Phase I Final Report

Production of New Biomass Waste-Containing Solid Fuels

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CQ Inc.
Homer City, Pennsylvania

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FINAL REPORT

(The Quarterly Technical Report for May 1 – July 14, 2000 is incorporated within)

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April 2001

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ABSTRACT

CQ Inc. and its team members (ALSTOM Power Inc., Bliss Industries, McFadden Machine Company, and industry advisors from coal-burning utilities, equipment manufacturers, and the pellet fuels industry) addressed the objectives of the Department of Energy and industry to produce economical, new solid fuels from coal, biomass, and waste materials that reduce emissions from coal-fired boilers. This project builds on the team's commercial experience in composite fuels for energy production.

The electric utility industry is interested in the use of biomass and wastes as fuel to reduce both emissions and fuel costs. In addition to these benefits, utilities also recognize the business advantage of consuming the waste byproducts of customers both to retain customers and to improve the public image of the industry. Unfortunately, biomass and waste byproducts can be troublesome fuels because of low bulk density, high moisture content, variable composition, handling and feeding problems, and inadequate information about combustion and emissions characteristics. Current methods of co-firing biomass and wastes either use a separate fuel receiving, storage, and boiler feed system, or mass burn the biomass by simply mixing it with coal on the storage pile.

For biomass or biomass-containing composite fuels to be extensively used in the U.S., especially in the steam market, a lower cost method of producing these fuels must be developed that includes both moisture reduction and pelletization or agglomeration for necessary fuel density and ease of handling. Further, this method of fuel production must be applicable to a variety of combinations of biomass, wastes, and coal; economically competitive with current fuels; and provide environmental benefits compared with coal.

Notable accomplishments from the work performed in Phase I of this project include the development of three standard fuel formulations from mixtures of coal fines, biomass, and waste materials that can be used in existing boilers, evaluation of these composite fuels to determine their applicability to the major combustor types, development of preliminary designs and economic projections for commercial facilities producing up to 200,000 tons per year of biomass/waste-containing fuels, and the development of dewatering technologies to reduce the moisture content of high-moisture biomass and waste materials during the pelletization process.

Dewatering technologies for pelletizing equipment were developed, including both the dewatering die technology, which incorporates a stack of die plates creating gaps between the plates for liquid to escape while material is being pressed through the

die holes, and a ram-style extruder press equipped with a die-plate stack. Pellets produced by the dewatering die showed moisture reductions of 5 to 20 percent as compared to the pelletizer feed. The laboratory-scale extruder reduced the moisture content of a coal/sewage sludge mixture by 36 percent.

Three fuel formulations with acceptable economics and environmental advantages were developed using combinations of commonly available biomass, waste materials, and recovered beneficiated coal fines that have application to a large number of U.S. boilers. These formulations represented three fuel categories:

- Premium Fuel   Anthracite Fines and Mixed Plastics
- Medium Cost/Medium Quality   Coal Fines and Sewage Sludge
- Low Cost/Low Quality   Coal Fines, Sawdust, and Asphalt Emulsion

Preliminary economic projections for commercial installations estimate that these fuels can be produced and sold at market price with after-tax ROIs ranging from 22 to 70 percent.

Based on Phase I ASTM fuel analyses, dewatering/pelletization evaluations, bench-scale pulverization and combustion test results, and boiler applicability assessments, it is recommended that a Phase II effort address the proof-of-concept (POC) and/or commercial-scale investigation of the following biomass/wastes/coal formulations: (1) Anthracite fines and mixed plastics at commercial scale, (2) Bituminous coal fines and treated sewage sludge at POC scale, and (3) Bituminous coal fines, sawdust, and asphalt emulsion at POC scale. Phase II will prove that the production and use of these new composite, solid fuels are viable at commercial scale, and will lead to future full-scale commercial demonstrations.

ACKNOWLEDGEMENTS

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- The Electric Power Research Institute, Upgraded Coal Interest Group, and Biomass Interest Group
- The Ben Franklin Partnership

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- ALSTOM Power Group, Windsor, Connecticut
- Allegheny Energy Supply, Greensburg, Pennsylvania
- Bliss Industries, Ponca City, Oklahoma
- Colona Terminal Services, Neville Island, Pennsylvania
- Electric Power Research Institute, Palo Alto, California
- General Bioenergy, Inc., Florence, Alabama
- McFadden Machine Co., Blairsville, Pennsylvania
- Pace Carbon Fuels, Fairfax, Virginia
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- Southern Company Services, Birmingham, Alabama
- Southern Indiana Gas & Electric, Evansville, Indiana
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- William Simmons, Southern Indiana Gas & Electric
- David Urchek, McFadden Machine Company

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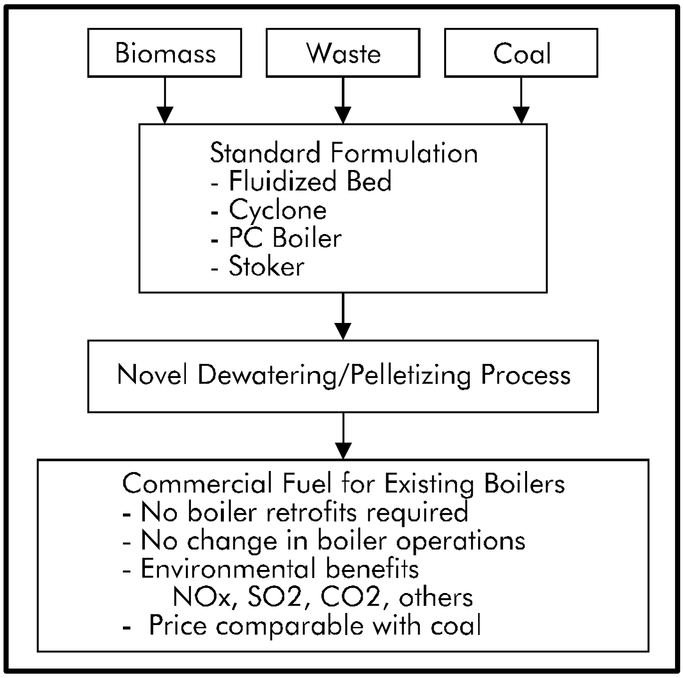
EXECUTIVE SUMMARY

CQ Inc. and its team members (ALSTOM Power Inc., Bliss Industries, McFadden Machine Company, and industry advisors from coal-burning utilities, equipment manufacturers, and the pellet fuels industry) addressed the objectives of DOE and industry to produce economical, new solid fuels from coal, biomass, and waste materials that reduce emissions from coal-fired boilers. The project builds on the team's commercial experience in composite fuels for energy production.



This report documents the results of research performed in Phase I of this project to develop standard fuel formulations from mixtures of beneficiated coal fines, available biomass, and waste materials. Bench-scale pulverization and combustion tests were conducted to determine the applicability of these fuels to various types of utility and industrial combustors.

In addition, novel dewatering technologies were developed and evaluated as a means to reduce the moisture content of feedstock materials during the pelletizing process.

Objectives

The objectives of this work were to:

- Develop a process to reduce the moisture content and economically produce biomass/waste composite fuels that can be used in existing coal-fired boilers without capital modifications or increased operating cost.

- Develop three fuel formulations using commonly available biomass, possibly mixed with coal and/or wastes, that have application to a large number of U.S. boilers and that reduce CO_2, SO_2, and NO_x emissions.

- Confirm that the fuel production process is both technically and economically feasible.

- Confirm that the three fuel formulations have broad application to U.S. boilers and assess the expected combustion and environmental impacts.

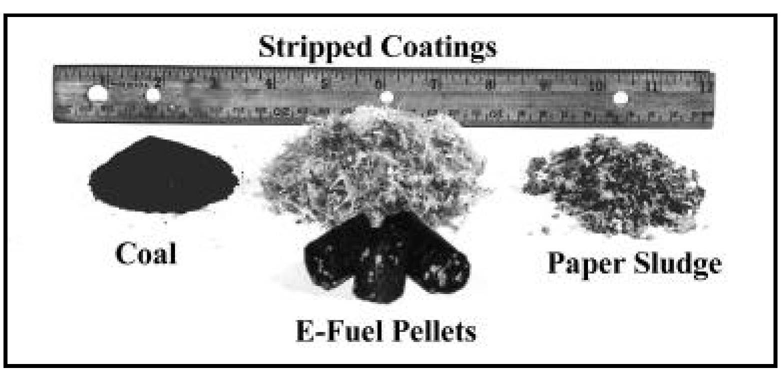
Background

The electric utility industry is interested in the use of biomass and wastes as fuel to reduce both emissions and fuel costs. In addition to these benefits, utilities also recognize the business advantage of consuming the waste byproducts of customers both to retain customers and to improve the public image of the industry. Unfortunately, biomass and waste byproducts can be troublesome fuels because of low bulk density, high moisture content, variable composition, handling and feeding problems, and inadequate information about combustion and emissions characteristics. Current methods of co-firing biomass and wastes either use a separate fuel receiving, storage, and boiler feed system, or attempt to blend the biomass by simply mixing it with coal on the storage pile.

For biomass or biomass-containing composite fuels to be extensively used in the U.S., especially in the steam market, a lower cost method of producing these fuels must be developed that includes both moisture reduction and pelletization or agglomeration for necessary fuel density and ease of handling. Further, this method of fuel production must be applicable to a variety of combinations of biomass, wastes, and coal. Finally, standard formulations of biomass and coal (possibly including waste) with broad application to U.S. boilers must be formulated. In addition to acceptable cost, these standard formulations must provide environmental benefits compared with coal.

Commercial Experience

CQ Inc. has developed and commercialized an economical method of producing fuel pellets from a paper-making waste sludge composed of wood fibers too short for use in paper manufacture, a waste plastic used to line food container cartons, and fine-sized coal. This technology minimizes some of the problems associated with the use of biomass/waste fuel by blending the biomass/waste with coal in the proper proportions to control combustion characteristics and by pelletizing the mixture to control fuel density and handling characteristics, and to prevent segregation of the components; the fuel produced by this process is E-Fuel®. Currently, CQ Inc. operates an E-Fuel production plant in



central Pennsylvania, serving a stoker boiler at Westvaco's Tyrone fine papers mill.

In effect, E-Fuel is engineered for a specific type of industrial boiler, using a specific source of biomass and waste. E-Fuel is a direct substitute for coal, and the boiler at Westvaco was not modified to utilize E-Fuel. Moreover, boiler operation procedures were only minimally adjusted. Westvaco saves over $300,000 per year in fuel purchase and waste disposal costs. Combustion tests at Westvaco demonstrated reductions of 40 percent in SO_x, 19 percent in NO_x and 52 percent in particulate emissions using E-Fuel rather than coal. Also, the use of the biomass component effectively reduces CO_2 emissions. The Pennsylvania Department of Environmental Protection accepted Westvaco's use of E-Fuel as a Reasonable Achievable Control Technology (RACT) to reduce NO_x emissions.


E-Fuel Plant Located in Tyrone, Pennsylvania

While E-Fuel represents a significant advance in the use of biomass/waste as fuel, the technology is proven only for a specific biomass/waste/coal combination. Additionally, the pellets are not weather resistant, processing costs are relatively high (over $10/ton), and the moisture content of the pellets is high. These factors limit the distance the pellets can be economically transported, the number of boilers that can use E-Fuel, and the type of biomass and waste that can be used. These factors also make it difficult for E-Fuel to be broadly price competitive with coal in the steam market.

Dewatering Die Development

Phase I of this project addressed:

- Reducing the cost of producing biomass fuels
- Developing standard formulations of biomass fuels.

The greatest single barrier to reducing processing costs is the high moisture content of biomass fuels and the high cost of pelletizing. CQ Inc. engineers developed an approach that takes advantage of the way pelletizing applies pressure to a material. If the material contains considerable moisture, the compaction process, which is integral to pelletization, is interrupted because water is not compressible. This prevents sufficient particle-to-particle contact to form a competent pellet.

Laboratory tests performed prior to this project indicated that properly-located small openings in a pelletizer die will discharge water from the die during the pelletization process. Materials to be pelletized often contain an excess of fine-sized particles, and it would be expected that any opening that would allow moisture discharge under pressure would also allow the discharge of fine-size particles, which would clog the opening. However, preliminary tests indicated that that this was not the case.

This finding promoted the development of a dewatering/pelletizing die that can be retro-fitted to existing pelletizers or extruders, or incorporated in the design of new pelletizing systems. Further, such a die could increase the effectiveness of the pelletizing process by removing excess moisture and enhancing the particle-to-particle contact required for proper pelletization. Proper die geometry must be designed to discharge water at the optimal compaction pressure, and to control pellet density as the volume of material decreases because of both water loss and compaction.

Biomass Utilization

Increasing environmental concerns about using fossil fuels for power generation have electric utilities and other power producers accelerating their pursuit of biomass and other renewable energy sources. According to some, combining biomass with coal in combustors is considered a near-term, low-risk, low-cost option for reducing greenhouse gas emissions, increasing renewable energy generation, and increasing sustainability of energy supplies for power production *("Key Issues when Cofiring Biomass with Coal in PC Boilers," L. Baxter and A. Robinson, Sandia National Laboratories)*. Renewable energy sources such as biomass have historically struggled to compete with traditional fossil fuels, and many suffer from low efficiencies and/or high technical risk when fired alone in dedicated plants.

Cofiring biomass with coal in existing utility boilers is one option to combine the renewable energy benefits of biomass with the efficiencies of large coal-fired power plants. Pollutants (SO_x and NO_x) and net greenhouse gas (CO_2) emissions will decrease with the right combination of coal, biomass, boiler design, and boiler operation. Another potential benefit is a significant use for local waste materials such as plastics and sewage sludge.

However, the combustion, physical, and handling properties of biomass can differ substantially from those of coal. In particular, the moisture content of many biomass materials is very high, often over 25 percent and sometimes greater than 50 percent. Further, low bulk density (sometimes as little as one-tenth that of coal) can cause segregation of the materials in boiler feed bins and bunkers and other handling problems, the end result being inconsistent boiler feed and reduced combustion efficiency. Other critical combustion issues associated with the firing of biomass with coal include pulverization characteristics, ash deposition, corrosion, ash disposal, and carbon burnout. The goal of this project is to develop standard fuel formulations from coal, biomass, and/or waste materials with broad applicability to U.S. combustors, and improve the densification and physical integrity of these materials by removing excess water during the fuel production process.

Project Management

In addition to the technical work, project activities included several supplemental activities under the Project Management task.

A Project Management Plan was prepared at the outset of the project to ensure its successful completion. The plan documented the teaming arrangement and summarized the responsibilities of the key project personnel. It also contained an expended, detailed description of the work scope required to complete the project, including a stated objective(s), background, technical approach, and deliverables for each of the seven major tasks. A Milestone Schedule, organized by the project Work Breakdown Schedule (WBS), was also prepared to guide the project. Quarterly Project Status reports were submitted to provide the Department of Energy with a summary of technical progress and budget status. These reports included a review of technical progress organized by major WBS elements, a cost management report, and a labor management report.

A Technical Advisory Committee (TAC) was formed to steer the project, providing technical review and industry perspective on the work. The committee consisted of representatives from the coal and electric utility industries, equipment manufacturers and fabricators, fuel technology developers, and several research organizations. TAC meetings allowed the project team an opportunity to share the results of the project tasks with industry representatives, and provided an opportunity for the industry representatives to review and comment on the results, and provide advice to the project team members for future work. Two TAC meetings were held during the course of the project.

Representatives from the following organizations served on the Technical Advisory Committee, providing technical insights and industry perspective on Phase I work:

- *Allegheny Energy Supply, Greensburg, PA*
- *Bliss Industries, Ponca City, OK*
- *Colona Terminal Services, Neville Island, PA*
- *Electric Power Research Institute, Palo Alto, CA*
- *General Bioenergy, Florence, AL*
- *McFadden Machine Co., Blairsville, PA*
- *Pace Carbon Fuels, Fairfax, VA*
- *Pellet Fuels Institute, Adams, MA*
- *Public Service Electric & Gas, Newark, NJ*
- *Southern Company Services, Birmingham, AL*
- *Southern Indiana Gas & Electric, Evansville, IN*
- *TJ Gundlach Machine, Belleville, IL*
- *US Department of Energy, Pittsburgh, PA*

Feedstock Characterization

Six biomass/waste sources were initially selected for study in Task 1-2: petroleum coke, mixed waste plastic, waxed cardboard, switchgrass, poultry manure, and sewage sludge. Also, two sources of coal, recovered from waste ponds, were collected for use in the project. Both coals are from Northern Appalachia: a medium-sulfur bituminous coal from western Pennsylvania and a high-sulfur bituminous coal from eastern Ohio.

Samples of the above materials were collected and analyzed as follows:

- Proximate--moisture, volatile matter, fixed carbon, ash
- Ultimate--carbon, hydrogen, nitrogen, sulfur, ash, oxygen
- Heating Value (Btu/lb)
- Chlorine and Sodium
- Ash Composition--SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, Na_2O, K_2O, TiO_2, MnO_2, P_2O_5, SO_3
- Ash Fusion Temperature--reducing and oxidizing
- Trace Elements--arsenic, beryllium, cadmium, chromium, cobalt, copper, fluorine, lead, manganese, mercury, nickel, selenium, zinc.
- Toxic Characteristic Leaching Procedure (TCLP)

Table S-1 provides a summary of relevant parameters from the ASTM analyses for each sample, plus an additional column detailing properties of a dewatered (10% final moisture) sewage sludge based on the as-received wet analysis.

ALSTOM Power, through it s US Power Plant Laboratory Group (US PPL), reviewed the ASTM analyses of the candidate feedstocks to qualitatively assess their applicability to four combustor types based on a review of five potential impact areas. The four combustor types were:

- Pulverized Coal (PC)
- Circulating Fluidized Bed (CFB)
- Stoker
- Cyclones

Relevant impact areas included the fuel s reactivity, slagging & fouling behavior, corrosion potential, fuel handling & preparation issues, and pellet size & integrity concerns. The candidate fuels were ranked with regard to their potential for performance impact as a means to identify those fuels with the most favorable/least deleterious overall characteristics for use in a composite, pelletized solid fuel.

Table S-1. Feedstock Analyses

Identification	Ginger Hill Coal Fines	Pleasant Ridge Coal Fines	Switch Grass	Petroleum Coke	Mixed Plastics	Waxed Cardboard	Sewage Sludge	*Sewage Sludge 10% Moisture*	Poultry Manure 1	Poultry Manure 2
Chemical Analyses										
VM	29.2%	32.8%	80.2%	13.0%	92.2%	79.6%	9.3%	*55.7%*	60.5%	23.5%
FC	45.7%	40.5%	7.7%	79.4%	5.3%	8.7%	1.3%	*7.9%*	8.1%	2.1%
FC/VM	1.56	1.23	0.10	**6.12**	0.06	0.11	0.14	*0.14*	0.13	0.09
HHV, BTU/lb	11,335	10,858	7,521	14,201	14,425	9,610	1,117	*6,715*	5,406	2,043
LHV, BTU/lb	10,721	10,251	6,895	13,753	13,374	8,741	**118**	*6,122*	4,902	**1,238**
Moisture	19.5%	*19.5%*	8.0%	7.2%	0.2%	9.3%	**85.0%**	*10.0%*	*9.1%*	**60.8%**
Hydrogen	4.2%	4.1%	5.6%	3.8%	10.8%	7.9%	0.8%	*5.0%*	4.2%	1.5%
Carbon	63.1%	58.5%	43.8%	**80.5%**	67.8%	50.2%	5.8%	*34.6%*	32.8%	12.1%
Sulfur	1.3%	3.3%	0.1%	**5.1%**	0.3%	0.2%	0.3%	*1.6%*	0.3%	0.1%
Nitrogen	1.0%	0.9%	1.4%	1.4%	0.1%	0.1%	0.8%	*5.0%*	3.8%	1.2%
Oxygen	5.3%	6.4%	37.1%	1.6%	18.4%	29.9%	2.9%	*17.4%*	27.4%	10.6%
Ash	5.6%	7.2%	4.1%	0.4%	2.3%	2.5%	4.4%	***26.4%***	**22.4%**	**13.6%**
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	*100.0%*	100.0%	100.0%
O/N	5.3	6.9	27.3	1.1	184.1	229.7	3.5	*3.5*	7.1	8.7
lb N/MMBTU	0.88	0.85	1.81	0.97	0.07	0.14	**7.43**	***7.43***	**7.10**	**5.97**
lb S/MMBTU	1.14	3.08	0.16	3.61	0.23	0.20	2.42	*2.42*	0.50	0.49
lb Ash/MMBTU	4.9	6.6	5.5	0.3	1.6	2.6	**39.3**	***39.3***	**41.4**	**66.6**
Chlorine	0.12%	0.06%	0.22%	0.03%	**0.98%**	0.20%	0.03%	*0.18%*	**0.45%**	0.15%
lb_Cl/MMBTU	0.11	0.05	**0.29**	0.02	**0.68**	**0.21**	**0.27**	***0.27***	**0.83**	**0.73**
Fluorine (ppm)	53	59	27	58	0	0	43	*261*	32	15
Ash Fusibility Temps. (°F)	Reducing Atm.	Reducing Atm.	Reducing Atm.	Reducing Atm.	Reducing Atm.	Reducing Atm.	Reducing Atm.	*Reducing Atm.*	Reducing Atm.	Reducing Atm.
I.T.	**2075**	**1940**	1,960	2,210	2,560	2,100	2,000	*2,000*	2,500	2,485
S.T.	2125	1990	2,000	2,240	2,565	2,140	2,020	*2,020*	2,550	2,505
H.T.	2180	2035	2,010	2,270	2,570	2,155	2,070	*2,070*	2,560	2,525
F.T.	**2280**	**2075**	2,030	2,295	2,575	2,165	2,120	*2,120*	2,570	2,545
Diff. (F.T. - I.T.)	205	135	70	85	15	na	120	*120*	70	60
Ash Fusibility Temps. (°F)	Oxidizing Atm.	Oxidizing Atm.	Oxidizing Atm.	Oxidizing Atm.	Oxidizing Atm.	Oxidizing Atm.	Oxidizing Atm.	*Oxidizing Atm.*	Oxidizing Atm.	Oxidizing Atm.
I.T.	2345	2375	2,040	2,050	2,500	2,200	2,080	*2,080*	2,595	2,570
S.T.	2370	2405	2,080	2,090	2,510	2,255	2,110	*2,110*	2,610	2,585
H.T.	2400	2420	2,100	2,110	2,515	2,290	2,145	*2,145*	2,620	2,600
F.T.	2430	2450	2,120	2,130	2,525	2,320	2,200	*2,200*	2,640	2,615
Diff. (F.T. - I.T.)	85	75	80	80	25	na	120	*120*	45	45
Ash Composition										
SiO2	47.1%	38.4%	35.4%	25.4%	0.8%	26.9%	34.4%	*34.4%*	3.4%	3.1%
Al2O3	20.7%	15.0%	5.9%	8.2%	0.6%	17.4%	12.8%	*12.8%*	1.7%	0.9%
Fe2O3	**15.1%**	**25.8%**	4.1%	8.9%	0.2%	4.9%	13.2%	*13.2%*	3.2%	4.5%
TiO2	1.1%	1.6%	0.3%	0.6%	0.3%	12.5%	1.6%	*1.6%*	0.1%	0.1%
CaO	5.8%	5.1%	12.2%	11.3%	1.3%	15.9%	9.0%	*9.0%*	29.0%	32.4%
MgO	1.1%	0.8%	9.8%	2.9%	0.2%	1.9%	2.1%	*2.1%*	3.6%	3.5%
Na2O	0.4%	0.6%	2.4%	1.2%	0.2%	**8.8%**	0.9%	*0.9%*	1.5%	1.4%
K2O	2.0%	1.3%	**15.1%**	1.3%	0.0%	1.5%	1.5%	*1.5%*	**8.0%**	**9.4%**
P2O5	0.1%	0.2%	8.1%	0.5%	0.2%	1.1%	15.4%	*15.4%*	13.3%	12.9%
SO3	7.4%	8.7%	5.0%	20.1%	0.6%	7.6%	2.1%	*2.1%*	2.2%	1.9%
Total	100.7%	97.6%	98.2%	80.4%	*4.4%*	98.3%	92.8%	*92.8%*	*66.0%*	*70.1%*
Base / Acid Ratio	0.35	**0.61**	1.05	0.75	1.04	**0.58**	**0.54**	***0.54***	8.71	12.45
Fe2O3 / CaO	2.61	5.04	**0.34**	0.79	**0.14**	**0.31**	1.47	*1.47*	**0.11**	0.14
SiO2 / Al2O3	2.28	2.56	**6.05**	3.10	1.30	1.54	2.69	*2.69*	1.97	3.68
lb K+Na/MMBTU	0.12	0.12	**0.95**	0.01	0.00	0.26	**0.92**	***0.92***	**3.94**	**7.22**
Ash Behavior										
Ash-Type	Bituminous	Bituminous	Lignitic-Like	Lignitic-Like	Lignitic-Like	Lignitic-Like	Bituminous-Like	*Bituminous-Like*	Lignitic-Like	Lignitic-Like
Slagging Potential	Medium - High	High	Severe	Low - Medium	Low	High	Medium	*Medium*	High	High
Fouling Potential	Low	Medium	Severe	Low - Medium	Low - Medium	Severe	High	*High*	Severe	Severe

Each of the candidate feedstocks was evaluated by ALSTOM Power personnel with regard to the above impact areas based on the analyses provided in Table S-1. A summary of these results is provided in Table S-2.

Table S-2. Combustor Assessment

Identification	Ginger Hill	Pleasant Ridge	Switch	Petroleum	Mixed	Waxed	Sewage	*Sewage Sludge*	Poultry	Poultry
	Coal Fines	Coal Fines	Grass	Coke	Plastics	Cardboard	Sludge	*10% Moisture*	Manure 1	Manure 2
PC										
Applicability	High	High	Low	Low	na	Low	na	*Low*	Low	na
Max Heat Input	100%	100%	10%	20%	0%	20%	0%	*10%*	10%	0%
Constraint	Slag. & Foul.	Slag. & Foul.	Slag. & Foul.	Reactivity	Preparation	Slag. & Foul.	Reactivity	*Slag. & Foul.*	Slag. & Foul.	Slag. & Foul.
								Reactivity	Reactivity	Reactivity
CFB										
Applicability	High	High	Low	High	Medium	High	na	*Low*	Low	na
Max Heat Input	>90%	>90%	10%	100%	25%	100%	0%	*15%*	15%	0%
Constraint	Size & Integ.	Size & Integ.	Slag. & Foul.	Size & Integ.	Corrosion	Slag. & Foul.	Reactivity	*Slag. & Foul.*	Slag. & Foul.	Slag. & Foul.
					Size & Integ.					Reactivity
Stoker										
Applicability	Medium	Medium	Low	Low	Medium	Medium	Low	*Low*	Low	Low
Max Heat Input	50%	50%	20%	10%	25%	50%	10%	*15%*	15%	10%
Constraint	Size & Integ.	Size & Integ.	Slag. & Foul.	Reactivity	Corrosion	Slag. & Foul.	Reactivity	*Slag. & Foul.*	Slag. & Foul.	Slag. & Foul.
					Size & Integ.					Reactivity
Cyclone										
Applicability	High	High	Low	Medium	Medium	Medium	na	*Low*	Low	na
Max Heat Input	100%	100%	20%	25%	25%	50%	0%	*15%*	15%	0%
Constraint	Size & Integ.	Size & Integ.	Slag. & Foul.	Reactivity	Corrosion	Slag. & Foul.	Reactivity	*Slag. & Foul.*	Slag. & Foul.	Slag. & Foul.
					Size & Integ.					Reactivity

Of the non-coal fuels and feedstocks, the waxed cardboard and the petroleum coke offer the best promise based on their ASTM properties for use in a pelletized, composite fuel. The waxed cardboard is desirable based on its high volatile matter content and acceptable chlorine content (~0.20% / 0.2 lb/MMBtu), while the petroleum coke is desirable due to its high heating value, and low chlorine content. However, the high sodium content in the waxed cardboard ash (9% by weight), and low volatile content (13%) in the petroleum coke place limits on their application due to fouling and reactivity/combustion efficiency, respectively, for all combustor types except a CFB. The high sulfur content (5.1%) of the petroleum coke will also likely be a concern for certain boilers both with regard to SO_2 formation and capture, and corrosion potential.

The switch grass and air-dried poultry manure were deemed undesirable for use except at extremely low mass fractions due to their previously noted high sodium and potassium contents considered on a pound per million BTU basis. Although better, the mixed plastics sample is similarly not desirable for use in significant mass fractions due to the high chlorine content of this particular sample (the chlorine content of a mixed waste plastics stream can vary substantially depending on the amount of PVC material in the stream). In addition, the mixed plastic may be undesirable for use in PC applications based on a potential problem with pasting in existing fuel handling and milling equipment.

Pursuant to the results of the fuel applicability analyses and preliminary economic considerations, three composite fuel blends were identified for further evaluation:

- 85% petroleum coke, 15% mixed plastics
- 80% medium-sulfur coal fines, 20% waxed cardboard
- 80% medium-sulfur coal fines, 20% dried sewage sludge

Pellet Characterization and Combustor Applicability

A laboratory pellet mill was fabricated and used to produce fuel pellets from the above three fuel formulations. These samples were then subjected to a series of chemical, physical, and combustion test procedures to assess their applicability to the four primary boiler types.

Pertinent analyses of the three tested pelletized fuels are given in Table S-3; the analysis for the medium-sulfur coal fines is also included for comparison.

ALSTOM Power Inc. assessed the pulverization and combustion characteristics of the three selected pelletized fuels, including bench-scale pulverization evaluations using a Grindability Index (AGI) machine, pyrolysis testing in a drop tube furnace system, thermo-gravimetric analyses (TGA) to determine relative reactivity as compared to a typical, bituminous coal char, and weak acid leaching to assess the relative slagging potential of the pellet ash constituents. In assessing the applicability of the three solid fuels to the four noted combustor types, consideration was given to five primary impact areas based on each fuel s previously identified ASTM analysis, and performed bench scale pulverization and reactivity testing reactivity, slagging and fouling characteristics, corrosion behavior, fuel handling and preparation, and pellet size and integrity. Results of an analysis considering the applicability of each of the three tested fuels for each of the four noted combustor types are summarized in Table S-4.

Of the tested fuels, the 80% coal and 20% sewage sludge is the most broadly applicable, being suitable for use at greater than or equal to 50% maximum continuous rating (MCR) heat input for each of the four considered combustor types. For PC and CFB firing, the as-tested coal/sewage sludge fuel may be used at ≥ 90% MCR maximum heat input, with limitations based on slagging & fouling concerns, which are related to the design and operation of the specific field unit (e.g., size of the box and firing rate), and pellet size & integrity, which is related to the raw feed size (size of fines) and pelletizing equipment characteristics, respectively. For stoker and cyclone firing, this fuel is rated at up to 50% maximum heat input, with limitations based on fuel pellet size and integrity as they affect the fuel handling equipment performance and the combustion process.

Table S-3. As-Received Composite, Pelletized Fuel Analyses

Identification	100% Ginger Hill	85% Pet Coke 15% Plastics	80% Ginger Hill 20% W. Crdbd.	80% Ginger Hill 20% S. Sludge
VM	29.2%	27.5%	38.0%	32.6%
FC	45.7%	71.1%	39.8%	50.2%
FC/VM	1.56	2.59	1.05	1.54
HHV, BTU/lb	11,335	15,373	12,200	12,374
LHV, BTU/lb	10,721	14,880	11,565	11,832
Moisture	19.5%	0.5%	16.2%	9.2%
Hydrogen	4.2%	5.0%	4.7%	4.6%
Carbon	63.1%	85.1%	61.3%	68.8%
Sulfur	1.3%	4.5%	1.2%	1.6%
Nitrogen	1.0%	1.0%	1.0%	1.2%
Oxygen	5.3%	2.9%	9.5%	6.6%
Ash	5.6%	1.0%	6.1%	8.1%
Total	100.0%	100.0%	100.0%	100.0%
O/N	5.3	2.9	9.6	5.3
lb N/MMBTU	0.88	0.64	0.81	1.00
lb S/MMBTU	1.14	2.95	0.99	1.26
lb Ash/MMBTU	4.9	0.6	5.0	6.5
Chlorine	0.12%	0.37%	0.08%	0.16%
lb Cl/MMBTU	0.11	0.24	0.07	0.13
Fluorine (ppm)	53	92	64	ND
FSI	ND	1.0	4.5	9.0
HGI	ND	44	34	67
Density (lbs/ft^3)	ND	33.3	ND	32.5

Source: "Feedstock Characterization: Phase 1 Task 5 Final Report for CQ Inc.," PPL-00-CT-05, C.Q. Maney, June, 2000, © Combustion Engineering, Inc.

Table S-3. As-Received Composite, Pelletized Fuel Analyses (continued)

Identification	100% Ginger Hill	85% Pet Coke 15% Plastics	80% Ginger Hill 20% W. Crdbd.	80% Ginger Hill 20% S. Sludge
Ash Fusion (^oF)	Reducing Atm.	Reducing Atm.	Reducing Atm.	Reducing Atm.
I.T.	2,075	2,065	2,170	2,045
S.T.	2,125	2,110	2,190	2,090
H.T.	2,180	2,135	2,230	2,130
F.T.	2,280	2,150	2,285	2,170
Diff. (F.T. - I.T.)	205	85	115	125
Ash Fusion (^oF)	Oxidizing Atm.	Oxidizing Atm.	Oxidizing Atm.	Oxidizing Atm.
I.T.	2,345	2,285	2,340	2,290
S.T.	2,370	2,330	2,400	2,350
H.T.	2,400	2,360	2,415	2,380
F.T.	2,430	2,425	2,430	2,400
Diff. (F.T. - I.T.)	85	140	90	110
Ash Comp.				
SiO2	47.1%	25.3%	46.6%	45.3%
Al2O3	20.7%	5.6%	20.5%	20.6%
Fe2O3	15.1%	9.0%	13.9%	15.7%
TiO2	1.1%	6.0%	1.7%	1.1%
CaO	5.8%	9.1%	4.6%	5.6%
MgO	1.1%	2.2%	1.2%	1.2%
Na2O	0.4%	1.7%	1.7%	1.2%
K2O	2.0%	*8.4%*	1.4%	2.3%
P2O5	0.1%	0.0%	0.1%	2.1%
SO3	7.4%	15.1%	7.4%	7.0%
Total	100.7%	82.3%	99.2%	102.0%
Base / Acid Ratio	0.35	0.82	0.33	0.39
Fe2O3 / CaO	2.61	0.99	3.04	2.83
SiO2 / Al2O3	2.28	4.48	2.27	2.20
lb K+Na/MMBTU	0.12	0.06	0.16	0.23
Slag Potent.	Medium-High	High	High	High
Foul Potent.	Low	Severe	Medium	High

Source: "Feedstock Characterization: Phase 1 Task 5 Final Report for CQ Inc.," PPL-00-CT-05, C.Q. Maney, June, 2000, © Combustion Engineering, Inc.

Table S-4. Combustor Applicability

Application	85% Pet Coke 15% Plastics	80% Ginger Hill 20% W Crdbd	80% Ginger Hill 20% S. Sludge
PC			
Applicability	na	na	High
Max Heat Input	0%	0%	>90%
Constraint(s)	Milling Corrosion	Milling	Slagging & Fouling
CFB			
Applicability	Medium	High	High
Max Heat Input	50%	>90%	>90%
Constraint(s)	Size & Integrity. Corrosion	Size & Integrity.	Size & Integrity.
Stoker			
Applicability	Low	Medium	Medium
Max Heat Input	10%	50%	50%
Constraint(s)	Ash Content Corrosion	Size & Integrity. Ash Content	Size & Integrity.
Cyclone			
Applicability	Medium	Medium	Medium
Max Heat Input	25%	50%	50%
Constraint(s)	Size & Integrity. React./Corrosion.	Size & Integrity.	Size & Integrity.

Neither the petroleum coke/mixed plastics fuel nor the coal/waxed cardboard fuel were found to be generally applicable to all combustor types, and only the coal/waxed cardboard fuel is applicable as a primary fuel in any one. Both of these fuels exhibited significant problems in the bench-scale pulverization testing, including difficulty in size reduction and bed pad formation making them inapplicable to PC firing as determined by this scale of testing. The petroleum coke/mixed plastics fuel, because of its low reactivity char combined with its small (~30 micron) particle size, may compound combustion efficiency issues for CFB, stoker, and cyclone fired boilers. In addition, the high chlorine content of this particular sample of mixed plastics resulted in the composite fuel pellet also having high chlorine content (0.37%), which is both undesirable due to boiler corrosion potential, and indicative of the issues in firing a mixed plastic blend.

A fourth formulation, comprised of coal fines, sawdust, and asphalt emulsion, was evaluated when the coal/waxed cardboard formulation indicated marginal economics. The addition of asphalt emulsion to fine coal is the GranuFlow™ Process technology developed by DOE, and results in an agglomerated product with improved dewatering characteristics and flowability properties, more resistant to freezing, and reduces dust generation during handling; it also improves the recovery of fine-sized coal during the beneficiation process. Tests at commercial coal-cleaning plants showed that fine coal recovery from mechanical dewatering devices increased 13-17 percent at emulsion dosages as low as 0.7 percent and as high as 3.6 percent.

Sawdust has been co-fired with coal in at least four cyclones and 12 PC boilers, and several utilities have successfully fired sawdust blended with coal prior to the pulverizer; however, segregation of the sawdust occurred during handling in some tests and the sawdust entered the pulverizer in slugs, reducing pulverizer capacity. These test results and conversations with industry experts indicate that, other than possible concerns about pulverizer performance, sawdust is an excellent fuel when fired with coal because of low fouling potential and SO_2, NO_x and CO_2 reduction.

The Department of Energy's National Energy Technology Laboratory (NETL) has successfully burned asphalt-treated coal produced using the GranuFlow technology in a test PC boiler. Two- to four-hour tests showed no difficulty in achieving the desired particle size distribution and moisture content at a typical mill outlet temperature. Further, only small differences in fly ash loss-on-ignition (LOI) and emissions as compared to the baseline coal were noted. The results of these tests establish the technical feasibility of burning GranuFlow-treated coal in a PC boiler. However, the combination of coal, sawdust, and asphalt has never been tested for combustion characteristics.

Process Design and Economic Assessment

Conceptual flowsheets and preliminary capital and operating costs were developed for commercial facilities to produce fuel pellets from the following fuel formulations:

- Anthracite Silt/Mixed Plastics 100,000 tons per year
- Bituminous Coal Fines/Waxed Cardboard 100,000 tons per year
- Bituminous Coal Fines/Sewage Sludge 200,000 tons per year

For the mixed plastics case, anthracite silt was used in place of petroleum coke due to the potential market attractiveness of the anthracite stove fuel market, availability of anthracite fines, and concerns about the high sulfur content of petroleum coke. A fourth formulation, comprised of coal fines, sawdust, and asphalt emulsion, was also evaluated when the coal/waxed cardboard formulation indicated marginal economics.

Premium Fuel: Anthracite Fines & Waste Plastic

This formulation was developed for a premium fuel market, specifically the stoker and home-heating market which requires a very high-quality solid fuel which can sell for up to $70 per ton FOB plant. Beneficiated anthracite silt (90% by weight, as-received) is pelletized using waste mixed plastics as a binder (10% by weight, as-received). The final pelleted low-moisture, high-btu product is projected to have the following quality (as-received):

- 1.5% Moisture
- 9.0% Ash
- 0.56% Total Sulfur
- 13,000 Btu/lb

The use of waste plastic as a binder reduces fuel production costs. Due to its high volatile content (>90%), the volatile content of the fuel pellets can be adjusted to meet customer needs by varying the amount of plastics in the formulation. Plastic also has essentially no ash or sulfur and is high in heating value. Low ash reduces particulate emissions, and the combination of high heat content and low sulfur reduces SO_2 emissions. Preliminary economic projections for a 100,000-tpy commercial plant indicate that fuel pellets made from anthracite fines and plastics can be produced and sold at market price with an after-tax ROI of almost 31 percent (assuming that the pellet plant owner collects no tipping fee for the waste plastics, and that the plastics are delivered at no cost to the plant owner).

Medium Cost/Medium Quality: Coal Fines & Sewage Sludge

This formulation was developed for a medium grade fuel market, specifically the electric utility steam coal market. Beneficiated coal fines (80% by weight, dry basis), such as the type recovered from waste coal slurry impoundments, and treated sewage sludge (20% by weight, dry basis) are mixed and pelletized. The sewage sludge is typically received with very high moisture content (80-85 percent), and a combination of thermal drying and the pelletizer dewatering die would be used to reduce the moisture content of the final product to 15 percent. The final pelleted product is projected to have the following quality (as-received):

- 15.0% Moisture
- 10.0% Ash
- 1.4% Total Sulfur
- 10,800 Btu/lb

Preliminary economic projections for a 200,000-tpy commercial plant indicate that fuel pellets made from coal fines and sewage sludge can be produced and sold at market price with an after-tax ROI of about 22 percent (assuming that the pellet plant owner collects a tipping fee of $40 per wet ton for the sewage sludge).

Low Cost/Low Quality: Coal Fines, Sawdust, and Asphalt Emulsion

This formulation was developed for a low grade fuel market, specifically the electric utility steam coal market. Beneficiated coal fines (90% by weight, as-received), such as the type recovered from waste coal slurry impoundments, and sawdust (10% by weight, as-received) are slurried during the coal preparation process. An asphalt emulsion (at 2% dosage) is added to the slurry prior to the mechanical dewatering step. This is the GranuFlow™ Process technology developed by DOE, and results in an agglomerated product with improved dewatering characteristics and flowability properties, more resistant to freezing, and reduces dust generation during handling; it also improves the recovery of fine-sized coal during the beneficiation process. This product is only considered to be "low quality" because of its finer size consist and high moisture content as compared to typical steam-grade bituminous coals. Applying this technology to an existing 50-tph fines circuit and adding 5-tph sawdust results in an agglomerated product with the following quality (as-received):

- 19.0% Moisture
- 5.2% Ash
- 1.2% Total Sulfur
- 11,000 Btu/lb

Phase I tests indicated that the same dewatering/handling benefits are realized when adding asphalt emulsion to the coal/sawdust mixture as that realized when adding the asphalt emulsion to just coal alone. Preliminary economic projections were made for a case in which 5 tph of sawdust (at a delivered cost of $6 per ton) were added to an existing 50-tph fine clean coal stream, and then that mixture treated with a 2-percent dosage of asphalt emulsion (at a delivered cost of $110 per ton) prior to mechanical dewatering. The addition of the emulsion was projected to increase fine coal recovery by about 10 percent. With an existing coal cleaning plant and only minimal retrofit capital investment required for the emulsion storage tanks, pumps, etc., this case showed an ROI of almost 70 percent.

Development of Dewatering Pelletizer Technologies

A 300 pounds-per-hour, semi-pilot scale dewatering pelletizing mill was fabricated to produce test batches of cylindrical pellets from mixtures of coal fines, biomass, and wastes (Figure S-1). Various die geometries, including die diameter, die length-to-diameter (L/D) ratio, die inlet tapers, and moisture discharge configurations, were investigated to optimize mill operation and performance.

The original dewatering die design was improved with the addition of back pressure plates, located just beneath the die stack, to increase the resistance of material flow through the die, thus increasing material residence time and compaction, and increasing the quantity of water discharged from between the die plates.

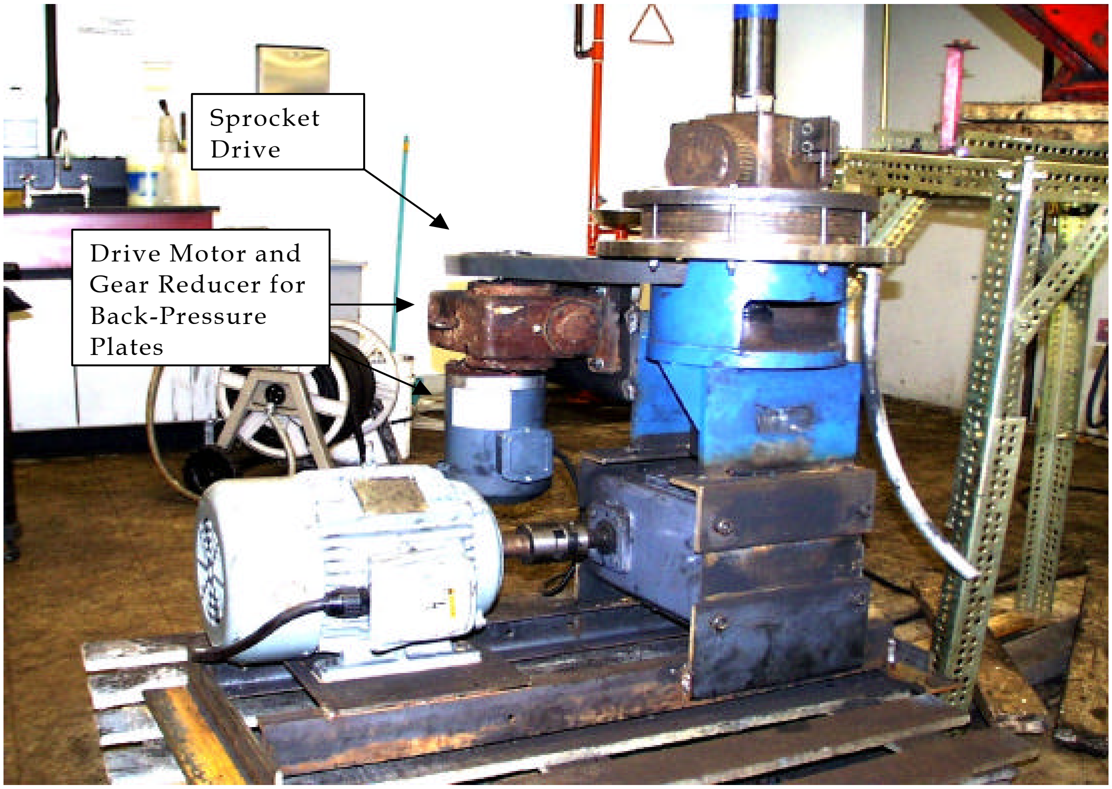


Figure S-1. Semi-Pilot-Scale Dewatering Pelletizer

Initial dewatering die tests were performed with beneficiated coal fines recovered from a slurry pond impoundment in western Pennsylvania. With feedstock moistures of 15-22 percent, moisture reductions of 5-10 percent were achieved. At feedstock moistures over 22 percent, moisture reductions of around 20 percent were achieved with the back-pressure plates installed (no dewatering occurred above feedstock moistures of 22 percent without the back pressure plates). Similar results were achieved with the coal/sewage sludge mixtures. At feedstock moistures less than 15 percent, the dies usually plugged and no dewatering occurred, with or without back-pressure plates.

The use of the back-pressure plate allowed lower length-to-diameter (L/D) ratios. The best dewatering results were achieved with the following mill configuration: back-pressure plates, low L/D ratios (1.7-2.1), a ¼-inch taper on the top die plate, and tapered shims (increasing in thickness from 0.005" on the shaft side of the die plate to 0.020" on the outer edge of the die plate) placed around the perimeter and between the die plates.

Pellet mills cannot feed materials with a moisture content over about 25 percent. To address the issue of high-moisture feedstocks, a laboratory-scale ram extruder was fabricated. This unit was able to process a feed consisting of 50-percent sewage sludge and 50-percent coal (as-received weight percent, total mix moisture of 47 percent) to produce pellets of about 23-percent moisture. A feed of 20-percent sewage sludge and 80-percent coal (total mix moisture of 25 percent) produced pellets at 16-percent moisture, a reduction of 36 percent.

Conclusions

Notable accomplishments from the work performed in Phase I of this project include the development of three standard fuel formulations from mixtures of coal fines, biomass, and waste materials that can be used in existing boilers, evaluation of these composite fuels to determine their applicability to the major combustor types, development of preliminary designs and economic projections for commercial facilities producing up to 200,000 tons per year of biomass/waste-containing fuels, and the development of dewatering technologies to reduce the moisture content of high-moisture biomass and waste materials during the pelletization process.

Dewatering technologies for pelletizing equipment were developed, including both the dewatering die technology, which incorporates a stack of die plates creating gaps between the plates for liquid to escape while material is being pressed through the die holes, and a ram-style extruder press equipped with a die-plate stack. Pellets produced by the dewatering die showed moisture reductions of 5 to 20 percent as compared to the pelletizer feed. The laboratory-scale extruder reduced the moisture content of a coal/sewage sludge mixture by 36 percent.

Three fuel formulations with acceptable economics and environmental advantages were developed using combinations of commonly available biomass, waste materials, and recovered beneficiated coal fines that have application to a large number of U.S. boilers. These formulations represented three fuel categories:

- Premium Fuel   Anthracite Fines and Mixed Plastics
- Medium Cost/Medium Quality   Coal Fines and Sewage Sludge
- Low Cost/Low Quality   Coal Fines, Sawdust, and Asphalt Emulsion

Preliminary economic projections for commercial installations estimate that these fuels can be produced and sold at market price with after-tax ROIs ranging from 22 to 70 percent.

Based on Phase I ASTM fuel analyses, dewatering/pelletization evaluations, bench-scale pulverization and combustion test results, and boiler applicability assessments, it is recommended that a Phase II effort address the proof-of-concept (POC) and/or commercial-scale investigation of the following biomass/wastes/coal formulations: (1) Anthracite fines and mixed plastics at commercial scale, (2) Bituminous coal fines and treated sewage sludge at POC scale, and (3) Bituminous coal fines, sawdust, and asphalt emulsion at POC scale. Phase II will prove that the production and use of these new composite, solid fuels are viable at commercial scale, and will lead to future full-scale commercial demonstrations of each formulation.

INTRODUCTION

CQ Inc. and its team members (ALSTOM Power Inc., Bliss Industries, McFadden Machine Company, and industry advisors from coal-burning utilities, equipment manufacturers, and the pellet fuels industry) addressed the objectives of DOE and industry to produce economical, new solid fuels from coal, biomass, and waste materials that reduce emissions from coal-fired boilers. The project builds on the team's commercial experience in composite fuels for energy production.

This report documents the results of research performed in Phase I of this project to develop standard fuel formulations from mixtures of beneficiated coal fines, available biomass, and waste materials. Bench-scale pulverization and combustion tests were conducted to determine the applicability of these fuels to various types of utility and industrial combustors. In addition, novel dewatering technologies were developed and evaluated as a means to reduce the moisture content of feedstock materials during the pelletizing process.

Phase I work was performed over an 18-month period, from January 22, 1999 to July 14, 2000.

Objectives

The objectives of this work were to:

- Develop a process to reduce the moisture content and economically produce biomass/waste composite fuels that can be used in existing coal-fired boilers without capital modifications or increased operating cost.

- Develop three fuel formulations using commonly available biomass, possibly mixed with coal and/or wastes, that have application to a large number of U.S. boilers and that reduce CO_2, SO_2, and NO_x emissions.

- Confirm that the fuel production process is both technically and economically feasible.

- Confirm that the three fuel formulations have broad application to U.S. boilers and assess the expected combustion and environmental impacts.

RESULTS AND DISCUSSION

Phase I of the project was completed according to the following major tasks:

- Task 1-2. Feedstock Characterization
- Task 1-3. Optimize Dewatering Die Geometry
- Task 1-4. Prototype Die Evaluation
- Task 1-5. Market Assessment of Biomass/Waste-Containing Fuel Formulations
- Task 1-6. Process Design and Economic Analysis

Task 1-1 encompassed the project management requirements for the project, including all contractor responsibilities, project reporting, scheduling, and budgeting requirements, technical advisory committee input and meetings, technology transfer, and QA/QC activities.

In brief, the work in Phase I of this project has:

- Developed three standard fuel formulations from mixtures of coal fines, biomass, and waste materials that can be used in existing boilers without major capital modifications or increased operating costs.

- Evaluated the individual components of these fuels and the composite fuels to determine their applicability to the four major combustor types: pulverized coal, circulating fluidized bed, stokers, and cyclones.

- Indicated that these new fuels can be transformed into solid, densified forms which can be handled, stored, and fired in a manner similar to coal.

- Developed preliminary design and economic projections for commercial facilities producing up to 200,000 tons per year of biomass/waste-containing fuels.

- Continued the development of the dewatering die to reduce the moisture content of high-moisture biomass and waste materials, and improve the pelletization process.

The results of Phase I of this project are documented by task in the following sections.

Task 1-1
PROJECT MANAGEMENT

Objective: Provide a comprehensive, coordinated project planning, scheduling, budgeting, and reporting effort.

Accomplishments:

- Prepared and submitted Management Plan, Milestone Schedule/Plan, Cost and Labor Plans.
- Quarterly management and technical status reports submitted on a timely basis.
- Two Technical Advisory Committee meetings held.
- Monitored analytical laboratory's quality assurance/quality control procedures for all sample handling and analytical procedures.

CQ Inc. had overall management responsibility for the project. Mr. David J. Akers, Vice-President for CQ Inc., served as the Project Manager and primary point-of-contact for the Department of Energy, Technical Advisory Committee members, and other project sponsors.

Mr. Glenn A. Shirey, Project Manager at CQ Inc., served as the task manager for all feedstock and pellet sample collection/characterization activities (tasks 1-2 and 1-5), as well as the economic assessment work performed in Task 1-6. He was also responsible for managing the subcontract issued to ALSTOM Power, Inc. under tasks 1-2 and 1-5. ALSTOM Power was contracted to assist in the selection and evaluation of the biomass/waste-containing solid fuels for application to existing solid fuel combustors. Mr. Charles Q. Maney, Technical Manager, Firing Systems at ALSTOM Power's US Power Plant Laboratories (U.S. PPL), was responsible for the technical and administrative execution of the fuel characterization work performed at ALSTOM.

Mr. Zalman Zitron, Senior Project Engineer at CQ Inc., served as the task manager for the dewatering investigations performed under tasks 1-3 and 1-4, and was intimately involved with the design, fabrication, operation, and testing of the laboratory pellet mill.

Project Planning and Reporting

A Project Management Plan was prepared at the outset of the project to ensure its successful completion. The plan documented the teaming arrangement and summarized the responsibilities of the key project personnel. It also contained an expanded, detailed description of the work scope required to complete the project, including stated objectives, background, technical approach, and deliverables for each of the seven major tasks.

A Milestone Schedule was also prepared during the first month of the project, organized by the project Work Breakdown Schedule (WBS) as shown as Table 1-1.

Table 1-1. Work Breakdown Schedule Phase I

Element	Description
1.0	PHASE I: LABORATORY RESEARCH AND DEVELOPMENT
1.1	Project Management
1.1.1	Project Reporting, Scheduling, and Budgeting
1.1.2	Project Technical Advisory Committee and Project Team Meetings
1.1.3	Technology Transfer
1.1.4	Quality Assurance/Quality Control and Total Quality Management
1.2	Feedstock Characterization
1.2.1	Survey Available Sources of Biomass and Waste
1.2.2	Collect Biomass, Waste, Bitumen, and Coal Samples
1.2.3	Characterize Samples
1.2.4	Initial Selection of Three Biomass/waste-Containing Fuel Formulations
1.3	Optimize Die Geometry
1.3.1	Fabricate Laboratory Test Unit
1.3.2	Evaluate Various Geometry's on the Coal and Biomass Samples
1.4	Testing of Prototype Dies
1.4.1	Laboratory Simulated Dynamic Testing of the Three Formulations Selected in 1.2.4.
1.4.2	Evaluation of Altering Size Distribution
1.4.3	Evaluation of Dewatering and Binding Additives
1.5	Market Assessment
1.5.1	Identify Potential Users of Biomass/waste-Containing Fuel
1.5.2	Finalize Selection of Three Fuel Formulations
1.5.3	Laboratory Combustion Characterization of Each Fuel Formulation
1.5.4	Environmental Characterization of Each Fuel Formulation
1.6	Process Design and Economic Analysis
1.6.1	Design a Flowsheet to Produce Each Fuel Formulation
1.6.2	Estimate Capital and Operating Costs for Each Flowsheet
1.6.3	Estimate Delivered Cost of Each Fuel
1.7	Final Report and Revised Proposal Volumes
1.7.1	Prepare Phase I Final Technical Report
1.7.2	Prepare Revised Summary Phase II Technical, Cost, and Business and Management Proposal Volumes

Project team members referenced the Project Management Plan and Milestone Schedule throughout the project, ensuring that milestones and budget projections were met. Progress review meetings, via teleconference and site visits, were held to maintain project schedule, review task activities and plan for future work.

Quarterly Project Status reports were submitted to provide the Department of Energy with a summary of technical progress and budget status. These reports included a review of technical progress organized by major WBS elements, a cost management report, and a labor management report.

Technical Advisory Committee

A Technical Advisory Committee (TAC) was formed to steer the project, providing technical review and industry perspective on the work. The committee consisted of representatives from the coal and electric utility industries, equipment manufacturers and fabricators, fuel technology developers, and several research organizations. Industry involvement of this type during the development stage will greatly enhance the commercialization prospects of technologies such as those being developed under this project.

TAC meetings allowed the project team an opportunity to share the results of the project tasks with industry representatives, and provided an opportunity for the industry representatives to review and comment on the results, and provide advice to the project team members for future work. Two TAC meetings were held during the course of the project. The first TAC meeting was held April 20-21, 1999, at CQ Inc.'s headquarters in Homer City, Pennsylvania; the second TAC meeting was held April 25-26, 2000 at the U.S. Department of Energy's National Energy Technology Laboratory (NETL) located in Pittsburgh, Pennsylvania.

Representatives from the following organizations served on the Technical Advisory Committee, providing technical insights and industry perspective on Phase I work:

- *Allegheny Energy Supply, Greensburg, PA*
- *Bliss Industries, Ponca City, OK*
- *Colona Terminal Services, Neville Island, PA*
- *Electric Power Research Institute, Palo Alto, CA*
- *General Bioenergy, Florence, AL*
- *McFadden Machine Co., Blairsville, PA*
- *Pace Carbon Fuels, Fairfax, VA*
- *Pellet Fuels Institute, Adams, MA*
- *Public Service Electric & Gas, Newark, NJ*
- *Southern Company Services, Birmingham, AL*
- *Southern Indiana Gas & Electric, Evansville, IN*
- *TJ Gundlach Machine, Belleville, IL*
- *US Department of Energy, Pittsburgh, PA*

Technology Transfer

A technical paper, "Production of New Biomass/Waste-Containing Solid Fuels," was presented at the 25th International Technical Conference on Coal Utilization and Fuel Systems, March 6 9, 2000, in Clearwater, Florida.

An application was submitted to the U.S. Patent Office covering the concept of the dewatering die in September 1998. The Patent Office subsequently informed CQ Inc. that the patent will issue. CQ Inc. intends to file for foreign patents and to file an apparatus patent covering the use of the back pressure plate developed during this project.

Quality Assurance/Quality Control

Quality assurance (QA) is the planning and implementation of systematic actions to provide adequate confidence that a product or service will satisfy given needs. Quality control (QC) is the purposeful direction of operational techniques and activities to sustain the characteristics of a product or service. QA/QC activities for this project were directed in two primary areas: data/sample collection and laboratory analytical procedures.

QA/QC Data and Sample Collection

QA/QC ensured that data generation, data gathering, and measurement activities during the testing of the laboratory pellet mill produced reliable and useful results. A detailed test log was maintained by the test engineer to document all tests performed during Phase I of the project. All test materials, conditions, and observations were recorded for each test. Sampling of the mill feedstock and final product occurred when the test engineer determined that the mill had reached steady-state operation (i.e., operating temperatures had been attained, desired uniform feed rate to the mill achieved, etc.).

For test samples requiring laboratory analysis, a sample tracking protocol was established. An eight-digit sample identification number was assigned, relating the test date and specific run number. For example, the 2nd test performed on September 14, 1999, would be identified as Run No. 99091402. Run numbers are documented in the test log. Every sample collected for each test (e.g., feedstock and product) was marked with the test's run number. An analytical service request (ASR) form was completed for each sample, and attached to the sample container for transport to the laboratory. The ASR lists the test date, run number, sample description, desired analyses, and responsible test engineer. Upon receipt at the laboratory, the samples were entered into a laboratory logbook, assigned a laboratory sample identification number, and placed in the custody of the person responsible for performing the analysis. Archived sample splits were routinely saved for 90 days unless otherwise noted on the ASR.

QA/QC Analytical

Sample analyses were determined using ASTM standards and procedures except where noted. The standards that apply for coal and coal ash analyses are given in Table 1-2. In addition, the standards and procedures used for analyzing trace elements in coal and coal ash are listed in Table 1-3.

As summarized in the QA/QC plan of the laboratory contractor for this project, Standard Laboratories, Inc., the quality control program for laboratory analysis made use of several different types of QC samples to document the validity of analytical precision and accuracy, including:

Blank Samples. Method blanks were processed through the sample preparation process to account for possible contamination introduced in the laboratory. At least one method blank accompanies each set of program samples through the entire analytical scheme.

Duplicate Samples. At least one sample in each analysis batch of 10 to 12 or fewer samples was analyzed in duplicate. The duplicate samples were submitted as known QC samples, as laboratory control samples (LCSs) such as a NIST Standard Reference material, or as "blind" QC samples that were not recognizable to the analyst. LCSs were used routinely to ensure that the analytical process was under control.

Table 1-2. ASTM Analytical Procedures Followed by the Project's Coal Laboratory

Analysis	Standard Number & Title
Sampling	D 2013: Standard Test Method for Preparing Coal Samples for Analysis *Referenced Documents:* D 197; D 410 Method for Sieve Analysis of Coal; D 431 Test Method for Designating the Size of Coal from its Sieve Analysis; D 2234; D 3173; D 3174; D 3302; E 11; E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods
Total Moisture	D 3302 Standard Test Method for Total Moisture in Coal *Referenced Documents:* D 121 Terminology of Coal and Coke; D 2013 Method of Preparing Coal Samples for Analysis; D 2234 Method for a Collection of a Gross Sample of Coal; D 2961 Test Method for Total Moisture in Coal Reduced to No. 8 (2.36-mm) Top Sieve Size (Limited Purpose Method); D 3173 Test Method for Moisture in the Analysis Sample of Coal and Coke
HGI	D 409: Standard Test Method for Grindability of Coal by the Hardgrove-Machine Method *Referenced Documents:* D 2013; D 2234; D 4749 Test Method for Performing the Sieve Analysis of Coal and Designating Coal Size
Heating Value	D 1989: Standard Test Method for Gross Calorific Value of Coal and Coke by Microprocessor Controlled Isoperibol Calorimeters *Referenced Documents:* D 121; D 346 Practice for Collection and Preparation of Coke Samples for Laboratory Analysis; D 388; D 1193 Specification for Reagent Water; D 2013; D 3173; D 3177 Test Method for Total Sulfur in the Analysis Sample of Coal and Coke; D 3180 Practice for Calculating Coal and Coke Analysis from As-Determined to Different Bases; D 4239 Test Methods for Sulfur in the Analysis Sample of Coal and Coke Using High Temperature Tube Furnace Combustion Methods; E 144 Practice for Safe Use of Oxygen Combustion Bombs D 2015: Standard Test Method for Gross Calorific Value of Coal and Coke by the Adiabatic Bomb Calorimeter *Referenced Documents:* D 121; D 346; D 1193; D 2013; D 3173; D 3177; D 3180; D 4239; E 1 Specification for ASTM Thermometers; E 144
Ultimate Analysis	D 3176: Standard Practice for Ultimate Analysis of Coal and Coke *Referenced Documents:* D 346; D 2013; D 2234; D 2361 Test Method for Chlorine in Coal; D 2795 Test Methods for Analysis of Coal and Coke Ash; D 3172 Practice for Proximate Analysis of Coal and Coke; D 3173; D 3174 Test Method for Ash in the Analysis Sample of Coal and Coke from Coal; D 3177; D 3178 Test Methods for Carbon and Hydrogen in the Analysis Sample of Coal and Coke; D 3179 Test Methods for Nitrogen in the Analysis Sample of Coal and Coke; D 4239
Proximate Analysis	D 3172: Standard Practice for Proximate Analysis of Coal and Coke *Referenced Documents:* D 346; D 388; D 2013; D 2234; D 3173; D 3174; D 3175 Test Method for Volatile Matter in the Analysis Sample of Coal and Coke
Sulfur Forms	D 2492: Standard Test Method for Forms of Sulfur in Coal *Referenced Documents:* D 1193; D 2013; D 3173; D 3177; D 3180; D 4239; E 832 Specification for Laboratory Filter Papers

Table 1-2. ASTM Analytical Procedures Followed by the Project's Coal Laboratory (Continued)

Analysis	Standard Number & Title
Ash Composition	D 2795: Standard Test Methods for Analysis of Coal and Coke Ash *Referenced Documents:* D 1757 Test Methods for Sulfur in Ash from Coal and Coke
	D 3682: Standard Test Method for Major and Minor Elements in Coal and Coke Ash by Atomic Absorption *Referenced Documents:* D 1193; D 1757; D 3180
Sizing	D 4749: Standard Test Method for Performing the Sieve Analysis of Coal *Referenced Documents:* D 197 Test Method for Sampling and Fineness Test of Pulverized Coal; D 346; D 388; D 2013; D 2234; D 4371 Test Method for Determining the Washability Characteristics of Coal; E 11 Specification for Wire-Cloth Sieves for Testing Purposes; E 323 Specification for Perforated-Plate Sieves for Testing Purposes
Ash Fusion	D 1857: Standard Test Method for Fusibility of Coal and Coke Ash *Referenced Documents:* D 2013; D 3174

Table 1-3. ASTM Analytical Procedures for Trace Elements in Coal and Coal Ash

Arsenic and Selenium	D 3684: Standard Test Method for Total Mercury in Coal by the Oxygen Bomb Combustion/Atomic Absorption Method (GFAAS). This method was modified for As and Se by using a quartz liner in the oxygen bomb. *Referenced Documents:* D 1193; D 2013; D 2234; D 3173; D 3180; E 144
Mercury	D 3684: Standard Test Method for Total Mercury in Coal by the Oxygen Bomb Combustion/Atomic Absorption Method (GFAAS). *Referenced Documents:* D 1193; D 2013; D 2234; D 3173; D 3180; E 144
Antimony, Beryllium, Cadmium, Cobalt, Chromium, Lead, Manganese, and Nickel	D 3683: Standard Test Method for Trace Elements in Coal/Coke Ash by Atomic Absorption *Referenced Documents:* D 346; D 1193; D 2013; D 3180
Chlorine	D 4208: Standard Test Method for Total Chlorine in Coal by the Oxygen Bomb Combustion/Ion Selective Electrode Method *Referenced Documents:* D 1193; D 3173; D 3180; E 144
Fluorine	D 3761: Standard Test Method for Total Fluorine in Coal by the Oxygen Bomb Combustion/Ion Selective Electrode Method *Referenced Documents:* D 3173; D 3180; E 144

Task 1-2
FEEDSTOCK CHARACTERIZATION

Objective: Develop three fuel formulations using commonly available biomass, mixed with coal fines and/or wastes, that have application to U.S. utility and industrial boilers with the potential to reduce CO_2, SO_2, and NO_x emissions.

Accomplishments:

- Samples collected of three biomass sources (switchgrass, poultry manure, and treated sewage sludge), three waste sources (petroleum coke, mixed waste plastic, and waxed cardboard), and two beneficiated coals recovered from coal refuse slurry impoundments.
- Samples characterized for typical industry fuel, ash, and combustion properties using industry-standard ASTM analytical procedures.

Survey Available Sources of Biomass and Waste

A survey was conducted to identify the sources of biomass and waste, and eventually select biomass and waste materials used in developing the three fuel formulations. The survey was aimed at identifying available biomass and wastes not being utilized (or being under-utilized), and available in sufficient quantities to be considered for commercial utilization as feedstock for a fuel pelleting process. Survey tools included a review of available technical/trade publications, internet access, telephone contact, and consultation with the Technical Advisory Committee.

The internet proved to be particularly useful in gathering information. Web pages of interest included the following:

- Biomass Energy Research Association http://www.crada.com/bera
- Biopower Home Page http://www.eren.doe.gov/biopower
- GEM Global Energy Marketplace http://gem.crest.org
- National Renewable Energy Laboratory http://www.nrel.gov
- Solstice Sustainable Energy & Development Online http://www.solstice.crest.org
- U.S. Department of Energy Regional Biomass Energy http://www.esd.ornl.gov/bfdp/rbep
- American Forest & Paper Association http://www.afandpa.org
- The Corrugated Packaging Council http://www.corrugated.org
- Plastics News http://www.plasticsnews.com
- Plastics Recycling http://www.recycle.net/recycle/Plastic
- Plastics Resource (American Plastics Council) http://www.plasticsresource.com
- EPA MSW Factbook http://www.epa.gov/epaoswer
- PA DEP Waste Management http://www.dep.state.pa.us

Biomass is all nonfossil organic materials that have an intrinsic chemical energy content *("An Introduction to Biomass Energy, A Renewable Resource," D.L. Klass, Entech International, Inc.)*. This includes all water- and land-based vegetation and trees (virgin biomass), and all waste biomass such as municipal solid waste (MSW), municipal biosolids (sewage sludge), animal wastes (manures), forestry and agricultural residues, and certain types of industrial wastes. The contribution of biomass energy to U.S. energy consumption in the late 1970s was over 850,000 barrels of oil equivalent (BOE) per day, or about 2% of total energy consumption. By 1990, the biomass energy contribution had increased to 1.4 million BOE per day, or about 3.3% of total energy consumption, and is expected to show continued significant growth. Global biomass energy consumption was almost 7% of the world's total energy consumption in 1990.

