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**COAL SURFACE CONTROL FOR ADVANCED
PHYSICAL FINE COAL CLEANING TECHNOLOGIES**

QUARTERLY REPORT

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(July 1, 1990 - September 30, 1990)

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DOE CONTRACT No. DE-AC22-88PC88877

**Chemical and Petroleum Engineering Department
University of Pittsburgh
Pittsburgh, PA 15261**

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**B. I. Morsi
S.-H. Chiang
A. Sharkey
J. Blachere
G. Klinzing
G. Araujo
R. Venkatadri**

**H. Bi
P. Campbell
M. Ciocco
L. Hittle
S. Kim
L. Perez**

**Chemical and Petroleum Engineering Department
University of Pittsburgh
Pittsburgh, PA 15261**

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SUMMARY

During this reporting period, research efforts were focused on Task 7. The progress achieved in this task is summarized in the following:

Several analytical techniques developed in Task 3 were utilized during this quarter to characterize coal samples obtained from agglomeration tests. Surface and near surface (1 μm depth) functional groups were analyzed using DRIFT spectroscopy. Surface composition analyses were conducted using LAMMA. The results of these analyses are being used to relate the agglomeration results with surface modifications to the properties of coal samples.

The development of a method for direct determination of pyrite using X-ray diffraction was continued. The sample preparation technique was improved in order to increase the reproducibility of the analysis.

The contact angle of n-heptane droplets on coal pellets immersed in water were measured. The results of these measurements suggest that high shear mixing is necessary for wetting coal surfaces with n-heptane.

Agglomeration tests using n-heptane as agglomerant were carried out this quarter. For Pittsburgh # 8 coal, better performance was obtained using n-heptane than using n-pentane. For Upper Freeport coal, however, lower pyritic sulfur rejection was obtained with n-heptane. A n-heptane to coal ratio between 1.25 and 1.5 was found to produce the best performance results for Illinois # 6 coal.

A study of the effect of agglomeration time on the agglomeration process performance for Illinois # 6 coal using n-pentane and n-heptane as agglomerants indicates that no significant gains in performance are possible using agglomeration times longer than 60 seconds.

The addition of tall oil as a binding agent after the high shear agglomeration step resulted in a large increase in overall coal yield and energy recovery for Illinois # 6 coal.

1.0 INTRODUCTION

This quarterly report covers the technical progress achieved from July 1 through September 31, 1990 on the Coal Surface Control for Advanced Physical Fine Coal Cleaning Technologies project, under PETC/DOE Contract No. DE-AC22-88PC88877.

The overall objective of the project is to develop techniques for coal surface control prior to the advanced physical fine coal cleaning process of selective agglomeration in order to achieve 90% pyrite sulfur rejection at a energy recovery greater than 90% based on run-of-mine coal. The surface control is meant to encompass surface modification during grinding and laboratory beneficiation testing. The project includes the following tasks:

- Task 1: Project Planning
- Task 3: Method for Analysis of Samples
- Task 4: Development of Standard Beneficiation Test
- Task 5: Grinding Studies
- Task 6: Modification of Particle Surface
- Task 7: Exploratory R&D and Support.

The coal samples used in this project include three base coals, Upper Freeport - Indiana County, PA, Pittsburgh # 8 - Belmont County, OH, and Illinois # 6 - Randolph County, IL, and three other coals, Upper Freeport - Grant County, WV, Kentucky # 9 - Hopkins County, KY, and Wyodak - Campbell County, WY. During this reporting period, no additional coal samples were received.

The project work plan (Task 1) was submitted to the DOE and was approved on 12/5/1988⁽¹⁾. Tasks 3 and 4 were completed, and the analytical methods established and tested for the characterization of coal samples and the experimental procedures developed for the agglomeration tests were reported in the first Annual Report⁽²⁾. Tasks 5 and 6 were completed in 1989 and the results and conclusions of grinding and surface

modification studies using the three base coals were also reported in the first Annual Report⁽²⁾.

During this quarter the research effort was focused on Task 7, Exploratory Research & Development and Support. Progress in this task of the project is presented in this report.

2.0 TASK 7: EXPLORATORY R&D AND SUPPORT

The main goal of Task 7 is to explore new and promising avenues leading to effective surface control for selective agglomeration processes and to provide support services to the DOE's Engineering Development Program. In order to achieve this goal, the specific objectives of Task 7 are:

1. To improve and optimize the coal surface control techniques developed in Tasks 4, 5, and 6 found to achieve high energy recovery and pyritic sulfur rejection.
2. To explore and develop new and promising avenues leading to effective coal surface control for selective agglomeration processes.
3. To provide support services to the DOE/PETC and other DOE contractors.

In this quarter, research was conducted in a number of subtasks in order to improve the agglomeration process performance. The progress during this period is presented in the following.

2.1 Surface Functional Groups

The objective of this analytical subtask is to monitor the functional group changes on the surface and in the bulk beneath the surface layer of the coal as a function of grinding and treatment. This was achieved by using Diffuse Reflectance Infrared Fourier Transform (DRIFT) Spectroscopy in the same manner employed by researchers at USX⁽³⁾ and CONOCO⁽⁴⁾.

The oxidation index is defined as the ratio of the integrated intensity of the carbonyl band ($1635\text{--}1850\text{ cm}^{-1}$) to that of the C-H stretching band ($2746\text{--}3194\text{ cm}^{-1}$) in the diffused reflectance FTIR spectrum. The limits associated with the latter area may vary slightly depending upon the baseline of the spectrum. A decrease in the $2746\text{--}3194\text{ cm}^{-1}$ band is attributed to the loss of C-H groups and an increase in the $1635\text{--}1850\text{ cm}^{-1}$ band to the production of carbonyl groups. Both absorption bands are related to the organic

structure of coal and the ratio may provide a good indication of changes in the organic matrix. The experimental procedure, including sample preparation, data acquisition, and analysis were described in the first Annual Report⁽²⁾.

During this quarter, oxidation indices of coal samples wet ground to 200 mesh x 0 in the presence of light hydrocarbons were evaluated. The effects of varying agglomeration times and different pH levels were also investigated. Additional determinations were conducted on Illinois # 6 coal feed, product, and refuse samples from agglomeration tests carried out using n-heptane as agglomerant.

2.1.1 Oxidation Indices for Illinois # 6 Coal Samples Wet Ground in the Presence of Hydrocarbons

Replicate data (the summation of 1000 scans) were obtained for feed samples of Illinois # 6 coal wet ground in the presence of cyclohexane and n-heptane. These samples were used in agglomeration tests conducted with n-pentane as agglomerant and reported in the last Quarterly Report⁽⁵⁾. A sample of Illinois # 6 coal wet ground without the addition of hydrocarbons was analyzed for reference. The oxidation indices with their respective 95% confidence intervals are shown in Table 2.1.1-1 and Figure 2.1.1-1.

The addition of light hydrocarbons during grinding did not have significant positive effects on the agglomeration process performance⁽⁵⁾. Similarly, Figure 2.1.1-1 shows that no significant difference between the oxidation indices of the samples ground without additives and with hydrocarbons was observed.

2.1.2 Oxidation Indices for Illinois # 6 Coal Samples Obtained at Different Agglomeration Times

The effect of agglomeration time on the agglomeration performance using n-pentane as agglomerant was studied for Illinois # 6 coal. Agglomeration times between 30 and 390 seconds were used and the results are reported in section 2.5.1. The oxidation indices of Illinois # 6 coal product samples from agglomeration tests conducted at agglomeration times of 30 and 180 seconds were determined and are shown in Table 2.1.2-1. In terms of ash, total and pyritic sulfur content, the product samples from the test conducted

using agglomeration times of 30 and 180 did not differ significantly. Table 2.1.2-1 shows that the oxidation index of the product samples analyzed was also very similar.

2.1.3 Oxidation Indices for Upper Freeport Coal Samples Wet Ground at Different pH

The oxidation indices of Upper Freeport coal samples wet ground at pH equal to 12.5 and pH equal to 3.9 (natural pH) were determined. These samples were used in agglomeration tests conducted using n-pentane as agglomerant and reported in section 2.5.2.2. The main finding in the study of high pH agglomeration using Upper Freeport coal was an increase in ash rejection of about 8 percentage points. This effect was not reflected in the oxidation index of the samples which, as Table 2.1.3-1 shows, did not exhibit a significant difference.

2.1.4 Oxidation Indices for Illinois # 6 Coal Samples Obtained Using N-heptane as Agglomerant

The oxidation index of Illinois # 6 coal product and refuse samples from agglomeration tests conducted using n-heptane as agglomerant were determined. The feed, product, and refuse samples had ash contents of approximately 16, 9, and 24%, respectively. Table 2.1.4-1 shows that similarly to the behavior observed in the agglomeration tests conducted using n-pentane as agglomerant, no difference between the oxidation indices of refuse, product, and feed samples was observed.

The extensive set of oxidation indices determined for wet ground feed, product, and refuse samples has shown no significant differences between the samples. Since, in general, only minor changes in performance due to the treatments applied to the coal samples have been observed, these findings are not surprising. Moreover, in the case of Illinois # 6 coal, because of the relatively low yields obtained in the agglomeration tests, the refuse samples do not greatly differ from the feed samples in terms of composition. Lumping of the peaks caused by several functional groups into a single number, and the effect of water on some parts of the spectra limits the effectiveness of the oxidation index as a probe for small changes in coal properties due to the grinding and surface modification techniques used in this project.

2.2 Surface Composition

Surface composition analyses were performed on samples of Upper Freeport, Pittsburgh # 8, and Illinois # 6 coals using the Laser Microprobe Mass Analyzer (LAMMA). The objectives of these measurements were to apply the LAMMA technique developed in Task 3 to samples wet ground to 200 mesh x 0 in the presence of light hydrocarbons.

Surface and near surface composition analyses were performed using the Leybold Heraeus LAMMA 1000. All spectra represent the summary data for 500 individual spectra obtained from various positions on the surface. Samples were prepared and analyzed as described in the first Annual Report⁽²⁾.

