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**ADVANCED TECHNOLOGY FOR ANCILLARY
COAL CLEANING OPERATIONS**

TECHNICAL PROGRESS REPORT

September - December 1987

Presented to

**U.S. Department of Energy
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By

**MANUFACTURING AND TECHNOLOGY CONVERSION
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PREFACE

This first Quarterly Technical Progress Report presents the results of work accomplished during the period September 15 through December 27, 1987, under Contract No. DE-AC22-87PC79881 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 is included in this First Quarterly Technical Progress Report. These will be omitted in future reports.

During this period, substantial progress was made in the design, fabrication and checkout of the direct dryer, the design of the indirect dryer, the procurement, renovation and installation of the extruder and finally, the design of a laboratory test apparatus for the HSC activities.

In addition, a topical report entitled "Hydraulic Shock Comminution: Literature Survey and Analysis" was submitted to the DOE Program Manager.

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TABLE OF CONTENTS

	<u>Page</u>
1.0 <u>INTRODUCTION</u>	1
1.1 BACKGROUND	1
1.2 OBJECTIVES	3
2.0 <u>WORK BREAKDOWN STRUCTURE</u>	4
2.1 TASK DESCRIPTIONS	4
2.2 SUMMARY STATUS	10
3.0 <u>TECHNICAL DISCUSSION</u>	11
3.1 TASK 2: LABORATORY-SCALE VERIFICATION OF PULSE- ENHANCED DRYER	11
4.0 <u>PLANNED ACTIVITY FOR NEXT PERIOD</u>	40
APPENDIX A <u>SUMMARY TEST PLAN</u>	A-1

LIST OF TABLES

1 TEST PLAN MATRIX	6
2 PERFORMANCE OF DIRECT DRYER ON SIMULATED WET FEED	28
A-1 ANTICIPATED TEST MATRIX	A-4

LIST OF FIGURES

1	TASK STRUCTURE	5
2	DIRECT DRYER SYSTEM LAYOUT	12
3	PULSE COMBUSTOR FOR PULSE DRYER	13
4	DRYER HOUSING AND PULSE COMBUSTOR SUBCOMPONENT DETAIL	14
5	FLOW STEAMLINES FOR AEROVALVE AND THRUST AUGMENTOR	15
6	DIRECT DRYER APPARATUS	18
7	PULSE COMBUSTION APPARATUS	18
8	CONTROL PANEL FOR COAL DRYER	19
9	VIBRASCREW DRY COAL FUEL FEEDER	19
10	INDIRECT COAL DRYER (LOWER PORTION - FRONT VIEW)	23
11	INDIRECT COAL DRYER (LOWER PORTION - SIDE VIEW)	24
12	FIRE TUBE LAYOUT (DETAIL A)	25
13	TUBEWALL TEMPERATURE PROFILES	26
14	EFFECT OF WATER INJECTION RATE AT CONSTANT FIRING RATE	29
15	EFFECT OF FIRING RATE	30
16	A: EXTRUDER AND CONTROL PANEL	34
	B: OIL CIRCULATION PUMP AND RESEVOIR	34
17	A: TWIN SCREW HOUSING B: TWIN SCREW ELEMENTS	35
18	IMPACT PISTON	36
19	SCHEMATIC OF BENCH-SCALE HYDRAULIC SHOCK COMMINUTION TEST APPARATUS	37
20	IMPACT CYLINDER	38
A-1	PRIMARY INSTRUMENTATION FOR DIRECT DRYER TEST UNIT	A-2

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.

The first part is aimed at providing a literature survey to identify information relevant to shock phenomenon. Baseline data for comparing the performance of novel comminution methods to be tested during this investigation will be provided by EPRI's Homer City grinding circuit, for which a substantial data base exists, operates in a wet grinding mode. Since recent experience with micronized coal production for advanced deep cleaning methods has involved the integration of a wet grinding circuit, it was determined that evaluation and characterization of product from the Homer city system would be appropriate as a baseline.

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 in this paper 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.

Section 2.0 is devoted to the description of the program tasks. This includes a brief discussion of the methods and technical approach which will be used during the execution of this work in order to achieve the objectives.

SECTION 2.0

WORK BREAKDOWN STRUCTURE

The overall program structure is shown in Figure 1. The overall program has six tasks: 1) project planning (not shown in Figure 1), 2) pulse-enhanced drying (direct and indirect), 3) fines reconstitution by extrusion, 4) comminution, 5) system evaluation, and 6) reporting. Tasks 2, 3, and 4 include laboratory-scale activities and are comprised of two major subtasks, namely: 1) equipment design, fabrication, and set-up, and 2) experimental evaluation. Task 5, the systems evaluation activity, contains three subtasks, namely: 1) engineering evaluation, 2) economic evaluation, and 3) scale-up design and development planning. With the exception of Task 1, Program Planning and Task 6, Management and Reporting Management, brief descriptions for each task and subtask of the program are presented in the following subsection.

2.1 TASK DESCRIPTIONS

TASK 2: Laboratory-scale Verification of Pulsed-Enhanced Dryers

Dewatering (drying) is an ancillary operation which has a significant impact on the cost and energy intensiveness of the overall coal cleaning process. In conventional cleaning plants, the clean coal product is dewatered by a filter to a range of 25 to 35 percent moisture, with finer coal particles typically yielding higher moisture contents. Additional dewatering (6 to 12 percent moisture range) is commonly achieved through thermal drying.

MTCI will verify two concepts for improving the economics and performance of coal dewatering, namely: pulse-enhanced direct drying, and pulse-enhanced indirect drying. The primary feature common to both of these concepts is the use of a pulse combustor as an improved means for supplying the energy requirements for water evaporation.

In order to verify the performance at these units of the laboratory-scale in fulfillment of the contract objectives, MTCI will undertake two primary activities (Subtask 2A, which includes equipment design, fabrication, and set-up followed by Subtask 2B, experimental evaluation of dryers).

