TECHNICAL REPORT
December 1, 1994 through February 28, 1995

Project Title: **COMBUSTION OF CHAR-COAL WASTE PELLETS FOR HIGH EFFICIENCY AND LOW NO_x**

DOE Cooperative Agreement Number: DE-FC22-92PC92521 (Year 3)
ICCI Project Number: 94-1/5.2A-1M
Principal Investigator: S. Rajan, Southern Illinois University at Carbondale
Project Manager: Frank Honea, Illinois Clean Coal Institute

ABSTRACT

High efficiencies can be obtained from combined cycle power plants where fuel gas produced in a carbonizer is used to power the topping cycle turbines, while the residual char is burnt to raise steam for the bottoming Rankine cycle plant. Illinois coals are excellent fuels for these high efficiency power plants as the sulfur in the fuel gas is removed in the carbonization process by adding dolomite, thus producing a clean burning fuel gas. The residual char has essentially no volatiles, and is of low density. Because of these characteristics the char requires a longer residence time for efficient combustion.

This research is directed towards improving the residence time of the char by pelletizing it with a waste coal, while at the same time reducing the sulfur dioxide emissions from the char combustion.

During this quarter, extensive experimentation has been performed to determine the char-gob waste proportions necessary for forming pellets with desirable compression strength for feeding into the circulating fluidized bed combustor. Carbonizer char-gob coal pellets have been made with 5, 10 and 15 weight percent of cornstarch binder. Based on the test data presented, it is concluded that 10-15% weight percent of binder will be required when pelletizing char-gob coal waste mixtures containing 30-40 percent by weight of gob coal.

During the next quarter, these pellets will be made in larger quantities and their combustion and emissions properties will be evaluated in a bench scale 4-inch diameter circulating fluidized bed combustor.

U.S. DOE Patent Clearance is NOT required prior to the publication of this document.

EXECUTIVE SUMMARY

Advanced power generation schemes using a carbonizer in conjunction with pressurized fluidized bed combustors offer definite advantages in terms of efficiency gains compared to single cycle units. The fuel gas produced in the carbonizer can be utilized as the heat input to the Brayton topping cycle, while the residual char from the carbonizer can be burnt in the Brayton cycle exhaust gas to raise steam for the Rankine bottoming cycle. To investigate the suitability of Illinois and other coals for these advanced power cycles, an investigation was conducted recently under ICCI sponsorship in collaboration with Foster Wheeler Development Corporation, wherein chars taken from different locations in the carbonizer were combusted in an atmospheric fluidized bed combustor. The combustion efficiency and the sulfur dioxide and NO_x emissions from the chars were measured. It was found that the combustion efficiency of the chars could be improved by increasing the combustor residence time of these fuels. The present work, which is an extension of the one mentioned above, investigates methods of improving the char burning characteristics while reducing sulfur dioxide and oxides of nitrogen emissions.

Thus, the research objectives are:

1. to pelletize the low volatile pyrolyzer char from Illinois coals obtained from FWDC with coal wastes using cornstarch or lignin as binder.
2. to conduct combustion experiments with the char pellets in a bench scale circulating fluidized bed combustor and measure carbon conversion efficiencies and SO_2, NO_x, N_2O, HCl, and other emissions.
3. to conduct similar experiments with the char alone.
4. to demonstrate the increased carbon conversion efficiency and lower SO_2, NO_x and other emissions obtainable from the char-waste coal pellets.

During the previous quarter, data on the particle size and elemental analysis of the test chars was reported. In addition, small quantities of pellets were made by mixing 0-30 percent parent coal with the chars.

In this quarter, the use of waste gob coal has been investigated as a blending component with the char. This will utilize a waste fuel while improving the combustion properties of the char. The tests show that gob waste can be easily blended with the pyrolyzer char to make pellets suitable for combustion. In addition, both wood lignin and cornstarch were tested as binders. It was found that cornstarch is better suited for holding together the char-gob waste pellets than wood lignin. Different amounts of both distilled and tap water was used in the experiments to study if distilled water offered any advantages.

Two sizes of pellets were made. Single pellets 0.5 inches in diameter and 0.5 inches long were made in a die press to study the influence of

(a) die force
(b) water type (distilled vs. tap water)
(c) amount of binder

on the compression strength of the pellets. These pellets did not have any other blended fuel. This was done to obtain baseline data with the char alone before blending.

The results from these tests show that ordinary tap water is just as suitable for use in the pellet-forming process than distilled water. The data also indicates that for the low density, powdery pyrolyzer char used in the experiments, no gain in compressive strength is realized by increasing the binder concentration over 10% when the char is pelletized without any other blended fuel.

To investigate the influence of gob coal as a blending agent, a second type of pellet 0.125 inches in diameter, 0.3-0.5 inches long was made. This size of pellet has been tested

previously in the circulating fluidized bed combustor. Experiments were conducted with the char-gob coal pellets to investigate the influence of

(a) char/coal weight ratio
(b) binder concentration

on the pellet compression strength.

The results of these tests show that increasing the char content of the pellets in proportion to the gob coal reduces the compression strength. Increasing the percentage of binder, however, increases the pellet compressive strength. No limestone was used in these pellets as the char itself contains calcium sulfide resulting from the use of dolomite or limestone during the carbonizing process.

Having established the char-gob coal blending proportions and the binder concentration necessary for making pellets suitable for combustion, it is planned to conduct tests in the circulating fluidized bed combustor during this next quarter to measure the combustion efficiency, sulfur and oxides of nitrogen emissions.

OBJECTIVES

The objectives of the research are:

1. to pelletize the low volatile pyrolyzer char from Illinois coals obtained from FWDC with coal wastes using cornstarch or lignin as binder.
2. to conduct combustion experiments with the char pellets in a bench scale circulating fluidized bed combustor and measure carbon conversion efficiencies and SO_2, NO_x, N_2O, HCl, and other emissions.
3. to conduct similar experiments with the char alone.
4. to demonstrate the increased carbon conversion efficiency and lower SO_2, NO_x and other emissions obtainable from the char-waste coal pellets.
5. to investigate the effects of cornstarch and lignin as binders.
6. to analyze the ash and spent limestone residues with a view to proposing waste disposal strategies.

INTRODUCTION

Illinois coals have good potential for use in advanced High Efficiency Power Plants (HIPPs) because of their good gasification properties and high reactivity. Companies such as Foster Wheeler Development Corporation and others are currently involved in developing such High Efficiency Power Plants. The approach here is to partially gasify the coal in a pyrolyzer producing a fuel gas that will power the topping cycle gas turbine. The residual char will then be burnt to raise steam for the Rankine cycle bottoming plant.

Because the char is low in volatiles and its density is lower than the original coal, it tends to elutriate from the bed during fluidized bed combustion and carbon conversion efficiencies are reduced. The work proposed here seeks to improve the char carbon conversion efficiency while also finding an end-use for waste coals from gob piles. This is accomplished by pelletizing the char with the gob pile wastes using cornstarch or wood lignin as binder. Additional limestone may be added to the pellets as necessary. The char pellets will be burnt in a 4-in. internal diameter circulating fluidized bed combustor to investigate carbon conversion efficiencies, SO_2, NO_x and HCl emissions. The results will be correlated with other literature data. The use of char from Foster Wheeler Development Corporation, a leading boiler manufacturing contractor to DOE on these IGCC projects, provides a direct link to near term commercialization of this technology. The successful utilization of Illinois high sulfur coals via IGCC plants will provide near term economic benefits to the coal industry by overcoming the roadblocks currently placed upon it by the current stringent Environmental Protection Agency (EPA) emissions requirements. The high volatility and good reactivity of Illinois coals make it a viable coal for IGCC applications, with good opportunities for success. The enhanced char-pellet combustion, emissions and reactivity data obtained from the research in the bench scale experiments will make Illinois coals more attractive for these IGCC applications. The research will extend the database and permit high efficiency IGCC plants to be designed and fired with Illinois high sulfur, high chlorine coals.

