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**ADVANCED TECHNOLOGY FOR ANCILLARY
COAL CLEANING OPERATIONS**

**TECHNICAL PROGRESS REPORT
JANUARY - MARCH 1988**

Presented to

**U.S. Department of Energy
Pittsburgh Energy Technology Center**

DOE Contract No. DE-AC22-87PC79881

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PREFACE

This second Quarterly Technical Progress Report presents the results of work accomplished during the period December 28, 1987 through April 3, 1988, under Contract No. DE-AC22-87-PC79881 entitled "Advanced Technology for Ancillary Coal Cleaning Operations." The program covers three ancillary operations: Drying, Reconstitution and Comminution. Each operation is at a different level of development ranging from the verification at the laboratory scale of direct and indirect drying concepts using pulse combustion technology, verification at the laboratory scale of the feasibility of coal fines extrusion for reconstitution and finally, the feasibility of hydraulic shock comminution (HSC) for the economic "fine grinding" of coal. A short description of each program task was included in the First Quarterly Technical Progress Report. These are omitted in this report.

During this past quarter, testing of the direct dryer neared completion with test data confirming the practicality and cost savings that could result from the application of the pulse combustion technology to this ancillary operation. The fabrication and assembly of the indirect dryer also proceeded well ahead of the baseline schedule with testing projected early during the next quarter.

Testing of the modified coal-fines extruder was also well ahead of schedule and these activities should also be completed early during the next quarter. A topical report entitled "Fine Coal Reconstitution by Extrusion: A Preliminary Technical and Economic Assessment," MTCI Report #79881-102, was also issued based on the results to date.

The Hydraulic Shock Comminution testing was completed during this past quarter and the technical feasibility of producing fines confirmed although the low level of effort involved was insufficient to establish either economy or practicality for the process.

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SECTION 1.0

INTRODUCTION

1.1 BACKGROUND

The Department of Energy's (DOE) Coal Preparation program is focused upon providing a scientific and engineering technology base which industry can apply to the competitive production of economically and environmentally clean coal products from a wide variety of coals. A number of these coal preparation processes, either at the research stage or in the development stage, offer great potential for cleaning coal with demonstrated deep cleaning performance. Key process steps in many of these technologies are burdened with the high costs and energy inefficiencies of ancillary operations which constrain their commercialization and market entry potential. The present program is aimed at overcoming the process constraints in economy, capacity and handling which will help to realize the benefits which will be achieved from competitively available clean coal as an alternative to petroleum-derived and natural gas-based fuels and/or as a substitute for costly back-end environmental control such as flue gas desulfurization.

Typically, these ancillary operations include processes such as comminution, dewatering/drying, and formulation/reconstitution of the product into a fuel form that could be transported to and used by the end-user. These ancillary operations are important facets of most coal-cleaning technologies, especially in their impact on the overall process cost and effectiveness. As a front-end operation, comminution is an operation that must yield a consistent, well-characterized superfine coal product, cheaply produced in commercial quantities for the coal-cleaning process. By selecting the appropriate approach to comminution and required product characteristics, additional benefits can accrue for coal-cleaning process optimization and efficiency in reducing ash and pyritic sulfur in physical coal cleaning as well as in improving chemical and microbiological reaction rates in reducing organic sulfur. In spite of its importance, comminution is perhaps the least developed of the ancillary operations and remains energy intensive and costly. This program includes a two-part task to address the high costs and energy intensiveness of comminution.

The comminution task of this program is devoted to evaluating the feasibility of an advanced MTCI concept which employs high pressure hydraulic shock for selectively micronizing the coal. The MTCI HSC process employs very short duration, high intensity hydraulic shock waves to fracture solids along and within grain boundaries. The application of the principles involved has not been reduced to practice for coal preparation but has been and is being used extensively in the metal-forming industry and other applications. Given feasibility, this concept promises to substantially reduce the energy cost for comminution while enhancing the selectivity in the product material on the basis of material density and grain boundaries. The latter is of significant importance to the effectiveness of the cleaning processes which follow the comminution of the coal.

Dewatering (drying) is also a significant ancillary operation affecting the cost and energy intensiveness of the coal-cleaning process. The energy requirements for evaporating the water from the clean coal are simply too high. In this task area of the program, MTCI will utilize its proprietary pulse combustion technology to reduce the overall cost of dewatering and drying. The result of a successful application of pulse combustion techniques to thermal drying, either with directly or indirectly fired dryers, will be a significant reduction in both capital and O&M costs, further enhancing the economics of coal cleaning.

The third ancillary activity to be considered is the reconstitution of fines from the comminution, cleaning and drying operations. In modern coal mining, the use of automated long-wall mining machines results in the generation of substantially more fines, perhaps as much as two to three times as many as had previously been generated. This results in higher capacity requirements for coal cleaning and preparation plants. Froth flotation systems, thermal dryers, and thickeners are especially susceptible to excess fines. In transportation, substantial amounts of fines can result in excessive dusting and/or bridging. In addition, problems with freezing and spontaneous combustion are also worsened when large amounts of fines are present. Nevertheless, the advantage of crushing coal to fine sizes to liberate more of the pyritic material and the subsequent cleaning of the fines by the new methods, such as froth flotation of micronized coal, results in deeper cleaning and provides a cleaner coal for combustion.

As a result of the trend towards micronization of coal prior to cleaning, the clean coal products are of a fine particle size distribution. Transportation of such clean coal products requires special handling or methods of formulation in a safe and economical transportable fuel form. Dry micronized clean coal is being transported in tanks under a blanket of inert gas in a limited set of applications in Europe. In other instances, the micronized clean coal is used to manufacture coal slurries having the appropriate rheology and coal mass loading. These approaches limit the distance for transportation and give rise to both cost and combustion performance issues. In the case of dry micronized coal, handling requirements and methods of transportation can become quite expensive for large power plant applications where the plant is at a location distant from the mine and the coal processing facility. In the case of coal slurries, new combustion and fuel handling equipment must be installed by the end-user at significant capital cost. In addition, boiler derating may also be required in some installations which further increases the resistance by the end-user to consider such slurry fuels.

The application of extrusion techniques to both reconstitute the fines and to produce an extrudate that can be transported and fired utilizing presently available equipment may resolve these cost issues. The extrusion technology is an adaptation of that which is employed by a well-developed industry based on the continuous economic extrusion of thermoplastics and ceramics at high temperatures and, if verifiable for coal processing, will also provide an application for which a large technology and product improvement base exists.

1.2 OBJECTIVES

The work under contract number DE-AC22-87PC97881 is devoted to experimental research and development to investigate the feasibility of novel ancillary coal-cleaning technologies that offer a potential for reduced capital and operating costs. The ancillary operations that are specifically addressed in this work include pulse enhanced drying, fines reconstitution by extrusion, and hydraulic shock wave comminution.

The specific objectives of the program shall be:

- o Verification, at the laboratory scale, of the benefits of the MTCI pulse-enhanced drying of clean coal fines for both directly heated and indirectly heated technologies.
- o Verification, at the laboratory scale, of the feasibility and performance of coal extrusion for the reconstitution of clean coal fines.
- o Investigation of the feasibility of hydraulic shock comminution as a feasible low-cost, efficient process for cost and energy reduction of the comminution step in coal preparation.

