ENGINEERING DEVELOPMENT OF ADVANCED PHYSICAL FINE COAL CLEANING FOR PREMIUM FUEL APPLICATIONS

US DOE Contract No. DE-AC22-92PC92208-21

Amax R&D Subcontract No. 91445-B

Task 11:

Topical Report

Commercial CWF Production Cost Study

Prepared for:

Amax R&D, Inc.

Golden, Colorado

Prepared by:

Technology & Consulting

Bechtel Corporation

San Francisco, CA

Principal Investigators:

Horst Huettenhain

M. K. V. Chari

June 1997

Notice

Contents

TABLES

ILLUSTRATIONS

Section 1
Executive Summary

1.1 INTRODUCUTION

Bechtel, together with Amax Research and Development Center (Amax R&D), has prepared this study which provides estimates of the cost of production of premium quality coal-water slurry fuel (CWF) in a commercial plant. Two plant scenarios are presented, one using advanced column flotation technology to clean the coal and the other, selective agglomeration for the same purpose. The study forms part of US Department of Energy program “Engineering Development of Advanced Physical Fine Coal Cleaning for Premium Fuel Applications,” (Contract No. DE-AC22-92PC92208), under Task 11, Project Final Report.

The primary objective of the Department of Energy program is to develop a design base for prototype commercial advanced fine coal cleaning facilities capable of producing ultra-clean coals suitable for conversion to stable and highly loaded CWF. The fuels should contain less than 2 lb of ash/MBtu (860 grams of ash/GJ) of HHV and preferably less than 1 lb of ash/MBtu (430 grams of ash/GJ). Advanced fine coal cleaning technologies to be employed are advanced column froth flotation and selective agglomeration. It is further stipulated that operating conditions during the advanced cleaning process should recover at least 80 percent of the heating value in the run-of-mine source coal. These goals for ultra-clean coal quality are to be met under the constraint that annualized coal production costs do not exceed $2.50/MBtu ($2.37/GJ), including the mine mouth cost of the raw coal. This cost compares with a No. 6 fuel oil cost of approximately $3.35 MBtu ($3.17/GJ).

Laboratory, bench-scale, and Process Development Unit (PDU) testing were completed earlier under the research program with selected raw coal samples. A PDU with a capacity of 2 st/h was designed by Bechtel and installed at Amax R&D, Golden, Colorado for process evaluation and testing. The tests successfully demonstrated the capability of column flotation as well as selective agglomeration to produce ultra-clean coal at specified levels of purity and recovery efficiency. Test results and the experience gained during the operation of the PDU have provided valuable insights into the processes studied the design bases for commercial plants.

To facilitate the cost estimating effort, conceptual designs for two commercial plants have been developed each using an advanced coal cleaning technology.

1.2 CONCEPTUAL DESIGNS

Based on process design bases obtained from the test work and a set of project design criteria, two sets of conceptual designs for commercial CWF production plants have been developed, one using column flotation and the other, selective agglomeration.

1.2.1 Plant Design Criteria

The following design criteria have been adopted for the plant designs.

Coal Feed Stock Bituminous high-volatile compliance coals which meet ash liberation requirements for advanced cleaning processes are suitable feed stocks for the plants. Pre-washed Taggart (Upper Elkhorn No. 3), Elkhorn No. 3, and Sunnyside seam coals and run of mine (ROM) Hiawatha seam coal were found to fulfill these requirements during evaluations conducted under this research program. Other coals, such as No. 2 Gas (Campbell Creek), could also be suitable. The named coals are low in organic form of sulfur which cannot be eliminated by physical coal cleaning processes such as column flotation and selective agglomeration.

Premium CWF Specifications In addition to ash and sulfur content limitations noted in the program objectives there are limits on slurry viscosity and slurry heating value to make the CWF an attractive fuel. Discussions with industry indicate that the viscosity of the fuel should not exceed 500 cp. at a 100 s^{-1} shear rate. Its HHV should be not less than 8900 Btu/lb which translates into a solids concentration of not less than 60 percent by weight of ultra-clean (dry) coal.

Plant Capacity and Location The plant designs are based on an annual out-put capacity of 1.5 million st (US ton) of ultra-clean coal (dry basis) formulated into 2.5 million st of CWF containing 60 dry solids percent by weight. This amount of fuel is adequate to fuel 500 MW of electric power plant. Other recent coal preparation studies have also used similar capacity as the basis for economic assessments.

The plants are designed to operate all 24 hours of the day in three shifts and all 7 days of the week. However, 2 shifts in a week and 2 weeks in a year are set aside for maintenance work. Based on the expected percentage yield of clean coal (weight recovery) and plant availability, the hourly design in-put capacities of the two plant scenarios have been calculated and found to be nearly the same at 233 st/h (dry basis). The plant using column flotation is expected provide a clean coal yield of 90.3 percent and have a plant availability of 81 percent. The second design based on selective agglomeration is expected to provide a higher yield of 93 percent, but, being more complex, have a lower plant availability of 79 percent.

The plants are located in the Ohio valley in an industrial area with good infrastructure facilities and close to a city like Cincinnati or Cleveland with many potential consumers of CWF in the proximity.

The selective agglomeration plant requires a significant amount of low pressure steam. It would perfectly complement an existing power plant which could provide low pressure steam as a by-product. The plant could be situated where steam could be purchased for approximately $3.00/MBtu. The cost estimates are based on buying steam for that price.

1.2.2 Plant Description

Figure 1.1 shows a block flow diagram of the facilities. A plant layout is shown in Figure 1.2. Except for the coal cleaning sections, Plant 300 Column Flotation and Plant 350 Selective Agglomeration as shown in the block flow diagram, the two designs are very similar. The description provided below addresses both plant designs.

Coal Receiving and Storage (Plant 100) Coal feed to the plant, 2 inch x 0 in size, is supplied in open gondola type rail cars which are unloaded by a car dumper at a rate of 2000 st/h. Storage facilities for raw coal at the plant site include three concrete silos with a total capacity of 30,000 st. This capacity equals a 5-day consumption.

Crushing and Grinding (Plant 200) After an initial crushing to size 1/2 in. x 0 in hammer mills, the coal is ground in wet closed-circuit ball mills to size 325 mesh (45 microns) (D80) at a rate of 233 st/h (dry basis). Two parallel and identical trains are used in the grinding section. The ground slurry is delivered to the coal cleaning section, Plant 300 (or Plant 350).

Column Flotation (Plant 300) Twelve identical and parallel trains of column flotation equipment are used to clean the coal. Each train has a capacity to process approximately 20 st/h. Each flotation column has a diameter of 14 feet.

Selective Agglomeration (Plant 350) The selective agglomeration section comprises ten identical trains each with a capacity of 23 st/h. Heptane is used as the bridging liquid which is recovered and reused in the process. Unlike the column flotation plant, plant design for the selective agglomeration process includes special facilities like the gas holders, cooling water ponds and flares as shown in the Layout, Figure 1.2.

Clean Coal Dewatering (Plant 400) Clean coal from column flotation (or selective agglomeration) is dewatered using vacuum filters. This plant section includes 6 identical and parallel filtration trains.

Water Clarification and Tailings Handling (Plant 500) Tailings from column flotation (or selective agglomeration) are thickened and clarified water is recovered in this plant section. The water is recycled in the plant. It is cooled with chilled water in the selective agglomeration case before recycling.

The thickened tailings are filtered and loaded into trucks for disposal as a solid waste.

CWF Preparation and Loading (Plant 600) Clean coal filter cake from Plant 400 is mixed with dispersant additive A-23 and the solids content adjusted by adding measured amounts of water. The product slurry is pumped to slurry storage tanks for loading into rail cars or pumping by pipeline to clients located in the area. The storage tanks have a total capacity equivalent to 48 hours of plant production.

1.3 COST OF PREMIUM CWF - COLUMN FLOTATION

The estimated capital cost of the plant based on column flotation is $69.6 million (First Quarter -1997). CWF production cost (without considering the cost of coal in the product) including capital charges is estimated at $0.91/MBtu.
Major elements of the cost are as follows:

Cost Element	$/MBtu	%	
Capital charges and interest on Working Capital	0.27	29.1	
CWF additive, A-23	0.23	25.6	
Labor	0.13	14.6	
Electric power	0.11	12.3	
Flotation reagents & Flocculant	0.07	7.5	
Btu Loss	0.05	5.5	
Others	0.05	5.4	
Total Cost of CWF	0.91	100	Less cost of coal

The above break down of costs of $0.91 is shown graphically in Figure 1.3. Including the cost of coal delivered to plant site at $1.24/MBtu, the total cost of production of premium CWF comes to $2.15/MBtu ($1.24+$0.91).

The target set under the research program for the cost of production of premium CWF is $2.50/MBtu including the mine mouth cost of coal. The above mentioned cost of $2.15/MBtu includes a transportation cost of 0.20 $/MBtu for the raw coal. Based on mine mouth coal cost, the estimated cost of production of premium CWF is $1.95/MBtu ($2.15 less $0.20) which is well below the targeted cost of production. This makes it an attractive replacement fuel for oil at current prices of petroleum products.

Sensitivity Studies One of the major elements in the cost of manufacture of CWF is the cost of A-23 additive dispersant. Use of the additive becomes necessary to meet the specified 60 percent solids loading of the product. If the solids loading could be reduced to around 54 percent, the slurry could be produced without the use of this additive. In such an event the total cost of CWF would be reduced from $2.15/MBtu to $1.92 representing a reduction of $0.23/MBtu. With a reduced solids content of 54 percent, the HHV of premium fuel is lowered to 8100 Btu/lb, a value below the target specification which calls for a minimum HHV of 8900 Btu/lb. It is believed that for the user, the penalty for reduced HHV will be more than off-set by the reduction of $0.23/MBtu in fuel costs.

A series of sensitivity analysis have been performed to evaluate the sensitivity of the cost of production of CWF to variations in other selected cost components. In addition to capital cost and the cost of raw coal, the factor that could affect the production cost most significantly, as may be expected, is the annual production rate.

1.4 COST OF PREMIUM CWF - SELECTIVE AGGLOMERATION

The estimated capital cost of the plant based on selective agglomeration is $97.2 (First Quarter -1997) million. CWF production cost (without considering the cost of coal in the product) including capital charges is estimated at $1.18/MBtu. Major cost elements are as follows:

Cost Element	$/MBtu	%	
Capital charges and Interest on Working Capital	0.37	31	
CWF additive, A-23	0.23	20	
Labor	0.17	15	
Electric power	0.15	13	
Steam	0.13	11	
Others (including Heptane)	0.13	10	
Total Cost of CWF	1.18	100	Less coal cost

The above break down of costs of $1.18 is shown graphically in Figure 1.4. Including the cost of coal delivered to plant site at $1.24/MBtu, the total cost of production of premium CWF is estimated at $2.42/MBtu ($1.24+$1.18).

The above mentioned cost of $2.42/MBtu includes a transportation cost of 0.20 $/MBtu for the raw coal to the plant site. Based on mine mouth coal cost, the estimated cost of production of premium CWF is $2.22/MBtu ($2.42 less $0.20). This value is well below the targeted cost of production of $2.50/MBtu set for the research program based on mine mouth cost of coal.

Sensitivity Studies A major element in the cost of manufacture of CWF is the cost of A-23 additive dispersant. Use of the additive becomes necessary to meet the specified 60 percent solids loading of the product. If the solids loading could be reduced to around 54 percent, the slurry could be produced without the use of this additive. In such an event the total cost of CWF would be reduced from $2.42/MBtu to $2.19 representing a reduction of $0.23/MBtu. A reduction in the solids content to 54 percent lowers the HHV of premium to 8,100 Btu/lb, a value below the target specification of 8,900 Btu/lb. It is believed that the penalty for the reduced HHV will be more than off-set to the consumer by the reduction of $0.23/MBtu in fuel costs.

A series of sensitivity analysis was performed to evaluate the sensitivity of the cost of production of CWF to variations in other selected cost input parameters. In addition to capital cost and the cost of raw coal, the factor that could affect the production cost most significantly, as may be expected, is the annual production rate.

1.5 CONCLUSIONS & RECOMMENDATIONS

The estimated cost of commercial production of premium CWF using either column flotation or selective agglomeration is encouraging. Column flotation, in particular, is more promising. This process, in spite of its lower energy and weight recovery, is found more economical than selective agglomeration while offering a comparable quality product. Total processing cost with column flotation at $0.91/MBtu is significantly lower than the cost of $1.18/MBtu estimated for the plant using the selective agglomeration.

As found during CWF cost sensitivity analysis, one of the significant factors that could vitally affect production costs is the annual sustainable production rate. Product costs would escalate drastically if the annual production rate of 1.5 million st cannot be achieved in plants built according to conceptual designs presented herein. Two significant technical factors that could adversely affect production are: (a) reduced plant availability due to worse than anticipated plant operability or maintenance requirements (b) feed coal harder to grind than expected. This will reduce the grinding capacity and thus the plant out-put.

These technical uncertainties are best resolved by operating experience with a larger scale plant and for a longer term than was possible with the PDU phase of the program. It was noticed during the conceptual design stage that plants with a capacity of 1.5 million st/year of ultra-clean coal will need 12 parallel trains of commercial size flotation columns or ten parallel trains of commercial size equipment for the selective agglomeration plant. This would suggest installation of demonstration/production plant using a single train of commercial size equipment with a capacity ranging from 125,000 to 150,000 st/y.

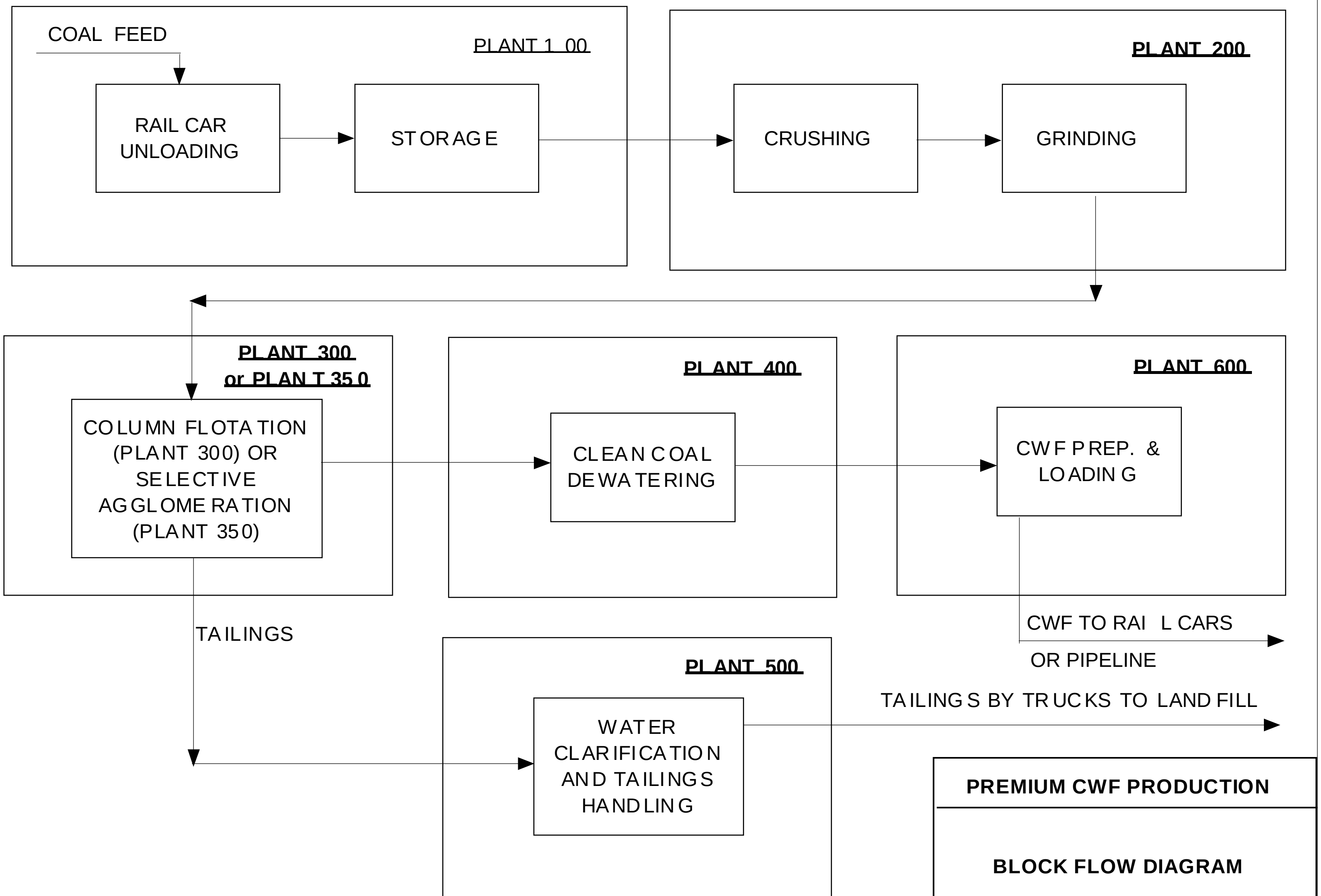
Another issue of uncertainty is the acceptability of the product. Before long-term commitments could be made, all potential clients would need verification, by meaningful plant scale testing, of the suitability of premium CWF for their applications. A single train demonstration/production plant of the capacity suggested will enable production of adequate quantities of premium CWF for this purpose.

The demonstration/production plant is preferably built close to a coal mine so that costs associated with coal transportation, refuse disposal and rail car unloading facilities can be eliminated or minimized.

1.6 ACKNOWLEDGMENTS

The project team consisted of Cyprus Amax Minerals Company through its subsidiaries Amax Research & Development Center (Amax R&D) and Cyprus Amax Coal Company (Midwest and Cannelton Division), Bechtel Technology & Consulting of Bechtel National Inc., Arcanum Corp. (of Ann Arbor, Michigan), Center for Applied Energy

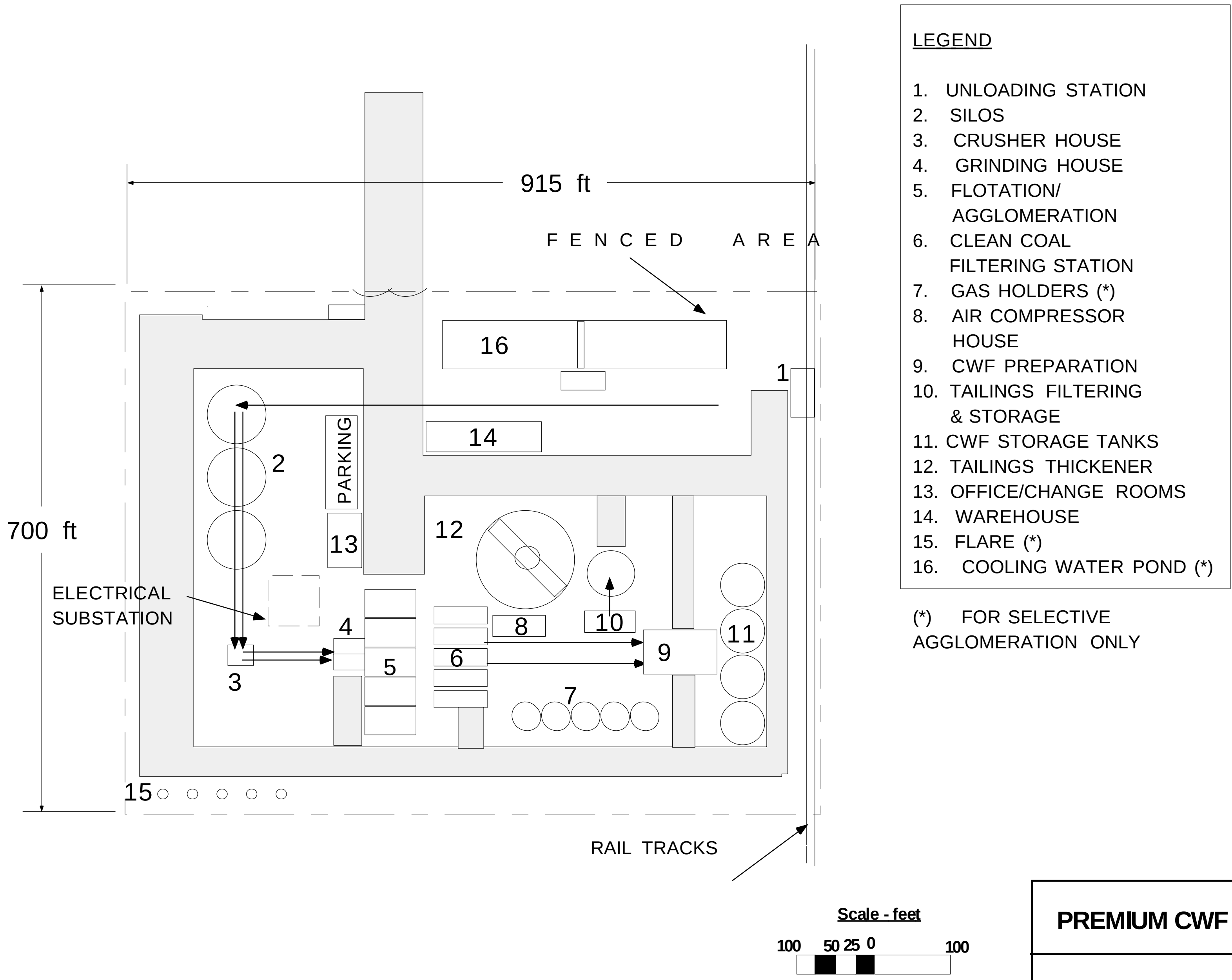
Research (CAER) of the University of Kentucky, and Center for Coal and Mineral Processing (CCMP) of the Virginia Polytechnic Institute and State University. Entech Global managed the project for Amax R&D. Dr. John Dooher of Adelphi University and DR. Douglas Keller, Jr. of Syracuse University were consultants to the project.



PREMIUM CWF PRODUCTION

BLOCK FLOW DIAGRAM

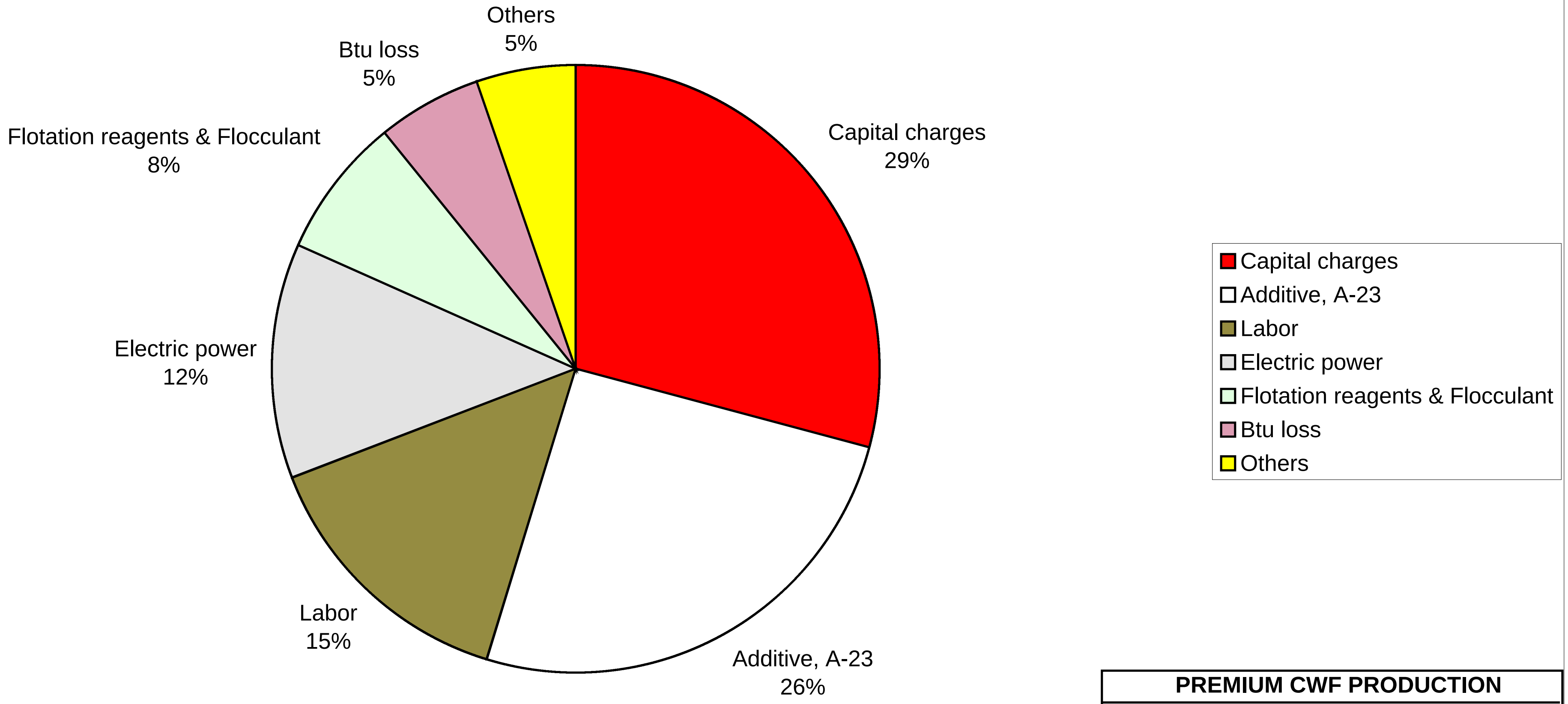
FIGURE 1.1



PREMIUM CWF PRODUCTION

PLANT LAYOUT

FIGURE 1.2

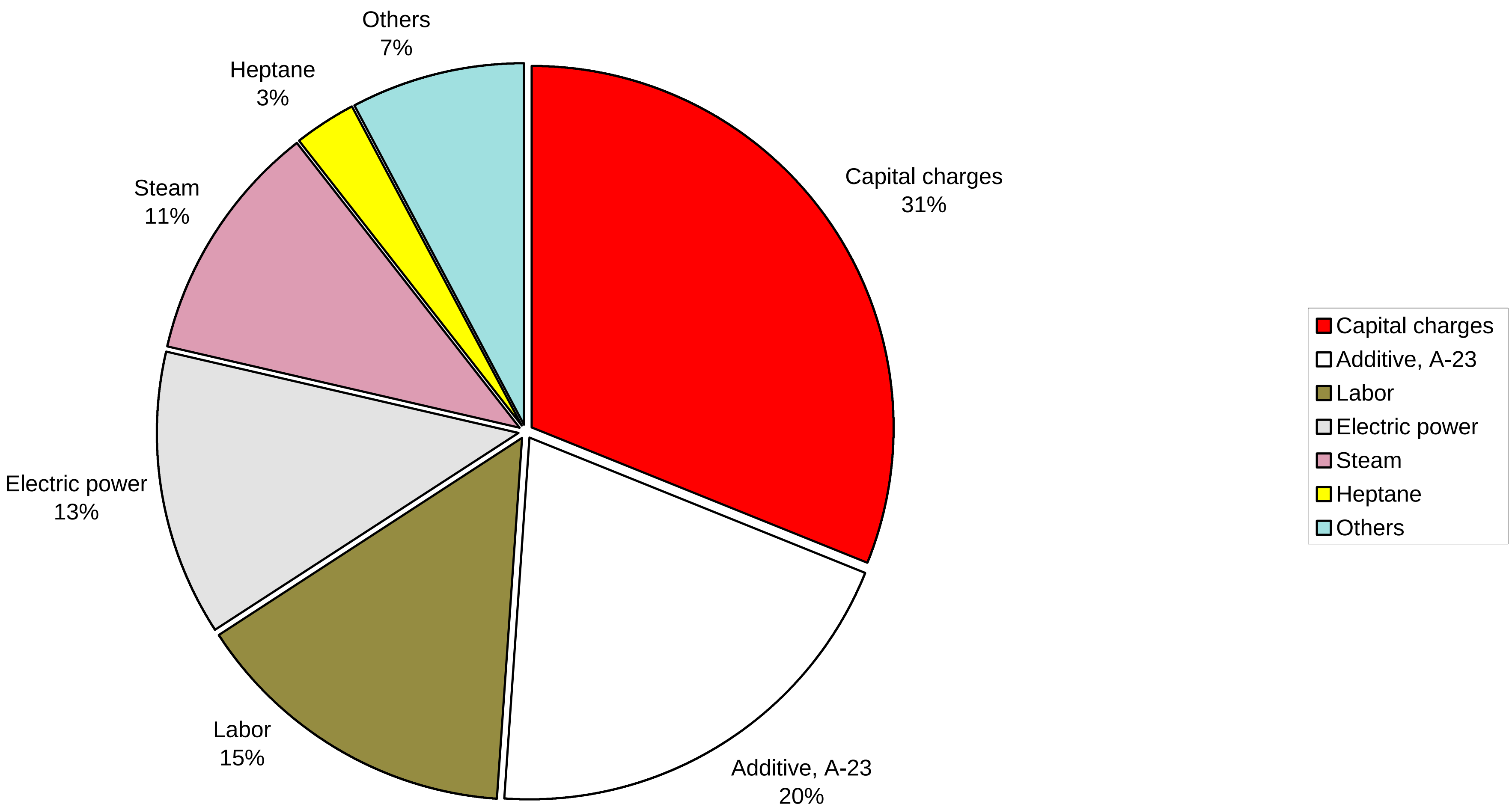


TOTAL COST OF PRODUCTION
$0.91/ MBtu - Less cost of coal

PREMIUM CWF PRODUCTION

COST OF CWF
SELECTIVE AGGLOMERATION

FIGURE 1.3



TOTAL COST OF PRODUCTION
$1.18/ MBtu - Less cost of coal

PREMIUM CWF PRODUCTION

COST OF CWF
SELECTIVE AGGLOMERATION

FIGURE 1.4

Section 2
Introduction

Bechtel, together with Amax Research and Development Center (Amax R&D), has prepared this study which provides conceptual cost estimates for the production of premium quality coal-water slurry fuel (CWF) in a commercial plant. Two scenarios are presented, one using column flotation technology and the other the selective agglomeration to clean the coal to the required quality specifications. This study forms part of US Department of Energy program "Engineering Development of Advanced Physical Fine Coal Cleaning for Premium Fuel Applications," (Contract No. DE-AC22-92PC92208), under Task 11, Project Final Report.

The primary objective of the Department of Energy program is to develop the design base for prototype commercial advanced fine coal cleaning facilities capable of producing ultra-clean coals suitable for conversion to stable and highly loaded CWF. The fuels should contain less than 2 lb ash/MBtu (860 grams ash/GJ) of HHV and preferably less than 1 lb ash/MBtu (430 grams ash/GJ). The advanced fine coal cleaning technologies to be employed are advanced column froth flotation and selective agglomeration. It is further stipulated that operating conditions during the advanced cleaning process should recover not less than 80 percent of the carbon content (heating value) in the run-of-mine source coal. These goals for ultra-clean coal quality are to be met under the constraint that annualized coal production costs does not exceed $2.5 /MBtu ($ 2.37/GJ), including the mine mouth cost of the raw coal. A further objective of the program is to determine the distribution of a selected suite of eleven toxic trace elements between product CWF and the refuse stream of the cleaning processes.

Laboratory, bench-scale and Process Development Unit (PDU) tests to evaluate advanced column flotation and selective agglomeration were completed earlier under this program with selected coal samples. A PDU with a capacity of 2 st/h was designed by Bechtel and installed at Amax R&D, Golden, Colorado by Entech Global for process evaluation tests. The tests successfully demonstrated the capability of advanced column flotation as well as selective agglomeration to produce ultra-clean coal at specified levels of purity and recovery efficiency. Test results and the experience gained during the operation of the PDU have provided valuable insights into the processes studied.

Based on the design data obtained from the test work and a set of project design criteria, two sets of conceptual designs for commercial CWF production plants have been developed, one using column flotation and the other using selective agglomeration process. Using these designs, Capital as well as Operating and Maintenance (O&M) cost estimates for the plants have been compiled. These estimates have then been used to derive the annualized cost of production of premium CWF on a commercial scale. Further, a series of sensitivity analysis have been completed to evaluate the effects of variations in selected cost components and process parameters on the overall economics of premium fuel production

The rest of this report is arranged as follows. Study results and Conclusions & Recommendations are provided under Section 3. The design criteria used in the development of conceptual designs for commercial CWF plants are included in Section 4. Descriptions of the conceptual designs based on column flotation and selective agglomeration technologies appear in Section 5 and 6 respectively. Capital and O&M cost estimates as well as the production cost of CWF are presented in Sections 7 and 8 for the two technologies. The two sections also discuss cost sensitivity to variations in selected parameters. A list of Acronyms and Abbreviations is placed under Section 9. Details of capital cost estimates are placed in Appendices A and B. Calculations relating to the sensitivity analysis are under Appendices C and D for column flotation and selective agglomeration cases respectively.

Section 3
Conclusions and Recommendations

Column Flotation and selective agglomeration test work with selected coals was completed earlier under the research program. The laboratory, bench-scale, and 2 st/h capacity Process Development Unit (PDU) tests successfully demonstrated the capability of column flotation as well as selective agglomeration to produce ultra-clean coal at specified levels of purity and recovery efficiency. Test results and the experience gained during the operation of the PDU have helped develop design bases for commercial plants.

Based on process design data obtained from the test work and a set of project design criteria, two sets of conceptual designs for commercial CWF production plants have been developed, one using column flotation and the other, selective agglomeration. Each design was for commercial plant with a capacity to produce 2.5 million st of premium CWF, containing 60% solids by weight (1.5 million st per year dry clean coal). Capital, O&M cost estimates have been developed based on these conceptual designs leading to the cost of production of premium CWF on a commercial scale.

3.1 COST OF PREMIUM CWF - COLUMN FLOTATION

The estimated capital cost of the plant based on column flotation is $69.6 million (First Quarter -1997). CWF production cost (without considering the cost of coal in the product) including capital charges is estimated at $0.91/MBtu. Major elements of the cost are as follows:

Cost Element	$/MBtu	%	
Capital charges and interest on Working Capital	0.27	29.1	
CWF additive, A-23	0.23	25.6	
Labor	0.13	14.6	
Electric power	0.11	12.3	
Flotation reagents & Flocculant	0.07	7.5	
Btu Loss	0.05	5.5	
Others	0.05	5.4	
Total Cost of CWF	0.91	100.0	Less cost of coal

Including the cost of coal delivered to plant site at $1.24/MBtu, the total cost of premium CWF comes to $2.15/MBtu ($1.24+$0.91).

The target set under the research program for the cost of production of premium CWF is $2.50/MBtu including the mine mouth cost of coal. The above mentioned cost of $2.15/MBtu includes a transportation cost of 0.20 $/MBtu for the raw coal. Based on mine mouth coal cost, the estimated cost of production of premium CWF is $1.95/MBtu ($2.15 less $0.20) which is well below the targeted cost of production.

