DOE/PC/88886--T2

MAY 31 1989

TECHNICAL PROGRESS REPORT

DOE/PC/88886--T2

DE89 013514

FOR THE

SECOND QUARTER

(January 1, 1989 - March 31, 1989)

DEVELOPMENT OF AN ADVANCED PROCESS FOR DRYING FINE COAL IN AN INCLINED FLUIDIZED BED

by

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Contract Number:

DE-AC22-88PC88886

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ABSTRACT

This research project is for the development of a technically and economically feasible process for drying and stabilizing of fine particles of high-moisture subbituminous coal. In the first quarter of this project, work was related to project planning. During the first quarter, a detailed project work plan was developed and reviewed. Recommendations for project redirection and acceleration provided by U.S. Department of Energy (DOE) personnel at the Pittsburgh Energy Technology Center (PETC) were incorporated into a revised project work plan.

During the second quarter, the final project work plan was prepared, distributed, and approved by the U.S. DOE project manager. Subsequent research activities were initiated with efforts concentrating on characterization of the two feed coals: (1) Eagle Butte coal from AMAX Coal Company's mine located in the Powder River Basin of Wyoming: and, (2) coal from Usibelli Coal Mine, Inc.'s mine located in central Alaska. Both of the feed coals are high-moisture subbituminous coals with "as received" moisture contents of 29% and 22% for the Eagle Butte and Usibelli coals, respectively. Coincidentally, both the Eagle Butte and Usibelli coals have a heating value of 8470 Btu/lb. However, physical analyses of the crushed coal samples (-28-mesh particle size range) indicate many differences.

Screen analyses of these two coals indicates that the fine particles of the Eagle Butte coal tend to clump together to form aggregates of a larger diameter. The -28-mesh Eagle Butte coal direct from the crusher and screen has a moisture content of 29% and a volume-surface mean diameter of 0.0092 inch (0.0234 μm). When this coal is dried by blowing ambient carbon dioxide through it, the moisture content is reduced to 22% and the volume-surface mean diameter is reduced to 0.0051 inch (130 μm). The -28-mesh Usibelli coal from the crusher has a moisture content of 22% and a volume-surface mean diameter of 0.0083 inch (211 μm). Drying of this coal to 17% moisture does not significantly change the volume-surface mean diameter. The Eagle Butte coal produces more fine particles when crushed than does the Usibelli coal. Also, the as received moisture content of the Eagle Butte coal is sufficient to cause these fines to form aggregates of a larger diameter which causes problems in the dry screen analysis. In addition, the ability of the fine Eagle Butte coal particles to stick together causes problems feeding this coal into the inclined fluidized-bed (IFB) reactor that do not occur when feeding the Usibelli coal.

The minimum fluidization velocity (MFV) of the feed coals were experimentally determined. The MFV for -28-mesh Eagle Butte coal is approximately 1 ft/min, and the MFV for -28-mesh Usibelli coal is approximately 3 ft/min.

Testing of the effects of IFB reactor slope and gas-to-solids ratio on the solids bed geometry and horizontal solids transport was also conducted using the IFB cold flow reactor. The results of these tests indicate that horizontal solids transport in the reactor occurs even at low reactor slopes and low gas-to-solids ratios. However, IFB operation at these conditions results in the creation of a static bed in the feed end of the reactor, batch fluidization in the center of the reactor, and continuous fluidization at the discharge end of the reactor. Increase of the reactor slope under these operating conditions results in decreased sizes of the static bed and batch fluidization zones. If the IFB slope is increased sufficiently, an even fluidized bed through the entire length of the reactor results. The solids bed geometry of Eagle Butte coal was considerably different than the solids bed geometry of Usibelli coal under similar conditions. However, the effect of increasing IFB reactor slope was similar with both coals.

Eleven four-hour IFB bench-scale drying tests were conducted using Eagle Butte coal and IFB reactor slopes of 3, 6, and 9 degrees. The first of these tests was a hot shakedown of equipment. During these tests gas-to-solids ratios ranging from 2.2 to 9.9 lb/lb (kg/kg) and average reactor temperatures ranging from 588 to 691°F (309 to 366°C). In all of these experiments the dried coal product contained less than 0.5 % moisture based upon proximate analysis. The heating value of these products was elevated from 8,470 Btu/lb for the feed coal to over 11,950 Btu/lb. The resulting product heating value correlates reasonably well to the heat input/mass of feed. Two preliminary IFB bench-scale drying tests of four hour duration were also conducted using Usibelli coal. Results were similar to those using Eagle Butte coal.

PROJECT OBJECTIVES

The main objective of this research is to develop a thermal process for drying fine coal that (1) reduces explosion potential, (2) uses a fluidized bed with minimum elutriation, (3) produces a stable dry coal by preventing moisture reabsorption and autogeneous heating while reducing fugitive dust emissions, and (4) is technically and economically feasible.

PROJECT TASKS

Task 1: **Project Planning**

This task is now complete. Table 1.1 and Figure 1.1 provide details regarding the project scope of work and schedule resulting from completion of this task.

The project scope of work requires completion of five tasks: (1) project planning, (2) characterization of the two feed coals, (3) bench-scale IFB drying studies, (4) product characterization and testing, and 5) technical and economic process evaluation.

The project schedule was accelerated to complete the five tasks in 15 months. The original project schedule was for 30 months.

Table 1.1 Project Scope of Work

TASK 1	Project Planning
TASK 2	Feed Coal Characterization
	2.1 Physical and Chemical Characterization
	2.2 Fundamental TGA Studies
	2.3 Optimizing TGA Studies
TASK 3	Bench-Scale IFB Drying Studies
	3.1 Minimum Fluidization Velocity
	3.2 IFB Drying Tests
TASK 4	Product Characterization and Testing
	4.1 Moisture Reabsorption
	4.2 Dust Formation
	4.3 Spontaneous Heating
	4.4 Surface Treating
TASK 5	Technical and Economic Evaluation

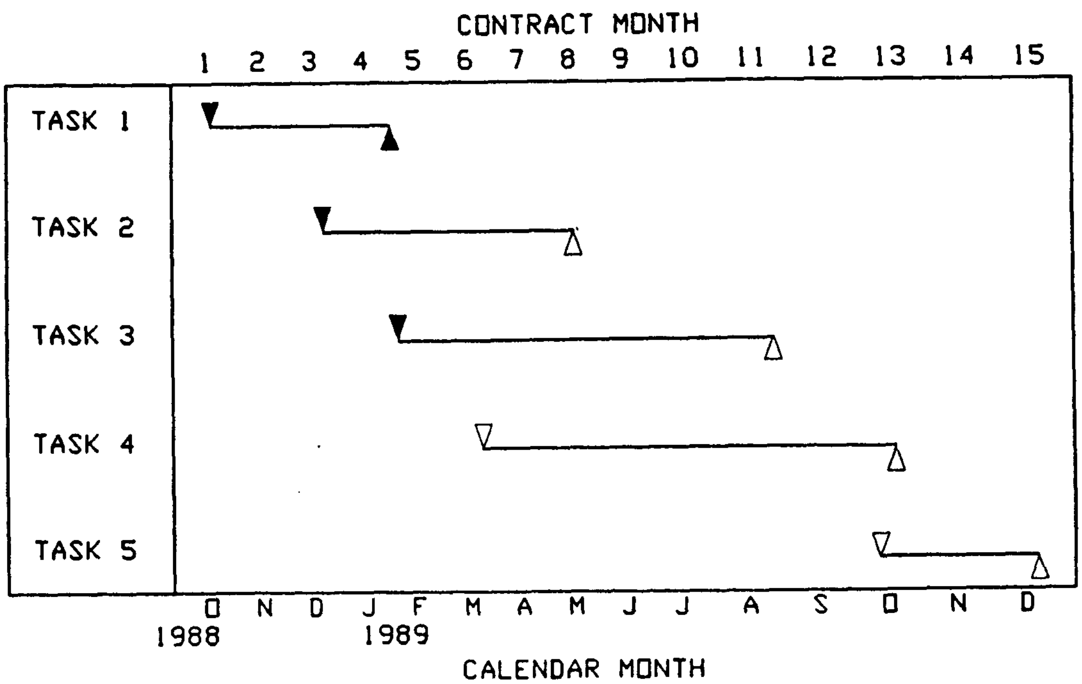


Figure 1.1 Project Schedule

Task 2: Feed Coal Characterization

Subtask 2.1: Physical and Chemical Characterization

This subtask was completed in the second quarter. Proximate, ultimate, and heating value analyses were performed on samples of Eagle Butte and Usibelli coals crushed to a -28-mesh particle size. In addition, samples of each crushed feed coal were subjected to dry screen analyses and solid density and void volume determinations. Both the chemical and physical analyses were performed in duplicate.