Currently, there are no virgin biomass species that are routinely grown in the U.S. for use as power plant fuels. Many renewable energy technologies that utilize biomass suffer from low efficiencies, high technical risk, and other market entry problems. Although some tax incentives have been provided to promote the use of biomass for power generation, many have expired or require certain conditions that prove to be very difficult to implement (e.g., 1992 Energy Policy Act 1.5¢/kWh "closed-loop" biomass tax credit). However, there are many power plants that are fueled (or co-fueled) with waste biomass. Such plants often receive credits for waste disposal, such as tipping fees for receiving MSW; or the power generated is a by-product and is used on-site; or the plant is located in an area near the biomass source whose disposal is a problem. Among the utilities that have been or are actively involved in biomass co-firing projects are GPU Generation Inc., Morristown, NJ; Tennessee Valley Authority, Chattanooga, TN; Niagara Mohawk Power Corp., Syracuse, NY; Illinois Power Co., Decatur, IL; Alliant Energy, Madison, WI; Southern Company, Atlanta, GA; and Northern Indiana Public Service Co. (NIPSCO), Hammond, IN *(Power, July/August 1999)*.

Six biomass/waste sources were initially selected for study: petroleum coke, mixed waste plastic, waxed cardboard, switchgrass, poultry manure, and sewage sludge. Also, two sources of coal, recovered from waste ponds, were collected for use in the project. Both coals are from Northern Appalachia: a medium-sulfur bituminous coal from western Pennsylvania and a high-sulfur bituminous coal from eastern Ohio.

Petroleum Coke

Coking is a thermal process which normally converts the heaviest fraction of crude oil that distills at over 1,000 °F to light products used mainly as transportation fuels. The thermal "cracking" process creates lighter boiling compounds and petroleum coke as a solid residue. The least valued, higher-sulfur grades of petroleum coke are sold in the fuel market as a substitute or supplementary fuel to coal. When compared to typical bituminous steam coals, petroleum coke has the following advantages and disadvantages:

Petroleum Coke vs. Coal Advantages

- Higher heating value (10-30% higher)
- Lower ash content (0.2-0.5% compared to coal at 10%)
- Lower fuel cost (20-30% less than coal)

Petroleum Coke vs. Coal Disadvantages

- High sulfur content (typically 4-5%)
- Low volatile content (about 12%)
- Hardness (<50 HGI) can cause grinding/blending problems
- High metals content (vanadium, nickel)

Petcoke production increased 64% between 1980 and 1990. Since 1992, world production of petroleum coke has grown 40 percent and is expected to increase with 15 new cokers expected to come on-line by 2003. North America produces 80 percent of the world's petroleum coke, with U.S. production at 90,000 tpd in 1998. Approximately 67 percent of the petroleum coke produced in the U.S. is exported overseas as fuel coke, with Japan being the largest importer.

Petroleum coke is available at a much lower price than coal in part because the low volatile matter content of petroleum coke provides poor carbon burnout in conventional boilers. This not only wastes energy, but also raises the carbon content of flyash, which can make it unsuitable for use in concrete.

The price of petroleum coke delivered to utilities was $0.78 per MMBtu in 1996 and, with coke production growing, the price of coke as a fuel is expected to decline, making it attractive to both cement kiln operators and utilities. Increase in fuel-grade coke consumption by cement kiln operators is expected to grow 5 percent annually.

Mixed Plastics

Plastics production in the U.S. increased from 25 million tons in 1989 to 40 million tons in 1999. Approximately 14 million tons of "post-use" plastics are disposed as MSW annually; these plastics constitute about 9% of all wastes generated in the U.S. The American Plastics Council estimates that 45-90 pounds/capita/year of post-use plastics are available from the residential sector, and another 25-50 pounds/capita/year of post-use plastics are available from the commercial sector (excluding PET and HDPE bottles). Approximately 750,000 tons of mixed thermoplastics are generated each year from shredded automobile residue.

Potential sources of mixed plastics for use in a composite fuel facility include (1) general residential and commercial municipal waste (MSW) streams, (2) commercial/industrial businesses thought to have high disposal rates for post-use plastic scrap (e.g., auto shredders, agricultural industry, etc.), and (3) plastic converters (e.g., plastic product manufacturers). Source materials for a composite fuel facility would likely consist of commingled post-use plastics, even with some minor levels of contamination, that traditional plastic recycling markets could not accommodate due to their need to separate plastics by resin type. Obviously, geographic regions with high populations and an abundance of plastics converters and major manufacturers would be best suited for siting a composite fuel facility that utilizes plastics as a component in producing fuel pellets. Table 2-1 estimates the daily quantities of plastics disposed by various converters and industries (*R.W. Beck/American Plastics Council, Recovery Options for Plastics)*.

Table 2-1. Converters and Major Commercial/Industrial Sources of Discarded Plastics

Plastic Source (Converter or Business)	Primary U.S. Geographic Locations	Potential Plastics Disposed (tons per facility per day)
Manufacturers using cross-linked plastic	East and Midwest	negligible - 0.8
Manufacturers using multi-layer packaging	East and Midwest	negligible – 0.5
Carpet manufacturers	Southeast	0.8 - 8.0
Diaper manufacturers	East and Midwest	8.0 - 24.0 [1]
Tape/label manufacturing	East and Midwest	0.1 – 0.4
Auto Assembly	Michigan	Minimal
Auto shredding	Texas, Michigan, Alabama, California	Significant
Agricultural film plastic	Central to Southern California; Central to Southern Florida; Rio Grande Valley of Texas; Ohio Valley; Selected Mid-Atlantic states	California, with 23,000 acres of strawberry crops, would generate approx. 2,700 tons per year (~8 tpd) of plastic mulch (at 240 lbs/acre)
Electronics/Computer Mfg.	Western U.S., North Carolina	Minimal
Pulp and Paper Mills (OCC and mixed paper consuming mills)	South/Southeast, West, Midwest, and Northeast	1.8 to 36.4

[1] Generally, quantities of disposed diaper scrap are used in waste-to-energy facilities or on-site industrial boilers. Includes only plastics quantities, and excludes other types of materials found in diaper scrap such as absorbent materials.

Depending on the capacity of the composite fuel facility and the quantity of mixed plastics required as feedstock, some portion of the materials may have to be sourced from the general residential and commercial sector to supplement the materials that could be obtained from plastic convertors and industrial generators.

Plastics, being derived from petroleum or natural gas, have higher heating value than any other material commonly found in MSW streams (Table 2-2).

Table 2-2. MSW Materials Heating Value

Material	Heating Value, Btu/lb
PET (Polyethylene Terephthalate)	10,900
HDPE (High Density Polyethylene)	18,700
Other Plastic Containers	16,400
Other Plastics	17,900
Rubber & Leather	12,800
Newspaper	8,000
Corrugated Boxes (paper)	7,000
Textiles	9,400
Wood	7,300
MSW (average)	5,900
Yard Wastes	2,900
Food Wastes	2,900

Source: www.plasticsindusty.org

Plastics are also typically very low in ash content (<3%) and sulfur content (<0.5%), and very high in volatile matter (>90%). Depending on the PVC content of a mixed plastics stream, chlorine levels can exceed those of typical bituminous steam coals.

Waxed Cardboard

Approximately 1.5 million tons of waxed corrugated cardboard (WCC) containers are produced annually in the U.S. Plastic, paper and cardboard comprise about 45 percent of total grocery waste streams, with WCC accounting for almost 10 percent of the total.

WCC containers are used for shipping produce that needs to be kept moist or on ice, such as fresh fruits and vegetables. The wax provides a highly effective moisture barrier so that the container maintains its strength. However, since wax is not water soluble and therefore difficult to repulp, most paperboard mills are not capable of recycling these types of containers, and they are often landfilled. It is estimated that 98-99% of the wax must be separated from the fibers for a waxed box to be considered truly recyclable into containerboard. Current technologies are able to separate a high percentage of the wax, but still not at those recovery levels. Other recovery/utilization options for WCC containers include composting (mixed in with other organic materials) and the manufacture of artificial fire logs *(Resource Recycling, March 1999)*.

WCC is typically low in ash (2-3 percent) and sulfur (0.2 percent), and high in volatile matter, with heating value in the 9,000 11,000 Btu/lb range. The Oxygen-to-Nitrogen (O/N) ratio of WCC is very high, an indicator of potential reduced NO_x generation from combustion. The primary combustion concern for WCC is the sodium content of the ash, and its potential impact on fouling the boiler if used as a major component in a fuel blend.

Switchgrass

Switchgrass is a native, warm-season perennial grass in North America, frequently used for hay, grazing, and resource conservation purposes. Compared to eastern bituminous coals, herbaceous energy crops such as switchgrass are typically higher in moisture content (about 15%) and volatile matter (65-85%), while lower in sulfur content (0.15%) and heating value (6,500-7,000 Btu/lb).

A primary concern when burning switchgrass in a boiler is increased slagging and fouling due to the high alkali content potassium, sodium, and calcium of the ash as compared to coal. Switchgrass and other growing plants selectively concentrate potassium in their cells which, along with nitrogen and phosphorous, are the key nutrients for plant growth *("Production of Electricity from Biomass Crops," R.P. Overend, National Renewable Energy Laboratory)*. Under combustion conditions, the potassium is mobilized at relatively low temperatures and can foul heat transfer surfaces and corrode high performance metals.

Some organizations and utilities have co-fired switchgrass with coal. In 1996, Madison Gas & Electric utilized a 49-MW wall-fired pulverized coal boiler to separately inject and co-fire 10% switchgrass (by heat content). A multi-year $20 million DOE/USDA project is underway in Iowa to study production of different forms of energy from switchgrass. Approximately 4,000 acres have been planted for harvest in 2000. IES Utilities will separately inject the switchgrass as part of a co-fire test program.

High production/harvesting costs also inhibit the use of switchgrass as an energy crop. Typical energy crops require approximately 1,000 acres for each megawatt of generation. Delivered price for switchgrass is estimated at $3.00-$5.00 per MMBtu, as compared to today's average delivered coal price of about $1.20 per MMBtu. Efforts to increase crop yields and reduce production costs are needed to make switchgrass and other energy crops more price competitive with coal and other fossil fuels.

Poultry Manure

Approximately 19.5 million tons of chicken and turkey manure are produced each year by the U.S. poultry industry. The most common use for poultry manure today is as a fertilizer for agricultural fields due to its high content of nitrogen and phosphorous. Fuel and feed are also options for poultry manure utilization. Chicken manure can be burned, producing about one-third the fuel value of coal, or converted to methane in biomass converts. Chicken manure can also be used to feed ruminant animals, such as cattle, that can extract unused nutrients *("Designing Chicken Manure," Dr. P. Patterson, The Pennsylvania State University)*.

Fresh manure is about 75 percent water and the moisture will evaporate from the accumulating manure while it is in the poultry house. Under adequate ventilation conditions, only about one-third of the original manure weight will remain. Manure output varies according to the size and feed intake of the poultry type. Laying chickens generate about 800 pounds per month per 100 birds; growing Broilers generate 1,000 pounds per month per 100 birds; and growing large Tom Turkeys generate 3,600 pounds per month per 100 birds. Table 2-3 summarizes the major fertilizer elements in fresh manure *("Poultry Manure Management and Utilization Problems and Opportunities," The Ohio State University Bulletin 804, www.ag.ohio-state.edu)*.

Table 2-3. Poultry Manure Composition

Component	Laying Chicken	Growing Broiler	Growing Turkey
Nitrogen	1.0-1.8%	1.4-2.2%	1.2-2.5%
Phosphorus (P_2O_5)	0.8-1.2%	0.9-1.2%	1.0-1.4%
Potassium (K_2O)	0.5-0.7%	0.5-0.8%	0.5-0.8%
Calcium	3.3-4.8%	1.2-2.5%	1.0-2.3%

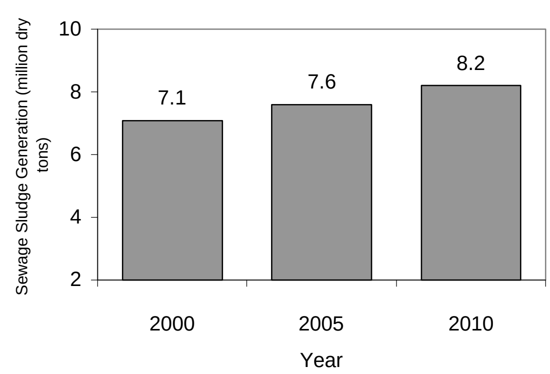
Source: The Ohio State University Bulletin 804, www.ag.ohio-state.edu

Some states have begun to regulate the land application of poultry manure in watershed areas due to nutrient runoff which can cause excessive plant growth in waterways, depleting the oxygen needed by fish and other aquatic animals. The state of Virginia, in particular, passed a bill directing the state Department of Environmental Quality to regulate poultry manure in the Chesapeake Bay watershed. Virginia has over 1,300 poultry houses which generate over 2 million tons of manure annually. This should result in some producers managing their poultry to minimize manure and nutrient production, essentially designing poultry manure to reduce environmental impacts. This may also force poultry farmers to more strongly consider other options for their manure, such as a blend component in biomass-based fuels.

Sewage Sludge

The U.S. generated approximately 6.9 million tons of sewage sludge (dry basis) in 1998 *(WaterWorld, November/December 1999, www.wwinternational.com)*. Of this amount, 60 percent was beneficially used and 40 percent disposed. EPA estimates that 2.8 million dry tons were land applied after being treated to a Class B pathogen status. An additional 0.8 million dry tons were beneficially used after further treatment (composting, alkaline stabilization, or heat treatment). About 20 percent (1.4 million tons) of the disposed sewage sludge was managed by MSW facilities via landfilling or landfill cover, while another 1.5 million tons were incinerated. Sewage sludge generation is expected to increase over the next ten years, from 7.1 million dry tons in 2000 to 8.2 million tons in 2010, Figure 2-1 *("Biosolids Generation, Use, and Disposal in the United States," Environmental Protection Agency, www.epa.gov)*.

Figure 2-1. Projected Sewage Sludge Generation, 2000 - 2010



The use of sewage sludge has increased as its generation has increased over the past 20 years for the following reasons:

- Federal and state regulatory actions have encouraged the beneficial use of sewage sludge as an alternative to landfilling and incineration.

- Research and technology have helped alleviate public concern regarding the human health and environmental impacts of treated sewage sludge.

- Education and marketing efforts have improved public perceptions in some readily compostable organic residues from their landfills.

Also, the quality of treated sewage sludge has improved over time as the industrial pretreatment of wastewater has advanced. Sewage sludge utilization is projected to grow from 63 percent of total sludge generation in 2000 to 70 percent of generation in 2010.

The state of Pennsylvania generates nearly 2.2 million tons of treated sewage sludge annually or about 0.25 ton per household (wet basis at 15-25 percent solids). Approximately 50 percent of all sewage sludge generated in Pennsylvania is reused for land application, primarily in agricultural production and mining, while the rest is composted, landfilled, or incinerated. For agricultural utilization, treated sewage sludge is required to meet quality standards established by the State's Department of Environmental Protection (DEP) and the U.S. EPA. Sewage sludge is analyzed for pathogens, nutrients, PCBs, and other metals including arsenic, cadmium, copper, lead, mercury, molybdenum, nickel, selenium, and zinc; the regulations include concentration limitations on these metals *(www.dep.state.pa.us/dep/biosolids)*.

To get an indication of the quantities of sewage sludge generated by a single treatment facility, a local municipality authority was contacted. Their treatment facility serves a population base of about 60,000 people, and treats approximately 11 million gallons per day using aerobic digesters. A belt filter press is used to increase the sludge solids content to 22-23 percent for landfill disposal. This facility disposes of about 125-140 wet tons per week (7,000 wet tons annually), or about 230 pounds per person per year. Projecting these rates for more populous communities indicates that a large sewage treatment plant (population base of 500,000) would generate almost 60,000 wet tons of sludge for disposal, or about 12,000 dry tons. Landfill tipping fees across the U.S. in 1999 ranged from $15 per ton (Texas) to over $100 per ton (New Jersey), averaging around $30 per ton.

Collect Biomass, Waste, and Coal Samples

Samples of the following materials were obtained:

- Petroleum Coke
- Commingled Waste Plastic
- Waxed Corrugated Cardboard
- Switchgrass
- Poultry Manure
- Sewage Sludge
- Coal Fines (medium sulfur PA)
- Coal Fines (high sulfur OH)

Table 2-4 provides a brief description of the materials, including the source of each sample and the date obtained.

Sample Characterization

Standard ASTM analyses provide a consistent way of characterizing fuels and understanding how they will behave in combustors. Because of the empirical nature of ASTM results, great value is placed on the ability to compare ASTM measurements of new fuel formulations with those of a fuel on which field experience is available. ASTM analyses, such as those listed below, provide a very reasonable starting point for making initial judgments about fuel performance.

Table 2-4. Sample Collection Log

Type	Source	Date	Description
Coal	Ginger Hill Synfuels Monongahela, PA	7/21/99	Beneficiated pond fines (screen bowl product @ 20% moisture)
Coal	Pleasant Ridge Synfuels Alledonia, OH	8/13/99	Beneficiated pond fines (screen bowl product @ 20% moisture)
Mixed Plastics	Conigliaro Industries, Inc. Framingham, MA	7/30/99	Waste commingled mixed HDPE & LDPE
Pet. Coke	Colona Terminal Services Neville Island, PA	8/9/99	Fuel grade petroleum coke
Switchgrass	USDA-ARS (Penn State) University Park, PA	8/9/99	"Cave-in-Rock" variety harvested green (oven dried @ 50C to 8% moisture)
Waxed Cardboard	Giant Eagle Indiana, PA	8/8/99	Wax impregnated cardboard produce boxes
Sewage Sludge	Sewage Treatment Plant Homer City, PA	8/3/99	Municipal sewage sludge (belt filter pressed @ 85% moisture)
Poultry Manure	PennAg Poultry Council Ephrata, PA	8/17/99	Broiler manure (2 samples) (Air dried and fresh)

Each sample of biomass, waste, and coal, were characterized for typical industry fuel, ash, and combustion properties, including the following:

- Proximate--moisture, volatile matter, fixed carbon, ash
- Ultimate--carbon, hydrogen, nitrogen, sulfur, ash, oxygen
- Heating Value (Btu/lb)
- Chlorine and Sodium
- Ash Composition--SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, Na_2O, K_2O, TiO_2, MnO_2, P_2O_5, SO_3
- Ash Fusion Temperature--reducing and oxidizing
- Trace Elements--arsenic, beryllium, cadmium, chromium, cobalt, copper, fluorine, lead, manganese, mercury, nickel, selenium, zinc.
- Toxic Characteristic Leaching Procedure (TCLP)

In addition, size consist of both coal samples were determined to assess the impact of particle size distribution on dewatering and pelletization (Table 2-5).

Table 2-5. Coal Fines Samples Size Distribution

Size Consist, Wt%	Ginger Hill	Pleasant Ridge
+ 28 mesh	0.52	ND
28 x 150 mesh	68.47	3.34
150 x 270 mesh	14.20	49.10
270 mesh x 0	16.81	47.56

Table 2-6 provides a summary of relevant parameters from the ASTM analyses for each sample, plus an additional column detailing properties of a dewatered (10% final moisture) sewage sludge based on the as-received wet analysis. **Bold** numbers indicate areas for concern because the specific index or component exceeds a desirable limit for one of the four combustor types, and is thus a resultant limitation to its use. The dewatered sewage sludge (10% moisture) is a calculated analysis determined from the provided wet analysis. The ash composition values for the plastics and poultry manure samples must be considered as questionable in that their as-received ash compositions do not approach 100%.

Table 2-6. Feedstock Analyses

Identification	Ginger Hill Coal Fines	Pleasant Ridge Coal Fines	Switch Grass	Petroleum Coke	Mixed Plastics	Waxed Cardboard	Sewage Sludge	Sewage Sludge 10% Moisture*	Poultry Manure 1	Poultry Manure 2
Chemical Analyses										
VM	29.2%	32.8%	80.2%	13.0%	92.2%	79.6%	9.3%	55.7%	60.5%	23.5%
FC	45.7%	40.5%	7.7%	79.4%	5.3%	8.7%	1.3%	7.9%	8.1%	2.1%
FC/VM	1.56	1.23	0.10	**6.12**	0.06	0.11	0.14	0.14	0.13	0.09
HHV, BTU/lb	11,335	10,858	7,521	14,201	14,425	9,610	1,117	6,715	5,406	2,043
LHV, BTU/lb	10,721	10,251	6,895	13,753	13,374	8,741	**118**	6,122	4,902	**1,238**
Moisture	19.5%	19.5%	8.0%	7.2%	0.2%	9.3%	**85.0%**	10.0%	9.1%	**60.8%**
Hydrogen	4.2%	4.1%	5.6%	3.8%	10.8%	7.9%	0.8%	5.0%	4.2%	1.5%
Carbon	63.1%	58.5%	43.8%	**80.5%**	67.8%	50.2%	5.8%	34.6%	32.8%	12.1%
Sulfur	1.3%	3.3%	0.1%	**5.1%**	0.3%	0.2%	0.3%	1.6%	0.3%	0.1%
Nitrogen	1.0%	0.9%	1.4%	1.4%	0.1%	0.1%	0.8%	5.0%	3.8%	1.2%
Oxygen	5.3%	6.4%	37.1%	1.6%	18.4%	29.9%	2.9%	17.4%	27.4%	10.6%
Ash	5.6%	7.2%	4.1%	0.4%	2.3%	2.5%	4.4%	**26.4%**	**22.4%**	**13.6%**
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%
O/N	5.3	6.9	27.3	1.1	184.1	229.7	3.5	3.5	7.1	8.7
lb N/MMBTU	0.88	0.85	1.81	0.97	0.07	0.14	**7.43**	**7.43**	**7.10**	**5.97**
lb S/MMBTU	1.14	3.08	0.16	3.61	0.23	0.20	2.42	2.42	0.50	0.49
lb Ash/MMBTU	4.9	6.6	5.5	0.3	1.6	2.6	**39.3**	**39.3**	**41.4**	**66.6**
Chlorine	0.12%	0.06%	0.22%	0.03%	**0.98%**	0.20%	0.03%	0.18%	**0.45%**	0.15%
lb_Cl/MMBTU	0.11	0.05	**0.29**	0.02	**0.68**	**0.21**	**0.27**	**0.27**	**0.83**	**0.73**
Fluorine (ppm)	53	59	27	58	0	0	43	261	32	15
Ash Fusibility Temps. (°F)	Reducing Atm.	Reducing Atm.	Reducing Atm.	Reducing Atm.	Reducing Atm.	Reducing Atm.	Reducing Atm.	Reducing Atm.	Reducing Atm.	Reducing Atm.
I.T.	**2075**	**1940**	1,960	2,210	2,560	2,100	2,000	2,000	2,500	2,485
S.T.	2125	1990	2,000	2,240	2,565	2,140	2,020	2,020	2,550	2,505
H.T.	2180	2035	2,010	2,270	2,570	2,155	2,070	2,070	2,560	2,525
F.T.	**2280**	**2075**	2,030	2,295	2,575	2,165	2,120	2,120	2,570	2,545
Diff. (F.T. - I.T.)	205	135	70	85	15	na	120	120	70	60
Ash Fusibility Temps. (°F)	Oxidizing Atm.	Oxidizing Atm.	Oxidizing Atm.	Oxidizing Atm.	Oxidizing Atm.	Oxidizing Atm.	Oxidizing Atm.	Oxidizing Atm.	Oxidizing Atm.	Oxidizing Atm.
I.T.	2345	2375	2,040	2,050	2,500	2,200	2,080	2,080	2,595	2,570
S.T.	2370	2405	2,080	2,090	2,510	2,255	2,110	2,110	2,610	2,585
H.T.	2400	2420	2,100	2,110	2,515	2,290	2,145	2,145	2,620	2,600
F.T.	2430	2450	2,120	2,130	2,525	2,320	2,200	2,200	2,640	2,615
Diff. (F.T. - I.T.)	85	75	80	80	25	na	120	120	45	45
Ash Composition										
SiO2	47.1%	38.4%	35.4%	25.4%	0.8%	26.9%	34.4%	34.4%	3.4%	3.1%
Al2O3	20.7%	15.0%	5.9%	8.2%	0.6%	17.4%	12.8%	12.8%	1.7%	0.9%
Fe2O3	**15.1%**	**25.8%**	4.1%	8.9%	0.2%	4.9%	13.2%	13.2%	3.2%	4.5%
TiO2	1.1%	1.6%	0.3%	0.6%	0.3%	12.5%	1.6%	1.6%	0.1%	0.1%
CaO	5.8%	5.1%	12.2%	11.3%	1.3%	15.9%	9.0%	9.0%	29.0%	32.4%
MgO	1.1%	0.8%	9.8%	2.9%	0.2%	1.9%	2.1%	2.1%	3.6%	3.5%
Na2O	0.4%	0.6%	2.4%	1.2%	0.2%	**8.8%**	0.9%	0.9%	1.5%	1.4%
K2O	2.0%	1.3%	**15.1%**	1.3%	0.0%	1.5%	1.5%	1.5%	**8.0%**	**9.4%**
P2O5	0.1%	0.2%	8.1%	0.5%	0.2%	1.1%	15.4%	15.4%	13.3%	12.9%
SO3	7.4%	8.7%	5.0%	20.1%	0.6%	7.6%	2.1%	2.1%	2.2%	1.9%
Total	100.7%	97.6%	98.2%	80.4%	4.4%	98.3%	92.8%	92.8%	66.0%	70.1%
Base / Acid Ratio	0.35	**0.61**	1.05	0.75	1.04	**0.58**	**0.54**	**0.54**	8.71	12.45
Fe2O3 / CaO	2.61	5.04	**0.34**	0.79	**0.14**	**0.31**	1.47	1.47	**0.11**	0.14
SiO2 / Al2O3	2.28	2.56	**6.05**	3.10	1.30	1.54	2.69	2.69	1.97	3.68
lb K+Na/MMBTU	0.12	0.12	**0.95**	0.01	0.00	0.26	**0.92**	**0.92**	**3.94**	**7.22**
Ash Behavior										
Ash-Type	Bituminous	Bituminous	Lignitic-Like	Lignitic-Like	Lignitic-Like	Lignitic-Like	Bituminous-Like	Bituminous-Like	Lignitic-Like	Lignitic-Like
Slagging Potential	Medium - High	High	Severe	Low - Medium	Low	High	Medium	Medium	High	High
Fouling Potential	Low	Medium	Severe	Low - Medium	Low - Medium	Severe	High	High	Severe	Severe

* Sewage Sludge ("dewatered") - calculated analysis at 10% moisture based on the as-received 85% moisture sewage sludge sample.

ALSTOM Power, through it s US Power Plant Laboratory Group (US PPL), reviewed the ASTM analyses of the candidate feedstocks to qualitatively assess their applicability to four combustor types based on a review of five potential impact areas. ALSTOM's complete task report is included as Appendix C. The four combustor types were:

- Pulverized Coal (PC)
- Circulating Fluidized Bed (CFB)
- Stoker
- Cyclones

Relevant impact areas included the fuel s reactivity, slagging & fouling behavior, corrosion potential, fuel handling & preparation issues, and pellet size & integrity concerns. The candidate fuels were ranked with regard to their potential for performance impact as a means to identify those fuels with the most favorable/least deleterious overall characteristics for use in a composite, pelletized solid fuel. As a basis for this evaluation, it was assumed that no modifications to the existing combustor or fuel handling equipment would be made, which would minimize the cost for potential application.

Each of the candidate feedstocks was evaluated by ALSTOM personnel with regard to the above impact areas based on the analyses provided in Table 2-6. A summary of the results of this evaluation is provided in Table 2-7.

Table 2-7. Combustor Assessment

Identification	Ginger Hill Coal Fines	Pleasant Ridge Coal Fines	Switch Grass	Petroleum Coke	Mixed Plastics	Waxed Cardboard	Sewage Sludge	*Sewage Sludge 10% Moisture*	Poultry Manure 1	Poultry Manure 2
PC										
Applicability	High	High	Low	Low	na	Low	na	*Low*	Low	na
Max Heat Input	100%	100%	10%	20%	0%	20%	0%	*10%*	10%	0%
Constraint	Slag. & Foul.	Slag. & Foul.	Slag. & Foul.	Reactivity	Preparation	Slag. & Foul.	Reactivity	*Slag. & Foul.*	Slag. & Foul.	Slag. & Foul.
								Reactivity	Reactivity	Reactivity
CFB										
Applicability	High	High	Low	High	Medium	High	na	*Low*	Low	na
Max Heat Input	>90%	>90%	10%	100%	25%	100%	0%	*15%*	15%	0%
Constraint	Size & Integ.	Size & Integ.	Slag. & Foul.	Size & Integ.	Corrosion	Slag. & Foul.	Reactivity	*Slag. & Foul.*	Slag. & Foul.	Slag. & Foul.
					Size & Integ.					Reactivity
Stoker										
Applicability	Medium	Medium	Low	Low	Medium	Medium	Low	*Low*	Low	Low
Max Heat Input	50%	50%	20%	10%	25%	50%	10%	*15%*	15%	10%
Constraint	Size & Integ.	Size & Integ.	Slag. & Foul.	Reactivity	Corrosion	Slag. & Foul.	Reactivity	*Slag. & Foul.*	Slag. & Foul.	Slag. & Foul.
					Size & Integ.					Reactivity
Cyclone										
Applicability	High	High	Low	Medium	Medium	Medium	na	*Low*	Low	na
Max Heat Input	100%	100%	20%	25%	25%	50%	0%	*15%*	15%	0%
Constraint	Size & Integ.	Size & Integ.	Slag. & Foul.	Reactivity	Corrosion	Slag. & Foul.	Reactivity	*Slag. & Foul.*	Slag. & Foul.	Slag. & Foul.
					Size & Integ.					Reactivity

As shown, Table 2-7 lists the overall applicability of each candidate fuel to a given combustor type, rated as low, medium, or high, depending on the recommended maximum heat input rate for that fuel as fired in that combustor type. As defined here, a fuel rated low in its applicability is not recommended for firing at more than 25% of maximum furnace heat input; a fuel rated as medium in its applicability is recommended for firing at 25% to 50% of maximum furnace heat input; and a fuel rated as high is capable of being fired at greater than 50% of the maximum allowable furnace heat input rate, and can thus act as the primary combustor fuel.

Only the two coal fuels, the Ginger Hill and Pleasant Ridge coal fines, are broadly applicable to each combustor type, being suitable for use at greater than or equal to 50% maximum continuous rating (MCR) heat input. The remaining fuels and feedstocks are shown to have a varying degree of applicability for a given combustor for a range of reasons. This includes reactivity (VM content) for the petroleum coke (as applied to PC, Stoker and Cyclone operation); corrosion (Cl content) for the mixed plastics and air dried (9% moisture) poultry manure; and slagging and fouling (Na & K content) for the switch grass, waxed cardboard and dewatered (10% moisture) sewage sludge, among other reasons. The as-received (85% moisture) sewage sludge and 60% moisture poultry manure were, for the purposes of this study, deemed not suitable for use as a fuel in any of the four considered combustor types based on their low reactivity/high moisture contents and resultant low Lower Heating Value (LHV). A dried, 10% moisture content sewage sludge was, however, added to the list of considered fuels owing to the economics for its use/disposal.

Of the non-coal fuels and feedstocks, the waxed cardboard and the petroleum coke offer the best promise based on their ASTM properties for use in a pelletized, composite fuel. The waxed cardboard is desirable based on its high volatile matter content and acceptable chlorine content (~0.20% / 0.2 lb/MMBtu), while the petroleum coke is desirable due to its high heating value, and low chlorine content. However, the high sodium content in the waxed cardboard ash (9% by weight), and low volatile content (13%) in the petroleum coke place limits on their application due to fouling and reactivity/combustion efficiency, respectively, for all combustor types except a CFB. The high sulfur content (5.1%) of the petroleum coke will also likely be a concern for certain boilers both with regard to SO_2 formation and capture, and corrosion potential.

Of the remaining fuels, the switch grass and air dried poultry manure were deemed undesirable for use except at extremely low mass fractions due to their previously noted high sodium and potassium contents considered on a pound per million BTU basis. Although better, the mixed plastics sample is similarly not desirable for use in significant mass fractions due to the high chlorine content of this particular sample (the chlorine content of a mixed waste plastics stream can vary substantially depending on the amount of PVC material in the stream). In addition, the mixed plastic may be undesirable for use in PC applications based on a potential problem with pasting in existing fuel handling and milling equipment.

The candidate feedstocks, plus the "dried" sewage sludge, were categorized as follows with regard to their overall applicability for the generation of a pelletized, composite solid fuel, based on a review of their physical and chemical characteristics.

Fuels that are **broadly recommended for use** include:

(1) Ginger Hills Coal Fines, and
(2) Pleasant Ridge Coal Fines.

Fuels that are **recommended for use primarily in CFB** applications include:

(3) Waxed Cardboard, and
(4) Petroleum Coke.

Feedstocks that are **recommended for use at low heat input levels** only include:

(5) Mixed Plastics,
(6) Switch Grass,
(7) 10% Moisture Sewage Sludge, and
(8) Poultry Manure 1 (Dried to 9% moisture).

Feedstocks that are **not recommended for use** at any level include:

(9) Poultry Manure 2 (61% moisture), and
(10) Sewage Sludge (as received/85% moisture).

These recommendations were based on an assumed, typical boiler in each of the four combustor classes. Specific performance issues affecting a given fuel s applicability will, however, need to be determined on a case by case basis. It should also be noted that the applicability of a given fuel within each noted category is subject to the firing rate limitations for a particular combustor as given in Table 2-7.

Pursuant to the results of the fuel applicability analyses and preliminary economic considerations, three composite fuel blends were identified for further evaluation:

- 85% petroleum coke, 15% mixed plastics
- 80% Ginger Hill coal fines, 20% waxed cardboard
- 80% Ginger Hill coal fines, 20% dried sewage sludge

All three combinations represent fuels that were recommended based either on their ASTM determined properties (petroleum coke, waxed cardboard, and Ginger Hills fines) or their economics (waste tipping fees for mixed plastics and 10% moisture sewage sludge). The mixed plastics have the added benefit of acting as a potential binding agent for the formation of durable pellets in the petroleum coke based fuel.

Task 1-3
OPTIMIZE DEWATERING DIE GEOMETRY

Objective: Fabricate a laboratory test unit so as to determine the appropriate geometry for dewatering pelletizer dies.

Accomplishments:

- Designed and fabricated a laboratory-scale pelletizer mill utilizing the dewatering die and capable of producing cylindrical pellets from biomass/wastes/coal mixtures at a nominal rate of 300 pounds per hour.
- Various die geometries to optimize mill operation and performance, including die diameter, die length-to-diameter (L/D) ratios, die tapers, and moisture discharge configurations were determined, allowing the design of the one ton per hour proof-of-concept dewatering extruder.

Fabricate a Dewatering Pelletizer Test Mill

A general view of the mill that was fabricated is shown in Figure 3-1 (the top has been removed to reveal the rollers.)

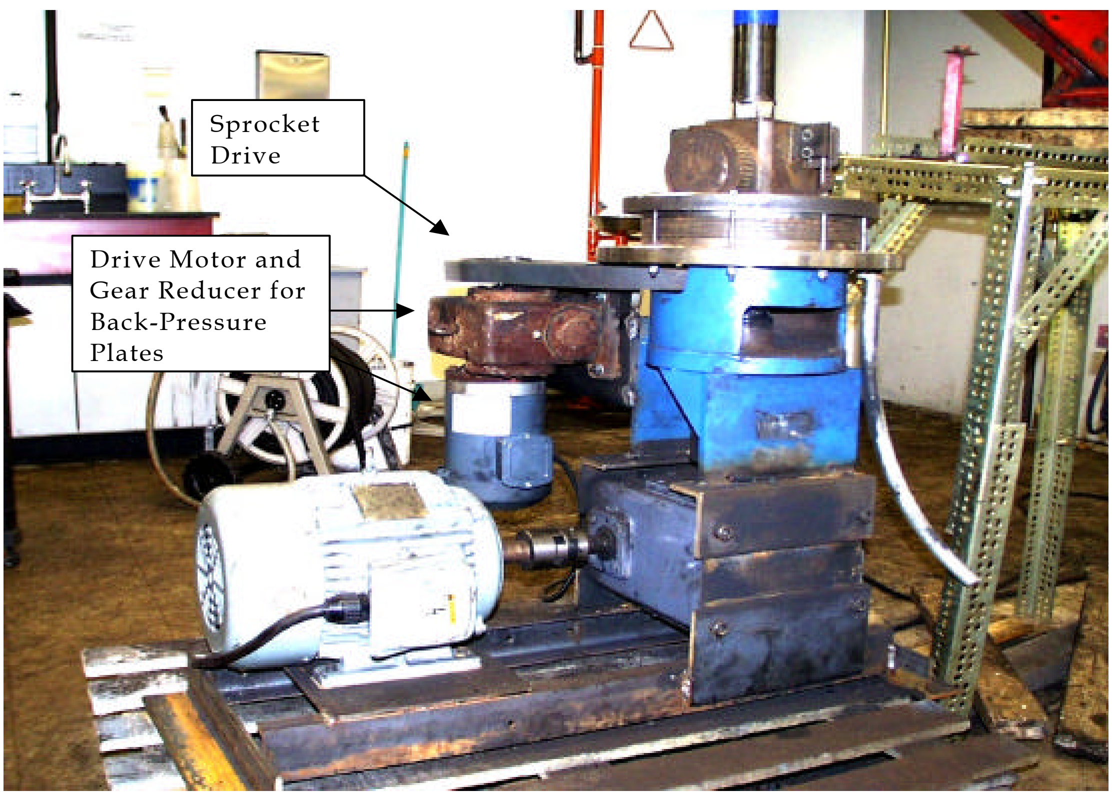


Figure 3-1. Semi-Pilot-Scale Dewatering Pelletizer Mill

The test mill is configured and operates as follows:

- Feedstock materials - various mixtures of biomass, wastes, and coal - are fed to the top of the pellet mill via a variable-speed, vibrating feeder.

- Conventional Kahl-type pelletizers have a die which consists of a single, thick disk with concentric rows of die holes through which the material to be pelletized is forced by rollers which rotate along its top surface. California Pellet Mills and similar pelletizers work on the same principle, but utilize a die consisting of a cylinder with sets of holes, with rollers inside the cylinder. The dewatering die is not fabricated from a solid disk, but from a series of plates, with holes, of various thicknesses (Figure 3-2), stacked and clamped together on a base around a central drive shaft. The plates are stacked vertically to produce various die length-to-diameter (L/D) ratios. The minute spaces between the

Figure 3-2. Dewatering Die Plates

plates create a means for moisture to escape as the feedstock materials are being pressed through the dies. Plates can be added or removed as desired to get a thicker or thinner die stack. The holes can be straight-sided, or have a taper. Shims can be inserted between the die plates to slightly increase the openings between the plates. It was found that chamfering the top of the holes of the topmost plate was beneficial, the chamfers acting as guides for material seeking to enter the holes.

- Material falls onto the upper die plate and is forced down through the die openings by two rollers mounted on a shaft driven by a 10 HP motor. The die and roller assembly is shown in Figure 3-3. Springs under adjustable pressure are used to force the roller assembly down while still allowing the assembly to rise in response to slugs or clumps of feedstock, in a manner similar to some commercial pelletizers. It was found best to remove the springs, and to have the roller assembly mechanically locked in direct contact with the die, as is the case in other commercial pelletizers. Two shear pins protect the gearbox.

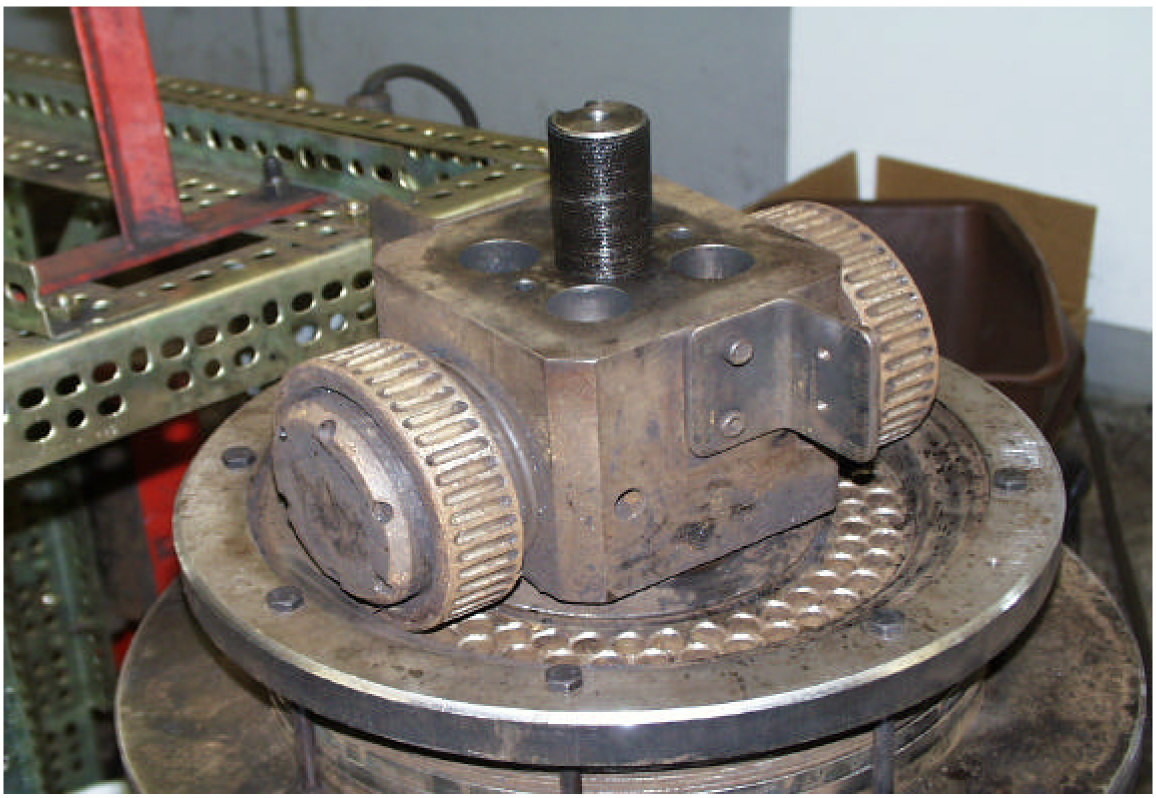


Figure 3-3. Roller and Die Assembly

- Assembly of the pelletizer is completed by installing scrapers and clamping a cylinder around the top of the die and roller assembly to prevent the material being pelletized from falling over the side. Water discharging from between the die plates, Figure 3-4, streams onto a flange and is collected in a tank via a drainage pipe.

- The formed pellets (typically cylindrical in shape, ½ to 1½ inches in length with diameters ranging from ¼ to ½ inches depending on the die openings) exit the bottom of the die into the product chamber from which they are swept away by a rotating sweeper arm into external containers.

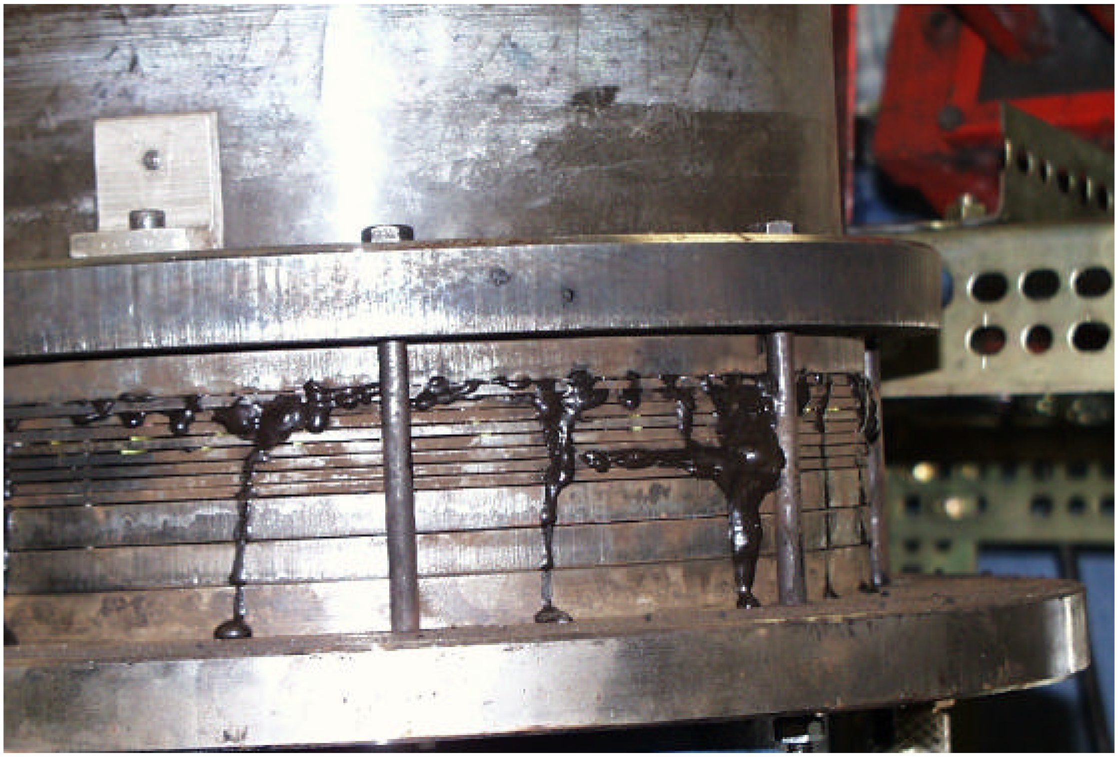


Figure 3-4. Water Discharging From Die Plates

During initial testing of some high-moisture materials (greater than 22 percent), it was observed that material was sliding through the die very quickly, resulting in only minimal compaction with very little water being released. When the dewatering die is fed high-moisture material, the moisture acts as a lubricant, allowing the material to slide through the die. Other slick materials, such as some sludges, appear to have natural lubrication properties. Without significant resistance to movement of the material through the die (back-pressure), the pelletizer rolls have little to push against and little compaction occurs.

The resistance to movement through the die can be increased by either lengthening the die or by using a tapered die. While this can be effective, dies whose resistance to flow has been increased in this manner were found to be prone to plugging with relatively small changes in the characteristics of the material being pelletized. Thinner dies are far more forgiving as they present less resistance to flow. A better way of increasing the resistance to flow without increasing a tendency to plug was devised. Two back-pressure plates were installed just beneath the die stack, Figure 3-5. These back-pressure plates are driven by a dedicated motor and sprocket chain so that the back-pressure plates travel around the bottom of the die stack slower than the pelletizer rolls travel around the top of the die stack. As the back-pressure plate rotates below a die opening, the material is compacted between the pelletizer roll and the plate. The pelletizer rolls rotate several times faster than the back-pressure plates, so the material is compacted on several occasions before the back-pressure plate revolves past the die opening, whereupon the roll passing over the top of the die extrudes part of the material from the bottom of the die. Again, as the pelletizer rolls rotate several times faster than the back-pressure plates, so the material is now extruded on several occasions before the second back-pressure plate comes round under the die opening. As this plate appears under the opening of the die, extruded

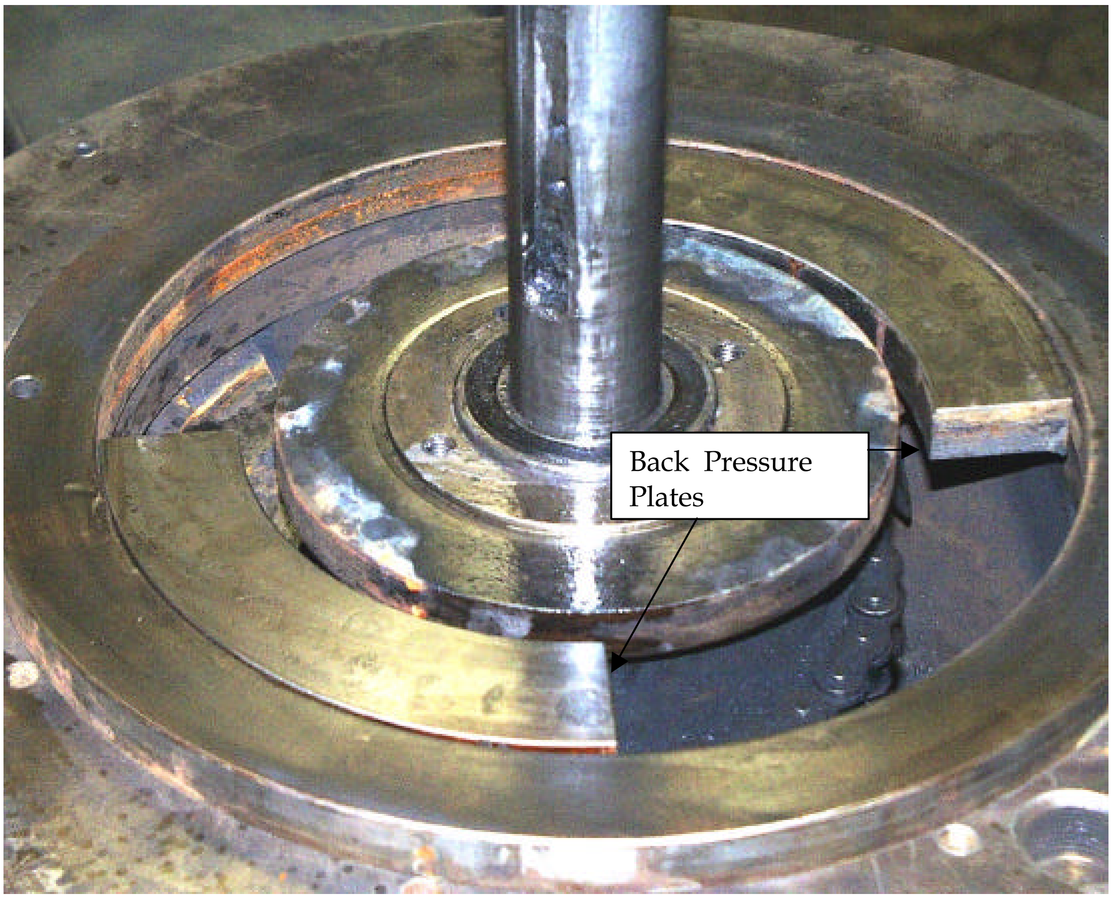


Figure 3-5. Back-Pressure Plates

material is cut off by its leading edge, and compaction of newly-introduced material in the die occurs as the discharge end of the die is temporarily blocked by the plate as the cycle starts again.

The back-pressure plates are so constructed that various pairs of two equal arcs, ranging from about 20° to 90° each, can be blocked off. Thus, for example, a back-pressure plate with two arcs of 45° each has 25 percent of the die openings blocked at any given time. It was found that two arcs of 90° each, blocking half the openings at any given moment gave best results, and this was used for the majority of tests.

Determine Die Geometries

It was found that the original design utilizing a one horsepower motor was substantially under powered. Comparison with commercial pelletizer mills power-to-die area ratios showed that *if* power requirements for pelletizing mills are directly proportional to their die areas, then the test mill would scale down to a 10-HP motor. A suitable 10-HP motor was installed, and the stalling problems were eliminated.

Table 3-1 provides a summary of initial test results, mainly with beneficiated coal fines from a pond recovery operation in western Pennsylvania. Table 3-2 provides a summary of additional work utilizing a back-pressure plate. Detailed discussion of the results follow the tables, but it was determined that:

- In the test unit, the die plugs at about 15% feed moisture because the lack of moisture for lubrication increases friction between the material being pelletized and the walls of the die. Commercial pelletizers can operate at somewhat lower moisture levels and special lubricants can be used. Test 27 is assumed to be experimental error as we could not duplicate this test.

- Between 15-22 percent feed moisture, the mill reduces the moisture content of the feedstock by about 5-10 percent (1-2 moisture points, absolute). These results are independent of whether or not a back-pressure plate is used.

- Above 22 percent feed moisture, no dewatering occurs without a back-pressure plate as the material is too slippery to offer the resistance required for compaction. The presence of a back-pressure plate has a dramatic effect at higher moisture levels, reducing the moisture content of wet coal by 15-25 percent (5-6 moisture points, absolute). For example, moisture was reduced from 26% to 20% in Test 56, and from 28% to 23% in Test 60.

- Similar results apply to the 20% sewage sludge/80% coal mixture and the 10% sewage sludge/90% coal mixture. Test 65 reduced the moisture content of a 10% sewage sludge feed from 22% to 16%.

Table 3-1. Initial Dewatering Die Test Results (without back-pressure plate)

No.	Plate Thickness and Configuration (See Explanatory notes at End of Table) 7/16" Thick top plate in all tests.	L/D Ratio	Feed H2O (Wt%)	Pellet H2O (Wt%)	Remarks (Tests were conducted on beneficiated coal fines unless otherwise stated)
1	2x7/16", 5x1/8", ¼" Taper. Spring length not measured.	4.4	27	21	Die plugged
2	8x1/8", 4x1/4", ¼" Taper. Spring length not measured.	3.9	35	ND	Die plugged
3	4x1/16", ¼" Taper. Spring length 27mm	1.9	16	ND	Die plugged
4	4x1/16", ¼" Taper. Spring length 25mm	1.9	16	ND	Die plugged
5	1x1/16", ¼" Taper. Spring length 21mm	1.5	13	13	
6	4x1/16", ¼" Taper. Spring length 19mm	1.9	16	ND	Die plugged
7	4x1/16", ¼" Taper	1.9	17	15	
8	8x1/8", 4x1/4", ¼" Taper	3.9	16	16	
9	8x1/8", 4x1/4", ¼" Taper	3.9	6	ND	Pin sheared
10	8x1/8", 4x1/16", 1x7/16", 7/16" Taper	5.1	14	ND	Die plugged
11	2x7/16", ¼" Taper	3.1	19	17	
12	2x7/16", ¼" Taper	3.4	20	17-18	
13	2x7/16", ¼" Taper	3.4	16	14	Die plugged
14	2x7/16", ¼" Taper	3.4	17	18	
15	2x7/16", ¼" Taper	3.4	9	9	Die plugged
16	2x7/16", 5x1/8", ¼" Taper	4.4	22	ND	Die plugged
17	5x1/8"	2.1	20	20	
18	5x1/8"	2.1	18	18	
19	5x1/8"	2.1	15	15	
20	7x1/8"	2.6	20	20	
21	7x1/8"	2.6	16	15	
22	7x1/8", 1x7/16"	1.8	23	22	
23	7x1/8", 1x7/16"	1.8	18	16	
24	8x1/8", 2x7/16"	4.6	20	18	
25	8x1/8", 2x7/16"	4.6	14	14	Pin sheared
26	8x1/8", 2x7/16"	4.6	21-22	18-21	
27	8x1/8", 2x7/16"	4.6	14	10	
28	2x7/16", 8x1/8"	4.6	22-23	21	
29	2x7/16", 8x1/8"	4.6	16	16	Pin sheared
30	2x7/16", 8x1/8",4x1/16"	5.1	15	ND	Tripped at circuit breaker
31	2x7/16", 8x1/8"	4.6	54	53	Paper sludge
32	2x7/16", 8x1/8"	4.6	36	36	50% coal, 50% paper sludge
33	2x7/16", 8x1/8"	4.6	25	24	75% coal, 25% paper sludge
34	2x7/16", 8x1/8"	4.6	18	18	
35	1x7/16", 3x1/16", 5x1/8". ¼" die holes	4.8	23	24	Pellets got hot – moisture 17% before powdery product emerged
36	4x1/16", 4x1/8"	2.4	19	19	
37	4x1/16", 8x1/8"	3.4	19	19	
38	4x1/16", 8x1/8"	3.4	18	18	80% coal, 20% waxed cardboard
39	4x1/16", 8x1/8"	3.4	19	19	
40	1x1/8", 1x7/16", 1x1/8", 1x7/16", 1x1/8"	3.4			85% pet coke, 15% waste plastic all heated to 260°F = 127°C
41	4x1/16", 8x1/8", ¼" Taper	2.4	19	19	
42	4x1/16", 8x1/8"	3.4	34	34	20% sewage sludge, 80% coal
43	4x1/16", 8x1/8"	3.4			85% pet coke, 15% waste plastic all heated to 260°F = 127°C
44	2x7/16", 4x1/16", 8x1/8"	5.1	34	ND	20% sewage sludge, 80% coal. Die plugged.

Table 3-1. Initial Dewatering Die Test Results (continued)

No.	Plate Thickness and Configuration (See Explanatory notes at End of Table) 7/16" Thick top plate in all tests.	L/D Ratio	Feed H2O (Wt%)	Pellet H2O (Wt%)	Remarks (Tests were conducted on beneficiated coal fines unless otherwise stated)
45	1x7/16", 4x1/16", 8x1/8"	4.2			85% pet coke, 15% waste plastic all heated to 260°F = 127°C
46	4x1/16", ¼" Taper, 8x1/16". 7/16" die holes below taper	2.9	34	ND	20% sewage sludge, 80% coal. Die plugged.
47	8x1/16". 7/16" die holes	2.1	34	34	20% sewage sludge, 80% coal.
48	1x1/8", ¼" Taper, 8x1/16". 7/16" die holes below taper	3.0	34	34	20% sewage sludge, 80% coal
49	1x1/8", ¼" Taper, 8x1/16". 7/16" die holes below taper	3.0	15	ND	Die plugged

- Plate configuration is number of plates by plate thickness, in order from top $^{7}/_{16}$in plate which had its holes chamfered on top - present in all tests, downward.
- Die holes are ½in diameter unless otherwise noted.
- Tapered holes taper from ½in to $^{7}/_{16}$in.
- The first six tests were the only ones where springs were used to hold the rollers down

ND = Not Determined moisture, usually because die plugged

Table 3-2. Dewatering Die Test Results (with back-pressure plate)

No.	Plate Thickness and Configuration (See Explanatory notes at Bottom of Table) Various thicknesses of the top plate	L/D Ratio	Feed H2O (Wt%)	Pellet H2O (Wt%)	Remarks (Tests were conducted on beneficiated coal fines unless otherwise stated)
50	3x7/16", 3x1/16", 8x1/8", 1x7/16"	5.0	34	20	20% sewage sludge, 80% coal. Die plugged.
51	1x7/16", 3x1/16", 8x1/8"	3.2	34	29	20% sewage sludge, 80% coal
52	1x7/16", 3x1/16", 8x1/8"	3.2	18	18	
53	2x7/16", 4x1/16", 8x1/8", 1x7/16"	4.2	30	31	20% sewage sludge, 80% coal
54	2x7/16", 4x1/16", 8x1/8", 1x7/16"	4.2	24	25	
55	¼" Taper, 8x1/16". 7/16" die holes below taper	1.7	17	16	
56	¼" Taper, 8x1/16". 7/16" die holes below taper	1.7	26	20	
57	¼" Taper, 8x1/16". 7/16" die holes below taper	1.7	20	19	
58	1x7/16", 3x1/16", 8x1/8"	3.2	30	30	20% sewage sludge, 80% coal
59	1x7/16", 3x1/16", 8x1/8"	3.2	25	25	
60	1x7/16", 4x1/16", 3x1/8"	2.1	28	23	
61	1x7/16", 4x1/16", 3x1/8"	2.1	23	20	
62	1x7/16", 4x1/16", 3x1/8"	2.1	16	17	
63	1x7/16", 4x1/16", 3x1/8"	2.1	15	15	
64	1x7/16", 4x1/16", 3x1/8"	2.1	26	23	20% sewage sludge, 80% coal
65	1x7/16", 4x1/16", 3x1/8"	2.1	22	16	10% sewage sludge, 90% coal
66	1x7/16", 4x1/16", 3x1/8"	2.1	20	18	
67	1x1/2", 3x1/16", 2x1/8", 1x1/2". ¼" die holes	5.8	20	ND	Die plugged
68	1x1/2", 3x1/16", 2x1/8". ¼" die holes	3.8	21	18	Die plugged
69	1x1/2", 3x1/16", 1x1/8". ¼" die holes	3.2	21	19	
70	1x1/8", 3x1/16", 1x1/2". ¼" die holes	3.2	24	7½	Die plugged. Pellet obtained just before plugging occurred
71	1x1/8", 3x1/16", 1x1/2". ¼" die holes	3.2	22	19	2½ hours steady run @ 120 lb/hr = 300 lb
72	1x1/8", 3x1/16", 1x1/2". ¼" die holes	3.2	19	17	Ran hot, pellets emerged at 130°F=55°C
Runs 73 to 89 were made with the top and bottom plates of 12" diameter, as usual, but with intermediate plates of only 9½" diameter					
73	1x7/16", 13x1/16", 1x7/16"	3.4	17	ND	Die plugged
74	1x7/16", 13x1/16", 1x7/16"	3.4	20	ND	Die plugged
75	1x7/16", 10x1/16", 1x7/16"	3.0	20	ND	Got very hot, with small tablet pellets, powder, caught fire.
76	1x3/8", 7x1/16", 1x7/16"	2.5	19	18	
77	1x3/8", 7x1/16", 1x7/16"	2.5	19	18	
78	1x3/8", 7x1/16", 1x7/16"	2.5	29	24	10% sewage sludge, 90% coal
79	1x3/8", 7x1/16", 1x7/16"	2.5	33	31	20% sewage sludge, 80% coal
80	1x7/16", 9x1/16", 1x7/16"	2.8	20	20	
81	1x3/8", 11x1/16", 1x7/16"	3.0	17	17	
82	1x3/8", 11x1/16", 1x7/16"	3.0	21	17	
83	1x3/8", 11x1/16", 1x7/16"	3.0	19	18	

Table 3-2. Dewatering Die Test Results (back pressure plate, continued)

No.	Plate Thickness and Configurations (See Explanatory notes at Bottom of Table) Various thicknesses of the top plate	L/D Ratio	Feed H2O (Wt%)	Pellet H2O (Wt%)	Remarks (Tests were conducted on beneficiated coal fines unless otherwise stated)
84	1x3/8", 11x1/16", 1x7/16"	3.0	20	ND	7% Monsey-Bakor asphalt emulsion added to coal Die plugged
85	1x3/8", 3x1/16", ¼" Taper	1.6	20	ND	Got very hot, with small tablet pellets, powder, caught fire.
86	1x3/8", 7x1/16", 1x7/16"	2.5	21	20	5% sewage sludge, 95% coal
87	1x3/8", 7x1/16", 1x7/16"	2.5	19	18	7% Heritage CCB emulsion added to coal. Strong shiny pellets.
88	1x3/8", 7x1/16", 1x7/16"	2.5	19	18	
89	1x3/8", 7x1/16", 1x7/16"	2.5	23	22	10% sewage sludge, 90% coal
Runs 90 to 92 were made with all the plates of 12" diameter					
90	1x3/8", 3x1/16", 2x1/8", 1x7/16"	2.5	22	20	5% sewage sludge, 95% coal
91	1x3/8", 3x1/16", 2x1/8", 1x7/16"	2.5	17	14	7% Heritage CCB emulsion added to coal. Strong shiny pellets
92	1x3/8", 3x1/16", 2x1/8", 1x7/16"	2.5	16	15	Plus 270#=53µm coal

- Plate configuration is number of plates by plate thickness, in order from top plate downward. Unlike the initial tests, recorded in table 3.1, which all used a $^{7}/_{16}$in top plate, various top plates, with holes chamfered on top, were used when working with the back-pressure plate.
- Die holes are ½in diameter unless otherwise noted.
- Tapered holes taper from ½in to $^{7}/_{16}$in.
- Tests 3,4, and 6, were the only ones where springs were used to hold the rollers down
- ND = Not Determined moisture, usually because die plugged

It had been thought, based on experience with commercial pelletizers, that the length to diameter (L/D) ratio would be the main variable effecting whether or not the dies would plug, and how much moisture would be removed. While an L/D ratio greater than 4 greatly increased the chances of a plug, L/D ratios less than 4 did not guarantee that the dies would not plug. Pelletization at L/D ratios of 2.5 or less was unlikely without a back-pressure plate. The use of a back-pressure plate allowed low L/D ratios to be used. The best results were obtained with low L/D ratios--tests 60 and 65 had L/D ratios of only 2.1. Test 56 had its top plate tapered, and an L/D ratio of only 1.7. Small differences in the properties of the feed, such as moisture content which are difficult to control, have a very large impact on commercial pelletizer performance. Plugging is a constant issue, necessitating the addition of considerable amounts of water to the feed at times. A method of allowing the use of low L/D ratios would alleviate this problem, reduce the need to add water to commercial pelletizer feeds to preclude plugging, and allow drier pellets to be made.

It was found that having a taper in the die, except at the very top, would almost guarantee plugging. The taper greatly increases resistance to flow, and should thus be placed only at the top (tests 55 to 57), close to where the pressure is applied. Any plugging tendency is reduced by the fact that the rollers are applying the pressure before it has been lessened by wall friction.

Some commercial pelletizers have mechanical or hydraulic springs that allow the rollers to ride higher when they encounter resistance, thus forming a bed of material above the die. Our tests often showed that a bed was present when the mill was dismantled after a plug, due to the roller block either working its way up the screw that was holding it down, or possibly not having been screwed down tightly enough during assembly. This was in accord with early work, which had only one plug-free run with the spring at the lowest L/D ratio tested (1.5). A bed was *never* found after a run that had not been brought to a premature stop by a plug.

Two types of plugging problems were encountered. The first, usually occurring when the material being fed was too dry (below 15% moisture), resulted in the material becoming a hard solid mass, appearing to be fused together. This had to be tapped out or even drilled out of the holes, very similar to the plugging encountered in commercial pelletizers when their feed is too dry.

The second type occurred when the material was too slippery, presumably due to very high moisture. The material in the die was not hard, and could be readily pushed out by hand. However, new material would not go into the holes, sliding away from the roller. Tests using a stroboscope indicated that some slippage of the rollers was occurring.

A substantial amount of heat was generated in many of the tests involving the 9½ inch diameter plates. Plugging of the first type often occurred. Alternatively, it was often found that the product emerged in a tablet-like form, with lots of fines.

The condition of the top plate and rollers surfaces was found to very important. This is dramatically illustrated by comparing tests 78 and 89 identical except for the fact that wear had occurred by test 89 to such an extent that the mill was sent back to the shop for refurbishment. On a previous occasion, when the mill had refused to accept material of more than about 24% moisture, it was found that machining the top plate and rollers raised this limit to about 30% moisture depending on the natural lubricating properties of the material being pelletized.

Shims were placed between the plates. It was found that with no shims, emerging liquid has very little solids. When 0.005" shims were employed, more liquid seemed to emerge, and this was found to have about 5% solids. When 0.010" shims were employed, the liquid contained very high solids content (72% solids), and steadily got less as the run progressed, indicating that the spaces between the plates were becoming blocked. There was no such problem with the 0.005" shims. Tests using a batch piston machine had shown that a gap as large as 0.025" did not result in undue amounts of solids being ejected, but it would appear that continuous operation in a mill is less forgiving of gaps larger than 0.005" 0.010".

A tapered shim, increasing in thickness from 0.005" on the shaft side of the die plate to 0.020" on the outside edge of the die plate, was found to improve water release rates. The slight bending of the plates this incurred was taken up by incorporating a 9½ inch diameter plate at the lower end of the stack. Test 71 utilized this arrangement, and ran for 2½ consecutive hours, producing 300 pounds of 19% moisture pellets from 22% moisture feedstock. The run was very constant, with the feed ranging from 21.7 % to 22.3% moisture, and the product ranging from 18.2% to 19.6% moisture.

This success led to the concept of reducing the distance the liquid had to travel by using dies whose diameter was just larger than that of the outermost row of holes, namely 9½ inches. Tests 73 to 89 investigated this. It was found that no extra water was removed under conditions which allowed continuous operation. However, this arrangement did result in the mill running much hotter, with steam being generated in many of the tests; conditions were hot enough in tests 75 and 85 for the coal to catch fire. It seems that the extra outer metal of the larger 12-inch diameter plates helps to dissipate the heat. Presumably, an optimum diameter could be found so as to utilize this heat.

Asphalt emulsion binders such as those from Monsey-Baker and Heritage were added to the wet coal in tests 84 and 87. Heritage s emulsion produced shiny strong pellets, with moisture being reduced from 17% to 13%. Another test (Test 92) was performed to determine the effect of feed particle size on dewatering. For this feedstock, the minus 270 mesh fines were removed to coarsen the feed, with no observable effect on mill performance.

Task 1-4
PROTOTYPE DIE EVALUATION

Objective: Develop methods of using the dewatering die to pelletize the three fuel formulations identified in task 1.2.

Accomplishments:

- Optimized test mill operation to produce acceptable pellets from the three fuel formulations identified in Task 1-2.
- Generated test batches of pellets required for standard ASTM analyses, physical/mechanical properties determinations, and fuel pulverization and combustion evaluations.
- Designed and tested a dewatering a die system for high moisture (50% sewage sludge, 50% coal) feeds for proof-of-concept testing in Phase II.
- Evaluated a low-cost agglomeration technology for production of composite fuels.