Sensitivity Studies One of the major elements in the cost of production of CWF is the cost of A-23 additive dispersant. Use of the additive becomes necessary to meet the specified 60 percent solids loading of the product. If the solids loading could be reduced to 54 percent, the slurry could be produced without the use of this additive. In such an event the total cost of CWF would be reduced from $2.15/MBtu to $1.92 representing a reduction of $0.23/MBtu. With a reduced solids content of 54 percent, the HHV of premium fuel is lowered to 8100 Btu/lb, a value below the target specification which calls for a minimum HHV of 8900 Btu/lb. It is believed that for the user, the penalty for reduced HHV will be more than off-set by the reduction of $0.23/MBtu in fuel costs.

A series of sensitivity analysis have been performed to evaluate the sensitivity of the cost of production of CWF to variations in other selected cost components. In addition to capital cost and the cost of raw coal, the factor that could affect the production cost most significantly, as may be expected, is the annual production rate.

3.2 COST OF PREMIUM CWF - SELECTIVE AGGLOMERATION

The estimated capital cost of the plant based on selective agglomeration is $97.2 million (First Quarter -1997). CWF production cost (without considering the cost of coal in the product) including capital charges is estimated at $1.18/MBtu. Major cost elements are as follows:

Cost Element	$/MBtu	%	
Capital charges and Interest on Working Capital	0.37	31	
CWF additive, A-23	0.23	20	
Labor	0.17	15	
Electric power	0.15	13	
Steam	0.13	11	
Others	0.13	10	
Total Cost of CWF	1.18	100	Less coal cost

Including the cost of coal delivered to plant site at $1.24/MBtu, the total cost of producing premium CWF is estimated at $2.42/MBtu ($1.24+$1.18) for the selective agglomeration process.

The target set under the research program for the cost of production of premium CWF is $2.50/MBtu including the mine mouth cost of coal. The above mentioned cost of $2.42/MBtu includes a transportation cost of 0.20 $/MBtu for the raw coal to the plant site. Based on mine mouth coal cost, the estimated cost of production of premium CWF is $2.22/MBtu ($2.42 less $0.20). This value is well below the targeted cost of production of $2.50/MBtu set for the research program based on mine mouth cost of coal.

Sensitivity Studies A major elements in the cost of production of CWF is the cost of A-23 additive dispersant. Use of the additive becomes necessary to meet the specified 60 percent solids loading of the product. If the solids loading could be reduced to 54 percent, the slurry could be produced without the use of this additive. In such an event the total cost of CWF would be reduced from $2.42/MBtu to $2.19 representing a reduction of $0.23/MBtu. A reduction in the solids content to 54 percent lowers the HHV of premium CWF to 8100 Btu/lb, a value below the target specification of 8900 Btu/lb. It is believed that the penalty for the reduced HHV will be more than off-set to the consumer by the reduction of $0.23/MBtu in fuel costs.

A series of sensitivity analysis are performed to evaluate the sensitivity of the cost of production of CWF to variations in other selected cost input parameters. In addition to capital cost and the cost of raw coal, the factor that could affect the production cost most significantly, as may be expected, is the annual production rate.

3.3 RECOMMENDATIONS

The estimated cost of commercial production of premium CWF using either column flotation or selective agglomeration is encouraging. Column flotation, in particular, is more promising. This process, in spite of its lower energy and weight recovery, is found more economical than selective agglomeration while offering a comparable quality product. Total processing cost with column flotation at $0.91/MBtu is significantly lower than the cost of $1.18/MBtu estimated for the plant using the selective agglomeration.

As found during CWF cost sensitivity analysis, one of the significant factors that could vitally affect production costs is the annual sustainable production rate. Product costs would escalate drastically if the annual production rate of 1.5 million st cannot be achieved in plants built according to conceptual designs presented herein. Two significant technical factors that could adversely affect production are: (a) reduced plant availability due to worse than anticipated plant operability or maintenance requirements (b) feed coal harder to grind than expected, which will reduce the grinding capacity and thus the plant out-put.

These technical uncertainties are best resolved by operating experience with a larger scale plant and for a longer term than was possible with the PDU phase of the program. It was noticed during the conceptual design stage that plants with a capacity of 1.5 million st/year of ultra-clean coal will need 12 parallel trains of commercial size flotation columns or ten parallel trains of commercial size equipment for the selective agglomeration plant. This would suggest installation of demonstration/production plant using a single train of commercial size equipment with a capacity of 125,000 st/y.

Another issue of uncertainty is the acceptability of the product. Before long-term commitments could be made, all potential clients would need verification, by meaningful plant scale testing, of the suitability of premium CWF for their applications. A single train demonstration/production plant of the capacity suggested will enable production of adequate quantities of premium CWF for this purpose.

The demonstration/production plant is preferably built close to a coal mine so that costs associated with coal transportation, refuse disposal and rail car unloading facilities can be eliminated or minimized.

Section 4

Commercial CWF Plant Design Criteria

This section presents design criteria which have been used for the development of two conceptual designs for commercial premium CWF production plants. One of the designs uses advanced column flotation for cleaning the coal and the other selective agglomeration. Process design and equipment selection criteria specific to column flotation and selective agglomeration are addressed in Section 5 and Section 6 respectively.

4.1 COAL FEED STOCK

Several dozen coals from different regions of the US were evaluated and many were tested in the laboratory under Task 2. The tests were designed to identify coals that could significantly benefit from advanced column flotation and/or selective agglomeration and produce economically ultra-clean coal to specifications. Coal characteristics tested included: (a) sulfur content and forms of sulfur occurrence (organic and mineral or pyritic) and (b) ash liberation characteristics. The latter determines to a large extent electric power requirements to prepare the coal by grinding ahead of the cleaning processes. Six coals were then selected for process research and development in bench scale. Finally, three coals were tested in the PDU. Based on these studies, the most appropriate coal feed stock for the commercial production of premium CWF is a bituminous high-volatile sulfur-compliance coal which also meets ash liberation requirements for advanced cleaning processes. Pre-washed Taggart (Upper Elkhorn No. 3), Elkhorn No. 3, and Sunnyside seam coals and the unwashed Hiawatha seam coal were found to fulfill these requirements during evaluations conducted earlier under this. Other coals, such as No. 2 Gas (Campbell Creek), are also likely to be suitable.

Feed Coal Sulfur Content Specifications for premium CWF call for a sulfur content below 0.6 lb/MBtu, the limit for compliance coals. Physical coal cleaning processes like column flotation and selective agglomeration can only remove the pyritic form of sulfur in coal and not the organic form. A special effort was made to identify non-compliance raw coals with significantly high pyritic sulfur content but a low (below the limit for compliance coals) organic sulfur component. No such coal could be found. The non-compliance coals that were evaluated had consistently more than 0.6 lb of sulfur per MBtu of organic sulfur. Thus it would appear that the feed stock to the commercial plant will most likely be a compliance coal to begin with.

Grinding Power Requirements Electric power required to grind the coal prior to cleaning is a major element in the cost of production of ultra-clean coals. Power consumption for grinding is affected largely by ash-mineral liberation characteristics of the coal and, to a lesser extent, its grindability. Grindability is often expressed in terms of the Hardgrove Grindability Index (HGI). A coal with unfavorable ash-mineral liberation characteristics contains ash disseminated in the coal mass as extremely fine particles. Such a coal will need ultra-fine grinding at an exorbitant power consumption to liberate ash minerals ahead of the cleaning step. Poor grindability further aggravates energy consumption.

The coals listed above (Taggart, Elkhorn # 3, Sunnyside, Hiawatha) were found to be the most appropriate feed stocks after taking the relevant factors into consideration.

Significant characteristics of the design feed coal, which could be a blend of more than one coal, are:

Proximate Analysis:		
Ash	wt %	7.0
Volatile Matter	wt %	30.0
Fixed Carbon	wt %	56.0
Moisture-total	wt %	7.0
Inherent Moisture	wt %	2.0
Surface Moisture	wt %	5.0
Ash-dry basis	wt %	7.5
Heating Value -as received basis	Btu/lb	13,070
Nominal Size	inch	2 x 0
Hardgrove Grindability Index		52

4.2 CWF SPECIFICATIONS

The target specifications for the CWF (product) are given below:

Ash-dry basis	wt %	< 2.8
Ash content	lb/MBtu	<1.8
Sulfur-dry basis	wt %	<0.88
Sulfur-dioxide emission potential	lb/MBtu	<1.2
Sulfur	lb/MBtu	<0.6
Solids loading -based on dry solids	wt %	60-62
Slurry viscosity at 100 s^{-1} shear rate	cp.	<500
Slurry viscosity at 1000 s^{-1} shear rate	cp.	<1,000
Higher Heating value of CWF	Btu/lb	8900-9,400
Maximum particle size	mesh	100

4.3 ANNUAL CAPACITY OF THE PLANTS

Conceptual designs and cost estimates are based on an annual out-put capacity 2.5 million st of CWF containing 60 percent by weight of dry solids. This quantity of CWF will require an annually production of 1.5 million st of ultra-clean coal on a dry basis.

4.4 PLANT LOCATION

The plant is to be located near an industrial center like Cincinnati or Cleveland in the Ohio river valley. It is assumed that the plant site has adequate infra-structure normally available in industrial areas.
The infra-structure facilities include utility lines, highways and rail tracks close to the property. In addition, the selective agglomeration plant will be located near a power station which could supply low pressure steam to the plant. Availability of efficient rail links to the sites is essential to permit flexibility in coal procurement from different sources and in the shipment of the product. Roads, utility distribution lines and rail tracks within the battery limits are included in the cost estimates.

4.5 PLANT OPERATING SCHEDULE

The plants are designed to operate three 8-hour shifts a day and 19 shifts a week. Two shifts in each week are set aside for maintenance. In addition, an annual 2 week shut down is taken for major maintenance work. This schedule gives 7,600 operating hours in a year.

4.6 COAL RECEIVING

Coal is supplied to the plants in unit trains of open gondola cars from one or more mines. Facilities are provided to unload cars during winter months under freezing conditions. Unlike the rest of the plants, coal unloading is designed to operate 2-shifts a day and 5 days a week. The shorter schedule and higher unloading rates are selected to minimize detention of rail cars at plant sites. The cars are unloaded using a rotary car dumper at a rate of 2000 st/h. The unloading section includes thawing sheds to heat frozen car loads. Rail tracks included within the battery limits are adequate to accept coal and product cars.

4.7 STORAGE

Facilities will store thirty thousand st of as received coal at the plant site. This level of on-site storage allows the production facilities to operate continuously at design rate for 5 days without any additional receipt of rail delivered coal. Silos have been selected as they represent environmentally the most acceptable method for large scale coal storage in the proximity of major settlements.

4.8 CRUSHING AND GRINDING

Raw coal is crushed and then ground to a nominal 100 mesh top size (D80= 325 mesh) for both column flotation and selective agglomeration plants. The coal is crushed to a top size of 1/2 inch ahead of the ball mills used for grinding the coal. Wet closed circuit grinding has been adopted to reduce both grinding energy consumption and generation of super fines. Super fines are difficult to dewater, tend to increase slurry viscosity, and, for column flotation, difficult to clean.

4.9 COAL CLEANING PROCESSES

Either column flotation or selective agglomeration are used to clean and enhance coal quality to the level specified for the premium CWF. Selective agglomeration includes recovery of the bridging liquid, heptane.

4.10 CLEAN COAL DEWATERING, WATER CLARIFICATION AND TAILINGS HANDLING

The circuits for clean coal and tailings dewatering and systems for water clarification use largely similar if not identical equipment for both column flotation and selective agglomeration plants.

Vacuum filters are used for filtering the clean coal. Tailings after thickening in a static thickener are dewatered using a continuous belt press.

4.11 TAILINGS DISPOSAL

The tailings after dewatering, the solid waste from the plant, are disposed off in a land fill by trucks. Depending upon site specific conditions, alternate and more economical disposal methods could be available

4.12 CWF PREPARATION

The plant is designed to produce highly loaded CWF with minimum water content. The slurry fuel must, at the same time, exhibit a viscosity low enough for easy pumping and handling. It is expected that the slurry viscosity must be below 500 cp. to be acceptable.
The highest solid loading achievable in a coal-water mixer without exceeding viscosity limits depends upon several variables. The most significant of these are: mass mean diameter of the particles, particle size distribution, particle shape, packing tendencies of the particles, type and quantity of additives and inherent coal moisture. It is well known that a 'bimodal' particle size distribution promotes high solid loading in a slurry. A bimodel particle size distribution is one with large concentrations of particles in the coarsest as well as the finest ends of the particle size distribution spectrum. Such a distribution helps pack the solids and thus improve solid loading without a significant increase in viscosity.

A series of slurry formulation tests were conducted with flotation and selective agglomeration concentrates during the program. Several tests were performed to evaluate benefits of modifying the size distribution and simulate a bimodal particle size distribution. A fine size fraction of the clean coal concentrates weighing up to 30 percent of the total was reground to sizes finer than 325 mesh and mixed back with the rest of the concentrates. The reformed concentrates with modified size distribution were slurried and tested in the laboratory to determine the improvement in the solid loading at the permitted level of viscosity. The tests produced less than satisfactory results. Blending of even large amounts of reground fines (30 percent) with the concentrates did not improve the solid loading with Taggart and Elkhorn No. 3 CWF. With Hiawatha and Sunnyside coals this procedure brought about only a marginal improvement, from 59-60 percent solids to 61 to 63 percent (Page 13, Subtask 6.4 CWF Formulation Studies-Topical-Report).

Further, duplicating this procedure for size consist modification on an industrial scale will be complicated. It would involve, (a) an operation to separate a fine coal fraction from the concentrate slurry stream, (b) partial dewatering of the stream so separated for additional regrinding, (c) regrinding, and (d) mixing the ground product with unground concentrates. These steps entail significant capital and operating costs. Considering the poor benefits seen with laboratory scale testing, it is considered that size consist modification will not be economically viable. No provision has therefore been made in the commercial plant designs for size consist modification. Consequently, the specification for solid loading for CWF have been reduced and set at 60 percent which was found to be achievable with the use of dispersant (A-23) additives alone.

The solids in the highly loaded CWF tend to settle out. The slurry has to be modified if it has to have adequate stability for long duration storage and transportation. One procedure would be to add a stabilizer additive such as Flocon. The additive is relatively expensive. At the required dosage of approximately 800 ppm of the slurry and a price of $ 3.50 per pound, the cost of the stabilizer alone is expected to be around $ 8 per ton of solids in the CWF or $0.27 per MBtu. Therefore the base design does not include stabilizers.

4.13 CWF STORAGE AND LOADING

Storage facilities for the product at the plant site are provided in the form of agitated tanks with a total capacity equivalent to 2 days of production.

CWF is shipped to customers in RR tank cars. Alternately, the product may be sent to customers from the storage tanks by pipeline.

.

Section 5

Conceptual Design of CWF Plant - Column Flotation

A conceptual design for a commercial premium CWF production plant based on column flotation technology is presented in this section. It includes a discussion of the process design criteria and a description of the integrated facility.

5.1 Process Design Criteria-Column Flotation

Process design and equipment selection criteria used in the conceptual design are summarized and presented in Table 5.1.1.

With the design coal, it is expected that column flotation will achieve a heating value recovery of over 96 percent while producing specification quality clean coal. A clean coal weight recovery of approximately 90 percent will also be attained. As noted in Section 4, the plant operates 3 shifts a day and 19 shifts a week. However, there is an annual shut down for two weeks for major maintenance work. Based on this schedule, the weight recovery, and an availability of 94 percent of scheduled operating time, a design input capacity of 233 st/h (dry basis) has been calculated to produce 1.5 million st of clean coal per year (on a dry basis). If the availability is calculated on the basis of 8,760 hours (365 x 24) in a year, the selected hourly design capacity reflects an availability of 81 percent. This level of availability is considered achievable with adequate complement of standby equipment at critical locations of the plant.

Significant process and equipment design parameters such as energy for grinding, solids concentration in the flotation feed, the number and size of columns, consumption of compressed air and reagents, wash water usage, and tailings recirculation are shown in Table 5.1.1. The data are based on laboratory, bench-scale, and PDU testing.

Table 5.1.1 also provides details of process and equipment design criteria for clean coal dewatering, water clarification, tailings dewatering and handling, CWF preparation, and loading sections of the plant.

5.2 Facility DESCRIPTION

The commercial column flotation based CWF plant consists of the following sections:

- Raw Coal Handling - Plant 100
- Crushing and Grinding - Plant 200
- Column Flotation - Plant 300
- Clean Coal Dewatering - Plant 400
- Water Clarification and Tailings Handling - Plant 500
- CWF Preparation and Loading - Plant 600

A list of major equipment appears under Table 5.2.1.

5.2.1 Raw Coal Handling - Plant 100

A process flow diagram for the raw coal handling section, Plant 100, is presented in Figure 5.1. Feed coal, crushed to a top size of 2 inch, is delivered to the CWF plant in RR cars. The cars are unloaded using a car dumper. The rail car unloading system includes thawing sheds for heating the cars during the winter months when freezing conditions could be encountered. A shunting locomotive is used to position the cars over the dumper. The cars are dumped, one car at a time, into a 200 ton dump hopper. A bar grid located at the top of the dump hopper prevents large lumps of frozen coal from entering the hopper. A frozen coal crusher (lump breaker) is used to break such lumps of coal over the grid.

Two variable capacity belt feeders located below the dump hopper deliver the coal to a raw coal conveyor which transports and elevates the coal to the top of the coal silos.

The raw coal conveyor working with two silo feed conveyors fills three raw coal concrete silos. Each silo has a capacity of 10,000 st.

The raw coal handling section is rated for a capacity of 2000 st/h. It includes a comprehensive dust collection system to control emission of dust during coal dumping and conveying operations.

5.2.2 Crushing and Grinding - Plant 200

Figure 5.2 represents a process flow diagram for this plant section. A material balance is also shown in the figure.

This section of the plant includes two parallel and identical trains to crush and grind the coal ahead of flotation. Two variable speed belt feeders are provided below each of the coal silos for withdrawal of coal. Two crusher feed conveyors receive coal from the belt feeders. The conveyors deliver the coal to two hammer mill type crushers. The crushers are designed to crush the coal to a top size of 1/2 inch. Tramp iron magnets are included for the protection of the hammer mills. Crushed coal from the hammer mills is delivered to the ball mills by two ball mill feed conveyors. Each conveyor serves a grinding train.

Each grinding system includes a 4000 HP ball mill served by a set of three cyclone clusters for closed circuit operation. Each cyclone cluster has multiple cyclones. Coal is ground in the mills with water. The discharge slurry from each ball mill is diluted and pumped to the cyclone clusters. A distributor is used to distribute the flow equally among the cyclone clusters. Partially ground material exiting the cyclone apex (cyclone underflow) is returned to the mills for further grinding.

Cyclone overflow represents the finish ground slurry. It is sluiced to the flotation section in Plant 300.

5.2.3 Column Flotation - Plant 300

Figure 5.3 presents a process flow diagram and a material balance for the column flotation section, Plant 300. The following description addresses one of two parallel and identical trains of equipment included in this section.

Ground slurry from the crushing and grinding plant (Plant 200) is received in a flotation feed sump provided with a mixer (agitator). Measured amount of water is added in the sump to ensure a constant pre-set solids content in the slurry fed to the flotation columns. There are six flotation columns in a train, a total of twelve in the plant. Each flotation column has a dedicated slurry feed pump. It is complete with dedicated reagent feeders, a tailings recirculation pump, a static air-slurry mixer, and a froth launder. A common air compressor provides air to six flotation columns. Froth from each flotation train (6 flotation columns) is collected in a clean coal sump, generously sized to accommodate and break the froth. Clean coal slurry from the sump is pumped to a slurry distributor which is included in Plant 400. All clean coal pumps are provided with installed spares of equal capacity.

5.2.4 Clean Coal Dewatering - Plant 400

Figure 5.4 shows a process flow diagram and a material balance for this plant section.

The clean coal dewatering section consists of two identical trains like the column flotation section (Plant 300). Each train is provided with six identical and parallel vacuum filtration lines. Clean coal slurry is dewatered and a filter cake with a surface moisture content of approximately 35 percent is produced. Filter cake from each set of six filters is collected by a dewatered coal conveyor. The two dewatered coal conveyors deliver the coal to two coal- additive mixers provided under Plant 600.

The water separated by the vacuum filters, the filtrate, may contain some solids. It is therefore recirculated through the flotation plant. It is pumped to the flotation feed sumps in Plant 300. All pumps in this section (Plant 400) are also provided with installed spares.

5.2.5 Water Clarification and Tailings Handling - Plant 500

Figure 5.5 presents a process flow diagram and a material balance for this plant section.

Tailings from flotation columns are collected in a thickener. The tailings solids are thickened and the water is clarified with the addition of measured amounts of flocculants to the feed slurry. The thick underflow from the thickener is pumped to a tailings filter sump. Additional amounts of flocculants are mixed with the slurry in the filter sump to facilitate filtering. A continuous Andritz type belt filter is used to dewater the tailings. The filtered tailings are collected by a tailings conveyor and conveyed to a storage pile under a shed. The tailings are loaded into trucks using front-end loaders for transport and disposal at a landfill. Clarified water from the thickener, the thickener overflow, is recirculated to the CWF preparation, flotation and grinding sections of the facility.

5.2.6 CWF Preparation and Loading - Plant 600

A process flow diagram and a material balance for this plant section is shown in Figure 5.6. This plant section also comprises two parallel and identical trains.

Dewatered flotation concentrates from the vacuum filters (the filter cake) is fed to two coal-additive mixers (one on each train). Here the cake is mixed intensely with the dispersant additive A-23 to obtain a good dispersal of the additive. The mixture is then fed to slurry mix tanks (one in each train) where measured amounts of water is added to obtain the desired solids content in the prepared CWF. From the slurry mix tanks, the CWF is pumped to storage tanks.

A total of four storage tanks are included with adequate capacity to hold a two day production of CWF. From the storage tanks, the CWF is pumped into RR tank cars. Alternately, the slurry fuel in the storage tanks may be pumped to nearby customers through pipe lines installed by others.

Table 5.1.1
COMMERCIAL CWF PLANT - COLUMN FLOTATION
Process Design Criteria

I COLUMN FLOTATION PERFORMANCE		
Heating value (HHV) recovery	%	96.1
Feed ash content- dry basis	%	7.5
Weight recovery	%	90.3
Feed HHV- dry basis	Btu/lb	14,054
Product HHV-dry basis	Btu/lb	14,962
Product ash per MBtu of HHV	lb/MBtu	<2.0
Product ash- dry basis	%	<2.8
II OPERATING SCHEDULE		
Hours per shift	h/shift	8
Shifts per day	shifts/day	3
Days per week	days/week	7
Scheduled maintenance shifts per week	shifts/week	2
Scheduled operating shifts per 7 day week	shifts/week	19
Scheduled operating weeks per year	weeks/y	50
Scheduled operating hours per year	h/y	7,600
III DESIGN HOURLY FEED RATE TO FLOTATION		
Annual output required - dry basis	Million st/y	1.5
Average output per operating hour-dry basis	st/h	197
Plant availability based on scheduled operating hours.	%	94
Design output capacity-dry basis	st/h	211
Design weight recovery	%	90.3
Plant design input capacity-dry basis	st/h	233
Inherent moisture	wt %	2.0
Plant design input capacity-surface dry basis	st/h	238
Plant availability based on 24 h/day and 365 d/y	%	81
IV FLOTATION FEED SLURRY PREPARATION		
Grinding circuit configuration		Wet, closed circuit
Ground product - nominal, 100 % passing	mesh	100
Size (D80)	mesh	325
Size of coal feed to grinding mills	in	1/2
Specific power for grinding	HP/(st/h)	34
Flotation feed solids content	wt %	6
V FLOTATION COLUMNS		
Flotation feed sump -retention time	min	1.5
Design clean coal flow rate-surface dry basis	st/h	215
Specific froth load at the column	$(st/ft^2)/h$	0.12
Column overflow surface area required	ft^2	1,792
Selected diameter of column (largest available)	ft	14
Overflow area available per column	ft^2	154

Table 5.1.1 (continued)
COMMERCIAL CWF PLANT - COLUMN FLOTATION
Process Design Criteria

V	**FLOTATION COLUMNS (Continued)**		
	No of columns required	unit	12
	Specific wash water usage- based on flotation feed	gpm/(st/h)	30
	Bias Ratio	%	64
	Tailings recirculation at column-based on flotation feed	gpm/(st/h)	240
	Solids content of froth	wt%	24
	Air requirement	scfm/(st/h)	18.3
	Frother dosage	lb/st	0.75
	Collector dosage	lb/st	0.75
VI	**CLEAN COAL DEWATERING**		
	Equipment type		Vacuum Filter
	Filter cake moisture content	wt %	35
VII	**WATER CLARIFICATION AND TAILINGS DEWATERING**		
	Equipment type		Thickener and Filter
	Tailings thickener -Specific thickening rate	gpm/ft^2	2.0
	Thickener under flow -surface moisture content	wt %	75
	Tailings filter- type		Belt press
	Moisture content of dewatered tailings, filter cake	wt %	40
VIII	**CWF PREPARATION AND LOADING**		
	Additives:		
	Dispersant Additive		A-23
	Dispersant (Solid) dosage per dry ton of coal	lb /st	10
	Water content of solution	wt %	55
	Stabilizer		Not used
	Storage capacity for CWF at site at normal production rate	h	48
	Type of storage		Agitated tanks
	Rail car loading rate:		
	CWF	gpm	3,000
	Coal on a dry basis	st/h	500

Table 5.2.1
COMMERCIAL CWF PLANT- COLUMN FLOTATION
Major Equipment List

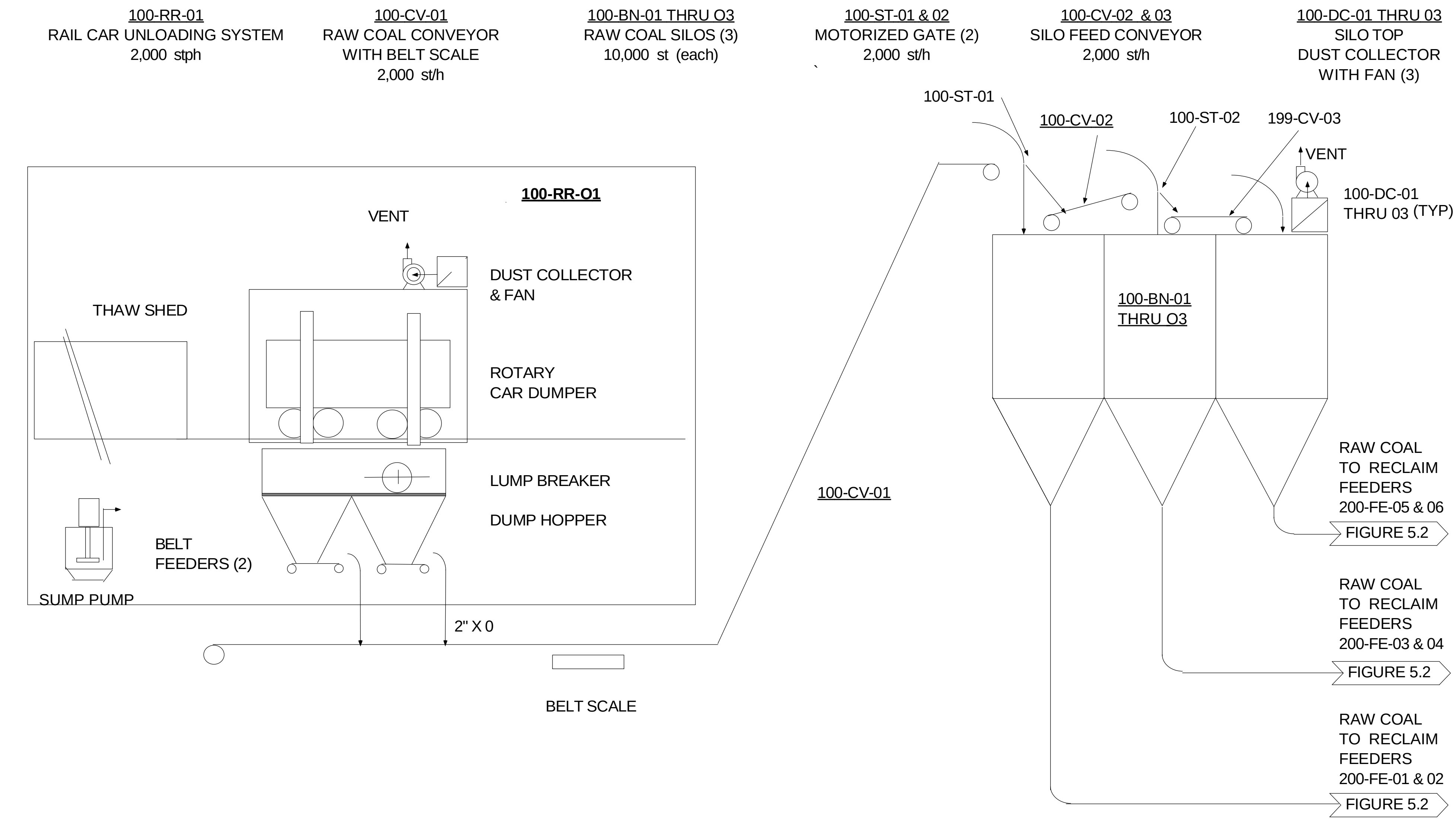
Equipment I.D		Qty	Title	Description	Power-ea. HP	Total installed HP
100	BN-01 thru 03	3	Raw coal silos, No. 1, 2, and 3	10,000 st (ea.), 70 ft dia x 150 ft ht		
100	CV-01	1	Raw coal conveyor	2000 st/h, 60 in wide x 750 ft lg., 220 ft lift, 500 fpm, with belt scale	600	600
100	CV-02	1	Silo feed conveyor No. 1	2000 st/h, 60 in wide x 80 ft lg., 10 ft lift, 500 fpm	50	50
100	CV-03	1	Silo feed conveyor No. 2	2000 st/h, 60 in wide x 80 ft lg., no lift, 500 fpm	50	50
100	DC-01 thru 03	3	Silo top dust collector with fan	7000 cfm, filtering area 1200 sq. ft including fan	40	120
100	RR-01	Lot	Rail car unloading system	For 2000 st/h unloading rate including rotary car dumper, shunting locomotive, 200 st dump hopper, grizzly, frozen coal crusher, thawing shed, dust collection, raw coal conveyor tunnel, sump pump, feeders, rail track of 2 miles	700	700
100	ST-01 & 02	2	Motorized gate	Capacity- 2000 st/h	10	20
200	AG-01 & 02	2	Cyclone feed pump sump mixers	For Cyclone feed sump	15	30
200	CN-01	1	Mill house crane	30 t main hook, 5 ton aux	75	75
200	CR-01 & 02	2	Hammer mill crusher	125 st/h, feed size 2" x 0 and product 1/2" x 0	300	600
200	CS-01 thru 06	6	Cyclone cluster	Flow 1200 gpm/cluster-20 no. of 4 in cyclones per cluster		
200	CV-10 & 11	2	Crusher feed conveyor	125 st/h, 30 in wide x 300 ft lg., 25 ft lift, 350 fpm, with belt scale	15	30
200	CV-12 & 13	2	Ball mill feed conveyor	125 st/h, 30 in wide x 100 ft lg., 25 ft lift, 350 fpm	15	30
200	DC-10 & 11	2	Crusher house dust collector with fan		50	100
200	FE-01 thru 06	6	Reclaim feeder	125 st/h, 36 in wide x 40 ft lg.,75 fpm, (max.) variable speed drive	10	60
200	MA-01 & 02	2	Tramp iron magnet	125 st/h, 36 in belt	10	20
200	ML-01 & 02	2	Ball mill	125 st/h, 14.5 ft dia x 29 ft	4000	8000
200	PP-01 thru 04	4	Cyclone feed pump	Horizontal slurry pump, flow 3500 gpm, sp gr 1.2, TDH 130 ft, 2 operating and 2 spare	225	900

Table 5.2.1
COMMERCIAL CWF PLANT- COLUMN FLOTATION
Major Equipment List (continued)

Equipment I.D		Qty	Title	Description	Power-ea. HP	Total installed HP
200	ST-03 thru 8	6	Motorized gate	Capacity- 125 st/h	5	30
200	ST-10 & 11	2	Cyclone feed sump	7000 gal capacity (2 min.)-14ft dia x 15 ft ht, conical		
200	ZM-01 & 02	2	Distributor	3 way-3500 gpm	5	10
300	AG-03 & 04	2	Flotation feed sump mixer		30	60
300	CP-01 & 02	2	Air compressor	2250 SCFM, 125 psig with air receiver	400	800
300	FT-01 thru 12	12	Column flotation unit	14 ft dia, Micro cell or equal		
300	PP-05 thru 16	12	Flotation feed pump	Horizontal slurry pump, flow 1100 gpm, sp gr 1.02, TDH 65 ft	30	360
300	PP-17 thru 28	12	Recirculation pump	Horizontal slurry pump, flow 5,000 gpm, sp gr 1.02, TDH 65 ft (14 x 12 Ash)	150	1800
300	PP-29 thru 32	4	Clean coal pump	Horizontal slurry pump, flow 2200 gpm, sp gr 1.02, TDH 65 ft (6 x 5 Ash)	60	240
300	PP-33 thru 44	12	Frother dosing pump	Variable speed peristaltic pump (Omega FPU258 or equal)	0.25	3
300	PP-45 thru 56	12	Collector dosing pump	Variable speed peristaltic pump (Omega FPU258 or equal)	0.25	3
300	ST-12 & 13	2	Flotation feed sump	17500 gal capacity (2.3 min.)-14 ft dia x 16 ft (Cylindrical)		
300	ST-16 & 17	2	Clean coal sump	17500 gal capacity (5 min.-froth factor 3)-14 ft dia x 16 ft ht Cylindrical		
300	ST-20 & 21	2	Frother storage drum	At 1.5 lb/st, 200 h, 460 ft3, 6.7 ft dia, 12 ft long, 3 st wt each		
300	ST-22 & 23	2	Collector storage drum	At 1.5 lb/st, 200 h, 460 ft3, 6.7 ft dia, 12 ft long, 3 st wt each		
400	CV-15	2	Coal solid conveyor	Capacity 130 st/h-24 in wide, 125 st/h, 30 ft lift,	5	10
400	FT-10 thru 15	6	Filtration systems	Capacity 40 st/h - vacuum filter systems	700	4200
400	PP-62 & 65	4	Filtrate pump	Flow 2500 gpm, TDH 30 ft, 2-Operating and 2- Spare	30	120
400	ST-26 & 27	2	Filtrate sump	Capacity- 5000 gal		
400	ZM-05 & 06	2	Slurry distributor	Capacity-3000 gpm	10	20
500	AG-09	1	Tailings filter sump agitator	Capacity of sump - 1000 gal	10	10

Table 5.2.1
COMMERCIAL CWF PLANT- COLUMN FLOTATION
Major Equipment List (continued)