In particular, the research will

(a) reduce the difficulties in burning the low volatility char
(b) ensure overall high plant efficiency which is not possible without the char utilization
(c) promote lower emissions of SO_2, NO_x, N_2O from char combustion

EXPERIMENTAL PROCEDURES

I. Equipment and Instrumentation

The experiments are being conducted in the 4-inch internal diameter circulating fluidized bed combustor shown schematically in Figure 1. The combustor is lined with a castable refractory to reduce heat losses. As shown in Figure 1, a blower supplies fluidizing air that is split into two streams. The main stream enters the fast fluidized bed section of the combustor through a distributor plate specially designed to provide even fluidization. This section of the air duct also houses a propane-fired preheat system, which is utilized to bring the bed solids up to temperatures required to ignite the main fuel. Unburnt fuel, limestone and ash entrained by the gases in the main bed column pass through a refractory-lined hot cyclone, which traps the larger particles and deposits them into an auxiliary bubbling bed attached to the bottom end of the hot cyclone. The second smaller air stream enters this bubbling bed into which the carry-over solids from the fast fluidized bed trapped by the hot cyclone are deposited. A non-mechanical seal ensures that this unburnt fuel and bed solids flow from the bubbling bed into the fast fluidized bed and not vice-versa. Both air streams are metered with ASME nozzles and incorporate control valves for adjusting the flow velocities in the fast fluidizing and bubbling bed sections of the combustor.

Crushed and sieved coal is fed from a pressurized hopper via a screw feeder pneumatically into the dense portion of the fast fluidized bed, using metered high pressure air. Sized limestone, stored in a separate hopper, is fed simultaneously into the air stream, conveying the coal into the bed. Both coal and limestone feed systems have been calibrated individually.

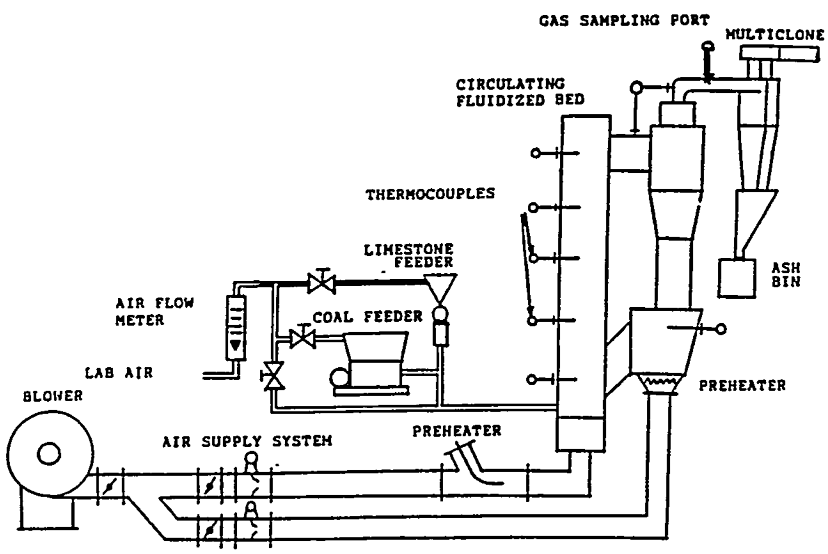


Figure 1. Schematic of 4-Inch Internal Diameter Circulating Fluidized Bed Combustor

Two quartz, glass-lined observation ports, one located in the dense bed at the bottom and the other located near the top in the dilute phase or transport section of the bed, serve for visual monitoring of the combustion process. The circulating fluidized bed combustor is instrumented with chromel-alumel thermocouples at various positions for measuring temperature. The thermocouples are connected to a selector switch and, thence, to a digital readout meter.

Solids too small to be captured by the hot cyclone are trapped in a multiclone, mounted at the hot cyclone exit. In the present system, these multiclone solids are not reinjected into the bed. The multiclone solids are later analyzed for heat content, using an adiabatic calorimeter. Combustion gases are drawn off from a point at the exit of the multiclone, filtered through 2-5 micron particulate filters, and conveyed via heated lines to an instrument panel for determining gas composition. Carbon monoxide and carbon dioxide are measured with Beckman NDIR analyzers, oxygen with a Beckman 755 paramagnetic analyzer, oxides of nitrogen, NO_x, with a Thermoelectron 10 AR chemiluminescent analyzer and sulfur dioxide with a Beckman IR analyzer. HCl is measured with a Thermoelectron gas filter correlation hydrogen chloride analyzer.

II. Test Procedures

CFBC Combustion and Emissions Tests

The combustion testing of the pellets involves the following steps:

* The CO, CO_2, O_2, NO_x and SO_2 analyzers are calibrated at the beginning and at several times during a test burn.
* The CFBC combustor is filled with the proper amount of bed material (sand or limestone).
* The propane preheat system is fired the bed material and unit is brought up to about 1100-1200°F. This step takes several hours.
* Coal and limestone hoppers are filled with prepared standard coal and limestone sorbent, respectively.
* The coal feed is initiated and the CFBC unit is brought up to operating temperatures of around 1500°F on the standard coal. The operation of all sampling and control systems are checked.
* For tests with the standard coals and the char-coal waste pellets, typical values of operating variables are as follows:

fluidization velocity 9 ft/sec
Ca/s ratio 1-4
Bed temperature≈1450-1650°F

These parameters are kept constant with all the fuels, so that comparison of the combustion and emissions parameters can be made under identical conditions of operation.

* No additional limestone sorbent will be injected during initial tests. If SO_2 emissions are higher than EPA limits, further tests will be conducted with limestone injection.
* Six to ten test runs are planned to be made. Each test run is made after the combustor has reached steady state conditions. Combustor steady state conditions are usually achieved after 30-48 hours of operation. Where test fuel supplies are limited, the procedure adopted is to first bring the combustor to steady state operation on the standard coal or another Illinois coal, and then change the fuel feed to the test coal, only for the duration of the steady state data acquisition period.
* The variables measured during a test include:

- fuel and air mass flows
- air superficial velocity
- bed temperature
- other temperatures at various combustor locations
- combustion gas analysis comprised of CO, CO_2, O_2, NO_x, HCl and SO_2 emissions
- test duration time
- quantity of ash collected in cyclones during test period

Combustion generated ash and spent limestone from the experiments are analyzed. The heat content of the elutriated unburnt carbon is determined from calorimetry tests. Spent limestone and ash are prepared on metal stubs and subjected to energy dispersive x-ray (EDX) analysis to determine the elements present in the samples.

Sample Analysis

(a) Proximate and Ultimate Analyses

Proximate and ultimate analyses of the parent coals and chars are obtained using standard ASTM procedures at the Coal Technology Laboratory at Carterville, Illinois.

(b) Particle Size Analysis

Particle size analysis in the range below 125 microns is measured utilizing a Leeds and Northrop Microtrak Model 7995-10 particle size analyzer. A schematic of the instrument is shown in Figure 2. In this version of the instrument, a laser beam is projected through a transparent cell that contains a stream of moving particles suspended in a liquid. Light rays that strike particles are scattered through angles that are inversely proportional to their sizes. The rotating optical filter transmits light at a number of predetermined angles and directs it to a photodetector. Electrical signals proportional to the transmitted light flux values are processed by a microcomputer system to form a multichannel histogram of the particle size distribution.

