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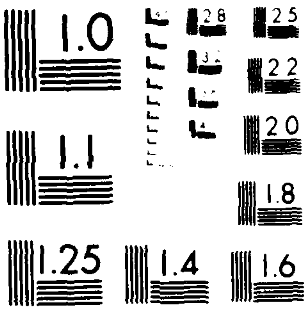

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU

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COAL-WATER SLURRY FUELS

AN OVERVIEW

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INTRODUCTION

The United States has measured recoverable energy reserves of 5,400 quads* of oil, natural gas, coal and uranium. This represents the energy supplies which are identified and essentially ready for recovery using available technology. At the 1982 consumption rate of approximately 72 quads, that equates to a seventy five year supply if we do not discover another BTU. This does not include the large reserves of oil shale and tar sands, nor does it include the significant extension of our uranium resources that would be possible with the introduction of breeder reactor technology. Of the fossil fuel reserves, oil represents 3%, natural gas 4%, and coal 88%. More than any other fuel resource, the coal beneath the U.S. is evidence of America's vast energy wealth. The measured and readily mineable coal reserves equates to 438 billion tons of coal. In terms of energy content, this coal we know can be mined is equivalent to almost ten times the recoverable supplies of oil in Saudi Arabia. Conservative estimates place the total amount of coal in the U.S., including that not yet discovered, at nearly 4 trillion tons or ten times that now known as mineable.

If we look at the consumption side, 45% of our energy use is oil, 3% nuclear, 26% natural gas and 20% coal. Of the oil which is consumed in this country, over 40%, or 5½ million barrels per day, is imported. These statistics seem to point out that because of our hugh coal reserves we do not have an energy shortage, but a mismatch between our most abundant resource--coal--and the consumption of our least abundant resource--oil.

In spite of the relative abundance of coal and the increasingly attractive fuel cost differentials between coal and oil, the rate at which coal is being substituted for oil is limited by four essential characteristics that distinguish coal from oil.

* 5.8 Quads = 1 Billion Barrels of Oil

First, coal is a solid. By being solid, coal is not only more difficult and more expensive to transport to the user's site, it is significantly more difficult to handle, store and distribute at the user's site. The difference is most striking if we look at the fuel handling system of an oil-fired boiler. The oil-fired plant essentially consists of a storage tank, some piping and pumps to move the oil, and meters and valves to control that flow, followed by the input nozzles to the boiler itself. A coal-fired system will typically have a storage pile and many other mechanical systems which crush, size, and pulverize the coal, move the coal from different sizes and types of storage facilities, and eventually to the boiler itself. Each of these conveyers, weigh belts, bucket elevators, screw feeders, pneumatic pumps, dryers, storage bins, lock hoppers and so on, are bulkier, more expensive and less reliable than the pipes and pumps that replace them in an oil-fired system, and require physical space that may not be available at many sites.

Second, coal differs from oil in that it contains larger quantities of ash or inorganic matter than oil. Oil is typically much less than 1% in total ash content whereas coal ranges anywhere from 5 to 35% in total noncombustible ash. This ash not only impacts on boiler performance and design, but disposal is also a problem.

Third, coal differs from oil in that it typically contains significantly larger percentages of sulfur. The presence of sulfur is primarily an SO_2 emissions problem. The total SO_2 released by the power plant must be controlled by either reducing the sulfur in the coal to acceptable limits by coal cleaning (or inherently low sulfur coal) or by post combustion cleanup.

Fourth, coal burns differently than oil. That is not to say that it does not burn well - which it does - but it does burn at a different heat release rate and a different temperature than oil, and it takes a longer time for coal particles to combust than finely atomized oil droplets.

As a result of these characteristics, oil or gas designed systems are effectively prevented from direct coal firing, and coal-fired systems have significantly higher capital costs than the oil or gas-fired systems they replace. These capital cost differences, coupled with the large emplaced inventory of long-lived oil and gas designed equipment (often accompanied by physical site constraints), constitute significant forces in decreasing the rate at which coal firing becomes the economic choice.

COAL SLURRY FUELS: MOVING TOWARD COMMERCIAL UTILIZATION

Oil price increases and supply manipulations during the past decade have caused large users of fuel oil to search for alternative fuels to fire in existing oil-designed steam generators. In the United States, approximately one-quarter of the fuel oil and natural gas consumed is used for power production in utility and industrial boilers, and for industrial process heat needs.

Coal water slurry technology has been under development in the United States and in other countries for quite a few years, and a number of organizations are progressing toward commercialization of the fuel, which is intended to be a replacement for heavy oil in industrial and utility boilers as well as other furnaces.

