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CHARACTERIZATION & SUPPLY OF COAL BASED FUELS

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"Characterization & Supply of Coal Based Fuels"

Quarterly Technical Report

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1.0 INTRODUCTION & BACKGROUND

Under the Department of Energy's Advanced Combustor Technology Program, approximately 11 combustor contractors (under 13 contracts) are developing combustion systems (during 1987-1989) for use in residential, commercial, light industrial and industrial retrofit markets. Sufficient quantities of well-characterized, coal-based fuels possessing specific, appropriate specifications are required by the contractors. Fuels may be dry pulverized coal or coal liquid fuels. In support of these equipment development efforts, the team of Energy International and Dravo Engineers (under DOE Contract No. DE-AC22-86 PC90258) will provide such fuels.

Nearly a third of the total energy use in the U.S. is in the residential, commercial, and light industrial sectors. Of this, about half of the energy is supplied by the direct consumption (not including electricity) of conventional oil and gas resources. Thus, there is a significant energy use component for which coal is not currently a viable user option. Using coal with today's combustion and fuel technologies is not user friendly, not environmentally acceptable nor economically competitive. The infrastructure of supply, transportation, distribution, and service for this application does not exist.

For coal to significantly penetrate this important market sector, several developments and demonstrations must be achieved. This includes the development and demonstration that:

- Premium coal-based fuels can be made, combusted, and used in low maintenance, automatic use systems to which such users are accustomed, i.e., be direct replacement of conventional fuels and require only simple installation changes.
- Advanced coal fuel combustion systems can effectively combust coal fuels while meeting economic, environmental, and performance standards.
- Coal fuels, combustion systems and service support are well matched, reliable, cost effective, and are anticipated to be available over the projected lifetime of the installations.

The key to development of fuel and combustor technologies for future application to the use of premium coal-based fuels in the residential, commercial and light industrial energy use sectors is to make available representative coal fuels for developmental testing. Current technologies in early development stages offer the promise to meet the market, performance and environmental acceptability that are expected to be required. However, the developmental testing of advanced combustion equipment systems requires fuels for testing; test experience and performance measures are needed to identify cost competitiveness in the market and specific market niches for early commercialization; and, commercial market opportunities are needed to justify and specify the development and installation of advanced fuels facilities for supplying the developmental testing needs.

The capability to produce significant quantities cannot be supported in the current economic and energy use situation. Once these pieces of experience and information begin to fall into place, the market driven needs will more clearly identify the suite of coals that will satisfy the markets and the performance requirements (cost, maintenance, energy efficiency, environmental). For now, it is important to provide sufficient quantities of surrogate fuels to enable development testing to proceed. While the definitions of market and performance are not finalized nor quantitatively fixed and the eventual, economically acceptable fuel processes are not determined, it is possible to make use of current understanding of coal resources, markets, combustor and environmental requirements and specific available coal properties and characteristics to make reasonable selections of coals for fuels representative of future advanced fuels. With selected coals, conventional beneficiation methods can be used to prepare current versions of advanced premium coal-based fuels even though the associated excessive grinding, special processing, low energy recoveries and process economics would not be acceptable for eventual commercial operations.

The analysis of fuels needs, the selection of candidate coals, the characterization and supply in this contract are then to be accomplished with the above in mind. The best choices of those available will be made based upon the available information, coal and processes. This will at least provide the developmental test fuels that will enable the DOE-PETC advanced combustion and fuels program to move forward. Following the fuels and combustor development activities that this supply contract will support, it is expected that additional optional candidate coals will become evident based on the new experience. In the meantime, these coal fuels will enable program proceed.

During the first quarter of this contract effort, the primary activities were involved with:

- Initiating and conducting Task 1 - "Analysis of Fuels Needs" which includes a market analysis, a resource assessment, and development of specifications for fuels.
- Completing the initial versions of those analyses and reviewing the preliminary coal selection recommendations with DOE-PETC project management.
- Initiating the procurement of coal supplies for initial candidates.
- Determination of supply requirements (i.e. specifications, quantities, schedule) with combustor developers.
- Development and scoping of coal supply and process strategies.

The progress on the above activities is reported in the following sections of this report.

