SLURRY PIPELINES FOR THE TRANSPORTATION OF COAL - THEIR HISTORY AND STATUS

Senior Thesis

by

Helen S. Truscott

****

The Ohio State University

1985

Approved By

Advisor

OUTLINE

Introduction
- -Largest coal dep osits in world
- -use of coal
- -problems with western and eastern coals
- -slurry-what is it?
  - 1)problems facing slurry industry
    - a)eminent domain
    - b)RR competition
    - c)water
  - 2)solutions to problems
    - a)federal eminent domain
    - b)state eminent domain
    - c)aquisition of property
  - 3)economics of slurry transport
    - a)variable vs. fixed costs
    - b)economy of scale
    - c)consumer benefit

Successful Slurry Pipelines in U.S.
- 1)Consolidation Coal
  - a)route
  - b)purpose
  - c)technical
    - 1)pumping stations
    - 2)flow
    - 3)amount transported
- 2)American Gilsonite
  - a)route
  - b)physical dimensions
- 3)Black Mesa
  - a)physical dimensions
  - b)route
  - c)transit time/velocity of material
  - d)source of coal
  - e)personnel required
  - f)problems
    - 1)clogging
  - g)solution to problem
  - h)start-up and shutdown requirements

Proposed ETSI Pipeline
- 1)partners-corporations involved
- 2)route proposed
- 3)technical aspects
  - a)length, dimensions
  - b)pumping stations
  - c)prep plants
- 4)CEP plant
  - a)results of experiments
    - 1)dewatering
    - 2)storage of slurry
    - 3)meeting water requirements
- 5)Water situation
  - a)Madison formation
    - 1)stipulation
  - b)Oahe Reservoir
    - 1)stipulation
    - 2)supply
    - 3)aqueduct

4)reservoir details
5)cost of water
6)why ETSI shelved?
a)window program

Microbial Reduction of Sulfur
1)organism-basic description
2)process
a)water preparation
b)"food" for organism
c)enviroment
3)growth rate
4)factors affect amount removed
5)cost of plant
a)with dewatering
b)without dewatering

Economic Analysis of Pipeline Proposal
1)BG&E contractor
2)coal source
3)DCF analysis
1)expense and calculation
4)$ saved in the future

Other Methods of Slurry
1)stabflow
2)oil agglomeration
3)coal/oil dispersion
4)coal/methanol
5)coal/liquid CO_2

Problems in Boiler Design to Burn CWS Fuel
1)no coal facilities
2)minimize plant changes
3)requirements for modification
4)ash content problems

Problems Facing the CWS Industry
1)maintain stable flame
2)complete burning
3)combustion chamber
4)ash quantity larger

CWS Composition

CWS cost vs. other costs

Improve market for CWS fuels
1)rise in oil prices
2)reduce CWS cost
3)coal quality improvement
4)create domestic and export markets
5)successful demonstration.

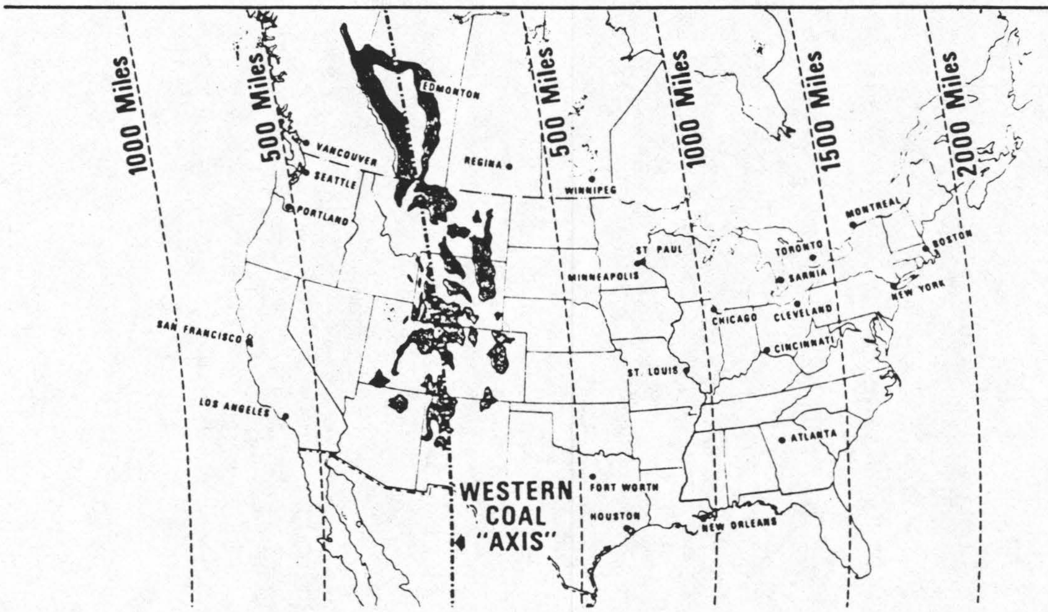
AEP View
1)their mode of transport
2)cost of east vs. west coal

Conclusion

INTRODUCTION

Today, we live in a world with a fluctuating economy and rising energy costs. Coal has been in the past, and is presently, one of the cheapest sources of energy. Three countries possess the majority of the world's coal resources, these are: Russia, China, and the United States. Our country is now attempting to become independent of foreign energy supplies; coal will play an important role in achieving this goal. The major use of coal is for generating electricity, the burning of coal generates problems as well. Acid rain is produced by the oxidation of sulfur (high concentrations are found predominantly in eastern coal) which forms sulfuric acid. The coal in the western United States generally contains low sulfur concentrations. One solution to the problem is to utilize western coal. The problem with western coal is the long distance to the major power generating plants. (Refer to diagram on p. 2). The transportation costs of the western coal are expensive, since the predominant mode of transportation is by rail. To cut transportation costs the method of utilizing slurry pipelines has been proposed. Slurrying, or transporting coal by pipeline in a mixture of 50% water and 50% pulverized coal, has proved to be successful. The construction and operation of the Consolidation Coal Pipeline in Ohio, and the American Gilsonite Pipeline in Utah, both in operation in 1957, marked the birth of a new transportation mode. Since then slurry pipelines have been used throughout the world to transport materials such as: coal, limestone, iron

WESTERN COAL
DISTANCE TO MAJOR MARKETS



Source: Wasp, Thompson, "Slurry Pipelines - Energy Movers of the Future", Interpipe Conference, Hoston, Texas, November 1, 1973.

concentrate, gilsonite, copper tailings, kaolin, and gold tailings.[1] (Refer to table on p. 4).

The major problems that are facing slurry pipelines today are to convince the utility companies that they are a reliable source of coal, and to attain the power of eminent domain. Presently, to cross highways, railroads, rivers, streams, and canals, a pipeline must have a permit. These permits are obtained from state or federal agencies. Due to the lobbying power of the railroads the securing of these permits has been obstructed. The options to circumvent this problem are: 1) attain federal eminent domain rights, 2) attain state eminent domain rights or 3) privately acquire the necessary land.[2]

Slurry pipelines have proven to be an economical method of transport. This is because 70% of the pipeline's cost is a fixed capital cost. The railroads presently have a 75-85% variable cost. (Refer to pp. 5-8). The low variable cost of slurry pipelines can save the consumers many dollars in the future. Pipelines use 1/8 of the labor railroads use, and 40% less steel over a 30 year period. They also incorporate economies of scale; the more material that is transported, the lower the cost. The consumer also benefits by the government not having to subsidize the pipeline, unlike the railroads.[3] A slurry pipeline can also be used to overcome the problems of difficult terrain at a lower cost than other methods of transport.