FLORIDA POWER & LIGHT COMPANY Florida Power and Light Company (FPL) is one of the largest utility consumers of fuel in the United States (40 million barrels in 1981), and consequently, has set a major R&D objective for the 1980's to identify and develop economically and technically sound fuel alternatives. FPL has nine 400 MW and four 800 MW oil designed units which are candidates for conversion to an alternative fuel. Many possibilities have been examined, or are still in the process of being evaluated, including pulverized coal, peat, synthetic gas from coal, synthetic liquids from coal, alcohol mixtures, petroleum coke, coal-oil mixtures (COM), coal-oil-water mixtures (COWM), and coal-water mixtures (CWM).

Coal which is an abundant domestic fossil fuel, is likely to be the fuel choice for new generating capacity installed during the next several decades. If coal could be successfully burned in existing oil designed boilers, the resultant fuel cost savings might significantly help hold down the cost of generating electricity.

Unfortunately, conversion to pulverized coal (or any other solid fuel) would require major capital expenditures. The liquid fuel feed systems would have to be replaced by solids handling systems. Pulverizers would have to be installed. Storage facilities for large quantities of solid fuel would be required, as well as ash handling equipment, emission control systems, and an infra-structure to transport fuel to generating stations. The additional land which would be required may be difficult to obtain at some candidate conversion sites. Engineering studies have shown that conversion to pulverized coal is not financially attractive at this time. Many of the above problems would be eliminated if coal could be burned and handled in a liquid form.

The technology for suspending finely ground coal particles in a liquid, to produce a stable and pumpable slurry fuel, has been developing rapidly. Such a slurry can be handled, transported, and stored much like conventional liquid fuels, thus requiring less modification of currently used equipment. Slurry fuels can also be commercialized in the near term, because no significant advances in hardward technology are needed to produce utility quantities of fuel.

CWM fuels are now being evaluated as an alternative to No. 6 fuel oil in oil-designed utility boilers. The fuel is prepared by suspending finely ground coal in water and adding various chemical additives to improve stability and viscosity. A typical CWM fuel consists of 70% coal, 29% water, and 1% chemical additives. Coal particle size control can also be used in increased solids loadings and reduce viscosity. CWM boiler fuel should not be confused with coal-water slurry for pipeline transportation, which generally consists of coarsely ground coal, not more than 50% solids by weight. The high solids loading of CWM boiler fuels produces viscosities one or more orders of magnitude greater than those of dilute transportation slurries. Pipeline transportation of CWM fuel for more than a few miles would be economically unattractive. Occidental Research Corporation has found that barge transportation is the most cost effective.

Preliminary economics comparing coal-water-mixture (CWM) with coal-oil-mixture (COM) for oil backout have shown CWM to be more attractive. On an energy basis, $/MM BTU, coal is presently a cheaper fuel than No. 6 fuel oil, and therefore, should be utilized to the greatest extent possible in any fuel mixture. A relatively simple calculation will show that in a COM fuel with 50% coal by weight only about 40% of the total energy is supplied by the coal. With CWM fuel, 100% of the energy is supplied by the coal. In addition, the energy penalty due to the presence of water in the fuel is surprisingly small, somewhere between 3 and 5% depending on solids loading and energy content of the coal.

CWM also appears to have some technical advantage over COM. For example, the lower flame temperature obtained due to the presence of water in the fuel helps to reduce formation of NO_x.

The lower temperature also helps to reduce slagging. In addition, CWM may benefit from a reduced slagging potential when compared with COM because some suspected detrimental synergistic effects of combining oil ash and coal ash are avoided. For these reasons, CWM has now become the primary focus for fuels research at Florida Power and Light.

At present, CWM fuel is not available to utilities in commercial quantities. Pilot production facilities have been built which are capable of producing industrial scale quantities. It is conceivable that enough fuel could be accumulated over time to run some utility tests, they would necessarily be short tests.

The commercialization of CWM presents a dilemma to both utilities and potential fuel suppliers. Large utility users are not readily willing to sign a long term fuel agreement until all technical and economic issues have been resolved by a full scale utility demonstration. Conversely, a potential CWM supplier is not readily willing to build a utility scale fuel preparation facility without the security of a long term contract. FPL believes that a solution to the quandary can be found, and will require an equitable distribution of risks and rewards among all parties.

Florida Power and Light has been following the development of CWM fuel for a number of years, and has been directly active in CWM research work since mid-1981. In an important program sponsored by FPL, Battelle Columbus Laboratories has recently completed laboratory scale (700,000 BTU/HR) combustion tests of five CWM fuels. These tests are described in more detail below.