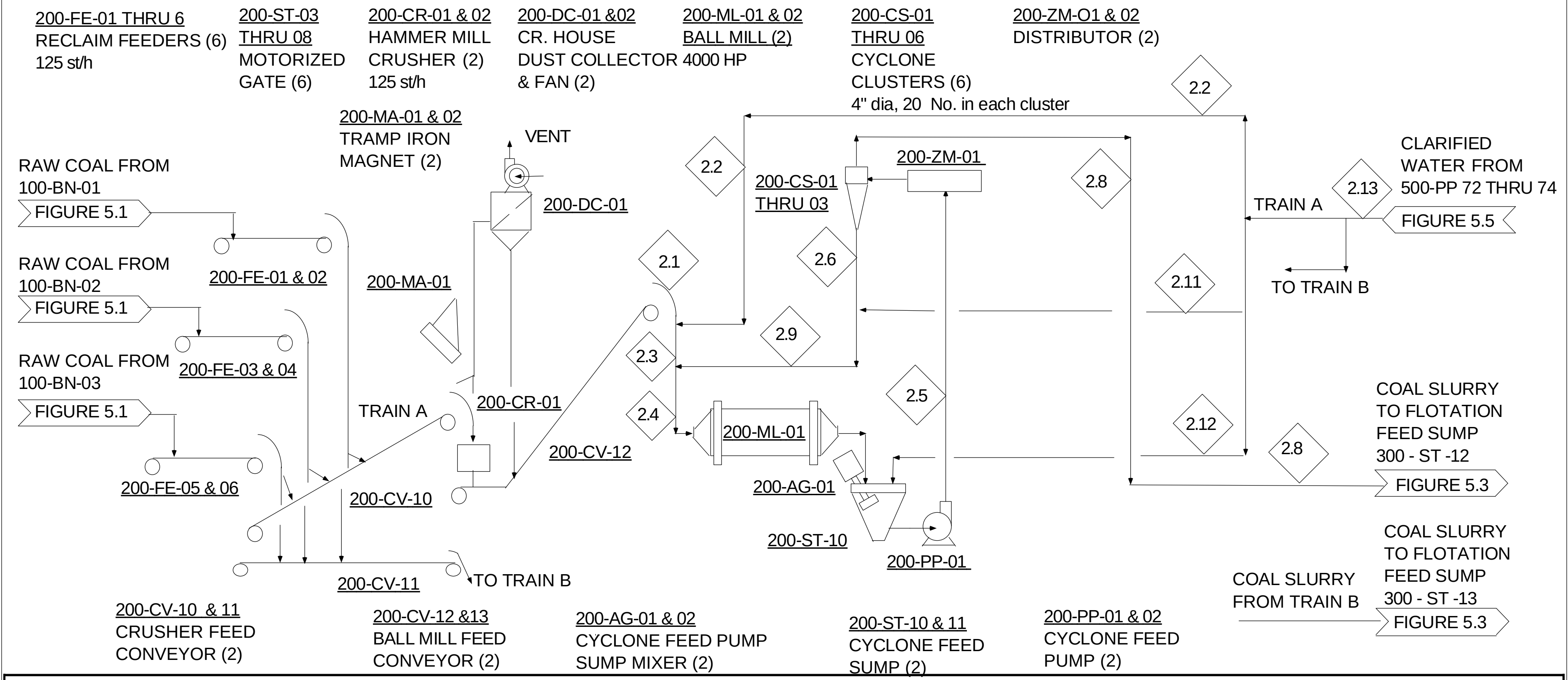
Equipment	I.D	Qty	Title	Description	Power-ea. HP	Total installed HP
500	BN-04	1	Tailings load-out shed	Capacity- 100 st		
500	CV-16	1	Tailings conveyor	Capacity - 50 st/h, 24 in x 100 ft	5	5
500	FL-01	1	Tailings filter	Capacity-30st/h, 3,5 m wide	22	22
500	PP-70 & 71	2	Thickener underflow pump	Horizontal slurry- capacity 500 gpm, 50 ft head, sp gr 1.07. 1-Operating, 1- Spare	15	30
500	PP-72 thru 74	3	Clarified water pump	Horizontal water- capacity 10,000 gpm, 35 ft head, sp gr 1.0, 2-Operating, 1- Spare	125	375
500	PP-75 & 76	2	Tailings filter feed pump	Capacity 420 gpm, 30 ft head, sp gr 1.07. 1- Operating, 1- Spare	15	30
500	ST-30	1	Tailings filter feed sump	Capacity 1000 gal		
500	TK-01	1	Tailings thickener tank	120 ft diameter thickener tank with tunnel (concrete)		
500	TK-02	1	Thickener overflow tank	Capacity 60,000 gal (concrete)		
500	TM-01	1	Thickener mechanism	120 ft dia thickener mechanism with controls	20	20
500	ZM-08	1	Flocculant storage,mixing and dosing system		5	5
600	AG-10 & 11	2	Coal additive mixer	Retention 5 min	40	80
600	AG-12 & 13	2	Slurry mixing tank agitator	For tanks 600-ST-31 & 32	40	80
600	AG-14 thru 17	4	Slurry storage tank agitator	For tanks 600-ST-33 thru 36	75	300
600	PP-78 & 79	2	CWF pump	Horizontal slurry- Capacity-1500 gpm, 60 ft head, sp gr 1.17	60	120
600	PP-80 thru 83	4	Slurry loading pump	Horizontal slurry- Capacity-dry solids 500 st/h- slurry 3,000 gpm, 60 ft head, sp gr 1.17, 4-Operating and 4- spare	100	400
600	ST-31 & 32	2	Slurry mixing tank	10 min. each. Volume:		
600	ST-33 thru 36	4	Slurry fuel storage tank	0.85 million gal- 55 ft dia and 53 ft high- total 48 hr.		
600	ZM-10 & 11	2	Flocculant storage, mixing and dosing system		10	20
	TOTAL MAJOR EQUIPMENT					20,538



PREMIUM CWF PRODUCTION

PLANT 100: RAW COAL HANDLING PROCESS FLOW DIAGRAM

FIGURE 5.1



Plant 200: Crushing and Grinding — **Material Balance**

Flow quantities are total for two trains

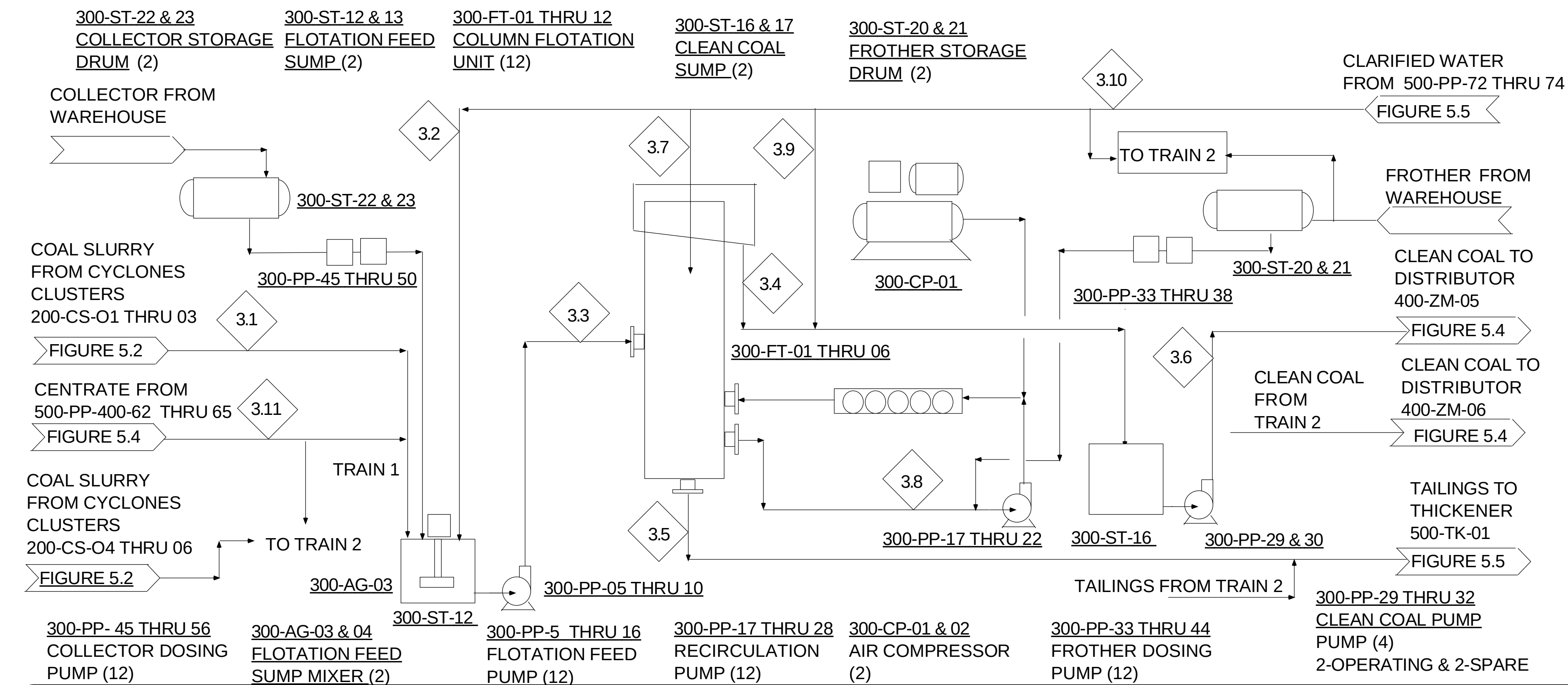
Stream Number		2.1	2.2	2.3	2.4	2.5	2.6	2.7	2.8	2.9	2.10	2.11	2.12	2.13
Stream Name		Feed coal	Water Addition at B' Mill	2.1 +2.2	Feed to Ball Mills	Feed to Cyclone	Cyclone U'flow	Not Used	Cyclone O'flow	Recycle to Mill	Not Used	Water to Cycl. U'flow	Water to Cyclone Feed Sump	Water to Plant 200
Coal -Surface Dry	st/h	238		238	357	357	119		238	119				
Free Moisture	gpm	75	560	635	1,211	5,971	476		5,495	576.0		100	4,760	5,420
Total Flow	gpm	807	560	1,367	2,309	7,069	842		6,227	942		100	4,760	5,420
Total Free Moisture	wt%	7.30		40	46	81	50		85	55				

NOTE:
ONE OF TWO IDENTICAL TRAINS OF EQUIPMENT SHOWN

COLUMN FLOTATION

PLANT 200: CRUSHING AND GRINDING PROCESS FLOW DIAGRAM

FIGURE 5.2



Plant 300: Column Flotation — **Material Balance**

Flow quantities are total for two trains

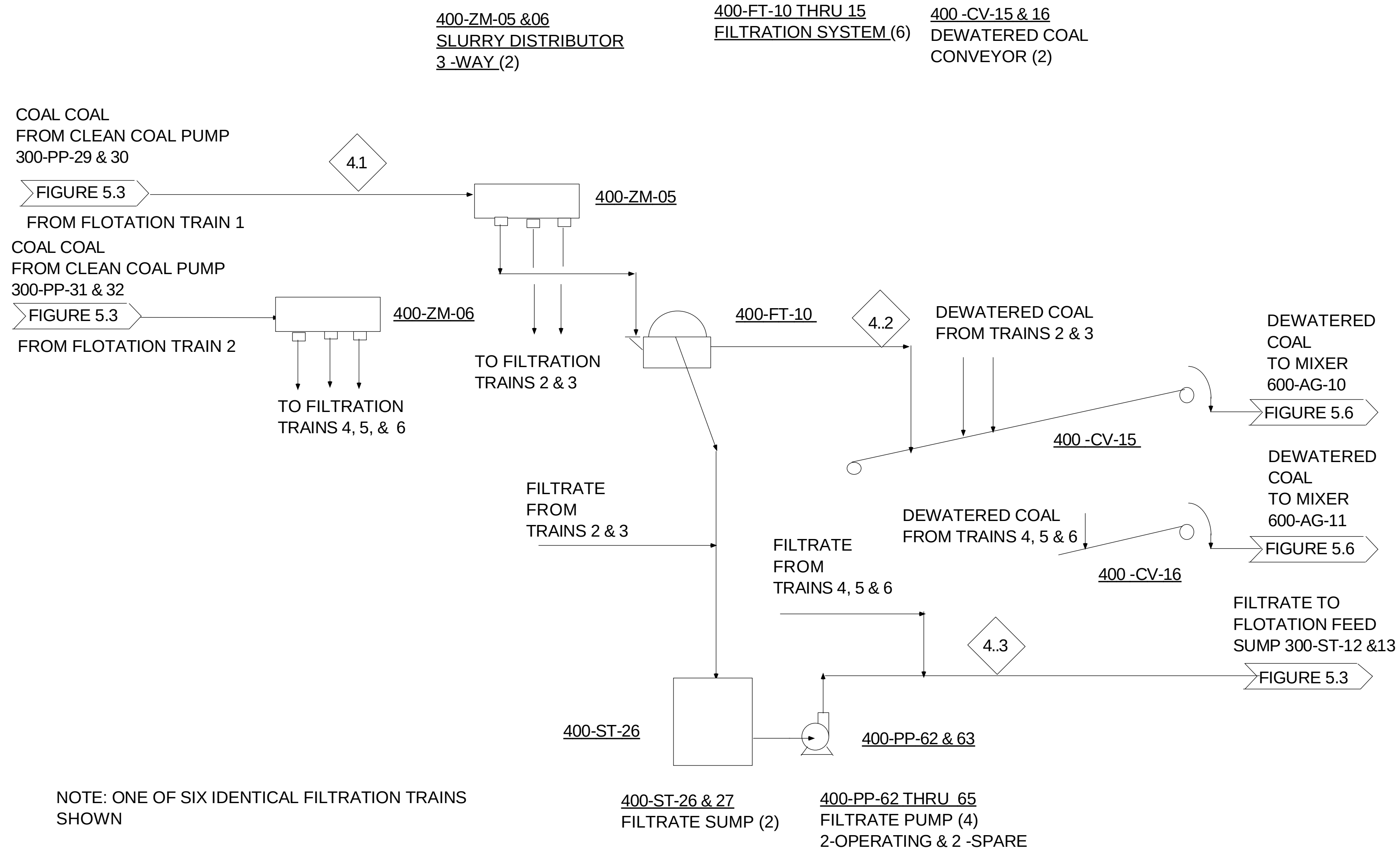
Stream Number		3.1	3.2	3.3	3.4	3.5	3.6	3.7	3.8	3.9	3.10	3.11
Stream Name		Cyclone U'flow	Dilution Water	Flotation Feed	Froth	Tailings	Clean Coal	Wash Water	Tailings Recycle	Froth Sprays	Water to Flotation	Filtrate
Coal -Surface Dry	st/h	238		238	215	23	215		69			
Free Moisture	gpm	5,495	9,420	14,915	2,722	19,290	3,439	7,098	57,420	716	14,259	2,976
Total Flow	gpm	6,227	9,420	15,647	3,384	19,361	4,100	7,098	57,631	716	14,259	2,976
Total Free Moisture	wt%	85		94	76	100	80		99			100.0

NOTE: ONE OF TWO IDENTICAL TRAINS OF EQUIPMENT SHOWN

COLUMN FLOTATION

PLANT 300: COLUMN FLOTATION PROCESS FLOW DIAGRAM

FIGURE 5.3



Plant 400: Clean Coal Dewatering **Material Balance**

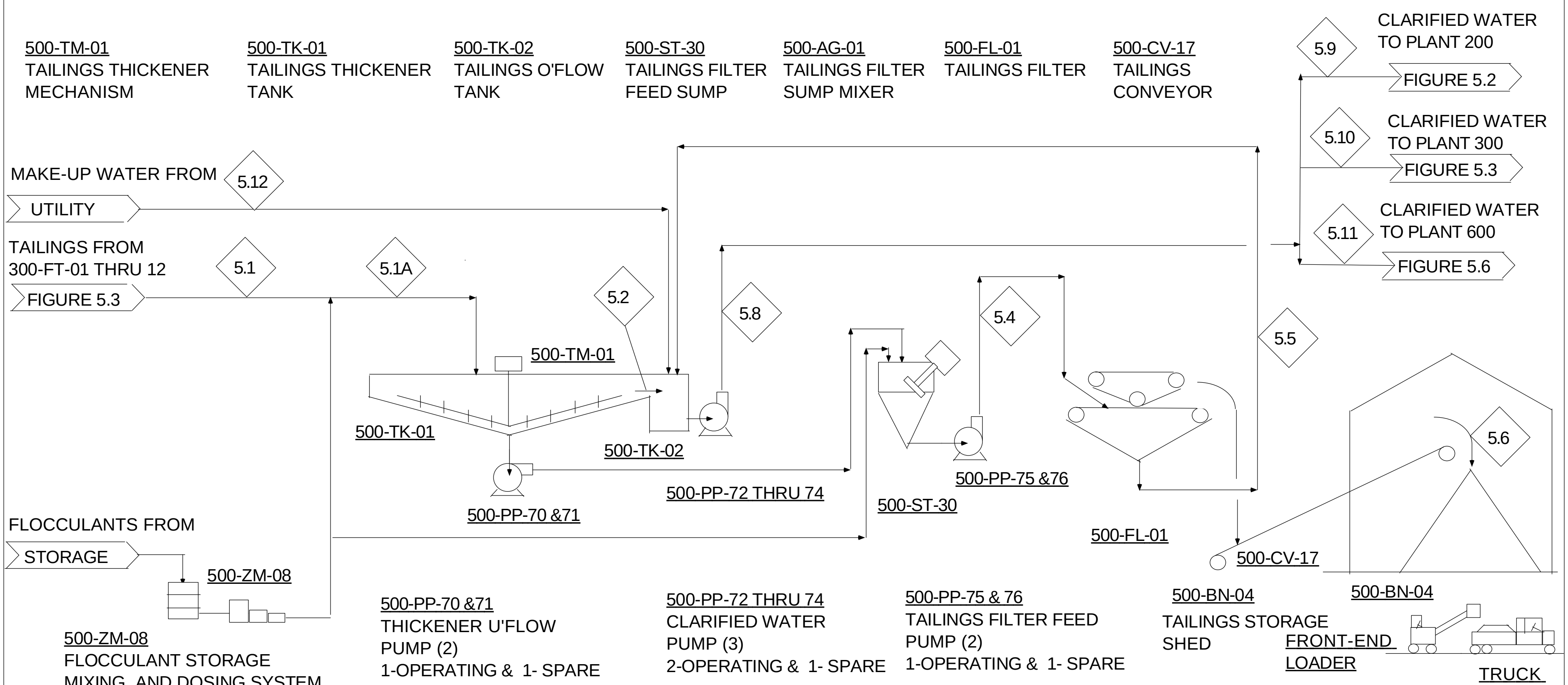
Flow quantities are total for all trains.

Stream Number		**4.1**	**4.2**	**4.3**
Stream Name		**Filter Feed**	**Filter Cake**	**Clean Coal Filtrate**
Coal -Surface Dry	**st/h**	**215**	**215**	
Free Moisture	**gpm**	**3,439**	**463**	**2,976**
Total Flow	**gpm**	**4,100**	**1,124**	**2,976**
Total Free Moisture	**wt%**	**80**	**35**	**100**

COLUMN FLOTATION

PLANT 400: CLEAN COAL DEWATERING PROCESS FLOW DIAGRAM

FIGURE 5.4

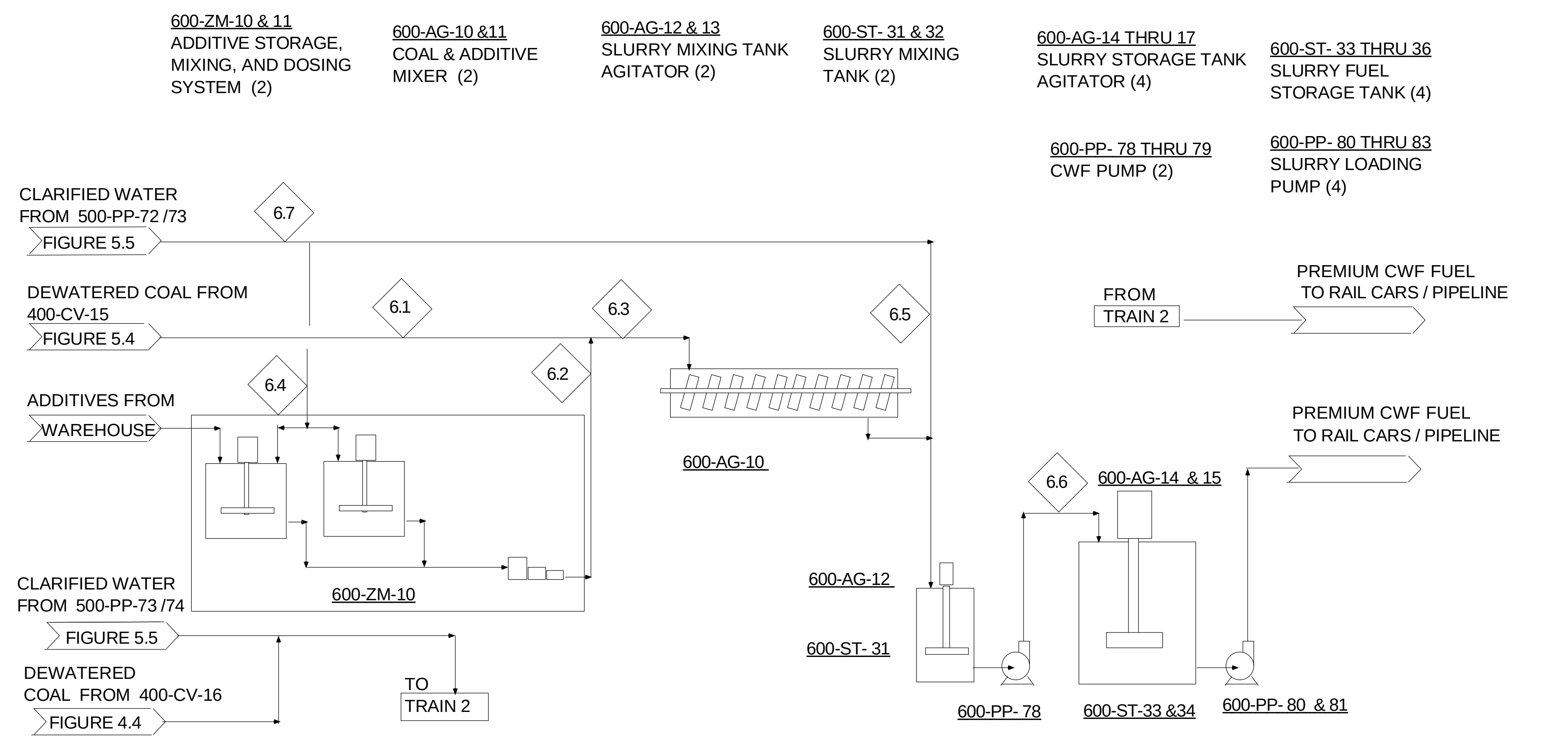


Plant 500: Water Clarification and Tailings Handling					Material Balance									
Stream Number		**5.1**	**5.1A**	**5.2**	**5.3**	**5.4**	**5.5**	**5.6**	**5.7**	**5.8**	**5.9**	**5.10**	**5.11**	**5.12**
Stream Name		**Tailings**	**Feed to Thick-ener**	**Thickener O'flow**	**Thickener U'flow**	**Tailings Filter Feed**	**Tailings Filtrate**	**Tailings Cake**	**Not used**	**Clarifed Water**	**Water to Plant 200**	**Water to Plant 300**	**Water to Plant 600**	**Total Plant Make-up Water**
Coal -Surface Dry	**st/h**	**23**	**23**		**23**	**23**		**23**						
Free Moisture	**gpm**	**19,290**	**19,290**	**19,013**	**277**	**277**	**215**	**62**		**19,760**	**5,420**	**14,259**	**82**	**531**
Total Flow	**gpm**	**19,361**	**19,361**	**19,013**	**348**	**348**	**215**	**133**		**19,760**	**5,420**	**14,259**	**82**	**531**
Total Free Moisture	**wt%**	**100**	**100**		**75**	**75**		**40**						

COLUMN FLOTATION

PLANT 500: WATER CLARIFICATION AND TAILINGS HANDLING PROCESS FLOW DIAGRAM

FIGURE 5.5



Plant 600: CWF Preparation & Loading **Material Balance**

Flow quantities are total for all trains

Stream Number		6.1	6.2	6.3	6.4	6.5	6.6	6.7
Stream Name		De-water-ed Coal	Additive	Feed to Coal/additive Mixer	Water in Additive Mixture	Water Addition	Premium Fuel (CWF)	Water for Plant 600
Coal -Dry	st/h	210		210			210	
Coal -Surface Dry	st/h	215		215			215	
Free Moisture	gpm	462	5	467	5	76	544	81
Total Flow	gpm	1,122	5	1,127	5	76	1,204	81
Total Free Moisture	wt%	35		35			39	
Solid Additive	st/h		1.05	1.05			1.05	
Total Moisture Content	wt%						40	

COLUMN FLOTATION

PLANT 600: CWF PREPARATION AND LOADING PROCESS FLOW DIAGRAM

FIGURE 5.6

Section 6
Conceptual Design of CWF Plant - Selective Agglomeration

A conceptual design for a commercial plant based on selective agglomeration technology for the production of premium CWF is presented in this section. A discussion of the process design criteria and a description of the integrated facility are also included.

6.1 PROCESS DESIGN CRITERIA-SELECTIVE AGGLOMERATION

The laboratory, bench-scale, and PDU testing conducted earlier form the bases for process design and equipment selection criteria used in the conceptual design. These are summarized in Table 6.1.1.

With the design coal, it is expected that selective agglomeration will achieve a heating value recovery of 99 percent while producing specification quality clean coal. A clean coal weight recovery of 93 percent will be achieved. As noted in Section 4, the plant operates 3 shifts a day and 19 shifts of the week. There is an annual shut down for two weeks for major maintenance work. Based on the schedule, the weight recovery, and an availability of 91 percent of scheduled operating time, a design input capacity of 233 st/h (dry basis) has been calculated to produce 1.5 million st of clean coal on a dry basis. If the availability is calculated on the basis of a total of 8,760 hours (365 x 24) in a year, the selected hourly design capacity reflects an availability of 79 percent. This level of availability is considered achievable with multiple (10 trains) and adequate complement of standby equipment at critical locations of the plant. Scale-up issues were considered in deciding the capacity and total number of trains used.

Significant process and equipment design parameters such as energy for grinding, solids concentration of the agglomeration feed, retention times for agglomeration, the number and stages of agglomeration, consumption of power for agglomeration, and the criteria for the heptane recovery circuit are shown in Table 6.1.1. The table also provides details of process and equipment design criteria for clean coal dewatering, water clarification, tailings dewatering and handling, CWF preparation, and loading sections of the plant.

Operating experience and recent analysis of test data from the PDU indicate certain potential improvements to agglomeration plant design and criteria. These are presented below for the benefit of future plant designs.

Froth Skimmer Design: A slender column with a relatively small cross section area would be more effective than the 5 feet diameter unit used in the 2 t/h PDU. Such an unit will allow improved nitrogen dispersion across the column and provide higher solids/area ratio for the froth layer.

Screen spraty/wash water: Recent experience would indicate a spray water rate of 8.3 gpm per ton per hour of clean coal agglomerates.

Solid Concentration in Low Shear Reactor: For some coals, a solid concentration of 8 percent combined with a retention time of 2 minutes improved product qualtity at the same level of energy recovery. The concept designs are based on a solids concentration of 10 percent and a retention time of 3 minutes.

Grind Size: Tests indicate that, for the same low ash content product, a finer coal grind is often needed with the Selective Agglomeration Process as compared to Column Flotation. Selective agglomeration tends to place coal particles aggressively in the clean coal. As a result, even particles with minor coal surface are collected as clean coal. Such behavior of the process dilutes product quality and creates a need for finer grinding and better liberation of the feed.

6.2 FACILITY DESCRIPTION

The commercial CWF plant based on selective agglomeration consists of the following sections:

- Raw Coal Handling - Plant 100
- Crushing and Grinding - Plant 200
- Selective Agglomeration - Plant 350
- Clean Coal Dewatering - Plant 400
- Water Clarification and Tailings Handling - Plant 600
- CWF Preparation and Loading - Plant 600

A list of major equipment is provided under Table 6.2.1

6.2.1 Raw Coal Handling - Plant 100

A process flow diagram for the raw coal handling section, Plant 100, is presented in Figure 6.1. It is identical to the raw coal handling section described under Section 5.2.1 for the plant based on column flotation.

Raw coal, pre-crushed to a top size of 2 inch, is delivered to the CWF plant in RR cars. The cars are unloaded using a car dumper. The rail car unloading system includes thawing sheds for heating the cars during the winter months when freezing conditions could be encountered. A shunting locomotive is used to position the cars over the dumper. The cars are dumped, one car at a time, into a 200 ton dump hopper. A bar grid located at the top of the dump hopper prevents large lumps of frozen coal from entering the hopper. A frozen coal crusher is used to break such lumps of coal over the grid.

Two variable capacity belt feeders located below the dump hopper deliver the coal to a raw coal conveyor which transports and elevates the coal to the top of the coal silos.

The raw coal conveyor working with two silo feed conveyors fills three raw coal concrete silos. Each silo has a capacity of 10,000 st.

The raw coal handling section is rated for a capacity of 2000 st/h. It includes a comprehensive dust collection system to control emission of dust during coal dumping and conveying operations.

6.2.2 Crushing and Grinding - Plant 200

Figure 6.2 represents a process flow diagram for this plant section. A material and heat balance is shown in Table 6.2.2. This plant section is similar to the one provided for the plant based on column flotation and described in Section 5.2.2.

The crushing and grinding section includes two parallel and identical trains to crush and grind the coal ahead of selective agglomeration. Two variable speed belt feeders are provided below each of the coal silos for withdrawal of coal. Two crusher feed conveyors receive coal from the belt feeders. The conveyors deliver the coal to two hammer mill type crushers. The crushers are designed to crush the coal to a top size of 1/2 inch. Tramp iron magnets are included for the protection of the hammer mills. Crushed coal from the hammer mills is delivered to the ball mills by two ball mill feed conveyors. Each conveyor serves a grinding system.

Each grinding system includes a 4000 HP ball mill served by a set of three cyclone clusters for closed circuit operation. Each cyclone cluster has multiple cyclones. Coal is ground in the mills with water. The discharge slurry from each ball mill is diluted and pumped to the cyclone clusters. A distributor is used to distribute the flow equally among the cyclone clusters. Partially ground material exiting the cyclone apex (cyclone underflow) is returned to the mills for further grinding.

The over flow from cyclones represents the ground slurry. The solids content of the slurry is controlled at a preset value of approximately 15 percent by the addition of water. The slurry is sluiced to the selective agglomeration section, Plant 350.

6.2.3 Selective Agglomeration - Plant 350

Sheets 1 through 5 of Figure 6.3 represent process flow diagrams for the selective agglomeration section, Plant 350. Material and heat balances are shown in Table 6.2.3.

Ground slurry from each of the two trains of the crushing and grinding plant (Plant 200) is received in a 5-way distributor. Each of the two distributors splits the feed slurry equally to 5 agglomeration trains. The ten parallel agglomeration trains included in the section are identical except for some equipment which are shared by two trains. Such shared equipment are clearly identified in the equipment list and process flow diagrams. The following description addresses one of the agglomeration trains.

<u>Production of Agglomerates</u> Feed coal slurry from the distributor is received in the agglomeration feed tank. The slurry is then pumped to a high shear reactor (HSR) vessel. A measured stream of heptane from a metering pump joins the feed coal slurry ahead of the HSR vessel. Under conditions of the intense agitation in HSR vessel created by the impeller a phase inversion takes place. Micro agglomerates of ultra-clean coal are formed. Particles of hydrophobic coal coalesce as agglomerates with heptane acting as the bridging liquid. Hydrophilic particles of mineral matter (the tailings) remain dispersed in water as discrete particles. The slurry with the micro agglomerates overflows from the HSR vessel and flows through a set of two low shear reactor (LSR) vessels. The vessels are arranged in series. A measured amount of water is added in the first LSR vessel to dilute the slurry. In the LSR vessel the micro agglomerates grow to approximately 3 mm in diameter, under relatively gentle agitation conditions. The slurry from the second LSR vessel overflows to a vibrating screen. Here the agglomerates are separated from the slurry which is laden with non-coal mineral matter. The agglomerates are sprayed with water on the screen deck to help remove tailings adhering to the agglomerates. The screened agglomerates are now ready for the heptane stripping.

The underflow from the screen, which is essentially water laden with mineral matter (tailings) flow into a froth skimmer tank with a conical bottom. The tank is provided with a rotating froth skimmer at the top. The tendency of coal agglomerates to float in water is used in this tank to capture any misplaced coal present in the tailings as part of the screen under flow. The floating coal agglomerates in the tank are skimmed and directed to the main agglomerate stream from the vibrating screen. Heated clarified water is used as push water in the launder for the floats.

The slurry from the bottom of the froth skimmer tank, the tailings, are pumped to a sampling pot. At the sampling pot a constant stream of purge nitrogen is passed through the slurry. A hydrocarbon detector constantly scans the nitrogen exiting the sampling pot for the presence of heptane. If no heptane is detected, the tailings stream is directed to a tailings thickener included in Plant 500. When the presence of heptane is detected, the tailings slurry is directed to a slop tank instead of the tailings thickener.

The slop tank serves as a holding vessel for off grade slurries and spills that could contain heptane. Periodically, the contents of the tank are heated with steam to vaporize the heptane and render the slurry heptane free. The processed slurry is sent to the tailings thickener.

Heptane Stripping Heptane in the coal agglomerates is vaporized and recovered during the heptane stripping operation. It is vaporized in two stages to enhance recovery of heptane.

The screened agglomerates and the material from the froth skimmer are collected in a steam stripper feed drum. The contents of the drum are diluted by the addition of heated clarified water to a pumpable consistency and pumped to the first stage steam stripper, steam stripper A. In this vessel which is provided with an agitator, the slurry is heated by steam from the second stage steam stripper (steam stripper B) to a temperature of approximately 225 degrees F. The vessel is maintained at a pressure of 1 to 3 psig. Close to the entire quantity (99%) of heptane in the agglomerates and some water are vaporized. The slurry in stripper A is then pumped to steam stripper B which is maintained at a higher pressure of 5 to 10 psig for the removal of last traces of heptane in the agglomerates. Steam at a pressure of 20 psig is sparged through the contents of stream stripper B to elevate slurry temperature and vaporize heptane and water. Vapors from steam stripper B are passed through steam stripper A. The vapors raises slurry temperature and vaporizes heptane with water in steam stripper A.

Vapors from steam stripper A are condensed in an air cooler. The condensed liquids, water and heptane, are further cooled to a temperature of 80^{o} F in a heat exchanger. Cooling is done with chilled water. The cooled liquids gravitate to an oil/water separator where the two liquids are separated using gravity. Liquid heptane from the separator is sent to a heptane drum for reuse. Metering pumps deliver heptane from the drum back to the feed end of the agglomeration section.

Water from the oil/water separator is passed through activated carbon in a carbon drum and used again for steam raising.