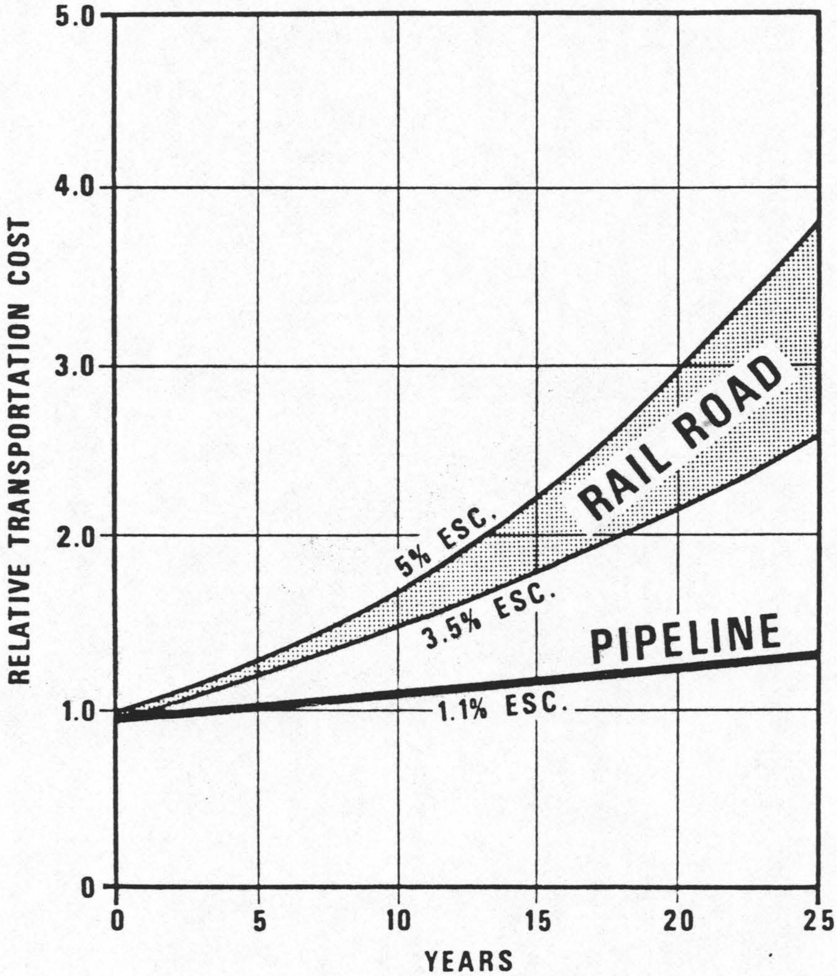
The next section of this paper will cover the successful operations of several slurry pipelines in the United States.

Location	Material	Length, Miles	Diameter, In.	Million Tons/Year
Ohio	Coal	108	10	1.30
Arizona	Coal	273	18	4.80
Canada***	Coal	500	24	12.00
Utah	Gilsonite	72	6	0.38
England	Limestone	57	10	1.70
Colombia	Limestone	9	5	0.35
Trinidad	Limestone	6	8	0.57
California	Limestone	17	7	2.00
South Africa	Gold Tailings	22	6 & 9	1.05
Tasmania	Iron Concentrate	53	9	2.25
Brazil	Iron Concentrate	246	20 & 18	14.00
Japan	Copper Tailings	40	8	1.00
Canada***	Sulphur/Hydro.	800	12 & 16	---
Bougainville	Copper Conc.	17	6	1.00
West Iran*	Copper Conc.	68	3	0.30
Africa*	Phosphate	3	12	5.00
Ohio	Wastes (Raw Sew.)	13	12	---
Ohio*	Wastes (Digested Sludge)	45	6	---
New Zealand*	Magnetite	6	8 & 12	1.00

* In design phase   ** Under construction   *** In planning phase

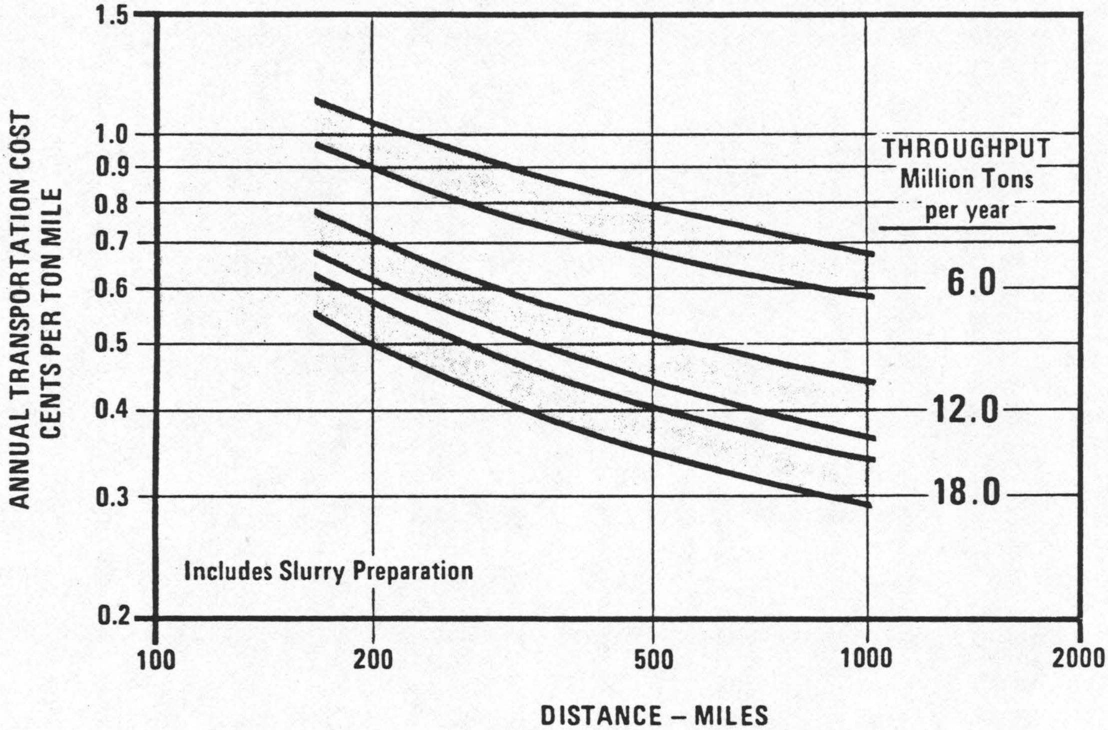
Source: Montfort, "Operation Of The Black Mesa Pipeline System", Peabody Coal, p. 2.

INFLATION EFFECT ON COAL TRANSPORT COSTS



Source: Wasp, Thompson, "Slurry Pipelines - Energy Movers of the Future", Interpipe Conference, Houston, Texas, November 1, 1973.

COAL SLURRY PIPELINE
TRANSPORTATION COSTS

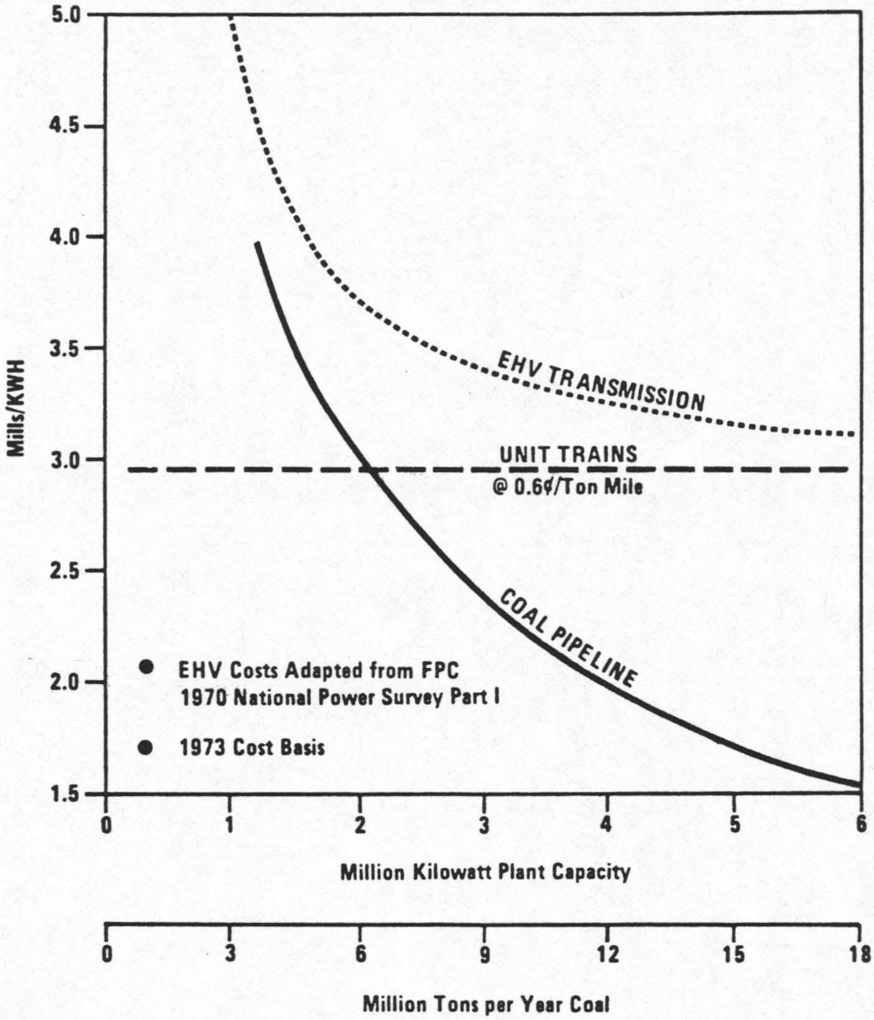


September 1973

Source: Wasp, Thompson, "Slurry Pipelines - Energy Movers of the Future", Interpipe Conference, Houston, Texas, November 1, 1973.