Dynamic Testing and Production of the Three Fuel Formulations

Pellets were produced from the three fuel formulations identified in Task 1-2 (as-received weight percent basis):

- 85% petroleum coke, 15% mixed waste plastics
- 80% beneficiated pond fines, 20% waxed cardboard
- 80% beneficiated pond fines, 20% sewage sludge

Samples of all three pelletized fuels were analyzed for standard ASTM chemical and combustion properties, as well as certain physical/mechanical properties to assess handling and storage characteristics. Additional samples were provided to ALSTOM Power Inc. for bench-scale pulverization and combustion evaluations (Task 1-5).

All three formulations produced good quality pellets.

The formulation using waxed cardboard pelletized very well because the wax tended to lubricate the pelletizing die and coat the pellets. The wax coated pellets had excellent water resistance and produced little dust. The waxed cardboard, shredded to a top size of about one-inch square, was readily fed through the pelletizer along with the coal with no problems (i.e., there was no need to shred the waxed cardboard to a finer size consist).

The petroleum coke/plastic pellets were also water resistant, but were somewhat dusty as a result of the mixture being heated prior to pelletization to soften the plastic (driving off the moisture at the same time). The petroleum coke gave off clouds of very fine dust. The weight percentage of coke which dusted may have been small, but a dust-collection system will be required for any commercial installation.

The only high-moisture pellets produced for testing at ALSTOM were those containing 20-percent sewage sludge. This feedstock was about 26-percent moisture as fed to the pelletizer, and about 23-percent moisture after pelletization in the dewatering die (Test 64 in Table 3-2). These pellets were air dried to about 9% moisture by spreading on the floor for three days before shipment to ALSTOM. While the pellets readily air dried to less than 10% moisture, the loss of such a high moisture content left the pellets low in density. These pellets readily absorbed moisture when directly exposed to water.

During pelletization tests with 20 percent sewage sludge, some problems feeding the pelletizer occurred. The wet sludge is slippery and, as discussed in Section 1-3, the material would slide away from, instead of down into, the die holes, apparently because the wheels of the pelletizer tend to slip like the wheels of a car on ice. Based on these tests, it appears that unless the sludge is pre-dried, a 20 percent sewage formulation is about the highest that can be fed to a pelletizer.

Design of Dewatering Die for Proof-of-Concept Testing

Economic analysis as outlined in Section 1-6 demonstrated that for a coal/sewage sludge composite fuel to make economic sense, a high proportion of sewage sludge is required. The proportion selected is 57% sewage sludge and 43% coal fines (as-received weight). As this material cannot be fed to a pellet mill, another approach was required.

The operation of an extruder is very similar to that of a pellet mill except the material to be extruded is fed by either a screw or a ram into and through a die. The dewatering die concept can be readily adapted to an extruder and, because the extruder has a positive feed system, high moisture materials and slippery materials can be fed.

To confirm that the concept worked in practice, a series of laboratory tests were performed as shown in Table 4-1. In these tests, a ram type extruder was fabricated with a series of plates on the solids discharge end (Figure 4-1).

Table 4-1. Piston Extruder Dewatering Tests

Coal (Wt%)	Sludge (Wt%)	Pressure (psi)	Time (secs)	Feed H_2O (Wt%)	Product H_2O (Wt%)
50	50	5,000	20	47.4	25.1
50	50	5,000	10	47.4	23.4
50	50	5,000	5	47.4	22.3
50	50	2,500	20	47.4	27.3
50	50	2,500	10	47.4	29.2
50	50	2,500	5	47.4	28.9
80	20	5,000	20	24.8	14.8
80	20	5,000	20	24.8	15.6
80	20	5,000	20	24.8	15.5
80	20	5,000	10	24.8	17.1
80	20	5,000	5	24.8	17.0
80	20	2,500	20	24.8	17.6
80	20	2,500	10	24.8	20.7
80	20	2,500	10	24.8	18.5
80	20	2,500	10	24.8	18.2
80	20	2,500	5	24.8	17.5

During testing, pressure was applied by a hydraulic press (Figure 4-2) over a time period varying from 5 to 20 seconds to simulate the effect of cycle time. Two pressure levels were also studied (2,500 and 5,000 psi), and both 20% and 50% sewage sludge was added to the coal.

As can be seen from Table 4-1, moisture reductions of over 50% were observed during some of the tests with the 50% sludge formulation. For the 20% sludge formulation, moisture reductions as high as 40% were observed. Strong to very strong pellets were produced during testing; however, the size of the pellets was too large to allow strength testing with the Kahl pellet strength tester. This performance exceeds the performance of the dewatering die when installed on a pellet mill.

In order to select a feed system, screw or ram, tests were performed by Dupps Company, Germantown, Ohio, a manufacturer of screw feed extruders. These tests indicated that the 50% sludge formulation could be fed by a screw; however, a ram extruder was selected for POC testing because a ram extruder is less expensive to build and offers greater testing flexibility The evaluation of the dewatering die concept is independent of the feed system, and the results of the ram tests are readily transferable to a screw-fed extruder or a pellet mill.

Figure 4-1. Ram Extruder with Attached Dewatering Die

Figure 4-2. Hydraulic Press and Dewatering Extruder

A number of extruder manufacturers were contacted to construct the POC unit for Phase II and Loomis Products Company of Levittown, Pennsylvania, was selected because of its reputation in the industry, level of interest in the project (Loomis will cost share construction of the POC unit and the president of Loomis will serve on the Advisory Committee), ability to meet the project schedule, and high quality of technical/engineering support. The POC unit will consist of a 40-ton force ram extruder press modified so that the body around the ram would incorporate a set of laminar plates with or without shims. The plates can be modified in the same manner as the laboratory pelletizer used during Phase I and will include provision for a taper at the end. A die cap or guillotine can be used to control the discharge of dewatered product in the same manner as the back pressure plate.

Evaluation of a Low Cost Dewatering/Agglomerating System

The work reported thus far in this section demonstrates that high-quality composite fuel pellets can be produced; however, the economic analysis in Section 1.6 also shows that pelletizing is expensive. In order to evaluate a less expensive technology that can prevent fuel component segregation and reduce moisture, an agglomeration technology developed by DOE was tested. This technology, called GranuFlow, involves the addition of a binding agent, such as an asphalt emulsion, to a coal/water slurry in a coal cleaning plant before the coal is mechanically dewatered.

During dewatering in a centrifuge or vacuum filter, the binding agent causes the coal particles to agglomerate, improving dewatering by making the cake more permeable. The agglomerates are also less prone to dusting and freezing and flow better than untreated coal.

Laboratory tests were performed to determine if GranuFlow could be used to produce a composite fuel containing both fine-sized coal and sawdust. Sawdust was selected for this test because co-firing sawdust and wood waste with coal has been done successfully by a number of electric utilities, and vast quantities of sawdust and waste wood are available in the U.S.

The tests were performed to simulate vacuum filtration using a 20.5 cm diameter Buchner funnel and a vacuum pump. The tests involved mixing 100 grams of coal or coal mixed with green sawdust and 900 milliliters (mls) of water. The material to be dewatered was mixed, placed in the filter, and the vacuum was applied for five seconds.

The results of these tests are summarized in Table 4-2. Tests 1 and 2 are coal only and provide the baseline of 14.4% moisture. The addition of an asphalt emulsion (CCB) in tests 3 and 4 reduced the moisture of the filter cake to 10.9%, demonstrating the effectiveness of the GranuFlow technology.

Table 4-2. Coal/Sawdust Granuflow Dewatering Tests

Test	Coal (Wt%)	Sawdust (Wt%)	CCB Dosage (Wt%)	Water Removed (mins.)	Moisture (Wt%)	Avg Moisture (Wt%)
1	100	0	0	2.25	14.8	
2	100	0	0	2.50	14.0	14.4
3	100	0	5	0.75	10.4	
4	100	0	5	1.00	11.3	10.9
5	95	5	0	2.75	18.0	
6	95	5	0	3.00	20.5	19.2
7	95	5	5	0.75	15.9	
8	95	5	5	0.75	14.5	15.2
9*	95	5	5	0.75	13.3	
10*	95	5	5	0.75	14.4	13.8

* CCB was added to the sawdust first and the treated sawdust then mixed with the coal.

Tests 5 and 6 utilize coal and five percent sawdust. The average moisture of this cake is 19.2%. In tests 7 and 8, 5% CCB was added to a mixture of coal and 5% sawdust and the cake moisture dropped to an average of 15.2%, only slightly higher than the baseline of 14.4% moisture.

In tests 9 and 10, the same proportions of coal, sawdust, and CCB were used as in tests 7 and 8, but the CCB was added to the sawdust first and the treated sawdust then mixed with the coal. The average moisture content of tests 9 and 10 is 13.8%, slightly lower than the baseline.

The increase in filter cake permeability caused by the GranuFlow treatment is indicated by the change in the time required for visible water to be removed during filtration. Without GranuFlow (tests 1 and 2), about 140 seconds were required for visible water to disappear from the coal. With GranuFlow (tests 3 and 4), about 50 seconds were required.

The change in time to remove visible water is especially striking with coal and sawdust. Without GranuFlow, about 170 seconds were required, while with GranuFlow, visible water disappeared in only 45 seconds. The removal of visible water is an indication of filtration time and translates into lower capital costs because filtration equipment can be smaller.

The various cakes produced during this testing were air dried and then shaken back and forth by hand in a manner similar to the method used in panning for gold to separate the gold from rocks and other minerals. With the untreated mixture of coal and sawdust (tests 5 and 6), the sawdust was readily separated from the coal by panning. However, this separation was not observed with the treated mixtures (tests 7, 8, 9, and 10), indicating that GranuFlow will prevent segregation during handling.

This laboratory evaluation indicates that it is technically feasible to use GranuFlow to produce a coal/sawdust composite fuel.

Task 1-5
MARKET ASSESSMENT OF BIOMASS/WASTE-CONTAINING FUEL FORMULATIONS

Objective: Finalize the three pelleted fuel formulations identified under Task 1.2, determine their fuel combustion and pulverization characteristics, and assess their applicability to utility/industrial boilers, specifically pulverized coal, cyclone, stoker, and fluidized bed units.

Accomplishments:

- Pellet samples of the three, candidate, pelletized fuel mixtures identified in Task 1-2 were produced by CQ Inc.'s laboratory pellet mill.

- Samples were characterized for typical industry fuel, ash, combustion, and physical properties using industry-standard ASTM analytical procedures.

- Samples were subjected to U.S. PPL developed bench scale pulverization and combustion test procedures in order to determine their applicability to Pulverized Coal (PC), Circulating Fluidized Bed (CFB), Stoker and Cyclone fired combustors.

CQ Inc.'s laboratory pellet mill was used to produce fuel pellets from the following formulations identified in Task 1-2: (1) a mixture of 85% petroleum coke (pet coke) with 15% mixed plastics, (2) a mixture of 80% Ginger Hill coal fines with 20% waxed cardboard, and (3) a mixture of 80% Ginger Hill coal fines with 20% sewage sludge, reported on a mass weight basis. These samples were then subjected to a series of chemical, physical, and combustion test procedures to assess their applicability to four primary boiler types.

Standard ASTM Sample Characterization

Each sample was characterized for typical industry fuel, ash, and combustion properties, including the following:

- Proximate--moisture, volatile matter, fixed carbon, ash
- Ultimate--carbon, hydrogen, nitrogen, sulfur, ash, oxygen
- Heating Value (Btu/lb)
- Chlorine and Sodium
- Ash Composition--SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, Na_2O, K_2O, TiO_2, MnO_2, P_2O_5, SO_3
- Ash Fusion Temperature--reducing and oxidizing

- Trace Elements--arsenic, beryllium, cadmium, chromium, cobalt, copper, fluorine, lead, manganese, mercury, nickel, selenium, zinc.
- Toxic Characteristic Leaching Procedure (TCLP)

Pertinent analyses of the three tested pelletized fuels are given in Table 5-1; the analysis for the Ginger Hill coal fines is also included for comparison. Complete analytical laboratory data sheets are given in Appendix B.

Physical/Mechanical Properties

The physical integrity of the fuel pellets (i.e., will they hold up during transport, handling, exposure to precipitation, etc.) will be critical to market acceptance of these fuels. Numerous pelletized fuels have failed to penetrate the utility and industrial fuel markets due to their inability to be handled, transported, and stored like coal and other solid fuels. Friability and weathering tests were conducted to provide an indication of the handling, transport, and storage characteristics of these three pelleted fuels.

A modified drop shatter test (ASTM Procedure D-440) was performed to determine the relative size stability and its complement, the friability, of the three selected pelletized fuels. Essentially, this test provides an indication of the pellet's ability to withstand breakage when subjected to handling at the pellet facility and during transit to the end user. Friable materials are those with the lowest size stability or, in other words, those which will produce the largest amount of fines when handled; the higher the friability number (expressed as a percentage), the more likely excessive fines will be generated during handling.

Friability of the three pellet types ranged from 12-15 percent. This compares very favorably to steam coals, which typically measure around 40 for bituminous coals and 20-30 for subbituminous coals.

Tests were performed to determine the water-resistant properties of the pellets, thereby providing an indication of how the pellets would hold up when exposed to rainfall as might be expected during storage and transport to the end user. Pellets were submerged in water and tested for pellet strength (using a Kahl pellet hardness tester) and water re-absorption (moisture gain) after being submerged for 24 hours, 48 hours, one week, and two weeks. The results are plotted in figures 5-1 and 5-2.

Table 5-1. As-Received Composite, Pelletized Fuel Analyses

Identification	100% Ginger Hill	85% Pet Coke 15% Plastics	80% Ginger Hill 20% W. Crdbd.	80% Ginger Hill 20% S. Sludge
VM	29.2%	27.5%	38.0%	32.6%
FC	45.7%	71.1%	39.8%	50.2%
FC/VM	1.56	2.59	1.05	1.54
HHV, BTU/lb	11,335	15,373	12,200	12,374
LHV, BTU/lb	10,721	14,880	11,565	11,832
Moisture	19.5%	0.5%	16.2%	9.2%
Hydrogen	4.2%	5.0%	4.7%	4.6%
Carbon	63.1%	85.1%	61.3%	68.8%
Sulfur	1.3%	4.5%	1.2%	1.6%
Nitrogen	1.0%	1.0%	1.0%	1.2%
Oxygen	5.3%	2.9%	9.5%	6.6%
Ash	5.6%	1.0%	6.1%	8.1%
Total	100.0%	100.0%	100.0%	100.0%
O/N	5.3	2.9	9.6	5.3
lb N/MMBTU	0.88	0.64	0.81	1.00
lb S/MMBTU	1.14	2.95	0.99	1.26
lb Ash/MMBTU	4.9	0.6	5.0	6.5
Chlorine	0.12%	0.37%	0.08%	0.16%
lb Cl/MMBTU	0.11	0.24	0.07	0.13
Fluorine (ppm)	53	92	64	ND
FSI	ND	1.0	4.5	9.0
HGI	ND	44	34	67
Density (lbs/ft^3)	ND	33.3	ND	32.5

Source: "Feedstock Characterization: Phase 1 Task 5 Final Report for CQ Inc.," PPL-00-CT-05, C.Q. Maney, June, 2000, © Combustion Engineering, Inc.

Table 5-1. As-Received Composite, Pelletized Fuel Analyses (continued)

Identification	100% Ginger Hill	85% Pet Coke 15% Plastics	80% Ginger Hill 20% W. Crdbd.	80% Ginger Hill 20% S. Sludge
Ash Fusion (^oF)	Reducing Atm.	Reducing Atm.	Reducing Atm.	Reducing Atm.
I.T.	2,075	2,065	2,170	2,045
S.T.	2,125	2,110	2,190	2,090
H.T.	2,180	2,135	2,230	2,130
F.T.	2,280	2,150	2,285	2,170
Diff. (F.T. - I.T.)	205	85	115	125
Ash Fusion (^oF)	Oxidizing Atm.	Oxidizing Atm.	Oxidizing Atm.	Oxidizing Atm.
I.T.	2,345	2,285	2,340	2,290
S.T.	2,370	2,330	2,400	2,350
H.T.	2,400	2,360	2,415	2,380
F.T.	2,430	2,425	2,430	2,400
Diff. (F.T. - I.T.)	85	140	90	110
Ash Comp.				
SiO2	47.1%	25.3%	46.6%	45.3%
Al2O3	20.7%	5.6%	20.5%	20.6%
Fe2O3	15.1%	9.0%	13.9%	15.7%
TiO2	1.1%	6.0%	1.7%	1.1%
CaO	5.8%	9.1%	4.6%	5.6%
MgO	1.1%	2.2%	1.2%	1.2%
Na2O	0.4%	1.7%	1.7%	1.2%
K2O	2.0%	*8.4%*	1.4%	2.3%
P2O5	0.1%	0.0%	0.1%	2.1%
SO3	7.4%	15.1%	7.4%	7.0%
Total	100.7%	82.3%	99.2%	102.0%
Base / Acid Ratio	0.35	0.82	0.33	0.39
Fe2O3 / CaO	2.61	0.99	3.04	2.83
SiO2 / Al2O3	2.28	4.48	2.27	2.20
lb K+Na/MMBTU	0.12	0.06	0.16	0.23
Slag Potent.	Medium-High	High	High	High
Foul Potent.	Low	Severe	Medium	High

Source: "Feedstock Characterization: Phase 1 Task 5 Final Report for CQ Inc.," PPL-00-CT-05, C.Q. Maney, June, 2000, © Combustion Engineering, Inc.

Table 5-1. As-Received Composite, Pelletized Fuel Analyses (continued)

Identification	100% Ginger Hill	85% Pet Coke 15% Plastics	80% Ginger Hill 20% W. Crdbd.	80% Ginger Hill 20% S. Sludge
Trace Metals (mg/kg, ppm)				
Arsenic	7.42	0.63	1.91	9.26
Beryllium	<0.71	<0.10	<0.73	<0.89
Cadmium	<0.89	<0.12	<0.91	<1.11
Chromium	14.87	3.77	15.59	20.20
Cobalt	22.66	3.67	19.94	20.42
Copper	8.85	12.24	16.13	36.41
Lead	11.15	25.92	188.50	9.99
Manganese	21.24	4.44	24.65	48.84
Mercury	0.15	0.05	0.08	0.06
Nickel	19.29	117.84	16.67	16.21
Selenium	1.53	1.15	0.93	1.57
Zinc	26.37	39.36	141.38	41.51
TCLP Extract. (mg/L, ppm)				
Arsenic	0.03	0.06	0.04	RC*
Beryllium	<0.71	<0.04	<0.04	<0.04
Cadmium	<0.05	<0.05	<0.05	<0.05
Chromium	<0.10	<0.10	<0.10	<0.10
Cobalt	<0.25	1.17	<0.25	0.32
Copper	0.05	0.89	0.12	<0.04
Lead	0.16	0.49	13.80	0.29
Manganese	2.13	3.70	1.80	4.90
Mercury	<0.0005	<0.0005	<0.0005	<0.0005
Nickel	0.19	8.32	0.12	0.31
Selenium	0.09	0.63	0.08	0.47
Zinc	0.70	23.90	13.90	0.07

*RC – Sample analysis recheck pending.

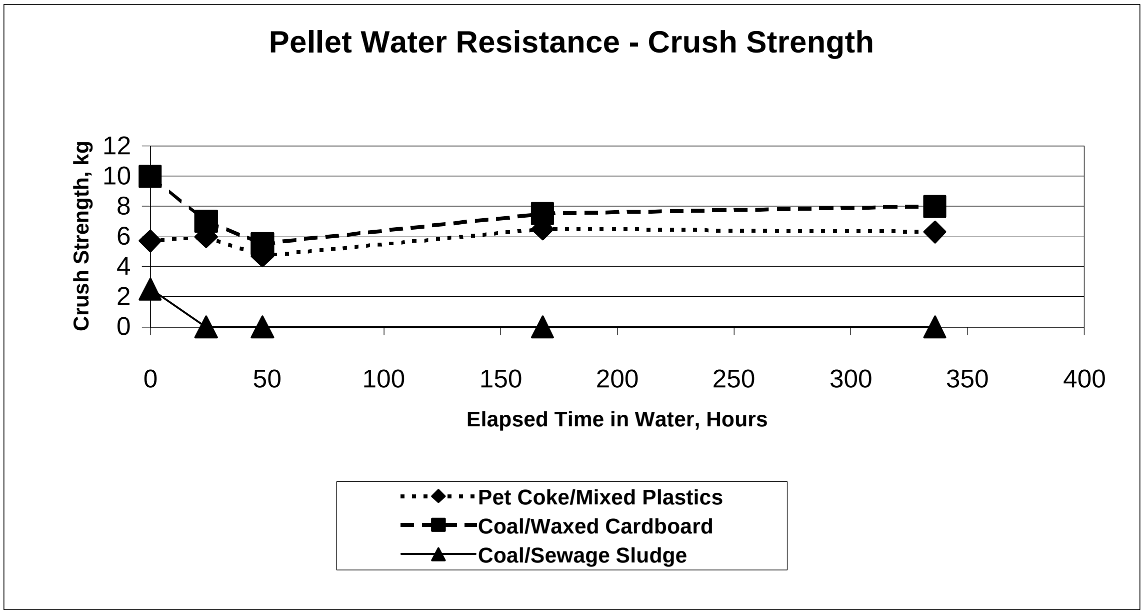


Figure 5-1. Effect of Weathering on Pellet Strength

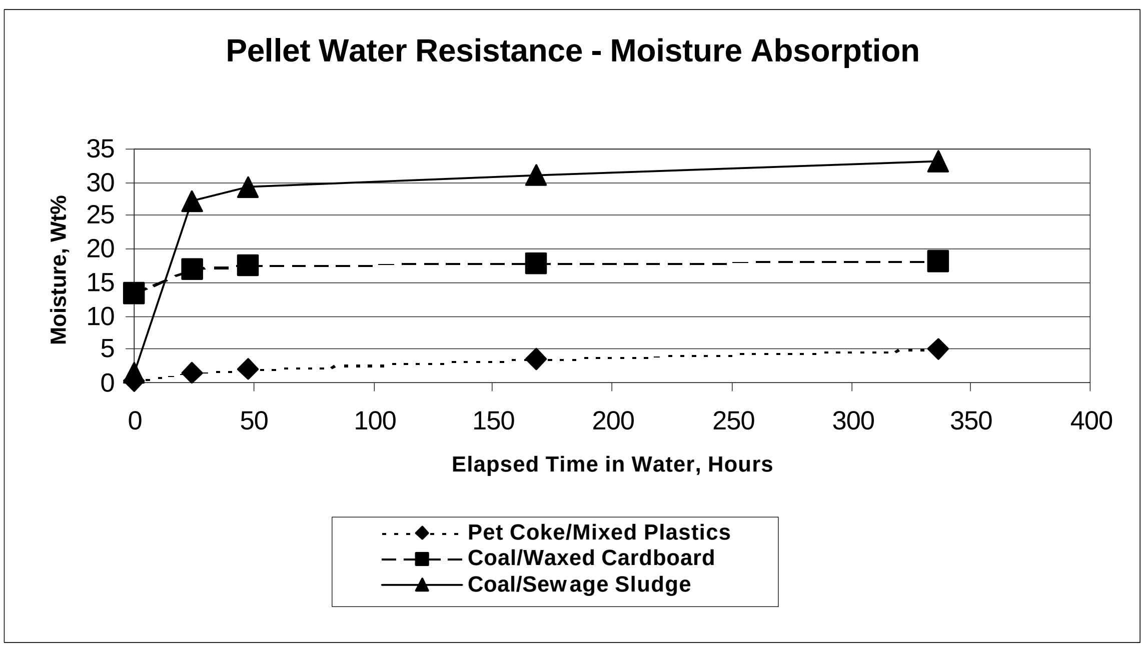


Figure 5-2. Water Absorption Characteristics of Pellets

The petroleum coke/plastics pellets retained their initial strength over the two-week period, with crushing strength consistently measured in the 5-6 kg range for all time intervals. The pellets did absorb a small amount of water over time, measuring 2% moisture after 48 hours and about 5% moisture after two weeks. The absorbed water did not adversely affect pellet strength.

The coal/waxed cardboard pellets had an initial crush strength of 10 kg, which was slightly reduced over time in water; after two weeks, crush strength was measured at 8 kg. After being submersed in water for 24 hours, the pellets increased in moisture content from about 13.5 percent to 17 percent; water absorption leveled off after that to the 17-18 percent range through the remainder of the two-week period. Both the petroleum coke/plastics pellets and coal/waxed cardboard pellets retained their form and most of their strength when submerged in water for two weeks.

The coal/sewage sludge pellets had a "green" moisture content of about 30 percent, but showed a propensity to quickly lose water when allowed to air dry under ambient conditions, with crush strengths in the 2-3 kg range. When submerged in water, air-dried pellets with moisture less than 2 percent immediately began to absorb water and soften. After 24 hours, the pellets were found to be very soft and would break apart upon routine handling. The 24-hour moisture content was 27 percent, and the pellets continued to absorb water over time, reaching a maximum of 33 percent moisture after two weeks. These tests indicate that coal/sludge pellets would have to be stored under cover and not exposed to wet weather, or a crusting agent or other type of sealant would be required to make the pellets water resistant.

Pulverization and Fireside Combustion Testing

ALSTOM Power Inc., through it s U.S. Power Plant Laboratory (US PPL), was subcontracted by CQ Inc. to assess the pulverization and combustion characteristics of the three selected pelletized fuels. The three candidate, pelletized fuel mixtures as identified during Task 1-2 of this program were subjected to US PPL developed bench scale pulverization and combustion test procedures in order to determine their applicability to Pulverized Coal (PC), Circulating Fluidized Bed (CFB), Stoker and Cyclone fired combustors. Examined fuels included (1) a mixture of 85% petroleum coke with 15% mixed plastics, (2) a mixture of 80% Ginger Hill coal fines with 20% waxed cardboard, and (3) a mixture of 80% Ginger Hill coal fines with 20% sewage sludge; all three formulations are stated on an as-received, mass weight basis.

Tests performed by ALSTOM Power included bench-scale pulverization evaluations using a Grindability Index (AGI) machine, pyrolysis testing in a drop tube furnace system, thermo-gravimetric analyses (TGA) to determine relative reactivity as compared to a typical, bituminous coal char, and weak acid leaching to assess the relative slagging potential of the pellet ash constituents. ALSTOM Power's complete task report is included as Appendix D.

Fuel Pulverization Characterization

Each of the three, candidate, pelletized fuels were subjected to testing in Alstom Power Inc. s Grindability Index machine (AGI). The AGI machine / methodology was developed to address shortcomings in the classical ASTM Hardgrove Grindability Index (HGI) method with regard to predicting pulverizer performance over the range of domestic and international coals encountered in commercial, pulverized coal applications.

The AGI apparatus, shown in Figure 5-3, incorporates much of the structure and logic of the HGI approach with high precision control of motor speed, continuous mechanical resistance measurements, and vertical spindle mill design grinding (roller) elements. Like the HGI, the starting sample for AGI use is size graded to 16 x 30 mesh (1190 by 590 microns). Unlike the HGI, the AGI uses sequential applications of a precise grinding force, where each sequence is followed by removal of undersize material (-200 mesh) from a 25 gram starting weight. The total, specific energy requirement is calculated when the amount of undersize material is equal to 60% of the starting weight. Results of the AGI testing have been shown to correlate well with field performance of commercial, vertical spindle mills for pulverized coal fired applications.

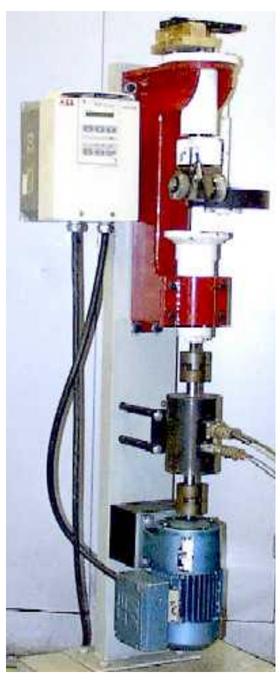


Figure 5-3. Alstom Power Inc.'s Grindability Index (AGI) Machine

Although the properties of some of these fuels precluded a precise measurement of specific energy requirements by this method, the observations made during testing are useful for assessing the fuel s overall grinding properties.

<u>85% Pet Coke / 15% Plastics AGI Results</u>
In preparation for the AGI testing, a 16 x 30 mesh, size graded test sample was prepared through the use of various bench scale fuel preparation procedures. For the 85% pet coke / 15% plastics mixture, this involved the use of US PPL s shredding mill. Coarse (<6 mm) shredding of the 85% pet coke / 15% Mixed plastics pellets segregated the sample to some extent. The fines in this shredded material were visibly all pet coke while the coarse material appeared to be predominantly plastic. However, the narrow sized 16 x 30 mesh material used for the AGI did contain both, although it appeared to be mostly plastic. The observed sample segregation is consistent with the particle size of the parent pet coke, which was shown to have a mass mean diameter of 32 microns (~400 mesh).

Seven iterations of the 30-second grind sequence were performed on the prepared sample until the test was aborted. The first iteration yielded the less than 3 grams of undersize (-200 mesh) material. However, this was the largest yield and appeared to consist primarily of pet coke. Subsequent iterations yielded less and less material as the remainder of the pet coke material was removed by sieving. The test was aborted after removal of less than 10 grams, or 40% of undersize material. However, the energy needed to overcome sample resistance for this removal was very high due to the unreduced plastic. From visual observations it appeared that none of the plastic in the sample was size reduced by the bench scale milling process.

During the milling process there was evidence that two types of bowl pads formed within the AGI machine. The first was from the pet coke and the second from the plastic. Examination of the bowl after the first test iteration showed a very tenacious pad consisting predominantly of pet coke. Subsequent iterations, which contained less pet coke, showed less evidence of this type of pad. However, as the ratio of plastic in the sample increased, a much weaker pad consisting of compacted plastic was evident (Figure 5-4). It is thought that the higher temperatures found in a commercial mill would be problematic for the retained plastic material, leading to substantial sticking and/or pasting of the plastic residue.

Figure 5-4. AGI Bowl with Pasted Material from Pet Coke/Plastic Pellets

Specific energy consumption in kWh/ton are normally calculated for an achieved grind of 60% minus 200 mesh using the AGI methodology. Although, this grind was not attained, a specific energy value for the pet coke and plastics mixture was calculated by extrapolation from the recorded data. Although not quantitative, as it is several times that of a typical bituminous coal (Figure 5-5), this value can be considered a qualitative indicator of a significant increase in mill power consumption for bowl mill preparation of the pet coke and plastic blend. The high energy consumption and tendency to form a bed pad on the bench scale grinding apparatus indicate a high likelihood of problem for use of this material in a commercial pulverizer system.

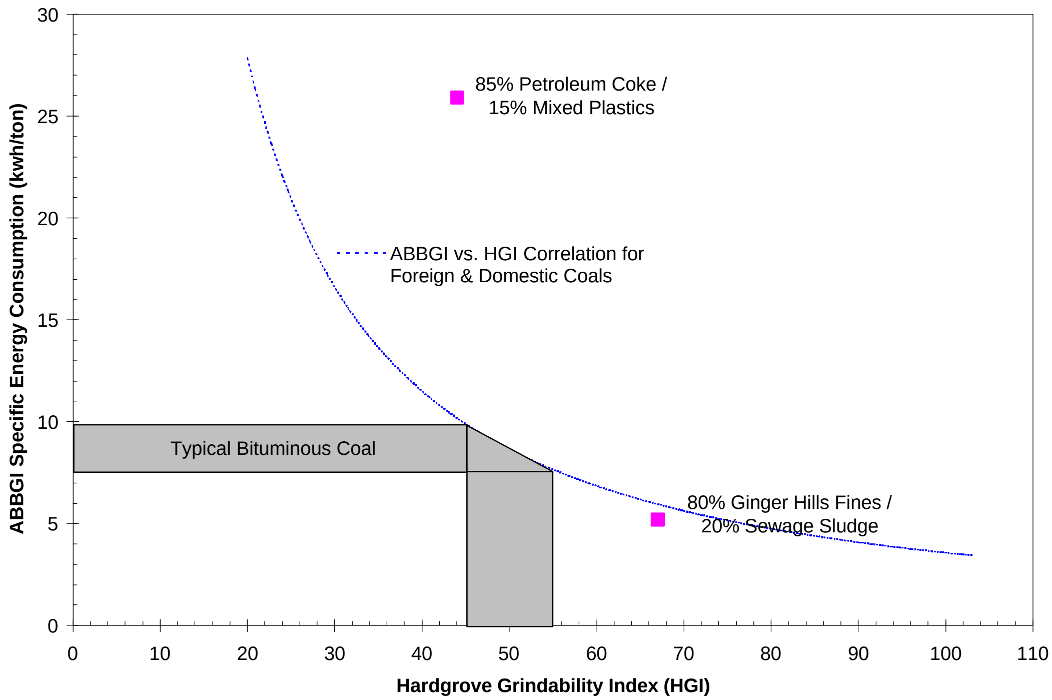


Figure 5-5. AGI Specific Energy Consumption vs. HGI for Test Pellets

80% Coal / 20% Waxed Cardboard AGI Results

This air-dried pellet sample was first shredded in a Wiley shredder mill to < 6-mm top size. Like the pet coke and plastics sample, this shredding resulted in a two component mixture with the first component being a fibrous portion consisting of the waxed cardboard with fine coal imbedded in it, and the second portion consisting entirely of the Ginger Hill coal fines. With sieving, all of the fibrous material was found to be in the coarse (>30 mesh) fraction. As a result, it was not possible to prepare a representative 16 x 30 mesh sample for the AGI measurement. With this result, it was decided to run the raw, non-size graded shredded material through the AGI machine without accumulating numerical energy/comminution data, but simply to observe compaction and pad formation behavior.

After 30 seconds of fully loaded operation, the shredded sample had noticeably compacted. The resultant pad, consisting of both the coal and the waxed fibers, had smeared over the bottom of the bowl. This pad had very little strength as it was easily broken apart and did not adhere well to the bottom of the bowl when inverted.

Based on these observations, it is expected that this material in an actual pulverizer will rapidly break into its base components. The coal, being very fine, will be carried out of the mill. However, the waxed cardboard will likely not be reduced in size, but instead tend to pack with roll pressure. At temperatures higher than the test temperature (21^{o}C), it is thought that this tendency will be exaggerated. Associated with this are potential problems relating to the softening and/or vaporization of the wax coating, which may exacerbate deposition and/or precipitate other problems up to and including mill fires.

80% Coal / 20% Sewage Sludge AGI Results

The 80% Ginger Hill coal fines/20% sewage sludge sample was reduced from the original pellet to the required 16 x 30 mesh grind by simple crushing and it did not require any shredding to achieve the desired size fraction. In addition, this material did not show any evidence of segregation during the size reduction. This material was very soft, requiring only three iterations of the AGI to attain greater than 60% through 200 mesh. The sample material remaining after size grading contained some easily broken flakes, but these did not adhere to either the bowl or the rollers. The appearance of some white material in the sample after the testing was complete suggest that the concentration of non-coal (sludge) material increased as the coal fines was preferentially pulverized.

The measured specific energy of 5.2 kWh/ton is in the range of many coals, and lower than that of typical bituminous coals (Figure 5-5). Unlike either the pet coke/plastics mixture, or the coal fines/waxed cardboard mix, the coal fines/sewage sludge results indicate that there will not likely be any inherent problems associated with commercial scale pulverization of this material rendering it applicable to pulverized coal fired boiler use.

Fuel Combustion and Fireside Characteristics

Fuel Pyrolysis Procedure

Two of the pelletized fuels, the 85% pet coke/15% mixed plastics fuel, and the 80% coal fines/20% sewage sludge fuel, were prepared for and pyrolized in U.S. PPL s Drop Tube Furnace System-1 (DTFS-1, Figure 5-6). The DTFS-1 is a vertical, entrained flow reactor that is used to provide controlled temperature conditions to study devolatilization, gasification and other combustion related phenomena.

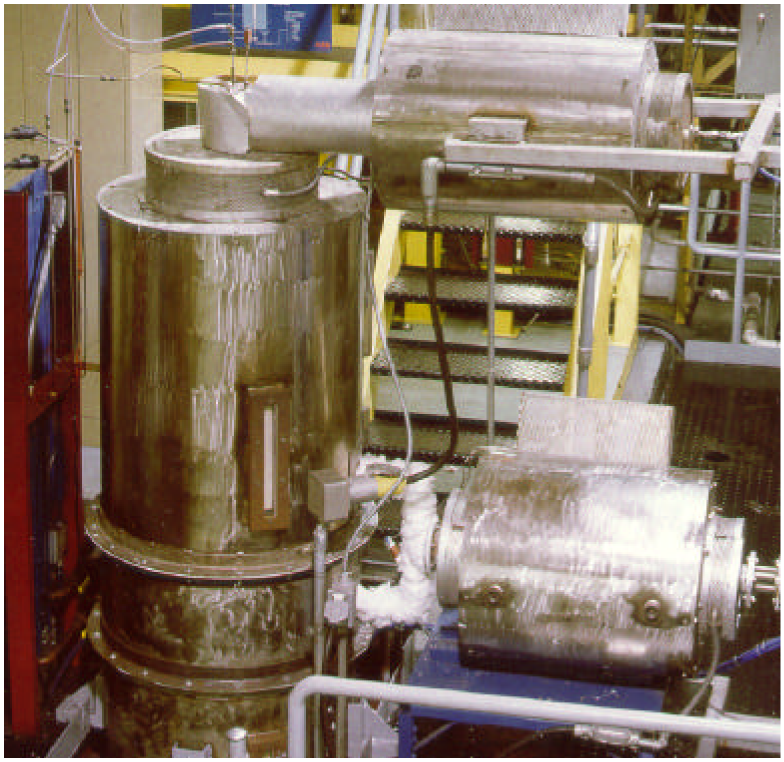


Figure 5-6. U.S. PPL s Drop Tube Furnace System-1 (DTFS-1)

The test fuels were pyrolized in an inert (Argon) atmosphere to generate chars for resultant reactivity testing in U.S. PPL s Thermogravimetric Analyzer (TGA). During the pyrolysis work, fuel nitrogen conversion to NO_x was also measured, as well as high temperature volatile yield (via post test char analysis using an ash tracer technique) in order to provide an index for use in predicting the combustion stageability for NO_x destruction. DTFS-1 high temperature volatile yield data and resultant char reactivity analyses provides a better basis for emissions prediction by providing input data with regard to the test fuels behavior under conditions that more accurately simulate those found in a commercial scale, utility boiler.

High Temperature Volatile Yield

The results of the DTFS-1 high temperature volatile yield are presented in Figure 5-7. Here, a proximate analysis of the as-fed DTFS-1 fuel and resultant char by-product was performed for the pet coke/plastic mixture, the coal/sewage sludge mixture, and the individual coal and pet coke portions of the above feeds as obtained via mechanical (crushing and sieve) separation of the as-received pellets. It is expected that some contamination of the as-separated coal and pet coke sample may have occurred by virtue of the mechanical and/or thermal stressing during the pelletizing process, thereby affecting the measured, individual constituent VM yield.

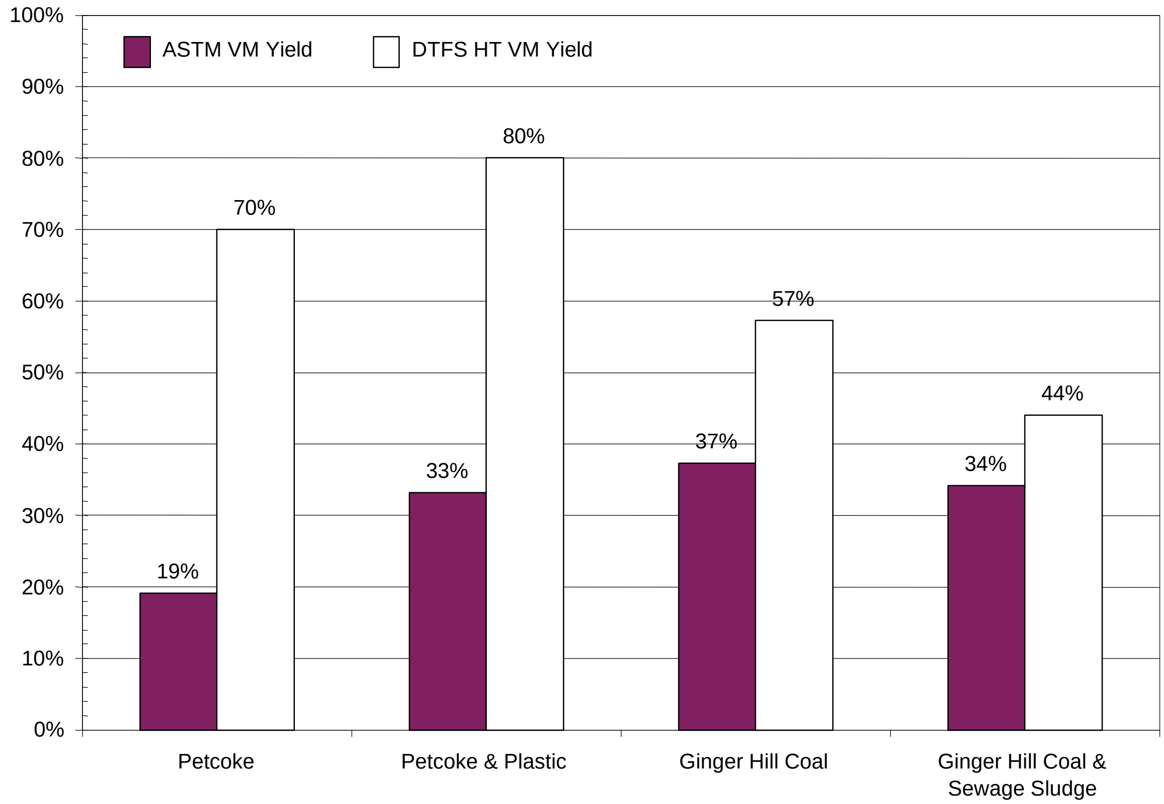


Figure 5-7. DTFS-1 Fuel Nitrogen Conversion and High Temperature Volatile Yield

As shown in Figure 5-7, both the pet coke individually, and the pet coke and plastics mixture exhibited significant increases in VM yields at the high DTFS-1 pyrolysis temperatures (~2,750 °F) as compared to the lower ASTM temperatures (~1,740 °F), with the high temperature (HT) yields doubling or tripling the ASTM values. The Ginger Hill coal, and Ginger Hill coal and sewage sludge, on the other hand, behaved more like a typical bituminous coal, showing increases in VM yield ranging from 30 to 50% at higher temperature.

Increased volatile yield correlates with increased stageability for improved NO_x control. As more volatile matter is released, it carries with it more of the fuel bound nitrogen. Under air-staged (substoichiometric) conditions, formation of N_2 is thermodynamically favored over NO, resulting in decreased overall fuel NO_x formation.

According to the test data, the pet coke and plastics mixture should be the most stageable of the fuels and therefore have the lowest fuel NO_x potential. However the results of the high temperature volatile yield experiments appear erroneous as a typical petroleum coke should, by definition, have limited to no volatile matter over the range of temperatures shown (ASTM to DTFS-1).

Prior, internal experimentation by ALSTOM Power Inc. has shown no appreciable increase in the volatile matter yield of a petroleum coke fuel at high temperature over that found via ASTM procedures, an expected result for this type of fuel. Given the above finding, this leads to the conclusion that either the result is spurious, or the pet coke is atypical for the class it represents.

One theory of analysis is that the as-fed DTFS-1 test sample had a greater than typical percentage of plastic, leading to the resultant increase in volatile yield as compared to the ASTM value. However, this possibility was reduced via testing of the pet coke component alone (obtained by mechanical separation from the composite fuel) which demonstrated a similar increase in volatile yield at high (DTFS-1) temperatures.

As a result of this work, it is preliminarily concluded that the tested pet coke is not representative of the typical class of petroleum coke derived fuels, containing more light hydrocarbons due to incomplete cracking during the coking process. Additional testing of the parent pet coke may be warranted to avoid issues associated with contamination of the pet coke with the plastic during the pelletizing process.

<u>TGA Coal/Char Analysis</u>

A Thermogravimetric Analyzer (TGA) was used to examine the relative reactivities of the DTFS-1 generated chars from the 85% pet coke/15% mixed plastics and 80% Ginger Hill Coal/20% sewage sludge composite fuels, and their mechanically separated parent constituents. An initial sample of ~5 mg in total weight from each of the four DTFS-1 generated chars, and each of the mechanically separated parent fuels was heated in an air/nitrogen (50/50, v/v) blend at a rate of 10 ^{O}C/min until they were completely oxidized (dwt-loss/dt = 0). The parent feeds were added for comparison to the chars and as an additional tool to understand the aforementioned, apparently anomalous high temperature volatile yield results for the pet coke based fuel.

The mechanically separated pet coke feed was, overall, as reactive as the Ginger Hill coal. Initially (0-800 °F), reaction rates for the pet coke are slower than that of the Ginger Hill coal. These results imply an expected delay in ignition associated with the pet coke that may affect flame stability in a commercial boiler. However, subsequently the demonstrated pet coke oxidation rates increase and surpass that of the Ginger Hill coal, ultimately arriving at the same overall level of oxidation as the Ginger Hill coal at the same final temperature and thus time. As for the high temperature volatile yield, it is unexpected that the pet coke should demonstrate similar overall oxidation rates to the Ginger Hill coal, supporting the theory that it may be an atypical petroleum coke.

As for the DTFS-1 generated chars, the most obvious result is that the pet coke/plastic mixture exhibits two distinct combustion regimes. That is, there is a high reactivity portion of the char that ignites in the 800 °F range, reaching a maximum rate of oxidation at ~920 °F. Following this, there is a lower reactivity portion that continues reacting, reaching a maximum rate of oxidation at ~1,100 °F. These distinct regimes suggest a carry over and/or re-condensation of some of the plastic portion of the pet coke and plastics mixture in char generated during the DTFS-1 pyrolysis work. It should be noted that in actual field combustion, the oxidation of this volatile/plastic component will enhance the overall combustion intensity for improved flame stability and lead to little differentiation between these two combustion regimes by virtue of creating a char consisting primarily of the unreacted pet coke fraction.

For a final comparison, the mechanically separated pet coke char sample was oxidized in the TGA. Results from this show it to be the least reactive of any of the tested feeds. Under field combustion conditions, it is likely that the more reactive plastics component will oxidize early on in the combustion process, leaving the pet coke fraction to make up the majority of the resultant char. As a result, it is expected that any pet coke based fuel will have unburned carbon loss related problems as compared to a typical bituminous coal impacting both boiler efficiency and ash disposal costs.

As for the Ginger Hill coal and the pet coke char, the Ginger Hill coal char and Ginger Hill coal/sewage sludge char exhibit only one combustion regime, with the maximum rate of combustion occurring at ~1,030 °F and ~1,060 °F, respectively. The Ginger Hill coal/sewage sludge char s behavior is comparable, but slightly less reactive than the Ginger Hill coal char, indicating a slight decrease in reactivity for the mixture as compared to the parent coal alone.

Weak Alkali Leachability

The alkali metal elements in a fossil fuel that contribute to upper furnace fouling have long been associated with that fraction of the overall alkali elements that are ion exchangeable with the organic matter of the coal. These ion exchangeable constituents are found primarily as metal humates, particularly in low rank coals. The determination of the ion exchangeable fraction of the alkali elements will thus shed additional light on the fouling behavior of a particular fuel s ash over and above that indicated by its overall elemental alkali concentration.

Alkali metal ions can be speciated from a fuel sample by a series of extractions. The water soluble fraction contains the alkali metals found as simple salts ($CaCl_2$, Na_2SO_4, $MgSO_4$). The ammonium acetate (NH_4AC) soluble fraction contains the water soluble species plus those that are ion exchangeable. The difference between the water soluble fraction and the ammonium acetate soluble fraction represents, then, the fraction of a given alkali element that is ion exchangeable with the fuel s organic matter and therefor is likely to contribute to upper furnace fouling and related problems. Results from water and ammonium acetate solubility extraction of the three composite, pelletized fuels are given in Appendix D.

The majority of the total sodium and potassium alkali were found to be tightly bound to the mineral matter (i.e., are not soluble in H_2O or NH_4AC). As a result, they are unlikely to contribute significantly to ash deposition and fouling. The calcium and magnesium, on the other hand, were largely extractable in ammonium acetate, thereby indicating that they would become available for fouling in the furnace convective pass. Of the three fuels, the Ginger Hill coal and sewage sludge mixture is, however, the best of the tested fuels by virtue of having the least ion exchangeable ash fractions on both a relative and absolute basis.

Combustor Applicability

The stated objective of this work was to evaluate three, candidate, composite solid fuels or fuel blends for potential use in large scale, commercial combustors. Evaluated fuels included: (1) a mixture of 85% pet coke with 15% mixed plastics, (2) a mixture of 80% Ginger Hill coal fines with 20% waxed cardboard, and (3) a mixture of 80% Ginger Hill coal fines with 20% sewage sludge. Considered combustors included: Pulverized Coal (PC), Circulating Fluidized Bed (CFB), Stoker, and Cyclone fired boilers.

In assessing the applicability of the three solid fuels to the four noted combustor types, consideration was given to five primary impact areas based on each fuel s previously identified ASTM analysis, and performed bench scale pulverization and reactivity testing. These areas include:

- **Reactivity**. The ability of the fuel to sustain ignition and provide for reasonable combustion efficiency in the absence of support fuel. Relevant fuel properties include as-fired volatile matter and moisture content, LHV, and char reactivity.

- **Slagging & Fouling Characteristics**. The propensity for the fuel s ash to form deposits on the waterwall surfaces (slagging) and within the boiler s convective pass (fouling) thereby impacting heat transfer rates and boiler heat balance. Relevant fuel properties include ash fusion temperatures and ash composition/chemistry (ash type, iron content, base/acid ratio, Na and K content, etc.).

- **Corrosion Behavior.** The propensity of the fuel to corrode waterwall and/or convective surfaces due to the formation of hydrochloric (HCl) and/or sulfuric acid (H_2SO_4) in the combustion gases and related compounds. Relevant fuel properties include chlorine and sulfur content (wt%) and loading (lb/MMBtu).

- **Fuel Handling & Preparation**. The ability of existing, field unit fuel handling and preparation equipment to process the fuel in pelletized form. Relevant fuel properties include pellet size and composition, and the higher heating value of the fuel (HHV) given in Btus per pound of fuel.

- **Pellet Size & Integrity**. The length and diameter of the individual pellets, the size of the raw (as-pelletized) constituents, and the pellet s physical integrity as they affect the combustion process. Relevant fuel properties include pellet size, and raw feed/constituent size within the pellet (i.e. % fines).

Results of an analysis considering the applicability of each of the three tested fuels for each of the four noted combustor types are summarized in Table 5-2.

Table 5-2. Combustor Applicability

Application	85% Pet Coke 15% Plastics	80% Ginger Hill 20% W Crdbd	80% Ginger Hill 20% S. Sludge
PC			
Applicability	na	na	High
Max Heat Input	0%	0%	>90%
Constraint(s)	Milling Corrosion	Milling	Slagging & Fouling
CFB			
Applicability	Medium	High	High
Max Heat Input	50%	>90%	>90%
Constraint(s)	Size & Integrity. Corrosion	Size & Integrity.	Size & Integrity.
Stoker			
Applicability	Low	Medium	Medium
Max Heat Input	10%	50%	50%
Constraint(s)	Ash Content Corrosion	Size & Integrity. Ash Content	Size & Integrity.
Cyclone			
Applicability	Medium	Medium	Medium
Max Heat Input	25%	50%	50%
Constraint(s)	Size & Integrity. React./Corrosion.	Size & Integrity.	Size & Integrity.

As shown, Table 5-2 lists the overall applicability of each candidate fuel to a given combustor type, rated as Low, Medium, or High, depending on the recommended maximum heat input rate for that fuel as fired in that combustor type. As defined here, a fuel rated Low in its applicability is not recommended for firing at more than 25% of maximum furnace heat input; a fuel rated as Medium in its applicability is recommended for firing at 25% to 50% of maximum furnace heat input; and a fuel rated as High is capable of being fired at greater than 50% of the maximum allowable furnace heat input rate, and can thus act as the primary combustor fuel.

Following the notation of overall applicability, a corresponding maximum recommended heat input is also given along with an itemization of the limiting constraint or series of constraints affecting the fuel s applicability. Noted constraints represent the predominant factors, and are not all inclusive in that an additional, unmentioned constraint may come into play at similar or slightly higher overall heat input levels. It should be noted that the results of this analysis, including recommended maximum allowable heat input rates, were subjectively determined based upon provided ASTM analyses, performed bench scale tests, and ALSTOM Power Inc. experience for typical PC, CFB, Stoker and Cyclone fired combustors. Actual, field performance will, however, vary depending upon the specific field unit design and operation, and the analyses of the actual as-fired fuel(s) in comparison to those shown in Table 5-1.

Of the tested fuels, the 80% Ginger Hill coal and 20% sewage sludge is the most broadly applicable, being suitable for use at greater than or equal to 50% maximum continuous rating (MCR) heat input for each of the four considered combustor types. For PC and CFB firing, the as-tested Ginger Hill/sewage sludge fuel may be used at ≥ 90% MCR maximum heat input, with limitations based on slagging & fouling concerns, which are related to the design and operation of the specific field unit (e.g., size of the box and firing rate), and pellet size & integrity, which is related to the raw feed size (size of fines) and pelletizing equipment characteristics, respectively. For stoker and cyclone firing, this fuel is rated at up to 50% maximum heat input, with limitations based on fuel pellet size and integrity as they affect the fuel handling equipment performance and the combustion process.

Of the remaining two fuels, the second most desirable combination is the 80% Ginger Hill coal and 20% waxed cardboard mixture, which is generally applicable to CFB, stoker and cyclone type combustors. Limitations on these three combustor types were primarily related to as-fired particle size and integrity (% fines), and ash content as it may affect bed cooling in a stoker-fired boiler (Note: the water content of the as-tested fuel at 16% is more than sufficient to compensate for the lower than desired ash content with regard to bed cooling). The fuel handling characteristics of the Ginger Hill coal/waxed cardboard blend was shown to be not favorable for PC applications as the fuel exhibited difficulty with both size reduction and bed pad (deposit) formation during the bench scale pulverization experiments, which indicate a strong potential for problems if applied to a commercial pulverizer.

The last fuel, the 85% pet coke and 15% mixed plastics blend is the least favorable of the tested fuels, regardless of the considered combustor type. For PC boilers, the difficulty encountered in bench scale pulverization with regard to size reduction and bed pad formation suggest problems for field application to a commercial pulverizer that need to be further explored before the fuel can be recommended at any level. For CFB s, the fineness of the pet coke fraction (nominally 30 microns mass mean diameter) will likely result in high levels of unburned carbon in the ash and poor combustion/boiler efficiency due to poor capture efficiency in the cyclone. For stoker-fired boilers, the combination of low ash (~1%) and water contents (>1%) make the fuel unsuitable at high mass fractions due to grate overheating concerns. Finally, for cyclone-fired combustors, the size and integrity of the particles, low ash content, and the low reactivity of the pet coke all contribute to limit the applicability of this as significant fractions of the total boiler heat input. In addition, owing to the random nature of the mixed plastics supply, the test fuel had a high (0.37%) chlorine content, which may lead to undesirable rates of corrosion for all four combustor types, further limiting the applicability of this fuel. The high sulfur content (4.5%) of the pet coke and plastics fuel will also likely be a concern for certain boilers both with regard to SO_2 formation and capture, and corrosion potential.

In all cases, these recommendations are based on an assumed, typical boiler in each of the four combustor classes. Specific performance issues affecting a given fuel s applicability will, however, need to be determined on a case by case basis.

Fuel Characteristics - Fuel Formulation No. 4

A fourth formulation, comprised of coal fines, sawdust, and asphalt emulsion, was evaluated when the coal/waxed cardboard formulation indicated marginal economics. The addition of asphalt emulsion to fine coal is the GranuFlow™ Process technology developed by DOE, and results in an agglomerated product with improved dewatering characteristics and flowability properties, more resistant to freezing, and reduces dust generation during handling; it also improves the recovery of fine-sized coal during the dewatering process (*"An Integrated Fine Coal Preparation Technology: The GranuFlow Process," W.W. Wen, U.S. DOE NETL, Pittsburgh, Pennsylvania).* Tests at commercial coal-cleaning plants showed that fine coal recovery from mechanical dewatering devices increased 13-17 percent at emulsion dosages as low as 0.7 percent and as high as 3.6 percent.

Sawdust has been co-fired with coal in at least four cyclones and 12 PC boilers in amounts ranging from 1% to 44% on a mass basis. TVA, GPU, and Southern Company have successfully fired sawdust blended with coal prior to the pulverizer; however, segregation of the sawdust occurred during handling in the GPU tests and the sawdust entered the pulverizer in slugs, reducing pulverizer capacity. These test results and conversations with experts from ALSTOM Power, Foster Wheeler, and Sandia National Laboratories indicate that, other than possible concerns about pulverizer performance, sawdust is an excellent fuel when fired with coal because of low fouling potential and SO_2, NO_x and CO_2 reduction.

DOE's National Energy Technology Laboratory has successfully burned asphalt-treated coal produced using the GranuFlow technology in a test PC boiler. Two- to four-hour tests showed no difficulty in achieving the desired particle size distribution and moisture content at a typical mill outlet temperature. Further, only small differences in fly ash loss-on-ignition (LOI) and emissions as compared to the baseline coal were noted. The results of these tests establish the technical feasibility of burning GranuFlow-treated coal in a PC boiler. However, the combination of coal, sawdust, and asphalt has never been tested for combustion characteristics.

Pulverizer performance will establish the upper limit of the proportion of coal/sawdust fuel that can be used in a PC boiler. However, from a fuel production standpoint, large quantities of sawdust can be agglomerated with fine-sized coal as long as the coal/sawdust mixture is blended with other coals so that the total amount of sawdust entering the boiler does not overload the pulverizer. This limitation does not exist with cyclone boilers, indicating that the coal/sawdust fuel could represent a large percentage of the feed to a cyclone boiler.

Task 1-6
PROCESS DESIGN AND ECONOMIC ANALYSIS

Objective: Develop a preliminary design and economic assessment of commercial facilities for producing biomass/waste-containing fuel pellets.

Accomplishments:

- Conceptual flowsheets for each of the three biomass/waste-containing fuel pellets evaluated in Task 1.5 were developed.
- A major equipment list for each scenario was compiled, and preliminary installed capital and operating costs estimated.
- For each of the three formulations, a revenues and expenses pro-forma was developed.

Conceptual flowsheets and preliminary capital and operating costs were developed for commercial facilities to produce fuel pellets from the following fuel formulations:

- Anthracite Silt/Mixed Plastics 100,000 tons per year
- Bituminous Coal Fines/Waxed Cardboard 100,000 tons per year
- Bituminous Coal Fines/Sewage Sludge 200,000 tons per year

For the mixed plastics case, anthracite silt was used in place of petroleum coke due to the potential market attractiveness of the anthracite stove fuel market, availability of anthracite fines, and concerns about the high sulfur content of petroleum coke. A fourth formulation, comprised of coal fines, sawdust, and asphalt emulsion, was evaluated when the coal/waxed cardboard formulation indicated marginal economics.

For each of the three initial formulations, a revenues and expenses pro-forma was developed. The detailed pro-forma and supporting calculations for each case are presented in Appendices E, F, and G as the following tables:

- Statement of Revenues and Expenses Pro-Forma
- Capital Costs (includes installation and project development costs)
- Annual Operating and Maintenance Costs
- Operator Labor & Fringe Costs
- Variable Costs Schedule
- Fuel Pellet Quality and Heat Requirement Estimates

Commercial Flowsheet Design and Plant Operation

Plant No. 1 Anthracite Fines and Mixed Plastics

Pellet plant No. 1 will process cleaned anthracite silt (minus ¼-inch coal fines) and mixed waste plastics according to the flowsheet shown as Figure 6-1. Projections are based on a weighted, as-received feedstock blend of 90 percent anthracite silt and 10 percent mixed plastics. Estimated feedstock/product quantities and qualities are summarized in Table 6-1.

Table 6-1. Anthracite Silt/Mixed Plastics Feedstocks and Product

(as-received)	TPH	TPY	Moisture Wt%	Ash Wt%	Sulfur Wt%	HV Btu/lb
Anthracite Silt	24.5	106,000	18.0	8.2	0.49	10,700
Mixed Plastics	2.7	11,800	0.2	2.3	0.33	14,400
Pellet Product	23.1	100,000	1.5	9.0	0.56	13,000

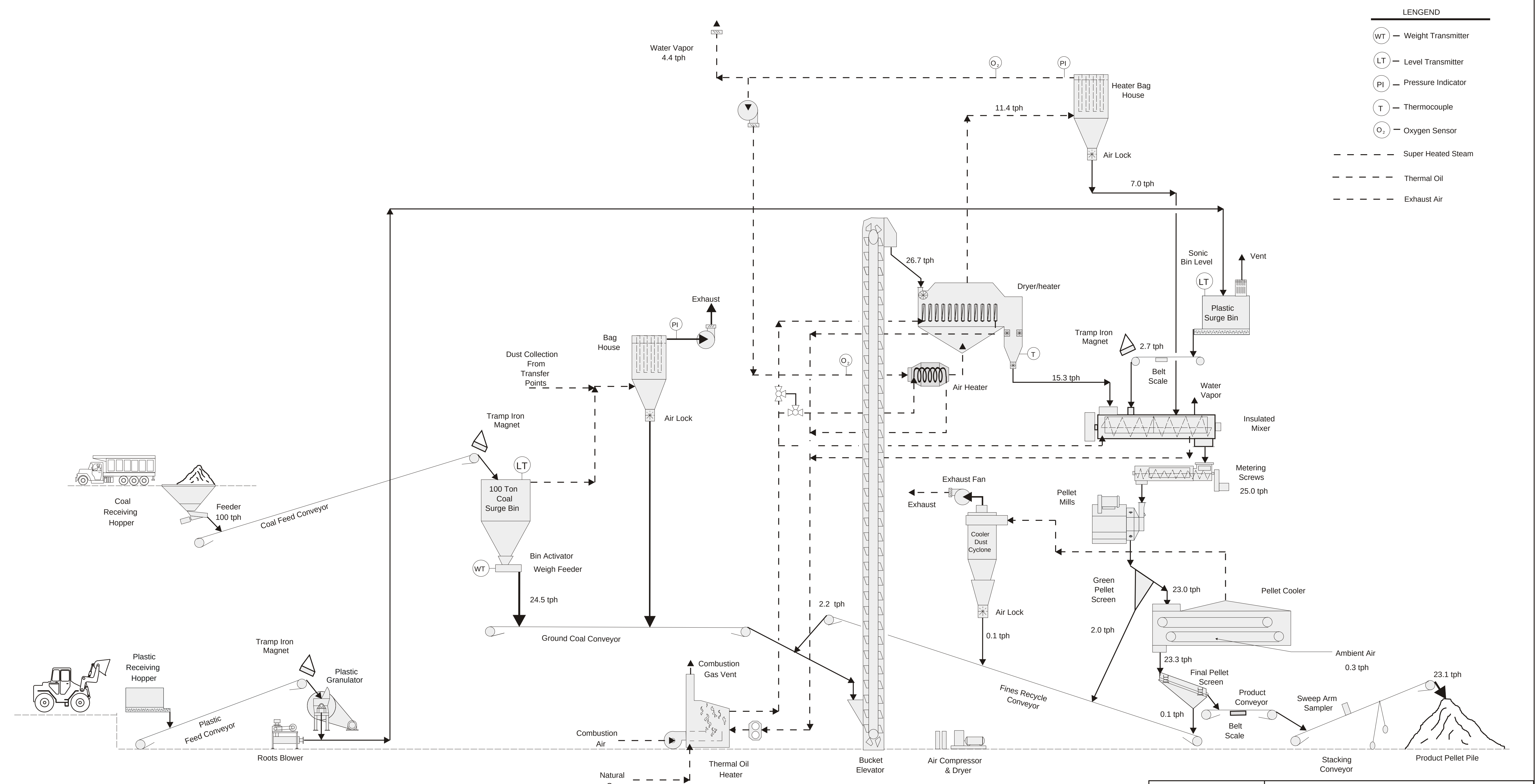
The plant is designed to process a feed of about 27 wet tons per hour (tph), consisting of approximately 2.7 tph plastics and 24.5 tph anthracite silt. The major processing steps are summarized as follows:

- Plastics are conveyed from a storage hopper to a plastics granulator; the shredded plastics are then fed to a surge bin and subsequently metered into a 25-tph insulated mixer.

- Cleaned anthracite silt at 18 percent moisture is received and transferred to a 100-ton surge bin and then conveyed by a belt conveyor and bucket elevator conveyor to a vibrating fluidized bed dryer/heater. A thermal oil heater provides hot gases to the dryer/heater. The dry heated coal exits the dryer/heater and is fed to the insulated mixer.

- The shredded plastics at ambient temperature (50°F) combines with the heated coal in the mixers; heat transferred from the coal to the plastics softens the plastic.

- The heated mix is metered via screw conveyors to two 15-tph pellet mills. Pellets exiting the mills are passed across a 30-tph "green pellet" screen and then into a 30-tph pellet cooler. The cooled pellets are then passed across a 30-tph final pellet screen and conveyed via a stacking conveyor to a pellet stockpile. Fines passing through the two sets of pellet screens and from the cooler dust cyclones are recycled back to the dryer/heater. Dust from materials handling transfer points and the dryer/heater are collected in baghouses and also returned to the circuit for pelletizing.



Revisions		
No.	By	Date
0	DEM	03/23/00

CQ Inc.

