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Economic Assessment of Coal-Burning Locomotives

Topical Report

February 1986

Work Performed Under Contract No.: DE-AC21-85MC22181

For
U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By
Transportation Systems Business Operations
General Electric Company
Erie, Pennsylvania

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Morgantown Energy Technology Center
P.O. Box 880
Morgantown, West Virginia 26507-0880

By
Transportation Systems Business Operations
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February 1986

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- Mr. Larry Carpenter
- Mr. John Eustis

Although these organizations and individuals, along with many individuals from Transportation Systems Business Operations, contributed to this study, it is understood that they have not necessarily endorsed the results and conclusions reported herein.

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Erie, Pennsylvania
February 3, 1986

COAL BURNING LOCOMOTIVE STUDY

EXECUTIVE SUMMARY

A coal burning locomotive study was conducted with Burlington-Northern and Norfolk Southern sponsorship, and later with additional funding from the United States Department of Energy. The objectives of the study were to validate the feasibility of coal as a fuel substitute and a locomotive design which uses it. This included tests and studies to understand or overcome technical barriers and to determine economic benefits plus any required changes to railroad infrastructure. The locomotive options studied were limited to those that use electric drives, capable of being environmentally acceptable, and applicable to all domestic railroads; i.e., not designed for a unique application on one or two railroads. The study excluded railroad electrification, stirling engines, fuel cells, and reciprocating steam engines. Also excluded were liquified coal fuel, wayside coal gasification and coal combustion on conventional grates. Coal was not to be considered as an "emergency" fuel due to a sudden unavailability of diesel fuel.

Many coal locomotive alternative designs were considered and the five most attractive alternatives are presented in this report. The main features and results of these locomotive alternatives are summarized below.

ALTERNATIVE	HP	FUEL	MANUFACTURABILITY
Single Unit Diesel	3800	CWS	Requires engine & fuel development
2-Unit Gas Turbine	5900	CWS	Requires engine & fuel development
3-Unit Gas Turbine w/Steam	8000	CWS	Unattractive
3-Unit Gasifier Gas Turbine	8000	ROM	Unattractive
3-Unit Steam Turbine	8000	ROM	Unattractive

Only the coal slurry fired diesel and the coal slurry fired simple cycle gas turbine look attractive to the manufacturer. Further, the gas turbine is only marginally attractive; i.e., railroads would have to accept a DCRR of less than 15% before it would be attractive to manufacture. The simple cycle gas turbine should continue to be developed as the fall-back alternative to the diesel, should technical development difficulties arise. Should the price of diesel fuel rise, the simple cycle turbine's attractiveness will gain relative to the coal diesel alternative. This is due to the assumption as to the need for some diesel oil injection for the diesel and not for the turbine, which remains to be proven by development. Both these alternatives require engine and fuel development.

The other three alternatives studied are unattractive to a locomotive manufacturer because of the low estimated allowable increase in locomotive selling price which would give the railroads a fair return on their investment.

A coal-fired locomotive using coal water slurry fuel and a diesel engine or a gas turbine, merits further technical development. The diesel engine locomotive could save the nation's railroads $350 million/year in operating expense which represents 15% to 20% return of their investment. Coal slurry fuel development processes also look promising. However, additional funding must be generated to cover the manufacturer's engine development costs, which are estimated to be about $40 million for the diesel engine only. Assuming the manufacturer would share in 1/2 the market of 6000 diesel locomotives, a

Executive Summary (continued)

simple analysis would indicate an additional locomotive cost of about $14,000 per locomotive would be required to cover the development cost.

However, the development funds are upfront money, and they represent a sizable risk to the locomotive manufacturer who is not assured of recouping this investment. Furthermore, given the tough current railroad business climate (caused by deregulated competition and low or no growth of traffic), the railroad industry will be hard pressed to risk scarce capital on long term development projects. Thus, the risks (and rewards) may have to be shared by all, and more federal government support may be needed if a coal-fired diesel-electric locomotive is to become a reality.

COAL BURNING LOCOMOTIVE STUDY

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COAL BURNING LOCOMOTIVE STUDY

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COAL BURNING LOCOMOTIVE STUDY

I. RESULTS

A. Introduction

The coal burning steam locomotive was displaced many years ago by the diesel electric locomotive which has well-known advantages. However, the recent escalation of diesel fuel oil prices and the relatively inexpensive and plentiful coal supply provides an incentive to relook at coal burning electric locomotives.

The success of the diesel electric locomotive is really the result of two major technological changes:

. The diesel engine
. The electric drive transmission

With the diesel electric locomotive we obtained several advantages:

. The smooth, controlled application of power to the rails, via electric motors, reduced the locomotive weight by nearly 30%.

. Track maintenance was reduced by eliminating reciprocating vertical forces.

. More horsepower is applied at low speed improving train acceleration.

Today's diesel engine now produces nearly as much horsepower as the largest steam locomotives but with less maintenance, higher reliability, and increased availability.

The current cost of diesel fuel is high enough to encourage a return to less expensive domestically available coal fuel. However, it would be a step backward to lose the advantages of the diesel electric locomotive.

About 3 years ago, the General Electric Company embarked upon a study to evaluate various alternatives for the design and manufacture a coal fired locomotive considering various prime movers, but retaining the electric drive transmission. The initial study was supported by the Burlington-Northern and Norfolk-Southern railroads, and included the following alternatives:

. Coal fired diesel locomotive
. Direct fired gas turbine locomotive
. Direct fired gas turbine locomotive with steam injection
. Raw coal gasifier gas turbine locomotive
. Raw coal fluid bed steam turbine locomotive

I. RESULTS

A. Introduction (continued)

All of the above alternatives use the electric drive transmission and were selected for final evaluation. Other alternatives were studied and rejected for final evaluation because of feasibility or economic considerations.

The first three alternatives would use a coal water slurry as a fuel, which must be produced by new processing plants. Therefore, use of a slurry would require a significant plant capital investment.

The last two alternatives would use classified run-of-the-mine (ROM) coal with much less capital expenditure. Coal fueling stations would be required but are significantly lower in capital cost than a coal slurry plant.

Further development of the coal fired diesel alternative has recently been sponsored by the U.S. Department of Energy. Documentation of the economic analysis for this alternative has been reported by General Electric on October 4, 1985.

For any coal fired locomotive to be commercially viable, it must pass all three of the following criteria:

. Be technically feasible and environmentally acceptable.
. Meet railroads' financial expectations.
. Offer an attractive return to the locomotive manufacturer.

These three criteria are reviewed in Sections B, C, & D respectfully.

The five coal burning locomotive alternatives are evaluated and compared to a baseline, modern oil fired diesel electric locomotive. A general configuration comparison of the locomotive concepts is shown below:

PART	LOCOMOTIVE TYPE	PRIMARY FUEL USAGE	CONFIG-URATION	HP
0	Oil Fired Diesel (Baseline)	Oil	1 Unit	3800
1	Coal Fired Diesel	Coal Slurry	1 Unit	3800
2	Direct Burning Gas Turbine	Coal Slurry	2 Unit	5900
3	Direct Burning Gas Turbine w/Steam Injection	Coal Slurry	2 Unit + Tender	8000
4	Gasified Coal Burning Gas Turbine w/Steam Injection	Raw Coal	2 Unit + Tender	8000
5	Fluidized Bed Boiler Feeding a Steam Turbine	Raw Coal	3 Unit	8000

I. RESULTS

B. Technical and Environmental Considerations

0. Oil Fired Diesel Electric Locomotive (Baseline)

General

The present design of diesel electric locomotive is the base against which all alternatives are to be judged. The General Electric "Dash 8" 6-axle model with a 16-cylinder engine and 3900 gallon fuel capacity (1000 mile range) is the specific model used for comparison (Fig. I.B.1). Selected performance factors for the locomotive are given in this section for comparison with other design options.

Fuel Requirements - Diesel Fuel No. 2

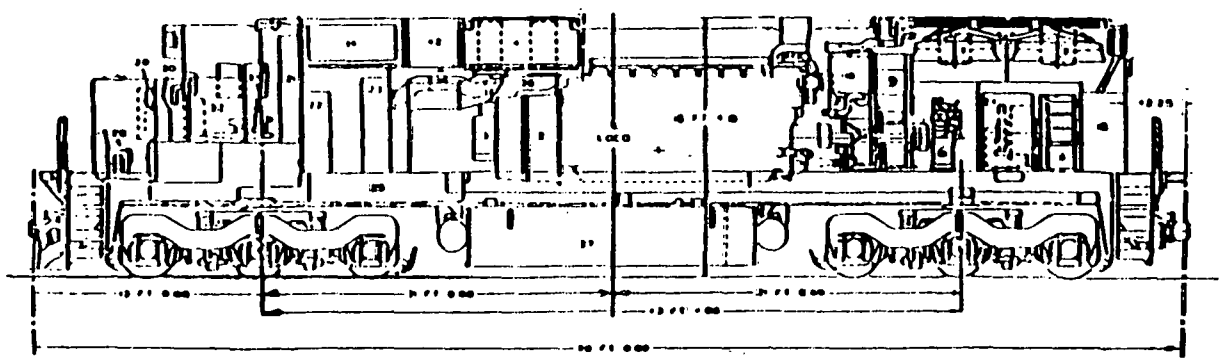
In establishing the on-board storage requirements for each locomotive design, several factors must be considered:

- The need to keep each individual axle load not greater than 70,000#.
- The desire to match the horsepower hour capability of the present locomotive, expressed in terms of approximate range.
- The net weight change when carrying minimum fuel does not leave the locomotive too light to achieve the required tractive effort.

A locomotive of this type will burn between 280,000 and 440,000 gallons of diesel fuel annually, depending on the type of service with a range of approximately 1000 miles.

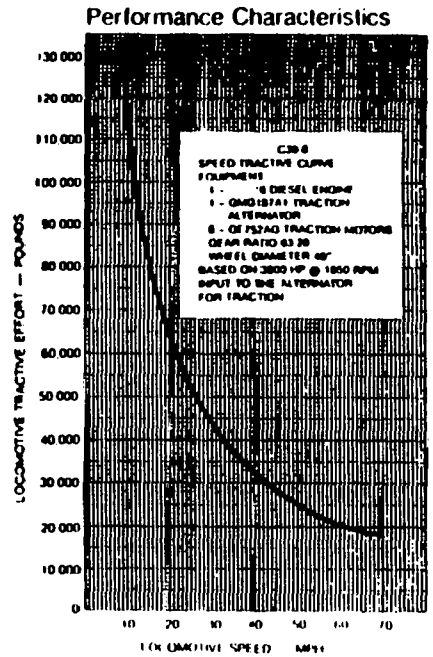
Prime Mover Thermal Efficiency

An inherent characteristic of the diesel engine is its relatively high thermal efficiency which prevails from about 10% to 100% rated power. This characteristic makes it very suitable for locomotive type service which demands variable power levels, for various amounts of time (duty cycle). This characteristic is depicted below (Fig. I.B.2).



LEGEND

1. Engine GE Model 7FDF16
2. Alternator
3. Auxiliary Alternator
4. No. 1 End Blower Package
5. No. 2 End Blower Package
6. Air Compressor
7. Radiator Fan
9. Engine Air Filter Compartment
10. Engine Water Tank
13. Radiator
14. Dynamic Braking Box
15. Sand Box
19. Battery Box
21. Control Compartment
26. Control Compartment
27. Fuel Tank
32. Control Console



OIL FIRED DIESEL ELECTRIC

TRACTION MAXIMUM HP		3800
WEIGHT PER AXLE	START FULL CONSUMABLES 70,000#	FINISH EMPTY 66,200#
STARTING T.E. (FINISH AND 35% ADHESION)		139,000
CONTINUOUS T.E.		107,000#
FUEL CAPACITY		3,900 GAL.
RANGE		1,000 MILES
LENGTH		70.7 FEET
DYNAMIC BRAKING HP		5,700

I. RESULTS

B. Technical and Environmental Considerations

0. Oil Fired Diesel Electric Locomotive (Base Line) (continued)

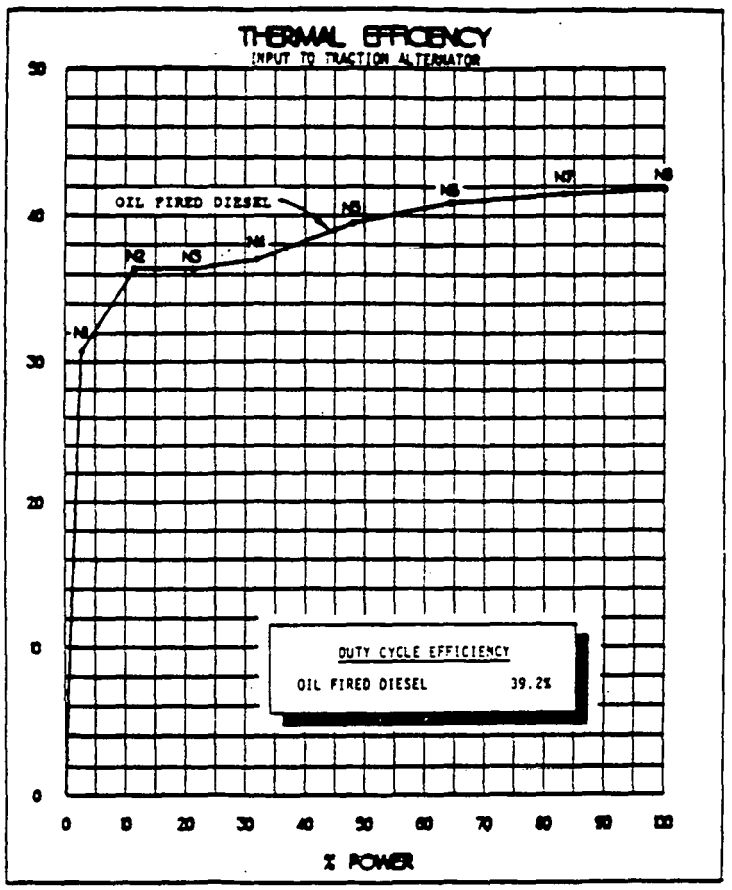


Fig. I.B.2

Emissions

The total exhaust emissions from the present oil fired diesel locomotives is a function of the fuel quality, and are typically:

	NOx	CO	HC	SOx	Particulate
Grams/HP-Hr	10.7	1.8	0.6	1.5*	0.3

* Sulphur quantity in fuel = 0.5%

I. RESULTS

B. Technical and Environmental Considerations

O. Oil Fired Diesel Electric Locomotive (Baseline) (continued)

Other Standards of Comparison

Reliability - A frequently used measure of reliability by railroads is that of road delays caused by equipment failure. Present day locomotives achieve high reliability of about 240 Mean Days Between Road Failures resulting from about 30 - 40% of 3.1 component failures per year. Reliability is considered to be an important factor in any final evaluation.

Maintenance--$69,000 to $79,000 per year - Maintenance costs are a direct input to the economic analysis. Such costs figure as prominently in value determination as does fuel.

The baseline modern oil burning diesel locomotive of today is highly utilized; kept as busy as possible pulling trains. While pulling these trains, as indicated above, this base line locomotive will consume between 280,000 and 440,000 gallons of fuel oil per year. Our maintenance cost study has determined that this highly utilized locomotive requires between $69,000 and $79,000 respectively in annual maintenance.

Availability--93% - Availability is commonly defined as the percent of operating time that the locomotive is available for use and is about 93%. This includes the time that the locomotive is withdrawn from service and turned over for maintenance, repair, or overhaul. The 7% loss does not include time spent fueling and servicing the locomotive, wreck repair, or out of service due to business conditions.

I. RESULTS

B. Technical and Environmental Considerations

1. Coal Fired Diesel Electric Locomotive

General Description

Figure I.B.3 shows a cross-section of a coal fired diesel locomotive (CFDL). It is similar to an oil fired diesel locomotive (OFDL), the difference is in the fuel storage and handling equipment. This results in a locomotive with 6 axles at 70,000#/axle fully loaded, and about 6 feet longer than today's 6-axle OFDL. This added size is a direct result of the need to carry more volume of fuel and still maintain about 1000 mile range between refueling. At the end of the trip, the locomotive weight is estimated to be 59,000#/axle (fuel tanks empty).

An auxiliary heat exchanger and circulating pump is provided to warm the fuel to keep it from freezing.

Propulsion, electric braking, air brakes and radiator systems are identical to the OFDL base line Dash 8 production model.

Coal Fired Diesel Engine

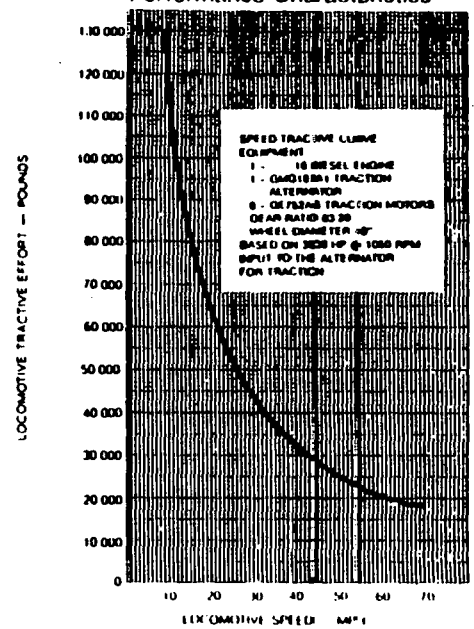
Rudolf Diesel, the inventor of the compression ignition engine, unsuccessfully experimented with coal. Between 1911 and 1940, one of Diesel's co-workers, Rudolf Pawlikowski, made significant advances and demonstrated the operation of engines on fuels ranging from flour to hard coal. Also, during this period, several people built and tested in Germany and Austria, some 19 experimental engines operating on coal dust; from 1 to 154 litres/cylinder, and from 160 to 1600 RPM. The engines used coal dust, not slurry fuels, with ash contents generally greater than 3%. It can be concluded from this early work that theoretically, coal fueled engines can be made to operate with speeds and efficiencies comparable to oil fired diesel engines, but that more work is needed in the areas of fuel development, fuel injection systems, and engine wear and lubrication.

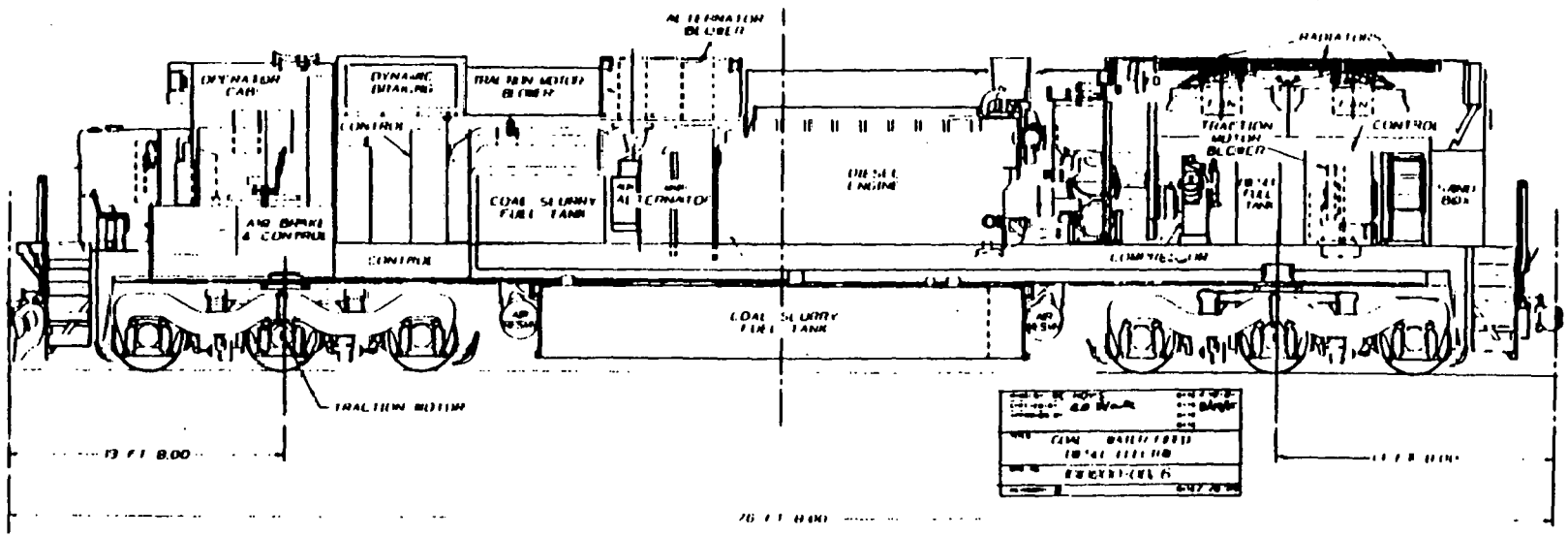
Within the past five years or so, there has been a renewed interest in the development of coal fuels, and coal fueled internal combustion engines. Physical and chemical coal cleaning processes are both being developed which will comminute coal to 3 to 5 micron mean size, and clean the coal to an ash content below .2%. Generally speaking, the low ash content should significantly reduce engine wear and lubrication problems. The process developments are currently at the pilot scale stage and are now ready for full scale trials.

COAL-WATER FIRED DIESEL

TRACTION MAXIMUM HP		3800	
WEIGHT PER AXLE	START FULL CONSUMABLES 70,000#		FINISH EMPTY 59,000#
STARTING T.E. (FINISH & 35% ADHESION)		124,100#	
CONTINUOUS T.E.		107,000#	
FUEL CAPACITY		6,500 GAL.	
RANGE		1,000 MILES	
LENGTH		76.8 FEET	
DYNAMIC BRAKING HP		5,700	

Performance Characteristics





I. RESULTS

B. Technical and Environmental Considerations

1. Coal Fired Diesel Electric Locomotive

Coal Fired Diesel Engine (continued)

Because of the difficulties in handling and transporting dry powdered fuels, within and externally to the engine, it is felt that coal in liquid slurry form offers significant advantages. In a diesel engine, it would appear that coal-oil mixtures would minimize the fuel characteristic differences, with oil to initiate and ensure complete combustion of the less certain coal particles. However, coal content appears to be limited to about 50% by weight in the mixture. Higher concentrations of coal in the oil increases the viscosity of the mixture making high speed injection nearly impossible.

Economically, however, there simply is not enough of a fuel cost savings with only 50% coal loading to warrant the development of a diesel locomotive using coal-oil mixture for fuel. It appears that recently this economic conclusion is being reached even in non-engine coal-oil slurry applications. The far more economically attractive concept of using coal water slurry (CWS)[1] as fuel has the attention of at least two companies, namely, GE and Sulzer Bros. of Switzerland.

Engine grade fuel is being developed by several companies including AMAX Extractive Research and Development, Inc., and Otisca Company, both of which have supplied fuel for diesel engine research. The AMAX process can be classified as primarily a chemical cleaning process, whereas the Otisca process is a mechanical cleaning process. Neither company is presently in commercial plant production. Conceptual plant designs are being developed and a conceptual plant based on the Otisca process was developed and used in this economic study.

[1]Assuming: Diesel fuel @ \$.85/gal & 18,400 BTU/lb = \$6.18/10^6 BTU
Micronized Clean Coal @ 14,000 BTU/lb = \$3.00/10^6 BTU
then, Savings using Coal/Oil Slurry @ \$4.81/10^6 BTU = 22%
Savings using Coal/Water Slurry @ \$3.00/10^6 BTU = 51%

I. RESULTS

B. Technical and Environmental Considerations

1. Coal Fired Diesel Electric Locomotive

Coal Fired Diesel Engine (continued)

General Electric (as part of this study)[1] and Sulzer Company have developed experimental fuel systems to inject fuel slurries. Both have run single cylinder engines with coal-water slurries under various load and temperature conditions. General Electric, at its Research and Development Laboratory, has been and continues to perform theoretical combustion experiments in a combustion "bomb" which provides direction to engine developments.[2]

Sulzer's testing of a 120 RPM slow speed, two[3] stroke, loop scavenged diesel has shown:

- Excellent ignition and combustion results using 47 to 50% coal loaded water slurry and with 1 to 5% standard diesel fuel (DF2) pilot injection.
- Thermal efficiencies are comparable to diesel fuel oil engines.
- Preliminary wear results indicate 50 to 75 times increase in ring wear and 10 to 20 times liner wear over oil engines using the same materials.

General Electric testing of a 1000 RPM medium speed, four-stroke locomotive diesel engine[1] has shown that:

- Excellent ignition and combustion are obtained using about 47% coal loaded water slurry and various DF2 pilot injection schemes of less than 5% total heat content.
- Thermal efficiency of a coal fired diesel engine is equal to the oil fired diesel engine except for the loss of the latent heat of vaporization from the water in the coal slurry fuel. At this point in the development, it is felt that the engine will idle on diesel fuel and pilot injection (less than 5%) will be required even at full power conditions to assist timely combustion initiation. The thermal efficiency of the coal-fired diesel engine is depicted below (Fig. I.B.4).

[1] Hsu, Bertrand D., Ignition Studies of CWS in GE7FDL Engine, GE Report 86DTSD001, 1986.

[2] Leonard, G. and Fiske, G., Coal Slurry Combustion Characteristics in a Medium-Speed Diesel Engine Environment, GE Report 84CRD304, December, 1984.

[3] Steibe, H. A., Sulzer Single-Cylinder Test Results with Various Coal-Water Slurries, presented at Coal Fueled Diesel for Cogeneration Seminar, 7/25/85, Rosemont, IL.

I. RESULTS

B. Technical and Environmental Considerations

1. Coal Fired Diesel Electric Locomotive

Coal Fired Diesel Engine (continued)

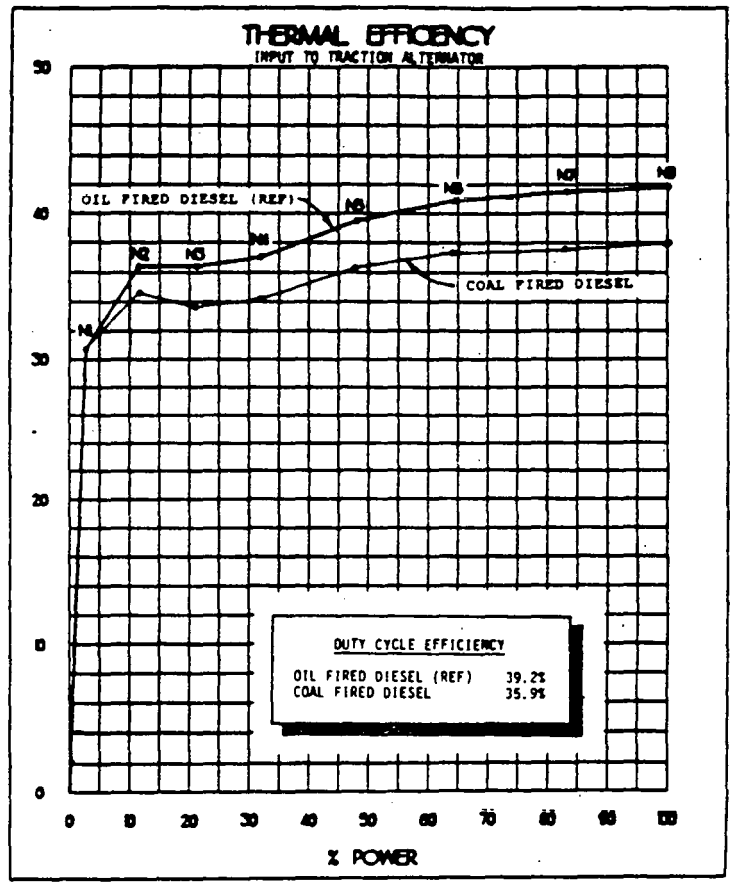


Fig. I.B.4

Very little new wear testing has been done to date and it must be understood that a significant development will be required to obtain an acceptable coal fired diesel engine (CFDE). However, modern materials appear to offer an approach which theoretically can provide engine attrition rate reduction of two orders of magnitude from presently used materials but with accompanying higher material cost, to produce a CFDE engine with a life expectancy of today's OFD engine. In making this economic analysis, these additional material costs have been added.

I. RESULTS

B. Technical and Environmental Considerations

1. Coal Fired Diesel Electric Locomotive

Exhaust Emissions

The coal water slurry fuel which is proposed for the diesel engine will be accompanied by a small amount of diesel fuel pilot, thus, the fuel will contain at least some level of all the emissions of diesel fuel as well as the emissions of the coal itself. It is apparent that the emissions from the engine will be a function of the cleanliness of the micronized and processed coal fuel. The cleaning of the exhaust is probably best accomplished as a fuel rather than using after combustion techniques. The exhaust emissions will also be influenced by the myriad of engine parameters which are now only partially understood. Since coal slurry exhaust emission testing of diesel engines is nearly non-existent, only estimates can be made of the quantity of emissions. These emissions will be compared with present day locomotive diesel exhaust.

NOx formation is combustion process related[1]. GE diesel engine testing revealed a 50% reduction in NOx using diesel fuel emulsified with 30% water.[2] Additional testing with 20% coal in diesel fuel (no water) was done.[3] The additional fuel bound nitrogen in the coal (many orders of magnitude greater) produced no measurable increase in NOx, which would indicate that the NOx is primarily thermal NOx. Since the water lowers the peak local temperatures and NOx is reduced, it is estimated that the NOx formation in a coal fired diesel engine will be about half that of the oil fired diesel. Preliminary test results by Sulzer Company[4] also substantiate this estimate.

Carbon monoxide (CO) is formed in the intermediate combustion stages, due to lack of oxidants and/or low temperature, and is also combustion process dependent. All other things being equal,

[1] MIT Report, 1984: Farmayan et al., NOx - Carbon Emission Control in Coal-Water Slurry Combustion.

[2] B.D. Hsu: Combustion of Water-in-Diesel Emulsion in an Experimental Medium Speed Diesel Engine. SAE Paper 860300, 1986.

[3] B.D. Hsu: Combustion of Coal-Diesel Slurry in Medium Speed GE-7FDL Diesel Engine. G.E. Company Technical Report TIS-84TSD029.

[4] Steiger, H.A.: Sulzer Single-Cylinder Test Results with Various Coal-Water Slurries. Presented at Coal-Fueled Diesel for Cogeneration Seminar, 7/25/85, Rosemont, IL.

I. RESULTS

B. Technical and Environmental Considerations

1. Coal Fired Diesel Electric Locomotive

Exhaust Emissions (continued)

the lower combustion temperature, due to the water in the slurry, should result in higher formation of CO. Using two different coal water slurry fuels, Sulzer Company's limited testing obtained both an increase (150%) and a decrease (50%) in CO formation, respectively. A 100% increase in CO over oil fired diesels is courageously estimated.

Hydrocarbon emissions are due primarily to incomplete combustion by quenching, impingement, late or bad atomization. It is assumed that the quantity of HC produced is at least proportional to the amount of diesel pilot fuel. Coal-water-slurry combustion, however, seems to follow the sequence water vaporization, ignition, burning of volatiles, burning of char. Thus, if the char has had time to burn, one should expect nearly complete combustion of the volatiles. It is estimated that the coal portion of the HC emission contribution is negligible, and with 16% diesel fuel (over the duty cycle) HC emissions will be about 16% of the oil diesel engine.

It is assumed that all of the sulfur present in the fuel (slurry plus pilot) will be converted to SOx. Thus, SOx is highly dependent upon the coal cleaning process.

Particulates are produced from the ash in the fuel as well as agglomerated carbon particles. Boiler studies of burning CWS indicated that the ash contribution was 20% to 60% of the particulate emissions. Using coal with a maximum of 0.2% ash content, approximately 0.4 grams of ash will pass through the engine per brake HP-hour. In the absence of better data, the particulates are estimated to be .7 to 2 grams/HP-hour.

In summary,

	Emissions Estimate (Grams/HP-HR)				
	NOx	CO	HC	SOx	Particulates
Oil Fired Diesel	10.7	1.8	0.6	1.5*	0.3
Coal Fired Diesel	5 to 6	3.5 to 4	.06 to 0.1	3.0**	0.7 to 2.0

* 1/2% sulfur fuel oil
** .7% sulfur in cleaned, process coal

I. RESULTS

B. Technical and Environmental Considerations

1. Coal Fired Diesel Electric Locomotive (continued)

Fuel Systems

Diesel fuel only will provide idle and first power level input. Further experimentation is required to determine the quantity of pilot diesel fuel at various other power levels. Over the duty cycle, it is assumed that 16% of the total fuel used will be diesel fuel.

Coal water slurry is drawn from the main tank, then introduced directly into the engine slurry injection system.

During periods of below freezing temperatures, the diesel engine is allowed to run continuously. Jacket water at approximately 165°F passes through a heat exchanger, which provides heat to coils in the main insulated fuel tank.

The fuel tanks, pumps and piping must be material such as stainless steel or a lined material, to prevent corrosion. Because the fuel is a slurry, filtering will be minimal.

Cooling System

A dual cooling system is anticipated, separating the intercooler circuits from the water jacket circuit. This will allow independent inlet manifold temperature control which may be required using a coal slurry fuel. Water pumps, intercoolers, radiators and fans will be of conventional locomotive design.

Propulsion Equipment and Running Gear

The propulsion equipment, control and running gear will be the same general design as that used in today's locomotives.

Technical and Environmental Summary

A locomotive size, medium speed, coal-fired diesel engine is feasible, and will provide acceptable performance, reliability, and maintenance. The initial cost and maintenance for a coal fired diesel will be higher than an oil fired which has been included in this economic analysis. Further, it is believed that a satisfactory CWS fuel and fuel process can be developed in a timely fashion to meet the engine needs.

It is further believed that the engine and its fuel could be developed within a time frame of 5 to 8 years, with sufficient economic incentive.

I. RESULTS

B. Technical and Environmental Considerations

2. Direct Fired Gas Turbine Locomotive (DFGTL)

General Description

About 1960, the Union Pacific Railroad purchased a small quantity of gas turbine powered locomotives from the General Electric Company which utilized Bunker C Oil. These locomotives were operated in revenue service for a few years and subsequently retired by the Union Pacific.

One of the major problems in the use of these early gas turbine (vs diesel) prime movers is the inherent high SFC at part load operation, which was one of the main reasons why UP retired these locomotives. More modern two-spool turbines have greatly reduced this part load high SFC problem.

Again, with the recent escalation of diesel fuel prices, attention is directed toward development of various coal burning locomotive options, including the DFGTL which will use coal water slurry (CWS).

A gas turbine of approximately 5900 HP can be accommodated in a unit shorter than the present diesel equivalent. Fuel storage of only 2600 gallons is on the locomotive, so a tender of 14,000 gallons is utilized. This minimizes the weight change and resultant adhesion loss. The tender is ballasted to a minimum weight of 32,900# per axle to minimize train handling problems that result from a light car at the beginning of a train. The locomotive is capable of operation without a tender at a reduced range (Fig. I.B.6 - a fold-out).

The turbine output shaft is coupled to a planetary gearbox which is coupled to an alternator at a suitable RPM. The alternator will incorporate an integral auxiliary alternator similar to that employed in the base line oil fired diesel.

Weight is not a problem with this engine since a gas turbine is inherently considerably lighter than a diesel engine.

Horsepower per axle is 737 with eight powered axles as shown. A 6-axle version is also possible for high speed service at 980 HP per axle and reduced continuous and starting tractive effort.

I. RESULTS

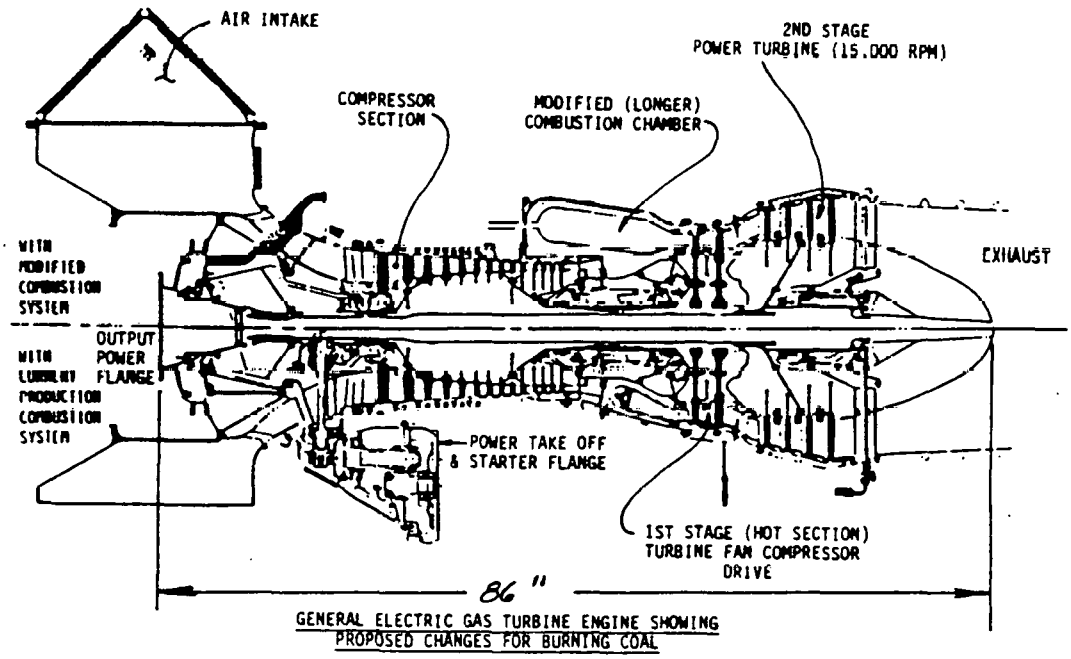
B. Technical and Environmental Considerations

2. Direct Fired Gas Turbine Locomotive

Gas Turbine Engine

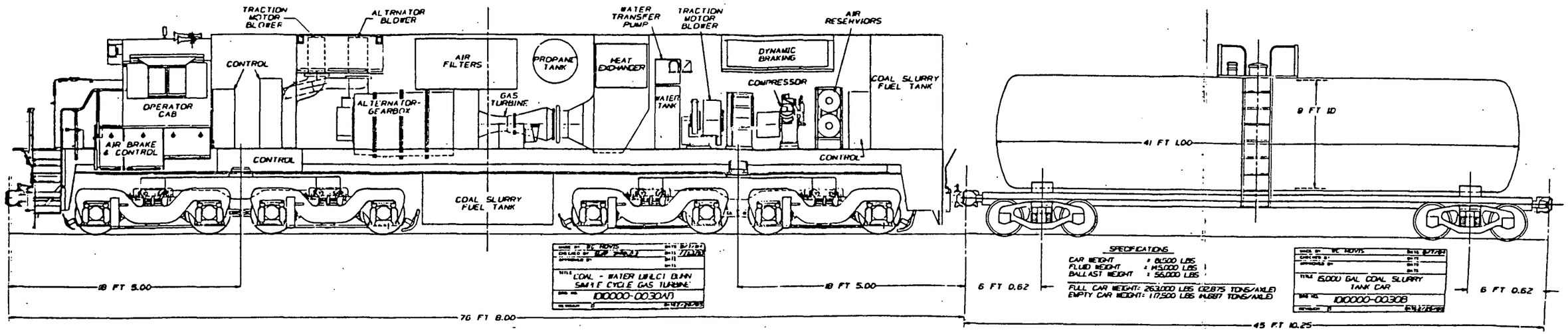
The GE27 General Electric Gas Turbine engine was selected as the most suitable engine to be used. It is still in the prototype stage, but incorporates the most modern techniques for performance, fuel efficiency, maintenance, and cost. It is similar and closest in rating and size to the fully developed GE LM500 engine. Preliminary testing using coal slurry fuel would be accomplished using the LM500 turbine hardware. Combustor designs must be optimized for CWS operation. They will require more length for adequate burning of coal particles which will require additional space.

An engine design is shown below (Fig. I.B.5) based on the LM500, but showing a sketch based on proposed combustor modifications for burning coal. The final engine will be based on the GE-27 and will be significantly shorter in length and weigh less than 1000 pounds.



GENERAL ELECTRIC GAS TURBINE ENGINE SHOWING
PROPOSED CHANGES FOR BURNING COAL

Fig. I.B.5



DIRECT BURN SIMPLE CYCLE GAS TURBINE

TRACTION MAXIMUM HP 5900

WEIGHT PER AXLE

	START FULL FUEL	FINISH EMPTY
POWER	70,000#	65,760#
FUEL TENDER	65,750#	29,375#

STARTING T.E. (FINISH & 35% ADH)	184,000#
CONTINUOUS T.E.	141,000#
RANGE	1,100 MILES
COAL SLURRY CAPACITY	
POWER	5,000 GAL.
FUEL TENDER	15,000 GAL.
TOTAL	20,000 GAL.
LENGTHS	
POWER	76.6 FEET
FUEL TENDER	45.9 FEET
TOTAL	122.6 FEET
DYNAMIC BRAKING HP	7,600

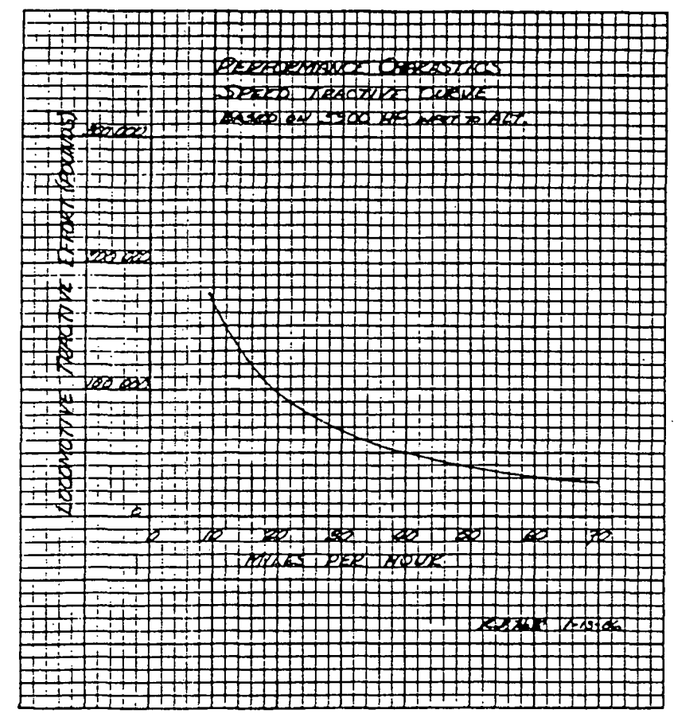


FIGURE I.B.6

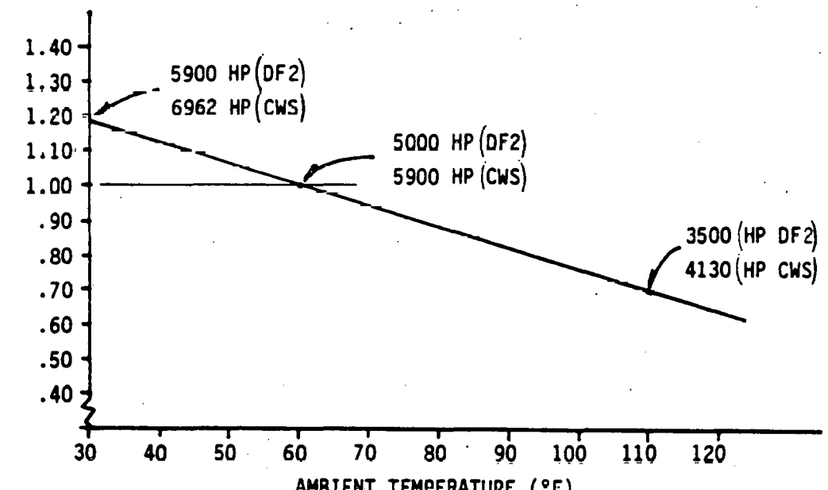
I. RESULTS

B. Technical and Environmental Considerations

2. Direct Fired Gas Turbine Locomotive

Gas Turbine Engine (continued)

The gas turbine engine rating is noticeably affected by ambient temperature as depicted below (Fig. I.B.7).



APPROXIMATE GE27 RATINGS USING COAL WATER SLURRY

Fig. I.B.7

Notice the HP using CWS is considerably increased over DF2. This is due to the increase in mass flow through the engine from the water content in the slurry. Engine thermal efficiency is also somewhat enhanced using CWS. The thermal efficiency is depicted below compared to the oil fired diesel engine (Fig. I.B.8).

Within the past 5 years or so, there has been a renewed interest in the development of coal fuels, and coal fueled internal combustion engines. Physical and chemical coal cleaning processes are both being developed which will comminute coal to 3 to 5 micron mean size, and clean the coal to an ash content below 0.2%. Generally speaking, a lower ash content should significantly reduce engine wear and lubrication problems. The process developments are currently at the pilot scale stage and are now ready for full scale trials.

I. RESULTS

B. Technical and Environmental Considerations

2 Direct Fired Gas Turbine Locomotive

Gas Turbine Engine (continued)

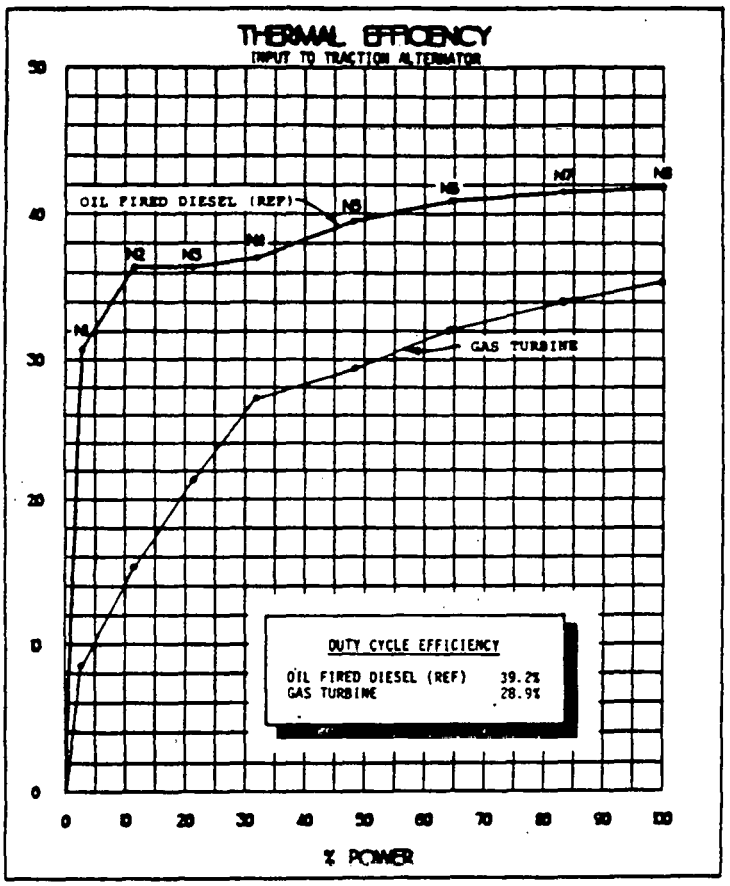


Fig. I.B.8

Because of the difficulties in handling and transporting dry powdered fuels, within and externally to the engine, it is felt that coal in liquid slurry form offers significant advantages. In a turbine engine, it would appear that coal-oil mixtures would minimize the fuel characteristic differences, with oil to initiate and ensure complete combustion of the less certain coal particles. However, coal content appears to be limited to about 50% by weight, because the high viscosity makes pumping and injection difficult.

I. RESULTS

B. Technical and Environmental Considerations

2. Direct Fired Gas Turbine Locomotive

Gas Turbine Engine (continued)

Economically, however, there simply is not enough of a fuel cost savings with only 50% coal loading to warrant the development of a turbine locomotive using coal-oil mixture for fuel. It appears that recently this economic conclusion is being reached even in non-engine coal-oil slurry applications. The far more economically attractive concept of using coal mixed with water is receiving maximum attention. Note 1 below compares the economics of coal slurries using oil (COS) and water (CWS).

Engine grade fuel is being developed by several companies including AMAX Extractive Research & Development, Inc., and Otisca Co., both of which have supplied fuel for diesel engine research. The AMAX process can be classified as primarily a chemical cleaning process, whereas the Otisca process is a mechanical cleaning process. Neither company is presently in commercial plant production. Conceptual plant designs are being developed and a conceptual plant based on the Otisca process was developed and used in this economic study.

Potential problems exist with protecting hot section components from abrasive/corrosive products of combustion.

