MIRL REPORT NO. 87

COAL IN ALASKA

REQUIREMENTS TO ENHANCE ENVIRONMENTALLY SOUND USE IN BOTH DOMESTIC AND PACIFIC RIM MARKETS

Prepared for
the Governor and Legislators - State of Alaska
under the Direction of Dr. Henry Cole, Science and Technology Advisor

Technical Editor - Dr. Warrack G. Willson,
Energy and Environmental Research Center,
University of North Dakota; and
Mineral Industry Research Laboratory, University of Alaska Fairbanks

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July 1, 1990

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This document originates from three meetings held in 1989 with the leaders of the Alaskan Coal Industry and coal technologists from the U.S. Department of Energy (DOE), Mineral Industry Research Laboratory (MIRL) and Geophysical Institute - University of Alaska Fairbanks, the Alaska Department of Natural Resources, the Alaska Science and Technology Commission, several of the Alaska Native Corporations, and a number of coal experts from private industries.

The information included is intended to illustrate the vast resource base and quality of Alaskan coals, show the projected size of the Pacific Rim steam coal market, discuss policy changes necessary to facilitate the development of an expanded coal industry, and describe the technology development needs for Alaskan coals to compete in the world market. It is aimed at increasing the general knowledge about the potential of coal in Alaska and providing data for use in marketing the resource.

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The following report presents a comprehensive analysis of the technical, environmental, and economic opportunities and constraints to increased use of the tremendous coal resources of Alaska, both at home and abroad. The primary objective is to develop a comprehensive technology development plan, prioritized according to the needs of the Alaskan coal industry and the requirements for an Alaskan coal to compete in the existing markets. This document certainly does not contain the final word on technology and research development needs, but rather should be viewed as a working document that can be amended as new technologies are developed and/or new environmental controls are mandated. The following objectives are also included:

- Provide information about the magnitude and quality of Alaskan coals.
- Show the environmentally benign nature of advanced coal conversion/utilization technologies and how the extremely low S content of Alaskan coals used in these processes would make them preferred feedstock to reduce SO_2 emissions.
- Detail the tremendous growth expected in the Pacific Rim steam coal market.
- Illustrate the impact to the Alaskan economy and the U.S. trade balance even if only a 3% market penetration is achieved.
- Contrast the long term employment opportunities that can be derived from expansion of the Alaskan coal industry to the shorter term opportunities in oil.
- Outline the opportunities to leverage Alaskan monies for coal R&D with the U.S. Department of Energy.
- Describe how the state can participate in major coal conversion/utilization demonstration projects by working with industry in the co-funded DOE Clean Coal Technology Program.
- Outline the changes necessary to facilitate opening of new coal properties and using new coal technologies.
- Assess methods to improve and lessen the cost of coal transportation

In an effort to formulate a coherent coal development program for the State of Alaska, three open meetings, attended by a significant portion of the

Alaskan coal community, as well as a number of outside coal technologists, were held in 1989. Individual contacts and contributions to this report are too numerous to list completely. However, the following people attended at least one of the open meetings and/or made significant contributions to this document:

W. (Bill) Irwin - Canadian Pacific Consulting Services, Inc.
Noel Kirshenbaum - Placer Dome U.S., Inc.
Bill Noll - Suneel Alaska Corp.
John Sims and Charlie Boddy - Usibelli Coal Mine, Inc.
Andy Milner and Jim Christianson - Ad. Tech.
Steve O'Hare - U.S. Bureau of Mines
Kaye Trafton and Marvin Brooks - U.S. DOE
Sam Dunaway and Jerry Galegher - Alaska DNR
Bill Sackinger - Geophysical Institute, UAF
Kent Grinage and Charlie Barnwell - Arctic Slope Consulting Group
Chang Yul-Cha and Dave Sheesley - Western Research Institute
Jim Cucullu and Dave Gitchell - Hobbs Industries
Dave Germer - McKinley Mining Consultants
Henry Cole - Governor's Office
P.D. Rao - Mineral Industry Research Lab, UAF
Warrack Willson - Energy & Mineral Research Center, UND & MIRL, UAF

2. GOALS FOR EXPANDING THE USE OF ALASKAN COAL

The following is a list of "achievable" goals which if accomplished will significantly increase the environmentally sound use of Alaska's largest energy resource, namely its coal.

- Improve public perception of coal mining and utilization technologies.
- Demonstrate the clean use of coal for energy and chemical feedstocks production.
- Improve the quality of coal products.
- Develop new coal products in response to new utilization technologies.
- Simplify permitting procedures for new mines and clean coal utilization facilities.
- Increase the current exports from around $28MM to over $100MM in the next decade.
- Expand coal use in state
- Increase the number of permanent coal related jobs by 450 by 1995.
- Establish a joint Alaskan - DOE coal R&D program
- Develop Clean Coal Technology Programs in Alaska.
- Enhance the scientific coal technology base in Alaska.

3. RECOMMENDATIONS

The following is a list of action items necessary to speed the development of the Alaskan coal industry. They are derived from detailed discussions of the technology development needs in the next section.

- Make more state lands available for coal leasing.
- Simplify and expedite permitting procedures for new coal mines and coal conversion/utilization facilities.
- Set royalties low enough to encourage development.
- Diversify energy production to utilize local coal sources.
- Update the Alaskan resource assessment, especially for coal of near term economic significance.
- Create an Alaskan coal data base of well-characterized, representative coal samples.
- Adapt or develop efficient methods for drying, stabilizing and transporting Alaskan low-rank coals.
- Apply or develop new conversion/utilization technologies to yield products that are competitive in the world market.
- Increase in-state capabilities for coal/product characterization.
- Develop bench-scale capabilities for simulating advanced coal conversion/utilization processes.
- Improve coal transportation to lower shipping costs.
- Enhance coal educational opportunities at the University.
- Develop a small but focused coal R&D program, jointly funded by the state and DOE.
- Make state funds available for use for cost sharing in the Clean Coal Demonstration Program.

4. COAL DEVELOPMENT NEEDS

4.1 INTRODUCTION

Alaska's 5.5 trillion tons of estimated coal resources comprise about half of the United States' coal resources.(1) In more general terms, this enormous energy resource would be sufficient to supply the entire nation's energy demand for several hundred years. The Northern Alaska Basin, the largest coal basin in Alaska, is estimated to hold over 4 trillion tons. It consists of a tremendous subbituminous coal deposit which in areas overlie a rich bituminous deposit.(1) The Cook Inlet-Susitna Basin, which is composed mainly of low-rank coal may contain over a trillion tons.(1) The remainder of the coal basins are small by Alaskan standards but still contain billions of tons of reserves. As an example, the Nenana Basin which boasts Alaska's only operating mine, the ultra modern Usibelli Coal Mine, has "only" about 20 billion tons of proven reserves. The locations of the major coal regions and the resource base in Alaska are shown in Figure 1.

The outstanding feature of almost all Alaskan coals, regardless of rank, is the extremely low sulfur content.(2) The majority of the Alaskan coals is already compliance coals. Much of the low-rank coals (LRCs) has sulfur levels below 0.2%; for example, the latest three year average for the Usibelli subbituminous coal was 0.17%. Much of the LRCs has moderate ash levels and reactivities typically an order of magnitude higher than the bituminous counterpart. They are prime candidates for use in advanced applications such as, gasifiers, fluid-bed combustors and even in diesels and turbines. Therefore, these coals should be able to demand a premium price as the remainder of the industrial world begins to follow the lead of the United States and adopts more stringent air quality standards in an attempt to reduce emissions, particularly of SO_2.