Subtask 2A: Equipment Design, Fabrication and Set-up

The dryer facility will consist of the following components:

- o pulse combustor
- o primary cyclone
- o quench scrubber
- o baghouse
- o wet and dry coal feeders
- o instrumentation and analyzers
- o fluidized bed.

FIGURE 1: TASK STRUCTURE

A design package covering all major facility components shall be prepared and submitted for approval. The design of equipment will be based on professional engineering standards including quality assurance control for all design and fabrication activities to ensure safe operation of each subsystem.

A design review process including safety will also be implemented.

Subtask 2B: Experimental Evaluation of Dryers

Experiments will be conducted to obtain data to compare the performance of the direct and indirect dryers and to permit technical and economic assessment of the pulse drying process in Task 4.

Direct Contact Dryer: The objective of this work is to verify the operation and performance of the pulse combustor as a means for direct drying of coal. In particular, verification of drying fine coal while supplying heat input through fine coal combustion will be a primary goal. Measurements of dryer thermal efficiency will be gathered so that a technical and economic comparison with existing drying processes can be made. This will include measurements made over a range of systematically varied process conditions thereby covering a broad spectrum of potential end-use applications.

Table 1 depicts the anticipated structure of the test plan matrix with the independently controlled variables shown.

TABLE 1: Test Plan Matrix

<u>Coal Types</u>	(Micron) Mean <u>Particle Size</u>	<u>Moisture Content</u>
Two (TBD)	7 to 25	25 to 35
(lbs/hr) <u>Feed Rate</u>	(°F) Dryer <u>Exit Temp.</u>	(lbs/lbs) Contact Gas <u>Mass Ratio</u>
100 to 200	150 to 200	TBD

Additional variables to be measured include pulse combustor fuel firing rate, dryer exhaust analysis, relative humidities, and pulse combustion boost, frequency and peak pressure.

Indirect Pulse-Enhanced Dryer: The objective of this work is to verify the performance of indirect coal drying using a pulse combustor as a heat source. The high heat transfer rates exhibited in pulse combustion systems

offers a means for compact and economic heat supply to a degree unattainable in alternate systems.

TASK 3: Reconstitution/Extrusion

The reconstitution of dried coal fines will be accomplished by using a twin screw extruder. The counter-rotating twin screw extruders are generally used in the manufacture of PVC pipe from extruding powdered PVC feed.

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

There is a general tendency in most processing industries today towards more rigid product quality and uniformity standard combined with a demand for substantially increased throughput rates. Because of inherent limitations, single-screw extruders often demonstrate serious shortcomings during attempts at scale-up to higher line rates. These problems come to light when attempts are made to scale-up seemingly satisfactory pilot-plant results to higher line rates that require a relatively large diameter single-screw. To overcome these recognized limitations more processing industries are turning to operationally proven twin-screw mechanisms for an economical solution to higher line rate requirements. An extruder selection will be made and procured for this task.

The set-up of the extrusion test facility will involve installing the extruder, coal feeder, spray quench and extrudate receiver drum installation, off-gas incineration hook-up, induced draft exhaust for hook-up, and gas analysis instrumentation hook-up. Necessary safety equipment will be incorporated in the design. The design package will be sent to the DOE TPO for review and approval.

All of the major components for this task are either off-the-shelf or have been utilized previously by MTCI, a formal design review procedure will not be initiated. However, a safety evaluation will be made. The design of the reconstitution system will include detailed descriptions, drawings, and equipment layout.

Extruder equipment and ancillary facility will be assembled, installed and checked-out. The operational characteristics of the major components, especially the extruder equipment, will be determined. All modification or adjustments necessary will be made and the components and system retested to establish baseline performance and operational range for the verification testing. This will establish the upper and lower bounds as well as baselines for the test matrix.

Subtask 3B: Experimental Evaluation of the Extruder

An analysis and evaluation of the extrusion test facility baseline operational data will be made to establish test procedures for the experimental evaluation work. A test plan will be prepared detailing the experiment/test data design in order to provide statistical significance to the data acquired. A test matrix will be established to acquire the following data for both test analysis and comparison of feed and product:

- o Particle size distribution
- o Feed rate
- o Feed preheat temperature
- o Heat and/or Power input (supply rate) to major components
- o Melt temperature
- o Total product yield
- o Ancillary operating characteristics or variables
- o Other items as required

Heat and material balances for each test will be provided as well as environmental emissions from the process and from the facility (these will meet California standards as a requirement).

TASK 4: Comminution

This task will consist of an exploratory research effort to determine the feasibility of comminution by the hydraulic shockwave technique and to design bench-scale hardware to explore that feasibility.

Subtask 4A: Exploratory Feasibility Investigation

A literature search will be conducted for applicable information concerning data and effects of hydraulic shocks on various crystalline and amorphous materials and for the various techniques including mechanical, electromechanical, electrical, and hydraulic servo-systems. Based on the literature information and with DOE TPO's concurrence, the contractor shall select a method for hydraulic shock and design a bench scale laboratory facility. The design will be reviewed for operational and safety aspects and then will construct the device for producing the shock and conducting the hydraulic shock comminution tests. Details of the laboratory facility including a description, diagrams, layout, material of construction, etc., shall be submitted to the DOE TPO for approval.

Subtask 4B: Characterization of Micronized Coal

Extensive testing will be conducted on the laboratory-scale comminution facility to assess the feasibility of HSC process and to examine its scale-up potential or limitations.

For all experiments the product particle size and size distribution, total energy required for grinding, and specific energy consumed in creating new surfaces will be determined. The process parameters shall be documented. The product shall be separated into different sized with a narrow band (for example, 5 micron band giving a particle size of 0-5 microns, 5-10 microns, 10-15 microns, and so on). Particle size separation will be performed by wet screening, cascade impingement separators, or vortex classifiers.

Narrow fractions of the coals investigated will be analyzed for ash and sulfur to determine the mineral matter liberation characteristics of the coal. If selective liberation of the mineral matter is observed, sufficient representative samples will be collected for outside, detailed petrographic or photomicrographic evaluation. The data collected will be analyzed to examine

the feasibility of the HSC approach. If the data are positive, a continuous laboratory-scale comminution device will be designed.