2.0 OBJECTIVES AND SCOPE OF WORK

2.1 Contract Objectives

Contract objectives are as follows:

- Develop fuel specifications to serve combustor requirements
- Select coals having appropriate compositional and quality characteristics as well as economically attractive reserve base
- Provide quality assurance for both the parent coals and the fuel forms
- Deliver premium coal-based fuels to combustor developers as needed for their contract work

2.2 Contract Scope of Work

Energy International/Dravo will perform the following:

- From information both obtained from the combustor PRDA and received from combustor contractors, develop fuel specifications and schedule.
- Using published reports and databases, perform a market assessment and a resource assessment in order to identify acceptable coals within reasonable proximity to markets. In other words, determine the availability and applicability of a wide range of coals in order to produce premium coal-based fuels for specific markets.
- From all coal ranks and all domestic resources select eight coals which satisfy the requirements of combustion systems being developed.
- Procure premium coals having the ability to be processed to contain <1% ash and <0.8% sulfur.
- Procure coals and produce coal liquid mixtures or dry pulverized coal and deliver these premium fuels to combustor contractors.

2.3 Task 1 Objectives

The objectives of Task 1, "Analysis of Fuels Needs", are as follows:

- To provide analyses, information and evaluation of coal resources, coal properties, and market opportunities to support the selection of coals for characterization, processing and supply.
- To assure that coals used in developmental testing are representative of future potential coal used in those applications and are:

- Available as U.S. domestic resource in sufficient quantity
 - Geographically proximate to the regional markets
 - Have suitable properties to be processed into premium coal-based fuels to satisfy the combustor needs and market constraints (such as environmental)
 - To meet the potential market opportunity.
- To evaluate, interpret and assess the available information on coal reserves, market opportunities, performance requirements, environmental acceptability, coal properties and specific characteristics to provide guidance in the selection of candidate coals for characterization and supply for developmental testing of advanced combustors for residential, commercial and light industrial applications.
 - To collect, review and evaluate information about specific, currently available coals that can be procured from existing mining operations to provide contracted quantities of developmental test fuels that satisfy the reserves, market, geographic, property, performance and environmental criteria.
 - To recommend candidate coals and then select specific coals to be purchased, processed into coal-based premium fuels, and supplied to DOE users.
 - To coordinate the performance requirements of combustor developers under DOE-PETC contract and in-house efforts with the selection and supply of coals.

2.4 Task 1 Approach

The approach used for the "Analysis of Fuels Needs" (Task 1) focuses on: the premises reviewed in the Introduction and Background section; the stated task objectives; and, the need to use currently available information, coals and processing in order to supply actual coal fuels meeting representative specifications in sufficient quantities to satisfy developmental testing needs. Therefore, the approach is to employ the results of previous DOE-sponsored studies, including broad-scale market assessments, national coal data compilations, current mining reserves and records, progress reports on fuels and combustion system requirements. This will be supplemented as appropriate by other documents from state-sponsored studies and commercial publications.

The approach is based on using existing information while the scope of work and funds of this contract do not include doing original work in cost estimation, market evaluation, process design and development. While much of the previous work cannot be directly used to analyze fuels needs, those documents provide useful guidance for selective interpretation to aid in the recommendation of candidate coals.

The supply contract will of necessity use coal from existing mining operations and existing process technology. While it is recognized that added candidate coals may eventually prove to be more appropriate to later developed technologies, this analysis is directed to use available information and sources as best possible. The most likely markets, performance requirements and coal selections are the basis for this analysis. For example, washability data is used as an important discriminating criteria in coal selection even though process specifications will undoubtedly push the processing beyond the levels of ash and sulfur reduction characterized by the washability data. Some potential candidates which don't meet the best category on the basis of washability data may later prove to be reasonable options. Such can't be determined until more definitive criteria are developed. Similarly, additional cost estimation of selling price for coal fuels and more detailed market studies could lead to other market driven candidates.

The approach for the task is to effectively use available coal resources and information based on previous DOE studies and experience and the good, professional judgements of the project participants. New ways of interpreting and assessing this information have been found and are discussed in the text. The focus is to provide fuels representative of future needs in the current timeframe as best available.

3.0 EXECUTIVE SUMMARY

Under the Department of Energy's Advanced Combustor Technology Program, approximately 11 combustor contractors (under 13 contracts) are developing combustion systems (during 1987-1989) for use in residential, commercial, light industrial and industrial retrofit markets. Sufficient quantities of well-characterized, coal-based fuels possessing specific, appropriate specifications are required by the contractors. Fuels may be dry pulverized coal or coal liquid fuels. In support of these equipment development efforts, the team of Energy International and Dravo Engineers (under DOE Contract No. DE-AC22-86 PC90258) will provide such fuels.

During the first quarter of this contract effort, the primary activities were involved with:

- Initiating and conducting Task 1 - "Analysis of Fuels Needs" which includes a market analysis, a resource assessment, and development of specifications for fuels.
- Completing the initial version of those analyses and reviewing the preliminary coal selection recommendations with DOE-PETC project management.
- Initiating the procurement of coal supplies for initial candidates.
- Determination of supply requirements (i.e., specifications, quantities, schedule) with combustor developers.
- Development and scoping of coal supply and process strategies.