The majority of the Alaskan coals near tidewater that is ice free all or nearly all of the year, those with near term economic significance, are classified as low-rank coals (LRCs) due to their high moisture and inherently low heating value. The high moisture has restricted most LRC usage worldwide to mine-mouth power generation which has limited export sales of Alaskan coal to only 0.75MM tons per year from the Usibelli Coal Mine. This comes at a

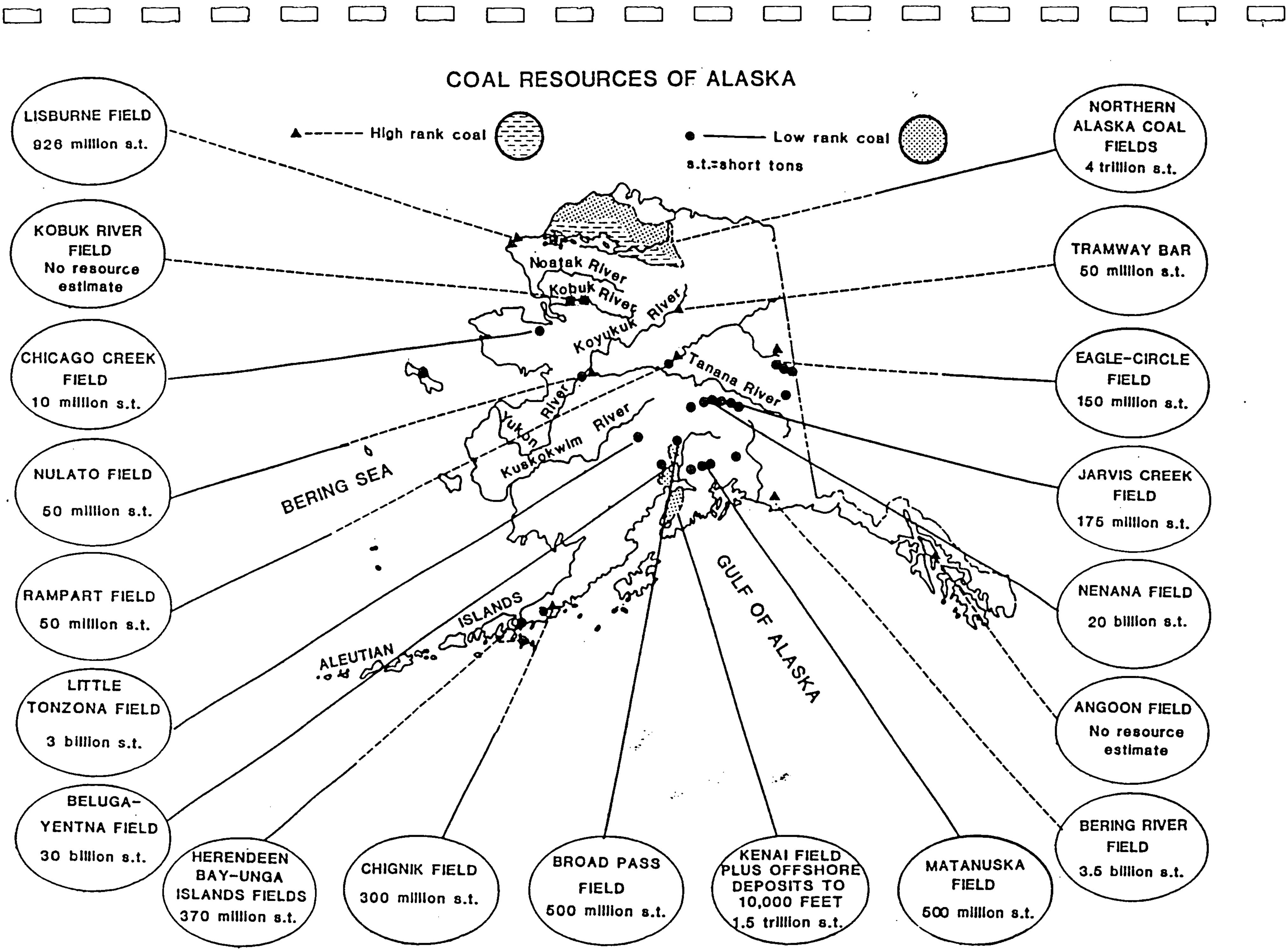

Figure 1. Coal Resources of Alaska

time when Australian coal exports have topped 100 MM tpy and the steam coal market is increasing rapidly and is expected to more than double in this decade.(3) Could Alaska capture only 3% of the projected new market, which is not an unreasonable expectation, the value of the state's coal exports would soar from nominally $28MM per year to over $100MM per year.

Without development of economical methods for drying/stabilizing Alaskan LRCs, however, making concentrated LRC-water fuels, or producing alternate fuels like form coke, the only increase in export of Alaskan coals will be from the few "higher rank" coals within a "reasonable" transport range of the existing Alaska rail system or tidewater. The only high-rank candidate yet identified is the Wishbone Hill property being developed by Idemitsu Kosan, near Palmer, Alaska.(4)

If Alaska is to truly participate in the "black bonanza" of the Pacific Rim steam coal market, existing technologies must be modified and/or new technologies developed for application to Alaskan coals which will yield a product that will be competitive in the open market. In addition to the State's need to develop environmentally sound industries that offer generations of employment opportunities, any increase in the export of Alaskan coal will be welcome to the U.S. economy in its struggle to reduce the trade deficit.

Since neither Alaska nor any other single state has the resources to commit to even a single commercial synfuels plant, i.e., the price for the Great Plains Gasification Plant was over $2 billion, technology development must rely heavily on support from the DOE. In the last several years the DOE has supported commercialization of new coal technologies through its Clean Coal Technology Program. This congressionally mandated program with over $2.7 billion in funding, has a goal of demonstrating technology options that can use coal in an environmentally responsible manner. Three separate Clean Coal solicitations, having a DOE cost share of nearly $1.5 billion available for joint ventures, have been issued. The DOE cost share can be no more than 50% with the balance coming from industry and states. A lion's share of the Clean Coal projects through the first three rounds have gone to states that have had the foresight to make state monies available for cost sharing, especially Ohio and Illinois.

The success of Clean Coal to date in securing industry and state participation has encouraged DOE to seek similar arrangements in even their more basic research activities. DOE has established Memorandum of Understandings (MOUs) with a number of states, including Alaska, which can serve as the vehicle for cofunded technology development activities. Addenda to the MOUs will enable the states to develop programs for fossil energy technology development consistent with the DOE mission.

In an effort to formulate a coherent coal development program for the State of Alaska, three open meetings, attended by most of the Alaskan coal community, were held in 1989. These meetings are summarized in the following sections and the recommendations formed the basis of the list of technology development requirements. In summary, it was concluded that the focus of coal research in Alaska should be on: 1) means of improving and economizing drying technologies, 2) increasing the energy density of the coal derived fuels, 3) decreasing mining/transportation costs to make a more competitive product and, 4) end use testing to demonstrate the product's performance for users in both the domestic and Pacific Rim markets.

4.2 COAL EXPORT MARKETS*

4.2.1 INTRODUCTION

The steam era began during the industrial revolution of the 19th century. The fires of that revolution were fuelled by coal, and coal industries sprang up in newly industrialized countries. The rapid rate of economic development and social progress made by the newly industrialized countries was due in large measure to the utilization of their own indigenous coal resources. Records show that from the late 19th century until the early 1950s, coal played a dominant role in world energy markets.

In the early 1950s, circumstances changed and almost all coal used for industrial energy, chemical feedstock, domestic heating, and transportation energy, was replaced by petroleum products and natural gas. The ready availability of cheap oil through the 1950s and 1960s led to a progressive reduction in the importance of coal as an energy source. Faced with competition from a world glut of cheap oil, coal was in serious danger of being phased out as a primary source of energy.

* This section is a condensation of a paper prepared by W. (Bill) Irwin, formerly with the Canadian Pacific Consulting Services, Ltd., presented at the Western Canada Geological Forum, April 1989.

The oil crisis of 1973 however, gravely affected the balance between supply and demand in the international oil market as prices escalated sharply and supplies were disrupted by political actions in the Middle East. The economic structure of the industrialized world that had by that time become heavily dependent upon oil, proved too rigid to absorb the shock and awakened the world to the need for some structural adjustment in the energy economy. To meet this challenge, the world's industrial nations began efforts to reduce their dependency upon oil, and seek a more balanced distribution among energy resources. As a consequence, we now see the beginning of a new multi-energy era in which steam coal is re-emerging as a primary source of energy.

The discussion that follows is related to steam coal, the properties and utilization considerations which are distinctly different from those of coking coals. In the absence of relevant records for historical market trends and other data required for interpretation purposes, the author has drawn from his own knowledge and experience gained since entering the coal industry in 1947.

4.2.2 CHANGING MARKET FORCES

To keep the energy scene in perspective, it should be remembered that the industrialized world has gone through several energy substitutions in some 140 years. For instance, between 1850 and 1910, wood was replaced by coal. In the late 1800s and early 1900s, work animals were partially replaced by railway locomotive coal; then between 1900 and 1950, both animals and coal were replaced by motor fuels and oil and gas. Direct wind and water sources were replaced by hydro electric power between 1890 and 1940. Throughout this period there has been a steady rise in the proportion of fossil fuels converted to electricity prior to consumption. What we are now witnessing, is a trend back to coal as a substitute for oil in the largest of all energy markets; power generation.