In order to address the problem of abrasion/corrosion, a deposition testing program was developed and conducted by General Electric at their Corporate Research & Development Center. This testing program was sponsored by GE's Transportation Systems Business Operations in Erie and partly by the U.S. DOE. The deposition test phase was conducted on a GE LM-500 turbine nozzle sector and was completed in Nov. 1985.[1]

Note 1: Assuming: Diesel fuel @ \$.85/gal and 18,400 BTU/lb = \$6.18/10^6 BTU
Micronized Clean Coal and 14,000 BTU/lb = \$3.00/10^6 BTU

Then, Savings using Coal/Oil Slurry @\$4.81/10^6 BTU = 22%
Savings using Coal/Water Slurry @ \$3.00/10^6 BTU = 51%

[1] Internal GE Memo Report by S.G. Kimura, CR&D on Summary of Deposition Testing, 11/13/85.

I. RESULTS

B. Technical and Environmental Considerations

2. Direct Fired Gas Turbine Locomotive

Gas Turbine Engine (continued)

Results were generally encouraging, the deposition rate was far lower than originally anticipated. In 23 hours of testing, the nozzle area was reduced by 3% with approximately 0.8% ash fuel. With 0.2% ash, this area reduction should be 0.75%. Although this is less than expected, this causes a performance deterioration which must be evaluated in the future. A concept for further study, sponsored by DOE, will be to clean the deposits by on-line nut shelling, and off-line by water wash.

Normally, when using liquid fuels, alkali sulphates are formed which are corrosive, and also tend to act as a glue for deposition. With coal water slurry, however, the alkali metals in the deposits are in the form of aluminosilicates which are far less corrosive.

Erosion and abrasion were expected to be reduced because of the small particle size of the ash due to the coal micronizing process. However, there had been some concern about agglomeration of the particles just before, during, or after combustion. It appears that agglomeration does take place in the form of cenospheres (hollow spheres). After the carbon has burned out, the fragile "egg shell" breaks up again into small particles which tend to follow the gas stream lines rather than impinge the blades and buckets causing erosion/abrasion.

One finding in this testing program which might be considered negative, was that in order to realize high combustion efficiency, supplemental JP-4 fuel was required (15% - 25%). If significant diesel fuel is required on a locomotive, then the resultant fuel savings with coal will be reduced. However, at this point in time, it is unfair to penalize the turbine, since the combustor design was not fully optimized to burn CWS. Accordingly, in this study, no diesel fuel was assumed for the DFGTL.

Exhaust Emissions

Limited exhaust emissions testing was conducted by General Electric, CRD, during the deposition testing. The results are shown below, and compared with today's production oil fired diesel locomotive.

I. RESULTS

B. Technical and Environmental Considerations

2. Direct Fired Gas Turbine Locomotive

Exhaust Emissions (continued)

The emissions estimate of SOx is straightforward. It is assumed that all of the sulfur present in the fuel which enters the engine will be converted to SOx and discharged in the exhaust. Thus, if the processed coal in the slurry has 1% sulfur and the duty cycle thermal efficiency is 28.9%, then 5.57 grams of SOx will be generated per HP-hour.

The formation of NOx was measured in the exhaust during the deposition testing using coal water slurry with 25% diesel fuel at 3.4 grams/HP-hour. With 100% diesel fuel NOx emissions produced is 2.0 grams/HP-hour. Although the combustors are not the same, nonetheless, we estimate 3.8 grams/HP-hour with straight coal water slurry using a linear relationship. It is also believed that development can lead to substantial improvements to this estimate.

The formation of HC in the exhaust was measured during the deposition testing using coal water slurry with 25% diesel fuel at 0.25 grams/HP-hr. Since HC is nearly immeasurable using diesel fuel only, one might estimate that HC was a result of coal combustion and that it could rise 33% if the diesel fuel were replaced by more coal slurry with other phenomenon of combustion being equal. Therefore, we estimate 0.33 grams/HP-hr would be expected. Assuming the same combustion temperature, the propensity to form CO would be nearly the same and the estimate for CO will be 0.8 grams/HP-hour.

The particulates measured in the deposition tests were 1.7 grams per HP-hour which was just about equal to the ash content of the fuel (.8%). Since normally the particulate output of the engine using diesel fuel is nearly zero, it has been concluded that the ash is the main contributor to the exhaust particulate emissions. Prorating to account for straight coal slurry with 0.2% ash, the particulate emissions estimate is 0.6 grams/HP-hour.

[1] LM500 Gas Turbine Installation Design Manual MID-1DM-500-1, May 1980

I. RESULTS

B. Technical and Environmental Considerations

2. Direct Fired Gas Turbine Locomotive

Exhaust Emissions (continued)

Summarizing,

	Exhaust Emissions Estimate (Grams/HP-HR)				
	NOx	CO	HC	SOx*	Parti-culates
Oil Fired Diesel	10.7	1.8	0.6	1.5	0.3
D.F. Gas Turbine	3.8	0.8	0.33	3.9	0.6

Fuel Systems

The locomotive fuel tank is normally kept full and fuel is drawn from the tender. To keep the fuel from freezing, an exhaust gas heat exchanger circulates hot water through heating coils on both the locomotive and tender. When the turbine is shut down during idle, a small auxiliary diesel engine of about 35 HP capacity (not shown) will furnish heat via a jacket water and exhaust heat exchanger to the circulating fuel system. The electrical output will provide battery charging and run the circulating pumps. Spot electrical heaters will also be provided if jacket heat is insufficient. Both fuel tanks are planned to have 4 inches of insulation.

Since the fuel is a slurry using water, stainless steel or lined tanks and piping must be provided to prevent corrosion.

A diesel fuel or propane supply will also be provided for turbine starting. The cranking power will be provided by the battery.

Propulsion and Auxiliaries

Dynamic braking, air brakes, ventilation, control and propulsion equipment will be the same type as on the base line oil fired diesel locomotive.

* .5% sulfur fuel oil, .7% in cleaned, processed coal

I. RESULTS

B. Technical and Environmental Considerations

2. Direct Fired Gas Turbine Locomotive

Technical & Environmental Considerations Summary

The limited testing to date shows an encouraging outlook for a direct fired coal water slurry gas turbine engine which could be used on a locomotive. The need to clean the engine of deposits requires development, and, if unsuccessful, could be a serious problem. Erosion and abrasion appear to be nearly absent due to the small ash particle size. Engine maintenance will be primarily inspection, with ultimate removal, return and overhaul (or unit exchange) which can be easily done due to the small size and weight of the turbine. Economically, the GT must be able to operate without using diesel fuel, only CWS. The economic results of this report assumes combustor design will improve, allowing this to happen.

Further, it is believed that a satisfactory fuel and fuel process can be developed in a timely fashion to meet the engine needs. An engine and its fuel could be developed within 5 to 8 years with sufficient economic incentive. The GE27 engine, however, requires additional development to advance from the prototype to production stage.

I. RESULTS

B. Technical and Environmental Considerations

3. Direct Burn Steam Injection Gas Turbine (DBSIGT)

General Description

The GE27 gas turbine with steam injection is similar to the DFGTL discussed in Section I.B.2 except that steam generated by heating water with the hot exhaust products is injected directly back into the gas turbine combustor. As a result, the output power of the gas turbine is increased from 5900 to 8000 HP.

With exhaust heat recovery provided by this process, the overall cycle efficiency is increased providing an increase in fuel savings. (See the economic analysis Section VIII).

The locomotive is composed of two units plus a tender. The 8000 HP rating requires about 10 traction motors and increased fuel capacity, dictating a 12-axle layout (Fig. I.B.9, a fold-out).

The locomotive has a cab at each end, thus, either end can lead. The tender can be attached at either end, avoiding turning the locomotive.

All fuel is carried aboard the powered units, whereas the tender is reserved for steam injection water

The axle weights have been kept within 70,000# limits. The weight change on the auxiliary unit of 21,000# per axle is higher than normally considered desirable. Controls will be arranged to initially use fuel in such a manner as to keep the weight balanced between the units. Further use of fuel will unbalance the units requiring dual propulsion systems with individual traction generators for each unit. Optimum control will now allow the tractive effort to vary as the weight changes. Both cabs are full width, the choice primarily dictated by the boiler.

Since it utilizes the same turbine (GE27) as the direct fired gas turbine option, a larger inlet air filter and silencer will be required proportional to the horsepower increase.

Gas Turbine Engine

The GE27 engine is recommended for this locomotive and is described in the direct burning simple cycle concept in Section I.B.2. The exhaust from the engine passes through a heat recovery exchanger (boiler) which generates steam to be fed back to the turbine combustion chamber. The waste heat in the exhaust is utilized to vaporize water and raise it to about 800°F (at full load). The steam is further raised to firing temp in the turbine combustion chamber to about 2000°F. This increases engine output to 8000 HP in traction as well as thermal efficiency (duty cycle thermal efficiency increase to 34.4% from 28.9).

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I. RESULTS

B. Technical and Environmental Considerations

3. Direct Burn Steam Injection Gas Turbine

Gas Turbine Engine (continued)

The exact program of steam injection versus load is not yet determined. The approach requiring the least water is to inject no steam below 3800 HP. The approach providing best thermal efficiency, lowest fuel cost and easiest control is to gradually increase steam injection with load. This latter approach appears most likely to succeed and has been utilized in the fuel cost calculations. It is assumed that the heat rate at idle power utilizes no steam. Injection linearly increases up to maximum at 8000 HP.

The required engine development and feasibility is the same as described in Section I.B.2 for the straight slurry burning GE27. The thermal efficiency of coal fired turbine with steam injection is shown below (Fig. I.B.10).

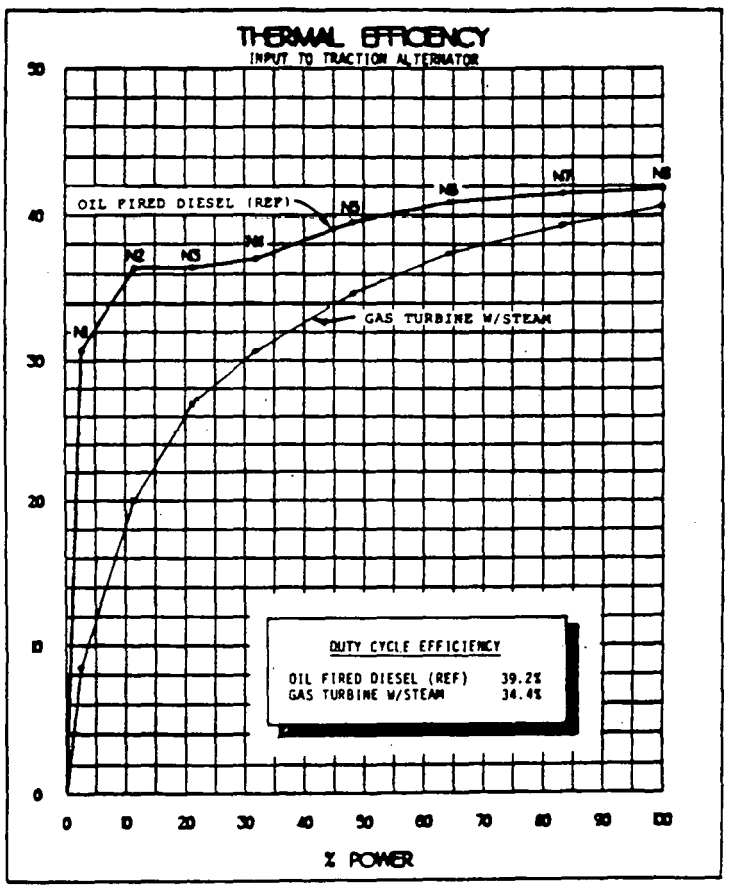

Fig. I.B.10

I. RESULTS

B. Technical and Environmental Considerations

3. Direct Burn Steam Injection Gas Turbine (continued)

Exhaust Emissions

Exhaust emissions will be the same as for the direct coal burning simple cycle except reduced inversely with the duty cycle efficiency. Thus,

	Exhaust Emissions Estimate (Grams/HP-HR)				
	NOx	CO	HC	SOx	Parti-culates
Oil Fired Diesel	10.7	1.8	0.6	1.5*	0.3
Direct Burning Gas Turbine w/Steam	3.1	0.7	0.3	3.2**	0.6

Injection Water & Fuel System

A 16,000 gallon capacity insulated tender furnishes injection water via a circulating pump. This same water is circulated during turbine shutdown to keep the coal slurry and water warm. A 35 HP auxiliary diesel engine furnishes this heat from its jacket water and exhaust as well as spot electric heating. Pumps and battery charging are also supplied by this engine.

Water is heated in the turbine exhaust boiler (heat exchanger) for injection into the combustion chamber. Steam injection is proportional to the power level; maximum planned injection rate is 8200#/hour.

A portion of the boiler water (steam) returns to the main water tank to prevent freezing. A heat exchanger in this same path provides preheat for the fuel slurry. Hot water is also circulated through coils in the slurry storage tanks.

* 1/2% Sulfur in Fuel Oil
** .7% Sulfur in Cleaned, Processed Coal

I. RESULTS

B. Technical and Environmental Considerations

3. Direct Burn Steam Injection Gas Turbine

Injection Water & Fuel System (continued)

Since the heat recovery steam generator is a once-through boiler, the water impurities entering the generation must either leave with the steam or be deposited within the unit. Thus, high purity water will be required to prevent the buildup of scale, prevent corrosion within the gas turbine and minimize exhaust emissions. Demineralized water will be required. The cost for demineralizing the water (approximately $.01/gal) has been included as part of the fuel cost.

Propulsion & Auxiliaries

The traction alternators, motors and control will be of the same design as present day locomotives, except that two back-to-back systems will be employed. This will assure optimum, separate control to each powered unit as the weight distribution is changed when fuel is consumed.

Because of the length of the powered, married pair, the locomotive cannot be easily turned, and therefore has a cab on each end to allow bi-directional operation. Dual cabs require some duplication of control and air brake equipment.

Summary of Technical & Environmental Considerations

To summarize, it may be said that limited testing shows an encouraging outlook for a direct fired coal water slurry gas turbine engine which may be used on a locomotive (See Section I.B.2). The need to clean the engine of deposits requires development, but erosion and abrasion appear to be nearly absent due to the small ash particle size. Engine maintenance will be primarily inspection, with ultimate removal, return and overhaul (or exchange) of the turbine which can be easily done due to its small size and weight.

Further, it is believed that a satisfactory fuel and fuel process can be developed in a timely fashion to meet the engine needs. An engine and its fuel could be developed within 5 to 8 years with sufficient economic incentive. The GE27 engine, however, requires additional development to advance from the prototype to production stage.

Demineralized water in large quantities must also be provided for steam injection to prevent scale buildup, minimize emissions, and prevent turbine corrosion.

I. RESULTS

B. Technical and Environmental Considerations

3. Direct Burn Steam Injection Gas Turbine

Summary of Technical & Environmental Considerations (continued)

8000 HP is about the maximum "block of power" compatible with railroad practice. In other words, such high horsepower in a locomotive limits its application to specific, dedicated high power trains, reducing application flexibility. More horsepower also requires larger fuel tanks, larger tender, and a larger heat recovery steam generator. On the other hand, less horsepower will not appreciably reduce the size of the locomotive. Two units and a tender would be required in any case. Interestingly, the turbine itself does not require much space.

I. RESULTS

B. Technical and Environmental Considerations (continued)

4. Classified Coal Gasifier Gas Turbine

General Description

This locomotive configuration uses coal gas as a fuel in conjunction with a gas turbine with steam injection as described in Section I.B.3. It would be designed to have 8000 HP for traction. The fuel gas is generated on board by a pressurized gasifier.

The primary reason for considering this configuration is the low cost of raw coal compared to the cost of CWS. This low cost advantage brings the coal processing on board the locomotive making it more complex.

A two unit locomotive with a water tender is required for this concept. In order to utilize the horsepower, 12 powered axles are used. To avoid turning this long two unit locomotive, operating cabs are placed at each end along with separate tender connections (Fig. I.B.11, a foldout).

The gasifier and turbine are mounted in one unit to avoid high pressure or big volume gas connections between units. Coal is delivered pneumatically from the auxiliary unit to the power unit.As in previous gas turbine options, inlet air filters and silencer are provided.

Preliminary weight estimates indicate the locomotive can probably be designed within acceptable standards. Volume of the equipment, particularly the gasifier, is high and careful attention to accessibility for maintenance must be observed during design. The design will be very tight. The initial size of gasifier equipment will require a two-unit locomotive, and so 8000 HP for traction was deemed desirable.

Gasifier & Emissions

A high pressure, fixed bed (countercurrent) gasifier was chosen for this locomotive application. It has high thermal efficiency (about 85%), and relatively low off gas temp (about 1400°F). However, there are liquid hydrocarbons in the gas, and the gasifier has a limited ability to use "caking" coal.

Coal gas is generated by the sub-stoichiometric burning of coal in an air and steam environment. The produced gas consists primarily of nitrogen (N_2), carbon monoxide (CO), hydrogen (H_2), carbon dioxide plus some methane (CH_4), and hydrogen sulfide (H_2S). A pressurized gasifier is employed, where coal is introduced through the top; steam and air from below through tuyeres. The hot gas exits near the top of the vessel while the accumulated ash is removed from the bottom.

I. RESULTS

B. Technical and Environmental Considerations (continued)

4. Classified Coal Gasifier Gas Turbine

Gasifier & Emissions (continued)

The generated gas from the gasifier first passes through a cyclone filter to remove entrained particulate matter. These removed solids contain unprocessed coal which are reinserted into gasifier for reprocessing.

The gas from the cyclone filter next passes through a zinc ferrite sorbent tank to remove hydrogen sulfide. Next, the gas then passes through a bank of porous ceramic "candle" filters which remove the very fine particulates before it passes into the gas turbine combustor.

Alkali metals, mostly potassium, will be in the condensed form because of the low temperature and are removed as particulates. Thermal Nox produced in the gasifier is very low due to the relatively low temperature. The nitrogen enters the combustion chamber of the turbine combined with hydrogen as ammonia (NH) which finally burns in the engine to NOx and H_2O. The relatively low combustion temperature in the turbine engine also limits the formation of NOx.

Actual tests run at GE's Corporate Research & Development Center with a fixed bed gasifier, MS6000 combustor, and just cyclone cleanup provides the data for the emissions estimate for this system.

	Exhaust Emissions Estimate (Grams/HP-HR)				
	NOx	CO	HC	SOx[1]	Parti-culates
Oil Fired Diesel	10.7	1.8	0.6	1.5	0.3
Gasifier-Gas Turbine	[2]2.6/2.3	0.05	0.05	0	1.3

[1]1/2% Sulfur in Fuel Oil
1% Sulfur in Cleaned Process Coal Water Slurry

[2]Based on N_2 content of fuel (1.6% Eastern, 1.3% Western)

[3]Water Cooled Component Testing Program; DOE Topical Report DE-AC21-83MC20192.

I. RESULTS

B. Technical and Environmental Considerations

4. Classified Coal Gasifier Gas Turbine

Gasifier & Emissions (continued)

The gasifier operates at a pressure slightly higher than engine combustion chamber pressure (300 psi max.) and thereby varies with engine output power. The pressurized air is supplied from the gas turbine compressor but needs a pressure boost by an air compressor driven off the engine P.T.O. The stirring mechanisms within the gasifier, coal feed system and ash removal system, must operate at gasifier pressure. The mechanical details of these various systems must be developed.

To save space and weight, the cyclone separators were placed within the zinc-ferrite sorbent vessel, balancing the pressure on both sides of the cyclone and reducing its wall thickness (GE patent pending). Connections, piping, flanges, etc., are all "hot" and subject to high pressure, mandating short pipe lengths and rigid assembly. For these reasons, the gasifier, ash removal system, scrubbers, particulate candle filter, turbine, and heat recovery steam generator are packaged on a single locomotive platform (unit). The conceptual layout shows that this may be possible, but it is extremely tight making maintenance difficult. Needless to say, detailed work must still be done before an acceptable design is obtained.

The sorbent utilizes zinc-ferrite pellets which must be removed and regenerated. The frequency of regeneration will depend upon the amount of SOx to be removed.

Gas Turbine Engine

It is normal practice for a gas turbine to burn a gaseous fuel. The fuel which is generated by the gasifier is clean but has a low heat content due to the large nitrogen content. Tests were conducted by General Electric using a simulated low BTU fuel.[1] The test results indicate that combustion was successful and efficient. Thus, it appears that required modifications to the engine are primarily to allow steam injection. No technological problems are seen that are unsolvable.

A tank of propane gas is planned to start the system - both the turbine and gasifier.

[1]Internal GE Evendale Monthly Status Report #2, September 5, 1984, titled "Gas Turbine System Development for Coal Burning".

I. RESULTS

B. Technical and Environmental Considerations

4. Classified Coal Gasifier Gas Turbine

Gas Turbine Engine (continued)

The thermal efficiency of the engine with steam injection is shown below (Fig. I.B.12).

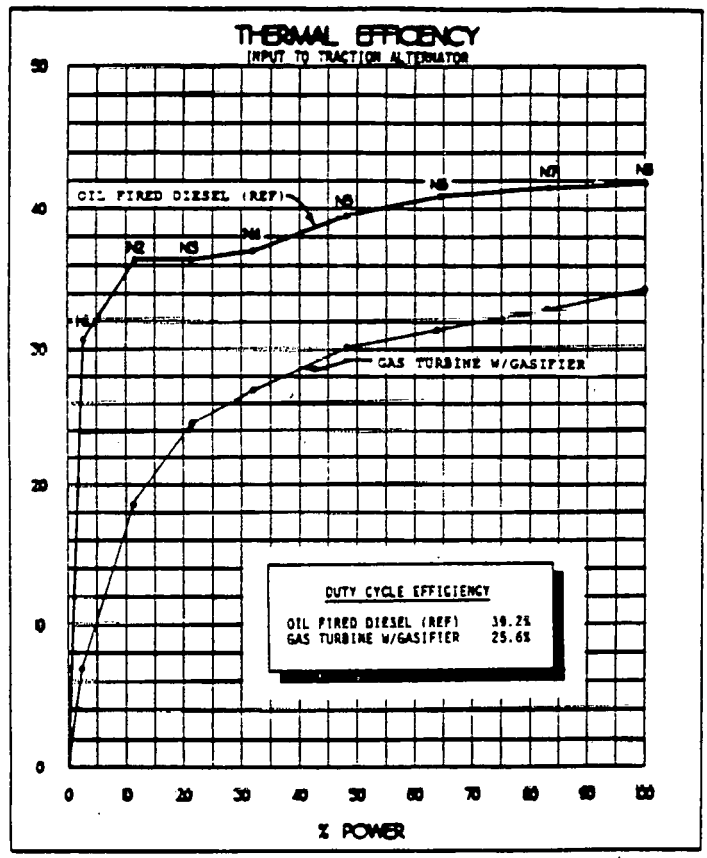

Fig. I.B.12

I. RESULTS

B. Technical and Environmental Considerations

4. Classified Coal Gasifier Gas Turbine

Water Supply

Water is required for two purposes: gasification and waste heat recovery steam for reinjection into the turbine. All water is stored in an insulated auxiliary tender.

The gasifier has a water jacket. Water from the tender flows to the gasifier for preheat. This heated water is circulated back to the tender and coal bin to keep them from freezing up.

Heated water is also supplied to the turbine exhaust gas heat exchanger. The steam output is injected into the turbine for supplemental mass flow, hence, augmenting the turbine power output. Steam output is also injected into the gasifier.

Since the heat recovery steam generator (boiler) is a "once-thru" system, all of the impurities in the water either scale the boiler or pass through the system. To minimize scaling, erosion, corrosion and emissions, high quality demineralized water will be required. This water and processing cost is added to the fuel cost in the economic analysis.

Solid Fuel System

Coal of 1/2" diameter or less is placed aboard the locomotive. Two augers in the bottom of the bin deliver this coal to one of two hoppers. The hopper is then sealed. Compressed air at 70 to 100 psi forces the coal onto the power unit into a similar high pressure hopper. A tap from the gasifier's process compressed air supply injects this coal into the gasifier at a rate determined by the power requirements.

Ash is mechanically withdrawn from the bottom of the gasifier and stored in an ash storage bin. Ash is also removed from bins below the candle filters. The candle filters are cleaned by compressed air blown through them periodically and automatically in the reversed flow direction.

Propulsion and Auxiliaries

As in the other turbine options, the turbine is coupled to the alternator through a speed reducing planetary gearbox.

Due to the weight change on the auxiliary unit, as fuel is used, two separately controlled alternators mounted on a common shaft plus an integral auxiliary alternator are provided. This allows separate control of the tractive effort level on each of the powered units. All auxiliaries are electrically powered for this option also.

I. RESULTS

B. Technical and Environmental Considerations

4. Classified Coal Gasifier Gas Turbine

Propulsion and Auxiliaries (continued)

Dynamic braking, air brakes and ventilation follow standard diesel electric locomotive practices.

Technical and Emissions Considerations Summary

A coal fired locomotive concept using an on-board gasifier and gas turbine engine is composed of a two-unit married assembly with a water tender. The turbine required would not need technological developments. The gasifier, being mobile, would entail considerable development to make it acceptable with respect to maintenance and reliability. Although the concept may be feasible, it appears that it is very tight and rather complex. Thus, the estimates for reliability are relatively low. As presently conceived, ash removal is also difficult, and regeneration of the sorbent is another task to be developed.

Demineralized water is required for operation. The complexity of the concept and probable high initial cost is offset by relatively low cost and high availability of raw coal, and low emissions. Control of the gasifier system will be a function of the particular coal fuel analysis, probably enhanced by the use of microcomputers.

I. RESULTS

B. Technical and Environmental Considerations

5. Classified ROM Fluidized Bed Steam Turbine

General Description

A coal fired steam turbine locomotive concept capable of burning classified ROM coal was analyzed. It was felt that the unit should be a condensing system minimizing the need for water replenishment. Early in the study, it was realized that at least two locomotive units would be required to handle all of the equipment. To keep locomotive size and horsepower in balance, something more than 5000 HP for traction was desirable. After the study had progressed, it was found that the minimum equipment for 5000 HP would probably not fit on two units. Three units are used and 8000 HP capability could be realized. This is also about as large a block of power that can be utilized by the railroads and still afford some application flexibility. To minimize exhaust emissions and maximize the variety of acceptable coals, a fluidized bed boiler was chosen[1]. Also, fluidized bed boilers are relatively compact due to the high heat transfer coefficient within the boiler, due to scrubbing action of the particles.

The fluidized bed boiler, turbine-generator, necessary pumps and blowers are mounted on the power unit. Because the weight remains constant, it has powered axles (six). The auxiliary unit contains the exhaust baghouse and heat rejection radiator system. The auxiliary also experiences relatively little change of weight during operation and so it also has six powered axles. The tender unit carries the coal fuel and water as well as auxiliary equipment such as air compressors and fuel transfer hoppers. It experiences a large change in weight during operation, and so the axles are not powered. The three-unit locomotive always operates as a single locomotive and therefore an operator's cab is provided on each end and eliminates the need for turning the locomotive around (see Fig. I.B.13 - fold-out).

Fuel, Combustion, & Emissions

Coal of 1/2" or less diameter, mixed with limestone, is taken from the bin by one of two augers. The coal is fed to a hopper, sealed and blown across the connection between units by compressed air, at approximately 70 psi.

Two blowers supply combustion air to the fluidized bed. The fluidized bed air box is compartmentalized to vary the combustion quantity, allowing energy turn-up (more of the bed fluidized) and energy turn-down.

[1]Preliminary studies eliminated the use of pulverized coal or coal slurry fired boilers for size and fuel handling reasons.

I. RESULTS

B. Technical and Environmental Considerations

5. Classified ROM Fluidized Bed Steam Turbine

Fuel, Combustion, & Emissions (continued)

An economizer located in the boiler exhaust preheats the boiler feed water.

Exhaust gas is then cleaned in one of two cyclone type separators. A percentage is returned to the boiler to reclaim any unburned coal. Exhaust is drawn through an induced draft fan, passed across the junction between units via a flexible boot and then into a baghouse for final ash removal before exhausting through exhaust stacks.

Combustion takes place at about 1600°F. At this temperature, most of the ash remains as a solid and is captured in the baghouse. The presence of limestone ($CaCO_3$) with the coal results in the formation of calcium sulphate ($CaSO_4$) which is a solid and is trapped in the baghouse. Ninety percent of the sulphur can be captured if calcium to sulfur ratio is approximately 2.5 to 1. Assuming the coal is 4% sulfur, this requires about .3 pounds of limestone per pound of coal. The sulfur which is not captured in this manner passes through the exhaust as SOx. Due to the low bed temperature, most of the NOx is generated from the nitrogen content of the fuel. For nitrogen values of 1.3%, about 3.5 grams of NOx will be generated per HP-hour. Unburned hydrocarbons are expected to be insignificant. Baghouses can be expected to capture most of the particulates. Particulates which are emitted are expected to be less than 0.14 grams/HP-hour. Carbon monoxide, CO, is anticipated 300 to 500 ppm or 10.2 grams/HP-hour .

The emissions are summarized below:

	Exhaust Emissions Estimate (Grams/HP-HR)[1]				
	NOx	CO	HC	SOx[2]	Particulates
Oil Fired Diesel	10.7	1.8	0.6	1.5	0.3
F-B Steam Turbine	3.5[3]	10.2	-	3.1	0.14

[1]Courtesy of Combustion Engineering, Inc.

[2]Assumes 1/2% sulfur in fuel, 2% sulfur in Western coal, and 90% capture.
[3]1.3% N_2 in coal fuel.

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I. RESULTS

B. Technical and Environmental Considerations

5. Classified ROM Fluidized Bed Steam Turbine

Steam and Water

High pressure steam (850 psig) leaves the boiler and enters the steam turbine. Turbine exhaust steam is condensed within a jet condenser. A circulating pump removes hot water from the condenser and circulates water in two parallel paths. The larger flow is to the radiators on the third auxiliary unit. Installed radiator fan capacity requires 400 HP. After cooling, this water returns to the jet condenser. Use of a jet condenser in this fashion results in a water to air heat exchanger in the radiators, instead of steam to air. This minimizes the area required for heat transfer. Since water is the medium for heat rejection rather than steam, piping and flexible connections between the units can be smaller.

A second parallel path circulates condensate through a water jacket on the coal bin to prevent freezing, then returns via a water make-up tank to the main circulating pump. Boiler feed water is also tapped off the condensate line from the jet condenser.

Fairly high purity water is used to minimize boiler scaling and repair.

The steam pressure of 850 psi represents the best compromise between thermal cycle efficiency and turbine mechanical efficiency for 8000 HP. In other words, although higher pressures result in higher cycle efficiencies, the turbine gets smaller with resulting decrease in mechanical efficiency. Highest thermal efficiency is obtained by varying boiler pressure for changes in power, rather than throttling. The cooling water system is designed to run about 1 psi gage pressure, and not under a vacuum. This is done because the unit is mobile, and it is deemed worthwhile for reliability in spite of a slight penalty in efficiency.

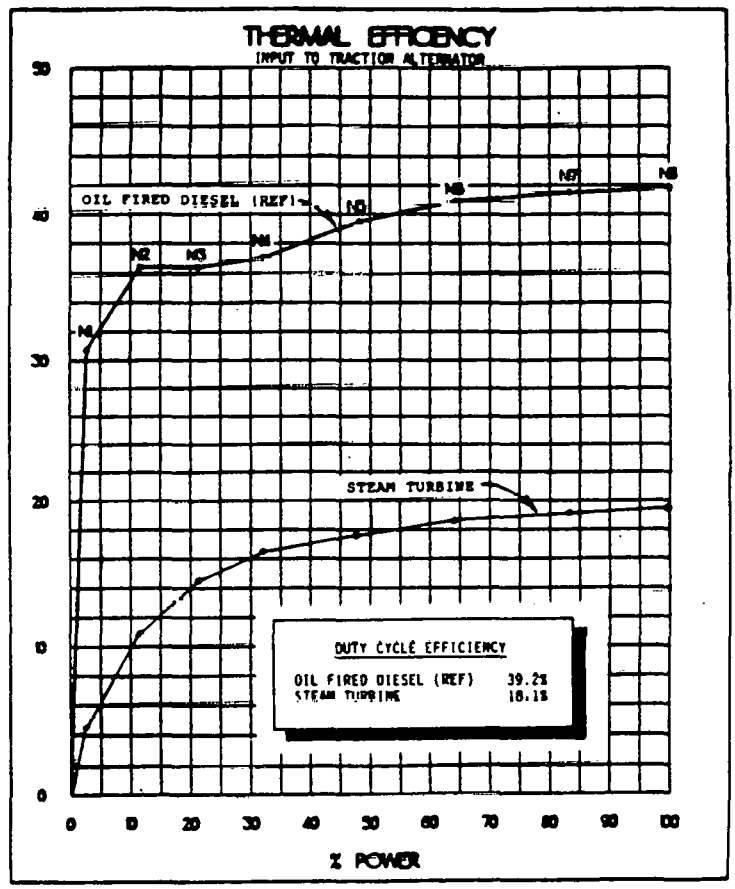
I. RESULTS

B. Technical and Environmental Considerations

5. Classified ROM Fluidized Bed Steam Turbine

Steam and Water

Overall thermal efficiency is shown below (Fig. I.B.14)



I. RESULTS

B. Technical and Environmental Considerations

5. Classified ROM Fluidized Bed Steam Turbine (continued)

Turbine Engine

The proposed turbine design is a 7-stage, 7200 rpm machine coupled to the traction alternator through a gear unit. The steam turbine is believed to be as mechanically efficient as a reciprocating engine, and it can be designed to be virtually maintenance free in the locomotive application. The reliability and maintenance challenge with the steam turbine locomotive is not with the turbine but with the boiler and its total support.

Propulsion & Auxiliaries

The main alternator is driven by the steam turbine through a planetary speed reducer gearbox, and has an integral auxiliary alternator within it.

All fans, blowers, pumps and compressors are electrically driven. Control would be enhanced by microprocessor control.

Propulsion control follows conventional diesel-electric practice except for dynamic braking.

Dynamic braking is accomplished by placing electrically heated resistors in the combustion blower air stream. The heat generated preheats the boiler combustion air. The energy in the resultant steam, bypasses the turbine and is dissipated in the radiator cooling system. This arrangement has the advantage of keeping the boiler hot during an otherwise low load condition thus allowing rapid load recovery while eliminating the need for separate dynamic braking grid blower.

Technical & Emissions Considerations Summary

The steam turbine locomotive as conceived does not require technological breakthroughs while having the advantage of burning inexpensive classified ROM coal. Emissions are greater than one would expect, even when using limestone. This is due primarily to the quantity of coal burned caused by the relatively low thermal efficiency. It is also a very large locomotive of 8000 HP with limited flexibility (application) on the railroad. It is complex and the design is tight which may lead to difficult maintenance. Maintenance is expected to be relatively high for the system. Modern electrical microprocessor control and the use of electrical driven pumps and blowers are required for control and reliability. It is estimated that the system can respond from idle to full power in 6 to 10 minutes, with only 5 to 10 seconds required from 60% to full power. Although this may appear to be unusually long, it is felt that it is an acceptable characteristic in the dedicated type of service these kinds of locomotives would see.

I. RESULTS

C. Railroads' Financial Expectations

0. Evaluation Procedure

As with any business, a new type machine, or in this case, a locomotive, will be commercially attractive only if it meets or surpasses certain financial objectives. The investment required for the purchase of a new locomotive fleet together with the cost of upkeep and changes in infrastructure competes with the present locomotive system as well as the attractiveness of other business investments. This competition for locomotive fleet funds can best be evaluated by calculating the "incremental" investment and savings which result from using an alternative locomotive system over the present oil fired diesel locomotive (OFDL) system. Competition with other investment needs can be evaluated by using a desired discounted rate of return (DCRR) of, say, 15% or 20%, on the cash flow of this investment.

Figure I.C.1 is a logic flow chart which describes the economic analysis procedure assumed to be used by the railroads.

The main elements of the financial analysis are:

- Coal fuel costs.
- Fuel cost savings.
- Incremental maintenance costs.
- Incremental infrastructure capital costs.
- Fleet size and fuel consumption
- DCRR analysis.

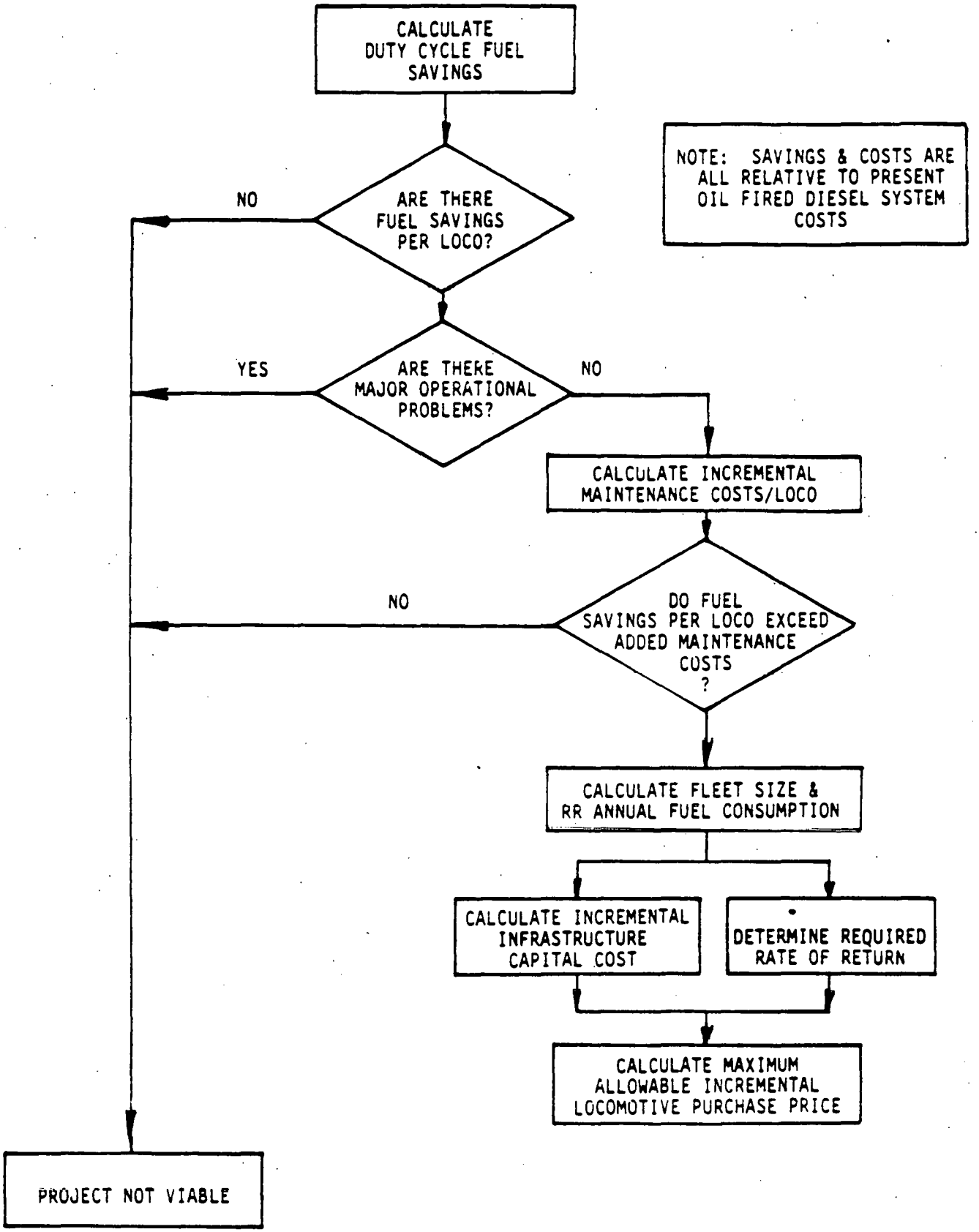
The object of the analysis is to calculate the incremental purchase price* of the locomotive (cost to the railroad) which a railroad should be willing to pay and still realize a given DCRR.

1. Coal Fuel Costs

Engine grade CWS is not presently commercially available. In order to introduce a CWS fleet to the railroads, fuel processing plants must be constructed. This analysis assumes that the railroads will build, own and operate the plants and that the fuel is manufactured per the Otisca Co. process. The analysis is then pursued on a railroad-by-railroad basis for six major railroads systems: 1) Santa Fe-Southern Pacific; 2) the Burlington-Northern; 3) the CSX Corporation; 4) Conrail; 5) Norfolk-Southern; and 6) Union Pacific-Missouri Pacific.

* Selling Price of the Coal-Fired Locomotive minus Selling Price of Equivalent Oil-Fired Diesel Locomotive.

COAL BURNING LOCOMOTIVE STUDY



I. RESULTS

C. Railroads' Financial Expectations

1. Coal Fuel Costs (continued)

Using the Otisca process as described in the literature, a conceptual processing plant was developed. A simplified flow diagram is shown in Figure I.C.2. The main inputs to the plant are coal, water, power and additives. The output is the coal-water slurry, and sludge (mineral matter and water).

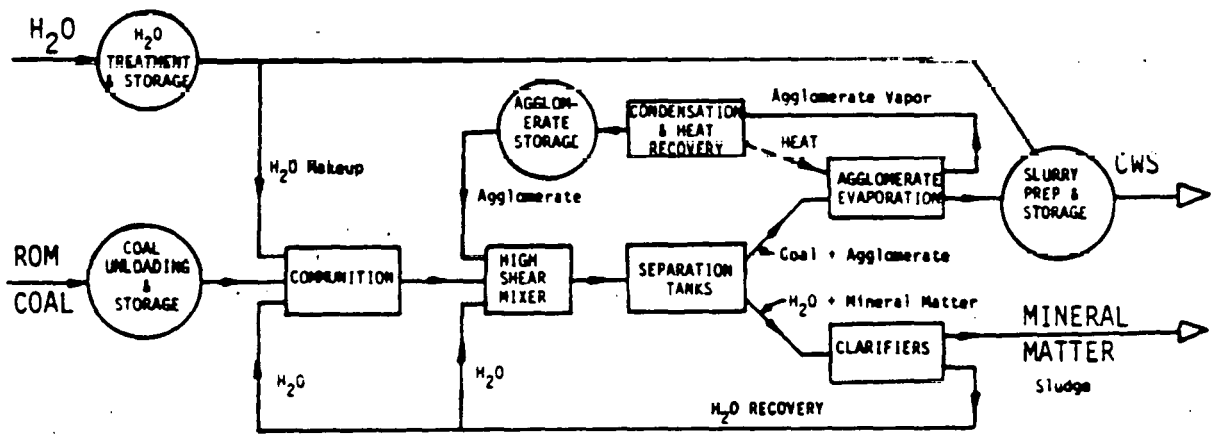


Figure I.C.2

Although the proximate analysis of coal is extremely variable for our purposes, washed-run-of-mine (ROM) coal can be adequately described as in Table I.C.1.

Coal	Rank	BTU/Lb	% Water	% Mineral Matter	% Combustibles
Eastern	Bituminous	12,000	5	10	85
Western	Sub-Bituminous	8,500	29	11	60

Table I.C.1

The input (ROM) coal cost to the plants is $33.00/ton for Eastern coal and $11.00/ton for Western coal.

The cost for processing the fuel has been determined as shown in Table I.C.2.

I. RESULTS

C. Railroads' Financial Expectations

1. Coal Fuel Costs (continued)

	Eastern Coal		Western Coal	
	$/10^6 BTU	%	$/10^6 BTU	%
Power	0.271	31.7	0.289	31.3
Water	0.099	11.6	0.064	6.9
Agglomerate	0.106	12.4	0.106	11.5
Additives	0.208	24.4	0.295	31.9
Plant Payroll	0.064	7.5	0.064	6.9
Plant Maintenance	0.106	12.4	0.106	11.5
Total	0.854	100.0	0.924	100.0

CWS Processing Costs

Table I.C.2

ROM coal will have to be transported to the plant site and slurry fuel will have to be transported from the plant site to various locomotive fueling depots. To ascertain the distances involved, locations for the plant sites (1 or 2 per railroad) and fueling depots (3 to 6 per railroad) were selected, using railroad maps, and recognizing the range of locomotive is less than 1000 miles. Typical selection results are shown in Figure I.C.3. Transportation costs are then calculated for each railroad using $.0175/ton-mile for ROM coal and $.0263/ton-mile for slurry as the railroad cost rate.

I. RESULTS

C. Railroads' Financial Expectations

1. Coal Fuel Costs (continued)

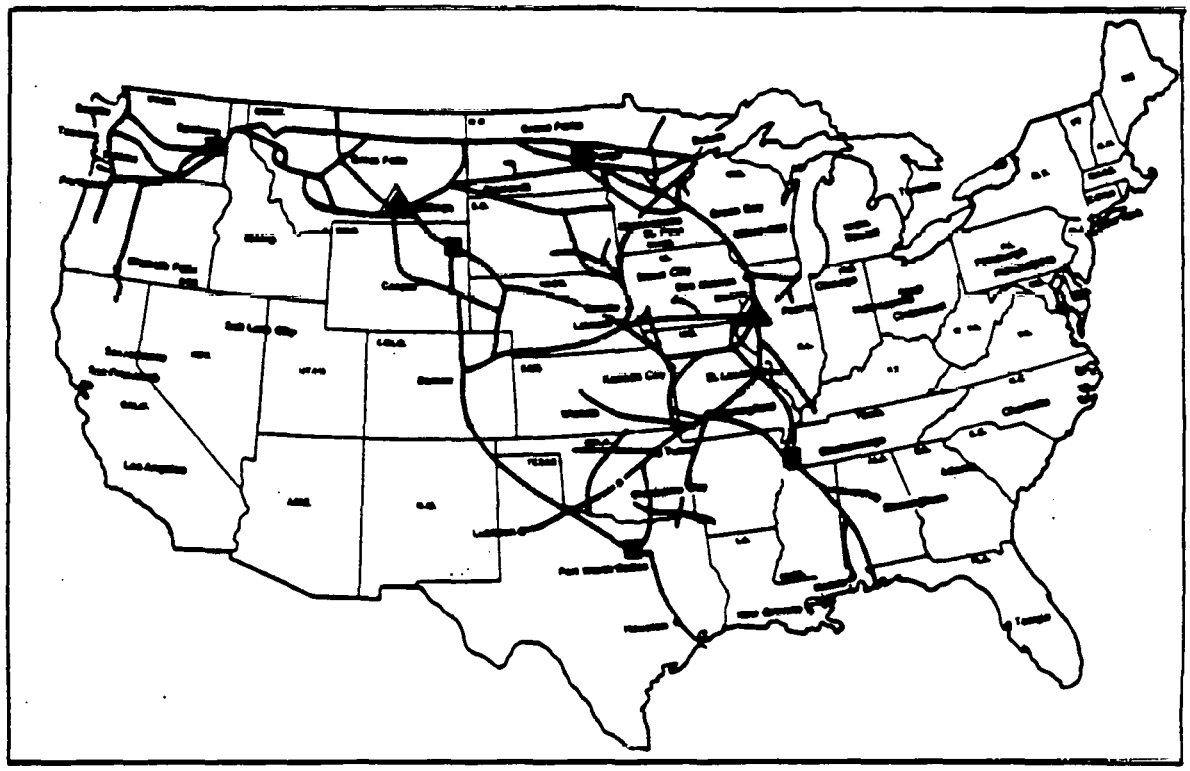


Figure I.C.3

Table I.C.3 summarizes the total fuel cost.

Railroad	ROM Coal Cost	Processing Cost	Transportation Cost	Total Cost
BN (W)	0.647	0.924	1.673	3.244
Conrail (E)	1.375	0.854	0.417	2.646
CSX (E)	1.375	0.854	0.759	2.988
NS (E)	1.375	0.854	0.571	2.800
ATSF/SP (W)	1.011	0.889	1.200	3.100
UP (W)	0.647	0.924	1.654	3.225

Average RR Cost = 3.033
Average Eastern RR Cost = 2.85
Average Western RR Cost = 3.19

(E) = Eastern RR
(W) = Western RR

Fuel Cost ($/MBTU)

Table I.C.3

I. RESULTS

C. Railroads' Financial Expectations

1. Coal Fuel Costs (continued)

Figure I.C.4 graphically illustrates that the greater shipping distance results in higher transportation costs for Western coal which more than compensates for the lesser ROM initial fuel cost.