1.3 SUMMARY STATUS

Progress in all tasks are significantly ahead of schedule. A topical report entitled "Fine Coal Reconstitution by Extrusion: A Preliminary Technical and Economic Assessment," was prepared and distributed as per contract requirement.

After several checkout tests and equipment configuration modifications to the direct dryer, a series of tests using coal-water slurry atomized with a small quantity of air were conducted. The dryer performed well with no signs of plugging or choking to the pulse combustor. Dryer exit temperatures were maintained below 300°F. The collected product consisted of a fine dry powder-like material, a portion of which had agglomerated. At a slurry feed rate of 330 lbs/hr with 35.3 wt.% moisture, the specific energy consumption was 1580 Btu/lb of water evaporated and the final moisture content was 5.15 wt.%. These results confirmed the technical and economic practicality of the pulse-enhanced direct drying concept.

The indirect fluid bed dryer was fabricated and assembled in preparation for testing during the next period.

In Task 3, fines reconstitution, testing during this period confirmed the basic feasibility of the process since extrudites were formed from both pulverized and micronized feed. However, the equipment (extruder) behaved erratically, resulting in plugged vents that also affected feeding. A series of tests performed early in the present quarter before preparing this report resulted in the successful production of extrudates on both fresh coal-fines

and wet cake indicating that the prior difficulties resulted from feed material problems such as age and oxidation rather than from the process.

In the hydraulic shock comminution activities the results appeared to confirm the feasibility of the process to produce fines for the beneficiation processes. This activity is a low-level effort aimed at demonstrating feasibility rather than economic and technical practicality. The results of the testing did demonstrate that the process was feasible. However, quantifying energy requirements and other parameters to determine the effectiveness or efficiency of the process is probably not appropriate at this stage.

In summary, progress in all areas was well ahead of schedule, primarily due to the early and successful accomplishments in all task areas.

SECTION 2.0

TECHNICAL DISCUSSION

Task 2.0 Laboratory Scale Verification of Pulse-Enhanced Dryer

Subtask A: Equipment Design, Fabrication, and Set-up

Direct Dryer

As reported in the previous quarterly, several design modifications were made to the direct dryer in order to improve system performance. These modifications included: 1) The addition of an air plenum around the pulse combustor aerovalve, 2) The addition of a three foot long mixing pipe at the tailpipe exit, and 3) An increase in the capacity of the primary drum and baghouse drum.

The first modification was intended to reduce heat loss and combustibles emissions during the aerovalve blow-back cycle. It was initially anticipated that the combustion air to the air plenum would be supplied through a damper provided on the dryer housing. In this configuration, the combustion air is drawn over the pulse combustor, thereby reducing the combustor surface temperature and preheating the air. The preheated combustion air then enters the air plenum where it is drawn into the aerovalve during the combustor suction stroke.

Test runs performed using this configuration proved unsatisfactory. The pulse combustor performed acceptably during an initial start-up period. Shortly thereafter the pulse combustor appeared to choke and die due to an inability to provide sufficient quantities of fresh combustion air through the aerovalve. This is now attributed to the high air preheat temperatures which occurred at the air plenum resulting in diminished performance of the aerovalve.

In order for proper functioning of the combustor, the aerovalve must serve as an effective fluid diode, i.e., it must present a low flow resistance for the influx of combustion air and a high flow resistance for the efflux of hot combustion products. This fluidic diodicity occurs naturally when the temperature differential between the combustion air and combustion products is high. However, when the combustion air is excessively preheated, this natural diodicity is compromised and the combustor becomes starved for air.

In order to circumvent this problem, an air inlet damper was provided directly to the air plenum. In this way, air is no longer drawn through the dryer housing and thus remains relatively cool. Only a small quantity of air is allowed to directly flow into the dryer housing to ensure that the combustor surface temperature does not exceed material limits. Experimental results verify that operation in this manner appears to be adequate for the intended service.

Indirect Dryer

The design of the indirect dryer was also presented in the previous quarterly. Fabrication of the indirect dryer is anticipated to be completed by the end of February, and initial testing will begin in early March.

Subtask B: Experimental Evaluation of Dryers

Extensive characterization of the direct dryer pulse combustor on natural gas was completed in January for the current configuration. The system characteristics are summarized in Table 1 for normal steady-state operation during drying of water injected at the tailpipe elbow. This characterization on natural gas will serve as a baseline for comparing operating results on coal fuels.

**TABLE 1: CHARACTERIZATION OF DIRECT DRYER
PULSE COMBUSTOR ON NATURAL GAS**

Operating Frequency, Hz	170
Chamber Temperature, °F	1800
Surface Temperature, °F	1625
Chamber Pressure, in. wc	8
Primary Drum Pressure, in. wc	- 1.5
AET at Primary Drum, °F	100
AET at Baghouse Entrance, °F	10
Dryer Exit Composition (dry)	
Oxygen, %	8
CO, ppm	150

AET - Approach to Equilibrium Temperature

Initial tests were conducted to investigate the performance of the direct dryer using wet coal feeds. The initial tests were conducted using a pulverized slurry containing approximately 38 percent moisture. The slurry was conveyed using a Moyno pump and entered through a micromotion flow meter. The slurry was introduced into the pulse combustor tailpipe at its 180° bend.

During the first test run, the slurry injector which protruded into the dryer housing became plugged. The dryer housing operated at a temperature of approximately 1000 to 1200°F. Since the 3/8" injector was initially unshielded, vaporization of the slurry water occurred prior to injection. In order to avoid this problem, a 1/4" injector tube was inserted inside the original 3/8" tube to act as an effective radiation and conduction shield and allowing proper operation of the injector.

During the second test run, operation on slurry was achieved only for a short period. After approximately two minutes, the pulse combustor began to perform poorly and additional slurry which was pumped into the tailpipe resulted in significant plugging.

This indicated that injection of the wet coal should occur at a point further from the combustor in order to prevent combustor choking. Additional tests are planned for injecting slurry closer to the tailpipe exit which expands to a 2" diameter flare.

Experimental testing of the pulse-enhanced direct dryer continued in February. Successful operation of the dryer on coal feed was demonstrated. However, a small quantity of support gas (natural gas) was necessary for long-term stable operation. The support gas represented approximately 10 to 20 percent of the total heat release. The need for support gas is due primarily to the difficulty in providing a smooth continuous stream of coal to the combustor. Discontinuities in the coal feed rate caused combustor instabilities and eventually resulted in combustor shut-down. Due to the small scale of the coal feeder, eductor, and feed lines, occasional disruptions in the coal feed necessitate a small quantity of support gas for safe stable operation. It is anticipated that larger scale combustors can be operated without support gas as demonstrated by MTCI in prior work.

