373-4772

LOCKHEED OCEAN SYSTEMS
P.O. Box 504
Sunnyvale, California 94086

February 24, 1982

Sample identification
by

Kind of sample reported to us Coal
Sample taken at xxxxx
Sample taken by Lockheed Ocean Systems
Date sampled 1-15-82
Date received 2-9-82

Lockheed Ocean Systems
Sample No. 197
Sample I.D. E-Bituminous Coal
and Limestone

Analysis report no. 72-117305 Page 1

SCREEN ANALYSIS (dried)

	<u>PERCENT</u>	<u>ACCUMULATIVE PERCENT</u>
RETAINED ON 20 MESH, PASSING - - -	0.2	0.2
RETAINED ON 48 MESH, PASSING 20 MESH	10.0	10.2
RETAINED ON 100 MESH, PASSING 48 MESH	17.8	28.0
RETAINED ON 200 MESH, PASSING 100 MESH	26.7	54.7
RETAINED ON 325 MESH, PASSING 200 MESH	17.9	72.6
RETAINED ON - - -, PASSING 325 MESH	27.4	100.0

JLK/lm

Respectfully submitted,
COMMERCIAL TESTING & ENGINEERING CO.
James L. Kendrick
JAMES L. KENDRICK, Manager, Denver Laboratory

A-27

Charter Member

OVER 40 BRANCH LABORATORIES STRATEGICALLY LOCATED IN PRINCIPAL COAL MINING AREAS,
TIDEWATER AND GREAT LAKES PORTS, AND RIVER LOADING FACILITIES

LOCKHEED OCEAN SYSTEMS

LAB NO. 72-117305 Page 2

IDENTIFICATION Sample No. 197
Sample I.D. E-Bituminous Coal & Limestone

TOTAL WEIGHT OF SAMPLE 636g

SCREEN ANALYSIS CURVE

NOTE: SCREEN OPENINGS ON LOGARITHMIC SCALE WITH $\frac{\text{IN. RD.}}{\text{IN. SQ.}} = 1.25$

COMMERCIAL TESTING & ENGINEERING CO.

COMMERCIAL TESTING & ENGINEERING CO.

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WESTERN DIVISION MANAGER
GAIL D. PALMER PLEASE ADDRESS ALL CORRESPONDENCE TO:
10775 EAST 51st AVE., DENVER, CO 80239
OFFICE TEL. (303) 373-4772

LOCKHEED OCEAN SYSTEMS
P.O. Box 504
Sunnyvale, California 94086

February 24, 1982

Sample identification
byKind of sample
reported to us Coal

Lockheed Ocean Systems

Sample taken at ~~XXXXX~~

Sample No. 200

Sample taken by Lockheed Ocean Systems

Sample I.D. Eastern-Bituminous &
Limestone

Date sampled 1-18-82

Date received 2-9-82

Analysis report no. 72-117307 Page 1

SCREEN ANALYSIS (dried)

	<u>PERCENT</u>	<u>ACCUMULATIVE PERCENT</u>
RETAINED ON 48 MESH, PASSING 20 MESH	5.5	5.5
RETAINED ON 100 MESH, PASSING 48 MESH	17.2	22.7
RETAINED ON 200 MESH, PASSING 100 MESH	28.4	51.1
RETAINED ON 325 MESH, PASSING 200 MESH	17.0	68.1
RETAINED ON - - -, PASSING 325 MESH	31.9	100.0

JLK/lm

Respectfully submitted,
COMMERCIAL TESTING & ENGINEERING CO

JAMES L. KENDRICK, Manager, Denver Laboratory

A-29

OVER 40 BRANCH LABORATORIES STRATEGICALLY LOCATED IN PRINCIPAL COAL MINING AREAS,
TIDEWATER AND GREAT LAKES PORTS, AND RIVER LOADING FACILITIES

LOCKHEED OCEAN SYSTEMS

LAB NO. 72-117307 Page 2

IDENTIFICATION Sample No. 200
Sample I.D. Eastern-Bituminous & Limestone

TOTAL WEIGHT OF SAMPLE 785g

SCREEN ANALYSIS CURVE

NOTE: SCREEN OPENINGS ON LOGARITHMIC SCALE WITH $\frac{\text{IN. RD.}}{\text{IN. SQ.}} = 1.25$

COMMERCIAL TESTING & ENGINEERING CO.

Appendix B
DEVELOPMENT OF A
PILOT-SCALE KINETIC EXTRUDER FEEDER
SYSTEM AND TEST PROGRAM

1-TPH KINETIC EXTRUDER
DESIGN SPECIFICATIONS AND
OPERATING INSTRUCTIONS
(Revision A)

LMSC-D812346 March 1982

Prepared for the United States
Department of Energy
Under Contract DE-AC21-80MC14602

LOCKHEED MISSILES & SPACE COMPANY, INC.
A Subsidiary of Lockheed Corporation
Sunnyvale, California 94086

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PATENT STATUS

This technical report is being transmitted in advance of DOE patent clearance and no further dissemination or publication shall be made of the report without prior approval of the DOE Patent Counsel.

TECHNICAL STATUS

This technical report is being transmitted in advance of DOE review and no further dissemination or publication shall be made of the report without prior approval of the DOE Project/Program Manager.

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Section 1
INTRODUCTION AND SYSTEM DESCRIPTION

In general, a Kinetic Extruder (KE) coal-pressurizing system consists of a number of subsystems in addition to the KE unit itself. These subsystems include (1) a transport system for bringing the coal to and from the KE unit, (2) a prime mover for supplying the required power to the KE, (3) lubrication and seal liquid systems for the bearings and seals, (4) a gas supply system for controlling the receiver pressure, supplying purge and fluidizing gases and providing control gas for turn-down control, (5) a rotor suction system to maintain the desired rotor inlet pressure, and (6) an instrumentation and control system to provide operation of the system. In addition, the present 1-TPH KE test loop has extra systems for coal handling, moisture enhancement, coal recycling, and gas cleanup.

The physical layout of the KE and its test loop is illustrated in Fig. 1-1. Figure 1-2 shows the principal schematic for the coal and gas process lines. The liquid systems flow sheet is included in Fig. 1-3. The KE and test loop can be broken down into 12 fairly distinct components or subsystems, as follows:

1. Coal Loading System
2. Storage/Mixing Vessel
3. Feed Hopper
4. Kinetic Extruder (KE)
5. Drive System (Diesel-Hydraulic)
6. Rotor Eye Suction System
7. KE Gas Systems
8. KE Receiver Vessel
9. Main Baghouse
10. Seal Liquid and Lubrication System
11. N₂ Supply System
12. Controls and Instrumentation System

— PLAN —

— SIDE ELEVATION —

— END ELEVATION —

Fig. 1-1 Test Loop, Phase I

Fig. 1-2 Coal Feeder Schematic

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These individual subsystems are described in the following sections:

1.1 COAL LOADING SYSTEM

Coal is loaded into the storage/mixing vessel by means of a system consisting of a barrel dump, vibratory feeder, cleated elevator, and a vibrating scalping screen. The barrel dump forms the inlet to the process. Thereafter, the coal is metered onto a Flexowall cleated elevator by a FMC Syntron vibrating feeder. The elevator feeds through a Sweco 18-in. vibrating screen (20 mesh) and into the storage/mixing vessel. The scalping screen prevents any oversize particles or tramp material from entering the test loop.