COMPARISON OF ALTERNATE MODES OF COAL ENERGY TRANSMISSION

(FOR 1,000 MILE TRANSPORT DISTANCE)



Source: Wasp, Thompson, " Slurry Pipelines - Energy Movers of the Future", Interpipe Conference, Houston, Texas, November 1, 1973.

TRANSPORTATION COSTS
(1 TRILLION BTU/DAY – 1000 MILES)

FUEL	¢/MILLION BTU/100 MILE
OIL	0.8
COAL EXTRACT	1.5
GAS	2.0
COAL SLURRY	2.4
RAILROAD (0.6 ¢/TM:) +10% Greater Distance	4.0

Source: Wasp, Thompson, "Slurry Pipelines - Energy Movers of the Future", Interpipe Conference, Houston, Texas, November 1, 1973.

SUCCESSFUL OPERATIONAL SLURRY PIPELINES

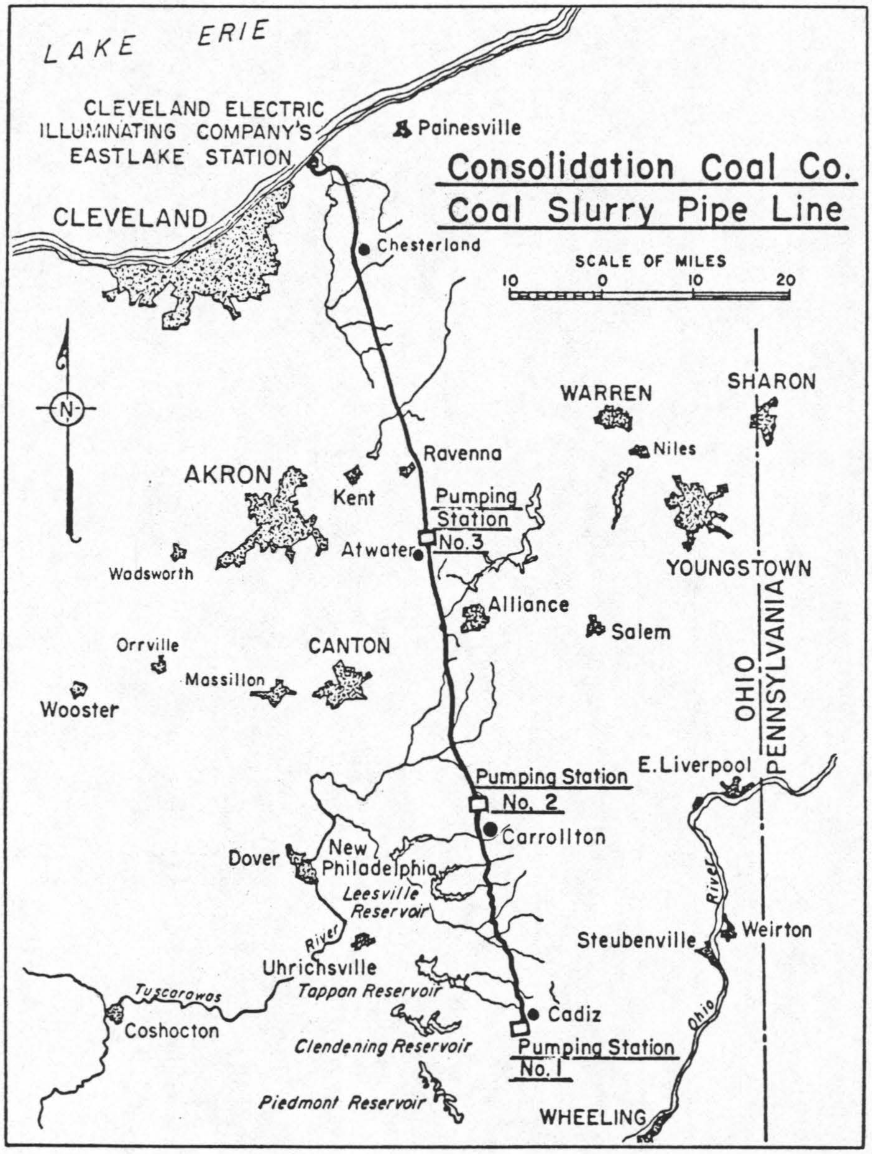
The Consolidation Coal Pipeline in Ohio, the American Gilsonite Pipeline in Utah, and the presently operating Black Mesa Pipeline in Arizona, are good examples of successful slurry pipelines.

The Consolidation Coal Pipeline

The Consolidation Coal Pipeline began operating in 1957. Its purpose was to transport coal at a cheaper rate than by rail. The project was a success. The original rail freight was $2.63/ton, the railroad later raised this to $3.47/ton. After the line was constructed and became operational, the railroad reduced its rate to $1.88/ton.[4] The line (10 inch diameter) extended for 108 miles between Cadiz, Ohio and Eastlake, Ohio. They used 3 pumping stations to keep the coal properly suspended. The flow was approximately 1/4 of the rate of the later constructed Black Mesa Pipeline, approximately .38 m/sec.--.43 m/sec.[5] The Ohio line transported 1.3 million tons of coal per year, or about 4,600 tons/day. The transit time for the coal was 32 hours. The line was buried 3.5 feet below the ground (to prevent freezing in the winter), and coated with a coal and glass wrap.[6] (The map on p. 10 shows the route of the Consolidation Coal Pipeline.)

The American Gilsonite Pipeline

The American Gilsonite Pipeline was 72 miles long, 6 inches in diameter, and extended from the Bonanza Mines, Utah, to the processing plant in Grand Junction, Colorado.[7]



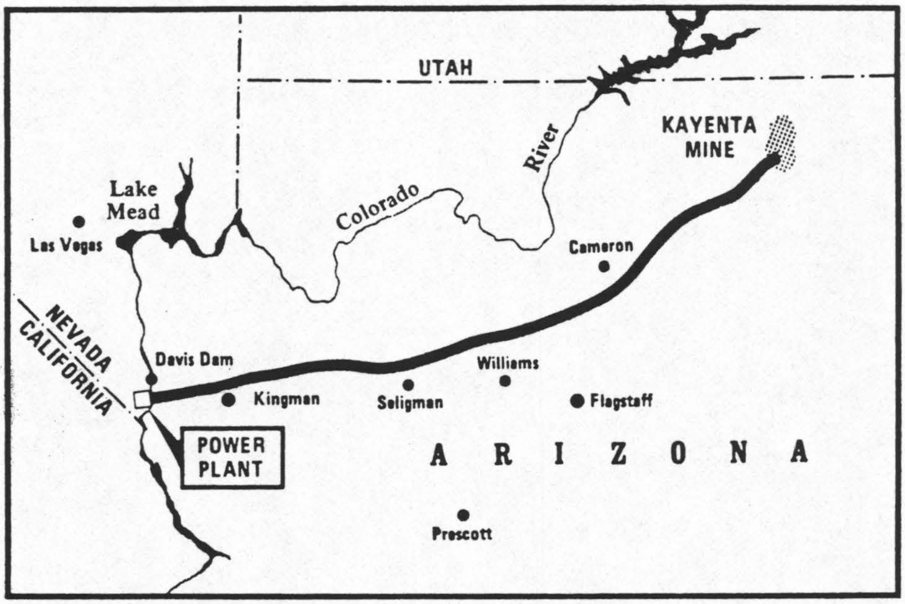
Source: Halvorsen, "Operating Experience of the Ohio Coal Pipeline", Coal Today and Tomorrow, June 1964, p. 3.