It is worth noting that all through this history of almost continual substitution of fuels, coal has always been available at competitive prices. It has been the scarcity of alternative fuels as reflected by their high prices at a particular time, which has brought about a substitution in favour of coal. Historical experience has shown that coal production increased or decreased to meet demand as reflected by prevailing market forces in the energy sector.

This characteristic is strongly supported by the geological evidence which shows that the massive global reserves of recoverable coal are many times greater than the equivalent oil reserves. Set against such evidence, the historically stable consumption pattern for coal cannot be attributed to production constraints. Since the late 1970s however, an upward trend can be seen in the supply curve, as coal begins to replace oil in the generation of electricity. This trend reflects a major growth in the international trade in steam coal.

Coal use today is essentially confined to (a) steam raising, and (b) manufacture of metallurgic coke. Identified as steam coal and coking coal respectively, each must possess the necessary properties to match their utilization needs. With few exceptions, they are not interchangeable. In the case of steam coal, it is particularly important that the coal properties and the combustion system employed to burn the coal are compatible.

4.2.3 COAL BY WIRE

"Coal by wire", is a phrase coined to identify the link between coal and electricity in order to publicize the coal's role in electricity markets. As a marketing slogan it is appropriate, because electricity is the world's largest energy market, and energy is an essential element of economic development and social progress of all countries. Of the four major sectors of world energy use, only electricity can power many of the functions vital to a developed, technological world. This is reflected in electricity demand which has tripled over the last twenty years in the Western World and continues to increase faster than both total energy use and overall economic growth. As can be seen from Figure 1, coal is the greatest source of electricity generation. It is no coincidence to find that today's largest market for coal, is that for power generation.

In comparison with competing fuels, coal has major advantages which are likely to ensure its expanded use in the power generation market. For instance, there are very few plans for major new oil or gas-fired power stations; most of the sites suitable for hydro power have already been used; renewable energy sources are as yet uneconomic; and plans for nuclear power have been drastically cut back and in many cases, abandoned. This leaves coal as the strongest candidate for meeting future demands, on the grounds that its abundance and diversity safeguard both security of supply and price stability.

Further, because of the constant upward trend in electricity demand, an expanding market for steam coal seems assured. Confidence in this forecast is reinforced by the growth in international steam coal trade, which is due almost entirely to the increased use of steam coal for power generation.

4.2.4 THE INTERNATIONAL COAL TRADE

Unlike the trade for coking coal, international trade in steam coal is a relatively recent development, only taking off after the 1973 oil crisis. Respective coking and steam coal tonnages within the international coal trade between 1973 and 1988, are shown in Table 1. Table 2 shows the main coal indicators for 1987 and Figure 2 shows the world coal movements in 1987.

The growth of international trade in steam coal coincided with the turn of events following the 1973 oil crises when coal began replacing oil. Until that time, oil demand had grown enormously to dominate the world's energy markets. New discoveries of oil in the Middle East has kept supply ahead of demand, but in the early 1970s the domination of one region and a single cartel inevitably brought instability and price escalation. This led to a drive by the industrialized world to reduce their dependency upon imported oil, and gave rise to a worldwide trend back to coal. Which in turn promoted an increase in world coal movements as coal was replaced by coal in existing power stations equipped with boilers that were coal tolerant. Construction programs for new coal-fired power stations were implemented, and forward energy plans based on coal began to be put in place.

This confidence in coal is attributable to the comfort factor that coal reserves exist in every continent of the world. By changing from oil to coal, power utilities can feel secure in the knowledge that it will neither run out in the foreseeable future, nor will supply become dominated by any one region or political grouping. The "BP Statistical Review of World Energy", shows accessible coal and lignite reserves at the end of 1986, to be in excess of one million million (10^{12}) tons; sufficient to last for 226 years at 1986 levels of production.

The infrastructure of international coal supply is now highly developed and flexible. Many mines are tailored specifically to the world market and producers have become skilled in responding quickly to market demand. More companies from an increasing number of countries are involved in the international steam coal trade, and world port capacity has expanded to such an extent that it would not be a constraint even if the entire export output from one supplying country ceased to be available.

4.2.5 PROSPECTS FOR INCREASED UTILIZATION OF STEAM COAL FOR POWER GENERATION

Based on the ever-increasing worldwide demand for electricity, a strong case can be made that power generation represents great potential for the expanded utilization of steam coal. Since electricity is already the biggest market for coal, it should remain so for the foreseeable future. Current trends support this conclusion, although it is recognized that almost any fuel can be used to generate electricity. While the choice of fuel will depend primarily on economic factors; strategic, environmental and safety consideration are equally significant issues which affect the eventual choice. In the setting of a large scale and rapidly expanding international electricity market, it is worth comparing the most significant fuel options.

Renewable sources which include solar, wind and geothermal power, provide less than 1% of the world's electricity; a small contribution reflecting their low cost effectiveness, especially for large scale use.

Gas prices have fluctuated almost as much as oil prices in the last fifteen years, and despite the expansion in international grids, only a very small percentage of natural gas enters world trade. Figure 3 shows world gas consumption in 1986, and as can be seen, internationally traded gas accounted for only 13% of the total. Because of the high demand for premium fuel in household heating and cooking, and for certain industrial processes which require very clean and controllable heat, gas is likely to remain prohibitively expensive for large scale power generation.

In the aftermath of the oil crises of the 1970s, almost all plans for major new oil-fired power stations in the Western World were abandoned. Because of the risk associated with oil, both in terms of its supply security and price stability, very few plans exist today for new oil-fired installations. The oil price shocks of the 1970s can be identified from Figure 4 which shows crude oil prices since 1880. It is of interest to note that although oil demand grew enormously from 1880 through to the 1970s, the price of crude oil hardly changed, a situation which is unlikely to be maintained when serving an ever increasing worldwide demand for electricity.

The history of nuclear power has been marked by a succession of optimistic claims - and subsequent disenchantments. Disappointing costs and performances have been a recurrent theme, but perhaps the most disturbing feature of nuclear power, is the poor record of operational safety and environmental impact. Decommissioning of nuclear stations when they reach the end of their operating life remains an unknown factor. Public concern over these issues, and debate among legislators are responsible for the decline in orders for nuclear plants across the world. This downward trend is reflected in a lowering of projections of the future level of nuclear capacity.

To illustrate this; in 1974, the International Atomic Energy Agency (IAEA) in Vienna predicted that world nuclear capacity in the year 2000, would be 4,450 GW; more than 16 times the current nuclear capacity and more than double the size of the world's entire electricity system in 1987. By 1986 the world's nuclear capacity was only 260 GW and the IAEA has scaled their projection down to 505 GW; less than one-ninth of their 1974 forecast.

Hydro power is the world's second largest source of electricity generation. If the initial site costs are modest, hydro power is an attractive option, as running costs are low. But hydro production is only possible when topography is favorable and rainfall is high. Most of the sites suitable for hydro power have already been exploited and the sites that remain have been left, either because they are difficult and expensive to develop, or because they are prized for their amenity value.

Coal is the only significant fuel with the potential for meeting the increasing worldwide demand for electricity in the foreseeable future. On the grounds that (1) renewable sources of energy for power generation can be discounted as uneconomic; (2) oil and gas are insecure and economically unstable; (3) site constraints prevent hydro power from being expanded to meet future demand, and (4) the operational safety and environmental safeguards for nuclear power cannot be guaranteed. The abundance and diversity of the world's coal resources should ensure security of supply. The case is strengthened because coal-fired power stations are based on proven technology and have a good record of reliability that extends over a century.

Coal is rapidly replacing oil as the standard fossil fuel for new electric power generation. The projected future demand for coal in international markets is illustrated in Figure 5. The upward trend which reflects the increased use of coal for power generation is unaffected by the current oil surplus.

4.2.6 NEW TECHNOLOGIES AND THEIR POTENTIAL FOR INCREASING COAL UTILIZATION

The replacement of oil by coal in steam generation is already well underway and despite the disadvantages inherent in handling coal in its dry bulk form, this major market will remain one for dry bulk coal. While power generation will continue to be coal's largest market, however, conversion of existing oil-fired industrial boilers also represents a large potential coal market. Historically, the principal factors that have adversely affected conversion from oil to coal, are:

- the high cost of plant conversion
- the more cumbersome and expensive handling/transportation
- the environmental constraints on burning.