It is anticipated that samples of micronized coal (preferably the same coal as those tested under this task) will be supplied by DOE from the wet fine grinding circuit employed at EPRI's coal quality development center located near Homer City, Pennsylvania. The fine coal samples will be analyzed for particle size distribution, and mineral matter liberation characteristics. The energy consumption of the grinding operation will also be documented. This data will then be used as a baseline for comparing the performance of the HSC process.

TASK 5: Systems Evaluation

The systems evaluation will be comprised of three separate elements, namely: 1) Engineering Evaluation, 2) Economic Evaluation, and 3) Scale-up Design and Development Plan. The objective of this work is to analyze data gathered from all laboratory-scale investigations to determine the commercial potential of the proposed concepts.

Subtask 5A: Engineering Evaluation

The objective of the engineering evaluation is to analyze laboratory-scale data in order to establish the technical merit and/or feasibility of each investigated process. The engineering evaluation will include consideration of the following items:

- o mechanical/structural design
- o floor space and siting logistics
- o thermal efficiency, consumables, etc.
- o environmental emissions
- o safety factors
- o control and operating requirements
- o reliability
- o potential applications to commercial systems

The results of the engineering evaluation will provide data necessary for completion of a preliminary economic evaluation and scale-up design.

Subtask 5B: Economic Evaluation

An Economic Evaluation will be made for those system concepts which were found to be technically feasible in the Engineering Evaluation. The objective of the economic evaluation is to project the cost (\$/MMBtu) of each feasible processing step for a typical commercial scale unit.

The cost of processing is comprised of three major components, namely: 1) capital, 2) operation and maintenance, and 3) consumables. Capital costs will be projected based on an estimate of the material, shop fabrication, and field installation costs for a preliminary commercial design configuration. Operating costs will be estimated based on a projection of staffing requirements made in the Engineering Evaluation. Maintenance costs will

include cost elements accounting for standard maintenance activities as well as amortized costs for replacement of major equipment components, if deemed necessary in the Engineering Evaluation. Consumables such as cooling water, electricity, fuel etc. will be estimated based on the analysis of laboratory data performed in the Engineering Evaluation.

Each of these cost elements will be considered in order to arrive at a realistic production cost for each processing step expressed in \$/MMBtu of coal processed. A sensitivity analysis for key economic variables including required payback period, capacity factor, and consumable costs will also be performed.

Subtask 5C: Scale-up Design and Development

Based on the results of the engineering and economic evaluations, systems exhibiting commercial potential will be identified. For these processes, a preliminary design of a pilot-scale demonstration plant will be made. This will include preparation of preliminary engineering documents including: 1) conceptual designs, 2) process flow diagram, 3) piping and instrument diagrams, and, where possible, 4) heat and material balances.

For the comminution concept, if feasibility is established, an experimental evaluation plan at the laboratory-scale will be prepared.

This work will also include preparation of a logical development plan for commercializing the feasible systems.

2.2 SUMMARY STATUS

Significant progress in Tasks 2-4 has been made during this period. The preliminary configuration designs for both the direct and indirect dryers were completed. The direct dryer was fabricated. Initial check-out test on the direct dryer were also initiated using water injection to simulate wet feed. Some modifications to the system were also initiated as a result of these check-out tests, e.g., particulate collection system to provide higher throughput capacities; relocation of aerovalve to utilize input combustion air for combustor surface temperature control.

For fines reconstitution, Task 3, a used LMP model RC-2 co-rotating, twin screw extruder was procured and completely reworked and checked out. Fabrication of the downstream processing train components was initiated.

A topical report entitled "Hydraulic Shock Comminution: Literature Survey and Analysis" was prepared and submitted as an attachment to a monthly progress report, PETC/PPC-79881-2. A finalized design for the bench-scale feasibility apparatus was completed and is in the process of being fabricated.

SECTION 3.0

TECHNICAL DISCUSSION

3.1 TASK 2: LABORATORY-SCALE VERIFICATION OF PULSE-ENHANCED DRYER

Subtask 2A: Equipment Design, Fabrication, and Set-up

System Design - Direct Dryer

The design and fabrication of the preliminary configuration for the pulse-enhanced direct dryer system was completed during this period. The direct dryer system layout is shown in Figure 2. The system has been designed to dry approximately 200 lbs/hr of micronized coal slurry or filter cake containing 30 to 35 wt.% moisture. The pulse combustor is designed to fire dry micronized coal at a rate of up to 100,000 Btu/hr and is capable of utilizing dried product as a fuel source.

Dry coal fuel is metered from a Vibrascrew feeder F-1 into a receiving funnel connecting to the suction line of an air eductor. The Vibrascrew feed has a maximum feed capacity of approximately 30 lbs/hr. Lift air to the eductor is supplied from an air compressor. The eductor typically operates with less than one pound of lift air per pound of coal fuel representing less than ten percent of the stoichiometric air requirement. Fuel supply systems of this type have operated with a high degree of reliability in several other MTCI investigations.

The dry coal fuel enters a pulse combustor of a Lockwood design as shown in Figure 3. The pulse combustor is of bare metal construction and consists of a 4.75 inch long aerodynamic valve, a 6.58 inch long combustor, and a flared U-tube tailpipe. The pulse combustor is capable of a heat release of 100,000 Btu/hr and has been tested on coal fuel in previous MTCI investigations. Alternate combustor designs may be tested during the course of this investigation.

The pulse combustor is situated in an insulated sheet metal housing with approximate dimensions of 20"L x 18"W x 8"H as shown in Figure 4. The pulse combustor is mechanically supported within the housing. The aerodynamic valve and the tailpipe penetrate the housing, extending approximately one inch from the outer wall. The aerodynamic valve directly faces the open throat of a flared thrust augmentor. The aero valve/thrust augmentor combination acts as an eductor to pump ambient air into the housing. The flow streamlines for the system are shown in Figure 5.