Tests on slurry drying were also initiated during this quarter. However, it was noted that the performance of the pulse combustor rapidly deteriorated over several days of operation. Good pulse combustor performance is typically associated with large peak-to-peak pressure fluctuations (several psi), high mean boost pressures within the chamber, and a clean sinusoidal wave forms. While these attributes were attained in early test runs, later runs showed diminished combustor pressures and an inability to achieve a clean sinusoidal wave form. The clean and degenerated wave forms are shown in Figure 1, corresponding to normal and off-spec operation of the pulse combustor. As seen, the degenerated wave form has lower peak-to-peak amplitudes and exhibits multiple frequencies. In order to identify the reasons for this reduction in performance, the pulse combustor was removed from the dryer housing for inspection. The inspection revealed signs of thermal failure in several regions of the combustor including: the chamber itself, the throat, and the injection elbow. Each of these failures occurred at points where connections were made to the combustor through bulkhead fittings in the dryer box (for instrumentation, injectors, etc). Since thermal expansion could not be accommodated with this configuration, failure of the thin walled combustor occurred. Figure 2 shows photographs of the failure zones. From the wave forms shown in Figure 1, it is evident that the failure at the injector elbow has introduced off-spec frequencies which have disrupted the fundamental frequency of the combustor. Due to the seriously distorted condition of the combustor, a new unit was fabricated. The new unit was constructed of standard fittings with heavier wall thicknesses than the prior model. Figure 3 shows the new combustor during fabrication, and the completed unit during test firing. Also, to provide means for thermal expansion, the bulk head fittings in the dryer housing were replaced by slots allowing free expansion. Additional surface thermocouples were also placed along the combustor to better monitor material temperatures. The revised combustor was

FIGURE 1: PULSE WAVEFORMS

A) THROAT

B) SLURRY INJECTOR

C) COAL INJECTOR

FIGURE 2: PULSE COMBUSTOR FAILURE ZONES

FIGURE 3: NEW COMBUSTOR DURING FABRICATING AND TESTING

tuned and was returned to service in March. Due to the need for reconstructing the combustor, the collection of experimental data was delayed. The basic geometry of the new combustor was identical to the old unit. It consisted of a U-tube configuration with a flared tailpipe. The tailpipe exhaust gases entered a 4" diameter extension pipe approximately 4' long which connected to a vertical cyclone collection drum. Several sets of drying tests were conducted in this configuration using natural gas fuel and a wet coal feed consisting of a 35 percent moisture coal-water slurry. Slurry injection was varied for three separate locations including: 1) at the 180° bend of the tailpipe, 2) at the flared tailpipe section approximately 8" from the exit, and 3) directly at the tailpipe exit. In each case, no attempt was made to atomize the slurry using air at the injection location.

In all of these test runs, excessive pyrolysis of the injected slurry occurred. In some cases, a steady temperature rise was noted indicating that a portion of the wet coal feed was combusting. Each of these tests were terminated due to plugging in the exhaust pipe which derated combustor performance. Post-test inspection of the dryer internals revealed that agglomerated material had deposited in the 4" extension pipe thereby constricting the flow of combustion gases. It was evident that the injected feed was not being uniformly dried and that portions of the feed were sticking to the exhaust pipe walls while other portions were being overheated.

It was believed that eliminating deposition of wet material on the exhaust pipe wall would result in uniform drying. Therefore, a second configuration was tested. Here, the 4" diameter extension pipe was replaced by a short conical expander which connected directly to the vertical collection drum. Tests were conducted by injecting slurry at the tailpipe exit just at the point of connection to the flared expansion cone. In these tests, the injector was operated with modest quantities of atomization air.

This configuration proved to result in somewhat better performance than the prior configuration. Slurry was fed for approximately 10 minutes under relatively controlled conditions. However, pyrolysis and combustor choking eventually necessitated termination of the test run.

Inspection of the dryer internals again revealed a significant accumulation of agglomerated material on the walls of the expansion cone. Based on these results, it was decided that the tailpipe exit of the pulse combustor must exhaust directly into a large collection drum. This would serve two purposes. First, the problem of wall deposition would be minimized by injecting feed at the tailpipe exit just prior to entering the collection drum. And second, flue gas recirculation within the collection drum would attenuate the hot exhaust gases which are in contact with the wet coal, thus minimizing the chance of overheating. A photograph of the final configuration is given in Figure 4 with the horizontal collection drum clearly visible. In addition, in order to accommodate the horizontal collection drum, the pulse combustor U-tube configuration was modified to a 90° bend only.

Tests were performed on March 28 in this configuration using coal-water slurry atomized with a small quantity of air. During these tests, the dryer performed well with no signs of plugging or choking of the combustor. Dryer

FIGURE 4: COLLECTION DRUM OF MODIFIED DIRECT DRYER

exit temperatures were maintained below 300°F, and only a minimal degree of pyrolysis was noted. A total of approximately 120 pounds of slurry was fed and the test was voluntarily terminated.

Collection of the product material revealed the production of both fine dry powder-like material and a portion of material which was agglomerated at the bottom of the collection drum in a crust-like form. The crust-like material could be easily crushed by hand to form a powder.

Several product samples were taken from various locations and tested for moisture content. Material in the baghouse and exit tee of the collection drum had a moisture content of 1.7 wt%. The bulk of the material in the collection drum had moisture contents ranging from 4.5 to 5.5 wt%. Two of the tested samples had moisture content in the 10 to 12 wt% range. The average moisture content was estimated at 5.15 wt%. A summary of the test results are given in Table 2.

**TABLE 2:
SUMMARY OF DIRECT DRYER TEST RESULTS**

Gas Firing Rate	165,800 Btu/h
Slurry Feed Rate	330 lb/h (35.3 wt% moisture)
Final Moisture Content (Ave)	5.15 wt%
Water Evaporated	104.9 lb/h
Specific Energy Consumption	1,580 Btu/lb water evap.

The specific energy consumption was calculated from the experimental data as 1580 Btu/lb evaporated water. Assuming a 300°F exit temperature, a heat balance was prepared based on identical conditions of the test run. The heat balance resulted in a theoretical specific energy consumption of approximately 1540 Btu/lb evaporated water which is quite close to the measured value. The lower specific energy consumptions can be obtained using coal fuel due to the lower latent heat losses for dry coal fuel compared to natural gas fuel (high hydrogen content).

The results of these tests confirmed the technical viability of direct drying of fine wet coal which is injected directly into the hot exhaust stream of the pulse combustor. Additional tests will be performed using coal-water slurry to confirm the preliminary test results. Future tests will be conducted while firing the pulse combustor on coal to compare its performance on natural gas. Tests will also be conducted using wet filter cake feed material.

Indirect Dryer

Fabrication of the indirect dryer was completed during this quarter. Drawings of the indirect, fluid bed dryer were presented in the January monthly. Figure 5 shows a photograph of the fire-tubes and reactor shell. Note that the shell has been designed with an expanded freeboard region using an 8" x 12" reducer. The fire-tubes are to be connected to the pulse combustor which will be located just below the reactor support plate. The fire-tubes provide the necessary heat transfer surface area for supplying the heat of drying within the fluid bed. The lower half of the fire-tubes is furnished with a radiation shield to reduce the wall surface temperature to avoid coal agglomeration and pyrolysis.

Fabrication of the fire-tube portion of the indirect, fluid bed dryer was completed in February. During March, activities focused on the fabrication of the tandem pulse combustors which attach at the base of the fire-tubes. In this configuration, the in-bed fire-tubes serve as the resonating tailpipe portion of the pulse combustion apparatus.

Figure 6 shows the pulse combustors during fabrication and initial test firing. The combustion chambers were constructed from standard SS 304 pipe fittings. The aerovalves were specially machined to form a fluid diode based on a proprietary MTCI design.

Each combustion chamber includes ports for natural gas fuel, coal fuel, a pilot flame tube, a pressure transducer, a manometer, and a thermocouple. The natural gas fuel injector is located near the connecting point between the aerovalve and combustion chamber. This location has been empirically shown to provide high shear and mixing rates which promote efficient pulse combustion.