Development of coal-liquid mixtures is one means of overcoming these disadvantages and now allows coal to be used as a direct replacement for oil to fire large utility and industrial boilers. Because these mixtures behave as a liquid, they have all the advantages and convenience enjoyed by oil.

The technology of feeding existing oil-fired power plants with a coal-oil mixture (COM) has been commercialized in Japan where a one million ton per year COM production facility at Onahama currently serves as a source of fuel for generating electricity in local power stations. Of the alternative coal-based fuels projected to meet future energy needs, however, coal-water mixtures (CWM) are the most promising. Like coal-oil mixtures, CWM has been developed for use as a direct replacement for oil to fire utility and industrial boilers. The largest boiler to be fired with CWM, is the No. 8 unit of 600 MW capacity at the Nakoso power station in Japan. This unit is currently fired by oil, coal, and CWM in a multi-fuel feed system in which 15% of the feed is CWM, 35% coal, and 50% oil. Prior to the current firing of the No. 8 unit at Nakoso, 100% CWM had been used to fire the No. 4 unit of 75 MW capacity. It is encouraging to note that while some derating was anticipated with CWM when it was used to replace oil, none occurred.

As a result of the experience gained at Nakoso, and other successful pilot projects conducted on an industrial scale over the past five years in several other countries, it has been widely demonstrated that a stable coal-water fuel can be manufactured, transported, stored, handled and burned in utility and industrial boilers. At the meeting of signatory countries to the IEA Coal-Liquid Mixture Agreement held in Tokyo, November 7-11, 1988, member countries agreed that CWM technology is now ready to be commercialized. It is expected that the technology will gain widespread acceptance as user confidence becomes established.

Japan is cited because that country is among those most earnestly striving to reduce their heavy dependency upon imported oil. Since it has very limited indigenous energy resources, Japan is in the vanguard of these new technologies out of necessity. Already the world's largest coal importing country their imports of steam coal are forecast to double within the next decade (Table 3). If the Alaskan coal industry were to capture only a 3% share of the Asian steam coal market, the export coal industry in Alaska would more than quadruple.

Although the world's abundant coal reserves are diverse, a significant proportion of them comprise low-rank coals which all share one major impediment to widespread commercial use - high inherent moisture. Until now high moisture ranging from 25% to 65% has made transportation costs prohibitive and relegated these coals to local use or generation of electricity at the mine site. This situation has been changed by a unique non-evaporative drying technique in which the structure of such coal is fundamentally altered and made similar to that of higher rank bituminous coal.

Commonly known as hot-water-drying this new technology is a major breakthrough in coal processing. The process can be represented as the irreversible removal of inherent moisture by induced coalification. In essence, the technology induces coalification in a condensed time scale of minutes rather than geological eras, thus effecting a permanent reduction in inherent moisture. The significance of this feature is that, unlike coal dried by conventional thermal drying in which evaporative processes are employed, water-dried coal does not re-absorb moisture when it is exposed to humid air or water. As a consequence, the high moisture levels and low heating values of these low-rank coals are no longer an economic barrier to their off-site use. From a utilization point of view, their positive features are an asset. They ignite easier, burn faster and are often lower in sulfur than many bituminous coals. Because they are highly reactive, good combustion efficiencies are achieved with maximum carbon burn-out. A major advantage resulting from beneficiating these low-rank coals, is that re-use of their inherent moisture as the vehicle solvent allows them to be manufactured into CWM with an energy density equal to or even greater than the parent coal.

The facility to beneficiate low-rank coals is particularly important to many of the world's development countries as they constitute the majority, and in some cases, their only carbonaceous reserves in large enough quantities to be of economic significance. In such countries, exploitation of these reserves would promote more rapid social and economic development and contribute towards making them more energy self-sufficient.

4.2.7 THE ENVIRONMENTAL IMPACT OF COAL UTILIZATION

No discussion on coal utilization would be complete without addressing the environmental issues. Public attention is focussed firmly on the impact all industrial activity has on the environment, and currently the "greenhouse effect" is a major topic of worldwide interest. All forms of combustion produce carbon dioxide, which accounts for about half the total radiative gases entering the atmosphere that give rise to the so-called "green house" hypothesis. Whether the hypothetical consequences of using fossil fuel are exaggerated, or not, the use of coal has always been associated with environmental problems that have had to be overcome. In a historical context, the first step was improving stack emissions.

Coal combustion equipment was specially designed to minimize smoke, and tall chimney stacks improved the dispersion, and thus reduced local ground level concentrations of SO_2 from large industrial sites. These measures dramatically improved local air quality and industrial areas that are still active, are much more pleasant places to live in than they were thirty years ago. Dispersion of combustion products (SO_2 and NO_x), however, produced during oil and coal combustion, is no longer enough. Expectations have increased and standards have rightly become more demanding. The spectrum of clean coal technology has been broadened to include long range as well as local effects on coal use.

In today's climate of more stringent environmental control, three basic approaches to burning coal more cleanly are being pursued. These are; advanced coal preparation techniques; advanced combustion technologies, and treatment of the flue gases.

Although nothing can be done about formation of undesirable combustion by-products, advanced coal preparation techniques can remove or reduce many of the impurities present in the as-mined coal. Control during combustion minimizes the formation of free sulfur dioxide, and allows combustion adjustments to avoid, or at least reduce, the formation of oxides of nitrogen.

Virtually all dust and grit can be removed, by treatment of the flue gases after combustion, This is also the major method for preventing a high proportion of sulfur reaching the atmosphere as SO_2.

Looking at the immediate future, current technological developments will allow coal-fired power plants to be cleaner; thus changing the traditional dirty smoke-stack image which has characterized the industry to date. New coal utilization technologies combined with advanced, higher efficiency power-generation cycles, will significantly lower emissions. In such a strong market, steam coal producers will find considerable growth opportunities to compete and participate in a clean stack power industry. The success of coal producers will depend on their ability to match reserves with the most appropriate technology to produce a user-specific marketable product.

Table 1

WORLD COAL TRADE
1973 - 1988
(Million Tons)

Year	TOTAL WORLD COAL TRADE	COKING COAL		STEAM COAL	
		Total	Seaborne	Total	Seaborne
1973	177.1	117.7	87.0	59.4	19.0
-	-	-	-	-	-
1979	232.5	127.8	104.0	104.7	53.0
1980	256.2	138.7	114.0	117.5	74.0
1981	271.3	144.9	122.0	126.4	86.0
1982	269.2	139.6	120.0	129.6	89.0
1983	266.0	135.3	112.0	130.7	87.6
1984	304.7	155.8	131.6	148.9	103.6
1985	335.8	165.0	140.7	170.8	133.1
1986	336.1	161.0	137.3	175.1	138.2
1987	340.9	164.4	141.9	176.5	141.1
1988e	345.3	165.9	144.6	179.4	147.0

"Seaborne" trade excludes overland, barge and lake deliveries.

Source: Chase Manhattan Bank e = estimate

Table 2
1987 MAIN COAL INDICATORS
(Million Tons)

Production		Exports		Imports	
China	925.0	Australia	102.0	Japan	92.5
US	831.6	US	71.1	S. Korea	21.8
USSR	758.4	S. Africa	42.6	Italy	19.7
Poland	193.0	Poland	31.0	France	14.6
W. Germany	191.2	USSR	27.1	Canada	14.3
India	187.2	Canada	26.7	Taiwan	13.4
S. Africa	176.5	China	13.1	Netherlands	12.6
Australia	152.1	Columbia	9.6	Denmark	12.0
UK	104.4	W. Germany	6.4	Belg/Lux	9.8
Yugoslavia	72.3	UK	2.3	UK	9.8

Source: International Coal Report (1988)

Table 3
WORLD SEABORNE IMPORTS
1985 - 2005
(Million Tons)

	Actual		Forecast			
	1985	1986	1990	1995	2000	2005
STEAM COAL						
US	1.8	2.0	2.9	4.2	5.2	6.6
W. Europe	72.2	69.1	79.3	103.4	121.2	140.5
Asia:						
Japan	22.8	22.6	26.5	37.4	53.8	65.0
Other Asia	27.5	31.8	37.2	47.0	56.9	71.9
Total Asia	50.3	54.4	63.8	84.4	110.7	136.9
Latin America	0.7	0.7	1.5	2.4	3.5	4.8
Africa/ME	3.7	4.2	6.4	8.4	11.5	12.8
CPE Europe	3.5	3.4	4.4	5.5	6.4	7.0
CPE Asia	1.5	1.5	1.5	1.2	1.0	1.0
Total World	133.7	135.3	159.6	209.5	259.7	309.6
COKING COAL						
PCI	1.2	3.0	8.3	17.5	27.1	31.8
Coking	139.9	137.6	138.1	133.2	128.6	128.8
Total	141.2	140.6	146.6	150.7	155.6	160.7

Source: Coal Year 1988

4.3 IN-STATE MARKETS FOR COAL*

Current Alaskan coal production, albeit from one producing mine, the Usibelli mine, is in balance between in-state consumption and export tonnage. Of the annual production, approximating 1.5 million tons, a little over 50% is being exported through Suneel's coal terminal at Seward to South Korea, with the remainder consumed in the Northern Railbelt region to generate electrical power and provide for district heating needs. Whereas future growth in Alaska's coal industry, as new producers come on line, will focus on exports, there is none-the-less a strong case to be made for greater in-state consumption of Alaska's most abundant energy resource -- coal. All major steam coal exporting countries complement their international energy business with significant and important use of coal within their own borders. This provides an important component of stability for the producer since reliance on exports alone can be precarious, and domestic markets help foster greater awareness among consumers of the positive role of the coal industry as a supplier of reliable inexpensive energy.