The LAMMA technique samples the surface to a depth of approximately 1 micron providing data for surface components and the bulk near the surface. LAMMA data are given in percent total ionization. While the percent total ionization does not represent absolute concentrations, trends in the concentration caused by physical and chemical treatment can be followed. The use of the percent total ionization is a standard technique in mass spectrometry where sensitivity factors are not readily available. Changes in percent total ionization are proportional to changes in the concentration of the elements.

The elemental distributions for the three base coals were obtained in order to establish a set of base data and are shown in Figure 2.2-1. In general, the elemental distributions were similar for Upper Freeport and Pittsburgh # 8 coals. Both showed surface concentrations of Al and K higher than those seen in Illinois # 6 coal. The surface concentrations of Mg, Si, and Fe, on the other hand, were lower for Upper Freeport and Pittsburgh # 8 coals.

2.2.1 Elemental Distribution of Illinois # 6 Coal Wet Ground in the Presence of Light Hydrocarbons

Illinois # 6 coal samples wet ground in the presence of hydrocarbons were analyzed using LAMMA to determine the surface elemental distribution. The results of the agglomeration tests using these samples were reported in the last Quarterly Report⁽⁵⁾.

The results of the LAMMA analyses, relative to grinding without adding light hydrocarbons, are shown in Table 2.2.1-1 and Figures 2.2.1-1 and 2.2.1-2.

Table 2.2.1-1 shows that in all cases the sulfur surface concentration increased relative to the base sample. An increase in the surface concentration of Ca and a decrease in the surface concentration of Na were also observed for all samples.

Figures 2.2.1-1 and 2.2.1-2 show that the samples wet ground in the presence of n-heptane, n-pentane, and cyclohexane at a cyclohexane to coal ratio of 1/20 exhibited similar trends in surface concentration relative to the base sample. For these samples, the surface concentration of S, Ca, Si, and Fe increased, while the surface concentration of Na, K, and Ti decreased.

However, as Figure 2.2.1-2 shows, for the sample wet ground in the presence of cyclohexane at a cyclohexane to coal ratio of 1/10 opposite trends were observed for several elements. In this case, the surface concentration of Fe and Si decreased, while the surface concentration of K and Ti increased. It is worth noting that for this sample, the highest pyritic sulfur rejection (72 %) of the series of agglomeration tests using Illinois # 6 coal wet ground in the presence of light hydrocarbons was obtained. The pyritic sulfur rejection base value (sample ground without additives) was 60 %. The addition of cyclohexane (except for the sample just mentioned) and n-heptane resulted in pyritic sulfur rejections between 58 and 64 %, (close to the base value) and the addition of n-pentane reduced the pyritic sulfur rejection as much as 5 to 20 percentage points from the base value. Additional tests are planned to investigate this seemingly anomalous finding for the case of wet grinding with cyclohexane at a cyclohexane to coal ratio of 1/10.

2.2.2 Elemental Distribution of Pittsburgh # 8 Coal Wet Ground in the Presence of N-Pentane

Pittsburgh # 8 coal samples ground in the presence of n-pentane at a n-pentane to coal ratio of 1/5 were analyzed to determine changes in elemental distribution relative to samples ground without additives. The results of these analyses are shown in Table 2.2.2-1 and Figure 2.2.2-1.

Table 2.2.2-1 and Figure 2.2.2-1 show that the surface concentration of Mg, Si, S, and Fe increased relative to the sample ground without additives. The surface concentration of Na, K, Al, and Ca decreased.

For Pittsburgh # 8 coal, as well as for Illinois # 6 coal, the addition of hydrocarbons during grinding seemed to have a modest effect on the surface elemental composition. The most significant result is that, in most cases, the addition of hydrocarbons during grinding increased the surface concentration of S and Fe. A decrease in the surface concentration of Na and K was also observed for most samples. It might be speculated that the removal of these highly soluble cations from the surface of mineral matter exposed more pyrite resulting in the increases in sulfur and iron surface concentration.

2.3 Direct Determination of Pyrite by X-ray Diffraction

A method for direct determination of the pyrite content of coal using X-ray diffraction (XRD) is currently being developed. A summary of the background of this technique was presented in the last quarterly report⁽⁵⁾.

The quantitative analysis of mixtures of crystalline powders is well established and has been described extensively by Klug and Alexander⁽⁶⁾. Fundamentally, the intensity of the diffraction peaks is proportional to the concentration of the phase responsible for these peaks in the mixture. During this quarter, several sample preparation methods were tested in order to improve reproducibility. The segregation of pyrite from the coal powder was the main problem affecting the measurements. It was found that grinding the crystalline powders (unknown and standards) to about 5 μm , increased the intensity of the pyrite peaks and improved the reproducibility of the results.

The coal samples were ground with tungsten-carbide (WC) balls in a Spex mill lined with WC. Ground mineral pyrite and 5 wt.% of magnesia were added as a standard and mixed in the Spex mill. Each mixture was based on 2 g of coal to which 3, 5, or 8% of pyrite were added. The powders were packed in a flat powder holder in order to minimize preferential orientation. The XRD patterns were obtained using a GE XRD700 diffractometer fitted with a monochromator. The sample was scanned at 2 degrees/min between $2\theta = 30$ and 65 degrees with $\text{CuK}\alpha$ radiation. The intensities of

selected pyrite peaks were plotted as a function of pyrite content. Each point of the plot was an average of 8 to 10 determinations in which the sample was mixed and repacked before recording the next X-ray pattern. The integrated intensities corrected for background were determined by measuring peak areas. The pyrite peak intensities were referred to that of the (200) line of periclase (MgO) in order to improve reproducibility. The corrected peak intensities were then plotted as a function of the pyrite additions and the pyrite content of the sample was given by the intercept of the best fit line through the points.

The experimental procedure was tested on an Illinois # 6 feed coal sample. The results are plotted in Figure 2.3-1. The solid line was obtained with the (200) line of pyrite. The dashed line was obtained with the sum of the intensities of the (200) and (311) lines of pyrite. The intercepts gave pyrite contents of 4.3 and 3.5%, corresponding to pyritic sulfur contents of 2.32 and 1.86%. The pyritic sulfur content measured using a conventional sulfur analyzer was 2.39%. Thus, the value obtained using both the (200) and (311) lines was comparable to that obtained by conventional sulfur analysis method. The value obtained with the (200) line of pyrite, however, appears to be lower.

The individual points showed good reproducibility but the extrapolation is a source of uncertainty as illustrated by the variation in intercepts in Figure 2.3-1.

Additional tests will be conducted to seek further improvement and to affirm its applicability to coal pyrite analysis.

2.4 Coal Wettability

The surface wettability of coal samples was studied by measuring contact angles on coal pellets. A preliminary attempt to investigate the dynamics of wetting was conducted using samples treated with additives during grinding or before agglomeration. Equilibrium contact angles were also measured with n-pentane and n-heptane droplets, and with air bubbles immersed in water.

2.4.1 Effect of Grinding Using Additives on Contact Angle

The contact angle of a water droplet placed on the surface of a coal pellet was measured as a function of time for Upper Freeport, Pittsburgh # 8, and Illinois # 6 coal samples wet ground in the presence of several reagents.

The coal samples were wet ground to 200 mesh x 0 in the presence of Arosurf MG-83A, Aerosol-OT, tall oil, styrene, n-pentane, n-heptane, cyclohexane, or without any reagent and dried in an oven at 60°C for 16 hours. 1-inch diameter pellets were prepared by compressing 5 g of coal at 4000 psig.

For Illinois # 6 and Pittsburgh # 8 coals, the droplet of water deposited on the pellet disappeared in less than a minute in all cases, which indicated strong hydrophilic behavior of the particles. During such a short life-span of the water droplet only the initial contact angle (or largest contact angle) and the life-span of the droplet were recorded. These data are shown in Tables 2.4.1-1 and 2.4.1-2.

A clear difference in both the largest contact angle (near zero time) and the drop life-span was observed between Illinois # 6 and Pittsburgh # 8 coals. In general, the contact angles for Illinois # 6 were smaller (27° to 42° versus 29° to 62° for Pittsburgh # 8), and the drop life-span shorter (12 to 26 sec versus 18 to 46 sec for Pittsburgh # 8). This trend agrees well with previous data on the wetting behavior of both coals (e.g. rank index).

In the case of Upper Freeport coal, the contact angles were considerably larger (between 49° and 97°) and the drops lasted between 1 and 30 minutes. This finding also agrees with the data on the wettability character of Upper Freeport coal. The data for Upper Freeport coal are plotted in Figures 2.4.1-1 through 2.4.1-3.

Figure 2.4.1-1 shows the results obtained for Upper Freeport coal samples ground in the presence of light hydrocarbons. A reduction in drop life-span was observed in all the cases studied. For the sample ground using a n-pentane to coal ratio of 1/10, the drop life-span was about 1 minute and the largest angle only 50° (compared with 6.7 min and 88° for the sample ground without additives). A decrease in drop life-span could be related to a decrease in the hydrophobicity of the sample. It is speculated that this

effect might be due to the roughness of the surface and to the evaporation of surface hydrophobic groups dissolved in the light hydrocarbons during drying.

The longest life-span of the water droplets deposited on Upper Freeport coal pellets was observed for the samples treated with Aerosol-OT (Figure 2.4.1-2). The formation of a double layer of surfactant that gives a hydrophobic character to the coal particles might explain the increase in the droplet life-span. For the samples treated with Arosurf MG-83A, a similar phenomenon was observed at a concentration of 10 ppm, but at a concentration of 80 ppm the effect was reversed. This is in agreement with previous observations for the effect of surfactant addition on fine coal dewatering⁽⁷⁾.

Figure 2.4.1-3 shows the effect of grinding in the presence of monomers on the contact angle as a function of time for Upper Freeport coal. For both monomers, the observed contact angle and the drop life-span decreased when reagents were used.

The measurement of the contact angle on a pellet as a function of time represents an initial attempt to study the dynamics of coal wetting. Further research in order to understand the wettability character of coal samples treated with surface modification reagents under dynamic conditions is being conducted.