Results of the chemical analyses for proximate and ultimate composition and heating value analyses of both feed coals are presented in Table 2.1. The values presented in the table are the arithmetic average of the two analyses. Both feed coals, Eagle Butte and Usibelli, are high-moisture subbituminous coals with somewhat similar chemical analyses. Both coals have a heating value of 8470 Btu/lb. All chemical analyses were performed using either ASTM procedures or standard methods for the automatic analyzers.

Screen analyses of the crushed feed coals were performed dry using standard screens and a shaker. The fines content of the coals required that 30-minute shake times be used. Screen sizes used were Tyler equivalent 35, 48, 65, 100, 150, and 200 mesh.

Table 2.1 Results of Chemical Analyses of Feed Coals (crushed to -28-mesh particle size range)

Analysis	Eagle Butte	Usibelli
Proximate (as received)		
Volatile Matter	30.9	36.4
Fixed Carbon	35.2	33.3
Ash	4.7	8.3
Moisture	29.2	22.0
Ultimate (as receive)		
Carbon	52.0	51.0
Hydrogen[a]	1.2	2.5
Nitrogen	0.6	0.6
Sulfur	0.5	0.2
Oxygen[a]	11.8	15.4
Heating Value, Btu/lb	8470	8470

[a] Do not include hydrogen and carbon in moisture.

Screen analysis results of these two coals indicated that the fine particles of the Eagle Butte coal tend to clump together to form aggregates of a larger diameter. The -28-mesh Eagle Butte coal direct from the crusher and screen had a moisture content of 29% and a surface mean particle diameter of 0.0092 inch (234 μm). When this coal was dried by blowing ambient carbon dioxide through it, the moisture content was reduced to 22% and the volume-surface mean diameter was decreased to 0.0051 in (130 μm). The -28-mesh Usibelli coal from the crusher had a moisture content of 22% and a volume-surface mean diameter of 0.0083 in (211 μm). Drying of this coal to 17% moisture did not significantly change the volume-surface mean diameter. The Eagle Butte coal produced more fines when crushed than the Usibelli coal and the as received moisture was sufficient to cause these fines to form aggregates of a larger diameter. In addition, the ability of the fine Eagle Butte coal particles to stick together caused problems feeding this coal into the inclined fluidized-bed (IFB) reactor that did not occur with the Usibelli coal.

Figures 2.1 and 2.2 are graphical representations of the results of screen analyses of the Eagle Butte coal direct from the crusher/screen and the predried samples. Data presented for the 29% moisture samples are the arithmetic average results of three screen analyses of samples with proximate moisture contents ranging from 29.1 to 29.4 %. Data presented for the 22% moisture samples are the average results of three screen analyses of samples with proximate moisture contents ranging from 21.0 to 24.3%. The weight fraction retained on each screen is displayed in the bar chart for the 29% and 22% moisture Eagle Butte samples (Figure 2.1). The effect of the drying in reducing the aggregation of particles is illustrated by the reduction of the +35-mesh weight fraction and the corresponding increase of the fractions smaller than 65 mesh. The cumulative percent retained as a function of particle size is also presented for the 29% and 22% moisture Eagle Butte samples (Figure 2.2). Again, the decrease in large particles and increase in fine particles resulting from drying is illustrated. Also, the relatively even particle size distribution of the 22% moisture crushed Eagle Butte coal is apparent.

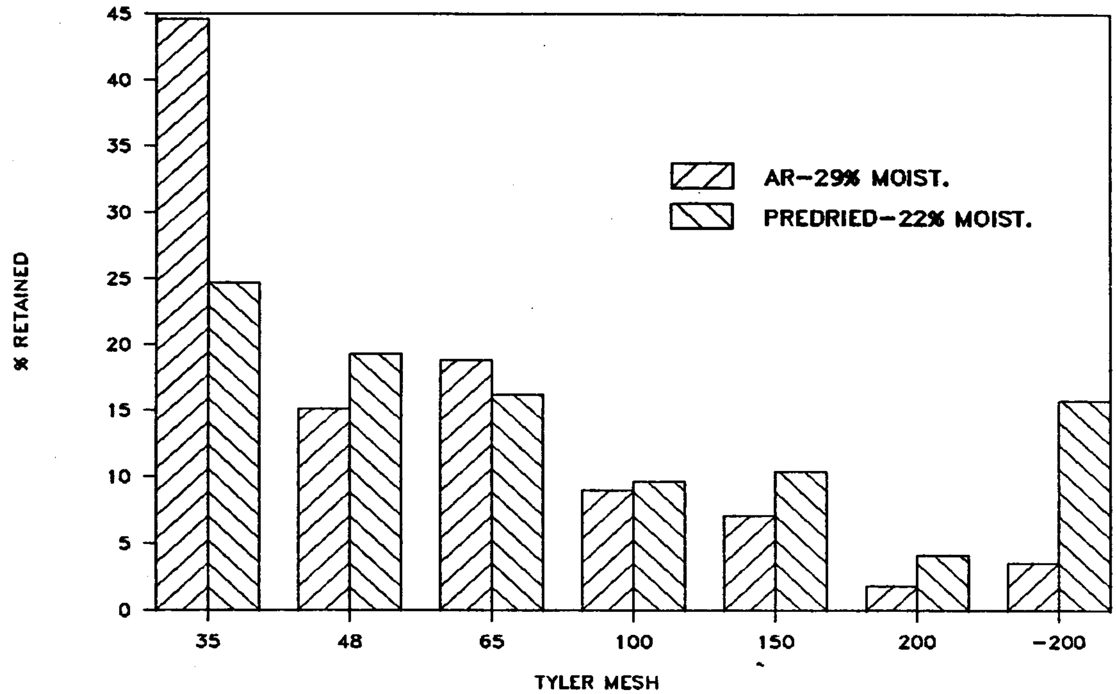


Figure 2.1 Eagle Butte Particle Size Distribution (crushed to -28-mesh)

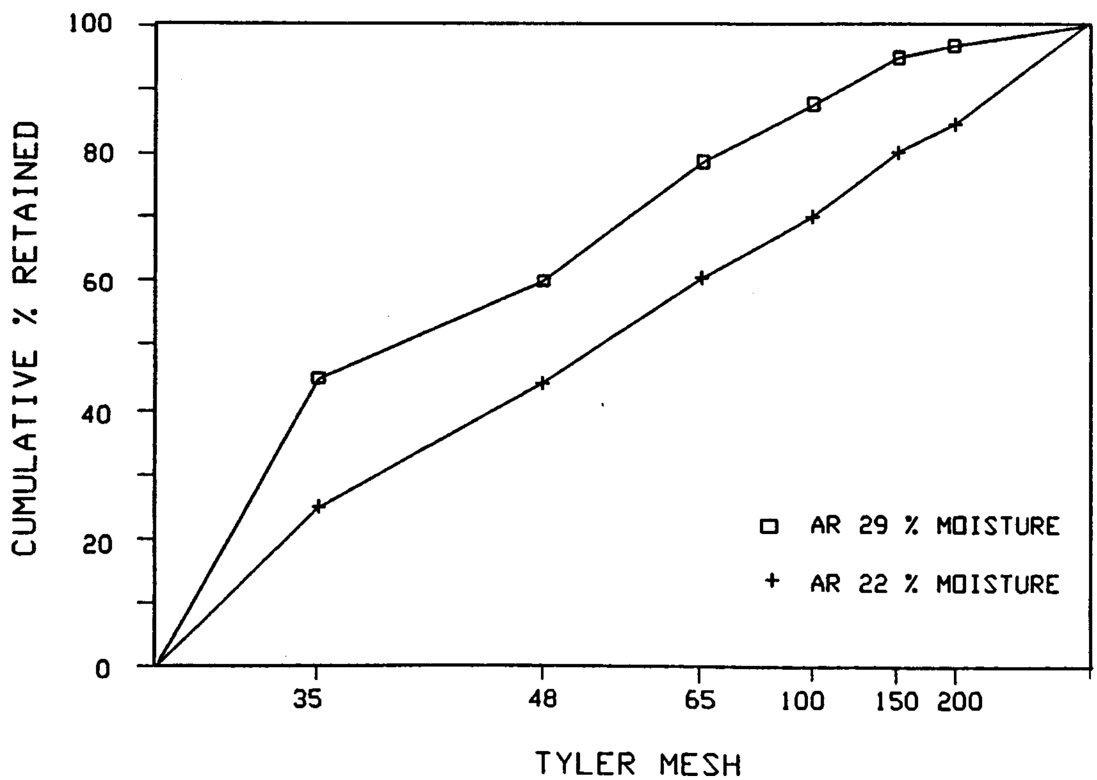


Figure 2.2 Eagle Butte Screen Analysis (crushed to -28-mesh)

Figures 2.3 and 2.4 are graphical representations of the screen analysis results of the Usibelli coal crushed to -28-mesh. As previously stated, moderate drying of this crushed coal does not significantly change screen analysis results. The weight fraction retained on each screen is displayed in the bar chart for the crushed Usibelli coal samples, and these data indicate that roughly one-half of the crushed Usibelli coal is +35 mesh in size (Figure 2.3). Comparison of Figures 2.1 and 2.3 illustrates the greater amount of large particles and the smaller amount of fine particles in the Usibelli coal than the Eagle Butte coal. The cumulative % retained as a function of screen opening is also shown for the Usibelli coal (Figure 2.4).