The Alaska Power Authority, in a 1989 report, estimates that only 2.8% of electrical power generated in Alaska is derived from coal. This excludes electrical power generated from coal on military bases in interior Alaska and which represents Usibelli's major in-state customer. That 2.8% silver is miniscule considering the enormous size of Alaska's coal resources and the fact that in the lower '48 states more than 56% of electrical power is generated from coal. Inherent in these statistics is both an opportunity and a need for Alaska coal to satisfy much greater in-state usage.

It may not be practical to think in terms of a state-wide energy policy. In the Railbelt region, however, within which the bulk of Alaska's population resides, there is the need for a balanced formal energy policy. As natural gas prices rise, as they surely will in the 1990's, the current economic advantage possessed by natural gas as a fuel for power generation will erode. It is highly probable that coal fired generation will be the most economical option for power generation throughout the entire Railbelt before the turn of the century. Currently the economics for coal favor the northern Railbelt region -- hence Usibelli's plan to add additional coal-fired capacity at Healy

* This document was prepared by Dr. John Sims, Vice President, Usibelli Coal Mine, Inc.

in the form of a technologically advanced powerplant. The sizing of this plant at 50MW implies a consumption of about 300,000 tons per year.

Currently, most electrical generation in the Railbelt is from natural gas-fired facilities in the Anchorage area. The geographic concentration of gas turbine generation should be of concern to those interested in energy security. Now that there is an intertied transmission system stretching from Homer to Fairbanks, it makes good economic and strategic sense to have generation more evenly spread along the entire system. Bradley Lake hydroelectric generation will expand the energy base and provide a significant increment at the southern end -- additional coal fired capacity could achieve this objective at the northern end of the Railbelt.

As current oil and gas generation facilities are retired, the opportunity will arise for new additional coal-fired capacity to be built thus increasing the percentage of electrical energy supplied from coal. This would be prudent for a state so abundantly endowed with coal. Changing economics are expected to progressively favor coal in the years ahead.

Besides the needs of the Railbelt region, there are significant opportunities for coal-use in rural Alaska. The high cost of diesel generation in small communities has resulted in annual subsidies of $20 million to bush communities. Means of providing more affordable energy to these communities need to be found and an obvious direction would be in coal/multifuel-fired barge-mounted fluidized bed units. Such units utilizing current technology could be sized from less than 1MW up to +10MW size. Besides generating electricity such plants might also service concentrated district heat systems employing affordable European technology. Capital cost could be minimized by constructing the barge-mounted units and towing them to river and coastal sites. Deliveries of bulk supplies of coal could be made by barge during the navigation season and in some instances local sources of coal could be developed and utilized. This concept should certainly form the basis of a demonstration project which could be co-funded by the Department of Energy (DOE) and the State of Alaska with perhaps the involvement of a leading edge boiler vendor.

Coal mining in Alaska will hopefully enjoy a bright future. Possessing the worlds largest accumulation of extremely low-sulfur coal means that there have to be sound opportunities for Alaska coal. First the inertia of waiting for something to happen must be overcome and then there has to be the effort to develop a proactive role through promoting coal usage. Thus, it is important for Alaskans not only to be informed about coal and the new technologies relating to its clean use, but also to be alert to the economic benefits that Alaska coal can deliver to the people of the state and our neighbors in the Pacific Basin.

4.4 COAL CHARACTERISTICS

The outstanding feature of almost all Alaskan coals, regardless of rank, is the extremely low sulfur content, Table 4.7.1.(1,2) Many of the low-rank coals (LRCs) have sulfur levels below 0.2%; for example, the latest three year average for the Usibelli subbituminous coal was 0.17%. In addition, many of the LRCs have low ash levels and reactivities typically an order of magnitude higher than their bituminous counterparts. LRCs are prime candidates for use in advanced applications, such as gasifiers, fluid-bed combustors and even in diesels or turbines. Most of the LRCs are recoverable by relatively low-cost strip mining. Many of the coals are near tidewater making them amenable to low-cost ocean transport.

The majority of the coals near tidewater, those with the most near term economic significance, are classified as low-rank coals (LRCs) due to their high moisture and inherently low heating value. The high moisture has restricted most LRC usage worldwide to mine-mouth power generation. It has limited export sales of Alaskan coal to only 0.75MM tons per year from the Usibelli Coal Mine. Alaska is able only to sell this small quantity of coal at a time when Australian coal exports have topped 100MM tpy and the steam coal market is expected to quadruple in a decade.(3) Without development of economical methods for drying/stabilizing Alaskan LRCs, making concentrated LRC-water fuels, or producing alternate fuels like form coke, the only increase in export of Alaskan coals will be from the few "higher rank" coals within a "reasonable" transport range of the existing Alaska Rail system or tidewater. The only high-rank candidate yet identified is the Wishbone Hill property being developed by Idemitsu Kosan, near Palmer, Alaska.(4)

Table 4.7.1 lists the proximate and ultimate analyses of some typical Alaskan coals and some typical coals from lower 48 states. Ash composition of the coals is shown in Table 4.7.2. Coals from the only producing Alaskan mine, Usibelli Coal Mine of the Nenana basin, and coal from Beluga-Yentna fields, west of Anchorage are similar in characteristics. Both are very low in sulfur, have low ash and are of subbituminous C rank. These coals are also high in calcium which serves to trap sulfur in fluid bed combustion systems.

An unusual Alaskan coal, from a seam of about 85' thick, with higher sulfur than other Alaskan coal is from the Little Tonzona coal field located west of Denali National Park. Transportation is the principal hurdle in development. Hot water drying followed by slurry transportation could be a viable option when economics permit development. The seam dips very steeply, which will limit the amount of coal mineable by surface mining methods.

High volatile B bituminous coal from Wishbone Hill of the Matanuska field is expected to be mined soon. These coals as mined are high in ash and need to be cleaned to meet export specifications. The analysis presented in Table 4.7.1 shows the quality that is expected to be shipped. For most seams in the Matanuska field, it would be advantageous to produce a high ash middling for power generation at the mine along with export quality clean coal. Otherwise the yield of clean coal may be too low and product price too high to be able to compete in the export market.

A large lignite deposit can be found at Chicago Creek on the Seward Peninsula. This coal is somewhat higher in sulfur and may require SO_X control. This is a very thick seam, but severe faulting and its steep dip will warrant special mining techniques for optimum coal recovery.

Northern Alaska coals range in rank from subbituminous B to high volatile A bituminous. Subbituminous B coals from near Wainwright and Mead River (Atkasuk) are low in ash and sulfur. These coals have been mined sporadically on a small scale. Development of a small mine could provide these two villages with low cost energy. High volatile B bituminous coals from Kokolik and Utukok rivers are of high quality but located at too remote a location for domestic use or for current export markets.

Western Alaskan coals located at Deadfall Syncline (near Point Lay) and Kukpowruk river are high quality, high volatile A bituminous coal. Coal has been mined on an experimental scale at Deadfall Syncline for domestic heating. The data presented in the table are for drill hole samples which retain coking qualities. Surface mineable coal is weathered and will have lost all coking quality. Ashes of these coals are high in calcium, which would help trap sulfur from the combustion products.

Low volatile bituminous coal from the Bearing River field near Cordova is a high quality and low ash coal. The coal seams are steeply dipping and most of the seams would have to be mined by underground methods, which is the principal hindrance to development.