The pressure transducers are shown in Figure 7. The transducers are used to monitor the pressure wave forms generated within the pulse combustion chambers. These wave forms provide information on the frequency of operation and peak pressures, and are particularly useful as a general diagnostic tool.

Figures 8 and 9 give a perspective of the pulse combustors as integrated with the fire-tubes. Combustion products from the chamber travel upwards through the 3/4" U-tube tailpipes located within the fluid bed region. As seen in Figure 9, the first leg of the U-tube is shielded by a 1 1/2" pipe. This radiation shield serves to limit surface temperatures in direct contact with coal during the drying process.

The combustion products exiting the tailpipes then enter a decoupling chamber which dampens pulsations from downstream equipment. The decoupling chamber is clearly seen in the right foreground of the lower photograph in Figure 8. Note that the combustion chambers will be enclosed in an air plenum during normal operation of the fluid bed dryer. This will serve to minimize heat loss and to mildly preheat the combustion air.

FIGURE 5: TWO-TUBE INDIRECT DRYER - FIRE TUBES AND SHELL

A) PULSE COMBUSTOR DURING FABRICATION

B) TANDEM PULSE COMBUSTORS DURING TEST FIRING

FIGURE 6: PULSE COMBUSTORS DURING FABRICATION AND TEST FIRING

FIGURE 7: PRESSURE TRANSDUCERS

FIGURE 8: PULSE COMBUSTORS INTEGRATED WITH FIRE-TUBES

**FIGURE 9: ELEVATION PERSPECTIVE OF FIRE-TUBES
WITH ATTACHED PULSE COMBUSTORS**

Figure 10A shows a close-up of the fire-tubes with tube-wall thermocouples mounted on the surface. Figure 10B also shows a six wire thermocouple bundle which is inserted inside the down-comer leg of the U-tube.

The bundle is used for monitoring inside flue gas temperatures. Spacers are connected to the thermocouple bundle to ensure that each junction is centrally located within the tube. One of the spacers can be seen in the upper portion of Figure 10B.

The six internal flue gas thermocouples and tube-wall thermocouples are located at identical elevations. This allows a direct measure of the heat transfer driving force on the inside of the tube. Using a heat balance, the inside heat transfer coefficient can be estimated for various longitudinal tube locations.

One of the significant advantages of using a pulse combustor for indirectly heated drying systems is the high heat transfer coefficients which are obtained due to the oscillating flow field within the resonant tube. These heat transfer coefficients increase toward the tailpipe exit due to the higher velocity fluctuations occurring there. This phenomenon is particularly beneficial since the temperature driving forces diminish near the exit.

The convective heat transfer coefficient in a non-pulsating fire-tube was estimated using the following well known correlation:

$$h = .023 (k/d) N_{RE}^{.8} N_{PR}^{1/3}, \text{ for } N_{RE} > 10,000$$

The enhancement of heat transfer in the pulsing mode has been modeled by Hanby using a quasi-steady state assumption. Based on this model, an enhancement factor (ratio between pulsating and non-pulsating heat transfer coefficient) can be expressed as a function of a single dimensionless variable B, known as the dimensionless pulsation velocity. The pulsation velocity increases as the peak oscillation pressure increases. Also, for B greater than 1.0, the enhancement factor is nearly a linear function of B.

Figure 11 shows the theoretical heat transfer coefficient inside the fire-tubes under non-pulsating conditions and 1000°F flue gas temperatures as a function of firing rate per tube. Preliminary experimental tests were made to measure the inside heat transfer coefficients near the exit of the fire-tubes under pulsating conditions. This data is plotted in Figure 11 showing the significant improvement in heat transfer coefficient achieved through the use of a pulse combustor. Based on the measured data, the typical heat transfer enhancement ratio for this design is approximately 1.4.

Additional check-out and system characterization tests are scheduled for early April. Petroleum coke has been ordered for use as ballasting material in the fluid bed dryer. Ancillary dryer components are being assembled and initial drying tests are anticipated to start in late April.

A) SURFACE THERMOCOUPLES FOR WALL
TEMPERATURE MEASUREMENT

B) THERMOCOUPLE BUNDLE FOR INSIDE
GAS TEMPERATURE MEASUREMENT

FIGURE 10: FIRE-TUBES WITH THERMOCOUPLES

FIGURE 11: THEORETICAL HEAT TRANSFER COEFFICIENTS UNDER NON-PULSATING CONDITIONS COMPARED TO MEASURED DATA IN PULSATING FIRE-TUBES

Task 3.0 Reconstitution/Extrusion

Subtask 3A: Design, Fabrication, and Set-up

The general layout for the fine coal reconstitution circuit is shown in Figure 12. Photographs of the fabricated system are provided in Attachment B.

The system consists of a twin-screw extruder which had been described in detail in the previous quarterly report. The fine coal is extruded through a barrel where it enters a cooling section and a collection drum. Pyrolysis products which are released during reconstitution are collected via an induced draft fan and destroyed in an incinerator.

Subtask 3B: Experimental Evaluation

Preliminary testing of the extruder was performed in January. The unit was tested on a micronized Upper Elkhorn #3 and a run-of-mine 3/8" x 0 Pittsburgh #8 coal. During tests on Upper Elkhorn, the extruder shaft coupling failed by shearing at the key way. The coupling was sent out to be annealed, refilled, machined and heat treated for refitting to the shaft. Fabrication and set-up of the reconstitution/extrusion test rig was completed during January. Photographs of the test rig were also included in the prior quarterly report. As experimental data has become available during the month of February, minor design revisions have been made to improve system operation and performance. These design revisions have currently been limited to modifications of the extruder die and extension barrel, and will be discussed in relation to experimental results in the following section.

System characterization and initial experimental testing of the reconstitution/extruder were performed during February. The feed metering screw was calibrated for two separate coals types which are to be explored during this investigation. The two coal types are 1) micronized Upper Elkhorn #3, and 2) Pittsburgh #8. The micronized coal has a mean diameter (volume) particle size of 7 microns and is representative of the size range generated from advanced coal preparation facilities. An analysis sheet for this coal feed is provided in Table 3. The Pittsburgh #8 coal feed contains 3/8" x 0 size material and has a typical analysis as shown in Table 4. The Pittsburgh #8 coal sample was supplied to MTCI by Consolidated Coal Company. It is anticipated that screened size fractions of the Pittsburgh #8 coal may be used in future extruder testing. The feed metering screw calibration curves are shown in Figure 13. Here, the feed rate from the coal hopper to the twin-screw extruder is plotted versus the control set point for the feed metering screw.