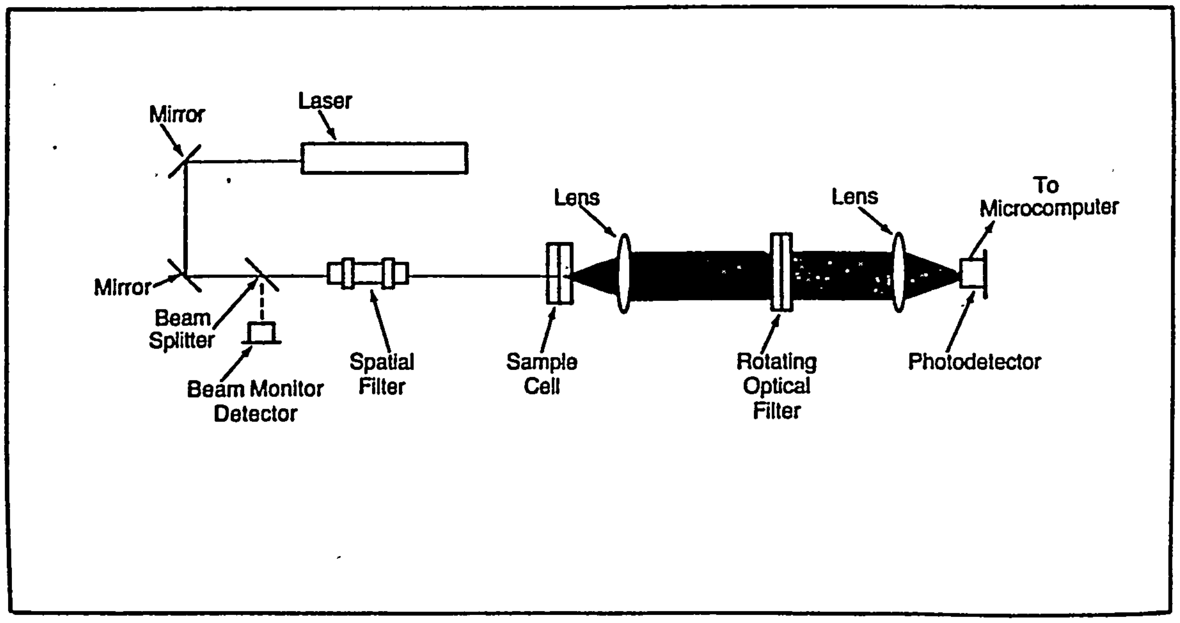


Figure 2. Schematic of Microtrak Particle Size Measurement System

(c) Mineral Matter Analysis

The mineral matter analysis of the coal in the pellet fuels and the reference Illinois No. 6 coal is conducted with a Hitachi H-600 analytical electron microscope operating both in the transmission and the scanning-transmission electron microscopy (STEM) modes. With STEM, a Tracor-Northern energy dispersive x-ray (EDX) Model 5500 analysis system was employed. The specimen samples were mounted on adhesive copper grids and examined at 100 kV in the electron microscope. The samples were uncoated.

Data Analysis

From the measured data the following parameters will be computed:

* excess-air ratios
* Ca/s mole ratios
* carbon conversion efficiency
* sulfur capture efficiency %
* SO_2 emissions levels in lb/10^6 Btu
* NO_x emissions levels in lbs/10^6 Btu
* HCl emissions levels in lbs/10^6 Btu
* carbon balances

RESULTS AND DISCUSSION

1. Pelletization of Carbonizer Char

(a) Pellets with No Binder

Tests were conducted to obtain baseline data on char pelletization. Since the char is of low density with high porosity, the strength of pellets formed from char will be different from that formed with coal. Hence, these tests were conducted with the char without adding any other fuel component to it to examine the compaction pressures necessary for forming the pellets.

The pellets were made using a mold and die press and were 0.5 inch in diameter and 0.3 to 0.5 inches long. The char was produced from an Illinois No. 6 coal in the Foster Wheeler Development Corporation pyrolyzer. Its analysis was given in the last quarterly report.

The char was mixed with water and pellets were made from it. Both tap water and distilled water were used to see if the water type had any influence on the pellets. The pellets were then dried and their compression strength determined. The binder used was cornstarch. The compaction force was varied during the tests.

Figures 3 and 4 show the influence of die force used while making the pellet on the compression pressure that the pellet was able to withstand before fracture. The compression pressure measured in lbs/in^2 (psi) has been divided by the ratio of the diameter to the height of the pellet (d/h) as shown in the figures. This is labeled as "Comp. Load/(d/h) ratio" in the graphs. The figures show that as the compaction force is increased from 1000 lbs to 3000 lbs, the maximum compression pressure increases. However, beyond a compaction pressure of 3000 lbs, the compression pressure actually decreases. As seen from the figures, the use of distilled water does not offer any significant advantages over ordinary tap water.

(b) Influence of Binder Concentration on Pellet Strength

To investigate the influence of binder concentration on pellet strength, char pellets were made with cornstarch binder. This particular brand of binder goes under the brand name PCF1000 and was used in previous tests sponsored by the Illinois Clean Coal Institute at the Illinois State Geological Survey. It is marketed by the Lauhoff Grain Company in Danville, Illinois, and is a pregelatinized cornstarch. Binder concentrations by weight of 5, 10 and 15 percent were investigated. Again, the pellet size is a nominal 0.5 inch diameter and 0.25 to 0.5 inches in height. The compressive strength (psi) of the dried pellets (which initially had 23% water) is plotted divided by the diameter/height (d/h) ratio for these pellets in Figures 5-7.

Figure 5 shows that the compressive pressure/(d/h) ratio for the pellets with 5% binder reaches its maximum value of about 710 psi at a die pressure of 3000 lbs. Further increase in compaction pressure does not produce any appreciable change in the compression strength. When the binder concentration is increased to 10% by weight, Figure 6, the compression strength is about 1400 psi, even at the low compaction force of 1000 lbs, which is much higher than that of the 5% binder pellets. With further increase in compaction force to 5000 lbs, the maximum compression load in psi increased to 2550 psi. Increasing the compaction die force further, however, only brought about a reduction in the compression strength to about 1050 psi.

These results indicate that 10% by weight binder in the char pellet gives the pellet good abrasion and attrition resistance with the particles of the char bound together at their surfaces of contact with adequate amounts of binder. With only 5% binder, not enough binder is present to give this bonding strength to the particles of char. With compaction pressures of over 5000 lbs, the compression strength reduces, possibly because the char particles are crushed in the pellet forming process and thereby lose their strength. With increase in binder concentration to 15%, Figure 7, there is a competing effect seen at die forces of over 5000 lbs. The char particles are being crushed on the one hand by the high compaction pressure, while on the other hand binder is being forced into the pores of the char as the compaction force is increased beyond 5000 lbs. Hence, we see an increase in compression strength beyond 5000 lbs compaction pressure, Figure 7.

2. <u>Pelletization of Carbonizer Char-Gob Coal Waste Mixtures</u>

Having established the characteristics of the pellets made with char alone, experiments were conducted with the formulation of the char-gob coal waste pellets. The gob coal used was that being burnt at the Southern Illinois Power Cooperative Plant, at the Lake of Egypt in Marion, Illinois. The percentages of char and gob coal used were as follows:

30% char	70% gob coal
60% char	40% gob coal
90% char	10% gob coal

Binder concentrations of 5, 10 and 15% were used with each char/coal combination.