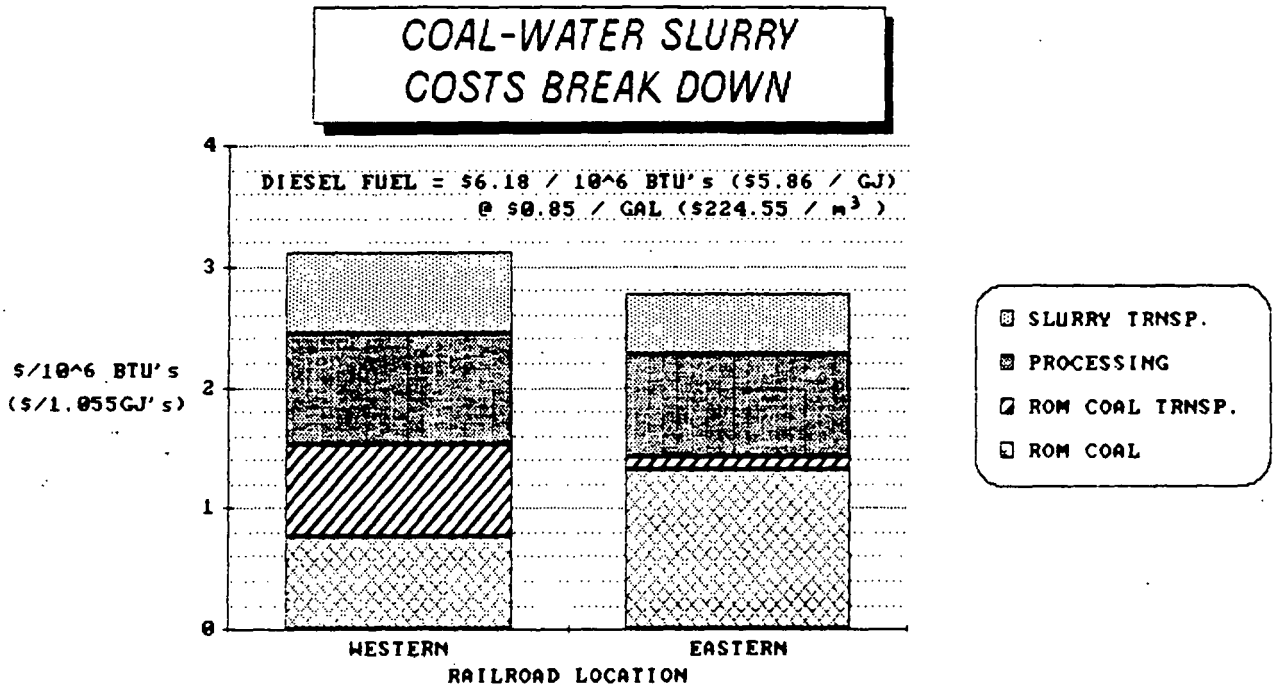


Figure I.C.4

2. CWS Fuel Cost Savings

It is apparent from the preceding that the cost per million BTU is less than half that of diesel fuel (@ 85¢/gallon = $6.18 MBTU). The total fuel savings per locomotive per year is a direct function of the amount of fuel burned per year, which in turn is different for the various railroads and duty cycles. Table I.C.4 shows the duty cycles used in this analysis which is somewhat different for Eastern and Western railroads. Notice that the time spent in Notch 8 (full power) is 22% for Western Railroads and less than 12% for Eastern Railroads. Nonetheless, although most of the fuel is consumed in Notch 8, engine part load thermal efficiency will have a measurable effect on fuel consumption.

Diesel engines inherently have very good part load efficiency as well as superior full load efficiency compared to other prime movers and it is expected that this type of performance will not

I. RESULTS

C. Railroads' Financial Expectations

2. CWS Fuel Cost Savings (continued)

change with the use of CWS as fuel. However, because the CWS fuel is about 50% water, the latent heat of vaporization of this water is lost and the full load thermal efficiency is estimated at about 38%. Full power thermal efficiency with the diesel fuel is about 42%. Table I.C.4 also illustrates the results of the analyses for Eastern and Western Duty Cycles, Locomotives Burning CWS.

		Eastern Railroads					Western Railroads				
		% Time	Total Fuel Costs (Equivalent 3800 HP)				% Time	Total Fuel Costs (Equivalent 3800 HP)			
Notch	% HP		Oil Fired Diesel	CWS Diesel	CWS Simple G.T.	CWS Steam G.T.		Oil Fired Diesel	CWS Diesel	CWS Simple G.T.	CWS Stean G.T.
1	2.7	6.3	20	20	53	39	6.5	20	20	62	45
2	11.5	5.8	65	54	71	55	4.5	50	43	62	48
3	21.2	4.8	99	68	78	64	4.2	87	63	76	63
4	31.9	3.6	110	70	74	62	4.9	150	102	113	90
5	48.1	2.6	112	67	70	60	4.5	194	127	136	116
6	64.3	2.8	156	91	93	80	4.8	268	170	178	154
7	83.2	2.4	170	97	97	84	2.8	199	124	126	109
8	100.0	11.3	957	536	521	452	22.0	1864	1150	1139	988
Idle	1.0	9.0	16	16	70	49	9.0	16	16	78	55
Yard Idle	1.0	47.6	64	64	--	--	33.0	44	44	--	--
Dyn Brake	2.0	3.8	12	12	32	22	3.8	12	12	35	25
Total (56 hour run)			$1781	$1094	$1157	$966		$2903	$1871	$2005	$1700

Duty Cycle Fuel Cost Comparison for CWS Burning Locomotives

Diesel Fuel = $6.18/MBTU

Eastern CWS = $2.85/MBTU

Western CWS = $3.19/MBTU

Table I.C.4

In spite of the greater thermal efficiency of the diesel engine, the gas turbine locomotives show a greater savings in fuel cost at full power. This results from the assumption that no pilot diesel fuel is required for the gas turbines (still to be verified) whereas pilot diesel fuel is employed for the CWS diesel.

Generally speaking, Western Railroad locomotives use more fuel/locomotive than Eastern Railroad locomotives. With the information above, fuel costs for an equivalent 3800 HP locomotive are depicted below (Figure I.C.5).

I. RESULTS

C. Railroads' Financial Expectations

2. Fuel Cost Savings (continued)

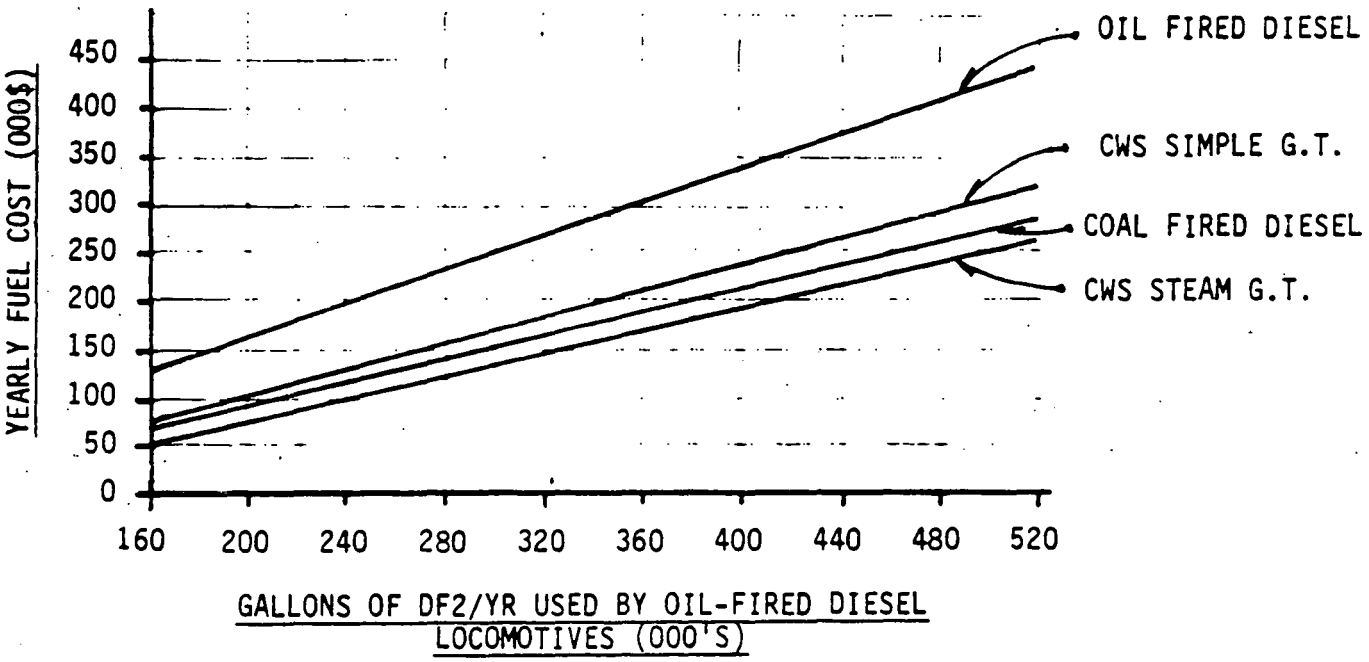


Figure I.C.5

Savings per year, increase with increased utilization of the coal-fired locomotives.

Fluidized Bed Steam Turbines & Gasifier Gas Turbines Burning Classified ROM Coal

The fluidized bed boiler and the gasifier alternatives both use classified ROM coal for fuel. Up to 3 fuel sources were evaluated for each fueling station for each of the six railroads. The coal sources were chosen using price and proximity as primary criteria. Coal heating value and quality were used as secondary criteria. The delivered cost of coal is determined by adding coal cost plus transportation cost using haulage mileage determined from railroad maps and a rate of $.0175 per ton-mile (large coal contract).

The cost of neutralizing the sulfur in the coal was calculated by supplying calcium in the form of limestone. To assure about 90% capture, a weight ratio of 3 1/3 lbs. of coal to 1 lb. of limestone is required for 4% sulfur coal. Crushed limestone is generally available throughout the country, so a constant price of $4 per ton is used with 100 miles of haulage at $0.03 per ton-mile.

I. RESULTS

C. Railroads' Financial Expectations

2. CWS Fuel Cost Savings (continued)

The gasifier does not use limestone, but it is assumed that the hot gas sulfur removal system involving zinc-ferrite regeneration will be a competitive process. For this reason, no distinction is made between the cost of fuel for the fluidized bed and the gasifier with water injection.

The cost of ash disposal of $4 per ton of ash is used throughout.

Table I.C.5 summarizes the total fuel cost.

Railroad	ROM Coal Cost	Transp Cost	Sulfur Removal Cost	Ash Disposal	Total Cost
BN (W)	.723	.490	.018	.030	1.261
Conrail (E)	1.354	.093	.037	.042	1.526
CSX (E)	1.359	.200	.036	.039	1.633
NS (E)	1.348	.108	.034	.038	1.528
SF/SP (W)	.666	.430	.017	.026	1.139
UP (W)	.696	.322	.019	.035	1.072

Average RR Cost = 1.36
Average Eastern RR Cost = 1.562
Average Western RR Cost = 1.157

(E) = Eastern RR
(W) = Western RR

Classified ROM Coal Fuel Cost ($/MBTU)

Table I.C.5

The duty cycle fuel cost comparison for Eastern and Western railroads is shown below (Table I.C.6).

I. RESULTS

C. Railroads' Financial Expectations

2. CWS Fuel Cost Savings (continued)

		Eastern Railroads					Western Railroads			
		% Time	Total Fuel Costs (Equivalent 3800 HP)				% Time	Total Fuel Costs (Equivalent 3800 HP)		
Notch	% Power		Oil Diesel	F.B. Steam	Gasifier G.T.			Oil Diesel	F.B. Steam	Gasifier G.T.
1	2.7	6.3	20	45	26		6.5	20	32	22
2	11.5	5.8	65	64	44		4.5	50	34	25
3	21.2	4.8	99	75	53		4.2	87	45	33
4	31.9	3.6	110	75	53		4.9	150	70	51
5	48.1	2.6	112	74	52		4.5	194	88	64
6	64.3	2.8	156	102	70		4.8	268	120	87
7	83.2	2.4	170	110	75		2.8	199	88	63
8	100.0	11.3	957	619	409		22.0	1864	830	575
Idle	1.0	9.0	16	57	36		9.0	16	40	27
Yard Idle	1.0	47.6	64	--	189		33.0	44	--	98
Dyn Brake	2.0	3.8	12	26	16		3.8	12	18	12
Total (56 Hour Run)			$1781	$1247	$1050			$2903	$1367	$1057

Duty Cycle Fuel Cost Comparison for
Classified ROM Coal Burning Locomotives
Table I.C.6

Note that for the assumed 56 hour run, it is no more fuel expensive to do twice as much work on the Western Railroad as the Eastern Railroad. This is because of the less expensive Western coal and the need for less limestone.

I. RESULTS

C. Railroads' Financial Expectations

3. Incremental Maintenance Costs

(See Section III for additional details)

Maintenance cost is divided into planned or scheduled (preventive) maintenance, and unscheduled maintenance. Over the years, railroad maintenance has evolved such that about 60% is planned and 40% is unplanned due to locomotive failures. Analysis of locomotive maintenance costs reveals that the costs tend to stay constant with lesser influence by duty and fuel usage.

The maintenance requirements for the coal fired locomotives can be estimated in the following manner.

Planned Maintenance

Running gear, platform, traction motors, alternators, propulsion control equipment can be prorated by number of equipments from oil diesel data, because it is in fact the same or similar equipment.

Coal fired diesel maintenance is modified by diesel engine parts affected either in projected life or parts cost as a result of using coal. Cooling system maintenance is the same as present oil engines.

Other planned maintenance requirements are estimated by using similar equipment data and is a function of the locomotive size or number of maintained parts and locomotive usage if applicable.

Certain planned maintenance due to regulations is a function of time only, independent of locomotive usage or condition.

Unplanned Maintenance

Unplanned maintenance by definition is a direct result of equipment failure, and therefore is a function of equipment usage and reliability estimates for the equipment. The reliability of the locomotive is expressed in terms of failures per locomotive-year, and the maintenance cost is estimated to be inversely proportional to the reliability. Experience indicates that the maintenance costs are dominated by labor costs expended in troubleshooting and changeout of single failed parts. The reliability of each of the locomotive alternatives is shown later in Section I.C.4, Table I.C.9.

Actual Maintenance for each locomotive alternative is based on actual locomotive horsepower and actual fuel consumed based on a

I. RESULTS

C. Railroads' Financial Expectations

3. Incremental Maintenance Costs (continued)

straight line relationship between 280,000 and 440,000 gallons DF2 equivalent. Because the analysis is determined upon incremental changes to the oil fired diesel locomotive, absolute value error is of second order importance.

Total maintenance cost of each of the locomotive alternatives is given below (@ equivalent 3800 HP) (Table I.C.7).

	Planned		Unplanned		Total	
Locomotive Alternative	280	440	280	440	280	440
Oil Fired Diesel	41.7	47.6	27.8	31.8	69.5	79.4
Coal Fired Diesel	62.0	66.2	30.4	34.7	92.4	100.9
Gas Turbine Simple Cycle	44.6	62.3	27.8	31.8	72.4	94.1
Gas Turbine w/Steam	57.1	76.2	43.1	47.8	100.2	124.0
Gasifier-Gas Turbine	94.6	117.9	51.4	58.8	146.0	176.7
Steam Turbine	63.3	70.9	75.2	85.9	138.6	156.8

Maintenance Cost for Given Oil Diesel Fuel Usage @ 3800 HP Engine

280 = 280,000 Gal. DF2/Yr.
440 = 440,000 Gal. DF2/Yr.

Table I.C.7

4. Incremental Infrastructure and Capital Costs

(For additional details, see Section VI)

Any new fuel locomotive trying to displace the already developed petroleum fuel locomotive system will require investment in the new locomotive infrastructure. This infrastructure system includes changes to locomotive maintenance systems as well as new fuel processing and handling systems. Thus, the net savings which result from fuel and maintenance considerations will be offset to some extent by the capital investment due to infrastructure changes as well as increased capital cost of new coal fired locomotives. This latter factor is addressed in Section I.C.6.

The coal fired diesel and coal slurry gas turbine locomotive alternatives require fuel processing plants and fuel handling systems.

I. RESULTS

C. Railroads' Financial Expectations

4. Incremental Infrastructure and Capital Costs (continued)

Coal Water Slurry Capital Costs

It is assumed that the railroads themselves will build, own and operate the plants which will manufacture the CWS fuel. Based on the Otisca process, conceptual plants were outlined and the capital expenditures determined. Table I.C.8 lists the estimated capital expenditures. Within appropriate limits, the estimates indicate that investment is a function of the 0.8 power of required plant CWS capacity.

PLANT CAPACITY (Nominal)	1.75 (10^{13}) BTU/YR (135 Ton/Hr) ($ 000)	5.85 (10^{13}) BTU/YR (450 Ton/Hr) ($ 000)
Raw Coal Storage & Handling	5,589	10,750
Communition	11,160	36,005
Separation & Mineral Matter Disposal	3,520	9,668
Heat Recovery	3,531	9,720
Water Conditioning Slurrying CWS Storage	6,701	12,176
Buildings, Lab & External Fueling Depots	7,906	22,027
SubTotal	38,407	100,346
Indirect (25%) Contingency (15%)	15,363	40,138
In-Process Material Inventory	1,526	5,085
Grand Total	55,296	145,569

Coal Water Slurry Fuel Plant Capital Costs

Table I.C.8

Other Possible Capital Costs

For the non-engine maintenance requirements (cabs, platforms, motors, generators, running gear, piping and wiring), there will be insignificant capital investment needs, because these parts of the locomotive are similar to present oil fired diesel.

For a coal fired diesel locomotive, the engine maintenance changes are relatively insignificant and, therefore, there will be little or no capital investments required for maintenance. (It is assumed that the railroads will continue to maintain the engine as they do for the present oil diesel.)

For the other locomotive alternatives, it is assumed that the major maintenance of the turbines will not be by the

I. RESULTS

C. Railroads' Financial Expectations

4. Incremental Infrastructure and Capital Costs

railroads, but rather by the turbine manufacturer, and this expense is covered in the yearly maintenance costs. Thus, there is no investment required for turbine maintenance. Similarly, major repair of boilers and heat recovery steam generators are assumed to be done by the manufacturer or non-railroad maintenance specialists.

Classified ROM Coal Fuel Capital Costs

For the steam turbine and gasifier gas turbine alternatives, new fueling station handling ROM coal and water rather than diesel fuel will be required. This includes storage silos, conveyors, etc. A railroad will require at least two fueling stations (one on each end of the line) for a cost of $2.65 million, which will handle up to 134 locomotives. Additional locomotives will require more investment, so that the total investment is estimated as:

0 to 134 locomotives	-	$2.64 million
134 to 200 locomotives	-	$3.96 million
200 to 267 locomotives	-	$5.28 million

Capital Costs to Cover "Unavailability"

Locomotive reliability affects locomotive availability as well as maintenance costs. Less reliable locomotives are less available and so additional monies must be invested in more locomotives for any given amount of work. Since the required fleet size will be determined by the number of oil fired diesels presently used whose availability is 92.9%, the additional capital investment required is determined by,

$$\left(\frac{NcHc}{3800}\right)\left(\frac{92.9 - Ac}{92.9}\right)\left(Pd\right) = \text{Investment for availability}$$

where, Nc = number of coal fired locomotives
Hc = horsepower per coal fired locomotive
Ac = availability of coal fired locomotive (%)
Pd = current price of oil fired diesel ($1,325,000)

which is summarized below (Table I.C.9).

I. RESULTS

C. Railroads' Financial Expectations

4. Incremental Infrastructure and Capital Costs

Locomotive Prime Mover Technology	HP for Traction	No. of Powered Axles	Reliability in F/LY	Availability %	Per Locomotive Additional Investment for Availability (000'$)
Standard, General Electric Oil Diesel	3800	6	3.090	92.0	---
CWS Burning Diesel	3800	6	3.376	92.5	0
CWS Burning G.T.	5900	8	3.091	92.9	0
CWS Burning G.T. with Steam Injection	8000	12	4.641	85.2	231
ROM Coal G.T. with Gasifier	8000	12	5.528	66.0	808
Steam Turbine with Fluidized Bed Boiler	8000	12	7.913	78.1	444

Comparison of Availability, Reliability and Investment Required for Coal Burning Locomotives

Table I.C.9

5. Fleet Size and Fuel Consumption

(See Sec. VII for further details)

The locomotive fleet size and total fuel consumption savings which will offset the capital investment must be determined. This determination is predicated upon the following precepts:

a) The highest mileage/year locomotives generally:

- . are the newest and most efficient
- . have the lowest average maintenance
- . are the highest horsepower

As older locomotives tend to have lower horsepower and higher maintenance per mile, they are usually assigned to lower mileage duty. Thus, it is possible to rank locomotives by descending mileage using available data and ascertain the following:

Western Railroad:

- . Top 10% of locomotives burn 17% of total fuel
- . Top 33.3% of locomotives burn 50% of total fuel
- . Top 66.6% of locomotives burn 90% of total fuel

I. RESULTS

C. Railroads' Financial Expectations

5. Fleet Size and Fuel Consumption (continued)

and,

Eastern Railroad:

- Top 10% of locomotives burn 24% of total fuel
- Top 33% of locomotives burn 59% of total fuel

Further examination of the data indicates that the top 2/3 of the western locomotive fleet and the top 1/3 of the eastern locomotive fleet have more than 3000 HP. Locomotives less than 3000 HP are not powerful enough or utilized enough (or both) to burn enough fuel to warrant the additional incremental capital investment required to replace them with coal fired locomotives. This conclusion is intuitively apparent and has been assumed, and it was born out by the analysis.

The potential oil fired locomotive fleet to be replaced and the corresponding fuel consumption scenario is estimated as shown below (Table I.C.10).

Railroad	Potential Fleet (Units)	DF2 Fuel Consumed (Gal Per Loco)
Conrail	492	272,000
NS	565	304,000
CSX	883	309,000
BN	1242	358,300
UP	1280	307,660
ATSF & SP	1606	281,700
Total	6068	

Potential Locomotive Market
Represented By Today's 3000 HP & Up
Oil Fired Locomotive Fleet

Table I.C.10

b) Average consist HP is expected to be between 10,000 and 12,000 HP. Thus, greatest application for a locomotive will be those with 4000 to 6000 HP, because multiples of this will result in maximum utilization of power. Locomotive alternatives with 8000 HP are less flexible and less useful and will replace a smaller portion of the oil fired

I. RESULTS

C. Railroads' Financial Expectations

5. Fleet Size and Fuel Consumption

locomotive fleet. Approximately 1/3 of the total ton miles is handled by trains of around 16,000 HP* and the 8000 HP coal fired units could be best used in this dedicated service.

c) The reliability of the locomotive affects maintenance cost and availability, and these costs have been accounted for in the maintenance costs and additional investment for lack of availability. Poor reliability also lessens the attractiveness of the locomotive because of the effects on delivery and overall railroad productivity. It is assumed that the actual potential market must be adjusted proportionally by reliability.

The potential market for each of the locomotive alternatives replacing present locomotives greater than 3000 HP is shown below (Table I.C.11).

	Present Oil Fired Diesel			3800 HP Coal Fired Diesel		5900 HP Gas Turbine Simple Cycle		8000 HP Units			
	No. Units	HP (ave)	DF2/ Loco (000's)	No. Units	DF2 Equiv /Loco	No. Units	DF2 Equiv /Loco	Gas Turbine w/Steam No. Units	Gasifier Gas Turbine No. Units	Steam Turbine No. Units	DF2 Equiv Gal/Loc
Conrail	589	3178	227	492	272	317	422	53	45	31	664
Norfolk Southern	673	3189	255	565	304	364	472	61	51	35	761
CSX	1073	3128	254	883	309	569	480	95	80	56	804
BN	1661	3041	287	1242	358	800	556	133	113	78	882
Un Pac & Mo Pac	1580	3078	249	1280	307	824	478	137	116	80	713
Santa Fe & So Pac	1863	3279	243	1606	282	1034	437	172	146	101	636
Total	7329			6068		3908		652	551	381	

Probable Market for Coal Burning Locomotives
Versus Equivalent DF2 Fuel Burned
Table I.C.11

I. RESULTS

C. Railroads' Financial Expectations

6. Discounted Cash Rate of Return (DCRR)

One of the prime objectives of this Coal Burning Locomotive Study has been to determine the incremental value to the railroads for the fuel savings obtainable from burning coal as a locomotive fuel. The study has employed the accepted technique of DCRR analysis as the means to determining the various coal burning technologies value to the railroads in the form of how much more they should be willing to pay versus a standard oil burning locomotive. The DCRR allows the railroad's investment in both increased locomotive price and new supporting capital structures to be offset by net expense savings (fuel and maintenance) at specified rates of return (15% and 20%). The following assumptions were used in the calculation:

a) The railroad has decided to buy locomotives.

b) The total fleet will be changed out over 10 years (10% per year).

c) Locomotive life = 15 years, with no salvage value.

d) . CWS plant investments in 1st and 3rd year for 1st plant and 6th and 8th year for 2nd plant for CWS burning loco options.

. Classified ROM coal refueling station investments for gasifier fed G.T. and steam turbine options.

e) 5-year accelerated depreciation.

f) 46% corporate tax with 10% tax investment credit.

g) The economics of what replaces the coal burning locomotive after its 15-year life does not affect this study.

Figures I.C.12 and I.C.13 summarize the results of the railroad by railroad analysis.

Note: Because the analysis is based on "incremental" costs and investments, some confusion may arise on what "total" price would a railroad have to pay for a coal burning locomotive. An example of how this "total" price can be estimated may help. Example, a 5900 HP DFGT locomotive:

. Assume the selling price of today's 3800 HP OFD loco is $1,325,000.

I. RESULTS

C. Railroads' Financial Expectations

6. Discounted Cash Rate of Return (DCRR) (continued)

- Base price is 5900 HP worth of 3800 HP OFD locomotives or

$$\frac{5900}{3800} \cdot (\$1,325,000) = \$2,057,000$$

- Add to the base the incremental loco sell price from Table I.C.11 for NS @ 15% DCRR; selling price estimate $2,057,000 + 497,600 = $2,554,600.

COAL BURNING LOCOMOTIVE STUDY

3800 HP COAL FIRED DIESEL

		PER LOCO YEAR		DELTA EXPENSES PER LOCO YEAR $(000)			CAPITAL INVESTMENT $(000)		LOCO SELL PRICE INCREASE OVER 1.00 3800 H.P. DFD'S	
RR	CASE FLEET	GAL DF2 FUEL	BTU 10^10	FUEL SAVINGS	MAINT. INCR.	NET SAVINGS	FUEL FACILITIES	LOCO AVAIL	$(000) @20% DCRR	$(000) @15% DCRR
SF	1606	281.7	3.9	92.2	-22.8	69.4	175937	0	229.1	327.9
BN	1242	358.3	4.9	111.9	-22.2	89.7	173630	0	298.7	426.3
CR	492	272.0	3.7	89.7	-22.9	66.8	66398	0	184.3	281.0
CSX	883	309.0	4.3	99.2	-22.6	76.6	117399	0	238.3	348.1
NS	565	304.2	4.2	98.0	-22.7	75.3	81114	0	218.0	326.7
UP	1280	307.7	4.2	98.9	-22.6	76.3	157471	0	249.1	357.7
TOT	6068									

5900 HP DIRECT COAL BURNING TURBINE-GE-27

		PER LOCO YEAR		DELTA EXPENSES PER LOCO YEAR $(000)			CAPITAL INVESTMENT $(000)		LOCO SELL PRICE INCREASE OVER 1.55 3800 H.P. DFD'S	
RR	CASE FLEET	GAL DF2 FUEL	BTU 10^10	FUEL SAVINGS	MAINT. INCR.	NET SAVINGS	FUEL FACILITIES	LOCO AVAIL	$(000) @20% DCRR	$(000) @15% DCRR
SF	1034	437.4	8.9	130.0	-4.5	125.4	240304	0	372.4	532.9
BN	800	556.3	11.3	154.5	-13.2	141.2	237153	0	376.8	581.9
CR	317	422.3	8.6	126.9	-3.4	123.4	90690	0	295.5	476.2
CSX	569	479.8	9.8	138.7	-7.6	131.1	160350	0	340.9	531.6
NS	364	472.3	9.6	137.2	-7.1	130.1	110790	0	306.7	497.6
UP	824	477.7	9.7	138.3	-7.5	130.8	215082	0	366.1	555.2
TOT	3908									

8000 HP GE-27 WITH STEAM INJECTION

		PER LOCO YEAR		DELTA EXPENSES PER LOCO YEAR $(000)			CAPITAL INVESTMENT $(000)		LOCO SELL PRICE INCREASE OVER 2.11 3800 H.P. DFD'S	
RR	CASE FLEET	GAL DF2 FUEL	BTU 10^10	FUEL SAVINGS	MAINT. INCR.	NET SAVINGS	FUEL FACILITIES	LOCO AVAIL	$(000) @20% DCRR	$(000) @15% DCRR
SF	172	636.2	10.9	242.7	-72.7	170.1	67368	39930.0	178.6	356.4
BN	133	881.9	15.1	314.1	-96.0	218.1	71876	30910.0	255.7	576.6
CR	53	663.8	11.4	250.7	-75.3	175.4	27010	12210.0	56.4	319.6
CSX	95	804.2	13.8	291.5	-88.6	202.9	50440	22000.0	181.2	481.3
NS	61	761.1	13.0	279.0	-84.5	194.5	33772	14080.0	79.5	375.5
UP	137	713.1	12.2	265.0	-80.0	185.1	61498	31790.0	178.8	452.9
TOT	652									

Summary of Economic Analysis of CWS Burning Locomotives
Fig. I.C.12

COAL BURNING LOCOMOTIVE STUDY

8000 HP GASIFIER FED GE-27

		PER LOCO YEAR		DELTA EXPENSES PER LOCO YEAR $(000)			CAPITAL INVESTMENT $(000)		LOCO SELL PRICE INCREASE OVER 2.11 3800 H.P. OFD'S	
RR	CASE FLEET	GAL DF2 FUEL	BTU 10^10	FUEL SAVINGS	MAINT. INCR.	NET SAVINGS	FUEL FACILITIES	LOCO AVAIL	$(000) @20% DCRR	$(000) @15% DCRR
SF	146	636.2	13.7	243.1	-168.9	74.2	3954	117888.0	*	-356.6
BN	113	881.9	19.1	390.0	-200.6	189.4	2636	91008.0	138.5	398.2
CR	45	663.8	14.3	259.6	-172.5	87.1	2636	36096.0	*	-339.1
CSI	80	804.2	17.4	343.5	-190.6	153.0	2636	64896.0	*	140.8
NS	51	761.1	16.4	317.7	-185.0	132.7	2636	41472.0	*	-26.5
UP	116	713.1	15.4	289.0	-178.8	110.2	2636	93696.0	*	-122.1
TOT	551									

8000 HP FLUID BED-STEAM TURBINE

		PER LOCO YEAR		DELTA EXPENSES PER LOCO YEAR $(000)			CAPITAL INVESTMENT $(000)		LOCO SELL PRICE INCREASE OVER 2.11 3800 H.P. OFD'S	
RR	CASE FLEET	GAL DF2 FUEL	BTU 10^10	FUEL SAVINGS	MAINT. INCR.	NET SAVINGS	FUEL FACILITIES	LOCO AVAIL	$(000) @20% DCRR	$(000) @15% DCRR
SF	101	636.2	20.6	197.5	-144.8	52.7	2636	44732.0	*	-142.5
BN	78	881.9	28.6	387.6	-155.6	232.0	2636	34604.0	705.7	1025.1
CR	31	663.8	21.5	218.8	-146.0	72.8	2636	13715.0	*	-118.2
CSI	56	804.2	26.1	327.5	-152.2	175.3	2636	24687.0	378.4	626.1
NS	36	761.1	24.7	294.1	-150.3	143.8	2636	15825.0	*	370.6
UP	80	713.1	23.1	257.0	-148.2	108.8	2636	35659.0	*	214.1
TOT	381									

* NOT CALCULATED-TOO LOW TO CONSIDER

Summary of Economic Analysis of
Classified ROM Coal Burning Locomotives

Fig. I.C.13

I. RESULTS

D. Manufacturer's Expectations

Both the 8000 HP steam turbine locomotive and the 8000 HP gasifier gas turbine locomotives are larger and more complex than the present day oil fired diesel. Figure I.C.13 indicates that no railroad could realize a 20% DCRR on an 8000 HP option unless the price was very near (or below) the equivalent oil fired diesel. Such relatively low selling prices will not interest a locomotive manufacturer to build the technology.

If only 15% DCRR is desired, then the Burlington-Northern Railroad should offer the greatest opportunity to the manufacturer, with incremental prices of $398,000 ($189,000 at 3800 HP) for the gasifier and $1,025,000 ($486,000 at 3800 HP) for the steam turbine. But a review of the potential costs associated with producing these locomotives (proprietary information) and at limited financial acceptance by our customers, reveals that this is not attractive business for a locomotive manufacturer.

Similarly, the estimated cost of producing a gas turbine with steam injection locomotive is too high relatively to the potential locomotive selling price, so that it too is unattractive to the locomotive manufacturer.

The projected costs of the coal fired diesel indicate that it is an attractive business worth further pursuit.

The simple cycle gas turbine locomotive which is predicated on the highly efficient, low cost projections of the GE27 turbine is marginally attractive, and would be pursued only as an alternative to the coal fired diesel locomotive.

I. RESULTS

E. Summary

Table I.E.1 summarizes the technical and economic data for each of the locomotive alternatives. The method used in the economic analysis renders each alternative equally economically attractive to the railroads. Thus, an incremental locomotive price adder (or subtractor) is calculated for each alternative and it is then up to the locomotive manufacturer to compare the incremental selling price to incremental cost to produce the alternative.

Only the coal slurry fired diesel and the coal slurry fired simple cycle gas turbine look attractive to the manufacturer. further, the gas turbine is only marginally attractive; i.e., railroads would have to accept a DCRR of less than 15% for it to be attractive to the manufacturer. The simple cycle gas turbine should continue to be developed as the fall-back alternative to the diesel, should technical development difficulties arise. Should the price of diesel fuel rise, the simple cycle turbine's attractiveness will gain relative to the coal diesel alternative. This is due to the assumption as to the need for DF2 pilot injection for the diesel and not for the turbine which remains to be proven by development.

Coal Fired Diesel Locomotive

The coal fired diesel engine tests conducted as part of this study have shown that a coal water slurry fuel can in fact be burnt in the diesel engine even without pilot injection under certain conditions and with thermal efficiency comparable to an oil fired diesel. Laboratory injection schemes have been developed and have led the way to development of prototype production hardware. The wear and oil contamination problems have not been addressed, but the new ceramic materials offer promise for a solution.

A locomotive using a coal slurry fired diesel engine is not greatly different than the present oil engine locomotive, and so that changes to the railroad infrastructure would be in the operation of plants to process the coal-slurry fuel. Such a locomotive would be dispatched in the same fashion as today's oil fired locomotives with 3800 HP.

The total emissions estimate is slightly less than an oil diesel, but higher in SOx and CO and particulate emissions, and lower in NOx.

Coal Fired Simple Cycle Gas Turbine Locomotive

The coal fired simple cycle gas turbine locomotive actually has greater net savings than does the diesel, but requires a relatively higher total investment. Combustion testing of this alternative has revealed considerably less deposition than would have been expected as a result of heavy fuel tests. This is very encouraging. However, as of this time the deposits appear to be harder than petroleum deposits and may be more difficult to remove. More development is needed. There appears to be little or no erosion as the agglomerated

COAL BURNING LOCOMOTIVE STUDY SUMMARY

LOCOMOTIVE ALTERNATIVE	OIL-FIRED DIESEL	COAL-FIRED DIESEL	GAS TURBINE SIMPLE CYCLE	GAS TURBINE W/ STEAM INJECTION	GASIFIER GAS TURBINE	STEAM TURBINE
NO. UNITS - TOTAL WEIGHT	1 - 420,000#	1 - 420,000#	2 - 823,000#	3 - 1,103,000#	3 - 1,091,000#	3 - 1,191,960#
HP - OVERALL LENGTH (FEET)	3800 - 70.6	3800 - 76.6	5900 - 122.6	8000 - 181.3	8000 - 200.5	8000 - 253.0
FUEL USED	DF2	CWS W/DF2 PILOT	CWS	CWS	CLASSIFIED ROM	CLASSIFIED ROM
DUTY CYCLE THERMAL EFFICIENCY	39.2%	36.2%	28.4%	34.4%	25.6%	18.1%
EMISSIONS ESTIMATE (G/HP-HR)						
CO	1.8	3.5 TO 4	0.8	0.7	0.05	10.2
1/2% S IN DF2 — HC	0.6	0.6 TO 0.1	0.33	0.3	0.05	--
1% S IN CWS — SOx	1.5	3.0	3.9	3.2		3.1**
2% S IN ROM* — NOx	10.7	5 TO 6	3.8	3.1	2.5	3.5
PARTICULATES	0.3	0.7 TO 2.0	0.6	0.6	1.3	0.14
TOTAL	14.9	12.26 TO 13.1	9.43	7.9	3.9	16.94
TOTAL RR FLEET SIZE (# OF LOCOS)	6068	6068	3908	652	551	381
TOTAL FUEL SAVINGS/YR (ALL RR'S)		$ 477(10^6)	$ 541(10^6)	$ 184(10^6)	$ 168.5(10^6)	$ 106.0(10^6)
TOTAL MAINT SAVINGS/YR (ALL RR'S)		-137(10^6)	- 26(10^6)	- 54(10^6)	-100.4(10^6)	- 57.1(10^6)
TOTAL NET SAVINGS/YR (ALL RR'S)		$ 340(10^6)	$ 525(10^6)	$ 130(10^6)	$ 68.1(10^6)	$ 48.9(10^6)
RELIABILITY (FAILURES/LOCO-YR)	3.09	3.38	3.09	4.64	5.49	7.91
AVAILABILITY (000'$)	92.9%	92.5% - $0	92.9% - $0	85.2% - $231	66.0% - $808	78.1% - $444
TOTAL SAVINGS OVER 25 YEARS		$5100($10^6$)	$7875($10^6$)	$1950($10^6$)	$1021($10^6$)	$733($10^6$)
TOTAL RR INVESTMENT (OVER 25 YRS)		$772($10^6$)	$1054($10^6$)	$461($10^6$)	$462($10^6$)	$185($10^6$)
TOTAL RR INVESTMENT (NON-LOCO) PER LOCO (000'$)		$127	$270	$707	$840	$486
INCREMENTAL SELL PRICE/LOCO (000'$)						
@ 3800 EQUIV HP (20% DCRR)		$184 TO $299	$190 TO $243	$ 26 TO $121	-------	-------
(15% DCRR)		$281 TO $426	$307 TO $375	$157 TO $273	$-169 TO $189	$ -67 TO $485
@ ACTUAL HP (20% DCRR)		$184 TO $299	$295 TO $377	$ 56 TO $256	-------	-------
(15% DCRR)		$281 TO $426	$476 TO $582	$320 TO $577	$-357 TO $398	$-142 TO $1025
ATTRACTIVENESS TO LOCO MANUFACTURER		GOOD	MARGINAL	UNACCEPTABLE	UNACCEPTABLE	UNACCEPTABLE
ISSUES		ENGINE DEVEL FUEL DEVEL	ENGINE DEVEL FUEL DEVEL ENGINE DERATION NEED FOR PILOT DF2 ENGINE EFF & COST	ENGINE DEVEL FUEL DEVEL NEED FOR PILOT DF2 ENGINE EFF & COST	GASIFIER DEVEL SCRUBBER REGEN "TIGHT" DESIGN	BOILER DEVEL "TIGHT" DESIGN

*WESTERN COAL
**(90% CAPTURE)

TABLE I.E.1

I. RESULTS

E. Summary

Coal Fired Simple Cycle Gas Turbine Locomotive (continued)

particles have a weak cenosphere structure which breaks up after combustion and follows the air stream. Although considerable development was expended in coal nozzle development, still the deposition testing required pilot injection of DF2, to achieve high combustion efficiency. Again, more development is needed. The economics are marginally favorable for this alternative and are predicated on the projected high efficiency and low cost of the GE27 gas turbine. Only prototype machines have been made and it is assumed that this development will happen under programs outside of a coal fired locomotive. Present production turbines such as GE's LM500 could be used to prove the feasibility of a coal fired turbine, but the efficiency and cost must be improved to the projected GE27 level to make the locomotive application economically viable.

The locomotive itself can be dispatched and used in much the same way as today's oil fired diesels. The 5900 HP unit of power is still relatively flexible and can be used for all mainline railroad applications.

The simple cycle gas turbine locomotive will experience deration at higher ambient temperatures.

It is anticipated the railroad maintenance infrastructure will change as engine overhaul and repair is eliminated. Engines are assumed to be returned to the manufacturer for this service.

Normal engine maintenance will be substantially less than the coal diesel alternative. The total exhaust emissions is estimated to be substantially less than oil diesel although higher in SOx and particulates.

8000 HP Coal Fired Locomotives

The three 8000 HP units, gas turbine with steam injection, gasifier gas turbine, and steam turbine, are all large, complex designs. Because of this, reliability and availability decrease along with an application flexibility decrease. So they have a smaller, more dedicated market and because of their poor availability, additional investment is needed in the form of more locomotive power (expressed in dollars in the analysis) to do the given job on a railroad.

The gas turbine with steam injection has the same engine and fuel development concerns as the simple cycle gas turbine alternative, except that additional steam injection at high ambient temperatures will probably eliminate the deration concern. Examination of the costs to build such a locomotive for the allowable selling price increase, however, would make it unacceptable to a locomotive manufacturer.

I. RESULTS

E. Summary

8000 HP Coal Fired Locomotives (continued)

The gasifier gas turbine will have no engine development worries, but the mobile gasifier is complex, large and heavy. The conceptual design is tight and maintenance may be very difficult. It is also dependent on sorbent pellet regeneration system development for sulfur removal. Although this alternative appears to generate the lowest emissions, it simply cannot be built to sell for the allowable increased selling price.

The steam turbine alternative is also a tight design. And in spite of the use of limestone, it has the highest total exhaust emissions (2% S in Western Coal). This results primarily from low temperature combustion and low thermal efficiency. The study shows that only one railroad, the Burlington-Northern, would burn sufficient amount of low cost western fuel, to be able to afford a locomotive selling price which would be attractive to the locomotive manufacturer. Even so, the DCRR for this railroad is only 15%. Such a small market, however, would probably not be sufficient to offset locomotive development cost which is not considered in this analysis.

F. Conclusions

A coal fired locomotive using coal water slurry and a diesel engine or a gas turbine merits further technical development. The diesel engine locomotive could save the nation's railroads $350 million/year in operating expense which represents 15% to 20% return of their investment. Coal slurry fuel development processes also looks promising. However, additional funding must be generated to cover the manufacturer's engine development costs, which are estimated to be about $40 million for the diesel engine only. Assuming the manufacturer would share in 1/2 the market of 6000 diesel locomotives, a simple analysis would indicate an additional locomotive cost of about $14,000 per locomotive would be required to cover the development cost.

However, the development funds are upfront money, and they represent a sizable risk to the locomotive manufacturer who is not assured of recouping this investment. Furthermore, given the tough current railroad business climate (caused by deregulated competition and low or no growth of traffic), the railroad industry will be hardpressed to risk scarce capital on long term development projects. Thus, the risks (and rewards) may have to be shared by all, and more federal government support may be needed if a coal-fired diesel-electric locomotive is to become a reality.

I. RESULTS

F. Conclusions (continued)

The coal fired locomotive should be economically attractive to both the railroads and the locomotive manufacturer provided that:

1) Technical developments for both engine and fuel which now look feasible can be truly achieved,

2) Development funding can be generated.

II. FUEL COST SAVINGS

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II. FUEL COST SAVINGS

A. Estimated Cost of Micronized Superclean Coal in Coal-Water Slurry with 50% Loading

1. Introduction

The superclean coal fuels needed to burn coal successfully in diesel engines are not commercially available today (February 1986). The precise degree of beneficiation needed to provide reliable, low maintenance operation of a diesel engine or gas turbine with environmentally acceptable emissions is an unknown as well. One cannot, therefore, put a precise number on the delivered cost of a suitable coal-water slurry fuel, in $/million BTU's.

It is known that a number of manufacturers are working on coal beneficiation processes because of the large market potential for coal-slurries as a petroleum substitute. Most of these efforts are aimed initially at a boiler or heater retrofit market where mineral levels of 1-3% can be tolerated. To reach these levels, the coal needs to be ground typically to 150 micron top particle sizes, which may result in 80% below 200 mesh (depends on raw coal mineral content).

The coal-water slurries described in most publications are of this type and may be referred to as "boiler grade" slurries. For direct combustion in diesel engines, however, coal particles must be much smaller and contain lower mineral levels in the order of 0.2% by weight. Coal-water slurries of this type are sometimes referred to as "engine grade", and they may have a top particle size as low as 20 microns with a mean size of 3-5 microns.

The preparation of superclean, "engine grade" slurries is even more developmental than that of "boiler grade" slurries. However, some manufacturers, notably Otisca Industries, Ltd. of Syracuse, New York have achieved small scale success in reaching particle sizes necessary for good combustion and in reaching mineral levels below 1% by weight. Test fuels are available for engine testing, but final production economics are not totally verified at this time.

Very important variables in the delivered fuel costs are raw coal cost at the mine site and transportation costs. These may vary widely depending on location of the operating railroad, location of a fuel processing facility, and the location of fueling stations on the railroad.

II. FUEL COST SAVINGS

A. Estimated Cost of Micronized Superclean Coal in Coal-Water Slurry with 50% Loading

2. Methodology

Because of the many variables, it is considered necessary to consider costs on a railroad by railroad basis. This can be accomplished with reasonable accuracy by the following technique:

2.1 Examine the railroad system in question and determine most likely coal sources. A few trials show that the impact of transportation costs are appreciable and that it will not usually pay to haul coal additional hundreds of miles to achieve a somewhat lower coal price. (See Fig. II.A.3.0).

2.2 Determine the location of fueling stations such that no part of the system is more than 400-500 miles from a fueling station. (The locomotives will be designed for a range of 1000 miles or more.) See Figs. II.A.3.1 thru 3.6.

2.3 Determine which fueling station sites would also be likely choices for location of a coal processing plant. This should be done to minimize transportation costs, both for raw coal and coal-water slurry (final product). Figs. II.A.3.1 thru 3.6.

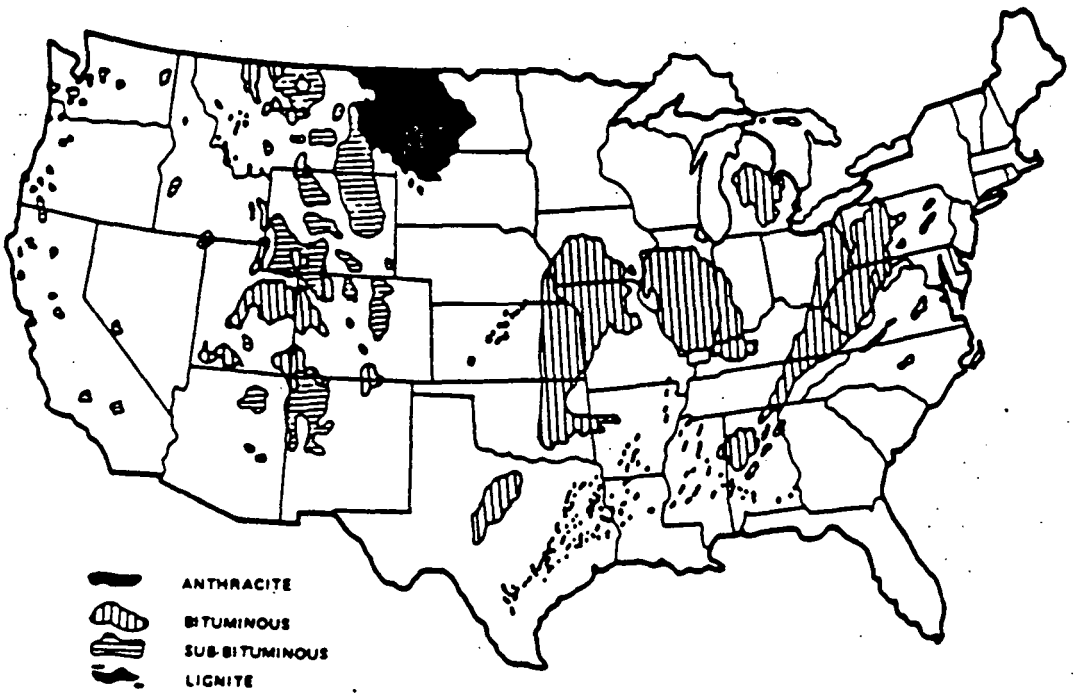
2.3.1 A summary of Railroad, Fuel Processing Plant & Fueling Center Locations and Distances are included in Table II.A.3-1.