The progress on the above activities is reported here.

The major coal fields of the U.S. were reviewed to correlate with the market needs analysis. Prior to the detailed coal resource evaluation, the locations of fields with major reserves of low sulfur coal potentially amenable to premium coal-based fuels specifications were identified.

An estimate of the total potential annual demand of between 3 and 6 Quads (or roughly 100 to 200 million tons per year of dry beneficiated coal) was provided by PETC on the basis of previous market studies. To provide a realistic focus of the market assessment information to aid in the selection of coals for this project, a three-tiered market demand assessment was adapted from the previous fall potential studies. With the assistance of representative coal fuel plants estimating factors, a reduced scope market potential was identified. This market need of over 0.5 Quads can be supplied by about 9 fuel process plants focused to satisfy the major component of that demand, which is the residential demand of the Northeast and Midwest. Therefore, the coals selected for developmental testing will need to satisfy the most stringent fuel requirements and stretch the fuel processing (deep cleaning) capabilities beyond the current state-of-the-art.

Using existing coal database information on reserves, properties and washabilities, selective searches of the coal resource data were conducted to identify candidate coals meeting the stringent fuel requirements. One set of candidates for the residential, commercial, and light industrial was prepared. That list was comprised of 4 coal beds from the Southern Appalachian low-sulfur coal fields and one coal bed in Colorado. A more extensive list of candidates for slagging coals was identified and included potential candidates from all major coal provinces.

The combustion contractors sponsored in DOE programs were contracted to identify their fuel specifications requirements and anticipated fuel delivery requirements (schedule and quantities). The results of that survey show that fuel specifications are consistent with initial contract plans but quantities are greater; results are tabulated later in this report.

During 1987-89 both coal and coal water slurry will be supplied to approximately eleven combustor contractors. Individual shipments will range from a few hundred pounds to 200 tons.

4.0 RESOURCES AND MARKET ASSESSMENTS

The major coal fields of the U.S. were reviewed to correlate with the market needs analysis. These coal fields are geographically characterized in the following coal provinces: Appalachian, the Interior Provinces (Eastern and Western), and Western.

A table summarizing the potentially available and suitable quantities of coal resources was prepared and is shown in Table 4.1. These data show that over 80% of the low sulfur coal is in the Western region (about 166 billion tons) with about 31 billion tons of low sulfur bituminous coal found in the Appalachian region.

Several general first-level conclusions regarding coal resources can be stated:

1. Because of sulfur emission regulations, the selected coals will be low sulfur coals, particularly low in organic sulfur since much of the pyritic sulfur can be removed by existing coal beneficiation methods.
2. The low ash requirement will require use of the best available particle reduction and coal beneficiation technologies.
3. Based on the relative size of the low sulfur coal reserves, candidate coals are most likely to be found in the Appalachian and Western regions. The Illinois Basin (Eastern Interior) has large coal reserves and very little low sulfur coal, so it is not likely to have suitable candidates for premium coal-based fuels.

An estimate of the total potential annual demand of between 3 and 6 Quads (or roughly 100 to 200 million tons per year of dry beneficiated coal) was provided on the basis of market analysis studies prepared by Eos and Burns and Roe for PETC to determine the maximum potential coal use. The total market potential is too broadly based and demanding to be of much value to coal selection guidance.

A major step in the market assessment was to conceive and implement an approach that could meaningfully incorporate the previous DOE-sponsored, broad scale market assessments with the need to provide focused market input to the selection of coals for preparation as test fuels. This was accomplished with the approach built upon two mechanisms: 1) a three-tiered market demand assessment approach, and 2) identification of a "representative CLM plant" for interpreting demand implications. The three tiers were comprised of the maximum coal use potential (MAXCUP), a focused reduced coal use potential (REDCUP), and an initial market entry coal use potential (MECUP).

After the market needs were determined by region and end use sector, the production requirements to satisfy the coal fuel quality requirements of various market segments were estimated. Using the estimating ratios for the representative plants as reviewed in Tables 4.2 and 4.3, the market implications and distribution of potential fuel plants were then identified.

A summary of the MAXCUP level of estimates is presented in Table 4.4 for each of the use sectors and regions. This maximum estimate is dominated by the potential for coal use in the residential sector in the Northeast and Midwest regions, which comes to over 40% of the total estimated market of 7.4 Quads. The implications of this level of market estimate are reviewed in Tables 4.5 and 4.6. This would indicate that the MAXCUP demand level would require the use of a variety of coals from several different locations in each of the population regions as some geographic dispersion would be expected. This MAXCUP level of premium coal use will have significant implications in terms of the variety of coals, distribution of sources, infrastructure for transportation, construction, engineering, supplies, and capital and the reserves of reasonably available coal.