Approximately 220,000 lb. per hour of steam at a pressure of 20 psig will be required for the heptane stripping operation. This amount of relatively low pressure steam is produced most economically in a local power station (It is assumed that a power station will be in the vicinity to produce and sell steam to the CWF plant).

After heptane stripping, the hot clean coal slurry from steam stripper B is cooled in two stages. In the first stage of cooling, clarified recycle water is used for cooling. The heated clarified water is used in the system to dilute and pre-heat the slurry in the steam stripper feed drum. It is also used as a push water in the froth skimmer. Thus a significant amount of heat in the hot clean coal slurry is recycled. In the second stage of cooling, the clean coal slurry is cooled using pond water. Cooled clean coal slurry at 80^{o} F is piped to slurry distributors in the clean coal dewatering section, Plant 400.

Gas Blanketing System All vessels in this plant section which could contain heptane are connected to a nitrogen gas blanketing system which is constantly maintained at a positive pressure of 3 to 6 inches of water. The gas blanket prevents ingress of atmospheric air into the vessels where it could form a flammable mixture with heptane vapors. A gas holder forms part of the nitrogen blanketing system. It helps maintain a constant positive pressure in the system. By increasing or decreasing the hold up, the variable volume gas holder accommodates volume changes in the blanketing system due to temperature changes and variations in the void volumes of vessels. Should nitrogen be lost from the system for any reason it will be indicated by a low level in the gas holder. In such an instance the losses are made-up by drawing gas from a liquid nitrogen package.

The liquid nitrogen package also provides gas for purging vessels and displace all air in them at the start of operations.

During occasions of excessive build up of nitrogen in the system indicated by a high level in the gas holder, the surplus gas is flared off.

The plant is also provided with a relief vent system. This system will kick-in if pressure in side any vessels should exceed pre-set value.

Building areas handling heptane are provided with heptane vapor detectors that are connected to dedicated ventilation fans. Should heptane vapors be detected due to a spill, the ventilation fans are activated immediately to thoroughly ventilate the area and render it safe. A comprehensive fire prevention and protection system is also included.

Cooling water supply for the plant is from two on-site lined ponds. The closed cooling water circuit will use atmospheric cooling and evaporation to maintain required water temperatures. In addition, a chiller is used to provide refrigerated cooling water during summer months for use in cooling circuits which need cooling water at 50^{o} F.

6.2.4 Clean Coal Dewatering - Plant 400

Figure 6.4 shows a process flow diagram for this plant section. A material and heat balance is given in Table 6.2.4. This section is very similar to the one described in Section 5.2.4 under Design of CWF Plant - Column Flotation.

The clean coal dewatering section consists of two identical trains. Each train is provided with six parallel vacuum filtration lines. Clean coal slurry is dewatered and a filter cake with a moisture content of approximately 37 percent (35 percent surface moisture) is produced. Filter cake from each set of six filters is collected by a dewatered coal conveyor. The two dewatered coal conveyors deliver the coal to two coal- additive mixers provided under Plant 600.

The water separated by the vacuum filters, the filtrate, may contain some solids. It is therefore pumped to the tailings thickener. Coal solids in the filtrate, if any, tends to float in the thickener. These are removed periodically.

All pumps in this section are provided with installed spares.

6.2.5 Water Clarification and Tailings Handling - Plant 500

Figure 6.5 presents a process flow diagram for this plant section. A material and heat balance appears in Table 6.2.5. This plant section is similar to the one described in Section 5.2.5 for plant design based on column flotation.

Tailings slurry from selective agglomeration are collected in a thickener. The tailings (solids) are thickened and the water is clarified with the addition of measured amounts of flocculants to the feed slurry. The thick underflow from the thickener is pumped to a tailings filter sump. Additional amounts of flocculants are mixed with the slurry in the filter sump to facilitate filtering. A continuous Andritz type belt filter is used to dewater the tailings.

The filtered tailings are collected by a tailings conveyor and conveyed to a storage pile under a shed. The tailings are loaded into trucks using front-end loaders for transport and disposal at a landfill.

Clarified water from the thickener, the thickener overflow, is recirculated to the CWF preparation, selective agglomeration, and grinding sections of the facility. The water sent to the later two plant sections is cooled in a heat exchanger for removal of excess heat from the plant system. Chilled water is used in this heat exchanger.

6.2.6 CWF Preparation and Loading - Plant 600

A process flow diagram for this plant section is shown in Figure 6.6. The material and heat balance is presented in table 6.2.6. This plant section also comprises two parallel and identical trains. This plant section comprises two parallel and identical trains. It is identical to the one described in Section 5.2.6 for plant design based on column flotation.

Dewatered clean coal from the vacuum filters (the filter cake) is fed to two coal-additive mixers (one on each train). Here the cake is mixed intensely with the dispersant additive A-23 to obtain a good dispersal of the additive. The mixture is then fed to slurry mix tanks (one in each train) where measured amounts of water is added to obtain the desired solids content in the prepared CWF. From the slurry mix tanks, the CWF is pumped to storage tanks.

A total of four storage tanks are included with adequate capacity to hold a two day production of CWF. From the storage tanks, the CWF is pumped into RR tank cars. Alternately, the slurry fuel in the storage tanks may be pumped to nearby clients through pipe lines installed by others.

Table 6.1.1
COMMERCIAL CWF PLANT- SELECTIVE AGGLOMERATION
Process Design Criteria

I	**SELECTIVE AGGLOMERATION PERFORMANCE**		
	Heating value recovery	%	99.0
	Feed ash content- dry basis	%	7.5
	Feed HHV- dry basis	Btu/b	14,054
	Weight recovery	%	93.0
	Product ash- dry basis	%	2.8
	Product HHV-dry basis	Btu/lb	14,962
	Ash per million Btu of HHV in the product	lb/MBtu	<2.0
II	**OPERATING SCHEDULE**		
	Hours per shift	h/shift	8
	Shifts per day	shifts/day	3
	Days per week	days/week	7
	Scheduled maintenance shifts per week	shifts/week	2
	Scheduled operating shifts per 7 day week	shifts/week	19
	Scheduled operating weeks per year	weeks/y	50
	Scheduled operating hours per year	h/y	7,600
III	**DESIGN HOURLY FEED RATE TO AGGLOMERATION**		
	Annual output required - dry basis	Million st/y	1.5
	Average output per operating hour-dry basis	st/h	197
	Plant utilization based on scheduled operating hrs	%	91
	Design output capacity-dry basis	st/h	217
	Design weight recovery	%	93.0
	Plant design input capacity-dry basis	st/h	233
	Inherent moisture	wt %	2.0
	Plant design input capacity-surface dry basis	st/h	238
	Plant availability based on 24 h/day and 365 d/y	%	79
IV	**AGGLOMERATION FEED SLURRY PREPARATION**		
	Grinding circuit configuration		Wet, closed circuit
	Ground product - nominal, 100 % passing	mesh	100
	Size (D80)	mesh	325
	Size of coal feed to grinding mills	in.	1/2
	Specific power for grinding	HP/(st/h)	34
	Agglomeration feed solids content	wt %	15
	Storage for ground slurry		Not required
V	**SELECTIVE AGGLOMERATION**		
	High shear reactor (HSR)		
	Feed solids content (dry basis)	wt %	15
	Retention time	seconds	30
	Design feed to agglomeration -dry basis	st/h	233
	Water flow rate	gpm	5,287
	Design slurry flow rate	gpm	6,004
	Power for agglomeration	kW/(st/h)	12.5
		HP/(st/h)	16.8

Table 6.1.1 (continued)
COMMERCIAL CWF PLANT- SELECTIVE AGGLOMERATION
Process Design Criteria

Total volume required in HSRs	gallon	3,002
Number of parallel circuits		10
Volume of each HSR	gallon	300
Required dia : ht ratio		1:2
Calculated minimum diameter of HSR	in.	35.32
Calculated minimum height of HSR	in.	70.6
Selected dia x ht (Arcanum recommendation)	in. x in.	38 x 80
Material of construction:		
Vessel		CS
Impeller, shaft, baffles, and vessel attachments		SS
Motor Power (Arcanum recommendation)	kW/(st/h)	12.5
Power per impeller based on total No. selected	kW	292
Variable speed drive		Not Required
Low shear reactor (LSR)		
Feed solids content -dry basis	wt %	10
Retention time	seconds	180
Design feed to agglomeration -dry basis	st/h	233
Design water flow rate	gpm	8,397
Design slurry flow rate	gpm	9,114
Volume required in LSR	gallons	27,343
Assumed number of trains		10
LSR Volume of each trains	gallons	2734
No. of LSR in each train- arranged in series		2
LSR Volume - each unit	gallons	1,367
Required dia : ht ratio		1:2
Calculated minimum diameter of LSR	in.	58.5
Calculated minimum height of LSR	in.	117.1
Selected dia x ht (Arcanum recommendation)	in. x in.	60 x 120
Material of construction:		
Vessel		CS
Impeller, shaft, baffles, and vessel attachments		SS
Motor Power (Arcanum recommendation)	kW/(st/h)	3.0
	HP/(st/h)	4.0
Power per impeller based on total No. selected	kW	35
Variable speed drive		Not Required
Agglomerate Screen		
Inclined screen-(6 ^{o}downhill), 48 mesh deck, thin solid layer with water sprays		
Dilution water addition in o'flow launder- temp.	^{o}F	190
Froth Skimmer		
Froth solids - wt % of total clean coal	wt %	1
Moisture content of froth (before water addition)	wt %	60
Temperature of flush water to froth launder	^{o}F	190

Table 6.1.1 (continued)
COMMERCIAL CWF PLANT- SELECTIVE AGGLOMERATION
Process Design Criteria

	Steam Stripper A		
	Solid content of slurry - stripper outlet	wt %	30
	Residence time	minutes	5
	Normal operating pressure	psig	3
	Normal vapor composition by wt; Heptane : Water	Ratio	100:70
	Steam Stripper B		
	Residence time	minutes	10
	Normal operating pressure	psig	10
VI	**CLEAN COAL DEWATERING**		
	Equipment type		Vacuum filter
	Filter cake moisture content	wt %	35
VII	**WATER CLARIFICATION AND TAILINGS DEWATERING**		
	Equipment type		Thickener and Filter
	Tailings thickener -Specific thickening rate	gpm/ft2	2.0
	Thickener under flow -surface moisture content	wt%	75
	Tailings filter- type		Belt press
	Moisture content of dewatered tailings, filter cake	wt %	40
VIII	**CWF PREPARATION AND LOADING**		
	Dispersant type		A-23
	Dispersant (Solid) dosage per dry ton of coal	lb /st	10
	Water content of additive solution	wt %	55
	Stabilizer		Not used
	Storage capacity for CWF at site	h	48
	Type of storage		Agitated tanks
	Rail car loading rate:		
	CWF	gpm	3,000
	Coal on a dry basis	st/h	500

Table 6.2.1
COMMERCIAL CWF PLANT- SELECTIVE AGGLOMERATION
Major Equipment List

Equipment I.D	Qty	Title	Description	Power (ea) HP	Total installed HP
100 BN-01,02,03	3	Raw coal silos, No. 1, 2, and 3	10,000 st (ea), 70 ft dia x 150 ft ht		
100 CV-01	1	Raw coal conveyor	2000 st/h, 60 in wide x 750 ft lg., 220 ft lift, 500 fpm, with belt scale	600	600
100 CV-02	1	Silo feed conveyor No. 1	2000 st/h, 60 in wide x 80 ft lg., 10 ft lift, 500 fpm	50	50
100 CV-03	1	Silo feed conveyor No. 2	2000 st/h, 60 in wide x 80 ft lg., no lift, 500 fpm	50	50
100 DC-01,02,03	3	Silo top dust collector with fan	7000 cfm, filtering area 1200 sq. ft including fan	40	120
100 RR-01	Lot	Rail car unloading system	For 2000 st/h unloading rate including rotary car dumper, shunting locomotive, 200 st dump hopper, grizzly, frozen coal crusher, thawing shed, dust collection, raw coal conveyor tunnel, sump pump, feeders, rail track of 2 miles	700	700
100 ST-01 & 02	2	Motorized gate	Capacity- 2000 st/h	10	20
200 AG-01 & 02	2	Cyclone feed pump sump mixers	For Cyclone feed sump	15	30
200 CN-01	1	Mill house crane	30 t main hook, 5 ton aux	75	75
200 CR-01,02	2	Hammer mill crusher	125 st/h, feed size 2" x 0 and product 1/4" x 0	300	600
200 CS-01 thru 06	6	Cyclone cluster	Flow 1200 gpm/cluster-20 no. of 4 in cyclones per cluster		
200 CV-10 & 11	2	Crusher feed conveyor	125 st/h, 30 in wide x 300 ft lg., 25 ft lift, 350 fpm, with belt scale	15	30
200 CV-12 & 13	2	Ball mill feed conveyor	125 st/h, 30 in wide x 100 ft lg., 25 ft lift, 350 fpm	15	30
200 DC-10 & 11	2	Crusher House dust collector with fan		50	100
200 FE-01 thru 06	6	Reclaim feeders	125 st/h, 36 in wide x 40 ft lg.,75 fpm, (max.) variable speed drive	10	60
200 MA-01 & 02	2	Tramp Iron Magnet	125 st/h, 36 in belt	10	20
200 ML-01 & 02	2	Ball Mill	125 st/h, 14.5 ft dia x 29 ft	4000	8000
200 PP-01 thru 04	4	Cyclone feed pump	Horizontal slurry pump, flow 3500 gpm, sp gr 1.2, TDH 130 ft, 2 operating and 2 spare	225	900
350 PP-175 thru 178		Not used			
200 ST-03 thru 8	6	Motorized gate	Capacity- 125 st/h	5	30
200 ST-10 & 11	2	Cyclone feed sump,	7000 gal capacity (2 min.)-14ft dia x 15 ft ht, conical		
200 ZM-01 & 02	2	Distributor	3 way-3500 gpm	5	10
350 AG-90 thru 99	10	Feed tank agitator	Tank volume -4000 gals.	1.5	15

Table 6.2.1 (continued)
COMMERCIAL CWF PLANT- SELECTIVE AGGLOMERATION
Major Equipment List

Equipment I.D	Qty	Title	Description	Power (ea) HP	Total installed HP
350 AG-100 thru 109	10	HSR impeller	Special	400	4000
350 AG-109 thru 129	20	LSR impeller	Special	50	1000
350 AG-130 thru 139	10	Froth skimmer		5	50
350 AG-140 thru 149		Not used			
350 AG-150 thru 159	10	Steam stripper A agitator		20	200
350 C-100 thru 109	10	HSR vessel	Volume: 360 gals. Diameter: 38 inch ht 88 inch - CS- Design Pressure 15 psig- Temp 145 deg F. 34 secs.		
350 C-110 thru 129	20	LSR vessel	Volume 1445 gals. Diameter: 60 inch ht 132 inch - CS- Design Pressure 15 psig- Temp 145 deg F. 184 secs.		
350 C-130 thru 139	10	Froth skimmer tank	Volume: 2000 gals.- 2.5 min		
350 C-140 thru 149	10	Steam stripper feed drum	Volume: 300 gals.- 1 min		
350 C-150 thru 159	10	Steam stripper A	Volume: 1500 gals.- 5 min		
350 C-160 thru 169	10	Steam stripper B	Volume: 3000 gals.- 10 min		
350 C-170 thru 179	10	Oil/water separator	Volume: 750 gals. - 15 min		
350 C-180 thru 189	10	Sampling pot	Volume: 200 gals. - 15 secs		
350 C-190 thru 194	10	Heptane drum	Volume: 700 gals. - 20 min		
350 C-195 thru 199	5	Emergency slop tank	Volume: 5000 gals		
350 C-200 thru 204	5	Carbon filter drum	Volume:600 gals		
350 C-204 thru 209	5	Relief KO drum	Volume: 800 gals		
350 CP-01	1	Air compressor	1000,SCFM, 125 psig with air receiver	200	200
350 D-100 thru 109	10	Floor sump	5000 gals. Concrete		
350 D-110 & 111	2	Boiler feed water tank	5000 gals. Concrete		
350 D-112 & 113	2	Cooling water pond	400,000 gals		
350 E-100 thru 109	10	Vapor condenser	Air Cooler-Heat Duty: 11 MBtu/h	60	600
350 E-110 thru 119	10	Condensate cooler	Plate type-Heat Duty: 1 MBtu/h		

Table 6.2.1 (continued)
COMMERCIAL CWF PLANT- SELECTIVE AGGLOMERATION
Major Equipment List

Equipment I.D	Qty	Title	Description	Power (ea) HP	Total installed HP
350 E-120 thru 129	10	Water preheater	Plate type-Heat Duty: 7 MBtu/h		
350 E-130 thru 139	10	Slurry cooler	Plate type-Heat Duty: 12 MBtu/h		
350 E-140 thru 149	10	Blanket gas cooler	Plate type-Heat Duty: 150,000 Btu/h		
350 F-100	1	Steam lines	Flow- 2500 lb of steam at 50 psia- heat required 300 MBtu/h-		
350 F-102 & 106	5	Flare			
350 PP-100 thru 109	10	HSR feed pump	Horizontal slurry pump, flow 800 gpm, sp gr 1.02, TDH 80 ft	30	300
350 PP-110 thru 119	10	Tailings transfer pump	Horizontal slurry pump, flow 1000 gpm, sp gr 1.01, TDH 50 ft	25	250
350 PP-120 thru 129	10	Sump pump	Vertical slurry pump, flow 50 gpm, sp gr 1.2, TDH 50 ft	5	50
350 PP-130 thru 139	10	Steam stripper A feed pump	Diaphragm type, flow 350 gpm, sp gr 1.05, Delta P 20 psi, Design temp 240 deg F		
350 PP-140 thru 149	10	Steam stripper B feed pump	Moyno type, flow 350 gpm, sp gr 1.05, Design Pressure 50 psi, Delta P 30 psi, Design temp 250 deg F	10	100
350 PP-150 thru 159	10	Clean coal slurry pump	Moyno type, flow 350 gpm, sp gr 1.05, Design Pressure 50 psi, Delta P 30 psi, Design temp 250 deg F	10	100
350 PP-160 thru 169	10	Heptane pump	Metering type, flow 400 gpm, sp gr 0.7, Design Pressure 30 psi, Delta P 30 psi, Design temp 100 deg F	10	100
350 PP-170 thru 174	5	Emergency slop pump	Diaphragm type, flow 350 gpm, sp gr 1.05, Delta P 20 psi, Design temp 220 deg F	10	50
350 PP-175 thru 178		Not used			
350 PP-179 thru 183	5	K. O. Drum pump	Horizontal water pump	3	15
350 PP-184 thru 187	4	Chilled water pump	Horizontal water pump, flow 1700 gpm, TDH 120 ft, 2 Operating and 2 spare	3	12
350 PP-188 thru 191	4	Cooling water pump	Horizontal water pump, flow 3000 gpm, TDH 120 ft, 2 Operating and 2 spare	150	600
350 ST-90 thru 99	10	Agglomeration feed tank	capacity- 4000 gal (6 min)		
350 ST-100 & 101	2	Chilled water tank	17500 gal capacity -14 ft dia x 16 ft ht Cylindrical-10 min total		
350 V-101 & 102	2	Nitrogen package			
350 V-103 & 104	2	Chiller	duty=8.5 MBtu/h	800	1600
					0

Table 6.2.1 (continued)
COMMERCIAL CWF PLANT- SELECTIVE AGGLOMERATION
Major Equipment List

Equipment I.D	Qty	Title	Description	Power (ea) HP	Total installed HP
350 Y-100 thru 109	10	Screen	Vibrating, Sizetech type, 45o upward, linear, 3.4 mm stroke,1800 rpm, 6' x 16' feet	15	150
350 Y-110 thru 114	5	Gas holder and			
350 ZM-100 & 101	2	5-way distributor	Flow- 3500 gpm		
400 FT-10 thru 15	6	Filtration systems	Capacity 40 st/h - vacuum filter systems	700	4200
400 CV-15 & 16	2	Coal conveyor	Capacity 130 st/h-24 in wide, 125 st/h, 30 ft lift,	5	10
400 PP-62 & 65	4	Filtrate pump	Flow 900 gpm, TDH 30 ft, 2- Operating and 2- Spare	15	60
400 ST-26 & 27	2	Filtrate sump	Capacity- 5000 gal		
400 ZM-05 & 06	2	Slurry distributor	Capacity-1500 gpm	10	20
500 AG-09	1	Tailings filter sump agitator	Capacity of sump - 1000 gal	10	10
500 BN-04	1	Tailings load-out shed	Capacity- 100 st		
500 CV-16	1	Tailings conveyor	Capacity - 50 st/h, 24 in x 100 ft	5	5
500 FL-01	1	Tailings filter	Capacity-30st/h, 3,5 m wide belt	22	22
500 PP-70 & 71	2	Thickener underflow pump	Horizontal slurry- capacity 500 gpm, 50 ft head, sp gr 1.0, 1- Operating, 1- Spare	15	30
500 PP-72 thru 74	3	Clarified water pump	Horizontal water- capacity 5,000 gpm, 80 ft head,. 2- operating, 1-spare	150	450
500 PP-75 & 76	2	Tailings filter feed pump	capacity 420 gpm,30 ft head, sp gr 1.07. 1- Operating, 1- Spare	15	30
500 ST-30	1	Tailings filter feed sump	Capacity 1000 gal		
500 TK-01	1	Tailings thickener tank	90 ft diameter thickener tank with tunnel		
500 TK-02	1	Thickener overflow tank	Capacity 30,000 gal (concrete)		
500 TM-01	1	Tailings thickener mechanism	90 ft dia thickener mechanism with controls	15	15
500 ZM-08	1	Flocculant storage,mixing and dosing system		5	5
600 AG-10 & 11	2	Coal additive mixer	Retention 5 min.:	40	80
600 AG-12 & 13	2	Slurry mixing tank agitator		40	80
600 AG-14 thru 17	4	Slurry storage tank agitator		75	300
600 PP-78 & 79	2	CWF pump	Horizontal slurry- Capacity-1500 gpm, 60 ft head, sp gr 1.17	60	120
600 PP-80 thru 83	4	Slurry loading pump	Horizontal slurry- Capacity-dry solids 500 st/h- slurry 3,000 gpm, 60 ft head, sp gr 1.17, 4-Operating and 4-spare	100	400
600 ST-31 & 32	2	Slurry mixing tank	10 min. each. Volume:		

Table 6.2.1 (continued)
COMMERCIAL CWF PLANT- SELECTIVE AGGLOMERATION
Major Equipment List

Equipment I.D		Qty	Title	Description	Power (ea) HP	Total installed HP
600	ST-33 thru 36	4	Slurry fuel storage tank	0.85 million gal- 55 ft dia and 53 ft high- total 24 hr.		
600	ZM-10 & 11	2	Flocculant storage, mixing and dosing system		10	20
	TOTAL MAJOR EQUIPMENT					26674

TABLE 6.2.2
PLANT 200: CRUSHING AND GRINDING
Material and Heat Balance

Quantities are total for all trains

STREAM NO.		201	202	203	204	205	206	207	208
STREAM NAME		RAW COAL	DILUTION WATER	201+202	BALL MILL FEED	MILL HEAT RELEASE	BALL MILL DISCHARGE	WATER TO CYCLONE FEED SUMP	FEED TO CYCLONE
SOLIDS (DRY)	lb/h	*466,000*	-	466,000	699,000		699,000		699,000
WATER	lb/h	37,784	605,740	643,524	876,524		876,524	1,997,143	2,873,667
STREAM TOTAL	lb/h	503,784	605,740	1,575,524	1,575,524		1,575,524	1,997,143	3,572,667
SOLIDS (DRY)	gpm	717		717	1,075		998.6		998.6
WATER	gpm	76	1,211	1,287	1,646		1,753.0	3,994.3	5,747.3
STREAM TOTAL	gpm	792	1,211	2,004	2,470		2,751.6	3,994.3	6,745.9
SOLIDS CONTENT	wt %	*92.5*		*42*	44		44	-	20
TEMPERATURE	deg °F	*70*	70	70	70		75	70	72
PRESSURE	psia	14.7	14.7	14.7	14.7		14.7	14.7	14.7
ENTHALPY (rounded)	Btu/h	6,748,000	23,018,000	29,766,000	41,831,000	5,091,000	46,922,000	75,891,000	122,814,000

% of total connected mill HP transferred as heat to the slurry 25% Total HP= 8,000

STREAM NO.		209	210	211
STREAM NAME		CYCLONE U'FLOW	GROUND PRODUCT	WATER TO GRINDING FROM PLNT 500
SOLIDS (DRY)	lb/h	*233,000*	466,000	
WATER	lb/h	233,000	2,640,667	2,602,883
STREAM TOTAL	lb/h	466,000	3,106,667	2,602,883
SOLIDS (DRY)	gpm	358	717	
WATER	gpm	466	5,281	5,206
STREAM TOTAL	gpm	824	5,998	5,206
SOLIDS CONTENT	wt %	*50*	*15*	
TEMPERATURE	deg °F	72	72	70
PRESSURE	psia	14.7	14.7	15.0
ENTHALPY (rounded)	Btu/h	12,065,000	110,749,000	98,910,000

Table 6.2.3
PLANT 350: SELECTIVE AGGLOMERATION
Material and Heat Balance

Note 1. Quantities are total for all trains
Note 2. Later tests indicate that spary to be 1800 gpm for better results

STREAM NO.		301	302	303	303A	304	305	305A	306	307	307A **(NOTE 2)**	308	309
STREAM NAME		AGGLOME-RATION FEED	BRIDGING LIQUID	MIXED FEED TO AGGLOME-RATION	HEAT OF HSR MIXER (*)	HSR DISCHARGE	DILUTION WATER	HEAT OF LSR MIXER (**)	LSR DISCHARGE	SCREEN SPRAY WATER	TOTAL SCREEN FEED	TAILINGS	AGGLO-MERATES & BRIG. LIQD.
SOLIDS (DRY)	lb/hr	466,000		466,000		466,000			466,000		466,000	32,620	**433,380**
WATER	lb/hr	2,640,667		2,640,667		2,640,667	1,436,943		**4,077,610**	250,000	4,327,610	4,010,614	316,997
HEPTANE	lb/hr		**116,384**	116,384		116,384			116,384		116,384		116,384
STEAM	lb/hr												
HEPTANE- VAPOR	lb/hr												
TOTAL STREAM	lb/hr	3,106,667	116,384	3,223,050		3,223,050	1,436,943		4,659,994	250,000	4,909,994	4,043,234	866,760
SOLIDS (DRY)	gpm	717		717		717			717		717	50	667
LIQUID	gpm	5,281	340	5,621		5,621	2,874		8,495	**500**	8,995	8,021	974
TOTAL FLOW	gpm	5,998	340	6,338		6,338	2,874		9,212	500	9,712	8,071	1,641
SOLIDS CONTENT	wt %	15		14		14			10			1	**50**
TEMPERATURE	°F	72	80	72		73	70		72	70	72	72	72
PRESSURE	psia	15	15	15		15	15		15	15	15	15	15
ENTHALPY (rounded)	Btu/h	110,749,000	2,950,000	113,698,000	2,484,000	116,183,000	54,604,000	599,000	171,385,000	9,500,000	180,885,000	160,577,000	20,308,000
							(*) HSR	(**) LSR		(*) HSR	(**) LSR		
						Reactor power kW	2912.5	**702**	% to slurry	**25**	25		

STREAM NO.		310	311	312	313	314	315	316	317	318	319	320	321
STREAM NAME		CLARIFIED WATER HEATER INLET	HEATED CLARIFIED WATER	FEED TO STEAM STRIPPER-A	FLOW FROM STEAM STRIPPER-B	FEED TO STEAM STRIPPER-B	STEAM	VAPOR TO TO AIR COOLER	LIQUID FROM AIR COOLER	COOLED CONDENSATE	SLURRY TO WATER PREHEATER	SLURRY FROM WATER PREHEATER	COOLED CLEAN COAL SLURRY
SOLIDS (DRY)	lb/hr			433,380		433,380					433,380	433,380	433,380
WATER	lb/hr	584,835	584,835	901,831		1,011,220			81,468	81,468	1,034,363	1,034,363	1,034,363
HEPTANE	lb/hr			116,384					116,384	116,384			
STEAM	lb/hr				**190,857**		**214,000**	**81,468**					
HEPTANE- VAPOR	lb/hr							116,384					
TOTAL STREAM	lb/hr	584,835	584,835	1,451,595	190,857	1,444,600	214,000	197,852	197,852	197,852	1,467,743	1,467,743	1,467,743
SOLIDS (DRY)	gpm			667		667					667	667	667
LIQUID	gpm	1,170	1,170	2,143		2,022			503	503	2,069	2,069	2,069
TOTAL STREAM	gpm	1,170	1,170	2,810		2,689			503	503	2,735	2,735	2,735
SOLIDS CONTENT	wt %			30		**30**					30	30	30
TEMPERATURE	°F	72	**190**	135	**240**	220	**256**	**224**	140	80	240	**177**	80
PRESSURE	psia	*20*	15	18	25	**25**	**33**	**19**	17	17	45	40	35
ENTHALPY (rounded)	Btu/h	23,295,000	92,404,000	112,712,000	221,509,000	214,229,000	249,470,000	119,992,000	15,636,000	6,860,000	242,190,000	173,081,000	55,890,000

STREAM NO.		322	323	324	325	326	327	328	329	330 TO 350
STREAM NAME		CHILLED WATER AT CONDENSATE COOLER INLET	CW AT CONDENSATE COOLER OUT LET	CW AT SLURRY COOLER INLET	CW AT SLURRY COOLER OUT LET	WATER CONDENSED	CONDENSED HEPTANE LIQUID	MAKE-UP BOILER FEED WATER	HEAT OUTPUT OF BOILER (ENTHALPY IN-CREASE OF FW)	STREAM NUMBERS NOT USED
SOLIDS (DRY)	lb/hr									
ASPHALT	lb/hr									
WATER	lb/hr	135,008	135,008	2,604,243	2,604,243	81,468	116,384	132,532		
HEPTANE	lb/hr									
STEAM	lb/hr									
HEPTANE- VAPOR	lb/hr									
TOTAL STREAM	lb/hr	135,008	135,008	2,604,243	2,604,243	81,468	116,384	132,532		
SOLIDS (DRY)	gpm									
LIQUID	gpm	270	270	5,208	5,208	163	340	265		
TOTAL STREAM	gpm	270	270	5,208	5,208	163	340	265		
TEMPERATURE	°F	50	115	70	115	80	80	70		
PRESSURE	psia	25	20	25	20	17	17	20		
ENTHALPY (rounded)	Btu/h	2,430,000	11,206,000	98,961,000	216,152,000	3,910,000	2,950,000	5,036,000	240,524,000	

(CONTINUED)

Table 6.2.3 (Continued)
PLANT 350: SELECTIVE AGGLOMERATION
Material and Heat Balance

STREAM NO.			351	352	353	354	355	356	357	358
STREAM NAME			CW RETURN TO CW POND	WATER FROM CW POND	POND WATER TO CHILLER DRUM	WATER TO CHILLER	WATER FROM CHILLER	CHILLED WATER-1N RECY WTR CLR	CHILLED WATER TO BLNKT GAS COOLER	CW RETURN FROM BLNKT GAS COOLER
SOLIDS (DRY)	lb/h									
WATER	lb/h		2,739,252	2,739,252	135,008	1,549,256	1,549,256	1,264,248	150,000	150,000
STREAM TOTAL	lb/h		2,739,252	2,739,252	135,008	1,549,256	1,549,256	1,264,248	150,000	150,000
SOLIDS (DRY)	gpm									
WATER	gpm		5,479	5,479	270	3,099	3,099	2,528	300	300
TOTAL FLOW	gpm		5,479	5,479	270	3,099	3,099	2,528	300	300
SOLIDS CONTENT	wt %									
TEMPERATURE	deg °F		115	70	70	60.9	50	50	50	60
PRESSURE	psia		18.0	50	15	70	60	25	50	15
ENTHALPY (round off)	Btu/h		227,358,000	104,092,000	5,130,000	44,729,000	27,887,000	22,756,000	2,700,000	4,200,000

Table 6.2.4
PLANT 400: CLEAN COAL DEWATERING
Material and Heat Balance
Quantities are total for all trains

STREAM NO.		401	402	403
STREAM NAME		CLEAN COAL SLURRY	CLEAN COAL FILTER CAKE	CLEAN COAL FILTRATE
SOLIDS (DRY)	lb/h	433,380	433,380	
WATER	lb/h	1,034,363	254,525	779,838
STREAM TOTAL	lb/h	1,467,743	687,905	779,838
SOLIDS (DRY)	gpm	667	667	
WATER	gpm	2,069	509	1,560
STREAM TOTAL	gpm	2,735	1,176	1,560
SOLIDS CONTENT	wt %	30	63	
TEMPERATURE	deg °F	80	80	80
PRESSURE	psia	15	15	15
ENTHALPY (rounded)	Btu/h	55,890,000	18,458,000	37,432,000

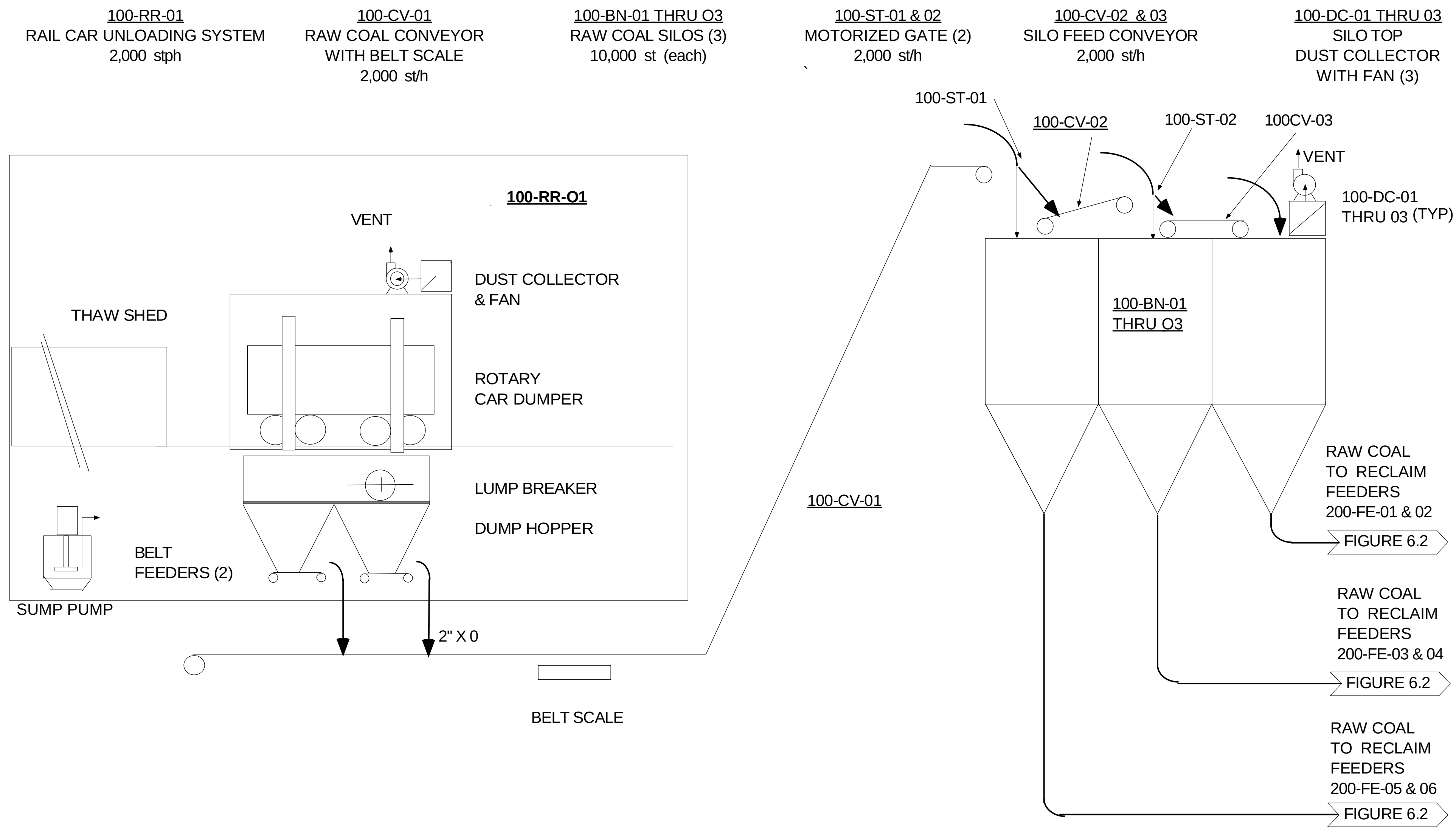
Table 6.2.5
PLANT 500: WATER CLARIFICATION AND TAILINGS HANDLING
Material and Heat Balance