160 Quality Road
Homer City, PA 15748

100,000 Tons per Year
pFuel Processing Flowsheet

Scale	Project	Drawing No.
None	99E0331	FS-1

Figure 6-1

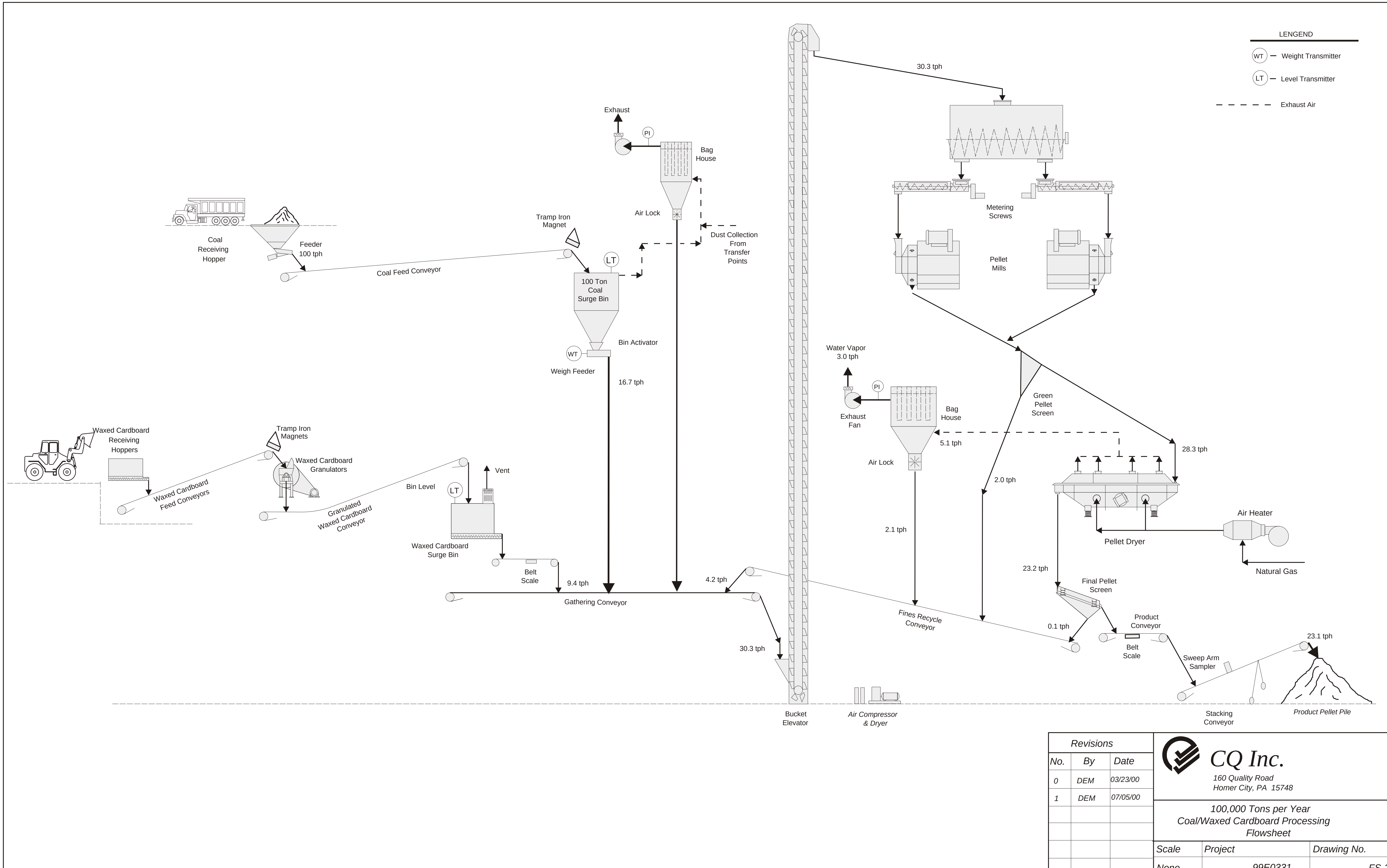

LENGEND
WT Weight Transmitter
LT Level Transmitter
Exhaust Air
30.3 tph
Exhaust
PI
Bag House
Air Lock
Dust Collection From Transfer Points
Metering Screws
Pellet Mills
Coal Receiving Hopper
Feeder 100 tph
Coal Feed Conveyor
Tramp Iron Magnet
LT
100 Ton Coal Surge Bin
Bin Activator
WT
Weigh Feeder
16.7 tph
Water Vapor 3.0 tph
PI
Exhaust Fan
Bag House
Air Lock
5.1 tph
Green Pellet Screen
28.3 tph
2.0 tph
2.1 tph
Air Heater
Pellet Dryer
Natural Gas
23.2 tph
Final Pellet Screen
0.1 tph
Product Conveyor
Belt Scale
23.1 tph
Sweep Arm Sampler
Stacking Conveyor
Product Pellet Pile
Waxed Cardboard Receiving Hoppers
Tramp Iron Magnets
Waxed Cardboard Granulators
Waxed Cardboard Feed Conveyors
Granulated Waxed Cardboard Conveyor
Bin Level
LT
Vent
Waxed Cardboard Surge Bin
Belt Scale
9.4 tph
Gathering Conveyor
4.2 tph
Fines Recycle Conveyor
30.3 tph
Bucket Elevator
Air Compressor & Dryer
Revisions
No. By Date
0 DEM 03/23/00
1 DEM 07/05/00
CQ Inc.
160 Quality Road
Homer City, PA 15748
100,000 Tons per Year
Coal/Waxed Cardboard Processing
Flowsheet
Scale None
Project 99E0331
Drawing No. FS-2

Figure 6-2

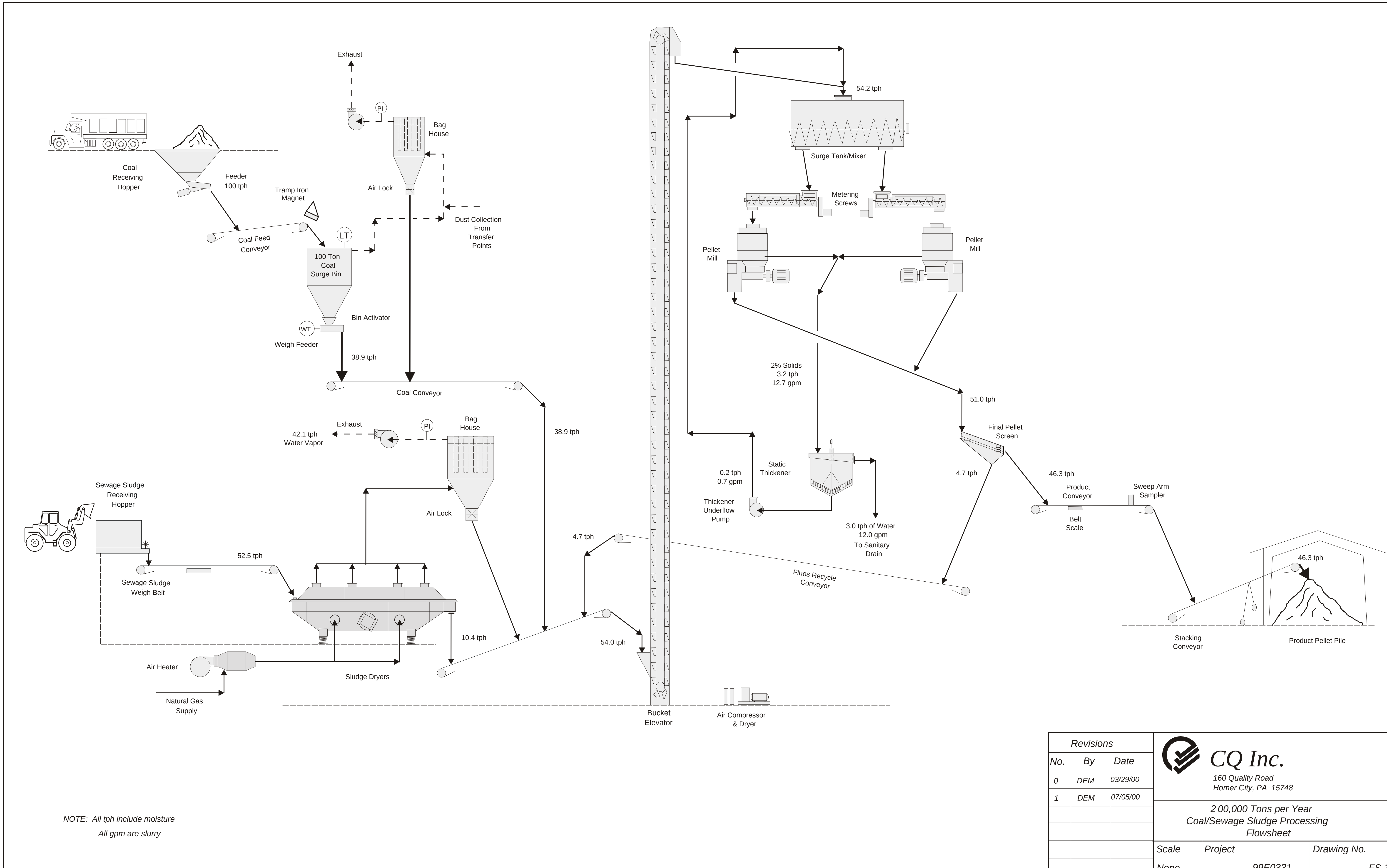

Exhaust
PI
Bag House
Coal Receiving Hopper
Feeder 100 tph
Tramp Iron Magnet
Air Lock
Dust Collection From Transfer Points
Coal Feed Conveyor
LT
100 Ton Coal Surge Bin
Bin Activator
WT
Weigh Feeder
38.9 tph
Coal Conveyor
Exhaust
42.1 tph Water Vapor
PI
Bag House
38.9 tph
Air Lock
Sewage Sludge Receiving Hopper
52.5 tph
Sewage Sludge Weigh Belt
10.4 tph
4.7 tph
54.0 tph
Air Heater
Natural Gas Supply
Sludge Dryers
Bucket Elevator
Air Compressor & Dryer
54.2 tph
Surge Tank/Mixer
Metering Screws
Pellet Mill
Pellet Mill
2% Solids
3.2 tph
12.7 gpm
51.0 tph
Final Pellet Screen
0.2 tph
0.7 gpm
Static Thickener
Thickener Underflow Pump
3.0 tph of Water
12.0 gpm
To Sanitary Drain
4.7 tph
46.3 tph
Product Conveyor
Belt Scale
Sweep Arm Sampler
Fines Recycle Conveyor
46.3 tph
Stacking Conveyor
Product Pellet Pile
NOTE: All tph include moisture
All gpm are slurry
Revisions
No. By Date
0 DEM 03/29/00
1 DEM 07/05/00
CQ Inc.
160 Quality Road
Homer City, PA 15748
2 00,000 Tons per Year
Coal/Sewage Sludge Processing
Flowsheet
Scale None
Project 99E0331
Drawing No. FS-3

Figure 6-3

Major equipment items are listed in Appendix E, Table E-2. Total installed horsepower for the plant is estimated at 1,650 hp, with the pellet mills (800 hp) and plastics granulator (350 hp) accounting for about 70 percent of the total installed horsepower requirements.

The plant would operate on a schedule of three shifts per day, 24 hours per day, and 240 days per year (5,760 scheduled operating hours annually). At an assumed availability of 75 percent, the plant would operate the equivalent of 4,320 full load hours annually. At a nominal production rate of 23 tph, the plant would process about 11,800 tpy of plastics and 106,000 tpy of coal (as-received basis) to produce 100,000 tons of pelletized product per year at an equilibrium moisture content of about 1.5 percent. The plant would employ 15 people, including three four-person crews for five days/week, 24 hour/day coverage; one additional laborer on the day shift for feedstock receiving/product loading; a plant manager and clerical/utility person.

Plant No. 2 Bituminous Coal Fines and Waxed Cardboard

Pellet plant No. 2 will process cleaned bituminous coal fines (e.g., coal fines recovered and beneficiated from a pond impoundment) and waxed cardboard according to the flowsheet shown as Figure 6-2. Initial projections were based on a weighted, as-received feedstock blend of 80 percent coal fines and 20 percent waxed cardboard. With this formulation, it was determined that a commercial operation would only be economical if the plant owner could collect tipping fees in excess of $80 per ton for the waxed cardboard. Subsequently, the formulation was revised to a feedstock of approximately 60 percent coal fines and 40 percent waxed cardboard. The estimated feedstock/product quantities and qualities are summarized in Table 6-2.

Table 6-2. Coal Fines/Waxed Cardboard Feedstocks and Product

(as-received)	TPH	TPY	Moisture Wt%	Ash Wt%	Sulfur Wt%	HV Btu/lb
Coal Fines	16.7	72,000	19.0	5.7	1.30	11,300
Waxed Cardboard	9.4	40,500	9.3	2.5	0.19	9,600
Pellet Product	23.1	100,000	5.0	5.1	1.01	12,050

The plant is designed to process a feed of about 26 wet tph, consisting of approximately 9.4 tph waxed cardboard and 16.7 tph coal fines. The major processing steps are summarized as follows:

- Waxed cardboard is conveyed from storage hoppers to two 5-tph granulators; the granulated waxed cardboard is then fed to a surge bin and subsequently conveyed to a 130 ft^3 ribbon mixer.

- Cleaned bituminous coal fines at 19 percent moisture are received and transferred to a 100-ton surge bin and then conveyed by a belt conveyor and bucket elevator conveyor to the ribbon mixer, where it combines with the granulated waxed cardboard.

- The mix is metered via weigh belt feeders to two 15-tph pellet mills. Pellets exiting the mills are passed across a 30-tph "green pellet" screen and then into a 30-tph pellet dryer. The pellets are dried to a moisture content of approximately 5 percent, are then passed across a 30-tph final pellet screen and conveyed via a stacking conveyor to a pellet stockpile. Fines passing through the two sets of pellet screens and dust collected in a baghouse from the dryer and materials handling transfer points are recycled back to the ribbon mixer.

Major equipment items are listed in Appendix F, Table F-2. Total installed horsepower for the plant is estimated at 2,170 hp, with the pellet mills (800 hp), pellet dryer (380 hp), and granulators (700 hp) accounting for about 86 percent of the total installed horsepower requirements.

The plant would operate on a schedule of three shifts per day, 24 hours per day, and 240 days per year (5,760 scheduled operating hours annually). At an assumed availability of 75 percent, the plant would operate the equivalent of 4,320 full load hours annually. At a nominal production rate of 23 tph, the plant would process about 40,500 tpy of waxed cardboard and 72,000 tpy of coal (as-received basis) to produce 100,000 tons of pelletized product per year at a moisture content of about 5 percent. The plant would employ 15 people, including three four-person crews for five days/week, 24 hour/day coverage; one additional laborer on the day shift for feedstock receiving/product loading; a plant manager and clerical/utility person.

<u>Plant No. 3 Bituminous Coal Fines and Sewage Sludge</u>

Pellet plant No. 3 will process cleaned bituminous coal fines (e.g., coal fines recovered and beneficiated from a pond impoundment) and treated sewage sludge according to the flowsheet shown as Figure 6-3. Initial projections were based on a weighted, as-received feedstock blend of 85 percent coal fines and 15 percent sewage sludge. With this formulation, it was determined that a commercial operation would only be economical if the plant owner could collect tipping fees in excess of $120 per ton for the sewage sludge. Subsequently, the formulation was revised to a feedstock of 80 percent coal fines and 20 percent sewage sludge (dry basis). On an as-received basis with sewage sludge delivered at 15 percent solids and the coal fines delivered at 19 percent moisture, the blend would be about 57 percent sewage sludge and 43 percent coal fines. The estimated feedstock/product quantities and qualities are summarized in Table 6-3.

Table 6-3. Coal Fines/Sewage Sludge Feedstocks and Product

(as-received)	TPH	TPY	Moisture Wt%	Ash Wt%	Sulfur Wt%	HV Btu/lb
Coal Fines	38.9	168,000	19.0	5.7	1.30	11,300
Sewage Sludge	52.5	227,000	85.0	4.4	0.27	1,100
Pellet Product	46.3	200,000	15.0	9.8	1.39	10,800

The plant is designed to process a feed of about 91 wet tons per hour (tph), consisting of approximately 52.5 tph sewage sludge (@ 15% solids) and 38.9 tph coal fines (@ 19% moisture). The major processing steps are summarized as follows:

- Sewage sludge received at 15 percent solids is conveyed from a storage hopper over a weigh belt feeder to sludge dryers. The sludge is dried to a moisture content of approximately 24 percent, and then conveyed via a bucket elevator conveyor to a 60-tph surge tank/mixer.

- Cleaned bituminous coal fines at 19 percent moisture are received, transferred to a 100-ton surge bin, and then conveyed along with the partially-dried sewage sludge to the surge tank/mixer.

- The mix, at approximately 20 percent moisture, is metered to two 30-tph pellet mills equipped with dewatering dies. Pellets exiting the mills at 15 percent moisture are screened and conveyed to a 3000-ton product storage building.

- Fines passing through the pellet screen are recycled back to the surge tank/mixer. Dust from materials handling transfer points and the dryer are collected in baghouses and also returned to the circuit for pelletizing.

- The water (at approximately 2 percent solids) removed from the pellets by the dewatering die is piped to an 8-ft diameter thickener for clarification. The clarified water is routed to a sanitary drain, and the thickened solids are pumped back to the surge tank/mixer.

Major equipment items are listed in Appendix G, Table G-2. Total installed horsepower for the plant is estimated at 2,960 hp, with the sludge dryers (1,950 hp) and pellet mills (800 hp) accounting for almost 93 percent of the total installed horsepower requirements.

The plant would operate on a schedule of three shifts per day, 24 hours per day, and 240 days per year (5,760 scheduled operating hours annually). At an assumed availability of 75 percent, the plant would operate the equivalent of 4,320 full load hours annually. At a nominal production rate of 46 tph, the plant would process about 227,000 tpy of sewage sludge and 168,000 tpy of coal (as-received basis) to produce 200,000 tons of pelletized product per year at a moisture content of about 15 percent. The plant would employ 15 people, including three four-person crews for five days/week, 24 hour/day coverage; one additional laborer on the day shift for feedstock receiving/product loading; a plant manager and one clerical/utility person.

Plant No. 4 Bituminous Coal Fines, Sawdust, and Asphalt Emulsion

The 4th formulation is beneficiated coal fines (90% by weight, as-received), such as the type recovered from waste coal slurry impoundments, mixed/slurried with sawdust (10% by weight, as-received) during the coal preparation process. An asphalt emulsion (at 2% dosage) is added to the slurry prior to the mechanical dewatering step.

This application would be a retrofit installation into an existing coal preparation facility, thus minimizing the capital costs of the installation. Preliminary economic projections were made for a case in which 5 tph of sawdust is added to an existing 50-tph fine clean coal stream (nominally minus 28 mesh), and then that mixture treated with a 2-percent dosage of asphalt emulsion prior to a centrifuge or other mechanical dewatering device. The addition of the emulsion was projected to increase fine coal recovery by about 10 percent.

On an as-received basis with the sawdust delivered at 38 percent moisture and the asphalt emulsion at 40 percent moisture, the estimated feedstock/product quantities and qualities are summarized in Table 6-4.

Table 6-4. Coal Fines/Sewage Sludge Feedstocks and Product

(as-received)	TPH	Moisture Wt%	Ash Wt%	Sulfur Wt%	HV Btu/lb
Coal Fines*	55.0	19.0	5.7	1.30	11,300
Sawdust	5.0	38.0	0.4	0.02	5,000
Asphalt Emulsion	1.0	40.0	0.1	1.47	9,440
Dewatered Product	61.0	19.0	5.2	1.21	11,000

* Includes additional 5 tph (10 percent) recovery from emulsion addition.

The major processing steps are summarized as follows:

- In the fines circuit of an existing coal preparation plant, sawdust at about 38 percent moisture is blended into the clean coal slurry stream.
- Prior to the mechanical dewatering step (e.g., screen bowl centrifuge), asphalt emulsion at 40 percent moisture is pumped from a storage tank to the coal/sawdust slurry at a dosage of nominally 2 percent.

- The coal/sawdust/emulsion mixture is fed through the centrifuge, and the dewatered product conveyed to a storage pile and/or blended in with the coarse clean coal product.

Major equipment items would include a storage tank for the asphalt emulsion, storage pad for the sawdust, and an asphalt emulsion pump. Total installed capital was estimated at $100,000.

For a plant operating 24 hours per day, 5 days per week, and 50 production weeks per year with an availability of 83 percent, the modified fines circuit would increase its output by about 55,000 tons per year (about 30,000 tons of additional coal and 25,000 tons of sawdust).

Economic Assessment

Estimates of the capital and operating costs (expenses) for all cases were prepared. Total expenses included installed capital and project development costs, amortization and interest expense, feedstock procurement, product delivery costs, operating and maintenance costs, royalties and product brokerage fees, insurances, and taxes. Revenues included product sales and applicable biomass/waste tipping fees. A revenues and expenses pro-forma was developed for each case over a 12-year period given the following conditions and assumptions:

- Coal fines feedstock cost of $0.80/MMBtu
- Biomass/waste delivered to pelletizing plant at no cost to plant owner
- Product delivery cost of $5.00/ton
- Product brokerage fees equal to 5% of product sales price
- Product royalty fee of $0.75/ton
- Equity investment of approximately 40%
- Seven year amortization schedule @ 9% interest
- Corporate tax rate @ 35%

A tipping fee of $40 per ton was used for the waxed cardboard and sewage sludge cases. The anthracite/mixed plastics case is projected to be profitable without collecting any tipping fee for the plastics. Table 6-5 summarizes the preliminary economic projections for the three fuel formulations.

Table 6-5. Economic Assessment Summary

	Unit	Anthracite/ Plastic	Coal Fines/ Wax Cardboard	Coal Fines/ Sewage Sludge
Product Sales Price	$/ton	65.00	38.55	24.80
Product Output	tpy	100,000	100,000	200,000
Coal Feedstock	tpy	105,800	71,900	167,900
Biomass/Waste Feedstock	tpy	11,800	40,500	226,700
Waste Tipping Fee	$/ton	0.00	40.00	40.00
Total Installed Capital	$1,000	7,877	7,640	20,520
Equity Investment	%	38.1	40.0	42.1
Annual Revenues	$1,000	6,500	5,470	14,030
Annual Expenses	$1,000	5,330	5,120	12,200
Revenues Less Expenses	$1,000	1,170	350	1,830
Operations Free Cash Flow	$1,000	1,290	484	2,250
Before Tax ROI	%	44.7	20.6	31.3
After Tax Cash Flow	$1,000	880	360	1,600
After Tax ROI	%	30.6	14.5	22.2

* Revenues and Expenses in Year No. 1.

Preliminary Economics Anthracite Fines and Mixed Plastics

A detailed pro-forma with supporting capital, operations, and economic data is presented in Appendix E. The total installed capital/project development costs are estimated at $7.88 million for a plant that produces 100,000 tpy of 13,000 Btu/lb fuel pellets. Total installed capital includes estimates for equipment; plant foundation and buildings; mechanical installation, electrical, and instrumentation; project development costs, loan origination fees, and interest expense during construction; site preparation and utility hookups; and plant commissioning (startup). Also included in the $7.88 million estimate is almost $1.0 million for engineering and project contingencies.

Total expenses (capital and operating) were estimated at $53.30 per ton, including the following major operating expenses ($/ton pellets):

Anthracite Fines (delivered)	$18.12
O&M (labor, supplies, rentals, etc.)	12.80
Dryer/Heater Fuel (natural gas)	3.28
Electricity	2.81
Product Brokerage Fee	3.25
Royalties	0.75
Insurance & Taxes	1.44

The balance of total expenses consists of capital depreciation, amortization, and interest expenses. For this case, the final product is priced FOB at the pellet plant; therefore, product transportation costs are not included as an expense or as part of the selling price.

Total revenues were projected based on a pellet sales price of $65 per ton. The target market for this type of product would be the anthracite industrial stoker boiler market and the "bagged" fuel market (for residential home-heating stoves). Anthracite coal used in industrial stoker boilers sells in the range of $50 to $80 per ton, while the bagged fuel market can bring prices over $100 per ton. The increase in volatile matter due to the plastics component of the anthracite/plastics pellet could be an issue for use in stoves which normally burn "smokeless" fuels.

The after-tax ROI for the anthracite/plastics is estimated at just over 30 percent without any tipping fee being collected for the waste plastics. Collection of any tipping fee would obviously increase revenues and ROI. For example, a tipping fee of $25/ton would add about $300,000 to the annual revenue stream and increase the after-tax ROI to over 36 percent. On the other hand, if the plant owner has to pay for the plastics, plant operating expenses would increase accordingly and the ROI would be less. For this scenario, it was estimated that the plant owner could pay up to $40/ton for waste plastics and still achieve an after-tax ROI of 20 percent.

The sensitivity of the product selling price was also evaluated (while holding tipping fee constant at $0). At a selling price of $65 per ton, first-year net cash flow is about $880,000 with an after-tax ROI of about 30 percent (in the eighth year of the project, net cash flow jumps to $1.8 million as a result of paying off the plant). At a price of $60 per ton, first-year net cash flow drops to about $570,000 with after-tax ROI of 20 percent. A "break-even" situation occurs at a selling price of around $50 per ton.

Preliminary Economics Bituminous Coal Fines and Waxed Cardboard

A detailed pro-forma with supporting capital, operations, and economic data is presented in Appendix F. The total installed capital/project development costs are estimated at $7.64 million for a plant that produces 100,000 tpy of 12,000 Btu/lb fuel pellets. Total installed capital includes estimates for equipment; plant foundation and buildings; mechanical installation, electrical, and instrumentation; project development costs, loan origination fees, and interest expense during construction; site preparation and utility hookups; and plant commissioning (startup). Also included in the $7.64 million estimate is almost $1 million for engineering and project contingencies.

Total expenses (capital and operating) were estimated at $51.23 per ton, including the following major operating expenses ($/ton pellets):

Bituminous Coal Fines (delivered)	$13.05
O&M (labor, supplies, rentals, etc.)	12.67
Dryer Fuel (natural gas)	2.45
Electricity	3.58
Product Delivery Costs	5.00
Product Brokerage Fee	1.93

Royalties	0.75
Insurance & Taxes	1.40

The balance of total expenses consists of capital depreciation, amortization, and interest expenses. For this case, the final product is priced delivered to the end user; therefore, product transportation costs estimated at $5.00 per pellet ton are included as an expense and as part of the selling price.

Total revenues were projected based on a pellet sales price of $38.55 per ton ($1.60/MMBtu) and a tipping fee of $40 per ton for the waxed cardboard. The target market for this type of product would be the bituminous industrial stoker boiler market. The pellets would have to be durable enough to withstand handling and transportation, maintaining their size integrity for use in stoker boilers.

At a tipping fee of $40 per ton for waxed cardboard, an after-tax ROI of 14.5 percent with first-year net cash flow of about $360,000 is projected. At a tipping fee of $25 per ton, the project is essentially a break-even proposition. Nationally, tipping fees for MSW landfills range between $15 and $100 per ton, while waste-to-energy facilities received average tipping fees of about $60 per ton in 1996.

Preliminary Economics Bituminous Coal Fines and Sewage Sludge

A detailed pro-forma with supporting capital, operations, and economic data is presented in Appendix G. The total installed capital/project development costs are estimated at $20.5 million for a plant that produces 200,000 tpy of 10,800 Btu/lb fuel pellets. Total installed capital includes estimates for equipment; plant foundation and buildings; mechanical installation, electrical, and instrumentation; project development costs, loan origination fees, and interest expense during construction; site preparation and utility hookups; and plant commissioning (startup).

Total expenses (capital and operating) were estimated at $61 per ton, including the following major operating expenses ($/ton pellets):

Bituminous Coal Fines (delivered)	$15.23
O&M (labor, supplies, rentals, etc.)	7.34
Dryer Fuel (natural gas)	13.70
Electricity	2.37
Product Delivery Costs	5.00
Product Brokerage Fee	1.24
Royalties	0.75
Insurance & Taxes	1.69

The balance of total expenses consists of capital depreciation, amortization, and interest expenses. For this case, the final product is priced delivered to the end user;

therefore, product transportation costs are included as an expense and as part of the selling price.

Total revenues were projected based on a pellet sales price of $24.81 per ton ($1.15/MMBtu) and a tipping fee of $40 per ton for the sewage sludge. The target market for this type of product would be the electric generation pulverized-coal boiler market. At a tipping fee of $40 per ton for sewage sludge, an after-tax ROI of 22.2 percent with first-year net cash flow of about $1.6 million is projected. At a tipping fee of $28 per ton, the project is essentially a break-even proposition.

Preliminary Economics   Coal Fines, Sawdust, and Asphalt Emulsion

A detailed pro-forma is presented in Appendix H. The total installed retrofit capital costs are estimated at $100,000 for a modified fines circuit that produces an additional 55,000 tpy of agglomerated coal/sawdust/asphalt product.

Operating expenses were estimated as follows ($ per incremental product ton, 55,000 additional tons per year):

Sawdust ($6/ton delivered)	$2.70
Asphalt Emulsion (2% @ $110/ton)	10.00
Maintenance/Repairs ($5,000/year)	0.09

Total revenues were projected based on a product sale price of $14.88 per ton ($0.80/MMBtu) for the 55,000 incremental tons. No additional labor is expected to be required for the circuit modification. Operating costs were escalated 2.5 percent annually over a seven-year period; product sales price was held constant over the same period. The target market for this type of product would be the electric generation pulverized-coal boiler market. An after-tax ROI of about 70 percent with first-year net cash flow of about $85,000 is projected.

CONCLUSIONS

Notable accomplishments from the work performed in Phase I of this project include the development of three standard fuel formulations from mixtures of coal fines, biomass, and waste materials that can be used in existing boilers, evaluation of these composite fuels to determine their applicability to the major combustor types, development of preliminary designs and economic projections for commercial facilities producing up to 200,000 tons per year of biomass/waste-containing fuels, and the development of dewatering technologies to reduce the moisture content of high-moisture biomass and waste materials during the pelletization process. Specifically, the major conclusions resulting from this work follow.

Interest in the use of biomass as a fuel source is high. Biomass includes all water- and land-based vegetation and trees (virgin biomass), and all waste biomass such as municipal solid waste (MSW), municipal biosolids (sewage sludge), animal wastes (manures), forestry and agricultural residues, and certain types of industrial wastes. The contribution of biomass energy to U.S. energy consumption in the late 1970s was over 850,000 barrels of oil equivalent (BOE) per day, or about 2% of total energy consumption. By 1990, the biomass energy contribution had increased to 1.4 million BOE per day, or about 3.3% of total energy consumption, and is expected to show continued significant growth. Global biomass energy consumption was almost 7% of the world's total energy consumption in 1990.

Many renewable energy technologies that utilize biomass suffer from low efficiencies, high technical risk, and other market entry problems. Although some tax incentives have been provided to promote the use of biomass for power generation, many have expired or require certain conditions that prove to be very difficult to implement. Co-firing biomass (typically sawdust) with coal has been done at 17 power plants; however, differences in combustion properties and physical characteristics can cause materials handling problems and combustion inefficiencies.

Three fuel formulations were developed using combinations of commonly available biomass, waste materials, and recovered beneficiated coal fines that have application to a large number of U.S. boilers. These formulations represented three fuel categories: Premium Fuel, Medium Cost/Medium Quality, and Low Cost/Low Quality.

Premium Fuel: Anthracite Fines & Waste Plastic. This formulation was developed for a premium fuel market, specifically the stoker and home-heating market which requires a very high-quality solid fuel which can sell for up to $70 per ton FOB plant. Beneficiated anthracite silt (90% by weight, as-received) is pelletized using waste mixed plastics as a binder (10% by weight, as-received). The final pelleted low-moisture, high-btu product is projected to have the following quality (as-received):

- 1.5% Moisture
- 9.0% Ash
- 0.56% Total Sulfur
- 13,000 Btu/lb

The use of waste plastic as a binder reduces fuel production costs. Due to its high volatile content (>90%), the volatile content of the fuel pellets can be adjusted to meet customer needs by varying the amount of plastics in the formulation. Plastic also has essentially no ash or sulfur and is high in heating value. Low ash reduces particulate emissions, and the combination of high heat content and low sulfur reduces SO_2 emissions. Preliminary economic projections for a 100,000-tpy commercial plant indicate that fuel pellets made from anthracite fines and plastics can be produced and sold at market price with an after-tax ROI of almost 31 percent (assuming that the pellet plant owner collects no tipping fee for the waste plastics, and that the plastics are delivered at no cost to the plant owner).

Medium Cost/Medium Quality: Coal Fines & Sewage Sludge. This formulation was developed for a medium grade fuel market, specifically the electric utility steam coal market. Beneficiated coal fines (80% by weight, dry basis), such as the type recovered from waste coal slurry impoundments, and treated sewage sludge (20% by weight, dry basis) are mixed and pelletized. The sewage sludge is typically received with very high moisture content (80-85 percent), and a combination of thermal drying and the pelletizer dewatering die would be used to reduce the moisture content of the final product to 15 percent. The final pelleted product is projected to have the following quality (as-received):

- 15.0% Moisture
- 10.0% Ash
- 1.4% Total Sulfur
- 10,800 Btu/lb

Preliminary economic projections for a 200,000-tpy commercial plant indicate that fuel pellets made from coal fines and sewage sludge can be produced and sold at market price with an after-tax ROI of about 22 percent (assuming that the pellet plant owner collects a tipping fee of $40 per wet ton for the sewage sludge).

Low Cost/Low Quality: Coal Fines & Sawdust. This formulation was developed for a low grade fuel market, specifically the electric utility steam coal market. Beneficiated coal fines (90% by weight, as-received), such as the type recovered from waste coal slurry impoundments, and sawdust (10% by weight, as-received) are slurried during the coal preparation process. An asphalt emulsion (at 2% dosage) is added to the slurry prior to the mechanical dewatering step. This is the GranuFlow™ Process technology developed by DOE, and results in an agglomerated product with improved dewatering characteristics and flowability properties, more resistant to freezing, and reduces dust generation during handling; it also improves the recovery of fine-sized coal during the beneficiation process. This product is only considered to be "low quality" because of its finer size consist and high moisture content as compared to typical steam-grade bituminous coals. Applying this technology to an existing 50-tph fines circuit and adding 5-tph sawdust results in an agglomerated product with the following quality (as-received):

- 19.0% Moisture
- 5.2% Ash
- 1.2% Total Sulfur
- 11,000 Btu/lb

Phase I tests indicated that the same dewatering/handling benefits are realized when adding asphalt emulsion to the coal/sawdust mixture as that realized when adding the asphalt emulsion to just coal alone. Preliminary economic projections were made for a case in which 5 tph of sawdust (at a delivered cost of $6 per ton) were added to an existing 50-tph fine clean coal stream, and then that mixture treated with a 2-percent dosage of asphalt emulsion (at a delivered cost of $110 per ton) prior to mechanical dewatering. The addition of the emulsion was projected to increase fine coal recovery by about 10 percent. With an existing coal cleaning plant and only minimal retrofit capital investment required for the emulsion storage tanks, pumps, etc., this case showed an ROI of almost 70 percent.

Dewatering Die Development. A 300 pounds-per-hour, semi-pilot scale dewatering pelletizing mill was fabricated to produce test batches of cylindrical pellets from mixtures of coal fines, biomass, and wastes. Various die geometries, including die diameter, die length-to-diameter (L/D) ratio, die inlet tapers, and moisture discharge configurations, were investigated to optimize mill operation and performance.

The original dewatering die design was improved with the addition of back pressure plates, located just beneath the die stack, to increase the resistance of material flow through the die, thus increasing material residence time and compaction, and increasing the quantity of water discharged from between the die plates.

Initial dewatering die tests were performed with beneficiated coal fines recovered from a slurry pond impoundment in western Pennsylvania. With feedstock moistures of 15-22 percent, moisture reductions of 5-10 percent were achieved. At feedstock moistures over 22 percent, moisture reductions of around 20 percent were achieved with the back-pressure plates installed (no dewatering occurred above feedstock moistures of 22 percent without the back pressure plates). Similar results were achieved with the coal/sewage sludge mixtures. At feedstock moistures less than 15 percent, the dies usually plugged and no dewatering occurred, with or without back-pressure plates.

The use of the back-pressure plate allowed lower length-to-diameter (L/D) ratios. The best dewatering results (15-25 percent reduction) were achieved with the following mill configuration: back-pressure plates, low L/D ratios (1.7-2.1), a ¼-inch taper on the top die plate, and tapered shims placed around the perimeter and between the die plates.

Other conclusions resulting from Phase I work follow below:

- To address the issue of high-moisture feedstocks, a laboratory-scale ram extruder was fabricated. This unit was able to process a feed consisting of 50-percent sewage sludge and 50-percent coal (as-received weight percent, total mix moisture of 47 percent) to produce pellets of about 23-percent moisture. A feed of 20-percent sewage sludge and 80-percent coal (total mix moisture of 25 percent) produced pellets at 16-percent moisture, a reduction of 36 percent.

- In order to evaluate a less expensive technology that can prevent fuel component segregation and reduce moisture, an agglomeration technology developed by DOE was tested. This technology, called GranuFlow , involves the addition of a binding agent, such as an asphalt emulsion, to a coal/water slurry in a coal cleaning plant before the coal is mechanically dewatered. Laboratory tests indicated that it is technically feasible to use GranuFlow to produce a coal/sawdust composite fuel, reducing the moisture content of an agglomerated coal/sawdust product from 19 percent to as low as 14 percent at a 5 percent emulsion dosage.

- Other fuel formulations investigated during Phase I included a mixture of petroleum coke and mixed plastics (issues of concern included high sulfur content and low reactivity of the petroleum coke) and a mixture of coal fines and waxed cardboard (pulverization issues and marginal economics).

- Based on ASTM fuel analyses and bench-scale pulverization and combustion test results, the coal/sewage sludge pelletized fuel was found to be applicable to each of the four major combustor types: pulverized coal (PC), circulating fluidized bed (CFB), stoker and cyclone. It exhibited no obviously detrimental behavior in the bench-scale pulverizer testing, and is sufficiently reactive to provide for stable ignition and reasonable carbon burnout levels as compared to a typical, eastern bituminous coal. The only significant drawback to the present composition is the ability of the fuel pellets to maintain a reasonable degree of integrity to allow for sufficient residence time for complete combustion as applied to stoker and cyclone fired boilers.

- Neither the petroleum coke/mixed plastics fuel nor the coal/waxed cardboard fuel were found to be generally applicable to all combustor types, and only the coal/waxed cardboard fuel is applicable as a primary fuel in any one. Both of these fuels exhibited significant problems in the bench-scale pulverization testing, including difficulty in size reduction and bed pad formation making them inapplicable to PC firing as determined by this scale of testing. The petroleum coke/mixed plastics fuel, because of its low reactivity char combined with its small (~30 micron) particle size, may compound combustion efficiency issues for CFB, stoker, and cyclone fired boilers. In addition, the high chlorine content of this particular sample of mixed plastics resulted in the composite fuel pellet also having high chlorine content (0.37%), which is undesirable due to boiler corrosion potential.

Based on Phase I ASTM fuel analyses, dewatering/pelletization evaluations, bench-scale pulverization and combustion test results, and boiler applicability assessments, it is recommended that a Phase II effort address the proof-of-concept (POC) investigation of the following biomass/wastes/coal formulations: (1) Anthracite fines and mixed plastics, (2) Bituminous coal fines and treated sewage sludge, and (3) Bituminous coal fines, sawdust, and asphalt emulsion. Phase II will prove that the production and use of these new composite, solid fuels are viable at commercial scale, and will lead to full-scale commercial demonstrations during or after Phase II.

In addition, the laboratory tests of the dewatering die during Phase I indicate that the technology has the potential to cost-effectively convert high-moisture biomass into an acceptable boiler fuel that reduces emissions of NO_x, SO_2, CO_2, and particulates. This technology should also be tested at POC scale in Phase II.

ACRONYMS/ABBREVIATIONS

AGI	ALSTOM Power's Grindability Index Machine
ASR	Analytical Service Request
ASTM	American Society for Testing and Materials
BTU	British Thermal Unit
CFB	Circulating Fluidized Bed Boiler
DOE	U.S. Department of Energy
DTFS	Drop Tube Furnace System
HHV	Higher Heating Value
L/D	Length-to-Diameter Ratio
LHV	Lower Heating Value
LOI	Loss on Ignition
MMBTU	Million British Thermal Units
MSW	Municipal Solid Waste
NETL	National Energy Technology Laboratory
PC	Pulverized Coal Boiler
POC	Proof of Concept
QA/QC	Quality Assurance/Quality Control
ROI	Return on Investment
TAC	Technical Advisory Committee
TCLP	Toxic Characteristic Leaching Procedure
TGA	Thermogravimetric Analyzer/Analysis
TPH	Tons per Hour
TPY	Tons per Year
US PPL	ALSTOM's US Power Plant Laboratories
WBS	Work Breakdown Schedule
WCC	Waxed Corrugated Cardboard

APPENDIX A

SAMPLE ANALYTICAL REPORTS
BIOMASS, WASTE, AND COAL

GOULD ENERGY DIVISION
P. O. BOX 214
CRESSON, PA 16630
(814) 886-7400
STANDARD LABORATORIES, INC.

DATE: 9-23-1999
SAMPLE NO. 595772

C. Q., INC.
160 QUALITY CENTER ROAD
HOMER CITY, PA 15748

SAMPLE ID: GINGER HILL SYNFUELS TEST 99072101

OPERATING CO.:
SAMPLED BY: CUSTOMER PROVIDED
MINE:
LOCATION:

DATE SAMPLED: 7/21/99 DATE RECEIVED: 8/10/99
WEATHER:
GROSS WEIGHT:

OTHER ID: SCREEN BOWL PRODUCT STANDARD SAMPLE # 593089 WET COAL FINES (2 8M X 0) PROJECT 99E0331 T1 2, BIOMASS FEEDBACK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

	ASTM METHOD	AS RECEIVED	DRY BASIS
MOISTURE	D2961 D3302 D3173	19.54%	XXX
VOLATILE MATTER		29.21%	36.31%
FIXED CARBON	D3172	45.67%	56.76%
ASH	D3174	5.58%	6.93%
SULFUR	D4239 METHOD 3.3	1.29%	1.60%
CARBON	D3178	63.11%	78.44%
HYDROGEN	D3178	4.15%	5.16%
NITROGEN	D3179	1.00%	1.25%
OXYGEN	D3176	5.33%	6.62%
BTU/LB	D2015 D1989	11335	14088
MAF BTU/LB			15137
LBS OF SO2 PER MILLION BTU			2.27
LBS OF SULFUR PER MILLION BTU		1.138	
CHLORINE	D4208	.12%	.15%
FLUORINE	D3761	52.54 PPM	65.30 PPM
PERCENT SOLIDS			80.46%

ASH FUSION TEMPERATURE(S)

D1857	REDUCING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	2075
SOFTENING TEMPERATURE	2125
HEMISPHERICAL TEMPERATURE	2180
FLUID TEMPERATURE	2280

D1857	OXIDIZING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	2345
SOFTENING TEMPERATURE	2370
HEMISPHERICAL TEMPERATURE	2400

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BLACK SEAL ANALYSIS

GOULD ENERGY DIVISION
P.O. BOX 214
CRESSON, PA 16630
STANDARD LABORATORIES, INC.

DATE : 7-23-1999
MASTER SAMPLE NO. 593089

C. Q., INC.
160 QUALITY CENTER ROAD
HOMER CITY, PA 15748

SAMPLE ID: SCREEN BOWL CLEAN COAL COKE WE T FINES ID 99072101

ERATING CO.: JOB 97E0313 T4
NE:
MPLED BY: CUSTOMER PROVIDED
OSS WEIGHT: 9.02

DATE SAMPLED: 7/21/99

DATE RECEIVED: 7/22/99

HER ID: PROJECT GINGER HILL SYNFUELS STARTUP WET SCREEN

CERTIFICATE OF ANALYSIS

FRACTION	WT%	MOISTURE	ASH	SULFUR	BTU	LBS SO2 PER MBTU	MAF BTU
28M	.52	1.52	6.90	1.40	14084	1.99	15128
3M X 150M	68.47	1.11	4.53	1.31	14467	1.81	15154
50M X 270M	14.20	1.57	4.68	1.51	14425	2.09	15132
70M X 0	16.81	1.22	18.59	3.19	12005	5.31	14745

CUMULATIVE RETAINED - DOWN

F TION	WT%	ASH	SULFUR	BTU	LBS SO2 PER MBTU
28M	.52	6.90	1.40	14084	1.99
3M X 150M	68.99	4.55	1.32	14465	1.82
50M X 270M	83.19	4.57	1.35	14458	1.87
70M X 0	100.00	6.93	1.66	14045	2.36

CUMULATIVE RETAINED - UP

FRACTION	WT%	ASH	SULFUR	BTU	LBS SO2 PER MBTU
28M	100.00	6.93	1.66	14045	2.36
8M X 150M	99.48	6.93	1.66	14045	2.36
50M X 270M	31.01	12.22	2.42	13113	3.69
70M X 0	16.81	18.59	3.19	12005	5.31

NALYTICAL RESULTS ARE STATED ON A DRY BASIS

AGE 1

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STANDARD LABORATORIES, INC.

DATE: 9-23-1999
SAMPLE NO. 595772

CERTIFICATE OF ANALYSIS (CONT.)

	AS RECEIVED	DRY BASIS
FLUID TEMPERATURE		2430

ASH MINERAL COMPOSITION
D2795 D3682

SILICON DIOXIDE	47.08 %
ALUMINIUM OXIDE	20.67 %
FERRIC OXIDE	15.07 %
TITANIUM DIOXIDE	1.05 %
PHOSPHORUS PENTOXIDE	.11 %
CALCIUM OXIDE	5.78 %
MAGNESIUM OXIDE	1.12 %
SODIUM OXIDE	.41 %
POTASSIUM OXIDE	2.04 %
SULFUR TRIOXIDE	7.35 %

APPROVED BY ____________

APPROVED BY ____________

78 Analytical Material Subjected To Accelerated Drying Procedure

BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.

CQ, INC.
160 QUALITY CENTER
HOMER CITY, PA 15748

DATE 9-23-99
SAMPLE NO: 595772

DATE SAMPLED: 7-21-99

DATE RECEIVED: 8-10-99

SAMPLE ID: GINGER HILL SYNFUELS TEST 99072101

OTHER ID: SCREEN BOWL PRODUCT STANDARD SAMPLE #593089 WET COAL FINES (28M X 0) PROJECT 99E0331 T1.2, BIOMASS FEEDBACK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

TOTAL METALS		METHOD NUMBER	PAGE NUMBER
Arsenic	7.42 Mg/Kg (ppm)	EPA SW-846	Method 8.51
Cadmium	< .89 Mg/Kg	EPA SW-846	Method 8.53
Chromium	14.87 Mg/Kg	EPA SW-846	Method 8.54
Cobalt	22.66 Mg/Kg	EPA 600/4-79-020	Method 219.1
Copper	8.85 Mg/Kg	EPA 600/4-79-020	Method 220.1
Lead	11.15 Mg/Kg	EPA SW-846	Method 8.56
Manganese	21.24 Mg/Kg	EPA 600/4-79-020	Method 243.1
Mercury	150.27 ug/Kg (ppb)	EPA SW-846	Method 8.57
Nickel	19.29 Mg/Kg (ppm)	EPA SW-846	Method 8.58
Selenium	1.53 Mg/Kg	EPA SW-846	Method 8.59
Zinc	26.37 Mg/Kg	EPA 600/4-79-020	Method 289.1
Beryllium	< .71 Mg/Kg	EPA 600/4-79-020	Method 210.1

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STANDARD LABORATORIES, INC.

CQ, INC.
160 QUALITY CENTER
HOMER CITY, PA 15748

DATE 9-23-99
SAMPLE NO: 595772

DATE SAMPLED: 7-21-99

DATE RECEIVED: 8-10-99

SAMPLE ID: GINGER HILL SYNFUELS TEST 99072101

OTHER ID: SCREEN BOWL PRODUCT STANDARD SAMPLE #593089 WET COAL FINES (28M X 0) PROJECT 99E0331 T1.2, BIOMASS FEEDBACK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

TCLP EXTRACTION				METHOD NUMBER	PAGE NUMBER
Arsenic	34.33	Ug/L	(ppb)	EPA SW-846	Method 8.51
Cadmium	< 0.05	Mg/L	(ppm)	EPA SW-846	Method 8.53
Chromium	< 0.10	Mg/L		EPA SW-846	Method 8.54
Cobalt	< 0.25	Mg/L		EPA 600/4-79-020	Method 219.1
Copper	0.05	Mg/L		EPA 600/4-79-020	Method 220.1
Lead	0.16	Mg/L		EPA SW-846	Method 8.56
Manganese	2.13	Mg/L		EPA 600/4-79-020	Method 243.1
Mercury	< 0.50	Ug/L	(ppb)	EPA SW-846	Method 8.57
Nickel	.19	Mg/L	(ppm)	EPA SW-846	Method 8.58
Selenium	91.84	Ug/L	(ppb)	EPA SW-846	Method 8.59
Zinc	.70	Mg/L	(ppm)	EPA 600/4-79-020	Method 289.1

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GOULD ENERGY DIVISION
P. O. BOX 214
CRESSON, PA 16630
(814) 886-7400
STANDARD LABORATORIES, INC.

DATE: 9-16-1999
SAMPLE NO. 599552

C. Q., INC.
160 QUALITY CENTER ROAD
HOMER CITY, PA 15748

SAMPLE ID: PLEASANT RIDGE SCREEN BOWL CLEAN COAL

OPERATING CO.:
SAMPLED BY: CUSTOMER PROVIDED
MINE:
LOCATION:

DATE SAMPLED:
DATE RECEIVED: 8/28/99
WEATHER:
GROSS WEIGHT:

OTHER ID:

CERTIFICATE OF ANALYSIS

	ASTM METHOD	AS RECEIVED	DRY BASIS
MOISTURE	D2961 D3302 D3173	1.99%	XXX
VOLATILE MATTER		39.97%	40.78%
FIXED CARBON	D3172	49.28%	50.29%
ASH	D3174	8.76%	8.93%
SULFUR	D4239 METHOD 3.3	4.08%	4.16%
CARBON	D3178	71.31%	72.76%
HYDROGEN	D3178	4.96%	5.06%
NITROGEN	D3179	1.13%	1.16%
OXYGEN	D3176	7.77%	7.92%
BTU/LB	D2015 D1989	13226	13495
MAF BTU/LB			14818
LBS OF SO2 PER MILLION BTU			6.16
LBS OF SULFUR PER MILLION BTU		3.085	
CHLORINE	D4208	.07%	.08%
FLUORINE	D3761	72.31 PPM	73.78 PPM

ASH FUSION TEMPERATURE(S)

D1857	REDUCING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	1940
SOFTENING TEMPERATURE	1990
HEMISPHERICAL TEMPERATURE	2035
FLUID TEMPERATURE	2075

D1857	OXIDIZING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	2375
SOFTENING TEMPERATURE	2405
HEMISPHERICAL TEMPERATURE	2420
FLUID TEMPERATURE	2450

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BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.

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RD 2, Box 227A
Battle Run Road
Triadelphia, WV 26059-9609

SIZE CONSIST AND FRACTIONAL ANALYSIS
SAMPLES COLLECTED: AUGUST 13, 1999
PRS - SNAPSHOT
RUN NUMBER: 99081301
PLEASANT RIDGE - SYNFUELS
CQ INC.

Size Consist	Screen Bowl Clean Coal							
	Incremental Analysis				Cumulative Analysis			
	Distribution %	Ash % (D/B)	Sulfur % (D/B)	BTU/lb. (D/B)	Distribution %	Ash % (D/B)	Sulfur % (D/B)	BTU/lb. (D/B)
Plus 150 Mesh	3.34	5.79	3.46	13,956	3.34	5.79	3.46	13,956
150 x 270 Mesh	49.10	5.60	3.44	13,956	52.44	5.61	3.44	13,956
270 x 400 Mesh	28.25	6.17	3.64	13,861	80.69	5.81	3.51	13,923
Minus 400 Mesh	19.31	21.41	6.02	11,317	100.00	8.82	4.00	13,420

Luther E. Hendricks, Jr. 9-2-99
Date

STANDARD LABORATORIES, INC.

DATE: 9-16-1999
SAMPLE NO. 599552

CERTIFICATE OF ANALYSIS (CONT.)

	AS RECEIVED	DRY BASIS
ASH MINERAL COMPOSITION D2795 D3682		
SILICON DIOXIDE		38.40 %
ALUMINIUM OXIDE		15.02 %
FERRIC OXIDE		25.75 %
TITANIUM DIOXIDE		1.63 %
PHOSPHORUS PENTOXIDE		.24 %
CALCIUM OXIDE		5.11 %
MAGNESIUM OXIDE		.83 %
SODIUM OXIDE		.58 %
POTASSIUM OXIDE		1.29 %
SULFUR TRIOXIDE		8.71 %

APPROVED BY ____________

APPROVED BY ____________

BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.

CQ, INC.
160 QUALITY CENTER
HOMER CITY, PA 15748

DATE 9-24-99
SAMPLE NO: 599552

DATE SAMPLED:

DATE RECEIVED: 8-28-99

SAMPLE ID: ~~GINGER HILL~~ PLEASANT RIDGE SYNFUELS SCREEN BOWL PRODUCT
WET COAL FINES (28M X 0) PROJECT 99E0331 T1.2
BIOMASS FEEDSTOCK CHARACTERIZATION

GROSS WEIGHT:

OTHER ID: **NOTE: INSUFFICIENT MATERIAL TO RUN TCLP ANALYSIS ON THIS SAMPLE**

CERTIFICATE OF ANALYSIS

TOTAL METALS		METHOD NUMBER	PAGE NUMBER
Arsenic	6.88 Mg/Kg (ppm)	EPA SW-846	Method 8.51
Cadmium	1.12 Mg/Kg	EPA SW-846	Method 8.53
Chromium	15.40 Mg/Kg	EPA SW-846	Method 8.54
Cobalt	21.43 Mg/Kg	EPA 600/4-79-020	Method 219.1
Copper	9.15 Mg/Kg	EPA 600/4-79-020	Method 220.1
Lead	9.38 Mg/Kg	EPA SW-846	Method 8.56
Manganese	48.45 Mg/Kg	EPA 600/4-79-020	Method 243.1
Mercury	73.77 ug/Kg (ppb)	EPA SW-846	Method 8.57
Nickel	15.63 Mg/Kg (ppm)	EPA SW-846	Method 8.58
Selenium	2.81 Mg/Kg	EPA SW-846	Method 8.59
Zinc	27.01 Mg/Kg	EPA 600/4-79-020	Method 289.1
Beryllium	2.01 Mg/Kg	EPA 600/4-79-020	Method 210.1

APPROVED BY

GOULD ENERGY DIVISION
P. O. BOX 214
CRESSON, PA 16630
(814) 886-7400
STANDARD LABORATORIES, INC.

DATE: 9-15-1999
SAMPLE NO. 596791

C. Q., INC.
160 QUALITY CENTER ROAD
HOMER CITY, PA 15748

SAMPLE ID: USDA-ARS (PENN STATE U) SWITCH GRASS #99081103

OPERATING CO.:
SAMPLED BY: CUSTOMER PROVIDED
MINE:
LOCATION:

DATE SAMPLED: 8/9/99 DATE RECEIVED: 8/12/99
WEATHER:
GROSS WEIGHT: 2.62 KG

OTHER ID: CAVE-IN-ROCK VARIETY HARVESTED GREEN (OVEN DRIED @50C) PROJECT 99E0331 T1.2, BIOMASS FEED STOCK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

	ASTM METHOD	AS RECEIVED	DRY BASIS
MOISTURE	D2961 D3302 D3173	7.95%	XXX
VOLATILE MATTER		80.22%	87.15%
FIXED CARBON	D3172	7.73%	8.40%
ASH	D3174	4.10%	4.45%
SULFUR	D4239 METHOD 3.3	.12%	.13%
CARBON	D3178	43.81%	47.60%
HYDROGEN	D3178	5.56%	6.04%
NITROGEN	D3179	1.36%	1.48%
OXYGEN	D3176	37.10%	40.31%
BTU/LB	D2015 D1989	7521	8171
MAF BTU/LB			8552
LBS OF SO2 PER MILLION BTU			.32
LBS OF SULFUR PER MILLION BTU		.160	
CHLORINE	D4208	.22%	.23%
FLUORINE	D3761	26.77 PPM	29.08 PPM

ASH FUSION TEMPERATURE(S)

D1857	REDUCING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	1960
SOFTENING TEMPERATURE	2000
HEMISPHERICAL TEMPERATURE	2010
FLUID TEMPERATURE	2030

D1857	OXIDIZING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	2040
SOFTENING TEMPERATURE	2080
HEMISPHERICAL TEMPERATURE	2100
FLUID TEMPERATURE	2120

APPROVED BY ____

APPROVED BY ____

BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.

DATE: 9-15-1999
SAMPLE NO. 596791

CERTIFICATE OF ANALYSIS (CONT.)

AS RECEIVED DRY BASIS

ASH MINERAL COMPOSITION
D2795 D3682

SILICON DIOXIDE	35.39 %
ALUMINIUM OXIDE	5.85 %
FERRIC OXIDE	4.10 %
TITANIUM DIOXIDE	.34 %
PHOSPHORUS PENTOXIDE	8.09 %
CALCIUM OXIDE	12.18 %
MAGNESIUM OXIDE	9.78 %
SODIUM OXIDE	2.42 %
POTASSIUM OXIDE	15.06 %
SULFUR TRIOXIDE	4.96 %

APPROVED BY ____________

APPROVED BY ____________

BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.

CQ, INC.
160 QUALITY CENTER
HOMER CITY, PA 15748

DATE 9-23-99
SAMPLE NO: 596791

DATE SAMPLED: 8-9-99

DATE RECEIVED: 8-12-99

SAMPLE ID: USDA-ARS (PENN STATE U) SWITCH GRASS #99081103

GROSS WEIGHT: 2.62 KG

OTHER ID: CAVE-IN-ROCK VARIETY HARVESTED GREEN (OVEN FRIED @50C)
PROJECT 99E0331 T1.2,BIOMASS FEED STOCK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

TOTAL METALS		METHOD NUMBER	PAGE NUMBER
Arsenic	1.33 Mg/Kg (ppm)	EPA SW-846	Method 8.51
Cadmium	< .56 Mg/Kg	EPA SW-846	Method 8.53
Chromium	1.45 Mg/Kg	EPA SW-846	Method 8.54
Cobalt	< 2.78 Mg/Kg	EPA 600/4-79-020	Method 219.1
Copper	10.46 Mg/Kg	EPA 600/4-79-020	Method 220.1
Lead	1.89 Mg/Kg	EPA SW-846	Method 8.56
Manganese	75.65 Mg/Kg	EPA 600/4-79-020	Method 243.1
Mercury	< 0.50 ug/Kg (ppb)	EPA SW-846	Method 8.57
Nickel	3.89 Mg/Kg (ppm)	EPA SW-846	Method 8.58
Selenium	.50 Mg/Kg	EPA SW-846	Method 8.59
Zinc	23.59 Mg/Kg	EPA 600/4-79-020	Method 289.1
Beryllium	<.45 Mg/Kg	EPA 600/4-79-020	Method 210.1

APPROVED BY [signature]

STANDARD LABORATORIES, INC.

CQ, INC.
160 QUALITY CENTER
HOMER CITY, PA 15748

DATE 9-23-99
SAMPLE NO: 596791

DATE SAMPLED: 8-9-99

DATE RECEIVED: 8-12-99

SAMPLE ID: USDA-ARS (PENN STATE U) SWITCH GRASS #99081103

GROSS WEIGHT: 2.62 KG

OTHER ID: CAVE-IN-ROCK VARIETY HARVESTED GREEN (OVEN FRIED @50C)
PROJECT 99E0331 T1.2,BIOMASS FEED STOCK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

TCLP EXTRACTION				METHOD NUMBER	PAGE NUMBER
Arsenic	3.96	Ug/L	(ppb)	EPA SW-846	Method 8.51
Cadmium	< 0.05	Mg/L	(ppm)	EPA SW-846	Method 8.53
Chromium	.30	Mg/L		EPA SW-846	Method 8.54
Cobalt	< 0.25	Mg/L		EPA 600/4-79-020	Method 219.1
Copper	< 0.04	Mg/L		EPA 600/4-79-020	Method 220.1
Lead	< 0.10	Mg/L		EPA SW-846	Method 8.56
Manganese	< 0.06	Mg/L		EPA 600/4-79-020	Method 243.1
Mercury	< 0.50	Ug/L	(ppb)	EPA SW-846	Method 8.57
Nickel	.11	Mg/L	(ppm)	EPA SW-846	Method 8.58
Selenium	45.66	Ug/L	(ppb)	EPA SW-846	Method 8.59
Zinc	.12	Mg/L	(ppm)	EPA 600/4-79-020	Method 289.1
Beryllium	< 0.04	Mg/L		EPA 600/4-79-020	Method 210.1
Potassium	4800.0	Mg/L		EPA 600/4-79-020	Method 258.1

Extraction Fluid Used #2
Sample Weight 15 grams

APPROVED BY [signature]

GOULD ENERGY DIVISION
P. O. BOX 214
CRESSON, PA 16630
(814) 886-7400
STANDARD LABORATORIES, INC.

DATE: 9-16-1999
SAMPLE NO. 597029

C. Q., INC.
160 QUALITY CENTER ROAD
HOMER CITY, PA 15748

SAMPLE ID: COLONA TERMINAL SERVICES
PETROLUEM COKE

OPERATING CO.: TEST #99081102
SAMPLED BY: CUSTOMER PROVIDED
MINE:
LOCATION:

DATE SAMPLED: 8/9/99 DATE RECEIVED: 8/13/99
WEATHER:
GROSS WEIGHT: 4772.9

OTHER ID: PROJECT 99E0331 T1.2, BIOMASS FEEDSTOCK CHARACTERIZATION FUEL GRADE PETROLEUM COKE

CERTIFICATE OF ANALYSIS

	ASTM METHOD	AS RECEIVED	DRY BASIS
MOISTURE	D2961 D3302 D3173	7.16%	XXX
VOLATILE MATTER		12.97%	13.97%
FIXED CARBON	D3172	79.43%	85.56%
ASH	D3174	.44%	.47%
SULFUR	D4239 METHOD 3.3	5.12%	5.51%
CARBON	D3178	80.52%	86.73%
HYDROGEN	D3178	3.81%	4.10%
NITROGEN	D3179	1.38%	1.49%
OXYGEN	D3176	1.57%	1.69%
BTU/LB	D2015 D1989	14201	15296
MAF BTU/LB			15368
LBS OF SO2 PER MILLION BTU			7.20
LBS OF SULFUR PER MILLION BTU		3.605	
CHLORINE	D4208	.03%	.04%
FLUORINE	D3761	58.07 PPM	62.55 PPM
PERCENT SOLIDS			92.84%

ASH FUSION TEMPERATURE(S)

D1857	REDUCING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	2210
SOFTENING TEMPERATURE	2240
HEMISPHERICAL TEMPERATURE	2270
FLUID TEMPERATURE	2295

D1857	OXIDIZING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	2050
SOFTENING TEMPERATURE	2090
HEMISPHERICAL TEMPERATURE	2110

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APPROVED BY ____________

BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.

DATE: 9-16-1999
SAMPLE NO. 597029

CERTIFICATE OF ANALYSIS (CONT.)

	AS RECEIVED	DRY BASIS
FLUID TEMPERATURE		2130

ASH MINERAL COMPOSITION
D2795 D3682

SILICON DIOXIDE	25.38 %
ALUMINIUM OXIDE	8.20 %
FERRIC OXIDE	8.87 %
TITANIUM DIOXIDE	.60 %
PHOSPHORUS PENTOXIDE	.50 %
CALCIUM OXIDE	11.29 %
MAGNESIUM OXIDE	2.87 %
SODIUM OXIDE	1.23 %
POTASSIUM OXIDE	1.31 %
SULFUR TRIOXIDE	20.12 %

APPROVED BY ____________

APPROVED BY ____________

BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.

CQ, INC.
160 QUALITY CENTER
HOMER CITY, PA 15748

DATE 9-23-99
SAMPLE NO: 597029

DATE SAMPLED: 8-9-99

DATE RECEIVED: 8-13-99

SAMPLE ID: COLONA TERMINAL SERVICES PETROLUEM COKE
OPERATING CO: TEST #99081102

GROSS WEIGHT: 4772.9

OTHER ID: PROJECT 99E0331 T1.2, BIOMASS FEEDSTOCK CHARACTERIZATION
FUEL GRADE PETROLEUM COKE

CERTIFICATE OF ANALYSIS

TOTAL METALS		METHOD NUMBER	PAGE NUMBER
Arsenic	1.72 Mg/Kg (ppm)	EPA SW-846	Method 8.51
Cadmium	0.06 Mg/Kg	EPA SW-846	Method 8.53
Chromium	2.22 Mg/Kg	EPA SW-846	Method 8.54
Cobalt	2.43 Mg/Kg	EPA 600/4-79-020	Method 219.1
Copper	0.67 Mg/Kg	EPA 600/4-79-020	Method 220.1
Lead	0.89 Mg/Kg	EPA SW-846	Method 8.56
Manganese	7.94 Mg/Kg	EPA 600/4-79-020	Method 243.1
Mercury	< 0.50 ug/Kg (ppb)	EPA SW-846	Method 8.57
Nickel	230.3 Mg/Kg (ppm)	EPA SW-846	Method 8.58
Selenium	1.72 Mg/Kg	EPA SW-846	Method 8.59
Zinc	7.40 Mg/Kg	EPA 600/4-79-020	Method 289.1
Beryllium	0.05 Mg/Kg	EPA 600/4-79-020	Method 210.1

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STANDARD LABORATORIES, INC.

CQ, INC.
160 QUALITY CENTER
HOMER CITY, PA 15748

DATE 9-23-99
SAMPLE NO: 597029

DATE SAMPLED: 8-9-99

DATE RECEIVED: 8-13-99

SAMPLE ID: COLONA TERMINAL SERVICES PETROLUEM COKE
OPERATING CO: TEST #99081102

GROSS WEIGHT: 4772.9

OTHER ID: PROJECT 99E0331 T1.2, BIOMASS FEEDSTOCK CHARACTERIZATION
FUEL GRADE PETROLEUM COKE

CERTIFICATE OF ANALYSIS

TCLP EXTRACTION				METHOD NUMBER	PAGE NUMBER
Arsenic	61.12	Ug/L	(ppb)	EPA SW-846	Method 8.51
Cadmium	< 0.05	Mg/L	(ppm)	EPA SW-846	Method 8.53
Chromium	< 0.10	Mg/L		EPA SW-846	Method 8.54
Cobalt	1.13	Mg/L		EPA 600/4-79-020	Method 219.1
Copper	.13	Mg/L		EPA 600/4-79-020	Method 220.1
Lead	.33	Mg/L		EPA SW-846	Method 8.56
Manganese	3.8	Mg/L		EPA 600/4-79-020	Method 243.1
Mercury	< 0.50	Ug/L	(ppb)	EPA SW-846	Method 8.57
Nickel	7.7	Mg/L	(ppm)	EPA SW-846	Method 8.58
Selenium	162.7	Ug/L	(ppb)	EPA SW-846	Method 8.59
Zinc	5.2	Mg/L	(ppm)	EPA 600/4-79-020	Method 289.1
Beryllium	< 0.04	Mg/L		EPA 600/4-79-020	Method 210.1

Extraction Fluid Used #1
Sample Weight 10 grams

APPROVED BY

GOULD ENERGY DIVISION
P. O. BOX 214
CRESSON, PA 16630
(814) 886-7400

STANDARD LABORATORIES, INC.

DATE: 9-17-1999
SAMPLE NO. 597030

C. Q., INC.
160 QUALITY CENTER ROAD
HOMER CITY, PA 15748

SAMPLE ID: CONIGLIARO INDUSTRIES, INC. MIXED PLASTICS

OPERATING CO.: TEST 99081101
SAMPLED BY: CUSTOMER PROVIDED
MINE:
LOCATION:

DATE SAMPLED: 7/30/99 DATE RECEIVED: 8/12/99
WEATHER:
GROSS WEIGHT: 3458.4

OTHER ID: COMINGLED MIXED PLASTICS AND WASTE (HDPE&LDPE) PROJECT 99E0331
T1.2, BIOMASS FEEDSTOCK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

	ASTM METHOD	AS RECEIVED	DRY BASIS
MOISTURE	D2961 D3302 D3173	.24%	XXX
VOLATILE MATTER		92.17%	92.39%
FIXED CARBON	D3172	5.30%	5.31%
ASH	D3174	2.29%	2.30%
SULFUR	D4239 METHOD 3.3	.33%	.33%
CARBON	D3178	67.84%	68.00%
HYDROGEN	D3178	10.79%	10.82%
NITROGEN	D3179	.10%	.10%
OXYGEN	D3176	18.41%	18.45%
BTU/LB	D2015 D1989	14425	14459
MAF BTU/LB			14799
LBS OF SO2 PER MILLION BTU			.46
LBS OF SULFUR PER MILLION BTU		.229	
CHLORINE	D4208	.98%	.98%
PERCENT SOLIDS			99.76%

ASH FUSION TEMPERATURE(S)

D1857	REDUCING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	2560
SOFTENING TEMPERATURE	2565
HEMISPHERICAL TEMPERATURE	2570
FLUID TEMPERATURE	2575

D1857	OXIDIZING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	2500
SOFTENING TEMPERATURE	2510
HEMISPHERICAL TEMPERATURE	2515
FLUID TEMPERATURE	2525

FLUORINE D3761 NONE DETECTED

APPROVED BY [signature]

APPROVED BY [signature]

BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.

DATE: 9-17-1999
SAMPLE NO. 597030

CERTIFICATE OF ANALYSIS (CONT.)

	AS RECEIVED	DRY BASIS
ASH MINERAL COMPOSITION D2795 D3682		
SILICON DIOXIDE	.83 %	
ALUMINIUM OXIDE	.64 %	
FERRIC OXIDE	.19 %	
TITANIUM DIOXIDE	.33 %	
PHOSPHORUS PENTOXIDE	.17 %	
CALCIUM OXIDE	1.33 %	
MAGNESIUM OXIDE	.17 %	
SODIUM OXIDE	.16 %	
POTASSIUM OXIDE	.03 %	
SULFUR TRIOXIDE	.58 %	

APPROVED BY

APPROVED BY

BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.

CQ, INC.
160 QUALITY CENTER
HOMER CITY, PA 15748

DATE 9-23-99
SAMPLE NO: 597030

DATE SAMPLED: 7-30-99
OPERATING CO: TEST 99081101

DATE RECEIVED: 8-12-99

SAMPLE ID: CONIGLIARO INDUSTRIES, INC. MIXED PLASTICS

GROSS WEIGHT: 3458.4

OTHER ID: COMINGLED MIXED PLASTICS AND WASTE (HDPE&LDPE)
PROJECT 99E0331 T1.2,BIOMASS FEED STOCK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

TOTAL METALS		METHOD NUMBER	PAGE NUMBER
Arsenic	4.06 Mg/Kg (ppm)	EPA SW-846	Method 8.51
Cadmium	.29 Mg/Kg	EPA SW-846	Method 8.53
Chromium	2.24 Mg/Kg	EPA SW-846	Method 8.54
Cobalt	2.59 Mg/Kg	EPA 600/4-79-020	Method 219.1
Copper	7.59 Mg/Kg	EPA 600/4-79-020	Method 220.1
Lead	2.53 Mg/Kg	EPA SW-846	Method 8.56
Manganese	3.05 Mg/Kg	EPA 600/4-79-020	Method 243.1
Mercury	< 0.50 ug/Kg (ppb)	EPA SW-846	Method 8.57
Nickel	16.1 Mg/Kg (ppm)	EPA SW-846	Method 8.58
Selenium	4.45 Mg/Kg	EPA SW-846	Method 8.59
Zinc	59.8 Mg/Kg	EPA 600/4-79-020	Method 289.1
Beryllium	.23 Mg/Kg	EPA 600/4-79-020	Method 210.1

APPROVED BY

STANDARD LABORATORIES, INC.