The rank classifications for the Alaskan coals were derived mainly from the heating values and moisture content. Chemically the Alaskan coals appear to be younger, i.e., carbon and oxygen contents of Beluga and Usibelli "subbituminous" coals on a moisture and ash free (MAF) basis are more like typical lignites, and the Wishbone Hill "bituminous" coal has values between a typical subbituminous and a medium volatile bituminous coal.(5) Unfortunately, the connotation "low-rank", especially lignite, have historically been associated with inferior fuels. This was valid based on classical stoker combustors, where energy content was the main criterion. In advanced combustors however, gasifiers and heat engines, where the time available for combustion is measured in milli-seconds, rather than minutes, factors such as ignition speed, carbon burnout and flame stability actually can be more important than energy content. Thus, many of the more sophisticated coal consumers are beginning to seek coals with low "fuel ratios." The fuel ratio is the ratio of fixed carbon to volatile matter and the lower the ratio the more reactive the fuel. LRCs typically have much lower fuel ratios than bituminous coals, and the Alaskan coals have even lower fuel ratios than their counterparts in the rest of the U.S., Table 4.5.1.

4.5 TECHNOLOGY DEVELOPMENT NEEDS

Three open meetings, attended by most of the Alaskan coal community, were held in 1989 to formulate a coherent coal development program for the State of Alaska. From these meetings, it was concluded that the focus of coal research in Alaska should be on means of improving and economizing drying technologies, increasing the energy density of the alternate coal derived fuels, decreasing mining/transportation costs to make a more competitive product and end use testing to demonstrate the product's performance for users in both the domestic and Pacific Rim markets. The following is a prioritized list of specific technology development needs that must be addressed to enhance the marketability of Alaskan coals.

4.5.1 COAL DRYING

Water is present in LRCs in basically two forms, as free water on the surface and in the pores, and as chemically bound water in hydrates of mineral matter and hydrogen bonded to cations and oxygen functionalities in the coal structure, Fig. 1. Free water is easily removed, requiring only the heat of vaporization. Chemical water is more difficult to remove requiring additional energy to break the electrostatic or hydrogen bonds. If nothing is done to alter the physio/chemical properties of the coal, water can be readily reabsorbed after drying when the coal is exposed to moisture or high humidity.(6)

Numerous evaporative coal drying technologies are available commercially. Most use hot flue gases to evaporate the free water, where the final product moisture dependent on feed size and residence time at temperature.(6) Due to the low temperatures used, these processes are the least expensive and are preferred if the dried product is to be used immediately. However, drying temperatures below about 240°C, are too low to cause permanent changes in the coal structure and the dried coals behave like sponges and reabsorb the lost moisture.(6) The untreated dried product is also susceptible to excessive fines generation and to spontaneous heating. Process developers have proposed a host of proprietary coating agents to stabilize the dried coal towards moisture readsorption, fines generation and spontaneous combustion (oxidation).

If LRCs are dried at temperatures above about 240°C, the basic chemical and physical coal characteristics begin to change. In addition to moisture loss through evaporation, decarboxylation occurs and CO_2 is evolved.(6 & 8) Loss of carboxylate functionality increases the energy density of the product by removing coal oxygen while decreasing the intrinsic water holding capacity by ridding the surface of hydrophyllic sites. Much of the coal's additional volatile matter, tars and oils, are also liberated and migrate to the coal's surface. If the hydrophobic tars are not stripped during drying, they can remain on the coal and further reduce the coal's ability to hold water. Product stability, especially towards fines generation and spontaneous combustion, remains a primary concern. As with lower temperature processes, methods for mitigating these problems include: coating the coal with residual tar or oil; drying only larger lump coal; or producing briquettes or pellets from dried pulverized coal.

4.5.1.1 COAL DRYING TECHNOLOGY DEVELOPMENT NEEDS

Since there are a myriad of commercial processes available and virtually every conceivable type of drying has been investigated, it's unlikely that monies spent on scaleup of "novel" processes will be fruitful. Although it's usually wise to keep an open mind and support some bench-scale activities aimed at new concepts. A similar approach should be adopted when looking at stabilizing agents, i.e. while some laboratory investigations may be worthwhile, it must be remembered that additives are costly and given the tremendous surface area of LRCs, the amount of stabilizer necessary to make an acceptable product may preclude its economic use.

The greatly increased friability of LRCs after drying makes it extremely doubtful that any lump coal product will withstand the rigors of handling during shipment abroad. Therefore, an area with a strong potential for economic pay back would be to investigate technologies to produce a strong, durable product through briquetting, extruding or pelletizing. Again, the added costs of binders must be kept in mind and processes that use no binder, such as the Australian brown coal pelletizing process(7), or those using cheap indigenous binders, like peat, should be evaluated initially.

In order to provide a rapid, low cost assessment of a dried product's stability and ultimate utility in a combustion application, laboratory test procedures must be developed and standardized. The ultimate goal should be to develop procedures that can be correlated to actual industry practices. This will enable a user to evaluate a variety of potential feed coals without the need to acquire hundreds of tons of coal and wait months for test data from stockpiles. Moisture stability can be effectively determined by existing ASTM procedures, providing that the high relative humidities (98%) expected for Alaskan coals are used in the test. Fines generation and spontaneous combustion procedures still require developmental work to reach the same level of credibility as moisture readsorption.

4.5.2 COAL-WATER FUEL (CWF)

An alternative process for applications that demand liquid fuels, is to produce concentrated coal-water fuels (CWFs) from the Alaskan low-rank coals. Until recently only dilute slurries, 40-50% dry solids loadings, were possible from LRCs due to the high inherent moisture, and coal-water slurry technology focused only on high-rank bituminous coals. A process developed by the Energy and Mineral Research Center (EMRC) however, University of North Dakota, allows the production of CWFs from LRCs, with solids loadings comparable to those obtained with high-rank coals.(6,8)

Hydrothermal processing, more commonly called hot-water drying (HWD) induces coalification in a condensed time scale of minutes, rather than millions of years, and alters the hydrophyllic nature of LRCs into a hydrophobic material that has equilibrium moisture levels similar to bituminous coals. Induced coalification occurs when coal is heated to coal specific temperatures, typically above 240 C in an aqueous phase at pressures slightly above the saturated steam pressure. CWFs have been successfully produced from LRCs from a number of countries in a 2.5 tpd process development unit at the EMRC. The ability to produce CWFs from LRCs takes on added significance as Pacific Rim countries, led by Japan, move rapidly to a diversified energy mix featuring CWFs.(3) No longer are the energy poor nations restricted to the purchase of CWFs, made from expensive high-rank coals, but with HWD, the lower cost, more reactive LRCs of Alaska, become available from a politically stable supplier.

During HWD, water is removed via expansion and expulsion by CO_2. Decarboxylation not only removes hydrophyllic sites but leads to an increased energy density of the CWF by ridding the coal of oxygen functionalities.(6) The largest contributors to a stable, non-reabsorbing particle are the evolved tars/oils. Tars are mainly hydrophobic and in a pressurized aqueous environment tend to remain on the coal in a uniformity not possible with any other means of coating the coal's reactive surface. The uniform tar coating effectively seals the pores against moisture readsorption.(6) The overall process can be represented as removing the inherent moisture and reusing this moisture as the vehicle solvent. For some high moisture coals the process may even become a net producer of water. In general there is little ash reduction during HWD. However, in coals with high alkali concentrations, the alkalis associated with the carboxyl groups are released into the aqueous phase and can be removed by washing during the final mechanical dewatering step, giving a product with a much lower fouling potential.

Advanced applications, such as in combustion turbines and/or diesel engines place new demands on the fuel's combustion characteristics due to the greatly shortened residence times allowable for combustion. Instead of the usual seconds available in conventional combustors, reaction times in heat engines are measured in milli-seconds. Thus, to achieve complete carbon burnout with bituminous coal water fuels, suppliers have gone to more costly fine grinding to produce "micronized" CWFs. The smaller size and much narrower particle size distributions negate any advantages bituminous coals might have held over LRCs in producing more concentrated CWFs, since their concentrations in the low 50%s are the rule. For advanced applications, the higher reactivity of low-rank CWFs could prove to be a decided advantage over bituminous CWFs by requiring less grinding to reach a PSD for complete carbon burnout or to enable use in higher speed engines.