The solid density and void volume of each of the crushed feed coals were experimentally determined using the following procedure:

(1) An amount of crushed feed coal of known weight was added to a graduated cylinder, and the volume was measured.

(2) A measured volume of water was then added to the sample and allowed to completely penetrate the solids in the graduated cylinder. The volume of the coal and water mixture was measured after the water had adequate mixing time to fill all void space in the solids.

(3) The bulk density of the crushed feed coal is the weight and volume of the coal measured in step 1. The void volume of the solids is the difference of the volume measured in step 1 plus the volume of water added in step 2 minus the volume of the mixture measured in step 2. The density of the solids is the bulk density divided by 1 minus the fraction void volume.

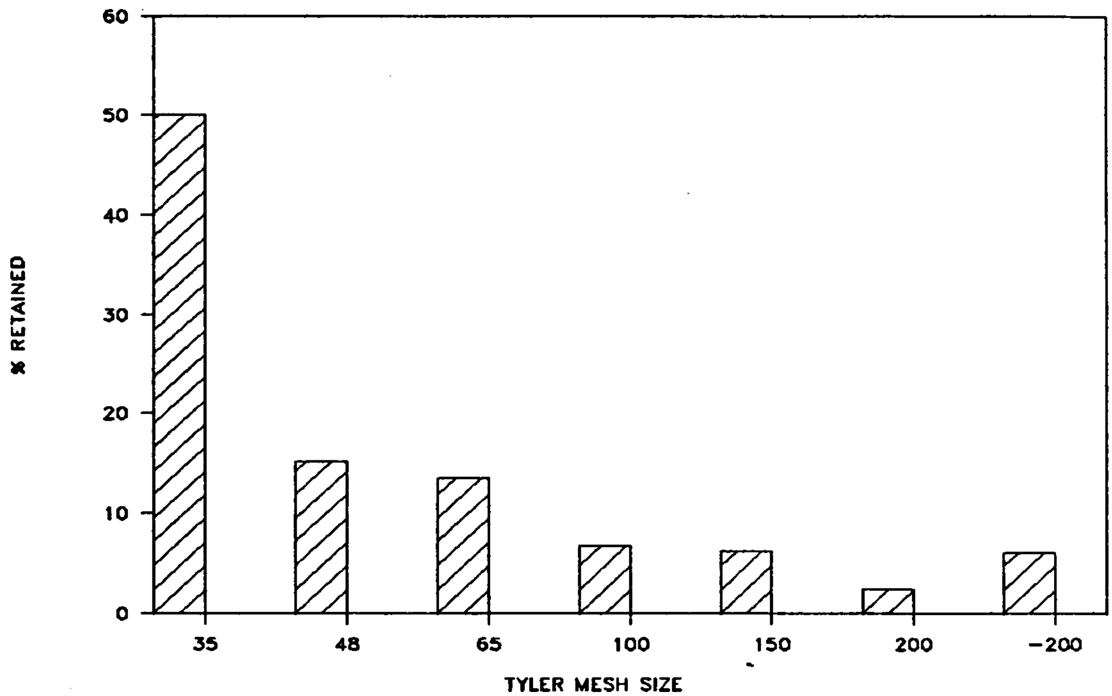


Figure 2.3 Usibelli Particle Size Distribution (crushed to -28-mesh)

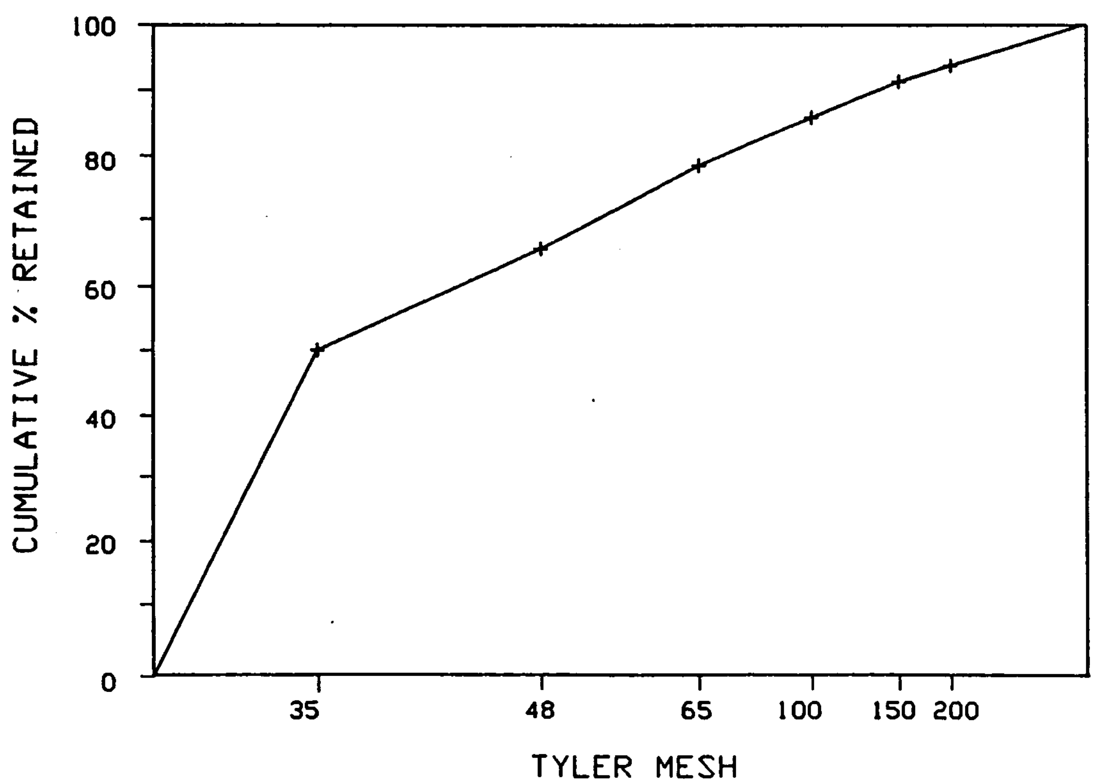


Figure 2.4 Usibelli Screen Analysis (crushed to -28-mesh)

The average solids density and void volume determined for the -28-mesh Eagle Butte feed coal are 67 lb/ft^3 and 36%, respectively. The average solids density and void volume determined for the -28-mesh Usibelli feed coal are 68 lb/ft^3 and 33%, respectively.

Subtask 2.2: Fundamental TGA Studies

The thermogravimetric analysis (TGA) research is behind schedule. No work in this area was conducted during the second quarter. The delay was due to a work backlog for the TGA analyzer that resulted from mechanical problems with the analyzer. This work is expected to be completed early in the third quarter.

Subtask 2.3: Optimizing TGA Studies

Same as Subtask 2.2.

Task 3: Bench-Scale IFB Drying Studies

Subtask 3.1: Minimum Fluidization Velocity

The minimum fluidization velocity (MFV) of the feed coals were experimentally determined. The experimental apparatus used for the MFV determination is a 4-inch diameter vertical pipe into which a metered and controlled amount of carbon dioxide is introduced (Figure 3.1). A 4-inch thick solids bed of the crush feed coal is placed in the reactor on a distributor screen located above the carbon dioxide fluidizing gas inlet at the bottom of the pipe. Fluidizing gas flow is incrementally increased from 0 scfm to a flow rate that results in complete fluidization of the solids bed. The fluidizing gas flow is then incrementally decreased until the flow rate is 0 scfm. The pressure drop through the solids bed is measured at each flow increment using a manometer or differential pressure gage with pressure taps located below and above the solids bed. The pressure drop across the solids bed is plotted versus the fluidizing gas velocity for both the increasing flow and decreasing flow conditions. These data are then qualitatively interpreted as outlined in the literature (Kunii and Levenspiel 1969). The first portion of the pressure drop versus fluidizing gas velocity curve is for the low-velocity conditions, and this portion of the curve increases in a near-linear fashion until the solids bed becomes at least partly fluidized. Just before the onset of fluidization the pressure drop across the solids bed should be maximum for both the increasing and decreasing flow data sets.