Based on a variety of assumptions concerning the flexibility of energy supplies and the penetration of these new fuels into the identified market sectors, a reduced coal use potential (REDCUP) estimate was made and is presented in Table 4.7. By imposing the environmental constraint and partial market capture assumptions, the market demand at the MAXCUP level is reduced by factors of about 10 to 20 to a little more than 0.5 Quad. The REDCUP level is also dominated by residential demand in the Northeast and Midwest, some 58% of the total. The implications of the REDCUP level market are shown in Tables 4.8 and 4.9. This REDCUP estimate is a much more modest estimate of the premium fuels business than the MAXCUP estimate. An industry comprised of 5 large scale residential-commercial product fuels plants in the Northeast and Midwest and 4 minimum economic plants singularly distributed elsewhere can more reasonably be expected. The singular plants in the South and West might well have to distribute product very long distances because of the size of those regions. There may be a reasonable trade-off with the additional transportation costs of bringing in the product from a Midwest location. Thus, it may be possible to supply the REDCUP demand from a much more limited coal resource base.

Identification of the specific market requirements for the initial market entry cannot be definitively made on the basis of the available studies and background information. Therefore, the market entry coal use potential (MECUP) is only reviewed qualitatively and probable market entry implications are only subjectively viewed. Since the MAXCUP and REDCUP levels are dominated by the residential-commercial sectors in the Northeast and Midwest, it is logical to assume that market entry would be initiated within that context. Market entry would likely occur where the best combination of low-cost coal fuel supply and high cost alternatives would exist.

SUMMARY OF U.S. COAL RESOURCES (Billions of Tons)

	<u>APPALACHIAN</u>	<u>INTERIOR PROVINCES</u> <u>EASTERN</u>	<u>WESTERN</u>	<u>WESTERN</u>	<u>U.S.</u> <u>TOTAL</u>			
<u>ESTIMATED IDENTIFIED AND HYPOTHETICAL</u>								
0 to 6000 feet	352	366	254	2995	3967			
0 to 3000 feet	342	366	249	2622	3579			
<u>IDENTIFIED RESOURCES</u>								
Bituminous	260	215	71	201				
Subbituminous	0	0	0	486				
Lignite	2	0	11	465				
Anthracite	<u>19</u>	<u>0</u>	<u>0.4</u>	<u>0</u>				
TOTAL	281	215	82	1152	1730			
<u>DEMONSTRATED RESERVE BASE</u>								
	<u>Und.</u>	<u>Surf.</u>	<u>Und.</u>	<u>Surf.</u>	<u>Und.</u>	<u>Surf.</u>		
Bituminous	91	18	89	21	5	7	22	3
Subbituminous	0	0	0	0	0	0	119	63
Lignite	0	1	0	0	0	14	0	30
Anthracite	<u>7</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>	<u>0</u>
TOTAL	117		110		26		237	490
<u>LOW-SULFUR PART OF DEMONSTRATED RESERVE BASE (1.0% S or less)</u>								
Underground	26.0		1.5		0.2		99.3	127
Surface	<u>5.2</u>		<u>0.2</u>		<u>0.8</u>		<u>67.0</u>	<u>73</u>
TOTAL	31.2		1.7		1.0		166.3	200
Low S as % of DRB	26.7%		1.5%		3.8%		70.2%	40.8%
<u>RECOVERABLE RESERVES AT EXISTING MINES</u>								
Underground	6.6		1.7		0		1.0	9
Surface	1.6		0.5		1.2		11.4	<u>15</u>

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Table 4.2

REPRESENTATIVE CLM PLANT

1. Defined in commercial case cost estimate study by EI for Combustion Engineering under DOE contract.
2. 183 tons/hr of clean coal product
 - at 16 hr/day = 2928 tons/day
 - at 330 days/year = 966,240 tons/year
 - at 14,300 Btu/lb = 30 trillion Btu/year
 - = 0.03 Quads
3. Capital investment required - coal cleaning and CLM
 - estimated in above study at \$40 to \$75 million for cleaning to higher ash level product
 - estimate: \$75 million
4. Coal reserves required
 - assume: 30 year plant life
 - 80% wt yield recovery
 - 60% mining recovery from reserve
 - reserve required = 2 billion tons/Quad
5. Above all for a minimum capacity economic plant, i.e., 0.03Quad standard replicate plant assumed at 0.08Quad

Table 4.3

	<u>Representative Plants</u>	
	<u>Minimum Economic</u>	<u>Standard Replicate</u>
Designation	ME	SR
Normal Size (Quads)	0.03	0.08
Clean Coal Product		
- tons/hr	183	500
- tons/yr	1 million	2.7 million
Capital Investment		
- millions \$	75	150
Coal Reserve Required		
- million of tons	60	160