2.4 Determine the likely processing cost to produce "engine grade" micronized coal water slurries from both Eastern and Western coals, independent of capital costs, raw coal costs and transportation costs. See Section II.A.5 of this report for the derivation of this processing cost.

2.5 Based on typical coal costs, transportation costs, and processing costs, an average fuel price per million BTU's can thus be calculated. These numbers, in $\$/10^6$ BTU's will then be used in the economic study to generate the fuel savings which can be achieved by a coal burning locomotive. Table II.A.3-2 provides a summary of results by railroad.

2.6 Based on the above methodology, a typical scenario is outlined. Two coal processing plant locations were selected for each railroad system, with the exception of Conrail.

LOCATIONS OF COAL DEPOSITS IN THE UNITED STATES



SOURCE: DOE/EDP-0012

FIGURE II.A.3.0

Locations of fields in which the many ranks of coals are found in the United States are shown on the above map. Note that, in general, the higher rank or oldest coals (anthracite) are found in the eastern part of the country and that the rank decreases going from east to west.

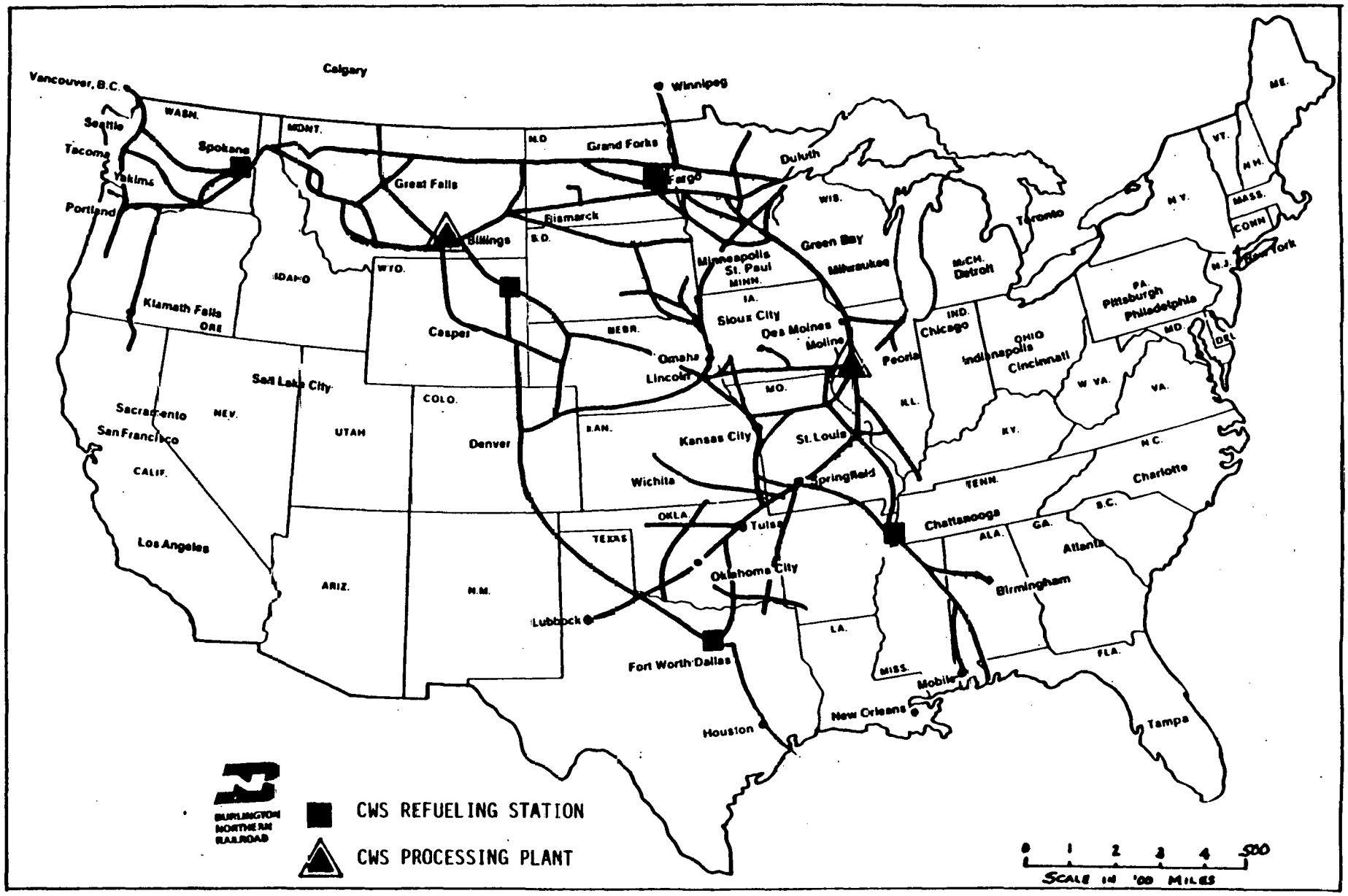
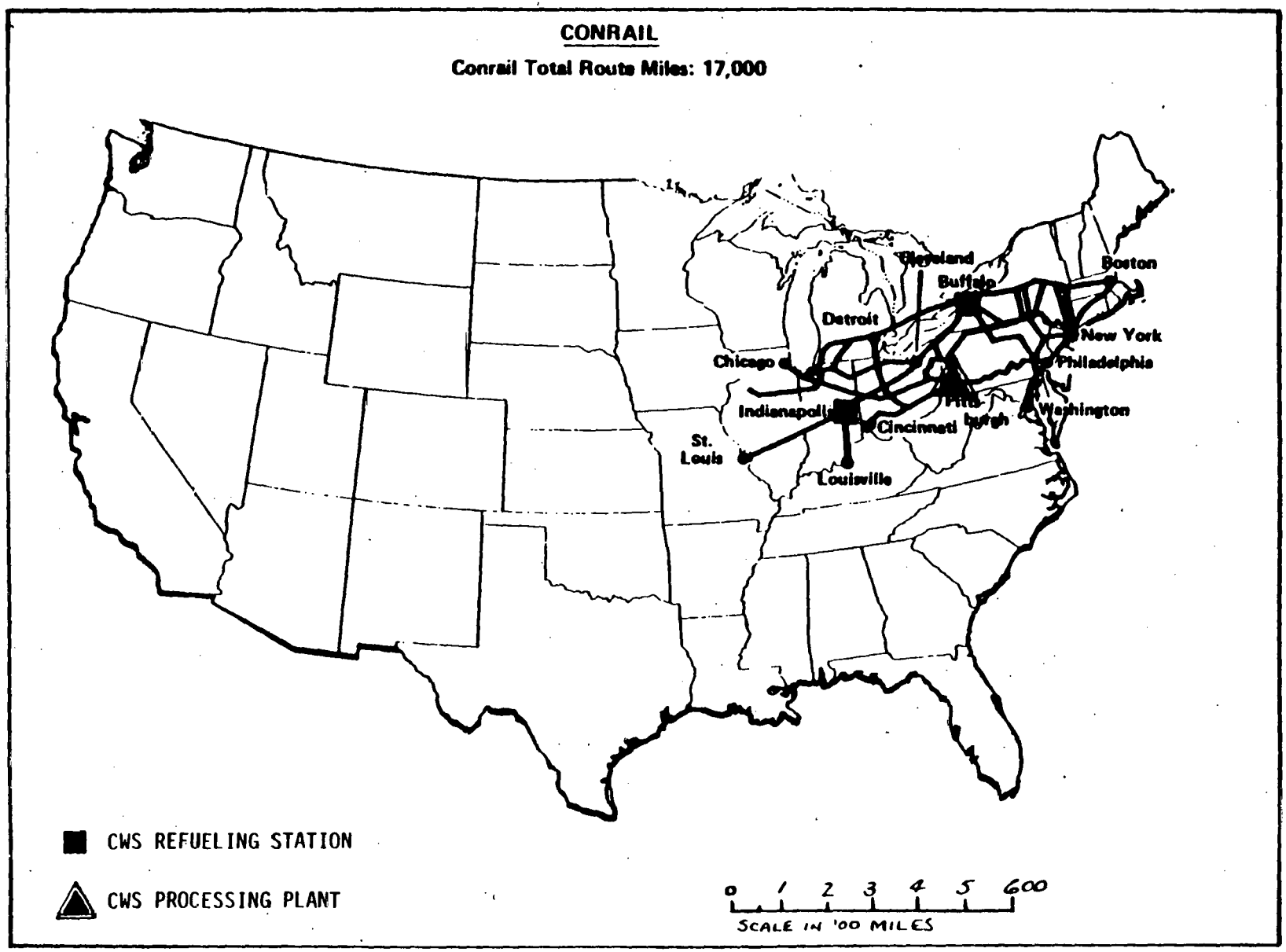
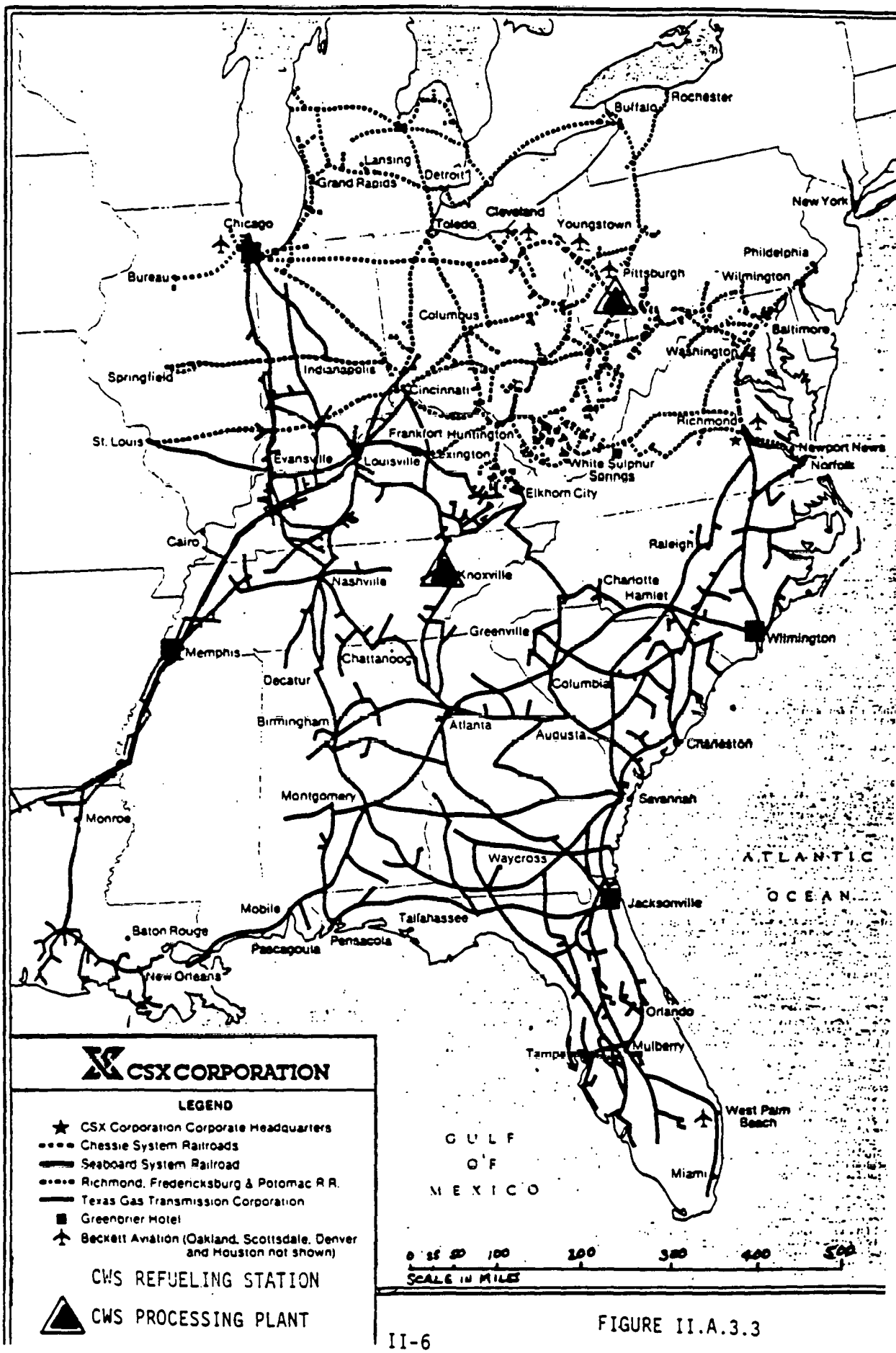


FIGURE II.A.3.1



SOURCE: DEAN WITLER RAILROAD QUARTERLY - JUNE 1985

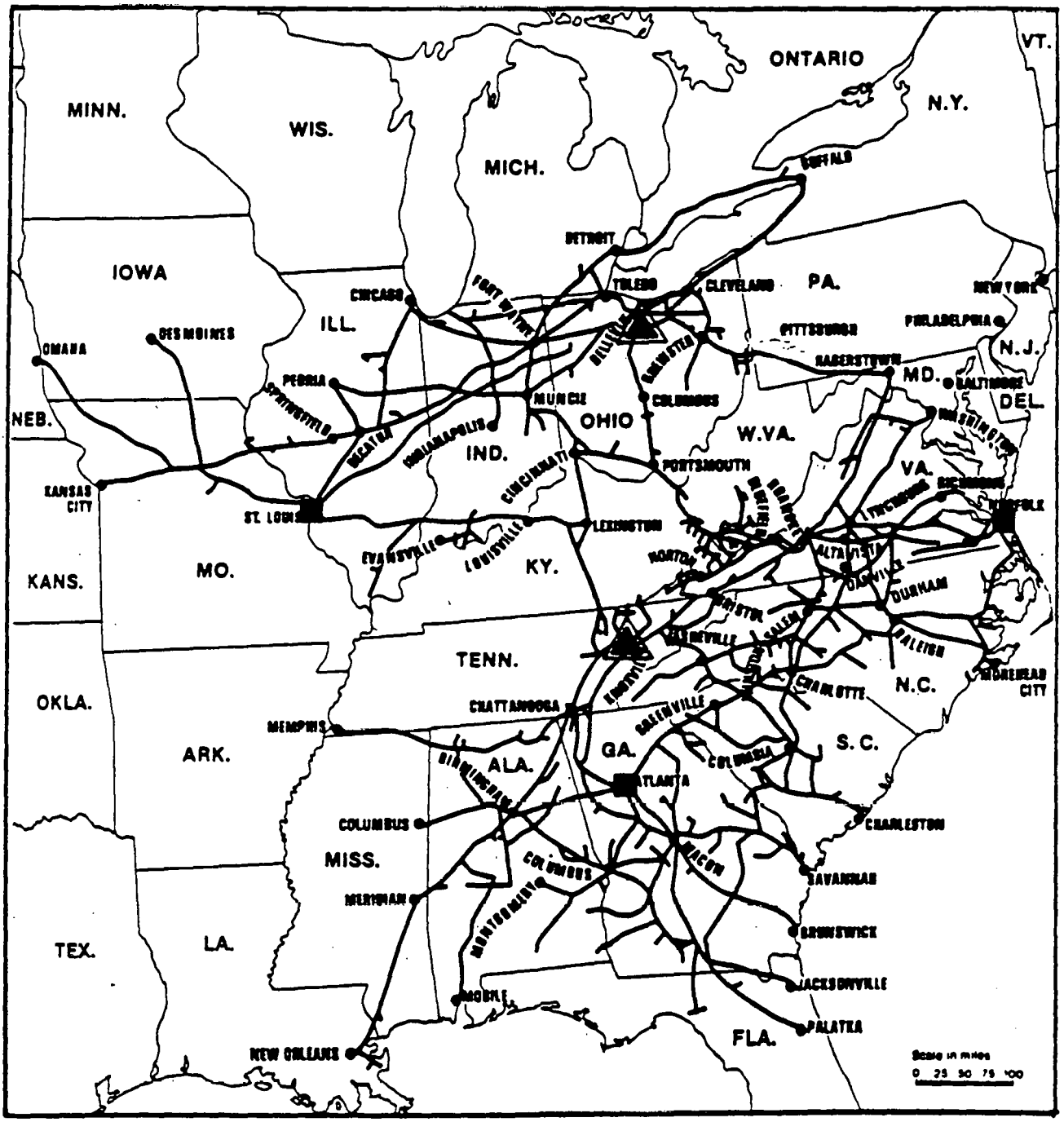
FIGURE II.A.3.2



SOURCE: MOODY'S TRANSPORTATION MANUAL - 1984

FIGURE II.A.3.3

SOURCE: MOODY'S TRANSPORTATION MANUAL - 1984



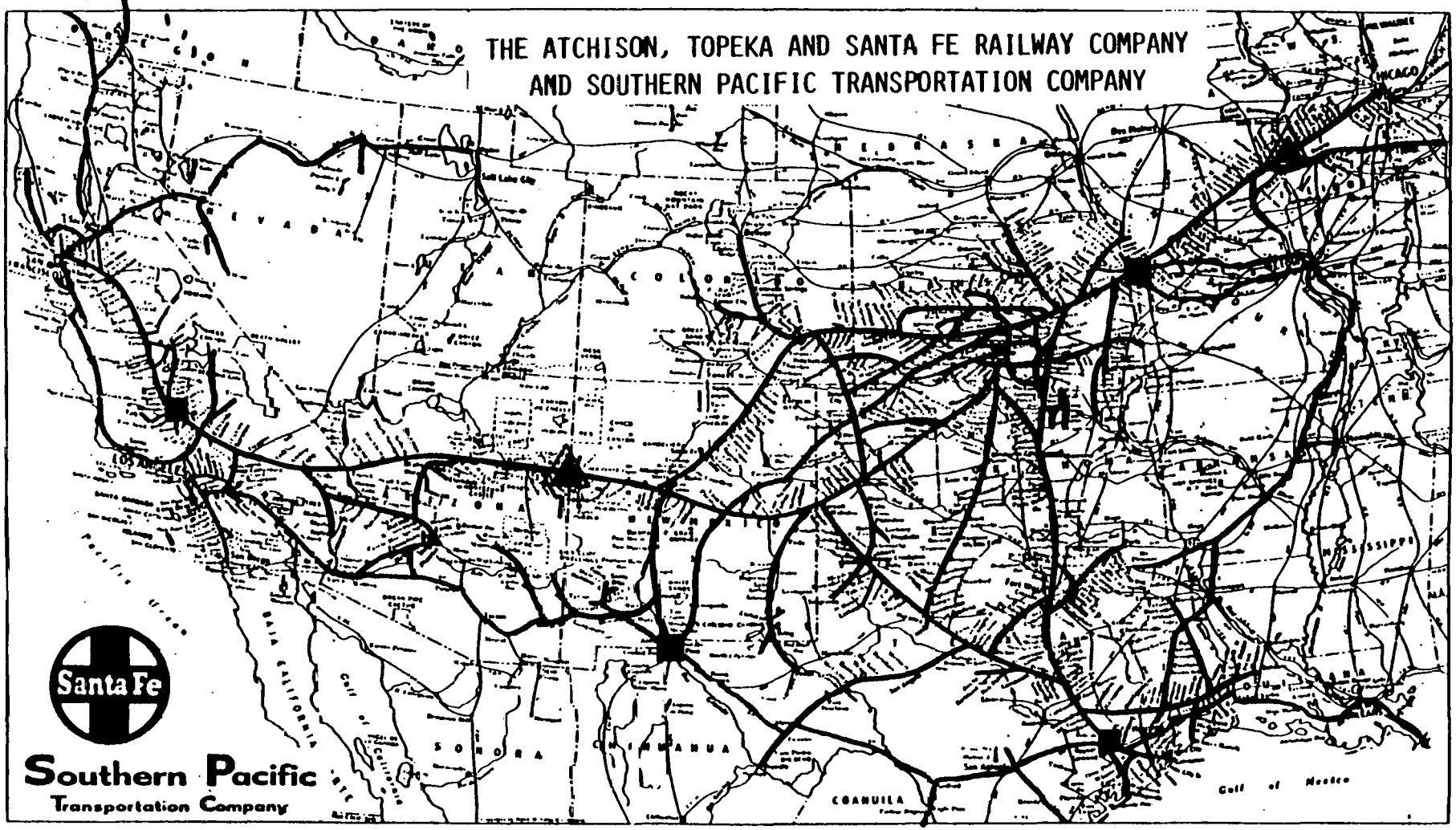
NORFOLK SOUTHERN

■ CWS REFUELING STATION

▲ CWS PROCESSING PLANT

FIGURE II.A.3.4

REFERENCE: MOODY'S TRANSPORTATION MANUAL - 1984



CWS REFUELING STATION

0 100 200 300 400 500

SCALE IN MILES

UNION PACIFIC RAILROAD
MISSOURI PACIFIC RAILROAD

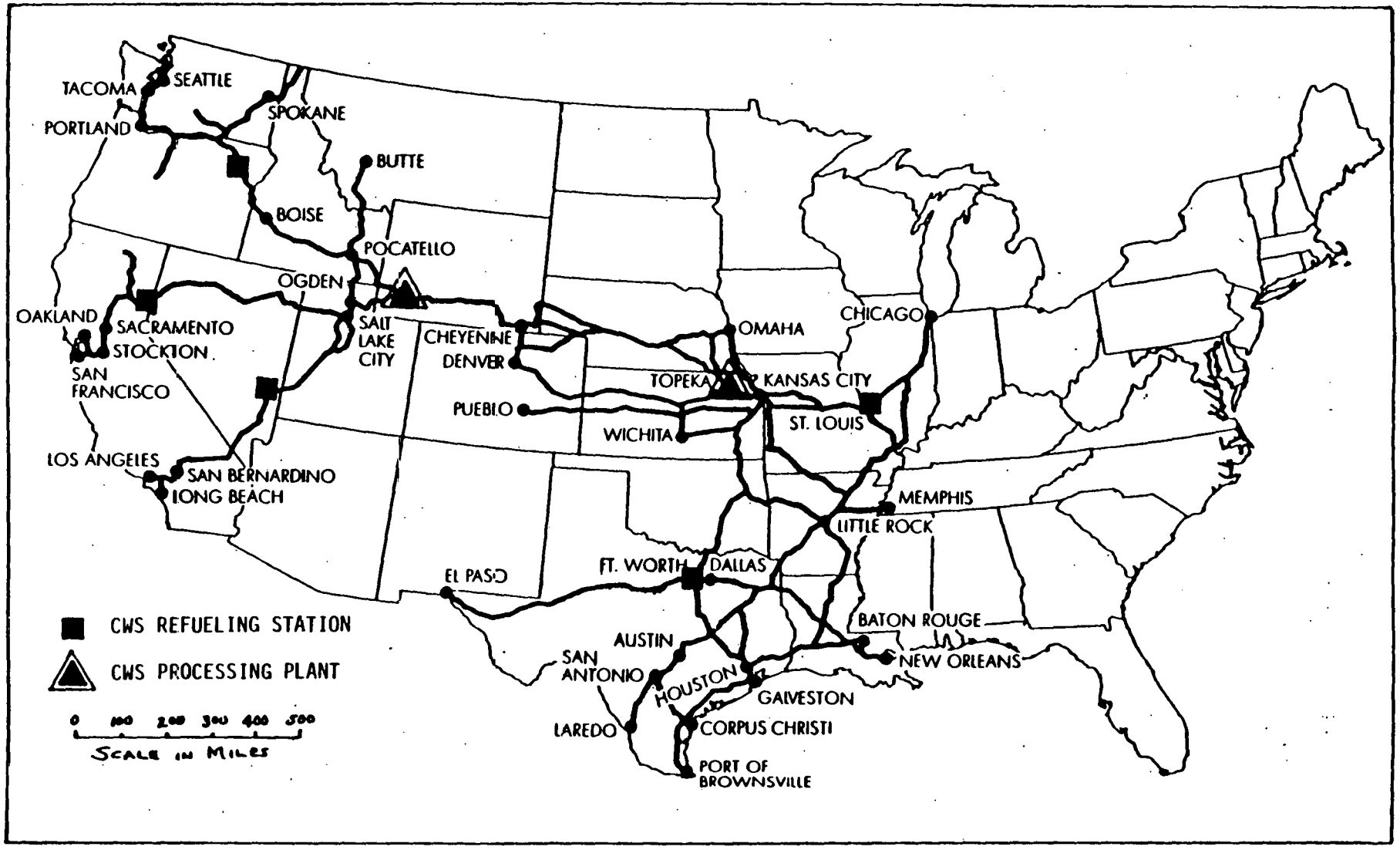


FIGURE II.A.3.6

TABLE II A 3-1

SUMMARY OF RR LOCATIONS,FUEL PROCESSING PLANTS AND FUELING CENTERS

RAILROAD	COAL SOURCE LOCATION	PROCESSING PLANT LOCATION	DISTANCE CL.TO PLNT MILES	FUELING STATION LOCATION	DISTANCE SLURRY-HL MILES	AVERAGE SLURRY-HL MILES
BN	WYOMING	GALESBURG,IL	900	GALESBURG	0	
				MEMPHIS	440	
				FT. WORTH	804	415
	WYOMING	BILLINGS,MON	188	BILLINGS	0	
				SPOKANE, WA	500	
				GOLDEN, CO	510	337
CONRAIL	PENNSYLVANIA	PITTSBRGH,PA	100	PITTSBRGH,PA	0	
				BUFFALO, NY	220	
				INDNPLS, IND	280	167
CSX	KENTUCKY	KNOXVILLE,TE	150	KNOXVILLE,TE	0	
				JCKSNVLLE,FL	520	
				WILMNGTON,NC	592	
				MEMPHIS,TE	520	408
	PENNSYLVANIA	PITTSBRGH,PA	100	PITTSBRGH,PA	0	
				CHICAGO, ILL	500	250
NS	KENTUCKY	KNOXVILLE,TE	150	KNOXVILLE,TE	0	
				ATLANTA, GA	200	
				ST.LOUIS, MO	440	213
	OHIO	BELLEVIEW, OH	100	BELLEVIEW, OH	0	
				NORFOLK, VA	505	253
SP-ATSF	ARZ/NMEX BRDR	ARZ/NMEX BRD	0	ARZ/NMX BRDR	0	
				CADIZ, CA	569	
				EL PASO, TEX	488	352
	KENTUCKY	SPRINGFLD,IL	460	SPRINGFIELD	0	
				KANSAS CY,MO	284	
				HOUSTON, TEX	975	420
UP	WYOMING	TOPEKA,KA	700	TOPEKA, KA	0	
				ST.LOUIS, MO	280	
				FT.WORTH, TE	500	260
	WYOMING (GILLETTE)	GR.RIVER,WYO	550	GREEN RIVER,W	0	
				CALLENTE,NE	380	
				RENO JCT.,CA	600	327

TABLE II.A.3-2

SUMMARY OF FUEL COSTS BY RAILROAD

RAILROAD	HEAVY DUTY WESTERN	HEAVY DUTY EASTERN	AVE.COST/10^6BTU PROCESSING PLANT NO.1	AVE.COST/10^6BTU PROCESSING PLANT NO.2	SYSTEM AVE.COST $/10^6BTU
BN	X		3.938	2.550	3.244
CONRAIL		X	2.646		2.646
CSX		X	3.166	2.810	2.988
NS		X	2.780	2.816	2.80
ATSF/SP	X		2.742	3.466	3.10
UP	X		3.287	3.163	3.225

AVERAGE COSTS FOR WESTERN RAILROADS= 3.191

AVERAGE COSTS FOR EASTERN RAILROADS= 2.844

AVERAGE COSTS FOR ALL RAILROADS= 3.033

TABLE II.A.3.1-1

BN RAILROAD

#	ITEM	UNITS	GALESBURG ILL.	COST IN $/10^6BTU	BILLINGS MONT.	COST $/10^6
1	MOISTURE-FINAL PROD.	%	53%		53%	
2	COAL SOURCE	STATE	WYOMING		WYOMING	
3	RAW COAL H.HTG.VAL.	BTU/#	8500		8500	
4	RAW COAL COST	$/TON	11.00	0.65	11.00	0
5	YIELD	%	60%		60%	
6	TONS HLD./TONS PROD.		1.67		1.67	
7	TRANSPORTATION	MILES	900		188	
8	"	$/T-MI	0.0175		0.0175	
9	"	$/TON-ROM	15.75		3.29	
10	"	$/10^6 BTU		1.544		0.
11	PROCESSING COST	$/10^6 BTU		0.924		0.
12	MINUS CAP.COSTS					
13	PRODUCT COST	$/10^6 BTU		3.115		1.
14	SLURRY TRANSP.	MILES	415		337	
15		$/T-MI	0.0263		0.0263	
16		$/TON-SL.	10.91	0.822	8.86	0.
17		$/TON-CL.	21.83		17.73	
18	H.HTG.VALUE(SLURRY)	BTU/#	6635		6750	
19						
20	DELIVERED PROD.COST	$/10^6 BTU		3.938		2.

TABLE II.A.3.2-1

CONRAIL RAILROAD

#	ITEM	UNITS	PTTSBURGH PA.	COST IN $/10^6BTU
1	MOISTURE-FINAL PROD.	%	50	
2	COAL SOURCE	STATE	PA.	
3	RAW COAL H.HTG.VAL.	BTU/#	12000	
4	RAW COAL COST	$/TON	33.00	1.38
5	YIELD	%	85%	
6	TONS HLD./TONS PROD.		1.18	
7	TRANSPORTATION	MILES	100	
8	"	$/T-MI	0.0175	
9	"	$/TON-ROM	1.75	
10	"	$/10^6 BTU		0.086
11	PROCESSING COST	$/10^6 BTU		0.854
12	MINUS CAP.COSTS			
13	PRODUCT COST	$/10^6 BTU		2.315
14	SLURRY TRANSP.	MILES	167	
15		$/T-MI	0.0263	
16		$/TON-SL.	4.39	0.331
17		$/TON-CL.	8.78	
18	H.HTG.VALUE(SLURRY)	BTU/#	6635	
19				
20	DELIVERED PROD.COST	$/10^6 BTU		2.646

TABLE II.A.3.3-1

CSX RAILROAD

#	ITEM	UNITS	KNOXVILLE TENN.	COST IN $/10^6BTU	PTTSBURGH PA.	COST IN $/10^6B
1	MOISTURE-FINAL PROD.	%	50		50	
2	COAL SOURCE	STATE	KENTUCKY		PA.	
3	RAW COAL H.HTG.VAL.	BTU/#	12000		12000	
4	RAW COAL COST	$/TON	33.00	1.38	33.00	1.
5	YIELD	%	85%		85%	
6	TONS HLD./TONS PROD.		1.18		1.18	
7	TRANSPORTATION	MILES	150		100	
8	"	$/T-MI	0.0175		0.0175	
9	"	$/TON-ROM	2.63		1.75	
10	"	$/10^6 BTU		0.129		0.0
11	PROCESSING COST	$/10^6 BTU		0.854		0.8
12	MINUS CAP.COSTS					
13	PRODUCT COST	$/10^6 BTU		2.358		2.3
14	SLURRY TRANSP.	MILES	408		250	
15		$/T-MI	0.0263		0.0263	
16		$/TON-SL.	10.73	0.809	6.58	0.4
17		$/TON-CL.	21.46		13.15	
18	H.HTG.VALUE(SLURRY)	BTU/#	6635		6635	
19						
20	DELIVERED PROD.COST	$/10^6 BTU		3.166		2.8

TABLE II.A.3.4-1

NS RAILROAD

#	ITEM	UNITS	KNOXVILLE TENN.	COST IN $/10^6BTU	PTTSBURGH PA.	COST IN $/10^6BTU
1	MOISTURE-FINAL PROD.	%	50		50	
2	COAL SOURCE	STATE	KENTUCKY		PA.	
3	RAW COAL H.HTG.VAL.	BTU/#	12000		12000	
4	RAW COAL COST	$/TON	33.00	1.38	33.00	1.38
5	YIELD	%	85%		85%	
6	TONS HLD./TONS PROD.		1.18		1.18	
7	TRANSPORTATION	MILES	150		100	
8	"	$/T-MI	0.0175		0.0175	
9	"	$/TON-ROM	2.63		1.75	
10	"	$/10^6 BTU		0.129		0.086
11	PROCESSING COST	$/10^6 BTU		0.854		0.854
12	MINUS CAP.COSTS					
13	PRODUCT COST	$/10^6 BTU		2.358		2.315
14	SLURRY TRANSP.	MILES	213		253	
15		$/T-MI	0.0263		0.0263	
16		$/TON-SL.	5.60	0.422	6.65	0.501
17		$/TON-CL.	11.20		13.31	
18	H.HTG.VALUE(SLURRY)	BTU/#	6635		6635	
19						
20	DELIVERED PROD.COST	$/10^6 BTU		2.780		2.816

TABLE II.A.3.5-1

SP/ATSF RAILROAD

#	ITEM	UNITS	ARIZ/NMEX BORDER	COST IN $/10^6BTU	SPRINGFLD. ILL.	COST $/10^6
1	MOISTURE-FINAL PROD.	%	50		50	
2	COAL SOURCE	STATE	ARIZ/NMEX		KENTUCKY	
3	RAW COAL H.HTG.VAL.	BTU/#	8500		12000	
4	RAW COAL COST	$/TON	11.00	0.647	33.00	1.3
5	YIELD	%	60%		85%	
6	TONS HLD./TONS PROD.		1.67		1.18	
7	TRANSPORTATION	MILES	276		460	
8	"	$/T-MI	0.0175		0.0175	
9	"	$/TON-ROM	4.83		8.05	
10	"	$/10^6 BTU		0.474		0.3
11	PROCESSING COST	$/10^6 BTU		0.924		0.8
12	MINUS CAP.COSTS					
13	PRODUCT COST	$/10^6 BTU		2.045		2.4
14	SLURRY TRANSP.	MILES	352		425	
15		$/T-MI	0.0263		0.0263	
16		$/TON-SL.	9.26	0.698	11.18	0.8
17		$/TON-CL.	18.52		22.36	
18	H.HTG.VALUE(SLURRY)	BTU/#	6635		6635	
19						
20	DELIVERED PROD.COST	$/10^6 BTU		2.742		3.4

TABLE II.A.3.6-1

#	ITEM	UNITS	UP RAILROAD TOPEKA KANSAS	COST IN $/10^6BTU	GRN.RIVER WYO.	COST IN $/10^6BTU
1	MOISTURE-FINAL PROD.	%	50		50	
2	COAL SOURCE	STATE	WYOMING		WYOMING	
3	RAW COAL H.HTG.VAL.	BTU/#	8500		8500	
4	RAW COAL COST	$/TON	11.00	0.65	11.00	0.65
5	YIELD	%	60%		60%	
6	TONS HLD./TONS PROD.		1.67		1.67	
7	TRANSPORTATION	MILES	700		550	
8	"	$/T-MI	0.0175		0.0175	
9	"	$/TON-ROM	12.25		9.63	
10	"	$/10^6 BTU		1.201		0.944
11	PROCESSING COST	$/10^6 BTU		0.924		0.924
12	MINUS CAP.COSTS					
13	PRODUCT COST	$/10^6 BTU		2.772		2.515
14	SLURRY TRANSP.	MILES	260		327	
15		$/T-MI	0.0263		0.0263	
16		$/TON-SL.	6.84	0.515	8.60	0.648
17		$/TON-CL.	13.68		17.20	
18	H.HTG.VALUE(SLURRY)	BTU/#	6635		6635	
19						
20	DELIVERED PROD.COST	$/10^6 BTU		3.287		3.163

II. FUEL COST SAVINGS

A. Estimated Cost of Micronized Superclean Coal in Coal-Water Slurry with 50% Loading

2. Methodology (continued)

The best location for these plants will ultimately be determined by many factors such as land cost and availability, water availability, and other factors. For this study, the processing plant locations were selected on major lines of the railroads and with the idea of minimizing overall transportation costs.

If the railroad chooses to provide fuel at more locations, it should have little impact on the economics as slurry transportation ton-miles are not likely to be impacted appreciably (on the average).

It should be noted that a freight rate of $0.02/ton-mile has been used for the raw coal since this appears typical of long term contracts* presently in force for supplying coal to utilities or parts of shipment. The slurry transportation costs were determined to be $0.03 per ton-mile with the need to transport equal weights of water and coal accounted for. This value is close to the average costs of shipping all commodities by railroad.

Removing the railroads' profit on commercial shipping of coal provides a slight reduction in cost per ton-mile and represents a more reasonable basis for the fuel transportation costs. With a net income of 6.75% on sales, it was estimated that costs would be 0.875 x selling price. The numbers for coal and slurry transportation costs used in the study without railroad profit are 1.75¢/ton-mile for raw coal and 2.63¢/ton-mile for the slurry.

The processing cost of the fuels is shown as 92.4¢/million BTU's. This value is for Western coals and is slightly higher than Eastern coal (85.4¢/MBTU) because of differences in coal chemical and physical properties. Details supporting the processing costs are covered in Section II.A.6 of this report.

3. Calculations by Railroad

3.1 Burlington Northern

The total BN system covers a large portion of the west and mid-west. Whereas initial use of a coal burning locomotive is likely to take place along heavy coal hauling corridors

* FROM VARIOUS TRADE PUBLICATIONS

II. FUEL COST SAVINGS

A. Estimated Cost of Micronized Superclean Coal in Coal-Water Slurry with 50% Loading

3. Calculations by Railroad

3.1 Burlington Northern (continued)

to maximize savings, it is assumed that, eventually, coal burning locomotives would be distributed to all portions of the railroad. See BN system map (Fig. II.A.3.1.). It was determined through map inspection that coal processing plants be situated in Billings, Montana and Galesburg, Illinois.

The Billings, Montana plant would receive raw coal from Powder River Basin (Wyoming) mines and its slurry product would be used to fuel locomotives at Billings, Spokane, Washington, and Golden, Colorado. By scaling, haulage distances were estimated to be 188 miles, on the average, for raw coal and 337 miles, on the average for slurry.

The second fuel processing plant site was selected as Galesburg, Illinois. This site appeared to involve several possible coal sources, such as Wyoming, Illinois or Kentucky. Transportation costs would be lowest for Illinois coal, but it was assumed that the coal in this area might not be low enough in sulphur. The next best source location was calculated to be Western, sub-bituminous coal and transportation and coal costs were therefore based on this source.

Table II.A.3.1-1 shows the average cost for slurry, including transportation costs to the fueling sites, based on the assumption of equal fuel consumed by each fueling station. The higher value of $3.94/10^6$ BTU's is based on the Galesburg, Illinois location. The lower value of $\$2.55/10^6$ BTU's is based on Billings, Montana.

3.2 Conrail

The Conrail system is an extensive one covering most of Northeastern United States. It was determined that one large coal processing plant, located at Pittsburgh, could serve their entire system, using coal from Pennsylvania or West Virginia.

In addition to a fueling station for slurries in Pittsburgh, one was tentatively located in Buffalo,

II. FUEL COST SAVINGS

A. Estimated Cost of Micronized Superclean Coal in Coal-Water Slurry with 50% Loading

3. Calculations by Railroad (continued)

3.2 Conrail (continued)

New York and one in Indianapolis, Indiana for purposes of calculating slurry transportation costs.

Average costs are estimated to be $2.65/million BTU's. See Table II.A.3.2-1.

3.3 CSX

The CSX system is a widespread system covering much of the Eastern United States. It was determined, largely by inspection of the maps, that a coal processing plant at or near Knoxville, Tennessee using coal from Tennessee or Kentucky and a second plant near Pittsburgh using Pennsylvania or West Virginia coal should be able to handle the needs of the CSX system.

The Knoxville plant would provide slurry to fueling facilities at Knoxville; Jacksonville, Florida; Wilmington, North Carolina; and Memphis, Tennessee. The Pittsburgh plant would provide slurry to fueling facilities in Pittsburgh and Chicago, Illinois.

Average costs are estimated/calculated to be $3.17/million BTU's for coal processed at Knoxville and $2.81/million BTU's for coal processed at Pittsburgh. The differences are entirely in transportation charges. See Table II.A.3.3-1.

3.4 NS

The Norfolk Southern coal processing plants appeared to be optimized for locations close to Knoxville and Belleview, Ohio. The NS fuel costs were calculated to be $2.78/MBTU and $2.82/MBTU for the Knoxville and Delleview portions of the system. Details are shown in Table II.A.3.4-1.

II. FUEL COST SAVINGS

A. Estimated Cost of Micronized Superclean Coal in Coal-Water Slurry with 50% Loading

3. Calculations by Railroad (continued)

3.5 Southern Pacific/Santa Fe

This anticipated merger of railroads operates primarily in the southwestern part of the United States. With fuel processing plants on the Arizona-New Mexico border and Springfield, Illinois, fuel costs are calculated to be as shown in Table II.A.3.5-1.

3.6 Union Pacific

The UP system operates in the far west and central south portions of the country. With fuel processing plants at Green River, Wyoming and Topeka, Kansas, the fuel costs are calculated to be as shown in Table II.A.3.6-1.

II. FUEL COST SAVINGS

A. Estimated Cost of Micronized Superclean Coal in Coal-Water Slurry With 50% Loading

4. Fuel Savings Equation

4.1 Coal Burning Diesel Locomotive

Fig. I.C.5. shows the method of calculation of fuel savings, based on two points, (1) Eastern railroad heavy duty cycle, and (2) Western railroad heavy duty cycle. These two cases correspond to the Digicalc spreadsheets WS-30 and WS-17 (Appendix 'A').

The annual fuel consumption for these two cases are known from railroad data to be 280,000 gallons for Eastern Heavy Duty and 440,000 gallons for Western Heavy Duty.

The fuel cost savings are obtained directly from WS-30 and WS-17. These worksheets show a cost per HP-HR for the engine operating on diesel fuel as well as the cost when operating on coal water slurry with pilot diesel injection only. The savings are 38.55% for Eastern duty cycle and 35.54% for Western duty cycle. There are two principal factors which contribute to these differences:

- The dominant factor is the lower slurry cost per 10^6 BTU's for Eastern railroads derived from the fact that coal transportation costs and processing costs were lower for Eastern than for Western railroads. This fact more than compensates for factor number 2.

- The Eastern duty cycle has less time in notch 8 and more time in yard idle. This tends to provide higher fuel costs for Eastern than for Western roads, since more BTU's are supplied from diesel fuel (at idle) and since the overall duty cycle thermal efficiency is lower (35.295% versus 36.440%).

Based on the two cases calculated, the fuel savings per year for the Eastern duty cycle is $91,749 and for the Western duty cycle is $132,920.

In applying these results to various railroads, it is assumed that there is a linear relationship in fuel cost savings as a function of the total gallons of diesel fuel normally consumed by the locomotives in question. The fuel cost savings, therefore, take the form of $a = b + cx$, where

b = the fuel savings for a low usage fleet of locomotives which burn only 160,000 gallons of fuel per year.

II. FUEL COST SAVINGS

A. Estimated Cost of Micronized Superclean Coal in Coal-Water Slurry With 50% Loading

4. Fuel Savings Equation

4.1 Coal Burning Diesel Locomotive (continued)

c = the slope of the line for increased fuel savings/year per additional gallon consumed above 160,000 gallons/year.

The equation then becomes (for the data analyzed):

Fuel Savings = $60,871 + 0.257 x (Gallons/yr. - 160,000).

This equation is included in each DCRR spreadsheet to determine the fuel cost savings per locomotive year.

4.2 Direct Fired GE27 Gas Turbine Locomotive

In a similar fashion, a fuel savings equation was developed for the direct fired GE27 gas turbine locomotive. Percent fuel savings taken directly from Digicalc Spreadsheets, WS36 and WS40 for the Eastern Duty Cycle & Western Duty Cycle respectively were 35% & 30.9%.

Using the same procedure as in Section 4.1, the fuel savings equation was found to be:

Fuel Savings = $58,663 + .2059 X (Gal/Year - 160,000)

4.3 Direct Fired GE27 Gas Turbine Locomotive With Steam Injection

By injecting steam, the GE27 output is increased from 5900 to 8000 HP with this alternative. Percent fuel savings taken directly from Digicalc Spreadsheets, WS8 and WS9 for the Eastern Duty Cycle and Western Duty Cycle respectively were 45.73% & 41.53%.

Using the same procedure as in Section 4.1, the fuel savings equation was found to be:

Fuel Savings = $73,980 + .2905 X (Gal/Year-160,000).

II. FUEL COST SAVINGS

A. Estimated Cost of Micronized Superclean Coal in Coal-Water Slurry with 50% Loading

5. Coal Processing Costs

Introduction

The following pages, with Fig. II.A.6-1 to Fig. II.A.6-3, provide a detailed estimate of the operating costs of the coal processing plants as covered under Section VI. Additionally, the operating costs are expressed as dollars per million BTU's to assist in determining the total fuel costs. The costs are broken down into input electrical power, water, maintenance, chemicals and salaries. Taxes were not included in the operating costs of the plant. (They are included in the capital costs.) It is assumed that whatever local taxes are affected would either be very small or replace taxes now in effect.

The figures also provide concise specifications of the plant capacity in BTU's and coal water slurry output.

B. Estimated Cost of ROM Coal for Fluid Bed Steam Turbine and Gasifier Concepts

1. Introduction

Fuel costs were determined previously for CWS fuels to be used for the coal burning diesel, direct fired gas turbine and direct fired gas turbine with steam injection alternatives. For fluidized bed steam turbine and gasifier options, ROM coal will be used with inherently lower costs because it is not processed prior to burning on the locomotive.

As for the CWS, transportation costs will also be important. Fueling stations have been selected as in Section IIA, but for the alternative locomotives, there will be no need for CWS processing plants. The coal is therefore transported directly from mine to the fueling station, saving the extra transportation step to the processing center.