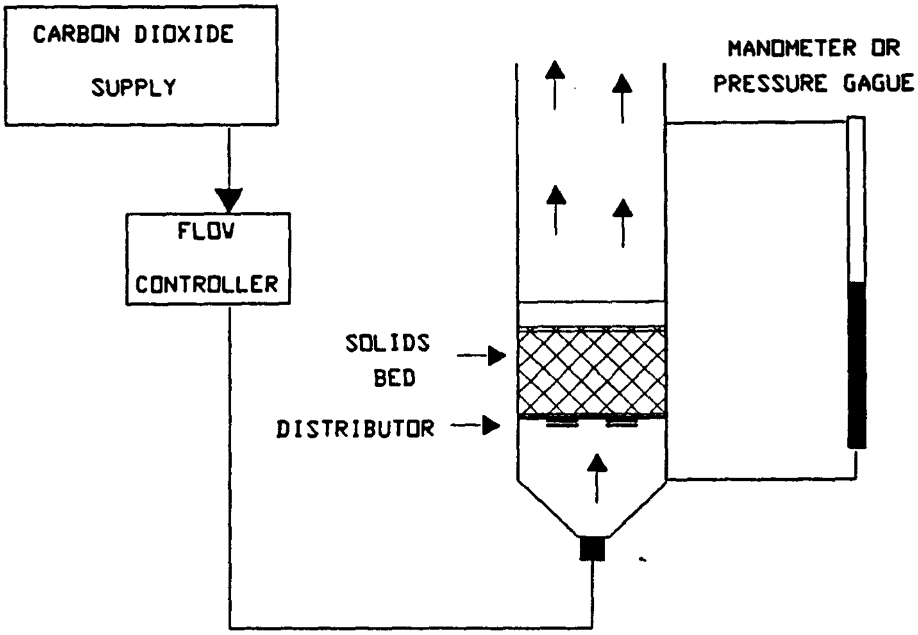


Figure 3.1 Experimental Apparatus for MFV

The velocity of the fluidizing gas at that pressure is the MFV. For gas velocities beyond the MFV, the pressure drop across the solids bed should remain constant. The point at which the pressure drop ceases to be constant with increasing gas velocity and begins to decrease with increasing gas velocity is the velocity at which entrainment is initiated. Also, if the portion of the curve with gas velocities greater than the MFV is very erratic and the pressure drop across the solids bed fluctuates, incomplete fluidization (slugging) and or gas channelling in the bed is occurring.

The pressure drop across the solids bed versus fluidizing gas velocity from the MFV experiments for the -28-mesh crushed feed coal is illustrated in Figures 3.2 and 3.3. Duplicate experiments of MFV determination for each of the crushed feed coals were performed, and the pressure drop data presented is the arithmetic average pressure drop of the two tests for that gas velocity. The average mean deviation of the pressure drop versus gas velocity is 0.62 and 0.26 psf for increasing and decreasing gas velocity MFV tests using Eagle Butte coal. The average mean deviation of the pressure drop versus gas velocity data sets is 0.45 and 0.18 psf for increasing and decreasing gas velocity MFV tests using Usibelli coal.

The MFV for -28-mesh Eagle Butte coal is approximately 1 ft/min (Figure 3.2) and the MFV for -28-mesh Usibelli coal is approximately 3 ft/min (Figure 3.3). The pressure drop across the solids bed at the MFV is approximately 25 psf per foot of solids bed for the -28-mesh Eagle Butte feed coal (Figure 3.2) and 31 psf per foot of solids bed for the -28-mesh Usibelli feed coal (Figure 3.3). Some particle entrainment is occurring at the onset of fluidization in both of the crushed feed coals. In addition, the behavior of the crushed Eagle Butte feed coal indicates some degree of slugging of the bed and channelling (Figure 3.2). The behavior of the crushed Usibelli feed coal indicates that a significant volume of material was entrained in the increasing flow portion of the test (Figure 3.3). This is apparent from the offset of the increasing and decreasing flow curves over the entire velocity range.

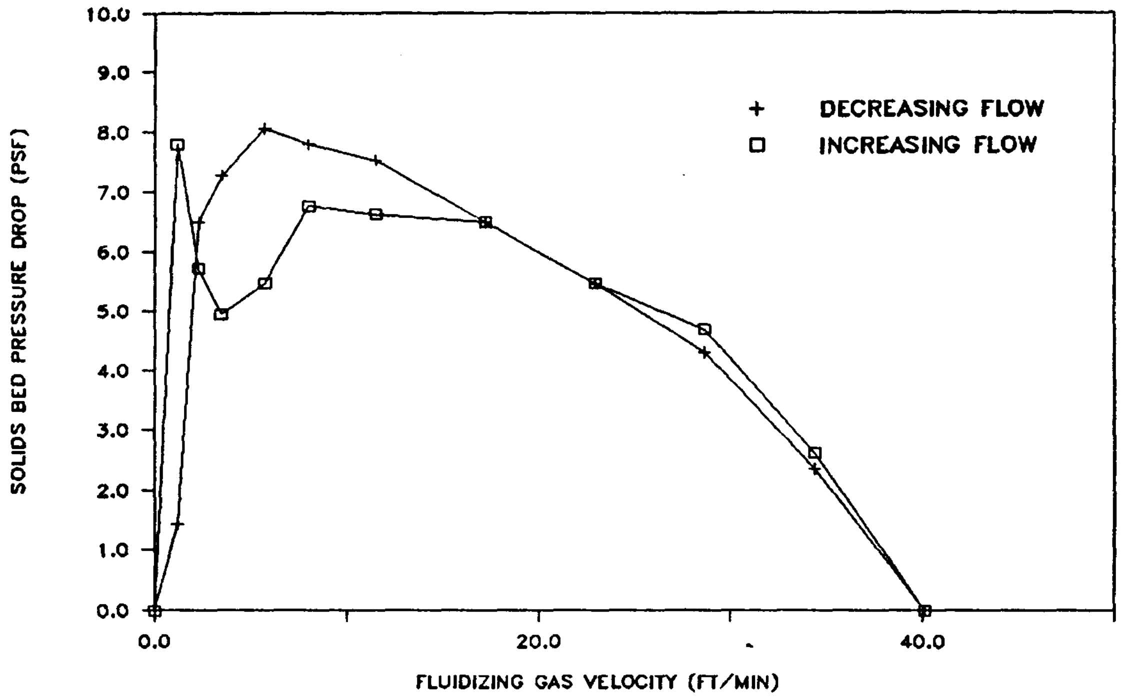


Figure 3.2 MFV Result for Eagle Butte Coal
(4-inch bed of -28-mesh particles)

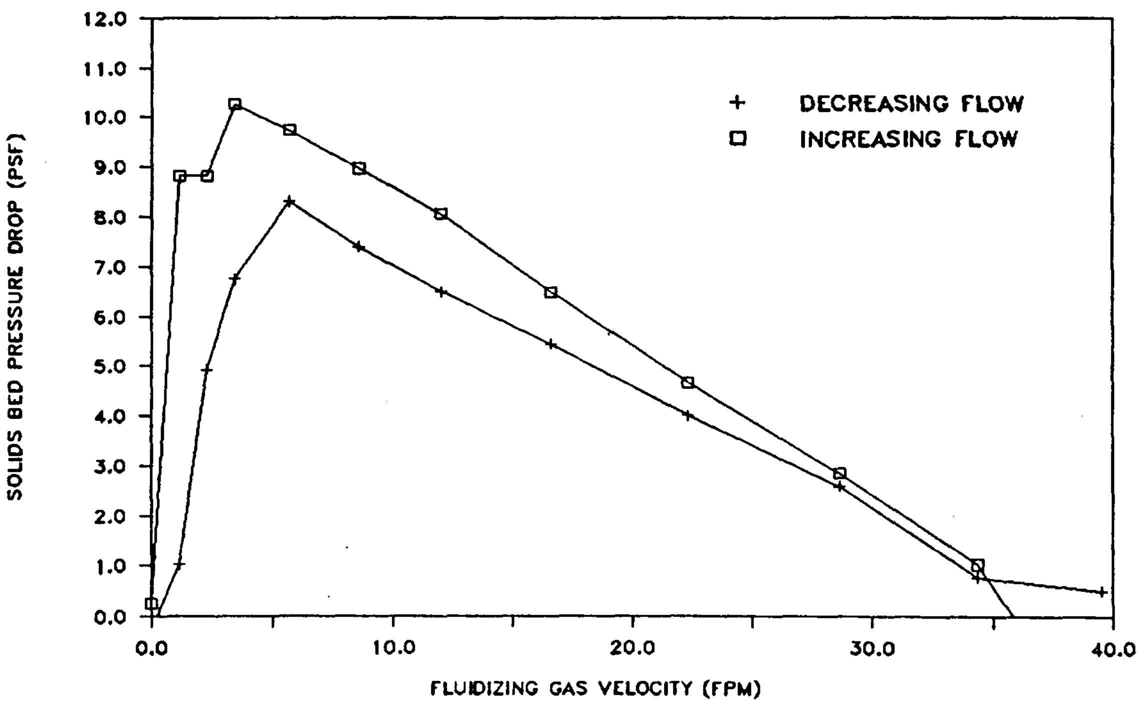


Figure 3.3 MFV Result for Usibelli Coal
(4-inch bed of -28-mesh particles)