Initial combustion test results support the higher reactivity of LRC CWFs, which leads to complete carbon burnout in short residence times and higher flame stability.(9,10) The enhanced reactivity of LRC-water fuels in comparison to bituminous CWFs is illustrated schematically in Figure 2.(10) High rank coals go through an agglomerating phase as the water is evaporated and combustion begins. During this time micronized bituminous coal particles can agglomerate into slower burning lumps many times their original diameters, which were attained through costly grinding. The reverse is true for LRCs whose enhanced friability after HWD yields particles that literally break into numerous smaller dried coal particles upon further heating. These highly reactive coal particles ignite readily, producing a stable flame.(9) Tars that seal the pores against moisture readsorption are volatilized at the inception of combustion and contribute fuel to the flame, while leaving behind the high surface area dried LRC. The fact that the HWD LRCs should have excellent combustion properties is also indicated by their low fuel ratios, which in some cases are improved even over those in the raw coal.

4.5.2.1 CWF TECHNOLOGY DEVELOPMENT NEEDS

HWD process economics are strongly influenced by the processing temperature, which is determined by coal characteristics. Therefore, screening tests are needed to select the preferred coals and operating parameters. Rheological and thermodynamic properties of the CWFs need to be obtained for the Alaskan coals that respond favorably to HWD. Pilot-scale drying and combustion tests would follow to be used as part of the economic evaluation. Finally, a small commercial scale test needs to be conducted to demonstrate CWF compatibility in an oil fired generating station, such as the 4 MW Coast Guard facility on Kodiak.

Advanced applications in diesels and/or turbines will require extensive testing to determine "acceptable" ash levels. Undoubtedly, most if not all Alaskan coals will require some level of ash reduction. Since the ash in LRCs is mainly inherent and not extraneous like that in bituminous coals, existing high-rank coal cleaning technology will probably not work well and newer technologies being developed for LRCs will need to be assessed with Alaskan LRCs. Following integration of cleaning and HWD, a commercial demonstration at any one of the small diesel generators in a village would be the next step towards commercialization.

Either or both of the demonstration tests could be candidates for application to the U.S. DOE Clean Coal Demonstration programs. Their successful operation would serve as a powerful marketing tool for Alaskan coals in the Pacific Rim.

4.5.3. CARBONIZATION/PYROLYSIS (MILD GASIFICATION) PROCESSES

A large number of pyrolysis and carbonization processes have been developed around the world. Very few have been commercialized, especially in the U.S., where the majority have relied on the value of the coal liquids to carry the process. In a technology where coal liquids comprise at best 30% of the feed carbon, this is an unrealistic expectation. The char, which amounts to at least 50% of the feed carbon, has undergone significant processing and must bring a premium if the process is to be a commercial success.

The preferred gasification conditions are rapid heating, to moderate temperatures, followed by rapid quenching of the volatiles, to preserve the quality of the coal liquids. This can be accomplished easily with LRCs in fluid-beds similar to those developed by FMC for their Form Coke process.(11) Coal liquids from low-rank coals are high in phenolics, which can be upgraded to valuable chemicals in a mild hydrotreating process.

Several premium char uses were identified, that may be particularly well suited to the low sulfur char made from Alaskan coals.(12) In the patented Pellet Technology Corporation (PTC) process, a low sulfur, low volatile char is used to produce iron at significantly lower costs than existing blast furnace technology.(13) This process may be applicable to the strategic chromite ore deposit on the Kenai Peninsula making ferrochrome steel production economically viable. The extremely low sulfur char, expected from Alaskan coals, may also find premiums in the Pacific Rim and lesser developed nations as form coke for steel making, annodes for aluminum production, activated carbon for wastewater treatment and acid gas control, and briquettes for home cooking and heating.(12)

4.5.3.1 CARBONIZATION TECHNOLOGY DEVELOPMENT NEEDS

Mild gasification products are strongly influenced by coal characteristics and process conditions. Therefore, screening tests are necessary to evaluate the potential product slate(s) as a function of the feed coal and operating conditions. These tests would be followed by pilot-scale gasification and upgrading tests to give quantities of coproducts for end use testing. The data would be combined with process engineering data as part of an economic evaluation.

The next phase in marketing carbonization products from Alaskan coals would be a demonstration program aimed at producing sufficient products for thorough end use testing. Data would also be obtained to allow a complete economic assessment of the process and to perform sensitivity analyses of the variety and quantities of products that could be produced from this flexible process. The commercial test would also be a candidate for DOE Clean Coal funding.

4.5.4. COAL/OIL CO-PROCESSING

Co-processing features the simultaneous upgrading of low quality petroleum residue and coal. The resid serves as a once-through vehicle solvent and hydrogen shuttling medium in converting most of the coal to liquids. The process, which will be commercially tested in the Ohio-Ontario Clean Fuels, Inc. Co-processing Project, as part of DOE's first round Clean Coal Technology Program, uses ebullating bed technology developed by Hydrocarbon Research Inc., to liquify high sulfur bituminous coal and to upgrade low quality resids.(14) The technology should be transferable to all ranks of coal and resids if the correct combinations of processing parameters and feedstocks are chosen. Heavy oil production and transport requires a large amount of light diluent to yield a product with a manageable viscosity. Co-processing of North Slope heavy oil with Northern Basin coal could enhance the marketability of both by yielding a diluent for additional oil production and a dried coal/char stabilized with heavy oil that has a higher energy density than even the dried coal alone. The wealth of heavy petroleum products available from

Alaska's North Slope, and an estimated 4 trillion tons of coal makes co-processing a technology well worth investigating.

4.5.4.1 CO-PROCESSING TECHNOLOGY DEVELOPMENT NEEDS

Since this technology is the least advanced, and longest range of the technologies described, a significant amount of exploratory, bench-scale research is still needed to assess the variety of oil/coal combinations available. If synergistic combinations can be found, then pilot-scale tests are warranted, to prepare quantities of product for end use testing and to process engineering data for an economic evaluation. If economically viable at this stage, a commercial demonstration program would follow.

4.5.5. COMBUSTION TESTING

An integral part of any technology that will produce a fuel from Alaskan coals, be it dried/stabilized coal, CWF, or coal liquids, will be to assess the combustion performance of the new fuel. This will require combustion tests in equipment ranging from laboratory scale thermogravimetric analyzers to full sized fluid-bed combustors, gasifiers, diesels and turbines. Test rigs must be well instrumented to give environmental performance, combustion efficiency, as well as ash and slag deposition data for an accurate assessment of the new fuel's performance. Obviously, many of the larger scale tests will be best handled by competitive bids with outside research agencies and companies, but development of some state combustion test facilities are warranted. This will insure that test procedures developed for lower 48 coals are not used improperly with Alaskan fuels, producing data that could halt development of an otherwise promising process.

4.5.6. RESOURCE ASSESSMENT UPDATE

In addition to the technology development needs described above, there is a clear need to update the resource data base. Many of the inferred reserves and coal characteristics are based largely on easily obtained samples, such as from outcrops or beach and river deposits. Hampered by the tremendous distances and remote, virtually inaccessible locations, the costs associated with a detailed resource characterization are enormous. None-the-less, additional resource definition should be undertaken. It should focus on resources most likely to be of commercial interest in the next decade, and should include the collection and preservation of representative samples for detailed characterization and bench-scale testing.

Table 4.5.1
Proximate and Ultimate Analyses of Selected Alaskan Coals (As Received Basis)

Coal Field and Seam	Apparent ASTM Rank	Thickness (feet)	Moisture %	Volatile Matter,%	Fixed Carbon, %	Ash %	Heating Value BTU/lb	C,%	H,%	N,%	O,%	Total Sulfur	Comments on Samples/Quality
Usibelli Coal Mine Seam 3	Subbit. C	17	26.3	35.5	31.6	6.6	7,975	46.0	6.4	0.6	40.2	0.2	Average of 12 samples of Usibelli production collected during a 6 month period. (15)
Usibelli Coal Mine Seam 4	Subbit. C	21	25.0	35.9	31.3	7.9	8,045	47.1	6.3	0.6	37.9	0.3	Average of 12 samples of Usibelli coal mine production collected during a 6 month period. (15)
Beluga Coal Field Waterfall Seam (UA-113)	Subbit. C	30	23.7	35.2	33.3	7.8	8,327	48.0	6.3	0.5	37.3	0.1	Sampled from subcrop opened by Placer U.S. for bulk sampling for shipment to Japan. (4)
Beluga Field Green Bed Lone Ridge Mine (UA-152)	Subbit. C	25	27.6	34.8	31.6	6.0	8,051	46.7	6.9	0.7	39.6	0.12	Sampled from subcrop opened by Placer U.S. for bulk sampling for shipment to Japan. (4)
Red 1, 2, & 3 Beds	Subbit. C	50' Approx.	27.1	33.0	29.8	10.1	7,650	44.6	6.1	0.7	38.4	0.1	Average analysis of future mine production by Diamond Alaska Coal Co. (16)
Yentna Canyon Creek (UA-150)	Subbit. C	34	20.8	35.8	28.5	14.9	7,857	45.2	6.2	0.7	32.9	0.1	Coal seam exposed along Canyon Creek. (4)
Yentna Locality 2 Lower (UA-115)	Lignite	55	29.8	38.3	28.6	3.3	7,943	45.2	6.8	0.5	44.1	0.1	Coal seam exposed along Sunflower Creek. Represents 10' of a 55' thick seam. (4)