The Black Mesa Pipeline

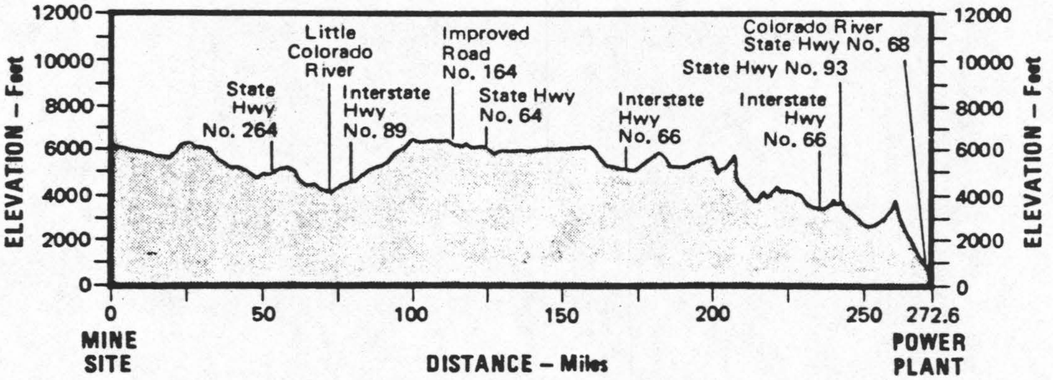
The operation of the Black Mesa Pipeline began in 1970. The system is 273 miles long, and mostly constructed of 18 inch diameter pipe. The final 13 miles of the line is 12 inch diameter, due to a 3000 foot drop in elevation.[8] The reduced diameter helps keep the velocity and pressure constant. (The map on p. 12 shows the route and profile of the Black Mesa Pipeline.) The slope of the line is 16% to reduce the solid build-up during shutdown. The corrosion allowance per year is 2 mils.[9] The average flow rate is between 1.5 m/sec.-1.7 m/sec. The capacity of the pipeline is 5 million tons of coal/year, 660 tons of coal/hour are transported. The total transit time for the slurry to complete the route is 3 days. When the line is full it contains 45,000 tons of coal.[10]

There is a main slurry preparation plant with four pumping stations to maintain suspension of the coal. The slurry pipeline receives its coal from a mine located in northeastern Arizona on the Navajo and Hopi reservations. Coal comes into the preparation plant on a conveyor belt and is dumped into bins. The dry coal is then crushed from 0"-1/4". Then it is ground with water to the proper size and further mixed with water and deposited into storage tanks with pumps to keep it suspended.[11] This slurry from the storage tank is later released through the line.[12] The main preparation station is manned by operators. The other pump stations are maintained automatically by mico-wave remote control with a few residents to handle maintenance,

BLACK MESA PIPELINE



PROFILE OF BLACK MESA PIPELINE



Source: Wasp, Thompson, "Slurry Pipelines - Energy Movers Of The Future", Interpipe Conference 1973, Houston, Texas, November 1, 1973.

There are approximately 52 permanent personnel. These include administrators, technicians, and maintenance personnel.[13]

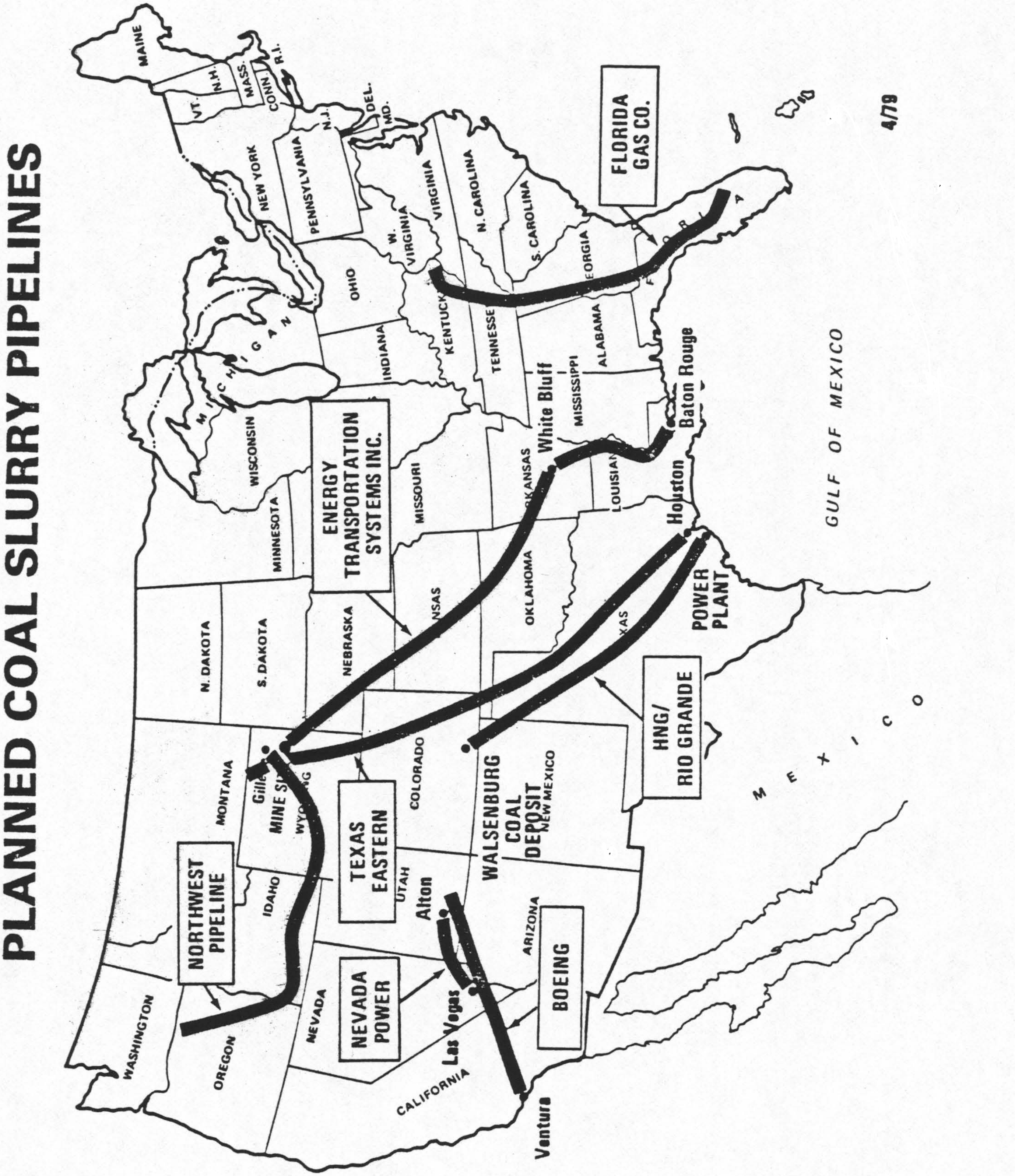
In 1971 some coarser size particles were pumped through the line, and led to clogging when the line was restarted. Clogs were located by using pressure taps. Taps were also used to remove the plugs and beating upon the pipe was also required. They eventually reduced the size from 14%-325 mesh or 44 micrometers to 19%-324 mesh or 44 micrometers.[14]

When the pipeline is shutdown the pump cylinders and valve chambers must be flushed out or the slurry will pack into the crevices. Most shutdowns have been caused by power failures. The start-up of the line is a critical and complex operation. The pressure and velocity of the fluid must gradually be established or it can lead to clogging.[15] The Black Mesa Pipeline has been shutdown for periods ranging to 4 days in length with successful restarting. The Black Mesa Pipeleine has been a technical success and has done much to advance the pipeline industry.[16]

Presently, there are several slurry pipelines proposed throughout the United States. (Refer to pp. 14-15). One of the largest pipelines proposed has been the ETSI Pipeline.

THE PROPOSED ETSI PIPELINE

In 1973 ETSI (Energy Transport Systems, Inc., a conglomeration of: Bechtel, Lehman Brothers Kuhn Loeb, Kansas-Nebraska Natural Gas Co., and United Energy Reources), was formed. They proposed a pipeline originating in Gillette,



Source: Wasp, American Petroleum Institute 1979 Pipeline Conference, Dallas, Texas, April 17, 1979.

PLANNED U.S. COAL SLURRY PIPELINES

PIPELINE SYSTEM	LENGTH (MILES)	CAPACITY (MMTA)
ETSI	1,378	25
NEVADA POWER	180	12
NORTHWEST/GULF	1,100	10
HNG/DENVER RIO GRANDE	900	15
TEXAS EASTERN	1,200	25
FLORIDA GAS	1,500	25-50
BOEING	650	10

TOTAL INVESTMENT IN PRESENT DAY DOLLARS
$10 BILLION

Source: Wasp, American Petroleum Institute 1979 Pipeline Conference, Dallas, Texas, April 17, 1979.