STREAM NO.		501	502	503	503A	504	505	506	507	508	509
STREAM NAME		TAILINGS	TAILINGS FILTRATE	THICKENER FEED	HEAT LOSS IN THICKENER (assumed)	THICKENER UNDERFLOW	THICKENER OVERFLOW	TAILINGS CAKE	CLARIFIED WATER TO PLANT 600	UTILITY WATER TO THICKENER O'FLOW TANK	THICKENER OVERFLOW + STREAM 508
SOLIDS (DRY)	lb/h	32,620		32,620		32,620		32,620			
WATER	lb/h	4,010,614	69,900	4,860,352		130,480	4,729,872	60,580	35,840	180,629	4,910,501
STREAM TOTAL	lb/h	4,043,234	69,900	4,892,972		163,100	4,729,872	93,200	35,840	180,629	4,910,501
SOLIDS (DRY)	gpm	50		50		50	0	50			
WATER	gpm	8,021	140	9,721		261	9,460	121	72	361	9,821
STREAM TOTAL	gpm	8,071	140	9,771		311	9,460	171	72	361	9,821
SOLIDS CONTENT	wt %	0.81		0.67		20		35			
TEMPERATURE	°F	72	73	73		73	73	73	73	70	73
PRESSURE	psia	14.7	15	15		20	12	12	45	12	60
ENTHALPY (rounded)	Btu/h	160,577,000	2,883,000	200,893,000	900,000	5,786,000	194,207,000	2,903,000	1,468,000	6,863,912	201,070,697

STREAM NO.		510	511	512	513	514	514A	515	516	517	518
STREAM NAME		CLARIFIED WATER TO 350-E-120 THRU 129	RECYCLE WATER COOLER INLET	RECYCLE WATER COOLER OUTLET	CLARIFIED WATER TO LSR & SCREEN	CLARIFIED WATER TO PLANT 200	RECYCLE WATER COOLER HEAT LOAD	CHILLED WATER-1N RECYCLE WATER CLR	COOLING WATER-OUT RECYCLE WATER CLR	TOTAL PLANT MAKE-UP WATER	BOILER FEED WATER MAKE-UP
SOLIDS (DRY)	lb/h										
WATER	lb/h	584,835	4,289,826	4,289,826	1,686,943	2,602,883		1,264,248	1,264,248	313,161	132,532
STREAM TOTAL	lb/h	584,835	4,289,826	4,289,826	1,686,943	2,602,883		1,264,248	1,264,248	313,161	132,532
SOLIDS (DRY)	gpm										
WATER	gpm	1,170	8,580	8,580	3,374	5,206		2,528	2,528	626	265
STREAM TOTAL	gpm	1,170	8,580	8,580	3,374	5,206		2,528	2,528	626	265
SOLIDS CONTENT	wt %										
TEMPERATURE	deg °F	73	73	70	70	70		50	60	70	70
PRESSURE	psia	45	45	45	50	50		25	15	15	20
ENTHALPY (rounded)	Btu/h	23,947,000	175,656,000	163,013,000	64,104,000	98,910,000	12,642,000	22,756,000	35,399,000	11,900,000	5,036,000

Table 6.2.6
PLANT 600: CWF PREPARATION AND LOADING
Material and Heat Balance
Note: Quantities are total for two trains

STREAM NO.		601	602	603	604	605	606	607	608
STREAM NAME		DEWATERED CLEAN COAL	CLARIFIED WATER TO PLANT 600	PREMIUM FUEL (CWF)	SOLID ADDITIVE	WATER IN ADDITIVE MIXTURE	ADDITIVE MIXTURE	FEED TO MIXERS	WATER FOR FINAL ADJUSTMENT
SOLIDS (DRY)	lb/h	433,380		433,380				433,380	
SOLID ADDITIVE	lb/h			2,167	2,167		2,167	2,167	
WATER	lb/h	254,525	35,840	290,365		2,648	2,648	257,173	33,191
STREAM TOTAL	lb/h	687,905	35,840	725,912	2,167	2,648	4,815	692,720	33,191
SOLIDS (DRY)	gpm	667		667	3		3	667	
WATER	gpm	509	72	581		5	5	514	66
STREAM TOTAL	gpm	1,176	72	1,247	3	5	8	1,181	66
SOLIDS CONTENT	wt %	63		60			45	63	
TEMPERATURE	°F	80	*73*	79	70	73	72	83	39
PRESSURE	psia	15	15	15	15	15	15	15	15
ENTHALPY	Btu/h	18,457,861	1,467,537	19,950,100	24,703	108,446	133,148	19,708,506	241,594
ENTHALPY (rounded)	Btu/h	18,458,000	1,468,000	19,950,000	25,000	108,000	133,000	19,708,000	242,000



SELECTIVE AGGLOMERATION

PLANT 100: RAW COAL HANDLING PROCESS FLOW DIAGRAM

FIGURE 6.1

200-FE-01 THRU 6
RECLAIM FEEDERS (6)
125 st/h

200-ST-03
THRU 08
MOTORIZED
GATE (6)

200-CR-01 & 02
HAMMER MILL
CRUSHER (2)
125 st/h

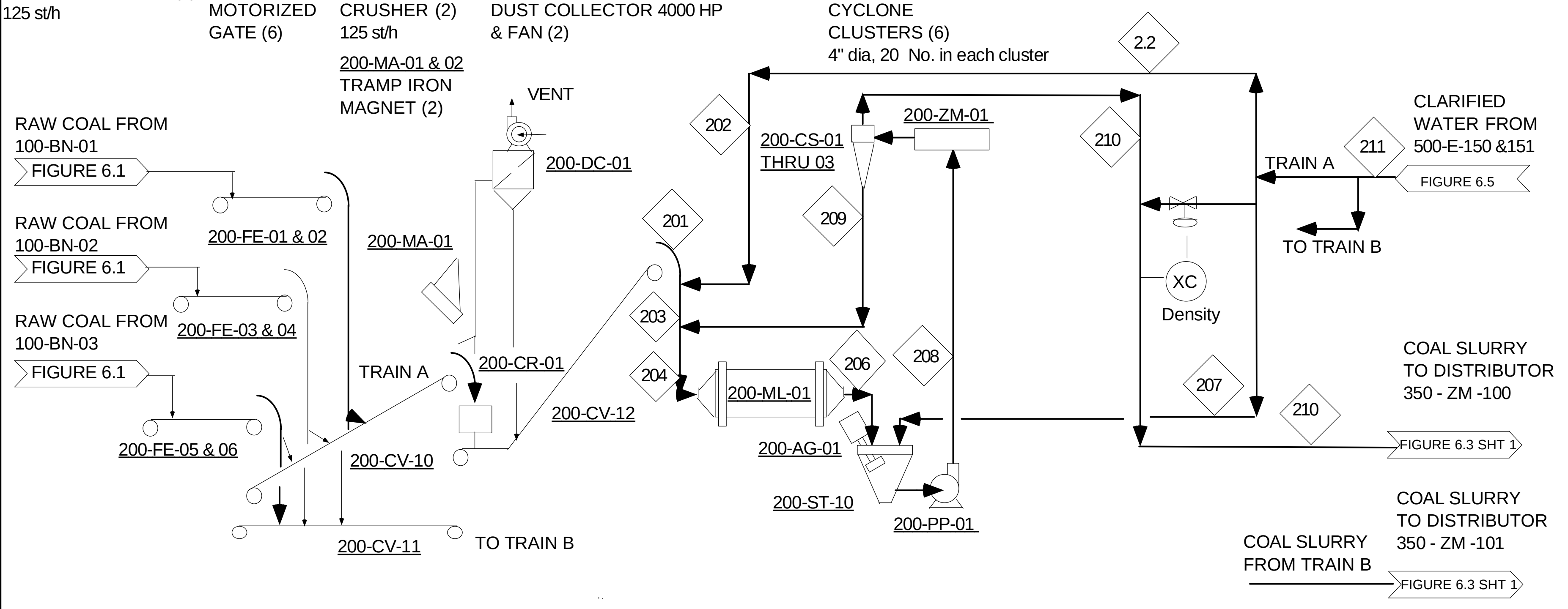
200-MA-01 & 02
TRAMP IRON
MAGNET (2)

200-DC-01 &02
CR. HOUSE
DUST COLLECTOR
& FAN (2)

200-ML-01 & 02
BALL MILL (2)
4000 HP

200-CS-01
THRU 06
CYCLONE
CLUSTERS (6)
4" dia, 20 No. in each cluster

200-ZM-O1 & 02
DISTRIBUTOR (2)



200-CV-10 & 11
CRUSHER FEED
CONVEYOR (2)

200-CV-12 &13
BALL MILL FEED
CONVEYOR (2)

200-AG-01 & 02
CYCLONE FEED PUMP
SUMP MIXER (2)

200-ST-10 & 11
CYCLONE FEED
SUMP (2)

200-PP-01 & 02
CYCLONE FEED
PUMP (2)

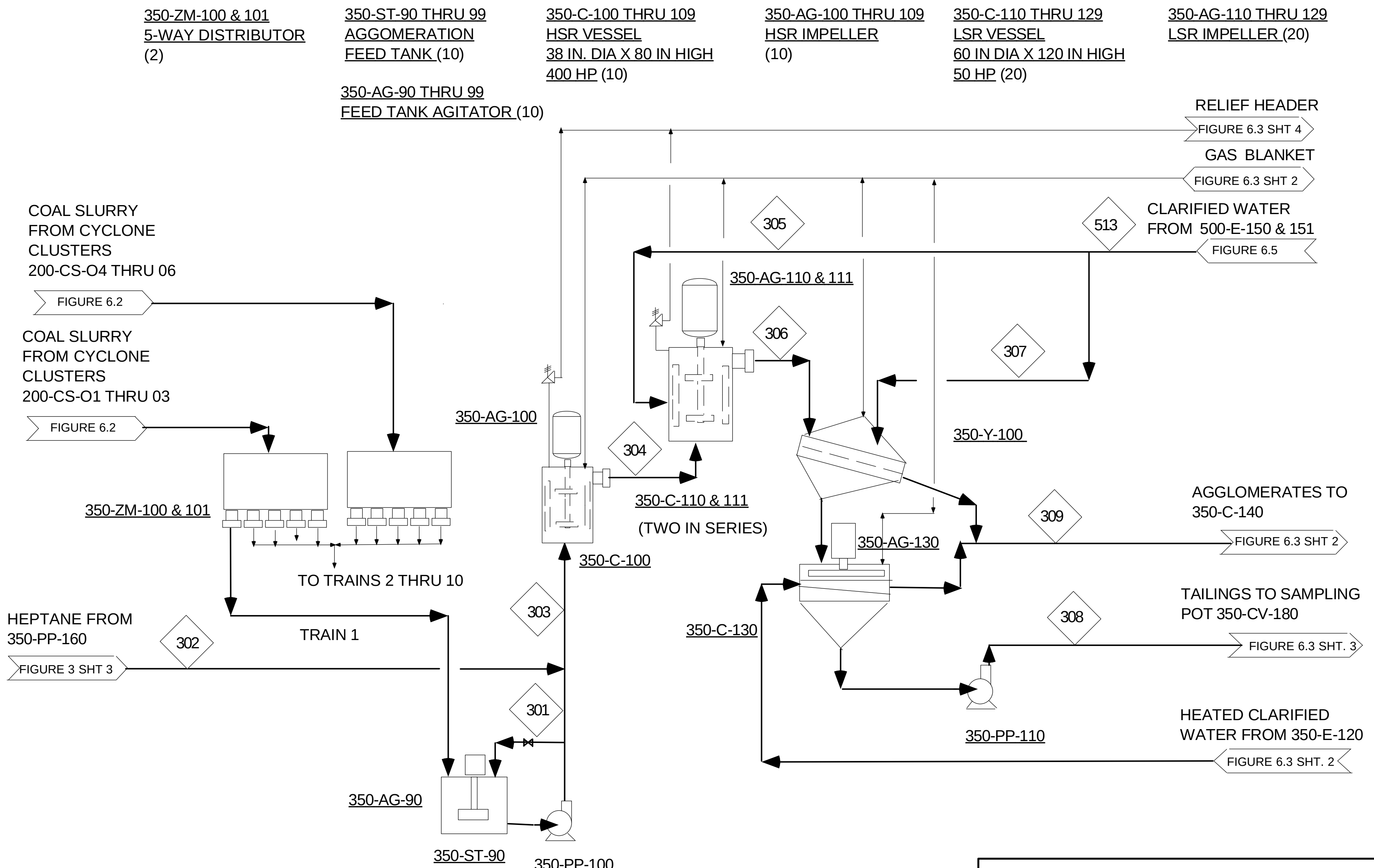
NOTES:

1. ONE OF TWO PARALLEL AND INDENTICAL TRAINS OF EQUIPMENT IS SHOWN
2. SEE TABLE 6. 2. 2 FOR MATERIAL AND HEAT BALANCE

SELECTIVE AGGLOMERATION

PLANT 200: CRUSHING AND GRINDING
PROCESS FLOW DIAGRAM

FIGURE 6.2



350-PP100 THRU 109
HSR FEED PUMP
(10)

350-PP-110 THRU 119
TAILINGS TRANSFER
PUMP
(10)

350-Y-100 THRU109
SCREEN
(10)

350-AG-130 THRU 139
FROTH SKIMMER
(10)

350-C-130 THRU 139
FROTH SKIMMER
TANK (10)

NOTES

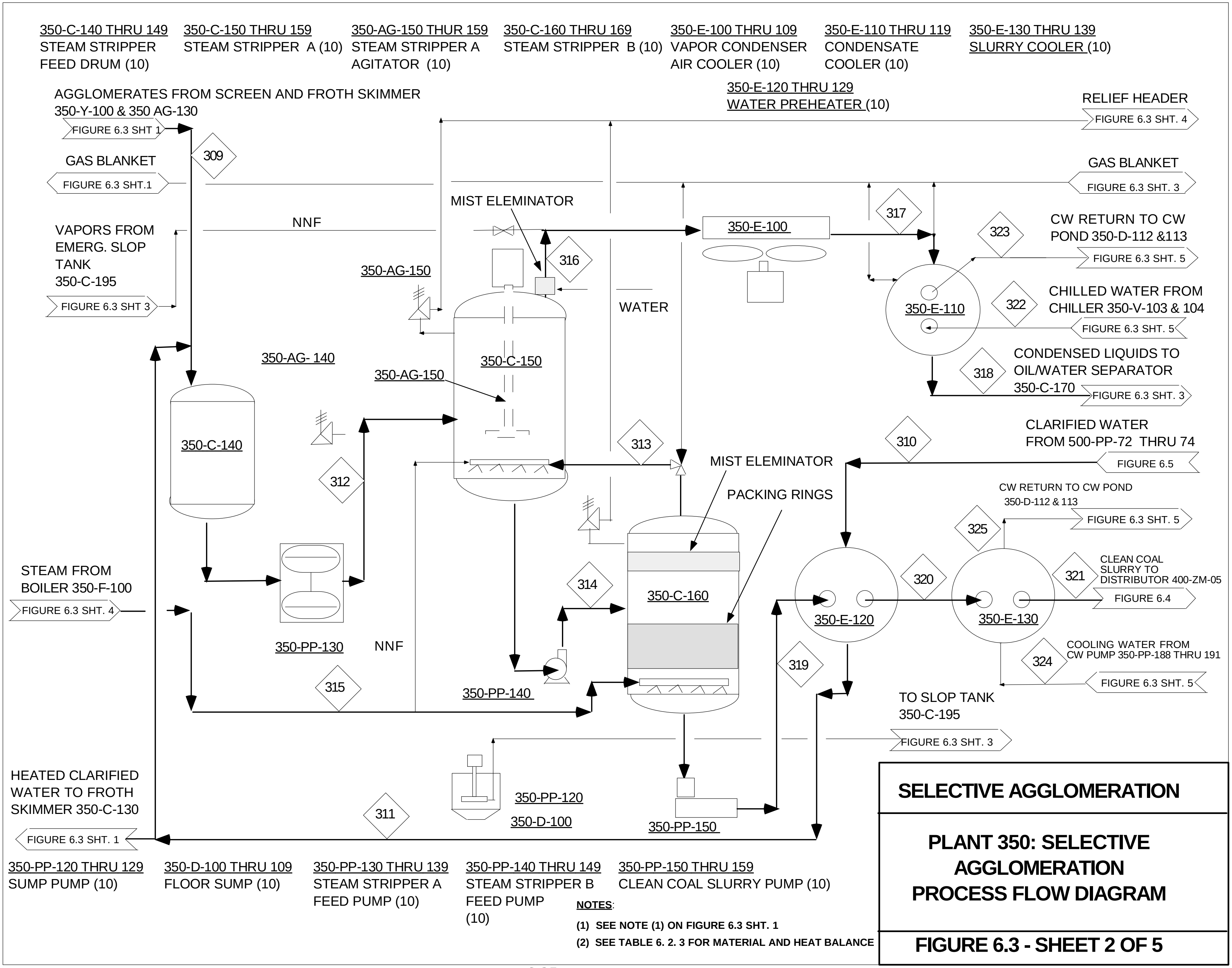
(1) ONE OF 10 PARALLEL AND IDENTICAL TRAINS OF EQUIPMENT IS SHOWN UNLESS OTHERWISE INDICATED. FOR LOCATIONS WHERE SINGLE UNIT SERVES TWO OR MORE TRAINS SEE TOTAL NUMBER OF UNITS INCLUDED

(2) SEE TABLE 6. 2. 3 FOR MATERIAL AND HEAT BALANCE

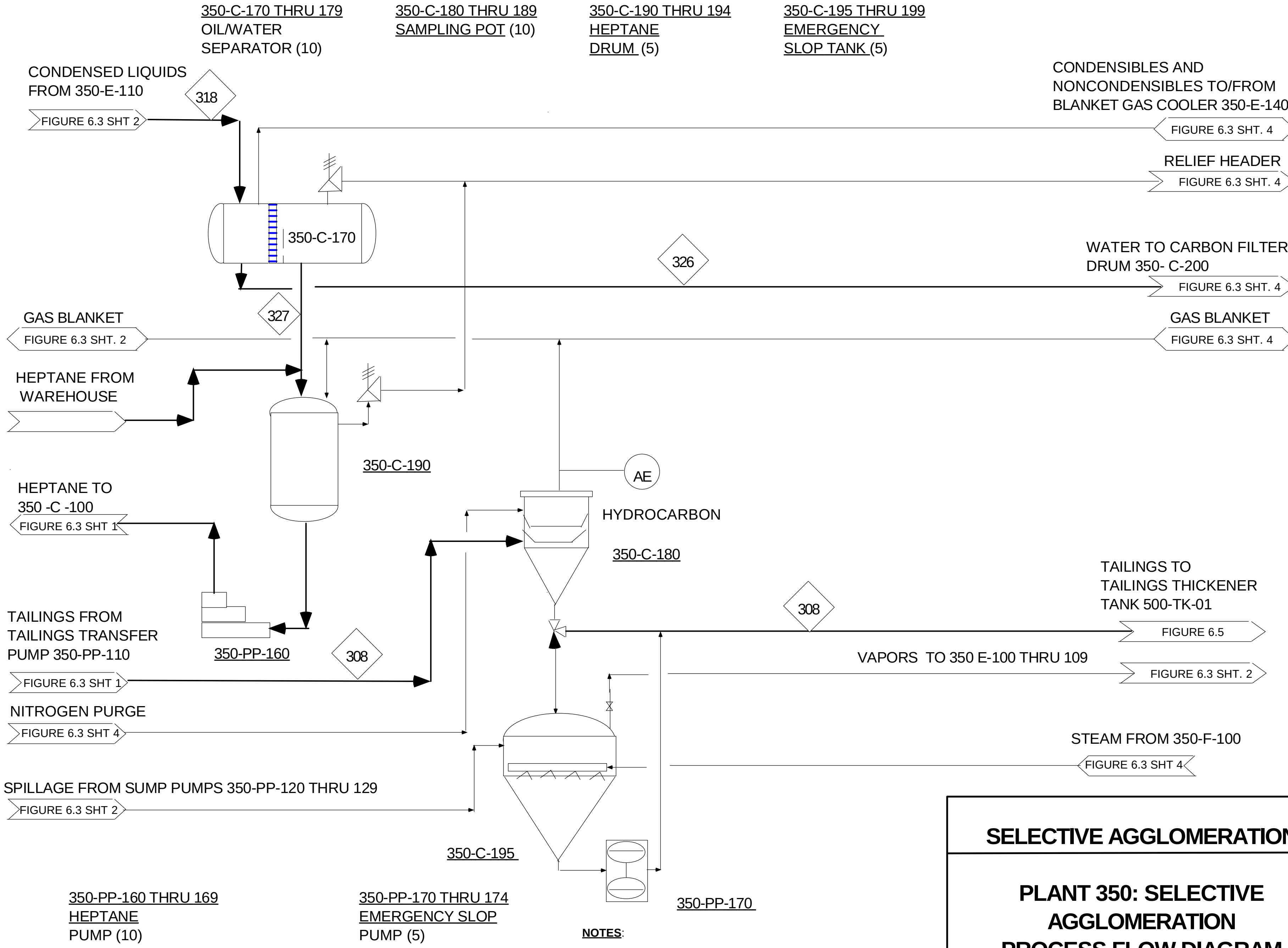
SELECTIVE AGGLOMERATION

PLANT 350: SELECTIVE AGGLOMERATION PROCESS FLOW DIAGRAM

FIGURE 6.3 - SHEET 1 OF 5



350-C-140 THRU 149
STEAM STRIPPER FEED DRUM (10)
350-C-150 THRU 159
STEAM STRIPPER A (10)
350-AG-150 THUR 159
STEAM STRIPPER A AGITATOR (10)
350-C-160 THRU 169
STEAM STRIPPER B (10)
350-E-100 THRU 109
VAPOR CONDENSER AIR COOLER (10)
350-E-110 THRU 119
CONDENSATE COOLER (10)
350-E-130 THRU 139
SLURRY COOLER (10)
350-E-120 THRU 129
WATER PREHEATER (10)
AGGLOMERATES FROM SCREEN AND FROTH SKIMMER
350-Y-100 & 350 AG-130
FIGURE 6.3 SHT 1
RELIEF HEADER
FIGURE 6.3 SHT. 4
309
GAS BLANKET
FIGURE 6.3 SHT.1
GAS BLANKET
FIGURE 6.3 SHT. 3
MIST ELEMINATOR
VAPORS FROM EMERG. SLOP TANK 350-C-195
FIGURE 6.3 SHT 3
NNF
350-E-100
317
323
CW RETURN TO CW POND 350-D-112 &113
FIGURE 6.3 SHT. 5
316
350-AG-150
WATER
350-E-110
322
CHILLED WATER FROM CHILLER 350-V-103 & 104
FIGURE 6.3 SHT. 5
350-AG- 140
350-C-150
350-AG-150
318
CONDENSED LIQUIDS TO OIL/WATER SEPARATOR 350-C-170
FIGURE 6.3 SHT. 3
350-C-140
313
310
CLARIFIED WATER FROM 500-PP-72 THRU 74
FIGURE 6.5
312
MIST ELEMINATOR
PACKING RINGS
CW RETURN TO CW POND 350-D-112 & 113
FIGURE 6.3 SHT. 5
325
STEAM FROM BOILER 350-F-100
FIGURE 6.3 SHT. 4
314
350-C-160
320
321
CLEAN COAL SLURRY TO DISTRIBUTOR 400-ZM-05
FIGURE 6.4
350-E-120
350-E-130
350-PP-130
NNF
319
324
COOLING WATER FROM CW PUMP 350-PP-188 THRU 191
FIGURE 6.3 SHT. 5
315
350-PP-140
TO SLOP TANK 350-C-195
FIGURE 6.3 SHT. 3
HEATED CLARIFIED WATER TO FROTH SKIMMER 350-C-130
FIGURE 6.3 SHT. 1
311
350-PP-120
350-D-100
350-PP-150
350-PP-120 THRU 129
SUMP PUMP (10)
350-D-100 THRU 109
FLOOR SUMP (10)
350-PP-130 THRU 139
STEAM STRIPPER A FEED PUMP (10)
350-PP-140 THRU 149
STEAM STRIPPER B FEED PUMP (10)
350-PP-150 THRU 159
CLEAN COAL SLURRY PUMP (10)
NOTES:
(1) SEE NOTE (1) ON FIGURE 6.3 SHT. 1
(2) SEE TABLE 6. 2. 3 FOR MATERIAL AND HEAT BALANCE
SELECTIVE AGGLOMERATION
PLANT 350: SELECTIVE AGGLOMERATION PROCESS FLOW DIAGRAM
FIGURE 6.3 - SHEET 2 OF 5



NOTES:

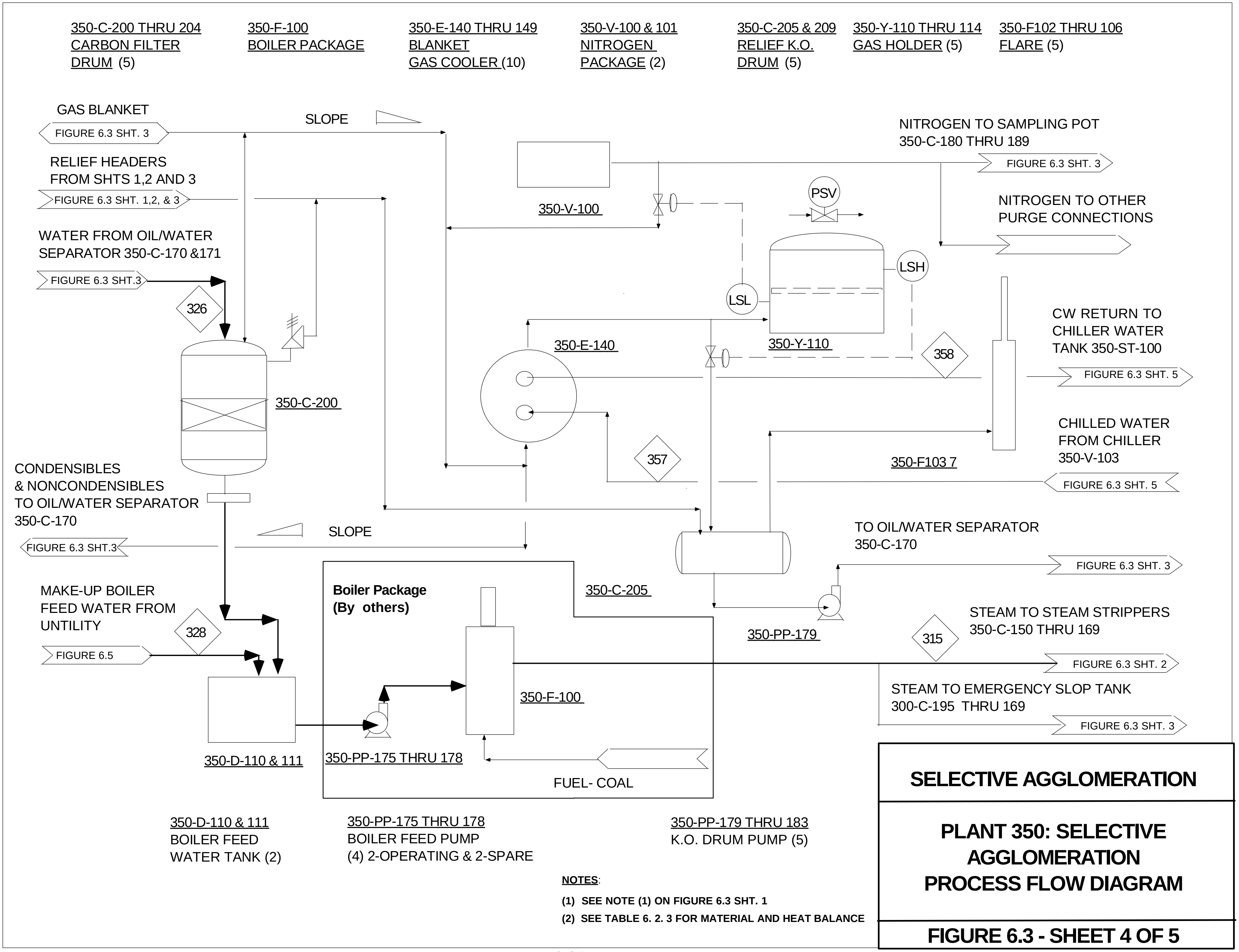
(1) SEE NOTE (1) ON FIGURE 6.3 SHT. 1

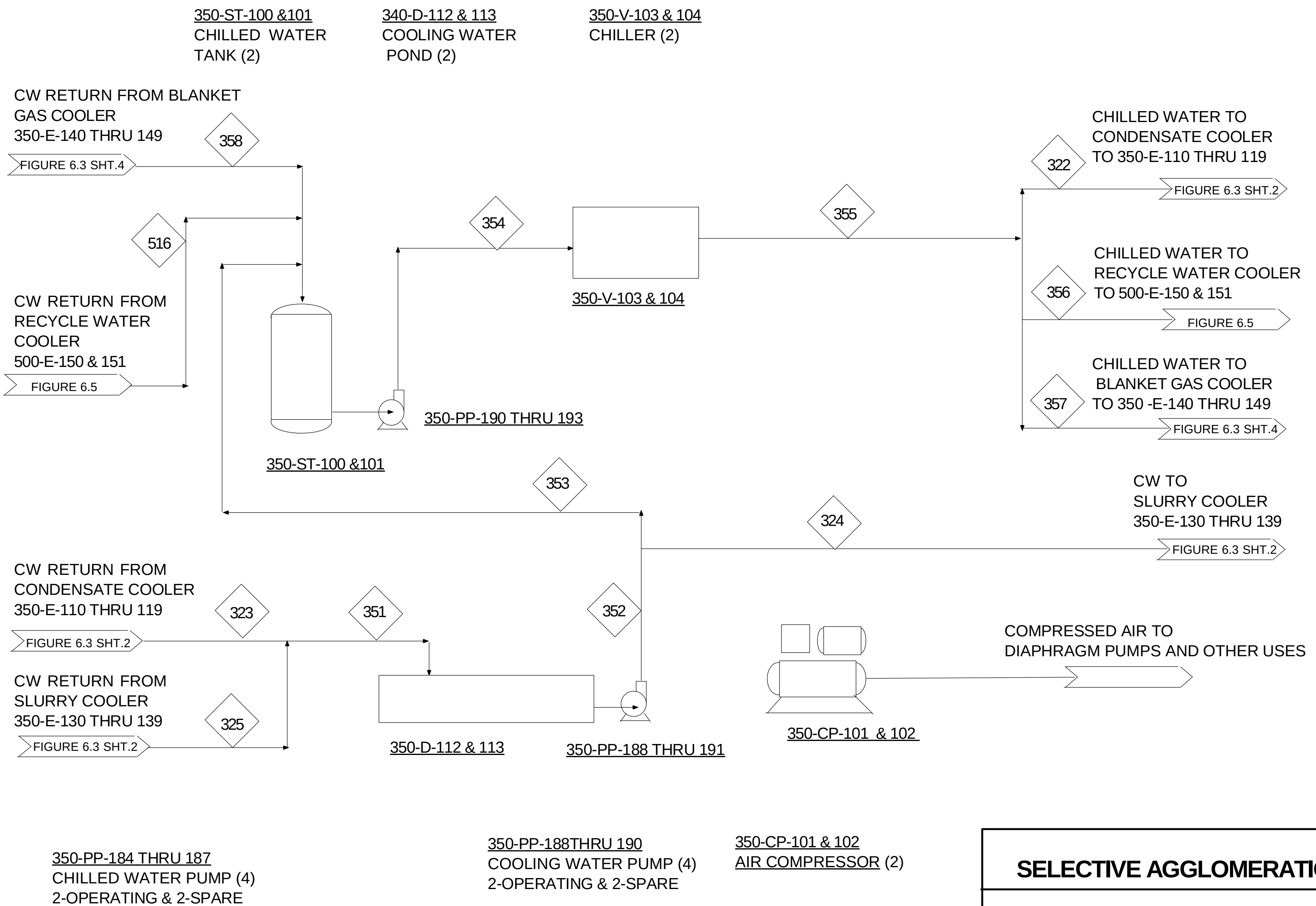
(2) SEE TABLE 6. 2. 3 FOR MATERIAL AND HEAT BALANCE