The thrust augmentor performs several functions. First, it utilizes the mechanical energy contained in the aerovalve exhaust to circulate air into the dryer housing thereby decreasing the energy which would otherwise be consumed by a fan or blower. Second, it recovers and conserves the thermal energy contained in the aerovalve exhaust. And finally, it reduces direct emission of unburned coal, if any, into the environment. This type of thrust

DIRECT DRYER SYSTEM LAYOUT

FIGURE 2:

Resonance Tube Length (Centerline) = 30.0"

FIGURE 3:
PULSE COMBUSTOR FOR PULSE DRYER

FIGURE 4:
DRYER HOUSING AND PULSE COMBUSTOR SUBCOMPONENT DETAIL

PULSE COMBUSTOR
INTAKE PHASE

PULSE COMBUSTOR
EXHAUST PHASE

FIGURE 5:
FLOW STREAMLINES FOR AEROVALVE AND THRUST AUGMENTER

augmentation has been successfully demonstrated by Sonodyne Corporation in natural gas fueled applications.

As depicted in Figure 4, the flared tailpipe exhausts into a 4" duct connecting to a decelerator. Here, the motive force of the exhausting gases provides a second eductor effect in order to pump air from the dryer housing into the mixing length of the 4" duct. Air which is circulated through the housing will absorb a portion of the heat emitted from the bare metal pulse combustor and resonance tubes.

The wet coal feed is supplied from a screw feeder into a funnel and drop-tube which directly connects to the end of the flared tailpipe. An Acrison double auger screw feeder is available at the MTCI facility for this purpose. The Acrison feeder is presently limited to a 150 lbs/hr capacity, however it can be easily upgraded to 200 lbs/hr. Alternately, a recently purchased Autoweigh belt feeder may be employed. This unit has 800 lbs/hr capacity with a 15:1 turndown ratio and includes an electronic mass rate indicator and totalizer. The wet coal feed is injected into the end of the tailpipe where the acoustic velocity oscillations attain a maximum. Here, the wet coal particles and agglomerates are rapidly sheared and scrubbed by the oscillating pulse flow field. The scrubbing action serves to significantly enhance the particle drying rate.

As the partially dried particles exhaust from the tailpipe and enter the 4" exit duct, they are met with preheated air which has been aerodynamically circulated through the dryer housing. The flow stream then enters a decelerator which serves three primary functions including: 1) acoustic decoupling of the pulse combustor which assists in noise reduction, 2) providing for increased residence time to complete the coal particle drying, and 3) particulate knockout. The decelerator consists of a 40-gallon drum to which a 12" conduit is connected. The 12" conduit extends approximately 2" inside the 40 gallon drum. At the inside face of the 12" conduit, a fabric filter is attached by means of a band clamp. The fabric filter offers a primary means for separating dry coal solids from the flue gas stream.

A novel feature of this particulate capture system is the use of combustor pulsations to keep the fabric filter surface in a relatively clean state thus limiting pressure build-up. As the solids accumulate on the fabric filter surface, they are continually vibrated by the pulsing action of the dryer. In effect, the filter oscillates like an acoustic drum head, thereby resulting in the disengagement of large solid chunks which fall into the particulate collection drum.

As a finishing stage, the dried coal stream then enters a more conventional baghouse where the particles are collected. A baghouse which is currently available at the MTCI facility will be modified for the intended service.

The dryer will typically be operated with a circulation air to flue gas mass ratios varying from less than 1:1 up to 3:1. Control of the circulation air ratio is provided by a series of dampers as shown in Figure 2. The induced draft blower B-1 is employed to provide a modest suction pressure

throughout the drying system. Since the blower is oversized for this particular application, a by-pass damper D-3 is provided to simply circulate air through the blower. This allows independent control of the suction pressure at the baghouse inlet.

Damper D-2 is provided to allow independent control of the suction pressure within the decelerator, and dryer housing. By varying the suction pressure in the dryer housing, the quantity of circulation air induced in the thrust augments can be controlled. Damper D-1 provides an additional means for controlling the circulation air rate. Operation of the unit at a modest vacuum provides several advantages including: 1) thermal losses through outflow of hot gases from the housing are avoided, and 2) dust emissions from the system are greatly minimized.

As shown in Figures 2 and 4, the system is provided with sufficient pressure, temperature and flow sensing elements to completely characterize the performance and operation of the unit.

Photographs of the "as constructed" unit are shown in Figures 6 through 9.

In Figure 6, the direct dryer housing and primary collection drum are shown. The pulse combustor itself is located within the insulated dryer housing as shown in Figure 7. The pulse combustor is a Lockwood-type design and consists of an air inlet valve, a combustion chamber and an exhaust pipe (resonance tube) which is bent in a U-tube configuration. The combustor ignitor, which consists of a spark plug and pilot flame, is shown penetrating the housing in Figure 6. The pressure transducer, used to measure combustion chamber pressure fluctuations, is also shown.

The wet coal feed funnel at the exit of the tailpipe is also identified in Figure 6. Wet feed may be metered into the dryer at this location or alternatively, particularly for slurries, wet feed may be pumped into a 1/2" injector located at the 90° bend of the tailpipe. Evaluation of both feed locations will be made during experimental testing.

The control panel for the direct dryer is shown in Figure 8. The control panel includes the spark ignitor transformer, switch, and filtering electronics which are used to substantially alleviate spurious electrical noise from the high voltage spark ignitor. The control panel includes a multichannel digital thermocouple readout, rotometers for ignitor gas and air, main gas, and excitation air, and pressure gauges for each flow stream.

Figure 9 shows two separate coal feeders which may be employed in the course of this experimental program. The lower portion shows a single screw feeder which will be used to meter dry coal fuel to the combustor. The upper portion shows an Autoweigh belt feeder which will be used for wet coal which cannot be pumped.