Once inside the storage vessel, the feedstock is transferred into the feed hopper by dense-phase pneumatic transport.

1.2 STORAGE/MIXING VESSEL

A storage/mixing vessel (of 50-ft³ volume) receives the coal upon initial loading. This vessel contains a 6-gph fog nozzle which is used for adding moisture to the coal. After loading, the coal-inlet connection is closed by a blind flange so that the vessel can be fluidized and pressurized for transfer of its coal load to the KE feed hopper. Water is added to the coal during repeated transfers back and forth between the feed hopper and the storage/mixing vessel. The coal transfer lines used are shown in Fig. 1-2. Process flows into and out of the storage/mixing vessel are controlled from a local panel near the vessel.

1.3 FEED HOPPER

A 50-ft³ feed hopper serves as the fluidized vessel which feeds coal to the suction side of the KE. This vessel is mounted on weigh cells which provide the primary measurement of the quantity of coal pumped in a particular test. The main process line valves connected to the feed hopper are equipped with remote operators so that the unit can be started and stopped from the control room.

1.4 KINETIC EXTRUDER (KE) SYSTEM

The KE system employs centrifugal force generated by the rotation of a high-speed rotor designed to pump pulverized coal into a high-pressure region. The KE rotor is illustrated by the cutaway drawing in Fig. 1-4.

The system consists of high-speed rotor, rotor casing, shaft, bearings, shaft seals, control gas seals, inlet feed pipe, and base support structure. The rotor casing is mounted immediately on top of the pressurized receiving hopper.

The following data are descriptive of the 1-TPH (nominal) KE unit tested in this program:

o Capacity (TPH)	1.5
o Rotor diameter (in.)	28
o Rotor speed (rpm)	3,600 (max)
o Turndown ratio	3:1
o Pressure (psig)	
- Inlet	Atmospheric
- Outlet	400
o Pressurization gas	Nitrogen
o Bearings type	Roller
o Sealing	Mechanical contact seal with bushing seal pressure breakdown
o Rotor power (hp)	80
o Sprue parameters:	
No. of sprues or channels	12
- Length (in.)	8.75
- Inlet radial position (in.)	4
- Outlet diameter (in.)	0.28
o Control Nozzle	
- Length (in.)	1.25
- Outlet diameter (in.)	0.075

Fig. 1-4 Lockheed Kinetic Extruder Rotor

Startup of the Kinetic Extruder, that is, the establishment of the moving coal plugs in the sprues, must take place at zero backpressure. To bring the Kinetic Extruder unit online, the coal flow is started by opening the feed valve PCV 12 while the rotor housing is at ambient pressure. Once the coal plugs are established, the unit is pressurized to the test level. To shut the feeder down, the procedure is reversed. The housing is depressurized, and then the coal flow through the rotor is shut off by closing valve PCV 12.

Bearings and Seals

The bearing and sealing assembly for the KE has been upgraded for the present programs. The physical arrangement of the parts now used is shown in Fig. 1-5. The high-pressure sealing water enters through ports 1 and 1a at a pressure of about 30 psi above case pressure. The water is prevented from entering the case by the low-pressure-differential face seal on the inboard side. On the outboard side, the pressure is reduced to near atmospheric by flow through the floating bushings and water drains through ports 2 and 2a. Oil for lubricating the bearings enters through ports 5 and 5a, and drains through ports 4 and 4a. The oil is sealed by shaft seals, but some seepage passes through the seals and is scavenged through ports 3, 3a, and 6. Ports 3 and 3a also scavenge water seepage past the back-up shaft seals.

Control gas for the fluidic coal flow control is admitted through port 10. Sealing water at a pressure of about 30 psi above the control gas pressure enters through ports 8 and 12. Water seepage past the shaft seals is scavenged through ports 9 and 11 by means of a pressure trap. Water pressure is reduced to near atmospheric through floating bushings and drained through ports 7 and 13.

The sealing and bearing system for the stationary coal feedpipe has not been changed. It consists of a low-pressure differential water-cooled face seal and a water-lubricated journal bearing which also served as a pressure breakdown structure.

Fig. 1-5 Rotor Bearing Seal Assembly

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1.5 DRIVE SYSTEM

An Allison Detroit Diesel (Model 5063-5398 Ser. 6D-70210) engine is presently installed as the system's prime mover. The drive train includes Dynapower Model 120 PV hydraulic pump and motor units, as well as a V-belt 2.9:1 speed increaser. The maximum useful power that can be delivered to the KE shaft is 80 hp.

1.6 ROTOR EYE SUCTION SYSTEM

The purpose of this system, shown in Fig. 1-2, is to maintain a negative pressure at the eye of the rotor by drawing off excess gases. Some coal dust is carried out along with the gases and provision for cleanup of this coal must be included.

This suction system presently consists of the following:

1. A Super Jet Model 16003.2 Cylindrical, Hi-Vacuum Filter Receiver dust collector with 60-deg cone hopper and leg set. Twelve ft² of cloth area is provided by 3 ea. 2 ft long Dacron Polyester bags.
2. Sutorbilt 2 MVB Vacuum Blower (Roots Type) Assembly with 230/3/60, TEFC, 2-hp electric motor drive, with outlet silencer and secondary air filter; the blower package is rated at 20 SCFM at 10 in. Hg.
3. A Series 13 HD/DT Rotary Airlock, 0.1 CFR, 30 in. Hg rating, cast iron, housing, round inlet/sq. outlet, 8 vane open-end rotor with flat tips. Complete with OSHA drive and guards and 1/2 hp Right Angle Gear Motor.

1.7 KE GAS SYSTEMS

The gas systems denote the auxiliary gas piping and instrumentation that is required for the KE, as shown in Fig. 1-2. Basically, the Kinetic Extruder pumps only coal; the gas flow through the sprues is always zero or nearly so. However, high-pressure gas must be supplied to pressurize the void space between the coal particles. A portion of this gas is injected into the

control nozzles as "control gas," and the remainder is injected directly into the rotor housing as "pressurization gas." In an actual plant, both flows would be continuous, but in the present batch-type test loop the "pressurization gas" flow is shut off once the receiver vessel has reached the desired test pressure. Thereafter, gas must be bled off through PCV 37 to maintain constant receiver vessel pressure.

A low-pressure gas supply (approximately 100 psig) is also required for feed-hopper fluidization, purge gas for the coal feed lines and suction lines as needed, and also to provide a source of rotor-eye flushing gas. The rotor-eye flushing gas stream is a small flow injected into the eye of the rotor near the suction line inlets. Its purpose is to provide a minimum gas flow in the suction lines at all times. This ensures a relatively high velocity and low coal density in these lines, eliminating any possibility of their plugging. The flushing gas flow is needed only when there is little or no gas back leakage through the sprues. The flow is therefore regulated based on the rotor-eye pressure.

1.8 KE RECEIVER VESSEL

A 50-ft³ receiver vessel is attached directly below the KE rotor casing and serves as a high-pressure reservoir for the coal pumped through the rotor. After a test run, the receiver vessel is fluidized and its contents recycled back to the feed hopper by opening PCV 11.

1.9 MAIN BAGHOUSE

A main baghouse (Micro D Pulseaire Collector Model Number 365-8) is provided for dust removal from all gas streams discharged from the test loop.