Table 4.4

MAXIMUM COAL USE POTENTIAL

MAXCUP

(Quads)

	<u>Northeast</u>	<u>Midwest</u>	<u>South</u>	<u>West</u>	<u>Total</u>
Residential	1.5	1.6	0.2	0.4	3.6
Commercial	0.6	0.6	0.06	0.08	1.3
Industrial-Boilers	0.1	0.3	0.4	0.1	0.9
- Process Heaters	<u>0.3</u>	<u>0.5</u>	<u>0.7</u>	<u>0.2</u>	<u>1.6</u>
TOTALS	2.5 ===	3.0 ===	1.4 ===	0.8 ===	7.4 ===

Note: Above summarizes market estimates by
Eos and Burns and Roe.

Table 4.5

MARKET IMPLICATIONS

MAXCUP

Coal Conversion Market	7.4 Quads
No. of Plants	95
Capital Investment	\$15 billion
Clean Coal Product	260 million tpy
ROM Coal Required	320 million tpy - major production increases needed*
Coal Reserve Required	15 billion tons - half of Appalachian low S DRB

*40% increase over total U.S. current level
70% increase over current Appalachian total

Table 4.6

DISTRIBUTION OF FUEL PLANTS
MAXIMUM COAL USE POTENTIAL

MAXCUP

	<u>Northeast</u>		<u>Midwest</u>		<u>South</u>		<u>West</u>		<u>Total</u>	
	<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>
Residential	1.5		1.6		0.2		0.4		3.6	
Commercial	0.6		0.6		0.06		0.08		1.3	
Residential/ Commercial		<u>26 SR</u>		<u>27 SR</u>		<u>3 SR</u>		<u>6 SR</u>		<u>62 SR</u>
Industrial										
- Boilers	0.1		0.3		0.4		0.1		0.9	
- Process Heaters	<u>0.3</u>		<u>0.5</u>		<u>0.7</u>		<u>0.2</u>		<u>1.6</u>	
Industrial		<u>5 SR</u>		<u>10 SR</u>		<u>14 SR</u>		<u>4 SR</u>		<u>33 SR</u>
TOTALS	2.5		3.0		1.4		0.8		7.4	
									TOTAL	95 SR

- Notes: 1. A column is market size in Quads.
2. B column is number of fuel process plants to supply market.
3. All plants are Standard Replicate (SR) plants of nominal 0.08 Quad size.
4. Residential and commercial markets can be supplied by product from the same plant.
5. Industrial market may use a different product
- higher ash and sulfur content may be acceptable in fuel.

Table 4.7

REDUCED COAL USE POTENTIAL

REDCUP

(10¹² Btu)

	<u>Northeast</u>	<u>Midwest</u>	<u>South</u>	<u>West</u>	<u>Total</u>
Residential	210	117	20	25	372
Commercial	33	36	3	4	76
Industrial-Boilers	7	12	18	6	43
- Process Heaters	<u>12</u>	<u>21</u>	<u>31</u>	<u>11</u>	<u>75</u>
TOTALS	262 ===	186 ===	72 ==	46 ==	566 ===

Notes on Reduced Potential:

1. Environmental constraints reduce the market to non-urban and half urban fringe for residential and commercial
 - about 50% as shown in residential analysis (Eos)
 - assume 25% for commercial
2. Assume fuel preference market capture
 - 50% of distillate & residual fuel oil users
 - 10% of natural gas users

Table 4.8

MARKET IMPLICATIONS

REDCUP

Coal Conversion Market	0.75 Quads
No. of Plants	5 SR, 4 ME
Capital Investment	\$1.05 billion
Clean Coal Product	18 million tpy
ROM Coal Required	23 million tpy - 3% expansion of production
Coal Reserve Required	1 billion tons

Table 4.9

DISTRIBUTION OF FUEL PLANTS
REDUCED COAL USE POTENTIAL

REDCUP

	<u>Northeast</u>		<u>Midwest</u>		<u>South</u>		<u>West</u>		<u>Total</u>	
	<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>
Residential	210		117		20		25		372	
Commercial	33		36		3		4		76	
Residential/ Commercial		<u>3 SR</u>		<u>2 SR</u>		<u>1 ME</u>		<u>1 ME</u>		<u>5 SR</u> <u>2 ME</u>
Industrial										
- Boilers	7		12		18		6		43	
- Process Heaters	<u>12</u>		<u>21</u>		<u>31</u>		<u>11</u>		<u>75</u>	
Industrial				<u>1 ME</u>		<u>1 ME</u>				<u>2 ME</u>
TOTALS	262		186		72		46		566	
									TOTAL	5 SR & 4 ME

- Notes:
1. A column is market size in Quads.
 2. B column is number of fuel process plants to supply market.
 3. Standard Replicate (SR) plants are nominal size of 0.08 Quads.
 4. Minimum Economic (ME) plants are nominal size of 0.03 Quads.
 5. Residential and commercial markets can be supplied by product from the same plant.
 6. Industrial market may use a different product
- higher ash and sulfur content may be acceptable in fuel.