SELECTIVE AGGLOMERATION

PLANT 350: SELECTIVE AGGLOMERATION PROCESS FLOW DIAGRAM

FIGURE 6.3 - SHEET 3 OF 5


350-C-200 THRU 204
CARBON FILTER
DRUM (5)
350-F-100
BOILER PACKAGE
350-E-140 THRU 149
BLANKET
GAS COOLER (10)
350-V-100 & 101
NITROGEN
PACKAGE (2)
350-C-205 & 209
RELIEF K.O.
DRUM (5)
350-Y-110 THRU 114
GAS HOLDER (5)
350-F102 THRU 106
FLARE (5)
GAS BLANKET
FIGURE 6.3 SHT. 3
SLOPE
NITROGEN TO SAMPLING POT
350-C-180 THRU 189
FIGURE 6.3 SHT. 3
RELIEF HEADERS
FROM SHTS 1,2 AND 3
FIGURE 6.3 SHT. 1,2, & 3
350-V-100
PSV
NITROGEN TO OTHER
PURGE CONNECTIONS
WATER FROM OIL/WATER
SEPARATOR 350-C-170 &171
FIGURE 6.3 SHT.3
LSH
LSL
326
350-E-140
350-Y-110
358
CW RETURN TO
CHILLER WATER
TANK 350-ST-100
FIGURE 6.3 SHT. 5
350-C-200
357
CHILLED WATER
FROM CHILLER
350-V-103
350-F103 7
FIGURE 6.3 SHT. 5
CONDENSIBLES
& NONCONDENSIBLES
TO OIL/WATER SEPARATOR
350-C-170
FIGURE 6.3 SHT.3
SLOPE
TO OIL/WATER SEPARATOR
350-C-170
FIGURE 6.3 SHT. 3
MAKE-UP BOILER
FEED WATER FROM
UNTILITY
328
FIGURE 6.5
Boiler Package
(By others)
350-C-205
350-PP-179
315
STEAM TO STEAM STRIPPERS
350-C-150 THRU 169
FIGURE 6.3 SHT. 2
350-F-100
STEAM TO EMERGENCY SLOP TANK
300-C-195 THRU 169
FIGURE 6.3 SHT. 3
350-D-110 & 111
350-PP-175 THRU 178
FUEL- COAL
SELECTIVE AGGLOMERATION
350-D-110 & 111
BOILER FEED
WATER TANK (2)
350-PP-175 THRU 178
BOILER FEED PUMP
(4) 2-OPERATING & 2-SPARE
350-PP-179 THRU 183
K.O. DRUM PUMP (5)
PLANT 350: SELECTIVE
AGGLOMERATION
PROCESS FLOW DIAGRAM
NOTES:
(1) SEE NOTE (1) ON FIGURE 6.3 SHT. 1
(2) SEE TABLE 6. 2. 3 FOR MATERIAL AND HEAT BALANCE
FIGURE 6.3 - SHEET 4 OF 5



NOTES:

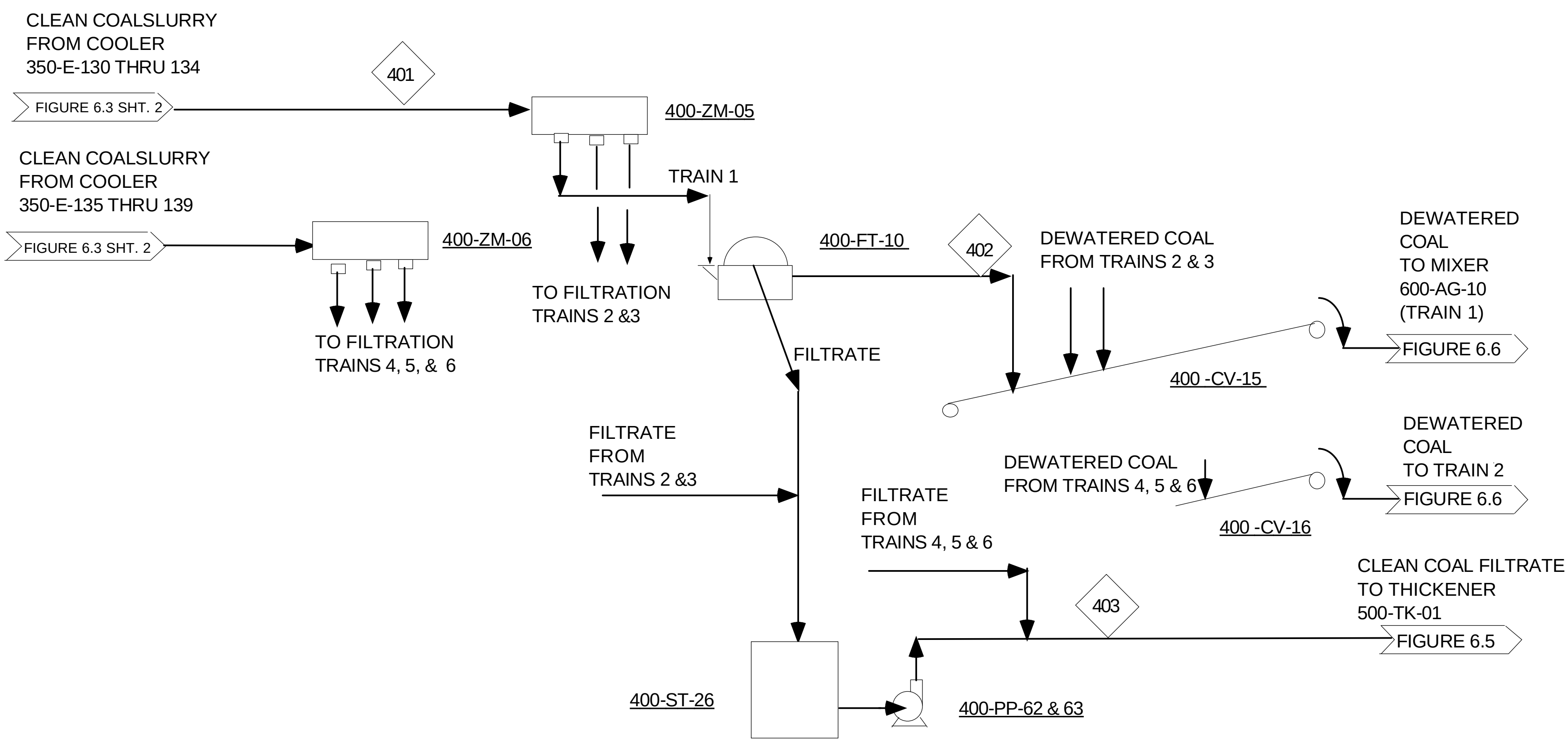
(1) SEE NOTE (1) ON FIGURE 6.3 SHT. 1

(2) SEE TABLE 6. 2. 3 FOR MATERIAL AND HEAT BALANCE

SELECTIVE AGGLOMERATION

PLANT 350: SELECTIVE AGGLOMERATION PROCESS FLOW DIAGRAM

FIGURE 6.3 SHEET 5 OF 5



400-ZM-05 &06
SLURRY DISTRIBUTOR
3 -WAY (2)

400-FT-10 THRU 15
FILTRATION SYSTEM (6)
5-OPERATING & 1- SPARE

400 -CV-15 & 16
DEWATERED COAL
CONVEYOR (2)

400-ST-26 & 27
FILTRATE SUMP (2)

400-PP-62 THRU 65
FILTRATE PUMP (4)
2-OPERATING & 2 -SPARE

NOTES

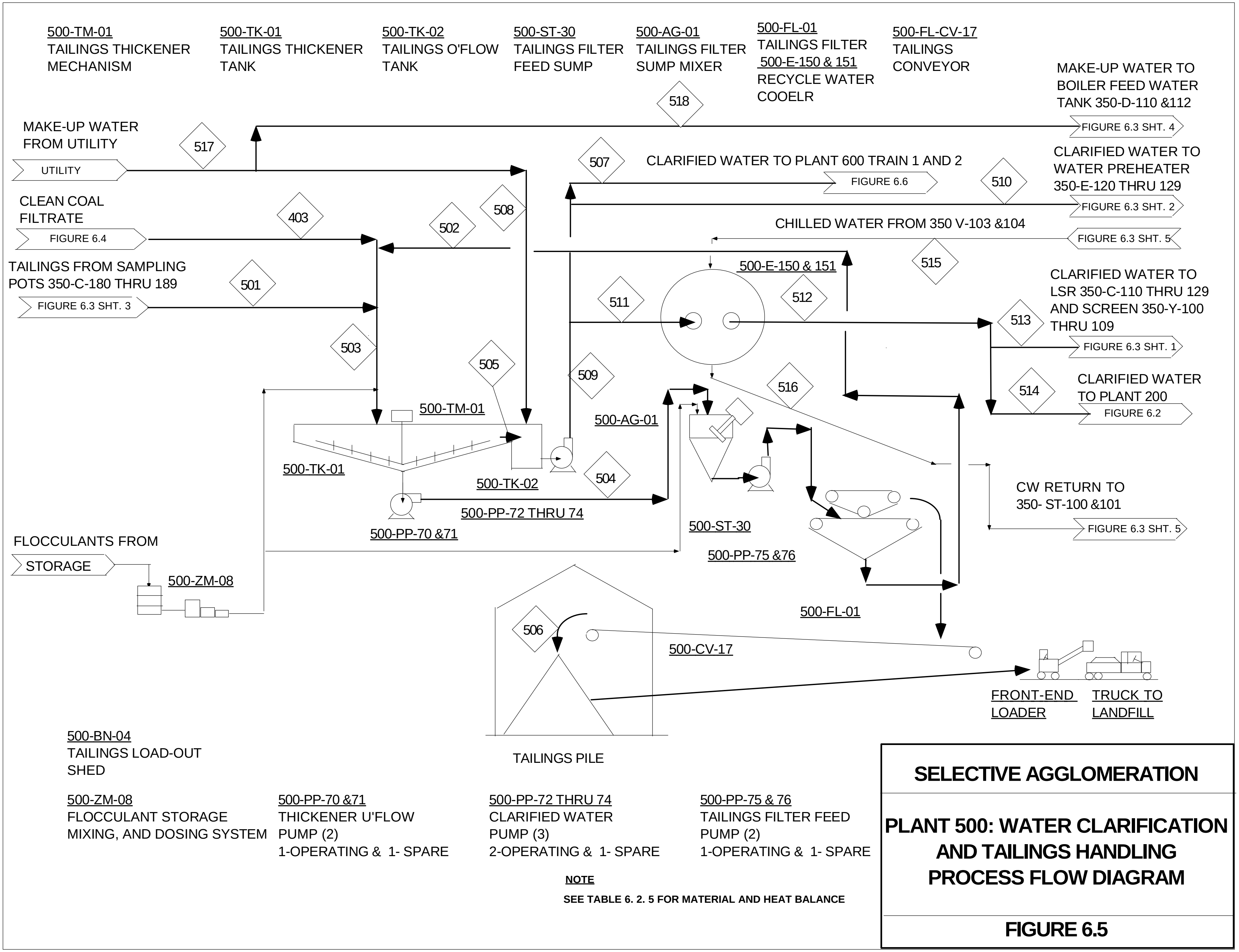
(1) SEE TABLE 6. 2. 4 FOR MATERIAL AND HEAT BALANCE

(2) ONE OF SIX IDENTICAL FILTERING TRAINS SHOWN

SELECTIVE AGGLOMERATION

PLANT 400: CLEAN COAL DEWATERING PROCESS FLOW DIAGRAM

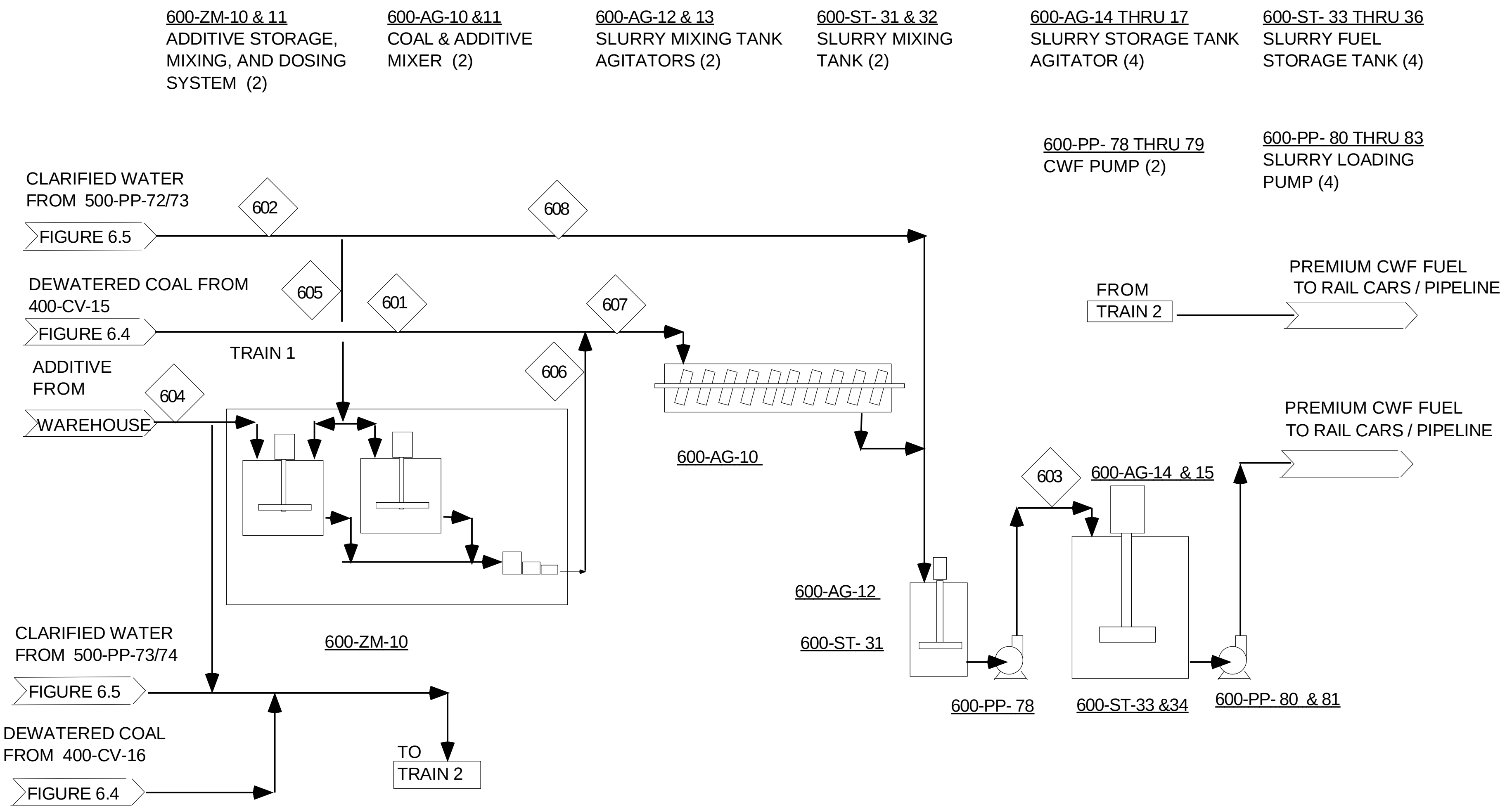
FIGURE 6.4



SELECTIVE AGGLOMERATION

PLANT 500: WATER CLARIFICATION AND TAILINGS HANDLING PROCESS FLOW DIAGRAM

FIGURE 6.5



NOTES:

(1) SEE TABLE 6. 2. 6 FOR MATERIAL AND HEAT BALANCE

(2) ONE OF TWO IDENTICAL AND PARALLEL TRAINS OF EQUIPMENT IS SHOWN

SELECTIVE AGGLOMERATION

PLANT 600: CWF PREPARATION AND LOADING PROCESS FLOW DIAGRAM

FIGURE 6.6

Section 7

Cost of Premium CWF - Column Flotation

This section presents conceptual capital and annual operating and maintenance (O&M) cost estimates for a commercial plant for the production of premium CWF. The plant employs the column flotation process. Based on the estimates, the cost of production of CWF ($/MBu) has been calculated. Further, a number of analysis have been performed to evaluate the sensitivity of the cost of production to variations in the process criteria, unit cost of selected in-puts, plant performance and capital investment.

7.1 CAPITAL COSTS

Capital cost estimates have been developed based on the criteria, description, flow diagrams, material balances and major equipment list included in Sections 4 and 5. Details of capital cost estimates are placed under Appendix A. A summary of the capital cost estimates is presented in Table 7.1.1 which includes a break down showing costs for different plant sections. The estimated capital cost of the project is $ 69.6 million (First Quarter 1997).

7.1.1 Total Field Costs

Procedures employed for the development of cost estimates are consistent with the conceptual nature of the plant engineering definition at this stage. These include informal vendor contacts for pricing major equipment such as the grinding mills as well as use of current Bechtel in-house data, with extrapolation and adjustment if appropriate.

Quantities of bulk materials for civil, structural, electrical, instrumentation and piping work necessary for the construction of the plant are not computed due to lack of more detailed engineering. As per normal accepted practice in such cases, the costs of these items are estimated as percentages of identified equipment costs. The percentages are derived from Bechtel experience with similar projects.

It is expected that equipment installation and field construction work will be performed by union labor. Job hours for equipment installation have been developed using typical job hours for machinery units of similar size and nature. An average labor rate of $30 per hour has been applied to the job hours. The rate which includes payroll additives, fringe benefits, workmen’s compensation, and spot overtime has also been used for field construction job hours. It is based on current union labor agreements for a 40-hour week in the Cleveland, Ohio area.

A 3% sales tax is included for procured items. An allowance for freight to plant site is included at 3 percent of the ex-works cost of equipment and bulks.

Indirect Field Costs which include items such as indirect manual labor, temporary construction facilities, tools and tackle, and field office are included at 60 percent of direct labor costs.

7.1.2 Total Project Capital Cost and Working Capital

Total Installed Plant Cost The Total Installed Plant Cost is derived by adding engineering and home office costs as well as contingencies to the Total Field Costs.

Engineering and home office costs (engineering, procurement, and project management) are calculated at 7 percent of Total Direct Field Costs (Total Field Costs less Indirect Field Costs).

The estimated capital costs are intended to reflect costs of a 'nth' CWF production facility after problems associated with initial ventures of a new technology application have been satisfactorily resolved. Also, the column flotation section (new technology) accounts for less than 15 percent of the total field costs. Based on these consideration a provision of 15 percent has been made for contingencies.

Startup and Land An allowance of 1 percent of the Total Installed Plant Cost has been made for plant start-up and operator training. Cost of land for plant and facilities is estimated at $120,000.

Exclusions in Capital Cost Estimates The Total Project Capital Cost does not include owners' permitting and other such costs, taxes, and escalation beyond the First Quarter of 1997. Cost of utility lines outside the plant battery limits are also not included.

Working Capital Working capital requirements have been calculated on the basis of a month's cost of coal and two month's expenditure against labor and variable O&M costs.

7.2 O&M COSTS AND COST OF CWF

The annual O&M cost estimates are based on the design criteria shown in Section 4 and 5 conceptual information generated during the study. Calculations of annual Variable and Fixed O&M costs are summarized in Table 7.2.1

7.2.1 Variable O&M Costs

Major reagents and consumable used in the CWF production facility are: collector and frother for flotation, ball charge, flocculants, CWF additive, power and water. O&M supplies, refuse disposal and loss of coal heating value (Btu) with tailings (refuse) are other items of Variable O&M costs. The usage or consumption rates of these consumable are shown in Table 7.2.1. Table 7.2.2 provides details of flocculant consumption.

The O&M cost estimates use consumption rates for the collector (fuel oil) and the frother (MIBC) at 0.75 lb/st based on the coal feed to flotation columns. This is the median value for all coals tested earlier under the program.

Consumption of balls for grinding coal is estimated at 1 lb/st of coal ground. Recommended dosage for flocculants shown in Table 8.2.2 is taken from EPRI's Coal Cleaning Cost Model (EPRI Report TRI 101025). Median values of the recommended ranges have been used in the estimates.

Based on tests conducted in the laboratory under the program an average consumption of 10 lb (solid) of additive A-23 has been recommended for producing the required solids loading and viscosity of the CWF.

The cost of consumable O & M supplies such as spare parts are estimated based on Bechtel experience at 5 percent of the cost of major equipment in the plant. Consumption rates for electric power and water have been derived from the major equipment list and material balances respectively.

An allowance of $5.00/st (dry) has been made for tailings disposal. Disposal costs could vary significantly depending upon conditions at the selected site.

The plant is expected to operate with a Btu recovery of 96.1 percent. Thus tailings from the plant include 3.9 percent of the energy supplied to the CWF production plant in the form of raw coal. The monetary value of the Btu lost with the tailings is calculated based on the delivered cost of coal energy ($/MBtu).

Based on annual consumption as described above, Variable O&M costs have been calculated using the following unit cost rates.

Cost Element	Unit	Cost ($)
Collector (fuel oil)	$/lb	0.20
Frother (MIBC)	$/lb	0.85
Ball charge	$/st	600
Flocculants	See Table	7.2.2
CWF additive (A-23) - solids	$/lb	0.70
Electric power	$/kWh	0.055
Water	$/1000 gal	0.60
Refuse disposal	$/dry ton	5.00
Cost of raw coal: delivered (as received)	$/st	32.5
	$/MBtu	1.24

7.2.2 Fixed O&M Costs

Labor costs and capital charges with interest on Working Capital are included in fixed O&M costs.

Table 7.2.3 provides a listing of management, operating and maintenance personnel required to staff the facility. A total of 81 employees is envisaged. Labor costs are estimated at an average cost of $75,000 per employee per annum.

Annual capital charges are calculated for the Total Project Capital cost based on a 20 year life and 15 percent rate of return which is considered reasonable. Interest on working capital has been calculated at 8 percent per annum.

7.2.3 Total Annual Variable and Fixed O&M Costs- Cost of CWF

As shown in Table 7.2.1 total Variable and Fixed O&M costs are estimated at $0.913/MBtu of heating value in the premium CWF without considering the cost of coal. A break down of the costs is as follows:

Cost Element	$/MBtu	%	
Capital Charges and interest on Working Capital	0.27	29.1	
CWF additive, A-23	0.23	25.6	
Labor	0.13	14.6	
Electric Power	0.11	12.3	
Flotation Reagents & Flocculant	0.07	7.5	
Btu Loss	0.05	5.5	
Others	0.05	5.4	
Total Cost of CWF	0.91	100.0	Less cost of coal

Including the cost of coal delivered to plant site at 1.24/MBtu, the total cost of production of premium CWF is estimated at $2.15/MBtu.

7.3 SENSITIVITY STUDIES

One of the major elements in the cost of production of CWF is the cost of A-23 dispersant additive. Use of the additive becomes necessary to meet the specified 60 percent solids loading of the product. If the solids loading could be reduced to around 54 percent, the product could be produced without the use of the additive A-23. In such an event the total cost of CWF would be reduced from $2.15/MBtu to $1.92 representing a reduction of $0.23/MBtu.

A series of sensitivity analysis was performed to evaluate the sensitivity of the cost of production of CWF to variations in other selected cost input parameters. The cases studied are listed in Table 7.3.1. Results of the analysis are shown in Table 7.3.2. Details of calculation are placed in Appendix C.

As may be expected, variations in coal prices have the maximum impact on the cost of CWF. The cost of coal accounts for nearly 60 percent (57.5+2.3) of the cost of the product in the base case. The other significant factor is the annual production rate.

Table 7.1.1
PREMIUM CWF PRODUCTION- COLUMN FLOTATION
Capital Cost Summary

		$ x 1000	%
Raw Coal Handling - Plant 100		13,886	24.7
Crushing and Grinding - Plant 200		19,249	34.2
Column Flotation - Plant 300		6,984	12.4
Clean Coal Dewatering - Plant 400		7,216	12.8
Water Clarification and Tailings Handling - Plant 500		3,135	5.6
CWF Preparation and Loading - Plant 600		5,799	10.3
Total Field Costs		56,268	100.0
Engineering and Home Office		3,535	
Contingency @ 15%		8,970	
Total Installed Plant Cost		68,773	
Startup and Operator training	1 %	688	
Land-60 acres at $ 2000 per acre		120	
Total Project Capital Cost		**69,581**	
Working Capital		**10,000**	

Not Included: Cost of permits and escalation beyond first quarter of 1997.

Table 7.2.1
PREMIUM CWF PRODUCTION - COLUMN FLOTATION
Variable and Fixed O & M Costs - Cost of CWF

Cost element	Usage unit	Usage value	Unit cost unit	Unit cost $	st/h	$/h	Plant Availability %	1000 x $/y	Cost of CWF $/st product coal	Cost of CWF $/MBtu	Cost of CWF % Excluding coal	Cost of CWF % Including coal
Variable O&M Costs												
Collector	lb/st of feed	0.75	$/lb	0.20	233	35	81	249	0.17	0.006	0.6	0.3
Frother	lb/st of feed	0.75	$/lb	0.85	233	149	81	1,059	0.71	0.024	2.6	1.1
Ball charge	lb/st of feed	*1.00*	$/ton	600	233	70	81	498	0.33	0.011	1.2	0.5
Flocculant	(1)		$/st	11.0	22.6	248	81	1,764	1.18	0.039	4.3	1.8
CWF additive-A23	lb/st (2)	10	$/lb	0.70	211	1474	81	10,500	7.00	0.234	25.6	10.8
O&M supplies (3)								773	0.52	0.017	1.9	0.8
Electric power (4)	10^6 kWh/st	61	$/kWh	0.055	211	705	81	5,023	3.35	0.112	12.2	5.2
Water	gpm	531	$/1000 gal	0.60		19	81	136	0.09	0.003	0.3	0.1
Refuse (tailings) disposal			$/st	5.0	22.6	113	81	806	0.54	0.018	2.0	0.8
Btu losses (5)	10^6 MBtu/h	253	$/MBtu	1.24		315	81	2,243	1.50	0.050	5.5	2.3
Total Variable O & M Costs								23,052	15.37	0.514	56.2	23.8
Fixed O & M Costs												
Labor	Employees	81	$/y/employee	75,000				6,075	4.05	0.135	14.8	6.3
Capital Charges & Interest on working capital (6)								11,916	7.94	0.265	29.0	12.3
Total Fixed O & M Costs								17,991	11.99	0.401	43.8	18.6
Total Variable and Fixed O & M Costs								41,043	27.36	0.914	100.0	42.4
Raw Coal			$/MBtu	1.243				55,807	37.2	1.243		57.6
Total cost of Premium CWF including cost of raw coal								96,850	64.57	2.158		100.0

(1) Per st of dry feed to tailings (refuse) thickener and belt press filter- See Table 7.2.2
(2) Per dry st of coal
(3) 5 % of major equipment cost
(4) Power consumption per st of dry coal in product
(5) Calculated Btu losses per hour = (233.2*14054*2000)-(211*14962*2000) = 253.3 MBtu/h
(6) Charges against capital cost: 69,581 ($x1000) , Terms- 15 %-20yr- factor= 15.98% Equals 11,116 ($x1000 per year)
'-Interest on Working Capital at 8% Equals 800 ($x1000 per year)

Table 7.2.1 (continued)
PREMIUM CWF PRODUCTION - COLUMN FLOTATION
Variable and Fixed O & M Costs - Cost of CWF

Calculation basis		
Raw coal-HHV (dry basis)	Btu/lb	14,054
Coal in product- HHV (dry basis)	Btu/lb	14,962
Feed (dry basis)	st/h	233
Product (dry basis)	st/h	211
Btu loss/h	MBtu/h	253
Energy recovery	%	96.1
Cost of raw coal (delivered)	$/st	32.5
Feed coal HV (as received)	Btu/lb	13,070
Cost /MBtu of raw coal	$/MBtu	1.24
Weight recovery	%	90.3

Table 7.2.2
PREMIUM CWF PRODUCTION- COLUMN FLOTATION
Flocculant Consumption

Tailings (Refuse) dry solid feed rate to thickener and belt press = 22.62 st/h

	Thickener		Belt press		Total usage	Reagent cost (2)	Flocculant cost
	Range (1) (2) lb/st	Value used lb/st	Range (2) lb/st	Value used lb/st	lb/st	$/lb	$/st of tailings
Anionic	1.5-2.5	2.0	2.5-3.5	3.0	5.0	1.75	8.8
Cationic	2.0-3.0	2.5	2.5-3.5	3.0	5.5	0.40	2.2
Total cost of flocculants							11.0

(1) Expected range of requirement per ton of tailings fed to the thickener and belt press
(2) Source: Coal Cleaning Cost Model - EPRI, Report TRI101025, March 1993 with unit cost escalated.

Table 7.2.3
PREMIUM CWF PRODUCTION - COLUMN FLOTATION
Operating and Maintenance Personnel

Management:	
Plant Manager	1
General Foreman	1
Chemist/Engineer	2
Clerk	1
Total Management	5
Operating and Maintenance labor / shift:	
Shift foreman	1
Control Room Operator	1
Electrician	1
Mechanic	3
Mechanic helper	3
Welder	1
Unloading and loading operations	1
Crushing and grinding plant	2
Flotation	1
CWF Plant	1
Thickener and centrifuge	2
Warehouse	1
Lab assistant	1
Total labor per shift	19
Summary	
Management	5
Labor strength based on (4) Operating shifts (*)	76
Total Employees	81

(*) Strength required to staff 3 shifts/day and 7 days/week operating schedule.

Table 7.3.1
COST OF PREMIUM CWF - COLUMN FLOTATION
Factors for Product Cost Sensitivity Analysis

Item		Base Unit	Base Value	Variation	Low Value	High Value	Remarks
A	**Process Parameters**						
(i)	Ash in feed coal -dry basis	wt %	7.5	+/- 50%	3.75	11.25	Raw coal price of $1.24/MBtu remains same at all ash levels- No change in Btu recovery
(ii)	Loss of Btu	%	4.9	+100 to (-) 50 %	2.45	9.80	
B	**Operating Cost Parameters**						
(i)	Price of feed coal	$/MBtu	1.24	+/- 10%	1.116	1.36	Base price equals $32.50/st-delivered
(ii)	Labor	1000 x $/y	6,075	+/- 10%	5,468	6,683	
(iii)	Electricity	1000 x $/y	5,023	+/- 10%	4,520	5,525	
(iv)	Reagents and additives	1000 x $/y	11,808	+/- 10%	10,627	12,989	Frother, Collector and A-23 (no flocculant)
C	**Plant Parameters**						
(i)	Plant Production- same operating schedule	10 ^6 st/y	1.5	+/- 10%	1.35	1.65	Better or worse equipment performance
(ii)	Plant Production- due to reduced operating schedule	10 ^6 st/y	1.5	- 46% / -21 %	0.79	1.18	Base=19 shifts/wk: Reduced High=15 shifts /wk: Reduced Low=10 shifts/wk
D	**Investment Parameters**						
(i)	Capital	1000 x $	69,581	- 10% /+ 20 %	62,623	83,497	

Table 7.3.2
PREMIUM CWF COST SENSITIVITY- FLOTATION

	Sensitivity Study Cases	Notes	Unit	Base Value	Low Value	High Value	Reference Table in Appendix C
A	Process Parameters						
(i)	Ash in feed coal -dry basis	(1)	wt %	7.5	3.75	11.25	
	Cost /MBtu of Premium CWF		$/MBtu	2.16	2.11	2.21	See Table C-3
(ii)	Loss of Btu	(1)	%	4.9	2.45	9.80	
	Cost /MBtu of Premium CWF		$/MBtu	2.16	2.14	2.17	See Table C-3
B	Operating Cost Parameters						
(i)	Price of feed coal		$/MBtu	1.24	1.12	1.36	
	Cost /MBtu of Premium CWF		$/MBtu	2.16	2.03	2.29	See Table C-3
(ii)	Labor		1000 x $/y	6,075	5,468	6,683	
	Cost /MBtu of Premium CWF		$/MBtu	2.16	2.14	2.17	See Table C-4
(iii)	Electricity		1000 x $/y	5,023	4,520	5,525	
	Cost /MBtu of Premium CWF		$/MBtu	2.16	2.15	2.17	See Table C-4
(iv)	Reagents and additives	(2)	1000 x $/y	11,808	10,627	12,989	Collector, Frother & A-23
	Cost /MBtu of Premium CWF		$/MBtu	2.16	2.13	2.18	See Table C-4
C	Plant Parameters						
(i)	Plant Production- same operating schedule	(3)	10 ^6 st/y	1.5	1.35	1.65	
	Cost /MBtu of Premium CWF		$/MBtu	2.16	2.20	2.12	See Table C-5
(ii)	Plant Production- due to reduced schedule	(4)	10 ^6 st/y	1.5	0.79	1.18	
	Cost /MBtu of Premium CWF		$/MBtu	2.16	2.40	2.23	See Table C-5
D	Investment Parameters						
(i)	Capital		1000 x $	69,581	62,623	83,497	See Table C-5
	Cost /MBtu of Premium CWF		$/MBtu	2.16	2.13	2.21	

(1) Raw coal price ($1.24/MBtu) and Btu recovery are same for these cases
(2) Flocculants not considered
(3) Better or worse equipment performance
(4) Base=19 shifts/wk: Reduced High=15 shifts /wk: Reduced Low=10 shifts/wk

Section 8
Cost of Premium CWF - Selective Agglomeration

This section presents conceptual capital and annual operating and maintenance (O&M) cost estimates for a commercial plant for the production of premium CWF. The plant employs the selective agglomeration process. Based on the estimates, the cost of production of CWF ($/MBtu) has been calculated. Further, a number of analysis have been performed to evaluate the sensitivity of the cost of production to variations in the process criteria, unit cost of selected in-puts, plant performance and capital investment.

8.1 CAPITAL COSTS

Capital cost estimates have been developed based on the criteria, description, flow diagrams, material balances and major equipment list included in Sections 4 and 6. Details of capital cost estimates are placed under Appendix B. A summary of the capital cost estimates is presented in Table 8.1.1 which includes a break down showing costs for different plant sections. The estimated capital cost of the project is $ 97.24 million (First Quarter 1997).

8.1.1 Total Field Costs

Procedures employed for the development cost estimates are consistent with the conceptual nature of the plant's engineering definition at this stage. These include informal vendor contacts for pricing major equipment such as the grinding mills as well as use of current Bechtel in-house data, with extrapolation and adjustment if appropriate.

Quantities of bulk materials for civil, structural, electrical, instrumentation and piping work necessary for the construction of the plant are not computed due to lack of more detailed engineering. As per normal accepted practice in such cases, the costs of these items are estimated as percentages of identified equipment costs. The percentages are derived from Bechtel experience with similar projects.

It is expected that equipment installation and field construction work will be performed by union labor. Job hours for equipment installation have been developed using typical job hours for machinery units of similar size and nature. An average labor rate of $30 per hour has been applied to the job hours. The rate which includes payroll additives, fringe benefits, workmen's compensation, and spot overtime has also been used for field construction job hours. It is based on current union labor agreements for a 40-hour week in the Cleveland, Ohio area.

A 3% sales tax is included for procured items. An allowance for freight to plant site is included at 3 percent of the ex-works cost of equipment and bulks.

Indirect Field Costs which include items such as indirect manual labor, temporary construction facilities, tools and tackle, and field office are included at 60 percent of direct labor costs.

8.1.2 Total Project Capital Cost and Working Capital

Total Installed Plant Cost The Total Installed Plant Cost is derived by adding engineering and home office costs as well as contingencies to the Total Field Costs.

Engineering and home office costs (engineering, procurement, and project management) are calculated at 7 percent of Total Direct Field Costs (Total Field Costs less Indirect Field Costs).

The estimated capital costs are intended to reflect costs of a 'nth' CWF production facility after problems associated with initial ventures of a new technology application have been satisfactorily resolved.

The selective agglomeration section, Plant 350, accounts for approximately 38 percent of the Total Field Costs. Considering the uncertainties in the estimate for this plant section, an enhanced contingency allowance of 22.5 percent has been made for this part of the Total Field Cost. A 15 percent contingency has been allowed for the rest of the plant sections which represent relatively proven technology. Average contingency for the entire plant works out to 17.7 percent.