These pellets were 0.125 inches in diameter, 0.4 to 0.5 inches long. They were made by mixing the char, gob coal and binder together with adequate amount of water to form a putty-like mixture. This was then formed into pellets by an extrusion process. The pellets were then let to dry. The dried pellets were tested in a compression tester. This data is shown in Figure 8. Again, the data presented is the same as that of the previous figures. The compression pressure has been divided by the (d/h) ratio of the pellets.

The results of Figure 8 show that the strength of the char-gob waste pellets increase as the binder concentration increases. Also, pellets containing more char than coal have lower compression strength.

3. <u>Combustion Testing of Char-Gob Waste Pellets</u>

During the combustion tests, it will be desirable to maximize the use of the char. Hence, the amount of gob coal will be chosen to be in the range of 30-10%. From the data of Figure 8, it is expected that a binder concentration of 10-15% will be required so that the pellets can have adequate strength for feeding into the combustor.

CONCLUSIONS

Extensive testing with the formulation of pellets made from pyrolyzer char alone and char-gob waste mixtures has established the proportions by weight of char, gob coal and binder necessary to make pellets suitable for feeding into the CFBC combustor. During the next quarter, these pellets will be produced in sufficient quantity for the combustion experiments, and their combustion and emissions performance will be evaluated.

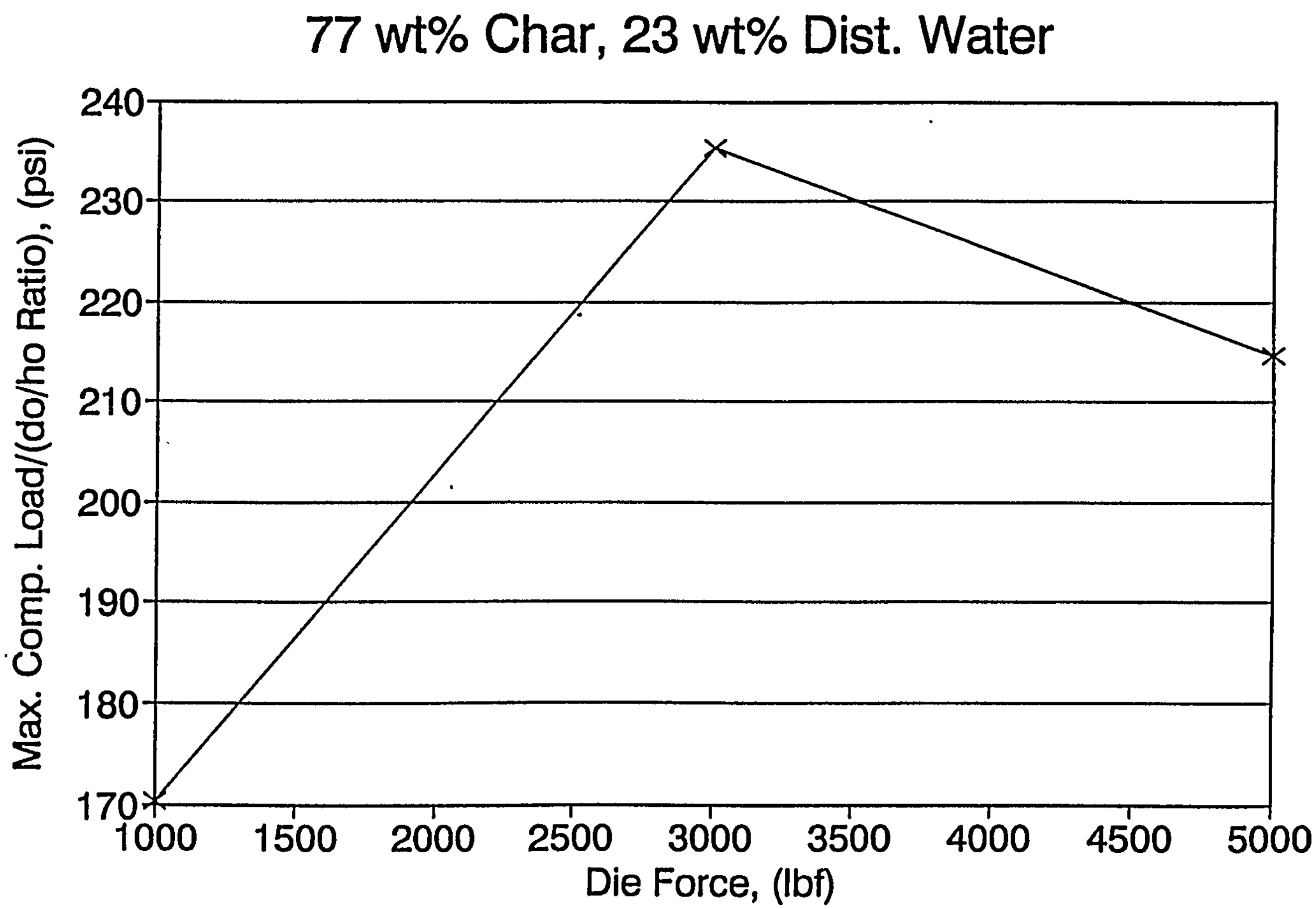


Figure 3. Effect of Die Force on Compression Strength of Char Pellets Formulated with Distilled Water