1.10 SEAL LIQUID AND LUBRICATION SYSTEM

Lubrication and seal liquid systems flow diagrams are included as Fig. 1-3. There are four distinct fluid subsystems: (1) a low-pressure oil system for bearing lubrication, (2) a water-seal liquid system for the main shaft seals, (3) a combined water-seal/bearing liquid system for the rotor inner seal and feed pipe bearing, and (4) a water-seal system to buffer the control gas injection seals.

All of the seal-water streams are pilot regulated to provide fluid approximately 30 psi in excess of the sealed gas pressure. The pilot reference pressure is either the rotor-casing pressure, the rotor-eye pressure, or the control-gas pressure, as required. A common reservoir is used for the water systems.

1.11 N₂ SUPPLY SYSTEM

A GN₂ supply trailer of approximately 50,000-SCF capacity is used as the primary gas supply for the test loop. The trailer is connected to an initial three-regulator manifold which supplies gas to the process at the three pressure levels required. These are approximately 800 psig for the sprue deplugger, 500 psig for receiver pressurizing and control gas, and 100 psig for the low-pressure system requirements.

1.12 CONTROLS AND INSTRUMENTATION SYSTEM

The main control instruments and console layout are shown in the Fig. 2 System Flow Sheet. A listing of instruments is given in Table 1. The KE and the major portion of the test loop is not automated, but is set up to be manually operated from the control room during test runs. Process valves associated with running the KE, pressurizing and depressurizing the receiver hopper, and recycling coal from the receiver back to the feed hopper, are remotely operable from the control room. Pilot-operated solenoid valves (S1-S10 in

Table 1-1 INSTRUMENTS LIST

ID No	DESCRIPTION	MFG / SPEC S.	LOCATION
-0	SPEED ACTUATOR CONTROL UNIT		5.D
S-1	SOLENOID VALVE - DEPLUGGER	ATKOMATIC VALVE CO. - SIZE 1/4, GN2, 500 PSI DIFF. INDIANA, IND - 1500 PSI MAX, MODEL 6000, 120V	3.D
S-2	" " - H.P. PRESSURIZATION	SAME 1500 PSI MAX MODEL 6000	"
S-3	" " - H.P. FLUIDIZATION	SAME	"
S-4	" " - LOWER TANK PRESS TAP	SAME	"
S-5	" " - RECYCLE/PURGE DOWN	SAME	"
S-6	" " - " / " UP	SAME	"
S-7	" " - L.P. FLUIDIZATION	SAME	"
S-8	" " - L.P. PRESSURIZATION	SAME	"
S-9	" " - FEED PIPE/PURGE DOWN	SAME	"
S-10	" " - " / " UP	SAME	"
PCY-11	PNEU. VALVE - RECYCLE LINE	KAYMR - 600 ANSI, 3/4 NPT PC-3/4, BALL TYPE W/ AIR ACTUATOR # BG-8	5.E
PCY-12	" " - FEED PIPE	SAME	7.E
PCY-13	" " - GAS VENT	CENTURY - 80 PSI, 2 NPT BALL TYPE C 7500 W/ AIR ACTUATOR # PVA5	5.G
HCV-14A	HAND CONT. VALVE - FEED VALVE	KAYMR - 600 ANSI, 3/4 NPT, BALL TYPE W 12007 CLASS 300 "W"	7.D
HCV-14B	" " " - " "	SAME	6.D
SCV-15	SOLENOID VALVE - H ₂ O LINE	SKINNER VALVE 1/4 DIA V-5 SERIES	SEE DWG SKJNM 1080 - 4.D
PCY-16	PNEU. VALVE - GAS VENT LINE	CENTURY - 80 PSI, 3/4 NPT, BALL TYPE C 7500 W/ AIR ACTUATOR # PVA2	2G
PSE-17	SAFETY VALVE - STORAGE HOPPER	CONTINENTAL RUPTURE DISC CO., DISC TYPE 1 1/2 UNION TYPE C 150 PSI BURST PRESS.	2G
PRV-18	PRESS. REGULATOR VALVE - H ₂ O LINE	NORGREN - 350/125 PSIG 1/4 DIA R11-200-NNLA	SEE DWG SKJNM 1080 - 5C
FI-19	FLOW INDICATOR - H ₂ O CONT. PANEL	BROOKS - 2-20 GPH, MODEL 2001 SIZE 6-38-D	" - 5C
SN-20	SPRAY NOZZLE - H ₂ O LINE	FOGJET SPRAY CO, #1-7N.60/#1-7N1	" - 4E
HCV-21	HAND CONT. VALVE - GAS VENT LINE	CENTURY - 80 PSI, 2 NPT BALL TYPE C 7500	6G
CV-22A	CHECK VALVE - FEED VALVE	MATHE SON - 1/4 DIA MODEL 400	7E
CV-22B	" " " "	SAME	"

Table 1-1 (Cont.)

CV -22C	" " - RECYCLE VALVE	SAME	5E
CV -22D	" " " "	SAME	"
HCV-23A	HAND CONT. VALVE - FEED LINE { STORAGE HOPPER	JAMESBURY - 3/4 NPT - BALL TYPE SCREW-END - 2000 PSI	3E
HCV-23B	" " " " { "	SAME	2E
HCV-24A	" " " - COAL LINE VALVE	MATHESON - 1/4 DIA - BALL TYPE MODEL 7115 F43	3E
HCV-24B	" " " " " "	SAME	"
HCV-24C	" " " - COAL DISPOSAL VALVE	SAME	2E
HCV-24D	" " " " " "	SAME	"
HCV-24E	" " " - FLUIDIZATION VALVE	SAME	2D
HCV-24F	" " " - FEED LINE VALVE	SAME	7E
HCV-24G	" " " " " "	SAME	"
HCV-24H	" " " - PRESSURIZATION LINE	SAME	6G
HCV-25A	HAND CONT. VALVE - LOCAL CONT. PANEL	MATHESON - 1/4 DIA - NEEDLE TYPE MODEL 177 6000 PSI	1D
HCV-25B	" " " - " " "	SAME	"
HCV-25C	" " " - " " "	SAME	"
HCV-25D	" " " - H ₂ O LINE	SAME	SEE DWG SKJWM 1080 - 5C
HCV-25E	" " " - FEED PIPE { PRESS. TAP	SAME	6E
HCV-26	" " " - PRESSURIZATION LINE	MATHESON - 1/2 DIA - NEEDLE TYPE - 6000 PSI	2D
DPR-27	DIFF. PRESS. REGULATOR- CONT. GAS INLET	JORDAN MARK 64. SIZE 1/4, 2-450 PSI CONTROLLED PRESS., 650 PSI INLET PRESS., 2-25 PSI DIFF. PRESS.	5D
DPR-28	" " " - CONT. REF. PRESS. DPRZ	LESLIE CLASS LXS-3 SIZE 1/2, 800 PSI INLET PRESS., 0-500 PSI OUT PRESS., 5-40 PSI DIFF. PRESS.	5B
PR-29A	PRESS. REGULATOR- { GNL PRESS CONTROL PANEL		3D
PR-29B	" " " "	SAME	"
PR-29C	" " " "	SAME	"
PT-30	PRESS. TRANSDUCER- LOWER TANK PRESS		5C
PT-31	" " " - EYE ROTOR PRESS		5E