The extruder barrel is furnished with sleeve heaters which are capable of supplying approximately 2 kw of power. Since the sensible heat required to plasticize coal at a temperature of 600 to 800°F is approximately .08 kwh/lb coal, the maximum allowable feed rate for the extruder is less than 25 lb/hr. As seen from Figure 13, this feed rate corresponds to a rather low extruder feed set point range. The test extruder was originally intended for the extrusion of low density plastic foam material. The low feed range limitation for operation on coal can be rationalized by considering the differences

FIGURE 12: RECONSTITUTION/EXTRUDER GENERAL LAYOUT

TABLE 3: MICRONIZED UPPER ELKHORN #3 ANALYSIS

PROXIMATE:

Moisture	1.92%
Volatile Matter	36.06%
Fixed Carbon	62.78%
Ash	1.16%
Sulfur	0.69%
Btu/lb	15016

ASH CHEMISTRY:

SiO ₂	40.30%
Al ₂ O ₃	27.80%
TiO ₂	1.65%
Fe ₂ O ₃	18.30%
CaO	3.45%
MgO	0.77%
K ₂ O	1.52%
Na ₂ O	1.52%
SO ₃	2.40%
P ₂ O ₅	1.52%
SrO	0.45%
BaO	0.45%
Mn ₃ O ₄	0.02%
Base Acid Ratio	0.37%
T-250 Temp.	2450°F

ULTIMATE:

Carbon	85.19%
Hydrogen	5.14%
Nitrogen	1.57%

ASH FUSION: REDUCING

Initial	2090°F
Softening	2230°F
Fluid	2370°F

FREE SWELLING INDEX : 6.5

HARDGROVE GRINDABILITY: N/A

SULFUR FORMS:

Pyritic	0.05%
Sulfate	0.01%
Organic (diff)	0.63%

**TABLE 4: PITTSBURGH #8 ANALYSIS
(Dry Basis)**

	<u>Consol Analysis</u>	<u>MTCI Analysis</u>
ASH	6.87	7.06
SULFUR	1.64	N/A
VOLATILE	37.18	33.69
CARBON	55.93	N/A
Btu	14,021	N/A

FIGURE 13: FEED METERING SCREW

between coal reconstitution and plastic extrusion. Since plastic extrusion occurs at temperature regime which is considerably lower than for coal reconstitution, the heater power requirements for plastic extrusion are approximately half that for coal reconstitution at an equivalent mass feed rate. Thus, the theoretical feed rate capacity for plastics in the test extruder ranges from 40 to 50 lbs/hr. Furthermore, due to the lower density of the plastic material relative to coal, plastic extrusion necessitates higher metering screw speeds for a given mass feed rate. Thus, for the originally intended extruder service (i.e., plastic extrusion), the heat-limited maximum feed rate is anticipated to closely correspond with the maximum controller set point range. However, when a typical plastic extruder is utilized for coal fines reconstitution, the metering screw feeder should optimally be geared down in order to allow full range control.

Calibration of the twin-screw rotational speed (RPM) versus the speed controller set point was performed under no load conditions. These results are plotted in Figure 14. Tick marks have been etched on the twin-screw shaft coupling in order to monitor screw speed under loaded conditions. The power draw from the twin-screw element is also monitored by measuring the current (amp) drain.

An initial test run on January 29, 1988 was made on the extruder using micronized coal without heating the twin-screw barrel and die. The purpose of this test was simply to verify the ability of the extruder to continuously feed micronized coal without seizing in the twin-screw barrel. The test results indicated that barrel seizing on micronized coal was not problematic.

Similar tests were performed under heated condition using unscreened 3/8" X 0 Pittsburgh #8. Occasional plugging and seizing of the twin-screw barrel was noted for this run. During seized conditions, the power draw for the twin-screw drive increased from 3 amps up to 13 amps, necessitating extruder shut down.

On February 1, 1988, extrusion tests were performed on unscreened Pittsburgh #8 while heating the twin-screw barrel. The barrel die was unheated and consisted of a 1 1/2" circular exit port. The barrel temperature was maintained in the range of 550 to 630°F. The feed rate for the Pittsburgh #8 coal sample was approximately 18 lb/hr and the twin-screw speed was set at a low rate of 4 rpm.

Under these conditions, the twin screw appeared to seize and plug at regular intervals. At one point, the excessive torque requirements on the twin-screw drive train resulted in failure of the shaft coupling. The shaft coupling was subsequently remachined and replaced. The results, however, indicated that the extruder could not process the largest particles in the 3/8" X 0 coal feed even under heated conditions. Extrusion tests were therefore performed using Pittsburgh #8 screened to -6 mesh.

FIGURE 14: TWIN SCREW

On February 9, 1988, extrusion tests were performed using -6 mesh Pittsburgh #8 coal feed. At the exit of the original 1 1/2" die, a 1 1/2" X 1" reducer extension piece was added. The first half of the twin-screw barrel was maintained at 640°F while the second half was typically 750°F. At the exit of the original 1 1/2" die typically ranged from 700 to 720°F and the unheated die extension piece was typically 480°F. The coal feed rate was 18 lb/hr and the screw speed was approximately 24 rpm. Under these conditions, definitive evidence for coal plasticization and extrusion was found. However, occasional plugging was noted at the unheated die extension piece. The run was aborted after approximately 30 minutes due to plugging in this region. Die plugging also resulted in back flow of plasticized coal into the feed bin, and noticeable emissions of pyrolysis gases. The primary conclusions from these tests was that all portions of the extrusion train must be sufficiently heated in order to prevent "freezing" and deplasticization of the extrudite before entering the collection drum.

On February 19, 1988, tests were performed using a heated die extension piece. Under these conditions, the temperature at the exit of the extension die was maintained at approximately 550°F. The test resulted in the production of well agglomerated extrudites for extended periods. The extrusion test was conducted for over three hours. Occasional plugging of the barrel or die, monitored by an increase in power draw, was alleviated by the addition of small quantities of lubricating oil to the feed material. Photographs of the extruded material are shown in Figure 15. The tests results confirmed the ability of the extruder to reconstitute -6 mesh Pittsburgh #8 coal for relatively prolonged periods at a feed rate of 18 lb/hr and at temperatures of 700 to 800°F in the twin-screw extruder barrel. The ability to reconstitute micronized Elkhorn #3 coal will be investigated in future tests under similar conditions. A summary of these test results to date are given in Tables 5 and 6 along with Figure 16 which depicts the temperature measurement points for each run.

These initial extrusion tests were performed primarily to confirm the basic operating principles of the coal reconstitution test rig. Samples of the reconstituted product were sent to an independent laboratory to evaluate and thus provide information relevant to organics loss during reconstitution. The product from the extruder was analyzed and compared to the initial feed material as shown in Table 6. Also, a gas chromatographic system has been installed to analyze the composition of pyrolysis products formed during extrusion. The gas chromatograph consists of a seven-column, automatically switched GC which is capable of identifying hydrocarbons through C₄.

It is anticipated that the extrusion tests will be continued through the next quarter. This will include more complete testing of the micronized upper Elkhorn #3, screened Pittsburgh #8, and possibly filter cake material from the experimental advanced coal-cleaning pilot plant in Homer City.