COAL PROCESSING COSTS

	EASTERN BITUMINOUS		WESTERN BITUMINOUS	
	DATA	COST/10^6 BTU	DATA	COST/10^6 BTU
PLANT SPECIFICATIONS				
A. PLANT SLURRY OUTPUT (BTU/YR)	1.755×10^{13}		1.755×10^{13}	
B. PLANT HRS/YR	6,500		6,500	
I. INPUT TONS/YR	731,250		1,035,940	
J. INPUT TONS/HR	112.5		159	
ROM COAL SPECIFICATIONS				
C. BTU/LB	12,000		8,500	
D. % MOISTURE	5		29	
E. % MINERAL MATTER	10		11	
G. COST/TON ($)	These costs shown separately			
H. COST/10^6 BTU	These costs shown separately			
INPUT POWER				
K. HAMMER MILLS KWH/INPUT TON	3.20		3.20	
L. HAMMER MILL YEARLY COST ($)	117,000		165,700	
M. HAMMER MILL (COST/10^6 BTU)		0.007		0.009
N. DRY COAL INPUT (TONS/YR)	694,688		735,517	
P. OTHER POWER (KWH/OUTPUT TON)	133.5		133.5	
Q. OTHER POWER YEAR COST ($)	$4,637,300		$4,909,600	
R. OTHER POWER (COST/10^6 BTU)		0.264		0.280
SLURRY SPECIFICATIONS				
F. DRY COAL OUTPUT (TONS/YR)	621,563		621,563	
S. WATER (TONS/YR)	700,910		700,910	
T. TOTAL SLURRY (TONS/YR)	1,322,473		1,322,473	
U. SLURRY HEAT CONTENT (BTU/#)	6,635		6,635	

FIG. II.A.6-1

COAL PROCESSING COSTS

	EASTERN BITUMINOUS		WESTERN BITUMINOUS	
	DATA	COST/10^6 BTU	DATA	COST/10^6 BTU
WATER USAGE				
V. WATER ADDED (TONS/YR)	664,347		400,487	
W. PROCESS MAKE-UP (TONS/YR)	29,248		45,580	
X. TOTAL WATER (TONS/YR)	693,595		446,067	
Y. WATER PROCESSING COST ($/YR)	1,733,988		1,115,168	
Z. WATER COST/10^6 BTU		0.099		0.064
MAINTENANCE				
AA. YEARLY MAINTENANCE (@ $3/OUTPUT DRY COAL)	1,864,689		1,864,689	
AB. MAINTENANCE ($/$10^6$ BTU)		0.106		0.106
AGGLOMERATE				
AC. AGGLOMERATE USAGE #/TON DRY COAL	10		10	
AD. YEARLY AGGLOMERATE COST $ (@ $1.50/GALLON)	1,864,689		1,864,689	
AE. AGGLOMERATE (COST/10^6 BTU)		0.106		0.106
ADDITIVES				
AF. YEARLY COST @ $5/INPUT TON	3,656,250		5,179,700	
AG. ADDITIVES COST/10^6 BTU		0.208		0.295
PAYROLL				
AH. YEARLY COST ($)	1,131,520		1,131,520	
AI. PAYROLL COST/10^6 BTU		0.064		0.064
AJ. TOTAL PROCESSING COST COST/10^6 BTU		$0.854		$0.924

FIG. II.A.6-2

COAL PROCESSING COSTS

* FOOTNOTES

1. A, B, C, D, E, F, G, K, P, AC are given.
2. I = A/(2000*C)
3. J = I/B
4. F = I x [1 - (D+E) / 100]
5. L = K * I * $.05
6. M = L/A * 1E6
7. N = I * [1 - D/100]
8. P = 133.5 KW/Ton
9. Q = P * N * .05
10. R = Q/A * 1E6
11. S = 53/47 * F
12. T = S + N
13. U = A/(T * 2000)
14. V = S - I(D/100)
15. W = (E/100)I * (.4)
16. X = V + W
17. Y = $.01 * X * 2000/8
18. Z = Y/A * 1E6
19. AA = N * $3.00
20. AB = AA/A * 1E6
21. AD = $1.50 * (AC/5) * F
22. AF = $5 * I
23. AG = AF/A * 1E6
24. AH = 832,000 * 1.36
25. AI = AH/A * 1E6
26. AJ = M + R + Z + AB + AE + AG + AI

FIG. II.A.6-3

II. FUEL COST SAVINGS

B. Estimated Cost of ROM Coal for Fluid Bed Steam Turbine and Gasifier Concepts (continued)

2. Methodology

The purpose of this study was to determine the most economical fuel sourcing strategies for railroads operating a coal fueled locomotive with a fluid bed boiler, steam turbine or a gasifier power plant. Coal ROM cost, transport cost, desulfurization cost and ash disposal costs were calculated and summed to determine the total fuel dependent cost.

Fuel sources were studied for six major domestic railroads, including BN, Conrail, CSX, NS, SP-ATSF and UP. Several fueling sites were evaluated for each railroad as listed in Table II B.3 (see maps Section IIA).

The fluid bed combustion system under study required 1/4X0 screened coal. The ROM coal prices were based on current reports on double screened stoker coal. Coal was considered from all the major domestic coal producing regions, but was limited to bituminous and sub-bituminous ranks. State-wide averages were used for coal heating value, sulfur, ash and ROM price. No attempt was made to minimize these quantities with reference to local conditions or contracts. Coals from 16 states were included in the study. They fell into four basic categories: (1) Low sulfur Appalachian bituminous; (2) High sulfur Midwest bituminous; (3) Western bituminous; (4) Western sub-bituminous. The heating value, sulfur, ash and ROM price of the coals are listed in Table II B.4.

Coal from up to three sources was evaluated at each fueling station. The coal sources were chosen based on price and proximity as primary criteria. Coal heating value and quality were used as secondary criteria.

The delivered cost was determined by adding the ROM price and transportation cost and normalizing by heating value. Coal haulage mileage was estimated for railline maps. Haulage rates were determined to be $.0175/ton mile for large coal contracts and $.03/ton mile for general freight. The lower rate was used for coal haulage and higher rate was used for limestone.[1,2,3]

The cost of neutralizing the sulfur in the coal was calculated by supplying Ca in the form of limestone. A Ca/S molar ratio of two is necessary for a high degree of removal. Since limestone ($CaCO_3$) has three times the molecular weight of sulfur, a weight ratio of six was used in this study. Crushed limestone is generally available throughout the country so a constant price of $4/ton and a distance of 100 miles was used[4,5].

II. FUEL COST SAVINGS

B. Estimated Cost of ROM Coal for Fluid Bed Steam Turbine and Gasifier Concepts

2. Methodology (continued)

The disposal cost of ash and spent limestone was determined to be $4/ton from the local power plant and was used for the entire study.[5]

The major drivers that determined the total fuel cost were ROM coal price and coal transport cost. The cost of sulfur neutralization and ash disposal normally contributed less than 10% of the total fuel cost. The sulfur and ash content of the fuel may have a major impact on the capital cost and maintenance cost of the locomotive, however.

The minimum cost fuel for each fueling station was chosen and an unweighted average taken for each railroad. These figures can be seen in Table II.B.5. The average fuel costs grouped the six railroads into two groups. The western railroads, UP, SP-ATSF, and BN, which had close access to low cost western coal had an average coal cost of 1.157 $/MBTU. The eastern railroads, ConRail, CSX, and NS, had to rely on more expensive eastern coal which had a higher average coal cost at 1.562 $/MBTU.

II. FUEL COST SAVINGS

B. Estimated Cost of ROM Coal For Fluid Bed Steam Turbine and Gasifier Concepts

3. Summary of Most Economical Coal Sources

Table II.B.3.a

Railroad	Fuel Station	Coal Source	Fuel Cost ($/M BTU)
BN	Galesburg, IL	Illinois	1.617
	Memphis, TN	Wyoming	1.578
	Ft. Worth, TX	New Mexico	1.216
	Billing, MN	Montana	.749
	Spokane, WA	Arizona	1.487
	Golden, CO	Wyoming	.919
		Average	1.261
CR	Buffalo, NY	Pennsylvania	1.578
	Pittsburgh, PA	Pennsylvania	1.453
	Indianapolis, IN	Indiana	1.546
		Average	1.526
CSX	Knoxville, TN	Tennessee	1.439
	Jacksonville, FL	Kentucky	1.804
	Wilmington, NC	Kentucky	1.731
	Memphis, TN	Indiana	1.746
	Pittsburgh, PA	Pennsylvania	1.452
	Chicago, IL	Indiana	1.626
		Average	1.633
NS	Knoxville, TN	Tennessee	1.439
	Atlanta, GA	Kentucky	1.622
	St. Louis, MO	Illinois	1.498
	Belleview, OH	Ohio	1.452
	Norfolk, VA	Pennsylvania	1.631
		Average	1.528
SF-SP	Arizona/New Mexico	Arizona	.612
	Cadiz, CA	Arizona	1.010
	El Paso, TX	Arizona	1.010
	Springfield, IL	Illinois	1.577
	Kansas City, MO	Wyoming	1.375
	Houston, TX	Arizona	1.249
		Average	1.139
UP	Topeka, KS	New Mexico	1.169
	St. Louis, MO	Illinois	1.498
	Ft. Worth, TX	New Mexico	1.216
	Green River, WY	Wyoming	.767
	Callento, NV	Arizona	.771
	Reno Junction, CA	Arizona	1.010
		Average	1.072

II. FUEL COST SAVINGS

B. Estimated Cost of ROM Coal For Fluid Bed Steam Turbine and Gasifier Concepts

3. Summary of Most Economical Coal Sources (continued)

Table II.B.3.b

Coal data used to calculate appropriate coal sources to fuel fluid bed boiler locomotive

State	BTU/LB	%S	$Ash	$ROM
Alabama	12129	1.40	12.30	39
Arizona	10998	.52	9.31	11
Colorado	10728	.46	8.20	30
Illinois	11027	2.66	9.99	30
Indiana	10937	2.53	10.01	30
Kentucky	12012	1.77	10.52	33
Missouri	10242	4.57	16.07	30
Montana	8968	.61	7.11	11
New Mexico	9350	.71	19.35	11
Ohio	11664	3.27	11.45	30
Pennsylvania	12266	1.83	13.53	33
Tennessee	12530	1.36	10.11	33
Utah	11575	.50	10.12	30
Virginia	12818	.98	9.93	33
West Virginia	12491	1.75	11.04	33
Wyoming	8638	.41	5.85	11

References:

Cost and Quality of Fuels for Electric Utility Plants 1984, DOE/EIA-9191 (84), Energy Information Administration, Washington, DC, July 1985.

Coal Outlook, January - July 1985.

Coal Fired Diesel Engine - Economic Study, DOE-GE TSBO, September 1985.

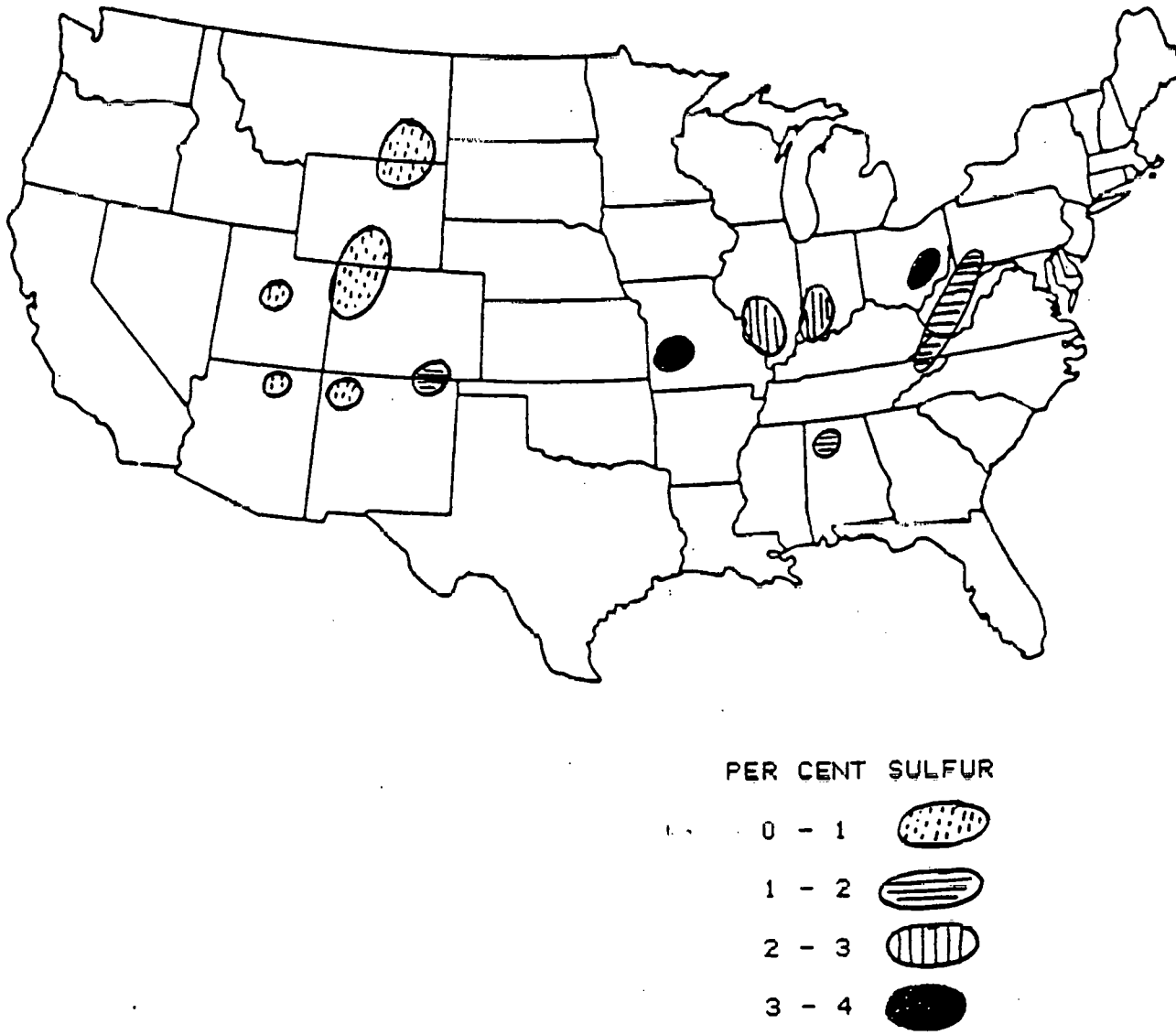
Keystone Coal Handbook, 1984.

II. FUEL COST SAVINGS

B. Estimated Cost of ROM Coal For Fluid Bed Steam Turbine and Gasifier Concepts (continued)

4. Distribution of Sulfur in Actively Mined Bituminous and Sub-Bituminous Coals

Fig. II.B.4



II. FUEL COST SAVINGS

B. Estimated Cost of ROM Coal For Fluid Bed Steam Turbine and Gasifier Concepts (continued)

5. Regional Fuel Averages

Table II.B.5

Western Railroads		Total Coal Cost ($/MBTU)
UP		1.072
SF-SP		1.139
BN		1.261
	Average	1.157
Eastern Railroads		
CR		1.526
CSX		1.633
NS		1.528
	Average	1.562

II. FUEL COST SAVINGS

B. Estimated Cost of ROM Coal For Fluid Bed Steam Turbine and Gasifier Concepts (continued)

6. Calculations by Railroad

As in Section IIA, calculations have been prepared for each railroad and for each fueling station.

These have been summarized in Tables II.B.6-1 - II.B.6-17.

Locations of these sites may be seen in the maps in Section II.A.3.

6.0 Calculations by Railroad

6.1 SP-ATSF RAILROAD

Table IIB.6-1

COAL FUELING STATION ARIZONA-NEW MEXICO BORDER

COAL SOURCE	STATE	WYOMING	ARIZONA
COAL HEAT VALUE	BTU/LB	8638	10998
COAL % SULFUR	%	.4	.5
COAL % ASH	%	5.8	9.3
ROM COAL COST	$/TON	11.00	11.00
COAL PROCESS COST	$/TON	0.00	0.00
COAL DISTANCE	MILES	600	100
COAL HAUL RATE	$/TON*MI	.018	.018
COAL TRANS. COST	$/TON	10.50	1.75
COAL DELIVERED COST	$/MBTU	1.245	.580
LIMESTONE COST	$/TON	4.00	4.00
LIMESTONE DISTANCE	MILES	100	100
LIMESTONE HAUL RATE	$/TON*MI	.030	.030
LIMESTONE/SULFUR	MOLE RATI	2	2
ASH DISPOSAL COST	$/TON	4.00	4.00
TOTAL L.S. & ASH	$/MBTU	.029	.033
TOTAL COAL COST	$/MBTU	1.274	.612

COAL FUELING STATION CADIZ,CALIFORIA

COAL SOURCE	STATE	WYOMING	UTAH	ARIZONA
COAL HEAT VALUE	BTU/LB	8638	11575	10998
COAL % SULFUR	%	.4	.5	.5
COAL % ASH	%	5.8	10.1	9.3
ROM COAL COST	$/TON	11.00	30.00	11.00
COAL PROCESS COST	$/TON	0.00	0.00	0.00
COAL DISTANCE	MILES	950	600	600
COAL HAUL RATE	$/TON*MI	.018	.018	.018
COAL TRANS. COST	$/TON	16.62	10.50	10.50
COAL DELIVERED COST	$/MBTU	1.599	1.749	.977
LIMESTONE COST	$/TON	4.00	4.00	4.00
LIMESTONE DISTANCE	MILES	100	100	100
LIMESTONE HAUL RATE	$/TON*MI	.030	.030	.030
LIMESTONE/SULFUR	MOLE RATI	2	2	2
ASH DISPOSAL COST	$/TON	4.00	4.00	4.00
TOTAL L.S. & ASH	$/MBTU	.029	.032	.033
TOTAL COAL COST	$/MBTU	1.628	1.781	1.010

II. FUEL COST SAVINGS

B. Estimated Cost of ROM Coal for Fluid Bed Steam Turbine and Gasifier Concepts

6.0 Calculations by Railroad

6.1 SP-ATSF RAILROAD

Table IIB.6-2

COAL FUELING STATION EL PASO, TEXAS

COAL SOURCE	STATE	WYOMING	NEW MEX	ARIZONA
COAL HEAT VALUE	BTU/LB	8638	9350	10998
COAL % SULFUR	%	.4	.7	.5
COAL % ASH	%	5.8	19.4	9.3
ROM COAL COST	$/TON	11.00	11.00	11.00
COAL PROCESS COST	$/TON	0.00	0.00	0.00
COAL DISTANCE	MILES	850	400	600
COAL HAUL RATE	$/TON*MI	.018	.018	.018
COAL TRANS. COST	$/TON	14.88	7.00	10.50
COAL DELIVERED COST	$/MBTU	1.498	.963	.977
LIMESTONE COST	$/TON	4.00	4.00	4.00
LIMESTONE DISTANCE	MILES	100	100	100
LIMESTONE HAUL RATE	$/TON*MI	.030	.030	.030
LIMESTONE/SULFUR	MOLE RATI	2	2	2
ASH DISPOSAL COST	$/TON	4.00	4.00	4.00
TOTAL L.S. & ASH	$/MBTU	.029	.066	.033
TOTAL COAL COST	$/MBTU	1.527	1.029	1.010

COAL FUELING STATION SPRINGFIELD, ILLNOIS

COAL SOURCE	STATE	ILLINOIS	KENTUCKY	WYOMONG
COAL HEAT VALUE	BTU/LB	11027	12012	8638
COAL % SULFUR	%	2.7	1.8	.4
COAL % ASH	%	10.0	10.5	5.8
ROM COAL COST	$/TON	30.00	33.00	11.00
COAL PROCESS COST	$/TON	0.00	0.00	0.00
COAL DISTANCE	MILES	150	500	750
COAL HAUL RATE	$/TON*MI	.018	.018	.018
COAL TRANS. COST	$/TON	2.63	8.75	13.13
COAL DELIVERED COST	$/MBTU	1.479	1.738	1.396
LIMESTONE COST	$/TON	4.00	4.00	4.00
LIMESTONE DISTANCE	MILES	100	100	100
LIMESTONE HAUL RATE	$/TON*MI	.030	.030	.030
LIMESTONE/SULFUR	MOLE RATI	2	2	2
ASH DISPOSAL COST	$/TON	4.00	4.00	4.00
TOTAL L.S. & ASH	$/MBTU	.098	.066	.029
TOTAL COAL COST	$/MBTU	1.577	1.804	1.426

II. FUEL COST SAVINGS

B. Estimated Cost of ROM Coal for Fluid Bed Steam Turbine and Gasifier Concepts

6.0 Calculations by Railroad

6.1 SP-ATSF RAILROAD

Table IIB.6-3

COAL FUELING STATION KANSAS CITY, MISSOURI

COAL SOURCE	STATE	ILLINOIS	KENTUCKY	WYOMING
COAL HEAT VALUE	BTU/LB	11027	12012	8638
COAL % SULFUR	%	2.7	1.8	.4
COAL % ASH	%	10.0	10.5	5.8
ROM COAL COST	$/TON	30.00	33.00	11.00
COAL PROCESS COST	$/TON	0.00	0.00	0.00
COAL DISTANCE	MILES	300	450	700
COAL HAUL RATE	$/TON*MI	.018	.018	.018
COAL TRANS. COST	$/TON	5.25	7.88	12.25
COAL DELIVERED COST	$/MBTU	1.598	1.701	1.346
LIMESTONE COST	$/TON	4.00	4.00	4.00
LIMESTONE DISTANCE	MILES	100	100	100
LIMESTONE HAUL RATE	$/TON*MI	.030	.030	.030
LIMESTONE/SULFUR	MOLE RATI	2	2	2
ASH DISPOSAL COST	$/TON	4.00	4.00	4.00
TOTAL L.S. & ASH	$/MBTU	.098	.066	.029
TOTAL COAL COST	$/MBTU	1.696	1.768	1.375

COAL FUELING STATION HOUSTON, TEXAS

COAL SOURCE	STATE	COLORADO	ALABAMA	ARIZONA
COAL HEAT VALUE	BTU/LB	10728	12129	10998
COAL % SULFUR	%	.5	1.4	.5
COAL % ASH	%	8.2	12.3	9.3
ROM COAL COST	$/TON	30.00	39.00	11.00
COAL PROCESS COST	$/TON	0.00	0.00	0.00
COAL DISTANCE	MILES	900	500	900
COAL HAUL RATE	$/TON*MI	.018	.018	.018
COAL TRANS. COST	$/TON	15.75	8.75	15.75
COAL DELIVERED COST	$/MBTU	2.132	1.968	1.216
LIMESTONE COST	$/TON	4.00	4.00	4.00
LIMESTONE DISTANCE	MILES	100	100	100
LIMESTONE HAUL RATE	$/TON*MI	.030	.030	.030
LIMESTONE/SULFUR	MOLE RATI	2	2	2
ASH DISPOSAL COST	$/TON	4.00	4.00	4.00
TOTAL L.S. & ASH	$/MBTU	.029	.058	.033
TOTAL COAL COST	$/MBTU	2.162	2.027	1.249

II. FUEL COST SAVINGS

B. Estimated Cost of ROM Coal for Fluid Bed Steam Turbine and Gasifier Concepts

6.0 Calculations by Railroad

6.2 BN RAILROAD

Table IIB.6-4

COAL FUELING STATION BILLINGS ,MONTANA

COAL SOURCE	STATE	MONTANA	WYOMING
COAL HEAT VALUE	BTU/LB	8968	8638
COAL % SULFUR	%	.6	.4
COAL % ASH	%	7.1	5.8
ROM COAL COST	$/TON	11.00	11.00
COAL PROCESS COST	$/TON	0.00	0.00
COAL DISTANCE	MILES	100	200
COAL HAUL RATE	$/TON*MI	.018	.018
COAL TRANS. COST	$/TON	1.75	3.50
COAL DELIVERED COST	$/MBTU	.711	.839
LIMESTONE COST	$/TON	4.00	4.00
LIMESTONE DISTANCE	MILES	100	100
LIMESTONE HAUL RATE	$/TON*MI	.030	.030
LIMESTONE/SULFUR	MOLE RATI	2	2
ASH DISPOSAL COST	$/TON	4.00	4.00
TOTAL L.S. & ASH	$/MBTU	.038	.029
TOTAL COAL COST	$/MBTU	.749	.869

COAL FUELING STATION GALESBURG, ILLINOIS

COAL SOURCE	STATE	ILLINOIS	PENNA	WYOMING
COAL HEAT VALUE	BTU/LB	11027	12266	8638
COAL % SULFUR	%	2.7	1.8	.4
COAL % ASH	%	10.0	13.5	5.8
ROM COAL COST	$/TON	30.00	33.00	11.00
COAL PROCESS COST	$/TON	0.00	0.00	0.00
COAL DISTANCE	MILES	200	600	900
COAL HAUL RATE	$/TON*MI	.018	.018	.018
COAL TRANS. COST	$/TON	3.50	10.50	15.75
COAL DELIVERED COST	$/MBTU	1.519	1.773	1.548
LIMESTONE COST	$/TON	4.00	4.00	4.00
LIMESTONE DISTANCE	MILES	100	100	100
LIMESTONE HAUL RATE	$/TON*MI	.030	.030	.030
LIMESTONE/SULFUR	MOLE RATI	2	2	2
ASH DISPOSAL COST	$/TON	4.00	4.00	4.00
TOTAL L.S. & ASH	$/MBTU	.098	.071	.029
TOTAL COAL COST	$/MBTU	1.617	1.844	1.578

II. FUEL COST SAVINGS

B. Estimated Cost of ROM Coal for Fluid Bed Steam Turbine and Gasifier Concepts

6.0 Calculations by Railroad

6.2 BN RAILROAD

Table IIB.6-5

COAL FUELING STATION GOLDEN, COLORADO

COAL SOURCE	STATE	COLORADO	WYOMING
COAL HEAT VALUE	BTU/LB	10728	8638
COAL % SULFUR	%	.5	.4
COAL % ASH	%	8.2	5.8
ROM COAL COST	$/TON	30.00	11.00
COAL PROCESS COST	$/TON	0.00	0.00
COAL DISTANCE	MILES	200	250
COAL HAUL RATE	$/TON*MI	.018	.018
COAL TRANS. COST	$/TON	3.50	4.38
COAL DELIVERED COST	$/MBTU	1.561	.890
LIMESTONE COST	$/TON	4.00	4.00
LIMESTONE DISTANCE	MILES	100	100
LIMESTONE HAUL RATE	$/TON*MI	.030	.030
LIMESTONE/SULFUR	MOLE RATI	2	2
ASH DISPOSAL COST	$/TON	4.00	4.00
TOTAL L.S. & ASH	$/MBTU	.029	.029
TOTAL COAL COST	$/MBTU	1.591	.919

COAL FUELING STATION FORT WORTH, TEXAS

COAL SOURCE	STATE	ALABAMA	NEW MEX	WYOMING
COAL HEAT VALUE	BTU/LB	12129	9350	8638
COAL % SULFUR	%	1.4	.7	.4
COAL % ASH	%	12.3	19.4	5.8
ROM COAL COST	$/TON	39.00	11.00	11.00
COAL PROCESS COST	$/TON	0.00	0.00	0.00
COAL DISTANCE	MILES	150	600	1000
COAL HAUL RATE	$/TON*MI	.018	.018	.018
COAL TRANS. COST	$/TON	2.63	10.50	17.50
COAL DELIVERED COST	$/MBTU	1.716	1.150	1.650
LIMESTONE COST	$/TON	4.00	4.00	4.00
LIMESTONE DISTANCE	MILES	100	100	100
LIMESTONE HAUL RATE	$/TON*MI	.030	.030	.030
LIMESTONE/SULFUR	MOLE RATI	2	2	2
ASH DISPOSAL COST	$/TON	4.00	4.00	4.00
TOTAL L.S. & ASH	$/MBTU	.058	.066	.029
TOTAL COAL COST	$/MBTU	1.774	1.216	1.679

II. FUEL COST SAVINGS

B. Estimated Cost of ROM Coal for Fluid Bed Steam Turbine and Gasifier Concepts

6.0 Calculations by Railroad

6.2 BN RAILROAD

Table IIB.6-6

COAL FUELING STATION MEMPHIS, TENNESSEE

COAL SOURCE	STATE	ILLINOIS	KEN.	WYOMING
COAL HEAT VALUE	BTU/LB	11027	12012	8638
COAL % SULFUR	%	2.7	1.8	.4
COAL % ASH	%	10.0	10.5	5.8
ROM COAL COST	$/TON	30.00	33.00	11.00
COAL PROCESS COST	$/TON	0.00	0.00	0.00
COAL DISTANCE	MILES	250	400	900
COAL HAUL RATE	$/TON*MI	.018	.018	.018
COAL TRANS. COST	$/TON	4.38	7.00	15.75
COAL DELIVERED COST	$/MBTU	1.559	1.665	1.548
LIMESTONE COST	$/TON	4.00	4.00	4.00
LIMESTONE DISTANCE	MILES	100	100	100
LIMESTONE HAUL RATE	$/TON*MI	.030	.030	.030
LIMESTONE/SULFUR	MOLE RATI	2	2	2
ASH DISPOSAL COST	$/TON	4.00	4.00	4.00
TOTAL L.S. & ASH	$/MBTU	.098	.066	.029
TOTAL COAL COST	$/MBTU	1.656	1.731	1.578

COAL FUELING STATION SPOKANE, WASHINGTON

COAL SOURCE	STATE	ARIZONA	WYOMING
COAL HEAT VALUE	BTU/LB	10998	8638
COAL % SULFUR	%	.5	.4
COAL % ASH	%	9.3	5.8
ROM COAL COST	$/TON	11.00	11.00
COAL PROCESS COST	$/TON	0.00	0.00
COAL DISTANCE	MILES	1200	1000
COAL HAUL RATE	$/TON*MI	.018	.018
COAL TRANS. COST	$/TON	21.00	17.50
COAL DELIVERED COST	$/MBTU	1.455	1.650
LIMESTONE COST	$/TON	4.00	4.00
LIMESTONE DISTANCE	MILES	100	100
LIMESTONE HAUL RATE	$/TON*MI	.030	.030
LIMESTONE/SULFUR	MOLE RATI	2	2
ASH DISPOSAL COST	$/TON	4.00	4.00
TOTAL L.S. & ASH	$/MBTU	.033	.029
TOTAL COAL COST	$/MBTU	1.487	1.679

II. FUEL COST SAVINGS

B. Estimated Cost of ROM Coal for Fluid Bed Steam Turbine and Gasifier Concepts

6.0 Calculations by Railroad

6.3 CONRAIL RAILROAD

Table IIB.6-7

COAL FUELING STATION BUFFALO, NEW YORK

COAL SOURCE	STATE	INDIANA	PENNA	WYOMING
COAL HEAT VALUE	BTU/LB	10937	12266	8638
COAL % SULFUR	%	2.5	1.8	.4
COAL % ASH	%	10.1	13.5	5.8
ROM COAL COST	$/TON	30.00	33.00	11.00
COAL PROCESS COST	$/TON	0.00	0.00	0.00
COAL DISTANCE	MILES	400	220	1300
COAL HAUL RATE	$/TON*MI	.018	.018	.018
COAL TRANS. COST	$/TON	7.20	3.96	22.75
COAL DELIVERED COST	$/MBTU	1.701	1.507	1.954
LIMESTONE COST	$/TON	4.00	4.00	4.00
LIMESTONE DISTANCE	MILES	100	100	100
LIMESTONE HAUL RATE	$/TON*MI	.030	.030	.030
LIMESTONE/SULFUR	MOLE RATI	2	2	2
ASH DISPOSAL COST	$/TON	4.00	4.00	4.00
TOTAL L.S. & ASH	$/MBTU	.095	.071	.029
TOTAL COAL COST	$/MBTU	1.795	1.578	1.983

COAL FUELING STATION PITTSBURGH, PA

COAL SOURCE	STATE	INDIANA	PENNA	WYOMING
COAL HEAT VALUE	BTU/LB	10937	12266	8638
COAL % SULFUR	%	2.5	1.8	.4
COAL % ASH	%	10.1	13.5	5.8
ROM COAL COST	$/TON	30.00	33.00	11.00
COAL PROCESS COST	$/TON	0.00	0.00	0.00
COAL DISTANCE	MILES	250	50	1200
COAL HAUL RATE	$/TON*MI	.018	.018	.018
COAL TRANS. COST	$/TON	4.38	.90	21.00
COAL DELIVERED COST	$/MBTU	1.572	1.382	1.852
LIMESTONE COST	$/TON	4.00	4.00	4.00
LIMESTONE DISTANCE	MILES	100	100	100
LIMESTONE HAUL RATE	$/TON*MI	.030	.030	.030
LIMESTONE/SULFUR	MOLE RATI	2	2	2
ASH DISPOSAL COST	$/TON	4.00	4.00	4.00
TOTAL L.S. & ASH	$/MBTU	.095	.071	.029
TOTAL COAL COST	$/MBTU	1.666	1.453	1.881

II. FUEL COST SAVINGS

B. Estimated Cost of ROM Coal for Fluid Bed Steam Turbine and Gasifier Concepts

6.0 Calculations by Railroad

6.3 CONRAIL RAILROAD

Table IIB.6-8

COAL FUELING STATION INDIANAPOLIS, INDIANA

COAL SOURCE	STATE	INDIANA	PENNA	WYOMING
COAL HEAT VALUE	BTU/LB	10937	12266	8638
COAL % SULFUR	%	2.5	1.8	.4
COAL % ASH	%	10.1	13.5	5.8
ROM COAL COST	$/TON	30.00	33.00	11.00
COAL PROCESS COST	$/TON	0.00	0.00	0.00
COAL DISTANCE	MILES	100	250	950
COAL HAUL RATE	$/TON*MI	.018	.018	.018
COAL TRANS. COST	$/TON	1.75	4.50	16.62
COAL DELIVERED COST	$/MBTU	1.451	1.529	1.599
LIMESTONE COST	$/TON	4.00	4.00	4.00
LIMESTONE DISTANCE	MILES	100	100	100
LIMESTONE HAUL RATE	$/TON*MI	.030	.030	.030
LIMESTONE/SULFUR	MOLE RATI	2	2	2
ASH DISPOSAL COST	$/TON	4.00	4.00	4.00
TOTAL L.S. & ASH	$/MBTU	.095	.071	.029
TOTAL COAL COST	$/MBTU	1.546	1.600	1.628

II. FUEL COST SAVINGS

B. Estimated Cost of ROM Coal for Fluid Bed Steam Turbine and Gasifier Concepts

6.0 Calculations by Railroad

6.4 CSX RAILROAD

Table IIB.6-9

COAL FUELING STATION KNOXVILLE, TENNESSEE

COAL SOURCE	STATE	TENN.	INDIANA	WYOMING
COAL HEAT VALUE	BTU/LB	12530	10937	8638
COAL % SULFUR	%	1.4	2.5	.4
COAL % ASH	%	10.1	10.1	5.8
ROM COAL COST	$/TON	33.00	30.00	11.00
COAL PROCESS COST	$/TON	0.00	0.00	0.00
COAL DISTANCE	MILES	100	250	1200
COAL HAUL RATE	$/TON*MI	.018	.018	.018
COAL TRANS. COST	$/TON	1.75	4.38	21.00
COAL DELIVERED COST	$/MBTU	1.387	1.572	1.852
LIMESTONE COST	$/TON	4.00	4.00	4.00
LIMESTONE DISTANCE	MILES	100	100	100
LIMESTONE HAUL RATE	$/TON*MI	.030	.030	.030
LIMESTONE/SULFUR	MOLE RATI	2	2	2
ASH DISPOSAL COST	$/TON	4.00	4.00	4.00
TOTAL L.S. & ASH	$/MBTU	.052	.095	.029
TOTAL COAL COST	$/MBTU	1.439	1.666	1.881

COAL FUELING STATION JACKSONVILLE, FLORIDA

COAL SOURCE	STATE	INDIANA	KENTUCKY	ALABAMA
COAL HEAT VALUE	BTU/LB	10937	12012	12129
COAL % SULFUR	%	2.5	1.8	1.4
COAL % ASH	%	10.1	10.5	12.3
ROM COAL COST	$/TON	30.00	33.00	39.00
COAL PROCESS COST	$/TON	0.00	0.00	0.00
COAL DISTANCE	MILES	700	500	400
COAL HAUL RATE	$/TON*MI	.018	.018	.018
COAL TRANS. COST	$/TON	12.25	8.75	7.00
COAL DELIVERED COST	$/MBTU	1.932	1.738	1.896
LIMESTONE COST	$/TON	4.00	4.00	4.00
LIMESTONE DISTANCE	MILES	100	100	100
LIMESTONE HAUL RATE	$/TON*MI	.030	.030	.030
LIMESTONE/SULFUR	MOLE RATI	2	2	2
ASH DISPOSAL COST	$/TON	4.00	4.00	4.00
TOTAL L.S. & ASH	$/MBTU	.095	.066	.058
TOTAL COAL COST	$/MBTU	2.026	1.804	1.955

II. FUEL COST SAVINGS

B. Estimated Cost of ROM Coal for Fluid Bed Steam Turbine and Gasifier Concepts

6.0 Calculations by Railroad

6.4 CSX RAILROAD

Table IIB.6-10

COAL FUELING STATION WILMINGTON, NORTH CAROLINA

COAL SOURCE	STATE	KENTUCKY	ALABAMA	INDIANA
COAL HEAT VALUE	BTU/LB	12012	12129	10937
COAL % SULFUR	%	1.8	1.4	2.5
COAL % ASH	%	10.5	12.3	10.0
ROM COAL COST	$/TON	33.00	39.00	30.00
COAL PROCESS COST	$/TON	0.00	0.00	0.00
COAL DISTANCE	MILES	400	500	650
COAL HAUL RATE	$/TON*MI	.018	.018	.018
COAL TRANS. COST	$/TON	7.00	8.75	11.38
COAL DELIVERED COST	$/MBTU	1.665	1.968	1.892
LIMESTONE COST	$/TON	4.00	4.00	4.00
LIMESTONE DISTANCE	MILES	100	100	100
LIMESTONE HAUL RATE	$/TON*MI	.030	.030	.030
LIMESTONE/SULFUR	MOLE RATI	2	2	2
ASH DISPOSAL COST	$/TON	4.00	4.00	4.00
TOTAL L.S. & ASH	$/MBTU	.066	.058	.095
TOTAL COAL COST	$/MBTU	1.731	2.027	1.986

COAL FUELING STATION MEMPHIS,TENNESSEE

COAL SOURCE	STATE	INDIANA	KENTUCKY	ALABAMA
COAL HEAT VALUE	BTU/LB	10937	12012	12129
COAL % SULFUR	%	2.5	1.8	1.4
COAL % ASH	%	10.1	10.5	12.3
ROM COAL COST	$/TON	30.00	33.00	39.00
COAL PROCESS COST	$/TON	0.00	0.00	0.00
COAL DISTANCE	MILES	350	500	200
COAL HAUL RATE	$/TON*MI	.018	.018	.018
COAL TRANS. COST	$/TON	6.13	8.75	3.50
COAL DELIVERED COST	$/MBTU	1.652	1.738	1.752
LIMESTONE COST	$/TON	4.00	4.00	4.00
LIMESTONE DISTANCE	MILES	100	100	100
LIMESTONE HAUL RATE	$/TON*MI	.030	.030	.030
LIMESTONE/SULFUR	MOLE RATI	2	2	2
ASH DISPOSAL COST	$/TON	4.00	4.00	4.00
TOTAL L.S. & ASH	$/MBTU	.095	.066	.058
TOTAL COAL COST	$/MBTU	1.746	1.804	1.810

II. FUEL COST SAVINGS

B. Estimated Cost of ROM Coal for Fluid Bed Steam Turbine and Gasifier Concepts

6.0 Calculations by Railroad

6.4 CSX RAILROAD

Table IIB.6-11

COAL FUELING STATION PITTSBURGH, PENNSYLVANIA

COAL SOURCE	STATE	PENNA.	OHIO	INDIANA
COAL HEAT VALUE	BTU/LB	12266	11664	10937
COAL % SULFUR	%	1.8	3.3	2.5
COAL % ASH	%	13.5	11.4	10.1
ROM COAL COST	$/TON	33.00	30.00	30.00
COAL PROCESS COST	$/TON	0.00	0.00	0.00
COAL DISTANCE	MILES	50	100	400
COAL HAUL RATE	$/TON*MI	.018	.018	.018
COAL TRANS. COST	$/TON	.88	1.75	7.00
COAL DELIVERED COST	$/MBTU	1.381	1.361	1.692
LIMESTONE COST	$/TON	4.00	4.00	4.00
LIMESTONE DISTANCE	MILES	100	100	100
LIMESTONE HAUL RATE	$/TON*MI	.030	.030	.030
LIMESTONE/SULFUR	MOLE RATI	2	2	2
ASH DISPOSAL COST	$/TON	4.00	4.00	4.00
TOTAL L.S. & ASH	$/MBTU	.071	.112	.095
TOTAL COAL COST	$/MBTU	1.452	1.473	1.786

COAL FUELING STATION CHICAGO, ILLINOIS

COAL SOURCE	STATE	INDIANA	KENTUCKY	WYOMING
COAL HEAT VALUE	BTU/LB	10937	12012	8638
COAL % SULFUR	%	2.5	1.8	.4
COAL % ASH	%	10.1	10.5	5.8
ROM COAL COST	$/TON	30.00	33.00	11.00
COAL PROCESS COST	$/TON	0.00	0.00	0.00
COAL DISTANCE	MILES	200	450	900
COAL HAUL RATE	$/TON*MI	.018	.018	.018
COAL TRANS. COST	$/TON	3.50	7.88	15.75
COAL DELIVERED COST	$/MBTU	1.531	1.701	1.548
LIMESTONE COST	$/TON	4.00	4.00	4.00
LIMESTONE DISTANCE	MILES	100	100	100
LIMESTONE HAUL RATE	$/TON*MI	.030	.030	.030
LIMESTONE/SULFUR	MOLE RATI	2	2	2
ASH DISPOSAL COST	$/TON	4.00	4.00	4.00
TOTAL L.S. & ASH	$/MBTU	.095	.066	.029
TOTAL COAL COST	$/MBTU	1.626	1.768	1.578

II. FUEL COST SAVINGS

B. Estimated Cost of ROM Coal for Fluid Bed Steam Turbine and Gasifier Concepts

6.0 Calculations by Railroad

6.5 NORFOLK-SOUTHERN RAILROAD

Table IIB.6-12

COAL FUELING STATION KNOXVILLE, TENNESSEE

COAL SOURCE	STATE	TENN.	INDIANA	WYOMING
COAL HEAT VALUE	BTU/LB	12530	10937	8638
COAL % SULFUR	%	1.4	2.5	.4
COAL % ASH	%	10.1	10.1	5.85
ROM COAL COST	$/TON	33.00	30.00	11.00
COAL PROCESS COST	$/TON	0.00	0.00	0.00
COAL DISTANCE	MILES	100	250	1200
COAL HAUL RATE	$/TON*MI	.018	.018	.018
COAL TRANS. COST	$/TON	1.75	4.38	21.00
COAL DELIVERED COST	$/MBTU	1.387	1.572	1.852
LIMESTONE COST	$/TON	4.00	4.00	4.00
LIMESTONE DISTANCE	MILES	100	100	100
LIMESTONE HAUL RATE	$/TON*MI	.030	.030	.030
LIMESTONE/SULFUR	MOLE RATI	2	2	2
ASH DISPOSAL COST	$/TON	4.00	4.00	4.00
TOTAL L.S. & ASH	$/MBTU	.052	.095	.029
TOTAL COAL COST	$/MBTU	1.439	1.666	1.881

COAL FUELING STATION ATLANTA, GEORGIA

COAL SOURCE	STATE	INDIANA	KENTUCKY	ALABAMA
COAL HEAT VALUE	BTU/LB	10937	12012	12129
COAL % SULFUR	%	2.5	1.8	1.4
COAL % ASH	%	10.07	10.53	12.3
ROM COAL COST	$/TON	30.00	33.00	39.00
COAL PROCESS COST	$/TON	0.00	0.00	0.00
COAL DISTANCE	MILES	400	250	150
COAL HAUL RATE	$/TON*MI	.018	.018	.018
COAL TRANS. COST	$/TON	7.00	4.38	2.63
COAL DELIVERED COST	$/MBTU	1.692	1.556	1.716
LIMESTONE COST	$/TON	4.00	4.00	4.00
LIMESTONE DISTANCE	MILES	100	100	100
LIMESTONE HAUL RATE	$/TON*MI	.030	.030	.030
LIMESTONE/SULFUR	MOLE RATI	2	2	2
ASH DISPOSAL COST	$/TON	4.00	4.00	4.00
TOTAL L.S. & ASH	$/MBTU	.095	.066	.058
TOTAL COAL COST	$/MBTU	1.786	1.622	1.774

II. FUEL COST SAVINGS

B. Estimated Cost of ROM Coal for Fluid Bed Steam Turbine and Gasifier Concepts

6.0 Calculations by Railroad

6.5 NORFOLK-SOUTHERN RAILROAD

Table IIB.6-13

COAL FUELING STATION ST. LOUIS, MISSOURI

COAL SOURCE	STATE	TENN.	ILLINOIS	WYOMING
COAL HEAT VALUE	BTU/LB	12530	11027	8638
COAL % SULFUR	%	1.4	2.7	.4
COAL % ASH	%	10.11	9.99	5.85
ROM COAL COST	$/TON	33.00	30.00	11.00
COAL PROCESS COST	$/TON	0.00	0.00	0.00
COAL DISTANCE	MILES	450	50	950
COAL HAUL RATE	$/TON*MI	.018	.018	.018
COAL TRANS. COST	$/TON	7.88	.88	16.62
COAL DELIVERED COST	$/MBTU	1.631	1.400	1.599
LIMESTONE COST	$/TON	4.00	4.00	4.00
LIMESTONE DISTANCE	MILES	100	100	100
LIMESTONE HAUL RATE	$/TON*MI	.030	.030	.030
LIMESTONE/SULFUR	MOLE RATI	2	2	2
ASH DISPOSAL COST	$/TON	4.00	4.00	4.00
TOTAL L.S. & ASH	$/MBTU	.052	.098	.029
TOTAL COAL COST	$/MBTU	1.683	1.498	1.628

COAL FUELING STATION BELLEVIEW, OH

COAL SOURCE	STATE	INDIANA	PENNA	WYOMING
COAL HEAT VALUE	BTU/LB	10937	12266	8638
COAL % SULFUR	%	2.5	1.8	.4
COAL % ASH	%	10.07	13.52	5.85
ROM COAL COST	$/TON	30.00	33.00	11.00
COAL PROCESS COST	$/TON	0.00	0.00	0.00
COAL DISTANCE	MILES	250	50	1200
COAL HAUL RATE	$/TON*MI	.018	.018	.018
COAL TRANS. COST	$/TON	4.38	.88	21.00
COAL DELIVERED COST	$/MBTU	1.572	1.381	1.852
LIMESTONE COST	$/TON	4.00	4.00	4.00
LIMESTONE DISTANCE	MILES	100	100	100
LIMESTONE HAUL RATE	$/TON*MI	.030	.030	.030
LIMESTONE/SULFUR	MOLE RATI	2	2	2
ASH DISPOSAL COST	$/TON	4.00	4.00	4.00
TOTAL L.S. & ASH	$/MBTU	.095	.071	.029
TOTAL COAL COST	$/MBTU	1.666	1.452	1.881

II. FUEL COST SAVINGS

B. Estimated Cost of ROM Coal for Fluid Bed Steam Turbine and Gasifier Concepts

6.0 Calculations by Railroad

6.5 NORFOLK-SOUTHERN RAILROAD

Table IIB.6-14

COAL FUELING STATION NORFOLK, VIRGINIA

COAL SOURCE	STATE	PENNA.	INDIANA	OHIO
COAL HEAT VALUE	BTU/LB	12266	10937	11664
COAL % SULFUR	%	1.8	2.5	3.3
COAL % ASH	%	13.52	10.07	11.45
ROM COAL COST	$/TON	33.00	30.00	30.00
COAL PROCESS COST	$/TON	0.00	0.00	0.00
COAL DISTANCE	MILES	300	600	400
COAL HAUL RATE	$/TON*MI	.018	.018	.018
COAL TRANS. COST	$/TON	5.25	10.50	7.00
COAL DELIVERED COST	$/MBTU	1.559	1.852	1.586
LIMESTONE COST	$/TON	4.00	4.00	4.00
LIMESTONE DISTANCE	MILES	100	100	100
LIMESTONE HAUL RATE	$/TON*MI	.030	.030	.030
LIMESTONE/SULFUR	MOLE RATI	2	2	2
ASH DISPOSAL COST	$/TON	4.00	4.00	4.00
TOTAL L.S. & ASH	$/MBTU	.071	.095	.112
TOTAL COAL COST	$/MBTU	1.631	1.946	1.698

II. FUEL COST SAVINGS

B. Estimated Cost of ROM Coal for Fluid Bed Steam Turbine and Gasifier Concepts

6.0 Calculations by Railroad

6.6 UNION PACIFIC RAILROAD

Table IIB.6-15

COAL FUELING STATION TOPEKA, KANSAS

COAL SOURCE	STATE	NEW MEX	ILLINOIS	WYOMING
COAL HEAT VALUE	BTU/LB	9350	11027	8638
COAL % SULFUR	%	.7	2.7	.4
COAL % ASH	%	19.4	10.0	5.8
ROM COAL COST	$/TON	11.00	30.00	11.00
COAL PROCESS COST	$/TON	0.00	0.00	0.00
COAL DISTANCE	MILES	550	400	700
COAL HAUL RATE	$/TON*MI	.018	.018	.018
COAL TRANS. COST	$/TON	9.63	7.00	12.25
COAL DELIVERED COST	$/MBTU	1.103	1.678	1.346
LIMESTONE COST	$/TON	4.00	4.00	4.00
LIMESTONE DISTANCE	MILES	100	100	100
LIMESTONE HAUL RATE	$/TON*MI	.030	.030	.030
LIMESTONE/SULFUR	MOLE RATI	2	2	2
ASH DISPOSAL COST	$/TON	4.00	4.00	4.00
TOTAL L.S. & ASH	$/MBTU	.066	.098	.029
TOTAL COAL COST	$/MBTU	1.169	1.775	1.375

COAL FUELING STATION ST. LOUIS, MISSOURI

COAL SOURCE	STATE	ILLINOIS	KENTUCKY	WYOMING
COAL HEAT VALUE	BTU/LB	11027	12012	8638
COAL % SULFUR	%	2.7	1.8	.4
COAL % ASH	%	10.0	10.5	5.8
ROM COAL COST	$/TON	30.00	33.00	11.00
COAL PROCESS COST	$/TON	0.00	0.00	0.00
COAL DISTANCE	MILES	50	500	950
COAL HAUL RATE	$/TON*MI	.018	.018	.018
COAL TRANS. COST	$/TON	.88	8.75	16.62
COAL DELIVERED COST	$/MBTU	1.400	1.738	1.599
LIMESTONE COST	$/TON	4.00	4.00	4.00
LIMESTONE DISTANCE	MILES	100	100	100
LIMESTONE HAUL RATE	$/TON*MI	.030	.030	.030
LIMESTONE/SULFUR	MOLE RATI	2	2	2
ASH DISPOSAL COST	$/TON	4.00	4.00	4.00
TOTAL L.S. & ASH	$/MBTU	.098	.066	.029
TOTAL COAL COST	$/MBTU	1.498	1.804	1.628

II. FUEL COST SAVINGS

B. Estimated Cost of ROM Coal for Fluid Bed Steam Turbine and Gasifier Concepts

6.0 Calculations by Railroad

6.6 UNION PACIFIC RAILROAD

Table IIB.6-16

COAL FUELING STATION FORT WORTH, TEXAS

COAL SOURCE	STATE	ALABAMA	NEW MEX	WYOMING
COAL HEAT VALUE	BTU/LB	12129	9350	8638
COAL % SULFUR	%	1.4	.7	.4
COAL % ASH	%	12.3	19.4	5.8
ROM COAL COST	$/TON	39.00	11.00	11.00
COAL PROCESS COST	$/TON	0.00	0.00	0.00
COAL DISTANCE	MILES	375	600	1000
COAL HAUL RATE	$/TON*MI	.018	.018	.018
COAL TRANS. COST	$/TON	6.56	10.50	17.50
COAL DELIVERED COST	$/MBTU	1.878	1.150	1.650
LIMESTONE COST	$/TON	4.00	4.00	4.00
LIMESTONE DISTANCE	MILES	100	100	100
LIMESTONE HAUL RATE	$/TON*MI	.030	.030	.030
LIMESTONE/SULFUR	MOLE RATI	2	2	2
ASH DISPOSAL COST	$/TON	4.00	4.00	4.00
TOTAL L.S. & ASH	$/MBTU	.058	.066	.029
TOTAL COAL COST	$/MBTU	1.937	1.216	1.679

COAL FUELING STATION GREEN RIVER, WYOMING

COAL SOURCE	STATE	WYOMING
COAL HEAT VALUE	BTU/LB	8638
COAL % SULFUR	%	.4
COAL % ASH	%	5.8
ROM COAL COST	$/TON	11.00
COAL PROCESS COST	$/TON	0.00
COAL DISTANCE	MILES	100
COAL HAUL RATE	$/TON*MI	.018
COAL TRANS. COST	$/TON	1.75
COAL DELIVERED COST	$/MBTU	.738
LIMESTONE COST	$/TON	4.00
LIMESTONE DISTANCE	MILES	100
LIMESTONE HAUL RATE	$/TON*MI	.030
LIMESTONE/SULFUR	MOLE RATI	2
ASH DISPOSAL COST	$/TON	4.00
TOTAL L.S. & ASH	$/MBTU	.029
TOTAL COAL COST	$/MBTU	.767

II. FUEL COST SAVINGS

B. Estimated Cost of ROM Coal for Fluid Bed Steam Turbine and Gasifier Concepts

6.0 Calculations by Railroad

6.6 UNION PACIFIC RAILROAD

Table IIB.6-17

COAL FUELING STATION CALLENTE, NEVADA

COAL SOURCE	STATE	WYOMING	UTAH	ARIZONA
COAL HEAT VALUE	BTU/LB	8638	11575	10998
COAL % SULFUR	%	.4	.5	.5
COAL % ASH	%	5.8	10.1	9.3
ROM COAL COST	$/TON	11.00	30.00	11.00
COAL PROCESS COST	$/TON	0.00	0.00	0.00
COAL DISTANCE	MILES	500	250	300
COAL HAUL RATE	$/TON*MI	.018	.018	.018
COAL TRANS. COST	$/TON	8.75	4.38	5.25
COAL DELIVERED COST	$/MBTU	1.143	1.485	.739
LIMESTONE COST	$/TON	4.00	4.00	4.00
LIMESTONE DISTANCE	MILES	100	100	100
LIMESTONE HAUL RATE	$/TON*MI	.030	.030	.030
LIMESTONE/SULFUR	MOLE RATI	2	2	2
ASH DISPOSAL COST	$/TON	4.00	4.00	4.00
TOTAL L.S. & ASH	$/MBTU	.029	.032	.033
TOTAL COAL COST	$/MBTU	1.172	1.517	.771

COAL FUELING STATION RENO JUNCTION, CALIFORNIA

COAL SOURCE	STATE	ARIZONA	WYOMING	UTAH
COAL HEAT VALUE	BTU/LB	10998	8638	11575
COAL % SULFUR	%	.5	.4	.5
COAL % ASH	%	9.3	5.8	10.1
ROM COAL COST	$/TON	11.00	11.00	30.00
COAL PROCESS COST	$/TON	0.00	0.00	0.00
COAL DISTANCE	MILES	600	500	200
COAL HAUL RATE	$/TON*MI	.018	.018	.018
COAL TRANS. COST	$/TON	10.50	8.75	3.50
COAL DELIVERED COST	$/MBTU	.977	1.143	1.447
LIMESTONE COST	$/TON	4.00	4.00	4.00
LIMESTONE DISTANCE	MILES	100	100	100
LIMESTONE HAUL RATE	$/TON*MI	.030	.030	.030
LIMESTONE/SULFUR	MOLE RATI	2	2	2
ASH DISPOSAL COST	$/TON	4.00	4.00	4.00
TOTAL L.S. & ASH	$/MBTU	.033	.029	.032
TOTAL COAL COST	$/MBTU	1.010	1.172	1.479

II. FUEL COST SAVINGS

B. Estimated Cost of ROM Coal for Fluid Bed Steam Turbine and Gasifier Concepts

7. References:

1. Donaldson, Lufken & Jenrette, Research Bulletin, DJIA: 1269.82, November 28, 1983.

2. Transportation in America, Page 11, March 1985.

3. Dean Winter, Quarterly Railroad Report, March 1985.

4. SOx and NOx Control in Combustion, O.W. Dykemer, Coal Technology, 1983.

5. Minerals Yearbook, 1983, Volume 1, Bureau of Mines, U.S. Government Printing Office, 1984, Pages 801-820.

II. FUEL COST SAVINGS

B. Estimated Cost of ROM Coal for Fluid Bed Steam Turbine & Gasifier Concepts (continued)

8. Fuel Savings Equation

8.1 ROM Coal Fluid Bed Steam Turbine Locomotive

For the ROM coal options, as shown in Section II B, the delivered coal costs are considerably cheaper than for the coal water slurry fuel, including the cost of limestone which is added to neutralize the effects of sulfur. As a result, the % fuel savings for the ROM coal options is expected to be higher.