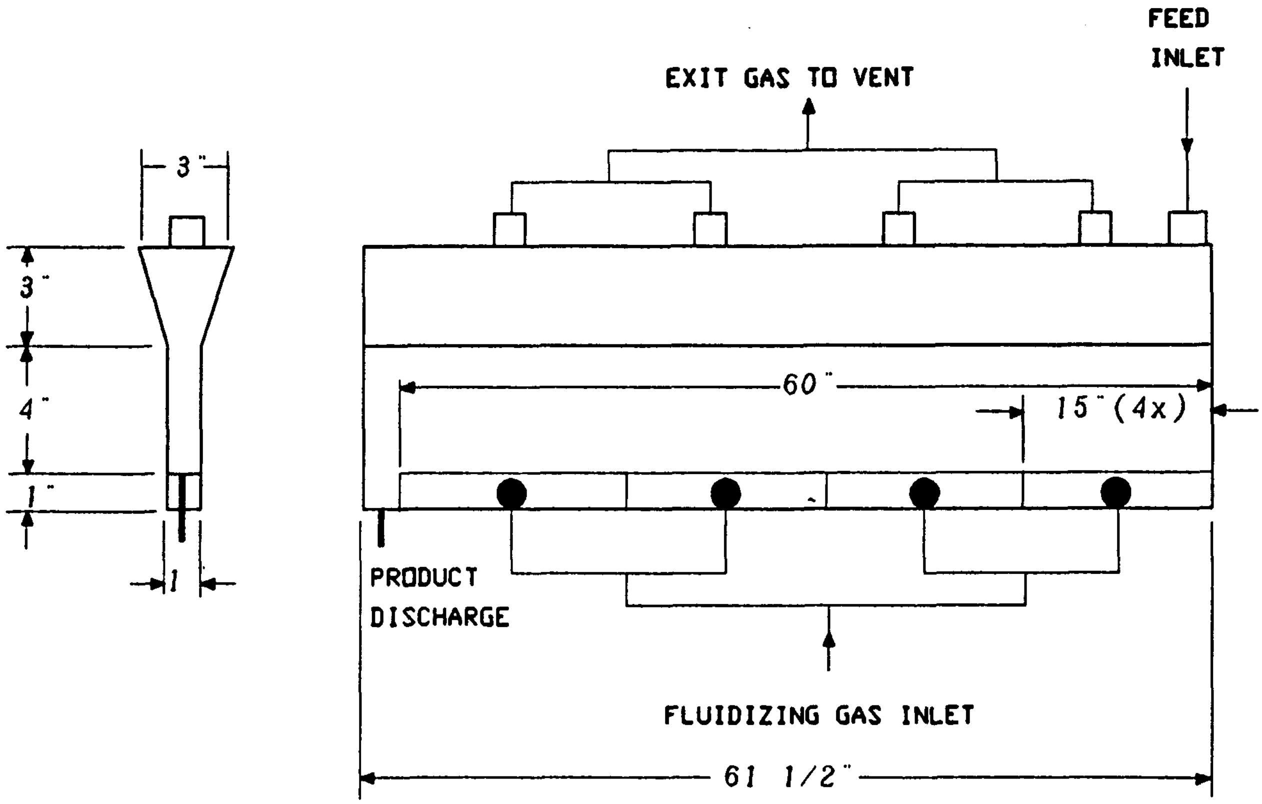


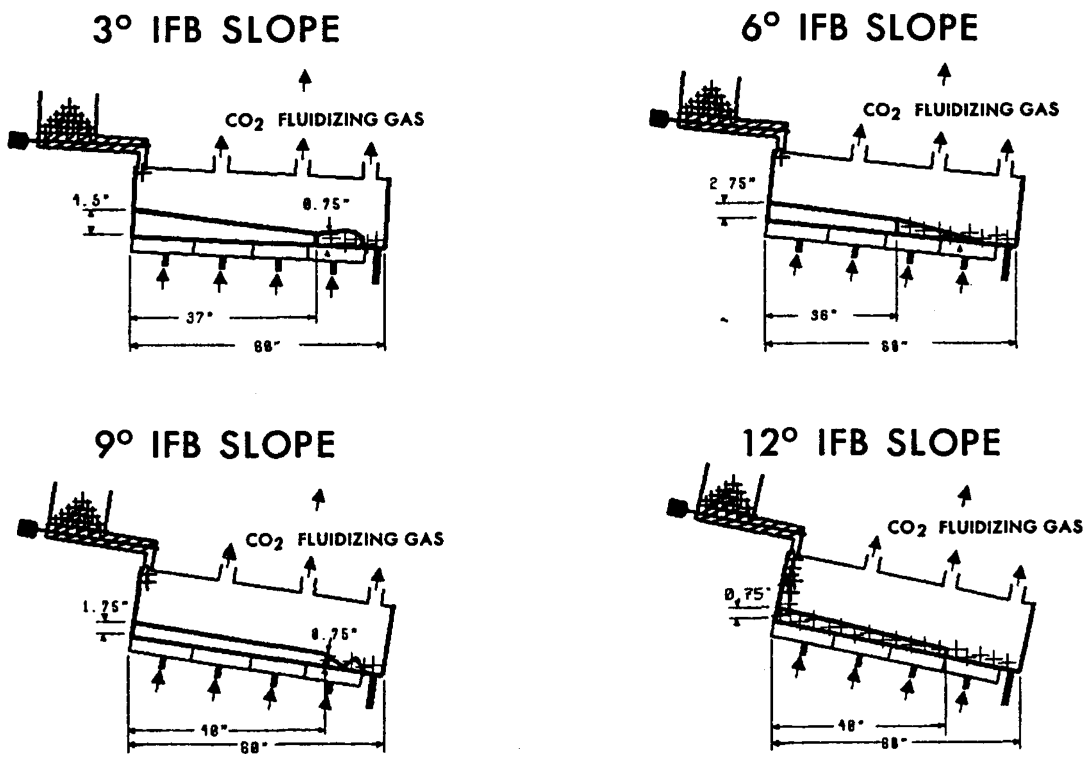
Figure 3.4 Inclined Fluidized Bed Cold Flow Model

Testing of the effects of IFB reactor slope and gas-to-solids ratio on the solids bed geometry and horizontal solids transport was also conducted using the IFB cold flow reactor. The IFB cold flow model is 61.5 inches long and 8 inches high (Figure 3.4). Crushed coal is fed to the reactor using a variable speed screw feeder and lock hopper (not shown in diagram). Carbon dioxide fluidizing gas is supplied to the reactor in controlled amounts using a thermal mass flow controller, and exits the reactor to an atmospheric vent (not shown in diagram).

The results of these tests indicate that horizontal solids transport in the reactor occurs even at low reactor slopes and low gas-to-solids ratios. However, IFB operation at these conditions results in the creation of a static bed in the feed end of the reactor, batch fluidization in the center of the reactor, and continuous fluidization at the discharge end of the reactor. Increase of the reactor slope under these operating conditions results in decreased sizes of the static bed and batch fluidization zones. If the IFB slope is increased sufficiently, an even fluidized bed through the entire length of the reactor results.

The solids bed geometry of Eagle Butte coal (Figure 3.5) was considerably different than the solids bed geometry of Usibelli coal (Figure 3.6) under similar conditions. The geometry of the static zone created using crushed Eagle Butte coal was not as high and was longer than the static zone created using Usibelli coal under similar conditions. However, the effect of increasing IFB reactor slope was similar with both coals. Increased reactor slope tended to reduce the volume of the static zone created at lower reactor slopes and also tended to increase the volume of the fluidized zone.

The observed changes in the solids bed geometry is related to the pressure drop across the solids bed and the configuration of the fluidizing gas distributor. As coal is fed into the IFB reactor it tends to create a pile of a solids bed of a greater depth near the solids inlet.