COMBUSTION EFFICIENCY Combustion efficiency was determined by analyzing fly ash collected in particulate samples for carbon content, and comparing the carbon particulate to the quantity of carbon fired. Combustion efficiency values determined in this way ranged from 98.9 to 99.9 percent. These values compared well to values for pulverized coal fired power plants, which range from 99.0 to 99.9, with most values between 99.3 and 99.9 percent. Thus, the CWM fuels fired in these tests gave good combustion efficiencies and the presence of 30 percent water was not detrimental to carbon burnout.

FUEL STABILITY One of the major factors in CWM fuel formulation is the selection of stabilizing additives. The problem of creating stable slurries is compounded by the fact that additives that increase stability are also likely to increase fuel viscosity, making the fuel difficult to pump and atomize. Also, the additive may be a significant part of the fuel cost and, hence, there is interest in minimizing the quantity of additive used.

Most CWM's evaluated in the laboratory trials showed evidence of coal particle settling, frequently within a few days. Major particle settling was observed after a few months with all but one. However, a major observed difference between the fuels was whether the settled particles could be reentrained by physical mixing (stirring) or whether a hard, concrete-like deposit formed at the bottom of the drums. The best fuels could be stored for two or three months with only moderate settling and the settled particles could be dispersed by stirring.

A one to two month stability for CWM fuel is likely to be satisfactory for most utility operations. However, in unusual circumstances (e.g., a strike by those delivering the fuel, or failure of a major plant component causing a long-term outage) this stability might not be adequate. It might be necessary to consider using minimum amounts of additives on a routine basis and using more additives when necessitated by other events.

COAL CLEANING CWM fuel technology appears to be developing at a faster rate than advanced coal cleaning technology, therefore, it is expected that there will be several generations of CWM fuel. The first generation fuel will most likely be prepared using conventional techniques. It is hoped that the 3% ash level will be economically achievable. It is possible that the second generation fuel will have an ash content as low as 1%.

FUEL COMPATIBILITY CWM fuel compatibility is an issue which has not yet been addressed. It may be premature to worry about fuel compatibility, however, if CWM is successfully commercialized and becomes available from several sources, compatibility may become important. What will happen if Fuel A is mixed with Fuel B in a large storage tank? Each fuel may have a different particle size distribution and a different choice of chemical additives. Early testing has shown some CWM fuels to be incompatible. Viscosities of fuel blends can be more than an order of magnitude greater than either of the original CMW fuels. It is possible that some industry standards for CWM fuel compatibility may be required at some point in the future.

<u>SUMMARY</u> FPL has drawn the following conclusions from experience to date.

1) CWM fuels are readily combustible
2) Fuels can be produced which exhibit acceptable handling and storage properties.
3) Preliminary economics appear attractive, however, more refinement is needed.
4) No significant advances in hardward technology are needed to produce CWM on a utility scale.
5) Advanced coal cleaning concepts may take longer to commercialize than CWM fuel, therefore, CWM will likely go through several generations of evolution.
6) A large scale demonstration of CWM fuel in an oil-design utility boiler is needed to resolve all technical and economical issues.

The FPL staff is optimistic about the potential of CWM as a near term alternative to No. 6 fuel oil, and plans to continue a thorough investigation of the remaining technical and economic issues. However, some questions can only be answered by a full scale utility demonstration.

FPL is currently exploring the possibility of conducting a full scale, 400 MW demonstration, most likely at the Sanford Plant. The costs and technical requirements of such a demonstration are being scoped. Data from this study is required before decisions regarding a demonstration can be made. Should a full scale demonstration prove successful, and the economics of CWM firing continue to look attractive, FPL would adapt CWM as a commercial alternative fuel for appropriate units.

U.S. DEPARTMENT OF ENERGY (DOE) PROGRAMS

Several combustion test programs have been performed at the Pittsburgh Energy Technology Center (PETC) of the U.S. Department of

Energy (DOE) to evaluate coal-liquid mixtures in oil-designed industrial boilers. The overall objective is to develop retrofit technology to permit use of these fuels in existing oil-fired boilers to reduce our dependency on petroleum imports. The coal-liquid mixtures investigated at PETC include coal-oil, coal-water, and coal-methanol mixtures.

To reduce our dependency on foreign oil, the U.S. Department of Energy (DOE) is pursuing both near and long term approaches to utilizing our abundant coal resources with the objective of displacing petroleum fuels from boilers and furnaces. In support of this program, the DOE Pittsburg Energy Technology Center (PETC) operates combustion test facilities to evaluate the handling and combustion characteristics of alternate fuels, determine pollutant emissions resulting from combustion of these fuels, and develop retrofit technology as required. Emphasis is placed on assessing the technical feasibility of utilizing these fuels in boilers originally designed to burn oil.