FIGURE 6:
DIRECT DRYER APPARATUS

FIGURE 7:
PULSE COMBUSTION APPARATUS

FIGURE 8: CONTROL PANEL FOR COAL DRYER

FIGURE 9: VIBRASCREW DRY COAL FUEL FEEDER

The Autoweigh feeder has an automatic feed rate controller. The unit operates by metering coal through a slide gate onto a moving conveyer belt. A load cell measures the weight of coal which is distributed onto the belt over a defined length. A magnetic pick-up then records the travel speed of the belt, adjusting the speed as necessary to provide the desired coal feed rate.

During preliminary calibration and testing of the belt feeder, a problem was identified regarding the continuity of feed as it dropped off the end of the conveyer belt into the feed chute. Although the weigh feeder gave a very continuous and uniform loading of coal onto the conveyer belt, it dropped from the belt in discontinuous surges or slugs, whereby the chute was heavily loaded at certain times and lightly loaded at others. This behavior is undesirable since effective coal drying requires a very uniform feed rate.

The problem with the feeder appears to be associated with the slow speed of the belt which is required for the small feed rates employed in this work (100 to 500 lb/hr). At these low belt speeds, the unpredictable instabilities of the coal load as it falls from the belt results in a slugging behavior, particularly for wet coal. Although the belt speed can be increased mechanically, the maximum practical speed is limited by the accuracy of the load cell. This is due to the fact that for a given feed rate, higher belt speeds require lower loading densities on the conveyer belt. If the loading density becomes too small, the load cell can no longer function properly.

In an initial attempt to resolve this problem, a screen was attached to the chute to aid in smoothing out the flow fluctuations by adding a hold-up capacitance. However, tests with different screens did not noticeably alleviate the problem. Another resolution for the feed issued was the use of a rotating tine at the end of the conveyer belt to actively smooth out the feed fluctuations. Several different rotating tines (fingers) are currently being tested including brushes, fins, pins, etc. The tines will be mounted horizontally and will be speed controlled using a stepper motor. Testing of the feeder is expected to be completed during the next quarter.

Preliminary evaluation tests were made during December using the direct dryer configuration previously shown. These tests were conducted using natural gas as the fuel, and water as the wet feed. The purpose of these tests was to verify general operation and to provide operator training experience. As a result of these tests, some further design modifications have been made to the unit and are currently being incorporated into the existing design. These design modifications include: 1) adding an air plenum around the pulse combustor airovalve thereby requiring combustion air to be drawn through the dryer housing thus also limiting direct exhaust emissions (during blow-back) into the atmosphere, 2) adding a three foot long mixing pipe extension (4" OD) to the exit of the tailpipe to increase residence time for drying, and 3) increasing the primary collection drum volume to allow increased feed rates and longer operating times before product change out is required. The reasons for these modifications will be described in subsequent sections covering "Experimental Evaluation of Dryers."

Design Review

A design review for the direct dryer system has been performed internally within MTCI and has included a multilevel review procedure involving the Manager of Engineering and the Director of Laboratory Operations. Design procedures conform to sound engineering practices consistent with the bench-scale research objectives of this work. When necessary, design modifications to existing equipment will be made to minimize the purchase of new components or parts.

Safety

Safety procedures for pulse combustion subsystems have been identified and employed in all of MTCI experimental work. Operator attendance is a prerequisite during testing of the pulse combustor. Typically, as a minimum, MTCI provides system operator and a separate data acquisition specialist for each test run. An engineer's presence is required at all times during plant operation.

Safety procedures are reviewed by all operating personnel prior to any experimental investigation. Fail safe parameters are identified for each test rig in order to ensure safe shut-down in the case of an out-of-limit test condition. Among the critical variables to be monitored for the direct dryer include: 1) combustor flame-out, 2) dryer exit temperature, and 3) carbon monoxide emission levels.

System Operation

Normal start-up and operating procedures for the direct dryer involve the following sequence of events. First, the induced draft fan is started and its operation verified. Second, control damper positions are tuned. Third, the pulse combustor is ignited on natural gas. If ignition is excessively delayed, then the system is purged completely before re-ignition.

Once the system has heated up sufficiently, the coal fuel is introduced while backing out the support gas. Water is sprayed into the feed tube in order to stabilize a safe dryer exit temperature prior to introducing wet coal. Finally, wet coal is introduced while backing out the water spray to achieve the desired operating temperature. If a safe dryer exit temperature is exceeded, a water spray will be re-initiated.

A computer model has been developed to simulate the performance of the direct dryer. This model will be used for design and analysis applications.

The design package for the direct dryer was included in the October monthly report. Fabrication of the preliminary direct dryer test apparatus was completed this month. The "as constructed" unit contains three minor modifications compared to the configuration presented in the design package. These are: 1) the dryer housing was increased in size to 24"l x 24"w x 12"h for greater flexibility in testing alternate pulse combustors, 2) the wet coal feed tube has been relocated to the tip of the exhaust pipe using a 2" tee, and 3) the exhaust conduit exiting from the deceleration chamber is now

vertical rather than horizontal. It should be recognized that further design modifications may be made during the course of development and testing. Pictures of the fabricated test apparatus are being transmitted to DOE's TPO. Although many of the design attributes of the test apparatus were covered in the October monthly, a more general discussion regarding the role of pulse drying application is given herein.

Indirect Dryer

A preliminary configuration design for the fluid bed indirect dryer has also been completed and is presented in Figures 10 through 12.

The primary purpose of the indirect dryer is to supply the drying heat load without direct contact of flue gas with the coal feed. In this manner, contact of air with ignitable coal is minimized and the thermal efficiency of the system can be enhanced by limiting the sensible heat losses due to the flow of contact gases. Furthermore, due to the low volumes of gas which contact the coal, downstream particulate collection and handling is simplified.

A front view of the indirect dryer lower portion is shown in Figure 10. The dryer consists of a fire tube bundle which is immersed within the dryer bed. Fuel is burned in the pulse combustor and the flue gases are conveyed inside the fire tubes. The fire tubes are fashioned in a U-tube arrangement to simplify removal. The tube bundle is completely self-contained, and therefore represents a module which may be directly employed in multiplicity for larger commercial applications. A total of two fire tubes are provided with a total firing capacity of approximately 100,000 to 150,000 Btu/hr.