CQ, INC.
160 QUALITY CENTER
HOMER CITY, PA 15748

DATE 9-23-99
SAMPLE NO: 597030

DATE SAMPLED: 7-30-99
DATE RECEIVED: 8-12-99
OPERATING CO: TEST 99081101

SAMPLE ID: CONIGLIARO INDUSTRIES, INC. MIXED PLASTICS

GROSS WEIGHT: 3458.4

OTHER ID: COMINGLED MIXED PLASTICS AND WASTE (HDPE&LDPE)
PROJECT 99E0331 T1.2,BIOMASS FEED STOCK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

TCLP EXTRACTION					METHOD NUMBER	PAGE NUMBER
Arsenic		5.80	Ug/L	(ppb)	EPA SW-846	Method 8.51
Cadmium	<	0.05	Mg/L	(ppm)	EPA SW-846	Method 8.53
Chromium	<	0.10	Mg/L		EPA SW-846	Method 8.54
Cobalt		.70	Mg/L		EPA 600/4-79-020	Method 219.1
Copper		.11	Mg/L		EPA 600/4-79-020	Method 220.1
Lead		.81	Mg/L		EPA SW-846	Method 8.56
Manganese		.10	Mg/L		EPA 600/4-79-020	Method 243.1
Mercury	<	0.50	Ug/L	(ppb)	EPA SW-846	Method 8.57
Nickel		.43	Mg/L	(ppm)	EPA SW-846	Method 8.58
Selenium		787.5	Ug/L	(ppb)	EPA SW-846	Method 8.59
Zinc		.37	Mg/L	(ppm)	EPA 600/4-79-020	Method 289.1
Beryllium	<	0.04	Mg/L		EPA 600/4-79-020	Method 210.1

Extraction Fluid Used #1
Sample Weight 20 grams

APPROVED BY

GOULD ENERGY DIVISION
P. O. BOX 214
CRESSON, PA 16630
(814) 886-7400
STANDARD LABORATORIES, INC.

DATE: 9-17-1999
SAMPLE NO. 597031

C. Q., INC.
160 QUALITY CENTER ROAD
HOMER CITY, PA 15748

SAMPLE ID: GIANT EAGLE WAXED CARDBOARD

OPERATING CO.: TEST 99081104
SAMPLED BY: CUSTOMER PROVIDED
MINE:
LOCATION:

DATE SAMPLED: 8/9/99 DATE RECEIVED: 8/12/99
WEATHER:
GROSS WEIGHT: 2438.8

OTHER ID: WAX IMPREGNATED CARDBOARD PRODUCE BOXES PROJECT 99E0331 T1.2, BIOMASS FEEDSTOCK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

	ASTM METHOD	AS RECEIVED	DRY BASIS
MOISTURE	D2961 D3302 D3173	9.26%	XXX
VOLATILE MATTER		79.58%	87.70%
FIXED CARBON	D3172	8.70%	9.59%
ASH	D3174	2.46%	2.71%
SULFUR	D4239 METHOD 3.3	.19%	.21%
CARBON	D3178	50.19%	55.31%
HYDROGEN	D3178	7.91%	8.72%
NITROGEN	D3179	.13%	.14%
OXYGEN	D3176	29.86%	32.91%
BTU/LB	D2015 D1989	9610	10591
MAF BTU/LB			10887
LBS OF SO2 PER MILLION BTU			.40
LBS OF SULFUR PER MILLION BTU		.198	
CHLORINE	D4208	.20%	.22%
PERCENT SOLIDS			90.74%

ASH FUSION TEMPERATURE(S)

D1857	REDUCING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	2100
SOFTENING TEMPERATURE	2140
HEMISPHERICAL TEMPERATURE	2155
FLUID TEMPERATURE	2165
D1857	**OXIDIZING ATMOSPHERE**
INITIAL DEFORMATION TEMPERATURE	2200
SOFTENING TEMPERATURE	2255
HEMISPHERICAL TEMPERATURE	2290
FLUID TEMPERATURE	2320

FLUORINE D3761 NONE DETECTED

APPROVED BY [signature]

APPROVED BY [signature]

BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.

DATE: 9-17-1999
SAMPLE NO. 597031

CERTIFICATE OF ANALYSIS (CONT.)

	AS RECEIVED	DRY BASIS
ASH MINERAL COMPOSITION D2795 D3682		
SILICON DIOXIDE		26.87 %
ALUMINIUM OXIDE		17.44 %
FERRIC OXIDE		4.89 %
TITANIUM DIOXIDE		12.50 %
PHOSPHORUS PENTOXIDE		1.06 %
CALCIUM OXIDE		15.88 %
MAGNESIUM OXIDE		1.86 %
SODIUM OXIDE		8.79 %
POTASSIUM OXIDE		1.47 %
SULFUR TRIOXIDE		7.56 %

APPROVED BY [signature]

APPROVED BY [signature]

BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.

CQ, INC.
160 QUALITY CENTER
HOMER CITY, PA 15748

DATE 9-24-99
SAMPLE NO: 597031

DATE SAMPLED: 8-9-99
DATE RECEIVED: 8-12-99
OPERATING CO: TEST 99081104

SAMPLE ID: GIANT EAGLE WAXED CARDBOARD

GROSS WEIGHT: 2438.8

OTHER ID: WAX IMPREGNATED CARDBOARD PRODUCE BOXES PROJECT
99E0331 T1.2, BIOMASS FEEDSTOCK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

TOTAL METALS		METHOD NUMBER	PAGE NUMBER
Arsenic	1.72 Mg/Kg (ppm)	EPA SW-846	Method 8.51
Cadmium	0.34 Mg/Kg	EPA SW-846	Method 8.53
Chromium	2.57 Mg/Kg	EPA SW-846	Method 8.54
Cobalt	3.46 Mg/Kg	EPA 600/4-79-020	Method 219.1
Copper	10.57 Mg/Kg	EPA 600/4-79-020	Method 220.1
Lead	107.72 Mg/Kg	EPA SW-846	Method 8.56
Manganese	19.65 Mg/Kg	EPA 600/4-79-020	Method 243.1
Mercury	< 0.50 ug/Kg (ppb)	EPA SW-846	Method 8.57
Nickel	4.54 Mg/Kg (ppm)	EPA SW-846	Method 8.58
Selenium	3.90 Mg/Kg	EPA SW-846	Method 8.59
Zinc	63.01 Mg/Kg	EPA 600/4-79-020	Method 289.1
Beryllium	0.27 Mg/Kg	EPA 600/4-79-020	Method 210.1

APPROVED BY [signature]

STANDARD LABORATORIES, INC.

CQ, INC.
160 QUALITY CENTER
HOMER CITY, PA 15748

DATE 9-24-99
SAMPLE NO: 597031

DATE SAMPLED: 8-9-99
DATE RECEIVED: 8-12-99
OPERATING CO: TEST 99081104

SAMPLE ID: GIANT EAGLE WAXED CARDBOARD

GROSS WEIGHT: 2438.8

OTHER ID: WAX IMPREGNATED CARDBOARD PRODUCE BOXES PROJECT
99E0331 T1.2, BIOMASS FEEDSTOCK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

TCLP EXTRACTION				METHOD NUMBER	PAGE NUMBER
Arsenic	4.37	Ug/L	(ppb)	EPA SW-846	Method 8.51
Cadmium	< 0.05	Mg/L	(ppm)	EPA SW-846	Method 8.53
Chromium	0.29	Mg/L		EPA SW-846	Method 8.54
Cobalt	< 0.25	Mg/L		EPA 600/4-79-020	Method 219.1
Copper	< 0.04	Mg/L		EPA 600/4-79-020	Method 220.1
Lead	.22	Mg/L		EPA SW-846	Method 8.56
Manganese	< 0.06	Mg/L		EPA 600/4-79-020	Method 243.1
Mercury	< 0.50	Ug/L	(ppb)	EPA SW-846	Method 8.57
Nickel	.12	Mg/L	(ppm)	EPA SW-846	Method 8.58
Selenium	149.9	Ug/L	(ppb)	EPA SW-846	Method 8.59
Zinc	.12	Mg/L	(ppm)	EPA 600/4-79-020	Method 289.1
Beryllium	< 0.04	Mg/L		EPA 600/4-79-020	Method 210.1

Extraction Fluid Used #1
Sample Weight 15 grams

APPROVED BY [signature]

GOULD ENERGY DIVISION
P. O. BOX 214
CRESSON, PA 16630
(814) 886-7400
STANDARD LABORATORIES, INC.

DATE: 9-15-1999
SAMPLE NO. 597288

C. Q., INC.
160 QUALITY CENTER ROAD
HOMER CITY, PA 15748

SAMPLE ID: INDIANA SEWAGE TREATMENT PLANT SEWAGE SLUDGE

OPERATING CO.:
SAMPLED BY: CUSTOMER PROVIDED
MINE:
LOCATION:

DATE SAMPLED: 8/9/99 DATE RECEIVED: 8/14/99
WEATHER:
GROSS WEIGHT: 5520.0

OTHER ID: MUNICIPAL SEWAGE SLUDGE TEST 99081105 PROJECT 99E0331 T1.2, BIOMASS FEEDSTOCK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

	ASTM METHOD	AS RECEIVED	DRY BASIS
MOISTURE	D2961 D3302 D3173	85.03%	XXX
VOLATILE MATTER		9.27%	61.96%
FIXED CARBON	D3172	1.31%	8.69%
ASH	D3174	4.39%	29.35%
SULFUR	D4239 METHOD 3.3	.27%	1.78%
CARBON	D3178	5.75%	38.43%
HYDROGEN	D3178	.83%	5.55%
NITROGEN	D3179	.83%	5.56%
OXYGEN	D3176	2.90%	19.33%
BTU/LB	D2015 D1989	1117	7463
MAF BTU/LB			10563
LBS OF SO2 PER MILLION BTU			4.77
LBS OF SULFUR PER MILLION BTU		2.418	
CHLORINE	D4208	.03%	.22%
FLUORINE	D3761	43.41 PPM	290.08 PPM
PERCENT SOLIDS			14.97%

ASH FUSION TEMPERATURE(S)

D1857	REDUCING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	2000
SOFTENING TEMPERATURE	2020
HEMISPHERICAL TEMPERATURE	2070
FLUID TEMPERATURE	2120

D1857	OXIDIZING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	2080
SOFTENING TEMPERATURE	2110
HEMISPHERICAL TEMPERATURE	2145

APPROVED BY

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BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.

DATE: 9-15-1999
SAMPLE NO. 597288

CERTIFICATE OF ANALYSIS (CONT.)

	AS RECEIVED	DRY BASIS
FLUID TEMPERATURE		2200

ASH MINERAL COMPOSITION
D2795 D3682

SILICON DIOXIDE	34.36 %
ALUMINIUM OXIDE	12.75 %
FERRIC OXIDE	13.19 %
TITANIUM DIOXIDE	1.64 %
PHOSPHORUS PENTOXIDE	15.40 %
CALCIUM OXIDE	8.95 %
MAGNESIUM OXIDE	2.08 %
SODIUM OXIDE	.88 %
POTASSIUM OXIDE	1.45 %
SULFUR TRIOXIDE	2.09 %

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BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.

CQ, INC.
160 QUALITY CENTER
HOMER CITY, PA 15748

DATE 9-24-99
SAMPLE NO: 597288

DATE SAMPLED: 8-9-99

DATE RECEIVED: 8-14-99

SAMPLE ID: INDIANA SEWAGE TREATMENT PLANT SEWAGE SLUDGE

GROSS WEIGHT: 5520.0

OTHER ID: MUNICIPAL SEWAGE SLUDGE TEST 99081105 PROJECT 99E0331
T1.2, BIOMASS FEEDSTOCK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

TOTAL METALS		METHOD NUMBER	PAGE NUMBER
Arsenic	4.84 Mg/Kg (ppm)	EPA SW-846	Method 8.51
Cadmium	6.60 Mg/Kg	EPA SW-846	Method 8.53
Chromium	55.77 Mg/Kg	EPA SW-846	Method 8.54
Cobalt	74.11 Mg/Kg	EPA 600/4-79-020	Method 219.1
Copper	660.38 Mg/Kg	EPA 600/4-79-020	Method 220.1
Lead	92.45 Mg/Kg	EPA SW-846	Method 8.56
Manganese	1540.88 Mg/Kg	EPA 600/4-79-020	Method 243.1
Mercury	835.56 ug/Kg (ppb)	EPA SW-846	Method 8.57
Nickel	70.44 Mg/Kg (ppm)	EPA SW-846	Method 8.58
Selenium	2.47 Mg/Kg	EPA SW-846	Method 8.59
Zinc	946.54 Mg/Kg	EPA 600/4-79-020	Method 289.1
Beryllium	2.94 Mg/Kg	EPA 600/4-79-020	Method 210.1

APPROVED BY [signature]

STANDARD LABORATORIES, INC.

CQ, INC.
160 QUALITY CENTER
HOMER CITY, PA 15748

DATE 9-24-99
SAMPLE NO: 597288

DATE SAMPLED: 8-9-99

DATE RECEIVED: 8-14-99

SAMPLE ID: INDIANA SEWAGE TREATMENT PLANT SEWAGE SLUDGE

GROSS WEIGHT: 5520.0

OTHER ID: MUNICIPAL SEWAGE SLUDGE TEST 99081105 PROJECT 99E0331
T1.2, BIOMASS FEEDSTOCK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

TCLP EXTRACTION				METHOD NUMBER	PAGE NUMBER
Arsenic	78.04	Ug/L	(ppb)	EPA SW-846	Method 8.51
Cadmium	< 0.05	Mg/L	(ppm)	EPA SW-846	Method 8.53
Chromium	< 0.10	Mg/L		EPA SW-846	Method 8.54
Cobalt	.61	Mg/L		EPA 600/4-79-020	Method 219.1
Copper	1.62	Mg/L		EPA 600/4-79-020	Method 220.1
Lead	.19	Mg/L		EPA SW-846	Method 8.56
Manganese	12.6	Mg/L		EPA 600/4-79-020	Method 243.1
Mercury	< 0.50	Ug/L	(ppb)	EPA SW-846	Method 8.57
Nickel	.39	Mg/L	(ppm)	EPA SW-846	Method 8.58
Selenium	153.3	Ug/L	(ppb)	EPA SW-846	Method 8.59
Zinc	2.21	Mg/L	(ppm)	EPA 600/4-79-020	Method 289.1
Beryllium	< 0.04	Mg/L		EPA 600/4-79-020	Method 210.1

Extraction Fluid Used #1
Sample Weight 30 grams

APPROVED BY

GOULD ENERGY DIVISION
P. O. BOX 214
CRESSON, PA 16630
(814) 886-7400
STANDARD LABORATORIES, INC.

DATE: 9-15-1999
SAMPLE NO. 598280

C. G., INC.
160 QUALITY CENTER ROAD
HOMER CITY, PA 15748

SAMPLE ID: BOILER MANURE TEST 99081106

OPERATING CO.:
SAMPLED BY: CUSTOMER PROVIDED
MINE:
LOCATION:

DATE SAMPLED: 8/17/99 DATE RECEIVED: 8/19/989
WEATHER:
GROSS WEIGHT: 6350.2 GR

OTHER ID: PENNAG POULTRY COUNCIL PROJECT 99E0331 T1.2, BIOMASS FEEDSTOCK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

	ASTM METHOD	AS RECEIVED	DRY BASIS
MOISTURE	D2961 D3302 D3173	9.09%	XXX
VOLATILE MATTER		60.45%	66.49%
FIXED CARBON	D3172	8.07%	8.88%
ASH	D3174	22.39%	24.63%
SULFUR	D4239 METHOD 3.3	.27%	.30%
CARBON	D3178	32.82%	36.10%
HYDROGEN	D3178	4.18%	4.60%
NITROGEN	D3179	3.84%	4.22%
OXYGEN	D3176	27.41%	30.15%
BTU/LB	D2015 D1989	5406	5946
MAF BTU/LB			7889
LBS OF SO2 PER MILLION BTU			1.01
LBS OF SULFUR PER MILLION BTU		.499	
CHLORINE	D4208	.45%	.49%
FLUORINE	D3761	32.01 PPM	35.21 PPM

ASH FUSION TEMPERATURE(S)

D1857	REDUCING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	2500
SOFTENING TEMPERATURE	2550
HEMISPHERICAL TEMPERATURE	2560
FLUID TEMPERATURE	2570

D1857	OXIDIZING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	2595
SOFTENING TEMPERATURE	2610
HEMISPHERICAL TEMPERATURE	2620
FLUID TEMPERATURE	2640

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BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.

DATE: 9-15-1999
SAMPLE NO. 598280

CERTIFICATE OF ANALYSIS (CONT.)

	AS RECEIVED	DRY BASIS
ASH MINERAL COMPOSITION D2795 D3682		
SILICON DIOXIDE		3.38 %
ALUMINIUM OXIDE		1.72 %
FERRIC OXIDE		3.19 %
TITANIUM DIOXIDE		.10 %
PHOSPHORUS PENTOXIDE		13.25 %
CALCIUM OXIDE		28.98 %
MAGNESIUM OXIDE		3.62 %
SODIUM OXIDE		1.50 %
POTASSIUM OXIDE		8.02 %
SULFUR TRIOXIDE		2.19 %

APPROVED BY ____________

APPROVED BY ____________

BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.

CQ, INC.
160 QUALITY CENTER
HOMER CITY, PA 15748

DATE 9-24-99
SAMPLE NO: 598280

DATE SAMPLED: 8-17-99

DATE RECEIVED: 8-19-99

SAMPLE ID: BOILER MANURE TEST 99081106

GROSS WEIGHT: 6350.2 GR

OTHER ID: PENNAG POULTRY COUNCIL PROJECT 99E0331 T1.2,
BIOMASS FEEDSTOCK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

TOTAL METALS		METHOD NUMBER	PAGE NUMBER
Arsenic	< 2.00 Mg/Kg (ppm)	EPA SW-846	Method 8.51
Cadmium	3.08 Mg/Kg	EPA SW-846	Method 8.53
Chromium	6.16 Mg/Kg	EPA SW-846	Method 8.54
Cobalt	15.39 Mg/Kg	EPA 600/4-79-020	Method 219.1
Copper	51.11 Mg/Kg	EPA 600/4-79-020	Method 220.1
Lead	8.62 Mg/Kg	EPA SW-846	Method 8.56
Manganese	264.77 Mg/Kg	EPA 600/4-79-020	Method 243.1
Mercury	< 0.50 ug/Kg (ppb)	EPA SW-846	Method 8.57
Nickel	12.93 Mg/Kg (ppm)	EPA SW-846	Method 8.58
Selenium	6.13 Mg/Kg	EPA SW-846	Method 8.59
Zinc	437.18 Mg/Kg	EPA 600/4-79-020	Method 289.1
Beryllium	2.46 Mg/Kg	EPA 600/4-79-020	Method 210.1

APPROVED BY

STANDARD LABORATORIES, INC.

CQ, INC.
160 QUALITY CENTER
HOMER CITY, PA 15748

DATE 9-24-99
SAMPLE NO: 598280

DATE SAMPLED: 8-17-99

DATE RECEIVED: 8-19-99

SAMPLE ID: BOILER MANURE TEST 99081106

GROSS WEIGHT: 6350.2 GR

OTHER ID: PENNAG POULTRY COUNCIL PROJECT 99E0331 T1.2, BIOMASS FEEDSTOCK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

TCLP EXTRACTION				METHOD NUMBER	PAGE NUMBER
Arsenic	< 2.00	Ug/L	(ppb)	EPA SW-846	Method 8.51
Cadmium	< 0.05	Mg/L	(ppm)	EPA SW-846	Method 8.53
Chromium	< 0.10	Mg/L		EPA SW-846	Method 8.54
Cobalt	< 0.25	Mg/L		EPA 600/4-79-020	Method 219.1
Copper	.12	Mg/L		EPA 600/4-79-020	Method 220.1
Lead	.33	Mg/L		EPA SW-846	Method 8.56
Manganese	< 0.06	Mg/L		EPA 600/4-79-020	Method 243.1
Mercury	< 0.50	Ug/L	(ppb)	EPA SW-846	Method 8.57
Nickel	.12	Mg/L	(ppm)	EPA SW-846	Method 8.58
Selenium	167.5	Ug/L	(ppb)	EPA SW-846	Method 8.59
Zinc	.22	Mg/L	(ppm)	EPA 600/4-79-020	Method 289.1
Beryllium	< 0.04	Mg/L		EPA 600/4-79-020	Method 210.1

Extraction Fluid Used #2
Sample Weight 15 grams

APPROVED BY

GOULD ENERGY DIVISION
P. O. BOX 214
CRESSON, PA 16630
(814) 886-7400
STANDARD LABORATORIES, INC.

DATE: 9-15-1999
SAMPLE NO. 598281

C. Q., INC.
160 QUALITY CENTER ROAD
HOMER CITY, PA 15748

SAMPLE ID: POULTRY MANURE TEST 99081106

OPERATING CO.:
SAMPLED BY: CUSTOMER PROVIDED
MINE:
LOCATION:

DATE SAMPLED: 8/17/99 DATE RECEIVED: 8/19/99
WEATHER:
GROSS WEIGHT: 1716.2 GR

OTHER ID: PENNAG POULTRY COUNCIL PROJECT 99E0331 T1.2, BIOMASS FEEDSTOCK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

	ASTM METHOD	AS RECEIVED	DRY BASIS
MOISTURE	D2961 D3302 D3173	60.82%	XXX
VOLATILE MATTER		23.49%	59.94%
FIXED CARBON	D3172	2.09%	5.36%
ASH	D3174	13.60%	34.70%
SULFUR	D4239 METHOD 3.3	.10%	.26%
CARBON	D3178	12.13%	30.95%
HYDROGEN	D3178	1.52%	3.88%
NITROGEN	D3179	1.22%	3.10%
OXYGEN	D3176	10.61%	27.11%
BTU/LB	D2015 D1989	2043	5213
MAF BTU/LB			7983
LBS OF SO2 PER MILLION BTU			1.00
LBS OF SULFUR PER MILLION BTU		.490	
CHLORINE	D4208	.15%	.39%
FLUORINE	D3761	15.03 PPM	38.36 PPM
PERCENT SOLIDS			39.18%

ASH FUSION TEMPERATURE(S)

D1857	REDUCING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	2485
SOFTENING TEMPERATURE	2505
HEMISPHERICAL TEMPERATURE	2525
FLUID TEMPERATURE	2545

D1857	OXIDIZING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	2570
SOFTENING TEMPERATURE	2585
HEMISPHERICAL TEMPERATURE	2600

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APPROVED BY ____________

BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.

DATE: 9-15-1999
SAMPLE NO. 598281

CERTIFICATE OF ANALYSIS (CONT.)

	AS RECEIVED	DRY BASIS
FLUID TEMPERATURE	2615	

ASH MINERAL COMPOSITION
D2795 D3682

SILICON DIOXIDE	3.13 %
ALUMINIUM OXIDE	.85 %
FERRIC OXIDE	4.45 %
TITANIUM DIOXIDE	.13 %
PHOSPHORUS PENTOXIDE	12.93 %
CALCIUM OXIDE	32.36 %
MAGNESIUM OXIDE	3.54 %
SODIUM OXIDE	1.41 %
POTASSIUM OXIDE	9.43 %
SULFUR TRIOXIDE	1.90 %

APPROVED BY ____________

APPROVED BY ____________

BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.

CQ, INC.
160 QUALITY CENTER
HOMER CITY, PA 15748

DATE 9-24-99
SAMPLE NO: 598281

DATE SAMPLED: 8-17-99

DATE RECEIVED: 8-19-99

SAMPLE ID: POULTRY MANURE TEST 99081106

GROSS WEIGHT: 1716.2 GR

OTHER ID: PENNAG POULTRY COUNCIL PROJECT 99E0331 T1.2,
BIOMASS FEEDSTOCK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

TOTAL METALS		METHOD NUMBER	PAGE NUMBER
Arsenic	.56 Mg/Kg (ppm)	EPA SW-846	Method 8.51
Cadmium	4.34 Mg/Kg	EPA SW-846	Method 8.53
Chromium	9.54 Mg/Kg	EPA SW-846	Method 8.54
Cobalt	31.23 Mg/Kg	EPA 600/4-79-020	Method 219.1
Copper	57.26 Mg/Kg	EPA 600/4-79-020	Method 220.1
Lead	8.68 Mg/Kg	EPA SW-846	Method 8.56
Manganese	312.30 Mg/Kg	EPA 600/4-79-020	Method 243.1
Mercury	< 0.50 ug/Kg (ppb)	EPA SW-846	Method 8.57
Nickel	15.62 Mg/Kg (ppm)	EPA SW-846	Method 8.58
Selenium	3.64 Mg/Kg	EPA SW-846	Method 8.59
Zinc	520.50 Mg/Kg	EPA 600/4-79-020	Method 289.1
Beryllium	3.47 Mg/Kg	EPA 600/4-79-020	Method 210.1

APPROVED BY [signature]

STANDARD LABORATORIES, INC.

CQ, INC.
160 QUALITY CENTER
HOMER CITY, PA 15748

DATE 9-24-99
SAMPLE NO: 598281

DATE SAMPLED: 8-17-99

DATE RECEIVED: 8-19-99

SAMPLE ID: POULTRY MANURE TEST 99081106

GROSS WEIGHT: 1716.2 GR

OTHER ID: PENNAG POULTRY COUNCIL PROJECT 99E0331 T1.2,
BIOMASS FEEDSTOCK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

TCLP EXTRACTION					METHOD NUMBER	PAGE NUMBER
Arsenic		3.04	Ug/L	(ppb)	EPA SW-846	Method 8.51
Cadmium	<	0.05	Mg/L	(ppm)	EPA SW-846	Method 8.53
Chromium		.51	Mg/L		EPA SW-846	Method 8.54
Cobalt	<	0.25	Mg/L		EPA 600/4-79-020	Method 219.1
Copper		.10	Mg/L		EPA 600/4-79-020	Method 220.1
Lead	<	0.10	Mg/L		EPA SW-846	Method 8.56
Manganese	<	0.06	Mg/L		EPA 600/4-79-020	Method 243.1
Mercury	<	0.50	Ug/L	(ppb)	EPA SW-846	Method 8.57
Nickel		.10	Mg/L	(ppm)	EPA SW-846	Method 8.58
Selenium		218.8	Ug/L	(ppb)	EPA SW-846	Method 8.59
Zinc		.27	Mg/L	(ppm)	EPA 600/4-79-020	Method 289.1
Beryllium	<	0.04	Mg/L		EPA 600/4-79-020	Method 210.1

Extraction Fluid Used #2
Sample Weight 15 grams

APPROVED BY [signature]

APPENDIX B

SAMPLE ANALYTICAL REPORTS
PELLETED FUEL FORMULATIONS

GOULD ENERGY DIVISION
P. O. BOX 214
CRESSON, PA 16630
(814) 886-7400
STANDARD LABORATORIES, INC.

DATE: 1-13-2000
SAMPLE NO. 616597

C. Q., INC.
160 QUALITY CENTER ROAD
HOMER CITY, PA 15748

SAMPLE ID: PELLETS 85% PETROLEUM COKE/15% PLASTICS

OPERATING CO.: 99111801
SAMPLED BY: CUSTOMER PROVIDED
MINE:
LOCATION:

DATE SAMPLED: 11/18/99 DATE RECEIVED: 11/30/99
WEATHER:
GROSS WEIGHT: 10359.9 G

OTHER ID: PROJECT 99E0331 T1.5, BIOMASS PELLET CHARACTERIZATION

CERTIFICATE OF ANALYSIS

	ASTM METHOD	AS RECEIVED	DRY BASIS
MOISTURE	D2961 D3302 D3173	.46%	XXX
VOLATILE MATTER		27.46%	27.59%
FIXED CARBON	D3172	71.12%	71.45%
ASH	D3174	.96%	.96%
SULFUR	D4239 METHOD 3.3	4.54%	4.56%
CARBON	D3178	85.14%	85.54%
HYDROGEN	D3178	5.02%	5.05%
NITROGEN	D3179	.99%	1.00%
OXYGEN	D3176	2.89%	2.90%
BTU/LB	D2015 D1989	15373	15444
MAF BTU/LB			15595
LBS OF SO2 PER MILLION BTU			5.90
LBS OF SULFUR PER MILLION BTU		2.953	
FREE SWELLING INDEX	D720	1.0	
HARDGROVE GRINDABILITY INDEX	D409	44	
CHLORINE	D4208	.37%	.37%
FLUORINE	D3761	91.94 PPM	92.37 PPM
PERCENT SOLIDS			99.54%
BULK DENSITY		33.29 LB./CU FT.	

PAGE 1

APPROVED BY ____________

APPROVED BY ____________

BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.

DATE: 1-13-2000
SAMPLE NO. 616597

CERTIFICATE OF ANALYSIS (CONT.)

AS RECEIVED DRY BASIS

ASH FUSION TEMPERATURE(S)

D1857	REDUCING ATMOSPHERE	
INITIAL DEFORMATION TEMPERATURE		2065
SOFTENING TEMPERATURE		2110
HEMISPHERICAL TEMPERATURE		2135
FLUID TEMPERATURE		2150
D1857	OXIDIZING ATMOSPHERE	
INITIAL DEFORMATION TEMPERATURE		2285
SOFTENING TEMPERATURE		2330
HEMISPHERICAL TEMPERATURE		2380
FLUID TEMPERATURE		2425

ASH MINERAL COMPOSITION
D2795 D3682

SILICON DIOXIDE	25.25 %
ALUMINIUM OXIDE	5.63 %
FERRIC OXIDE	8.97 %
TITANIUM DIOXIDE	5.95 %
PHOSPHORUS PENTOXIDE	.04 %
CALCIUM OXIDE	9.08 %
MAGNESIUM OXIDE	2.17 %
SODIUM OXIDE	1.68 %
POTASSIUM OXIDE	8.39 %
SULFUR TRIOXIDE	15.14 %

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BLACK SEAL ANALYSIS

GOULD ENERGY DIVISION
P.O. BOX 214
CRESSON, PA 16630
(814) 886-7400

STANDARD LABORATORIES, INC.

DATE: 1-13-2000
SAMPLE NO. 616597

C.G., INC.
160 QUALITY CENTER ROAD
HOMER CITY, PA 15748

SAMPLE ID: PELLETS 85% PETROLEUM COKE/15% PLASTICS

OPERATING CO.: 99111801
SAMPLED BY: CUSTOMER PROVIDED
MINE:
LOCATION:

DATE SAMPLED: 11/18/99
DATE RECEIVED: 11/30/99
WEATHER:
GROSS WEIGHT: 10359.9 G

OTHER ID: PROJECT 99E0331 T1.5, BIOMASS PELLET CHARACTERIZATION

CERTIFICATE OF ANALYSIS

ASTM METHOD — AS RECEIVED — DRY BASIS

D3683 D3684 D3684 (MODIFIED)

TRACE ELEMENTS IN COAL

ARSENIC		.63 PPM
CADMIUM	<	.12 PPM
CHROMIUM		3.77 PPM
LEAD		25.92 PPM
MERCURY		51.80 PPB
NICKEL		117.84 PPM
SELENIUM		1.15 PPM
ZINC		39.36 PPM
BERYLLIUM	<	.10 PPM
COBALT		3.67 PPM
MANGANESE		4.44 PPM
Copper		12.24 ppm

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BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.
GOULD ENERGY DIVISION
P.O. BOX 214
CRESSON, PA 16630

DATE: 01-14-00
SAMPLE NO: 616597

CQ, INC.
160 QUALITY CENTER ROAD
HOMER CITY, PA 15748

DATE SAMPLED: DATE RECEIVED: 11-30-99

SAMPLE ID: PELLETS 85% PETROLEUM COKE 15% PLASTICS
OPERATING CO: 99111801
SAMPLED BY: CUSTOMER PROVIDED

GROSS WEIGHT: 10359.9 G.
OTHER ID: PROJECT 99E0331 T1.5 BIOMASS PELLET CHARACTERIZATION

CERTIFICATE OF ANALYSIS

TCLP ANALYSIS

ARSENIC		58.80	ppb
BERYLLIUM	<	0.04	ppm
CADMIUM	<	0.05	ppm
CHROMIUM	<	0.10	ppm
COBALT		1.17	ppm
COPPER		0.89	ppm
LEAD		0.49	ppm
MANGANESE		3.7	ppm
MERCURY	<	0.50	ppb
NICKEL		8.32	ppm
SELENIUM		633.5	ppb
ZINC		23.90	ppm

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GOULD ENERGY DIVISION
P.O. BOX 214
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(814) 886-7400
STANDARD LABORATORIES, INC.

DATE: 1-14-2000
SAMPLE NO. 613527

C.Q., INC.
160 QUALITY CENTER ROAD
HOMER CITY, PA 15748

SAMPLE ID: PELLETS 80% QHS COAL/20% WAXED CARDBOARD

OPERATING CO.: 99110901
SAMPLED BY: CUSTOMER PROVIDED
MINE:
LOCATION:

DATE SAMPLED:
DATE RECEIVED: 11/23/99
WEATHER:
GROSS WEIGHT: 12135.

OTHER ID: PROJECT 99E0331 T1.5 BIOMASS PELLET CHARACTERIZATION

CERTIFICATE OF ANALYSIS

	ASTM METHOD	AS RECEIVED	DRY BASIS
MOISTURE	D2961 D3302 D3173	16.22%	XXX
VOLATILE MATTER		37.96%	45.31%
FIXED CARBON	D3172	39.75%	47.44%
ASH	D3174	6.07%	7.25%
SULFUR	D4239 METHOD 3.3	1.21%	1.44%
CARBON	D3178	61.12%	72.96%
HYDROGEN	D3178	4.72%	5.64%
NITROGEN	D3179	.99%	1.18%
OXYGEN	D3176	9.67%	11.53%
BTU/LB	D2015 D1989	10933	13050
MAF BTU/LB			14070
LBS OF SO2 PER MILLION BTU			2.20
LBS OF SULFUR PER MILLION BTU		1.107	
FREE SWELLING INDEX	D720	4.5	
HARDGROVE GRINDABILITY INDEX	D409	34	
CHLORINE	D4208	.08%	.10%
FLUORINE	D3761	64.30 PPM	76.75 PPM
PERCENT SOLIDS			83.78%

PAGE 1

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BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.

DATE: 1-13-2000
SAMPLE NO. 613527

CERTIFICATE OF ANALYSIS (CONT.)

	AS RECEIVED	DRY BASIS

ASH FUSION TEMPERATURE(S)

D1857	REDUCING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	2170
SOFTENING TEMPERATURE	2190
HEMISPHERICAL TEMPERATURE	2230
FLUID TEMPERATURE	2285

D1857	OXIDIZING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	2340
SOFTENING TEMPERATURE	2400
HEMISPHERICAL TEMPERATURE	2415
FLUID TEMPERATURE	2430

ASH MINERAL COMPOSITION
D2795 D3682

SILICON DIOXIDE	46.60 %
ALUMINIUM OXIDE	20.51 %
FERRIC OXIDE	13.89 %
TITANIUM DIOXIDE	1.70 %
PHOSPHORUS PENTOXIDE	.09 %
CALCIUM OXIDE	4.57 %
MAGNESIUM OXIDE	1.22 %
SODIUM OXIDE	1.73 %
POTASSIUM OXIDE	1.42 %
SULFUR TRIOXIDE	7.44 %

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BLACK SEAL ANALYSIS

GOULD ENERGY DIVISION
P.O. BOX 214
CRESSON, PA 16630
(814) 886-7400
STANDARD LABORATORIES, INC.

DATE: 1-13-2000
SAMPLE NO. 613527

C.Q., INC.
160 QUALITY CENTER ROAD
HOMER CITY, PA 15748

SAMPLE ID: PELLETS 80% QHS COAL/20% WAXED CARDBOARD

OPERATING CO.: 99110901
SAMPLED BY: CUSTOMER PROVIDED
MINE:
LOCATION:

DATE SAMPLED:
DATE RECEIVED: 11/23/99
WEATHER:
GROSS WEIGHT: 12135.

OTHER ID: PROJECT 99E0331 T1.5 BIOMASS PELLET CHARACTERIZATION

CERTIFICATE OF ANALYSIS

ASTM METHOD	AS RECEIVED	DRY BASIS
D3683 D3684 D3684 (MODIFIED)		

TRACE ELEMENTS IN COAL

ARSENIC		1.91 PPM
CADMIUM	<	.91 PPM
CHROMIUM		15.59 PPM
LEAD		188.50 PPM
MERCURY		78.19 PPB
NICKEL		16.67 PPM
SELENIUM		.93 PPM
ZINC		141.38 PPM
BERYLLIUM	<	.73 PPM
COBALT		19.94 PPM
MANGANESE		24.65 PPM
Copper		16.13 ppm

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BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.
GOULD ENERGY DIVISION
P.O. BOX 214
CRESSON, PA 16630

DATE: 01-14-00
SAMPLE NO: 613527

CQ, INC.
160 QUALITY CENTER ROAD
HOMER CITY, PA 15748

DATE SAMPLED: DATE RECEIVED: 11-23-99

SAMPLE ID: PELLETS 80% GHS COAL 20% WAXED CARDBOARD
OPERATING CO: 99110901
SAMPLED BY: CUSTOMER PROVIDED

GROSS WEIGHT: 12135.
OTHER ID: PROJECT 99E0331 T1.5 BIOMASS PELLET CHARACTERIZATION

CERTIFICATE OF ANALYSIS

TCLP ANALYSIS

ARSENIC		39.15	ppb
BERYLLIUM	<	0.04	ppm
CADMIUM	<	0.05	ppm
CHROMIUM	<	0.10	ppm
COBALT	<	0.25	ppm
COPPER		0.12	ppm
LEAD		13.8	ppm
MANGANESE		1.80	ppm
MERCURY	<	0.50	ppb
NICKEL		0.12	ppm
SELENIUM		83.61	ppb
ZINC		13.9	ppm

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GOULD ENERGY DIVISION
P.O. BOX 214
CRESSON, PA 16630
(814) 886-7400
STANDARD LABORATORIES, INC.

DATE: 1-28-2000
SAMPLE NO. 618774

C. Q., INC.
160 QUALITY CENTER ROAD
HOMER CITY, PA 15748

SAMPLE ID:

OPERATING CO.: TEST 99121001
SAMPLED BY: CUSTOMER PROVIDED
MINE:
LOCATION:

DATE SAMPLED: 12/10/99
DATE RECEIVED: 12/14/99
WEATHER:
GROSS WEIGHT: 7641.8 GR

OTHER ID: PROJECT 99E0331 T1.5, BIOMAS PELLET CHARACTERIZATION PELLETS 8 0% QHS COAL/20% SEWAGE SLUDGE (PELLETS AIR DRIED FOR 72 HOURS)

CERTIFICATE OF ANALYSIS

	ASTM METHOD	AS RECEIVED	DRY BASIS
MOISTURE	D2961 D3302 D3173	9.17%	XXX
VOLATILE MATTER		32.55%	35.84%
FIXED CARBON	D3172	50.22%	55.28%
ASH	D3174	8.06%	8.88%
SULFUR	D4239 METHOD 3.3	1.56%	1.71%
CARBON	D3178	68.80%	75.75%
HYDROGEN	D3178	4.56%	5.02%
NITROGEN	D3179	1.24%	1.36%
OXYGEN	D3176	6.61%	7.28%
BTU/LB	D2015 D1989	12374	13624
MAF BTU/LB			14951
LBS OF SO2 PER MILLION BTU			2.51
LBS OF SULFUR PER MILLION BTU		1.261	
FREE SWELLING INDEX	D720	9.0	
HARDGROVE GRINDABILITY INDEX	D409	67	
CHLORINE	D4208	.16%	.18%
PERCENT SOLIDS			90.83%
BULK DENSITY		32.48 LB./CU.FT.	

PAGE 1

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BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.

DATE: 1-28-2000
SAMPLE NO. 61877

CERTIFICATE OF ANALYSIS (CONT.)

	AS RECEIVED	DRY BASIS

ASH FUSION TEMPERATURE(S)

D1857	REDUCING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	2045
SOFTENING TEMPERATURE	2090
HEMISPHERICAL TEMPERATURE	2130
FLUID TEMPERATURE	2170

D1857	OXIDIZING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	2290
SOFTENING TEMPERATURE	2350
HEMISPHERICAL TEMPERATURE	2380
FLUID TEMPERATURE	2400

ASH MINERAL COMPOSITION
D2795 D3682

SILICON DIOXIDE	45.27 %
ALUMINIUM OXIDE	20.58 %
FERRIC OXIDE	15.72 %
TITANIUM DIOXIDE	1.10 %
PHOSPHORUS PENTOXIDE	2.11 %
CALCIUM OXIDE	5.56 %
MAGNESIUM OXIDE	1.24 %
SODIUM OXIDE	1.20 %
POTASSIUM OXIDE	2.28 %
SULFUR TRIOXIDE	6.97 %

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BLACK SEAL ANALYSIS

GOULD ENERGY DIVISION
P. O. BOX 214
CRESSON, PA 16630
(814) 886-7400
STANDARD LABORATORIES, INC.

DATE: 1-28-2000
SAMPLE NO. 618774

C. Q., INC.
160 QUALITY CENTER ROAD
HOMER CITY, PA 15748 SAMPLE ID:

OPERATING CO.: TEST 99121001
SAMPLED BY: CUSTOMER PROVIDED
MINE:
LOCATION:

DATE SAMPLED: 12/10/99 DATE RECEIVED: 12/14/99
WEATHER:
GROSS WEIGHT: 7641.8 GR

OTHER ID: PROJECT 99E0331 T1.5, BIOMAS PELLET CHARACTERIZATION PELLETS 8 0% GHS COAL/20% SEWAGE SLUDGE (PELLETS AIR DRIED FOR 72 HOURS)

CERTIFICATE OF ANALYSIS

ASTM METHOD AS RECEIVED DRY BASIS

D3683 D3684 D3684 (MODIFIED)

TRACE ELEMENTS IN COAL

ARSENIC		9.26 PPM
CADMIUM	<	1.11 PPM
CHROMIUM		20.20 PPM
LEAD		9.99 PPM
MERCURY		63.85 PPB
NICKEL		16.21 PPM
SELENIUM		1.57 PPM
ZINC		41.51 PPM
BERYLLIUM	<	.89 PPM
COBALT		20.42 PPM
MANGANESE		48.84 PPM
Copper		36.41 ppm

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BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.
GOULD ENERGY DIVISION
P.O. BOX 214
CRESSON, PA 16630

DATE: 1-28-00
SAMPLE NO: 618774

CQ, INC.
160 QUALITY CENTER ROAD
HOMER CITY, PA 15748

DATE SAMPLED: 12-10-99 DATE RECEIVED: 12-14-99

SAMPLE ID: PROJECT 99E0331 T1.5, BIOMASS PELLET CHARACTERIZATION PELLETS 80% GHS COAL/20% SEWAGE SLUDGE (PELLETS AIR DRIED FOR 72 HOURS)

CERTIFICATE OF ANALYSIS

TCLP ANALYSIS

ARSENIC		4820.5	ppb
BERYLLIUM	<	0.04	ppm
CADMIUM	<	0.05	ppm
CHROMIUM	<	0.10	ppm
COBALT		0.32	ppm
COPPER	<	0.04	ppm
LEAD		0.29	ppm
MANGANESE		4.90	ppm
MERCURY	<	0.50	ppb
NICKEL		0.31	ppm
SELENIUM		466.6	ppb
ZINC		0.07	ppm

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APPENDIX C

FEEDSTOCK CHARACTERIZATION: PHASE I TASK 2 FINAL REPORT

ALSTOM POWER INC.
US POWER PLANT LABORATORIES

ABB ALSTOM POWER

Technical Report

Reporting CRC (full name and address): ABB Alstom Power
US Power Plant Laboratories
Combustion Engineering, Inc.
2000 Day Hill Road
Windsor, CT 06095, USA
Tel.: (860) 285-2275 Fax: (860) 285-3473

Responsible Person: Woody Fiveland

Project Name: Production of New Biomass / Waste-Containing Solid Fuels

Document Title: **Feedstock Characterization: Phase 1 Task 2 Final Report for CQ Inc.**

Document Ref. No.: PPL-99-CT-28

Date of Issue: 7.1.00 No. of pages: 48

Client: CQ Inc.

Author(s): Charles Q. Maney

Distribution: see separate page

Distribution page 1: see separate page

Keywords: CQ Inc., DOE, Biomass, Fuels, Feedstock, and Combustor

Summary:
This report is presented in fulfillment of the Phase 1, Task 2 work scope of US DOE contract DE-AC26-99FT40159 performed by ABB Alstom Power's US Power Plant Laboratories (US PPL) under subcontract to CQ Inc. The objective of this work was to identify three candidate biomass / waste containing solid fuels or fuel blends for application to existing solid fuel combustors in pelletized form based on a review of the ASTM analyses, and economics for use of nine candidate feedstocks, as provided by CQ Inc. The reviewed analyses included: two bituminous coal cleaning plant fines (Ginger Hills and Pleasant Ridge), a switch grass, a petroleum coke, a mixed plastics sample, a waxed cardboard sample, a sewage sludge, and two poultry manures.

For the review, the feedstocks were rated with regard to their applicability (high, medium, and low) to each of four combustor types: Pulverized Coal (PC), Circulating Fluidized Bed (CFB), Stokers, and Cyclones, based on an identified series of constraints including the fuel's reactivity, slagging & fouling behavior, corrosion characteristics, fuel handling & preparation issues, and pellet size & integrity concerns. Following this rating, an overall assessment of the individual fuels were made with regard to their general applicability to solid fuel combustors as a means to identify the most favorable / least deleterious fuels for potential field use.

The above information was then combined with an estimate of the as-pelletized cost for each candidate feed, as provided by CQ Inc., in order to identify three composite, candidate, pelletized fuels for further evaluation. The first such fuel is a combination of 80% Ginger Hills coal fines with 20% dewatered (~10% moisture) sewage sludge, which has a projected cost of -$0.16 / MMBtu (re. results in a revenue) based on a $28 / ton tipping fee for the sewage sludge. The second fuel is a combination of 85% petroleum coke with 15% mixed plastics, which has a projected cost of $0.60 / MMBtu. The third is a mixture of 80% Ginger Hills coal fines with 20% waxed cardboard, which has a projected cost of $0.87 / MMBtu. Pelletized mixtures of these fuels will be prepared and evaluated for their pulverizer characteristics and combustion behavior in US PPL's Grindability Index Machine and Drop Tube Furnace System (DTFS) under Task 5 of the above mentioned program.

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Dept_9005

1. Introduction

ABB Alstom Power, through it's US Power Plant Laboratory (US PPL) was subcontracted by CQ Inc. to qualitatively assess the applicability of various biomass and / or waste containing solid fuels and feedstocks to existing combustors in pelletized form in support of Phase I, Task 2 of US DOE contract DE-AC26-99FT40159. The objective of this work was to identify three candidate biomass / waste containing solid fuels or fuel blends for pelletization testing, and further laboratory analysis and bench scale combustion testing as part of the continuation of the DOE contract.

For the subject work, US PPL reviewed the ASTM analyses of nine (9) candidate feedstocks provided by CQ Inc. in order to qualitatively assess their applicability to each of four combustor types based on a review of five potential impact areas. Considered combustor types included: Pulverized Coal (PC), Circulating Fluidized Bed (CFB), Stoker, and Cyclone fired boilers. Relevant impact areas included the fuel's reactivity, its slagging & fouling behavior, its corrosion potential, fuel handling & preparation issues, and pellet size & integrity concerns. Upon completion of this assessment, the nine fuels were ranked with regard to their potential for performance impact as a means to identify those fuels with the most favorable / least deleterious overall characteristics for use in a composite, pelletized solid fuel.

Following the technical assessment, an economic evaluation was performed to determine which of the available fuels were most cost effective for commercial use as compared to the cost of a typical eastern bituminous coal. This work was supported by economic information provided by CQ Inc. including an estimate of the as-delivered cost for the individual fuels, with applicable tipping fees (if any), and the cost to prepare / pelletize them in keeping with the overall objectives of the DOE program.

Considered as a whole, the combined results from the technical and economic evaluations were then used by US PPL and CQ Inc. personnel to jointly make recommendations for the formulation of three composite fuels based on the reviewed feedstocks. Further evaluation of the recommended fuels in pellet form by US PPL, including composite ASTM analyses, and Drop Tube Furnace System (DTFS) pyrolysis / Thermogravimetric Analysis (TGA) char reactivity testing, and ABB Grindability Index (ABB GI) testing will be performed under Task 5 of the US DOE contract to further assess the suitability of these fuels for commercial combustor use.

2. Feedstock Sample Analyses

For this project, USPPL received analyses from CQ Inc. on nine (9) biomass and waste containing solid fuel and feedstock samples comprised of two coal fine samples, one each from the Ginger Hill and Pleasant Ridge coal cleaning plants, a switch grass sample, a petroleum coke sample, a mixed plastic sample, a waxed cardboard sample, a sewage sludge sample, and two poultry manure samples, one air dried and one as received (i.e. pond reclaim). Received analyses for each sample included:

1. Total moisture,
2. Inherent moisture,
3. Ultimate analysis,
4. Proximate analysis,
5. Ash fusibilities (oxidizing and reducing),
6. Ash composition,
7. Chlorine content,
8. Sodium content,
9. Toxic Characteristic Leaching Procedure (TLCP), and
10. Trace elements, including:

    Arsenic, Beryllium, Cadmium, Copper, Cobalt, Chromium, Fluorine, Mercury, Manganese, Nickel, Lead, Selenium, and Zinc.

Table 1 provides a summary of relevant parameters from the ASTM analyses received from CQ Inc. of the nine reviewed feedstocks, plus an additional column detailing properties of a dewatered (10% final moisture) sewage sludge based on the as-received "wet" analysis. **Bold** numbers indicate areas for concern because the specific index or component exceeds a desirable limit for one of the four combustor types, and is thus a resultant limitation to its use. Questionable or estimated data, in this case the composition of a fictitious, dewatered sewage sludge determined from the provided "wet" analysis, and as-received ash compositions that do not approach 100%, are presented in *Italics*. Laboratory analyses sheets detailing these and other measured properties for each of the nine fuels can be found in the Appendix.

Table 1: Feedstock Analyses

Identification	Ginger Hill Coal Fines	Pleasant Ridge Coal Fines	Switch Grass	Petroleum Coke	Mixed Plastics	Waxed Cardboard	Sewage Sludge	*Sewage Sludge 10% Moisture*	Poultry Manure 1	Poultry Manure 2
Chemical Analyses										
VM	29.2%	32.8%	80.2%	13.0%	92.2%	79.6%	9.3%	*55.7%*	60.5%	23.5%
FC	45.7%	40.5%	7.7%	79.4%	5.3%	8.7%	1.3%	*7.9%*	8.1%	2.1%
FC/VM	1.56	1.23	0.10	**6.12**	0.06	0.11	0.14	*0.14*	0.13	0.09
HHV, BTU/lb	11,335	10,858	7,521	14,201	14,425	9,610	1,117	*6,715*	5,406	2,043
LHV, BTU/lb	10,721	10,251	6,895	13,753	13,374	8,741	**118**	*6,122*	4,902	**1,238**
Moisture	19.5%	*19.5%*	8.0%	7.2%	0.2%	9.3%	**85.0%**	*10.0%*	*9.1%*	**60.8%**
Hydrogen	4.2%	4.1%	5.6%	3.8%	10.8%	7.9%	0.8%	*5.0%*	4.2%	1.5%
Carbon	63.1%	58.5%	43.8%	**80.5%**	67.8%	50.2%	**5.8%**	*34.6%*	32.8%	**12.1%**
Sulfur	1.3%	3.3%	0.1%	**5.1%**	0.3%	0.2%	0.3%	*1.6%*	0.3%	0.1%
Nitrogen	1.0%	0.9%	1.4%	1.4%	0.1%	0.1%	0.8%	*5.0%*	3.8%	1.2%
Oxygen	5.3%	6.4%	37.1%	1.6%	18.4%	29.9%	2.9%	*17.4%*	27.4%	10.6%
Ash	5.6%	7.2%	4.1%	0.4%	2.3%	2.5%	4.4%	***26.4%***	**22.4%**	**13.6%**
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	*100.0%*	100.0%	100.0%
O/N	5.3	6.9	27.3	1.1	184.1	229.7	3.5	*3.5*	7.1	8.7
lb N/MMBTU	0.88	0.85	1.81	0.97	0.07	0.14	**7.43**	***7.43***	**7.10**	**5.97**
lb S/MMBTU	1.14	3.08	0.16	3.61	0.23	0.20	2.42	*2.42*	0.50	0.49
lb Ash/MMBTU	4.9	6.6	5.5	0.3	1.6	2.6	**39.3**	***39.3***	**41.4**	**66.6**
Chlorine	0.12%	0.06%	0.22%	0.03%	**0.98%**	0.20%	0.03%	*0.18%*	**0.45%**	0.15%
lb_Cl/MMBTU	0.11	0.05	**0.28**	0.02	**0.68**	**0.21**	**0.27**	***0.27***	**0.83**	**0.73**
Fluorine (ppm)	53	59	27	58	0	0	43	*261*	32	15
Ash Fusibility Temps. (°F)	Reducing Atm.	Reducing Atm.	Reducing Atm.	Reducing Atm.	Reducing Atm.	Reducing Atm.	Reducing Atm.	*Reducing Atm.*	Reducing Atm.	Reducing Atm.
I.T.	**2075**	**1940**	1,960	2,210	2,560	2,100	2,000	*2,000*	**2,500**	2,485
S.T.	2125	1990	2,000	2,240	2,565	2,140	2,020	*2,020*	2,550	2,505
H.T.	2180	2035	2,010	2,270	2,570	2,155	2,070	*2,070*	2,560	2,525
F.T.	**2280**	**2075**	2,030	2,295	2,575	2,165	2,120	*2,120*	2,570	2,545
Diff. (F.T. - I.T.)	205	135	70	85	15	na	120	*120*	70	60
Ash Fusibility Temps. (°F)	Oxidizing Atm.	Oxidizing Atm.	Oxidizing Atm.	Oxidizing Atm.	Oxidizing Atm.	Oxidizing Atm.	Oxidizing Atm.	*Oxidizing Atm.*	Oxidizing Atm.	Oxidizing Atm.
I.T.	2345	**2375**	2,040	2,050	2,500	**2,200**	2,080	*2,080*	2,595	2,570
S.T.	2370	2405	2,080	2,090	2,510	2,255	2,110	*2,110*	2,610	2,585
H.T.	2400	2420	2,100	2,110	2,515	2,290	2,145	*2,145*	2,620	2,600
F.T.	2430	2450	2,120	2,130	2,525	2,320	2,200	*2,200*	2,640	2,615
Diff. (F.T. - I.T.)	85	75	80	80	25	na	120	*120*	45	45
Ash Composition										
SiO2	47.1%	38.4%	35.4%	25.4%	0.8%	26.9%	34.4%	*34.4%*	3.4%	3.1%
Al2O3	20.7%	15.0%	5.9%	8.2%	0.8%	17.4%	12.8%	*12.8%*	1.7%	0.9%
Fe2O3	**15.1%**	**25.8%**	4.1%	8.9%	0.2%	**4.9%**	13.2%	*13.2%*	3.2%	4.5%
TiO2	1.1%	1.6%	0.3%	0.6%	0.3%	12.5%	1.6%	*1.6%*	0.1%	0.1%
CaO	5.8%	5.1%	12.2%	11.3%	1.3%	15.9%	9.0%	*9.0%*	29.0%	32.4%
MgO	1.1%	0.8%	9.8%	2.9%	0.2%	1.9%	2.1%	*2.1%*	3.6%	3.5%
Na2O	**0.4%**	0.6%	2.4%	1.2%	0.2%	**8.8%**	0.9%	*0.9%*	1.5%	1.4%
K2O	2.0%	1.3%	**15.1%**	1.3%	0.0%	1.5%	1.5%	*1.5%*	**8.0%**	**9.4%**
P2O5	0.1%	0.2%	8.1%	0.5%	0.2%	1.1%	15.4%	*15.4%*	13.3%	12.9%
SO3	7.4%	8.7%	5.0%	20.1%	0.6%	7.6%	2.1%	*2.1%*	2.2%	1.9%
Total	100.7%	97.6%	98.2%	80.4%	*4.4%*	98.3%	92.8%	*92.8%*	*66.0%*	*70.1%*
Base / Acid Ratio	0.35	**0.61**	1.05	0.75	1.04	**0.58**	**0.54**	*0.54*	8.71	12.45
Fe2O3 / CaO	2.61	5.04	**0.34**	0.79	**0.14**	**0.31**	1.47	*1.47*	**0.11**	0.14
SiO2 / Al2O3	2.28	2.56	**6.05**	3.10	1.30	1.54	2.69	*2.69*	1.97	3.68
lb K+Na/MMBTU	0.12	0.12	**0.95**	0.01	0.00	0.26	**0.92**	*0.92*	**3.94**	**7.22**
Ash Behavior										
Ash-Type	Bituminous	Bituminous	Lignitic-Like	Lignitic-Like	Lignitic-Like	Lignitic-Like	Bituminous-Like	*Bituminous-Like*	Lignitic-Like	Lignitic-Like
Slagging Potential	Medium - High	High	Severe	Low - Medium	Low	High	Medium	*Medium*	High	High
Fouling Potential	Low	Medium	Severe	Low - Medium	Low - Medium	Severe	High	*High*	Severe	Severe

3. Feedstock Evaluation

3.1 Combustor Applicability

As noted, the objective of this work was to identify three, candidate, composite solid fuels or fuel blends for potential use in large scale, commercial combustors. As a means to this end, each of the above identified nine solid fuels was evaluated for its applicability to each of four combustor types including Pulverized Coal (PC), Circulating Fluidized Bed (CFB), Stoker, and Cyclone fired boilers. As a basis for this evaluation, it was assumed that no modifications to the existing combustor or fuel handling equipment would be made, which would minimize the cost for potential application.

In assessing the applicability of the nine solid fuels to the four noted combustor types, consideration was given to five primary impact areas based on each fuel's previously identified ASTM analysis. These areas include:

1. Reactivity

   Defined here as the ability of the fuel to sustain ignition in the absence of support fuel. Relevant fuel properties include as-fired volatile matter and moisture content, or LHV.

2. Slagging & Fouling Characteristics

   Defined here as the propensity for the fuel's ash to form deposits on the waterwall surfaces (slagging) and within the boiler's convective pass (fouling) thereby impacting heat transfer rates and boiler heat balance. Relevant fuel properties include ash fusion temperatures and ash composition / chemistry (ash type, iron content, base / acid ratio, Na and K content, ...).

3. Corrosion Behavior

   Defined here as the propensity of the fuel to corrode waterwall and / or convective surfaces due to the formation of hydrochloric (HCl) and / or sulfuric acid in the combustion gases, or related reduced compounds on the heat transfer surfaces. Relevant fuel properties include chlorine and sulfur content (%) and loading (lb/MMBtu).

4. Fuel Handling & Preparation

   Defined here as the ability of existing, field unit fuel handling and preparation equipment to process the fuel in pelletized form. Relevant fuel properties include pellet size and composition, and the higher heating value of the fuel (HHV) given in BTU's per pound of fuel.

5. Pellet Size & Integrity

   Defined here as the length and diameter of the individual pellets, the size of the raw (as-pelletized) constituents, and the pellet's physical integrity as they affect the combustion process. Relevant fuel properties include pellet size, and raw feed / constituent size within the pellet (i.e. % fines) (*Note: the size and physical integrity of the pellets were not measured parameters as none of the fuels were pelletized for this work. Thus the terms are used here only to identify a feed size constraint that should be considered in designing pelletizing equipment for a particular application, and / or the potential for a size and integrity problem in particular combustor type*).

Each of the nine potential feedstocks were evaluated by ABB Alstom Power personnel with regard to the five above mentioned impact areas, based on the analyses provided in Table 1. A summary of the results of this evaluation is provided in Table 2.

As shown, Table 2 lists the overall applicability of each candidate fuel to a given combustor type, rated as "low," "medium," or "high," depending on the recommended maximum heat input rate for that fuel as fired in that combustor type. As defined here, a fuel rated low in its applicability is not recommended for firing at more than 25% of maximum furnace heat input, a fuel rated as medium in its applicability is recommended for firing at 25% to 50% of maximum furnace heat input, while a fuel rated as high is capable of being fired at greater than 50% of the maximum allowable furnace heat input rate, and can thus act as the primary combustor fuel.

Following the notation of overall applicability, a corresponding maximum recommended heat input is also given along with an itemization of the limiting constraint or series of constraints affecting the fuel's applicability. Noted constraints represent the predominant factors, and are not all inclusive in that an additional, not mentioned constraint may come into play at similar or slightly higher overall heat input levels.

It should be noted that the results of this analysis, including recommended maximum allowable heat input rates, were subjectively determined based upon provided ASTM analyses and ABB Alstom Power experience for typical PC, CFB, Stoker and Cyclone fired combustors. Actual, field performance will, however, vary depending upon the specific field unit design and operation, and the analyses of the actual as-fired fuel(s) in comparison to that shown in Table 1.

Table 2: Combustor Assessment

Identification	Ginger Hill Coal Fines	Pleasant Ridge Coal Fines	Switch Grass	Petroleum Coke	Mixed Plastics	Waxed Cardboard	Sewage Sludge	*Sewage Sludge 10% Moisture*	Poultry Manure 1	Poultry Manure 2
PC										
Applicability	High	High	Low	Low	na	Low	na	*Low*	Low	na
Max Heat Input	100%	100%	10%	20%	0%	20%	0%	*10%*	10%	0%
Constraint	Slag. & Foul.	Slag. & Foul.	Slag. & Foul.	Reactivity	Preparation	Slag. & Foul.	Reactivity	*Slag. & Foul.*	Slag. & Foul.	Slag. & Foul.
								Reactivity	Reactivity	Reactivity
CFB										
Applicability	High	High	Low	High	Medium	High	na	*Low*	Low	na
Max Heat Input	>90%	>90%	10%	100%	25%	100%	0%	*15%*	15%	0%
Constraint	Size & Integ.	Size & Integ.	Slag. & Foul.	Size & Integ.	Corrosion	Slag. & Foul.	Reactivity	*Slag. & Foul.*	Slag. & Foul.	Slag. & Foul.
					Size & Integ.					Reactivity
Stoker										
Applicability	Medium	Medium	Low	Low	Medium	Medium	Low	*Low*	Low	Low
Max Heat Input	50%	50%	20%	10%	25%	50%	10%	*15%*	15%	10%
Constraint	Size & Integ.	Size & Integ.	Slag. & Foul.	Reactivity	Corrosion	Slag. & Foul.	Reactivity	*Slag. & Foul.*	Slag. & Foul.	Slag. & Foul.
					Size & Integ.					Reactivity
Cyclone										
Applicability	High	High	Low	Medium	Medium	Medium	na	*Low*	Low	na
Max Heat Input	100%	100%	20%	25%	25%	50%	0%	*15%*	15%	0%
Constraint	Size & Integ.	Size & Integ.	Slag. & Foul.	Reactivity	Corrosion	Slag. & Foul.	Reactivity	*Slag. & Foul.*	Slag. & Foul.	Slag. & Foul.
					Size & Integ.					Reactivity

3.2 Discussion

As shown, only the two coal fuels, the Ginger Hill and Pleasant Ridge coal fines, are broadly applicable to each combustor type, being suitable for use at greater than or equal to 50% maximum continuous rating (MCR) heat input. For PC and Cyclone firing, the two coal fines may be used at up to 100% maximum heat input, with limitations based on slagging & fouling concerns, which are related to the design of the specific field unit (e.g. size of the box per unit heat input), and pellet size & integrity, which is related to the raw feed size (i.e. size of fines) and pelletizing equipment characteristics, respectively. For CFB use, either fuel is suitable for use at ≥ 90% MCR heat input, with limitations existing based on particle size (% fines) as it affects combustor hydrodynamics and fly ash recycle rate, and thus combustion efficiency. For Stoker firing, however, both fuels are rated at 50% maximum heat input due to their low ash / water content which affects grate cooling and, therefor, mechanical integrity. In all cases, the as-received pellet size and integrity may affect the final degree of applicability as it impacts fuel feed system and / or combustion (boiler) performance.

Of the two coal fines, the Ginger Hill fines are more desirable for use in a pelletized, composite fuel than the Pleasant Ridge fines. This is because the Ginger Hills ash has a lower slagging potential than the Pleasant Ridge ash based on its higher fusion temperatures, and a lower iron oxide content (Table 1). As a result it is recommended to use the Ginger Hill fines as the basis for any coal based pelletized fuel formulation rather than Pleasant Ridge.

The remaining fuels and feedstocks are shown to have a varying degree of applicability for a given combustor for a range of reasons. This includes reactivity (VM content) for the petroleum coke (as applied to PC, Stoker and Cyclone operation), corrosion (Cl content) for the mixed plastics and air dried (9% moisture) poultry manure, and slagging and fouling (Na & K content) for the switch grass, waxed cardboard and dewatered (10% moisture) sewage sludge, among other reasons. The as-received (85% moisture) sewage sludge and 60% moisture poultry manure were, for the purposes of this study, deemed not suitable for use as a fuel in any of the four considered combustor types based on their low reactivity / high moisture contents and resultant low Lower Heating Value (LHV). A dried, 10% moisture content sewage sludge was, however, added to the list of considered fuels owing to the economics for its use / disposal, which will be considered in more detail in Section 3.3, Economic Evaluation.

Of the non-coal fuels and feedstocks, the waxed cardboard and the petroleum coke offer the best promise based on their ASTM properties for use in a pelletized, composite fuel. The waxed cardboard is desirable based on its high volatile matter content and "acceptable" chlorine content (~0.20% / 0.2 lb/MMBtu), while the petroleum coke is desirable due to its high heating value, and low chlorine content. However, the high (9% by weight) sodium content in the waxed cardboard ash, and low (13%) volatile content in the petroleum coke place limits on their application due to fouling and reactivity / combustion efficiency, respectively, for all combustor types except a CFB (*Note, the high, 5.1% sulfur content of the petroleum coke will also likely be a concern for certain boilers both with regard to SO2 formation and capture, and corrosion potential*).

Of the remaining fuels, the switch grass and air dried poultry manure are undesirable for use except at extremely low mass fractions due to their previously noted high sodium and potassium contents, considered on a pound per million BTU basis (Table 1). Although better, the mixed plastics sample is similarly not desirable for use in significant mass fractions due to its high chlorine content (Table 1). In addition, the mixed plastic is presently considered undesirable for use in PC applications based on a potential problem with pasting in existing fuel handling and milling equipment.

In summary, the nine reviewed feedstocks, plus the dried sewage sludge, can be categorized as follows with regard to their overall applicability for the generation of a pelletized, composite solid fuel, based on a review of their physical and chemical characteristics.

Fuels that are **broadly recommended for use** include:

(1) Ginger Hills Coal Fines, and
(2) Pleasant Ridge Coal Fines.

Fuels that are **recommended for use primarily in CFB** applications include:

(3) Waxed Cardboard, and
(4) Petroleum Coke.

Feedstocks that are **recommended for use at low heat input levels** only include:

(5) Mixed Plastics,
(6) Switch Grass,
(7) 10% Moisture Sewage Sludge, and
(8) Poultry Manure 1 (Dried / 9% moisture).

Feedstocks that are **not recommended for use** at any level include:

(9) Poultry Manure 2 (61% moisture), and
(10) Sewage Sludge (as received / 85% moisture).

In all cases these recommendations are based on an assumed, "typical" boiler in each of the four combustor classes. Specific performance issues affecting a given fuel's applicability will, however, need to be determined on a case by case basis. It should also be noted that the applicability of a given fuel within each noted category is subject to the firing rate limitations for a particular combustor as given in Table 2.

As will be seen, economic considerations can change the balance with regard to which feeds are desirable for use based upon their potential for fuel costs savings. In the above analysis it was assumed that existing field equipment would be used without modification, thereby limiting the applicability of a given fuel to a given combustor type based upon the design requirements of typical, related field equipment. However, additional considerations, up to and including extensive modifications to the combustor and / or fuel handling equipment, could change the resultant maximum level at which a given fuel can be fired, thereby impacting its applicability, and resultant economics.

3.3 Economic Evaluation

The impetus for using any of the above mentioned fuels and feedstocks as a constituent of a composite fuel is largely economic, as in the absence of an economic benefit, none of the noted fuels would be without problem if fired in their as-received state. Therefore in selecting feedstocks for use in a composite, solid fuel, consideration needs to be given to the particular feedstock's cost in comparison to available alternatives in order to justify its use.

Table 3 provides an estimate of the economics associated with each of the fuels and feedstocks considered for use in the manufacture of a composite solid fuel. As shown, consideration was given to the as-received costs of the raw feed, including transportation, and the costs to prepare / pelletize the fuel in order to generate a total cost for the composite fuel on a dollars per ton and dollars per million BTU basis. Estimates of the delivered cost of a given fuel, and the cost per ton to pelletize were provided by CQ Inc.

Table 3: Economic Evaluation

Identification	Ginger Hill Coal Fines	Pleasant Ridge Coal Fines	Switch Grass	Petroleum Coke	Mixed Plastics	Waxed Cardboard	Sewage Sludge	*Sewage Sludge 10% Moisture*	Poultry Manure 1	Poultry Manure 2
$/ton fuel	$18.14	$17.37	$45.13	$18.46	($25)	$0.00	($28)	*($70)*	-	-
$/ton pelletize	$5.00	$5.00	$5.00	$5.00	$5.00	$5.00	$5.00	*$5.00*	-	-
$/ton, total	$23.14	$22.37	$50.13	$23.46	($20.00)	$5.00	($23.00)	*($65.35)*	-	-
$/MMBtu	$1.02	$1.03	$3.33	$0.83	($0.69)	$0.26	($10.30)	*($4.87)*	-	-
Typ. Coal, $/MMBtu	$1.20	$1.20	$1.20	$1.20	$1.20	$1.20	$1.20	$1.20	-	-
Delta, $/MMBtu	($0.18)	($0.17)	$2.13	($0.37)	($1.89)	($0.94)	($11.50)	($6.07)	-	-
Delta, %	-15%	-14%	178%	-31%	-158%	-78%	-958%	-505%	-	-

Taking the as-received cost of coal to be $1.20 per million BTU, Table 3 shows that most of the raw fuel feedstocks, including the coal fines, have favorable, comparative economics for use in pelletized, composite form. As shown, the two coal fines are estimated to cost ~$1/MMBtu, or ~17% less than the estimated, average delivered coal price. Following this is the petroleum coke which is estimated to cost $0.83/MMBtu pelletized, or ~30% less than a "typical" coal, based on a delivered cost of $0.65/MMBtu to the pelletizing plant. Next in line is the waxed cardboard which is estimated to cost $0.26/MMBtu, or ~80% less than the coal, based on the cost to pelletize the raw feed if it is provided at no cost to the pelletization plant fee / in the absence of a tipping fee.