5.0 COAL RESOURCE ANALYSIS

With discussions of the U.S. coal resources and potential market needs as a background, the major thrust of the Analysis of Fuel Needs (Task 1) was to identify specific coals having the required characteristics and sufficient reserves for projected needs. Specific resource data listings for coal beds and characteristics were reviewed against selection criteria based on combustor requirements, emission constraints and market needs. A series of searches of coal data were conducted for the different requirements in order to recommend candidates for coals to be prepared as test fuels. The searches, criteria, and findings are discussed in the following sections.

For the larger combustors, amenable to a slagging type retrofit, the required fuel specifications differed significantly from the non-slagging combustors. Having a capability of high slag rejection affords an added benefit for potential removal for significant amounts of sulfur. Lime based chemicals (sorbent) introduced into the combustors have been shown to capture 30-50 percent of available sulfur in the coal feed, thus minimizing the release of SO_2 into the flue gases. Desulfurization technology in this form has exhibited this level of results using a stoichiometric ratio of 2:1 of lime to sulfur. At the 90 percent rejection level, these operating parameters calculate the maximum range of feed quality values from 0.5 % ash @ ≤ 1.8 % sulfur and up to 10 % ash @ ≤ 1.6 % sulfur.

For the slagging type of combustor, the ash chemistry becomes even more critical to the unit operation than the overall ash content. For this reason the ash softening temperature, which is a pre-determination to the T250 temperature, (i.e. slag flow temperature equivalent to a viscosity of 250 poise) was surveyed for coal selectivity. Ash fusion temperatures in the low (< 2100 degrees F) to medium (2101 to 2400 degrees F) coupled with a feed content meeting the particle and sulfur dioxide emission standards after slagging, assuming a 50% SO_2 reduction and 90% maximum ash rejection level, denotes the specific criteria used for resource evaluation and candidate selection for the classification.

Coal cleaning technology utilizing surface and leaching chemistry concepts has advanced to stages of increased Btu recovery at finer sizes; however, much of the information is still proprietary and potentially process selective. These technologies are generally independent of washability characteristics. Based on the best information available on a broad survey of U.S. coals, the approach taken by this investigation was to apply the liberation potential found by analyzing washabilities of crushed products.

The Pittsburgh Energy Technology Center (PETC) database had been electronically compiled of nearly 1000 washability samples regionally collected from the major coal fields. An initial search was performed to determine the magnitude of analyses approaching the stringent specifications for commercial and light industrial process heating.

RESOURCE EVALUATION CONCLUSIONS

Given a defined set of stringent fuel characteristics, two suites of coal candidates have been selected, one for the residential, commercial and light industrial markets and the second for the slagging type combustor market. These sets are shown in Tables 5.1 and 5.2.

Residential, Commercial, Light Industrial

- From a database of nearly 1000 samples representing over 200 coal beds, a select few coal seams have been identified which can be "Semi" conventionally beneficiated for the production of 1.5 percent dry ash at compliance levels. These fuel characteristics allow coal-based fuel to be competitive with natural gas and oil. Residential market candidates will be selected from the most cleanable of these.
- The resources associated with the select coal beds identified are proportionately distributed to the regional market areas. The suite of candidate coals is within a 700 mile radius to all market areas.
- For the one billion tons of reserve required for CBF production, an excess of 14 billion tons have been correlated to the select coal beds.
- The coals identified, with the exception of Coal Basin D and E coals of Colorado, have been previously used by several slurry manufacturers and proven to be slurryable.
- Ash slagging and fouling characteristics of the select coals appear to be within specifications at conventional cleaning plant specific gravities, however, the effect of "deep" cleaning on ash characterization will need to be further investigated.
- Slurry stability and dry dense power flowability depend on grinding characteristics of the select fuels. These factors will have to be further evaluated by slurry manufacturers and the intrinsic effect of the hardgrove grindability index.
- Additional coal beds, either not included in the database or which could be beneficiated with advanced cleaning technology, could significantly expand the regional diversity of the resource base. For the near term projected use of CBF, the identified suite of candidate coals will satisfy all demands. A large number of coal producers have been identified as mining these select coals.

Slagging Combustor

- Use of slagging type combustors can decrease the strict requirement of feed ash and sulfur content for potential resource expansion, but places a second demand, namely, ash softening and T250 temperatures, on the selection of fuel candidates.