The fluidizing medium, which will be steam for these tests, enters a manifold ring which surrounds the dryer. The steam is then directed into the bed through a series of nozzles located around the circumference of the dryer shell. A side view of the indirect dryer is given in Figure 6 along with the fire tube layout in Figure 12.

A fundamental feature of the fire tube involves the use of a radiation shield to limit the temperature of the fire tube wall which is in direct contact with the coal contained in the fluid bed. This is critical since exposing the coal to excessive temperatures at the tube wall will result in overheating, pyrolysis, and potential fouling of tube surfaces. The effect of the radiation shield is shown in Figure 13. Here, the tube wall temperature profile within the bed (100,000 Btu/hr firing rate) is shown for two cases: 1) bare tubes only, and 2) bare tubes with radiation shields. The maximum tube wall temperature for the bare tubes is 1257°F, while the maximum wall temperature for the shielded tube is only 706°F. Note that the maximum temperature in the later case occurs at the shielded tube to bare tube transition. It is evident that the shielded tube significantly limits the maximum tube wall temperature without significantly altering the overall thermal efficiency of the unit.

FIGURE 10: INDIRECT COAL DRYER (LOWER PORTION - FRONT VIEW)

FIGURE 11: INDIRECT COAL DRYER (LOWER PORTION - SIDE VIEW)

FIGURE 12: FIRE TUBE LAYOUT (DETAIL A)

FIGURE 13: TUBEWALL TEMPERATURE PROFILES

In all, the fire tube bundle will consist of two separate resonance tubes. Approximately 50 percent of the tube length is shielded with the remaining 50 percent as a bare tube. The bare tube is allowed in the last 50 percent length since flue gas temperatures here are sufficiently low to avoid excessive tube wall temperatures.

This configuration is expected to be significantly more economical than existing indirect designs which employ intermediate heat transfer fluids. In these other systems, a heating circuit is required consisting of a combustor and heat exchanger for heating the fluid, and a second heat exchange coil within the dryer for releasing the heat. In comparison, MTCI's system consists of a single integral combustor/heat exchanger which can be directly immersed within the dryer. This is expected to reduce the required floor space and system control requirements, minimize heat losses, reduce maintenance and operating costs, and of course substantially reduce equipment capital costs.

Fabrication of the indirect dryer is anticipated to begin in January.

Subtask B: Experimental Evaluation of Dryers

A preliminary test plan has been prepared for the direct dryer. The purpose of the test plan is to provide a template for conducting systematic experiments to characterize the performance of the direct dryer. Due to the developmental nature of this work, it is important to recognize the need for flexibility in restructuring the test plan as new information becomes available during the course of early test runs. Appendix A contains a Summary of the Test Plan.

As previously mentioned, natural gas tests were conducted to evaluate the general performance characteristics of the direct dryer using a simulated wet feed (e.g., water injection). The purpose of these tests were: 1) verify performance of controls and ancillary equipment, 2) identify any potential operating problems or limitations, 3) monitor the effect of firing rate on drying efficiency, 4) monitor the effect of injection location on drying efficiency, and 5) gain operator experience.

After initial equipment and instrument check-out, the unit was tested over three days covering a range of firing rates and water injection rates. Two separate injection points were also evaluated. These were: 1) at the tailpipe exit (feed funnel), and 2) at the 90° elbow of the tailpipe. A summary of the experimental data is shown in Table 2 and Figures 14 and 15. Note that the firing rate is given as the higher heating value.

Figure 14 shows the measured temperatures at the dryer exit as a function of the water injection rate. Two parametric curves are also shown based on theoretical calculations assuming 50 percent excess air and complete evaporation of the injected water down to the saturation temperature. These curves assume 0 percent heat loss and 20 percent heat loss, respectively. It is evident that the flue gas temperature appears to asymptotically converge to a value of about 290°F which is well above the approximate saturation temperature of 178°F. This result indicates that the injected water is not

TABLE 2:
PERFORMANCE OF DIRECT DRYER ON SIMULATED WET FEED

<u>INJECTION POINT</u>	<u>FIRING RATE (Btu/hr) (1)</u>	<u>WATER INJECTION RATE (lb/hr)</u>	<u>DRYER EXIT TEMPERATURE (2) (°F)</u>
ELBOW	194,000	149	386
ELBOW	194,000	185	373
ELBOW	194,000	220	351
ELBOW	292,000	149	405
ELBOW	292,000	185	313
ELBOW	292,000	192	302
ELBOW	292,000	220	293
ELBOW	322,000	220	282
ELBOW	364,000	220	263
FUNNEL	265,000	192	445
FUNNEL	265,000	220	431
FUNNEL	308,000	220	401
FUNNEL	308,000	243	393

(1) Natural gas fuel

(2) Average temperature at exit of primary drum

FIGURE 14:
 EFFECT OF WATER INJECTION RATE AT CONSTANT FIRING RATE

FIGURE 15:
EFFECT OF FIRING RATE

fully vaporized as the flue gas exits the dryer. This may be due to insufficient mixing at the tailpipe exit, or may simply be the result of insufficient residence time for drying.

In the existing design, the bulk of the vaporization process occurs within the tailpipe. The high velocity gases at the injection elbow (approximately 1000 ft/sec) rapidly shear the injected water into fine droplets. The finest of these droplets vaporize almost instantaneously while the larger droplets may not have completed the vaporization process by the time they reach the tailpipe exit. Note that the mean residence time in the tailpipe is only approximately 5 milliseconds. These larger droplets must then vaporize in the short section of the mixing pipe located at the exit of the tailpipe. In this configuration, a small quantity of ambient air is drawn into the housing through the thrust augments in order to keep the surface temperature of the combustor within manageable limits. This air is preheated as it travels through the housing before it is combined with the tailpipe exhaust in the mixing pipe. Since part of the heat released in the combustor is removed by this cooling air, it is evident from a heat balance that part of the vaporization must occur in the mixing pipe. However, mass transfer in the mixing pipe is anticipated to be less efficient than in the tailpipe itself. Furthermore, mixing of the cooling air which surrounds the tailpipe jet in an annular fashion may not be sufficient.