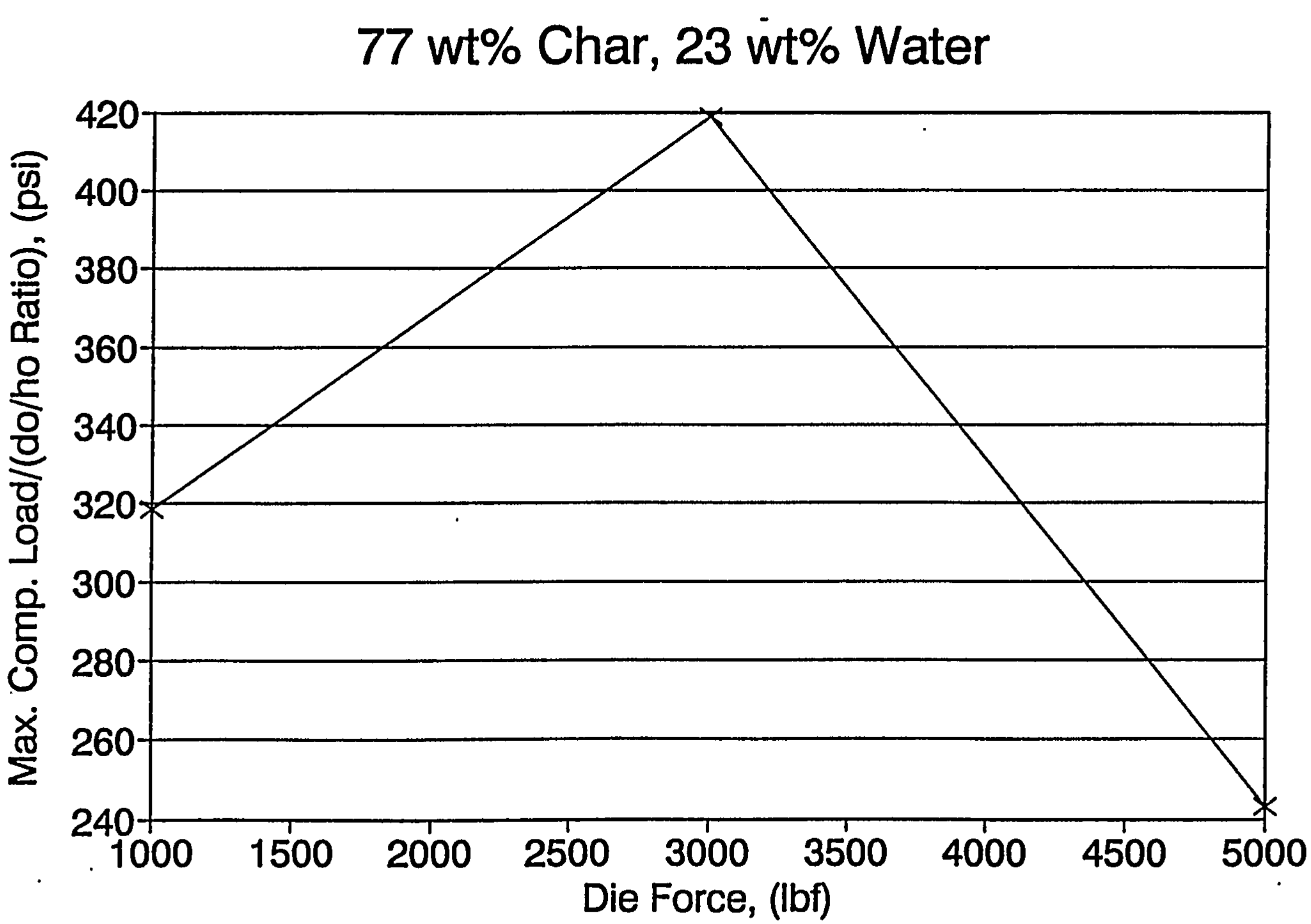


Figure 4. Effect of Compaction Force on Compression Strength of Char Pellets Formulated with Tap Water

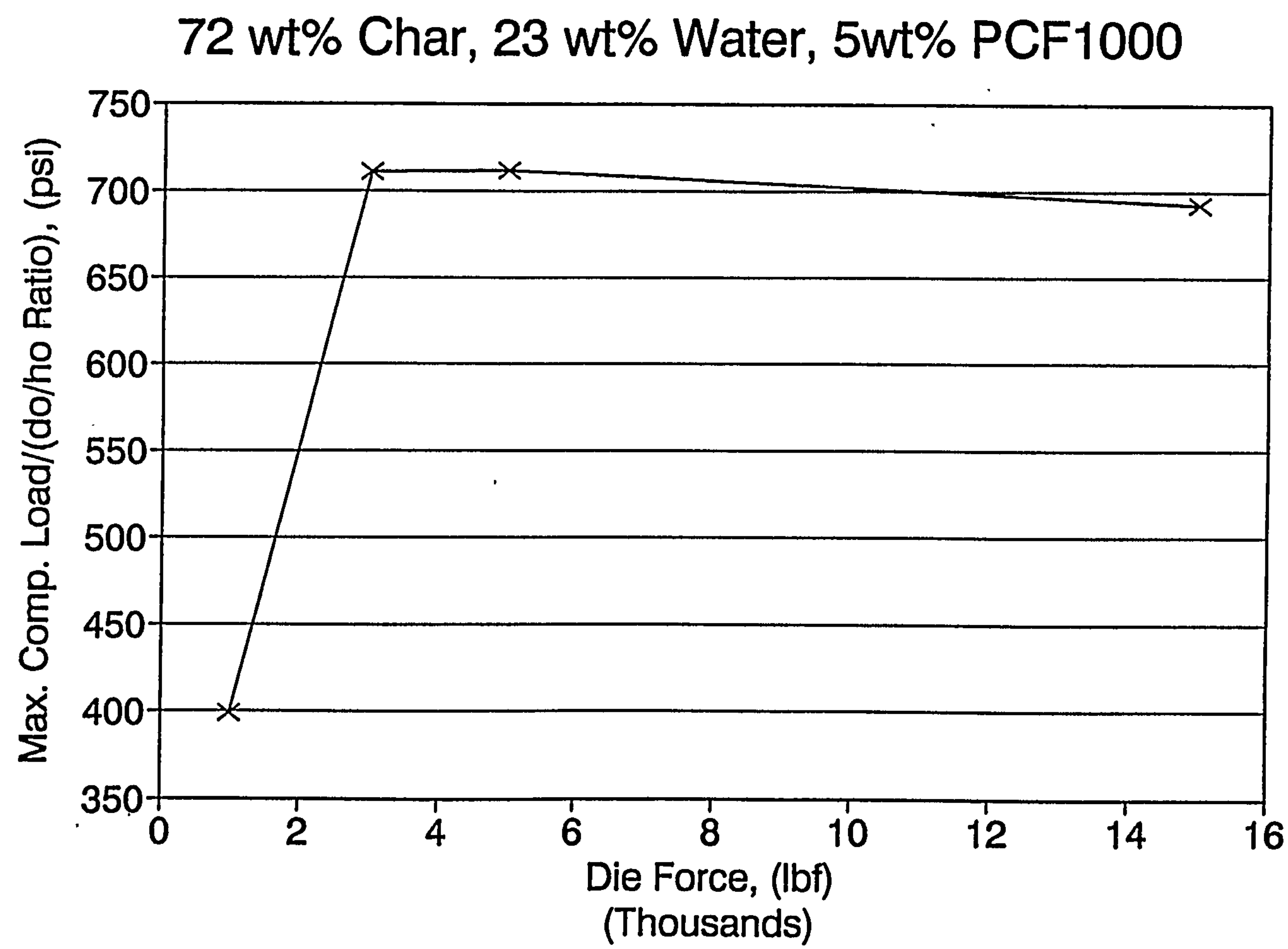


Figure 5. Effect of Compaction Force on Compression Strength of Char Pellets with 5% Cornstarch Binder