PT-32	- HYD MOTOR PRESS.		5D
TM-33	TACHOMETER UNIT - HYD MOTOR SPEED		5D
ARR-34	AIR PRESS. REGULATOR - CONTROL ROOM	FISHER - 67FR FILTER REGULATOR	7A
S-35	SOLENOID VALVE -	AUTO. CONT. CO. MODEL RCA 3D2 SIZE 1/8 NPT CY 0.32, 120V/60HZ	4C
LC-36A	LOAD CELL - # 3/8 - FEED/STOW. HOPPER		7F/2F
LC-36B	" " - # 2/5 " " "		7F/2F
LC-36C	" " - # 1/4 " " "		7F/2F
PVC-37	PRESS. VALVE CONTROLLER	FISHER - VALVE ACTUATOR ANSI 600-3/4 NPT TYPE G57 F2, 1/4 INNER VALVE, FAIL OPEN	6D
LS-38	LEVEL SENSOR - FEED HOPPER		7G
LI-39	LEVEL INDICATOR - FEED HOPPER		8B
RTI-40	RUNNING TIME INDICATOR - MAIN CONT. CONSOLE		7C
TI-41	TORQUE INDICATOR - "		"
SI-42	SPRUE INDICATOR - "		"
RI-43	RPM INDICATOR - "		"
CR-44	CHART RECORDER -		"
C-45	CONTROLLER -		"
O-46	OSCILLOSCOPE -		"
HCV-47A	HAND CONTROL VALVE - SHUT-OFF	MATHESON - 1/4 DIA - BALL TYPE MODEL T115 F4B	6E
HCV-47B	" " "		"
HCV-47C	" " "		"
HCV-47D	" " "		"
HCV-48A	" " " "	CENTURY - 80 PSI, 3/4 NPT, BALL TYPE C7500 MANUALLY CONTROLLED	"
HCV-48B	" " " "	SAME	"
PT-49	PULSE TIMER - SOLENOID 35	AUTO. CONT. CO. - ATC 342A 200 Q 10 PX FLIP-FLOP MULTI-RANGE REPEAT CYCLE TIMER	3B
HCV-50A	HAND CONTROL VALVE - L.P. FLUIDIZING PANEL	MATHESON - 1/4 DIA NEEDLE TYPE MODEL 177 6000 PSI	8D

Table 1-1 (Cont.)

Table 1-1 (Cont.)

HCV-50B	" " " " "	SAME	"
HCV-50C	" " " " "	SAME	"
HCV-51A	" " " H.P. " "	SAME	"
HCV-51B	" " " " " "	SAME	"
HCV-51C	" " " " " "	SAME	"
CV-52A	CHECK VALVE - H.P. FLUIDIZATION LINE	MATHESON - 1/4 DIA MODEL 400	8C
CV-52B	" " - LOW TANK PRESS. TAP LINE	SAME	6C
CV-52C	" " - DEPLUGGER LINE	SAME	6C
RV-53	RELIEF VALVE - L.P. CONT. PANEL		4E
RV-54	" " - " " "		4E
CV-55	CHECK VALVE - " " "		4E
HCV-56	HAND CONTROL VALVE - BY PASS VALVE		4E
HCV-57A	" " " - SHUT-OFF VALVE	MATHESON - 1/4 DIA - BALL TYPE MODEL 7115 F4B	4F
HCV-57B	" " " - "		4F
HCV-58	" " " - "		4E
HCV-59	" " " - "		4D
HCV-60A	" " " - { BLEED VALVE		"
HCV-60B	" " " - "		4E
HCV-60C	" " " - "		"
HCV-61	" " " - BY-PASS VALVE		4D
HCV-62	" " " - "		6B
HCV-63	" " " - VENT VALVE		5B
HCV-64A	HAND CONT. VALVE - BY-PASS VALVE		3D
HCV-64B	" " " - "		3D
HCV-64C	" " " - "		3D

HCY-64D	" " " "		3D
FV-65	FLAPPER VALVE - BAGHOUSE OUTLET		1G
HCY-66	HAND CONT. VALVE - GN ₂ SUPPLY LINE		2D
PCY-67	PNEU. VALVE - GAS VENT LINE	KAYMR - 600 ANSI, 3/4 NPT, BALL TYPE W-12007 CLASS 300 "W"	6C
T-68	TORQUEM		5E
LCI-69A	LOAD CELL INDICATOR - CONTROL CONSOLE		8B
LCI-69B	" " " " " "		8B
LCI-69C	" " " " " "		8B
HCY-70	HAND CONT. VALVE - SHUT-OFF		4E
SN-71A	FILTER SNUBBER		5E
SN-71B	" "		5E
SN-72	" "		5C
VRV-73	VACUUM REGULATOR VALVE		4E
PSE-74	SAFETY VALVE - RECEIVER TOPPER		5D
FM-75A	FLOWMETER - SUCTION LINE		3H
FM-75B	" " " "		

Table I-1 (Cont.)

Table 1-1 (Cont.)

ID No.	NAME	MFG.	SPECS.	LOCATION
G-1	GAGE PRESS.		0-60 PSI	8D
G-2	"		"	"
G-3	"		"	"
G-4	"		0-600 PSI	"
G-5	"		"	"
G-6	"		"	"
G-7	AIR SUPPLY		0-30 PSI	7B
G-8	" OUTPUT		"	"
G-9	PRESS.		0-600 PSI	6B
G-10	"		0-60 PSI	"
G-11	"	DANTON	0-600 PSI	"
G-12	"		0-60 PSI	"
G-13	"		0-30 PSI	"
G-14	"	DANTON	"	4F
G-15	"		"	"
G-16	"		"	"
G-17	"		0-600	4E
G-18	"		"	"
G-19	"		"	"
G-20	"		"	"
G-21	H ₂ O		"	2D
G-22	"		"	"
G-23	"		"	"
G-24	OIL		"	"
G-25	PRESS.	ROBERT	0-1000 PSI	"
G-26	"	MARSH	0-600 PSI	"
G-27	"		0-300 PSI	2D
G-28	"	MARSH	0-300 PSI	1D
G-29	"		"	"
G-30	"		"	"
G-31	"		"	"
G-32	H ₂ O		0-100 PSI	E
G-33	HYD.	CONTECH	0-1000 PSI	See D/S-100, 1000
G-34	PRESS.	MARSH	0-1000 PSI	CC
G-35	SUCTION	DANTON	0-30 PSI	LC
G-36	"		"	"
G-37	"	MARSH	"	GE

Fig. 1-2) are used in the clean N_2 process lines, pneumatic actuators are used for coal lines or dirty gas lines.

Initial set-up and powering up of systems is by local controls. Secondary tasks such as transfer of coal between the feed and storage hoppers also are carried out locally.

Section 2

KINETIC EXTRUDER START-UP, SHUTDOWN AND OPERATING PROCEDURES

The various procedures can be summarized as follows:

1. KE Start-up Procedure. This will require certain preadjusted positions for the valves in the system before start-up can begin.
2. KE Shutdown Procedure. This procedure is to be followed when the unit is stopped under normal conditions.
3. Coal Transfer Procedures. These procedures are to be followed when coal is pneumatically transferred between the storage, feed, and receiving hoppers. There are three modes of transfer:
 - 3.1 Recycle from receiving hopper to feed hopper
 - 3.2 Transfer from feed hopper to storage hopper (with and without water addition)
 - 3.3 Transfer from storage hopper to feed hopper
4. Emergency Shutdown Procedure. This procedure will depressurize the receiving hopper and stop the rotor in as short a time as possible.