2.4.2 Contact Angle of Hydrocarbon Droplets Immersed in Water

The contact angle of n-pentane and n-heptane droplets placed on a coal pellet immersed in water were measured for Upper Freeport, Pittsburgh # 8, and Illinois # 6 coals. The pellets were prepared using wet ground 200 mesh x 0 coal-water slurry and were not subjected to drying during preparation. The results of these measurements, together with the contact angles for air bubbles measured in the same manner, are shown in Table 2.4.2-1. The contact angles in the hydrocarbon phase are exceedingly high (greater than 125 degrees for n-pentane and greater than 105 degrees for n-heptane) and do not vary with time. This results indicate a hydrophilic behavior of the coal which can be explained by the presence of an adsorbed water film on the surface of the coal pellet.

A second set of pellets was treated by conditioning them in n-heptane for 20 hours before immersion in water. The contact angle of a n-heptane droplet immersed in water was measured for Upper Freeport, Pittsburgh # 8, and Illinois # 6 coals. These data are also shown in Table 2.4.2-1. In this case, the contact angles in the hydrocarbon phase

were significantly smaller and all of them less than 90 degrees. This result suggests that wetting first by n-heptane enhances the hydrophobicity of the coal surface. This finding suggests the need for high shear mixing in order to remove the water film surrounding the clean coal particles and to allow the contact between n-heptane and the coal surface. Consequently, the coal surface acquires a hydrophobic character that favors agglomeration and recovery of clean coal particles from the aqueous phase.

2.5 Optimization of the Agglomeration Process

The study of the agglomeration process using n-pentane as agglomerant was continued by performing several series of tests in which the effects of different feed preparation procedures and operation variables on agglomeration performance were investigated. Appendix C lists the detailed results of these tests and the analysis of the results is presented in the following.

2.5.1 Effect of Agglomeration Time on Performance

The effect of agglomeration time on the agglomeration performance was studied for Illinois # 6 coal using n-pentane as agglomerant. Previous agglomeration tests had shown that increasing the agglomeration time from 15 seconds to 60 seconds resulted in significant improvements in energy recovery⁽⁶⁾.

In order to explore the effect of using longer agglomeration time on performance, tests were conducted using agglomeration times between 30 and 360 seconds. The experiments were carried out using a slurry concentration of 2 wt.%, a n-pentane to coal ratio of 0.5, and a mixing speed of 9000 rpm. Figures 2.5.1-1, 2.5.1-2, and 2.5.1-3 show the test results in terms of energy recovery, ash and pyritic sulfur rejections, respectively. These data indicate that there was no significant effect of the agglomeration time on energy recovery. Ash rejection, on the other hand, steadily decreased as agglomeration time increased. A similar behavior was observed for pyritic sulfur rejection, which decreased markedly for agglomeration times longer than 120 seconds.

These results suggest that in the case of Illinois # 6 coal, improvements in performance can not be achieved by increasing the agglomeration time. Therefore, other methods of enhancement, such as the use of additives, should be considered.

2.5.2 Effect of pH on Agglomeration Performance

The effect of wet grinding and performing agglomeration tests at high pH was studied in two sets of experiments. Illinois # 6 coal was used to conduct experiments at pH equal to 10.5 and Upper Freeport coal was used in tests at pH equal to 12.5.

2.5.2.1 Effect of High pH on Illinois # 6 Coal

The effect of pH on the agglomeration performance was studied using samples prepared by wet grinding pulverized coal (14 mesh x 0) to 200 mesh x 0 at pH values of 4.5 and 10.2. The agglomeration tests were conducted using a slurry concentration of 2 wt.% and a agglomeration time of 60 seconds. N-pentane to coal ratios of 0.5 and 1.0 were utilized. For the agglomeration tests at pH 4.5, no additives were used since the pH of coal-water slurry after grinding was 4.5 ± 0.2 . For the agglomeration tests at high pH, sodium hydroxide (NaOH) was added during grinding to adjust the pH to 10.2 ± 0.3 .

The results of the agglomeration tests are listed in Table 2.5.2.1-1. Figure 2.5.2.1-1 shows that a significantly lower ash rejection was obtained in the tests at high pH compared with the tests conducted at low pH. The results of the ash analysis for product and refuse also reveal that for both samples the ash content was higher for the tests at high pH. The overall increase in ash content was probably due to the addition of sodium hydroxide to the samples.

Figures 2.5.2.1-2 and 2.5.2.1-3 indicate that the pH had no consistent effect on either the pyritic sulfur rejection and tended to slightly improve the energy recovery.

2.5.2.2 Effect of High pH on Upper Freeport Coal

The effect of pH on agglomeration performance was studied using n-pentane as agglomerant. Coal samples were wet ground at pH equal to 4.5 (natural pH) and at pH equal to 12.5. The wet ground coal samples were then used in agglomeration tests after adding sodium hydroxide to the slurry in order to adjust the pH to 12.5 and without any

further treatment. The results of these tests are shown in Table 2.5.2.2-1. Figure 2.5.2.2-1 shows an increase in ash rejection of about 8 percentage points for the experiments carried out at high pH. The energy recovery remained between 97 and 99% in all cases.

Because of the presence of sodium hydroxide in the high pH samples, the leaching procedure using HNO_3 utilized in the pyritic sulfur analysis was not reliable. Table 2.5.2.2-1 shows that anomalous results were obtained for the pyritic sulfur analyses of the high pH test product samples. The results for product total sulfur, however, indicate that no significant effect of pH on total sulfur rejection was observed. This finding is illustrated in Figure 2.5.2.2-2.

2.6 Agglomeration Tests Using N-heptane as Agglomerant

The study of the agglomeration process using n-heptane as agglomerant was initiated by performing several series of tests in which the effect of operating variables on the agglomeration performance was investigated for the three base coals. Appendix D lists the detailed results of these tests. The analysis of the results is presented in the following.

2.6.1 Agglomeration Tests Using Upper Freeport Coal

The effect of the n-heptane to coal ratio on performance was studied by conducting agglomeration tests using a 4% slurry concentration, a mixing speed of 14000 rpm, and an agglomeration time of 30 seconds. The n-heptane to coal ratios used were 0.25, 0.50, and 0.75. For comparison purposes, a test was also conducted using n-pentane as agglomerant at a n-pentane to coal ratio of 0.5.

Figure 2.6.1-1 shows that no significant difference was observed between the ash rejections obtained using n-pentane and n-heptane. This figure also shows that the n-heptane to coal ratio did not have a significant influence on ash rejection. Similarly, the energy recovery was not significantly affected by either the agglomerant or the n-heptane to coal ratio, with values between 97 and 99% in all cases.

The pyritic sulfur rejections, however, were greatly affected by the agglomerant and the n-heptane to coal ratio, as Figure 2.6.1-2 shows. The pyritic sulfur rejections obtained using n-heptane were lower than those obtained using n-pentane. As can also be seen that the pyritic sulfur rejection decreased as the n-heptane to coal ratio increased.

2.6.2 Agglomeration Tests Using Pittsburgh # 8 Coal

The effect of slurry concentration on the agglomeration performance was studied by conducting agglomeration tests at a n-heptane to coal ratio of 0.5, a mixing speed of 9000 rpm, and an agglomeration time of 60 seconds. The slurry concentrations used were 2, 4, and 6% by weight. Agglomeration tests using n-pentane as agglomerant were also conducted for comparison.

Figure 2.6.2-1 shows that an improvement in both ash rejection and energy recovery was observed in the tests conducted using n-heptane compared with those performed using n-pentane. For the three slurry concentrations used, the improvement in energy recovery was about 7 percentage points. It is worth noting that the best energy recovery (99.5%) was obtained at the highest slurry concentration used, 6 wt.%.

Figure 2.6.2-2 shows that the pyritic sulfur rejections were higher in the agglomeration tests conducted using n-heptane than in those performed using n-pentane as agglomerant. An improvement in pyritic sulfur rejection of about 3 percentage points was observed for all slurry concentrations in the tests conducted using n-heptane compared with those conducted using n-pentane. The higher pyritic sulfur rejections obtained with n-heptane were similar to improvements observed for ash rejection and energy recovery. The same figure shows that for both agglomerants, higher slurry concentrations resulted in higher energy recoveries but at the expense of lower pyritic sulfur rejections. This finding may be attributed to a detrimental effect of higher slurry concentrations on the dispersion of coal particles. Thus, a larger amount of particles were agglomerated but the selectivity of the process decreased resulting in an increase in the amount of pyrite entrapped in the agglomerates.

2.6.3 Agglomeration Tests Using Illinois # 6 Coal

A study of the effect of the slurry concentration and agglomeration time on the agglomeration performance using n-heptane was conducted. Three slurry concentrations, 2, 4, and 6 % by weight were utilized in tests conducted at agglomeration times ranging from 30 to 390 seconds.

Figures 2.6.3-1, 2.6.3-2, and 2.6.3-3, show the results of the tests in terms of energy recovery, ash rejection, and pyritic sulfur rejection, respectively. The experiments were carried out using a n-heptane to coal ratio of 1.0 and a mixing speed of 9000 rpm.

Because no replicates of the agglomeration tests have been conducted yet in this study, considerable scattering is present in the data, as shown in Figures 2.6.3-1 through 2.6.3-3. A number of preliminary conclusions, however, can be drawn from these tests.

In general, as the slurry concentration increased, the ash and pyritic sulfur rejections decreased. A comparison of Figures 2.6.3-2 and 2.6.3-3 reveals that this effect was more pronounced for the ash rejection. The enhancement of the entrapment of mineral matter in the agglomerates because of poorer particle dispersion at higher slurry concentrations is likely to be the cause of this effect.

A trend showing an increase in energy recovery and a decrease in ash and pyritic sulfur rejections was observed at the three slurry concentrations used when the agglomeration time was increased from 30 to 60 seconds. For longer agglomeration times, however, no clear trends for the effect of slurry concentration on the agglomeration process performance were observed.

A comparison with the results obtained using n-pentane as agglomerant reveals that for Illinois # 6 coal no significant gains in performance were achieved, with either n-pentane or n-heptane, by using agglomeration times longer than 60 seconds.