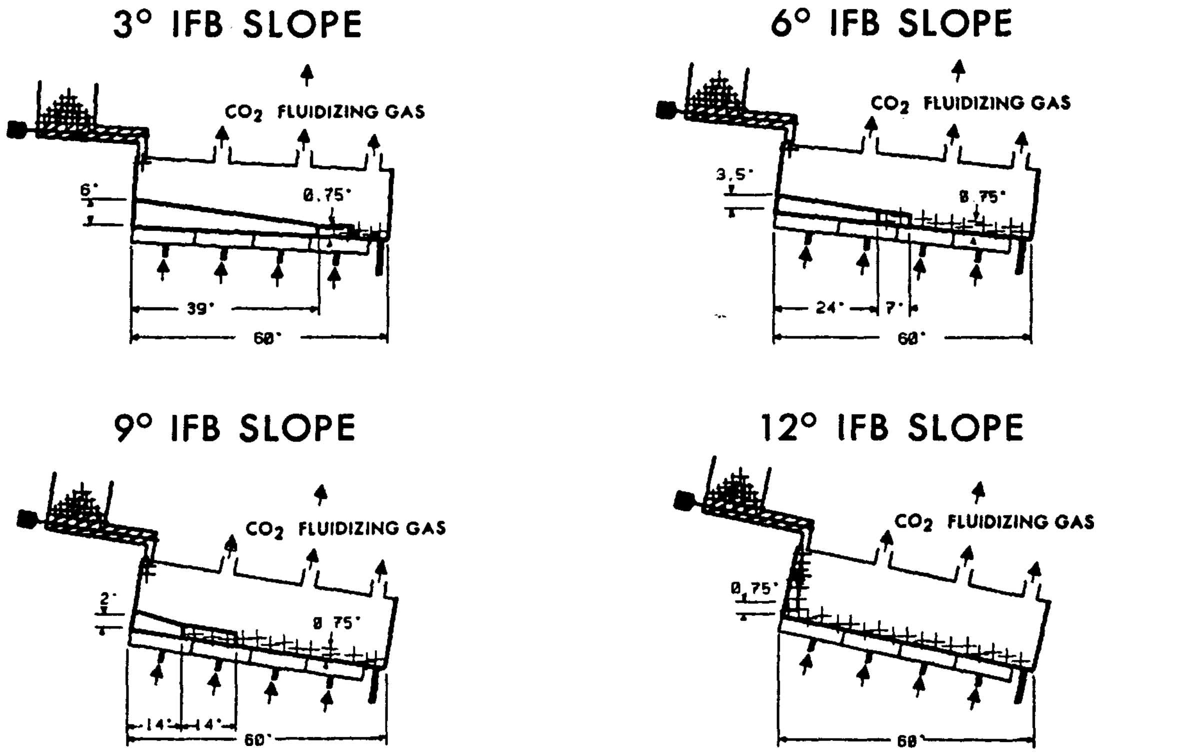


LEGEND

- STATIC BED
- BATCH FLUIDIZATION
- CONTINUOUS FLUIDIZATION

NOTE: EAGLE BUTTE COAL FEED RATE = 10 LB/HR
FLUIDIZING GAS FLOWRATE = 6 SCFM
-28 MESH FEED COAL

Figure 3.5 Effect of IFB Reactor Slope on Solids Bed Geometry for -28-mesh Eagle Butte Coal



LEGEND

STATIC BED

BATCH FLUIDIZATION

CONTINUOUS FLUIDIZATION

NOTE: USIBELLI COAL FEED RATE = 10 LB/HR
FLUIDIZING GAS FLOWRATE = 6 SCFM
-28 MESH FEED COAL

Figure 3.6 Effect of IFB Reactor Slope on Solids Bed Geometry for -28-mesh Usibelli Coal

Because the fluidizing gas distributor feeds the entire length of the reactor, the variations in the depth of the solids bed through the length of the reactor causes an uneven flow distribution with respect to the reactor length. Thus, at low gas-to-solids ratios and small reactor slopes, the fluidizing gas velocity increases through the length of the IFB reactor. The fluidizing gas velocity is the lowest near the reactor inlet and the greatest near the reactor outlet. Figure 3.7 illustrates the effect of the fluidizing gas velocity upon the solids bed porosity and upon the type of solids bed that develops. This diagram is a graphical representation from the literature of the relationship of the log of the solids bed porosity versus the log of the superficial gas velocity (McCabe and Smith 1967). Figure 3.8 relates the MFV data and the cold flow data. This diagram is a graphical representation from the literature of the log of pressure drop across the solids bed versus the log of the superficial gas velocity (McCabe and Smith 1967). Comparison of Figures 3.7 and 3.8 is useful to relate the MFV data (Figures 3.1, 3.2, and 3.3) to the cold flow data (Figures 3.4, 3.5, and 3.6).

At gas-to-solids ratios or reactor slopes that are large enough to prevent solids build up at the solids inlet, we find that the gas velocity appears to be near uniform in the reactor and an even fluidized bed results. Solids residence times were estimated by observing the active bed in the cold flow tests. In all cases, the solids residence time is less than 5 minutes, which agrees with previous tracer tests.

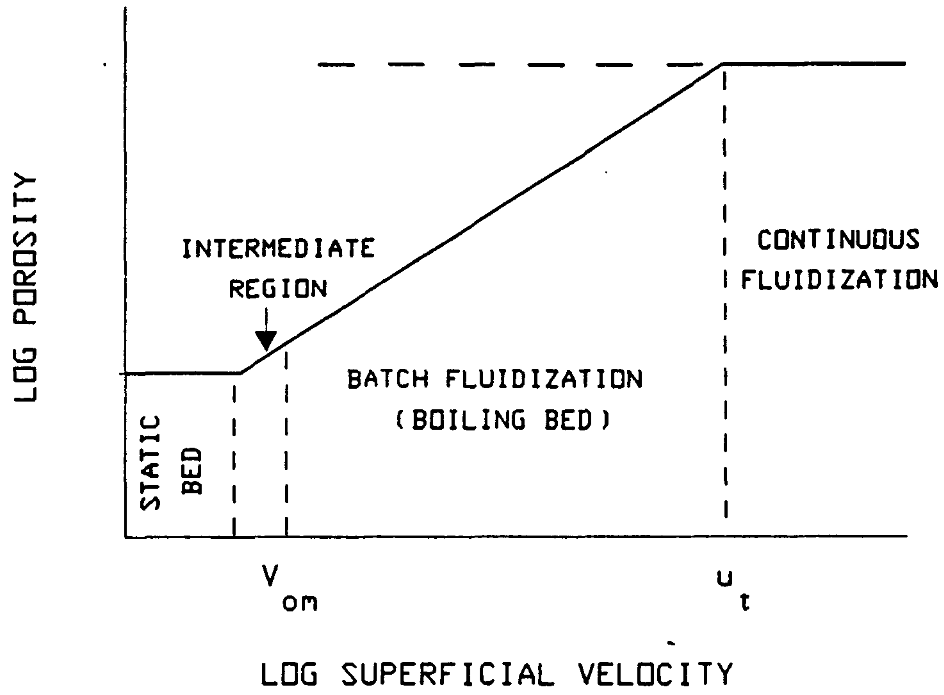


Figure 3.7 Porosity of Fluidized Solids
(from McCabe and Smith 1967)

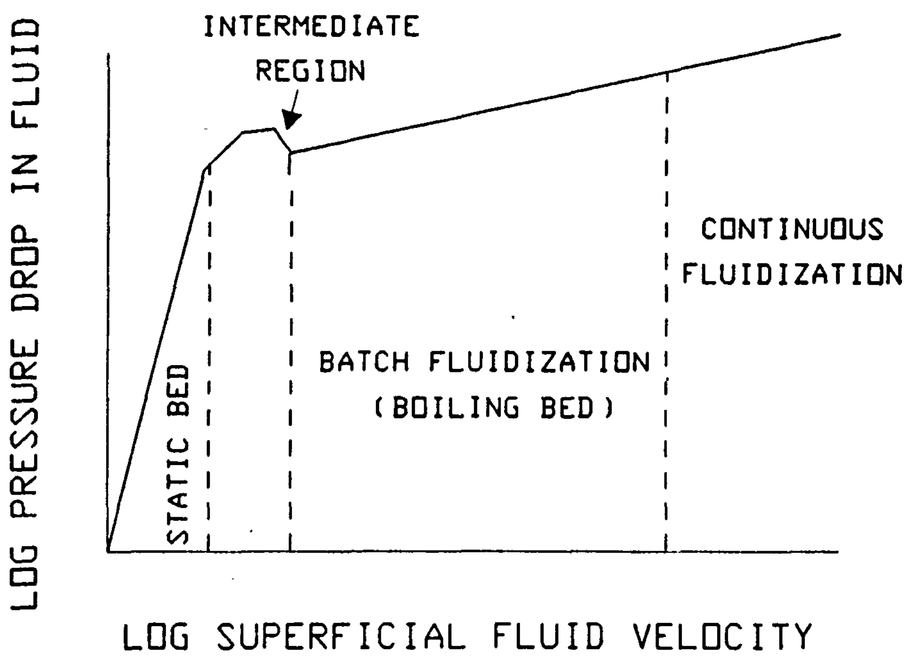


Figure 3.8 Pressure Drop in Fluidized Solids
(from McCabe and Smith 1967)

Testing of the IFB cold flow model will continue and should be completed in the first month of the third quarter. The relationship of particle entrainment to the gas-to-solids ratio and the IFB reactor slope will be investigated.