1. START-UP PROCEDURE FOR THE KE UNIT

Preadjustments:

For initiating the start-up procedure, all valve positions should be as shown in Table 2-1. These positions generally correspond to the situation at the moment following a KE shutdown. Check and verify these positions before proceeding with start-up. Instrument numbers refer to Flow Sheet Dwg. No. SKESJ-181. (Fig. 2, Section 1)

In addition, the following safety inspections must be made before start-up:

- o Check suction and vent bag house filters; empty them if required
- o Check N₂-supply pressure (1000 psi minimum) and N₂-manifold pressures (800 psi, 500 psi, 100 psi). Adjust if required.
- o Check instrument air pressure (20 psi). Adjust if required.
- o Check diesel and hydraulic power transmission system for fuel level leaks, worn hoses and the like.
- o Check lube and seal liquid systems for leaks and to make sure reservoir levels are adequate

KINETIC EXTRUDER TEST LOOP OPERATING PROCEDURES

Table 2-1 INITIAL VALVE POSITIONS BEFORE START-UP

Item	Valve or Instrument	Flow Sheet Number	Valve Position or Setting
1	F.H. Gas Vent Valve	PCV 13	Open
2	KE Feed Line Valve	PCV 12	Closed
3	Main Gas-Supply Valve	66	Open
4	R.H. Vent Valve	PCV 67	Open
5	Deplugger Valve	S1	Closed
6	Deplugger Bypass Needle Valve	64A	Open N turns
7	High-Pressure Fluidization ON/OFF Valve	S3	Closed
8	High-Pressure Fluidization Bypass Needle Valve	64B	Open N turns
9	Recycle Line Purge Valve (Up)	S10	Closed
10	Recycle Line Purge Valve (Down)	S9	Closed
11	High-Pressure Console Supply Valve	S2	Open
12	R.H. Pressurization	S4	Closed
13	Low-Pressure Fluidization ON/OFF Valve	S7	Closed
14	Low-Pressure Fluidization Bypass Needle Valve	64C	Open N turns
15	Low-Pressure Console Supply Valve	S8	Open
16	KE Feed-Pipe Purge (Up)	S10	Closed
17	KE Feed-Pipe Purge (Down)	S9	Closed
18	R.H. Fluidization Valves (Inner Ring)	51C	Open N turns
19	R.H. Fluidization Valves (Middle Ring)	51B	Open N turns

F.H. = KE Feed Hopper (Upper Tank)

R.H. = KE Receiving Hopper (Lower Tank)

S.H. = Storage Hopper

Table 2-1 (Cont.)

Item	Valve or Instrument	Flow Sheet Number	Valve Position or Setting
20	R.H. Fluidization Valves (Outer Ring)	51A	Open N turns
21	F.H. Fluidization Valves (Inner Ring)	50C	Open N turns
22	F.H. Fluidization Valves (Middle Ring)	50B	Open N turns
23	F.H. Fluidization Valves (Outer Ring)	50A	Open N turns
24	Manual KE Feed-Pipe Valve	HCV 14B	Open
25	Manual Coal Feed-Pipe S.H. Branch Valve	HCV 14A	Closed
26	R.H. to F.H. Recycle Line Valve	CV28	Closed
27	Control-Gas Bypass Bleed Valve	61	Open N turns
28	R.H. Pressure Tap Bleed Valve	60A	Open N turns
29	Manual Control-Gas Shutoff Valves	58, 59	Open
30	Suction Line Shutoff Valves	48A, 48B	Open
31	Suction Line Purge Valves	47A, 47B, 47C, 47D	Closed
32	Rotor Eye Pressure Tap Bleed Valve	60B	Open N turns
33	Flushing Gas Manual Shutoff Valves	57A, 57B	Open
34	Flushing Gas Bypass Needle Valve	56	Open N turns
35	Flushing Gas Vacuum Regulator Reference Pressure Tap Valve	HCV 56	Open
36	F.H. Pressure Tap Bleed Valve	60C	Open N turns
37	Control Gas Pressure Regulator (Local)	DPR 27	N turns of Handwheel
38	Control-Gas Pressure Regulator (Control Room)	DPR 28	N turns of Handwheel
39	DPR 28 Off Bleed to Atm Needle Valve	63	Open N turns
40	R.H. Pressure-Controller Air-Supply Regulator	APR 64	Off
41	Flushing Gas-Vacuum Regulator	VR	Preset
42	S.H. Coal-Pipe Valves	HCV 23A	Closed
43	S.H. Gas-Vent Valve	HCV 16	Open
44	S.H. Fluidization Valve (Inner Ring)	24E	Cracked

Table 2-1 (Cont.)

Item	Valve or Instrument	Flow Sheet Number	Valve Position or Setting
45	S.H. Fluidization Valve (Middle Ring)	24A	Cracked
46	S.H. Fluidization Valve (Outer Ring)	24B	Cracked
47	S.H. Pressurization Valve	26	Closed
48	S.H. Water-Spray Valve	CV 15	Closed
49	S.H. Water-Spray Needle Valve	HCV 25G	Closed
50	Hydraulic Motor Displacement	-	Zero
51	Diesel Engine Clutch	-	Disengaged
52	Suction System Filter Blowback Air Valve	-	Closed
53	Pulse Cycle Timer for R.H. Vent Filter	49	Preset
54	N ₂ Supply Valve for R.H. Filter Pulse	37	Closed
55	S.H. Water Spray Head N ₂ Purge Valve	-	Open N turns

KINETIC EXTRUDER TEST LOOP OPERATING PROCEDURES

Table 2-2 KE UNIT START-UP

Step	Action Taken	Flow Sheet Number	Position or Setting
<u>READY SYSTEM</u>			
1	Switch on H.P. Seal-System Pump	-	On
2	Switch on L.P. Seal-System Pump	-	On
3	Switch on Lub. System Pump	-	On
4	Switch on Main Baghouse Blower	-	On
5	Switch on Suction-System Blower	-	On
6	Switch on Suction-System Rotary Valve	-	On
7	Switch on Suction-System Pulseair Timer	-	On
8	Open Suction-System Filter Blowback Air Supply Valve	-	Open
9	Start Diesel - Warmup	-	1,200 rpm
10	Engage Diesel Clutch	-	Engaged
11	Spin Rotor to 1,800 rpm via Displacement Speed Control Switch	-	1,800 rpm
12	Adjust Control Gas P to + 5 psi	DPR 28	+ 5 psi
13	Open Pressure Controller Instrument Air Supply Valve	APR 34	Open
14	Set Pressure Controller to 50 psig (This will close valve)	45	50 psig
15	Open N ₂ Supply Valve for R.H. Filter Pulse	37	Open
16	Purge Suction Lines In and Out	47A, 47B, 48A, 48B	Open - Close
17	Open Suction Line Valves	HCV 48A, 48B	Open

F.H. = KE Feed Hopper (Upper Tank)

R.H. = KE Receiving Hopper (Lower Tank)

S.H. = Storage Hopper

Table 2-2 (Cont.)