Coal-oil mixtures (COM) have the potential for partially displacing petroleum used in existing oil-fired boilers. A coal-oil mixture combustion test program was systematically carried out at PETC from 1978 to 1981 using an oil-designed 700-hp (24,000 lb/hr steam) water-tube boiler. The test program included the evaluation of COMs containing coal concentrations of up to 50 percent, prepared with coal particle size consists varying from 90-percent minus 325 mesh to 60-percent minus 200 mesh and with three types of coal. A 500-hour-duration test was conducted to examine the effects of ash deposition, erosion, and corrosion.

Coal water mixtures (CWM) have the potential for fully displacing petroleum used in existing boilers. The CWM test program at PETC was initiated in February 1981 after the completion of the COM program. Initial CWM testing was performed using an oil-designed 100-hp (3,500 lb/hr steam) firetube boiler. A comprehensive CWM test program is now underway using the 700-hp watertube boiler.

A series of parametric CWM tests was conducted to evaluate the effect of fuel ash content on boiler performance. Current CWM testing in the 700 hp boiler includes an evaluation of the effects of coal particle size consist and the use of oxygen-enriched air on boiler performance.

TEST RESULTS As a result of advances in COM technology achieved at PETC and elsewhere, the use of COM in oil-designed boilers has been shown to be technically feasible. Commercialization of the technology is now being pursued in the industrial sector.

The results of the CWM combustion tests conducted in the PETC oil-designed 700-hp boiler led to the following observation: (1) CWMs containing 60 percent by weight of three different hvAb [illegible]als could be burned at carbon conversion efficiencies in excess o[illegible] [illegible] percent using preheated air at 500°F (coal particle size consis[illegible] [illegible]re 90-percent minus 200 mesh). (2) The ash content of the [illegible] had a marked effect on the rate of deposition in both the radiant and the convective sections of the boiler, resulting in a significant lowering of the average flue-gas temperature and an increase in boiler efficiency during the period of a test as ash content of the coal decreased from 11.4 to 2.6 percent. (3) Even when burning CWMs prepared with coal containing only 2.6 percent ash, deposition in both the radiant and the convective sections of the boiler was significant. Beneficiated coals with substantially less ash content will be required if CWMs are to be burned without the assistance of ash removal equipment (such as soot blowers) in a boiler of the same general configuration as the PETC unit.

The DOE has initiated a program to investigate the potential for coal water mixtures (CWM's) to serve as direct substitutes in combustion processes for liquid petroleum and natural gas. As a part of this overall DOE effort, Morgantown Energy Technology Center (METC) is investigating the feasibility for the combustion of ultra-clean coal water mixtures (UCCWM's) in gas turbines. A necessary goal of this program is to develop an understanding of the chemistry of the products of combustion (POC) of UCCWM's. Both experimental and modeling efforts are in progress to investigate POC chemistry. Based on these results, specifications for a UCCWM turbine fuel can be developed. In support of the modeling and experimental efforts, detailed characterization studies of coal, CWM's, and UCCWM's have been conducted to quantify levels and the distribution of minerals and trace elements. An analytical scheme has been developed for the detailed analysis of these feed fuels for input to the modeling program for prediction of UCCWM products of combustion. The extensive chemical and physical analysis of CWM's includes determinations of percent water, ultimate and proximate analysis of the coal, elemental and compositional analysis of low-temperature ash of coal, heating values of CWM, viscosity, and coal particle size distributions. Similar analysis of samples of ash from the POC have allowed comparisons of composition and evaluations of the change in ash composition during combustion.

FORNEY ENGINEERING COMPANY (FECO) FECO has provided combustion equipment to the utility, industrial, and marine market for over 50 years, and has a considerable history of involvement with fuel slurries as liquid fuel alternatives. They have furnished burners and participated in coal-oil-mixture combustion demonstrations at a number of companies such as General Motors and are now very active in the development of equipment for the combustion of CWS fuels. The coal and water slurry test program began in 1981 when Advanced Fuels Technology, a Gulf & Western Company, approached FECO to test their Coal-Aqueous Mixture (CAM) fuel. The test program included requirements to store, pump, transport, and burn the CAM fuel. The intent of the program was to use conventional equipment where possible and modifications where necessary.

The coal and water mixture fuel combustion proved to be unsatisfactory using conventional burner designs. FECO decided to design and test atomizers and burner configuration specifically designed for the

Coal-water fuel. The tests conducted with this design proved to be successful. Future tests are planned to document performance and critical adjustments of the burner and atomizers.

A demonstration project using four burners of this type is scheduled for the Summer of 1983. The project is sponsored by New Brunswick Electric Power Commission and will use fuel provided by Cape Breton Development Corporation. This project will allow Forney to evaluate performance of the burner in a commercial application and near performance of several special materials proposed for atomizers.