Startup and Land An allowance of 1 percent of the Total Installed Plant Cost has been made for plant start-up and operator training. Cost of land for plant and facilities is estimated at $120,000.

Exclusions in Capital Cost Estimates The Total Project Capital Cost does not include owners' permitting and other such costs, taxes, and escalation beyond the First Quarter of 1997. Cost of utility lines outside the plant battery limits are also not included.

Working Capital Working capital requirements have been calculated on the basis of a month's cost of coal and two month's expenditure against labor and variable O&M costs.

8.2 O&M COSTS AND COST OF CWF

The annual O&M cost estimates are based on the design criteria shown in Section 4 and 6 conceptual information generated during the study. Calculations of annual Variable and Fixed O&M costs are summarized in Table 8.2.1

8.2.1 Variable O&M Costs

Major reagents and consumable used in the CWF production facility are: heptane, steam, ball charge, flocculants, CWF additive (A-23), power, and water. O&M supplies, refuse disposal and loss of coal heating value (Btu) with tailings (refuse) are other items of Variable O&M costs. The usage or consumption rates of these consumable are shown in Table 8.2.1. Table 8.2.2 provides details of flocculant consumption.

Of the reagents used, approximately 1 percent of heptane is lost with the solids, coal and minerals, leaving the process. In addition, handling losses have been estimated at 0.05 percent of the heptane in circulation. This reflects a recovery efficiency of 98.95 percent. This level of recovery should be achievable in a continuous with completely enclosed processing vessels .

Quantities of steam consumption are derived from heat and material balances. Consumption of ball charge for grinding coal is estimated at 1 lb/st of coal ground. Recommended dosage for flocculants shown in Table 8.2.2 is taken from EPRI's Coal Cleaning Cost Model (EPRI Report TRI 101025). Median values of the recommended ranges have been used in the estimates.

Based on tests conducted in the laboratory under the program an average consumption of 10 lb (solid) of additive A-23 has been recommended for producing the required solids loading and viscosity of the CWF.

Consumption rates for electric power and water have been derived from the major equipment list and material balances respectively.

The cost of consumable O & M supplies such as spare parts are estimated based on Bechtel experience at 5 percent of the cost of major equipment in the plant.

An allowance of $5.00/st (dry) has been made for tailings disposal. Disposal costs could vary significantly depending upon conditions at the selected site.

The plant is expected to operate with a Btu recovery of 99.0 percent. Thus tailings from the plant include 1.0 percent of the energy supplied to the CWF production plant in the form of raw coal. The cost of the heating value (Btu) lost with the tailings is calculated based on the delivered cost of coal energy ($/MBtu).

Based on annual consumption as described above, Variable O&M costs have been calculated using the following unit cost rates.

Cost Element	Unit	Cost ($)
Heptane	$/lb	0.175
Steam	$/MBtu	3.00
Ball charge	$/st	600
Flocculant	See Table	8.2.2
CWF additive (A-23) - solids	$/lb	0.70
Electric power	$/kWh	0.055
Water	$/1000 gal	0.60
Refuse disposal	$/dry ton	5.00
Cost of raw coal: delivered	$/st	32.5
	$/MBtu	1.24

8.2.2 Fixed O&M Costs

Labor costs and capital charges with interest on working capital are included in Fixed O&M costs.

Table 8.2.3 provides a listing of management, operating and maintenance personnel required to staff the facility. A total of 104 employees is envisaged. Labor costs are estimated at an average cost of $75,000 per employee per annum.

Annual capital charges are calculated for the Total Project Capital cost based on a 20 year life and 15 percent rate of return which is considered reasonable. Interest on working capital has been calculated at 8 percent per annum.

8.2.3 Total Annual Variable and Fixed O&M Costs- Cost of CWF

As shown in Table 8.2.1 total Variable and Fixed O&M costs are estimated at $1.14/MBtu of heating value in the premium CWF without considering the cost of coal. A break down of the costs is as follows:

Cost Element	$/MBtu	%	
Capital charges and interest on Working Capital	0.37	31	
CWF additive, A-23	0.23	19	
Labor	0.17	15	
Electric power	0.15	13	
Steam	0.13	11	
Others (including Heptane)	0.10	10	
Total Cost of CWF	1.18	100	Less cost of coal

The above data is shown graphically in Figure 1.4. Including the cost of coal (delivered to site) at 1.24/MBtu, the total cost of production of premium CWF is estimated at $2.42/MBtu.

The target set for the program for the cost of production of CWF is $2.50/MBtu including the mine mouth cost of raw coal. The above mentioned cost of $2.42/MBtu is based on coal cost delivered to the plant site in Ohio. It includes a transportation cost of $0.20/MBtu for the raw coal. Based on mine mouth coal cost, the estimated production cost is $2.22/MBtu ($2.42 less $0.20) which is well below the targeted cost of production.

8.3 SENSITIVITY STUDIES

One of the major elements in the cost of production of CWF is the cost of A-23 dispersant additive. Use of the additive becomes necessary to meet the specified 60 percent solids loading of the product slurry. If the solids loading could be reduced to around 54 percent, the slurry could be produced without the use of the additive. In such an event the total cost of CWF would be reduced from $2.42/MBtu to $2.19/MBtu representing a reduction of $0.23/MBtu.

A series of sensitivity analysis was performed to evaluate the sensitivity of the cost of production of CWF to variations in other selected cost input parameters. The cases considered are listed in Table 8.3.1. Results of the analysis are shown in Table 8.3.2. Details of calculation are placed in Appendix D.

As may be expected, variations in coal prices have the maximum impact on the cost of CWF. The cost of coal accounts for nearly 51.9 (51.4 + 0.5) percent of the cost of the product in the base case. The other significant factor is the annual rate of production.

Table 8.1.1
PREMIUM CWF PRODUCTION- SELECTIVE AGGLOMERATION
Capital Cost Summary

		$ x 1000	%
Raw Coal Handling - Plant 100		13,886	18.1
Crushing and Grinding - Plant 200		19,249	25.0
Selective Agglomeration - Plant 350		27,868	36.2
Clean Coal Dewatering - Plant 400		7,216	9.4
Water Clarification and Tailings Handling - Plant 500		2,873	3.7
CWF Preparation and Loading - Plant 600		5,799	7.5
Total Field Costs		76,891	100.0
Engineering and Home Office		4,790	
Contingency-%	17.72 (*)	14,472	
Total Installed Plant Cost		96,153	
Startup and Operator training	**1** %	962	
Land-60 acres at $ 2000 per acre		120	
Total Project Capital Cost		97,235	
Working Capital		11,000	

Not Included: Cost of permits and escalation beyond first quarter of 1997.
(*) Contingency % = (22.5 % on Selective agglomeration and 15 % on rest) 17.72

Table 8.2.1
PREMIUM CWF PRODUCTION - SELECTIVE AGGLOMERATION
Variable and Fixed O & M Costs - Cost of CWF

Cost element	Usage unit	Usage value	Unit cost unit	Unit cost $	st/h	$/h	Plant Availability %	1000 x $/y	Cost of CWF $/st product coal	Cost of CWF $/MBtu	Cost of CWF % Excluding coal	Cost of CWF % Including coal
Variable O&M Costs												
Heptane	lb/st of feed	5.40	$/lb	0.175	233	220	79	1,524	1.02	0.034	2.89	1.40
Steam	MBtu/st	1.27	$/MBtu (1)	3.0	217	825	79	5,706	3.80	0.127	10.81	5.25
Ball charge	lb/st of feed	1.00	$/ton	600	233	70	79	483	0.32	0.011	0.92	0.45
Flocculant			$/st (2)	11.0	16.3	179	79	1,238	0.83	0.028	2.35	1.14
CWF additive-A23	lb/st (3)	10	$/lb	0.70	217	1518	79	10,500	7.00	0.234	19.89	9.67
O&M supplies (4)								1,123	0.75	0.025	2.13	1.03
Electric power (5)	10^6 kWh/st	82	$/kWh	0.055	217	975	79	6,743	4.50	0.150	12.77	6.21
Water	gpm	531	$/1000 gal	0.60		19	79	132	0.09	0.003	0.25	0.12
Refuse (tailings) disposal			$/st	5.0	16.3	82	79	565	0.38	0.013	1.07	0.52
Btu losses (5)	10^6 MBtu/h	66	$/MBtu	1.24		82	79	564	0.38	0.013	1.07	0.52
Total Variable O & M Costs								28,579	19.05	0.637	54.13	26.32
Fixed O & M Costs												
Labor	Employees	104	$/y/employee	75,000				7,800	5.20	0.174	14.77	7.18
Capital Charges & Interest on Working Capital (6)								16,414	10.94	0.366	31.09	15.11
Total Fixed O & M Costs								24,214	16.14	0.539	45.87	22.30
Total Variable and Fixed O & M Costs								52,793	35.20	1.176	100.00	48.61
Raw Coal			$/MBtu	1.24				55,807	37.20	1.243		51.39
Total cost of Premium CWF including cost of raw coal								108,600	72.40	2.419		100.00

(1) Based on $ 6 per st of steam - EPRI Tag 1983 escalated to January 1997
(2) Per st of dry feed to tailings (refuse) thickener and belt press filter- See Table 8.2.2 15,744
(3) Per dry st of coal
(4) 5 % of major equipment cost
(5) Power consumption per st of dry coal in product
(6) Calculated Btu losses per hour = (233.2*14054*2000)-(217*14962*2000) = 65.6 MBtu/h
(7) Charges against capital cost of 97,235 ($x1000) : Terms- 15 %-20yr- factor 15.98% Equals 15534 ($x1000 per year)
-Interest on working capital at 8% Equals 880 ($x1000 per year)

Table 8.2.1 (continued)
PREMIUM CWF PRODUCTION - SELECTIVE AGGLOMERATION
Variable and Fixed O & M Costs - Cost of CWF

Calculation basis

Raw coal-HHV (dry basis)	Btu/lb	14,054
Coal in product-HHV (dry basis)	Btu/lb	14,962
Feed (dry basis)	st/h	233
Product (dry basis)	st/h	217
Btu loss/h	MBtu/h	66
Energy recovery	%	99.0
Cost of raw coal (delivered)	$/st	32.5
Feed coal HHV (as received)	Btu/lb	13,070
Cost /MBtu of raw coal (delivered)	$/MBtu	1.24
Weight recovery	%	93.0

Table 8.2.2
PREMIUM CWF PRODUCTION - SELECTIVE AGGLOMERATION
Flocculant Consumption

Tailings (Refuse) dry solid feed rate to thickener and belt press = **16.35** st/h

	Thickener		Belt press		Total	Reagent	Flocculant
	Range (1) (2) lb/st	Value used lb/st	Range (2) lb/st	Value used lb/st	usage lb/st	cost (2) $/lb	cost $/st of tailings
Anionic	1.5-2.5	2.0	2.5-3.5	3.0	5.0	1.75	8.8
Cationic	2.0-3.0	2.5	2.5-3.5	3.0	5.5	0.40	2.2
Total cost of flocculants							11.0

(1) Expected range of requirement per ton of tailings fed to the thickener and belt press
(2) Source: Coal Cleaning Cost Model - EPRI, Report TRI101025, March 1993 with unit cost escalated.

Table 8.2.3
PREMIUM CWF PRODUCTION - SELECTIVE AGGLOMERATION
Operating and Maintenance Personnel

Management:	
Plant Manager	1
General Forman	1
Chemist/Engineer	1
Clerk	1
Total Management	4
Operating and Maintenance labor / shift:	
Shift foreman	1
Plant operator	1
Electrician	1
Mechanic	3
Mechanic helper	3
Welder	1
Unloading and loading operations	1
Crushing and grinding plant	2
Agglomeration	6
Thickener and centrifuge	2
Product handling and CWF plant	2
Lab assistant and Warehouse	2
Total labor per shift	25
Summary	
Management	4
Labor strength based on (4) Operating shifts (*)	100
Total Employees	104

(*) Strength required to staff 3 shifts/day and 7 days/week
operating schedule.

Table 8.3.1
COST OF PREMIUM CWF - SELECTIVE AGGLOMERATION
Factors for Product Cost Sensitivity Analysis

Item	Base Unit	Base Value	Variation	Low Value	High Value	Remarks
A <u>Process Parameters</u>						
(i) Ash in feed coal -dry basis	wt %	7.5	+/- 50%	3.75	11.25	Raw coal price of $1.24/MBtu remains same at all ash levels- No change in Btu recovery
(ii) Loss of Btu	%	1.0	+100 to (-) 50 %	0.50	2.00	
B <u>Operating Cost Parameters</u>						
(i) Price of feed coal	$/MBtu	1.24	+/- 10%	1.116	1.36	Base price equals $32.50/st (delivered)
(ii) Labor	1000 x $/y	7,800	+/- 10%	7,020	8,580	
(iii) Electricity	1000 x $/y	6,743	+/- 10%	6,069	7,418	
(iv) Reagents and additives	1000 x $/y	12,024	+/- 10%	10,822	13,227	
(v) Steam	1000 x $/y	5,706	+/- 10%	5,135	6,276	
C <u>Plant Parameters</u>						
(i) Plant Production- same operating schedule	10 ^6 st/y	1.5	+/- 10%	1.35	1.65	Better or worse equipment performance
(ii) Plant Production- due to reduced operating schedule (*)	10 ^6 st/y	1.5	-54 %/- 21%	0.69	1.18	Base=19 shifts/wk Reduced High=15 shifts /wk Reduced Low=10 shifts/wk
D <u>Investment Parameters</u>						
(i) Capital	1000 x $	97,235	- 10% / +20%	87,511	116,682	

(*) When operated 10 shifts a week, or 2 shifts a day- approximately 2 hours on each working day will be lost due orderly starts and shut downs- plant availability suffers by additional (100*2/16= 12.5%) 12.5 % compared to 3 shift operation. Selective agglomeration plant takes significantly more time than flotation systems to start and shut down.

Table 8.3.2
PREMIUM CWF COST SENSITIVITY - SELECTIVE AGGLOMERATION

	Sensitivity Study Cases	Notes	Unit	Base	Low Value	High Value	Reference Table in Appendix D
A	**Process Parameters**						
(i)	Ash in feed coal -dry basis	(1)	wt %	7.5	3.75	11.25	
	Cost of Premium CWF		$/MBtu	2.41	2.36	2.47	See Table D-3
(ii)	Loss of Btu	(1)	%	1	0.5	1.5	
	Cost of Premium CWF		$/MBtu	2.41	2.40	2.41	See Table D-3
B	**Operating Cost Parameters**						
(i)	Price of feed coal		$/MBtu	1.24	1.12	1.37	
	Cost of Premium CWF		$/MBtu	2.41	2.28	2.53	See Table D-3
(ii)	Labor		1000 x $/y	7,800	7,020	8,580	
	Cost of Premium CWF		$/MBtu	2.41	2.39	2.43	See Table D-4
(iii)	Electricity		1000 x $/y	6,743	6,069	7,418	
	Cost of Premium CWF		$/MBtu	2.41	2.39	2.42	See Table D-4
(iv)	Reagents and additives (Heptane & A-23)	(2)	1000 x $/y	12,024	10,822	13,227	
	Cost of Premium CWF		$/MBtu	2.41	2.38	2.44	See Table D-4
(v)	Steam		1000 x $/y	5,706	5,135	6,276	
	Cost of Premium CWF		$/MBtu	2.41	2.40	2.42	
C	**Plant Parameters**						
(i)	Plant Production- same operating schedule	(3)	10 ^6 st/y	1.5	1.35	1.65	
	Cost of Premium CWF		$/MBtu	2.41	2.47	2.36	See Table D-5
(ii)	Plant Production- due to reduced schedule	(4)	10 ^6 st/y	1.5	0.69	1.18	
	Cost of Premium CWF		$/MBtu	2.41	2.86	2.50	See Table D-5
D	**Investment Parameters**						
(i)	Capital		1000 x $	97,235	87,511	106,958	See Table D-5
	Cost of Premium CWF		$/MBtu	2.41	2.37	2.48	

(1) Raw coal price ($1.24/MBtu- delivered to site) and Btu recovery are same for these cases
(2) Flocculants not considered
(3) Better or worse equipment performance
(4) Base=19 shifts/week: Reduced High=15 shifts /week: Reduced Low=10 shifts/week

Section 9
List of Acronyms and Abbreviations

A list of Acronyms and Abbreviations used in the report is given below.

$	U. S. Dollar
acfm	actual cubic feet per minute
bar	one atmospheric pressure
Btu	British Thermal Unit
ft	foot or feet
GJ	Giga (10^9) Joules
gm	gram
gpm	gallons per minute
h	hour
HV	Heating Value
HHV	Higher Heating Value
HP	Horse Power
k	kilo
kg	kilogram
kJ	kilo (10^3) Joules
kW	kilowatt electricity
in.	inch
lb	pound
m	meter
min	minute
mm	millimeter
MJ	Mega (10^6) Joules
MJ/kg	Mega Joules per kilogram
MBtu	Million British thermal unit
O&M	Operating and Maintenance
PDU	Process Development Unit
ROM	Run-of-Mine
scfm	standard cubic feet per minute
st	short ton (1 short ton = 2,000 lb)
t	metric ton (metric ton = 1,000 kg)
wt	weight
y	year

APPENDICES

APPENDIX A

Capital Cost Estimate- Column Flotation

All costs are $ x1000

Equipment I.D	Qty	Title	Description	Power-ea. HP	Total HP	Installed Equipment Cost		Sub-contract	Total cost	Equip-unit cost supply-ea	Installation cost each	Installation cost total	
100 BN-01,02,03	3	Raw coal silos, No. 1, 2, and 3	10,000 st (ea.), 70 ft dia x 150 ft ht					5,250	5,250				subcontract
100 CV-01	1	Raw coal conveyor	2000 st/h, 60 in wide x 750 ft lg., 220 ft lift, 500 fpm, with belt scale	600	600	810			810	675	135	135	
100 CV-02	1	Silo feed conveyor No. 1	2000 st/h, 60 in wide x 80 ft lg., 10 ft lift, 500 fpm	50	50	101			101	86	14	14	
100 CV-03	1	Silo feed conveyor No. 2	2000 st/h, 60 in wide x 80 ft lg., no lift, 500 fpm	50	50	101			101	86	14	14	
100 DC-01,02,03	3	Silo top dust collector with fan	7000 cfm, filtering area 1200 sq. ft including fan	40	120	100			100	85	15	45	
100 RR-01	Lot	Rail car unloading system	For 2000 st/h unloading rate including rotary car dumper, shunting locomotive, 200 st dump hopper, grizzly, frozen coal crusher, thawing shed, dust collection, raw coal conveyor tunnel, sump pump, feeders, rail track of 2 miles	700	700			6,000	6,000				subcontract, installed
100 ST-01 & 02	2	Motorized gate	Capacity- 2000 st/h	10	20	36			36	15	3	6	
200 AG-01 & 02	2	Cyclone feed pump sump mixer	For Cyclone feed sump	15	30	40			40	18	2	4	
200 CN-01	1	Mill house crane	30 t main hook, 5 ton aux	75	75	201			201	175	26	26	
200 CR-01,02	2	Hammer mill crusher	125 st/h, feed size 2" x 0 and product 1/4" x 0	300	600	138			138	60	9	18	PENN CR QUOTE
200 CS-01 thru 06	6	Cyclone cluster	Flow 1200 gpm/cluster-20 no. of 4 in cyclones per cluster			780			780	115	15	90	
200 CV-10 & 11	2	Crusher feed conveyor	125 st/h, 30 in wide x 300 ft lg., 25 ft lift, 350 fpm, with belt scale	15	30	270			270	108	27	54	
200 CV-12 & 13	2	Ball mill feed conveyor	125 st/h, 30 in wide x 100 ft lg., 25 ft lift, 350 fpm	15	30	102			102	42	9	18	
200 DC-10 & 11	2	Crusher House dust collector with fan		50	100	180			180	75	15	30	
200 FE-01 thru 06	6	Reclaim feeder	125 st/h, 36 in wide x 40 ft lg.,75 fpm, (max.) variable speed drive	10	60	360			360	50	10	60	
200 MA-01 & 02	2	Tramp Iron Magnet	125 st/h, 36 in belt	10	20	120			120	50	10	20	
200 ML-01 & 02	2	Ball Mill	125 st/h, 14.5 ft dia x 29 ft	4000	8000	5,676			5,676	2,470	368	736	SWADELA Q
200 PP-01 thru 04	4	Cyclone feed pump	Horizontal slurry pump, flow 3500 gpm, sp gr 1.2, TDH 130 ft, 2 operating and 2 spare	225	900	184			184	40	6	24	
200 ST-03 thru 8	6	Motorized gate	Capacity- 125 st/h	5	30	90			90	13	2	12	
200 ST-10 & 11	2	Cyclone feed sump	7000 gal capacity (2 min.)-14ft dia x 15 ft ht, conical			21			21	9	2	3	
200 ZM-01 & 02	2	Distributor	3 way-3500 gpm	5	10	56			56	24	4	8	

APPENDIX A
Capital Cost Estimate- Column Flotation
All costs are $ x1000

Equipment I.D	Qty	Title	Description	Power-ea. HP	Total HP	Installed Equipment Cost		Sub-contract	Total cost	Equip-unit cost supply-ea	Installation cost each	Installation cost total	
300 AG-03 & 04	2	Flotation feed sump mixer		30	60	70			70	30	5	10	
300 CP-01 & 2	2	Air compressor	2250 SCFM, 125 psig with air receiver	400	800	420			420	180	30	60	
300 FT-01 thru 12	12	Column flotation unit	14 ft dia, Micro cell or equal	*		1,680			1,680	120	20	240	
300 PP-05 thru 16	12	Flotation feed pump	Horizontal slurry pump, flow 1100 gpm, sp gr 1.02, TDH 65 ft	30	360	240			240	15	5	60	
300 PP-17 thru 28	12	Recirculation pump	Horizontal slurry pump, flow 5,000 gpm, sp gr 1.02, TDH 65 ft (14 x 12 Ash)	150	1800	372			372	27	4	48	
300 PP-29 thru 32	4	Clean coal pump	Horizontal slurry pump, flow 2200 gpm, sp gr 1.02, TDH 65 ft (6 x 5 Ash) 2 and Operating 2- Spare	60	240	60			60	13	2	8	
300 PP-33 thru 44	12	Frother dosing pump	Variable speed peristaltic pump (Omega FPU258 or equal)	0.25	3	8			8	1	0	1	
300 PP-45 thru 56	12	Collector dosing pump	Variable speed peristaltic pump (Omega FPU258 or equal)	0.25	3	8			8	1	0	1	
300 ST-12 & 13	2	Flotation feed sump	17500 gal capacity (2.3 min.)-14 ft dia x 16 ft ht Cylindrical			50			50	22	3	7	
300 ST-16 & 17	2	Clean coal sump	17500 gal capacity (4 min.-froth factor 2)-14 ft dia x 16 ft ht Cylindrical			50			50	22	3	7	
300 ST-20 & 21	2	Frother storage drum	At 1.5 lb/st, 200 h, 460 ft3, 6.7 ft dia, 12 ft long, 3 st wt each			20			20	8	2	5	
300 ST-22 & 23	2	Collector storage drum	At 1.5 lb/st, 200 h, 460 ft3, 6.7 ft dia, 12 ft long, 3 st wt each			20			20	8	2	5	
400 FT-10 thru 15	6	Filtration systems	Capacity 40 st/h - vacuum filter systems	700	4200	2,580			2,580	400	30	180	
400 CV-15	2	Coal solid conveyor	Capacity 130 st/h-24 in wide, 125 st/h, 30 ft lift,	5	10	371			371	137	49	98	
400 PP-62 & 65	4	Filtrate pump	Flow 2500 gpm, TDH 30 ft, 2- Operating and 2- Spare	30	120	30			30	6	2	6	
400 ST-26 & 27	2	Filtrate sump	Capacity- 5000 gal			22			22	9	2	4	
400 ZM-05 & 06	2	Slurry distributor	Capacity-3000 gpm	10	20	36			36	15	3	6	
500 AG-09	1	Tailings filter sump agitator	Capacity of sump - 1000 gal	10	10	10			10	8	2	2	
500 BN-04	1	Tailings load-out shed	Capacity- 100 st			0		60	60				
500 CV-16	1	Tailings conveyor	Capacity - 50 st/h, 24 in x 100 ft	5	5	32			32	24	8	8	
500 FL-01	1	Tailings filter	Capacity-30st/h, 3,5 m wide	22	22	680			680	600	80	80	
500 PP-70 & 71	2	Thickener underflow pump	Horizontal slurry- capacity 500 gpm, 50 ft head, sp gr 1.07. 1- Operating, 1- Spare	15	30	40			40	15	5	10	

APPENDIX A
Capital Cost Estimate- Column Flotation
All costs are $ x1000

Equipment I.D	Qty	Title	Description	Power-ea. HP	Total HP	Installed Equipment Cost		Sub-contract	Total cost	Equip-unit cost supply-ea	Installation cost each	Installation cost total	
500 PP-72 thru 74	3	Clarified water pump	Horizontal water- capacity 10,000 gpm, 35 ft head, sp gr 1.07. 2-Operating, 1- Spare	125	375	72			72	20	4	12	
500 PP-75 & 76	2	Tailings filter feed pump	Capacity 420 gpm, 30 ft head, sp gr 1.07. 1- Operating, 1- Spare	15	30	40			40	15	5	10	
500 ST-30	1	Tailings filter feed sump	Capacity 1000 gal			11			11	8	3	3	
500 TK-01	1	Tailings thickener tank	120 ft diameter thickener tank with tunnel					400	400			0	
500 TK-02	1	Thickener overflow tank	Capacity 60,000 gal (concrete)					70	70			0	
500 TM-01	1	Tailings thickener mechanism	120 ft dia thickener mechanism with controls	20	20	205			205	178	27	27	
500 ZM-08	1	Flocculant storage,mixing and dosing system		5	5	25			25	20	5	5	
600 AG-10 & 11	2	Coal additive mixer	Retention 5 min.:	40	80	360			360	150	30	60	
600 AG-12 & 13	2	Slurry mixing tank agitator		40	80	82			82	35	6	12	
600 AG-14 thru 17	4	Slurry storage tank agitator		75	300	600			600	120	30	120	
600 PP-78 & 79	2	CWF pump	Horizontal slurry- Capacity-1500 gpm, 60 ft head, sp gr 1.17	60	120	52			52	22	4	8	
600 PP-80 thru 83	4	Slurry loading pump	Horizontal slurry- Capacity-dry solids 500 st/h- slurry 3,000 gpm, 60 ft head, sp gr 1.17, 4-Operating and 4- spare	100	400	144			144	30	6	24	
600 ST-31 & 32	2	Slurry mixing tank	10 min. each. Volume:			60			60	25	5	10	
600 ST-33 thru 36	4	Slurry fuel storage tank	0.85 million gal- 55 ft dia and 53 ft high- total 48 hr.					2500	2,500				
600 ZM-10 & 11	2	Flocculant storage, mixing and dosing system		10	20	140			140	50	20	40	
TOTAL MAJOR EQUIPMENT					20538	17,956		14280	32236			2,493	

APPENDIX A
Capital Cost Estimate- Column Flotation
All costs are $ x1000

Equipment I.D	Qty	Title	Description	Power-ea. HP	Total HP	Installed Equipment Cost		Sub-contract	Total cost	Equip-unit cost supply-ea	Installation cost each	Installation cost total	
						Equipment	**Bulks**		**Labor**	**SC**			**Total**
Total Major Equipment						**15,463**			**2,493**	**14,280**			**32,236**
Bulks													
J Instruments							928		279				1,207
L Piping							1,546		1,020				2,566
M Structurals							2,320		1,043				3,363
N Insulation													0
P Electrical							2,320		1,739				4,059
Q Concrete							2,010		2,474				4,484
R Building										928			928
S Site work		(incuding internal roads)					464		572				1,036
X Painting										155			155
Total Bulk Materials						**15,463**	**9,587**		**7,127**	**1,082**			**17,797**
Freight				%	0.03	464							464
Total Direct Field Costs						**15,927**	**9,587**		**9,620**	**15,362**			**50,497**
Indirect Field Costs				%	60								5,772
Total Field Costs													**56,268**
Home Office and Engineering				%	7								3,535
Total Installed Plant Costs less Contingency													**59,803**
Contingency				%	15								8,970
Total Installed Plant Costs Including Contingency													**68,773**

SUMMARY
Cost Breakdown

		Total field cost-less home office	**Total project-less contingency**		**Total project-with contingency**
Plant 100 Raw Coal Handling		**13,886**	**14,831**		**17,056**
Plant 200 Raw Coal Crushing and Grinding		**19,249**	**20,412**		**23,474**
Plant 300 Column Flotation		**6,984**	**7,404**		**8,515**
Plant 400 Clean Coal Dewatering		**7,216**	**7,656**		**8,804**
Plant 500 Water Clarification		**3,135**	**3,329**		**3,829**
Plant 600 Coal Slurry Preparation		**5,799**	**6,171**		**7,096**
Total Plant		**56,268**	**59,803**		**68,773**

APPENDIX B
PREMIUM CWF PRODUCTION FACILITY - AGGLOMERATION
Conceptual Cost Estimate
All costs are $ x1000

Equipment I.D	Qty	Title	Description	Power ea HP	Total HP	Installed Equipment Cost	Sub-contract	Total cost	Equip-unit cost supply-ea	Installation cost each	Installation cost total	
100 BN-01,02,03	3	Raw coal silos, No. 1, 2, and 3	10,000 st (ea.), 70 ft dia x 150 ft ht				5,250	5,250				subcontract
100 CV-01	1	Raw coal conveyor	2000 st/h, 60 in wide x 750 ft lg., 220 ft lift, 500 fpm, with belt scale	600	600	810		810	675	135	135	
100 CV-02	1	Silo feed conveyor No. 1	2000 st/h, 60 in wide x 80 ft lg., 10 ft lift, 500 fpm	50	50	101		101	86	14.4	14.4	
100 CV-03	1	Silo feed conveyor No. 2	2000 st/h, 60 in wide x 80 ft lg., no lift, 500 fpm	50	50	101		101	86	14.4	14.4	
100 DC-01,02,03	3	Silo top dust collector with fan	7000 cfm, filtering area 1200 sq. ft including fan	40	120	100		100	85	15	45	
100 RR-01	Lot	Rail car unloading system	For 2000 st/h unloading rate including rotary car dumper, shunting locomotive, 200 st dump hopper, grizzly, frozen coal crusher, thawing shed, dust collection, raw coal conveyor tunnel, sump pump, feeders, rail track of 2 miles	700	700		6,000	6,000				subcontract, installed
100 ST-01 & 02	2	Motorized gate	Capacity- 2000 st/h	10	20	36		36	15	3	6	
200 AG-01 & 02	2	Cyclone feed pump sump mixers	For Cyclone feed sump	15	30	40		40	18	2	4	
200 CN-01	1	Mill house crane	30 t main hook, 5 ton aux	75	75	201		201	175	26.25	26.25	
200 CR-01,02	2	Hammer mill crusher	125 st/h, feed size 2" x 0 and product 1/4" x 0	300	600	138		138	60	9	18	
200 CS-01 thru 06	6	Cyclone cluster	Flow 1200 gpm/cluster-20 no. of 4 in cyclones per cluster			780		780	115	15	90	
200 CV-10 & 11	2	Crusher feed conveyor	125 st/h, 30 in wide x 300 ft lg., 25 ft lift, 350 fpm, with belt scale	15	30	270		270	108	27	54	
200 CV-12 & 13	2	Ball mill feed conveyor	125 st/h, 30 in wide x 100 ft lg., 25 ft lift, 350 fpm	15	30	102		102	42	9	18	
200 DC-10 & 11	2	Crusher House dust collector with fan		50	100	180		180	75	15	30	
200 FE-01 thru 06	6	Reclaim feeders	125 st/h, 36 in wide x 40 ft lg.,75 fpm, (max.) variable speed drive	10	60	360		360	50	10	60	
	2	Tramp Iron Magnet	125 st/h, 36 in belt	10	20	120		120	50	10	20	
200 ML-01 & 02	2	Ball Mill	125 st/h, 14.5 ft dia x 29 ft	4000	8000	5,676		5,676	2,470	368	736	SWADELA C
200 PP-01 thru 04	4	Cyclone feed pump	Horizontal slurry pump, flow 3500 gpm, sp gr 1.2, TDH 130 ft, 2 operating and 2 spare	225	900	184		184	40	6	24	
					0						0	
200 ST-03 thru 8	6	Motorized gate	Capacity- 125 st/h	5	30	90		90	13	2	12	
200 ST-10 & 11	2	Cyclone feed sump,	7000 gal capacity (2 min.)-14ft dia x 15 ft ht, conical			21		21	9	1.5	3	

APPENDIX B

PREMIUM CWF PRODUCTION FACILITY - AGGLOMERATION

Conceptual Cost Estimate

All costs are $ x1000

Equipment I.D	Qty	Title	Description	Power ea HP	Total HP	Installed Equipment Cost	Sub-contract	Total cost	Equip-unit cost supply-ea	Installation cost	
										each	total
200 ZM-01 & 02	2	Distributor	3 way-3500 gpm	5	10	56		56	24	4	8
350 AG-90 thru 99	10	Feed tank agitator	Tank volume -4000 gals.	1.5	15	55		55	5	0.5	5
350 AG-100 thru 109	10	HSR impeller		400	4000	1,815		1,815	166	15	150
350 AG-109 thru 129	20	LSR impeller		50	1000	760		760	33	5	100
350 AG-130 thru 139	10	Froth skimmer		5	50	251		251	21	4	40
350 AG-140 thru 149	10	Steam stripper feed mixer	deleted								
350 AG-150 thru 159	10	Steam stripper A agitator		20	200	400		400	36	4	40
350 C-100 thru 109	10	HSR vessel	Volume: 360 gals. Diameter: 38 inch ht 88 inch - CS- Design Pressure 15 psig- Temp 145 deg F. 34 secs.	0	0	160		160	13	3.5	35
350 C-110 thru 129	20	LSR vessel	Volume 1445 gals. Diameter: 60 inch ht 132 inch - CS- Design Pressure 15 psig- Temp 145 deg F. 184 secs.	0	0	437		437	15	7	140
350 C-130 thru 139	10	Froth skimmer tank	Volume: 2000 gals.- 2.5 min		0	184		184	16	2	20
350 C-140 thru 149	10	Steam stripper feed drum	Volume: 300 gals.- 1 min		0	94		94	7	2	20
350 C-150 thru 159	10	Steam stripper A	Volume: 1500 gals.- 5 min		0	267		267	23	4	40
350 C-160 thru 169	10	Steam stripper B	Volume: 3000 gals.- 10 min		0	448		448	39	6	60
350 C-170 thru 179	10	Oil/water separator	Volume: 750 gals. - 15 min		0	115		115	9	2	20
350 C-180 thru 189	10	Sampling pot	Volume: 200 gals. - 15 secs		0	60		60	5	1	10
350 C-190 thru 194	10	Heptane drum	Volume: 700 gals. - 20 min		0	98		98	8	2	20
350 C-195 thru 199	5	Emergency slop tank	5000 gals		0	119		119	20	3.5	17.5
350 C-200 thru 204	5	Carbon filter drum	600 gals		0	325		325	60	5	25
350 C-204 thru 209	5	Relief KO drum	800 gals		0	59		59	10	2	10
350 CP-01	1	Air compressor	1000,SCFM, 125 psig with air receiver	150	150	158		158	150	8.00	8
350 D-100 thru 109	10	Floor sump	5000 gals. Concrete		0	0	8	8			
350 D-110 & 111	2	Boiler feed water tank	5000 gals. Concrete		0	0	120	120			
350 D-112 & 113	2	Cooling water pond	400,000 gals		0	0	200	200			
					0	0		0			
350 E-100 thru 109	10	Vapor condenser	Air Cooler-Heat Duty: 11 MMBtu/h	60	600	692		692	67	2.0	20
350 E-110 thru 119	10	Condensate cooler	Plate type-Heat Duty: 1 MMBtu/h		0	68		68	5	2.0	20
350 E-120 thru 129	10	Water preheater	Plate type-Heat Duty: 7 MMBtu/h		0	176		176	16	2.0	20
350 E-130 thru 139	10	Slurry cooler	Plate type-Heat Duty: 12 MMBtu/h		0	565		565	51	5.0	50
350 E-140 thru 149	10	Blanket gas cooler	Plate type-Heat Duty: 150,000 Btu/h		0	92		92	7	2.0	20
350 F-100	1	Steam lines	9	0	0		196	196			
350 F-102 & 106	5	Flare		0	0	364		364	64	9.0	45