In order to minimize the quantity of cooling air which is mixed with the tailpipe exhaust. The thrust augments will be removed and the annular mixing port at the tailpipe exit closed. The combustor surface temperature will be maintained within material limits by using the combustion as a cooling media. In order to accommodate this, the aerovale will be placed within the dryer housing. This may be beneficial for other reasons as well, including reduced emissions and heat losses to the environment as discussed below.

Although the actual quantity of heat loss from the apparatus is difficult to determine, a value of 20 percent is not unlikely and appears to be consistent with the experimental data. Note that most of this heat loss is probably due to blowback from the aerodynamic valve. This type of heat loss can be considerably reduced by placing the aerovale inside the dryer housing so that combustion air is drawn from within the housing rather than from the ambient environment. As mentioned in the previous section, this modification is now being made to the apparatus.

If we compare the theoretical curve for 20 percent heat loss with the experimental data, it can be concluded that approximately 90 percent of the injected water is vaporized at the theoretical saturation limit. Although this performance level may alone be sufficient for the intended coal drying application, the additional modifications which are being made should further enhance performance.

One particularly significant piece of information gained during these initial tests is the extreme importance of intense combustion for high efficiency drying. This result is clearly demonstrated in Figure 15 which shows the dryer exit temperature as a function of firing rate for a constant water injection rate.

The results indicate that as the firing rate increases, the dryer exit temperature actually decreases. At first, this appears to contradict intuition. However, as the firing rate increases the intensity of pulsations also increase. The direct relation between acoustic decibel level and firing rate can be easily discerned by ear and can be measured with a decibel meter.

As the intensity of oscillations increases, the rate of drying of the water droplets, particular large ones which exhibit higher heat and mass transport limitations also increases. This effect is known to be highly non-linear and thus the increase in the drying efficiency more than compensates for the increase in the firing rate resulting in a lower exit temperature. Of course, as the firing rate exceeds the saturation limit for a given water injection rate, the temperature will eventually rise.

It was noted during the test runs that incomplete combustion was occurring for gas firing rates exceeding approximately 325,000 Btu/hr. Therefore, in order to achieve both high combustion intensity and efficiency, the optimum firing rate was determined to be in the 200,000 to 300,000 Btu/hr range for this unit operating on gas. The optimum range for coal is expected to be somewhat lower. Since this optimum firing rate is somewhat higher than originally anticipated, the particulate collection system will be modified to allow higher through-put capacities.

TASK 3: Reconstruction/Extrusion

Subtask 3A: Design, Fabrication and Set-up

MTCI explored the availability of twin-screw extruders with several new and used extruder vendors. Werner and Pfleiderer Corporation has co-rotating twin-screw extruders. They have tested the coal melt pumping concept under JPL/DOE sponsorship and are now not willing to test coal in their research/test facilities. Their new machines cost over \$200,000. MTCI located a used Krauss Maffei (90 MM/50 Hp) counter-rotating twin-screw extruder in Chicago via Aaron Equipment Company. This would have cost about \$35,000 to buy. A used Cincinnati Millicron CT-90/6L counter-rotating twin-screw extruder with 25 Hp drive (\$15,000) was located in Buena Park, California.

A LMP model RC-2 co-rotating, twin-screw extruder was also located in Westminster, California. After discussions with the owners and mechanics about the condition of the latter two machines which were located in Southern California, we chose to negotiate for LMP model RC-2 extruder. It was in better operating condition than the CT-90/6L which needed major repairs. This unit was purchased for \$8,500.

It has a variable-speed drive motor for the screws with a maximum rating of 3.5 HP and a feeder with a separate motor. The barrel has two heaters and a third heater is located in the die section. The power supply for heating is 6 kW and has provision for a fourth heater, if needed. The temperature controllers are only capable of 300°C maximum and need to be replaced to obtain higher temperatures of up to 500°C. The size of the screws are nominally 2" diameter (56 MM x 60 MM) and 20" long after the feed which means an effective L/D ration of 10.

The extruder and control panel were moved to MTCI's new research facility. Preparation, set-up and check-out of the extruder has been initiated. Preliminary design of the extruder apparatus and ancillary systems is now in progress.

A complete mechanical and electrical check-out of the reconstitution extruder was also performed. Some electrical rework was required including addition of a new temperature controller. The downstream processing train is currently under fabrication. This will include: 1) a water jacket extension at the exit of the extruder to cool the reconstituted coal product, 2) a product collection drum, 3) an incinerator for combustion of potential pyrolysis products, and 4) an induced draft fan.

Photographs of the extruder apparatus are shown in Figures 16 and 17. The sleeve heaters surrounding the twin screw housing are identified in Figure 16a. The housing and twin screws are shown in Figures 17a and 17b, respectively.

TASK 4.0: Comminution

Subtask A: Exploratory Feasibility Investigation

A literature survey was conducted during this period with the objective of identifying information relevant to hydraulic shock phenomena and its effect on crystalline and amorphous materials. A summary report of this literature survey has been completed. The report includes a treatment of mechanical properties of coal, considerations for size reduction and energy consumption, and the theoretical basis of hydraulic shock comminution. The phenomena of water hammer, impact shock, and cavitation are analytically explored. This information was intended to provide a basis for developing conceptual designs for the novel hydraulic shock coal comminution technique.

A finalized design for the bench-scale, hydraulic shock, comminution apparatus was completed and is shown in Figures 18 through 20. The system was designed to provide a simple means for exploring the mechanical effect of applying rapid and intense loads on a coal sample by transmission of transient hydraulic compression and expansion waves.

The bench-scale apparatus shown in Figure 18 consists of an impact cylinder and piston, an impact mass, a guide rig, and a hydraulic reservoir. The piston and cylinder is shown in Figures 19 and 20. The cylinder is machined and bored from a 6" OD block of stainless steel. The cylinder bore is 2" OD by 8" in length. The piston is approximately 4" long and is machined to a .003" tolerance from a stainless steel stock.