Coal Field and Seam	Apparent ASTM Rank	Thickness (feet)	Moisture %	Volatile Matter,%	Fixed Carbon, %	Ash %	Heating Value BTU/lb	C,%	H,%	N,%	O,%	Total Sulfur	Comments on Samples/Quality
					MATANUSKA COAL FIELD								
No. 7A Bed Evan Jones Mine (UA-142)	HvBb	10	4.8	34.6	42.3	18.2	10,730	60.3	5.3	1.3	14.5	0.4	Coal seam exposed by Evan Jones mining that ceased operation in 1967. (4)
Wishbone Hill Average 1.5 Float	HvBb	Variable	5.9	37.0	44.2	12.9	11,533	64.4	4.7	1.3	10.4	0.4	Average analysis of 1.50 S.P.G. float drill core samples. (17)
					NORTHERN ALASKA COAL FIELD								
Deadfall Syncline DF 84-122	HvAb	12.7	4.6	33.9	53.9	7.6	12,722	72.5	5.1	1.2	13.4	0.2	Drill core sample intersecting the seam at 95 ft. depth. (18)
No. 3 Bed Elusive Creek (UA-125)	HvBb	11.5	11.9	30.3	55.4	2.3	11,242	65.9	5.2	1.3	25.0	0.3	An outcrop along Elusive Creek. (4)
Kokolik River (UA-126)	HbAb	11.6	15.6	26.4	52.6	5.4	10,904	63.5	5.6	1.0	24.3	0.2	An outcrop along Kokolik River. (4)
Wainwright (UA-109)	Subbit. B	5	20.3	30.2	44.7	4.8	9,292	54.8	5.7	1.1	33.3	0.3	Outcrop along Kuk River. (4)
Meade River (UA-110)	Subbit. B	5	17.9	30.3	48.2	3.6	10,425	60.0	5.9	1.4	28.7	0.4	A outcrop along Meade River. (4)
					MISCELLANEOUS FIELDS								
Chicago Creek DHI 150'-160'	Lignite	Variable	37.1	24.2	28.1	10.6	6,493	37.6	6.9	0.6	42.8	1.5	A sample or a drill core from a seam with maximum thickness up to 85'. (19)

Coal Field and Seam	Apparent ASTM Rank	Thickness (feet)	Moisture %	Volatile Matter,%	Fixed Carbon, %	Ash %	Heating Value BTU/lb	C,%	H,%	N,%	O,%	Total Sulfur	Comments on Samples/Quality
Little Tonzona CS-691	Lignite	5" Section out of 137' coal	30.4	34.7	26.9	8.0	7,245	42.2	6.6	0.4	41.9	0.9	A 5' sample from a 137 ' thick coal seam. Steeply dipping. (20)
Jarvis Creek Mine Seam UA-106	Subbit C.	10	20.6	36.2	34.1	9.1	8,746	49.8	5.8	0.8	33.4	1.1	Sampled from exposure on Ober Creek. (4)
Bering River K-81 (5-1)	LVB	13.7	1.9	12.8	81.5	3.8	14,868	85.9	4.3	1.3	3.5	1.2	From a drill core supplied by KADCO. (21)
					LOWER 48 FIELDS								
Wasatch Plateau Utah B PSOC-435	hvBb	9	5.2	45.8	44.6	4.4	13,188	68.5	6.9	1.3	18.4	0.5	(22)
Kemmerer, Wyoming Adaville, #2 PSOC-472	Sub. B	28.5	20.3	36.8	39.8	3.1	9,991	61.7	5.4	1.1	28.1	0.6	(22)
Decker, Montana Dietz PSOC-531	Sub. B	51	20.1	33.9	42.5	3.5	9,970	57.9	6.2	0.7	31.5	0.2	(22)
Gulf, Texas Lower Wilcox PSOC-785	Sub. C	10.3	28.3	33.3	29.4	9.0	7,873	45.0	6.5	0.8	37.9	0.8	(22)
Illinois #5 Seam PS0C-580	HvBb	5.4	6.7	38.5	40.4	14.4	11,303	61.2	5.3	1.0	12.0	6.1	(22)
West Virginia Pittsburgh Seam PS0C-702	HvAb	7.3	2.1	39.2	52.0	6.7	13,684	75.4	5.3	1.2	8.8	2.6	(22)

Table 4.5.2
Concentration of Major Elements in the Raw Coal Ash (750°C), in weight percent

Coal Field/Mine	SiO_2	Al_2O_3	Fc_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	SO_3	MnO
Usibelli Coal Mine No. 3 Seam	34.5	14.7	8.1	3.7	30.4	0.6	0.9	0.6	3.2	0.17
Usibelli Coal Mine No. 4 Seam	38.4	17.7	6.7	3.4	23.8	0.2	1.1	0.7	5.1	0.12
Waterfall Seam (UA-113)	41.0	28.9	6.7	1.9	16.6	0.7	2.1	0.8	7.9	0.10
Green Bed Lone Ridge Mine (UA-152)	34.5	22.6	7.7	4.1	21.5	0.3	0.8	0.7	4.6	0.08
Red 1, 2 and 3 Seams	41.0	20.2	8.9	4.1	13.4	1.6	1.1	1.3	2.5	0.1
Yentna Canyon Creek (UA-150)	55.8	26.6	2.6	1.6	5.3	0.3	2.0	1.1	0.9	0.02
Yentna Locality 2 Lower (UA-115)	16.8	33.3	9.5	6.3	28.0	.2	1.0	1.1	9.1	0.12
No. 7A Bed Evan Jones Mine (UA-142)	51.9	27.4	7.6	1.8	2.5	0.6	1.6	1.6	0.8	0.09
Wishbone Hill AU-15F	48.0	28.0	8.5	3.4	3.7	0.5	1.1	1.5	2.0	0.13
Deadfall Syncline DF 84-122	30.9	29.2	4.8	6.7	17.5	6.9	0.6	0.7	1.5	0.02
No. 3 Bed Elusive Creek (UA-125)	22.3	26.5	12.3	6.6	15.0	2.1	0.7	0.8	3.0	0.03

Coal Field/Mine	SiO_2	Al_2O_3	Fe_2O_3	MgO	CaO	Na_2O	K_2O	TiO_2	SO_3	MnO
Kokolik River (UA-126)	42.4	27.1	5.5	3.0	6.1	1.6	1.9	2.2	4.6	0.03
Wainwright (UA-109)	41.7	5.9	18.8	13.0	13.2	2.2	1.0	0.1	13.1	0.29
Meade River (UA-110)	43.8	23.3	6.1	3.3	4.4	1.0	1.8	1.3	2.1	0.06
Little Tonzona CS-691	28.8	22.4	5.5	3.3	19.0	0.1	1.2	0.8	14.0	0.18
Jarvis Creek Mine Seam (UA-106)	42.7	16.6	11.2	2.2	20.8	0.4	0.7	1.1	21.7	0.12
Bering River K81(5-1)	48.8	26.0	10.9	0.87	4.0	0.7	1.9	1.2	-	0.04
PS0C-435	52.5	12.6	5.4	0.9	12.2	3.1	0.3	0.9	9.1	0.04
PS0C-472	47.1	12.1	12.7	4.0	9.1	0.3	0.7	0.5	11.4	0.04
PS0C-531	27.7	19.0	4.3	4.0	18.0	10.0	0.6	1.3	12.5	0.04
PS0C-785	34.1	14.4	5.6	3.6	20.0	0.3	0.3	1.3	17.0	0.04
PS0C-580	31.3	11.6	37.3	0.6	7.2	0.2	1.2	0.6	9.3	-
PS0C-702	23.5	18.7	45.6	0.8	4.7	0.3	0.8	0.8	5.1	-

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