APPENDIX B
PREMIUM CWF PRODUCTION FACILITY - AGGLOMERATION
Conceptual Cost Estimate
All costs are $ x1000

Equipment I.D	Qty	Title	Description	Power ea HP	Total HP	Installed Equipment Cost	Sub-contract	Total cost	Equip-unit cost supply-ea	Installation cost each	Installation cost total	
350 PP-100 thru 109	10	HSR feed pump	Horizontal slurry pump, flow 800 gpm, sp gr 1.02, TDH 80 ft	30	300	200		200	15	5.0	50	
350 PP-110 thru 119	10	Tailings transfer pump	Horizontal slurry pump, flow 1000 gpm, sp gr 1.01, TDH 50 ft	25	250	30		30	3		0	
350 PP-120 thru 129	10	Sump pump	Vertical slurry pump, flow 50 gpm, sp gr 1.2, TDH 50 ft	5	50	100		100	8	2.0	20	
350 PP-130 thru 139	10	Steam stripper A feed pump	Diaphragm type, flow 350 gpm, sp gr 1.05, Delta P 20 psi, Design temp 240 deg F		0	230		230	20	3.0	30	
350 PP-140 thru 149	10	Steam stripper B feed pump	Progressive cavity pump, flow 350 gpm, sp gr 1.05, Design Pressure 50 psi, Delta P 30 psi, Design temp 250 deg F	10	100	350		350	30	5.0	50	
350 PP-150 thru 159	10	Clean coal slurry pump	Progressive cavity pump, flow 350 gpm, sp gr 1.05, Design Pressure 50 psi, Delta P 30 psi, Design temp 250 deg F	10	100	350		350	30	5.0	50	
350 PP-160 thru 169	10	Heptane pump	Metering type, flow 400 gpm, sp gr 0.7, Design Pressure 30 psi, Delta P 30 psi, Design temp 100 deg F	10	100	310		310	25	6.0	60	
350 PP-170 thru 174	5	Emergency slop pump	Diaphragm type, flow 350 gpm, sp gr 1.05, Delta P 20 psi, Design temp 220 deg F	10	50	340		340	60	8.0	40	
350 PP-175 thru 178	4	Not used										
350 PP-179 thru 183	5	K. O. Drum pump		3	15	30		30	5	1.0	5	
350 PP-184 thru 187	4	Chilled water pump	Horizontal water pump, flow 1700 gpm, TDH 120 ft, 2 Operating and 2 spare	3	12	30		30	6	1.5	6	
350 PP-188 thru 191	4	Cooling water pump	Horizontal water pump, flow 3000 gpm, TDH 120 ft, 2 Operating and 2 spare	150	600	40		40	8	2.0	8	
350 ST-90 thru 99	10	Agglomeration feed tank	capacity- 4000 gal (6 min)		0	70		70	6	1.0	10	
350 ST-100 & 101	2	Chilled water tank	17500 gal capacity -14 ft dia x 16 ft ht Cylindrical-10 min total	0	0	34		34	15	2.0	4	
350 V-101 & 102	2	Nitrogen package			0	0	300	300	0	0.0	0	
350 V-103 & 104	2	Chiller	duty=8.5 MBtu/h	800	1600	346		346	153	20.0	40	
					0	0		0			0	
350 Y-100 thru 109	10	Screen	6' x 16' feet	15	150	730		730	65	8.0	80	
350 Y-110 thru 114	5	Gas holder and blanketing			0	0	250	250			0	
350 ZM-100 & 101	2	5-way distributor	Flow- 3500 gpm		0	22		22	9	2.0	4	
400 FT-10 thru 15	6	Filtration systems	Capacity 40 st/h - vacuum filter systems	700	4200	2,580		2,580	400	30	180	

APPENDIX B
PREMIUM CWF PRODUCTION FACILITY - AGGLOMERATION
Conceptual Cost Estimate
All costs are $ x1000

Equipment I.D	Qty	Title	Description	Power ea HP	Total HP	Installed Equipment Cost	Sub-contract	Total cost	Equip-unit cost supply-ea	Installation cost each	Installation cost total	
400 CV-15	2	Coal solid conveyor	Capacity 130 st/h-24 in wide, 125 st/h, 30 ft lift,	5	10	371		371	137	49.08	98.16	
400 PP-62 & 65	4	Filtrate pump	Flow 2500 gpm, TDH 30 ft, 2- Operating and 2- Spare	30	120	30		30	6	1.5	6	
400 ST-26 & 27	2	Filtrate sump	Capacity- 5000 gal			22		22	9	2	4	
400 ZM-05 & 06	2	Slurry distributor	Capacity-3000 gpm	10	20	36		36	15	3	6	
500 AG-09	1	Tailings filter sump agitator	Capacity of sump - 1000 gal	10	10	10		10	8	2	2	
500 BN-04	1	Tailings load-out shed	Capacity- 100 st			0	60	60				
500 CV-16	1	Tailings conveyor	Capacity - 50 st/h, 24 in x 100 ft	5	5	32		32	24	8	8	
500 FL-01	1	Tailings filter	Capacity-30st/h, 3,5 m wide	22	22	680		680	600	80	80	
500 PP-70 & 71	2	Thickener underflow pump	Horizontal slurry- capacity 500 gpm, 50 ft head, sp gr 1.07. 1- Operating, 1- Spare	15	30	40		40	15	5	10	
500 PP-72 thru 74	3	Clarified water pump	Horizontal water- capacity 5,000 gpm, 80 ft head,. 2- operating, 1- spare	150	450	72		72	20	4	12	
500 PP-75 & 76	2	Tailings filter feed pump	capacity 420 gpm,30 ft head, sp gr 1.07. 1- Operating, 1- Spare	15	30	40		40	15	5	10	
500 ST-30	1	Tailings filter feed sump	Capacity 1000 gal			11		11	8	3	3	
500 TK-01	1	Tailings thickener tank	90 ft diameter thickener tank with tunnel				327	327			0	
500 TK-02	1	Thickener overflow tank	Capacity 30,000 gal (concrete)				43	43			0	
500 TM-01	1	Tailings thickener mechanism	90 ft dia thickener mechanism with controls	15	15	167		167	146	22	22	
500 ZM-08	1	Flocculant storage,mixing and dosing system		5	5	25		25	20	5	5	
600 AG-10 & 11	2	Coal additive mixer	Retention 5 min.:	40	80	360		360	150	30	60	
600 AG-12 & 13	2	Slurry mixing tank agitator		40	80	82		82	35	6	12	
600 AG-14 thru 17	4	Slurry storage tank agitator		75	300	600		600	120	30	120	
600 PP-78 & 79	2	CWF pump	Horizontal slurry- Capacity-1500 gpm, 60 ft head, sp gr 1.17	60	120	52		52	22	4	8	
600 PP-80 thru 83	4	Slurry loading pump	Horizontal slurry- Capacity-dry solids 500 st/h- slurry 3,000 gpm, 60 ft head, sp gr 1.17, 4-Operating and 4- spare	100	400	144		144	30	6	24	
600 ST-31 & 32	2	Slurry mixing tank	10 min. each. Volume:			60		60	25	5	10	
600 ST-33 thru 36	4	Slurry fuel storage tank	0.85 million gal- 55 ft dia and 53 ft high- total 24 hr.				2,500	2,500				

APPENDIX B

PREMIUM CWF PRODUCTION FACILITY - AGGLOMERATION

Conceptual Cost Estimate

All costs are $ x1000

Equipment I.D	Qty	Title	Description	Power ea HP	Total HP	Installed Equipment Cost	Sub-contract	Total cost	Equip-unit cost supply-ea	Installation cost each	Installation cost total	
600 ZM-10 & 11	2	Flocculant storage, mixing and dosing system		10	20	140		140	50	20	40	
TOTAL MAJOR EQUIPMENT					26684	25,894	15,254	41,148			3431	

Summary

	%			Equipment	Bulks		Labor	SC	Total
Total Major Equipment				**22,464**			**3,431**	**15,254**	**41,148**
Bulks									
J Instruments	8				1,797		540		2,337
L Piping	10				2,246		1,481		3,728
M Structurals	14				3,145		1,414		4,559
N Insulation and Fire protection	3				674		444		1,118
P Electrical	14				3,145		2,358		5,503
Q Concrete	13				2,920		3,593		6,514
R Building	5							1,123	1,123
S Site work	3	(incuding internal roads)			674		832		1,505
X Painting	1							225	225
Total Bulk Materials	**71**			**22,464**	**14,601**		**10,663**	**1,348**	**26,612**
Freight			0.03	674					674
Total Direct Field Costs				**23,137**	**14,601**		**14,094**	**16,602**	**68,434**
Indirect Field Costs			60						8,456
Total Field Costs									**76,891**
Home Office and Engineering			7						4,790
Total Installed Plant Costs less Contingency									**81,681**
Contingency			17.72						14,472
Total Installed Plant Costs Including Contingency									**96,153**

APPENDIX B
PREMIUM CWF PRODUCTION FACILITY - AGGLOMERATION
Conceptual Cost Estimate
All costs are $ x1000

Equipment I.D	Qty	Title	Description	Power ea HP	Total HP	Installed Equipment Cost	Sub-contract	Total cost	Equip-unit cost supply-ea	Installation cost each	Installation cost total	

Cost Breakdown

		Cont/ ra	contin	%	Total field cost (less home office)	Total project-less contingency	Total project-with contingency
Plant 100 Raw Coal Handling		0.15	2.7	18.1	**13,886**	**0**	**0**
Plant 200 Raw Coal Crushing and Grinding		0.15	3.8	25.0	**19,249**	**0**	**0**
Plant 350 Selective Agglomeration		0.225	8.2	36.2	**27,868**	**58,067**	**68,355**
Plant 400 Clean Coal Dewatering		0.15	1.4	9.4	**7,216**	**12,398**	**14,594**
Plant 500 Water Clarification		0.15	0.6	3.7	**2,873**	**8,218**	**9,674**
Plant 600 Coal Slurry Preparation		0.15	1.1	7.5	**5,799**	**2,999**	**3,530**
Total Plant		Total	17.72	100.0	**76,891**	**81,681**	**96,153**

APPENDIX C
CWF COST SENSITIVITY CALCULATIONS - COLUMN FLOTATION
Table C-1
Changes in Coal Feed Rates and Tailings Generation for the Same Output

CASE		Base	Low	High	Remarks
Item A-(1)	Variation in Feed Ash				
	Ash in Feed Coal (Dry basis) wt%	7.5	3.75	11.25	(+) or (-) 50% over Base
	Feed Coal HV (Dry basis) Btu/lb	14,054	14,763	13,346	HV'= 15472-Ash%*189
	Clean coal ash - (Dry basis) wt %	2.7	2.7	2.7	
	Clean Coal HV (Dry basis) Btu/lb	14,962	14,962	14,962	
	lb Ash /MBtu	1.8	1.8	1.8	
	Heating value recovery -%	96.1	96.1	96.1	same in all cases- assumed
	Weight recovery-%	90.3	94.9	85.8	
	Feed coal st/st of Clean Coal	1.11	1.05	1.17	
	Feed coal wt as proportion of base case	1.00	0.95	1.05	Effect Capital: on raw coal handling, grinding, flotation 0&M grinding power, flotation reagents
	Tailings st/st of clean coal	0.11	0.05	0.17	
	Tailings generation as proportion of base	1.00	0.50	1.55	Capital: refuse filter and thickener; O&M flocculants, Refuse disposal
Item A-(2)	Variation in heating value losses				
	Ash in Feed Coal (Dry basis) wt%	7.5	7.5	7.5	No change
	Heating value losses -%	3.9	1.9	5.8	(+) or (-) 50% over Base
	Heating value recovery -%	96.1	98.1	94.2	Based on feed coal Btu
	Feed Coal HV (Dry basis) Btu/lb	14,054	14,054	14,054	
	Clean Coal HV (Dry basis) Btu/lb	14,962	14,962	14,962	
	Weight recovery-%	90.3	92.1	88.5	
	Feed coal st/st of Clean Coal	1.11	1.09	1.13	
	Feed coal wt as proportion of Base case	1.00	0.98	1.02	Effect Capital : on raw coal handling, grinding, flotation 0&M grinding power, flotation reagents-Both Negligible
	Tailings- st/st of clean coal	0.11	0.09	0.13	
	Tailings wt as proportion of Base case	1.00	0.80	1.21	Capital: refuse filter and thickener; O&M flocculants, Refuse disposal
	Btus lost as % of Btu in Product	4.0	2.0	6.2	
	Btu loss as proportion of Base case	1.0	0.49	1.53	O&M cost Btu loss- to be accounted

APPENDIX C
Table C-2
CWF COST SENSITIVITY CALCULATIONS - COLUMN FLOTATION
IMPACTS ON CAPITAL COSTS

		Base Case	Low Case	High Case	Remarks
I Capital Cost Impacts					
A (i) Variations in Feed Coal ash content- wt %					
Ash in Feed Coal (Dry Basis)	%	7.5	3.8	11.25	Variation +/- 50 %
Coal feed and Processing rate (Table C-1)	Ratios	1.00	0.952	1.053	
Tailings generation as proportion of base coal (Table C-	%	1.00	0.50	1.55	
Capital cost-Crushing, Grinding and Flotation	$ x 1000	33,135	32,012	34,355	C2=C1*(Q2/Q1)^.7
Capital cost- Water clarification & Tailings Handling	$ x 1000	3,135	1,942	4,255	C2=C1*(Q2/Q1)^.7
Rest of plant	$ x 1000	33,312	33,312	33,312	
Total Project Capital Cost	$ x 1000	69,581	67,266	71,922	
Capital Cost Impact	**$ x 1000**	Base	**-2,316**	**2,341**	
A (ii) Variations in Loss in Btu					
Btu losses	%		1.95	7.5	Variation (+)100 to (-) 50 %
Coal feed and Processing rate (Table C-1)	Ratios	1.00	0.98	1.02	
Refuse generation rate (Table C-1)	Ratios	1.00	0.80	1.21	
Capital cost-Crushing, Grinding and Flotation	$ x 1000	33,135	33,135	33,135	Negligibe change
Capital cost- Water clarification & Tailings Handling	$ x 1000	3,135	2,674	3,585	C2=C1*(Q2/Q1)^.7
Rest of plant	$ x 1000	33,312	33,312	33,312	
Total Project Capital Cost	**$ x 1000**	**69,581**	**69,121**	**70,032**	
Capital Cost Impact	**$ x 1000**	Base	**-461**	**450**	

APPENDIX C
Table C-3
CWF COST SENSITIVITY CALCULATIONS - COLUMN FLOTATION
Case A (i) and A (ii) Process Parameters
Case B (i) Price of Feed Coal
Variable and Fixed O & M Costs- Cost of CWF

Cost element	Cost of CWF Base			Cost of CWF Case A (i)-Ash in Feed Coal					
				Low			High		
	1000 x $/y	$/st product coal	$/MBtu	Factor	1000 x $/y	$/MBtu	Factor	1000 x $/y	$/MBtu
Variable O&M Costs									
Collector	249	0.17	0.01	0.95	237	0.01	1.05	262	0.01
Fother	1,059	0.71	0.02	0.95	1,008	0.02	1.05	1,115	0.02
Flocculant	1,764	1.18	0.04	0.50	890	0.02	1.55	2,729	0.06
CWF additive-A23	10,500	7.00	0.23	1.00	10,500	0.23	1.00	10,500	0.23
O&M supplies and ball charge	1,272	0.85	0.03	0.97	1,229	0.03	1.03	1,314	0.03
Electric power	5,023	3.35	0.11	0.95	4,781	0.11	1.05	5,289	0.12
Water	136	0.09	0.00	1.00	136	0.00	1.00	136	0.00
Refuse (tailings) disposal	806	0.54	0.02	0.50	406	0.01	1.55	1,246	0.03
Btu loss	2,243	1.50	0.05	1.00	2,243	0.05	1.00	2,243	0.05
Total Variable O & M Costs	23,052	15.37	0.51	-	21,432	0.48	-	24,836	0.55
Fixed O & M Costs									
Labor	6,075	4.05	0.14	1.00	6,075	0.14	1.00	6,075	0.14
Capital Charges	11,916	7.94	0.27	0.97	11,520	0.26	1.03	12,317	0.27
Total Fixed O & M Costs	17,991	11.99	0.40		17,595	0.39		18,392	0.41
Total O & M Costs	41,043	27.36	0.91		39,026	0.87		43,228	0.96
Raw Coal	55,807	37.20	1.2433	1.00	55,807	1.24	1.00	55,807	1.24
Total Premium CWF	96,850	64.57	2.1577		94,833	2.11		99,035	2.21

Cost element	Cost of CWF Case A (ii)-Loss of Btu					
	Low			High		
	Factor	1000 x $/y	$/MBtu	Factor	1000 x $/y	$/MBtu
Variable O&M Costs						
Collector	0.98	244	0.01	1.02	254	0.01
Fother	0.98	1,038	0.02	1.02	1,081	0.02
Flocculant	0.80	1,406	0.03	1.21	2,137	0.05
CWF additive-A23	1.00	10,500	0.23	1.00	10,500	0.23
O&M supplies and ball charge	0.99	1,263	0.03	1.01	1,280	0.03
Electric power	0.98	4,924	0.11	1.02	5,126	0.11
Water	1.00	136	0.00	1.00	136	0.00
Refuse (tailings) disposal	0.80	642	0.01	1.21	976	0.02
Btu loss	1.00	2,243	0.05	1.00	2,243	0.05
Total Variable O & M Costs	-	22,396	0.50	-	23733	0.53
Fixed O & M Costs						
Labor	1.00	6,075	0.14	1.00	6,075	0.14
Capital Charges	0.99	11,837	0.26	1.01	11,993	0.27
Total Fixed O & M Costs		17,912	0.40		18,068	0.40
Total O & M Costs		40,309	0.90		41,801	0.931
Raw Coal	1.00	55,807	1.24	1.00	55,807	1.24
Total Premium CWF		96,116	2.14		97,608	2.17

Cost element	Cost of CWF Case B (i)- Coal Price					
	Low			High		
	Factor	1000 x $/y	$/MBtu	Factor	1000 x $/y	$/MBtu
Variable O&M Costs						
Collector	1.00	249	0.01	1.00	249	0.01
Fother	1.00	1,059	0.02	1.00	1,059	0.02
Flocculant	1.00	1,764	0.04	1.00	1,764	0.04
CWF additive-A23	1.00	10,500	0.23	1.00	10,500	0.23
O&M supplies and ball charge	1.00	1,272	0.03	1.00	1,272	0.03
Electric power	1.00	5,023	0.11	1.00	5,023	0.11
Water	1.00	136	0.00	1.00	136	0.00
Refuse (tailings) disposal	1.00	806	0.02	1.00	806	0.02
Btu loss	0.90	2,019	0.045	1.10	2,468	0.05
Total Variable O & M Costs	-	22,827	0.51	-	23,276	0.52
Fixed O & M Costs						
Labor	1.00	6,075	0.14	1.00	6,075	0.14
Capital Charges	1.00	11,916	0.27	1.00	11,916	0.27
Total Fixed O & M Costs		17,991	0.40		17,991	0.40
Total O & M Costs		40,819	0.91		41,267	0.92
Raw Coal	0.90	50,226	1.119	1.10	61,388	1.37
Total Premium CWF		91,045	2.0284		102,655	2.29

APPENDIX C
Table C-4
CWF COST SENSITIVITY CALCULATIONS - COLUMN FLOTATION
Case B (ii) Labor, Case B (iii) Electricity, Case B (iv) Reagents and Additives

Case I. D	Cost Element	Variation		Base Case		Increase/	Revised
				Total	Element	Decrease	Cost of CWF
		Type	%	$/MBtu	$/MBtu	$/MBtu	$/MBtu
Case B (ii)	Labor	Low	-10%	2.16	0.135	-0.014	2.14
		High	10%	2.16	0.135	0.014	2.17
Case B (iii)	Electricity	Low	-10%	2.16	0.112	-0.011	2.15
		High	10%	2.16	0.112	0.011	2.17
Case B (iv)	Reagents & Additives	Low	-10%	2.16	0.263	-0.026	2.13
		High	10%	2.16	0.263	0.026	2.18

APPENDIX C
Table C - 5
CWF COST SENSITIVITY CALCULATIONS - COLUMN FLOTATION
Case C (i) Lower or Higher Plant Production- Same Operating Schedule
Case C (ii) Reduced Plant Production Due to fewer Operating Shifts

Case I. D	Production		Variable O&M		Fixed O&M		Coal		**Revised Cost of CWF**
	Base	Variant	Base	Variant	Base	Variant	Base	Variant	
	10^6st/y	10^6st/y	$/MBtu	$/MBtu	$/MBtu	$/MBtu	$/MBtu	$/MBtu	**$/MBtu**
Case C (i)-Low	1.5	1.35	0.51	0.51	0.40	**0.45**	1.24	1.24	**2.20**
Case C (i)-High	1.5	1.65	0.51	0.51	0.40	**0.36**	1.24	1.24	**2.12**

Case I. D	Production		Schedule		Employees		Variable O&M		Labor		Capital charges		Coal		**Revised Cost of CWF**
	Base	Variant	Base	Variant	Base	Variant	Base	Variant	Base	Variant	Base	Variant	Base	Variant	
	10^6st/y	10^6st/y	sht/wk	sht/wk	No.	No.	$/MBtu	$/MBtu	$/MBtu	$/MBtu	$/MBtu	$/MBtu	$/MBtu	$/MBtu	**$/MBtu**
Case C (ii)-Low	1.5	0.79	19	10	81	44	0.51	0.51	0.14	**0.14**	0.27	**0.50**	1.24	1.24	**2.40**
Case C (ii)- High	1.5	1.18	19	15	81	64	0.51	0.51	0.14	**0.14**	0.27	**0.34**	1.24	1.24	**2.23**

Case D (i), D (ii) Lower or Higher Capital Costs

	Capital Cost		Base Cost of CWF	Capital charges		Revised Cost of CWF
	Base	Variant		Base	Variant	
	$ x 1000	%	$/MBtu	$/MBtu	$/MBtu	$/MBtu
Case D (i)-Low	69,581	-10%	2.158	0.265	-0.027	2.131
Case D (i)- High	69,581	20%	2.158	0.265	0.053	2.211

APPENDIX D
Table D-1
SENSITIVITY CALCULATIONS- AGGLOMERATION
Changes in Coal Feed Rates and Tailings Generation for the Same Output

CASE		Base	Low	High	Remarks
Item A-(i)	Variation in Feed Ash				
	Ash in Feed Coal (Dry basis) wt%	7.5	3.75	11.25	(+) or (-) 50% over Base
	Feed Coal HHV (Dry basis) Btu/lb	14,054	14,763	13,346	HHV'= 15472-Ash%*189
	Clean coal ash - (Dry basis) wt %	2.7	2.7	2.7	
	Clean Coal HHV (Dry basis) Btu/lb	14,962	14,962	14,962	
	lb Ash /MBtu	1.8	1.8	1.8	
	Heating value recovery -%	99.0	99.0	99.0	same in all cases- assumed
	Weight recovery-%	93.0	97.7	88.3	
	Feed coal st/st of Clean Coal	1.08	1.02	1.13	
	Feed coal wt as proportion of base case	1.00	0.95	1.05	Effect Capital: on raw coal handling, grinding, flotation 0&M grinding power, flotation reagents
	Tailings st/st of clean coal	0.08	0.02	0.13	
	Tailings generation as proportion of base	1.00	0.31	1.76	Capital: refuse filter and thickener; O&M flocculants, Refuse disposal
Item A-(2)	Variation in heating value losses				
	Ash in Feed Coal (Dry basis) wt%	7.5	7.5	7.5	No change
	Heating value losses -%	1	0.5	1.5	(+) or (-) 50% over Base
	Heating value recovery -%	99	99.5	98.5	Based on feed coal Btu
	Feed Coal HHV (Dry basis) Btu/lb	14,054	14,054	14,054	
	Clean Coal HHV (Dry basis) Btu/lb	14,962	14,962	14,962	
	Weight recovery-%	93.0	93.5	92.5	
	Feed coal st/st of Clean Coal	1.08	1.07	1.08	
	Feed coal wt as proportion of Base case	1.00	0.99	1.01	Effect Capital : on raw coal handling, grinding, flotation 0&M grinding power, flotation reagents-Both Negligible
	Tailings- st/st of clean coal	0.08	0.07	0.08	
	Tailings wt as proportion of Base case	1.00	0.93	1.07	Capital: refuse filter and thickener; O&M flocculants, Refuse disposal
	Btus lost as % of Btu in Product	1.0	0.5	1.5	
	Btu loss as proportion of Base case	1.0	0.50	1.51	O&M cost Btu loss- to be accounted

APPENDIX D
Table D-2
SENSITIVITY CALCULATIONS- AGGLOMERATION
CAPITAL COST IMPACTS

		Base Case	Low Case	High Case	Remarks
I Capital Cost Impacts					
A (i) Variations in Feed Coal ash content- wt %					
Ash in Feed Coal (Dry Basis)	%	7.5	3.75	11.25	Variation +/- 50 %
Coal feed and Processing rate (Table D-1)	Ratios	**1.00**	**0.952**	**1.053**	
Tailings generation as proportion of base (Table D-1)	Ratios	**1.00**	**0.31**	**1.76**	
Capital cost-Crushing, Grinding and Flotation	$ x 1000	33,135	32,012	34,355	C2=C1*(Q2/Q1)^.7
Capital cost- Water clarification & Tailings Handling	$ x 1000	2,873	1,278	4,263	C2=C1*(Q2/Q1)^.7
Rest of plant	$ x 1000	61,227	61,227	61,227	
Total plant	$ x 1000	97,235	94,517	99,845	
Capital Cost Impact	$ x 1000	Base	**-2,718**	**2,610**	
A (ii) Variations in Loss in Btu					
Btu losses	%	1.00	0.50	2.00	Variation (+)100 to (-) 50 %
Coal feed and Processing rate (Table D-1)	Ratios	1.00	0.99	1.01	Negligible changes in these pl
Tailings generation (Table D-1)	Ratios	1.00	0.93	1.07	
Capital cost- Water clarification & Tailings Handling	$ x 1000	2,873	2,728	3,018	C2=C1*(Q2/Q1)^.7
Rest of plant	$ x 1000	94,361	94,361	94,361	
Total plant	$ x 1000	97,235	97,089	97,379	
Capital Cost Impact	$ x 1000	Base	**-146**	**144**	

APPENDIX D
Table D-3
SENSITIVITY CALCULATIONS - AGGLOMERATION

Case A (i) and A (ii) Process Parameter Variations
Case B (i) Feed Coal Price Variations
Variable and Fixed O & M Costs- Cost of CWF

	Cost of CWF Base			Cost of CWF Case A (i)-Ash in Feed Coal						Cost of CWF Case A (ii)-Loss of Btu						Cost of CWF Case B (i)- Coal Price					
				Low			High			Low			High			Low			High		
Cost element	1000 x $/y	$/st product coal	$/MBtu	Factor	1000 x $/y	$/MBtu	Factor	1000 x $/y	$/MBtu	Factor	1000 x $/y	$/MBtu	Factor	1000 x $/y	$/MBtu	Factor	1000 x $/y	$/MBtu	Factor	1000 x $/y	$/MBtu
Variable O&M Costs																					
Heptane	1,524	1.02	0.03	0.95	1,451	0.03	1.05	1,605	0.04	0.99	1,517	0.03	1.01	1,532	0.03	1.00	1,524	0.03	1.00	1,524	0.03
Steam	5,706	3.80	0.13	0.95	5,431	0.12	1.05	6,008	0.13	0.99	5,677	0.13	1.01	5,735	0.13	1.00	5,706	0.13	1.00	5,706	0.13
																			0.00	0	0.00
Flocculant	1,238	0.83	0.03	0.31	389	0.01	1.76	2,175	0.05	0.93	1,149	0.03	1.07	1,328	0.03	1.00	1,238	0.03	1.00	1,238	0.03
CWF additive-A23	10,500	7.00	0.23	1.00	10,500	0.23	1.00	10,500	0.23	1.00	10,500	0.23	1.00	10,500	0.23	1.00	10,500	0.23	1.00	10,500	0.23
O&M supplies and ball charge	1,607	0.75	0.03	0.97	1,562	0.02	1.03	1,650	0.03	0.999	1,604	0.02	1.001	1,609	0.03	1.00	1,607	0.03	1.00	1,608	0.03
Electric power	6,743	4.50	0.15	0.95	6,419	0.14	1.05	7,101	0.16	0.99	6,709	0.15	1.01	6,778	0.15	1.00	6,743	0.15	1.00	6,743	0.15
Water	132	0.09	0.00	1.00	132	0.00	1.00	132	0.00	1.00	132	0.00	1.00	132	0.00	1.00	132	0.00	1.00	132	0.00
Refuse (tailings) disposal	565	0.38	0.01	0.31	178	0.00	1.76	993	0.02	0.93	525	0.01	1.07	606	0.01	1.00	565	0.01	1.00	565	0.01
Btu loss	564	0.38	0.01	1.00	564	0.01	1.00	564	0.01	1.00	564	0.01	1.00	564	0.01	0.90	507	0.011	1.10	620	0.01
Total Variable O & M Costs	28,579	18.73	0.63	-	26,626	0.58	-	30,729	0.67	-	28,377	0.62	-	28783	0.63	-	28,523	0.62	-	28,636	0.63
Fixed O & M Costs																					
Labor	7,800	5.20	0.17	1.00	7,800	0.17	1.00	7,800	0.17	1.00	7,800	0.17	1.00	7,800	0.17	1.00	7,800	0.17	1.00	7,800	0.17
Capital Charges and Interest	16,414	10.94	0.37	0.97	15,955	0.36	1.03	16,855	0.38	1.00	16,390	0.37	1.00	16,439	0.37	1.00	16,414	0.37	1.00	16,414	0.37
Total Fixed O & M Costs	24,214	16.14	0.54		23,755	0.53		24,655	0.55		24,190	0.54		24,239	0.54		24,214	0.54		24,214	0.54
Total O & M Costs	52,793	34.87	1.17		50,382	1.11		55,383	1.22		52,567	1.16		53,022	1.170		52,737	1.16		52,850	1.17
Raw Coal	55,807	37.20	1.24	1.00	55,807	1.24	1.00	55,807	1.24	1.00	55,807	1.24	1.00	55,807	1.24	0.90	50,226	1.12	1.10	61,388	1.37
Total Premium CWF	108,600	72.08	2.41		106,189	2.36		111,190	2.47		108,374	2.40		108,829	2.41		102,963	2.28		114,237	2.53

APPENDIX D
Table D-4
SENSITIVITY CALCULATIONS- AGGLOMERATION
Case B (ii) Labor, Case B (iii) Electricity, Case B (iv) Reagents and Additives, Case B (v) Steam

	Cost Element	Variation		Base Case		Increase/ Decrease	Revised Cost of CWF
		Type	%	Total $/MBtu	Element $/MBtu	$/MBtu	$/MBtu
Case B (ii)	Labor	Low	-10%	2.41	0.174	-0.017	2.39
		High	10%	2.41	0.174	0.017	2.43
Case B (iii)	Electricity	Low	-10%	2.41	0.150	-0.015	2.39
		High	10%	2.41	0.150	0.015	2.42
Case B (iv)	Reagents & Additives	Low	-10%	2.41	0.268	-0.027	2.38
		High	10%	2.41	0.268	0.027	2.44
Case B (v)	Steam	Low	-10%	2.41	0.127	-0.013	2.40
		High	10%	2.41	0.127	0.013	2.42

APPENDIX D
Table D - 5
SENSITIVITY CALCULATIONS- AGGLOMERATION

Case C (i) Lower or Higher Plant Production- Same Operating Schedule
Case C (ii) Reduced Plant Production Due to fewer Operating Shifts

Case I. D	Production		Variable O&M		Fixed O&M		Coal		Revised Cost of CWF
	Base	Variant	Base	Variant	Base	Variant	Base	Variant	
	10^6st/y	10^6st/y	$/MBtu	$/MBtu	$/MBtu	$/MBtu	$/MBtu	$/MBtu	$/MBtu
Case C (i)-Low	1.5	1.35	0.63	0.63	0.54	0.60	1.24	1.24	2.47
Case C (i)-High	1.5	1.65	0.63	0.63	0.54	0.49	1.24	1.24	2.36

Case I. D	Production		Schedule		Employees		Variable O&M		Labor		Capital charges		Coal		Revised Cost of CWF
	Base	Variant	Base	Variant	Base	Variant	Base	Variant	Base	Variant	Base	Variant	Base	Variant	
	10^6st/y	10^6st/y	sht/wk	sht/wk	No.	No.	$/MBtu	$/MBtu	$/MBtu	$/MBtu	$/MBtu	$/MBtu	$/MBtu	$/MBtu	$/MBtu
Case C (ii)-Low	1.5	0.69	19	10	104	*54*	0.63	0.63	0.17	0.20	0.37	0.79	1.24	1.24	2.86
Case C (ii)- High	1.5	1.18	19	15	104	*79*	0.63	0.63	0.17	0.17	0.37	0.46	1.24	1.24	2.50

Case D (i), D (ii) Lower or Higher Capital Costs

Case I. D	Capital Cost		Base Cost of CWF	Capital charges		Revised Cost of CWF
	Base	Variant		Base	Variant	
	$ x 1000	%	$/MBtu	$/MBtu	$/MBtu	$/MBtu
Case D (i)-Low	97,235	*-10%*	2.409	0.366	0.329	2.372
Case D (i)- High	97,235	*20%*	2.409	0.366	0.439	2.482