The impact mass is supported above the piston and cylinder apparatus between guide runners. The mass is accelerated downward by the force of gravity to initiate impact. The mass is furnished with spring loaded pulleys to ensure uniform and repeatable travel of the mass down the guide runners. It is approximately 6" OD by 2' in length and weighs 200 lbs. The apparatus is designed to allow a freefall of about 4 feet. The spherical impact surface

FIGURE 16a: EXTRUDER AND CONTROL PANEL

FIGURE 16b: OIL CIRCULATION PUMP AND RESERVOIR

FIGURE 16

FIGURE 17a: TWIN SCREW HOUSING

FIGURE 17b: TWIN SCREW ELEMENTS

FIGURE 17

FIGURE 18: IMPACT PISTON

37

FIGURE 20: IMPACT CYLINDER

is employed to minimize torque on the piston during impact. The piston end is machined to form a smooth curvature on one side to ensure that the piston does not seize within the cylinder. The hydraulic reservoir is connected to the cylinder and can be pressurized by nitrogen. This allows hydraulic removal of the piston after impact.

The cylinder and piston was machined by an outside vendor and have been completed. Fabrication of the remainder of the test rig is currently underway and exploratory testing is anticipated to begin in January.

SECTION 4.0

PLANNED ACTIVITY FOR NEXT PERIOD

During the next period, extensive characterization of the direct dryer on natural gas will be undertaken to serve as a baseline for comparing results with coal fuels. Wet coal feed tests will be conducted. The fabrication of the indirect dryer is also scheduled for completion with initial testing to begin in March.

Testing of the extruder for fines reconstitution will also be initiated. The laboratory apparatus for HSC is expected to be completed and testing of the device initiated.

APPENDIX A

SUMMARY TEST PLAN

Instrumentation

Primary instrumentation for the direct dryer test unit is depicted in Figure A-1. Instrumentation includes the following components:

Thermocouples. Thermocouples will be furnished in the following locations:

- o Pulse combustion chamber
- o Resonance tube at 50% length
- o Dryer housing
- o Mixing tube at tailpipe exit
- o Decelerator (primary collection drum) exit
- o Secondary baghouse inlet
- o Secondary baghouse exit

Pressure Monitors. Pressure sensing devices will be furnished in the following locations:

Piezoelectric Pressure Transducer -

- o Combustion chamber

Water Column Manometer -

- o Dryer housing
- o Decelerator (primary collection drum) exit
- o Secondary baghouse inlet
- o Secondary baghouse exit

A wire anemometer flow sensor will also be located at the decelerator exit. In addition, a sample port at the exit of the baghouse is provided for monitoring the gas species in the exit stream. Continuous analyzers (Horiba model PIR-2000) are available for NO and SO₂ measurements. Also, a seven column Carle model 4397 gas chromatograph is available to detect, oxygen, nitrogen, unburned hydrocarbons, carbon monoxide, and carbon dioxide down to the .1% level. With the exception of the gas analysis equipment mentioned above, all instrumentation is mounted on a single control rack. The control panel also includes metering valves and rotometers for start-up gas, pilot gas, and excitation air, and transformers and switches for the manual ignition system. The coal feeders (wet coal and dry coal fuel) are each furnished with independent control panels.

FIGURE A-1:

PRIMARY INSTRUMENTATION FOR DIRECT DRYER TEST UNIT

Objective

The test objectives for the experimental direct dryer investigation are defined below:

1. Verify method and location for feeding wet coal into the oscillating flow field of the pulse combustor.
2. Measure the extent of drying for two different coal feeds as a function of a two-dimensional test matrix, with dryer exit temperature and air flow as the two variables.
3. Calculate the dryer efficiency (Btu fuel/lb water evaporated) for each test matrix condition.
4. Measure the collection efficiency of the pulsating primary collection system.
5. Verify safe operation over the range of test conditions.

System Checkout

System checkout will consist of the following items:

1. Calibration of instrumentation, analyzers, flow meters, and coal feeders.
2. Ignition and light-off tests.
3. Gas-fueled heat-up profile.
4. Verification of temperature control via water spray temperature.
5. Calibration of air flows as a function of damper setting and suction pressures.
6. Checkout of Autoweigh belt feeder.
7. Preliminary verification of wet coal feed to dryer and development of start-up protocol, particularly transition from gas firing to coal firing and initiation of wet coal feed.
8. Verify operation of particulate collectors.

Initial coal drying tests will be made using natural gas firing in order to gain useful operating experience.

Test Matrix

The experimental program will consist of two-dimensional test matrix, with dryer exit temperature and air circulation ratio as the key variables. The anticipated test matrix is given below in Table A-1. This test matrix will be repeated for two different wet coal feeds. The test matrix is based on a coal firing rate of 100,000 Btu/hr. We anticipate that one of the coal feeds will be a wet filter cake material supplied from the Homer City demonstration plant containing approximately 35% moisture by weight. The second feed is anticipated to be a clean micronized coal slurry supplied to MTCI from a previous project. The slurry feed will require the use of a Moyno pump for injection.

**TABLE A-1:
ANTICIPATED TEST MATRIX**

of Dryer Exit Temp.	<u>Circulation Air To Flue Gas Ratio</u>			
	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>
180		X	X	X
200	X	X	X	X
220	X	X	X	X

Test Procedure

The wet coal feed will be initiated following stabilization of dryer temperatures. A typical run period will be one hour following initiation of wet coal feed.

Product samples will be taken from both the primary and secondary particulate collection drums. The samples will be batch-dried to determine moisture content at each test matrix condition. From the known firing rate, wet coal feed rate, and product moisture content, the overall dryer efficiency will be calculated.

Also, the total quantity of product collected in the primary chamber will be weighed to determine the collection efficiency for this system.

The key test conditions will be those operated at low (or zero) circulation air to flue gas mass ratios. It is anticipated that these conditions will permit achievement of maximum dryer efficiency.

DATE

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9/29/94

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