Subtask 3.2: IFB Drying Tests

Four-hour long drying tests using nominally a 10-lb/hr coal feed rate were conducted. In these experiments the IFB reactor slope, fluidizing gas-to-solids feed ratio, and the average reactor temperature were varied to determine their effects upon drying behavior and particle entrainment. The experimental bench-scale IFB coal dryer process equipment consists of two 5-ft long IFB reactor in series separated by hopper valves that pneumatically isolate the two reactors while allowing for solids transfer from the first reactor to the second (Figure 4.1).

Controlled amounts of CO_2 fluidizing gas are introduced into each of the IFB reactors. In the first reactor, the IFB coal dryer, the CO_2 fluidizing gas is heated prior to introduction into the dryer, and this hot fluidizing gas supplies the process heat required for drying the coal fed to the reactor system. The coal is fed to the dryer from a sealed hopper using a variable-speed screw conveyor. Fine coal particles that are entrained in the fluidizing gas that exits from the dryer are collected in a cyclone separator and in a settling chamber (secondary fines collector).

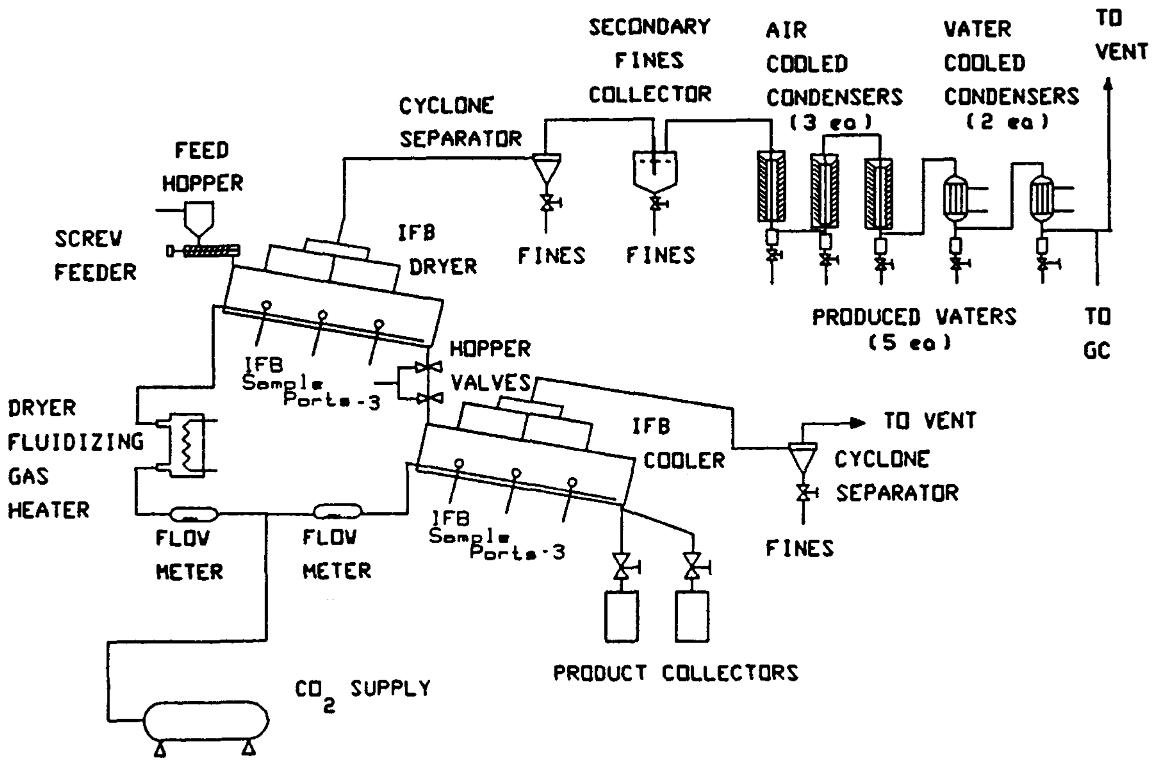


Figure 4.1 Experimental IFB Coal Dryer

The exit gas from the settling chamber flows into a series of three air-cooled and two water-cooled condensers to remove water from the gas. A small amount of the dry solids free gas is sampled and analyzed using a gas chromatograph (GC). The remainder of this gas is vented to atmosphere (Figure 4.1).

The fluidizing gas introduced into the second IFB reactor (IFB cooler) is at ambient temperature and is used to cool the dried coal fed to the second reactor from the IFB dryer. Entrained solids in the exit gas are collected in a cyclone separator prior to venting the gas to atmosphere. The cooled dry coal is collected as product after it exits the IFB cooler (Figure 4.1).

Eleven 4-hr IFB bench-scale drying tests were conducted using Eagle Butte coal and IFB reactor slopes of 3, 6, and 9 degrees. The first of these test was a hot shakedown. During these tests, gas-to-solids ratios ranging from 2.2 to 9.9 lb/lb (kg/kg) and average reactor temperatures ranging from 588 to 691°F (309 to 366°C) were investigated. In all of these experiments, the dried coal product contained less than 0.5 % moisture based upon proximate analysis. The heating value of these products was elevated from 8470 Btu/lb for the feed coal to over 11,950 Btu/lb. The resulting product heating value correlates reasonably well to the heat input/mass of feed. Two preliminary 4-hr IFB bench-scale drying tests were also conducted using Usibelli coal. Results were similar to those of testing using Eagle Butte coal. Experimental conditions, product proximate moisture content, and product heating values for the four hour tests are listed in Table 4.1.

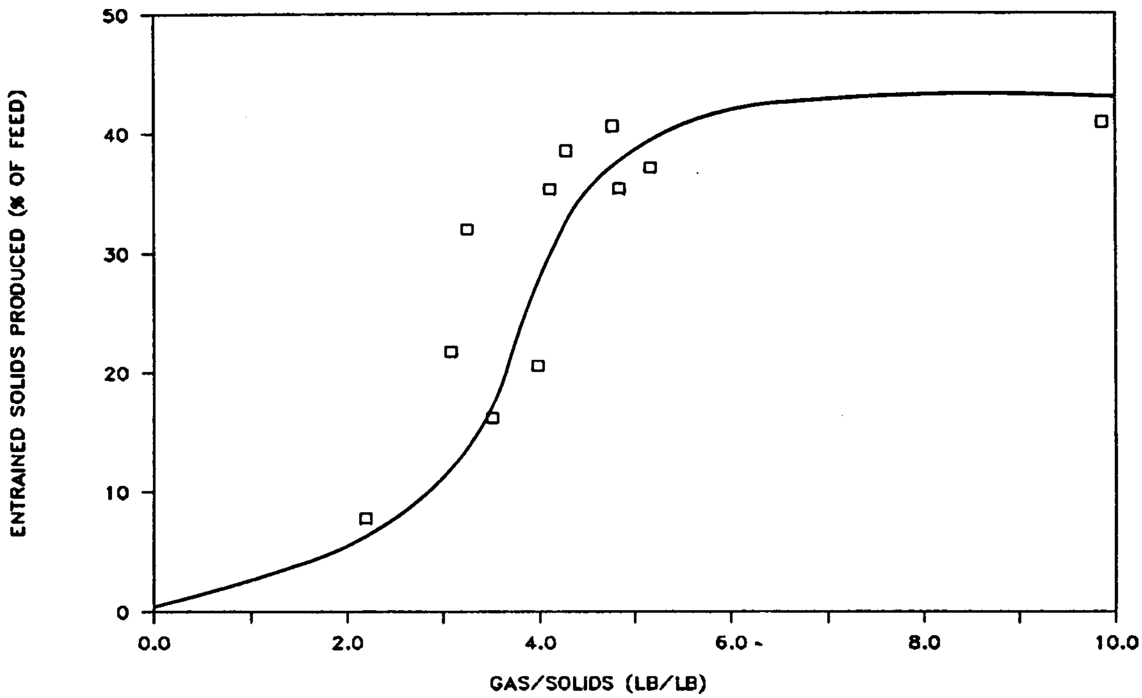


Figure 4.2 Entrained Solids versus Gas/Solids (-28-mesh Eagle Butte feed coal)