A study of the effect of the n-heptane to coal ratio on the agglomeration performance was also conducted by performing agglomeration tests at n-heptane to coal ratios ranging from 1.0 to 2.0. A slurry concentration of 4 wt.%, an agglomeration time of 180 seconds, and a mixing speed of 9000 rpm were employed. Figures 2.6.3-4, 2.6.3-5, and 2.6.3-6 show the results of the tests in terms of energy recovery, ash rejection, and pyritic sulfur rejection, respectively.

Figure 2.6.3-4 shows that a significant increase in energy recovery was observed as the n-heptane to coal ratio increased, particularly as the n-heptane to coal ratio increased from 1 to 1.25. This effect became smaller for higher n-heptane to coal ratios.

On the other hand, Figures 2.6.3-5 and 2.6.3-6 show that increasing the n-heptane to coal ratio from 1 to 1.25 resulted in a reduction in the ash and pyritic sulfur rejections. For higher n-heptane to coal ratios, no further decrease in the ash and pyritic sulfur rejections was observed.

The results of these experiments suggest that an agglomeration time of at least 60 seconds and a n-heptane to coal ratio between 1.25 and 1.5 yields the optimum agglomeration performance for Illinois # 6 coal.

2.6.4 Use of Tall Oil as Binder

Agglomeration tests using n-heptane as agglomerant followed by the addition of tall oil as binding agent were conducted. The following experimental procedure was utilized:

1. 500 g of a 4 wt.% coal/water slurry with 20 g of n-heptane (an agglomerant to coal ratio of 1.0) were mixed for 3 min at a mixing speed of 9000 rpm in the high-shear waring blender.
2. The slurry was transferred to a container and 200 g of water were added.
3. 2 g of tall oil (tall oil to coal ratio of 1/10) were added.
4. The container was shaken gently until large and strong agglomerates were formed.

The results of this test are shown in Table 2.6.4-1, together with the results obtained without using tall oil as a binder.

The data in Table 2.6.4-1 show a large increase in the yield and energy recovery, as a result of the addition of tall oil as a binder after the high-shear agglomeration step. However, the ash and pyritic sulfur rejections were lower, probably due to entrapment of mineral matter and pyrite during the formation of the large agglomerates.

The decrease in the pyritic sulfur rejection as a consequence of the addition of a binder was more pronounced (14 percentage points) than the decrease in ash rejection (5 percentage points). This negative effect will be further studied to seek for the cause

and remedy. Additional experiments using a combined low-shear/high-shear agglomeration step will also be conducted.

3.0 CONCLUSIONS

A summary of the most important conclusions obtained in this quarter is presented in the following.

- No relationship between the oxidation index and agglomeration time or pH was found. Also, no difference was observed between the oxidation indices of product and refuse samples agglomerated using n-heptane.
- For Illinois # 6 coal, high pH tests using n-pentane did not result in improvement of agglomeration performance improvements. For Upper Freeport coal, an improvement in ash rejection of 8 percentage points was observed in the tests at high pH.
- For Upper Freeport coal, the use of n-heptane as agglomerant resulted in similar ash rejections and energy recoveries as those obtained using n-pentane. The pyritic sulfur rejection, however, was lower in the tests conducted using n-heptane and decreased as the agglomerant to coal ratio increased.
- For Pittsburgh # 8 coal, higher energy recoveries, ash and pyritic sulfur rejections were obtained in tests conducted using n-heptane as agglomerant than in those using n-pentane.
- For Illinois # 6 coal, agglomeration times longer than 60 seconds did not result in significant improvements in performance for the tests conducted using n-pentane or n-heptane as agglomerant.
- For Illinois # 6 coal, a n-heptane to coal ratio between 1.25 and 1.5 resulted in the best agglomeration performance using n-heptane as agglomerant.
- The use of tall oil as binding agent in the agglomeration process using n-heptane as agglomerant resulted in a large increase in energy recovery at the expense of a reduction in ash and pyritic sulfur rejection for Illinois # 6 coal.

4.0 WORK SCHEDULE AND PLAN

The work schedule is shown in Table 4.0-1. The darkened bars indicate the completed portions of each task, and the empty bars refer to the scheduled future work. In the coming quarter, the research work on Task 7 will be continued focusing on the following research subtasks:

1. Optimization of agglomeration tests using n-heptane as agglomerant.
2. Evaluate agglomeration process using Southern Company Services coals.
3. Study the effect of pre-conditioning time.
4. Conduct multi-stage agglomeration tests.
5. Study the effect of desliming.
6. Perform agglomeration tests at higher slurry concentrations.
7. Use pyrite depressants.
8. Improve the technique for direct measurement of pyrite using XRD.
9. Use ESCA technique to examine coal surfaces.

5.0 REFERENCES

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APPENDIX A: TABLES

**Table 2.1.1-1 Effect of the Presence of Light Hydrocarbons on the
Oxidation Index for Illinois # 6 Coal Samples Wet
Ground to 200 mesh x 0**

SAMPLE	Oxidation Index	No. of Runs
No Additives	2.61 $\pm$ 0.41	4
Cyclohexane/Coal = 1/10	2.68 $\pm$ 0.13	4
Cyclohexane/Coal = 1/20	2.17 $\pm$ 0.48	4
N-heptane/Coal = 1/5	2.47 $\pm$ 0.48	4
N-heptane/Coal = 1/2	2.75 $\pm$ 0.81	2

Table 2.1.2-1 Effect of Agglomeration Time on the Oxidation Index for Illinois # 6 Coal Product Samples

Agglomeration Time, s	Oxidation Index	No. of Runs
30	2.33 $\pm$ 0.14	4
180	2.23 $\pm$ 0.18	4

Table 2.1.3-1 Effect of Grinding pH on the Oxidation Index for Upper Freeport Coal Samples

pH	Oxidation Index	No. of Runs
3.9	0.91 ± 0.15	4
12.5	1.05 ± 0.02	4

Table 2.1.4-1 Oxidation Indices for Illinois # 6 Coal Feed, Product, and Refuse Samples from Agglomeration Tests Conducted Using N-heptane as Agglomerant

SAMPLE	Oxidation Index	No. of Runs
Feed	2.61 $\pm$ 0.41	4
Product	2.62 $\pm$ 0.26	4
Refuse	2.54 $\pm$ 0.41	4

**Table 2.2.1-1 Change in Surface Composition for Illinois # 6 Coal Wet
Ground in the Presence of N-pentane and Cyclohexane
Relative to the Sample Ground Without Additives**

SAMPLE	Elements Increasing	Elements Decreasing
N-pentane/Coal = 1/5	S Ca Si Fe	K Na Ti Mg
Cyclohexane/Coal = 1/20	S Ca Si Fe	K Al
Cyclohexane/Coal = 1/10	S Ca K Ti Al	Si Na Mg Fe
N-heptane/Coal = 1/5 and 1/2	S Ca Si Fe Al	Na K Ti

**Table 2.2.2-1 Change in Surface Composition for Pittsburgh # 8 Coal
Wet Ground in the Presence of N-pentane Relative to
the Sample Ground Without Additives**

SAMPLE	Elements Increasing	Elements Decreasing
N-pentane/Coal = 1/10	S Fe Si	Na Ca K
	Mg	Al

Table 2.4.1-1 Contact Angles for Pittsburgh # 8 Coal

REAGENT	RCR	Largest Angle Recorded, degrees	Drop Life-span, s
No Additives		56	28
N-Pentane	1/10	45	25
	1/5	31	18
N-Heptane	1/50	49	25
	1/20	40	25
	1/10	44	46
Cyclohexane	1/50	45	24
	1/20	38	23
	1/10	44	26
REAGENT	Conc. ppm	Largest Angle Recorded, degrees	Drop Life-span, s
Aerosol-OT	10	46	29
	80	49	30
	150	29	18
Arosurf MG-83A	10	45	20
	80	48	33
Styrene	20	53	22
	200	50	23
Tall Oil	20	55	23
	200	62	40

RCR: Reagent to Coal Ratio

Table 2.4.1-2 Contact Angles for Illinois # 6 Coal

REAGENT	RCR	Largest Angle Recorded, degrees	Drop Life-span, s
No Additives		41	21
		36	20
N-Pentane	1/20	39	26
	1/10	39	22
	1/10	32	17
	1/5	35	23
	1/2	26	19
N-Heptane	1/10	27	19
	1/5	33	20
	1/2	31	21
Cyclohexane	1/20	28	20
	1/10	35	20
	1/5	33	19
REAGENT	Conc. ppm	Largest Angle Recorded, degrees	Drop Life-span, s
Aerosol-OT	10	42	24
	80	34	
Arosurf MG-83A	10	27	15
	80	32	14
Styrene	20	32	22
	200	34	20
Tall Oil	20	30	22
	200	30	12

RCR: Reagent to Coal Ratio

Table 2.4.2-1 Contact Angle Results

Medium	Contact Angle, degrees		
	Upper Freeport	Pittsburgh # 8	Illinois # 6
Air	149	135	134
N-pentane	126	132	141
N-heptane			
Non-treated pellet	127	150	137
Treated pellet	52	84	81

Table 2.5.2.1-1 Effect of pH on Agglomeration Performance for Illinois # 6 Coal

Feed Ash Content = 15.08 %
 Feed Sulfur Content = 3.49 %
 Feed Pyritic Sulfur Content = 2.55 %
 Feed Calorific Value = 11321 Btu/lb

Grinding pH	Pentane to Coal Ratio	Ash Content		Product		Yield	Ash Rejection	Total Sulfur Rejection		Pyritic Sulfur Rejection	Energy Recovery
		Product	Refuse	Total Sulfur	Pyritic Sulfur			%	%		
4.5	0.5	6.18	29.17	2.42	1.16	64.3	73.7	55.5	71.0	72.1	
10.3	0.5	7.34	37.69	2.13	0.78	68.4	66.7	58.3	79.0	75.6	
4.5	1.0	6.24	32.97	2.63	1.53	68.0	71.9	48.7	59.2	76.2	
10.1	1.0	6.89	36.26	2.59	1.53	70.1	68.0	48.0	58.1	77.9	

Table 2.5.2.2-1 Effect of pH on Agglomeration Performance for Upper Freeport Coal

Feed Ash Content = 12.48 %
 Feed Sulfur Content = 2.22 %
 Feed Pyritic Sulfur Content = 1.40 %
 Feed Calorific Value = 13255 Btu/lb