FIGURE 15: RECONSTITUTED COAL SAMPLE

**TABLE 5: SUMMARY OF RECONSTITUTION TEST RESULTS
(PITTSBURGH #8)**

<u>Date (1988)</u>	<u>Run No.</u>	<u>Feed Coal</u>	<u>(lb/h) Feed Rate</u>	<u>(RPM) Screw Speed</u>	<u>(°F) Temperature Profile (1)</u>					<u>Notes</u>
					<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	
1/29	1	Micro UE #3	Calibration		- Ambient -					See Calibra- tion Curves
1/29	2	3/8" x 0 Pitt #8	Calibration		- Ambient -					See Calibra- tion Curves
2/01	3	3/8" x 0 Pitt #8	18	4	550	629	579	NA	NA	Failure At Shaft Coupling
2/09	4	- 6 Mesh Pitt #8	18	24	640	741	754	716	480	1" Die Extrusion Plugging
2/19	5	- 6 Mesh Pitt #8	18	26	635	737	763	788	543	Extrudites Noted

(1) See figure for temperature position

**TABLE 6:
ANALYSIS OF FEED MATERIAL AND EXTRUDITE PRODUCT**

<u>Extrudite Sample No.</u>	<u>Ash %</u>	<u>Volatile %</u>
1	-----	26.96
2	-----	28.57
3	6.84	-----
4	<u>7.11</u>	<u>-----</u>
Average	6.98	27.76
 Pittsburgh #8 Feed		
<u>Sample No.</u>	<u>Ash %</u>	<u>Volatile %</u>
1	-----	33.66
2	-----	33.67
3	-----	32.43
4	7.14	-----
5	7.11	-----
6	<u>6.93</u>	<u>-----</u>
Average	7.06	33.25

FIGURE 16: TEMPERATURE MONITORING POINTS IN EXTRUDER

The average ash content of the extrudite was 6.98% compared to 7.06% for the feed material. Within the limits of experimental error, it is evident that little or no organic material was lost by pyrolysis during the extrusion process. The average volatile content of the extrudite was 27.76% compared with 33.25% for the feed material. These results indicate that a portion of the volatile matter is converted to fixed carbon upon extrusion at temperatures of 700 to 800°F.

Additional tests were conducted during March using both pulverized and micronized feed materials. Although extrudites were formed at some points during these tests indicating the basic feasibility of the process, feed problems were encountered for these fine coal materials.

The feed problem appeared to stem from the blow-back of water vapor and small quantities of pyrolysis gases which prevent positive feeding into the twin screw. In some cases, condensed vapors near the inlet screws and feed hopper appeared to cause bridging which starved the feed screw. When this occurs, there is an interruption of solids conveyed through the die. The increased residence time of solids in the die results in coking which then creates jamming.

The transition between the feed and compression regions of the twin screw are shown in the upper photograph of Figure 17. The feed screw portion is on the left where the deeper flights are found. In order to have a greater feed control range, a separate feed metering screw is now being used to supply fine coal to the twin screws. The metering screw is shown in the lower portion of Figure 17.

FIGURE 17: COAL FEEDER AND FEED SCREEN SECTION

MTCI personnel visited several local companies specializing in the extrusion of powder-like PVC materials in order to discuss the feed problem. Based on these visits, it was learned that suction vents in the twin-screw barrel are necessary to prevent blow-back. Several vent ports were machined into MTCI's extruder barrel as shown in Figure 18.

The first vent port is located near the exit of the feed screws. The second vent port is located approximately at the mid-section of the barrel. And the third vent port is located approximately two thirds of the way down the barrel.

If the vent port is located in a region where the coal is not sufficiently plasticized, then excessive quantities of fine coal will be sucked out of the barrel. However, if the vent port is located in a region of compression, plastic coal may be extruded out of the vent port. It should be mentioned that the placement of vent ports in the MTCI extruder was constrained by the existing location of the barrel heaters which was not easily modified.

Tests were performed using the described vented barrel configuration. The vent ports were connected to a canister filter and then to a vacuum pump. Preliminary test runs indicated that the vent ports substantially alleviated any feed problems. However, large quantities of fine coal were entrained from the barrel using the first vent port. Although this material can be recycled to the feed hopper, it is more desirable to operate without such a high degree of entrainment.

The second and third feed ports appeared to plug quite rapidly. This is probably due to the condensation of water vapor and for which captures some fine coal particles. It was noted that material at the second vent port was not highly plastic, however material at the third vent port exhibited a high degree of plasticity. Testing of fine coals will continue in April using the vented configuration.

Task 4.0 Comminution

Subtask A: Exploratory Feasibility Investigation

Fabrication of the hydraulic shock apparatus has been completed. The final design is shown in Figure 19. Early tests have shown evidence for the production of extremely fine material from an initial coal charge in the size range of 1/2" to 1/4".

Subtask B: Characterization of Micronized Coal

Several experimental test runs were conducted to verify the basic operating principles and performance of the hydraulic shock apparatus. For all tests, the impact mass consisted of a 200 lb solid steel cylinder. The free fall distance of the weight was varied from four to six feet for different runs. Two different pistons were also used. One piston was machined with a smooth spherical cap. The second piston had a flat face with beveled edges.

FIGURE 18: EXTRUDER BARREL WITH VENT PORTS

FIGURE 19: SCHEMATIC OF BENCH-SCALE HYDRAULIC SHOCK CONTINUATION TEST APPARATUS

The feed charge material typically consisted of coal particles in the size range of 1/4" to 1/2". The coal feed was thoroughly rinsed with water before charging the piston to ensure that no coal fines adhered to the particle surface prior to the comminution test. The charge mass was typically in the range of 25 to 50 grams.

The cylinder bore was filled with water to a level which allowed a minimum-piston travel of 2". The coal charge was at a level sufficiently below the maximum piston travel such that no direct contact between the piston itself and the coal could occur. Thus, the energy of impact was transmitted to the coal only through the hydraulic medium.

The piston was lubricated with a petroleum jelly prior to the impact. This ensured smooth piston travel within the bore, and provided a seal preventing blow-back of hydraulic fluid during impact. When the impact mass was released, it was accelerated by gravity, striking the piston head and driving the piston into a compressed state. No fluid blow-back was noted during the initial strike. The piston rebound was typically one to two foot in height indicating that approximately 75 percent of the energy was dissipated through system inelasticities in the first strike. On the second rebound strike, the weight was noted to compress the piston by displacing water from the cylinder by blowback. Note that the impact mass at rest upon the 2" piston exerts an internal cylinder pressure of 64 psi.

After the impact mass and piston attained a rest condition, the fluid in the cylinder was discharged into a receiving flask. This water typically contained a significant quantity of fines and was a muddy-brown to black color. The contents of the cylinder were then removed and the coal charge was rinsed to collect additional fines adhered to its surface. The combined fines material was then dried.

Several observations were made during the initial testing. The first was that the fines production per impact appears to be at a maximum for the first strike of the piston using a fresh coal charge. Subsequent levels of fines production appears to diminish with increased number of impacts. This is probably due to the fact that the most easily fractured coal surfaces are removed during the initial impacts.

The second observation is that the hydraulic shock generates mostly fine material only, with very little production of large fractured chunks or coarse material. It should be mentioned, however, that one test did result in a large mass of coarse material. This phenomena was generally not reproducible.

It was thought that the hydraulic shock comminution process may have been limited by dissolved gases in the cylinder fluid. Dissolved gases can greatly influence the maximum pressures attained in the cylinder due to its enormous effect on the bulk compressibility of the fluid. In order to test this hypothesis, the hydraulic fluid charge was degassed by boiling before the impact test. The degassing step did not appear to produce noticeably different results.

Drying of the generated product is currently being performed to determine the specific mass of fines generated per impact. Selected samples were sent to an independent laboratory to determine the size distribution of the generated material.

As mentioned previously, the maximum theoretical pressure which can be attained within the cylinder is of the order of 15,000 psi. However, several dissipating phenomena may result in achievement of only a fraction of this peak pressure. It is generally thought that a maximum peak pressure of at least 5,000 to 10,000 psi is necessary for effective comminution.