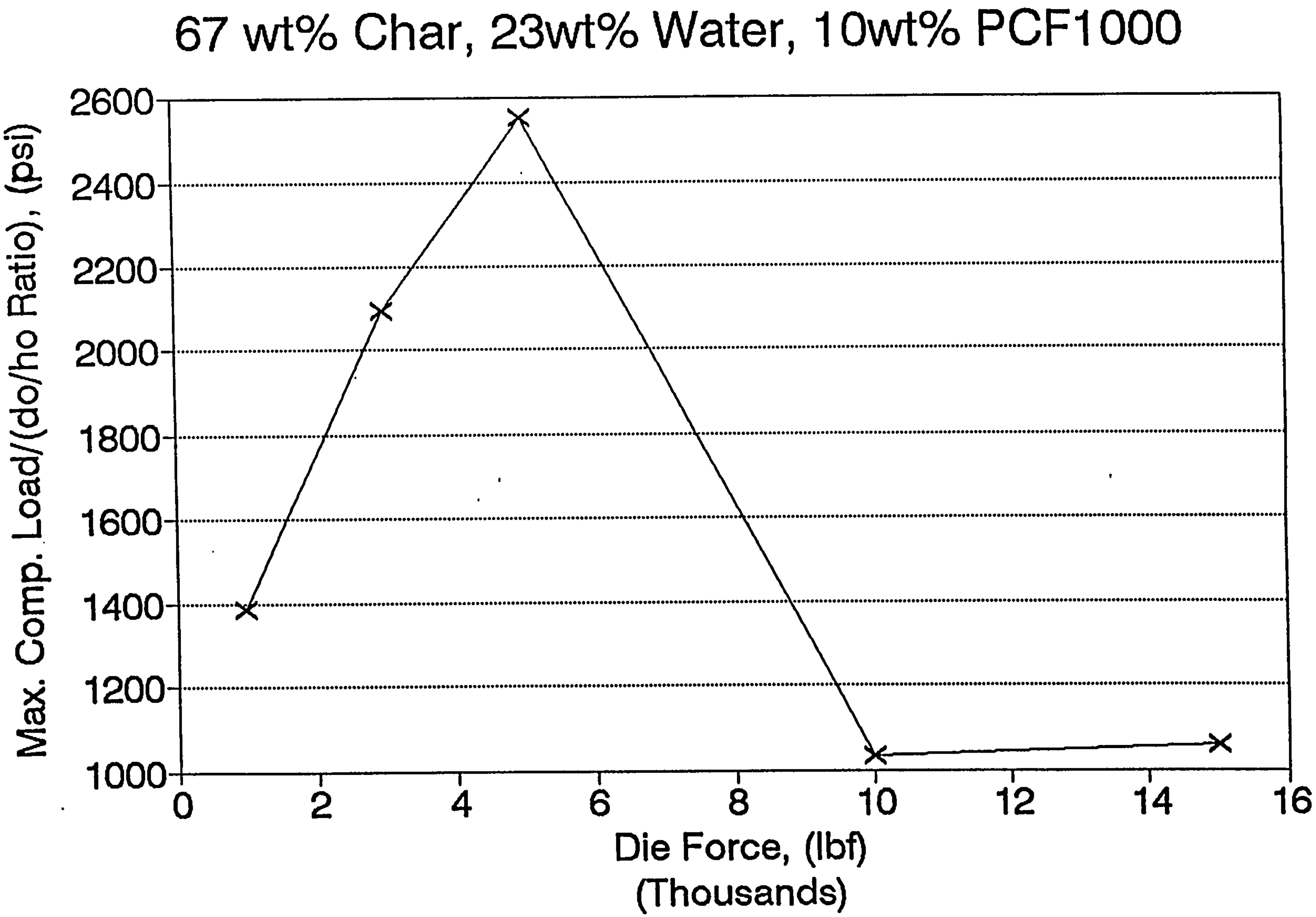


Figure 6. Effect of Compaction Force on Compression Strength of Char Pellets Containing 10% Cornstarch Binder

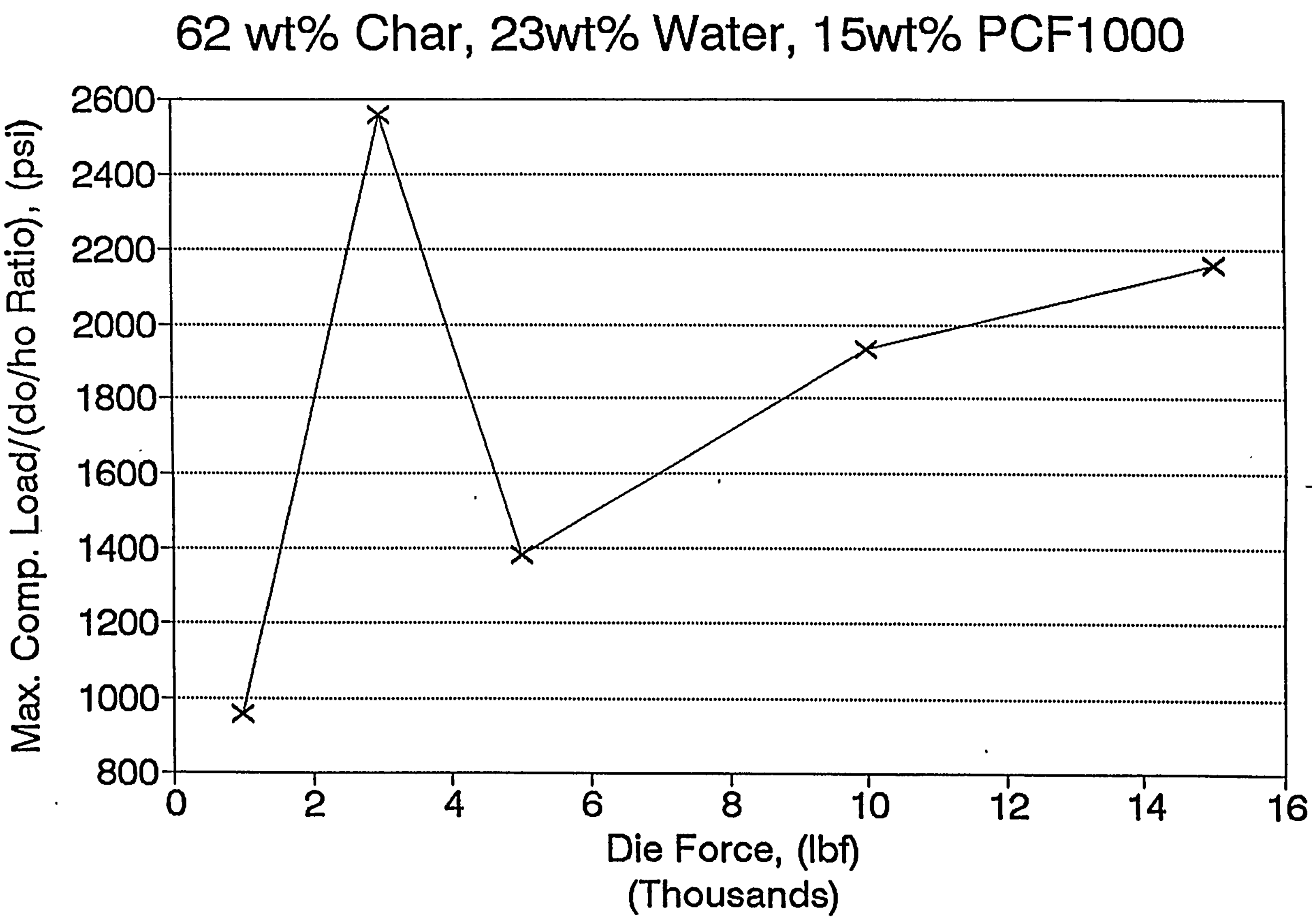


Figure 7. Effect of Compaction Force on Compression Strength of Char Pellets Containing 15% Cornstarch Binder