The mixed plastics, on the other hand, are shown to result in a revenue for use of $0.69/MMBtu in pelletized form, having costs that are 157% below that of the estimated coal costs, based on an assumption of a $25/ton tipping fee for its disposal. Similarly, the wet (as-received) sewage sludge is shown to result in a revenue of $10.30/MMBtu, having a prepared cost 958% below that of the coal, based on an assumed tipping fee of $28/ton, and a high (85%) moisture content.

Unlike the other considered fuels, the switch grass, at $3.33 / MMBtu fired, is shown to cost more than double that of a typical coal. When coupled with inherently poor slagging and fouling properties, this reasonably eliminates switch grass from further consideration as part of a composite fuel feedstock, absent a tax or other not considered economic benefit.

It should be noted that at the time of this analysis, costs for use of the poultry manures were not available and are thus not included in the above table. However, given their high moisture, chlorine and potassium contents, neither of these fuels would be desirable for use alone, or in combination against the available alternatives.

As noted above, the most favorable economics exist for the mixed plastics and sewage sludge due to the receipt of a tipping fee associated with their disposal. As a result, there is sufficient impetus to manage their use to "acceptable levels" within a composite fuel such that their cost benefit can be used to reduce the overall, composite fuel cost, without adverse impact to overall combustor performance.

In order for the sewage sludge to be useful as a fuel (i.e. provide BTU's), and be managed within the feed system of an existing combustor, a dewatering / drying operation is desired to reduce the moisture content to an "acceptable" level. The analysis of such a fuel is given in Table 1, with resulting boiler impacts and economics being provided in Tables 2 and 3, respectively.

As shown in Table 3, a 10% moisture sewage sludge, generated through the use of a natural gas fired dryer operated at 50% efficiency with a cost for natural gas of $4.25 / MMBtu, would produce a fuel with a resultant cost of -$4.87 / MMBtu, based on the high, $28 / ton tipping fee expected for such a feed. Factored against a $1.20/MMBtu cost for a typical coal, this produces a net savings of $6.07/MMBtu, or 505%, which is still significantly better than any of the current alternatives, including the cost for drying.

4. Composite Fuel Recommendations

Pursuant to the results of the fuel applicability and economic analyses presented in Tables 1 through 3, three composite fuel blends were identified by US PPL and CQ Inc. personnel for further evaluation. These include: (1) an 85% petroleum coke / 15% mixed plastics composite, (2) an 80% Ginger Hill coal fines / 20% waxed cardboard composite, and (3) an 80% Ginger Hills fines / 20% dried sewage sludge composite fuel, reported on a weight basis. All three combinations represent fuels that were recommended based either on their ASTM determined properties (re. petroleum coke, waxed cardboard, and Ginger Hills fines), or their economics (re. mixed plastics and 10% moisture sewage sludge). The mixed plastics have the added benefit of acting as a binding agent for the formation of durable pellets in the petroleum coke based fuel.

Composite analyses, based on the mass weighted combination of the individual feedstocks, and resultant composite economics, are presented in Tables 4 and 5, respectively. An assessment of the performance of the resultant, composite fuels in each of the four combustor types will, however, need to be performed based upon analyses of the actual composite fuels, including ash fusion temperatures which can not be determined through mass weighted averages, and are thus not presented here.

Further work to examine the performance attributes of the three recommended fuel blends will be performed under Task 5 of the US DOE contract and reported on under a related title.

Table 4: Estimated Composite Fuel Analyses

Identification	85% Pet Coke	80% Ginger Hill	80% Ginger Hill
	15% Plastics	20% W. Crdbd.	20% *S. Sludge*
Chemical Analyses			
VM	24.9%	39.3%	34.5%
FC	68.3%	38.3%	38.1%
FC/VM	2.75	0.97	1.10
HHV, BTU/lb	14,235	10,990	10,411
LHV, BTU/lb	13,696	10,325	9,801
Moisture	6.1%	17.5%	17.6%
Hydrogen	4.9%	4.9%	4.3%
Carbon	78.6%	60.5%	57.4%
Sulfur	4.4%	1.1%	1.4%
Nitrogen	1.2%	0.8%	1.8%
Oxygen	4.1%	10.2%	7.8%
Ash	0.7%	5.0%	9.7%
Total	100.0%	100.0%	100.0%
O/N	3.4	12.4	4.3
lb N/MMBTU	0.83	0.75	1.73
lb S/MMBTU	3.09	0.97	1.30
lb Ash/MMBTU	0.5	4.5	9.4
Chlorine	0.17%	0.14%	0.13%
lb_Cl/MMBTU	0.12	0.13	0.14
Fluorine (ppm)	49	42	94
Ash Fusibility Temps. (°F)	Reducing Atm.	Reducing Atm.	Reducing Atm.
I.T.	-	-	-
S.T.	-	-	-
H.T.	-	-	-
F.T.	-	-	-
Diff. (F.T. - I.T.)	-	-	-
Ash Fusibility Temps. (°F)	Oxidizing Atm.	Oxidizing Atm.	Oxidizing Atm.
I.T.	-	-	-
S.T.	-	-	-
H.T.	-	-	-
F.T.	-	-	-
Diff. (F.T. - I.T.)	-	-	-
Ash Composition			
SiO2	21.7%	43.0%	44.5%
Al2O3	7.1%	20.0%	19.1%
Fe2O3	7.6%	13.0%	14.7%
TiO2	0.6%	3.3%	1.2%
CaO	9.8%	7.8%	6.4%
MgO	2.5%	1.3%	1.3%
Na2O	1.1%	2.1%	0.5%
K2O	1.1%	1.9%	1.9%
P2O5	0.5%	0.3%	3.2%
SO3	17.2%	7.4%	6.3%
Total	69.0%	100.2%	99.1%
Base / Acid Ratio	0.75	0.39	0.38
Fe2O3 / CaO	0.77	1.67	2.29
SiO2 / Al2O3	3.07	2.15	2.33
lb K+Na/MMBTU	0.01	0.18	0.23
Ash Behavior			
Ash-Type	-	-	-
Slagging Potential	-	-	-
Fouling Potential	-	-	-

Table 5: Estimated Composite Fuel Economics

Identification	85% Pet Coke	80% Ginger Hill	80% Ginger Hill
	15% Plastics	20% W. Crdbd.	20% *S. Sludge*
$/ton fuel	$11.94	$14.51	$0.44
$/ton pelletize	$5.00	$5.00	$5.00
$/ton, total	$16.94	$19.51	$5.44
$/MMBtu	$0.60	$0.87	($0.16)
Typ. Coal, $/MMBtu	$1.20	$1.20	$1.20
Delta, $/MMBtu	($0.60)	($0.33)	($1.36)
Delta, %	-50%	-28%	-113%

5. Appendix

Standard Laboratory Sample Analysis Sheets

GOULD ENERGY DIVISION
P. O. BOX 214
CRESSON, PA 16630
(814) 886-7400

STANDARD LABORATORIES, INC.

DATE: 9-28-1999
SAMPLE NO. 595772

Q., INC.
50 QUALITY CENTER ROAD
OMER CITY, PA 15748

SAMPLE ID: GINGER HILL SYNFUELS TEST
99072101

ATING CO.:
LED BY: CUSTOMER PROVIDED

TION:

SAMPLED: 7/21/99 DATE RECEIVED: 8/10/99

HER:
S WEIGHT:

R ID: SCREEN BOWL PRODUCT STANDARD SAMPLE # 593089 WET COAL FINES (2
8M X 0) PROJECT 99E0331 T1.2, BIOMASS FEEDBACK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

	ASTM METHOD	AS RECEIVED	DRY BASIS
ISTURE	D2961 D3302 D3173	19.54%	XXX
LATILE MATTER		29.21%	36.31%
XED CARBON	D3172	45.67%	56.76%
H	D3174	5.58%	6.93%
LFUR	D4239 METHOD 3.3	1.29%	1.60%
RBON	D3178	63.11%	78.44%
DROGEN	D3178	4.15%	5.16%
TROGEN	D3179	1.00%	1.25%
YGEN	D3176	5.33%	6.62%
J/LB	D2015 D1989	11335	14088
F BTU/LB			15137
S OF SO2 PER MILLION BTU			2.27
S OF SULFUR PER MILLION BTU		1.138	
LORINE	D4208	.12%	.15%
UORINE	D3761	52.54 PPM	65.30 PPM
RCENT SOLIDS			80.46%

ASH FUSION TEMPERATURE(S)

D1857	REDUCING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	2075
SOFTENING TEMPERATURE	2125
HEMISPHERICAL TEMPERATURE	2180
FLUID TEMPERATURE	2280

D1857	OXIDIZING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	2345
SOFTENING TEMPERATURE	2370
HEMISPHERICAL TEMPERATURE	2400

APPROVED BY ____________

APPROVED BY ____________

BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.

DATE: 9-23-1999
SAMPLE NO. 595772

CERTIFICATE OF ANALYSIS (CONT.)

	AS RECEIVED	DRY BASIS
FLUID TEMPERATURE		2430

ASH MINERAL COMPOSITION
D2795 D3682

LICON DIOXIDE	47.08 %
UMINIUM OXIDE	20.67 %
RRIC OXIDE	15.07 %
TANIUM DIOXIDE	1.05 %
OSPHORUS PENTOXIDE	.11 %
LCIUM OXIDE	5.78 %
GNESIUM OXIDE	1.12 %
DIUM OXIDE	.41 %
TASSIUM OXIDE	2.04 %
LFUR TRIOXIDE	7.35 %

APPROVED BY

APPROVED BY

78 Analytical Material Subjected To Accelerated Drying Procedure

BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.

CQ, INC.
160 QUALITY CENTER
HOMER CITY, PA 15748

DATE 9-23-99
SAMPLE NO: 595772

DATE SAMPLED: 7-21-99

DATE RECEIVED: 8-10-99

SAMPLE ID: GINGER HILL SYNFUELS TEST 99072101

OTHER ID: SCREEN BOWL PRODUCT STANDARD SAMPLE #593089 WET COAL FINES (28M X 0) PROJECT 99E0331 T1.2, BIOMASS FEEDBACK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

TOTAL METALS		METHOD NUMBER	PAGE NUMBER
Arsenic	7.42 Mg/Kg (ppm)	EPA SW-846	Method 8.51
Cadmium	< .89 Mg/Kg	EPA SW-846	Method 8.53
Chromium	14.87 Mg/Kg	EPA SW-846	Method 8.54
Cobalt	22.66 Mg/Kg	EPA 600/4-79-020	Method 219.1
Copper	8.85 Mg/Kg	EPA 600/4-79-020	Method 220.1
Lead	11.15 Mg/Kg	EPA SW-846	Method 8.56
Manganese	21.24 Mg/Kg	EPA 600/4-79-020	Method 243.1
Mercury	150.27 ug/Kg (ppb)	EPA SW-846	Method 8.57
Nickel	19.29 Mg/Kg (ppm)	EPA SW-846	Method 8.58
Selenium	1.53 Mg/Kg	EPA SW-846	Method 8.59
Zinc	26.37 Mg/Kg	EPA 600/4-79-020	Method 289.1
Beryllium	< .71 Mg/Kg	EPA 600/4-79-020	Method 210.1

APPROVED BY [signature]

STANDARD LABORATORIES, INC.

CO, INC.
160 QUALITY CENTER
HOMER CITY, PA 15748

DATE 9-23-99
SAMPLE NO: 595772

DATE SAMPLED: 7-21-99

DATE RECEIVED: 8-10-99

SAMPLE ID: GINGER HILL SYNFUELS TEST 99072101

OTHER ID: SCREEN BOWL PRODUCT STANDARD SAMPLE #593089 WET COAL FINES (28M X 0) PROJECT 99E0331 T1.2, BIOMASS FEEDBACK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

TCLP EXTRACTION				METHOD NUMBER	PAGE NUMBER
Arsenic	34.33	Ug/L	(ppb)	EPA SW-846	Method 8.51
Cadmium	< 0.05	Mg/L	(ppm)	EPA SW-846	Method 8.53
Chromium	< 0.10	Mg/L		EPA SW-846	Method 8.54
Cobalt	< 0.25	Mg/L		EPA 600/4-79-020	Method 219.1
Copper	0.05	Mg/L		EPA 600/4-79-020	Method 220.1
Lead	0.16	Mg/L		EPA SW-846	Method 8.56
Manganese	2.13	Mg/L		EPA 600/4-79-020	Method 243.1
Mercury	< 0.50	Ug/L	(ppb)	EPA SW-846	Method 8.57
Nickel	.19	Mg/L	(ppm)	EPA SW-846	Method 8.58
Selenium	91.84	Ug/L	(ppb)	EPA SW-846	Method 8.59
Zinc	.70	Mg/L	(ppm)	EPA 600/4-79-020	Method 289.1

APPROVED BY [signature]

GOULD ENERGY DIVISION
P. O. BOX 214
CRESSON, PA 16630
STANDARD LABORATORIES, INC.

DATE : 7-23-1999
MASTER SAMPLE NO. 593089

, INC.
QUALITY CENTER ROAD
:R CITY, PA 15748

SAMPLE ID: SCREEN BOWL CLEAN COAL COKE WE
T FINES ID 99072101

:NG CO. : JOB 97E0313 T4

DATE SAMPLED: 7/21/99

) BY: CUSTOMER PROVIDED
VEIGHT: 9.02

DATE RECEIVED: 7/22/99

ID: PROJECT GINGER HILL SYNFUELS STARTUP WET SCREEN

CERTIFICATE OF ANALYSIS

ION	WT%	MOISTURE	ASH	SULFUR	BTU	LBS SO2 PER MBTU	MAF BTU
	.52	1.52	6.90	1.40	14084	1.99	15128
150M	68.47	1.11	4.53	1.31	14467	1.81	15154
270M	14.20	1.57	4.68	1.51	14425	2.09	15132
0	16.81	1.22	18.59	3.19	12005	5.31	14745

CUMULATIVE RETAINED - DOWN

ION	WT%	ASH	SULFUR	BTU	LBS SO2 PER MBTU
	.52	6.90	1.40	14084	1.99
150M	68.99	4.55	1.32	14465	1.82
270M	83.19	4.57	1.35	14458	1.87
0	100.00	6.93	1.66	14045	2.36

CUMULATIVE RETAINED - UP

ION	WT%	ASH	SULFUR	BTU	LBS SO2 PER MBTU
	100.00	6.93	1.66	14045	2.36
150M	99.48	6.93	1.66	14045	2.36
270M	31.01	12.22	2.42	13113	3.69
0	16.81	18.59	3.19	12005	5.31

'ICAL RESULTS ARE STATED ON A DRY BASIS

1

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GOULD ENERGY DIVISION
P.O. BOX 214
CRESSON, PA 16630
(814) 886-7400
STANDARD LABORATORIES, INC.

DATE: 9-16-1999
SAMPLE NO. 599552

.Q., INC.
60 QUALITY CENTER ROAD
OMER CITY, PA 15748

SAMPLE ID: PLEASANT RIDGE SCREEN BOWL CLEAN COAL

ATING CO.:
LED BY: CUSTOMER PROVIDED
TION:
SAMPLED:
DATE RECEIVED: 8/28/99
HER:
S. WEIGHT:
R ID:

CERTIFICATE OF ANALYSIS

	ASTM METHOD	AS RECEIVED	DRY BASIS
ISTURE	D2961 D3302 D3173	1.99% 19.4%	XXX
LATILE MATTER		39.97%	40.78%
XED CARBON	D3172	49.28%	50.29%
H	D3174	8.76%	8.93%
LFUR	D4239 METHOD 3.3	4.08%	4.16%
RBON	D3178	71.31%	72.76%
DROGEN	D3178	4.96%	5.06%
TROGEN	D3179	1.13%	1.16%
YGEN	D3176	7.77%	7.92%
U/LB	D2015 D1989	13226	13495
F BTU/LB			14818
S OF SO2 PER MILLION BTU			6.16
S OF SULFUR PER MILLION BTU		3.085	
LORINE	D4208	.07%	.08%
UORINE	D3761	72.31 PPM	73.78 PPM

ASH FUSION TEMPERATURE(S)

D1857	REDUCING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	1940
SOFTENING TEMPERATURE	1990
HEMISPHERICAL TEMPERATURE	2035
FLUID TEMPERATURE	2075

D1857	OXIDIZING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	2375
SOFTENING TEMPERATURE	2405
HEMISPHERICAL TEMPERATURE	2420
FLUID TEMPERATURE	2450

APPROVED BY ____________

APPROVED BY ____________

BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.

DATE: 9-16-1999
SAMPLE NO. 399552

CERTIFICATE OF ANALYSIS (CONT.)

	AS RECEIVED	DRY BASIS
ASH MINERAL COMPOSITION D2795 D3682		
LICON DIOXIDE		38.40 %
UMINIUM OXIDE		15.02 %
RRIC OXIDE		25.75 %
TANIUM DIOXIDE		1.63 %
OSPHORUS PENTOXIDE		.24 %
LCIUM OXIDE		5.11 %
GNESIUM OXIDE		.83 %
DIUM OXIDE		.58 %
TASSIUM OXIDE		1.29 %
LFUR TRIOXIDE		8.71 %

APPROVED BY ________

APPROVED BY ________

BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.

CQ, INC.
160 QUALITY CENTER
HOMER CITY, PA 15748

DATE 9-24-99
SAMPLE NO: 599552

DATE SAMPLED:

DATE RECEIVED: 8-28-99

SAMPLE ID: GINGER HILL SYNFUELS SCREEN BOWL PRODUCT
WET COAL FINES (28M X 0) PROJECT 99E0331 T1.2
BIOMASS FEEDSTOCK CHARACTERIZATION

GROSS WEIGHT:

OTHER ID: NOTE: INSUFFICIENT MATERIAL TO RUN TCLP ANALYSIS
ON THIS SAMPLE

CERTIFICATE OF ANALYSIS

TOTAL METALS		METHOD NUMBER	PAGE NUMBER
Arsenic	6.88 Mg/Kg (ppm)	EPA SW-846	Method 8.51
Cadmium	1.12 Mg/Kg	EPA SW-846	Method 8.53
Chromium	15.40 Mg/Kg	EPA SW-846	Method 8.54
Cobalt	21.43 Mg/Kg	EPA 600/4-79-020	Method 219.1
Copper	9.15 Mg/Kg	EPA 600/4-79-020	Method 220.1
Lead	9.38 Mg/Kg	EPA SW-846	Method 8.56
Manganese	48.45 Mg/Kg	EPA 600/4-79-020	Method 243.1
Mercury	73.77 ug/Kg (ppb)	EPA SW-846	Method 8.57
Nickel	15.63 Mg/Kg (ppm)	EPA SW-846	Method 8.58
Selenium	2.81 Mg/Kg	EPA SW-846	Method 8.59
Zinc	27.01 Mg/Kg	EPA 600/4-79-020	Method 289.1
Beryllium	2.01 Mg/Kg	EPA 600/4-79-020	Method 210.1

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STANDARD LABORATORIES, INC.

Mailing Address:
P. O. Box 2019
Wheeling, WV 26003-0219
(304) 547-9094
FAX (304) 547-9097

Shipping Address:
RD 2, Box 227A
Battle Run Road
Triadelphia, WV 26059-9609

SIZE CONSIST AND FRACTIONAL ANALYSIS
SAMPLES COLLECTED: AUGUST 13, 1999
PRS - SNAPSHOT
RUN NUMBER: 99081301
PLEASANT RIDGE - SYNFUELS
CQ INC.

Size Consist	Screen Bowl Clean Coal							
	Incremental Analysis				Cumulative Analysis			
	Distribution %	Ash % (D/B)	Sulfur % (D/B)	BTU/lb. (D/B)	Distribution %	Ash % (D/B)	Sulfur % (D/B)	BTU/lb. (D/B)
Plus 150 Mesh	3.34	5.79	3.46	13,956	3.34	5.79	3.46	13,956
150 x 270 Mesh	49.10	5.60	3.44	13,956	52.44	5.61	3.44	13,956
270 x 400 Mesh	28.25	6.17	3.64	13,861	80.69	5.81	3.51	13,923
Minus 400 Mesh	19.31	21.41	6.02	11,317	100.00	8.82	4.00	13,420

Luther E. Hendricks, Jr.

9-2-99
Date

GOULD ENERGY DIVISION
P.O. BOX 214
CRESSON, PA 16630
(814) 886-7400
STANDARD LABORATORIES, INC.

DATE: 9-15-1999
SAMPLE NO. 596791

C. Q., INC.
160 QUALITY CENTER ROAD
HOMER CITY, PA 15748

SAMPLE ID: USDA-ARS (PENN STATE U) SWITCH GRASS #99081103

PERATING CO.:
MPLED BY: CUSTOMER PROVIDED
ME:
OCATION:

TE SAMPLED: 8/9/99 DATE RECEIVED: 8/12/99
ATHER:
OSS WEIGHT: 2.62 KG

THER ID: CAVE-IN-ROCK VARIETY HARVESTED GREEN (OVEN DRIED @50C) PROJECT 99E0331 T1.2, BIOMASS FEED STOCK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

	ASTM METHOD	AS RECEIVED	DRY BASIS
MOISTURE	D2961 D3302 D3173	7.95%	XXX
VOLATILE MATTER		80.22%	87.15%
FIXED CARBON	D3172	7.73%	8.40%
ASH	D3174	4.10%	4.45%
SULFUR	D4239 METHOD 3.3	.12%	.13%
CARBON	D3178	43.81%	47.60%
HYDROGEN	D3178	5.56%	6.04%
NITROGEN	D3179	1.36%	1.48%
OXYGEN	D3176	37.10%	40.31%
BTU/LB	D2015 D1989	7521	8171
MAF BTU/LB			8552
LBS OF SO2 PER MILLION BTU			.32
LBS OF SULFUR PER MILLION BTU		.160	
CHLORINE	D4208	.22%	.23%
FLUORINE	D3761	26.77 PPM	29.08 PPM

ASH FUSION TEMPERATURE(S)

D1857	REDUCING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	1960
SOFTENING TEMPERATURE	2000
HEMISPHERICAL TEMPERATURE	2010
FLUID TEMPERATURE	2030

D1857	OXIDIZING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	2040
SOFTENING TEMPERATURE	2080
HEMISPHERICAL TEMPERATURE	2100
FLUID TEMPERATURE	2120

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BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.

DATE: 9-15-1999
SAMPLE NO. 596791

CERTIFICATE OF ANALYSIS (CONT.)

	AS RECEIVED	DRY BASIS
ASH MINERAL COMPOSITION D2795 D3682		
SILICON DIOXIDE		35.39 %
ALUMINIUM OXIDE		5.85 %
FERRIC OXIDE		4.10 %
TITANIUM DIOXIDE		.34 %
PHOSPHORUS PENTOXIDE		8.09 %
CALCIUM OXIDE		12.18 %
MAGNESIUM OXIDE		9.78 %
SODIUM OXIDE		2.42 %
POTASSIUM OXIDE		15.06 %
SULFUR TRIOXIDE		4.96 %

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APPROVED BY ______________

BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.

CQ, INC.
160 QUALITY CENTER
HOMER CITY, PA 15748

DATE 9-23-99
SAMPLE NO: 596791

DATE SAMPLED: 8-9-99

DATE RECEIVED: 8-12-99

SAMPLE ID: USDA-ARS (PENN STATE U) SWITCH GRASS #99081103

GROSS WEIGHT: 2.62 KG

OTHER ID: CAVE-IN-ROCK VARIETY HARVESTED GREEN (OVEN FRIED @50C)
PROJECT 99E0331 T1.2, BIOMASS FEED STOCK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

TOTAL METALS		METHOD NUMBER	PAGE NUMBER
Arsenic	1.33 Mg/Kg (ppm)	EPA SW-846	Method 8.51
Cadmium	< .56 Mg/Kg	EPA SW-846	Method 8.53
Chromium	1.45 Mg/Kg	EPA SW-846	Method 8.54
Cobalt	< 2.78 Mg/Kg	EPA 600/4-79-020	Method 219.1
Copper	10.46 Mg/Kg	EPA 600/4-79-020	Method 220.1
Lead	1.89 Mg/Kg	EPA SW-846	Method 8.56
Manganese	75.65 Mg/Kg	EPA 600/4-79-020	Method 243.1
Mercury	< 0.50 ug/Kg (ppb)	EPA SW-846	Method 8.57
Nickel	3.89 Mg/Kg (ppm)	EPA SW-846	Method 8.58
Selenium	.50 Mg/Kg	EPA SW-846	Method 8.59
Zinc	23.59 Mg/Kg	EPA 600/4-79-020	Method 289.1
Beryllium	< .45 Mg/Kg	EPA 600/4-79-020	Method 210.1

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STANDARD LABORATORIES, INC.

CQ, INC.
160 QUALITY CENTER
HOMER CITY, PA 15748

DATE 9-23-99
SAMPLE NO: 596791

DATE SAMPLED: 8-9-99

DATE RECEIVED: 8-12-99

SAMPLE ID: USDA-ARS (PENN STATE U) SWITCH GRASS #99081103

GROSS WEIGHT: 2.62 KG

OTHER ID: CAVE-IN-ROCK VARIETY HARVESTED GREEN (OVEN FRIED @50C)
PROJECT 99E0331 T1.2,BIOMASS FEED STOCK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

TCLP EXTRACTION				METHOD NUMBER	PAGE NUMBER
Arsenic	3.96	Ug/L	(ppb)	EPA SW-846	Method 8.51
Cadmium	< 0.05	Mg/L	(ppm)	EPA SW-846	Method 8.53
Chromium	.30	Mg/L		EPA SW-846	Method 8.54
Cobalt	< 0.25	Mg/L		EPA 600/4-79-020	Method 219.1
Copper	< 0.04	Mg/L		EPA 600/4-79-020	Method 220.1
Lead	< 0.10	Mg/L		EPA SW-846	Method 8.56
Manganese	< 0.06	Mg/L		EPA 600/4-79-020	Method 243.1
Mercury	< 0.50	Ug/L	(ppb)	EPA SW-846	Method 8.57
Nickel	.11	Mg/L	(ppm)	EPA SW-846	Method 8.58
Selenium	45.66	Ug/L	(ppb)	EPA SW-846	Method 8.59
Zinc	.12	Mg/L	(ppm)	EPA 600/4-79-020	Method 289.1
Beryllium	< 0.04	Mg/L		EPA 600/4-79-020	Method 210.1
Potassium	4800.0	Mg/L		EPA 600/4-79-020	Method 258.1

Extraction Fluid Used #2
Sample Weight 15 grams

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GOULD ENERGY DIVISION
P. O. BOX 214
CRESSON, PA 16630
(814) 886-7400
STANDARD LABORATORIES, INC.

DATE: 9-16-1999
SAMPLE NO. 597029

Q., INC.
50 QUALITY CENTER ROAD
OMER CITY, PA 15748

SAMPLE ID: COLONA TERMINAL SERVICES
PETROLUEM COKE

ATING CO.: TEST #99081102
LED BY: CUSTOMER PROVIDED

TION:

SAMPLED: 8/9/99   DATE RECEIVED: 8/13/99
HER:
S WEIGHT: 4772.9
R ID: PROJECT 99E0331 T1.2, BIOMASS FEEDSTOCK CHARACTERIZATION FUEL GRADE PETROLEUM COKE

CERTIFICATE OF ANALYSIS

	ASTM METHOD	AS RECEIVED	DRY BASIS
ISTURE	D2961 D3302 D3173	7.16%	XXX
LATILE MATTER		12.97%	13.97%
XED CARBON	D3172	79.43%	85.56%
H	D3174	.44%	.47%
LFUR	D4239 METHOD 3.3	5.12%	5.51%
RBON	D3178	80.52%	86.73%
DROGEN	D3178	3.81%	4.10%
TROGEN	D3179	1.38%	1.49%
YGEN	D3176	1.57%	1.69%
U/LB	D2015 D1989	14201	15296
F BTU/LB			15368
S OF SO2 PER MILLION BTU			7.20
S OF SULFUR PER MILLION BTU		3.605	
LORINE	D4208	.03%	.04%
UORINE	D3761	58.07 PPM	62.55 PPM
RCENT SOLIDS			92.84%

ASH FUSION TEMPERATURE(S)

D1857	REDUCING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	2210
SOFTENING TEMPERATURE	2240
HEMISPHERICAL TEMPERATURE	2270
FLUID TEMPERATURE	2295

D1857	OXIDIZING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	2050
SOFTENING TEMPERATURE	2090
HEMISPHERICAL TEMPERATURE	2110

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APPROVED BY ____________

BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.

DATE: 9-16-1999
SAMPLE NO. 597029

CERTIFICATE OF ANALYSIS (CONT.)

	AS RECEIVED	DRY BASIS
FLUID TEMPERATURE	2130	

ASH MINERAL COMPOSITION
D2795 D3682

ILICON DIOXIDE	25.38 %
LUMINIUM OXIDE	8.20 %
FERRIC OXIDE	8.87 %
TITANIUM DIOXIDE	.60 %
HOSPHORUS PENTOXIDE	.50 %
ALCIUM OXIDE	11.29 %
MAGNESIUM OXIDE	2.87 %
SODIUM OXIDE	1.23 %
OTASSIUM OXIDE	1.31 %
ULFUR TRIOXIDE	20.12 %

APPROVED BY ______

APPROVED BY ______

BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.

CQ, INC.
160 QUALITY CENTER
HOMER CITY, PA 15748

DATE 9-23-99
SAMPLE NO: 597029

DATE SAMPLED: 8-9-99

DATE RECEIVED: 8-13-99

SAMPLE ID: COLONA TERMINAL SERVICES PETROLUEM COKE
OPERATING CO: TEST #99081102

GROSS WEIGHT: 4772.9

OTHER ID: PROJECT 99E0331 T1.2, BIOMASS FEEDSTOCK CHARACTERIZATION
FUEL GRADE PETROLEUM COKE

CERTIFICATE OF ANALYSIS

TOTAL METALS		METHOD NUMBER	PAGE NUMBER
Arsenic	1.72 Mg/Kg (ppm)	EPA SW-846	Method 8.51
Cadmium	0.06 Mg/Kg	EPA SW-846	Method 8.53
Chromium	2.22 Mg/Kg	EPA SW-846	Method 8.54
Cobalt	2.43 Mg/Kg	EPA 600/4-79-020	Method 219.1
Copper	0.67 Mg/Kg	EPA 600/4-79-020	Method 220.1
Lead	0.89 Mg/Kg	EPA SW-846	Method 8.56
Manganese	7.94 Mg/Kg	EPA 600/4-79-020	Method 243.1
Mercury	< 0.50 ug/Kg (ppb)	EPA SW-846	Method 8.57
Nickel	230.3 Mg/Kg (ppm)	EPA SW-846	Method 8.58
Selenium	1.72 Mg/Kg	EPA SW-846	Method 8.59
Zinc	7.40 Mg/Kg	EPA 600/4-79-020	Method 289.1
Beryllium	0.05 Mg/Kg	EPA 600/4-79-020	Method 210.1

APPROVED BY [signature]

STANDARD LABORATORIES, INC.

CQ, INC.
160 QUALITY CENTER
HOMER CITY, PA 15748

DATE 9-23-99
SAMPLE NO: 597029

DATE SAMPLED: 8-9-99

DATE RECEIVED: 8-13-99

SAMPLE ID: COLONA TERMINAL SERVICES PETROLUEM COKE
OPERATING CO: TEST #99081102

GROSS WEIGHT: 4772.9

OTHER ID: PROJECT 99E0331 T1.2, BIOMASS FEEDSTOCK CHARACTERIZATION
FUEL GRADE PETROLEUM COKE

CERTIFICATE OF ANALYSIS

TCLP EXTRACTION				METHOD NUMBER	PAGE NUMBER
Arsenic	61.12	Ug/L	(ppb)	EPA SW-846	Method 8.51
Cadmium	< 0.05	Mg/L	(ppm)	EPA SW-846	Method 8.53
Chromium	< 0.10	Mg/L		EPA SW-846	Method 8.54
Cobalt	1.13	Mg/L		EPA 600/4-79-020	Method 219.1
Copper	.13	Mg/L		EPA 600/4-79-020	Method 220.1
Lead	.33	Mg/L		EPA SW-846	Method 8.56
Manganese	3.8	Mg/L		EPA 600/4-79-020	Method 243.1
Mercury	< 0.50	Ug/L	(ppb)	EPA SW-846	Method 8.57
Nickel	7.7	Mg/L	(ppm)	EPA SW-846	Method 8.58
Selenium	162.7	Ug/L	(ppb)	EPA SW-846	Method 8.59
Zinc	5.2	Mg/L	(ppm)	EPA 600/4-79-020	Method 289.1
Beryllium	< 0.04	Mg/L		EPA 600/4-79-020	Method 210.1

Extraction Fluid Used #1
Sample Weight 10 grams

APPROVED BY [signature]

GOULD ENERGY DIVISION
P. O. BOX 214
CRESSON, PA 16630
(814) 886-7400

STANDARD LABORATORIES, INC.

DATE: 9-17-1999
SAMPLE NO. 597030

G., INC.
50 QUALITY CENTER ROAD
OMER CITY, PA 15748

SAMPLE ID: CONIGLIARO INDUSTRIES, INC.
MIXED PLASTICS

ATING CO.: TEST 99081101
LED BY: CUSTOMER PROVIDED

TION:

SAMPLED: 7/30/99 DATE RECEIVED: 8/12/99
HER:
G WEIGHT: 3458.4

R ID: COMINGLED MIXED PLASTICS AND WASTE (HDPE&LDPE) PROJECT 99E0331
T1.2/ BIOMASS FEEDSTOCK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

	ASTM METHOD	AS RECEIVED	DRY BASIS
ISTURE	D2961 D3302 D3173	.24%	XXX
LATILE MATTER		92.17%	92.39%
XED CARBON	D3172	5.30%	5.31%
H	D3174	2.29%	2.30%
LFUR	D4239 METHOD 3.3	.33%	.33%
RBON	D3178	67.84%	68.00%
DROGEN	D3178	10.79%	10.82%
TROGEN	D3179	.10%	.10%
YGEN	D3176	18.41%	18.45%
J/LB	D2015 D1989	14425	14459
F BTU/LB			14799
S OF SO2 PER MILLION BTU			.46
S OF SULFUR PER MILLION BTU		.229	
LORINE	D4208	.98%	.98%
RCENT SOLIDS			99.76%

ASH FUSION TEMPERATURE(S)

D1857	REDUCING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	2560
SOFTENING TEMPERATURE	2565
HEMISPHERICAL TEMPERATURE	2570
FLUID TEMPERATURE	2575

D1857	OXIDIZING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	2500
SOFTENING TEMPERATURE	2510
HEMISPHERICAL TEMPERATURE	2515
FLUID TEMPERATURE	2525

ORINE D3761 NONE DETECTED

APPROVED BY [signature]

APPROVED BY [signature]

BLACK SEAL ANALYSIS

DATE: 9-17-1999
SAMPLE NO. 597030

CERTIFICATE OF ANALYSIS (CONT.)

AS RECEIVED DRY BASIS

ASH MINERAL COMPOSITION
D2795 D3682

LICON DIOXIDE	.83 %
UMINIUM OXIDE	.64 %
RRIC OXIDE	.19 %
TANIUM DIOXIDE	.33 %
OSPHORUS PENTOXIDE	.17 %
LCIUM OXIDE	1.33 %
GNESIUM OXIDE	.17 %
DIUM OXIDE	.16 %
TASSIUM OXIDE	.03 %
LFUR TRIOXIDE	.58 %

APPROVED BY [signature]

APPROVED BY [signature]

BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.

CQ, INC.
160 QUALITY CENTER
HOMER CITY, PA 15748

DATE 9-23-99
SAMPLE NO: 597030

DATE SAMPLED: 7-30-99
DATE RECEIVED: 8-12-99
OPERATING CO: TEST 99081101

SAMPLE ID: CONIGLIARO INDUSTRIES, INC. MIXED PLASTICS

GROSS WEIGHT: 3458.4

OTHER ID: COMINGLED MIXED PLASTICS AND WASTE (HDPE&LDPE)
PROJECT 99E0331 T1.2,BIOMASS FEED STOCK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

TOTAL METALS		METHOD NUMBER	PAGE NUMBER
Arsenic	4.06 Mg/Kg (ppm)	EPA SW-846	Method 8.51
Cadmium	.29 Mg/Kg	EPA SW-846	Method 8.53
Chromium	2.24 Mg/Kg	EPA SW-846	Method 8.54
Cobalt	2.59 Mg/Kg	EPA 600/4-79-020	Method 219.1
Copper	7.59 Mg/Kg	EPA 600/4-79-020	Method 220.1
Lead	2.53 Mg/Kg	EPA SW-846	Method 8.56
Manganese	3.05 Mg/Kg	EPA 600/4-79-020	Method 243.1
Mercury	< 0.50 ug/Kg (ppb)	EPA SW-846	Method 8.57
Nickel	16.1 Mg/Kg (ppm)	EPA SW-846	Method 8.58
Selenium	4.45 Mg/Kg	EPA SW-846	Method 8.59
Zinc	59.8 Mg/Kg	EPA 600/4-79-020	Method 289.1
Beryllium	.23 Mg/Kg	EPA 600/4-79-020	Method 210.1

APPROVED BY [signature]

STANDARD LABORATORIES, INC.

CQ, INC.
160 QUALITY CENTER
HOMER CITY, PA 15748

DATE 9-23-99
SAMPLE NO: 597030

DATE SAMPLED: 7-30-99
DATE RECEIVED: 8-12-99
OPERATING CO: TEST 99081101

SAMPLE ID: CONIGLIARO INDUSTRIES, INC. MIXED PLASTICS

GROSS WEIGHT: 3458.4

OTHER ID: COMINGLED MIXED PLASTICS AND WASTE (HDPE&LDPE)
PROJECT 99E0331 T1.2,BIOMASS FEED STOCK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

TCLP EXTRACTION				METHOD NUMBER	PAGE NUMBER
Arsenic	5.80	Ug/L	(ppb)	EPA SW-846	Method 8.51
Cadmium	< 0.05	Mg/L	(ppm)	EPA SW-846	Method 8.53
Chromium	< 0.10	Mg/L		EPA SW-846	Method 8.54
Cobalt	.70	Mg/L		EPA 600/4-79-020	Method 219.1
Copper	.11	Mg/L		EPA 600/4-79-020	Method 220.1
Lead	.81	Mg/L		EPA SW-846	Method 8.56
Manganese	.10	Mg/L		EPA 600/4-79-020	Method 243.1
Mercury	< 0.50	Ug/L	(ppb)	EPA SW-846	Method 8.57
Nickel	.43	Mg/L	(ppm)	EPA SW-846	Method 8.58
Selenium	787.5	Ug/L	(ppb)	EPA SW-846	Method 8.59
Zinc	.37	Mg/L	(ppm)	EPA 600/4-79-020	Method 289.1
Beryllium	< 0.04	Mg/L		EPA 600/4-79-020	Method 210.1

Extraction Fluid Used #1
Sample Weight 20 grams

APPROVED BY [signature]

GOULD ENERGY DIVISION
P. O. BOX 214
CRESSON, PA 16630
(814) 886-7400
STANDARD LABORATORIES, INC.

DATE: 9-17-1999
SAMPLE NO. 597031

Q., INC.
50 QUALITY CENTER ROAD
OMER CITY, PA 15748

SAMPLE ID: GIANT EAGLE WAXED CARDBOARD

ATING CO.: TEST 99081104
LED BY: CUSTOMER PROVIDED

TION:

SAMPLED: 8/9/99 DATE RECEIVED: 8/12/99
HER:
S WEIGHT: 2438.8

R ID: WAX IMPREGNATED CARDBOARD PRODUCE BOXES PROJECT 99E0331 T1.2.
BIOMASS FEEDSTOCK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

	ASTM METHOD	AS RECEIVED	DRY BASIS
ISTURE	D2961 D3302 D3173	9.26%	XXX
LATILE MATTER		79.58%	87.70%
XED CARBON	D3172	8.70%	9.59%
H	D3174	2.46%	2.71%
LFUR	D4239 METHOD 3.3	.19%	.21%
RBON	D3178	50.19%	55.31%
DROGEN	D3178	7.91%	8.72%
TROGEN	D3179	.13%	.14%
YGEN	D3176	29.86%	32.91%
U/LB	D2015 D1989	9610	10591
F BTU/LB			10887
S OF SO2 PER MILLION BTU			.40
S OF SULFUR PER MILLION BTU		.198	
LORINE	D4208	.20%	.22%
RCENT SOLIDS			90.74%

ASH FUSION TEMPERATURE(S)

D1857	REDUCING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	2100
SOFTENING TEMPERATURE	2140
HEMISPHERICAL TEMPERATURE	2155
FLUID TEMPERATURE	2165

D1857	OXIDIZING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	2200
SOFTENING TEMPERATURE	2255
HEMISPHERICAL TEMPERATURE	2290
FLUID TEMPERATURE	2320

ORINE D3761 NONE DETECTED

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BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.

DATE: 9-17-1999
SAMPLE NO. 597031

CERTIFICATE OF ANALYSIS (CONT.)

	AS RECEIVED	DRY BASIS

ASH MINERAL COMPOSITION
D2795 D3682

LICON DIOXIDE		26.87 %
UMINIUM OXIDE		17.44 %
RRIC OXIDE		4.89 %
TANIUM DIOXIDE		12.50 %
OSPHORUS PENTOXIDE		1.06 %
LCIUM OXIDE		15.88 %
GNESIUM OXIDE		1.86 %
DIUM OXIDE		8.79 %
TASSIUM OXIDE		1.47 %
LFUR TRIOXIDE		7.56 %

APPROVED BY [signature]

APPROVED BY [signature]

BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.

CQ, INC.
160 QUALITY CENTER
HOMER CITY, PA 15748

DATE 9-24-99
SAMPLE NO: 597031

DATE SAMPLED: 8-9-99
DATE RECEIVED: 8-12-99
OPERATING CO: TEST 99081104

SAMPLE ID: GIANT EAGLE WAXED CARDBOARD

GROSS WEIGHT: 2438.8

OTHER ID: WAX IMPREGNATED CARDBOARD PRODUCE BOXES PROJECT
99E0331 T1.2, BIOMASS FEEDSTOCK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

TOTAL METALS		METHOD NUMBER	PAGE NUMBER
Arsenic	1.72 Mg/Kg (ppm)	EPA SW-846	Method 8.51
Cadmium	0.34 Mg/Kg	EPA SW-846	Method 8.53
Chromium	2.57 Mg/Kg	EPA SW-846	Method 8.54
Cobalt	3.46 Mg/Kg	EPA 600/4-79-020	Method 219.1
Copper	10.57 Mg/Kg	EPA 600/4-79-020	Method 220.1
Lead	107.72 Mg/Kg	EPA SW-846	Method 8.56
Manganese	19.65 Mg/Kg	EPA 600/4-79-020	Method 243.1
Mercury	< 0.50 ug/Kg (ppb)	EPA SW-846	Method 8.57
Nickel	4.54 Mg/Kg (ppm)	EPA SW-846	Method 8.58
Selenium	3.90 Mg/Kg	EPA SW-846	Method 8.59
Zinc	63.01 Mg/Kg	EPA 600/4-79-020	Method 289.1
Beryllium	0.27 Mg/Kg	EPA 600/4-79-020	Method 210.1

APPROVED BY [signature]

STANDARD LABORATORIES, INC.

CO. INC.
160 QUALITY CENTER
HOMER CITY, PA 15748

DATE 9-24-99
SAMPLE NO: 597031

DATE SAMPLED: 8-9-99
DATE RECEIVED: 8-12-99
OPERATING CO: TEST 99081104

SAMPLE ID: GIANT EAGLE WAXED CARDBOARD

GROSS WEIGHT: 2438.8

OTHER ID: WAX IMPREGNATED CARDBOARD PRODUCE BOXES PROJECT
99E0331 T1.2, BIOMASS FEEDSTOCK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

TCLP EXTRACTION				METHOD NUMBER	PAGE NUMBER
Arsenic	4.37	Ug/L	(ppb)	EPA SW-846	Method 8.51
Cadmium	< 0.05	Mg/L	(ppm)	EPA SW-846	Method 8.53
Chromium	0.29	Mg/L		EPA SW-846	Method 8.54
Cobalt	< 0.25	Mg/L		EPA 600/4-79-020	Method 219.1
Copper	< 0.04	Mg/L		EPA 600/4-79-020	Method 220.1
Lead	.22	Mg/L		EPA SW-846	Method 8.56
Manganese	< 0.06	Mg/L		EPA 600/4-79-020	Method 243.1
Mercury	< 0.50	Ug/L	(ppb)	EPA SW-846	Method 8.57
Nickel	.12	Mg/L	(ppm)	EPA SW-846	Method 8.58
Selenium	149.9	Ug/L	(ppb)	EPA SW-846	Method 8.59
Zinc	.12	Mg/L	(ppm)	EPA 600/4-79-020	Method 289.1
Beryllium	< 0.04	Mg/L		EPA 600/4-79-020	Method 210.1

Extraction Fluid Used #1
Sample Weight 15 grams

APPROVED BY [signature]

GOULD ENERGY DIVISION
P. O. BOX 214
CRESSON, PA 16630
(814) 886-7400

STANDARD LABORATORIES, INC.

DATE: 9-15-1999
SAMPLE NO. 597288

. G., INC.
60 QUALITY CENTER ROAD
OMER CITY, PA 15748

SAMPLE ID: INDIANA SEWAGE TREATMENT PLANT SEWAGE SLUDGE

ATING CO.:
LED BY: CUSTOMER PROVIDED

TION:

SAMPLED: 8/9/99 DATE RECEIVED: 8/14/99
HER:
S WEIGHT: 5520.0

R ID: MUNICIPAL SEWAGE SLUDGE TEST 99081105 PROJECT 99E0331 T1.2, BIOMASS FEEDSTOCK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

	ASTM METHOD	AS RECEIVED	DRY BASIS	
ISTURE	D2961 D3302 D3173	85.03%	XXX	
LATILE MATTER		9.27%	61.96%	
XED CARBON	D3172	1.31%	8.69%	
H	D3174	4.39%	29.35%	
LFUR	D4239 METHOD 3.3	.27%	1.78%	
RBON	D3178	5.75%	38.43%	
DROGEN	D3178	.83%	5.55%	
TROGEN	D3179	.83%	5.56%	
YGEN	D3176	2.90%	19.33%	
U/LB	D2015 D1989	1117	7463	
F BTU/LB				10563
S OF SO2 PER MILLION BTU			4.77	
S OF SULFUR PER MILLION BTU		2.418		
LORINE	D4208	.03%	.22%	
UORINE	D3761	43.41 PPM	290.08 PPM	
RCENT SOLIDS			14.97%	

ASH FUSION TEMPERATURE(S)

D1857	REDUCING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	2000
SOFTENING TEMPERATURE	2020
HEMISPHERICAL TEMPERATURE	2070
FLUID TEMPERATURE	2120

D1857	OXIDIZING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	2080
SOFTENING TEMPERATURE	2110
HEMISPHERICAL TEMPERATURE	2145

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BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.

DATE: 9-15-1999
SAMPLE NO. 597288

CERTIFICATE OF ANALYSIS (CONT.)

	AS RECEIVED	DRY BASIS
FLUID TEMPERATURE		2200

ASH MINERAL COMPOSITION
D2795 D3682

SILICON DIOXIDE	34.36 %
ALUMINIUM OXIDE	12.75 %
FERRIC OXIDE	13.19 %
TITANIUM DIOXIDE	1.64 %
PHOSPHORUS PENTOXIDE	15.40 %
CALCIUM OXIDE	8.95 %
MAGNESIUM OXIDE	2.08 %
SODIUM OXIDE	.88 %
POTASSIUM OXIDE	1.45 %
SULFUR TRIOXIDE	2.09 %

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BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.

CQ, INC.
160 QUALITY CENTER
HOMER CITY, PA 15748

DATE 9-24-99
SAMPLE NO: 597288

DATE SAMPLED: 8-9-99

DATE RECEIVED: 8-14-99

SAMPLE ID: INDIANA SEWAGE TREATMENT PLANT SEWAGE SLUDGE

GROSS WEIGHT: 5520.0

OTHER ID: MUNICIPAL SEWAGE SLUDGE TEST 99081105 PROJECT 99E0331
T1.2, BIOMASS FEEDSTOCK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

TOTAL METALS		METHOD NUMBER	PAGE NUMBER
Arsenic	4.84 Mg/Kg (ppm)	EPA SW-846	Method 8.51
Cadmium	6.60 Mg/Kg	EPA SW-846	Method 8.53
Chromium	55.77 Mg/Kg	EPA SW-846	Method 8.54
Cobalt	74.11 Mg/Kg	EPA 600/4-79-020	Method 219.1
Copper	660.38 Mg/Kg	EPA 600/4-79-020	Method 220.1
Lead	92.45 Mg/Kg	EPA SW-846	Method 8.56
Manganese	1540.88 Mg/Kg	EPA 600/4-79-020	Method 243.1
Mercury	835.56 ug/Kg (ppb)	EPA SW-846	Method 8.57
Nickel	70.44 Mg/Kg (ppm)	EPA SW-846	Method 8.58
Selenium	2.47 Mg/Kg	EPA SW-846	Method 8.59
Zinc	946.54 Mg/Kg	EPA 600/4-79-020	Method 289.1
Beryllium	2.94 Mg/Kg	EPA 600/4-79-020	Method 210.1

APPROVED BY [signature]

STANDARD LABORATORIES, INC.

CQ, INC.
160 QUALITY CENTER
HOMER CITY, PA 15748

DATE 9-24-99
SAMPLE NO: 597288

DATE SAMPLED: 8-9-99

DATE RECEIVED: 8-14-99

SAMPLE ID: INDIANA SEWAGE TREATMENT PLANT SEWAGE SLUDGE

GROSS WEIGHT: 5520.0

OTHER ID: MUNICIPAL SEWAGE SLUDGE TEST 99081105 PROJECT 99E0331
T1.2, BIOMASS FEEDSTOCK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

TCLP EXTRACTION					METHOD NUMBER	PAGE NUMBER
Arsenic		78.04	Ug/L	(ppb)	EPA SW-846	Method 8.51
Cadmium	<	0.05	Mg/L	(ppm)	EPA SW-846	Method 8.53
Chromium	<	0.10	Mg/L		EPA SW-846	Method 8.54
Cobalt		.61	Mg/L		EPA 600/4-79-020	Method 219.1
Copper		1.62	Mg/L		EPA 600/4-79-020	Method 220.1
Lead		.19	Mg/L		EPA SW-846	Method 8.56
Manganese		12.6	Mg/L		EPA 600/4-79-020	Method 243.1
Mercury	<	0.50	Ug/L	(ppb)	EPA SW-846	Method 8.57
Nickel		.39	Mg/L	(ppm)	EPA SW-846	Method 8.58
Selenium		153.3	Ug/L	(ppb)	EPA SW-846	Method 8.59
Zinc		2.21	Mg/L	(ppm)	EPA 600/4-79-020	Method 289.1
Beryllium	<	0.04	Mg/L		EPA 600/4-79-020	Method 210.1

Extraction Fluid Used #1
Sample Weight 30 grams

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GOULD ENERGY DIVISION
P.O. BOX 214
CRESSON, PA 16630
(814) 886-7400
STANDARD LABORATORIES, INC.

DATE: 9-15-1999
SAMPLE NO. 598280

C.Q., INC.
160 QUALITY CENTER ROAD
HOMER CITY, PA 15748

SAMPLE ID: BOILER MANURE TEST 99081106

PERATING CO.:
PLED BY: CUSTOMER PROVIDED
E:
CATION:

TE SAMPLED: 8/17/99 DATE RECEIVED: 8/19/989
THER:
SS WEIGHT: 6350.2 GR

THER ID: PENNAG POULTRY COUNCIL PROJECT 99E0331 T1.2. BIOMASS FEEDSTOCK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

	ASTM METHOD	AS RECEIVED	DRY BASIS
MOISTURE	D2961 D3302 D3173	9.09%	XXX
VOLATILE MATTER		60.45%	66.49%
IXED CARBON	D3172	8.07%	8.88%
SH	D3174	22.39%	24.63%
SULFUR	D4239 METHOD 3.3	.27%	.30%
ARBON	D3178	32.82%	36.10%
YDROGEN	D3178	4.18%	4.60%
ITROGEN	D3179	3.84%	4.22%
OXYGEN	D3176	27.41%	30.15%
TU/LB	D2015 D1989	5406	5946
AF BTU/LB			7889
LBS OF SO2 PER MILLION BTU			1.01
BS OF SULFUR PER MILLION BTU		.499	
CHLORINE	D4208	.45%	.49%
UORINE	D3761	32.01 PPM	35.21 PPM

ASH FUSION TEMPERATURE(S)

D1857	REDUCING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	2500
SOFTENING TEMPERATURE	2550
HEMISPHERICAL TEMPERATURE	2560
FLUID TEMPERATURE	2570

D1857	OXIDIZING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	2595
SOFTENING TEMPERATURE	2610
HEMISPHERICAL TEMPERATURE	2620
FLUID TEMPERATURE	2640

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BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.

DATE: 9-15-1999
SAMPLE NO. 598280

CERTIFICATE OF ANALYSIS (CONT.)

	AS RECEIVED	DRY BASIS

ASH MINERAL COMPOSITION
D2795 D3682

SILICON DIOXIDE	3.38 %
ALUMINIUM OXIDE	1.72 %
ERRIC OXIDE	3.19 %
ITANIUM DIOXIDE	.10 %
PHOSPHORUS PENTOXIDE	13.25 %
CALCIUM OXIDE	28.98 %
AGNESIUM OXIDE	3.62 %
ODIUM OXIDE	1.50 %
OTASSIUM OXIDE	8.02 %
SULFUR TRIOXIDE	2.19 %

APPROVED BY

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BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.

CQ, INC.
160 QUALITY CENTER
HOMER CITY, PA 15748

DATE 9-24-99
SAMPLE NO: 598280

DATE SAMPLED: 8-17-99

DATE RECEIVED: 8-19-99

SAMPLE ID: BOILER MANURE TEST 99081106

GROSS WEIGHT: 6350.2 GR

OTHER ID: PENNAG POULTRY COUNCIL PROJECT 99E0331 T1.2,
BIOMASS FEEDSTOCK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

TOTAL METALS		METHOD NUMBER	PAGE NUMBER
Arsenic	< 2.00 Mg/Kg (ppm)	EPA SW-846	Method 8.51
Cadmium	3.08 Mg/Kg	EPA SW-846	Method 8.53
Chromium	6.16 Mg/Kg	EPA SW-846	Method 8.54
Cobalt	15.39 Mg/Kg	EPA 600/4-79-020	Method 219.1
Copper	51.11 Mg/Kg	EPA 600/4-79-020	Method 220.1
Lead	8.62 Mg/Kg	EPA SW-846	Method 8.56
Manganese	264.77 Mg/Kg	EPA 600/4-79-020	Method 243.1
Mercury	< 0.50 ug/Kg (ppb)	EPA SW-846	Method 8.57
Nickel	12.93 Mg/Kg (ppm)	EPA SW-846	Method 8.58
Selenium	6.13 Mg/Kg	EPA SW-846	Method 8.59
Zinc	437.18 Mg/Kg	EPA 600/4-79-020	Method 289.1
Beryllium	2.46 Mg/Kg	EPA 600/4-79-020	Method 210.1

APPROVED BY

STANDARD LABORATORIES, INC.

CQ, INC.
160 QUALITY CENTER
HOMER CITY, PA 15748

DATE 9-24-99
SAMPLE NO: 598280

DATE SAMPLED: 8-17-99

DATE RECEIVED: 8-19-99

SAMPLE ID: BOILER MANURE TEST 99081106

GROSS WEIGHT: 6350.2 GR

OTHER ID: PENNAG POULTRY COUNCIL PROJECT 99E0331 T1.2,
BIOMASS FEEDSTOCK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

TCLP EXTRACTION				METHOD NUMBER	PAGE NUMBER
Arsenic	< 2.00	Ug/L	(ppb)	EPA SW-846	Method 8.51
Cadmium	< 0.05	Mg/L	(ppm)	EPA SW-846	Method 8.53
Chromium	< 0.10	Mg/L		EPA SW-846	Method 8.54
Cobalt	< 0.25	Mg/L		EPA 600/4-79-020	Method 219.1
Copper	.12	Mg/L		EPA 600/4-79-020	Method 220.1
Lead	.33	Mg/L		EPA SW-846	Method 8.56
Manganese	< 0.06	Mg/L		EPA 600/4-79-020	Method 243.1
Mercury	< 0.50	Ug/L	(ppb)	EPA SW-846	Method 8.57
Nickel	.12	Mg/L	(ppm)	EPA SW-846	Method 8.58
Selenium	167.5	Ug/L	(ppb)	EPA SW-846	Method 8.59
Zinc	.22	Mg/L	(ppm)	EPA 600/4-79-020	Method 289.1
Beryllium	< 0.04	Mg/L		EPA 600/4-79-020	Method 210.1

Extraction Fluid Used #2
Sample Weight 15 grams

APPROVED BY [signature]

GOULD ENERGY DIVISION
P.O. BOX 214
CRESSON, PA 16630
(814) 886-7400
STANDARD LABORATORIES, INC.

DATE: 9-15-1999
SAMPLE NO. 598281

Q., INC.
50 QUALITY CENTER ROAD
OMER CITY, PA 15748

SAMPLE ID: POULTRY MANURE TEST 99081106

ATING CO.:
LED BY: CUSTOMER PROVIDED

TION:

SAMPLED: 8/17/99 DATE RECEIVED: 8/19/99
HER:
S WEIGHT: 1716.2 GR

R ID: PENNAG POULTRY COUNCIL PROJECT 99E0331 T1.2, BIOMASS FEEDSTOCK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

	ASTM METHOD	AS RECEIVED	DRY BASIS	
ISTURE	D2961 D3302 D3173	60.82%	XXX	
LATILE MATTER		23.49%	59.94%	
XED CARBON	D3172	2.09%	5.36%	
H	D3174	13.60%	34.70%	
LFUR	D4239 METHOD 3.3	.10%	.26%	
RBON	D3178	12.13%	30.95%	
DROGEN	D3178	1.52%	3.88%	
TROGEN	D3179	1.22%	3.10%	
YGEN	D3176	10.61%	27.11%	
U/LB	D2015 D1989	2043	5213	
F BTU/LB				7983
S OF SO2 PER MILLION BTU			1.00	
S OF SULFUR PER MILLION BTU		.490		
LORINE	D4208	.15%	.39%	
UORINE	D3761	15.03 PPM	38.36 PPM	
RCENT SOLIDS			39.18%	

ASH FUSION TEMPERATURE(S)

D1857	REDUCING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	2485
SOFTENING TEMPERATURE	2505
HEMISPHERICAL TEMPERATURE	2525
FLUID TEMPERATURE	2545

D1857	OXIDIZING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	2570
SOFTENING TEMPERATURE	2585
HEMISPHERICAL TEMPERATURE	2600

APPROVED BY ____________

APPROVED BY ____________

BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.

DATE: 9-15-1999
SAMPLE NO. 598281

CERTIFICATE OF ANALYSIS (CONT.)

	AS RECEIVED	DRY BASIS
FLUID TEMPERATURE		2615

ASH MINERAL COMPOSITION
D2795 D3682

ICON DIOXIDE	3.13 %
MINIUM OXIDE	.85 %
RIC OXIDE	4.45 %
ANIUM DIOXIDE	.13 %
SPHORUS PENTOXIDE	12.93 %
CIUM OXIDE	32.86 %
NESIUM OXIDE	3.54 %
IUM OXIDE	1.41 %
ASSIUM OXIDE	9.43 %
FUR TRIOXIDE	1.90 %

APPROVED BY ____________

APPROVED BY ____________

BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.

CQ, INC.
160 QUALITY CENTER
HOMER CITY, PA 15748

DATE 9-24-99
SAMPLE NO: 598281

DATE SAMPLED: 8-17-99

DATE RECEIVED: 8-19-99

SAMPLE ID: POULTRY MANURE TEST 99081106

GROSS WEIGHT: 1716.2 GR

OTHER ID: PENNAG POULTRY COUNCIL PROJECT 99E0331 T1.2, BIOMASS FEEDSTOCK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

TOTAL METALS		METHOD NUMBER	PAGE NUMBER
Arsenic	.56 Mg/Kg (ppm)	EPA SW-846	Method 8.51
Cadmium	4.34 Mg/Kg	EPA SW-846	Method 8.53
Chromium	9.54 Mg/Kg	EPA SW-846	Method 8.54
Cobalt	31.23 Mg/Kg	EPA 600/4-79-020	Method 219.1
Copper	57.26 Mg/Kg	EPA 600/4-79-020	Method 220.1
Lead	8.68 Mg/Kg	EPA SW-846	Method 8.56
Manganese	312.30 Mg/Kg	EPA 600/4-79-020	Method 243.1
Mercury	< 0.50 ug/Kg (ppb)	EPA SW-846	Method 8.57
Nickel	15.62 Mg/Kg (ppm)	EPA SW-846	Method 8.58
Selenium	3.64 Mg/Kg	EPA SW-846	Method 8.59
Zinc	520.50 Mg/Kg	EPA 600/4-79-020	Method 289.1
Beryllium	3.47 Mg/Kg	EPA 600/4-79-020	Method 210.1

APPROVED BY [signature]

STANDARD LABORATORIES, INC.

CO, INC.
160 QUALITY CENTER
HOMER CITY, PA 15748

DATE 9-24-99
SAMPLE NO: 598281

DATE SAMPLED: 8-17-99

DATE RECEIVED: 8-19-99

SAMPLE ID: POULTRY MANURE TEST 99081106

GROSS WEIGHT: 1716.2 GR

OTHER ID: PENNAG POULTRY COUNCIL PROJECT 99E0331 T1.2,
BIOMASS FEEDSTOCK CHARACTERIZATION

CERTIFICATE OF ANALYSIS

TCLP EXTRACTION				METHOD NUMBER	PAGE NUMBER
Arsenic	3.04	Ug/L	(ppb)	EPA SW-846	Method 8.51
Cadmium	< 0.05	Mg/L	(ppm)	EPA SW-846	Method 8.53
Chromium	.51	Mg/L		EPA SW-846	Method 8.54
Cobalt	< 0.25	Mg/L		EPA 600/4-79-020	Method 219.1
Copper	.10	Mg/L		EPA 600/4-79-020	Method 220.1
Lead	< 0.10	Mg/L		EPA SW-846	Method 8.56
Manganese	< 0.06	Mg/L		EPA 600/4-79-020	Method 243.1
Mercury	< 0.50	Ug/L	(ppb)	EPA SW-846	Method 8.57
Nickel	.10	Mg/L	(ppm)	EPA SW-846	Method 8.58
Selenium	218.8	Ug/L	(ppb)	EPA SW-846	Method 8.59
Zinc	.27	Mg/L	(ppm)	EPA 600/4-79-020	Method 289.1
Beryllium	< 0.04	Mg/L		EPA 600/4-79-020	Method 210.1

Extraction Fluid Used #2
Sample Weight 15 grams

APPROVED BY

APPENDIX D

MARKET ASSESSMENT: PHASE I TASK 5
FINAL REPORT

ALSTOM POWER INC.
US POWER PLANT LABORATORIES

ALSTOM

Technical Report

Reporting CRC (full name and address): U.S. Power Plant Laboratories
ALSTOM Power Inc.
2000 Day Hill Road
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Tel.: (860) 285-2275 Fax: (860) 285-3473

Responsible Person: Woody Fiveland

Project Name: Production of New Biomass / Waste-Containing Solid Fuels

Document Title: **Market Assessment: Phase 1 Task 5 Final Report for CQ Inc.**

Document Ref. No.: PPL-00-CT-13

Date of Issue: 20.6.00 No. of pages: 37

Client: CQ Inc.

Author(s): Charles Q. Maney, Kurt W. Johnson, Nsakala ya Nsakala

Distribution: see separate page

Keywords: CQ Inc., DOE, Biomass, Fuels, Feedstock, and Combustor

Summary:

This report is presented in fulfillment of the Phase I, Task 5 of U.S. DOE contract DE-AC26-99FT40159. For this work, the three, candidate, pelletized fuel mixtures as identified during Phase I, Task 2 of this program were subjected to U.S. PPL developed bench scale pulverization and combustion test procedures in order to determine their applicability to Pulverized Coal (PC), Circulating Fluidized Bed (CFB), Stoker and Cyclone fired combustors. Examined fuels included (1) a combination of 85% petroleum coke (pet coke) with 15% mixed plastics, (2) a mixture of 80% Ginger Hill coal fines with 20% waxed cardboard, and (3) a combination of 80% Ginger Hill coal fines with 20% sewage sludge, reported on a mass weight basis.

Results of this work indicate that of the tested fuels, only the 80% Ginger Hill coal / 20% sewage sludge pelletized fuel is generally applicable to each of the four noted combustor types: PC, CFB, Stoker and Cyclone. It exhibited no obviously detrimental behavior in the bench scale pulverizer testing, and is sufficiently reactive to provide for stable ignition and reasonable carbon burnout levels as compared to a typical, eastern bituminous coal. The only significant drawback to the present composition is the ability of the fuel pellets to maintain a reasonable degree of integrity to allow for sufficient residence time for complete combustion as applied to Stoker and Cyclone fired boilers.

As for the remaining two fuels, neither the 85% pet coke / 15% mixed plastics fuel nor the 80% Ginger Hill / 20% waxed cardboard fuels are generally applicable to all four combustor types. Both of these fuels exhibited significant problems in the bench scale pulverization testing including difficulty in size reduction and bed pad formation, rendering them largely inapplicable to through-the-mill PC firing. Similar to the Ginger Hill coal / sewage sludge blend, additional problems for both of these fuels include pellet size and integrity as it impacts the ability of the fuel to be transported to and combusted in a CFB, Cyclone or Stoker fired boiler. The pet coke and mixed plastics fuel has the additional problem of having a low reactivity char, which combined with the pet coke's small (~30 micron) particle size, may compound combustion efficiency issues with respect to reduced (bed) residence times for CFB and Stoker application. In addition, even with only 15% mixed plastics content, the pet coke and plastics mix suffers from high (0.37% by wt) chlorine which is undesirable with regard to its potential impact on waterwall wastage rates.

As a result of this analysis, only the 80% Ginger Hill / 20% sewage sludge fuel is recommended for further evaluation during Phase II of this work.

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ALSTOM Power Inc.

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1. Introduction

ALSTOM Power Inc., through it's U.S. Power Plant Laboratory (US PPL) was subcontracted by CQ Inc. to assess the pulverization and combustion characteristics of various, pelletized, biomass and / or waste containing solid fuels and feedstocks in support of Phase I, Task 5 of U.S. DOE contract DE-AC26-99FT40159. For this work, the three, candidate, pelletized fuel mixtures as identified during Phase I, Task 2 of this program were subjected to US PPL developed bench scale pulverization and combustion test procedures in order to determine their applicability to Pulverized Coal (PC), Circulating Fluidized Bed (CFB), Stoker and Cyclone fired combustors. Examined fuels included (1) a combination of 85% pet coke Coke with 15% mixed plasitcs, (2) a mixture of 80% Ginger Hill coal fines with 20% waxed cardboard, and (3) a combination of 80% Ginger Hill coal fines with 20% sewage sludge, reported on a mass weight basis[1].

Pertinent analyses of the three tested pelletized fuels, as provided by CQ Inc., are given in Table 1. Complete analytical laboratory data sheets are given in Section 6.1 of the Appendix.

Table 1: As-Received Composite, Pelletized Fuel Analyses

Identification	**85% Pet Coke 15% Plastics**	**80% Ginger Hill 20% W. Crdbd.**	**80% Ginger Hill 20% S. Sludge**
Chemical Analyses			
VM	27.5%	38.0%	32.6%
FC	71.1%	39.8%	50.2%
FC/VM	2.59	1.05	1.54
HHV, BTU/lb	15,373	12,200	12,374
LHV, BTU/lb	14,880	11,565	11,832
Moisture	0.5%	16.2%	9.2%
Hydrogen	5.0%	4.7%	4.6%
Carbon	85.1%	61.3%	68.8%
Sulfur	4.5%	1.2%	1.6%
Nitrogen	1.0%	1.0%	1.2%
Oxygen	2.9%	9.5%	6.6%
Ash	1.0%	6.1%	8.1%
Total	100.0%	100.0%	100.0%
O/N	2.9	9.6	5.3
lb N/MMBTU	0.64	0.81	1.00
lb S/MMBTU	2.95	0.99	1.26
lb Ash/MMBTU	0.6	5.0	6.5
Chlorine	0.37%	0.08%	0.16%
lb_Cl/MMBTU	0.24	0.07	0.13
Fluorine (ppm)	92	64	-

[1] "*Feedstock Characterization: Phase I, Task 2 Final Report for CQ Inc.*," PPL-99-CT-28, C.Q. Maney, January, 2000, © Combustion Engineering, Inc.