Step	Action Taken	Flow Sheet Number	Position or Setting
<u>COAL FLOW START</u>			
18	Open F.H. Fluidization Valve	S7	Open
	Start Coal Flow		
19	Purge Feed Pipe (Down)	S9	Open - Close
20	Cycle Deplugger Valve Switch several times	S1	Open - Close Cycle
21	Purge Feed Pipe (Up)	S10	Open - Close
22	Open Coal Feed Valve to start coal flow	PCV 12	Open
23	Monitor Rotor Eye Pressure (should drop to -7 in. Hg Vac)	13	
24	If Coal Flow fails to start, close F.H. Vent Valve and allow F.H. to pressurize to 5 psig to start coal flow	PCV 13	Close - Open
25	Monitor Sprue Detector and Cycle Deplugger as required	S1	Cycle
<u>PRESSURIZE RECEIVER</u>			
26	Close R.H. Vent Valve	PCV 67	Close
27	Open R.H. Pressurization Valve until pressurized to 50 psi	S4	Open - Close
28	Reset Pressure Controller to test level	PSV 47	As required
29	Increase Diesel rpm if required		
30	Readjust Control Gas Differential Pres. Regulator if required	DPR 28	As required
31	Increase rotor speed to maintain adequate margin as R.H. pressure rises	43	As required
<u>CONDUCT TEST</u>			
32	Open R.H. Pressurization Valve until test pressure is reached	S4	Open - Close
33	Adjust Pressure Controller to maintain pressure	PCV 47	Test pressure
34	Adjust Control Gas Differential Regulator to obtain test coal throughput	DPR 28	As required

Table 2-2 (Cont.)

Step	Action Taken	Flow Sheet Number	Position or Setting
35	Finalize Speed Setting	43	As required
36	Record Data as Required During Steady-State Test Run	-	As required
<u>DEPRESSURIZE RECEIVER</u>			
37	After test, reduce R.H. pressure to 50 psi by opening Vent Valve	PCV 67	Open - Close
38	Reset Pressure Controller to maintain 50 psi	PCV 47	50 psi
39	Reduce Speed to 1,800 rpm	43	1,800 rpm
40	Reset Control Gas P to + 5 psi	DPR 28	5 psi
41	Proceed with Coal Recycle or Shutdown Sequences as required	-	As required

KINETIC EXTRUDER TEST LOOP OPERATING PROCEDURES

2. SHUTDOWN PROCEDURE FOR THE KE UNIT

The procedure shown in Table 2-3 assumes the KE unit is initially operating at 50 psi in a condition corresponding to Table 2-2, Step 40.

Table 2-3 KE SHUTDOWN PROCEDURE

Step	Action Taken	Flow Sheet Number	Position or Setting
1	Open R.H. Vent Valve to bring Unit to atmospheric pressure	PCV 67	Open
2	Allow pressure to drop to 5 psig or less	11	
3	Close Coal Feed Valve	PCV 12	Close
4	Allow Rotor to drain free of Coal as Shown by Rotor Eye Pressure or Sprue Detector	46, 13	
5	Cycle Deplugger several times as Required	S1	Open - Close Cycle
6	Purge Feed Pipe down	S5	Open - Close
7	Close Suction-Line Valves	HCV 48A, HCV 48B	Close
8	Purge Suction Line Valves	47A, 47B, 47C, 47D	Open - Close
9	Purge Feed-Pipe Branch Section	24G	Open - Close
10	Cycle Deplugger as required	S1	Open - Close Cycle
11	Stop Rotor via Hydraulic-Pump Displacement Control	0	Zero displacement
12	Turn off F.H. Fluidization	S7	Close
13	Turn off pressure controller air	APR 34	Close
14	Close R.H. Filter Pulse Valve	37	Close
15	Reduce Control-Gas Pressure to minimum	DPR 28	Low
16	Disengage Diesel Clutch	-	Disengage

Table 2-3 (Cont.).

Step	Action Taken	Flow Sheet Number	Position or Setting
17	Stop Diesel	-	Stop
18	Close Suction System Filter Blowback Air Valve	64D	Close
19	Switch off Suction System Pulse Air Timer	-	Off
20	Switch off Suction System Blower	-	Off
21	Switch off Suction System Rotary Valve	-	Off
22	Switch off Main Baghouse Blower	-	Off
23	Close Main N ₂ Supply Valve	66	Close
24	Allow N ₂ System Pressure to bleed off	-	-
25	Switch off Lub. System Pump	-	Off
26	Switch off L.P. Seal System Pump	-	Off
27	Switch off H.P. Seal System Pump	-	Off

KINETIC EXTRUDER TEST LOOP OPERATING PROCEDURES

3. COAL TRANSFER PROCEDURES

3.1 Recycle coal from Receiver Hopper (R.H.) to KE Feed Hopper (F.H.). For the sequence of actions shown in Table 2-4, the initial condition corresponds to running at 50-psig pressure, 1,800 rpm (i.e., Table 2-2, Step 40).

Table 2-4 RECYCLE COAL FROM R.H. TO F.H. WHILE RUNNING KE UNIT

Step	Action Taken	Flow Sheet Number	Position or Setting
1	Purge Recycle Line (Up)	S6	Open - Close
2	Fluidize R.H. - Open Valve S3	S3	Open
3	Open Recycle Line Valve	PCV 11	Open
4	Continue Coal Recycle Until R.H. is empty of coal as shown by Level Sensor, Load Cells, or Gas Blowby Into F.H.		
5	Close Recycle Line Valve	PCV 11	Close
6	Purge Recycle Line (Up)	S6	Open - Close
7	Purge Recycle Line (Down)	S5	Open - Close
8	Close R.H. Fluidization Valve	S3	Close
9	Proceed with Test or Shutdown as required		

KINETIC EXTRUDER TEST LOOP OPERATING PROCEDURES.

3.2 Discharge coal from Feed Hopper to Storage Hopper. Initial state of system is to be put in shutdown mode with valve positions as in Table 2-1.

Table 2-5 COAL TRANSFER FROM FEED HOPPER (F.H.) TO STORAGE HOPPER (S.H.)*

Step	Action Taken	Flow Sheet Number	Position or Setting
1	Close Manual KE Feed Pipe Valve	HCV 14B	Close
2	Turn on Main Baghouse		On
3	Open F.H. Fluidization Valve - Fluidize Feed Hopper	S7	Open
4	Purge S.H. Transfer Line	24F	Open - Close
5	Open S.H. Transfer Line Valve	HCV 14A	Open
6	Purge Feed Pipe (Down)	S5	Open - Close
7	Close F.H. Vent Valve to pressurize F.H.	PCV 13	Close
8	Allow F.H. to pressurize to 25 psig		25 psig
9	Purge Feed Pipe (Up)	S10	Open - Close
10	Open Coal Feed-Pipe Valve to start coal transfer	PCV 12	Open
11	Adjust F.H. Fluidization Valve if necessary to maintain pressure	50A, 50B, 50C	Adjust as required
12	Continue Transfer until F.H. empty as evidenced by Loss of F.H. pressure	10	-
13	Open F.H. Gas Vent Valve	PCV 13	Open
14	Close Feed Pipe Coal Valve	PCV 12	Close
15	Purge Feed Pipe (Up)	S10	Open - Close
16	Purge Feed Pipe (Down)	S9	Open - Close
17	Close F.H. Fluidization Valve	S7	Close
18	Reset Fluidization Valves as Required	50A, 50B, 50C	As required
19	Close S.H. Transfer Line Valve	HCV 14A	Closed
20	Purge S.H. Transfer Line Valve	24F	Open - Close

Table 2-5 (Cont.)

Step	Action Taken	Flow Sheet Number	Position or Setting
21	Turn Off Main Baghouse	-	Off
22	Turn Off Main N ₂ Supply Valve	66	Off

*Water for spray into S.H. is used during coal transfer if coal moisture level is to be increased.