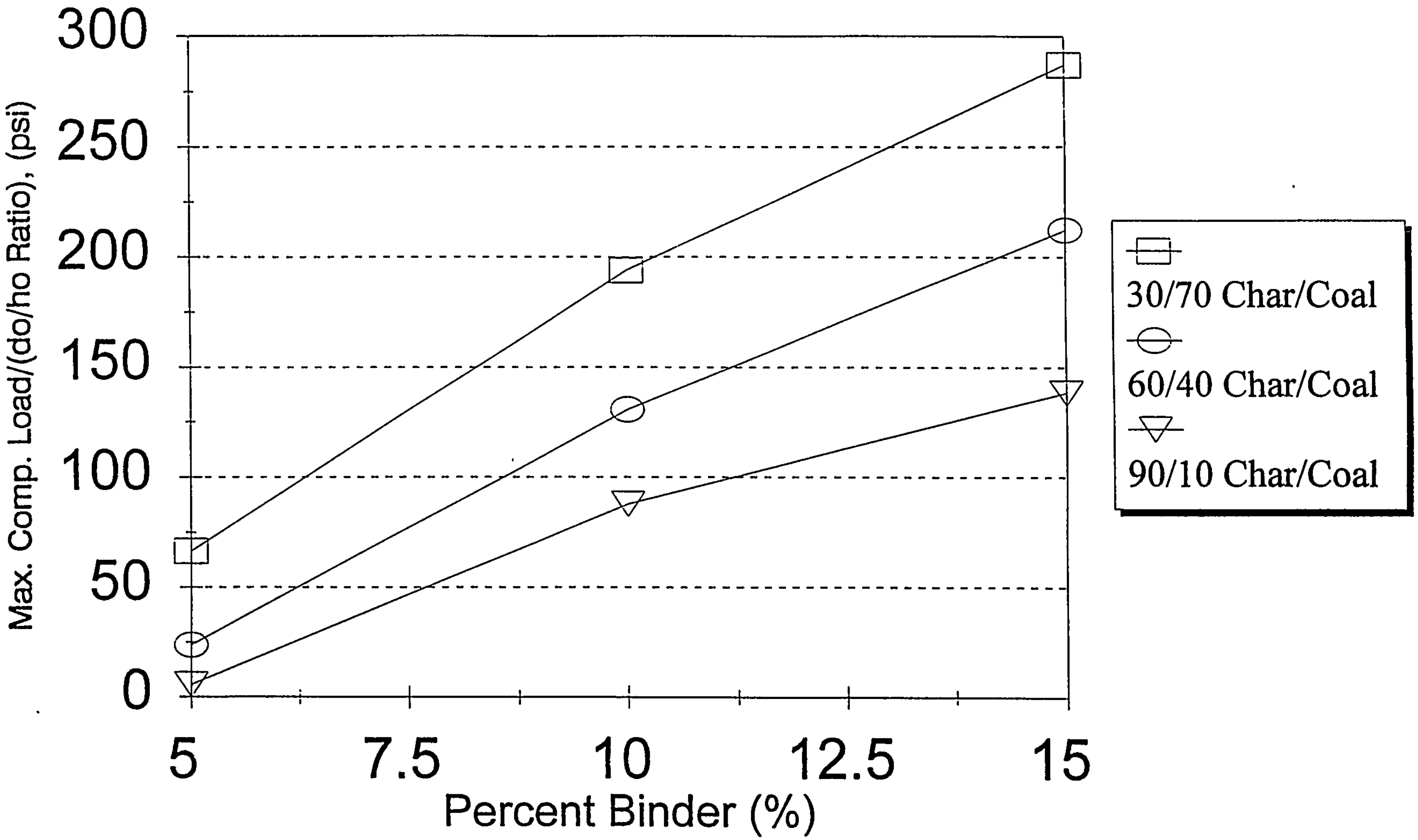


Figure 8. Effect of Binder Concentration on Compression Strength of Char-Gob Waste Pellets

TABLE 1
Compression Strength Data of Char Pellets Formulated with Distilled Water

	WT. %	Die Pressure =	1000	lbf
Coal	76.92			
Dist.Water	23.08			
Argo	0			

Height, (in)	Dia. (in)	Max Comp. Load, (lbf)	Area, (sq.in.)	Max.Comp.Load, (psi)	do/ho Ratio	MCL/Ratio, (psi)
0.481	0.508	31.87	0.2027	157.24	1.056	148.88
0.445	0.508	39.37	0.2027	194.24	1.142	170.15
0.368	0.508	53.68	0.2027	264.85	1.380	191.86
		AVERAGE —>	0.2027	205.44	1.193	170.30

	WT. %	Die Pressure =	3000	lbf
Coal	76.92			
Dist.Water	23.08			
Argo	0			

Height, (in)	Dia. (in)	Max Comp. Load, (lbf)	Area, (sq.in.)	Max.Comp.Load, (psi)	do/ho Ratio	MCL/Ratio, (psi)
0.425	0.508	46.87	0.2027	231.25	1.195	193.47
0.442	0.509	54.93	0.2035	269.95	1.152	234.42
0.342	0.509	84.25	0.2035	414.04	1.488	278.20
		AVERAGE —>	0.2032	305.08	1.278	235.36

	WT. %	Die Pressure =	5000	lbf
Coal	76.92			
Dist.Water	23.08			
Argo	0			

Height, (in)	Dia. (in)	Max Comp. Load, (lbf)	Area, (sq.in.)	Max.Comp.Load, (psi)	do/ho Ratio	MCL/Ratio, (psi)
0.381	0.509	54.56	0.2035	268.13	1.336	200.70
0.385	0.511	57.25	0.2051	279.15	1.327	210.32
0.355	0.508	67.56	0.2027	333.33	1.431	232.94
		AVERAGE —>	0.2037	293.54	1.365	214.65

TABLE 2

Compression Strength Data of Char Pellets Formulated with Ordinary Tap Water

	WT. %	Die Pressure =	1000	lbf
Coal	76.93			
Water	23.07			
Argo	0			

Height, (in	Dia. (in)	Max Comp. Load, (lbf	Area, (sq.in.)	Max.Comp.Load, (psi	do/ho Ratio	MCL/Ratio, (psi
0.392	0.505	87.00	0.2003	434.36	1.288	337.16
0.390	0.505	85.12	0.2003	424.97	1.295	328.20
0.339	0.509	88.81	0.2035	436.45	1.501	290.68
		AVERAGE --->	0.2014	431.93	1.362	318.68

	WT. %	Die Pressure =	3000	lbf
Coal	76.93			
Water	23.07			
Argo	0			

Height, (in	Dia. (in)	Max Comp. Load, (lbf	Area, (sq.in.)	Max.Comp.Load, (psi	do/ho Ratio	MCL/Ratio, (psi
0.355	0.510	118.31	0.2043	579.15	1.437	403.13
0.325	0.509	116.18	0.2035	570.96	1.566	364.56
0.237	0.507	210.87	0.2019	1044.50	2.139	488.26
		AVERAGE --->	0.2032	731.54	1.714	418.65

	WT. %	Die Pressure =	5000	lbf
Coal	76.93			
Water	23.07			
Argo	0			

Height, (in	Dia. (in)	Max Comp. Load, (lbf	Area, (sq.in.)	Max.Comp.Load, (psi	do/ho Ratio	MCL/Ratio, (psi
0.379	0.509	61.25	0.2035	301.01	1.343	224.13
0.338	0.507	65.62	0.2019	325.04	1.500	216.69
0.284	0.508	104.87	0.2027	517.41	1.789	289.26
		AVERAGE --->	0.2027	381.15	1.544	243.36

DISCLAIMER STATEMENT

PROJECT MANAGEMENT REPORT
December 1, 1994 through February 28, 1995

Project Title: **COMBUSTION OF CHAR-COAL WASTE PELLETS FOR HIGH EFFICIENCY AND LOW NO_x**

DOE Cooperative Agreement Number: DE-FC22-92PC92521 (Year 3)
ICCI Project Number: 94-1/5.2A-1M
Principal Investigator: S. Rajan, Southern Illinois University at Carbondale
Project Manager: Frank Honea, Illinois Clean Coal Institute