OCCIDENTAL RESEARCH CORPORATION (ORC) Since the energy crisis of 1973, industry has found it increasingly difficult to project and plan for future energy conditions. Oil and gas prices have been characterized by uncertainty, but have followed a general upward trend.

There has also been significant interest in replacing energy imported by the U.S. with domestic fuels. Because of its abundant supply and inherent low costs, coal is an attractive replacement fuel candidate. Solid coal is usually not an acceptable substitute because of the extensive cost of retrofitting a boiler designed to burn oil and gas. In most situations existing sites are inappropriate for coal delivery, storage piles and grinding equipment.

The use of solid coal in a liquid form, such as a coal-water mixture, minimizes the disadvantages of dry pulverized coal. CWM is nearly as convenient as fuel oil to handle and store. Small scale combustion tests indicate that CWM is a viable fuel oil replacement that could offer the user an attractive fuel option.

ORC has been involved in CWM research and development for several years. An extensive program with the objective of developing a leadership position in CWM science and technology was undertaken. ORC's development strategy includes a generalized formulation approach that is applicable to a wide variety of coals and not dependent on intensive coal beneficiation. Additives used in the Occidental formulation to stabilize the slurry and assure good fuel handling properties will not have adverse effects on combustion equipment. The ORC process is based on readily available grinding and mixing equipment.

In parallel with its formulation and process development work, ORC has conducted commercial assessments and economic evaluations from both CWM producer and potential user viewpoints. Results of these studies have been used to guide research towards the development of a fuel that not only meets the end user's combustion requirements but does so at a fuel cost competitive with No. 6 fuel oil.

CWM formulation work has been done at ORC's laboratory in Irvine, California. This is also the location of their pilot plant which has a coal capacity of one ton per hour and is now fully automated. The pilot plant has been used to study and optimize the grinding, mixing and chemical addition operations in CWM preparation.

The COM Energy, Inc. (an Occidental subsidiary) coal slurry preparation facility in Jacksonville, Florida, is the planned location of a large scale demonstration of Oxy's CWM preparation technology. The plant is rated at 15 tons per hour of coal and will require only minor modification to convert the existing COM operation to CWM since much of the equipment is compatible with both modes. The CWM changes will cost less than $1.0 million. Flow sheets and equipment lists are now being prepared.

Occidental has also retrofitted an industrial steam boiler to burn coal slurry fuel. The boiler is located at the Oxy Chem Suwanee River Plant in White Springs, Florida. The boiler is a Babcock and Wilcox Model FM-117-88 package boiler. It was originally designed to burn No. 6 fuel oil or natural gas and has a rated capacity of 130,000 lbs/hr steam. The addition of coal slurry as an alternate fuel required the installation of a new fuel feed system, boiler control modifications, burner changes, and a flyash collection system. This retrofit was engineered and installed in 10 months at a cost of $2 million. COM has been successfully burned in the boiler and with some modification to the burner and fuel feed system, the boiler will be capable of firing CWM. The cost of the CWM modifications will be minor compared to the original retrofit.

Occidental's experience with the Oxy Chem boiler and the slurry preparation plant in Jacksonville provide a realistic background for determining boiler retrofit and CWM plant costs. These facilities also provide an opportunity to demonstrate CWM combustion feasibility on a commercial scale. Extended combustion testing with CWM will provide answers to long-term ash effect questions on boilers designed for fuel oil. A successful test program of this type will reduce user risk and will bring CWM closer to commercial acceptance.

ORC's initial CWM marketing strategy has been organized to concentrate on potential industrial users of CWM. Industrial users will likely be more receptive to CWM technology than utilities because the capital required to retrofit an industrial boiler is less than that needed to convert larger utility boilers. In addition, industrials are not subject to Public Utility Commission approvals for capital expenditures. However, the key to large volume CWM consumption is the utility market, and this market is not expected to develop until CWM has been demonstrated on the industrial level.

A market study conducted by Island Creek Coal Company identified industrial users consuming more than 300,00 barrels of oil annually as representing the industrial sector for potential CWM fuel conversion. Approximately 88 percent of the total consumption of residual fuel oil takes place in states east of the Mississippi River. There is a concentration of potential CWM customers in the New England and Mid-Atlantic Coastal areas. Significant residual fuel oil consumption is also seen in Florida and in the Mid-Western states of Ohio, Indiana, and Michigan.

To serve these markets, two proposed locations for CWM preparation plants have been studied. Site "A" is on the Ohio River near Portsmouth, Ohio. Location "B" is on the Norfolk Harbor in Virginia. Island Creek Coal Company delivers coal to both of these locations and operates a coal terminal at the proposed Ohio River site. The Ohio River CWM preparation facility could be built on Island Creek property and utilize some of the coal handling equipment that is there. Both proposed locations can take advantage of barge transport of CWM which was found to be the most cost effective transportation method.