Wyoming, (in the Powder River Basin) extending to the south central United States. The length would be approximately 1400 miles long, with a diameter of 38 inches, pump stations would be located every 80-100 miles (approximately 19 pumping stations). The slurry would move 3.8 mph, with a total transit time of 7-8 days.[17] The line was to have transported 25-30 million tons of coal/year. The estimated cost in 1985 dollars was $2 billion.[18]

A "coal evaluation plant" (CEP was constructed in Redfield, Arkansas at the Arkansas Power and Light's coal burning generating plant. This plant tested all aspects of the grinding and dewatering processes of the Wyoming coal. A dewatering plant was to be located at each destination point of the slurry pipeline.[19] Presently, there has been no problem in treating the water to meet EPA standards. The water is clearified to 10 parts per million, lower than the public requirements. Coal also acts as an absorbant, so even uranium, lead, and arsenic that are sometimes present in coal were not noticeably dissolved.[20] The study also concluded that the dewatered coal could be stockpiled and stored without affecting the quality. The experiment also involved transporting the dewatered coal by barge to another location. This experiment was also successful. There was no packing or deterioration of the coal.[21]

In 1974 ETSI was given permission by the state of Wyoming to use water from the Madison formation. The Madison formation is a deep aquifer beneath the northern

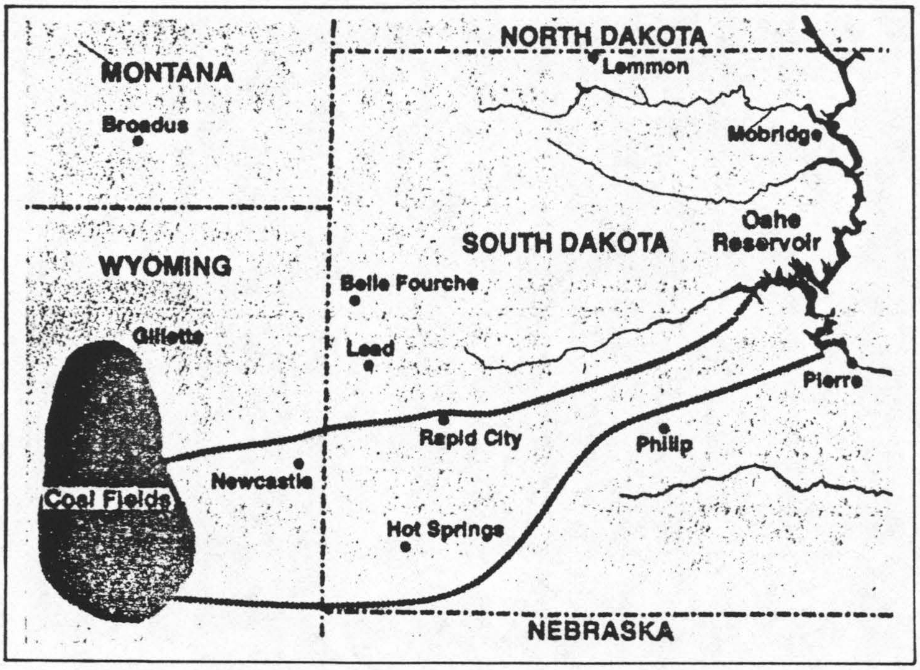
Great Plains. There was a stipulation that they must drill below 2500 feet.[22] ETSI also proposed to build a 270 mile long, 136 inches in diameter aqueduct from the Oahe Reservoir, S.D., to the coal slurry preparation station in Wyoming.[23] (Refer to p. 18 for route of aqueduct.) The Oahe Reservoir has 1 million acre feet/year availible for industrial use. The reservoir stores 23.5 million feet/year with an average downstraem flow of 18.5 million acre feet. The Oahe Reservoir would have provided up to 50,000 acre feet/year to ETSI, well over what their actual need would have been. It has been estimated that the cost of transporting the water would have been approximately 6% of the total cost of the transport of coal (approximately $10/ton for total water cost).[24]

The ETSI line proposal was shelved in July, 1984, due to problems in procuring water and eminent domain rights. ETSI had attempted to circumvent eminent domain problems through their "Window Program". This program secured the easement rights where the railroads only held the surface easements, subsurface rights belonged to the landowners.[25]

MICROBIAL REDUCTION OF SULFUR CONTENT IN COAL

To make eastern coal more desirable for slurry line development, research has been carried on to reduce the sulfur content of the coal.

"In 1983, Atlantic Research Corporation developed a



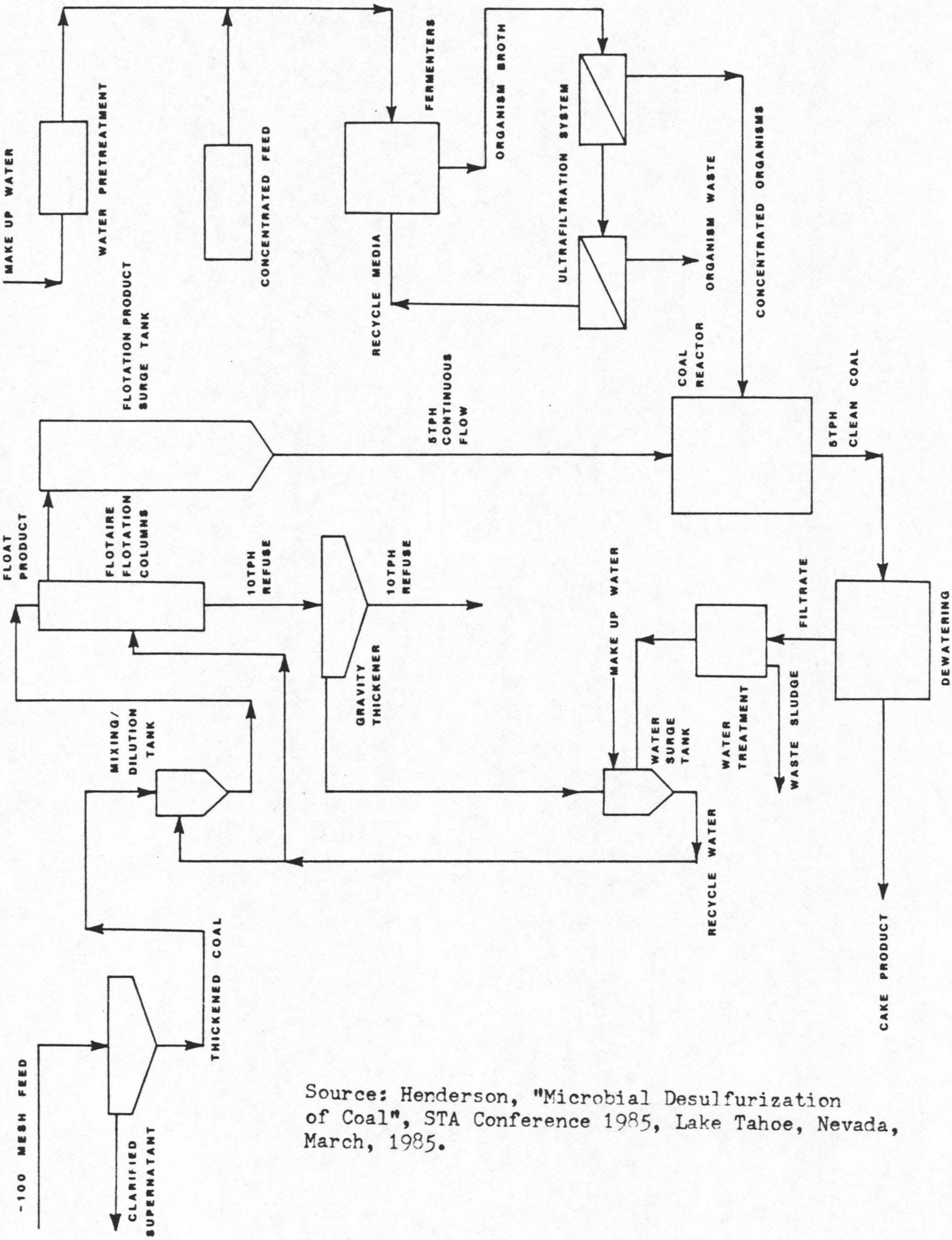
Surface water for Powder River Basin coal development. Water source is Oahe Reservoir.

Source: Wasp, "$10 Billion For Slurry Pipelines Expected During Next Decade", Pipeline & Gas Journal, February 1979, p. 1.

microorganism capable of removing thiophenic sulfur from coal and converting the sulfur to water soluble sulfate. This microorganism, CB1, was developed from a mixed culture through mutagenic alteration of the genetic characteristics of the microbes to enable the survivor to utilize sulfur but not carbon from the model compound dibenzothiophene. CB1 is a unique microorganism having physical and biochemical characteristics that differ from other known microbes of its species. A patent application on CB1 and its use in desulfurizing fossil fuels has been filed."

The first step in the process was to dechlorinate the water used to produce the medium for CB1 growth and incubation. A salt and carbon mixture was added to this to "feed" the CB1. This feed was kept under UV light to prevent the growth of unwanted microorganisms. The Ph was kept constant between 25-35° C. The microorganisms were then filtered and concentrated into a thick broth. The coal slurry was then pumped into the coal reactor which was kept aerated and at a constant temperature. The slurry was then dewatered and washed to remove the sulfate and any metals. The water then went back to the coal feed tank to be reused.[27]

The growth rate of CB1 was replication every sixty minutes. Samples of high sulfur coal were treated with CB1 to test the ability of the microbe to remove sulfur. There are two factors which affect the amount of sulfur removed; these are: 1)the amount of sulfur present in the coal, 2) the surface properties of the coal. The ideal coal surface shouldbe finely ground and no oxidation of coal should have taken place. Oxidation of the coal inhibits the attachment of the enzyme to the coal.[28]



Demonstration Plant Flow Schematic

Source: Henderson, "Microbial Desulfurization of Coal", STA Conference 1985, Lake Tahoe, Nevada, March, 1985.