Table 1: As-Received Composite, Pelletized Fuel Analyses, cont.

Identification	85% Pet Coke 15% Plastics	80% Ginger Hill 20% W. Crdbd.	80% Ginger Hill 20% S. Sludge
Ash Fusibility Temps. (°F)	Reducing Atm.	Reducing Atm.	Reducing Atm.
I.T.	2,065	2,170	2,045
S.T.	2,110	2,190	2,090
H.T.	2,135	2,230	2,130
F.T.	2,150	2,285	2,170
Diff. (F.T. - I.T.)	85	115	125
Ash Fusibility Temps. (°F)	Oxidizing Atm.	Oxidizing Atm.	Oxidizing Atm.
I.T.	2,285	2,340	2,290
S.T.	2,330	2,400	2,350
H.T.	2,360	2,415	2,380
F.T.	2,425	2,430	2,400
Diff. (F.T. - I.T.)	140	90	110
Ash Composition			
SiO2	25.3%	46.6%	45.3%
Al2O3	5.6%	20.5%	20.6%
Fe2O3	9.0%	13.9%	15.7%
TiO2	6.0%	1.7%	1.1%
CaO	9.1%	4.6%	5.6%
MgO	2.2%	1.2%	1.2%
Na2O	1.7%	1.7%	1.2%
K2O	8.4%	1.4%	2.3%
P2O5	0.0%	0.1%	2.1%
SO3	15.1%	7.4%	7.0%
Total	82.3%	99.2%	102.0%
Base / Acid Ratio	0.82	0.33	0.39
Fe2O3 / CaO	0.99	3.04	2.83
SiO2 / Al2O3	4.48	2.27	2.20
lb K+Na/MMBTU	0.06	0.16	0.23
Slagging Potential	High	High	High
Fouling Potential	Severe	Medium	High

For the subject work, US PPL prepared the three (3) pelletized, waste containing solid fuels for pulverization testing in ALSTOM Power Inc.'s Grindability Index (AGI) machine. The AGI test work was performed according to US PPL developed procedures (refer to Section 2) to determine the power requirements for pulverization of the pelletized fuels as compared to typical, bituminous coals. In addition, qualitative information with regard to the pasting behavior of the test fuels was determined from visual observation of the resultant blend during the bench scale pulverization experiment.

Subsequent to the AGI testing, two (2) of the three (3) pelletized fuels were prepared for pyrolysis testing in ALSTOM Power Inc.'s Drop Tube Furnace System-1 (DTFS-1). The selected fuels were fuel (1), the 85% pet coke / 15% mixed plastics blend, and fuel (3), the 80% Ginger Hill coal fines / 20% sewage sludge mix. Selection of the first fuel was based on the ready availability of its constituents, and the potential for it to become a "synthetic coal" with proprietary benefit to CQ Inc., while the second was based on an initial projection of more favorable economics for its use as compared to either of the other noted fuels.

Subsequent to the DTFS-1 testing, the resultant chars were oxidized in a Thermo-gravimetric Analyzer (TGA) to determine their relative reactivity as compared to a typical, bituminous coal char. In addition, all three pelletized fuels were subjected to weak acid leaching to assess the relative slagging potential of the ash constituents. Results from the overall analysis procedures were then interpreted with respect to the applicability of the given pelletized fuels for use in a Pulverized Coal (PC), Circulating Fluidized Bed (CFB), Stoker, and / or Cyclone fired combustor.

2. Fuel Pulverization Characterization

Each of the three, candidate, pelletized fuels were subjected to testing in ALSTOM Power Inc.'s Grindability Index machine (AGI). The AGI machine / methodology was developed by ALSTOM Power Inc. to address shortcomings in the classical ASTM Hardgrove Grindability Index (HGI) method with regard to predicting pulverizer performance over the range of domestic and international coals encountered in commercial, pulverized coal applications.

The AGI apparatus, shown in Figure 1, incorporates much of the structure and logic of the HGI approach with high precision control of motor speed, continuous mechanical resistance measurements, and vertical spindle mill design grinding (roller) elements. Like the HGI, the starting sample for AGI use is size graded to 16 x 30 mesh (1190 by 590 microns). Unlike the HGI, the AGI uses sequential applications of a precise grinding force, where each sequence is followed by removal of undersize material (-200 mesh) from a 25 gram starting weight. The total, specific energy requirement is calculated when the amount of undersize material is equal to 60% of the starting weight. Results of the AGI testing have been shown to correlate well with field performance of commercial, vertical spindle mills for pulverized coal fired applications.

Although the properties of some of these fuels precluded a precise measurement of specific energy requirements by this method, the observations made during testing are useful for assessing the fuel's overall grinding properties.

<u>85% Pet Coke / 15% Plastics AGI Results</u>

In preparation for the AGI testing, a 16 x 30 mesh, size graded test sample was prepared through the use of various bench scale fuel preparation procedures. For the 85% pet coke / 15% plastics mixture this involved the use of US PPL's shredding mill. Coarse (<6 mm) shredding of the 85% pet coke / 15% Mixed plastics pellets segregated the sample to some extent. The fines in this shredded material were visibly all pet coke while the coarse material appeared to be predominantly plastic. However, the narrow sized 16 x 30 mesh material used for the AGI did contain both, although it appeared to be mostly plastic (Figure 2). The observed sample segregation is consistent with the particle size of the parent pet coke, which was shown to have a mass mean diameter of 32 microns (~400 mesh) by a laser diffraction technique (refer to Section 6.2 of the Appendix).

Seven iterations of the 30-second grind sequence were performed on the prepared sample until the test was aborted. The first iteration yielded the less than 3 grams of undersize (-200 mesh) material. However, this was the largest yield and appeared to consist primarily of pet coke. Subsequent iterations yielded less and less material as the remainder of the pet coke material was removed by sieving. The test was aborted after removal of less than 10 grams, or 40% of undersize material. However, the energy needed to overcome sample resistance for this removal was very high due to the unreduced plastic. From visual observations it appeared that none of the plastic in the sample was size reduced by the bench scale milling process.

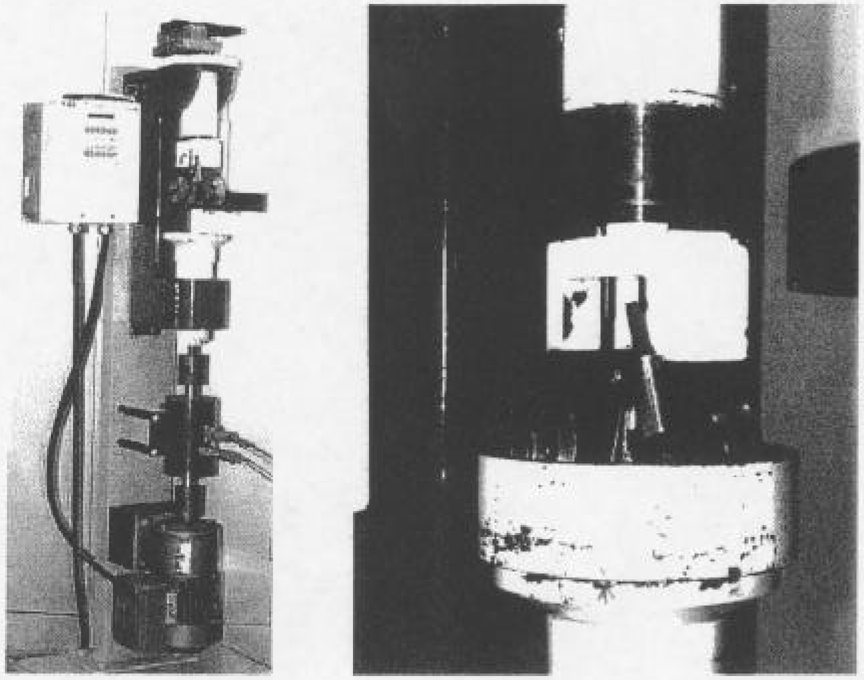

Figure 1 – ALSTOM Power Inc.'s Grindability Index (AGI) Machine

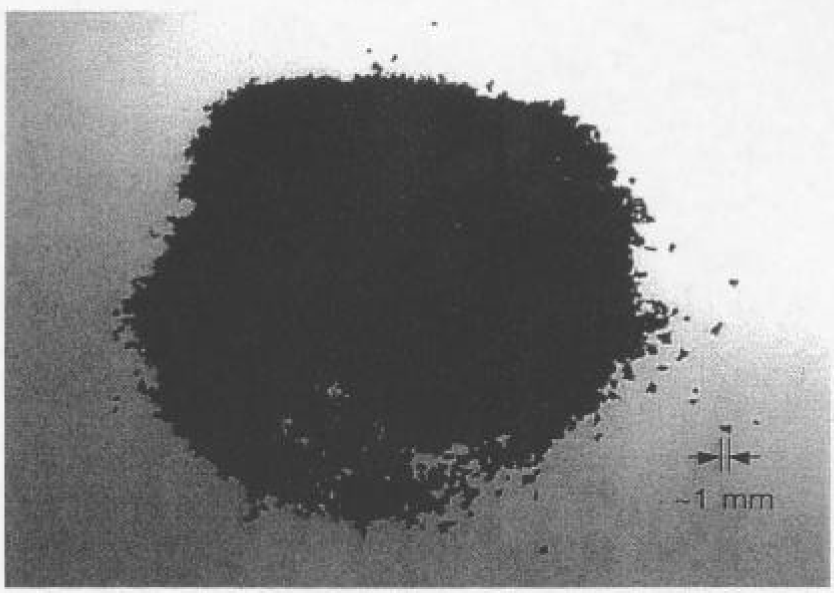

Figure 2 - 80% Pet Coke / 20% Plastic Pellet Prepared to 16 x30 mesh

During the milling process there was evidence that two types of bowl pads formed within the AGI machine. The first was from the pet coke and the second from the plastic. Examination of the bowl after the first test iteration showed a very tenacious pad consisting predominantly of pet coke. Subsequent iterations, which contained less pet coke, showed less evidence of this type of pad. However, as the ratio of plastic in the sample increased, a much weaker pad consisting of compacted plastic was evident (Figure 3). It is thought that the higher temperatures found in a commercial mill would be problematic for the retained plastic material, leading to substantial sticking and / or pasting of the plastic residue.

Specific energy consumption in kWh/ton are normally calculated for an achieved grind of 60% minus 200 mesh using the AGI methodology. Although, this grind was not attained, a specific energy value for the pet coke and plastics mixture was calculated by extrapolation from the recorded data. Although not quantitative, as it is several times that of a typical bituminous coal (Figure 4), this value can be considered a qualitative indicator of a significant increase in mill power consumption for bowl mill preparation of the pet coke and plastic blend. The high energy consumption and tendency to form a bed pad on the bench scale grinding apparatus indicate a high likelihood of problem for use of this material in a commercial pulverizer system.

Figure 3 – AGI Bowl with Pasted Material from Pet Coke/Plastic Pellets

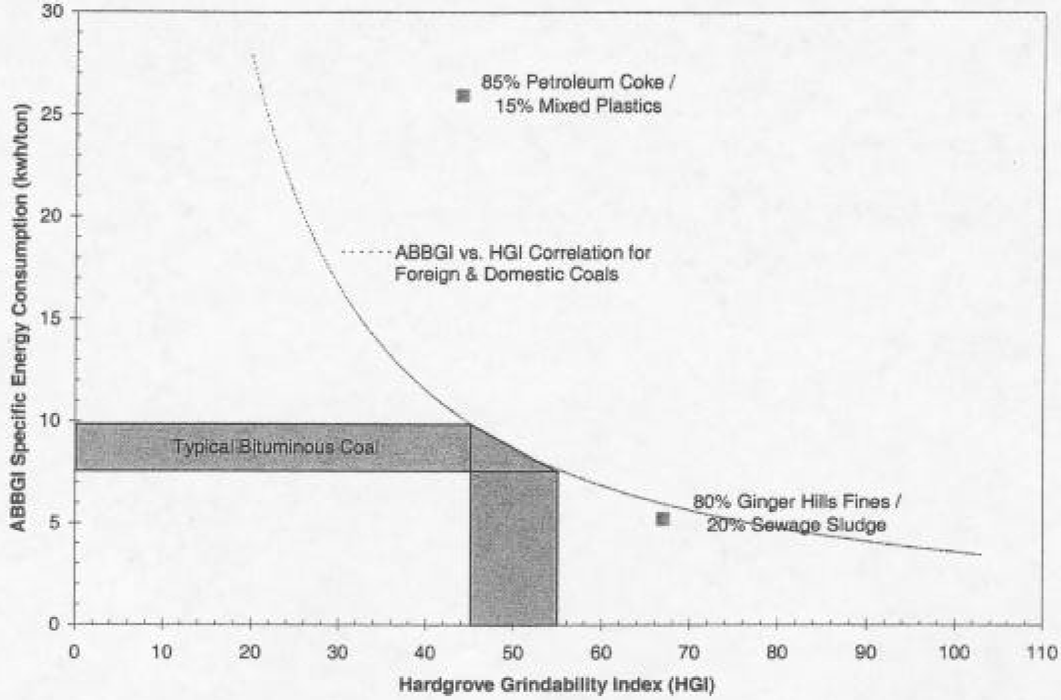

Figure 4 – AGI Specific Energy Consumption vs. HGI for Test Pellets

80% Coal / 20% Waxed Cardboard AGI Results

This air-dried pellet sample was first shredded in a Wiley shredder mill to < 6-mm top size. Like the pet coke and plastics sample, this shredding resulted in a two component mixture with the first component being a fibrous portion consisting of the waxed cardboard with fine coal imbedded in it, and the second portion consisting entirely of the Ginger Hill coal fines. With sieving, all of the fibrous material was found to be in the coarse (>30 mesh) fraction (Figure 5). As a result, it was not possible to prepare a representative 16 x 30 mesh sample for the AGI measurement. With this result, it was decided to run the raw, non-size graded shredded material through the AGI machine without accumulating numerical energy / comminution data, but simply to observe compaction and pad formation behavior.

After 30 seconds of fully loaded operation, the shredded sample had noticeably compacted (Figure 6). The resultant pad, consisting of both the coal and the waxed fibers, had smeared over the bottom of the bowl. This pad had very little strength as it was easily broken apart and did not adhere well to the bottom of the bowl when inverted.

Based on these observations, it is expected that this material in an actual pulverizer will rapidly break into its base components. The coal, being very fine, will be carried out of the mill. However, the waxed cardboard will likely not be size reduced, but instead tend to pack with roll pressure. At temperatures higher than the test temperature (21°C), it is thought that this tendency will be exaggerated. Associated with this are potential problems relating to the softening and / or vaporization of the wax coating, which may exacerbate deposition and / or precipitate other problems up to and including mill fires.

Figure 5 - Shredded 80% Coal / 20% Waxed Cardboard Sample

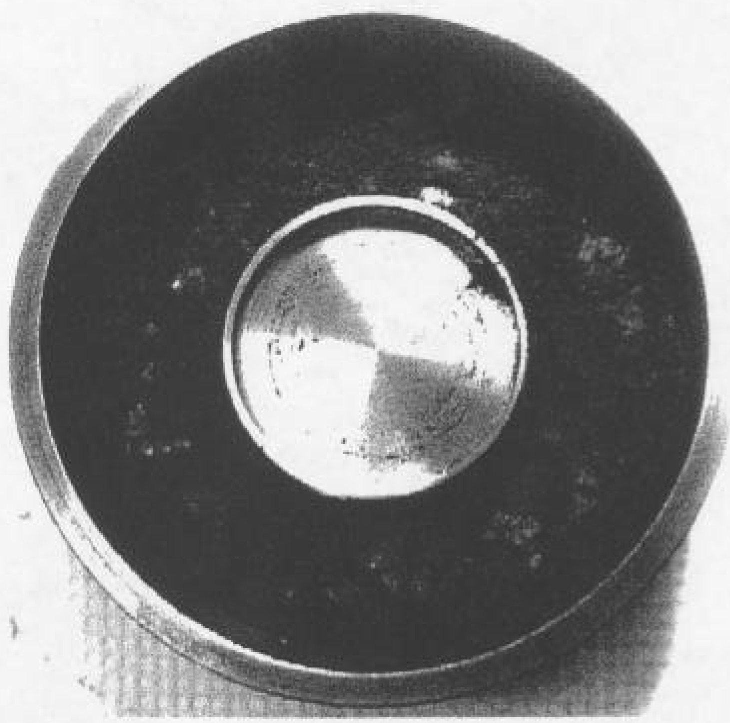

Figure 6 - 80% Coal / 20% Waxed Cardboard After 30 Seconds of AGI Operation

80% Coal / 20% Sewage Sludge AGI Results

The 80% Ginger Hill coal fines / 20% sewage sludge sample was reduced from the original pellet to the required 16 x 30 mesh grind by simple crushing and it did not require any shredding to achieve the desired size fraction. In addition, this material did not show any evidence of segregation during the size reduction (Figure 7). The 80% coal / 20% sludge was very soft material requiring only three iterations of the AGI to attain greater than 60% through 200 mesh. The sample material remaining after size grading contained some easily broken flakes, but these did not adhere to either the bowl or the rollers. The appearance of some white material in the sample after the testing was complete suggest that the concentration of non-coal (sludge) material increased as the coal fines was preferentially "pulverized."

The measured specific energy of 5.2 kWh/ton is in the range of many coals, and lower than that of typical bituminous coals (Figure 4). Unlike either the pet coke / plastics mixture, or the Ginger Hill coal fines / waxed cardboard mix, the Ginger Hill coal fines / sewage sludge results indicate that there will not likely be any inherent problems associated with commercial scale pulverization of this material rendering it applicable to pulverized coal fired boiler use.

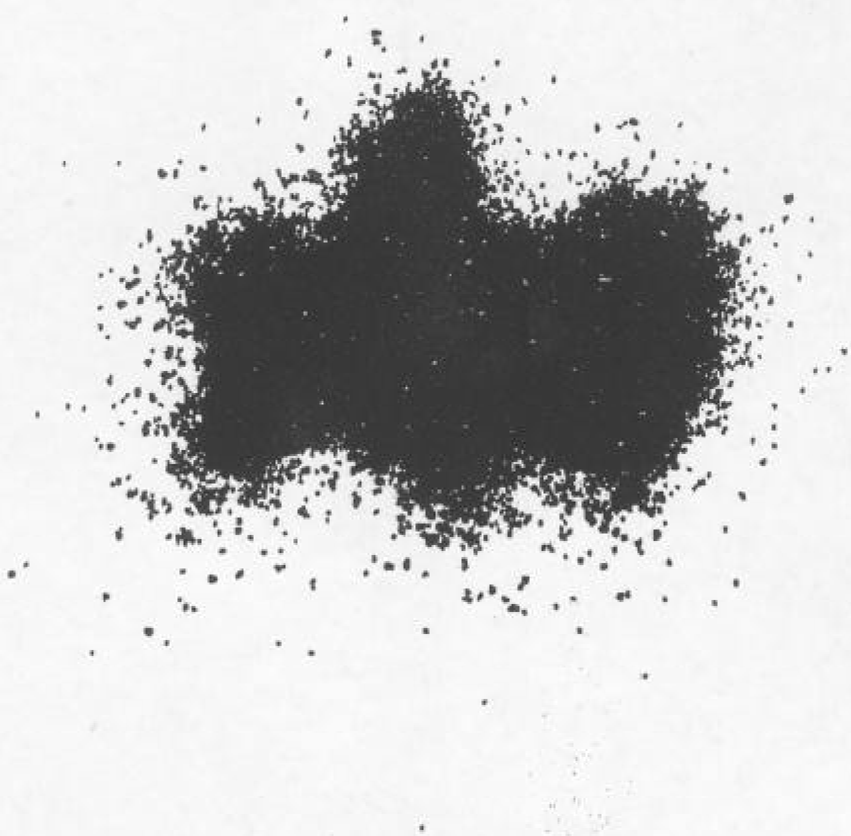

Figure 7 - 16 x 30 Mesh Coal / Sewage Sludge Pellets

3. Fuel Combustion and Fireside Characteristics

3.1 Fuel Pyrolysis Procedure

Two of the pelletized fuels, the 85% pet coke / 15% mixed plastics fuel, and the 80% Ginger Hill coal fines / 20% sewage sludge fuel, were prepared for and pyrolized in U.S. PPL's Drop Tube Furnace System-1 (DTFS-1). The DTFS-1 is a vertical, entrained flow reactor that is used to provide controlled temperature conditions to study devolatilization, gasification and other combustion related phenomena. The DTFS-1, which is electrically heated with silicon carbide elements, is capable of heating reacting particles to temperatures of up to 2650 °F and sustaining particle residence times of up to one second to simulate the suspension firing conditions encountered in pulverized coal-fired boilers. A photo of the DTFS-1 is provided in Figure 8.

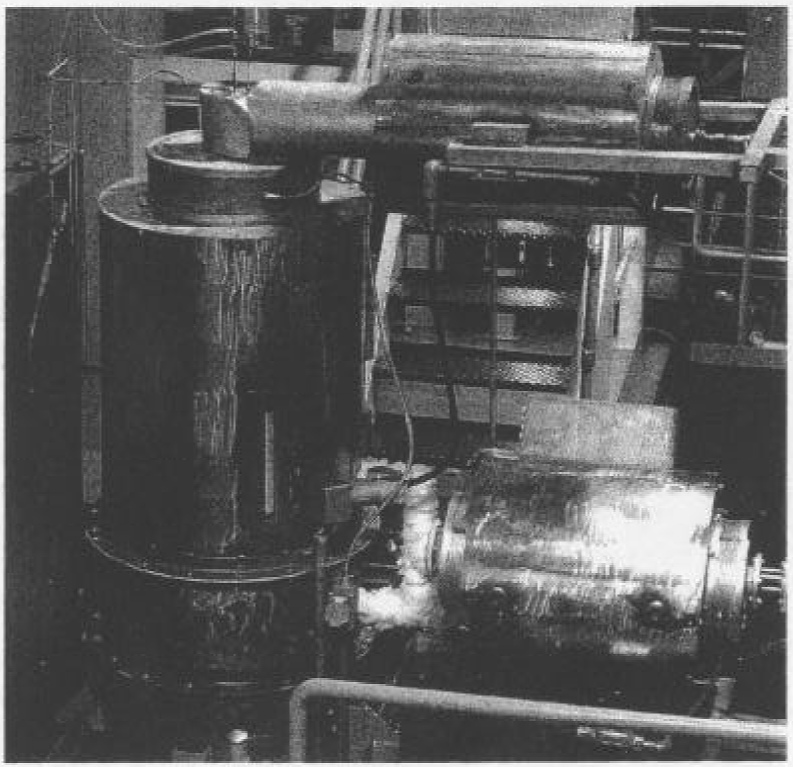

Figure 8 – U.S. PPL's Drop Tube Furnace System-1 (DTFS-1)

For typical DTFS-1 work, the test fuels are prepared to a 200 x 400 mesh size fraction (75 x 38 micron), which produces a sample with an overall mass mean diameter that is consistent with that found for commercial pulverized coal fired boilers (i.e. ~55 microns). A top size of up to 300 microns (i.e. less than 50 mesh) can, however, be fed with the current syringe feed system, which consists of a 0.065" O.D. hypodermic injector assembly.

For the subject work, the Ginger Hill coal / sewage sludge sample was amenable to preparation to the within the allowable top size specification for hypodermic feed. However the pet coke / plastics sample was not, owing to the difficulty with which it could be prepared via conventional preparation and pulverization techniques (refer to Section 2). As a result, the DTFS-1 was specifically modified for the firing of the pet coke / plastics fuel via the use of a screw feeder and a ¼" O.D. fuel injector in order to accommodate the large (~2 mm top size) pet coke / plastic mixture particles.

For the subject work, the test fuels were pyrolized in an inert (Argon) atmosphere to generate chars for resultant reactivity testing in U.S. PPL's Thermogravimetric Analyzer (TGA). During the pyrolysis work, fuel nitrogen conversion to NOx was also measured, as well as high temperature volatile yield (via post test char analysis using an ash tracer technique) in order to provide an index for use in predicting the combustion stageability for NOx destruction. DTFS-1 high temperature volatile yield data and resultant char reactivity analyses provides a better basis for emissions prediction by providing input data with regard to the test fuels behavior under conditions that more accurately simulate those found in a commercial scale, utility boiler.

3.2 High Temperature Volatile Yield

The results of the DTFS-1 high temperature volatile yield are presented in Figure 9. Here, a proximate analysis of the as-fed DTFS-1 fuel and resultant char by-product was performed by ALSTOM Power Inc. for the pet coke and plastic, and Ginger Hill coal and sewage sludge mixture and, individually, the Ginger Hill coal and pet coke portions of the above feeds as obtained via mechanical (crushing and sieve) separation of the as-received pellets[2].

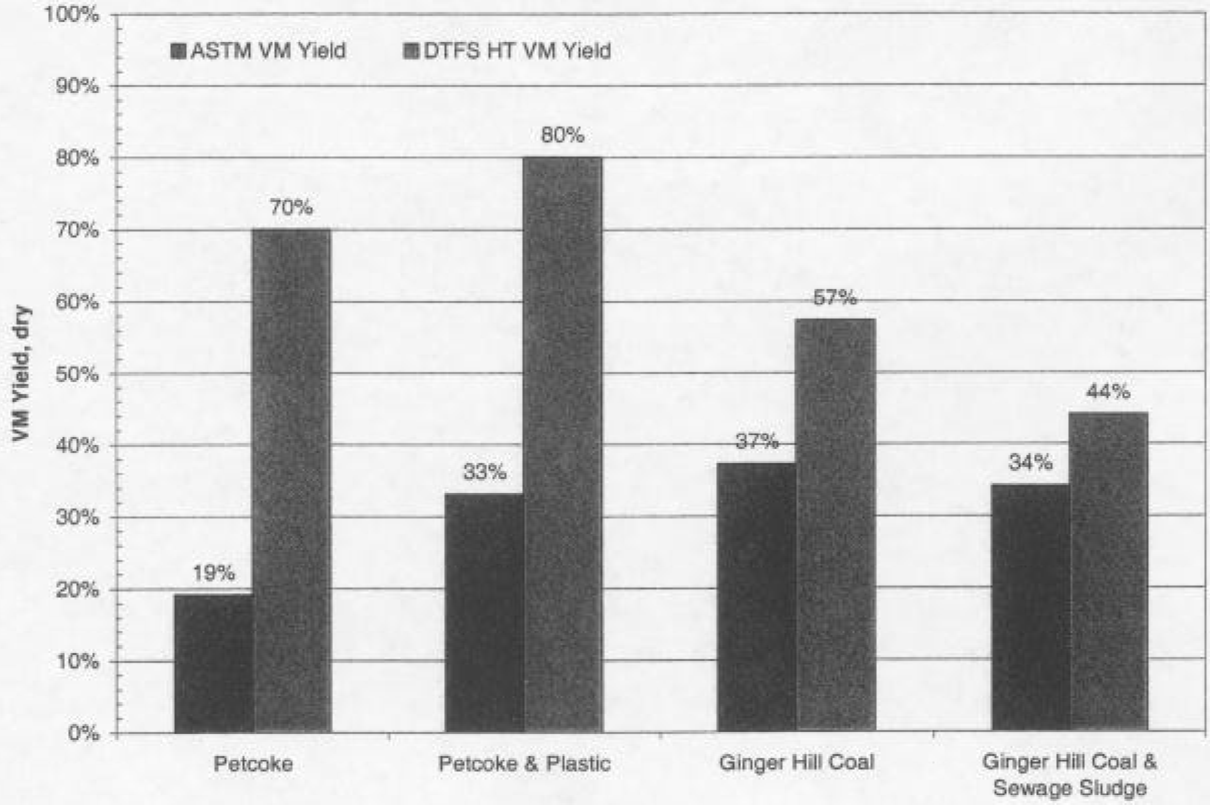

Figure 9 - DTFS-1 Fuel Nitrogen Conversion and High Temperature Volatile Yield Results

As shown in Figure 9, both the pet coke individually, and the pet coke and plastics mixture exhibited significant increases in VM yields at the high DTFS-1 pyrolysis temperatures (~2750 °F) as compared to the lower ASTM temperatures (~1740 °F), with the high temperature (HT) yields doubling or tripling the

[2] Note: It is expected that some contamination of the as-separated Ginger Hill and Pet Coke sample may have occurred by virtue of the mechanical and / or thermal stressing during the pelletizing process thereby affecting the measured, individual constituent VM yield.

ASTM values. The Ginger Hill coal, and Ginger Hill coal and sewage sludge, on the other hand, behaved more like a typical bituminous coal, showing increases in VM yield ranging from 30 to 50% at higher temperature.

Increased volatile yield correlates with increased stageability for improved NOx control. As more volatile matter is released, it carries with it more of the fuel bound nitrogen. Under air staged (substoichiometric) conditions, formation of N2 is thermodynamically favored over NO, resulting in decreased overall fuel NOx formation.

According to the test data, the pet coke and plastics mixture should be the most stageable of the fuels and therefore have the lowest fuel NOx potential. However the results of the high temperature volatile yield experiments appear erroneous as a typical petroleum coke should, by definition, have limited to no volatile matter over the range of temperatures shown (ASTM to DTFS-1).

Prior, internal experimentation by ALSTOM Power Inc. has shown no appreciable increase in the volatile matter yield of a petroleum coke fuel at high temperature over that found via ASTM procedures, an expected result for this type of fuel. Given the above finding, this leads to the conclusion that either the result is spurious, or the pet coke is a-typical for the class it represents.

One theory of analysis is that the as-fed DTFS-1 test sample had a greater than typical percentage of plastic, leading to the resultant increase in volatile yield as compared to the ASTM value. However, this possibility was reduced via testing of the pet coke component alone (obtained by mechanical separation from the composite fuel) which demonstrated a similar increase in volatile yield at high (DTFS-1) temperatures.

As a result of this work it is preliminarily concluded that the tested pet coke is not representative of the typical class of petroleum coke derived fuels, containing more light hydrocarbons due to incomplete cracking during the coking process. Additional testing of the parent pet coke may be warranted to avoid issues associated with contamination of the pet coke with the plastic during the pelletizing process.

3.3 TGA Coal / Char Analysis

U.S. PPL's Thermogravimetric Analyzer (TGA) was used to examine the relative reactivities of the DTFS-1 generated chars from the 85% pet coke / 15% mixed plastics and 80% Ginger Hill Coal / 20% sewage sludge composite fuels, and their mechanically separated parent constituents. U.S. PPL's TGA apparatus is designed to measure the rate of combustible material loss per unit time as a function of temperature for a reactant sample exposed to a known gas composition and flow rate. For subject work, an initial sample of ~5 mg in total weight from each of the four DTFS-1 generated chars, and each of the mechancially separated parent fuels was heated in an air/nitrogen (50/50, v/v) blend at a rate of 10 ^{o}C/min until they were completely oxidized (dwt-loss/dt = 0). The parent feeds were added for comparison to the chars and as an additional tool to understand the aforementioned, apparently anomalous high temperature volatile yield results for the pet coke based fuel. Figure 10 depicts the rates of oxidation as a function of temperature for each of the aforementioned chars and parent feeds.

In Figure 10, it can be seen first that the mechanically separated pet coke feed is, overall, as reactive as the Ginger Hill coal. Initially (0-800 °F), reaction rates for the pet coke are slower than that of the Ginger Hill coal. These results imply an expected delay in ignition associated with the pet coke that may affect flame stability in a commercial boiler. However, subsequently the demonstrated pet coke oxidation rates increase and surpass that of the Ginger Hill coal, ultimately arriving at the same overall level of oxidation as the Ginger Hill coal at the same final temperature and thus time. As for the high temperature volatile yield, it is unexpected that the pet coke should demonstrate similar overall oxidation rates to the Ginger Hill coal, supporting the theory that it may be an a-typical petroleum coke.

As for the DTFS-1 generated chars, the most obvious result is that the pet coke / plastic mixture exhibits two distinct combustion regimes. That is, there is a high reactivity portion of the char that ignites in the 800 °F range, reaching a maximum rate of oxidation at ~920 °F. Following this there is a lower reactivity portion that continues reacting, reaching a maximum rate of oxidation at ~1,100 °F. These distinct regimes suggest a carry over and / or recondensation of some of the plastic portion of the pet coke and plastics mixture in char generated during the DTFS-1 pyrolysis work. It should be noted that in actual field combustion, the oxidation of this volatile / plastic component will enhance the overall combustion intensity for improved flame stability and lead to little differentiation between these two combustion regimes by virtue of creating a char consisting primarily of the unreacted pet coke fraction.

For a final comparison, the mechanically separated pet coke char sample was oxidized in the TGA. Results from this show it to be the least reactive of any of the tested feeds. Under field combustion conditions it is likely that the more reactive plastics component will oxidize early on in the combustion process, leaving the pet coke fraction to make up the majority of the resultant char. As a result, it is expected that any pet coke based fuel will have unburned carbon loss related problems as compared to a typical bituminous coal impacting both boiler efficiency and ash disposal costs.

As for the Ginger Hill coal and the pet coke char, the Ginger Hill coal char and Ginger Hill coal / sewage sludge char exhibit only one combustion regime, with the maximum rate of combustion occurring at ~1,030 °F and ~1,060 °F, respectively. As shown, the Ginger Hill coal / sewage sludge char's behavior is comparable, but slightly less reactive than the Ginger Hill coal char, indicating a slight decrease in reactivity for the mixture as compared to the parent coal alone.

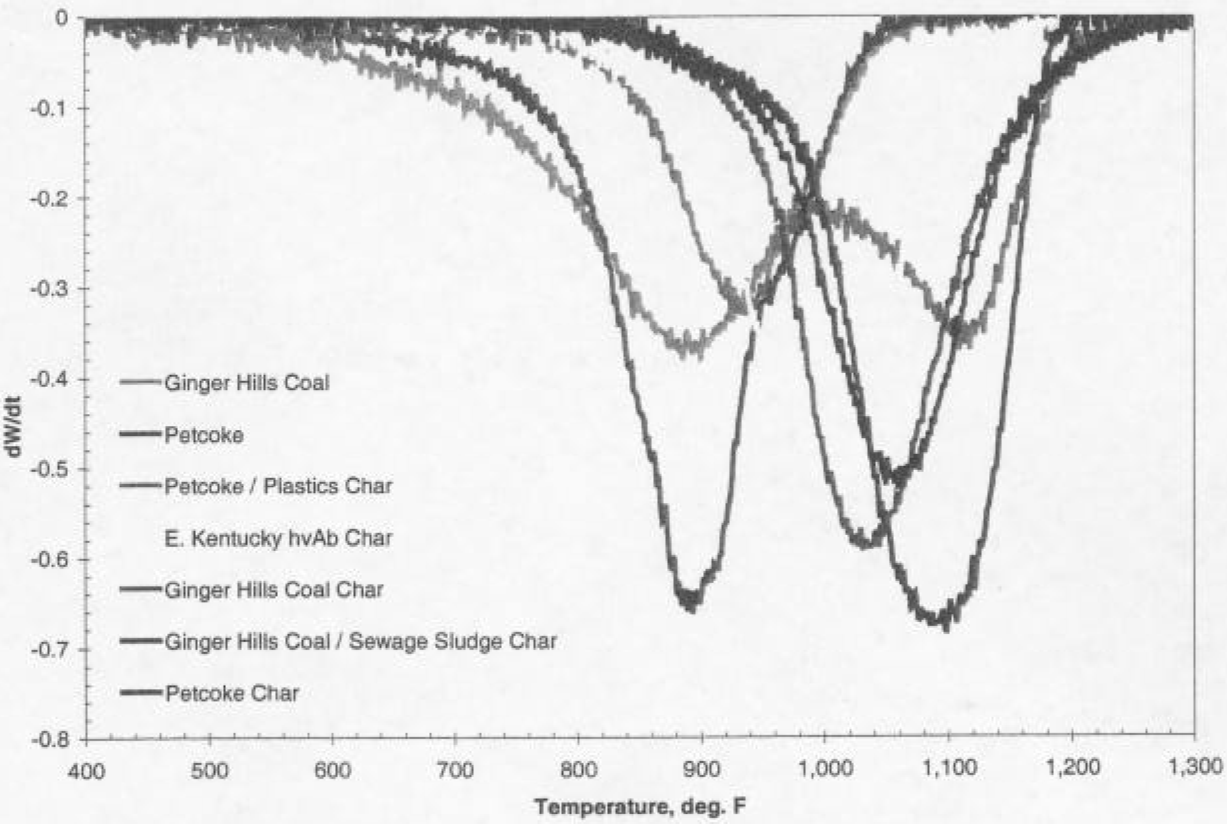

Figure 10 – Thermogravimetric Analyzer (TGA) Rate of Oxidation

3.4 Weak Alkali Leachability

The alkali metal elements in a fossil fuel that contribute to upper furnace fouling have long been associated with that fraction of the overall alkali elements that are ion exchangeable with the organic matter of the coal. These ion exchangeable constituents are found primarily as metal humates, particularly in low rank coals. The determination of the ion exchangeable fraction of the alkali elements will thus shed additional light on the fouling behavior of a particular fuel's ash over and above that indicated by its' overall elemental alkali concentration.

Alkali metal ions can be speciated from a fuel sample by a series of extractions. The water soluble fraction contains the alkali metals found as simple salts (CaCl2, Na2SO4, MgSO4). The ammonium acetate (NH4AC) soluble fraction contains the water soluble species plus those that are ion exchangeable. The difference between the water soluble fraction and the ammonium acetate soluble fraction represents, then, the fraction of a given alkali element that is ion exchangeable with the fuel's organic matter and therefor is likely to contribute to upper furnace fouling and related problems. Results from water and ammonium acetate solubility extraction of the three composite, pelletized fuels are given in Table 2, and Figures 11 and 12.

Table 2 – Leachable Alkali Analysis Data

Sample I.D.		**85% Pet Coke / 15% Mixed Plastics**		**80% Ginger Hill Coal / 20% Waxed Cardboard**		**80% Ginger Hill Coal / 20% Sewage Sludge**	
Basis		As-Test'd	As-Rcv'd	As-Test'd	As-Rcv'd	As-Test'd	As-Rcv'd
Air Dry Loss (wt%)			0.05		14.80		8.44
Moisture	(wt %)	0.27	0.32	1.67	16.22	1.32	9.65
Volatile Matter		31.94	31.92	42.36	36.09	34.10	31.22
Fixed Carbon		66.65	66.67	33.06	40.78	47.43	51.15
Ash		1.09	1.09	8.11	6.91	8.71	7.97
Basis		As-Test'd	% Oxide	As-Test'd	% Oxide	As-Test'd	% Oxide
H2O Leachable							
Na	(wt %)	0.003	0.37	0.018	0.30	0.015	0.23
K		0.001	0.11	0.002	0.03	0.005	0.07
Ca		0.010	1.28	0.049	0.85	0.071	1.14
Mg		0.001	0.15	0.001	0.02	0.009	0.17
NH4AC Leachable							
Na	(wt %)	0.004	0.49	0.023	0.38	0.013	0.20
K		0.001	0.11	0.003	0.04	0.006	0.08
Ca		0.065	8.34	0.353	6.09	0.254	4.08
Mg		0.010	1.52	0.016	0.33	0.014	0.27
Ash Composition Data - (Percent of Total Ash)							
Na2O	(wt %)		1.7		1.7		1.2
K2O			*8.4*		1.4		2.3
CaO			9.1		*4.6*		5.6
MgO			2.2		1.2		1.2

Sample I.D.		85% Pet Coke / 15% Mixed Plastics		80% Ginger Hill Coal / 20% Waxed Cardboard		80% Ginger Hill Coal / 20% Sewage Sludge	
Water Leachable (Percent of Element)							
Na	(wt %)		21.8		17.6		19.3
K			1.3		2.1		3.0
Ca			14.1		18.4		20.4
Mg			6.9		1.7		14.3
NH4AC - H2O Leachable (Percent of Element)							
Na	(wt %)		7.3		4.9		-2.6
K			0.0		1.1		0.6
Ca			77.6		*114.0*		52.5
Mg			62.2		25.6		7.9
Delta (Percent of Element)							
Na	(wt %)		70.9		77.5		83.2
K			98.7		96.8		96.4
Ca			8.3		*-32.4*		27.1
Mg			30.9		72.7		77.8

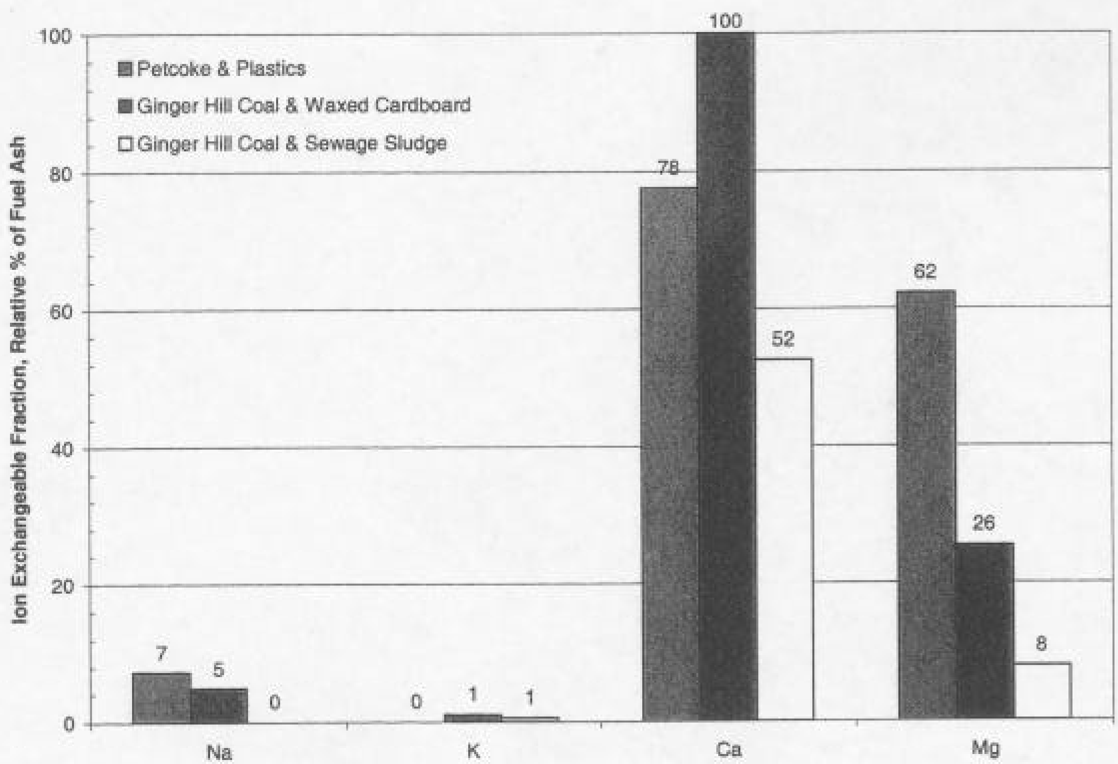

Figure 11 – Relative Ion Exchangeable Ash Fraction

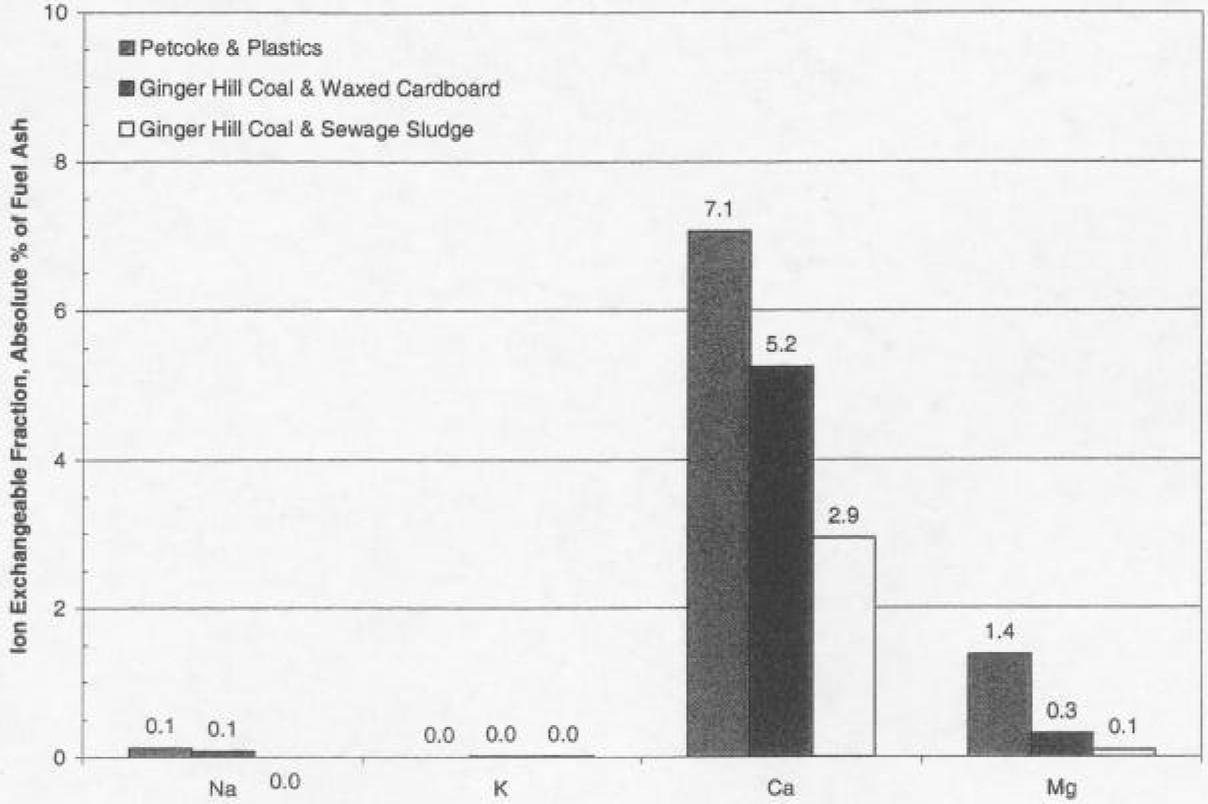

Figure 12 – Absolute Ion Exchangeable Ash Fraction

As shown, the majority of the total sodium and potassium alkali are tightly bound to the mineral matter (i.e. are not soluble in H2O or NH4AC). As a result, they are unlikely to contribute significantly to ash deposition and fouling. The calcium and magnesium, on the other hand, were largely extractable in ammonium acetate, thereby indicating that they would become available for fouling in the furnace convective pass. Of the three fuels, the Ginger Hill coal and sewage sludge mixture is, however, the best of the tested fuels by virtue of having the least ion exchangeable ash fractions on both a relative and absolute basis.

4. Combustor Applicability

4.1 Approach / Methodology

The stated objective of this work was to evaluate three, candidate, composite solid fuels or fuel blends for potential use in large scale, commercial combustors. Evaluated fuels included: (1) a combination of 85% pet coke with 15% mixed plastics, (2) a mixture of 80% Ginger Hill coal fines with 20% waxed cardboard, and (3) a combination of 80% Ginger Hill coal fines with 20% sewage sludge. Considered combustors included: Pulverized Coal (PC), Circulating Fluidized Bed (CFB), Stoker, and Cyclone fired boilers.

In assessing the applicability of the three solid fuels to the four noted combustor types, consideration was given to five primary impact areas based on each fuel's previously identified ASTM analysis, and performed bench scale pulverization and reactivity testing. These areas include:

1. Reactivity

   Defined here as the ability of the fuel to sustain ignition and provide for reasonable combustion efficiency in the absence of support fuel. Relevant fuel properties include as-fired volatile matter and moisture content, LHV, and char reactivity.

2. Slagging & Fouling Characteristics

   Defined here as the propensity for the fuel's ash to form deposits on the waterwall surfaces (slagging) and within the boiler's convective pass (fouling) thereby impacting heat transfer rates and boiler heat balance. Relevant fuel properties include ash fusion temperatures and ash composition / chemistry (ash type, iron content, base / acid ratio, Na and K content, ...).

3. Corrosion Behavior

   Defined here as the propensity of the fuel to corrode waterwall and / or convective surfaces due to the formation of hydrochloric (HCl) and / or sulfuric acid (H_2SO_4) in the combustion gases and related compounds. Relevant fuel properties include chlorine and sulfur content (wt%) and loading (lb/MMBtu).

4. Fuel Handling & Preparation

   Defined here as the ability of existing, field unit fuel handling and preparation equipment to process the fuel in pelletized form. Relevant fuel properties include pellet size and composition, and the higher heating value of the fuel (HHV) given in BTU's per pound of fuel.

5. Pellet Size & Integrity

   Defined here as the length and diameter of the individual pellets, the size of the raw (as-pelletized) constituents, and the pellet's physical integrity as they affect the combustion process. Relevant fuel properties include pellet size, and raw feed / constituent size within the pellet (i.e. % fines).

Results of an analysis considering the applicability of each of the three tested fuels for each of the four noted combustor types are summarized in Table 3.

As shown, Table 3 lists the overall applicability of each candidate fuel to a given combustor type, rated as "Low," "Medium," or "High," depending on the recommended maximum heat input rate for that fuel as fired in that combustor type. As defined here, a fuel rated Low in its applicability is not recommended for firing at more than 25% of maximum furnace heat input, a fuel rated as Medium in its applicability is recommended for firing at 25% to 50% of maximum furnace heat input, while a fuel rated as High is capable of being fired at greater than 50% of the maximum allowable furnace heat input rate, and can thus act as the primary combustor fuel.

Following the notation of overall applicability, a corresponding maximum recommended heat input is also given along with an itemization of the limiting constraint or series of constraints affecting the fuel's applicability. Noted constraints represent the predominant factors, and are not all inclusive in that an additional, unmentioned constraint may come into play at similar or slightly higher overall heat input levels.

It should be noted that the results of this analysis, including recommended maximum allowable heat input rates, were subjectively determined based upon provided ASTM analyses, performed bench scale tests, and ALSTOM Power Inc. experience for typical PC, CFB, Stoker and Cyclone fired combustors. Actual, field performance will, however, vary depending upon the specific field unit design and operation, and the analyses of the actual as-fired fuel(s) in comparison to those shown in Table 1.

Table 3 - Combustor Assessment

Application	85% Pet Coke	80% Ginger Hill	80% Ginger Hill
	15% Plastics	20% W. Crdbd.	20% S. Sludge
PC			
Applicability	*na*	*na*	High
Max Heat Input	0%	0%	>90%
Constraint(s)	Milling	Milling	Slagging &
	Corrosion		Fouling
CFB			
Applicability	Medium	High	High
Max Heat Input	50%	>90%	>90%
Constraint(s)	Size & Integ.	Size & Integ.	Size & Integ.
	Corrosion		
Stoker			
Applicability	Low	Medium	Medium
Max Heat Input	10%	50%	50%
Constraint(s)	Ash Content	Size & Integ.	Size & Integ.
	Corrosion	*Ash Content*	
Cyclone			
Applicability	Medium	Medium	Medium
Max Heat Input	25%	50%	50%
Constraint(s)	Size & Integ.	Size & Integ.	Size & Integ.
	React. / Corr.		

4.2 Discussion

Of the tested fuels, the 80% Ginger Hill coal and 20% sewage sludge is the most broadly applicable, being suitable for use at greater than or equal to 50% maximum continuous rating (MCR) heat input for each of the four considered combustor types. For PC and CFB firing, the as-tested Ginger Hill / sewage sludge fuel may be used at ≥ 90% MCR maximum heat input, with limitations based on slagging & fouling concerns, which are related to the design and operation of the specific field unit (e.g. size of the box and firing rate), and pellet size & integrity, which is related to the raw feed size (re. size of fines) and pelletizing equipment characteristics, respectively. For Stoker and Cyclone firing, this fuel is rated at up to 50% maximum heat input, with limitations based on fuel pellet size and integrity as they affect the fuel handling equipment performance and the combustion process.

Of the remaining two fuels, the second most desirable combination is the 80% Ginger Hill coal and 20% waxed cardboard mixture, which is generally applicable to CFB, Stoker and Cyclone type combustors. Limitations on these three combustor types were primarily related to as-fired particle size and integrity (re. % fines), and ash content as it may affect bed cooling in a Stoker fired boiler (Note: the water content of the as-tested fuel at 16% is more than sufficient to compensate for the lower than desired ash content with regard to bed cooling). The fuel handling characteristics of the Ginger Hill coal / waxed cardboard blend was shown to be not favorable for PC applications as the fuel exhibited difficulty with both size reduction and bed pad (deposit) formation during the bench scale pulverization experiments which indicate a strong potential for problems if applied to a commercial pulverizer.

The last fuel, the 85% pet coke and 15% mixed plastics blend is the least favorable of the tested fuels, regardless of the considered combustor type. For PC boilers, the difficulty encountered in bench scale pulverization with regard to size reduction and bed pad formation suggest problems for field application to a commercial pulverizer that need to be further explored before the fuel can be recommended at any level. For CFB's, the fineness of the pet coke fraction (nominally 30 microns mass mean diameter) will likely result in high levels of unburned carbon in the ash and poor combustion / boiler efficiency due poor capture efficiency in the cyclone. For Stoker fired boilers, the combination of low ash (~1%) and water contents (>1%) make the fuel unsuitable at high mass fractions due to grate overheating concerns. Finally, for Cyclone fired combustors, the size and integrity of the particles, low ash content, and the low reactivity of the pet coke all contribute to limit the applicability of this as significant fractions of the total boiler heat input. In addition, owing to the random nature of the mixed plastics supply, the test fuel had a high (0.37%) chlorine content, which may lead to undesirable rates of corrosion for all four combustor types, further limiting the applicability of this fuel. *Note: the high, 4.5% sulfur content of the pet coke and plastics fuel will also likely be a concern for certain boilers both with regard to SO2 formation and capture, and corrosion potential.*

In all cases these recommendations are based on an assumed, "typical" boiler in each of the four combustor classes. Specific performance issues affecting a given fuel's applicability will, however, need to be determined on a case by case basis.

5. Conclusions and Recommendations

Based on the ASTM fuel analyses and bench scale test results it was found that the 80% Ginger Hill coal / 20% sewage sludge pelletized fuel is the best of the three examined fuel blends, being generally applicable to each of the four noted combustor types: PC, CFB, Stoker and Cyclone. It exhibited no obviously detrimental behavior in the bench scale pulverizer testing, and is sufficiently reactive to provide for stable ignition and reasonable carbon burnout levels as compared to a typical, eastern bituminous coal. The only significant drawback to the present composition is the ability of the fuel pellets to maintain a reasonable degree of integrity to allow for sufficient residence time for complete combustion as applied to Stoker and Cyclone fired boilers.

As for the remaining two fuels, neither of the 85% pet coke / 15% mixed plastics fuel and the 80% Ginger Hill / 20% waxed cardboard fuels are generally applicable to all combustor types, and only the Ginger Hill / waxed cardboard fuel is applicable as a primary fuel in any one. Both of these fuels exhibited significant problems in the bench scale pulverization testing including difficulty in size reduction and bed pad formation making them inapplicable to PC firing with this work as the only screening tool. As for the Ginger Hill coal / sewage sludge blend, common problems for both these fuels include pellet size and integrity as it impacts the ability of the fuel to be transported to and combusted in a CBF, Cyclone or Stoker fired boiler. The pet coke and mixed plastics fuel compounds this problem with the addition of a low reactivity char, which combined with its small (~30 micron) particle size may compound combustion efficiency issues for these three combustor types. In addition, it suffers from high (0.37%) chlorine, which is both undesirable, and indicative of the issues in firing a mixed plastic blend.

As a result of the foregoing analysis, only the 80% Ginger Hill / 20% sewage sludge fuel is recommended for further evaluation during Phase II of this work.

6.0 Appendix

6.1 Standard Laboratory Pelletized Fuel Sample Analysis Sheets

P. O. BOX 214
CRESSON, PA 16630
(814) 886-7400
STANDARD LABORATORIES, INC.

DATE: 1-13-2000
SAMPLE NO. 616597

C. Q., INC.
160 QUALITY CENTER ROAD
HOMER CITY, PA 15748

SAMPLE ID: PELLETS 85% PETROLEUM COKE/15% PLASTICS

:RATING CO.: 99111801
IPLED BY: CUSTOMER PROVIDED
IE:
:ATION:

'E SAMPLED: 11/18/99 DATE RECEIVED: 11/30/99
ITHER:
ISS WEIGHT: 10359.9 G

IER ID: PROJECT 99E0331 T1.5, BIOMASS PELLET CHARACTERIZATION

CERTIFICATE OF ANALYSIS

	ASTM METHOD	AS RECEIVED	DRY BASIS
IOISTURE	D2961 D3302 D3173	.46%	XXX
'OLATILE MATTER		27.46%	27.59%
'IXED CARBON	D3172	71.12%	71.45%
SH	D3174	.96%	.96%
ULFUR	D4239 METHOD 3.3	4.54%	4.56%
ARBON	D3178	85.14%	85.54%
YDROGEN	D3178	5.02%	5.05%
ITROGEN	D3179	.99%	1.00%
XYGEN	D3176	2.89%	2.90%
TU/LB	D2015 D1989	15373	15444
AF BTU/LB			15595
BS OF SO2 PER MILLION BTU			5.90
BS OF SULFUR PER MILLION BTU		2.953	
REE SWELLING INDEX	D720	1.0	
ARDGROVE GRINDABILITY INDEX	D409	44	
HLORINE	D4208	.37%	.37%
LUORINE	D3761	91.94 PPM	92.37 PPM
ERCENT SOLIDS			99.54%
ULK DENSITY		33.29 LB./CU.FT.	

AGE 1

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BLACK SEAL ANALYSIS

STANDARD LABORATORIES, INC.

DATE: 1-13-2000
SAMPLE NO. 616597

CERTIFICATE OF ANALYSIS (CONT.)

	AS RECEIVED	DRY BASIS
ASH FUSION TEMPERATURE(S)		
D1857	REDUCING ATMOSPHERE	
INITIAL DEFORMATION TEMPERATURE	2065	
SOFTENING TEMPERATURE	2110	
HEMISPHERICAL TEMPERATURE	2135	
FLUID TEMPERATURE	2150	
D1857	OXIDIZING ATMOSPHERE	
INITIAL DEFORMATION TEMPERATURE	2285	
SOFTENING TEMPERATURE	2330	
HEMISPHERICAL TEMPERATURE	2380	
FLUID TEMPERATURE	2425	
ASH MINERAL COMPOSITION		
D2795 D3682		
ILICON DIOXIDE		25.25 %
LUMINIUM OXIDE		5.63 %
ERRIC OXIDE		8.97 %
ITANIUM DIOXIDE		5.95 %
HOSPHORUS PENTOXIDE		.04 %
ALCIUM OXIDE		9.08 %
AGNESIUM OXIDE		2.17 %
ODIUM OXIDE		1.68 %
OTASSIUM OXIDE		8.39 %
ULFUR TRIOXIDE		15.14 %

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STANDARD LABORATORIES, INC.

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160 QUALITY CENTER ROAD
HOMER CITY, PA 15748

SAMPLE ID: PELLETS 85% PETROLEUM COKE/15% PLASTICS

RATING CO.: 99111801
PLED BY: CUSTOMER PROVIDED
E:
ATION:

E SAMPLED: 11/18/99 DATE RECEIVED: 11/30/99
THER:
SS WEIGHT: 10359.9 G

ER ID: PROJECT 99E0331 T1.5, BIOMASS PELLET CHARACTERIZATION

CERTIFICATE OF ANALYSIS

ASTM METHOD	AS RECEIVED	DRY BASIS
D3683 D3684 D3684 (MODIFIED)		
TRACE ELEMENTS IN COAL		
RSENIC		.63 PPM
ADMIUM		< .12 PPM
HROMIUM		3.77 PPM
EAD		25.92 PPM
ERCURY		51.80 PPB
ICKEL		117.84 PPM
ELENIUM		1.15 PPM
INC		39.36 PPM
ERYLLIUM		< .10 PPM
OBALT		3.67 PPM
ANGANESE		4.44 PPM
opper		12.24 ppm

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P. O. BOX 214
CRESSON, PA 16630
(814) 886-7400
STANDARD LABORATORIES

DATE: 1-14-
SAMPLE NO. 6

C. Q., INC.
160 QUALITY CENTER ROAD
HOMER CITY, PA 15748

SAMPLE ID: PELLETS 80% QHS COAL/20% WAXED CARDBOARD

OPERATING CO.: 99110901
SAMPLED BY: CUSTOMER PROVIDED
MINE:
LOCATION:

DATE SAMPLED:
WEATHER:
GROSS WEIGHT: 12135.

DATE RECEIVED: 11/23/99

OTHER ID: PROJECT 99E0331 T1.5 BIOMASS PELLET CHARACTERIZATION

CERTIFICATE OF ANALYSIS

	ASTM METHOD	AS RECEIVED	DRY BASIS
MOISTURE	D2961 D3302 D3173	16.22%	XXX
VOLATILE MATTER		37.96%	45.31%
FIXED CARBON	D3172	39.75%	47.44%
ASH	D3174	6.07%	7.25%
SULFUR	D4239 METHOD 3.3	1.21%	1.44%
CARBON	D3178	61.12%	72.96%
HYDROGEN	D3178	4.72%	5.64%
NITROGEN	D3179	.99%	1.18%
OXYGEN	D3176	9.67%	11.53%
BTU/LB	D2015 D1989	10933	13050
MAF BTU/LB			140[illegible]
LBS OF SO2 PER MILLION BTU			2.20
LBS OF SULFUR PER MILLION BTU		1.107	
FREE SWELLING INDEX	D720	4.5	
HARDGROVE GRINDABILITY INDEX	D409	34	
CHLORINE	D4208	.08%	.10%
FLUORINE	D3761	64.30 PPM	76.75 PPM
PERCENT SOLIDS			83.78%

PAGE 1

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DATE: 1-14-
SAMPLE NO. 6

C. Q., INC.
160 QUALITY CENTER ROAD
HOMER CITY, PA 15748

SAMPLE ID: PELLETS 80% QHS COAL/20% WAXED CARDBOARD

OPERATING CO.: 99110901
SAMPLED BY: CUSTOMER PROVIDED
MINE:
LOCATION:

DATE SAMPLED:
WEATHER:
GROSS WEIGHT: 12135.

DATE RECEIVED: 11/23/99

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CERTIFICATE OF ANALYSIS

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MOISTURE	D2961 D3302 D3173	16.22%	XXX
VOLATILE MATTER		37.96%	45.31%
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CARBON	D3178	61.12%	72.96%
HYDROGEN	D3178	4.72%	5.64%
NITROGEN	D3179	.99%	1.18%
OXYGEN	D3176	9.67%	11.53%
BTU/LB	D2015 D1989	10933	13050
MAF BTU/LB			140[illegible]
LBS OF SO2 PER MILLION BTU			2.20
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FLUORINE	D3761	64.30 PPM	76.75 PPM
PERCENT SOLIDS			83.78%

PAGE 1

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BLACK SEAL ANALYSIS

STANDARD LABORATORIES

DATE: 1-13-
SAMPLE NO.

CERTIFICATE OF ANALYSIS (CONT.)

AS RECEIVED DRY BASIS

ASH FUSION TEMPERATURE(S)

D1857	REDUCING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	2170
SOFTENING TEMPERATURE	2190
HEMISPHERICAL TEMPERATURE	2230
FLUID TEMPERATURE	2285
D1857	**OXIDIZING ATMOSPHERE**
INITIAL DEFORMATION TEMPERATURE	2340
SOFTENING TEMPERATURE	2400
HEMISPHERICAL TEMPERATURE	2415
FLUID TEMPERATURE	2430

ASH MINERAL COMPOSITION
D2795 D3682

SILICON DIOXIDE	46.60 %
ALUMINIUM OXIDE	20.51 %
FERRIC OXIDE	13.89 %
TITANIUM DIOXIDE	1.70 %
PHOSPHORUS PENTOXIDE	.09 %
CALCIUM OXIDE	4.57 %
MAGNESIUM OXIDE	1.22 %
SODIUM OXIDE	1.73 %
POTASSIUM OXIDE	1.42 %
SULFUR TRIOXIDE	7.44 %

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BLACK SEAL ANALYSIS

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(814) 886-7400
STANDARD LABORATORIES

DATE: 1-13-
SAMPLE NO. 6

C. Q., INC.
160 QUALITY CENTER ROAD
HOMER CITY, PA 15748

SAMPLE ID: PELLETS 80% GHS COAL/20% WAXED CARDBOARD

OPERATING CO.: 99110901
SAMPLED BY: CUSTOMER PROVIDED
MINE:
LOCATION:

DATE SAMPLED:
WEATHER:
GROSS WEIGHT: 12135.

DATE RECEIVED: 11/23/99

OTHER ID: PROJECT 99E0331 T1.5 BIOMASS PELLET CHARACTERIZATION

CERTIFICATE OF ANALYSIS

ASTM METHOD	AS RECEIVED	DRY BASIS

D3683 D3684 D3684 (MODIFIED)

TRACE ELEMENTS IN COAL

ARSENIC		1.91 PPM
CADMIUM	<	.91 PPM
CHROMIUM		15.59 PPM
LEAD		188.50 PPM
MERCURY		78.19 PPB
NICKEL		16.67 PPM
SELENIUM		.93 PPM
ZINC		141.38 PPM
BERYLLIUM	<	.73 PPM
COBALT		19.94 PPM
MANGANESE		24.65 PPM
Copper		16.13 ppm

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BLACK SEAL ANALYSIS

STANDARD LABORATORIES

GOULD ENERGY DIVISION
P.O. BOX 214
CRESSON, PA 16630

DATE: 01-14-00
SAMPLE NO: 613527

CQ, INC.
160 QUALITY CENTER ROAD
HOMER CITY, PA 15748

DATE SAMPLED: DATE RECEIVED: 11-23-99

SAMPLE ID: PELLETS 80% GHS COAL 20% WAXED CARDBOARD
OPERATING CO: 99110901
SAMPLED BY: CUSTOMER PROVIDED

GROSS WEIGHT: 12135.
OTHER ID: PROJECT 99E0331 T1.5 BIOMASS PELLET CHARACTERIZATI

CERTIFICATE OF ANALYSIS

TCLP ANALYSIS

ARSENIC		39.15	ppb
BERYLLIUM	<	0.04	ppm
CADMIUM	<	0.05	ppm
CHROMIUM	<	0.10	ppm
COBALT	<	0.25	ppm
COPPER		0.12	ppm
LEAD		13.8	ppm
MANGANESE		1.80	ppm
MERCURY	<	0.50	ppb
NICKEL		0.12	ppm
SELENIUM		83.61	ppb
ZINC		13.9	ppm

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GOULD ENERGY DIVISI
P. O. BOX 214
CRESSON, PA 16630
(814) 886-7400
STANDARD LABORATORIES

DATE: 1-28-
SAMPLE NO. (

C. Q., INC.
160 QUALITY CENTER ROAD
HOMER CITY, PA 15748

SAMPLE ID:

OPERATING CO.: TEST 99121001
SAMPLED BY: CUSTOMER PROVIDED
MINE:
LOCATION:

DATE SAMPLED: 12/10/99 DATE RECEIVED: 12/14/99
WEATHER:
GROSS WEIGHT: 7641.8 GR

OTHER ID: PROJECT 99E0331 T1.5, BIOMAS PELLET CHARACTERIZATION PELLI
0% GHS COAL/20% SEWAGE SLUDGE (PELLETS AIR DRIED FOR 72 HOURS)

CERTIFICATE OF ANALYSIS

	ASTM METHOD	AS RECEIVED	DRY BASIS
MOISTURE	D2961 D3302 D3173	9.17%	XXX
VOLATILE MATTER		32.55%	35.84%
FIXED CARBON	D3172	50.22%	55.28%
ASH	D3174	8.06%	8.88%
SULFUR	D4239 METHOD 3.3	1.56%	1.71%
CARBON	D3178	68.80%	75.75%
HYDROGEN	D3178	4.56%	5.02%
NITROGEN	D3179	1.24%	1.36%
OXYGEN	D3176	6.61%	7.28%
BTU/LB	D2015 D1989	12374	13624
MAF BTU/LB			14951
LBS OF SO2 PER MILLION BTU			2.51
LBS OF SULFUR PER MILLION BTU		1.261	
FREE SWELLING INDEX	D720	9.0	
HARDGROVE GRINDABILITY INDEX	D409	67	
CHLORINE	D4208	.16%	.18%
PERCENT SOLIDS			90.83%
BULK DENSITY		32.48 LB./CU FT.	

PAGE 1

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BLACK SEAL ANALYSIS

STANDARD LABORATORIES

DATE: 1-28
SAMPLE NO.

CERTIFICATE OF ANALYSIS (CONT.)