CWM economics can be significantly impacted by costs incurred in the transportation of coal to the slurry preparation plant and CWM transport to the customer. These issues are considered by ORC to be key in the selection of a proposed site for a CWM preparation plant.

CWM economics presented have all been geared to the industrial user because that is the first expected CWM market. The utility market offers several potential savings over the industrial market for both CWM users and producers. These savings include economics of scale for a larger CWM preparation plant and larger boiler retrofits. A utility would likely require a dedicated CWM production plant which could be located in close proximity to the utility site. A pipeline CWM delivery system would lower transportation costs. Product stability and storage may not be a critical issue for a dedicated utility user and could significantly both reduce CWM additive package costs and CWM storage facility requirements.

ATLANTIC RESEARCH CORPORATION

During calendar year 1982, the Atlantic Research Corporation (ARC) designed, constructed and began operations in a 600 barrel per day coal-water fuel facility near Fredericksburg, Virginia. This standalone plant, completely company financed, is a prototype of a commercial facility, and can supply sufficient quantities of fuel that operational experience can be gained in commercial applications. It uses commercial equipment that is representative of those equipments to be used in a commercial sized plant.

This is the third processing plant that ARC has built in addition to the dedicated laboratories and the one million BTU per hour burner facility. The progression of plants has been from a one barrel per hour batch facility, the three barrel per hour continuous facility, to the 600 barrel per day pilot plant.

Coal water slurry continues to show the promise of an economical alternate fuel for industrial use. On a world-wide front, considerable work has been down by many parties since 1977 to bring this fuel to a state of maturity, ready for large scale industrial and utility testing for commercial applications. There is no longer a question that a reliable coal-water slurry fuel can be manufactured and processed utilizing standard grinding and mixing equipment in conjunction with normal quality control procedures.

ARC looks forward to continued improvements in quality and reduced cost of fuel through process improvements and operating experience. Their experience in operating this pilot plant indicates no problems in future plant scale-up for commercial operations.

The final challenge is to establish a data base through long-duration testing in various types of boilers and in various types of applications. Events now in motion will permit ARC to acquire this data during this calendar year. This will permit serious examination for industrial conversions that could begin in 1984.

Using equipment quotes from representative and, in many cases, competitive suppliers, the product price for a 20,000 barrel-per-day plant located on the East Coast using $55 per ton (delivered) coal will be less than $3.00 per million BTU. This can be compared to oil at $29/barrel or approximately $5/million BTU.

STANDARD HAVENS, INC.

Standard Havens is a leading manufacturer of hot-mix asphalt production equipment for the road maintenance and construction industry, and fabric filter air pollution control equipment for a wide variety of industrial applications. In addition, Standard Havens supplies replacement parts and maintenance services for all makes of hot-mix asphalt production and fabric filter equipment.

It serves these markets in North America and Europe with manufacturing facilities in Glasgow and Slater, Missouri as well as Ahlen, West Germany.

Since its inception in 1967, Standard Havens has grown rapidly in size from $500,000 to $35 million in annual revenues. In mid-1982, Standard Havens established Standard Havens Research Corporation to act as General Partner on behalf of a group of limited investors collectively known as Standard Havens Research Associates. This partnership attracted over $2 million in R&D funds for CWM. Currently, the CWM program at Standard Havens is in the research stage. SHRC has performed two (2) combustion tests, and will be performing further combustion characterization testing over the next 6 months. Test goals are to maximize combustion efficiency, determine the effects of CWM prepared with different types of coals and evaluate air pollution control issues.

In the meantime, engineers are preparing plans for a full-scale CWM preparation facility to be installed at Gallagher Asphalt Co., Chicago, Illinois in the Fall of 1983. CWM produced by this facility will be used, first, to fire the company's hot-mix asphalt plant rock dryers. Later, this contractor will explore the potential for supplying CWM to other industrial fuel-users in his immediate area.

After the 1st Combustion Test in January, 1983, a 10-minute videotape of the proceedings was prepared and shown to several large hot-mix asphalt contractors. Their response to this tape and the concepts underlying the Standard Havens approach to CWM was unexpectedly enthusiastic.

This response led, in turn, to the formation of plans for a CWM Conference in Kansas City in March, 1983 sponsored by Standard Havens, Inc., which would feature the 2nd Combustion Test on SHRC's research schedule.

This CWM Conference was indeed held March 16 - 18, 1983, and over 120 contractors met to discuss the potential for utilizing CWM, and to see the actual combustion of CWM in a rotary rock dryer.

The results of this very successful meeting are the following:

1. Twenty-one (21) contractors in the U.S. have agreed to put-up a deposit of $50,000 each for "advanced delivery positions" of CWM preparation plants and burner conversion systems provided that the full-scale demonstration in Chicago is successful.