EXPENDITURES - EXHIBIT B

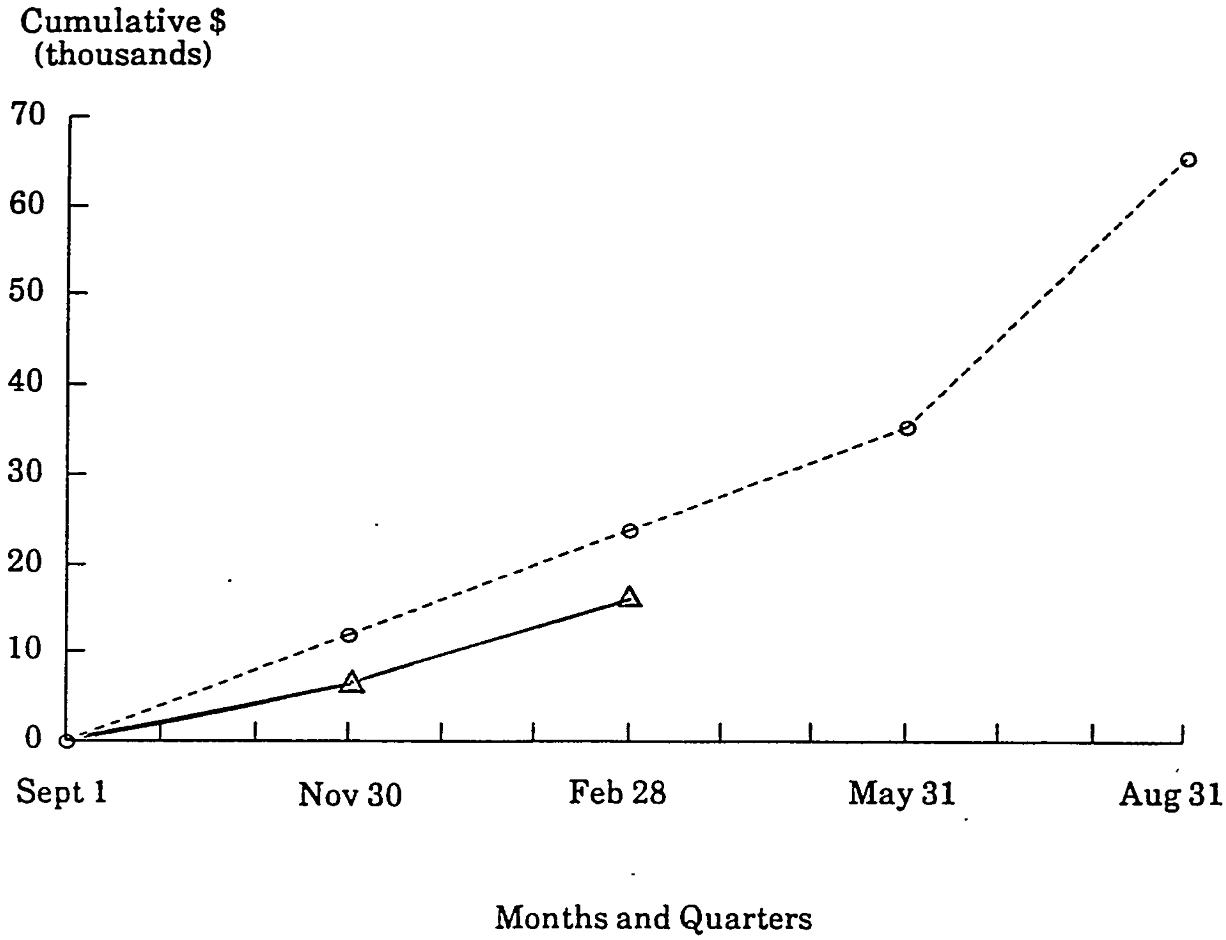
CUMULATIVE PROJECTED AND ESTIMATED EXPENDITURES BY QUARTER

Quarter*	Types of Cost	Direct Labor	Fringe Benefits	Materials and Supplies	Travel	Major Equipment	Other Direct Costs	Indirect Costs	Total
Sept 1, 1994	Projected	7,466	923	1,125	0	0	1,250	1,076	11,840
to Nov 30, 1994	Estimated	3,500	100	500	0	0	600	400	5,100
Sept 1, 1994	Projected	14,931	1,846	2,250	0	0	2,500	2,153	23,680
to Feb 28, 1995	Estimated	8,500	500	1,500	0	0	1,800	1,500	13,800
Sept 1, 1994	Projected	22,397	2,769	3,375	0	0	3,750	3,229	35,520
to May 31, 1995	Estimated								
Sept 1, 1994	Projected	43,962	6,140	4,500	500	0	5,000	6,010	66,112
to Aug 31, 1995	Estimated								

*Cumulative by Quarter

CUMULATIVE COSTS BY QUARTER - EXHIBIT C

Combustion of Char-Coal Waste Pellets for High Efficiency and Low NO_x



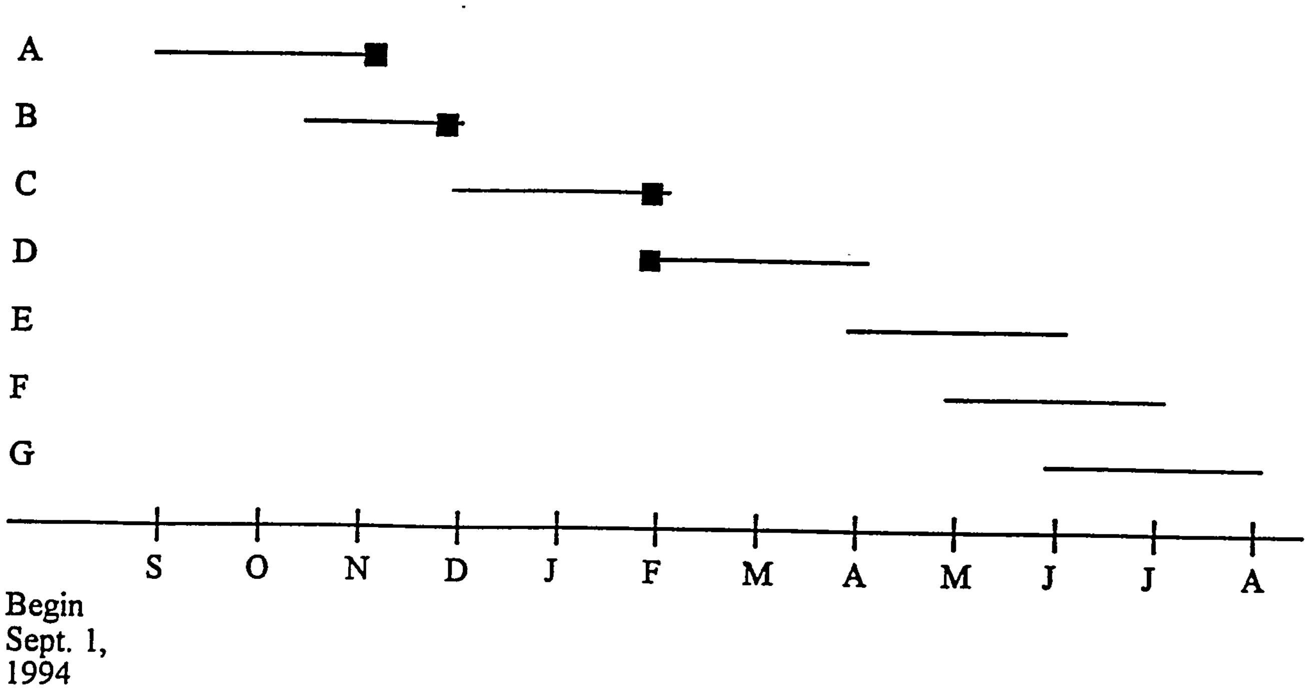
O = Projected Expenditures --------------

Δ = Actual Expenditures _______

Total ICCI Award $66,112

The schedule for this one year project is shown below.

PROJECT SCHEDULE



A. Fuels Procurement

B. Fuels Analysis

C. Char-Coal Pellets Manufacture

D. CFBC Combustion Tests

E. Combustion Residues Analysis

F. Data Analysis

G. Final Report