- A list of 13 coal beds have been identified meeting both quality and reserve specifications. The coals are regionally located to supply the required demand for all market sectors in this classification.
- Even with the expanded quality specifications no coal seams from the Midwest Region, including the Illinois Basin, have been identified with reliable confidence conformity.
- Final selection of fuel candidates for fuel characterization Task 2.0 will be made after final receipt of all combustion questionnaires (Section 7.0).

Table 5.1

POTENTIAL FUEL CANDIDATES FOR COMMERCIAL/INDUSTRIAL APPLICATION (<1.5% ASH, COMPLIANCE)

SEAM	BED NO.	LOCATION*	ESTIMATED RESERVES (MILLIONS OF TONS)	YLD***	AVG %		AVG BTU/LB
					COAL ASH	COAL SULFUR	
Brookville	095	** PA, OH, MD	952.14	66.7	1.3	0.68	15030
No. 2 Gas	168	KY, TN, VA, WV	>2,500	69.3	1.2	0.76	14747
Black Creek	299	AL	71.52	83.0	1.0	0.62	15210
Hazard 5A	111	WV, VA, KY	>1,100	74.8	1.0	0.75	14519
Upper Elkhorn #3	151	WV, VA, TN, KY	>2,000	74.8	1.0	0.73	14594
Upper Elkhorn #2	154	KY, VA, WV	>1,200	73.6	1.3	0.79	14555
Upper Elkhorn #1	157	WV, VA, TN, KY	>1,000	73.2	1.2	0.67	14780
Chilton	135	WV, VA, TN, KY	>775	31.7	1.3	0.72	14998
Powelton	170	WV	206.32	53.3	1.3	0.69	15047
Coal Basin D	755	CO	83.13	65.2	1.5	0.60	14069
Coal Basin E	756	CO	83.64	80.9	1.3	0.33	14219

* Location refers to all states in which a particular seam has been identified.

** Underlined states reflect basis on which reserves and analyses are shown.

*** Average analysis only reflects composite results of samples meeting residential application criteria for level 5 cleaning (i.e., 14X100M 1.30 float).

Table 5.2

<u>DOE Sample No.</u>	<u>Coal Bed Name</u>	<u>Bed No.</u>	<u>State</u>
	<u>Ash Softening Temperature <2100°F</u>		
709	Dietz #3	697	WY
	<u>Ash Softening Temperature 2101-2400°F</u>		
153	Lower Bakerstown	63	MD
188	Upper Freeport	71	PA
200	Upper Freeport	71	PA
403	Upper Banner	214	VA
406	Tiller	269	VA
545	Croweburg	496	OK
546	Croweburg	496	OK
618	H-Seam	154	CO
624	Upper Williamson	169	CO
625	Upper Williamson	169	CO
626	Upper Williamson	169	CO
710	Wyodak	699	WY
713	Wyodak	699	WY
737	Laramie No. 3	768	CO
847	Princess No. 7	77	KY (East)
860	Upper Elkhorn #3	151	KY (East)

6.0 COAL CANDIDATES

The following tables exhibit the two suites of candidate coals for use in Tasks 2 and 3 of this contract. The reserve quantities reported have been updated to concur with the latest geological documentation.

Those coals which meet the stringent specifications for the RCLI market include:

<u>Bed Number</u>	<u>Coal Bed Name</u>	<u>Related Names</u>	<u>Locations Found</u>	<u>Original Estimated Reserves (tons)</u>
151	Upper Elkhorn #3	Cedar Grove, Jellico, Taggart	WV,VA,KY,TN	12,558,191,000
154	Upper Elkhorn #2	Lower Cedar Grove	WV,VA,KY	3,525,101,400
157	Upper Elkhorn #1	Alma, Blue Gem	WV,VA,KY,TN	9,402,073,300
168	Lower Elkhorn	No. 2 Gas, Pond Creek	WV,VA,KY,TN	11,015,747,000
756	Coal Basin E			83,000,000

Those coals with quantifiable reserves which meet the quality parameters for slagging combustors include:

<u>Bed Number</u>	<u>Coal Bed Name</u>	<u>Related Names</u>	<u>Locations Found</u>	<u>Original Estimated Reserves (tons)</u>
63	Lower Bakerstown	Thomas Three Foot	MD,PA,WV	
71	Upper Freeport	Big UGN	MD,OH,WV,PA KY	
77	Princess No. 7	Coalton	KY	
151	Upper Elkhorn #3	(See above)	WV,VA,KY,TN	12,558,191,000
154	H-Seam		CO	
169	Upper Williams		CO	
214	Upper Banner		KY,VA	
269	Tiller	Lower Iaegel, Tono	WV,VA,WA	
495/ 496	Deadman (Upper/Lower)			
496	Croweburg	Fireclay No. 2	KY,IN,KN,OK, IL,MO,ID	
697	Dietz #3	Canyon	WY,MN	
699	Anderson- Wyodak		MN,WY	
768	Laramie No. 3		CO	
782	Adaville		WY	
927	Anderson/Dietz		MN,WY	