Grinding Agglomeration		Ash Content		Product		Product		Yield		Ash		Total Sulfur		Pyritic Sulfur		Energy Recovery	
pH	pH	Product	Refuse	Total Sulfur	Pyritic Sulfur	Yield	Rejection	Rejection	Rejection	Rejection	Rejection	Rejection	Rejection	Rejection	Rejection	Rejection	Rejection
		%	%	%	%	%	%	%	%	%	%	%	%	%	%	%	%
3.9	3.9	6.56	80.62	1.11	0.26	91.2	52.0	54.4	83.3	98.5							
3.9	12.5	5.83	80.21	0.96	0.52	89.5	58.2	61.3	67.0	97.5							
12.5	11.9	5.56	78.55	0.94	0.37	89.7	60.0	61.9	76.3	98.0							
12.5	12.5	5.38	75.60	1.03	0.45	89.0	61.7	58.7	71.6	97.5							

Table 2.6.4-1 Use of Tall Oil as a Binder

Illinois # 6 Coal

	Without Binder	Using Binder
Yield, %	49.7	86.0
Energy Recovery, %	54.8	98.2
Ash Rejection, %	73.1	68.6
Pyritic Sulfur Rejection, %	73.6	56.4

Table 4.0-1 Work Schedule

APPENDIX B: FIGURES

Figure 2.1.1-1 Effect of the Presence of Light Hydrocarbons on the Oxidation Index for Illinois # 6 Coal Samples Wet Ground to 200 mesh x 0

Figure 2.2-1 LAMMA Results for the Three Base Coals Wet
Ground to 200 mesh x 0 Without Additives

Figure 2.2.1-1 Change in Surface Composition for Illinois # 6 Coal Wet Ground in the Presence of N-heptane Relative to the Sample Ground Without Additives

Figure 2.2.1-2 Change in Surface Composition for Illinois # 6 Coal Wet Ground in the Presence of N-pentane and Cyclohexane Relative to the Sample Ground Without Additives

Figure 2.2.2-1 Change in Surface Composition for Pittsburgh # 8 Coal Wet Ground in the Presence of N-pentane Relative to the Sample Ground Without Additives

Figure 2.3-1 XRD Determination of Pyrite

Figure 2.4.1-1 Effect of Grinding Using Hydrocarbons on Contact Angle for Upper Freeport Coal

Figure 2.4.1-2 Effect of Grinding Using Surfactants on Contact Angle for Upper Freeport Coal

Figure 2.4.1-3 Effect of Grinding Using Monomers on Contact Angle for Upper Freeport Coal

Figure 2.5.1-1 Effect of Agglomeration Time on Energy Recovery for Illinois # 6 Coal

Figure 2.5.1-2 Effect of Agglomeration Time on Ash Rejection for Illinois # 6 Coal

Figure 2.5.1-3 Effect of Agglomeration Time on Pyritic Sulfur Rejection for Illinois # 6 Coal

Figure 2.5.2.1-1 Effect of pH on Ash Rejection
for Illinois # 6 Coal

Figure 2.5.2.1-2 Effect of pH on Pyritic Sulfur Rejection for Illinois # 6 Coal

Figure 2.5.2.1-3 Effect of pH on Energy Recovery for Illinois # 6 Coal

Figure 2.5.2.2-1 Effect of pH on Ash Rejection
for Upper Freeport Coal

Figure 2.5.2.2-2 Effect of pH on Total Sulfur Rejection for Upper Freeport Coal

Figure 2.6.1-1 Comparison of Energy Recoveries and Ash Rejections Between Agglomerants for Upper Freeport Coal

Figure 2.6.1-2 Comparison of Energy Recoveries and Pyritic Sulfur Rejections Between Agglomerants for Upper Freeport Coal

Figure 2.6.2-1 Comparison of Energy Recoveries and Ash Rejections Between Agglomerants for Pittsburgh # 8 Coal

Figure 2.6.2-2 Comparison of Energy Recoveries and Pyritic Sulfur Rejections Between Agglomerants for Pittsburgh # 8 Coal

Figure 2.6.3-1 Effect of Slurry Concentration and Agglomeration Time on Energy Recovery for Illinois # 6 Coal

Figure 2.6.3-2 Effect of Slurry Concentration and Agglomeration Time on Ash Rejection for Illinois # 6 Coal

Figure 2.6.3-3 Effect of Slurry Concentration and Agglomeration Time on Pyritic Sulfur Rejection for Illinois # 6 Coal

Figure 2.6.3-4 Effect of N-heptane to Coal Ratio on Energy Recovery for Illinois # 6 Coal

Figure 2.6.3-5 Effect of N-heptane to Coal Ratio on Ash Rejection for Illinois # 6 Coal

Figure 2.6.3-6 Effect of N-heptane to Coal Ratio on Pyritic Sulfur Rejection for Illinois # 6 Coal

**APPENDIX C: RESULTS OF AGGLOMERATION TESTS USING
N-PENTANE AS AGGLOMERANT**

RESULTS OF OPTIMIZATION TESTS USING N-PENTANE AS AGGLOMERANT

NOMENCLATURE

Af: Feed Ash Content (%)

Ap: Product Ash Content (%)

Ar: Refuse Ash Content (%)

ARD: Ash Reduction (%)

$$ARD = (1 - Ap/Af) \times 100$$

ARJ: Ash Rejection (%)

$$ARJ = 100 - Y \times Ap / Af$$

(Btu)f: Feed Calorific Value (Btu/lb)

(Btu)p: Product Calorific Value (Btu/lb)

BTU: Energy Recovery (%),

$$BTU = (Btu)p / (Btu)f \times Y$$

C: Coal-Water Slurry Concentration (Wt.%)

N: Mixing Speed (rpm)

P: Product Weight (g)

PCR: Pentane to Coal Ratio (Weight Basis)

pH AGGL: Agglomeration Test pH

RESULTS OF OPTIMIZATION TESTS USING N-PENTANE AS AGGLOMERANT

pH GRIND: Grinding pH

PSf: Feed Pyritic Sulfur Content (%)

PSp: Product Pyritic Sulfur Content (%)

PSRJ: Pyritic Sulfur Rejection (%)

$$PSRJ = (100 - Y \times PSp / PSf)$$

R: Refuse Weight (g)

Sf: Feed Total Sulfur Content (%)

Sp: Feed Total Sulfur Content (%)

SRJ: Total Sulfur Rejection (%)

$$SRJ = (100 - Y \times Sp / Sf)$$

T: Agglomeration Time (sec)

TEMP: Agglomeration Test Final Temperature (F)

Y: Overall Yield (%)

$$Y = P / (P + R) \times 100$$

Yc: Clean Coal Yield (%)

$$Yc = Y \times (1 - Ap) / (1 - Af)$$

RESULTS OF OPTIMIZATION TESTS USING N-PENTANE AS AGGLOMERANT

Effect of Agglomeration Time on Performance for Illinois # 6 Coal Wet Ground to 200 mesh x 0

Run #	C (%)	TEMP (F)	PCR (-)	T (s)	N (rpm)	P (g)	R (g)	Af		Sf		PSf		Y (%)	ARJ (%)	ARD (%)	SRJ (%)	PSRJ (%)	Yc (%)	BTU (%)
								Ap (%)	Ar (%)	Sp (%)		Psp (%)								
								17.50		5.14		3.51								(Btu)f 10949
1180/1.1	4	74	0.5	30	14097	12.4800	6.7900	9.02	23.59	3.28		1.31		64.8	66.6	48.5	58.7	75.8	71.4	72.5
1180/1.2	4	74	0.5	30	14224	11.1600	7.9000	8.63	22.26	3.60		1.94		58.6	71.1	50.7	59.0	67.7	64.8	65.9
AVE	4	74	0.5	30	14161	11.8200	7.3450	8.83	22.93	3.44		1.63		61.7	68.9	49.6	58.3	71.7	68.1	69.2
1180/2.1	4	75	0.5	60	14478	10.9300	6.9800	8.82	21.75	3.10		1.51		61.0	69.2	49.6	63.2	73.7	67.4	68.5
1180/2.2	4	76	0.5	60	14097	10.0100	5.8300	8.09	23.52	3.04		1.80		63.2	70.8	53.8	62.6	67.6	70.4	71.6
1180/2.3	4	76	0.5	60	14097	10.5000	8.9300	9.89	19.76	3.09		1.46		54.0	69.5	43.5	67.5	77.5	59.0	59.8
AVE	4	76	0.5	60	14224	10.4800	7.2467	8.93	21.68	3.08		1.59		59.4	69.8	49.0	64.4	73.0	65.6	66.6
1180/3.1	4	78	0.5	120	14351	10.0500	8.1300	9.49	19.57	3.14		1.47		55.3	70.0	45.8	66.2	76.8	60.6	61.5
1180/3.2	4	78	0.5	120	14224	11.4300	7.0700	9.12	20.56	2.95		1.03		61.8	67.8	47.9	64.5	81.9	68.1	69.1
1180/3.3	4	79	0.5	120	14224	12.5500	6.6400	9.52	21.47	3.22		1.36		65.4	64.4	45.6	59.0	74.6	71.7	72.7
AVE	4	78	0.5	120	14266	11.3433	7.2800	9.38	20.53	3.10		1.29		60.8	67.4	46.4	63.3	77.8	66.8	67.8
1180/4.1	4	81	0.5	180	14097	11.6600	6.3000	9.58	23.49	3.33		1.48		64.9	64.5	45.3	57.9	72.6	71.2	72.2
1180/4.2	4	82	0.5	180	14478	10.8500	6.1300	8.65	23.13	3.29		1.63		63.9	68.4	50.6	59.1	70.3	70.8	71.9
1180/4.3	4	82	0.5	180	14224	11.7800	5.6700	9.38	23.03	3.17		1.34		67.5	63.8	46.4	58.4	74.2	74.2	75.2
AVE	4	82	0.5	180	14266	11.4300	6.0333	9.20	23.22	3.26		1.49		65.4	65.6	47.4	58.5	72.4	72.0	73.1