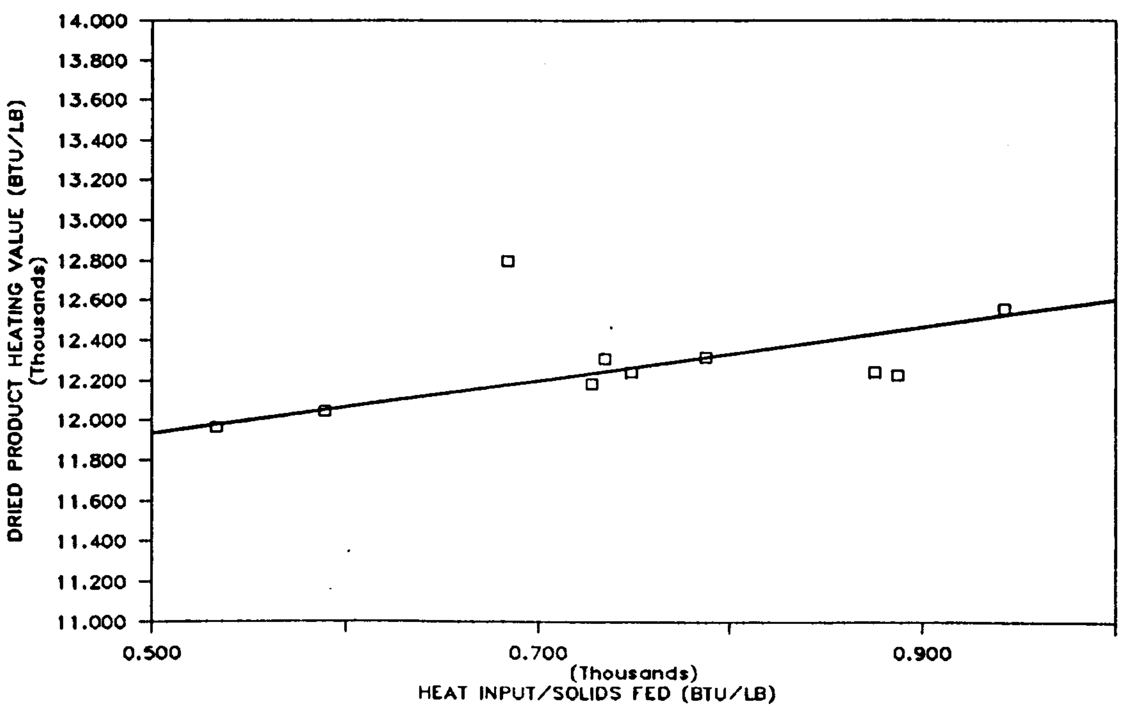


Figure 4.3 Product Heating Value versus Heat Input/Solids (-28-mesh Eagle Butte feed coal)

Table 4.1 Experimental Conditions for 4-Hr IFB Bench-Scale Drying Tests

Feed Coal -28-mesh	Reactor Slope, degrees	Gas to Solids, lb/lb	Av. Dryer Temperature, °F	Product Moisture, %	Product HHV, Btu/lb
Eagle Butte	3	9.9	588	***	*****
"	3	5.2	598	0.0	12250
"	"	4.8	589	0.1	12230
"	6	4.3	594	0.2	12250
"	"	4.1	597	0.0	12320
"	"	4.0	624	0.0	12320
"	9	3.2	608	0.0	12050
"	"	3.5	588	0.0	12801
"	"	2.2	591	0.1	11970
"	"	4.8	690	0.0	12560
"	"	3.1	691	0.0	12190
Usibelli	9	2.5	621	0.0	11520
"	"	2.7	657	0.0	11170

The amount of entrained solids produced from the IFB dryer is of economic significance to plans for use of coal fines. The entrained solids production is related to the fluidizing gas velocity, the solids feed rate, and the particle size distribution of the coal. The relationship of the entrained solids production to the gas-to-solids ratio for each experiment using -28-mesh Eagle Butte feed coal is graphically illustrated in Figure 4.2. If the gas-to-solids ratio is maintained below 3 lb/lb (kg/kg), entrained solids production from the dryer is less than 10% of the feed coal. Further, the entrained solids production is approximately 40 wt % of the feed coal for gas-to-solids ratios greater than 4.5 lb/lb (kg/kg). The particle size distribution of the predried -28-mesh Eagle Butte feed coal (Figure 2.2) illustrates that 40 wt % of this crushed feed coal is -65-mesh.

The heating value of the dried coal product as a function of the heat input rate into the IFB dryer divided by the coal feed rate is also presented for the experiments using Eagle Butte feed coal (Figure 4.3). These data correlate reasonably well, and the heating value of the product increases slightly with increasing heat input per solids feed. The heat input rate for the experiments was calculated based upon the temperature of the fluidizing gas entering the reactor and the temperature of the gas in the secondary fines collector. We assumed an average heat capacity of the CO_2 fluidizing gas of 0.27 Btu/lb °F (Pcu/kg °C) for the calculation.

Task 4: Product Characterization and Testing

Subtask 4.1: Moisture Reabsorption

Equipment required for this subtask was calibrated and made ready in the final part of the second quarter. Samples of experimental products will be sent to AMAX Research and Development early in the third quarter. No schedule problems exist or are anticipated.

Subtask 4.2: Dust Formation

Same as subtask 4.1.

Subtask 4.3: Spontaneous Heating

Same as subtask 4.1.

Subtask 4.4: Surface Treating

Not scheduled in the second quarter.

Task 5: Technical and Economic Evaluation

Not scheduled in the second quarter.

SUMMARY, STATUS AND PLANNED ACTIVITIES

The project technical achievements at the end of the second quarter are primarily related to understanding of the behavior of the two coals in the IFB reactor. The chemical analyses of the two feed coals indicate that they are similar in nature. However, subsequent physical characterization of the crushed feed coals indicate different physical properties. When crushed, the Eagle Butte coal produces more fine particles than the Usibelli coal. This observed difference in particle size distribution results in differences in the MFVs of the two coals, and the differences in the MFVs result in the development of solids bed with differing geometries when tested in the IFB cold flow model under similar operating conditions. In short, the two coals, which appear to be chemically similar, will behave somewhat differently with respect to entrained solids production and particle residence times when dried in the IFB reactor. We also found that a dry product with minimal proximate moisture an substantial increased heating value can be produced from either of these coals under a wide variety of fluidizing gas-to-solids ratios and IFB operating temperatures when they are processed in the IFB reactor. The production of entrained solids from the fluidized-bed reactor can be kept near 10 wt % of the feed coal by reducing the fluidizing gas-to-solids ratio in the IFB reactor below 3 lb/lb (kg/kg).

The project financial status is summarized by the fact that the total project expenses are 90% of the planned cost at the end of the second quarter. The delay in completion of the TGA studies (subtasks 2.2 and 2.3) is the reason the project expenses are under the budgeted figure.

Task 1 and Subtask 2.1 are complete. Subtasks 2.2 and 2.3 are behind schedule because of a backlog of experimental work that resulted from mechanical problems before the second quarter. Efforts were made to reduce this backlog in the second quarter and arrangements have been made to complete these tasks early in the third quarter. Subtask 3.1 is nearing completion and it is also expected to be completed early in the third quarter. Subtask 3.2 is proceeding at a pace that is ahead of the project schedule. This pace is expected to be maintained and it is anticipated that this subtask will be completed ahead of schedule, at the end of the third quarter or early in the fourth quarter. Task 4 is on schedule and strong progress in this area is anticipated in the third quarter and the planned completion of this task early in the fifth quarter is expected to be on schedule. No problems are expected that would delay the start of Task 5 at the beginning of the fifth quarter.

Activities planned for the third quarter are:

(1) All TGA studies required to complete subtasks 2.2 and 2.3 are expected to be performed.

(2) IFB cold flow tests required for the completion of subtask 3.1 are expected to be performed.

(3) The twenty remaining four hour duration IFB drying tests and four of the eight required twelve-hour duration drying tests are expected to be performed.

(4) Preliminary results for characterization of the experimental products from selected four-hour experiments and possibly the twelve-hour experiments are expected to be performed.

In closing, the project is being performed in a manner that is close to schedule and budget. Some areas are behind the schedule and some are ahead of the schedule. At this time the project is expected to be completed on schedule and at the budgeted cost.

REFERENCES

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McCabe, W.L., J. C. Smith, **Unit Operation of Chemical Engineering**, 2nd ed, McGraw-Hill, 1967.