In order to measure the experimentally attained peak pressure, furnished with a fast response, pressure transducer. The pressure transducer has a 10,000 psi full scale and has a high natural frequency allowing accurate measurement of peak pulses with periods less than 1 millisecond. The peak pulse will be recorded using a storage scope or by photographic means.

The pressure transducer receiving well has been machined into the impact cylinder, and testing with the transducer began in March. A diagram of the pressure transducer and well are shown in Figure 20.

Extensive testing of the hydraulic shock comminution apparatus was conducted during March. Tests were performed using a 2" and a 1/2" piston. Tests were conducted for drop heights of 2', 4', and 6' using coal of several different size fractions.

Figure 21 shows the dimensions of the 2" piston shock apparatus. Figure 22 shows the 1/2" piston apparatus and Figure 23 shows the placement of the 1/2" insert into the 2" cylinder. The 1/2" insert cylinder is shown in Figure 24.

Upon impact, the peak pressure attained in the cylinder, the time of the peak pressure, and the maximum piston displacement can be calculated from theory as described in prior monthly reports. These values are summarized in Table 7 for the 2" and 1/2" piston for drop heights of 4' and 6'.

**TABLE 7:
THEORETICAL IMPACT VALUES FOR
SHOCK APPARATUS**

O.D. (in)	P _{max}		Time		Displacement	
	4' drop (PSI)	6' drop (PSI)	4' drop (msec)	6' drop (msec)	4' drop (in)	6' drop (in)
2	18,422	22,568	2.7	2.7	0.32	0.4
0.5	66,228	81,130	10.9	10.9	1.33	1.63

ANC-Q.00

FIGURE 21: 2" HYDRAULIC SHOCK APPARATUS

FIGURE 22: 1/2" HYDRAULIC SHOCK APPARATUS

FIGURE 23: PLACEMENT OF 1/2" INSERT IN 2" CYLINDER

FIGURE 24: CYLINDER INSERT WITH 1/2" PISTON

As seen from Table 7, the theoretical peak pressure for the 2" piston is 18,422 psi and 22,568 psi for a 4' and 6' drop height. The achievable pressure peaks for the 1/2" piston are considerably higher for equivalent drop heights. Note that the time of the pressure peak for the 2" piston is only 2.7 milliseconds. This compares with 10.9 milliseconds for the 1/2" piston. Figure 25 shows the theoretical positive cycle wave form for the two different pistons. In order to determine the actual character of the pressure wave forms within the cylinder upon impact, the 2" cylinder was fitted with a fast response pressure transducer. The cylinder and the pressure transducer are shown in Figure 26.

The pressure transducer was connected to an oscilloscope containing provisions for photographic recording of the screen. The oscilloscope sweep was triggered from the rising wave form after impact. The oscilloscope with camera is shown in Figure 27.

Figure 28 shows the actual peak wave form as measured in the 2" cylinder for a 4' drop height. The vertical scale is 2500 psig/Div and the horizontal scale is 1 msec/Div. The horizontal line across the screen shows a calibrated 10,000 psi level.

As seen in Figure 28, the actual peak pressure is approximately 12,000 psi compared to the theoretical value of 18,422 psi. The peak time occurs at approximately 2.4 msec which compares closely with the theoretical value of 2.7 msec. From these results, it determined that the peak pressures in the 2" cylinder were in the range of two thirds of the predicated value. However, it was noted that for a 2' drop, the actual peak pressures more closely approached the predicted value.

Test Results

Approximately 41 separate shock tests were conducted using the 2" and 1/2" hydraulic shock comminution apparatus. Except where specifically noted, all tests were performed using Pittsburgh #8 feed material. Table 8 summarizes the results of these tests.

The drop height for each test is recorded in Table 8. The impact # identifies the condition of the feed material and the number of times it was shocked in the current test. The first number to the left of the slash designates how many times the feed material was previously shocked prior to the current test run. The second number to the right of the slash indicates how many successive impacts were conducted for the current test run. For instance, if the coal sample was shocked twice in prior tests and then shocked three successive times for the current test, then its impact identification would be 2/3.

The weight of fines generated during the test run is recorded in the third column. Fines in this case represent -30 mesh material. This material is easily distinguished from the original feed material which was typically much larger in size.

FIGURE 25: FLUID PRESSURE VS. TIME

FIGURE 26: CYLINDER WITH PRESSURE TRANSDUCER

FIGURE 27: OSCILLOSCOPE WITH CAMERA

VERTICAL: 2500 PSI/DIV
HORIZONTAL: 1 MSEC/DIV

FIGURE 28: PRESSURE PEAK FROM IMPACT APPARATUS

**TABLE 8:
SUMMARY OF HYDRAULIC SHOCK COMMINUTION DATA**

RUN	HEIGHT (ft)	IMPACT /	TOTAL WEIGHT OF FINES (g)	CYLINDER O.D. (in)	% FINES <100 MESH	% FINES <200 MESH	REMARKS
4	6	0/1	0.15	2	-----	-----	COARSE FEED COAL
8	6	0/1	0.22	2	-----	-----	"
10	6	0/1	0.28	2	-----	-----	"
11	4	0/1	0.21	2	58.89	28.89	"
12	6	0/1	0.18	2	65.50	35.91	"
13	6	0/1	0.20	2	48.12	32.62	FINER FEED COAL
14	6	1/1	0.15	2	-----	-----	"
15	6	2/1	0	2	-----	-----	"
16	4	0/1	0.19	0.5	43.00	23.38	COARSE FEED COAL
17	4	1/1	0.14	0.5	3.36	1.70	"
18	6	0/1	0.20	0.5	44.16	22.08	"
19	6	1/1	0.06	0.5	16.67	0	"
20	6	2/1	0.05	0.5	25.00	0	"
21	6	3/1	0.03	0.5	100.00	0	"
22	6	0/1	0.05	0.5	25.93	7.41	ONE CHUNK OF COAL
23	6	1/1	0.09	0.5	3.92	0	FEED SAMPLE WAS CRUSHED
24	6	0/1	0.95	0.5	6.05	1.60	SATURATED FEED COAL IN 100% MET
25	6	1/1	0.46	0.5	8.23	5.81	"
26	6	2/1	0.30	0.5	2.00	0	"
27	6	0/1	0.14	0.5	22.35	7.06	5% MET
28	6	0/1	0.19	0.5	18.18	13.90	50% MET
29	6	0/1	0.10	0.5	26.00	19.00	25% MET
30	6	0/3	0.73	0.5	18.34	10.21	100% METHANOL
31	6	0/1	2.38	0.5	9.20	1.68	1/4" SUB-BITUMINOUS COAL
32	6	0/1	2.16	0.5	6.90	4.60	1/4" SUB-BITUMINOUS COAL
34	6	0/1	1.08	2	47.3	27.1	PARTIAL MECHANICAL CRUSHING BY PISTON
39	2	0/1	0.52	2	100.00	35.7	-14/+100 MESH
40	2	0/1	0.41	2	36.1	22.4	COARSE FEED COAL
41	2	0/1	0.293	2	58.3	38.9	COARSE FEED COAL

The fine material was screened into two additional fractions: -100 mesh and -200 mesh. The percentage of the fines in these size fractions are shown for each test in Table 8. Remarks pertaining to the details of the tests are given in the last column of Table 8. Note that coarse feed material generally refers to coal in the size range of 1/8" to 1/2".