For fluid bed steam turbine locomotive, a fuel savings equation was developed in a similar fashion as for the previous coal water slurry options. Percent fuel savings taken directly from Digicalc Spreadsheets, WS10 & WS11 for the Eastern Duty Cycle and Western Duty Cycle respectively were 32.2% & 53.6%. In this case, there are greater fuel savings for the Western Duty Cycle because the ROM coal costs are cheaper than for the Eastern.

The resultant fuel savings equation was found to be:

Fuel Savings = $-16239 + .7739 X (Gallons/Year-160,000)

8.2 ROM Coal Gasifier with GE27

Similarly, for the gasifier option with the GE27 gas turbine, the fuel savings is expected to be higher for this locomotive than for coal water slurry fuels.

For this option, the % fuel savings taken directly from Digicalc Spreadsheets WS2 & WS3 for the Eastern Duty Cycle and Western Duty Cycle respectively were 42.7% & 63.7%. Again, there are greater fuel savings for the Western Duty Cycle because of the lower Western ROM coal costs.

The resultant fuel savings equation for this alternative was found to be:

Fuel Savings = $-551 + .8515 (Gallons/Year - 160,000)

II. FUEL COST SAVINGS

C. Duty Cycle Fuel Calculations

1. Introduction

For purposes of economic evaluation of alternative coal burning locomotives, it is deemed necessary to derive a cost in mills per horsepower-hour for fuel, consumables, and disposables. These costs should properly include raw coal costs, processing costs, transportation costs, costs of consumables for environmental clean-up, water costs, and costs to dispose of tars, ash, and any other materials which do not go out the stack.

Since a locomotive does not spend a large percentage of time at full horsepower, a duty cycle comparison was chosen for the analysis. Two duty cycles were selected; one representing heavy duty, drag service for Western railroads, and one representing heavy duty, drag service for Eastern railroads. These duty cycles are shown as Figure II.C.1.

2. General Assumptions and Guidelines

2.1 Basis for Comparisons

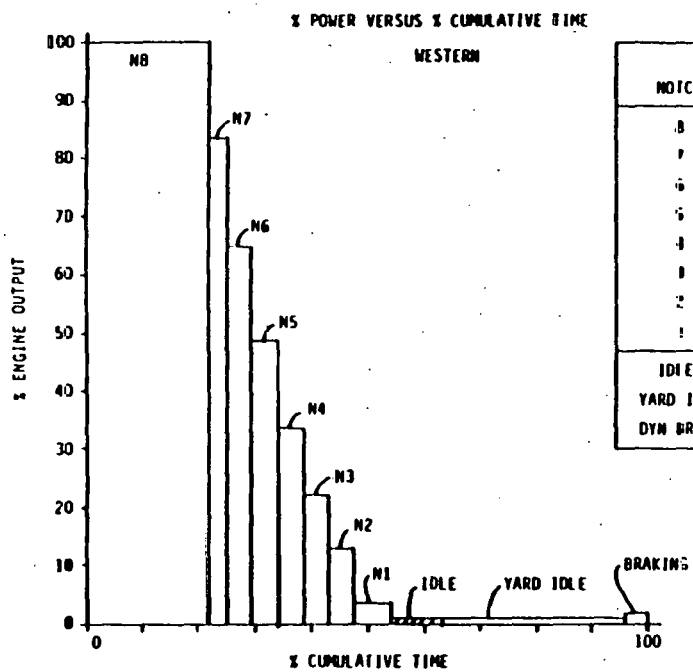
The General Electric Dash 8 locomotive was selected as the base case for comparison, burning diesel fuel (DF2). This is General Electric's latest production model locomotive (brochure attached). A 1% thermal efficiency improvement over initial Dash 8 fuel economy was also included for expected improvements using a new injector.

2.2 Traction Drive Losses

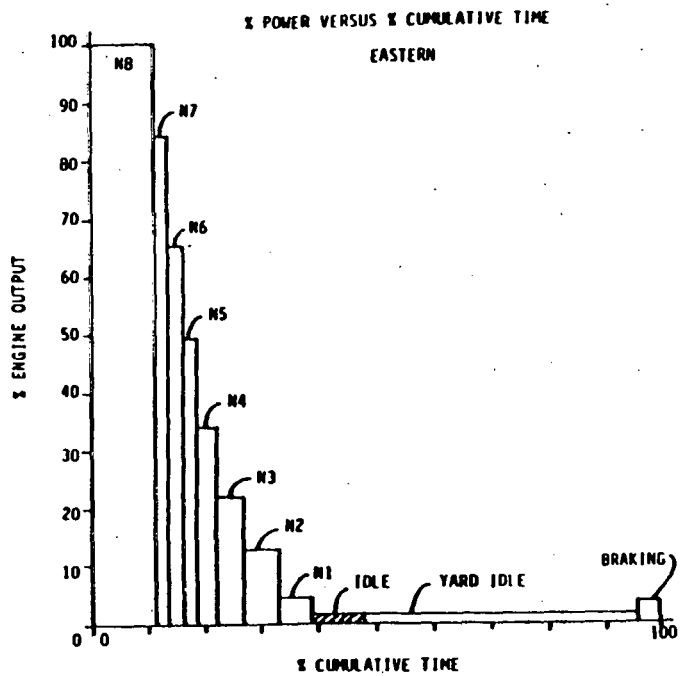
Although alternator, traction motor, and traction motor cooling losses are appreciable, it was assumed that they present the same efficiency to both coal burning and diesel burning options. The fuel costs are, therefore, compared in mills per hp-hr. delivered to the alternator input shaft. Although some small amount of power is delivered from the alternator during dynamic braking and at idle, these horsepower-hours are not considered as useful work accomplished by the locomotive in calculating thermal efficiency.

2.3 Engine Auxiliaries

The engine auxiliaries drawing the most HP from the engine are the radiator fans, equipment blowers, and the air compressor. In all cases, these auxiliaries are controlled on modern locomotives by varying fan, blower or compressor speeds to provide, on the average only the required air to



NOTCH	% ENGINE OUTPUT	WESTERN % TIME IN NOTCH	EASTERN % TIME IN NOTCH
8	100	22	11.3
7	83	2.8	2.4
6	64	4.8	2.8
5	48	4.5	2.6
4	32	4.9	3.6
3	21	4.2	4.8
2	12	4.5	5.8
1	3	6.5	6.3
IDLE	1	9	9
YARD IDLE	1	33	47.6
DYN BRKG	2	3.8	3.8
	% TOTAL	100.0	100.0



RAILROAD LOCOMOTIVE DUTY CYCLES

Fig. II.C.1

II. FUEL COST SAVINGS

C. Duty Cycle Fuel Calculations

2. General Assumptions and Guidelines

2.3 Engine Auxiliaries (continued)

maintain proper engine temperatures, traction motor temperatures, and braking air pressure. The horsepower for the air compressor and traction motor cooling will not change, assuming similar load and environmental conditions, whether the diesel engine is burning diesel fuel or coal slurry.

The cooling requirements of the engine may change slightly, even though roughly comparable heat input is provided. Since insufficient data are available at this time to know whether a coal burning engine has different requirements, the auxiliary horsepower is assumed to be the same, whether the engine fuel is diesel or coal-water slurry. The auxiliary horsepower included in both cases is that required for 60°F, 1000 ft. altitude conditions.

For the direct burning gas turbine and gas turbine with steam injection alternative, no additional engine auxiliaries were assumed. However, at this time it is not known if additional engine compartment cooling is required because of higher radiation energy inherent in the coal fired turbine combustor gases.

The fluid bed steam turbine system will require additional auxiliaries as follows:

. Boiler Fan
. Condenser Fan
. Boiler Feed Pump

The auxiliary horsepower required for these have been included in the analyses.

For the gasifier alternative, only an additional air supply fan auxiliary load was included.

II. FUEL COST SAVINGS

C. Duty Cycle Fuel Calculations

3. Fuel Costs

As shown in the previous section, the total picture emerges that the cost per million BTU's of processed coal at the fueling station is higher for Western railroads. Two different costs were, therefore, selected for inputs to the duty cycle fuel savings calculations, one for Western and one for Eastern railroads.

A summary of these costs in $/million BTU's is shown in Figure II.C.3 for coal-water mixture (CWM).

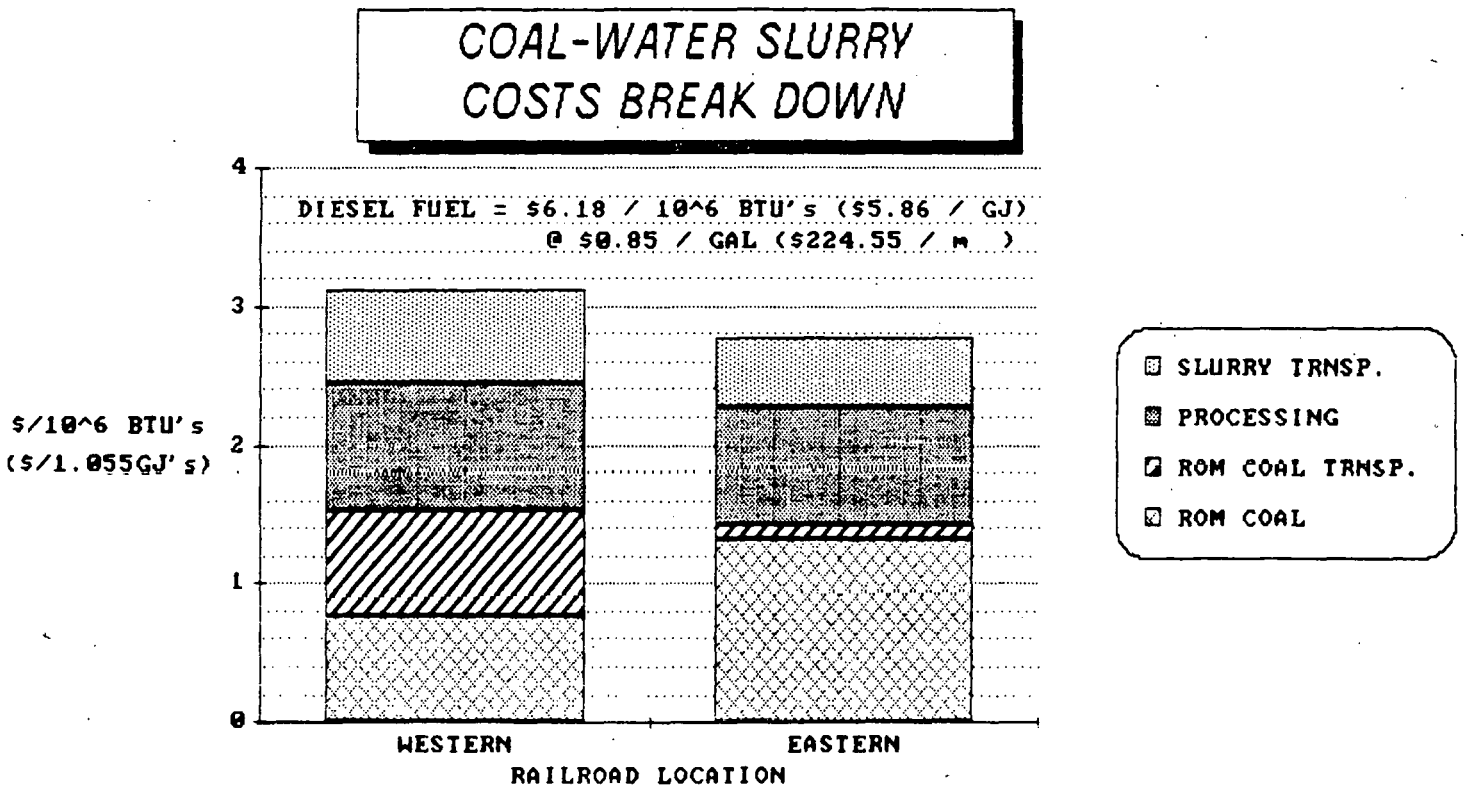


Fig. II.C.3

II. FUEL COST SAVINGS

C. Duty Cycle Fuel Calculations (continued)

4. Results - Fuel Costs for Coal-Oil Mixture (COM) and Coal-Water Mixtures (CWM)

A comparison of the duty cycle cost calculations are summarized in Figure II.C.4 for Western and Eastern duty cycles. The measurement of cost per work done (mills/HP-Hr.) evaluates #2 diesel oil, COM, and CWM on an equal basis.

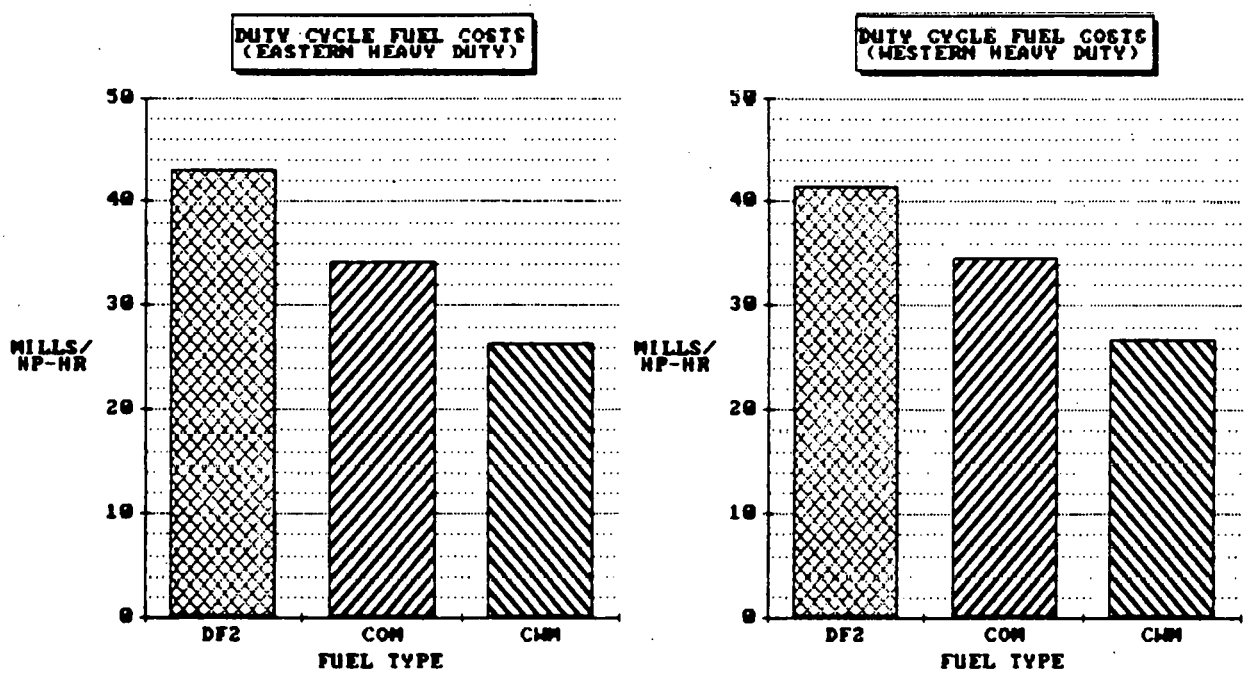


Fig. II.C.4

II. FUEL COST SAVINGS

C. Duty Cycle Fuel Calculations

4. Results - Fuel Costs for Coal-Oil Mixtures (COM) and Coal-Water Mixtures (CWM) (continued)

From the results, a decision has been made to discontinue consideration of diesel engine burning coal-oil mixtures. This decision is made for two basic reasons:

1. Rheology of micronized coal particles appears to limit the coal loading to 50% or less. (Higher loadings become highly viscous and defy injection.)

2. The savings available from even a 50% by weight coal-oil mixture do not substantially reduce the use of diesel fuel and do not result in low enough fuel costs to justify the development expense.

Since railroads do not burn the same annual quantities of fuel nor do they have the same duty cycles, a convenient way to show fuel cost savings was derived so that an analysis of discounted rate of return could be run, railroad by railroad. This derivation is shown as Figure II.B.4-1. The final equation for fuel cost savings was given in Section II.A. This equation automatically takes care of duty cycle and geographical variations between railroads.

II. FUEL COST SAVINGS

C. Duty Cycle Fuel Calculations (continued)

5. Use of Spread Sheet Methodology

It was decided that Digicalc® spreadsheet calculations would be utilized with the Digital Equipment Corporation VAX11780 to perform the duty cycle fuel cost comparisons. A low and high coal fuel cost spreadsheet has been created for heavy duty applications on both Eastern and Western railroads.

The basic method used is to take an arbitrary time period (in this case, 56 hours), and to impose the specified duty cycle. Fuel consumed at each notch as well as the other consumables are calculated for each notch condition. By summation of fuel costs and work performed, costs are normalized and put on a common basis of mills per hp-hr.

5.1 Explaining the Spreadsheet Layout

The spreadsheets have much in common as can be shown by referring to the sample work sheet, WS-17 (Appendix 'A'), Direct Burning Diesel.

In each spreadsheet, there is a heading which includes input conditions and ratings such as coal slurry costs, diesel fuel costs and the horsepower for traction at the alternator input shaft. Also shown is an arbitrarily assumed time over which the duty cycle is run.

Beneath the heading is the first of two calculation segments. In the upper segment of WS-17, the twelve columns are as follows:

A. Notch position
B. % Rated HP (for traction)
C. % of Duty Cycle Time at this notch
D. HP at alternator input shaft, minus HP for auxiliaries
E. Specific fuel consumption from graphical data or look-up table
F. Pounds/hr. of diesel fuel (if used alone)
G. Radiator fan horsepower, at 60°F, S.L.
H. Total BTU's required/hr. if burning dry coal or diesel fuel
I. Pilot injection BTU's/hr. (DF2) (up to first 2 million BTU's/hr.)
J. HP-hrs. of useful work accomplished in each notch
K. Thermal efficiency using diesel fuel at each notch
L. BTU's consumed at each notch

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II. FUEL COST SAVINGS

C. Duty Cycle Fuel Calculations

5. Use of Spreadsheet Methodology

5.1 Explaining the Spreadsheet Layout (continued)

The lower segment has the following columns:

A. Notch position (repeated)
B. % Rated HP for traction (repeated)
C. BTU's supplied from coal, if dry coal, at each notch
D. Blank
E. BTU's supplied from coal if CW slurry, at each notch
F. Pounds of coal consumed at each notch (coal in slurry)
G. Pounds of diesel fuel for pilot injection
H. Total fuel costs by notch, burning coal-water slurry with diesel pilot injection
I. Fuel costs by notch if burning diesel fuel only
J. Gallons of CW slurry by notch
K. Gallons of pilot diesel fuel
L. Thermal efficiency (LHV basis) with CW slurry and DF2 pilot injection

Beneath the lower segment are the principal answers of interest, the fuel costs in mills per hp-hr. and the full power and duty cycle thermal efficiencies.

The detailed equations stored in each cursor block of the spreadsheet, (i.e.) relationships between columns is shown in Appendix 'B'. The worksheets for each alternate, with low and high fuel costs are shown in Appendix 'A'.

II. FUEL COST SAVINGS

C. Duty Cycle Fuel Calculations (continued)

6. Special Considerations and Assumptions by Alternate

It is not intended that this report describe the alternates in any detail.

6.1 Diesel Engine Burning Coal Water Slurry (Appendix 'A' - WS-17 and WS-30)

Since this engine has not been developed, a number of assumptions were made as to how it would perform, in order to estimate fuel costs. These are the following:

6.1.1 A 53-47 by weight slurry of water and super clean, micronized coal will be burned. Any moisture not removed from the coal during cleaning is considered to be part of the 53% water content of the slurry. Additives as may be required for the slurry are ignored.

6.1.2 A pilot injector will be used at all loads which will provide up to the first 2,000,000 BTU's/hr. from diesel fuel. All remaining input energy will come from the slurry.

6.1.3 100% combustion is assumed.

6.1.4 A fuel cost penalty of the ratio of 52.7/47.3 is used for all BTU's supplied from coal water slurry to take into account heat needed to vaporize the water in the slurry. (See Appendix 'C' for derivation.)

6.1.5 Engine will be run at yard idle conditions as in today's railroad practice.

6.2 Diesel Engine Burning A Coal-Oil Slurry (Appendix 'A' - WS-16 and WS-13)

Assumptions for this undeveloped engine are as follows:

6.2.1 Dry, micronized coal with higher heating value of 14,500 BTU/Lb. is used in a 50-50 by weight slurry with diesel fuel (DF2).

6.2.2 100% combustion is achieved.

6.2.3 Engine will be idled as today's practice in yard idle.

Note: The fuel savings of this coal-oil slurry (17% and 21%) were so low that the alternate was dropped. The coal-water slurry above, provides savings of 37% and 40% for equivalent duty.

II. FUEL COST SAVINGS

C. Duty Cycle Fuel Calculations

6. Special Considerations and Assumptions by Alternate (continued)

6.3 Direct Fired GE27 Gas Turbine

The gas turbine candidate selected for this study is the highly efficient General Electric GE27 variable geometry gas turbine.

This version does not employ steam injection and is nominally rated for 5900 HP. Assumptions for this case are shown on the bottom of Spreadsheets WS-36 & WS-40, for Eastern and Western Railroads in Appendix A.

For the gas turbine, it is assumed that it will be shut down during yard idle (in contrast to the diesel constantly running) with attendant fuel savings.

6.4 Direct Fired GE27 Gas Turbine with Steam Injection

The GE27 gas turbine was also selected for this alternative because of its high efficiency.

For this alternative, steam has been injected into the gas turbine in order to increase total efficiency and to increase the HP level from 5900 to 8000. A feedwater pump delivers water from a tank to a heat recovery steam generator located in the exhaust stream of the GE27. The hot gas from the GE27 causes the water in the steam generator to flash into steam. The feedwater pump provides sufficient pressure head to make up for the line and heat exchanger losses to enable flow.

Additional assumptions for this case are shown on the bottom of the Spreadsheets WS-8 & WS-9 for Eastern and Western Railroads in Appendix A.

6.5 ROM Coal Fluid Bed Steam Turbine

An 8000 HP steam turbine was sized and performance estimated by GE as the prime mover for this locomotive alternative.

This alternative locomotive requires a boiler feed pump to circulate water in the system. It also requires condensing fans for condensing steam from the turbine exhaust into the radiators and air supply and exhaust fans for the fluid bed.

II. FUEL COST SAVINGS

C. Duty Cycle Fuel Calculations

6. Special Considerations and Assumptions by Alternate

6.5 ROM Coal Fluid Bed Steam Turbine (continued)

Various assumptions pertaining to this alternative locomotive system are shown on the bottom of the Spreadsheets WS-10 & WS-11 for Eastern and Western Railroads in Appendix A.

6.6 ROM Coal Gasifier with GE27

A GE27 gas turbine was selected for this configuration, with additional steam injection to increase the HP to 8000.

This alternative requires air supply bled from the turbine compressor plus a steam driven booster fan to provide sufficient high pressure air to the gasifier.

For this alternative, it is necessary to keep the GE27 gas turbine and gasifier running as opposed to shutting down the turbine for the direct fired turbine options.

Various assumptions pertaining to this alternative locomotive system are shown on the bottom of the Spreadsheets WS-2 & WS-3 for Eastern and Western Railroads in Appendix A.

APPENDIX 'A'

SPREADSHEETS

FOR

LOCOMOTIVE ALTERNATES

WITH

LOW AND HIGH FUEL COSTS

FOR

EASTERN AND WESTERN

DUTY CYCLES

ROW COL

A	B	C	D	E	F	G	H	I	J	K	L

3 TIME OF TOTAL RUN - HRS = 56 UNIT HP RATING= 3822

4 SCM CW-SLURRY CSTS,$/10^6 BTU'S = 3.13 DF2 COSTS IN $/GALLON= 0.85

10 UPPER SEGMENT

NOTCH POSITION	% RATED HP	DUTY CYCLE % TIME	ENGINE HP	SFC $/HP-HR	DF2/HR (#)	RAD. FAN HP	DRY COAL BTU'S/HR.	PILOT BTU'S HR.	HP-HRS (000)	DF2 THERM EFF (%)	BTU'S CONS (000)
1	2.7	6.5	103	0.450	47	0.1	856,130	856,130	0.4	30.7	3,116
2	11.5	4.5	439	0.378	166	0.6	3,057,500	2,000,000	1.1	36.5	7,705
3	21.2	4.2	811	0.378	308	3.5	5,664,202	2,000,000	1.9	36.4	13,322
4	31.9	4.9	1,219	0.372	456	6.5	8,387,673	2,000,000	3.3	37.0	23,016
5	48.1	4.5	1,839	0.348	644	11	11,843,947	2,000,000	4.6	39.5	29,847
6	64.3	4.8	2,458	0.336	831	16	15,298,198	2,000,000	5.6	40.9	41,122
7	83.2	2.8	3,182	0.331	1,059	19	19,492,671	2,000,000	5.0	41.5	30,565
8	100	22	3,822	0.328	1,263	30	23,247,590	2,000,000	47.1	41.8	285,410
IDLE	1.0	9	38		27	0.1	496,800	496,800			2,504
YRD.IDLE	1.0	33	38		20	0.1	368,000	368,000			5,801
DYN.BRAKE	2	3.8	76		46	0.2	846,400	846,400			1,801
									70.1	<--TOTAL-->	446,208

27 LOWER SEGMENT

NOTCH POSITION	% RATED HP	BTU CONS.COAL (IF DRY)	SLURRY BTU COAL CONSUMBED	SLURRY CLEAN COAL CONSBD #	DF2 #	TOTAL FUEL COST CONSUMBED	EQUIV DF2 FUEL COSTS	GALLONS OF SLURRY REQ.	GALLONS OF DF2 REQ.	THERM EFF SLRY.,%
1	2.7	0	0	0	169	20	20	0	24	30.7%
2	11.5	2,665,152	2,968,164	440	274	43	50	46	39	35.2%
3	21.2	8,618,203	9,598,041	1,422	256	63	87	149	36	33.9%
4	31.9	17,527,775	19,520,579	2,892	298	102	150	303	42	34.0%
5	48.1	24,806,747	27,627,125	4,093	274	127	194	429	39	36.1%
6	64.3	35,745,557	39,809,613	5,898	292	170	268	519	41	37.2%
7	83.2	27,628,508	30,546,945	4,525	170	124	199	475	24	37.7%
8	100	261,770,314	291,532,027	43,190	1,339	1,150	1,864	4,530	199	37.9%
IDLE	1.0	0	0	0	136	16	16	0	19	0.0%
YRD.IDLE	1.0	0	0	0	370	44	44	0	52	0.0%
DYN.BRAKE	2	0	0	0	98	12	12	0	14	0.0%
COL TOTALS - - ->			421,602,583	62,460	3,676	1,871.34	2,903.22	6,551	518	

40 ON DF2 FULL POWER THERMAL EFFICIENCY = 41.841%

41 DUTY CYCLE THERMAL EFFICIENCY = 39.995%

FUEL COST, MILLS / HP-HR = 26.71

EQUIV. DF2 COST, MILLS / HP-HR = 41.44

43 ON SLURRY FULL POWER THERMAL EFFICIENCY = 37.902%

44 DUTY CYCLE THERMAL EFFICIENCY = 36.440%

FUEL COST SAVINGS = 35.54%

DIRECT COAL-WATER SLURRY BURNING DIESEL

WESTERN-HEAVY DUTY CYCLE

WS-17

TIME OF TOTAL RUN-HRS= 56
SCM CW-SLURRY COSTS,$/10^6 BTU'S= 2.35

UNIT HP RATING = 3822
DF2 COSTS IN $/GALLON= 0.85
COAL (BTU) IN SLURRY = 14500 (UHV)

NOTCH POSITION	% RATED HP	DUTY CYCLE % TIME	ENGINE HP	SFC #/HP-HR	# DF2/ HR.	RAD.FAN HP	TOTAL BTU'S/HR.	PILOT BTU'S HR.	HP-HRS (000)	THERMAL EFF DF2 (%)	BTU CONS (000)
1	2.7	6.3	103	0.450	47	0.1	856,130	856,130	0.4	30.7	3,020
2	11.5	5.8	439	0.378	166	0.6	3,057,600	2,000,000	1.4	36.5	9,931
3	21.2	4.8	811	0.379	308	3.5	5,664,202	2,000,000	2.2	36.4	15,225
4	31.9	3.6	1,219	0.372	456	6.5	8,387,673	2,000,000	2.5	37.0	16,910
5	48.1	2.6	1,839	0.348	544	11	11,843,947	2,000,000	2.7	39.5	17,245
6	64.3	2.8	2,458	0.336	831	16	15,298,198	2,000,000	3.9	40.9	23,998
7	83.2	2.4	3,182	0.331	1,059	19	19,492,671	2,000,000	4.3	41.5	26,198
8	100	11.3	3,822	0.328	1,263	30	23,247,590	2,000,000	24.2	41.8	147,111
IDLE	1.0	9	38		27	0.1	496,800	496,800			2,504
YRD.IDLE	1.0	47.6	38		20	0.1	368,000	368,000			9,809
DYN.BRAKE	2	3.8	76		46	0.2	846,400	846,400			1,801
									41.4	<--TOTAL-->	273,742

NOTCH POSITION	% RATED HP	BTU CONS.COAL (IF DRY)		SLURRY BTU COAL CONSUMBED	SLURRY CLEAN COAL CONSBD #	DF2 (#)	TOTAL FUEL COST CONSUMBED	EQUIV. DF2 FUEL COSTS	GALLONS OF SLURRY REQ.	GALLONS OF DF2 REQ.	THERM.EFF. SLRY.,%
1	2.7	0		0	0	164	20	20	0	23	30.7%
2	11.5	3,435,095		3,825,633	528	353	54	65	59	50	35.2%
3	21.2	9,849,375		10,969,190	1,513	292	68	99	170	41	33.9%
4	31.9	12,977,550		14,341,650	1,978	219	70	110	223	31	34.0%
5	48.1	14,332,797		15,962,339	2,202	158	67	112	249	22	36.1%
6	64.3	20,851,575		23,222,274	3,203	170	91	156	351	24	37.2%
7	83.2	23,510,150		26,183,113	3,611	146	97	170	407	21	37.7%
8	100	134,454,752		149,741,450	20,654	688	536	957	2,327	97	37.9%
IDLE	1	0		0	0	136	16	16	0	19	0.0%
YRD.IDLE	1	0		0	0	533	64	64	0	75	0.0%
DYN.BRAKE	2	0		0	0	98	12	12	0	14	0.0%
COL TOTALS - - - - ->			0	244,245,649	33,689	2,958	1,034	$1,781.08	3,795	417	

ON DF2 FULL POWER THERMAL EFFICIENCY = 41.841%
DUTY CYCLE THERMAL EFFICIENCY = 38.509%

ON SLURRY FULL POWER THERMAL EFFICIENCY = 37.902%
DUTY CYCLE THERMAL EFFICIENCY = 35.235%

FUEL COST, MILLS / HP-HR = 26.42
EQUIV. DF2 COST, MILLS / HP-HR = 43.00

FUEL COST SAVINGS = 38.55%

DIRECT COAL-WATER SLURRY BURNING DIESEL
EASTERN-HEAVY DUTY CYCLE
WS-30

TIME OF TOTAL RUN-HRS= 56
SCM DRY COAL COSTS IN $/10^6 BTU= 3.14
DRY COAL ADDER = 0.35

UNIT HP RATING = 3822
DF2 COSTS IN $/GALLON= 0.85
COAL HHV IN SLURRY = 14500 (HHV)

NOTCH POSITION	% RATED HP	DUTY CYCLE % TIME	ENGINE HP	SFC #/HP-HR	# DF2/ HR.	RAD.FAN HP	LIQ.FUEL BTU'S/HR.	HP-HRS (000)	THERMAL EFF DF2 (%)	BTU'S CONS (000)
1	2.7	6.3	103	0.450	47	0.1	856,130	0.4	30.7	3,020
2	11.5	5.8	439	0.378	166	0.6	3,057,600	1.4	35.5	9,931
3	21.2	4.8	811	0.378	308	3.5	5,664,202	2.2	35.4	15,225
4	31.9	3.6	1,219	0.372	456	6.5	8,387,673	2.5	37.0	16,910
5	48.1	2.6	1,839	0.348	644	11	11,843,347	2.7	39.5	17,245
6	64.3	2.8	2,458	0.338	831	16	15,298,198	3.9	40.9	23,988
7	83.2	2.4	3,182	0.331	1,059	19	19,492,671	4.3	41.5	26,198
8	100	11.3	3,822	0.328	1,263	30	23,247,590	24.2	41.8	147,111
IDLE	1	9	38		27	0.1	496,800			2,504
YRD.IDLE	1	47.6	38		20	0.1	368,000			9,839
DYN.BRAKE	2	3.8	76		46	0.2	846,400			1,801
								41.4	<--TOTAL-->	273,742

NOTCH POSITION	% RATED HP	SLURRY CONS #	14500 BTU COAL CONS #	DF2 GALLONS	TOT.COSTS FUEL CONS.	EQUIV DF2 FUEL COST	THERMAL EFF SLURRY (%)
1	2.7	189	94	13	16	20	30.7%
2	11.5	620	310	44	51	65	36.5%
3	21.2	951	475	67	79	99	36.4%
4	31.9	1,056	528	74	87	110	37.0%
5	48.1	1,077	538	76	89	112	39.5%
6	54.3	1,498	749	105	124	156	40.9%
7	83.2	1,636	818	115	135	170	41.5%
8	100	9,186	4,593	647	759	957	41.8%
IDLE	1.0	156	78	11	13	16	0.0%
YRD.IDLE	1.0	613	306	43	51	64	0.0%
DYN.BRAKE	2	112	56	8	9	12	0.0%
			8,546	1,204	$1,412.41	$1,781.08	

ON DF2 FULL POWER THERMAL EFF 41.84%
DUTY CYCLE THERMAL EFF 38.51%

FUEL COST,MILLS/HP-HR= 34.10
EQUIVALENT DF2 COST,MILLS/HP-HR= 43.00

ON SLURRY FULL POWER THERMAL EFF 41.84%
DUTY CYCLE THERMAL EFF 38.51%

FUEL COST SAVINGS = 20.70%

DIRECT COAL-OIL SLURRY BURNING DIESEL
EASTERN-HEAVY DUTY CYCLE
WS-16

TIME OF TOTAL RUN-HRS= 56
SCM DRY COAL COSTS IN $/10^6 BTU= 3.51
DRY COAL ADDER = 0.39

UNIT HP RATING = 3822
DF2 COSTS IN $/GALLON= 0.85
COAL HHV IN SLURRY = 14500 (HHV)

NOTCH POSITION	% RATED HP	DUTY CYCLE % TIME	ENGINE HP	SFC #/HP-HR	# DF2/ HR.	RAD.FAN HP	LIQ.FUEL BTU'S/HR.	HP-HRS (000)	THERMAL EFF DF2 (%)	BTU'S CONS (000)
1	2.7	6.5	103	0.450	47	0.1	856,130	0.4	30.7	3,116
2	11.5	4.5	439	0.378	166	0.6	3,057,600	1.1	35.5	7,705
3	21.2	4.2	811	0.378	308	3.5	5,664,202	1.9	35.4	13,322
4	31.9	4.9	1,219	0.372	456	6.5	8,387,673	3.3	37.0	23,016
5	48.1	4.5	1,839	0.348	644	11	11,843,947	4.6	39.5	29,847
6	64.3	4.8	2,458	0.336	831	16	15,298,198	6.6	40.9	41,122
7	83.2	2.8	3,182	0.331	1,059	19	19,492,671	5.0	41.5	30,565
8	100	22	3,922	0.328	1,263	30	23,247,590	47.1	41.8	286,410
IDLE	1.0	9	38		27	0.1	496,800			2,504
YRD.IDLE	1.0	33	38		20	0.1	368,000			6,801
DYN.BRAKE	2	3.8	76		46	0.2	846,400			1,831
								70.1	<--TOTAL-->	446,208

NOTCH POSITION	% RATED HP	SLURRY CONS #	14500 BTU COAL CONS #	DF2 GALLONS	TOT.COSTS FUEL CONS.	EQUIV DF2 FUEL COST	THERMAL EFF SLURRY (%)
1	2.7	195	97	14	17	20	30.7%
2	11.5	481	241	34	42	50	36.5%
3	21.2	832	416	59	72	87	36.4%
4	31.9	1,437	719	101	125	150	37.0%
5	48.1	1,864	932	131	162	194	39.5%
6	64.3	2,568	1,284	181	223	268	40.9%
7	83.2	1,908	954	134	166	199	41.5%
8	100	17,884	8,942	1,259	1,555	1,864	41.8%
IDLE	1.0	156	78	11	14	16	0.0%
YRD.IDLE	1.0	425	212	30	37	44	0.0%
DYN.BRAKE	2	112	56	8	10	12	0.0%
			13,931	1,962	$2,422.28	$2,903.22	

ON DF2 FULL POWER THERMAL EFF 41.84%
DUTY CYCLE THERMAL EFF 39.95%

ON SLURRY FULL POWER THERMAL EFF 41.84%
DUTY CYCLE THERMAL EFF 39.95%

FUEL COST,MILLS/HP-HR= 34.58
EQUIVALENT DF2 COST,MILLS/HP-HR= 41.44

FUEL COST SAVINGS = 16.57%

DIRECT COAL-OIL SLURRY BURNING LOCOMOTIVE
WESTERN-HEAVY DUTY CYCLE
WS-13

TIME OF TOTAL RUN-HRS= 55 UNIT HP RATING (DF2)= 5940

SCM COAL COSTS IN $/ 10^6 BTU'S = 2.844

NOTCH POSITION	% RATED HP	DUTY CYCLE % TIME	ENGINE HP	PER UNIT FUEL RATE	14500 BTU/# SCM COAL REQ.,#/HR	#/HR WATER FOR STM INJ	SLURRY BTU'S/HR/ 10^6
1	2.7	6.3	161	0.185	573	0	7.8
2	11.5	5.8	682	0.264	820		11.2
3	21.2	4.8	1,250	0.351	1089		14.8
4	31.9	3.6	1,894	0.444	1379		18.8
5	48.1	2.6	2,858	0.583	1810		24.7
6	64.3	2.8	3,821	0.718	2229		30.4
7	83.2	2.4	4,945	0.870	2701		36.8
8	100	11.3	5,940	1.000	3105		42.3
IDLE	1	9	59	0.169	525		7.2
YRD.IDLE	1	47.6	59		0		0.0
DYN.BRAKE	2	3.8	119	0.178	553	0	7.5

NOTCH POSITION	% RATED HP	BTU'S CONS. (000)	TOT COST COAL CONS.	HP-HRS	WORK (BTU)	THERM EFF (%)
1	2.7	27,556	83	566	1,441,455	5.2%
2	11.5	36,258	110	2,216	5,639,979	15.5%
3	21.2	39,904	121	3,388	8,621,274	21.6%
4	31.9	37,905	115	3,819	9,719,525	25.6%
5	48.1	35,924	109	4,161	10,588,974	29.5%
6	64.3	47,629	144	5,991	15,247,399	32.0%
7	83.2	49,491	150	6,646	16,913,072	34.2%
8	100	267,802	810	37,588	95,662,274	35.7%
IDLE	1	35,049	109			0.0%
YRD.IDLE	1	0	0			
DYN.BRAKE	2	15,044	49			0.0%
COL TOTAL - - - - ->		594,592	1,799	64,375	163,833,943	

FUEL COSTS IN MILLS / HP - HR = 27.945

DUTY CYCLE THERMAL EFFICIENCY = 27.55%

FUEL COSTS OF DIESEL BURNING DF2(SAME D.C.) IN MILLS / HP - HR = 43.00

FUEL COST SAVINGS (OVER DIESEL) = 35.012%

GAS TURBINE CWS BURNING LOCOMOTIVE

EASTERN DUTY CYCLE - GE27 ENGINE

TIME OF TOTAL RUN-HRS= 56 UNIT HP RATING (DF2)= 5940

SCM COAL COSTS IN $/ 10^6 BTU'S = 3.191

NOTCH POSITION	% RATED HP	DUTY CYCLE % TIME	ENGINE HP	PER UNIT FUEL RATE	SCM COAL REQ,#/HR	#/HR WATER FOR STM INJ	SLURRY BTU'S/HR/ 10^6
1	2.7	6.5	161	0.185	654	0	7.8
2	11.5	4.5	692	0.264	936		11.2
3	21.2	4.2	1,250	0.351	1243		14.8
4	31.9	4.9	1,894	0.444	1574		18.8
5	48.1	4.5	2,859	0.583	2066		24.7
6	54.3	4.8	3,821	0.718	2544		30.4
7	83.2	2.8	4,945	0.870	3083		36.8
8	100	22	5,940	1.000	3545		42.3
IDLE	1	9	59	0.169	599		7.2
YRD.IDLE	1	33	59		0		0.0
DYN.BRAKE	2	3.8	119	0.178	631		7.5

NOTCH POSITION	% RATED HP	BTU'S CONS (000)	TOT.COSTS COAL CONS.	HP-HRS	WORK IN BTU'S	THERM EFF (%)
1	2.7	28,422	96	584	1,487,215	5.2%
2	11.5	28,154	96	1,719	4,375,845	15.5%
3	21.2	34,905	118	2,964	7,543,614	21.6%
4	31.9	51,577	175	5,198	13,229,354	25.6%
5	48.1	62,157	211	7,201	18,327,071	29.5%
6	64.3	81,625	277	10,270	26,138,384	32.0%
7	83.2	57,710	195	7,753	19,731,917	34.2%
8	100	521,343	1,770	73,181	186,245,136	35.7%
IDLE	1	36,938	122			0.0%
YRD.IDLE	1	0	0			
DYN.BRAKE	2	16,039	54			0.0%
COL TOTAL - - - - ->	0.0	311,970	3,116	108,872	277,078,536	