KINETIC EXTRUDER TEST LOOP OPERATING PROCEDURES.

3.3 TRANSFER FROM STORAGE HOPPER (S.H.) TO FEED HOPPER (F.H.)

Most of these control actions are performed from the local panel near the storage hopper (See Table 2-6). The initial state of the system is that shown in Table 2.

Table 2-6 TRANSFER COAL FROM STORAGE HOPPER TO KE FEED HOPPER

Step	Action Taken	Flow Sheet Number	Position or Setting
1	Turn on Main Baghouse	-	On
2	Set S.H. Fluidization Valve (Inner Ring)	24E	Open L turns
3	Set S.H. Fluidization Valve (Outer Ring)	25A	Open M turns
4	Set S.H. Fluidization Valve (Middle Ring)	25B	Open N turns
5	Purge Coal Line (Down)	24A	Open - Close
6	Purge Coal Line (Up)	24B	Open - Close
7	Purge Coal Line (Up)	24C	Open - Close
8	Close S.H. Vent Valve	HCV 16	Close
9	Open Gas Valve to Pressurize S.H. to 25 psig	26	Open - Close
10	When S.H. reach 25 psig, open Coal Valve	HCV 23A	Open
11	Should Coal Flow Fail to Start, Close HCV 23A and purge as required, Reopen HCV 23A		-
12	Monitor S.H. Pressure and adjust Fluidization and Pressure as required	24E, 25A, 25B, 26	Adjust as Required
13	Relieve Pressure with Gas Vent if required	HCV 16	Open - Close
14	After Coal Transfer is complete, Close Feed Line Valve	HCV 23A	Close
15	Without delay, purge Coal Line	24A, 24B, 24C	Open - Close
16	Open S.H. Vent Valve to depressurize	HCV 16	Open
17	Close Gas Pressurization Line (If Open)	26	Close

Table 2-6 (Cont.)

Step	Action Taken	Flow Sheet Number	Position or Setting
18	Close Fluidization Valves (Leave Cracked)	25A, 25B, 24E	Cracked
19	Repurge Coal Lines	24A, 24B, 24C	Open - Close
20	Turn Off Main Baghouse		Off
21	Turn Off Main N ₂ Supply Valve	66	Off

KINETIC EXTRUDER TEST-LOOP OPERATING PROCEDURES

4. EMERGENCY SHUTDOWN PROCEDURE FOR THE KE UNIT

In any emergency (e.g, blowback, rotor imbalance, vibration, gas/coal dust leak) the KE unit should be depressurized and stopped as shown in Table 2-7. In the event of power failure, process valves will fail safe; that is, gas supply valves will fail close and vent valves will fail open, depressurizing the loop. Diesel engine should then be unclutched and shut down manually.

Table 2-7 KE EMERGENCY SHUTDOWN PROCEDURE

Step	Action Taken	Flow Sheet Number	Position or Setting
1	Open R.H. Vent	PCV-67	Open
2	Close R.H. Pressurization Valve (if open)	S4	Closed
3	Close R.H. Fluidization Valve (if open)	S3	Closed
4	Stop Rotor via Hydraulic Pump Displacement Control	0	Zero displacement
5	Open F.H. Vent Valve (if closed)	PCV13	Open
6	Shut Main N ₂ Supply Valve off (only if required on power failure or valve failure)	66	Closed
7	Proceed with Normal Shutdown Procedures depending on exact circumstances		

Section 3

SAFETY PRECAUTIONS

3.1 PURPOSE

To apprise program personnel, the customer and any potential operators of minimum safety precautions to be employed whenever the 1 TPH KE is operated.

3.2 OVERVIEW

The 1 TPH KE has been analyzed to identify potential hazards associated with the equipment and its operation. These hazards have been resolved or minimized to the maximum extent possible within the scope of this technology demonstration program. The safe operation of this coal feeder facility depends on the practical judgment and knowledge of program personnel and operators. It is a management responsibility to ensure individuals working around or on the facility are aware of inherent risks involved in facility and equipment operations. As a minimum, fire, explosion, inhalation and noise hazards shall be discussed. Once introduced to the safety and health hazards presented by coal dust and the associated KE equipment, each individual is responsible for asserting all reasonable efforts to assure safe conditions and operations pursue.

3.3 EMERGENCY OPERATIONS

Experience shows that fire and explosion associated with pulverized fuel systems are most likely to occur during startup or shutdown or after an emergency shutdown. Personnel at the KE facility shall know the location and operation of fire fighting equipment and shall call appropriate emergency organization (dial 117) whenever necessary.

At least one person who knows emergency shutdown conditions and procedures by heart, shall be present whenever the KE is in operation. Emergency shutdown procedures are specified in Section 2, para. 4, and Table 2-7 of this document.

4.0 GENERAL PRECAUTIONS

Good housekeeping is essential. Old and new coal dust accumulations, solid and liquid combustibles and other materials not necessary for safe and efficient facility operation shall be removed as often as necessary. As a minimum, horizontal ledges of the building and equipment shall be cleaned weekly. Coal dust shall be removed by vacuum suctioned to a closed, vented 55 gal drum. Residual coal dust may be flushed away with water. In no case will compressed air be used to remove coal dust accumulations since it creates dust clouds.

Severe injury and property damage can result from careless handling of unconfined pulverized fuel; therefore, extreme caution shall be used in cleaning out plugged parts of the system. Pulverized fuel that may flood out or spill from such places can be ignited by a random spark or hot surfaces on which it falls. Since pulverized fuel drifts freely in air, ignition may take place at a considerable distance from the point of initial disturbance.

All personnel shall eliminate potential ignition sources. Open flames and smoking are prohibited except in designated authorized areas. Use of welding and flame-cutting equipment are prohibited except in coal dust free areas when done in accordance with the LMSC C-12 Industrial Safety Manual or OSHA regulations.

Gun-type tools using powder or cartridges shall not be used where coal dust is present.

Non-sparking protective footwear shall be worn.

Only non-sparking tools, such as brass tools, wooden shovels, etc., shall be used whenever coal dust is present.

If trouble shooting lighting is required, only extension cords with lamp guards and vaporproof globes shall be used.

5.0 COAL DUST STORAGE AND HANDLING

Vehicles and handling equipment shall comply with the NFPA requirements for Class II, Division 2 locations and the LMSC C-12 Industrial Safety Manual.

All coal dust will be in drum quantities, and stored in the allocated waterproofed area or building.

All spills and leaks must be vacuum suctioned to a closed, vented 55-gal drum. Residuals are to be flushed away with water.

The immediate supervisor of any persons handling coal dust must be warned of the breathing hazard and explosive characteristics of coal dust mixed with air.

In areas where the concentration of coal dust may go above the allowable limit, all personnel must wear approved, self-contained or supplied air-breathing equipment.

Good general ventilation must be maintained in the coal-feeder main building.

6.0 COAL DUST DISPOSAL

Used or discarded coal dust is to be placed in 55-gal steel open-ended drums, sealed and tagged for disposal. Proper procedure for removal or coal-dust-laden drums must be followed.

7.0 EYE AND EAR PROTECTION

Safety glasses must be worn in the main building at times when equipment is being checked or during tests.

The eye wash faucet must be checked daily and kept clear for access.

Ear plugs must be worn in the main building during long exposure to the running machinery; i.e., whenever an 8 hr/day exposure to running equipment occurs.