RESULTS OF OPTIMIZATION TESTS USING N-PENTANE AS AGGLOMERANT

Effect of Agglomeration Time on Performance for Illinois # 6 Coal Wet Ground to 200 mesh x 0

Run #	C (%)	TEMP (F)	PCR (-)	T (s)	N (rpm)	P (g)	R (g)	Ap (%)	Ar (%)	Sp (%)	PSp (%)	Y (%)	ARJ (%)	ARD (%)	SRJ (%)	PSRJ (%)	Yc (%)	BTU (%)
								13.78		3.94	1.94							11522
I181/1.1	4	82	0.5	180	14224	9.6700	8.6300	9.27	18.62	3.26	1.33	52.8	64.5	32.7	56.3	63.6	55.6	56.0
I181/1.2	4	83	0.5	180	14605	11.6200	7.6500	8.35	21.13	2.68	0.68	60.3	63.5	39.4	59.0	78.7	64.1	64.7
I181/1.3	4	84	0.5	180	14351	12.7000	7.1100	8.56	21.45	2.95	1.04	64.1	60.2	37.9	52.0	65.6	68.0	68.6
AVE	4	83	0.5	180	14393	11.3300	7.7967	8.73	20.40	2.96	1.02	59.1	62.7	36.7	55.8	69.3	62.6	63.1
I181/2.1	4	86	0.5	240	14224	11.2800	5.6100	8.30	23.42	3.10	1.21	66.8	59.8	39.8	47.5	58.2	71.0	71.7
I181/2.3	4	86	0.5	240	14224	12.1700	7.5800	9.16	21.26	3.14	1.11	61.6	59.0	33.5	50.9	64.7	64.9	65.4
AVE	4	86	0.5	240	14224	11.7250	6.5950	8.73	22.34	3.12	1.16	64.2	59.4	36.6	49.2	61.4	68.0	68.6
I181/3.1	4	91	0.5	300	14224	11.7300	6.0100	8.40	23.27	3.22	1.44	66.1	59.7	39.0	46.0	50.7	70.2	70.9
I181/3.2	4	88	0.5	300	14605	11.4000	6.8000	8.49	21.75	3.01	1.14	62.6	61.4	38.4	52.1	63.1	66.5	67.1
I181/3.3	4	89	0.5	300	14605	11.6900	6.7600	8.14	22.87	3.01	0.97	63.4	62.6	40.9	51.6	68.3	67.5	68.1
AVE	4	89	0.5	300	14478	11.6067	6.5233	8.34	22.63	3.08	1.18	64.0	61.2	39.5	49.9	60.7	68.1	68.7
I181/4.1	4	92	0.5	360	14478	14.4000	7.3700	9.31	20.80	3.25	1.54	66.1	55.3	32.4	45.4	47.2	69.6	70.1
I181/4.2	4	93	0.5	360	14478	12.3000	6.2800	7.90	23.14	3.11	1.16	66.2	62.0	42.7	47.7	60.3	70.7	71.4
I181/4.3	4	90	0.5	360	14224	12.4700	6.3800	9.51	22.10	3.27	1.46	66.2	54.3	31.0	45.1	50.0	69.4	69.9
AVE	4	92	0.5	360	14393	13.0567	6.6767	8.91	22.01	3.21	1.39	66.2	57.2	35.4	46.1	52.5	69.9	70.5

RESULTS OF OPTIMIZATION TESTS USING N-PENTANE AS AGGLOMERANT

Effect of pH on Agglomeration Performance for Illinois # 6 Coal Wet Ground to 200 mesh x 0

Run #	C (%)	pH	PCR (-)	T (s)	N (rpm)	P (g)	R (g)	Af		Sp	Psp	Y (%)	ARJ (%)	ARD (%)	SRJ (%)	PSRJ (%)	Yc (%)	(Btu)f	
								Ap (%)	Ar (%)									11321	
16.BW171.1	2	4.6	0.5	60	9398	4.7485	2.9845	6.72	29.26	2.62	1.35	61.4	72.6	55.4	53.9	68.0	67.5	68.4	
16.BW171.2	2	4.4	0.5	60	10287	3.8145	2.0105	5.77	29.20	2.51	1.43	65.5	74.9	61.7	52.9	63.9	72.7	73.8	
16.BW171.3	2	4.6	0.5	60	9271	4.9045	2.5355	6.04	29.05	2.13	0.77	65.9	73.6	59.9	59.8	80.4	72.9	74.0	
Ave	2	4.5	0.5	60	9652	4.4892	2.5102	6.18	29.17	2.42	1.18	64.3	73.7	59.0	55.5	70.8	71.0	72.1	
16.BMPH172.4	2	10.1	0.5	60	9271	5.2655	2.3740	7.50	38.31	1.90	0.77	68.9	65.7	50.3	62.5	79.6	75.1	76.0	
16.BMPH172.5	2	10.4	0.5	60	9271	5.7825	2.9065	7.54	36.98	2.49	1.11	66.5	66.7	50.0	52.5	71.6	72.5	73.4	
16.BMPH172.6	2	10.3	0.5	60	9525	5.4025	2.3315	6.99	37.79	1.99	0.53	69.9	67.6	53.6	60.2	85.6	76.5	77.5	
Ave	2	10.3	0.5	60	9356	5.4835	2.5373	7.34	37.69	2.13	0.80	68.4	66.7	51.3	58.4	78.9	74.7	75.7	
16.BW171.7	2	4.3	1.0	60	9271	6.1695	2.9875	6.59	29.70	2.59	1.48	67.4	70.6	56.3	50.0	61.5	74.1	75.2	
16.BW171.8	2	4.6	1.0	60	9462	4.4840	2.5765	5.75	29.76	2.58	1.54	63.5	75.8	61.9	53.1	62.3	70.5	71.6	
16.BW171.9	2	4.6	1.0	60	9335	5.7825	2.1665	6.37	39.45	2.72	1.66	72.7	69.3	57.8	43.3	53.4	80.2	81.4	
Ave	2	4.5	1.0	60	9356	5.4787	2.5768	6.24	32.97	2.63	1.56	67.9	71.9	58.6	48.8	59.1	74.9	76.0	
16.BMPH172.10	2	9.9	1.0	60	9271	5.5115	2.0550	6.99	39.32	2.45	1.35	72.8	66.2	53.6	48.9	62.2	79.8	80.9	
16.BMPH172.11	2	10.2	1.0	60	9271	5.0315	2.1775	6.71	37.69	2.53	1.44	69.8	68.9	55.5	49.4	61.3	76.7	77.7	
16.BMPH172.12	2	10.3	1.0	60	9208	5.5865	2.6635	6.97	31.76	2.79	1.88	67.7	68.7	53.8	45.9	50.9	74.2	75.2	
Ave	2	10.1	1.0	60	9250	5.3765	2.2987	6.89	36.26	2.59	1.56	70.1	68.0	54.3	48.0	58.1	76.9	77.9	

RESULTS OF OPTIMIZATION TESTS USING N-PENTANE AS AGGLOMERANT

Effect of pH on Agglomeration Performance for Upper Freeport Coal Wet Ground to 200 mesh x 0

Run #	C (%)	pH	GRIND	pH	PCR	T (s)	N (rpm)	P (g)	R (g)	Af		Sp (%)	Sf	PSf	Y (%)	ARJ (%)	ARD (%)	SRJ (%)	PSRJ (%)	Yc (%)	BTU (%)
										Ap (%)	Ar (%)										
U177A.3	4	3.9	3.9	0.5	30	14288	21.3200	2.0600	6.61	81.02	1.12	0.26	91.2	51.7	47.0	54.0	83.1	97.3	98.3		
U177A.2	4	3.9	3.9	0.5	30	14034	20.2200	1.9000	6.52	81.22	1.09	0.22	91.4	52.2	47.8	55.1	85.6	97.6	98.7		
U177A.1	4	3.9	3.9	0.5	30	14034	19.1400	1.8700	6.55	79.62	1.12	0.29	91.1	52.2	47.5	54.0	81.1	97.3	98.3		
Ave	4	3.9	3.9	0.5	30	14118	20.2267	1.9433	6.56	80.62	1.11	0.26	91.2	52.0	47.4	54.4	83.3	97.4	98.5		
U177B.3	4	3.9	12.5	0.5	30	14034	20.4800	2.4600	6.05	79.96	0.96	0.55	89.3	56.7	51.5	61.4	65.1	95.8	97.0		
U177B.2	4	3.9	12.5	0.5	30	14288	19.7600	2.2800	5.72	80.32	0.99	0.51	89.7	58.9	54.2	60.0	67.4	96.6	97.8		
U177B.1	4	3.9	12.5	0.5	30	14034	18.8900	2.2000	5.72	80.34	0.93	0.49	89.6	58.9	54.2	62.5	68.8	96.5	97.7		
Ave	4	3.9	12.5	0.5	30	14118	19.7100	2.3133	5.83	80.21	0.96	0.52	89.5	58.2	53.3	61.3	67.1	96.3	97.5		
U178A.3	4	12.5	11.9	0.5	30	14034	21.4100	2.4900	5.66	78.13	0.96	0.36	89.6	59.4	54.6	61.3	77.0	96.6	97.8		
U178A.2	4	12.5	11.9	0.5	30	14034	18.2500	2.1100	5.49	78.93	0.89	0.38	89.6	60.6	56.0	64.1	75.7	96.8	98.0		
U178A.1	4	12.5	11.9	0.5	30	14288	20.5400	2.2900	5.53	78.58	0.98	0.37	90.0	60.1	55.7	60.3	76.3	97.1	98.3		
Ave	4	12.5	11.9	0.5	30	14118	20.0667	2.2967	5.56	78.55	0.94	0.37	89.7	60.0	55.4	61.9	76.3	96.8	98.0		
U178B.3	4	12.5	12.5	0.5	30	14034	18.9800	2.4500	5.36	75.77	1.01	0.45	88.6	62.0	57.1	59.7	71.6	95.8	97.0		
U178B.2	4	12.5	12.5	0.5	30	14034	21.1500	2.5300	5.16	76.22	1.07	0.41	89.3	63.1	58.7	57.0	73.9	96.8	98.1		
U178B.1	4	12.5	12.5	0.5	30	14034	19.8200	2.4100	5.61	74.82	1.01	0.48	89.2	59.9	55.0	59.4	69.5	96.2	97.3		
Ave	4	12.5	12.5	0.5	30	14034	19.9833	2.4633	5.38	75.60	1.03	0.45	89.0	61.7	56.9	58.7	71.7	96.2	97.5		