FUEL COSTS IN MILLS / HP - HR = 28.62

DUTY CYCLE THERMAL EFFICIENCE = 30.2%

FUEL COSTS OF DIESEL BURNING DF2(SAME D.C.) IN MILLS / HP - HR = 41.44

FUEL COST SAVINGS (OVER DIESEL) = 30.93%

GAS TURBINE CWS BURNING LOCOMOTIVE
WESTERN DUTY CYCLE - GE27 ENGINE
WS-40

TIME OF TOTAL RUN-HRS= 56 UNIT HP RATING = 8000

SCM COAL COSTS IN $/ 10^6 BTU'S = 2.844

NOTCH POSITION	% RATED HP	DUTY CYCLE % TIME	ENGINE HP	PER UNIT FUEL RATE	14500 BTU/# SCM COAL REQ.,#/HR	#/HR WATER FOR STM INJ	SLURRY BTU'S/HR/ 10^6
1	2.7	6.3	216	0.154	558	1,264	7.6
2	11.5	5.8	919	0.239	866	1,962	11.8
3	21.2	4.8	1,697	0.331	1200	2,719	16.3
4	31.9	3.6	2,551	0.429	1557	3,530	21.2
5	48.1	2.6	3,849	0.574	2084	4,723	28.4
6	64.3	2.8	5,146	0.714	2589	5,869	35.3
7	83.2	2.4	6,659	0.859	3153	7,146	43.0
8	100	11.3	8,000	1.000	3627	8,221	49.4
IDLE	1	9	80	0.137	497	1,127	6.8
YRD.IDLE	1	47.6	80		0	0	0.0
DYN.BRAKE	2	3.8	160	0.147	533	1,207	7.3

NOTCH POSITION	% RATED HP	WATER CONS.,GAL.	BTU'S CONS (000)	TOT. COST COAL CONS	HP-HRS	WORK (BTU'S)	THERM EFF (%)
1	2.7	535	26,814	81	763	1,941,354	7.2%
2	11.5	765	38,319	116	2,985	7,595,931	19.8%
3	21.2	877	43,949	133	4,562	11,611,143	26.4%
4	31.9	854	42,794	129	5,144	13,090,269	30.6%
5	48.1	826	41,352	125	5,604	14,261,245	34.5%
6	64.3	1,105	55,336	167	8,069	20,535,206	37.1%
7	83.2	1,153	57,752	175	8,950	22,778,548	39.4%
8	100	6,245	312,831	946	50,624	128,838,080	41.2%
IDLE	1	582	34,156	103			0.0%
YRD.IDLE	1	0	0	0			
DYN.BRAKE	2	308	15,451	47			0.0%
COL TOTALS - - ->		13,351	668,753	2,023	86,700	220,651,775	

FUEL COSTS IN MILLS / HP - HR. = 23.34

DUTY CYCLE THERMAL EFFICIENCY = 33.0%

FUEL COSTS OF DIESEL BURNING DF2(SAME D.C.) IN MILLS / HP-HR = 43.00

FUEL COST SAVINGS (OVER DIESEL) = 45.73%

GAS TURBINE CWS BURNING LOCOMOTIVE WITH STEAM INJECTION

EASTERN DUTY CYCLE, GE27 ENGINE

WS 9

TIME OF TOTAL RUN-HRS= 56 UNIT HP RATING (DF2)= 8000

SCM COAL COSTS IN $/ 10^6 BTU'S = 3.191

NOTCH POSITION	% RATED HP	DUTY CYCLE % TIME	ENGINE HP	PER UNIT FUEL RATE	14500BTU/# SCM COAL REQ.,#/HR	#/HR WATER FOR STM INJ	SLURRY BTU'S/HR/ 10^6
1	2.7	6.5	216	0.154	558	1,264	7.6
2	11.5	4.5	919	0.239	866	1,962	11.8
3	21.2	4.2	1,697	0.331	1200	2,719	16.3
4	31.9	4.9	2,551	0.429	1557	3,530	21.2
5	48.1	4.5	3,849	0.574	2084	4,723	28.4
6	64.3	4.8	5,146	0.714	2589	5,869	35.3
7	83.2	2.8	6,659	0.869	3153	7,146	43.0
8	100	22	8,000	1.000	3627	8,221	49.4
IDLE	1	9	80	0.137	497	1,127	6.9
YRD.IDLE	1	33	80		0	0	0.0
DYN.BRAKE	2	3.8	160	0.147	533	1,207	7.3

NOTCH POSITION	% RATED HP	BTU'S CONS.,(000)	TOT.COSTS COAL CONS.	HP-HRS	WORK IN BTU'S	THERM EFF (%)
1	2.7	27,655	94	787	2,002,984	7.2%
2	11.5	29,730	101	2,316	5,893,395	19.8%
3	21.2	38,455	131	3,992	10,159,750	26.4%
4	31.9	58,248	198	7,001	17,817,311	30.6%
5	48.1	71,570	243	9,699	24,682,923	34.5%
6	64.3	94,861	322	13,832	35,203,213	37.1%
7	83.2	67,377	229	10,442	26,574,973	39.4%
8	100	609,052	2,068	98,560	250,835,203	41.2%
IDLE	1	34,156	116			0.0%
YRD.IDLE	1	0	0			
DYN.BRAKE	2	15,451	52			0.0%
COL TOTAL - - - - - ->		1,046,565	3,553	146,629	373,169,746	

FUEL COSTS IN MILLS / HP - HR = 24.23

DUTY CYCLE THERMAL EFFICIENCY = 35.7%

FUEL COSTS OF DIESEL BURNING DF2(SAME D.C.) IN MILLS / HP - HR = 41.44

FUEL COST SAVINGS (OVER DIESEL) = 41.53%

GAS TURBINE CWS BURNING LOCOMOTIVE WITH STEAM INJECTION
WESTERN DUTY CYCLE, GE27 ENGINE
WS-9

TIME OF TOTAL RUN - HRS = 56
HP AUXILLARY = 173
ROM COAL COSTS IN $ / MBTU'S = 1.562

UNIT HP RATING = 8000
ROM COAL BTU'S/# = 12500
DF2 COSTS $/GAL = 0.85

NOTCH POSITION	% RATED HP	DUTY CYCLE % TIME	ENGINE HP	AIR SUPPLY FAN HP	PU FUEL RATE	14673 BTU CL/HR,100%	ACTUAL CL CONS,#/HR	BTU'S CONS PER HR	THEM EFF (%)	WATER/STM CONS,#/HR
1	2.7	5.3	216	0	0.125908	528	623	7,315,631	7.52	2,515
2	11.5	5.8	919	2	0.209142	877	1,035	12,161,479	19.23	3,816
3	21.2	4.8	1,697	8	0.300474	1,260	1,487	17,472,385	24.72	5,256
4	31.9	3.6	2,551	18	0.399484	1,676	1,977	23,229,753	27.95	6,837
5	48.1	2.6	3,949	40	0.547422	2,296	2,709	31,832,232	30.77	9,237
6	64.3	2.8	5,146	72	0.692323	2,904	3,426	40,258,102	32.53	11,638
7	83.2	2.4	6,659	120	0.857423	3,597	4,243	49,858,581	33.93	14,439
8	100	11.3	8,000	173	1.000000	4,195	4,949	59,149,341	35.01	16,920
IDLE	1	9	80	0	0.109558	460	542	6,370,719		2,263
YRD.IDLE	1	47.6	80	0	0.109558	460	542	6,370,719		2,263
DYN.BRAKE	2	3.8	160	0	0.119105	500	589	6,925,835		2,411

NOTCH POSITION	% RATED HP	HP-HRS (000)	DF2 (GAL)	TOTAL COAL (#)	CONSUMED WATER (#)	# REGEN LIMESTONE	TOTAL COSTS $ FUEL	WATER + LIMESTONE	TOTAL
1	2.7	0.8		2,197	799	725	42.39	11.67	54.56
2	11.5	3.0		3,362	9,699	1,109	65.64	26.34	91.98
3	21.2	4.6		3,997	11,532	1,319	78.04	31.32	103.36
4	31.9	5.1		3,986	11,499	1,315	77.82	31.23	109.05
5	48.1	5.6		3,946	11,381	1,302	77.02	30.91	107.92
6	64.3	8.1		5,372	15,500	1,773	104.89	42.09	145.99
7	83.2	9.0		5,703	16,454	1,882	111.35	44.68	155.03
8	100	50.6		31,317	90,354	10,334	611.45	245.37	856.83
IDLE	1			2,733	7,884	902	53.35	21.41	74.77
YRD.IDLE	1			14,453	41,699	4,769	282.19	113.24	395.43
DYN.BRAKE	2			1,254	3,619	414	24.49	9.83	34.32
COLUMN TOTAL - - - - ▸		85.7		78,317	220,422	25,845	1,529.14	608.09	2,137.23

GALLONS H2O CONSUMED = 26,461
FULL POWER THERMAL EFFICIENCY = 35.01%
DUTY CYCLE THERMAL EFFICIENCY = 23.98%
FUEL COST SAVINGS (OVER DIES) = 42.67%

FUEL COSTS DIES, DF2
(SAME DC) MILLS/HP-HR= 43.00
FUEL CSTS,MILLS/HP-HR= 17.64
(FUEL ONLY)
FUEL CSTS,MILLS/HP-HR= 24.65
(FUEL PLUS WATER)

GAS TURBINE WITH GASIFIER LOCOMOTIVE
EASTERN DUTY CYCLE
WS-2

TIME OF TOTAL RUN - HRS = 56
HORSE POWER - AUXIL = 173
ROM COAL COSTS IN $/MBTU'S = 1.157

UNIT HP RATING = 8000
ROM COAL BTU'S/# = 8500
DF2 COSTS IN $/GAL = 0.85

NOTCH POSITION	% RATED HP	DUTY CYCLE % TIME	ENGINE HP	AIR SUPPLY FAN HP	PJ FUEL RATE	14673 BTU CL/HR,85%	ACTUAL CL CONS,#/HR	BTU'S CONS PER HR,LHV	THERM EFF LHV %	WATER/STM CONS,#/HR
1	2.7	5.5	216	0	0.125808	528	959	7,654,305	7.2%	2,515
2	11.5	4.5	919	2	0.209142	877	1,595	12,741,115	18.4%	3,816
3	21.2	4.2	1,697	8	0.300474	1,260	2,291	18,305,150	23.6%	5,256
4	31.9	4.9	2,551	18	0.399484	1,676	3,046	24,336,922	26.7%	6,837
5	48.1	4.5	3,849	40	0.547422	2,296	4,174	33,349,410	29.4%	9,237
6	64.3	4.8	5,146	72	0.692323	2,904	5,279	42,176,871	31.1%	11,538
7	83.2	2.8	6,659	120	0.857423	3,597	6,538	52,234,925	32.4%	14,439
8	100	22	8,000	173	1.000000	4,195	7,625	60,920,837	33.4%	16,920
IDLE	1	9	80	0	0.109558	460	835	6,674,359		2,263
YRD.IDLE	1	33	80	0	0.109558	460	835	6,674,358		2,263
DYN.BRAKE	2	3.8	160	0	0.119105	500	908	7,255,984		2,411

NOTCH POSITION	% RATED HP	HP-HRS (000)	TOTAL CONSUMBED DF2 (GAL)	COAL (#)	WATER (#)	# REGEN LIMESTONE	TOTAL COST $ FUEL	WATER + LIMESTONE	TOTAL
1	2.7	0.8		3,492	8,143	244	34.34	11.81	46.15
2	11.5	2.3		4,018	8,450	281	39.52	12.67	52.19
3	21.2	4.0		5,388	10,800	377	52.99	16.46	69.45
4	31.9	7.0		8,358	16,336	585	82.20	25.11	107.31
5	48.1	9.7		10,518	20,228	736	103.44	31.27	134.71
6	64.3	13.8		14,189	27,169	993	139.54	42.07	181.61
7	83.2	10.4		10,251	19,668	718	100.81	30.43	131.24
8	100	98.6		93,936	181,213	6,575	923.81	279.85	1,203.65
IDLE	1			4,210	10,185	295	41.40	14.61	56.01
YRD.IDLE	1			15,437	37,344	1,081	151.82	53.55	205.37
DYN.BRAKE	2			1,933	4,570	135	19.01	6.60	25.60
COLUMN TOTALS - - ->		146.6		171,730	344,105	12,021	1,688.88	524.42	2,213.30

GALLONS H2O CONSUMED = 41,309
FULL POWER THERMAL EFFICIENCY = 33.42%
DUTY CYCLE THERMAL EFFICIENCY = 27.20%
FUEL COST SAVINGS (OVER DIES) = 63.57%

FUEL COSTS DIES, DF2
(SAME DC) MILLS/HP-HR= 41.44
ACT.COSTS/ KHP-HR= 11.52
(FUEL ONLY)
ACT.COSTS/ KHP-HR= 15.09
(FUEL PLUS WATER)

GAS TURBINE WITH GASIFIER LOCOMOTIVE
WESTERN DUTY CYCLE
WS-3

HP FL 3.FAN 400
(AUXILIARIES FROM TURBINE OUTPUT)HP FL 3.FAN 485
TIME OF TOTAL RUN,HRS. 56

UNIT HP RATING = 8000
ROM COAL COSTS IN $/ 10 ^6 BTU'S= 1.562 (UHV)

NOTCH POSITION	% RATED HP	DUTY CYCLE % TIME	ENGINE HP	AFB BOILER FAN BHP	CONDENSER FAN BHP	BLR.FEED PUMP BHP	HP TOTAL	TONS COAL/ HR,12500BTU	INPUT HEAT RATE MBTU/HR	WORK BTU'S	(LHV) INPUT KBTU'S
1	2.7	6.3	215	25	0	0.8	245	0.544	12.780	1,941,354	45,087
2	11.5	5.8	919	56	0	3	985	0.850	19.967	7,595,931	64,853
3	21.2	4.8	1,697	90	1	9	1,808	1.193	28.047	11,611,143	75,391
4	31.9	3.6	2,551	127	3	16	2,714	1.575	37.022	13,090,259	74,637
5	48.1	2.6	3,849	184	11	31	4,100	2.167	50.934	14,261,245	74,159
6	54.3	2.8	5,146	240	27	51	5,500	2.775	65.209	20,535,206	102,248
7	83.2	2.4	6,659	307	59	81	7,155	3.505	82.377	22,778,548	110,715
8	100	11.3	8,000	365	102	111	8,642	4.173	98.062	128,838,080	620,536
IDLE	1	9	90	19	0	0.6	102	0.485	11.396	1,026,144	57,438
YRD.IDLE	1	47.6	80	19	0	0.6	102	0	0.000	5,427,152	0
DYN.BRAKE	2	3.8	160	23	0	0.3	186	0.519	12.204	866,522	25,970
										227,971,602	1,251,034

NOTCH POSITION	% RATED HP	HP-HRS (000)	MAKE-UP H2O (GAL)	DF2 (GAL/HR)	COAL CONSUMED (TONS)	THERM EFF (%)	LIMESTONE CONSUMED (TONS)	FUEL CONSUMED	TOTAL COST $ WATER + LIMESTONE	TOTAL
1	2.7	0.8	12.52		1.92	4.3%	0.64	74.92	19.19	94.11
2	11.5	3.0	46.26		2.76	11.7%	0.92	107.77	27.60	135.36
3	21.2	4.6	70.31		3.21	15.4%	1.07	125.28	32.08	157.36
4	31.9	5.1	79.15		3.18	17.5%	1.06	124.02	31.76	155.78
5	48.1	5.6	86.35		3.16	19.2%	1.05	123.23	31.56	154.79
6	54.3	8.1	124.74		4.35	20.1%	1.45	169.91	43.51	213.42
7	83.2	9.0	139.10		4.71	20.6%	1.57	183.98	47.11	231.09
8	100	50.5	791.00		26.41	20.8%	8.80	1,331.15	264.06	1,295.20
IDLE	1	0.4	7.46		2.44	1.8%	0.81	95.44	24.44	119.89
YRD.IDLE	1	2.1	39.45		0.00	0.0%	0.00	0.00	0.00	0.00
DYN.BRAKE	2	0.3	5.72		1.11	3.3%	0.37	43.15	11.05	54.21
COLUMN TOTAL - - ->		89.5	1402.07		53.24		17.75	2,378.85	532.35	2,611.20

MAKE-UP WATER, GAL / 24 HRS = 841

FULL POWER THERMAL EFFICIENCY = 20.762%
DUTY CYCLE THERMAL EFFICIENCE = 18.223%

FUEL ONLY COSTS, MILLS/HP-HR = 23.21
FUEL + CONSBL COSTS,MILLS/HP-HR = 29.15
FUEL COSTS DF2, MILLS/HP-HR = 43

FUEL COSTS SAVINGS (OVER DF2) = 32.21%

ROM COAL STEAM TURBINE LOCOMOTIVE
EASTERN DUTY CYCLE
WS-10

TIME OF TOTAL RUN,HRS. 56 UNIT HP RATING= 8000

(AUXILIARIES FROM TURBINE OUTPUT)HP FL 9.FAN 485 ROM COAL COSTS IN $/ 10 ^6 BTU'S= 2.03 (UHV)

HP FL C.FAN 400

NOTCH POSITION	% RATED HP	DUTY CYCLE % TIME	ENGINE HP	AFB BOILER FAN BHP	CONDENSER FAN BHP	BLR.FEED PUMP BHP	HP TOTAL	TONS COAL/ HR,12500BTU	INPUT HEAT RATE MBTU/HR	WORK BTU'S	(LHV) INPUT KBTU'S
1	2.7	6.5	216	25	0	0.8	245	0.544	12.780	2,002,984	49,131
2	11.5	4.5	919	56	0	3	985	0.850	19.967	5,893,335	53,143
3	21.2	4.2	1,697	90	1	9	1,808	1.193	28.047	10,159,750	69,672
4	31.9	4.9	2,551	127	3	16	2,714	1.575	37.022	17,817,311	107,295
5	48.1	4.5	3,849	184	11	31	4,100	2.167	50.934	24,682,923	135,562
6	54.3	4.8	5,146	240	27	51	5,500	2.775	65.209	35,203,210	185,127
7	83.2	2.9	6,659	307	59	81	7,155	3.505	82.377	26,574,973	136,422
8	100	22	8,030	365	102	111	8,642	4.173	98.062	250,835,200	1,275,982
IDLE	1	9	80	19	0	0.6	102	0.495	11.395	1,026,144	60,664
YRD.IDLE	1	33	80	19	0	0.6	102	0	0.000	3,762,528	0
DYN.BRAKE	2	3.8	150	23	0	0.3	186	0.519	12.204	866,522	27,429
										378,824,939	2,100,429

NOTCH POSITION	% RATED HP	HP-HRS (000)	MAKE-UP H20 GALLONS	DF2 (GAL/HR)	COAL CONSUMED (TONS)	THERM EFF (%)	LIMESTONE CONSUMED (TONS)	FUEL CONSUMED	TOTAL COST $ WATER + LIMESTONE	TOTAL
1	2.7	0.8	12.92		3.07	4.08	0.22	106.21	6.45	112.66
2	11.5	2.3	35.89		3.33	11.09	0.23	114.88	6.98	121.85
3	21.2	4.3	61.52		4.36	14.58	0.31	150.61	9.15	159.77
4	31.9	7.3	107.73		6.71	16.61	0.47	231.94	14.13	246.04
5	48.1	9.7	149.45		8.48	18.21	0.59	293.05	17.81	310.86
6	54.3	13.8	213.84		11.58	19.02	0.81	400.19	24.33	424.52
7	83.2	10.4	162.28		8.54	19.48	0.60	294.90	17.93	312.83
8	100	98.5	1540.00		79.85	19.66	5.59	2,758.29	167.68	2,925.98
IDLE	1	0.4	7.46		3.80	1.69	0.27	131.14	7.97	139.11
YRD.IDLE	1	1.5	27.35		0.00	0.00	0.00	0.00	0.00	0.00
DYN.BRAKE	2	0.3	5.72		1.72	3.16	0.12	59.29	3.60	62.90
		148.9	2324.87		131.44		9.20	4,540.50	276.03	4,816.53

MAKE-UP WATER, GAL / 24 HRS = 1,395

FULL POWER THERMAL EFFICIENCY = 19.658%
DUTY CYCLE THERMAL EFFICIENCY = 18.036%

FUEL COST ONLY MILLS/HP-HR = 30.50
FUEL + CONSBL COSTS,MILLS/HP-HR = 32.36
FUEL COSTS DF2 , MILLS/HP-HR = 41.44

FUEL COST SAVINGS (OVER (DF2) = 21.92%

ROM COAL STEAM TURBINE LOCOMOTIVE
WESTERN DUTY CYCLE
WS-11

24-Jan-86

COAL BURNING LOCOMOTIVE STUDY

APPENDIX B

EQUATIONS FOR DIGICALC SPREADSHEETS

COAL WATER SLURRY BURNING DIESEL

EQUATIONS FOR DBDIESWE.(WS17) AND DBDIESEA.(WS30) DUTY CYCLE FUEL COSTS

```
1.    D10=B10*I3/100
2.    F10=(D10+G10)*E10
3.    H10=F10*18400
4.    J10=D3*D10*C10/100/1000
5.    K10=D10*2545*100/H10
6.    L10=D3*C10*H10/100/1000
7.    C28=(H11-I11)*C11*D3/100
8.    E28=C28*52.7/47.32
9.    F28=E28*2/I7
10.   G28=I11*D3*C11/18400/100
11.   H28=E28*D4/10^6/.94+G28*I4/7.1
12.   I28=D3*C11*F11*I4/7.1/100
13.   J28=E28/(6635*9.7)
14.   K28=G28/7.1
15.   L28=J11*2545*1000/(E28+G28*18400)
16.   F40=K17/100
17.   F41=J21*2545/L21
18.   F43=J17*1000*2545/(E34+G34*18400)
19.   F44=J21*2545*1000/(E38+G38*18400)
20.   L40=H38/J21
21.   L41=I38/J21
22.   L43=(L41-L40)/L41
```

24-Jan-86

COAL BURNING LOCOMOTIVE STUDY

APPENDIX B

EQUATIONS FOR DIGICALC SPREADSHEETS

COAL OIL SLURRY BURNING DIESEL

EQUATIONS FOR SLBDIESWE.(WS13) AND SLBDIESEA.(WS16) DUTY CYCLE FUEL COST

```
1.    D3=56
2.    D5=3.121+D6
3.    D5=.39 (WEST) OR .362 (EAST)
4.    I3=3822
5.    I4=.85
6.    I5=14500
7.    F10=(D10+G10)*E10
8.    H10=F10*18400
9.    I10=D3*D10*C10/100/1000
10.   J10=D10*2545*100/H10
11.   K10=D3*C10*H10/100/1000
12.   C26=K10*2*1000/(18400+I5*.94)
13.   F26=C26/2
14.   G26=C26/2/7.1
15.   H26=F26*14500*D4/10^6/.94+G26*I4 (WEST)
16.   H26=F26*14500*D4/10^6+G26*I4 (EAST)
17.   I26=H10*D3*C10*I4/18400/7.1/100
18.   J26=I10*2545/K10
19.   E41=J17/100
20.   E42=I21*2545/K21
21.   E44=E41
22.   E45=E42
23.   J41=H38/I21
24.   J42=I38/I21
25.   J44=1-J41/J42
```

24-Jan-86

COAL BURNING LOCOMOTIVE STUDY

APPENDIX B

EQUATIONS FOR DIGICALC SPREADSHEETS

GE-27 GAS TURBINE WITHOUT STEAM INJECTION

EQUATIONS FOR DBGTEAWOI27(WS36) & DBGTWEWOI27(WS40) DUTY CYCLE FUEL COS

1. D10=B10*H3/100
2. E10=.159858+.00015419037*D10-.0000000021411552 8*D10^2
3. F10=3105*E10 (EAST) & 3544*E10 (WEST)
4. H10=F10*12700*.94/10^6
5. D25=H10*D3*C10*10^6/100/1000
6. E25=D4*D25/1000/.94
7. H25=D10*C10*D3/100
8. I25=H25*2545
9. J25=I25/D25/1000
10. E40=E37*1000/H37
11. E42=I37/D37/1000
12. I42=43.00 (EAST) OR 41.44 (WEST)
13. I45=1-E40/I42

24-Jan-86

COAL BURNING LOCOMOTIVE STUDY

APPENDIX B

EQUATIONS FOR DIGICALC SPREADSHEETS

GE-27 GAS TURBINE WITH STEAM INJECTION

EQUATIONS FOR DBGTEAWI27(WS8) AND DBGTWEWI27(WS9) DUTY CYCLE FUEL COSTS

1. E10=C10*I3/100
2. F10=(.159858+.00015419037*E10-.0000000021411552 8*E10^2)*1/1.256
3. I10=I17*F10
4. I10=I17*F10
5. K10=G10*14500*.94/10^6
6. E25=I10*D10*E3/100/8.33
7. F25=K10*E3*D10*10^6/100/1000
8. H25=E4*F25/1000/.94
9. I25=E10*D10*E3/100
10. J25=I25*2545
11. K25=J25/F25/1000
12. F42=H37*1000/I37
13. F44=J37/F37/1000
14. J46=1-F42/J43

24-Jan-86

COAL BURNING LOCOMOTIVE STUDY

APPENDIX B

EQUATIONS FOR DIGICALC SPREADSHEETS

ROM COAL GE-27 GAS TURBINE-GASIFIER

EQUATIONS FOR GSFREAST (WS2) AND GSFRWEST (WS3) DUTY CYCLE FUEL COSTS

```
1.    E10=C10*K3/100
2.    F10=F17*(E10/E17)^2
3.    G10=0.1+.977*(E10+F10)/(E17+F17)-.077*(E10+F10)^2/(E17+F17)^2
4.    H10=G10*H17
5.    I10=H10*14673*1.0005/K4
6.    J10=I10*K4*.94
7.    K10=E10*2545/J10*100
8.    L10=L17*(.125+E10/E17*.875)
9.    E26=G3*D10*E10/100/1000
10.   G26=D10*G3*I10/100
11.   H26=L10*D10*G3/100-G26*.04
12.   I26=.33*G26
13.   J26=G26*G5*K4/1000000
14.   K26=H26*.001+I26*30/2000
15.   L26=J26+K26
16.   I40=H38/8.33
17.   I41=K17
18.   I42=E38*1000*2545/(G38*K4*.94)
19.   I43=1-L44/L41
19.   L41=41.44 (WEST) OR 43.00 (EAST)
20.   L42=J38/E38
21.   L44=L38/E38
22.   I46=1-L44/L41
```

24-Jan-86

COAL BURNING LOCOMOTIVE STUDY

APPENDIX B

EQUATIONS FOR DIGICALC SPREADSHEETS

ROM COAL STEAM TURBINE

EQUATIONS FOR STMEAST (WS10) AND STMWEST (WS11) DUTY CYCLE FUEL COSTS

1. D10=B10*J3/100
2. E10=16+D10*(365-16)/D17
3. F10=(D10/D17)^3*F17
4. G10=0.8
5. H10=D10+E10/0.9+F10/0.9+G10/0.9
6. I10=.44290905+.0004106667*H10+.0000000024237*H10^2
7. J10=I10*12500*.94*2000/1000000
8. K10=D10*C10*E5*2545/100
9. L10=1000*E5*J10*C10/100
10. D26=E5*C10*D10/100/1000
11. E26=H10*50*E5*C10/H17/40
12. G26=I10*E5*C10/100
13. H26=K10/L10/1000
14. I26=G26/3
15. J26=L10*J4/1000/.94
16. K26=I26*30
17. L26=J26+K26
18. G40=E38*24/40
19. L40=H33
20. K41=K21/L21/1000
21. L43=J38/D38
22. L44=L38/D38
23. L45=43 (EAST) OR 41.44 (WEST)
24. L47=1-L44/L45

APPENDIX 'C'

Derivation of Diesel Efficiency Using Slurry-Coal Fuel

The diesel engine produces power by the exertion of pressure from the cylinder gaseous contents on the moving piston head. Starting with the identical air trapped in a cylinder at the beginning of a 12.7 to 1 compression, the identical work will be produced if the identical sequence of P-V pressure and cylinder volume) is traced out. Such a sequence is illustrated for one pound of air starting at 44 PSIA, being compressed to 1400 PSIA, having fuel added and burned to reach 2860 PSIA and thereafter expanding to 103 PSIA. Omitting losses by heat transfer, a thermodynamic analysis determines the amount of diesel fuel (DF2) required. The efficiency based on the fuel higher heating value would be 52.7%. Since the latent heat of vaporization of the water vapor formed cannot be utilized to produce work, the efficiency based on the lower heating value is a better representation of thermodynamic accomplishment. This value would be 56.5%. (Actual diesel engine efficiency would be 42% for similar cylinder pressures due to heat transfer, slower fuel burning and engine friction effects.)

When a coal-water slurry is substituted for diesel fuel, the peak pressure of 2860 PSIA would be reached at a lower temperature, but with a greater quantity of liquid injected and burned. The slurry evaluated was 50% by weight of water and 50% coal that was free of all mineral matter. The higher heating value of the coal portion was 14673 BTU per pound. The water vapor of combustion would result in a lower heating value of 14250 BTU per pound. In the combustion of the slurry fuel, it would be necessary to evaporate the associated half pound of water as well as the combustion product water. As a result, the effective lower heating value of one pound of slurry (50% water and 50% ash and mineral free coal) would be 6544 BTU per pound. Tracing the identical P-V path would require firing an amount of slurry such that the efficiency would be 47.3% based on slurry higher heating value of 7336.5 BTU per pound (14673 ÷ 2) and 53.1% based on the slurry effective lower heating value of 6544 BTU per pound.

For equal power from diesel engines experiencing the identical P-V characteristics, these evaluations indicate a ratio of efficiencies of 1.11 on a higher heating value basis and 1.065 on an effective lower heating value basis for diesel fuel as compared to a slurry of 50% water and 50% ash and mineral free coal. Comparing slurry to diesel fuel, the ratios become 0.898 on the higher heating value basis.

Based on the foregoing discussion of diesel engine theoretical efficiencies (HHV) of 52.7% for diesel fuel and 47.3% for coal water slurry, the ratio of 52.7/47.3 is applied to those BTU's in the combustion process supplied from the slurry. This has no impact on the thermal efficiency at very light loads where all fuel is DF2, but reduces the thermal efficiency at higher loads where substantial slurry is consumed.

The question of engine power derating due to lack of combustion air was also considered. For an identical engine, some 17% more air would be required to provide full power entirely from slurry. For purposes of fuel cost calculations, it was finally decided to ignore this factor since the final coal burning engine is expected to be different from today's diesel burning engine. The rating can therefore be selected at the time of final design.

III. MAINTENANCE COSTS

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III. MAINTENANCE COSTS

A. Maintenance Costs - Background

Locomotives, like all forms of equipment, have minimum total costs when a proper balance is accomplished between planned inspections and equipment changeouts on the one side with unplanned (failures) on the other. The railroads have evolved a split very close to 60% planned versus 40% unplanned maintenance cost for this balance. To each of these portions of maintenance, the infrastructure is carried as overhead.

The direct coal burning locomotive maintenance cost is estimated by adding to/changing the recommended planned maintenance for a standard diesel electric locomotive and by estimating the impact of the coal burning locomotives reliability (see Sec. V) on unplanned maintenance.

B. Planned Maintenance

The objective of planned maintenance and inspections is:

Minimize Total Costs
- Balance In-service Reliability
- Attain Planned Locomotive Availability

Assure Safety
- Meet Regulatory Requirements

Planned maintenance is truly the railroad's prime mechanism for keeping its operation predictable. By planning equipment changeout just right, road failures due to "wear out" phenomena can be minimized. To assure the safe operation of a locomotive, a plan can also be put together that accounts for new or additional risks thus assuring acceptable margin for operation. For the direct coal water slurry burning diesel and gas turbine locomotives, there are no new or additional risks, no known new regulatory requirements to be met. For the gas turbine locomotives employing steam injection or gasifier: the planned maintenance must include time for elaborate inspections to assure that all pressure vessels never catastrophically fail; inspections that will detect any incipient failure while the equipment is shut down. The steam turbine locomotive also fits this category of additional safety inspection requirements.

1. Estimates Procedure

Railroad maintenance data and GE recommended plan provides approximately 60% of the total maintenance costs for planned activities for oil burning diesel locomotives, the base from which all technologies will be evaluated.

III. MAINTENANCE COSTS

B. Planned Maintenance

1. Estimate Procedure (continued)

The technique employed in establishing planned maintenance costs is started with the plan and costs for today's diesel electric. With this plan and base costs, the coal technology for powering a locomotive is examined for differences only. Primarily all of the technologies examined substitute something new for today's diesel engine and fuel handling system. All else employed on the locomotive is the same as the diesel electric except for quantity and this is directly proportional to developed horsepower for traction. Things like traction motors, alternators, air compressors, propulsion control, running gear, etc., are all merely a multiple of an oil diesel electric, a multiple directly related to how many oil diesel locomotives the new locomotive is proportional to.

The base case oil diesel electric maintenance costs is the beginning for costing of all coal burning technologies. The maintenance costs associated with the diesel engine are subtracted (GE data on diesel engine maintenance), the remainder is then ratioed up to a locomotive of equivalent tractive horsepower to the technology being examined. Next, an estimate for maintenance just for the coal burning power plant is added plus any fuel handling or inspections that are not in the base oil burning diesel costs.

The coal water slurry burning diesel option examined in report No. DEAC21-85MC22181 (Copy reproduced in III. F.) varied from the above slightly. In this case, the basic diesel engine costs were left in and only those changes to the diesel engine maintenance were costed. The fuel handling system was also different and figured in the cost.

For each technology, the planned estimates will be made for the same type of service as used with the oil burning diesel. Two fuel service consumptions are examined, service equivalent to consuming 280,000 gallons of DF2 and 440,000 gallons of DF2. These two points allow an equation to be written expressing maintenance costs as a function of use. This allows specific maintenance costs to be determined for each major railroad with the information of fleet size and fuel consumption given in Sec. VII.

C. Unplanned Maintenance Estimate Procedure

1. Estimate Procedure

By definition, unplanned maintenance is a direct result of an equipment failure outside of planned maintenance activities.

III. MAINTENANCE COSTS

C. Unplanned Maintenance

1. Estimate Procedure (continued)

Therefore, unplanned maintenance is a result of the relative reliability of the equipment that failed. As would be expected, railroad maintenance data shows that unplanned maintenance costs are dominated by labor costs expended in troubleshooting the problem and changing out single failed parts. The technique used for estimating unplanned maintenance is to keep it in a direct ratio of the reliability of the new equipment versus the base.

For a coal burning diesel locomotive,the failure rate expectation of an oil burning locomotive and its unplanned maintenance cost is ratioed with the reliability expectation for coal burning locomotive.

This is conservatively done at the 3800 HP level, the results then ratioed to that horsepower available for traction. The reliability for each locomotive option is given in Section V. The oil burning diesel base cost for unplanned maintenance is derived in Report No. DEAC21-85MC22181 copy reproduced in Chapter III.F.

D. Maintenance Cost Estimates

The following tables III-1 to III-6, provide the maintenance cost estimates for the following technologies:

a. Summary listing of all technologies

b. Coal Water Slurry (CWS) Burning Diesel Locomotive

c. Coal Water Slurry (CWS) Burning Gas Turbine Locomotive

d. CWS Burning Gas Turbine Locomotive

- Exhaust heat recovery via steam generation
- Generated steam reinjected into turbine

e. Classified ROM Coal Burning Gas Turbine Locomotive

- Included pressurized gasifier generates low BTU gas

f. Classified ROM Coal Burning Steam Turbine Locomotive

- Coal burned in a fluidized bed boiler

TABLE III-1

MAINTENANCE COSTS FOR COAL BURNING LOCOMOTIVES
ALL RATIOED TO 3800 HP IN $ X 1000

	PLANNED				UNPLANNED				TOTAL	
GALLONS DF2 (000)	280		440		280		440		280	440
OPTION	ADD	TOTAL	ADD	TOTAL	ADD	TOTAL	ADD	TOTAL	TOTAL	TOTAL
OIL BURNING DIESEL BASE	0	41.7	0	47.6	0	27.8	0	31.8	69.5	79.4
CWS BURNING DIESEL	20.3	62.0	18.6	66.2	2.6	30.4	2.9	34.7	92.4	100.9
CWS GAS TURBINE	2.9	44.6	14.7	62.3	0	27.8	0	31.8	72.4	94.1
CWS GAS TURBINE W/STEAM	15.4	57.1	28.6	76.2	15.3	43.1	16.0	47.8	100.2	124.0
GASIFIER - GAS TURBINE	52.9	94.6	70.3	117.9	23.6	51.4	27.0	58.8	146.0	176.7
STEAM TURBINE	21.6	63.3	23.3	70.9	47.4	75.2	54.1	185.9	138.6	156.8

Table III-2

Maintenance Cost Variance From An Oil Burning Diesel Locomotive
For
CWS Burning Diesel Locomotive - 3800 HP

	DF2 Service Equivalent Gallons 280,000	440,000
Planned Maintenance Cost Variance (3800 HP Level)		
Add		
. 3-Month Maintenance	$ 4,020	$ 1,020
. 6-Month	1,600	1,830
. Yearly	2,530	2,890
. 4-Year	2,050	9,180
. Contingency	4,050	3,730
Net Additional Planned Maintenance (3800 HP) =	$20,250	$18,650
Unplanned Maintenance Variance (3800 HP) =	$ 2,600	$ 2,940

$\frac{\text{CWS Diesel Reliability}}{\text{Oil Diesel Reliability}} - 1$ X Oil Diesel Unplanned Reliability Cost

CWS Diesel Reliability = 3.38 F/LY

Oil Diesel Reliability = 3.09 F/LY

Total Maintenance Variance @ 3800 HP =	$22,850	$21,590

Maintenance Cost Increase vs Fuel Consumed
= $.0079/Gallon X Gallons Consumed + $25,070

Table III-3

Maintenance Costs Variance from an Oil Burning Diesel Locomotive
for
CWS Burning Gas Turbine - 5900 HP for Traction

	DF2 Service Equivalent Gallons 280,000	440,000
Planned Maintenance Cost Variance (3800 HP Level)		
Remove		
. Diesel Engine Work	($29,190)	($33,320)
Add		
. Gas Turbine	22,270	37,440
. Aux Power - Operates in cold weather - GT shut down on yard idle	680	630
. Gear Box - Connects GT to Alternator	640	640
. Noise & Heat Suppression	260	260
. Fuel and Lube System	200	200
. Air Intake Filters - (3 X Diesel)	1,500	2,350
. Water Wash System - Water Injection to Clean Turbine	100	100
. Contingency	6,440	6,440
Net Additional Planned Maintenance (3800 HP) =	2,900	14,740
Unplanned Maintenance Variance (3800 HP) =	0	0
GT Locomotive has same reliability as Oil Burning Diesel		
Total Maintenance Cost Variance @ 3800 HP =	$ 2,900	$14,740

Maintenance Cost as a Function of Fuel Consumed

= $.07375/Gal X Gallons of DF2 - $17,750

Table III-4

Maintenance Cost Variance from an Oil Burning Diesel Locomotive
for
CWS Burning Gas Turbine with Steam Injection - 8000 HP

	DF2 Service Equivalent Gallons 280,000	440,000
Planned Maintenance Cost Variance (3800 HP Level)		
Remove		
. Diesel Engine Work	($29,190)	($33,320)
Add		
. Gas Turbine	22,270	37,440
. Aux Power	680	630
. Alternator Gear Box	640	640
. Noise & Heat Suppression	260	260
. Fuel and Lube System	200	200
. Air Filter	1,500	2,350
. Water Wash	100	100
. Boiler & Feedwater System	10,000	11,400
. Contingency	8,900	8,900
Net Additional Planned Maintenance (3800 HP)=	15,360	28,600
Unplanned Maintenance Variance (3800 HP) =	$15,300	$15,970

$$\frac{\text{Gas Turbine Reliability}}{\text{Oil Diesel Reliability}} - 1 \times \text{Oil Diesel Unplanned Reliability}$$

Gas Turbine Reliability = 4.644 F/LY
Oil Diesel Reliability = 3.09 F/LY

Total Maintenance Variance @ 3800 HP =	$30,660	$44,570

Maintenance Cost Increase vs Fuel Consumed
= $.087/Gallon X Gallons Consumed + $6,290

Table III-5

Maintenance Cost Variance from an Oil Burning Diesel Locomotive
for
Gas Turbine Locomotive Fed From a Coal Gasifier - 8000 HP

	DF2 Service Equivalent Gallons 280,000	440,000
Planned Maintenance Cost Variance (3800 HP Level)		
Remove		
. Diesel Engine Work	($29,190)	($33,320)
Add		
. Gas Turbine	22,270	37,440
. Aux Power	680	630
. Alternator/GT Gear Box	640	640
. Noise & Heat Suppression	260	260
. Fuel and Lube System	200	200
. Air Filter	1,500	2,350
. Water Wash	100	100
. Boiler & Feedwater System	20,000	22,800
. Gasifier & Gas Clean-Up	20,000	22,800
. Contingency	16,410	16,410
Net Additional Planned Maintenance (3800 HP) =	$52,870	$70,310
Unplanned Maintenance Variance (3800 HP) =	$23,600	$26,950

$\frac{\text{Gas Turbine Reliability}}{\text{Oil Diesel Reliability}}$ -1 X Oil Diesel Unplanned Reliability

Gas Turbine Reliability = 5.49 F/LY
Oil Diesel Reliability = 3.09 F/LY

Total Maintenance Variance @ 3800 HP =	$76,470	$97,260

Maintenance Cost Increase vs Fuel Consumed
= $.130/Gallon X Gallons Consumed + $40,600

Table III-6

Maintenance Cost Variance from an Oil Burning Diesel Locomotive
for
Steam Turbine Powered Locomotive - 8000 HP

	DF2 Service Equivalent Gallons 280,000	440,000
Planned Maintenance Cost Variance (3800 HP Level)		
Remove		
. Diesel Engine Work	($29,190)	($33,320)
Add		
. Steam Turbine	2,400	2,710
. Aux Power	680	630
. Alternator Gear Box	640	640
. Lube System	100	100
. Boiler & Feedwater System	20,000	22,830
. Fluidized Bed Burner & Fuel System	10,000	11,410
. Condenser (2X Radiator)	4,550	4,550
. Baghouse (4X Diesel Air Filter)	2,250	3,530
. Contingency	$10,200	10,200
Net Additional Planned Maintenance (3800 HP) =	$21,630	23,280
Unplanned Maintenance Variance (3800 HP Level)	= $47,420	$54,130

$$\frac{\text{Steam Turbine Reliability}}{\text{Oil Diesel Reliability}} - 1 \times \text{Oil Diesel Unplanned Reliability}$$

Steam Turbine Reliability = 7.91 F/LY
Oil Diesel Reliability = 3.09 F/LY

Total Maintenance Variance at 3800 HP =	$69,050	$77,410

Maintenance Cost Increase vs Fuel Consumed
= $.052/Gallon X Gallons Consumed + $54,530

III. MAINTENANCE COSTS

E. Source of Cost Estimates

a. Planned cost for maintaining a gas turbine used in all coal options came from General Electric's Gas Turbine Business Group. Help in estimating the maintenance cost of direct auxiliaries to the gas turbine also was obtained from GE data.

b. Pressure vessel maintenance costs help was obtained from vendor information.

c. Auxiliary systems not covered by obtainable estimates were formulated from part maintenance costs in our own oil diesel locomotive files.

d. Maintenance Cost for oil burning diesel from Report No. DEAC21-MC22181. Copy reproduced in Chapter III.F.5.

Page

III. MAINTENANCE COSTS (From Sec. III, Report #DEAC21-85MC22181)[1]

F. Coal Burning Diesel Locomotives

1. Planned Maintenance, Coal Burning Diesel

2. Unplanned Maintenance, Coal Burning Diesel

3. Total Maintenance Cost, Coal Burning Diesel

4. Calculation of Maintenance Cost versus Fuel Burned

5. Maintenance Costs of Oil Burning Diesel Locomotive

[1] Section III has been extracted, repeating only those portions necessary to fill the needs of this general analysis on all coal burning options considered. The page numbers and subject numbers have been changed to follow this report.

III. MAINTENANCE COSTS

F. Coal Burning Diesel Locomotive

1. Planned Maintenance Coal Burning Diesel

	Eastern Road Fuel Cons. 280,000 GAL	Western Road Fuel Cons. 440,000 GAL
a. Standard Oil Diesel	$41,700/Yr	$47,600/Yr

To this standard diesel electric planned maintenance cost, the expense associated with the unit exchange (UX) of those different parts or material on the coal burning diesel whose wear rate is expected to be different or the basic equivalent parts are just more expensive. Predominantly, these increases in planned expenses are associated with the coal slurry fuel delivery system to the engine and directly into the cylinders. They are, as a function of cyclic maintenance periods:

Item	Eastern	Western
b. 3-Month Maintenance		
Lubrication System	$ 4,020/Yr	$1,020/Yr

- Eastern Roads will need additional oil changes because of high sulfur content in slurry (approximately 2.5% versus average .3% for oil).
- Both need additional filter changeouts.

c. 6-Month Maintenance		
UX Fuel Injectors	$ 1,600/year	$1,825/Yr

- Increase caused by changing injectors every 6 months instead of every year on diesel oil engines.
- Includes increase cost of UX parts due to ceramic coating for improved wear.
- Western Roads will pay slightly more on the average because of increased fuel consumption.

d. 1-Year Maintenance		
UX Fuel Delivery System to Injector	$ 2,530/year	$2,890/Yr

- Normally changed every two years on oil burning locomotive.
- Includes pilot oil delivery
- Includes new diaphragm pump to change the slurry to the cylinder through the injector.
- Diaphragm pump operated by closed loop cam driven injector pump similar to today's.
- Higher usage will add cost to Western Roads.

(1)See Sec. III.F.5. for Standard Diesel Electric Maintenance Costs

III. MAINTENANCE COSTS

F. Coal Burning Diesel Locomotive

1. Planned Maintenance - Coal Burning Diesel Locomotive (continued)

Item	Eastern	Western
e. 4 Year Maintenance		
UX Cylinder Assembly (includes jacket, valves, pistons & rings)	$ 7,250/Yr	$ 8,280/Yr
- Normal changeout is four years, increase cost is for ceramic wear coating on jacket wall, valves and valve seats, rings and pistons.		
UX Turbocharger	$ 700/Yr	$ 800/Yr
- Normal changeout time; cost increase for ceramic coating		
UX Water Pump	$ 100/Yr	$ 100/Yr
- Increase covers 2nd water pump		
f. Contingency (25%)	$ 4,050/Yr	$ 3,730/Yr
g. Total Added Planned Maintenance (b,c,d,e,f)	$20,250/Yr	$18,645/Yr
h. Total Planned Maintenance for Coal Burning Locomotive (a,g)	$61,950/Yr	$66,245/Yr

2. Unplanned Maintenance

By definition, unplanned maintenance is a direct result of an equipment failure outside of planned maintenance activities. Therefore, unplanned maintenance is a result of the relative reliability of the equipment that failed. As would be expected, railroad maintenance data shows that unplanned maintenance costs are dominated by labor costs expanded in troubleshooting the problem and changing out single failed parts. The technique used for estimating unplanned maintenance is to keep it in a direct ratio of the reliability of the new equipment versus the base.

For a coal burning diesel locomotive, the failure rate expectation of an oil burning locomotive and its unplanned maintenance cost is ratioed with the reliability expectation for coal burning locomotive (see Sec. V for reliability determination).