2. In the meantime, negotiations are underway with ten (10) of these contractors regarding the formation of "consortiums". These new corporations will be funded by the contractors, Standard Havens and other investors for the purpose of constructing and operating large-scale CWM preparation plants. In addition, CWM customers will be provided with coal conversion equipment and services, including air pollution control systems, burner conversion packages, ash handling systems, computerized electronic controls and engineering services.

3. Finally, further negotiations are at an advanced stage with four (4) European groups based on the same "consortium" approach. But there will be major departure by the Europeans from the U.S. experience; namely, the former groups will tend toward fewer but much larger CWM production facilities.

In conclusion, the essentials are falling into place for wide-spread commercialization of CWM in both the U.S. and Europe. By the end of 1984, Standard Havens will have participated in the establishment of a widespread network of CWM preparation plants, and in the conversion of many industrial fuel-users to the economics of CWM. Total coal grinding capability in the U.S. will be, at least, 250 TPH. In Europe, total capacity will be, at least, 150 TPH.

COMBUSTION ENGINEERING, INC.

A three year research project for the Department of Energy on coal-water mixture has as its overall objective to provide sufficient data on coal-water mixture chemical, physical, and combustion properties to assess the potential for commercial use in furnaces designed for oil firing. Combustion Engineering (C-E) and its sub-contractor Gulf Research and Development Company (GRDC) are under contract to the DOE's Pittsburgh Energy Technology Center (PETC) to develop the required data.

The test program concentrates on two major areas of CWM utilization: combustion behavior/burner modification; and performance characteristics/unit derating and availability. The program has been separated into six subtasks:

1) CWM Selection and Preparation
   a) Coal Acquisition and Screening Tests
   b) Test Coal Beneficiation
   c) Slurries Preparation
2) Bench-Scale Characterization and Screening Tests
3) CWM Preparation and Test Slurry Supply
4) Combustion Evaluation/Atomization and Burner Testing
5) Ash Deposition Performance Testing
6) Commercial Application and Performance Predictions

The program has been structured in a sequence so that each task will use knowledge gained during the preceding task. It is believed that the use of beneficiation will be critical to the successful development of CWMs. During the CWM selection and preparation, an in-depth evaluation of the washing characteristics of selected coals will be conducted to provide the required data for technical and economic assessment of the fuel's potential for CWM use. Tasks 1 and 2 will address the selection of CWMs to be studied during the large-scale combustion and performance testing. Bench-scale, pilot-scale and full-scale laboratory testing will be conducted. Combustion evaluations and performance testing (Tasks 4 and 5) will be performed separately and conducted in parallel. Most of the testing will be completed within three years.

TRW ENERGY DEVELOPMENT GROUP

One of the promising industrial and utility applications of advanced coal combustors is the conversion to coal of existing coal, oil, and gas-fired boilers, furnaces, and process heaters. Based on the technology developed over the past seven years, TRW has designed and operated four different sized entrained slagging coal combustors. The combustor is generically suited for retrofitting coal, oil, and gas-fired boilers, kilns, process heaters, smelters, etc. The outstanding characteristics of this combustor are:

1. Compact size, enabling easy retrofits. For example, a 50 MM BTU/hr combustor will fit in a space approximately 3 feet in diameter and 6 feet in length.

2. Low No_x operation, since this combustor burns coal completely at stoichiometries on the order of 0.7, resulting in combustion temperatures on the order of 2800°F and producing a hot burnable product gas which can be completely burned in the heat utilizing furnace or boiler.

3. Up to 90% of the ash in the coal is removed within the slagging combustor through a slag tap. Therefore, because of this low ash carryover, the retrofitted boiler or furnace can be operated with little or no derating.

4. The ash particles which are carried over with the product gas are spheroidal fused particles and, therefore, less erosive on downstream components than normal fly ash.

5. The combustor can burn coal either in a pulverized form or as a water-based slurry.

TRW is now taking an essential step toward commercialization of this technology. A field demonstration program using a representative

50 MM BTU/hr commercial-type combustor, integrated with an existing boiler at one of TRW's manufacturing sites, is planned for a 1984 start date.

UNITED COAL COMPANY.

During the past three years, the largest coal company headquartered in Virginia, United Coal Company, has developed, through its Research & Development Division, the capability to convert coal directly into a liquid form. This liquid form of coal is similar in viscosity and burning characteristics to that of oil and has been burned at several government owned facilities by the Department of Energy to verify combustion capabilities. As a result of this technology being developed by United Coal Company and other companies in this country, the opportunity now exists to be able to directly develop a coal-based resource into a liquid form that can meet the needs of many of our defense supply facilities. In addition, technology that is rapidly being developed by United Coal Company in Bristol, Virginia, establishes that even a much improved liquid coal product which uses a 100% coal base rather than mixing with oil, methanol, or water is in developmental stages. It appears that this technology is a continuing hybrid growth from the technology base already established for coal-water mixtures. This new coal-based liquid coal does provide significant advantages in the ignition properties over coal-water mixtures but is not as yet as highly developed as coal-water mixture fuels.