**APPENDIX D: RESULTS OF AGGLOMERATION TESTS USING
N-HEPTANE AS AGGLOMERANT**

RESULTS OF AGGLOMERATION TESTS USING N-HEPTANE AS AGGLOMERANT

NOMENCLATURE

Af: Feed Ash Content (%)

Ap: Product Ash Content (%)

Ar: Refuse Ash Content (%)

ARD: Ash Reduction (%)

$$ARD = (1 - Ap/Af) \times 100$$

ARJ: Ash Rejection (%)

$$ARJ = 100 - Y \times Ap / Af$$

(Btu)f: Feed Calorific Value (Btu/lb)

(Btu)p: Product Calorific Value (Btu/lb)

BTU: Energy Recovery (%),

$$BTU = (Btu)p / (Btu)f \times Y$$

C: Coal-Water Slurry Concentration (Wt.%)

HCR: N-heptane to Coal Ratio

N: Mixing Speed (rpm)

RESULTS OF AGGLOMERATION TESTS USING N-HEPTANE AS AGGLOMERANT

P: Product Weight (g)

PCR: Pentane to Coal Ratio (Weight Basis)

PSf: Feed Pyritic Sulfur Content (%)

PSP: Product Pyritic Sulfur Content (%)

PSRJ: Pyritic Sulfur Rejection (%)

$$PSRJ = (100 - Y \times PSP / PSf)$$

R: Refuse Weight (g)

Sf: Feed Total Sulfur Content (%)

Sp: Feed Total Sulfur Content (%)

SRJ: Total Sulfur Rejection (%)

$$SRJ = (100 - Y \times Sp / Sf)$$

T: Agglomeration Time (sec)

Y: Overall Yield (%)

$$Y = P / (P + R) \times 100$$

Yc: Clean Coal Yield (%)

$$Yc = Y \times (1 - Ap) / (1 - Af)$$

RESULTS OF AGGLOMERATION TESTS USING N-HEPTANE AS AGGLOMERANT

Upper Freeport Coal		Effect of N-heptane to Coal Ratio (HCR) on Agglomeration Performance														(Btu) f		
Run #	C (%)	HCR (-)	PCR (-)	T (s)	N (rpm)	P (g)	R (g)	Ap (%)	Ar (%)	Sp (%)	PSp (%)	Y (%)	ARJ (%)	ARD (%)	SRJ (%)	PSRJ (%)	Yc (%)	BTU
								13.40		Sf	PSf							13093
										1.54	0.73							
U182/1.3	4	0.5	0.5	30	14034	16.6000	1.7300	7.43	81.44	1.02	0.21	90.6	49.8	44.6	40.0	73.6	96.8	97.9
U182/1.2	4	0.5	0.5	30	14288	20.8300	1.9700	7.77	81.62	1.01	0.22	91.4	47.0	42.0	40.1	72.1	97.3	98.3
U182/1.1	4	0.5	0.5	30	14034	18.3000	1.6500	7.14	81.07	1.01	0.23	91.7	51.1	46.7	39.8	70.7	98.4	99.5
AVE	4	0.5	0.5	30	14118	18.5767	1.7833	7.45	81.38	1.01	0.22	91.2	49.3	44.4	40.0	72.1	97.5	98.6
U182/2.3	4	0.25	0.5	30	14034	19.1700	2.0100	7.61	72.61	1.03	0.26	90.5	48.6	43.2	39.5	67.3	96.6	97.6
U182/2.2	4	0.25	0.5	30	14034	19.2900	2.2200	8.47	69.84	1.03	0.26	89.7	43.3	36.8	40.0	67.6	94.8	95.7
U182/2.1	4	0.25	0.5	30	14288	18.4400	2.0400	8.03	69.15	1.14	0.39	90.0	46.0	40.1	33.3	51.3	95.6	96.6
AVE	4	0.25	0.5	30	14118	18.9667	2.0900	8.04	70.53	1.07	0.31	90.1	46.0	40.0	37.6	62.1	95.7	96.6
U182/3.3	4	0.50	0.5	30	14034	19.7800	1.8000	7.95	82.18	1.10	0.34	91.7	45.6	40.7	34.5	56.7	97.4	98.4
U182/3.2	4	0.50	0.5	30	14034	20.4800	1.8800	7.84	81.39	1.07	0.30	91.6	46.4	41.5	36.4	61.9	97.5	98.5
U182/3.1	4	0.50	0.5	30	14034	19.1100	1.7900	7.79	81.78	1.15	0.36	91.4	46.8	41.9	31.7	54.3	97.4	98.4
AVE	4	0.50	0.5	30	14034	19.7900	1.8233	7.86	81.78	1.11	0.34	91.6	46.3	41.3	34.2	57.6	97.4	98.4
U182/4.3	4	0.75	0.5	30	14288	19.8200	2.1000	7.89	80.95	1.18	0.41	90.4	46.8	41.1	30.7	48.5	96.2	97.2
U182/4.2	4	0.75	0.5	30	14034	19.3000	2.1900	7.45	80.16	1.18	0.43	89.8	50.1	44.4	31.2	46.4	96.0	97.0
U182/4.1	4	0.75	0.5	30	14034	18.5200	2.0300	7.53	79.88	1.18	0.39	90.1	49.4	43.8	30.9	51.2	96.2	97.3
AVE	4	0.75	0.5	30	14118	19.2133	2.1067	7.62	80.33	1.18	0.41	90.1	48.7	43.1	30.9	48.7	96.1	97.2

RESULTS OF FLOCCULATION TESTS USING N-HEPTANE AS AGGLOMERANT

Pittsburgh # 8 Coal Effect of Slurry Concentration (C) and Agglomerant on Agglomeration Performance

Run #	C (%)	HCR (-)	PCR (-)	T (s)	N (rpm)	P (g)	R (g)	Af		Sp	Psp	Y (%)	ARJ (%)	ARD (%)	SRJ (%)	PSRJ (%)	Yc (%)	BTU (%)
								Ap (%)	Ar (%)									
								12.50		3.76	2.85							(Btu) f 12343
BU202.PEN.1	2	0.5	0.5	60	9779	8.3350	2.0075	4.22		2.09	1.16	80.6	72.3	65.6	55.2	65.8	88.0	89.1
BU202.PEN.2	2	0.5	0.5	60	9652	10.1233	2.6875	5.30		2.31	1.36	79.0	65.9	56.8	51.5	60.6	85.3	86.3
AVE	2	0.5	0.5	60	9716	9.2292	2.3475	4.76		2.20	1.26	79.8	69.1	61.2	53.3	63.2	86.6	87.7
BU202.HAP.1	2	0.5	0.5	60	9398	7.5525	1.0675	3.36		1.99	0.96	87.6	76.0	72.6	53.6	69.3	96.5	97.9
BU202.HAP.2	2	0.5	0.5	60	9398	10.2313	1.8577	3.58		2.03	1.02	84.6	75.3	70.8	54.3	68.5	93.0	94.3
BU202.HAP.3	2	0.5	0.5	60	9525	12.6815	3.1855	4.34		2.17	1.20	86.1	69.5	71.7	50.3	62.1	94.8	96.1
AVE	2	0.5	0.5	60	9440	10.1551	2.0369	3.76		2.06	1.06	86.1	73.6	71.7	52.7	66.6	94.8	95.1
BU202.PEN.4	4	0.5	0.5	60	9589	9.2944	2.3350	4.20		2.09	1.11	79.9	72.6	65.8	55.6	67.5	87.3	88.4
BU202.PEN.5	4	0.5	0.5	60	9462	13.4155	2.9207	5.56		2.34	1.40	82.1	62.8	54.7	48.9	58.1	88.4	89.4
AVE	4	0.5	0.5	60	9525	11.3550	2.6279	4.88		2.22	1.25	81.0	67.7	60.2	52.2	62.8	87.8	88.9
BU202.HAP.4	4	0.5	0.5	60	9716	11.5990	1.5365	3.63		1.99	1.02	88.3	73.9	70.4	53.3	67.1	97.0	98.3
BU202.HAP.5	4	0.5	0.5	60	9716	11.5015	1.5450	3.76		2.09	1.10	88.2	73.0	69.4	51.0	64.5	96.7	98.0
BU202.HAP.6	4	0.5	0.5	60	9652	14.9510	2.4316	4.28		2.15	1.16	86.0	70.9	65.1	50.8	63.5	93.8	95.1
AVE	4	0.5	0.5	60	9694	12.6838	1.8377	3.89		2.08	1.09	87.5	72.3	68.3	51.7	65.0	95.9	97.1
BU203.PEN.7	6	0.5	0.5	60	9525	20.5100	3.8955	4.20		2.29	1.38	84.0	72.3	67.0	52.1	60.6	92.3	93.5
BU203.PEN.8	6	0.5	0.5	60	9525	26.2165	4.9327	5.56		2.46	1.50	84.2	63.2	56.3	48.5	57.3	91.1	92.2
AVE	6	0.5	0.5	60	9525	23.3633	4.4141	4.88		2.38	1.44	84.1	67.8	61.7	50.3	59.0	91.7	92.8
BU203.HAP.7	6	0.5	0.5	60	9716	25.0663	2.8284	4.75		2.21	1.23	89.9	66.5	62.7	50.6	62.5	98.1	99.4
BU203.HAP.8	6	0.5	0.5	60	9652	22.4549	2.5585	4.06		2.16	1.16	89.8	71.4	68.1	51.8	61.7	98.7	100.1
BU203.HAP.9	6	0.5	0.5	60	9271	26.8838	3.3125	4.16		2.15	1.22	89.0	70.9	67.3	52.4	63.2	97.8	99.1
AVE	6	0.5	0.5	60	9546	24.8017	2.8998	4.32		2.17	1.21	89.6	69.6	66.0	51.6	63.4	98.2	99.5