AS RECEIVED DRY BASIS

ASH FUSION TEMPERATURE(S)

D1857	REDUCING ATMOSPHERE
INITIAL DEFORMATION TEMPERATURE	2045
SOFTENING TEMPERATURE	2090
HEMISPHERICAL TEMPERATURE	2130
FLUID TEMPERATURE	2170
D1857	**OXIDIZING ATMOSPHERE**
INITIAL DEFORMATION TEMPERATURE	2290
SOFTENING TEMPERATURE	2350
HEMISPHERICAL TEMPERATURE	2380
FLUID TEMPERATURE	2400

ASH MINERAL COMPOSITION
D2795 D3682

SILICON DIOXIDE	45.27 %
ALUMINIUM OXIDE	20.58 %
FERRIC OXIDE	15.72 %
TITANIUM DIOXIDE	1.10 %
PHOSPHORUS PENTOXIDE	2.11 %
CALCIUM OXIDE	5.56 %
MAGNESIUM OXIDE	1.24 %
SODIUM OXIDE	1.20 %
POTASSIUM OXIDE	2.28 %
SULFUR TRIOXIDE	6.97 %

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BLACK SEAL ANALYSIS

Y

GOULD ENERGY DIVISI
P. O. BOX 214
CRESSON, PA 16630
(814) 886-7400
STANDARD LABORATORIES

DATE: 1-28-
SAMPLE NO. (

C. Q., INC.
160 QUALITY CENTER ROAD
HOMER CITY, PA 15748

SAMPLE ID:

OPERATING CO.: TEST 99121001
SAMPLED BY: CUSTOMER PROVIDED
MINE:
LOCATION:

DATE SAMPLED: 12/10/99 DATE RECEIVED: 12/14/99
WEATHER:
GROSS WEIGHT: 7641.8 GR

OTHER ID: PROJECT 99E0331 T1.5, BIOMAS PELLET CHARACTERIZATION PELLE
0% GHS COAL/20% SEWAGE SLUDGE (PELLETS AIR DRIED FOR 72 HOURS)

CERTIFICATE OF ANALYSIS

	ASTM METHOD	AS RECEIVED	DRY BASIS
	D3683 D3684 D3684 (MODIFIED)		
	TRACE ELEMENTS IN COAL		
ARSENIC			9.26 PPM
CADMIUM		<	1.11 PPM
CHROMIUM			20.20 PPM
LEAD			9.99 PPM
MERCURY			63.85 PPB
NICKEL			16.21 PPM
SELENIUM			1.57 PPM
ZINC			41.51 PPM
BERYLLIUM		<	.89 PPM
COBALT			20.42 PPM
MANGANESE			48.84 PPM
Copper			36.41 ppm

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BLACK SEAL ANALYSIS

STANDARD LABORATORIES
GOULD ENERGY DIVISION
P.O. BOX 214
CRESSON, PA 16630

DATE: 1-28-00
SAMPLE NO: 618774

CQ, INC.
160 QUALITY CENTER ROAD
HOMER CITY, PA 15748

DATE SAMPLED: 12-10-99 DATE RECEIVED: 12-14-99

SAMPLE ID: PROJECT 99E0331 T1.5, BIOMASS PELLET CHARACTERIZATIO
PELLETS 80% GHS COAL/20% SEWAGE SLUDGE (PELLETS AIR DRIED FOR 72 HOURS)

CERTIFICATE OF ANALYSIS

TCLP ANALYSIS

ARSENIC		4820.5	ppb
BERYLLIUM	<	0.04	ppm
CADMIUM	<	0.05	ppm
CHROMIUM	<	0.10	ppm
COBALT		0.32	ppm
COPPER	<	0.04	ppm
LEAD		0.29	ppm
MANGANESE		4.90	ppm
MERCURY	<	0.50	ppb
NICKEL		0.31	ppm
SELENIUM		466.6	ppb
ZINC		0.07	ppm

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6.2 ALSTOM Power Inc. Pet Coke Analyses Sheets

1

ABB COMBUSTION ENGINEERING
POWER PLANT LABORATORIES CHEMICAL ANALYTICAL SERVICES
WINDSOR, CONNECTICUT
FUEL ANALYSIS REPORT

COMPANY : CQ INC
LOCATION : PPL DTFS
SAMPLE ID: CQ PETCOKE NO. 99110801
CONTRACT :

KDL NUMBER: 0-0626-C
ANAL DATE : 06/02/00
PROJECT : 8904XX

	AS RECEIVED	MOISTURE FREE	MOISTURE & ASH FREE
AIR DRY LOSS, WT. PERCENT	6.8		
PROXIMATE ANAL., WT. PERCENT			
MOISTURE (TOTAL)	7.2		
VOLATILE MATTER	13.3	14.3	14.4
FIXED CARBON (DIFF.)	78.9	85.1	85.6
ASH	0.6	0.6	
TOTAL	100	100	100
HHV. BTU/LB	14123	15219	15313
LB ASH/MM BTU	0.4		
ULTIMATE ANAL., WT. PERCENT			
MOISTURE (TOTAL)	7.2		
HYDROGEN	3.9	4.2	4.2
CARBON	81.4	87.7	88.2
SULFUR	5.0	5.4	5.4
NITROGEN	1.4	1.5	1.5
OXYGEN (DIFF)	0.5	0.6	0.7
ASH	0.6	0.6	
TOTAL	100	100	100

ÉÍÍÍ»
º REMARKS/OTHER DATA º
º CILAS PARTICLE SIZING DONE ON -60 MESH º
º DTFS FEED SAMPLE º
º º
º º
º º
º º
º º

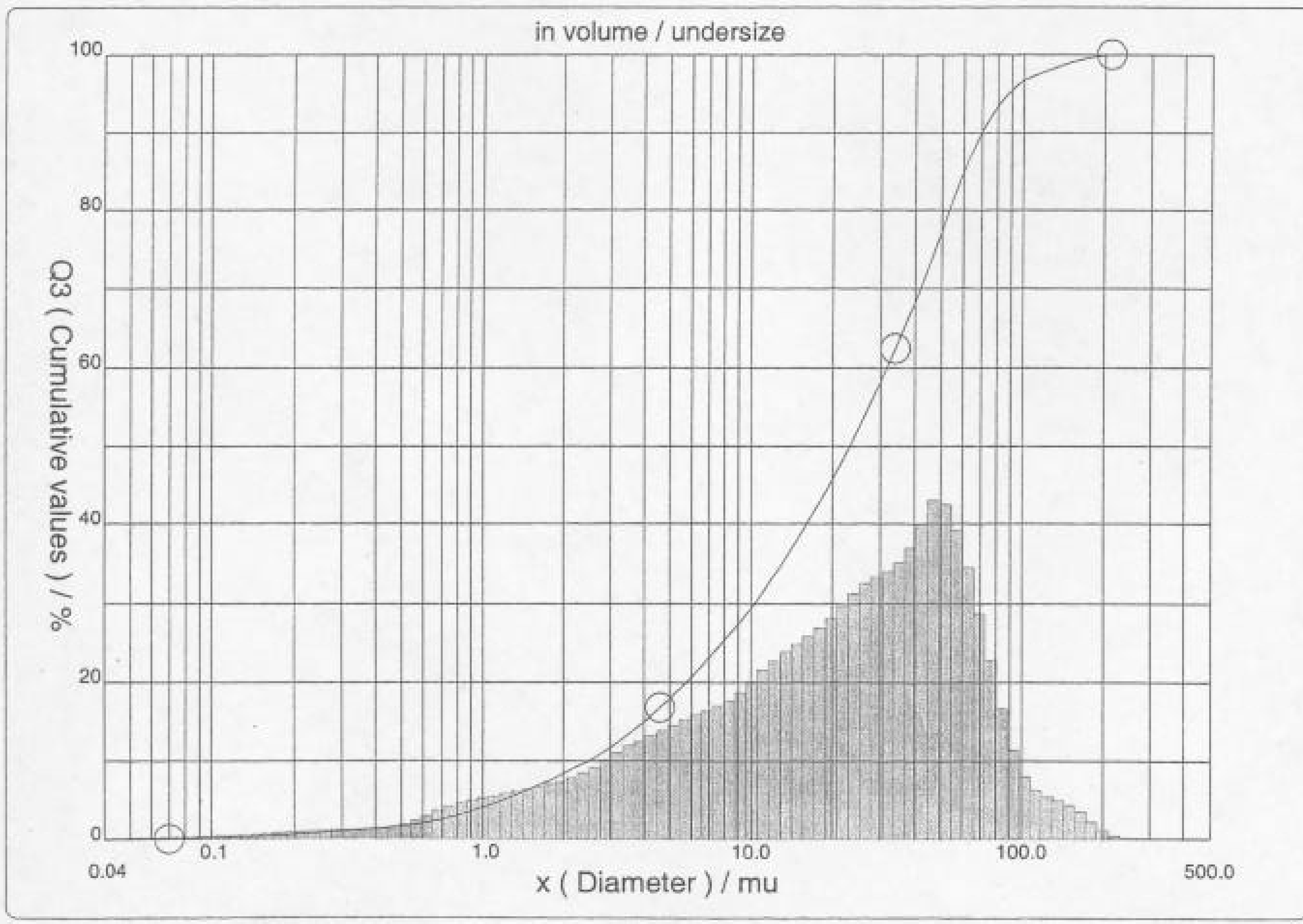
PARTICLE SIZE DISTRIBUTION

CILAS 1064 Liquid

Range : 0.04 mu - 500.00 mu / 100 Classes

Sample Ref	: 0-0626-C
Type produit	: PetCoke
Client	: AAP PPL Chemistry Lab
Comments	: CQ Inc Petcoke - <60 mesh
Liquid	: Water (eau)
Dispersing agent	: Triton x-100
Operator	: Kurt
Company	: ABB Alstom Power
Location	: Power Plant Laboratories
Date : 05/31/2000	Time : 10:42:39AM
Index meas.	: 658

Ultrasounds	: 60 s
Concentration	: 109
Diameter at 10%	: 2.47 mu
Diameter at 50%	: 23.20 mu
Diameter at 90%	: 70.04 mu
Mean diameter	: 31.84 mu
Fraunhofer	
Density/Factor	----------
Specific surface	----------
Auto. dilution/top up	: Yes / No
Nb Measur./Rins.	: 20 / 4



CILAS

PARTICLE SIZE DISTRIBUTION

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Diameter at 50%	: 23.20 mu
Diameter at 90%	: 70.04 mu
Mean diameter	: 31.84 mu
Fraunhofer	
Density/Factor	----------
Specific surface	----------
Auto. dilution/top up	: Yes / No
Nb Measur./Rins.	: 20 / 4

Standards classes in volume / undersize

x	0.04	0.07	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80
Q3	0.01	0.11	0.23	0.66	1.10	1.46	1.77	2.14	2.58	3.10
q3	0.00	0.01	0.02	0.04	0.07	0.09	0.09	0.14	0.20	0.27
x	0.90	1.00	1.10	1.20	1.30	1.40	1.60	1.80	2.00	2.20
Q3	3.63	4.15	4.65	5.12	5.58	6.02	6.85	7.63	8.37	9.07
q3	0.31	0.34	0.36	0.37	0.39	0.41	0.42	0.45	0.48	0.50
x	2.40	2.60	2.80	3.00	3.20	3.40	3.60	3.80	4.00	4.30
Q3	9.75	10.42	11.08	11.74	12.41	13.07	13.72	14.37	15.00	15.92
q3	0.53	0.57	0.61	0.65	0.71	0.74	0.78	0.82	0.84	0.87
x	4.60	5.00	5.30	5.60	6.00	6.50	7.00	7.50	8.00	8.50
Q3	16.81	17.96	18.79	19.59	20.63	21.87	23.06	24.19	25.28	26.32
q3	0.90	0.94	0.97	0.99	1.03	1.06	1.10	1.12	1.15	1.17
x	9.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00
Q3	27.33	29.29	31.20	33.06	34.85	36.58	38.25	39.85	41.39	42.88
q3	1.21	1.27	1.37	1.46	1.53	1.60	1.66	1.70	1.74	1.78
x	19.00	20.00	21.00	22.00	23.00	25.00	28.00	30.00	32.00	34.00
Q3	44.32	45.72	47.08	48.42	49.73	52.28	55.91	58.19	60.34	62.40
q3	1.82	1.87	1.91	1.97	2.01	2.09	2.19	2.26	2.28	2.32
x	36.00	38.00	40.00	43.00	45.00	50.00	53.00	56.00	60.00	63.00
Q3	64.38	66.29	68.15	70.90	72.71	77.19	79.70	82.02	84.76	86.56
q3	2.37	2.42	2.48	2.60	2.72	2.91	2.95	2.88	2.72	2.52
x	66.00	71.00	75.00	80.00	85.00	90.00	95.00	100.0	112.0	125.0
Q3	88.16	90.42	91.89	93.38	94.53	95.42	96.09	96.60	97.45	98.10
q3	2.35	2.12	1.83	1.58	1.30	1.06	0.85	0.68	0.51	0.40
x	130.0	140.0	150.0	160.0	170.0	180.0	190.0	200.0	212.0	224.0
Q3	98.31	98.69	99.01	99.29	99.51	99.69	99.80	99.89	99.95	99.99
q3	0.37	0.35	0.32	0.30	0.25	0.22	0.14	0.12	0.07	0.05
x	240.0	250.0	280.0	300.0	315.0	355.0	400.0	425.0	450.0	500.0
Q3	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
q3	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

x : diameter / mu Q3 : cumulative value / % q3 : population density / %

APPENDIX E

PRO-FORMA and SUPPORTING CALCULATIONS
for
PLANT 1: ANTHRACITE FINES and MIXED PLASTICS

Table E-1
Statement of Revenues and Expenses Pro-Forma
Anthracite/Plastic

							Esc.	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
								6,500.0	6,597.5	6,696.5	6,796.9	6,898.9	7,002.3	7,107.4	7,214.0	7,322.2	7,432.0
			100,000	tpy				6,500.0	6,597.5	6,696.5	6,796.9	6,898.9	7,002.3	7,107.4	7,214.0	7,322.2	7,432.0
	65.00	$/ton	100,000	tpy		65.000	1.5%	6,500.0	6,597.5	6,696.5	6,796.9	6,898.9	7,002.3	7,107.4	7,214.0	7,322.2	7,432.0
	2.50	/$/MBtu															
	0.00	$/ton	0	tpy			1.5%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
								0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.00	$/ton	11,758	tpy		0.000	2.5%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	0.00	$/ton	0	tpy			2.5%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
						53.298		5,329.8	5,357.4	5,381.9	5,402.8	5,419.8	5,432.2	5,439.5	5,482.0	5,571.8	5,663.4
	12.80	$/ton	100,000	tpy		12.800	2.5%	1,280.0	1,312.0	1,344.8	1,378.5	1,412.9	1,448.2	1,484.4	1,521.6	1,559.6	1,598.6
	17.12	$/ton	105,818	tpy		18.118	1.5%	1,811.8	1,838.9	1,866.5	1,894.5	1,922.9	1,951.8	1,981.1	2,010.8	2,040.9	2,071.6
	0.80	/$/MBtu															
	0.060	$/kWh	4,681,760	kWh/yr		2.809	1.5%	280.9	285.1	289.4	293.7	298.1	302.6	307.2	311.8	316.4	321.2
	4.25	$/k-cu-ft	77,277	k-cu-ft/yr		3.284	2.5%	328.4	336.6	345.1	353.7	362.5	371.6	380.9	390.4	400.2	410.2
	0.00	$/ton	100,000	tpy		0.000	2.5%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	5.0%	fuel sales	100,000	tpy		3.250		325.0	329.9	334.8	339.8	344.9	350.1	355.4	360.7	366.1	371.6
								75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0
ler	0.75	$/ton	100,000	tpy		0.750		75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0
	1.0%		7,876,637				1.5%	78.8	79.9	81.1	82.4	83.6	84.9	86.1	87.4	88.7	90.1
	25,000	$/year					1.5%	25.0	25.4	25.8	26.1	26.5	26.9	27.3	27.7	28.2	28.6
	1.0%		4,029,480				0.0%	40.3	40.3	40.3	40.3	40.3	40.3	40.3	40.3	40.3	40.3
nse	12	years	7,876,637					656.4	656.4	656.4	656.4	656.4	656.4	656.4	656.4	656.4	656.4
	7	years	$5,000,000		9.0%			428.2	377.8	322.7	262.4	196.5	124.3	45.5	0.0	0.0	0.0
s								1,170.2	1,240.1	1,314.5	1,394.1	1,479.1	1,570.2	1,667.9	1,731.9	1,750.4	1,768.6
ation								656.4	656.4	656.4	656.4	656.4	656.4	656.4	656.4	656.4	656.4
t								(537.1)	(587.5)	(642.6)	(702.9)	(768.9)	(841.0)	(919.9)	0.0	0.0	0.0
ow								1,289.5	1,308.9	1,328.3	1,347.5	1,366.6	1,385.6	1,404.4	2,388.3	2,406.8	2,425.0
	38.1%	Equity					(3,076.6)	0.0	0	0	0	0	0	0	0	0	0
								0	0	0	0	0	0	0	0	0	0
e	15.0%	of aquisition bare equipment costs						0	0	0	0	0	0	0	0	0	0
al								0	0	0	0	0	0	0	0	0	0
		ROI=	44.74%				(3,076.6)	1,289.5	1,308.9	1,328.3	1,347.5	1,366.6	1,385.6	1,404.4	2,388.3	2,406.8	2,425.0
s	35.0%							(409.6)	(434.0)	(460.1)	(487.9)	(517.7)	(549.6)	(583.8)	(606.2)	(612.6)	(619.0)
		ROI=	30.55%				(3,076.6)	879.9	874.9	868.2	859.6	848.9	836.0	820.6	1,782.2	1,794.1	1,806.0

99E0331\T1-6\PERF_A-P.WK4

Table E-2
Capital Costs
Anthracite/Plastic

Equipment	No.	Capacity	Units	Unit HP	Total HP	Unit Cost	Cost
Coal Receiving Hopper	1	100	cu-ft	0	0	15,000	15,000
Coal Receiving Hopper Feeder	1	100	tph	5	5	10,000	10,000
Coal Feed Conveyor	1	100	tph	15	15	25,000	25,000
Tramp Iron Magnet	1			5	5	7,500	7,500
100 Ton Coal Surge Bin	1	100	tons	0	0	100,000	100,000
Coal Bin Activator	1	50	tons	2	2	13,000	13,000
Coal Weigh Feeder	1	50	tph	2	2	23,000	23,000
Coal Conveyor	1	50	tph	7.5	7.5	20,000	20,000
Coal Elevator	1	50	tph	10	10	25,000	25,000
Coal Crusher Bag House	1	11,000	cfm	30.5	30.5	40,000	40,000
Dryer/Heater System	1	30	tph	150	150	875,000	875,000
Plastic Receiving Hopper and Feeder	1	20	tph	7.5	7.5	75,000	75,000
Plastic Feed Conveyor	1	2.7	tph	7.5	7.5	15,000	15,000
Tramp Iron Magnet	1			5	5	6,500	6,500
Plastic Granulator	1	2.7	tph	350	350	295,000	295,000
Plastic Pneumatic Conveying System	1	10	tph	7.5	7.5	30,000	30,000
Plastic Surge Bin and Feeder	1	10	tph	15	15	70,000	70,000
Plastic Surge Bin Vent	1	10	tph	2	2	5,000	5,000
Plastic Weigh Feeder	1	5	tph	5	5	23,000	23,000
Insulated Mixer	1	25	tph	25	25	125,000	125,000
Screw Feeders	2	15	tph	2	4	23,000	46,000
Pellet Mills	2	15	tph	400	800	285,000	570,000
Product Cooler	1	30	tph	1.0	1	67,000	67,000
Cooler Dust Cyclone w/ Exhaust Fan	1	36,000	cfm	126.8	126.8	64,000	64,000
Pellet Screen	1	30	tph	1.5	1.5	20,000	20,000
Fines Recycle Conveyor	1	10	tph	5	5	15,000	15,000
Product Conveyor	1	60	tph	10	10	25,000	25,000
Stacking Conveyor	1	60	tph	10	10	25,000	25,000
Floor Clean Up Pump	1	250	gpm	10	10	5,000	5,000
Air Compressor & Dryer	1	100	scfm	30	30	30,000	30,000
Total Plant Bare Equipment Total	**32**				**1,650**		**2,665,000**
Multipliers							
Plant Foundation and Building						0.20	533,000
Mechanical Package						0.78	2,078,700
Electrical/Instrumentation						0.28	746,200
Subtotal						1.26	**3,357,900**
Total							**6,022,900**
Engineering						0.06	361,374
Contingency						0.10	602,290
Total This Page					**1,650**		**6,986,564**

Table E-2(Continued)
Capital Cost
Anthracite/Plastic

Total from Previous Page			**1,650**		**6,986,564**
Other Project Expenses	1				
Project Development Costs	1			125,000	125,000
Loan Origination Fees		2.0%			100,000
Interest During Construction		2 months of full interest			75,000
Spare Parts	1	0.06 of bare equipment cost			159,900
Site Preparation	1			25,000	25,000
Road Work	1			15,000	15,000
Electricity Hook-up	1			75,000	75,000
Plastic Storage Building (60'x40'x24')	1			60,000	60,000
Truck Scale	1			40,000	40,000
Commissioning (4 weeks)	1			84,173	84,173
Office/Bath House Set Up (Double-wideTrailer)	1			20,000	20,000
Office/Bath House (Double-wideTrailer)	1			50,000	50,000
Warehouse/Shop (20'x40'x20')	1			24,000	24,000
Large Wheel Loader (Lease on two units) 2 Mo Deposit	1	Deposit		9,500	9,500
Small Wheel Loader (Lease on one units) 2 Mo Deposit	1	Deposit		2,500	2,500
Pick-up Truck (F-150)				25,000	25,000
Other Expenses Subtotal			**0**		**890,073**
GRAND TOTAL			**1,650**		**$7,876,637**

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Table E-3
Annual Operating & Maintenance Costs
Anthracite/Plastic

Operating parameters for three shift operation

	wet tph	wet tpy	dry tpy
Average Feed	27.2	117,575	98,500
Waste	2.7	11,758	11,729
Coal	24.5	105,818	86,771
Average Product	23.1	100,000	

Scheduled Operating Hours	5,760	240 days per year 24 hrs per day
Availability	75.0%	
Equivalent Full Load Hours	4,320	

Operating Costs

			$ Per Wet Feed Ton	$ Per Ton of Pellets	Average Monthly Dollars	Annual Dollars	
Fixed Costs							
Operator Labor & Fringe	From Labor Schedule		5.207	6.122	51,018	$612,212	
G&A Expense	30.0%	of Labor	1.562	1.837	15,305	183,664	
Other Insurances			0.021	0.025	208	2,500	
1 7 yd Loader Rental	4,750	/mo	0.485	0.570	4,750	57,000	
1 1 yd Loader Rental	1,250	/mo	0.128	0.150	1,250	15,000	
Licenses & Bonds	1,000	/mo	0.102	0.120	1,000	12,000	
Miscellaneous			0.170	0.200	1,667	20,000	27,016
Total Fixed Costs			$7.675	$9.024	$75,198	$902,375	
Variable Costs							
Mobile Equipment Fuel	$0.06	/Feed & Product	0.111	0.131	1,088	13,055	
Laboratory Costs	$0.10	/prod ton	0.085	0.100	833	10,000	
O&M Supplies/Services	$1.20	/dry feed ton	1.005	1.182	9,850	118,200	
Equipt. Replacement Parts	$2.00	/dry feed ton	1.676	1.970	16,417	197,000	
Miscellaneous	$0.40	/dry feed ton	0.335	0.394	3,283	39,400	
Total Variable Costs			$3.212	$3.777	$31,471	$377,655	
ost			$10.887	$12.800	$106,669	$1,280,030	

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Table E-4
Operator Labor & Fringe
Anthracite/Plastic

Three Operating Crews eight hours a day (five days a week)

Labor & Fringe

Job Classification		Manager	Skilled Labor	Semi-Skilled Labor	Unskilled Labor	Clerical/ Utility	Total
No. Positions		1	4	5	4	1	15
Straight Time Hourly Rate		$30.00	$12.50	$11.00	$10.00	$6.50	
Straight time hours		2,080	2,271	2,271	2,271	1,000	32,604
Overtime Hourly Rate		Exempt	$18.75	$16.50	$15.00	$9.75	
Overtime Hours (4 Hrs/day)		0	104	104	104	0	1,352
Individual Base		$62,400	$28,389	$24,982	$22,711	$6,500	
Individual Premium		0	1,950	1,716	1,560	0	
Total Individual		62,400	30,339	26,698	24,271	6,500	
Total Base		62,400	113,556	124,911	90,844	6,500	$398,211
Total Premium Portion		0	7,800	8,580	6,240	0	$22,620
Total Base Plus Premium		62,400	121,356	133,491	97,084	6,500	$420,831
FICA (6.2% on $60,600)	6.2%	3,757	7,524	8,276	6,019	403	$25,980
MCare (1.45 % on $135k)	0.0145	905	1,760	1,936	1,408	94	$6,102
FUTA (0.8% on $7,000)	0.8%	56	224	280	224	52	$836
Workers Compensation	10.98%	6,852	13,325	14,657	10,660	714	$46,207
Pension (6.0% of Gross)	6.0%	3,744	7,281	8,009	5,825		$24,860
SUI (5.7464% on $8,000)	5.7464%	460	1,839	2,299	1,839	460	$6,896
Group Insurance	$5,750	5,750	23,000	28,750	23,000		$80,500
Total Fringe		21,523	54,953	64,207	48,975	1,723	$191,381
Total Labor & Fringe		$83,923	$176,308	$197,699	$146,059	$8,223	$612,212

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Table E-5
Variable Costs Schedule
Anthracite/Plastic

Annual Electricity Costs	kW	Diversification	Annual Hours	kWh
Motors	1,247	0.75	4320	4,039,360
Lighting	100	0.5	8760	438,000
Heating	100	0.7	2920	204,400
Total (kWh/year)				4,681,760
Electricity Costs ($/kWh)				0.060
Annual Electricity Costs				$280,906

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Table E-6
Fuel Pellet Quality Estimate
Anthracite/Plastic

	As Received Basis						Dry Basis					
	Annual Tons	Proportion (Wt %)	Moisture (Wt %)	Ash (Wt %)	Sulfur (Wt %)	Heating Value (Btu/lb)	Annual Tons	Proportion (Wt %)	Ash (Wt %)	Sulfur (Wt %)	Heating Value (Btu/lb)	Sulfur Dioxide (lb/MBtu)
Waste Materials												
Granulated Mixed Plastics	11,758	10.0%	0.24	2.29	0.33	14,424	11,729	11.9%	2.30	0.33	14,459	0.46
Other Waste	0	0.0%	0.00	0.00	0.00	0	0	0.0%	0.00	0.00	0	
Total Waste Materials	11,758	10.0%	0.24	2.29	0.33	14,424	11,729	11.9%	2.30	0.33	14,459	0.46
Anthracite Coal (Clean Silt)	105,818	90.0%	18.00	8.20	0.49	10,701	86,771	88.1%	10.00	0.60	13,050	0.92
Coal & Waste Mixture	117,575	100.0%	16.22	7.61	0.48	11,073	98,500	100.0%	9.08	0.57	13,218	0.86
Net Evaporative/Re-Absorbtion Loss	(17,575)	14.95%	100.00	0.00	0.00	0	0		0.00	0.00	0	0
Final Fuel Pellets	100,000		1.50 *	8.95	0.56	13,020	98,500		9.08	0.57	13,218	0.86

* While heating all moisture is driven off, then during cooling, moisture is absorbed from the atmosphere to return the material to its equilibrium moisture content.

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Table E-7
Hot Mix Pelletizing
Estimated Heat Requirement
Anthracite/Plastic

Coal Dryer and Heater

Initial Temperature (F) = 50
Recycle IT (F) = 169
Final Temperature (F) = 320

	Moisture	Ingredients: As-Received		Ingredients: Dry Basis		Ingredients: Mix		Thermal Properties: Specific Heat		Thermal Properties: Latent Heat of Vaporization		Delta-T	Heat Input (MBtu/hr): Heating Material	Heat Input (MBtu/hr): Evaporating Water	Heat Input (MBtu/hr): Total	Btu/lb Evap.
	(Wt%)	(tph)	(Wt%)	(tph)	(Wt%)	(tph)	(Wt%)	(Btu/lbm F)	(Btu/ton F)	(Btu/lbm)	(Btu/ton)	(F Deg.)				
Coal Fines	18.0	24.49	91.8%	20.09	90.1%	20.09	75.2%	0.30	600	--	--	270	3.25	--	3.25	369
Water						4.41	16.5%	1.00	2,000	897.5	1,795,000	162	1.43	7.91	9.34	1,060
Recycle		2.2	8.2%	2.2		2.2	8.2%	0.30	600	--	--	151	0.20	--	0.20	
Total		**26.69**	**100.0%**	**22.29**	**90.1%**	26.69	**100.0%**						4.68	7.91	12.80	1,451
														Heating Efficiency =	0.75	
														Total =	**17.06**	1,935

Natural Gas 1,000 Btu/cu-ft
Natural Gas Required 17.06 k-cu-ft/hr

Plastic and Hot Coal Mixer

65%Coal IT (F) = 320
35%Coal IT (F) = 165
Plastic IT (F) = 50
Desired Product FT (F) = 260.42

	Moisture	Ingredients: As-Received		Ingredients: Dry Basis		Ingredients: Mix		Thermal Properties: Specific Heat		Thermal Properties: Latent Heat of Vaporization		Delta-T	Heat Input (MBtu/hr): Heating Material	Heat Input (MBtu/hr): Evaporating Water	Heat Input (MBtu/hr): Total	
	(Wt%)	(tph)	(Wt%)	(tph)	(Wt%)	(tph)	(Wt%)	(Btu/lbm F)	(Btu/ton F)	(Btu/lbm)	(Btu/ton)	(F Deg.)				
Hot Coal	0.0	22.29	89.1%	22.29	89.1%	22.29	89.1%									
65% Hot Coal		14.49		14.49		14.49		0.30	600	--	--	(60)	(0.52)	--	(0.52)	
35% Hot Coal		7.80		7.80		7.80		0.30	600	--	--	95	0.45	--	0.45	
Plastics	0.2	2.72	10.9%	2.72	10.9%	2.72	10.9%	0.52	1,041	--	--	210.42	0.59	--	0.59	
Water						0.007	0.0%	1.00	2,000	897.5	1,795,000	180	0.00	0.01	0.01	
Total		25.01	100.0%	25.00	100.0%	25.01	100.0%						0.53	0.01	0.54	
														Heating Efficiency =	0.65	
														Total =	**0.83**	63,293

Grand Total = 17.89

Natural Gas 1,000 Btu/cu-ft
Natural Gas Required 17.89 k-cu-ft/hr

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APPENDIX F

PRO-FORMA and SUPPORTING CALCULATIONS
for
PLANT 2: COAL FINES and WAXED CARDBOARD

Table F-1
Statement of Revenues and Expenses Pro-Forma
Coal/Waxed Cardboard - 60%/40% Dry Basis

						Esc.	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Revenues							5,474.5	5,572.8	5,673.0	5,775.1	5,879.2	5,985.2	6,093.3	6,203.5	6,315.8	6,430.3	6,546.9	6,665.9
Fuel Sales			100,000 tpy				3,855.3	3,913.1	3,971.8	4,031.4	4,091.9	4,153.3	4,215.6	4,278.8	4,343.0	4,408.1	4,474.2	4,541.3
Sales (delivered)	38.55	$/ton	100,000 tpy		38.553	1.5%	3,855.3	3,913.1	3,971.8	4,031.4	4,091.9	4,153.3	4,215.6	4,278.8	4,343.0	4,408.1	4,474.2	4,541.3
	1.60	/$/MBtu																
Other Sales	0.00	$/ton	0 tpy			1.5%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Waste Tipping Fees							1,619.2	1,659.7	1,701.2	1,743.7	1,787.3	1,832.0	1,877.8	1,924.7	1,972.8	2,022.2	2,072.7	2,124.5
Waxed Cardboard Waste	40.00	$/ton	40,480 tpy		16.192	2.5%	1,619.2	1,659.7	1,701.2	1,743.7	1,787.3	1,832.0	1,877.8	1,924.7	1,972.8	2,022.2	2,072.7	2,124.5
Other Waste	0.00	$/ton	0 tpy			2.5%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Expenses					51.227		5,122.7	5,155.0	5,184.5	5,211.0	5,233.9	5,252.7	5,267.1	5,314.8	5,407.2	5,501.6	5,598.0	5,696.5
O&M Expenses	12.67	$/ton	100,000 tpy		12.671	2.5%	1,267.1	1,298.8	1,331.3	1,364.6	1,398.7	1,433.6	1,469.5	1,506.2	1,543.9	1,582.5	1,622.0	1,662.6
Delivered Coal Costs	18.14	$/ton	71,936 tpy		13.052	1.5%	1,305.2	1,324.8	1,344.7	1,364.8	1,385.3	1,406.1	1,427.2	1,448.6	1,470.3	1,492.4	1,514.8	1,537.5
	0.80	/$/MBtu																
Electricity	0.060	$/kWh	5,962,921 kWh/yr		3.578	1.5%	357.8	363.1	368.6	374.1	379.7	385.4	391.2	397.1	403.0	409.1	415.2	421.4
Natural Gas	4.25	$/k-cu-ft	57,704 k-cu-ft/yr		2.452	2.5%	245.2	251.4	257.7	264.1	270.7	277.5	284.4	291.5	298.8	306.3	313.9	321.8
Product Delivery Costs	5.00	$/ton	100,000 tpy		5.000	2.5%	500.0	512.5	525.3	538.4	551.9	565.7	579.8	594.3	609.2	624.4	640.0	656.0
Product Brokerage Fee	5.0%	fuel sales	100,000 tpy		1.928		192.8	195.7	198.6	201.6	204.6	207.7	210.8	213.9	217.1	220.4	223.7	227.1
Royalties							75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0
Technology Patent Holder	0.75	$/ton	100,000 tpy		0.750		75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0	75.0
Property Insurance	1.0%		7,639,542			1.5%	76.4	77.5	78.7	79.9	81.1	82.3	83.5	84.8	86.1	87.3	88.7	90.0
Liability Insurance	25,000	$/year				1.5%	25.0	25.4	25.8	26.1	26.5	26.9	27.3	27.7	28.2	28.6	29.0	29.4
Property Taxes	1.0%		3,901,716			0.0%	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0	39.0
Depreciation/Amort Expense	12	years	7,639,542				636.6	636.6	636.6	636.6	636.6	636.6	636.6	636.6	636.6	636.6	636.6	636.6
Interest Expense	7	years	$4,700,000	9.0%			402.5	355.1	303.3	246.7	184.7	116.9	42.7	0.0	0.0	0.0	0.0	0.0
Revenues Less Expenses							351.8	417.8	488.5	564.1	645.3	732.5	826.2	888.7	908.6	928.7	949.0	969.4
Adjustments:																		
Depreciation & Amortization							636.6	636.6	636.6	636.6	636.6	636.6	636.6	636.6	636.6	636.6	636.6	636.6
Debt Principal Payment							(504.9)	(552.3)	(604.1)	(660.8)	(722.7)	(790.5)	(864.7)	0.0	0.0	0.0	0.0	0.0
Operations Free Cash Flow							483.5	502.2	521.0	540.0	559.2	578.6	598.1	1,525.3	1,545.2	1,565.3	1,585.6	1,606.0
Initial Investment	40.0%	Equity				(3,139.5)	0.0	0	0	0	0	0	0	0	0	0	0	0
Decomissioning Costs							0	0	0	0	0	0	0	0	0	0	0	(300.0)
Equipment Salvage Value	15.0%	of aquisition bare equipment costs					0	0	0	0	0	0	0	0	0	0	0	387.1
Return of Working Capital							0	0	0	0	0	0	0	0	0	0	0	200.0
Before Tax Cash Flow		ROI=	20.58%			(3,139.5)	483.5	502.2	521.0	540.0	559.2	578.6	598.1	1,525.3	1,545.2	1,565.3	1,585.6	1,893.1
Provision for Income Taxes	35.0%						(123.1)	(146.2)	(171.0)	(197.5)	(225.9)	(256.4)	(289.2)	(311.0)	(318.0)	(325.0)	(332.1)	(339.3)
After Tax Cash Flow		ROI=	14.47%			(3,139.5)	360.4	355.9	350.1	342.6	333.3	322.2	309.0	1,214.3	1,227.2	1,240.3	1,253.5	1,553.8

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Table F-2
Capital Costs
Coal/Waxed Cardboard - 60%/40% Dry Basis

Equipment	No.	Capacity	Units	Unit HP	Total HP	Unit Cost	Cost
Coal Receiving Hopper	1	100	cu-ft	0	0	15,000	15,000
Coal Receiving Hopper Feeder	1	100	tph	5	5	10,000	10,000
Coal Feed Conveyor	1	100	tph	15	15	25,000	25,000
Tramp Iron Magnet	1			5	5	7,500	7,500
100 Ton Coal Surge Bin	1	100	tons	0	0	75,000	75,000
Coal Bin Activator	1	50	tons	2	2	13,000	13,000
Coal Weigh Feeder	1	50	tph	5	5	23,000	23,000
Coal Bag House	1	11,000	cfm	30.5	30.5	40,000	40,000
Waxed Cardboard Receiving Hopper and Feeder	2	20	tph	7.5	15	75,000	150,000
Waxed Cardboard Feed Conveyor	2	4.5	tph	7.5	15	15,000	30,000
Tramp Iron Magnet	2			5	10	6,500	13,000
Waxed Cardboard Granulator	2	4.7	tph	350	700	295,000	590,000
Granulated Waxed Cardboard Conveyor	1	10	tph	7.5	7.5	30,000	30,000
Surge Bin and Feeder	1	10	tph	15	15	70,000	70,000
Waxed Cardboard Weigh Feeder	1	9.4	tph	5	5	23,000	23,000
Gathering Conveyor	1	50	tph	7.5	7.5	20,000	20,000
Feed Bucket Elevator	1	50	tph	10	10	25,000	25,000
Ribbon Mixer	1	130	cuft	75	75	75,000	75,000
MeteringScrew Feeder	2	30	tph	2	4	23,000	46,000
Pellet Mills	2	15	tph	400	800	285,000	570,000
Dryer/Heater System	1	30	tph	380	380	600,000	600,000
Pellet Screen	1	30	tph	1.5	1.5	20,000	20,000
Fines Recycle Conveyor	1	10	tph	5	5	15,000	15,000
Belt Scale	1	10	tph	-	0	10,000	10,000
Product Conveyor	1	60	tph	10	10	25,000	25,000
Stacking Conveyor	1	60	tph	10	10	25,000	25,000
Floor Clean Up Pump	1	250	gpm	10	10	5,000	5,000
Air Compressor & Dryer	1	100	scfm	30	30	30,000	30,000
Total Plant Bare Equipment Total	**32**				**2,173**		**2,580,500**
Multipliers							
Plant Foundation and Building						0.20	516,100
Mechanical Package						0.78	2,012,790
Electrical/Instrumentation						0.28	722,540
Subtotal						1.26	**3,251,430**
Total							**5,831,930**
Engineering						0.06	349,916
Contingency						0.10	583,193
Total This Page					**2,173**		**6,765,039**

Table F-2(Continued)
Capital Cost
Coal/Waxed Cardboard - 60%/40% Dry Basis

Total from Previous Page			**2,173**		**6,765,039**
Other Project Expenses	1				
Project Development Costs	1			125,000	125,000
Loan Origination Fees		2.0%			94,000
Interest During Construction		2 months of full interest			70,500
Spare Parts	1	0.06 of bare equipment cost			154,830
Site Preparation	1			25,000	25,000
Road Work	1			15,000	15,000
Electricity Hook-up	1			75,000	75,000
Waxed Cardboard Storage Building (60'x40'x24')	1			60,000	60,000
Truck Scale	1			40,000	40,000
Commissioning (4 weeks)	1			84,173	84,173
Office/Bath House Set Up (Double-Wide Trailer)	1			20,000	20,000
Office/Bath House (Double-Wide Trailer)	1			50,000	50,000
Warehouse/Shop (20'x40'x20')	1			24,000	24,000
Large Wheel Loader (Lease on two units) 2 Mo Deposit	1	Deposit		9,500	9,500
Small Wheel Loader (Lease on one units) 2 Mo Deposit	1	Deposit		2,500	2,500
Pick-up Truck (F-150)	1			25,000	25,000
Other Expenses Subtotal			**0**		**874,503**
GRAND TOTAL			**2,173**		**$7,639,542**

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Table F-3
Annual Operating & Maintenance Costs
Coal/Waxed Cardboard - 60%/40% Dry Basis

Operating parameters for three shift operation

	wet tph	wet tpy	dry tpy
Average Feed	26.0	112,416	95,000
Waste	9.4	40,480	36,732
Coal	16.7	71,936	58,268
Average Product	23.1	100,000	

Scheduled Operating Hours	5,760	240 days at 24 hours per day
Availability	75.0%	
Equivalent Full Load Hours	4,320	

Operating Costs

			$ Per Wet Feed Ton	$ Per Ton of Pellets	Average Monthly Dollars	Annual Dollars	
Fixed Costs							
Operator Labor & Fringe	From Labor Schedule		5.446	6.122	51,018	$612,212	
G&A Expense	30.0%	of Labor	1.634	1.837	15,305	183,664	
Other Insurances			0.022	0.025	208	2,500	
1 7 yd Loader Rental	4,750	/mo	0.507	0.570	4,750	57,000	
1 1 yd Loader Rental	1,250	/mo	0.133	0.150	1,250	15,000	
Licenses & Bonds	1,000	/mo	0.107	0.120	1,000	12,000	
Miscellaneous			0.178	0.200	1,667	20,000	27,016
Total Fixed Costs			$8.027	$9.024	$75,198	$902,375	
Variable Costs							
Mobile Equipment Fuel	$0.06	/Feed & Produc	0.113	0.127	1,062	12,745	
Laboratory Costs	$0.10	/prod ton	0.089	0.100	833	10,000	
O&M Supplies/services	$1.20	/dry feed ton	1.014	1.140	9,500	114,000	
Equipment Replacement Parts	$2.00	/dry feed ton	1.690	1.900	15,833	190,000	
Miscellaneous	$0.40	/dry feed ton	0.338	0.380	3,167	38,000	
Total Variable Costs			$3.245	$3.647	$30,395	$364,745	
ost			$11.272	$12.671	$105,593	$1,267,120	

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Table F-4
Operator Labor & Fringe
Coal/Waxed Cardboard - 60%/40% Dry Basis

Three Operating Crews eight hours a day (five days a week)

Labor & Fringe

Job Classification		Manager	Skilled Labor	Semi-Skilled Labor	Unskilled Labor	Clerical/ Utility	Total
No. Positions		1	4	5	4	1	15
Straight Time Hourly Rate		$30.00	$12.50	$11.00	$10.00	$6.50	
Straight time hours		2,080	2,271	2,271	2,271	1,000	32,604
Overtime Hourly Rate		Exempt	$18.75	$16.50	$15.00	$9.75	
Overtime Hours (2 Hrs./Wk.)		0	104	104	104	0	1,352
Individual Base		$62,400	$28,389	$24,982	$22,711	$6,500	
Individual Premium		0	1,950	1,716	1,560	0	
Total Individual		62,400	30,339	26,698	24,271	6,500	
Total Base		62,400	113,556	124,911	90,844	6,500	$398,211
Total Premium Portion		0	7,800	8,580	6,240	0	$22,620
Total Base Plus Premium		62,400	121,356	133,491	97,084	6,500	$420,831
FICA (6.2% on $60,600)	6.2%	3,757	7,524	8,276	6,019	403	$25,980
MCare (1.45 % on $135k)	0.0145	905	1,760	1,936	1,408	94	$6,102
FUTA (0.8% on $7,000)	0.8%	56	224	280	224	52	$836
Workers Compensation	10.98%	6,852	13,325	14,657	10,660	714	$46,207
Pension (6.0% of Gross)	6.0%	3,744	7,281	8,009	5,825		$24,860
SUI (5.7464% on $8,000)	5.7464%	460	1,839	2,299	1,839	460	$6,896
Group Insurance	$5,750	5,750	23,000	28,750	23,000		$80,500
Total Fringe		21,523	54,953	64,207	48,975	1,723	$191,381
Total Labor & Fringe		$83,923	$176,308	$197,699	$146,059	$8,223	$612,212

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Table F-5
Variable Costs Schedule
Coal/Waxed Cardboard - 60%/40% Dry Basis

Annual Electricity Costs	kW	Diversification	Annual Hours	kWh
Motors	1,642	0.75	4320	5,320,521
Lighting	100	0.5	8760	438,000
Heating	100	0.7	2920	204,400
Total (kWh/year)				5,962,921
Electricity Costs ($/kWh)				0.060
Annual Electricity Costs				$357,775

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Table F-6
Fuel Pellet Quality Estimate
Coal/Waxed Cardboard - 60%/40% Dry Basis

	As Received Basis						Dry Basis					
	Annual Tons	Proportion (Wt %)	Moisture (Wt %)	Ash (Wt %)	Sulfur (Wt %)	Heating Value (Btu/lb)	Annual Tons	Proportion (Wt %)	Ash (Wt %)	Sulfur (Wt %)	Heating Value (Btu/lb)	Sulfur Dioxide (lb/MBtu)
Waste Materials												
Granulated Waxed Cardboard	40,480	36.0%	9.26	2.46	0.19	9,610	36,732	38.7%	2.71	0.21	10,591	0.40
Other Waste	0	0.0%	0.00	0.00	0.00	0	0	0.0%	0.00	0.00	0	
Total Waste Materials	40,480	36.0%	9.26	2.46	0.19	9,610	36,732	38.7%	2.71	0.21	10,591	0.40
Coal (-1/4" Fines)	71,936	64.0%	19.00	5.67	1.30	11,340	58,268	61.3%	7.00	1.60	14,000	2.29
Coal & Waste Mixture	112,416	100.0%	15.49	4.51	0.90	10,717	95,000	100.0%	5.34	1.06	12,682	1.68
Net Evaporative/Re-Absorbtion Loss	(12,416)	11.04%	100.00	0.00	0.00	0	0		0.00	0.00	0	0
Final Fuel Pellets	100,000		5.00	5.07	1.01	12,048	95,000		5.34	1.06	12,682	1.68

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Table F-7

Estimated Heat Requirement
Coal/Waxed Cardboard - 60%/40% Dry Basis

Coal/Waxed Cardboard Pellet Dryer

Initial Temperature (F) = 50
Final Temperature (F) = 160

	Moisture	Ingredients: As-Received		Ingredients: Dry Basis		Ingredients: Mix		Thermal Properties: Specific Heat		Thermal Properties: Latent Heat of Vaporization		Delta-T	Heat Input (MBtu/hr): Heating Material	Heat Input (MBtu/hr): Evaporating Water	Heat Input (MBtu/hr): Total	Btu/lb Evap.
	(Wt%)	(tph)	(Wt%)	(tph)	(Wt%)	(tph)	(Wt%)	(Btu/lbm F)	(Btu/ton F)	(Btu/lbm)	(Btu/ton)	(F Deg.)				
Coal Fines	19.0	16.65	64.0%	13.49	61.3%	13.49	51.8%	0.30	600	--	--	110	0.89	--	0.89	110
Waxed Cardboard	9.3	9.37	36.0%	8.50	38.7%	8.50	32.7%	0.62	1,240	--	--	110	1.16	--	1.16	144
Coal Water						3.16	12.2%									
Waxed Cardboard Water						0.87	3.3%									
Total Water		4.03				4.03	15.5%	1.00	2,000	897.5						
Water in Product		1.16				1.16		1.00	2,000	897.5		110	0.25	--	0.25	5
Water removed		2.874				2.87		1.00	2,000	897.5	1,795,000	212	1.22	5.16	6.38	1,110
Total	15.5%	26.02	100.0%	21.99	100.0%	26.02	100.0%						3.52	5.16	8.68	1,077
Final Product	5.0%	23.15												Heating Efficiency =	0.65	
														Total =	13.36	1,657

Natural Gas 1,000 Btu/cu-ft
Natural Gas Required 13.36 k-cu-ft/hr

APPENDIX G

PRO-FORMA and SUPPORTING CALCULATIONS
for
PLANT 3: COAL FINES and TREATED SEWAGE SLUDGE

Table G-1
Statement of Revenues and Expenses Pro-Forma
Coal/Sewage Sludge - 80%/20% Dry Basis

	Rate	Quantity			Esc.	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Revenues						14,028.9	14,330.0	14,637.8	14,952.7	15,274.6	15,603.8	15,940.4	16,284.7	16,636.7	16,996.7	17,364.9	17,741.4
Fuel Sales		200,000 tpy				4,962.6	5,037.0	5,112.6	5,189.3	5,267.1	5,346.1	5,426.3	5,507.7	5,590.3	5,674.2	5,759.3	5,845.7
Sales	24.81 $/ton	200,000 tpy		24.813	1.5%	4,962.6	5,037.0	5,112.6	5,189.3	5,267.1	5,346.1	5,426.3	5,507.7	5,590.3	5,674.2	5,759.3	5,845.7
	1.15 /$/MBtu																
Other Sales	0.00 $/ton	0 tpy			1.5%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Waste Tipping Fees						9,066.3	9,292.9	9,525.3	9,763.4	10,007.5	10,257.7	10,514.1	10,777.0	11,046.4	11,322.5	11,605.6	11,895.7
Treated Sewage Sludge	40.00 $/ton	226,657 tpy		45.331	2.5%	9,066.3	9,292.9	9,525.3	9,763.4	10,007.5	10,257.7	10,514.1	10,777.0	11,046.4	11,322.5	11,605.6	11,895.7
Other Waste	0.00 $/ton	0 tpy			2.5%	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Expenses				61.014		12,202.8	12,274.1	12,338.3	12,394.5	12,441.5	12,478.1	12,503.2	12,613.3	12,837.3	13,066.3	13,300.4	13,539.7
O&M Expenses	7.34 $/ton	200,000 tpy		7.343	2.5%	1,468.5	1,505.2	1,542.9	1,581.4	1,621.0	1,661.5	1,703.0	1,745.6	1,789.3	1,834.0	1,879.8	1,926.8
Delivered Coal Costs	18.14 $/ton	167,894 tpy		15.231	1.5%	3,046.3	3,092.0	3,138.3	3,185.4	3,233.2	3,281.7	3,330.9	3,380.9	3,431.6	3,483.1	3,535.3	3,588.4
	0.80 /$/MBtu																
Electricity	0.060 $/kWh	7,888,641 kWh/yr		2.367	1.5%	473.3	480.4	487.6	494.9	502.4	509.9	517.5	525.3	533.2	541.2	549.3	557.5
Natural Gas	4.25 $/k-cu-ft	644,760 k-cu-ft/yr		13.701	2.5%	2,740.2	2,808.7	2,879.0	2,950.9	3,024.7	3,100.3	3,177.8	3,257.3	3,338.7	3,422.2	3,507.7	3,595.4
Product Delivery Costs	5.00 $/ton	200,000 tpy		5.000	2.5%	1,000.0	1,025.0	1,050.6	1,076.9	1,103.8	1,131.4	1,159.7	1,188.7	1,218.4	1,248.9	1,280.1	1,312.1
Product Brokerage Fee	5.0% fuel sales	200,000 tpy		1.241		248.1	251.9	255.6	259.5	263.4	267.3	271.3	275.4	279.5	283.7	288.0	292.3
Royalties						150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0
Technology Patent Holder	0.75 $/ton	200,000 tpy		0.750		150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0	150.0
Property Insurance	1.0%	20,519,675			2.5%	205.2	210.3	215.6	221.0	226.5	232.2	238.0	243.9	250.0	256.3	262.7	269.2
Liability Insurance	25,000 $/year				1.5%	25.0	25.4	25.8	26.1	26.5	26.9	27.3	27.7	28.2	28.6	29.0	29.4
Property Taxes	1.0%	10,850,868			0.0%	108.5	108.5	108.5	108.5	108.5	108.5	108.5	108.5	108.5	108.5	108.5	108.5
Depreciation/Amort Expense	12 years	20,519,675				1,710.0	1,710.0	1,710.0	1,710.0	1,710.0	1,710.0	1,710.0	1,710.0	1,710.0	1,710.0	1,710.0	1,710.0
Interest Expense	7 years	$12,000,000	9.0%			1,027.7	906.8	774.5	629.8	471.5	298.4	109.1	0.0	0.0	0.0	0.0	0.0
Revenues Less Expenses						1,826.0	2,055.8	2,299.5	2,558.2	2,833.1	3,125.6	3,437.2	3,671.4	3,799.4	3,930.4	4,064.5	4,201.7
Adjustments:																	
Depreciation & Amortization						1,710.0	1,710.0	1,710.0	1,710.0	1,710.0	1,710.0	1,710.0	1,710.0	1,710.0	1,710.0	1,710.0	1,710.0
Debt Principal Payment						(1,289.1)	(1,410.1)	(1,542.3)	(1,687.0)	(1,845.3)	(2,018.4)	(2,207.7)	0.0	0.0	0.0	0.0	0.0
Operations Free Cash Flow						2,246.9	2,355.7	2,467.1	2,581.1	2,697.8	2,817.2	2,939.4	5,381.3	5,509.4	5,640.4	5,774.5	5,911.7
Initial Investment	42.1% Equity				(8,719.7)	0.0	0	0	0	0	0	0	0	0	0	0	0
Decomissioning Costs						0	0	0	0	0	0	0	0	0	0	0	(300.0)
Equipment Salvage Value	15.0% of aquisition bare equipment costs					0	0	0	0	0	0	0	0	0	0	0	1,076.5
Return of Working Capital						0	0	0	0	0	0	0	0	0	0	0	200.0
Before Tax Cash Flow	ROI=	31.30%			(8,719.7)	2,246.9	2,355.7	2,467.1	2,581.1	2,697.8	2,817.2	2,939.4	5,381.3	5,509.4	5,640.4	5,774.5	6,888.2
Provision for Income Taxes	35.0%					(639.1)	(719.5)	(804.8)	(895.4)	(991.6)	(1,094.0)	(1,203.0)	(1,285.0)	(1,329.8)	(1,375.6)	(1,422.6)	(1,470.6)
After Tax Cash Flow	ROI=	22.16%			(8,719.7)	1,607.8	1,636.2	1,662.3	1,685.8	1,706.2	1,723.3	1,736.4	4,096.4	4,179.6	4,264.7	4,351.9	5,417.6

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Table G-2
Capital Costs
Coal/Sewage Sludge - 80%/20% Dry Basis

Equipment	No.	Capacity	Units	Unit HP	Total HP	Unit Cost	Cost
Coal Receiving Hopper	1	100	cu-ft	0	0	15,000	15,000
Coal Receiving Hopper Feeder	1	100	tph	5	5	10,000	10,000
Coal Feed Conveyor	1	100	tph	15	15	25,000	25,000
Tramp Iron Magnet	1			5	5	7,500	7,500
100 Ton Coal Surge Bin	1	100	tons	0	0	75,000	75,000
Coal Bin Activator	1	50	tons	2	2	13,000	13,000
Coal Weigh Feeder	1	50	tph	5	5	23,000	23,000
Coal Conveyor	1	50	tph	7.5	7.5	20,000	20,000
Coal Bag House	1	11,000	cfm	30.5	30.5	40,000	40,000
Sewage Sludge Receiving Hopper and Feeder	1	10	tph	7.5	7.5	75,000	75,000
Sewage Sludge Feed Conveyor	2	10	tph	7.5	15	15,000	30,000
Dryer System	13	10	tph	150	1950	450,000	5,850,000
Gathering Conveyor	1	50	tph	7.5	7.5	20,000	20,000
Bucket Elevator	1	60	tph	10	10	25,000	25,000
Surge Tank/Mixer	1	60	tph	25	25	75,000	75,000
Pellet Mills with Feed Screws	2	30	tph	400	800	350,000	700,000
Thickener	1	8	Ft. Dia.	3	3	50,000	50,000
Thickener Underflow Pump	1	5	gpm	5	5	3,000	3,000
Pellet Screen	1	30	tph	1.5	1.5	20,000	20,000
Fines Recycle Conveyor	1	10	tph	5	5	15,000	15,000
Product Conveyor	1	60	tph	10	10	25,000	25,000
Stacking Conveyor	1	60	tph	10	10	25,000	25,000
Floor Clean Up Pump	1	250	gpm	10	10	5,000	5,000
Air Compressor & Dryer	1	100	scfm	30	30	30,000	30,000
Total Plant Bare Equipment Total	**38**				**2,960**		**7,176,500**
Multipliers							
Plant Foundation and Building						0.20	1,435,300
Mechanical Package						0.78	5,597,670
Electrical/Instrumentation						0.28	2,009,420
Subtotal						1.26	**9,042,390**
Total							**16,218,890**
Engineering						0.06	973,133
Contingency						0.10	1,621,889
Total This Page					**2,960**		**18,813,912**

Table G-2(Continued)
Capital Cost
Coal/Sewage Sludge - 80%/20% Dry Basis

Total from Previous Page			**2,960**		**18,813,912**
Other Project Expenses	1				
Project Development Costs	1			125,000	125,000
Loan Origination Fees		2.0%			240,000
Interest During Construction		2 months of full interest			180,000
Spare Parts	1	0.06 of bare equipment cost			430,590
Site Preparation	1			25,000	25,000
Road Work	1			15,000	15,000
Electricity Hook-up	1			75,000	75,000
Sewage Sludge Storage Building (120'x60'x24')	1			180,000	180,000
Pellet Product Storage Bldg (120'x60'x24')	1			180,000	180,000
Truck Scale	1			40,000	40,000
Commissioning (4 weeks)	1			84,173	84,173
Office/Bath House Set Up (Double-wideTrailer)	1			20,000	20,000
Office/Bath House (Double-wideTrailer)	1			50,000	50,000
Warehouse/Shop (20'x40'x20')	1			24,000	24,000
Large Wheel Loader (Lease on two units) 2 Mo Depos	1	Deposit		9,500	9,500
Small Wheel Loader (Lease on one units) 2 Mo Depos	1	Deposit		2,500	2,500
Pick-up Truck (F-150)				25,000	25,000
Other Expenses Subtotal			**0**		**1,705,763**
GRAND TOTAL			**2,960**		**$20,519,675**

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Table G-3
Annual Operating & Maintenance Costs
Coal/Sewage Sludge - 80%/20% Dry Basis

Operating parameters for three shift operation

	wet tph	wet tpy	dry tpy
Average Feed	91.3	394,551	169,993
Waste	52.5	226,657	33,999
Coal	38.9	167,894	135,994
Average Product	46.3	200,000	
Scheduled Operating Hours	5,760	240 days at 24 hours per day	
Availability	75.0%		
Equivalent Full Load Hours	4,320		

Operating Costs			$ Per Wet Feed Ton	$ Per Ton of Pellets	Average Monthly Dollars	Annual Dollars
Fixed Costs						
Operator Labor & Fringe	From Labor Schedule		1.552	3.061	51,018	$612,212
G&A Expense	30.0%	of Labor	0.466	0.918	15,305	183,664
Other Insurances			0.006	0.012	208	2,500
1 7 yd Loader Rental	4,750	/mo	0.144	0.285	4,750	57,000
1 1 yd Loader Rental	1,250	/mo	0.038	0.075	1,250	15,000
Licenses & Bonds	1,000	/mo	0.030	0.060	1,000	12,000
Miscellaneous			0.051	0.100	1,667	20,000
Total Fixed Costs			$2.287	$4.512	$75,198	$902,375
Variable Costs						
Mobile Equipment Fuel	$0.06	/Feed & Produc	0.090	0.178	2,973	35,673
Laboratory Costs	$0.06	/prod ton	0.030	0.060	1,000	12,000
O&M Supplies/Services	$1.00	/dry feed ton	0.431	0.850	14,166	169,993
Maintenance Supplies	$1.75	/dry feed ton	0.754	1.487	24,791	297,487
Miscellaneous	$0.30	/dry feed ton	0.129	0.255	4,250	50,998
Total Variable Costs			$1.435	$2.831	$47,179	$566,151
ost			$3.722	$7.343	$122,377	$1,468,526

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Table G-4
Operator Labor & Fringe
Coal/Sewage Sludge - 80%/20% Dry Basis

Three Operating Crews eight hours a day (five days a week)

Labor & Fringe

Job Classification		Manager	Skilled Labor	Semi-Skilled Labor	Unskilled Labor	Clerical/ Utility	Total
No. Positions		1	4	5	4	1	15
Straight Time Hourly Rate		$30.00	$12.50	$11.00	$10.00	$6.50	
Straight time hours		2,080	2,271	2,271	2,271	1,000	32,604
Overtime Hourly Rate		Exempt	$18.75	$16.50	$15.00	$9.75	
Overtime Hours (2 Hrs./Wk.)		0	104	104	104	0	1,352
Individual Base		$62,400	$28,389	$24,982	$22,711	$6,500	
Individual Premium		0	1,950	1,716	1,560	0	
Total Individual		62,400	30,339	26,698	24,271	6,500	
Total Base		62,400	113,556	124,911	90,844	6,500	$398,211
Total Premium Portion		0	7,800	8,580	6,240	0	$22,620
Total Base Plus Premium		62,400	121,356	133,491	97,084	6,500	$420,831
FICA (6.2% on $60,600)	6.2%	3,757	7,524	8,276	6,019	403	$25,980
MCare (1.45 % on $135k)	0.0145	905	1,760	1,936	1,408	94	$6,102
FUTA (0.8% on $7,000)	0.8%	56	224	280	224	52	$836
Workers Compensation	10.98%	6,852	13,325	14,657	10,660	714	$46,207
Pension (6.0% of Gross)	6.0%	3,744	7,281	8,009	5,825		$24,860
SUI (5.7464% on $8,000)	5.7464%	460	1,839	2,299	1,839	460	$6,896
Group Insurance	$5,750	5,750	23,000	28,750	23,000		$80,500
Total Fringe		21,523	54,953	64,207	48,975	1,723	$191,381
Total Labor & Fringe		$83,923	$176,308	$197,699	$146,059	$8,223	$612,212

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Table G-5
Variable Costs Schedule
Coal/Sewage Sludge - 80%/20% Dry Basis

Annual Electricity Costs	kW	Diversification	Annual Hours	kWh
Motors	2,236	0.75	4320	7,246,241
Lighting	100	0.5	8760	438,000
Heating	100	0.7	2920	204,400
Total (kWh/year)				7,888,641
Electricity Costs ($/kWh)				0.060
Annual Electricity Costs				$473,318

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Table G-6
Fuel Pellet Quality Estimate
Coal/Sewage Sludge - 80%/20% Dry Basis

	As Received Basis						Dry Basis					
	Annual Tons	Proportion (Wt %)	Moisture (Wt %)	Ash (Wt %)	Sulfur (Wt %)	Heating Value (Btu/lb)	Annual Tons	Proportion (Wt %)	Ash (Wt %)	Sulfur (Wt %)	Heating Value (Btu/lb)	Sulfur Dioxide (lb/MBtu)
Waste Materials												
Sewage Sludge	226,657	57.4%	85.00	4.40	0.27	1,119	33,999	20.0%	29.35	1.78	7,463	4.77
Other Waste	0	0.0%	0.00	0.00	0.00	0	0	0.0%	0.00	0.00	0	
Total Waste Materials before Dryer	226,657	57.4%	85.00	4.40	0.27	1,119	33,999	20.0%	29.35	1.78	7,463	4.77
Net Dryer Loss	(182,051)	80.32%	100.00	0.00	0.00	0	0		0.00	0.00	0	0.00
Total Waste Materials after Dryer	44,606		23.78	4.40	0.27	1,119	33,999	20.0%	29	1.78	7,463	4.77
Coal (-1/4" Fines)	167,894	42.6%	19.00	5.67	1.30	11,340	135,994	80.0%	7.00	1.60	14,000	2.29
Coal & Waste Mixture	212,500	100.0%	20.00	9.18	1.31	10,154	169,993	100.0%	11.47	1.64	12,693	2.58
Net Dewatering Die Loss	(12,500)	5.88%	100.00	0.00	0.00	0	0		0.00	0.00	0	0
Final Fuel Pellets	200,000		15.00	9.75	1.39	10,788	169,993		11.47	1.64	12,693	2.58

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	wet tph	wet tpy	dry tpy
Average Feed	91.3	394,551	169,993
Sewage Sludge	52.5	226,657	33,999
Coal	38.9	167,894	135,994
Average Product	46.296	200,000	

Table G-7

Estimated Heat Requirement
Coal/Sewage Sludge - 80%/20% Dry Basis

Coal/Sewage Sludge Pellet Dryer

Initial Temperature (F) = 50
Final Temperature (F) = 160

		Ingredients						Thermal Properties					Heat Input (MBtu/hr)			
	Moisture	As-Received		Dry Basis		Mix		Specific Heat		Latent Heat of Vaporization		Delta-T	Heating Material	Evaporating Water		Btu/lb
	(Wt%)	(tph)	(Wt%)	(tph)	(Wt%)	(tph)	(Wt%)	(Btu/lbm F)	(Btu/ton F)	(Btu/lbm)	(Btu/ton)	(F Deg.)	Material	Water	Total	Evap.
Sewage Sludge	85.00	52.47	100.0%	7.87	100.0%	7.87	15.0%	0.60	1,200	--	--	110	1.04	--	1.04	12
Sewage Sludge Water						44.60	85.0%									
Total		52.47	0.0%	0.00	100.0%	52.47	100.0%									
Water removed by dryer		42.14				42.14		1.00	2,000	970.3	1,940,600	162	13.65	81.78	95.43	1,132
Water in Product afer dryer		2.46		0.00		2.46		1.00	2,000	970.3	1,940,600	110	0.54	--	0.54	6
Total		52.47	100.0%	7.87	100.0%	52.47							15.23	81.78	97.01	1,151
														Heating Efficiency =	0.65	
Sewage Sludge After Dryer	23.78	10.33		7.87		10.33										
														Total =	149.25	1,771

Natural Gas 1,000 Btu/cu-ft
Natural Gas Required 149.25 k-cu-ft/hr

APPENDIX H

PRO-FORMA and SUPPORTING CALCULATIONS for PLANT 4: COAL FINES, SAWDUST, and ASPHALT EMULSION

PROFORMA – Coal Fines, Sawdust, and Asphalt Emulsion
(incremental tons)

		All $s in 1000s									
				1	2	3	4	5	6	7	
			Esc.	2001	2002	2003	2004	2005	2006	2007	TOTALS
1	PRODUCTION										
2	Staffing Hours Per Day			24	24	24	24	24	24	24	24
3	Tons Per Hour			11	11	11	11	11	11	11	11
4	Days Per Week			5	5	5	5	5	5	5	5
5	Production Weeks Per Year			50	50	50	50	50	50	50	50
6	Availability			83.3%	83.3%	83.3%	83.3%	83.3%	83.3%	83.3%	83.3%
7											
8	Coal Fines (12,000 Btu/lb)										
9	Blend %			55%	55%	55%	55%	55%	55%	55%	55%
10	Raw Tons Per Year			30,250	30,250	30,250	30,250	30,250	30,250	30,250	211,750
11	Recovery			100%	100%	100%	100%	100%	100%	100%	100%
12	Clean Tons Per Year			30,250	30,250	30,250	30,250	30,250	30,250	30,250	211,750
13											
14	Sawdust (6,000 Btu/lb)										
15	Blend %			45%	45%	45%	45%	45%	45%	45%	45%
16	Raw Tons Per Year			24,750	24,750	24,750	24,750	24,750	24,750	24,750	173,250
17	Recovery			100%	100%	100%	100%	100%	100%	100%	100%
18	Clean Tons Per Year			24,750	24,750	24,750	24,750	24,750	24,750	24,750	173,250
19											
20	Total Raw Tons Per Year			55,000	55,000	55,000	55,000	55,000	55,000	55,000	385,000
21	Total Clean Tons Per Year			55,000	55,000	55,000	55,000	55,000	55,000	55,000	385,000
22											
23	MMBtus Per Clean Ton if @	9,300 Btu/lb		18.60	18.60	18.60	18.60	18.60	18.60	18.60	18.60
24											
25	SALES PRICES										
26	Net Sale Price of Clean Tons	$14.88 per ton		$14.88	$14.88	$14.88	$14.88	$14.88	$14.88	$14.88	$14.88
27											
28											
29	**TOTAL PROJECTED REVENUES**			**$818**	**$818**	**$818**	**$818**	**$818**	**$818**	**$818**	**$5,729**
30											
31	**OPERATING COSTS**										
32	Emulsion ($/ton)	110									
33	Concentration (wt%)	2.00%									
34	Coal Fines Treated (TPH)	50									
35	Sawdust Fee	$6.00 per ton	0.00%	150.0	150.0	150.0	150.0	150.0	150.0	150.0	1,050.0
36	Maintenance/Repairs	$5,000 per year	2.50%	5.0	5.1	5.3	5.4	5.5	5.7	5.8	37.7
37	Emulsion	$2.200 per treated ton	2.50%	550.0	563.8	577.8	592.3	607.1	622.3	637.8	4,151.1
38	Total of Operating Costs			705.0	718.9	733.1	747.7	762.6	777.9	793.6	5,238.8
39											
40	**Net Income Pre Tax**			**$113**	**$100**	**$85**	**$71**	**$56**	**$40**	**$25**	**$490**
41											
42	**After Tax Income**	**Capital Investment = $100,000**		**$85**	**$75**	**$64**	**$53**	**$42**	**$30**	**$19**	**$367**
43	**After Tax ROI =**	**69.9%**									