Based on present information, the estimated cost of a large scale processing plant to reduce the amount of sulfur approximately 40% is $35,000,000.00. This plant would treat 100 tons/hour. For a plant with dewatering facilities the cost is $26/ton, without dewatering facilities the cost is $21/ton.[29] Refer to p. 20 for a schematic of a plant.

ECONOMIC ANALYSIS OF A PIPELINE PROPOSAL

The Baltimore Gas and Electric Company (BG&E) contracted with Bechtel in September, 1983, to study the feasibility of constructing a slurry line to transport coal from southwestern West Virginia and Maryland to a port on the shore of the Chesapeake Bay.[30] The coal sources which were investigated were in West Virginia, Pennsylvania, and Maryland; these sources comprised coal reserves of over 29 billion tons. The line would transport 15 million tons/year, with an expected operating life of 25 years.[31]

A DCF (discounted cash flow) analysis was used to calculate the feasibility of the line. The operation and maintenance expenses were first put into 1984 dollars, then escalated to approximate the cost of the construction and operational period. The result of the cost approximation of transporting coal for a 1984 rate was $12.60/ton, this included the weighing and transportation to a barge terminal. The comparable rail rate presently is $15.42/ton. The monetary savings for the slurry pipeline will come in the future, since the escalation rate for the slurry pipelines has been at the most 6%, wheras the estimated rail escalation rates have been 8-10% (which are not an accurate reflection of past rates). A projected $11-23 billion dollar savings was predicted for a 25 year period.[32] On pp. 23-27 there are maps of the proposed pipeline route as well as the detailed DCF analysis.

Other methods of transporting coal by slurry instead of the 50/50 coal/water mix have been proposed. Some of the other methods under consideration are: stabflow, oil agglomeration, coal/oil dispersion, coal/methanol, and coal/liquid CO_2.[33]

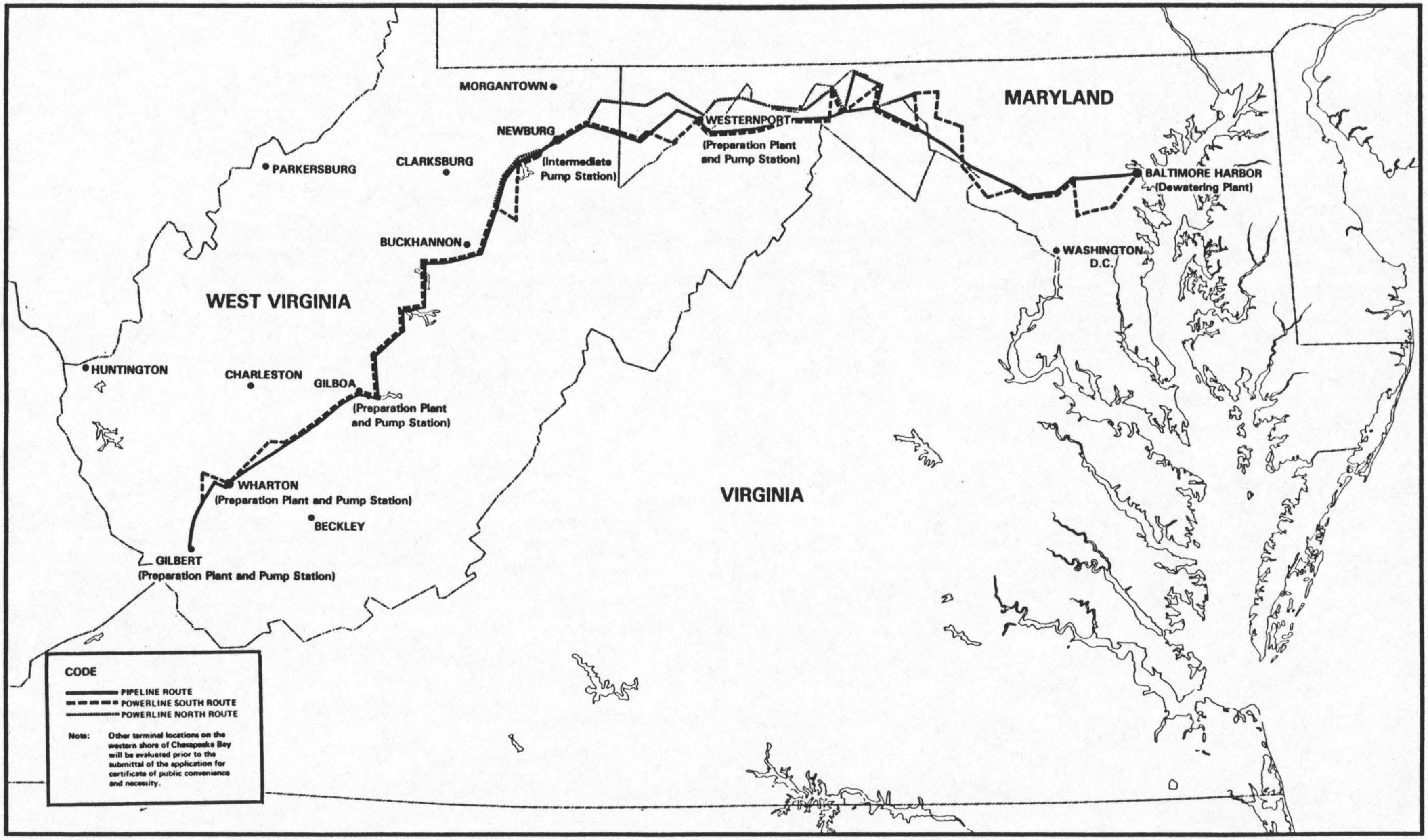
Stabflow

Stabflow, or stabilized flow is coarser coal (50 mm) supported and carried by a mix of fine coal and water. One advantage of this method is that dewatering is much easier. The rate of degradation of the particles, and the stability of the mix during the loading and unloading, and the wear on the pipeline has not been studied in detail.[34]