8.0 OPERATIONS

The minimum number of personnel essential for facility operations will be allowed in and around the facility whenever operational tests are conducted.

Personnel are not allowed in the KE area when (a) the rotor is operated above 2,500 rpm, or (b) the receiver is pressurized in excess of 350 psig.

During critical operations, an operator will be stationed in the Diesel Engine area and be in direct communication with the control room operator.

9.0 LARGER SYSTEMS

The LMSC KE type equipment will be used in conjunction with other apparatus or systems when it is placed into industrial use or tested in larger scope technology demonstration programs. Accordingly, the user who integrates LMSC equipment into larger systems is responsible for preparing written operating instructions and check lists to coordinate the operation of the KE with associated apparatus.

Appendix C
TESTING LABORATORY REPORT ON NOZZLE DEPOSIT

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COMMERCIAL TESTING & ENGINEERING CO.

GENERAL OFFICES: 228 NORTH LA SALLE STREET, CHICAGO, ILLINOIS 60601 • AREA CODE 312 726-8434

Reply to

Instrument Analysis Division
490 Orchard Street
Golden, CO 80401

February 10, 1982

Phone: 303-278-9521

To: Mr. John Meyers
Lockheed Missiles & Space Co., Inc.
Department 5233
Building 131
Sunnyvale, CA 94086

P O No.: YTV6G2830X

Sample I.D.: Lockheed No. 118

IAD #97-H747-555-03

*Western Bituminous Causings
Nozzle Deposits*

PROXIMATE ANALYSIS

	<u>As Received</u>	<u>Dry Basis</u>
% Moisture	2.63	xxxxx
% Ash	8.57	8.80
% Volatile	40.61	41.71
% Fixed Carbon	48.19	49.49
	<hr/>	<hr/>
	100.00	100.00
Btu/lb	13120	13474
% Sulfur	0.69	0.71
<hr/>		
% Moisture, Ash-free Volatile =	45.73	% Dry, Mineral matter free Volatile = 45.19
% Moisture, Ash-free Fixed Carbon =	54.27	% Dry, Mineral matter free Fixed Carbon = 54.81
Moisture, Ash-free Btu =	14774	Moist, Mineral matter free Btu * = 14481
Pounds of SO ₂ per 10 ⁶ Btu =	1.05	(Based on as received moisture)*
		Pounds of Sulfur per 10 ⁶ Btu = 0.53

Robert L. Jacobs, Jr.

M. L. Jacobs, Ph.D., Mgr.
Instrumental Analysis Div.

11 Feb 82

Charter Member

C-3

OVER 40 BRANCH LABORATORIES STRATEGICALLY LOCATED IN PRINCIPAL COAL MINING AREAS,
TIDEWATER AND GREAT LAKES PORTS, AND RIVER LOADING FACILITIES

COMMERCIAL TESTING & ENGINEERING CO.

GENERAL OFFICES: 228 NORTH LA SALLE STREET, CHICAGO, ILLINOIS 60601

AREA CODE 312 726-8434

Reply to

Instrument Analysis Division
490 Orchard Street
Golden, CO 80401

February 10, 1982

Phone: 303-278-9521

Mr. John Meyers
Lockheed Missiles & Space Co., Inc.
Department 5233
Building 131
Sunnyvale, CA 94086

Re: IAD #97-H747-555-03

Dear Mr. Meyers:

Enclosed, please find the proximate analysis on your Sample No. 118 as you requested. Your Sample Nos. 118 and 122 were logged into our lab as Batch No. 97-H747-555-03.

The two included histograms are for samples 118 and 122. The plotted values for the two coals indicate the percent reflectance of the two coals. They appear to be identical (0.59%).

Because of the extreme fluorescence of these two coals while under the microscope, it can only be concluded that some kind of organic substance has been added to the coal. This additive (if organic) will result in lower reflectance values than the same coal without this additive. You indicated that this is likely to be ethylene glycol.

To check this premise, equal portions of each coal sample were soaked overnight in equal volumes of ethylene glycol. The coal was separated from the liquid by filtration and the filtrate permitted to drain in the funnel for 48 hours.

Equal volumes of the filtrate were eluted chromatographically; sample 118 produced much more color change than did sample 122. To check this with a control, equal volumes of the "as received" coals were similarly treated. Again, sample 118 produced much more color change than did sample 122. If the coals are almost identical, then the question must be asked as to why there was a differing response to the elutriating agent.

Photograph A is of sample 122 at a magnification of 400 times. Most of the gray objects (C) are coal; the smaller bright bodies are pyrite (iron sulfide). Photograph B is of sample 118 similarly prepared. Photograph C is of the nozzle scrapings at a magnification of 160 times. Most of the larger gray objects are of coal; many of the smaller gray objects are a mixture of mineral matter and coal. The bright spots of 5 μ m (and less) are pyrite. Photograph D is also of nozzle scrapings at the same magnification as C. The entire area is dominated by pyrite particles of approximately 5 μ m (or less) in a diameter in a matrix of smaller coal and mineral particles.

C-4

OVER 40 BRANCH LABORATORIES STRATEGICALLY LOCATED IN PRINCIPAL COAL MINING AREAS,
TIDEWATER AND GREAT LAKES PORTS, AND RIVER LOADING FACILITIES

Generally, it appears to me that the occlusion of the nozzle openings is caused primarily by accumulation of very fine grained pyrite in an exceptionally fine matrix. The cementing of material is probably attributable to the (fluorescing) additive in the coal or possibly to a sequential heating-softening-impact fusion of particles as they impinge on the wall of the nozzle opening. Very likely, it is a combination of both. Possibly, an inexpensive petroleum derivative was added to the coal in order to raise BTU values or as a dust control substance. This would soften and solubilize some of the coal ingredients. A much more sophisticated organic analytical procedure would be necessary to determine the nature of this substance.

Thank you for the opportunity to help you with this problem.

Respectfully yours,

Peter R. Kremer
Coal Petrographer

M. L. Jacobs, Ph.D., Manager
Instrumental Analysis Division

C-5

COMMERCIAL TESTING & ENGINEERING CO.

Photo A. Sample 122: Coal which did not cause Nozzle Deposits. (400x, C = coal)

Photo B. Sample 118: Coal which did cause Nozzle Deposits. (400x, C = coal, P = pyrite)

Photo C. Nozzle Scrapings (160x, C = coal)

Photo D. Nozzle Scrapings (160x)

REFLECTANCE ANALYSIS

IAD Batch: 97-H747-555-03

Report of Analysis on Sample: 118

Mean-Maximum Vitrinite Ro: 0.59

Distribution of Vitrinite Reflectance Readings:

Number of

Counts

(Total = 101)

V-Type Table for Vitrinites (=100%)

<u>V- 5</u>	<u>V- 6</u>	<u>V- 7</u>	<u>V- 8</u>
74.2	24.8	1.0	

COMMERCIAL TESTING & ENGINEERING CO.

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For Your Protection

F-466

REFLECTANCE ANALYSIS

IAD Batch: 97-H747-555-03

Report of Analysis on Sample: 122

Mean-Maximum Vitrinite Ro: 0.59

Distribution of Vitrinite Reflectance Readings:

%Ro

Number of
Counts
(Total = 102)

V-Type Table for Vitrinites (=100%)

<u>v- 4</u>	<u>v- 5</u>	<u>v- 6</u>	<u>v- 7</u>
2.9	57.9	37.2	2.0

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