7.0 FUEL SPECIFICATIONS & SUPPLY

During this quarter each of the combustion contractors were contacted by telephone to explain the role of Energy International and Dravo as suppliers of fuel for the advanced coal combustion program. This was followed up by a letter survey asking the contractors to detail as quantitatively as possible their fuel specifications for the coal-water slurries and/or the micronized coal. In addition, the survey asked for their scheduling needs for the fuel over the length of their contract. A copy of the survey questions sent to each of the contractors are attached.

The reply to this survey along with the requirement to meet certain emissions standards detailed in the original PRDA was to aid in the coal selection process. Unfortunately, the replies to the survey have been slow in coming in. It can be said, however, that with the exception of the slagging type boiler applications, all contractors are requesting fuels with sulfur contents equal to or less than 0.50 lbs/MMBtu and ash contents of 0.80 lbs/MMBtu as spelled out in the PRDA. This applies to the micronized coal as well as to the coal-water slurries. Therefore, the cleanability, as described in the previous section, becomes the important coal selection criteria. The next important criteria is the ash fusion temperature of the coal. From the replies received, most combustors request high ash fusion temperatures ($>2200^{\circ}\text{F}$) to prevent slagging. The main differences between contractors' specifications seems to be in the particle sizes. A Schedule of Deliveries of Coal Based Fuels has been tabulated in Tables 7.1 and 7.2 and Properties of Coal Based Fuels has been tabulated in Tables 7.3 and 7.4.

Those contractors who have not replied to the survey will be contacted again. When sufficient information is gathered, fuel specifications will be established with the hope that only a few fuels will have to be prepared; that is, that a consensus on fuel specifications among the contractors can be obtained. Ideally, fewer fuels used by combustors would provide a commonality among combustion testing. The quantity of fuel required and a delivery schedule will also be established.

8.0 FUTURE PLANS

In the next quarter a Topical Report of Task 1 activities and findings will be issued. Starting in February candidate coals will be sampled and characterized, i.e., washabilities and flotation studies. Quality Assurance of fuels will be made. Visits to mine/wash plants will be made in order to observe the origin and handling of the coals, in an attempt, to ensure integrity of the sample. Coals will be cleaned and sized according to requirements of the combustors. A slurry technology will be selected from those available now and during the next 2 1/2 years.

Fuel Specification and Supply Survey

COAL - WATER SLURRY

For Coal

1. Coal Rank: _____

	Min.	Max.	Preferred
2. % Moisture	_____	_____	_____
3. % Fixed Carbon (MF)*:	_____	_____	_____
4. % Volatiles (MF):	_____	_____	_____
5. % Ash (MF):	_____	_____	_____
6. % Sulfur (MF):	_____	_____	_____
7. Heating Value, Btu/lb. (MF):	_____	_____	_____
8. Ash Fusion Temperature**:	_____	_____	_____

*MF= moisture free

** Initial softening in reducing atmosphere

For Slurry

1. Solids Loading:	_____	_____	_____
2. Viscosity at Shear Rate:	_____	_____	_____
3. Particle Size: Top Size:	_____	_____	_____
Mean Size:	_____	_____	_____

Schedule Requirements.

Amount

Date Needed (or Lapsed Time
from Contract Start)

Coals Previously Tested

Submitted By: _____ For: _____
(Name) (Company)

Fuel Specification and Supply Survey

MICRONIZED COAL

1. Coal Rank:	_____	_____	_____
	Min.	Max.	Preferred
2. % Moisture	_____	_____	_____
3. % Fixed Carbon (MF)*:	_____	_____	_____
4. % Volatiles (MF):	_____	_____	_____
5. % Ash (MF):	_____	_____	_____
6. % Sulfur (MF):	_____	_____	_____
7. Heating Value, Btu/lb. (MF):	_____	_____	_____
8. Ash Fusion Temperature**:	_____	_____	_____
9. Particle Size: Mean:	_____	_____	_____
Top Size:	_____	_____	_____

* MF=moisture free

** Initial softening in reducing atmosphere

Schedule Requirements.

Amount

Date Needed (or Lapsed Time
from Contract Start)

Coals Previously Tested

Submitted By: _____ For: _____
(Name) (Company)

END

**DATE
FILMED**

9/22/93