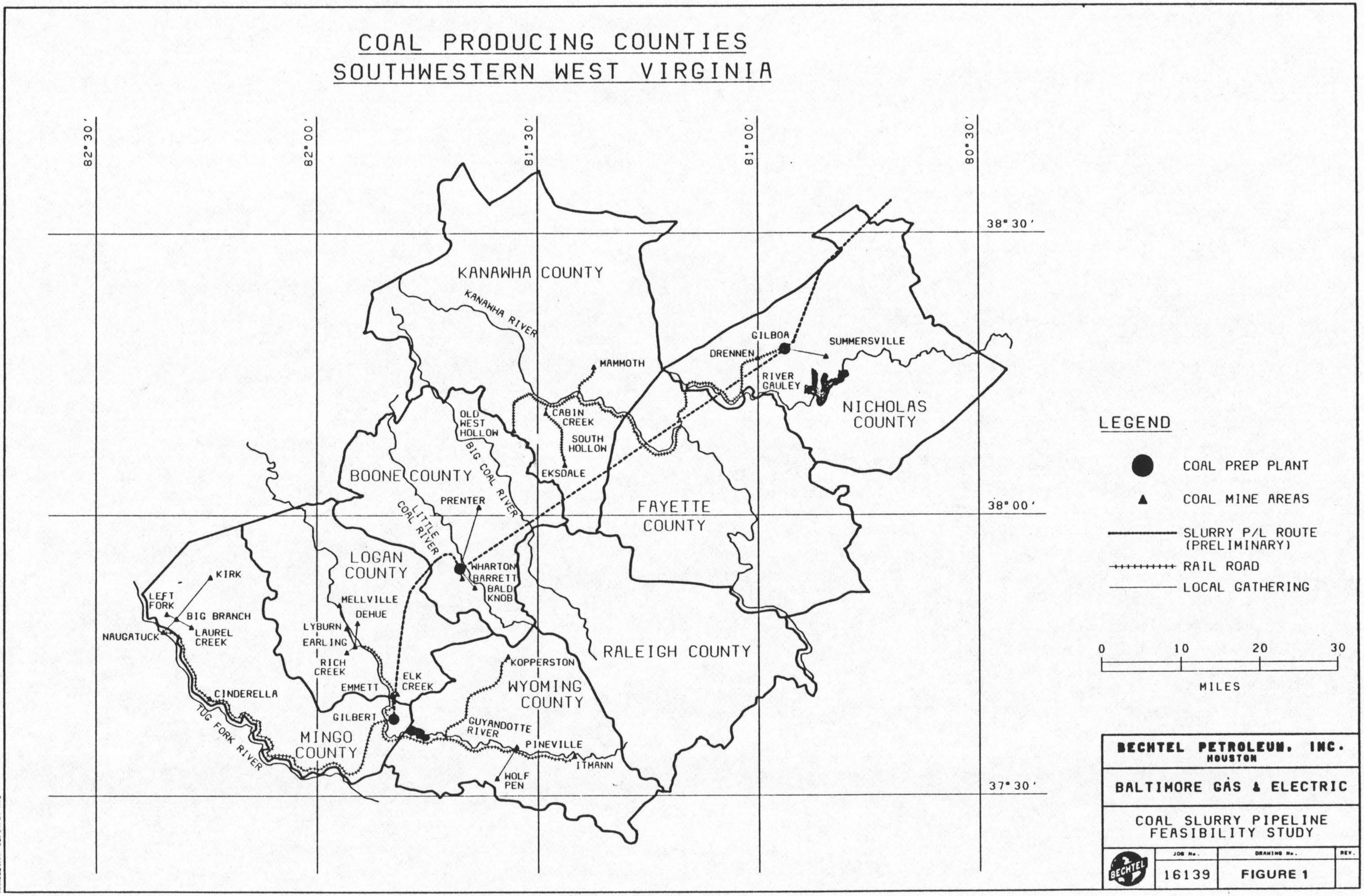
Oil Agglomeration

Oil agglomeration has been a method of coal cleaning for years. The coal is finely ground and oil is added. The oil adheres to the surface of the coal but not the ash, allowing the ash to be separated out. One of the problems with this method has been the high cost of the oil used. A 15-20% mix of oil is necessary. There have been proposals to inject the oil at points that are a distance from the end of the pipeline. The agglomeration would occur in the pipeline and the separation would occur at the end of the pipeline with the use of screens and the oil could later be recycled.[35]

PROPOSED PIPELINE ROUTE

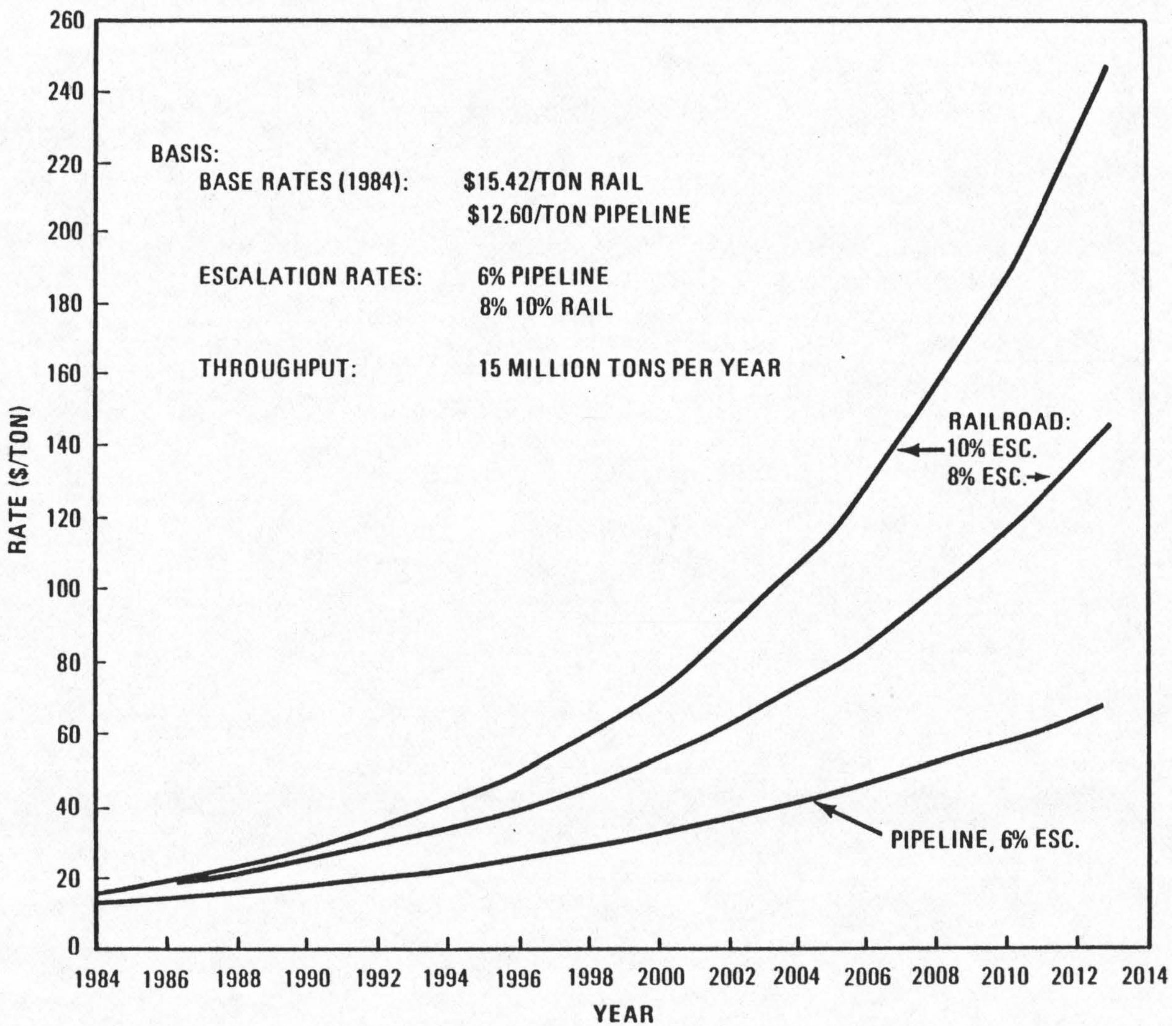


Source: Haim, "Economic Evaluation of a Coal Slurry Pipeline from West Virginia to Maryland", STA Conference 1985, Lake Tahoe, Nevada, March 1985.



Source: Haim, "Economic Evaluation of a Coal Slurry Pipeline from West Virginia to Maryland", STA Conference 1985, Lake Tahoe, Nevada, March 1985.

PROJECTED RAIL AND PIPELINE RATES
SOUTHWESTERN WEST VIRGINIA TO BALTIMORE, MARYLAND



Source: Haim, "Economic Evaluation Of A Coal Slurry Pipeline From West Virginia To Maryland", STA Conference 1985, Lake Tahoe, Nevada, March 1985.

Financial, Accounting and Econmic Bases

Capital Cost (1st quarter 1984)	$615 million
Annual Operating Cost (1st quarter 1984)	$103.5 million
Construction Period	3 years (1986, 1987, 1988)
Operating Period	25 years (1989-2013 inclusive)
Financial Structure	
Debt	75 percent
Equity	25 percent
Debt Service	
Term Loan	15 years (1986-2000 inclusive)
Repayment Schedule	
1991-1994 inclusive	5 percent per year
1995-1997 inclusive	10 percent per year
1998-1999	15 percent per year
2000	20 percent per year
Interest Rate	11 percent
DCF Return on Equity	20 percent
Ad Valorem Taxes	1.5 percent of investment
Combined Federal and State Income Tax Rate	50 percent
Investment Tax Credit	10 percent
Base Time Period	1st quarter 1984
Working Capital	50 percent of first-year operating and maintenance costs
Escalation Rates	
Capital Costs	5 percent
Ad Valorem Taxes	2 percent
Operating and Maintenance Expenses	6 percent after startup, 5 percent before startup
Unit Cost (or tariff)	6 percent

Source: Haim, "Economic Evaluation of a Coal Slurry Pipeline from West Virginia to Maryland", STA Conference 1985, Lake Tahoe, Nevada, March 1985.

Estimate Summary

Item	$ millions Total
Preparation Plants	86
Pipeline	158
Pump Stations	77
Terminal Facilities and Water Treatment	158
Other Costs	136
TOTAL	$615

OPERATING AND MAINTENANCE EXPENSES

Order-of-magnitude annual operating and maintenance expenses are summarized in Table 4.

Summary of Operating and Maintenance Expenses

Item	Annual Cost (1984 Dollars)
Power	$ 30.7 million
Operating Maintenance Labor	12.7 million
Supplies	25.0 million
Indirects (Headquarters)	1.0 million
Coal Gathering	34.1 million
Total	$103.5 million

Source:Haim, "Economic Evaluation of a Coal Slurry Pipeline from West Virginia to Maryland", STA Conference, Lake Tahoe, Nevada, March, 1985.