During the writer's recent visit to their Bristol, Virginia headquarters, their Dr. Richard Wolfe, Vice President, Research and Development indicated a strong interest in working with DFSC in further developing and commercializing this new liquid coal product to meet DFSC requirements in selected installations. Further, Dr. Wolfe is extremely anxious to make a presentation to DFSC.

CONCLUSIONS

Coal-water slurry fuel is a fuel that is domestic, in large supply, can be handled like a liquid, burns like coal, costs like coal, and has the potential as a near term alternative to No. 6 fuel oil.

Unlike the coal gasification and liquefaction processes, the capital investment required is modest. While those synthetic fuel processes cost in the order of $4 billion for a 50,000 barrel per day manufacturing facility, a coal-water plant of that size is estimated at about $80 million (one fiftieth). While the cost of synthetic fuels has been projected at about double that of oil, the costs for coal-water are estimated at 30% to 40% less than oil. Put another way, assuming a 4% energy loss in the coal-water slurry, the resulting fuel cost of the CWM is approximately $3/million BTU. This can be compared to oil at $29/barrel or approximately $5/million BTU.

It should be noted that the cost of CWM will be about $10 per barrel less than that of residual oil. In FY 1982 DFSC customers consumed 7,516,124 barrels of residual oil, of which approximately 85% was FS6. If eventually only 10% of these customers converted to CWM the resulting savings would be $6.3 million annually.

Initial financial support was primarily provided by the DOE and Electric Power Research Institute (EPRI). More recently, it has been almost entirely supported by private funds, and today the three largest boiler manufacturers are burning CWM in large scale test facilities, up to 100 million BTU per hour, and supporting tests in typical industrial and utility boilers. EPRI is supporting a long term test run in a commercial industrial boiler, and intends to help support a utility-scale test in 1984. Many utilities are sponsoring studies and plan to fund some combustion testing prior to their use. Over a dozen utilities are actively involved, mainly located in the Atlantic Region from Maine to Florida. In May 1983 the Fifth International Symposium on Coal

Slurry Combustion and Technology was held in Tampa, Florida. Approximately 700 people attended from some 18 countries. The proceedings of this symposium are shown in a separate 3-ring binder. Perhaps DFSC could be represented at the 1984 meeting.

The fuel has been developed mainly by five industrial organizations over the past six years. The largest manufacturing facility has just been completed by the Atlantic Research Corporation at Fredericksburg, Virginia. This facility can continuously supply commercial boiler tests of 100,000 pounds of steam per hour. ARC estimates that a 20,000 barrel a day facility can be constructed in 18 months, which is about the time a large power plant can be modified from oil to CWM and obtain the necessary permits.

How fast might the market progress? It is estimated that a 20,000 barrel per day plant will be in operation by late 1985 with the number of plants increasing progressively to supply 200,000 barrels per day by 1990. The utilization of this fuel could reach 1,000,000 barrels per day by the year 2000 using about 55 million tons per year of eastern coal.

The market potential for these coal-based slurry fuels is significant. Today in the electric utility sector, approximately 400,000 barrels of oil per day are consumed in units originally designed for coal and now firing oil. Additionally, there are approximately 1,000,000 barrels of oil per day consumed in units that were designed for oil and over 1,000,000 barrels of oil a day equivalent consumed in natural gas-fired utility boilers. The conversion of those units originally designed for coal to coal-water slurry fuels represents the applications with minimal technical impediments.

If we then look at the industrial market, there are approximately 1.4 million barrels of oil a day consumed in industrial boilers originally designed for oil. This does not include direct firing applications. There are also approximately 2 million barrels of oil a day equivalent consumed in natural gas designed boilers in the industrial sector. It is anticipated that the modifications required to make the coal slurry fuels compatible with the oil designed units are less in the smaller industrial boilers than for the larger utility boilers, but with the recent test results of the Pittsburg Energy Technology Center activities, the potential for coal-water slurry fuels in these applications is also encouraging.

The successful introduction of coal slurry technology into the marketplace as a replacement for oil has very significant potential. The hand-in-hand development of advanced coal cleaning technologies could allow the U.S. to make an economical and rapid transition away from our least abundant resource-oil-to our most abundant resource-coal. Coal-based slurries hold the promise of truly being the fuel of the 80's and beyond.

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