Test runs 4 through 12 were conducted using coarse Pittsburgh #8 in the 2" cylinder. Each of these tests were single impact tests using a fresh charge material (i.e., 0/1). Test runs 11 and 12 were screened by MTCI. The product from tests 4, 8, and 10 were combined and sent to an independent laboratory for particle size analysis. The report is included as Attachment A. The results obtained by screening and by Coulter counter analysis were almost identical for the 6 foot drop case. The analysis revealed approximately 65 wt.% of the fine material was in the -100 mesh range and 35% was in the -200 mesh range. It is interesting to note that very little material in the 30 to 70 micron range was generated. Approximately 7 wt.% of the material was found in the minus 10 micron range.

Test runs 13 through 15 were conducted primarily to determine the effect of repeated shocks on the fines production efficiency. As seen in Table 8, when a coal charge was repeatedly shocked, diminishing quantities of fines were produced. This may be due to the fact that the most friable surface layers are shattered in the first shocks. Alternatively, the coal particle after impact may contain large quantities of micro-fissures generated from the shock. These fissures may then tend to compress like a sponge during subsequent shocks, thereby damping the shock energy. Figure 29 shows the effect of the number of successive impacts on the incremental mass of fines generated per impact and includes results from the 1/2" piston.

Based on the results of these feasibility tests, it was believed that the critical peak pressure necessary to effectively comminute coal was not being achieved in the 2" cylinder. Therefore, it was decided to machine a 1/2" cylinder insert which would theoretically allow higher peak pressures to be obtained.

Tests runs 16 through 21 were performed with the 1/2" cylinder to test this hypothesis. Note that the pressure transducer could not be practically fitted to the 1/2" cylinder so that the actual peak pressures could not be experimentally measured.

The results from these tests were not significantly different than those with the 2" cylinder. Since the volume of the 1/2" cylinder was significantly less than for the 2" cylinder, the mass of the charge material was also less. In order to test if the small mass loading for the 1/2" cylinder contributed to its poor comminution performance, test run 22 was conducted using only a single piece of coal. This test actually yielded a lower quantity of fines product. Since coal is highly heterogeneous, certain particles are particularly weak while others may exhibit a considerably degree of hardness. Since the mass loading in the 2" piston is higher than for the 1/2", the probability of weak particles being included is also higher.

**FIGURE 29: INCREMENTAL MASS OF FRACTURED MATERIAL
FOR SUCCESSIVE IMPACTS FIRE-TUBES**

Additional tests on coarse feed coal were performed in the 2" cylinder at lower drop heights (2'). The results from test runs 40 and 41 in conjunction with prior tests revealed that the specific applied energy to produce -200 mesh material decreased with decreasing drop height. Figure 30 shows the relation between drop height and specific applied energy.

Test 39 was conducted under conditions similar to that for test runs 40 and 41; however, the feed material was -14/+100 mesh. The results indicated that the specific applied energy efficiency for the production of -200 mesh material improved compared to tests with coarse feed. However, considering the large size differential between the feeds for these test, the energy reduction was not highly significant.

Some additional exploratory tests were conducted using various solvent pretreatments of the feed coal prior to testing in the shock apparatus. For instance, in test runs 24 through 29, coal was presoaked in various water-methanol solutions. Methanol is known to weaken and partially dissolve coal. The results indicated that a significant improvement in total fines production after soaking in 100 percent methanol. However, only a small portion of the fines were in the -100 mesh and -200 mesh size ranges. It is also interesting to note that a similar result was found for tests conducted without methanol using a sub-bituminous feed coal which was weak and fracture prone compared to the Pittsburgh #8 material. Here, a large quantity of total fines was produced, but only a small fraction was found in the -200 mesh range.

The preliminary results of the hydraulic shock comminution tests appear to confirm the feasibility of the process to produce fines. Quantifying energy requirements and other parameters to determine the effectiveness or efficiency of the process at this feasibility stage would probably not be appropriate. It is possible that the rate of load application for the existing device does not achieve the energy plateau required. Some additional exploratory tests will be conducted during the next quarter prior to evaluating the feasibility of the process.

Task 5.0 Systems Evaluation

Based on early results, reconstitution of fine coal using a twin-screw extruder appears to be technically feasible. A preliminary systems evaluation study covering the technical and economic merits of reconstitution by extrusion has been prepared and was included in a prior monthly report as an attachment. This analysis will be revised as necessary when further experimental data becomes available.

FIGURE 30: SPECIFIC APPLIED ENERGY VS. DROP HEIGHT FOR
DIFFERENT PISTON DIAMETERS, SINGLE IMPACT TESTS

3.0 PLANNED ACTIVITY FOR NEXT PERIOD

The project is well ahead of schedule in all task areas, approximately 2-3 months. It is anticipated that all test activities will be completed during the next quarter with the completion of experimental laboratory demonstration of the indirect dryer. If progress continues at the same rate, it is anticipated that Task 5 will also be completed and that the preparation of a final report will be initiated.

ATTACHMENT A

COMMERCIAL TESTING AND ENGINEERING COMPANY

INDEPENDENT PARTICLE SIZE ANALYSIS

Member of the SDS Group (Political Activities in Germany)

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1469 CALDWAY AVE LONG BEACH CA
TELEPHONE (213)

March 4, 1968

Sample Identification
by

Kind of sample reported to us Coal

M. I. C. I.

Sample taken at _____

"Coal / .34 grains"

Sample taken by

Data extracted _____

Date received 3/1/88

Analytic report no. 77-63724

PARTICLE SIZE DISTRIBUTION

SCREEN ANALYSIS

MICRON SIZE

[illegible]

2% ABOVE STATED MICRON
(% WEIGHT - CUMULATIVE)

<u>Run - 1</u>	<u>Run - 2</u>
20.75	20.75
33.95	33.95
49.04	49.04
62.24	62.24
66.01	66.01

Members of the SDS Group Targeted Overlap in 1968-1969

PLEASE ADVISE ALL CLASSIFIED
MATERIAL OF THE DECLASSIFICATION
DATE AND AUTHORITY

M.I.C.I.
13050 PARK STREET
SANTA FE SPRINGS, CA 90670

March 4, 1988

Sample Identification
by

Kind of sample reported to us (Coal)

M. I. C. I.

Sample 12.000 g

"Cont / .59 grams"

Sample taken by _____

Date dictated _____

Date received 3/1/88

Analysis report no. 77-03729

PARTICLE SIZE DISTRIBUTION

CULTER COUNTER

<u>MICRON SIZE</u>	<u>Run - 1</u>	<u>Run - 2</u>
40.30	66.21	66.21
32.00	67.20	67.32
25.40	71.26	71.47
20.20	76.51	77.05
16.00	82.83	83.37
12.70	88.30	88.24
10.08	92.60	92.47
8.00	95.84	95.76
6.35	97.91	97.79
5.05	99.06	99.02
4.00	99.40	99.50
3.17	99.66	99.70
2.52	99.91	99.92
2.00	99.80	99.85
1.00	100.00	100.00

FORGETTING THE PAST,
COMMERCIAL TESTING & ENGINEERING CO.

44-1987, Long Beach Long, Calif.

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COVERED BY 200+ LABS STRATEGICALLY LOCATED IN PRINCIPAL COAL MINING AREAS,
TIDAL WATER AND GREAT LAKES PORTS, AND RIVER LOADING FACILITIES

F-104

DATE

FILMED

9/29/94

END