Coal/Oil Dispersion

Coal/Oil dispersion is the suspension of ultra-fine coal in oil. The purpose of developing it was to substitute the mixture for fuel oil in conventional oil burning units for direct combustion. The coal is ground to 50 micrometers and mixed with a no. 6 fuel oil in a 40% Cw(slurry concentration by weight) mix. One disadvantage to this method is that the mixture must be kept hot to be pumpable. In experimental tests no settling has occurred during storage. A low ash coal would probably burn the easiest in the oil burning equipment presently used.[36]

Coal/Methanol

A coal/methanol mix has also been proposed and studied for direct combustion. The coal is ground to -150 um particles and mixed with methanol to a 50% Cw or methyl alcohols to a 50-75% Cw mix. The major disadvantage with this method is the high cost of producing methanol or methyl fuel. Methanol also requires large quantities of water for preparation.[37]

Coal/Liquid CO_2

Coal/liquid CO_2 slurry pipelines have been proposed and closely studied for use in the western United States where the limited water supply is a problem. The coal/liquid CO_2 mixtures which have been tested show little friction loss, and low pipeline wear rates (even at high velocities and heavy loading of solids). The major restriction on coal/liquid CO_2 slurry lines is temperature. The critical temperature of 32°C and constant pressure must be maintained.[38]

Burning coal in boilers designed for oil can present problems. The first problem is that existing boilers have no facilities to handle coal, the coal must be prepared somewhere else and transported. The second problem is utilizing the coal in order to minimize changing the plant's construction.[39] Modifying an oil burning boiler usually requires a steeper furnace hopper, deslaggers, soot blowers, new burners, larger fans, and ash removal and handling equipment. The ash content from coal forces the boilers to be retro-fitted. The trade-off of retro-fitting the boiler compared with the cost of cleaning coal is about equivalent.[40] Ultra-fine grinding of the coal needs to be tested, they hope this will reduce the slagging, fouling, and tube erosion of the conventional boiler.[41]

Some of the problems facing the CWS(Coal Water Slurry) fuel today are: 1) maintenance of a stable flame over load fluctuations and coal types, 2) complete burning of the slurry fuel, 3) smaller combustion chambers than coal has been previously burned 4), larger quantities of ash (100x greater than oil). The ash can create problems on the surface that transfers the heat of the flame to the water to produce steam. Ash in a molten state can stick to boiler tubes and act as an insulating layer, reducing heat transfer.[42]

The CWS fuel being used in oil fired boilers today is generally composed of 70-75% coal, 24-29% water, and a

1% chemical additive (to stabilize the slurry for storage). It has a consistency similiar to latex paint, and stores and burns like fuel oil.[43] The cost of the additive is high, $7/ton. The cost of reducing the ash level of the coal is also an expensive process.[44] Today the price of no. 6 oil is $29.00/barrel ($4.6 per MBtu), CWS fuel is $3.2 per MBtu, the differnce is $1.40 per MBtu. For the market to grow the pricedifferential needs to increase.[45]

To improve the CWS fuel market the followingare needed: 1) a rise in oil prices, 2) reduced CWS fuel production costs, 3) reduced de-rating costs of boilers, 4) an improvement of coal quality, 5) a creation of domestic and export markets, and 6) a successful demonstration for the consumers of the product.[46]

With the technology existing for slurry pipelines it is suprising how the largest purchaser of coal in the United States, American Electric and Power (AEP), has not considered building a slurry pipeline. AEP delivers coal by the following methods:

<u>AEP Transportation in 1984</u>[48]

15.5 million tons	36% rail
6.4	14.8% rail to barge
6.1	14.0% barge alone
5.4	12.6% truck
9.7	22.6% conveyor systems

AEP also uses large quantities of western coal, suprisingly, their transportation costs for eastern and western coal are approximately the same. Western coal is worth $10/ton, with transportation costs of $20-25/ton ($40/ton total). Eastern coal is worth \$30-35/ton, with transportation costs of \$5/ton (\$40/ton total).[49]

****

CONCLUSION

****

The development of the coal slurry pipeline has been a long, uphill battle. As our country's dependence on foreign resources increases, the development of our own resources continues to grow. Hopefully, in the future, the traditional American ideals, free enterprise, and American ingenuity, will dominate. The technology exists, only the opportunity to expand awaits the slurry pipeline industry. Meanwhile, the rest of the world uses American technology, constructing numerous pipelines. Unfortunately, here in the United States the battle rages on between the railroads and the slurry pipelines.

FOOTNOTES

[1] Snoek, Thompson, Wasp, Chemical Technology, p.1.

[2] Wasp, Pipeline & Gas Journal, p.2.

[3] Ibid, p.5.

[4] Halvorsen, Coal Today & Tomorrow, p.3.

[5] Snoek, Thompson, Wasp, Chemical Technology, p.4.

[6] Halvorsen, Coal Today & Tomorrow, p.4.

[7] Snoek, Thompson, Wasp, Chemical Technology, p.4.

[8] Montfort,(Operating Experience of the Black Mesa Pipeline), p. 16.

[9] Ibid, p. 16.

[10] Ibid, p. 16.

[11] Montfort, (Operating Experience of the Black Mesa Pipeline), p. 16.

[12] Ibid, p.16.

[13] Ibid, p. 16.

[14] Ibid, p.16.

[15] Ibid, p.18.

[16] Ibid, p.18.

[17] Wasp, (Society of Mining Engineers Meeting), p. 7.

[18] Wasp, (7th PLM Coal Conference), p. 14.

[19] Ibid, p.12.

[20] Ibid, p. 10.

[21] Wasp, (Society of Mining Engineers), p.15.

[22] Wasp, (7th PLM Coal Conference), p.5.

[23] Wasp, (Society of Mining Engineers Meeting), p. 21.

[24] Wasp, Pipeline & Gas Journal, p. 4.

[25] Wasp, (7th PLM Coal Conference), p.5.

[26] Henderson, (Microbial Desulfurization of Coal), p.1.

[27] Ibid, p.5.

28 Ibid, p.5.

29 Ibid, p. 8.

30 Haim, (Economic Evaluation),p.2.

31 Ibid, p.31.

32 Ibid, p. 32.

33 Brookes, Dodwell, (BP Coal), p.4.

34 Ibid, p.4.

35 Ibid, p.5.

36 Ibid, p.6.

37 Ibid, p.6.

38 Ibid, p.7.

39 E-lab, p.2.

40 EPRI Journal, p.9.

41 Manfred, (Quo Vadis Coal Slurry?), p. 7.

42 E-lab, p. 2.

43 EPRI Journal, p. 9.

44 Brookes, Dodwell, (BP Coal), p. 11.

45 Manfred, (Quo Vadis Coal Slurry?),p. 4.

46 Ibid, p. 6.

47 Romanoski, Interview.

48 AEP Coal Courier, p. 28.

49 Romanoski, Interview.

BIBLIOGRAPHY

Brookes, Dodwell, "The Economic and Technical Evaluation of Slurry Pipeline Transport Techniques in the International Coal Trade", BP Coal.

"Coal-Water Slurries", E-lab, January-March 1984, pp. 1-3.

Haim, "Economic Evaluation of a Coal Slurry Pipeline from West Virginia to Maryland", STA Conference, Lake Tahoe, Nevada, March 1985.

Halvorsen, "Operating Experience of the Ohio Coal Pipeline", Coal Today and Tomorrow, June, 1964.

Henderson, "Microbial Desulfurization of Coal", STA Conference 1985, Lake Tahoe, Nevada, March 1985.

Manfred, "Quo Vadis Coal Slurry?", STA Conference 1985, Lake Tahoe, Nevada, March 1985.

Montfort, "Operation of the Black Mesa Pipeline System", November 9, 1978.

Montfort, "Operating Experience of the Black Mesa Pipeline", Peabody Coal.

"News Digest", AEP Coal Courier, March 1985, p. 28.

Romanoski, Bernie, interviewed by Helen Truscott, Lancaster, Ohio, 2:00, May 1, 1985.

Snoek, Thompson, Wasp, "The Era of Slurry Pipelines", Chemical Technology, September 1971, pp. 552-562.

Wasp, E., "Coal Slurry Transportation Alternatives and the Prospects for Another Western Coal Slurry Pipeline", Society of Mining Engineers, Salt Lake City, Utah, October 19, 1983.

Wasp, Thompson, "Slurry Pipelines - Energy Movers of the Future", Interpipe Conference 1973, Houston, Texas, November, 1, 1973.

Wasp, E., "$10 Billion for Slurry Pipelines Expected During the Next Decade", Pipeline & Gas Journal, February, 1979.

Wasp, American Petroleum Institute 1979 Pipeline Confernece, Dallas, Texas, April 17, 1979.

Wasp, "Outlook for the Long Distance Slurry Pipeline Industry", 7th Annual PIM Coal Conference on Production and Transportation, Houston, Texas, February 25-27, 1981.

Many of the sources cited were obtained by my attendance at the Slurry Technology Association's Conference at Lake Tahoe, Nevada, March 26 & 27, 1985.

My sincere thanks are extended to Mr. Anderson for his encouragement and patience.