RESULTS OF AGGLOMERATION TESTS USING N-HEPTANE AS AGGLOMERANT

Illinois # 6 Coal		Effect of Agglomeration Time (T) and Slurry Concentration (C) on Agglomeration Performance															(Btu) f
Run #	C (%)	HCR (-)	T (s)	N (rpm)	P (g)	R (g)	Ap (%)	Af (%)	Sf	PSf	Y (%)	ARJ (%)	SRJ (%)	PSRJ (%)	Yc (%)	BTU	
								16.15	4.93	3.41							11157
8W205.3	2	1.00	30	9525	2.9400	5.8100	6.20	17.09	3.37	1.79	33.6	87.4	77.0	82.3	37.7	38.4	
8W205.4	2	1.00	60	9462	3.1900	4.8100	6.34	17.11	3.40	2.13	39.9	84.7	72.5	75.1	44.7	45.5	
8W205.5	2	1.00	90	9398	3.4400	4.8600	6.69	18.74	3.44		41.4	83.2	71.1		46.3	47.1	
8W205.6	2	1.00	180	9462	3.9800	3.7800	6.82	20.93	3.49	2.26	51.3	78.8	63.7	66.0	57.2	58.2	
8W205.7	2	1.00	240	9462	3.8700	4.6700	6.59	17.39	3.37	1.87	45.3	81.9	60.1	7.1	50.7	51.6	
8W205.8	2	1.00	270	9398	3.8700	4.4600	6.76	19.03	3.53	1.39	46.5	81.0	66.7	74.3	51.9	52.7	
8W205.9	2	1.00	300	9335	4.4300	4.2100	7.65	20.91	3.47	1.77	51.3	76.2	63.9	73.4	56.7	57.6	
8W205.10	2	1.00	360	9271	4.2300	5.0700	7.24	18.05	3.57	1.94	45.5	80.0	56.1	74.1	50.5	51.3	
8W205.11	2	1.00	390	9525	4.5800	8.2600	7.85	17.57	3.65	2.40	35.7	83.0	73.6	74.9	39.4	40.0	
8W207.1	4	1.00	30	9335	9.1650	12.7900	9.20		3.54	1.91	41.7	76.2	43.0	76.6	45.2	45.7	
8W207.2	4	1.00	60	9271	8.3700	11.2600	8.88		3.59	2.19	42.6	76.6	45.0	69.0	46.3	46.9	
8W207.3	4	1.00	90	9081	9.8200	14.0400	9.75		3.61	2.22	41.2	75.2	39.6	69.9	44.3	44.8	
8W207.4	4	1.00	120	9208	8.8000	12.6200	9.08		3.55	1.91	41.1	76.9	43.8	70.4	44.5	45.1	
8W207.5	4	1.00	150	9271	9.1800	13.2900	9.25		3.71	2.35	40.9	76.6	42.7	69.3	44.2	44.7	
8W207.6	4	1.00	180	9271	8.2100	8.3200	8.75		3.63	2.15	49.7	73.1	45.8	68.7	54.1	54.7	
8W207.7	4	1.00	210	9144	8.4300	11.1900	8.87		3.66	2.11	43.0	76.4	45.1	67.9	46.7	47.3	
8W207.8	4	1.00	240	9144	9.5800	14.0400	9.77		3.82	2.16	40.6	75.5	39.5	68.6	43.6	44.1	
8W207.9	4	1.00	270	9271	9.4000	10.0400	9.15		3.58	1.97	48.4	72.6	43.3	63.9	52.4	53.0	

RESULTS OF AGGLOMERATION TESTS USING N-HEPTANE AS AGGLOMERANT

Effect of Agglomeration Time (T) and Slurry Concentration (C) on Agglomeration Performance																	
Run #	C (%)	HCR (-)	T (s)	N (rpm)	P (g)	R (g)	Ap (%)	Ar (%)	Sp (%)	Psp (%)	Y (%)	ARJ (%)	ARD (%)	SRJ (%)	PSRJ (%)	Yc (%)	BTU)
							16.15		4.93	3.41							11157
BM208.1	6	1.00	30	8954	11.9500	18.8000	10.07	18.10	3.57	2.19	38.9	75.8	37.6	71.9	75.1	41.7	42.1
BM208.2	6	1.00	60	9081	11.4000	12.2400	9.23	18.68	3.69	2.09	48.2	72.4	2.8	63.9	70.5	52.2	52.8
BM208.3	6	1.00	90	9144	12.8200	14.8900	9.24	18.37	3.66	2.04	46.3	73.5	42.8	65.7	72.3	50.1	50.7
BM208.4	6	1.00	120	9017	13.4500	14.1100	10.48	18.38	3.84	2.13	48.8	68.3	55.1	62.0	69.5	52.1	52.6
BM208.5	6	1.00	150	8827	10.4300	11.0700	9.21	18.95	3.67	2.06	48.5	72.3	43.0	63.9	70.7	52.5	53.2
BM208.6	6	1.00	180	8890	11.1100	10.1600	8.94	19.77	3.72	1.99	52.2	71.1	44.6	60.6	69.6	56.7	57.4
BM208.7	6	1.00	210	8954	16.0900	12.4000	10.35	19.91	3.88	2.26	56.5	63.8	35.9	55.6	62.6	60.4	51.0
BM208.8	6	1.00	240	8954	13.6700	13.4900	10.08	19.17	3.76	2.06	50.3	68.6	37.6	61.6	69.7	54.0	54.6
BM208.9	6	1.00	300	9144	15.6600	8.4900	9.12	20.93	3.70	2.06	64.8	63.4	43.5	51.3	60.9	70.3	71.1
BM208.10	6	1.00	360	9017	15.2400	13.0400	11.41	19.57	4.13	2.41	53.9	61.9	29.3	54.9	61.9	56.9	57.4
BM208.15	6	1.00	30	8954	10.9700	16.4500	10.61	16.77	3.85		40.0	73.7	34.3	68.8		42.7	43.1

RESULTS OF AGGLOMERATION TESTS USING N-HEPTANE AS AGGLOMERANT

Illinois # 6 Coal Effect of N-heptane to Coal Ratio (HCR) on Agglomeration Performance

Run #	C (%)	HCR (-)	T (s)	N (rpm)	P (g)	R (g)	Af		Sf		PSf		SRJ (%)	PSRJ (%)	Yc (%)	BTU (%)
							Ap (%)	Ar (%)	Sp (%)		PSP (%)	Y (%)				
							9.95	22.57	3.51	1.78	66.0	59.3	38.4	53.0	65.6	70.9
BW211.1	4	1.00	180	8827	13.3500	6.8800	9.95	22.57	3.51	1.78	66.0	59.3	38.4	53.0	65.6	70.9
BW211.6	4	1.00	180	8890	13.6300	7.8900	8.61	22.01	3.56	1.86	63.3	66.2	46.7	54.3	65.5	69.0
Ave	4	1.00	180	8858	15.4900	7.3850	9.28	22.29	3.54	1.82	64.7	62.8	42.5	53.6	65.5	70.0
							9.76		3.59	1.98	71.7	56.7	39.6	47.8	58.4	77.2
BW211.2	4	1.25	180	8890	15.3600	6.0600	9.76		3.59	1.98	71.7	56.7	39.6	47.8	58.4	77.2
BW211.7	4	1.25	180	8954	14.6000	5.5100	9.24	24.24	3.65	1.97	72.6	58.5	42.8	46.2	58.0	78.6
Ave	4	1.25	180	8922	14.9800	5.7850	9.50	24.24	3.62	1.98	72.2	57.6	41.2	47.0	58.2	77.9
							9.77	26.93	3.54	1.90	75.1	54.6	39.5	46.1	58.2	80.8
BW211.3	4	1.50	180	8827	14.2300	4.7200	9.77	26.93	3.54	1.90	75.1	54.6	39.5	46.1	58.2	80.8
BW211.8	4	1.50	180	8954	14.8000	4.7100	9.56	27.94	3.59	1.96	75.9	55.1	40.8	44.8	56.4	81.8
Ave	4	1.50	180	8890	14.5150	4.7150	9.67	27.44	3.57	1.93	75.5	54.8	40.2	45.4	57.3	81.3
							8.79	30.29	3.53	1.83	75.8	58.8	45.6	45.7	59.4	82.4
BW211.4	4	1.75	180	9144	13.3200	4.2600	8.79	30.29	3.53	1.83	75.8	58.8	45.6	45.7	59.4	82.4
BW211.9	4	1.75	180	8827	13.9900	4.5800	9.58	28.83	3.73	2.08	75.3	55.3	40.7	43.0	54.2	81.2
Ave	4	1.75	180	8985	13.6550	4.4200	9.19	29.56	3.63	1.95	75.6	57.0	43.1	44.4	56.8	81.8
							10.75	29.76	3.83	2.51	78.0	48.1	33.4	39.4	42.7	83.0
BW211.5	4	2.00	180	9017	17.7000	4.9900	10.75	29.76	3.83	2.51	78.0	48.1	33.4	39.4	42.7	83.0
BW211.10	4	2.00	180	8954	15.7500	4.6200	9.74	29.97	3.63	1.89	77.3	53.4	39.7	43.1	57.1	83.2
Ave	4	2.00	180	8985	16.7250	4.8050	10.25	29.87	3.75	2.20	77.7	50.7	36.6	41.2	49.9	83.1

RESULTS OF AGGLOMERATION TESTS USING N-HEPTANE AS AGGLOMERANT

Use of Tall Oil as a Binder																		
Illinois # 6 Coal																		
		Af		Sf		PSf												(Btu)f
		16.15		4.93		3.31												11157
Run #	C (%)	HCR (-)	T (s)	H (rpm)	P (g)	R (g)	Ap (%)	Ar (%)	Sp (%)	PSp (%)	Y (%)	ARJ (%)	ARD (%)	SRJ (%)	PSRJ (%)	Yc (%)	BTU (%)	
BW207.12	4	1.0	180	9462	20.3200	3.3100	5.90	71.67	3.50	1.82	86.0	68.6	63.5	39.0	54.1	96.5	98.2	

END

DATE FILMED

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