Unplanned Cost for Maintenance Calculation

$$\text{Coal Burning Loco} = \frac{\text{Failures/Loco Year (F/LY) Coal}}{\text{Failures/Loco Year (F/LY) Oil}} \times \text{Unplanned Oil Loco Maintenance Costs}$$

III. MAINTENANCE COSTS

F. Coal Burning Diesel Locomotive

2. Unplanned Maintenance

Unplanned Cost for Maintenance Calculation (continued)

Item	Eastern	Western
i. Oil Burning Loco Unplanned Cost	$27,800/Yr	$31,760/Yr
j. Ratio of Reliability	3.38 F/LY / 3.09 F/LY	3.38 F/LY / 3.09 F/LY
k. Coal Burning Diesel Unplanned Costs (i. x j.)	$30,400/Yr	$34,700/Yr
Total Cost for Maintenance		
h. Planned Maintenance for Coal Burning Locomotive (above)	$61,950/Yr	$66,245/Yr
3. TOTAL MAINTENANCE COST (k & h)	$92,350/Yr	$100,945/Yr

III. MAINTENANCE COSTS

F. Coal Burning Diesel Locomotive

4. Calculation of Maintenance Costs Versus Fuel Burned

An analysis has been made to determine the relationship between input fuel cost of a locomotive and the maintenance cost. This relationship will be used in the economic evaluation of the various alternate fuel technologies on various railroad duty cycles.

The basic maintenance cost information for Western and Eastern railroad high duty cycle is derived under Sec. III.F. Briefly, these fuel costs for specific high duty applications were determined from data obtained from various railroads and data collected by ICC.

Figure III.F.1 depicts average data for all railroads, including Eastern/Western average, as a straight line (solid). Another straight line (dashed) plot is shown for highly utilized locomotives. This is labeled "HEAVY DUTY" and includes points for Average High Eastern, and High Western Railroads.

Also shown in Figure III.F.1 is a dotted-dashed curve showing the transition from highly utilized to lowly utilized locomotives based on data from fleet segments in this mode of operation.

The resulting curve shows the maintenance costs of locomotives to vary with usage in an unexpected manner.

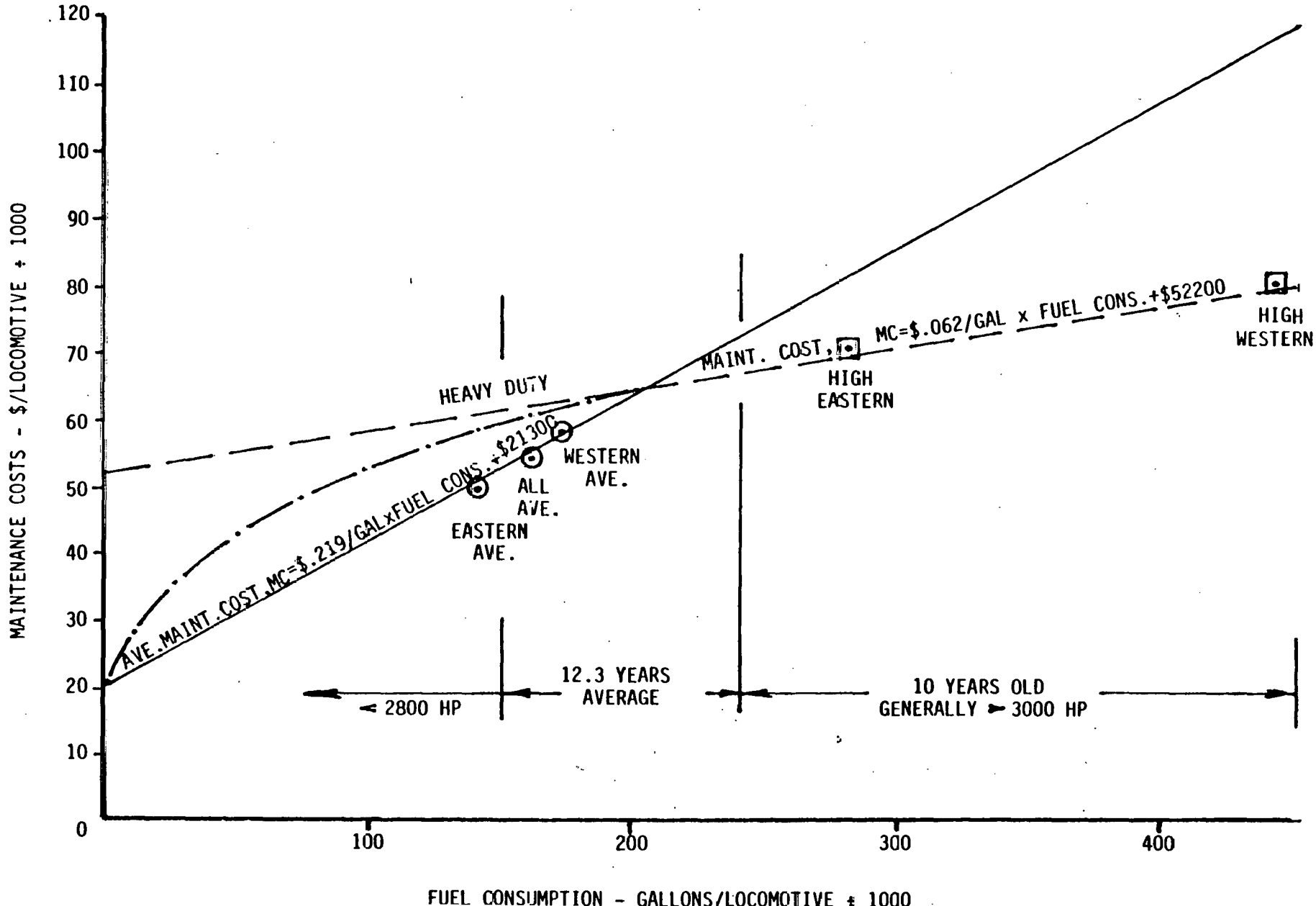
The harder a locomotive is used (the more fuel burned in the process of working), the higher the cost of maintenance, in direct proportion, would be the expected results. If the total fleet and its individual locomotive duty assignments were random, then the intuitive direct proportionality of fuel used versus maintenance cost would have technical justification. The assignment of duty to locomotives is highly structured and random only within narrow defined limits. In running the railroad, the assignment of locomotives has been structured to both maximize train performance (minimize delays from equipment failures) and minimize maintenance and fuel costs.

Heavy duty locomotive applications are assigned to locomotive pools whose average age is the lowest in the total fleet and whose average horsepower per unit is the highest.

This process keeps the number of locomotives (horsepower) per train to a minimum while it uses the newest, most efficient and reliable units to gain maximum effect on fuel costs.

As the locomotive ages, on the average, it is placed in locomotive pools that require less duty. As the locomotive ages, the cost of maintenance goes up reflecting the major overhauls due and failures as the equipment wears out.

ANNUAL TOTAL MAINTENANCE COSTS/LOCOMOTIVE VERSUS FUEL CONSUMPTION/LOCOMOTIVE



III. MAINTENANCE COSTS

F. Coal Burning Diesel Locomotive

4. Calculation of Maintenance Costs Versus Fuel Burned (continued)

Examining the average maintenance cost of the various locomotive pools based on assigned duty, one finds the maintenance cost tends to stay constant with but a minor influence on duty and fuel usage. As the age and duty progressively reaches the point before retirement, the maintenance cost falls off. The usage becomes so low that essentially no maintenance need be performed or is performed. The intercept with the 0 fuel consumption line representing those regulated inspections and tests required for a locomotive considered active and usable, yet not used.

One must be careful in examining maintenance data for individual locomotives. Remembering that planned maintenance is very time cyclic, even relatively young locomotives have peak planned cost when they reach approximately four years old. In any sample, enough locomotives must be averaged to smooth out variations caused by purchased date. Statistics are best viewed by looking at increments of locomotives that represent significant portions of a total pool assigned to particular railroad sections/duty.

The curve provides additional information on the typical structure of a locomotive fleet as to age, where fuel is consumed and unit horsepower.

For the purposes of the economic analysis for coal burning locomotives, only the heavy duty application portion of the curve should be used. Any locomotive purchased new and based on fuel cost savings will accentuate their application to the highest duty applications; those that burn the most fuel. Therefore, the maintenance cost of any oil burning locomotive entering the fleet and for 10 to 15 years of its life is:

Maintenance Cost = $52,200 + .062 x fuel consumed in gallons

The cost of each coal burning technology will start with these costs as a base.

III. MAINTENANCE COSTS

F. Coal Burning Diesel Locomotive

5. Maintenance Costs of Oil Burning Diesel Locomotive

Source

- From latest, December 31, 1982 copy of Transport Statistics in the U.S. Railroads, Part 1, published by ICC, Bureau of Accounts.
- Data from railroads directly.
- GE maintained data file on active and stored locomotives for each railroad.
- The yearbook of railroad facts (AAR publication).

Derivation

Line 356 of ICC Publication lists variable costs (in period $ x 1000) for locomotive repair and maintenance by:

	All Districts	Eastern	Southern	Western
a.	$1,184,367	$325,451	$211,612	$647,304

Line 703 (page 14) lists the total number of locomotives.

	All Districts	Eastern	Southern	Western
b.	26,675	8,001	4,962	13,712

This number includes both active and stored locomotives. It also includes locomotives in all service classifications, including switchers.

From General Electric file, average percent of locomotive in service during 1982 is:

	All Districts	Eastern	Southern	Western
c.	80.2%	77.3%	84.6%	80.3%

The average maintenance cost in period $ per locomotive is: A ÷ (B x C).

	All Districts	Eastern	Southern	Western
d.	$55,400	$ 52,600	$ 50,400	$ 58,800

III. MAINTENANCE COSTS

F. Coal Burning Diesel Locomotive

5. Maintenance Costs of Oil Burning Diesel Locomotive (continued)

Through 1983 and 1984, there has been 7% (GE data) inflation in the kind of split between material and labor represented by the dollars shown in Line D. Normally, these average maintenance costs should be inflated, but the railroads have done well in cost containment. Examining the railroad's performance in productivity improvements between the ICC statistics of 1981 and 1982 and the trend line for total equipment maintenance as shown in the AAR Railroad Facts indicates the railroads have stayed even or beat inflation over the past three or four years. Therefore, the average maintenance cost dollars for the active fleets shown in Line D are assumed to be the same average in 1985 dollars.

Data received from various railways provides a snapshot of how the cost for each locomotive compares with the average from hardly used locomotives (switchers) up to heavy haul, high mileage locomotives. Heavily used locomotives average 35% higher yearly maintenance costs than the fleet average. On the other hand, lightly used locomotives average 35% lower yearly maintenance costs. Because any alternate fuel locomotives primary objective is cost savings, they would naturally find their way into high usage categories. For purposes of all alternate fuel cost studies, a comparative average cost for diesel electric locomotives is Line D x 1.35 or:

	All Districts	Eastern	Southern	Western
e.	$74,800	$71,000	$68,000	$79,400

Because the duty of Eastern and Southern railroads are very similar and with recent consolidations, these two are combined and averaged at:

Eastern-Southern	Western
$69,500	$79,400

IV. AVAILABILITY

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IV. AVAILABILITY

A. Background

Locomotive availability is a measurement made by railroads as an index of both the locomotive builder's quality/reliability and as a means of measuring their own overall maintenance performance. Generally, the availability index is derived from number of days the locomotive is ready for service during a full year (365 days). Credited to the unavailability is the time it takes to move the locomotive to the service area and queue time waiting for action (8 to 12 hours).

Contributing to the time the locomotive is "unavailable" for service are two broad categories. The first, "Planned Maintenance" activities include inspections (FRA mandated), servicing (excluding fueling, addition of various consumables such as lubricants, water, etc.), and routine maintenance through major overhauls (prorated to an annual basis). The second category is "Unplanned Maintenance". This includes anything and everything that has not been planned even down to locomotive consumable servicing if it requires attention more frequently then planned. Locomotive reliability is the driving factor in unplanned maintenance.

Diesel-electric locomotives presently require "Planned Maintenance" activities on a 90-day cycle for the most routine activities all the way up to 12 years for major overhauls.

B. Method

As in the determination of maintenance costs, availability is calculated primarily by measuring those differences between today's standard oil burning locomotive and the coal burning technology being examined. These measured differences are then added to or subtracted from the availability of the oil burning diesel locomotive. In reality, unavailability is calculated which in turn allows availability to be calculated. Unplanned unavailability (locomotive failures) is ratioed directly from the coal burning locomotives' reliability versus that for the oil burning diesel and its unplanned availability. Reliability for each coal burning technology is covered under Sec. V

IV. AVAILABILITY

C. Availability Results

The following sections (D to H) provide the derivation of the various coal burning locomotive technologies. The results are given below:

Sec.	Locomotive Prime Mover	Unavailable Days Planned	Unavailable Days Unplanned	Availability %
-	DF2 Diesel[1]	15.0	11	92.9
D.	CWS Burning Diesel	15.8	12	92.5
E.	CWS Burning Gas Turbine	15.0	11	92.9
F.	CWS Burning Gas Turbine with Steam Injection	34	20	85.2
G.	ROM Coal Burning GT with Gasifier	101	23	66.0
H.	Steam Turbine with Fluidized Bed	52	28	78.1

[1]Availability of the standard, DF2 Diesel Electric Locomotive has been obtained from General Electric records on mainline locomotives.

IV. AVAILABILITY

D. Calculation of Availability of Coal Burning Diesel Locomotive

Planned Maintenance	Unavailable/Year
1. Standard Oil Burning	15 days
In addition to standard oil diesel locomotive from the Maintenance Cost Study (Sec. III), the additional planned activities and their impact on"time out of service" follows. Note, only that time which extends the maintenance period is included in the total. More labor may be planned to be done, but done in parallel so it shows up only in cost. Because all planned maintenance occurs at fixed intervals, there is no increase in queue.	
2. 90-Day (3 Month Maintenance)	0 days
Lubrication System Activities 2 hours/period - no increased elapsed time	
3. 6-Month Maintenance	.25 days
UX Fuel Injectors, double the frequency of oil burning locomotives - 8 hours/period extends yearly time	
4. 1 Year Maintenance	0 days
UX Fuel Injection Pumps Normally done every two years - no extension	
5. 2 Year Maintenance	
UX Cylinder Assemblies 50 hours normally done every 4 years Extends period by 1 day - average extension	.5 days
UX Pistons & Rings Accomplished with cylinder assembly UX - no extension	0 days
6. 4 Year Maintenance	
UX Turbocharger Normal changeover period - no extension	0 days
UX Water Pump Normal period for changeout - no extension	0 days
Total Planned Maintenance Time	15.75 days

IV. AVAILABILITY

D. Calculation of Availability of Coal Burning Diesel Locomotive

Unplanned Maintenance

The unplanned maintenance time is directly proportional to the reliability change between the oil diesel locomotive and the coal. Queue time does increase and is taken care of by direct ratioing.

	Unavailable/Year
Standard Diesel Locomotive Unplanned Time	11 days
Reliability Ratio (from Sec. V) $\frac{3.38 \text{ F/LY}}{3.09 \text{ F/LY}} = 1.094$	
Total Unplanned Maintenance Time	12 days
Total Unavailability of Coal Burning Diesel Locomotive	27.75 days

Availability of a Coal Burning Diesel Locomotive

$$\frac{365 - 27.75}{365} = 92.5\%$$

IV. AVAILABILITY

E. Gas Turbine Locomotive Availability

Planned Maintenance (and Inspection)	Unavailable/Year
1. Gas Turbine and Auxiliaries (See Steam Turbine, Sec G).	3 days
2. All other Locomotive Systems (Same as Diesel Electric)	12 days
Total Planned Maintenance Time	15 days

Note: The gas turbine is expected to cause little change in the time a locomotive is unavailable. As with today's diesels, most inspections and equipment changeout will be accomplished while maintenance on other subsystems is being performed.

Unplanned Maintenance and Inspection Time	11 days

Equal to standard diesel because reliability is equal.

Total Days/Locomotive Year Unavailability	26 days

Availability of Gas Turbine Locomotive

$$\frac{365 \text{ Days} - 26 \text{ Days} \times 100}{365 \text{ Days}} = 92.9\%$$

IV. AVAILABILITY

F. Gas Turbine Locomotive With Steam Injection Availability

Planned Maintenance and Inspection Time

1.	Gas turbine and Auxiliaries (See Steam Turbine Sec. G)	3 days
2.	Heat Recovery and Steam Injection Boiler and Feed Water System	13 days
3.	All Other - 1.5 X Standard Diesel This is a three-unit locomotive at 8000 HP, additional inspections and equipment conservatively will absorb the additional 6 days per year.	18 days
	Total Planned Maintenance Time	34 days

Note: The boiler estimate for unavailability has been taken as 2/3 of the estimate used for a steam turbine boiler (Sec. H). This steam turbine boiler has approximately 3 times the steam capacity of this heat recovery boiler yet most of the time a boiler is unavailable is spent in assuring boiler safety via inspections. It has been assumed that unavailability maintenance time on a boiler is primarily independent of capacity.

Unplanned Maintenance and Inspection Time 20 days

Direct ratio of projected reliability (from Sec. V) of the steam injected gas turbine and a standard oil burning diesel locomotive times 11 days for the oil diesel.

Total Unavailability of Gas Turbine With Steam Injection 54 days

Availability of Gas Turbine Locomotive With Steam Injection

$$\frac{365 \text{ Days} - 54 \text{ Days}}{365 \text{ Days}} \times 100 = 85.2\%$$

IV. AVAILABILITY

G. Gasifier Fed Turbine Locomotive Availability

Planned Maintenance and Inspections	Unavailable/Year
1. Gasifier	51 days
2. Fuel, Ash Handling and Gas Processor (See Note Below)	29 days
3. All other Locomotive Systems (Same as a Diesel-Electric X 1.5 to account for 3 units)	18 days
4. Turbine and Auxiliaries (See Steam Turbine, Sec. H.)	3 days
Total Planned Maintenance Time	101 days
Total Unplanned Maintenance Time	23 days
Total Days Unavailability for Gasifier Fed Turbine	124 days

Note: The values for unavailability for both gasifier and the auxiliaries were derived from data taken from P.F.H. Rudolph's chapter on Lurgi type gasifiers (Chapter 3-7, Pages 3-141 & 3-142 of the Handbook of Synthetic Fuels). Quoted is 86% availability (14% unavailability or 51 days) for the gasifier and 92% for all else (8% unavailability).

Direct Ratio of Predicted Reliability of Gasifier Fed Turbine Locomotive and Diesel-Electric (Sec. V) and the diesel's unplanned maintenance average time of unavailability - 11.0 days

(Planned [101 days] + Unplanned [23 days])

Availability of Gasifier Fed Turbine

$$\frac{365 - 124}{365} = 66.0\%$$

IV. AVAILABILITY

H. Steam Turbine Locomotive Availability

Planned Maintenance and Inspection Time	Unavailable/Year
1. Steam Turbine and Auxiliaries (Estimated from General Electric Erie, PA Plant) (Power Generation Plant Experience)	3 days
2. Boiler Estimated from vendor expressed maintenance requirements. Approximately 60% of the time required for routine maintenance was excluded, daily inspections would be unsatisfactory in today's railroading. Every three days or trip turnaround might be possible and was included (not at all desirable, railroads want a minimum of planned maintenance on 90-day cycles).	23 days
3. Fuel, Ash Handling and Flue Gas Processor There is more routine maintenance work to be accomplished in cleaning and lubricating the fuel, ash, and flue gas systems than with the boiler, but none of the safety related inspections. The 8 days is additional time taken to handle these routine things while the locomotive is being refueled (assumed to be 1/2 hour per refueling).	8 days
4. All other Locomotive Systems (1.5 X Diesel) (Takes care of the 8000 HP, 3 Unit Locomotive)	18 days
Total Planned Maintenance Time	52 days
Unplanned Maintenance Time	
Direct ratio of predicted reliability of the steam turbine locomotive and the diesel electric (Sec. V) and the diesel's unplanned average maintenance time of 11 days.	28 days
Total Unavailability of Steam Turbine Locomotive	80 days

Availability of Steam Turbine Locomotive

$$\frac{365 \text{ days} - 80 \text{ days}}{365 \text{ Days}} \times 100 = 78.1\%$$

V. RELIABILITY

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V. RELIABILITY

A. Approach and Rationale for Reliability Estimate

A considerable amount of statistics have been accumulated for the standard oil burning locomotives over the past years. Enough hard data is in-hand to make reliability predictions for new oil burning locomotives reasonably accurate. Attached are "Reliability Allocation Matrices" established for General Electric's coal-burning locomotives. These reliability allocations are the goals established for an actual reliability "growth" program involving each major locomotive functional modules and types of technologies.

For all coal-burning locomotive analysis of reliability, the experience with oil burning locomotives will be the base. By examining the proposed conceptual design for each locomotive, by major functional module and the understanding of the technologies required, a comparison factor can be generated relating the new locomotive to present experience.

Comparing functional modules between today's oil burning diesel and a new coal burning technology as a means of building up a reliability model is a realistic and practical approach. All considered locomotives have electrical propulsion, therefore, the reliability of all the propulsion modules will be directly proportional to the number (complexity) employed. If a locomotive has twice the rated horsepower, it will have near twice as many traction motors (assuming the same application) and power transmission devices. It will have one-half the reliability of traction motor and accessories (twice the failures/loco year).

Occasionally, the technology is not directly related to present practice. Under these circumstances, the model must break that module down to a level that reliability assignments can be made. This has been handled in the following model by special subscripts. The accumulated data available today does have expected reliability for many "parts" employed in the make-up of these new modules.

On some of the coal burning technologies, the report relies on vendor estimates of reliability. The subscripted note will provide this information where applicable.

The first matrix, the coal-burning diesel locomotive is exactly the same as an oil burning diesel except for the engine and fuel delivery. Therefore, 90% of the reliability prediction is a copy of today's General Electric Dash 8 reliability program.

V. RELIABILITY (continued)

B. Summary of Results

Locomotive Prime Mover Technology	HP for Traction	No. of Powered Axles	Reliability in F/LY
Standard, General Electric Oil Diesel	3800	6	3.090
CWS Burning Diesel	3800	6	3.376
CWS Burning GT	5900	8	3.091
CWS Burning GT with Steam Injection	8000	12	4.641
ROM Coal GT with Gasifier	8000	12	5.528
Steam Turbine with Fluidized Bed Boiler	8000	12	7.913

V. RELIABILITY (continued)

C. Target Reliability Predictions - CWS Burning Diesel Locomotive

Subsystem	Standard[1] Oil Diesel F/LY	Factor for Comparison	Coal[2] Burning Diesel F/LY
Diesel Engine	.829	X1.15	.953[3]
Radiator & Fans			
Ventilation (Blower Motor & Control)			
Alternator			
Traction Motors & Acc			
Electric Braking			
Propulsion Control	2.192	X1	2.192
Aux Power & Control			
Power Control & Distr.			
Sensors & Instruments			
Cabs, Platforms & Trucks			
Air Brake & Sand			
Air Compressor (.073)			
Misc (.020)			
Fuel Handling & Air Compressor Drive	.069	--	.231[4]
Total	3.09		3.376

Notes:

(1) Estimated reliability for General Electric's new Dash 8 locomotives. This standard is a 3800 hp, 6-axle locomotive.

(2) The CWS burning diesel is the same configuration as the standard described under note[1], a 3800 HP single unit, 6-axle locomotive.

V. RELIABILITY (continued)

C. Target Reliability Predictions - CWS Burning Diesel Locomotive

(3) Fuel Handling on the Diesel Engine - The complexity of the combined coal slurry, diesel oil fuel system on the coal burning engine is 50% more than that of a standard oil burning enghine. The portion of the .829 F/LY associated with fuel delivery is .247 as determined by GE field failure data since 1977. The added failures are .124 per locomotive year.

The design of the coal burning diesel is expected to be different in the cylinder area and fuel delivery. The reliability of the engine has not been decreased (except as shown above because of parts increase) because the engine preventative maintenance plan has been adjusted to accommodate both design and application variations.

(4) Fuel Handling on the Locomotive Adds

	F/LY
1 Motor & Pump	.042
1 Control	.020
1 Heat Exchanger & Heaters	.100
To C39-8	.079
Total	.231

V. RELIABILITY (continued)

D. Target Reliability Predictions - CWS Burning Gas Turbine Locomotive

Subsystem	Standard[1] Oil Diesel F/LY	Factor for Comparison	Coal[2] Burning Diesel F/LY
Engine (Diesel or GT)	.829	---	.300[3]
Radiator & Fans	.346	---	---
Aux Power & Control			
Sensors & Instruments	.468	X1	.468
Air Brakes & Sand Including Air Compressor			
Ventilation (Blower Motors & Control)	.267	X1.33	.365
Alternator			
Traction motors & Acc			
Electric Braking	1.055	X1.5	1.583
Propulsion Control			
Power Control & Distr.			
Cabs, Platforms & Trucks	.056	X2	.102
Fuel Handling	.069	---	.231[4]
Intercar Connections	---	---	.050[5]
	3.090		3.091

Notes:

(1) Estimated reliability for General Electric's new Dash 8 locomotive. The standard is a 3800 HP single unit locomotive with 6 axles.

(2) The gas turbine locomotive burns a coal water slurry (CWS) stored in an attached tank car. The unit develops 5900 HP for traction and has eight axles in two 'D; trucks each made up from two B, 4-axle trucks connected by a "span bolster".

V. RELIABILITY (continued)

D. Target Reliability Predictions - CWS Burning Gas Turbine Locomotive (continued)

(3) Reliability estimate obtained from General Electric's Gas Turbine Division.

(4) Fuel Handling Adds

1 Motor and Pump	.042
Plus Control	.020
Heat Exchanger for Slurry Antifreeze	.100
To Oil Diesel	.069
Total	.231

(5) Intercar Connections

Equated to reliability of total fixed loco wire & cable failure rate	.050

V. RELIABILITY (continued)

E. Target Reliability Predictions - CWS GT Locomotive w/Steam Injection

Subsystem	Standard[1] Oil Diesel F/LY	Factor for Comparison	GT Loco[2] w/Steam Inj. F/LY
Engine (Diesel or Turbine)	.829	---	.300[3]
Boiler & Auxiliaries	---	---	.312[4]
Radiator & Fans	.346	---	---
Ventilation (Blower Motor & Control			
Alternator			
Traction Motors & Acc			
Electric Braking			
Propulsion Control	1.790	X2	3.580
Aux Power & Control			
Power Control & Distribution			
Sensors & Instruments			
Air Brake, Sand and Air Compressors			
Cabs, Platform & Trucks	.056	X3	.168
Fuel Handling	.069	---	.231[5]
Intercar Connections	---	---	.050[6]
Total	3.090		4.641

Notes:

(1) Estimated reliability for General Electric's new Dash 8 locomotives.
This standard is a 3800 HP single unit locomotive.

(2) The GT locomotive with heat recover and steam injection burns CWS stored in an attached tank car with powered trucks, 6 axles total. The power unit with GT, alternator and heat recovery boiler also has 6 powered axles. A 4-axle water tender is also in the total locomotive make-up. The locomotive produces 8000 HP for traction.

(3) Reliability estimate obtained from General Electric's Gas Turbine Division.

V. RELIABILITY (continued)

E. Target Reliability Predictions - CWS GT Locomotive w/Steam Injection (continued)

(4)	Boiler & Auxiliaries	F/LY
	4 Year average between boiler failures	.250
	1 Motor, Load	.042
	1 Motor Control	.020
	Total	.312
(5)	Fuel Handling Adds	
	1 Motor and Pump	.042
	Plus Control	.020
	Heat Exchanger for Slurry Antifreeze	.100
	To Oil Diesel	.069
	Total	.231
(6)	Intercar Connections	
	Equated to reliability of total fixed loco wire and cable failure rate	.050

V. RELIABILITY (continued)

F. Target Reliability Predictions - ROM Coal GT Loco with Gasifier

Subsystem	Standard[1] Oil Diesel F/LY	Factor for Comparison	Gasifier Fed GT Loco[2] F/LY
Engine (Diesel or Turbine)	.829	---	.300[3]
Gasifier, Boiler & Auxiliaries	---	---	.810[4]
Radiator & Fans	.346	---	
Ventilation (Blower Motor & Control)			
Electric Generator			
Traction Motors & Acc			
Electric Braking			
Propulsion Control	1.585	X2	3.17
Aux Power & Control			
Power Control & Distr.			
Sensors & Instruments	.168	X3	.504
Cabs, Platforms & Truck			
Air Brake & Sand plus Air Compressor	.093	X4	.372
Fuel Handling & Air Compressor Drive	.069	---	.322[5]
Intercar Connections	---	---	.050[6]
Total	3.09		5.528

Notes:

(1) Estimated reliability for General Electric's new Dash 8 locomotive. The standard is a 3800 HP single unit locomotive with 6 axles.

(2) The gasifier fed gas turbine locomotive has 3 units. One unit has the gasifier and gas clean-up equipments along with 6 powered axles. The power car has the turbine, alternator and controls, the heat recovery boiler (for steam used in gasifier) plus 6 powered axles (12 total power axles). The third unit contains fuel, water and miscellaneous equipments and does not have powered trucks. The locomotive produces 8000 hp for traction.

V. RELIABILITY (continued)

F. Target Reliability Predictions - ROM Coal GT Loco with Gasifier

Notes: (continued)

(3) Reliability estimate obtained from General Electric's Gas Turbine Division.

(4)

Gasifier, Boiler & Auxiliaries	F/LY
2 year average between minor or	.5
5 Motors & Loads	.210
Control for Motors	.100
Total	.810

(5)

Fuel Handling & Air Supply	
5 Motors & Loads	.210
5 Motor Controls	.100
2 Solenoid Operated Valves	.012
Total	.322

(6)

Intercar Connections	
Equated to reliability of total fixed loco wire and cable	.050

V. RELIABILITY (continued)

G. Target Reliability Prediction - Steam Turbine Locomotive

Subsystem	Standard Oil Diesel[1] F/LY	Factor for Steam Turbine Comparison	Locomotive[2] F/LY
Engine (Diesel or Turbine)	.829	---	.1[3]
Boiler & Auxiliaries	---	---	.686[4]
Electric Generator			
Traction Motors & Acc			
Electric Braking	1.055	X2	2.110
Propulsion Control			
Power Control & Distribution			
Ventilation (Blower Motors & Control)			
Auxiliary Power and Control			
Sensors & Instruments	.791	X3	2.373
Cabs, Platforms & Trucks			
Air Brakes and Sand (Air Compressor)			
Radiator or Condenser	.346	X4	1.384
Flue Gas Clean-Up and Ash Systems	---	---	.330[5]
Fuel Handling	.069	---	.880[6]
Intercar Connections	---	---	.050(7)
Total	3.090		7.913

Notes:

(1) Estimated reliability for General Electric's new Dash 8 locomotives.

(2) The steam turbine locomotive is made up of 3 units: A coal, lime and water tender; a power unit with boiler, turbine and fluidized bed equipment; and a condenser car with flue gas clean-up. The power car and condenser/flue gas clean-up car each have 6 power axles (12 total). The locomotive produces 8000 HP for traction.

(3) Steam turbines are very reliable systems. GE experience has shown that with proper planned maintenance, a minor failure every 10 years can be expected.

V. RELIABILITY (continued)

G. Target Reliability Prediction - Steam Turbine Locomotive

Notes:

(4)	Boiler & Auxiliaries	F/LY
	Two-year average between minor or major boiler failures (GE Erie Power House experience)	.5
	Three blowers and motor	.126
	Control for blowers (GE Locomotive reliability data)	.060
	Total	.686
(5)	Flue Gas Clean-Up & Ash Handling Systems	
	3 years average between minor or major system failures is expected. These systems need service every time the locomotive is refueled. Improper servicing will cause an automatic shutdown (not an equipment failure but it counts in reliability measurements) to prevent passing these waste materials directly to the environment.	.330
(6)	Fuel Handling	
	14 Motors & Loads	.588
	14 Motor Controls	.280
	2 Solenoid Operated Valves	.012
	Total	.880
(7)	Intercar Connections	
	Equated to reliability of total fixed loco wire and cable	.050

VI. COAL PROCESSING PLANT CAPITAL COSTS

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Note: Sections B through G abstracted from Contract No. DEAC21-85MC2218 Section VI, except page numbers and subject numbers changed to correspond to this report.

VI. COAL PROCESSING PLANT CAPITAL COSTS

A. Forward

This analysis of the economics of running a railroad on coal assumes the railroad buys coal directly from a mine; transports it either to raw coal fuel stations for those technologies that burn Run of the Mine (ROM) coal or to a coal processing plant where it is turned into a slurry. In treating the coal fuel in this manner, the railroads must make additional capital expenditures above those for locomotives. This economic analysis therefore provides detailed estimates of the capital investment required in a manner that it can be customized for each railroad, depending on locomotive fleet size and locomotive utilization (fuel usage).

Sect. VI. B. repeats the coal processing plant capital cost derivation generated for the coal burning diesel report. The capital costs results for these processing plans (and included fueling stations) is used for all coal water slurry burning options for a railroad fleet.

Sect. VI. H. derives the capital costs necessary for fueling stations for those coal burning options using raw, ROM coal.

VI. COAL PROCESSING PLANT CAPITAL COSTS

B. Capital Cost Estimate for a 135 Ton/Hour Plant

1. Raw Coal Unloading & Storage

Storage

Plant has three weeks (15 days) of coal in storage for processing. For 135 tons per hour (20-hour days), temporary on-site storage needs to be 45,000 tons or 1.8×10^6 cubic ft. This temporary storage is accomplished with six identical silos, 54 feet in diameter and 150 feet high, single point draw, jump form construction. These are budgetary estimates obtained from a silo manufacturer and installer.

	Installed
A. Cost/Silo	$ 675,000
For 6 Silos	$4,050,000

Unloading

Plant is equipped to accept a full unit train every two days (6,000 tons). The unit train is stored on a siding and emptied in one 8-hour shift. The coal is dropped from the cars into a pit and conveyed up to the top of the above silos at 15° incline.

B. Railroad siding installed; approximately 8500 feet of track and 7 turnouts. Installed cost, $833,200.

C. Feeder, $40,000; installation cost, $100,000; total cost, $140,000.

D. Unloading conveyor, 1100 feet of 36-inch wide covered. Unit cost, $345,000; installation, $221,000; total cost, $566,000.

Total Coal Unloading & Storage

Unit	$5,281,900
Installation	$ 321,000
Total	$5,589,200

VI. COAL PROCESSING PLANT CAPITAL COSTS

B. Capital Cost Estimate for a 135 Ton/Hour Plant (continued)

2. Raw Coal Crushing & Pulverizing Costs

The stored coal in the silos is removed from the bottom of the silo, transported via conveyor to the hammer mills, mixed with water, pumped to the stirred ball mills and into a surge tank; all at the rate of 135 tons of coal per hour.

A. Input Conveyor Cost - 1100 feet of 24" wide covered conveyor to bottom of hammer mill. Cost, $300,300 plus installation cost, $192,000; total cost, $492,300.

B. Hammer Mill Cost - 135 tons per hour (two mills @ 75 tons each). Cost, $109,600 plus installation cost, $76,700; total cost, $186,300.

C. Input Conveyor to Hammer Mill Cost - 600 feet of 24" wide conveyor to top of hammer mill; cost, $202,500 plus installation cost, $140,000; total cost, $342,500.

D. Ball Mill Feeder - $30,000 each installed; total cost for six, $180,000.

E. Ball Mill Cost - Six mills are costed at 25 tons/hour each and with 3000 HP drive motors. This item's unit cost has not been derived from the updated Guthrie Listings because the technology involved is in the formative stages, very new. Budgetary estimates were sought from mill vendors and motor-gear manufacturers resulting in an estimate of 1.5 million per machine. The installation costs included are those suggested by the Guthrie report. For 6 mills, $9,000,000 plus installation, $470,500.

F. Conveyor, Hammer Mill to Ball Mill - 600 feet of 24" wide covered conveyor to top of ball mill. Cost, $202,500 plus installation, $140,000; total cost, $342,500.

G. Heat Exchanger, Ball Mill Output Cooling - Heat exchanger couples ball mill output heat energy into the chill water system and cooling tower covered under Section IV. Unit cost, $126,800 plus installation, $19,000; total cost, $145,800.

Total Raw Coal Crushing & Pulverizing Costs

Unit Cost	$10,121,700
Installation	$ 1,038,200
Total	$11,159,900

VI. COAL PROCESSING PLANT CAPITAL COSTS

B. Capital Cost Estimate for a 135 Ton/Hour Plant (continued)

3. Powdered Coal Clean-up & Waste Solid Removal

The coal coming from the ball mill is mixed with additional water and pumped to the agglomeration process after cooling to 80°F. The coal-water mixture is blended with the agglomerate in a high shear mixer, then it flows into the separator room. The coal, water and agglomerate mixture resides in the separator room for approximately 1/2 hour. As the mixture slowly flows from the input end towards the output end, the pulverized coal and agglomerate coagulates and rises to the top where it is skimmed off with the output conveyor. The coal and agglomerate is then conveyed to the evaporator where the agglomerate is removed (Section IV, Agglomerate Recycle). The residue of water and non-organic solids is drained off through a clarifier, removing the water from the solids for reuse. The solids, in sludge form, is conveyed directly to a tailings pond.

The coal-water mixture coming into the process is approximately 15% coal, 85% water. This amounts to 1000 tons of liquid per hour at the 150-ton per hour coal rate. The pump must handle 1000 tons per hour or 4200 gallons per minute at 20 PSI.

A. Pump - 4200 GPM at 20 PSI; monel metal. Unit cost, $32,480; installation cost, $45,800; total cost, $78,280.

B. Surge Tank - Sized to hold 10 minutes of flow or 42,000 gallons and special internal coating. Unit cost, $40,400; installation cost, $34,400; total cost, $74,800.

C. High Shear Mixer; 375 HP drive. Unit cost, $19,000; installation cost, $11,800; total cost, $30,800.

D. Separator - Four enclosed tanks with built in conveyors. The coal, water and agglomerate occupy 1/3 of the volume of each. The mixture is now 85% water, 10% coal, and 5% agglomerate. Each tank is 64' x 64' x 8' high.

Tanks - 33,000 cu. ft. each or 240,000 gallons with special coating for rust.

- Unit cost, $126,300 plus installation, $107,400; total cost, $233,700.

Each tank has 128 feet of 18" covered conveyor.

- Unit cost, $61,800 plus installation, $42,700; total cost, $104,500.

Total for four tanks, $752,400 plus installation, $600,400; total cost, $1,352,800.

VI. COAL PROCESSING PLANT CAPITAL COSTS

B. Capital Cost Estimate for a 135 Ton/Hour Plant

3. Powdered Coal Clean-up & Waste Solid Removal (continued)

E. Clarifiers - The effluent to be separated amounts to 7000 gallons per minute. Two 64 ft. diameter clarifiers reduce the water content to 40%. Unit cost, $100,000 each; installation cost, $50,000 each. Total for two, $200,000; installation cost, $100,000; total cost, $300,000.

F. Solid Waste Sludge Pumping System - Pumps must handle 15 tons/hour of which 40% is water. Effluent discharges into a hopper which delivers fluid to the pump. The pump then delivers waste to a large 60 acre tailings pond.

Pump Unit Cost = $5410; total pump cost, $27,050; total installation cost, $30,080

Conduit unit cost, $10/ft. x 3500 ft. = $35,000.

Total Pump Cost	=	$27,050
Conduit Cost	=	$35,000
Installation Cost	=	$30,080
		$92,130

G. Tailings Pond - Effluent will be discharged into a tailing pond to be used as a "clean" landfill. Landfill will be approximately 61 acres, and to be 20 feet deep by 1650 feet x 1280 feet, or approximately 13 x 10^6 ft.^{3}. Costs for clearing, grading, leveling and excavation are:

	Field Cost	Labor	Total
Grading, Clearing	$ 735,600	$ 29,420	$ 765,020
Excavations	$ 734,100	$ 91,760	$ 825,830
	$1,469,680	$121,180	$1,590,860

Total Powdered Coal Clean-up

Unit Costs	$2,576,040
Installation	$ 943,650
Total	$3,519,690

VI. COAL PROCESSING PLANT CAPITAL COSTS

B. Capital Cost Estimate for a 135 Ton/Hour Plant

4. Agglomerate Recovery & Storage

The cleaned coal comes out of the separator with both water and agglomerate intermixed. The output conveyor delivers the coal mixture to an evaporator where it is heated, driving the agglomerate out of the mixture. The agglomerate vapors are conducted to a condenser (regeneration subsystem) where it is cooled and compressed back to liquid. Recovered heat from the cooling and compressing is employed to heat the evaporator. The product coal is conveyed to the next stage; water mixing and storage.

A. Evaporator and Regenerator or Condenser are costed by applying an industrial refrigeration system with its evaporator (agglomerate condenser) operating at 20°F and its condenser heating the agglomerate coal mixture. This is using the refrigeration system as a heat pump. One ton of refrigeration can process 12,000 BTU/hour. Refrigeration capacity need is 2000 tons for the agglomerate recovery. The following cost includes sufficient capacity to assist in managing the temperature of the separator tanks. Cost, $2,179,000 plus installation, $675,000; total cost, $2,854,000.

   The approach of using a refrigeration system is approximately the same cost as that for heat exchangers and a vapor pump. A fan in the system assure that the agglomerate evaporation occurs below atmospheric pressure and condensing occurs at a positive pressure. This assures the flow of agglomerate vapor to the condenser.

B. Cooling Tower - The industrial refrigeration system dumps its losses into chilled water from the cooling tower. The single tower is sized to also handle the heat input to the slurry coming out of the ball mills (6 x 3000 HP). Tower handles 7000 gallons of water/minute providing a 15° temperature change. Unit cost, $419,000; installation, $67,000; total cost, $486,000.

C. Agglomerate Storage Tank - The tank is sized to hold one hour of process time of the agglomerate fluid (total system has 1.5 hours, 1/2 hour in the separator tanks). The agglomerate density is approximately 1/2 that of coal and is mixed in equal weight proportion to coal. Tank must hold 12,000 cu. ft. or 90,000 gallons and have rustproof coating; cost, $70,300 plus installation cost, $59,700; total cost, $130,000.

VI. COAL PROCESSING PLANT CAPITAL COSTS

B. Capital Cost Estimate for a 135 Ton/Hour Plant

4. Agglomerate Recovery & Storage (continued)

D. Product coal conveyor from evaporator to slurry mixer. Two required, 64 ft. each. Unit cost, $18,000; installation cost, $12,400. For two conveyors, $36,000 plus installation cost, $24,800; total cost, $60,800.

Total Agglomerate Recovery & Storage

Unit Costs	$2,704,300
Installation	$ 826,500
Total	$3,530,800

5. Product Coal Slurry Mixing, Storing and Delivery to User Locomotives

The product coal comes from the evaporator with little contained water. Conveyors deliver the coal to mixing tanks were the proper quantity of water is added (50% coal to 50% water) along with any chemicals necessary to condition the slurry. From the mixing tanks, the slurry is pumped to rubberized-lined storage tanks. Sufficient capacity is retained in the storage tanks for 10 days of plant output; 18×10^6 gallons. The storage is split between four equal size tanks. Railroad sidings are included to allow trains to pull in for refueling.

A. Mixing Tank - Same as high shear mixer. For two units, $38,000 plus installation cost, $23,600; total cost, $61,600.

B. Pump - 1250 gallons per minute at 50 PSI made with monel. Unit cost, $36,100 plus installation, $51,000; total cost $87,100.

C. Rust protected steel storage tanks with sufficient capacity to store 10 days (2 weeks) of output. Each tank has 4.4×10^6 gallons capacity (123 ft. dia. and 50 ft. high). Cost for each, $744,050 plus $632,450 installation. Total cost for four, $2,976,200 and $2,529,800 for installation.

D. Rail Siding - 3000 feet and 5 turnouts. Total cost, $330,000.

E. Two Locomotive Fueling Facilities - costed as shipping facilities. Total cost, $27,300.

Total Product Coal Slurry Mixing to Delivery Costs

Unit Costs	$3,407,600
Installation	$2,604,400
Total	$6,012,000

VI. COAL PROCESSING PLANT CAPITAL COSTS

B. Capital Cost Estimate for a 135 Ton/Hour Plant

6. Buildings, Power, Heat and Land Preparation

A. Process Building - The total facility includes a process building housing the ball mills through to the coal-water slurry output pump. This building encloses 120,000 square feet, under a steel truss roof with a concrete floor. The building also includes the heating, ventilation, plumbing (general) and lighting at a cost of $20.45 per square foot. Total, $2,454,700.

B. Office and Quality Laboratory - 6400 square feet; air conditioned with furniture and lab equipment. Cost at $53.75 per square foot. Total, $344,000.

C. Roadways and Parking Lots - There are approximately 5800 feet of 16 foot wide, 6-inch concrete roadways with a 6-inch subbase. The parking lot has 4000 square feet of 4-inch concrete with 6-inch subbase. Total cost, $231,300.

D. Process Power

	KW
1. Coal Grinding	
2 Hammer Mills 175HP ea.+ 140' of conveyors	483
6 Ball Mills 90KW per ton	13,500
2. Clarifiers & Pumps for solid waste.	250
3. All Process Pumps (total 435 HP)	360
4. Conveyors, Mixers, Fans, Cooling Tower & Misc.	585
5. Agglomerate Recovery Process	4,330
37.3×10^6 BTU/hour are being transferred between evaporation and condensing	
Total Load	19,508KW
At .93 P.F.	20,980KVA
Substation Costs	$619,230

VI. COAL PROCESSING PLANT CAPITAL COSTS

B. Capital Cost Estimate for a 135 Ton/Hour Plant

6. Buildings, Power, Heat and Land Preparation (continued)

E. Fencing - Approximately 9000 feet of chain link fencing with 8 corner posts and 9 gates. Total cost, $144,600.

F. Land Preparation - The lot is 1280 feet by 1600 feet, totalling 290,000 square yards. The land is assumed to need only clearing and grading on 1/4 of the total area (with exception of the tailings pond). Total cost, $162,100.

G. Process water deionizer and demineralizer, 1600 gallons/minute. Cost, $689,000.

Buildings through Land Preparation

Total Cost, $4,644,900

VI. COAL PROCESSING PLANT CAPITAL COSTS

B. Capital Cost Estimate for a 135 Ton/Hour Plant

7. External Fueling Stations

The total storage capacity of the required external fueling stations will be in exact proportion to the number of locomotives served and the average fuel each locomotive consumes. In short, the storage capacity varies directly with the size of the processing plant.

The ability for this total external storage facility to service locomotives is in direct ratio to the amount of fuel needed to be pumped, or in the same dimensions the original plant was chosen; number of locomotives served and the consumption per locomotive.

The total facility can be broken down into smaller facilities. The design employs fuel storage tanks, each of which can hold 2,500,000 gallons, about equal to a full fuel train of tankers (100 cars, 25,000 gallons each). There are four of these tanks in the total facility with pumps and docks for fueling two trains to each tank (8 fueling points).

The total external fueling tanks will hold approximately 7 days of fuel for the fleet. Combined with the storage capability at the plant, 10 days; total storage is 17 days (3 days more than 2 weeks). Therefore, if the utilization of all storage was equal, each external tank would need servicing average of once per week.

The external storage tanks can be broken up into as many as four individual facilities.

Rubberlined Tank - Cost, each $471,900 plus $401,115 installation cost.

Pumps - Cost, each $36,100 plus $51,000 installation cost.

Fueling Facility - Cost, each $27,300 total.

For each tank - unit cost, $535,300 plus $452,115 installation cost.

Total External Fueling Costs

Unit Cost	$2,141,200
Installation	$1,808,460
Total	$3,949,660

VI. COAL PROCESSING PLANT CAPITAL COSTS

C. Capital Cost Estimate for a 450 Ton/Hour Plant

(As derived from the design of a 135 Ton/Hour Plant)

	450 Ton/ Hour Cost
1. Raw Coal Unloading & Storage	
A. Increase Conveyor from 36 to 42-inch with two shifts unloading, conveyor operates at approximately 500 ft/min. Same length, 1160 ft.	$ 638,500
B. Storage Silos - Because this new system will use close to 7 coal cars per hour, the number of cars will be 140 per day. The facility will depend on having a portion of input coal storage in coal cars nearby the plant. Increase storage silos by six. (12 Silos)	$ 8,100,000
C. Railroad Siding - in line with the silo capacity, double.	$ 1,773,700
D. Feeder (957 Tons/hour) installed	$ 238,000
(135 Ton/Hour Plant - $5,589,200)	$10,750,200
2. Raw Coal Crushing & Pulverizing Costs	
A. Input convey from 24" to 36" wide covered	$ 566,000
B. Hammer Mills from 2 @ 75 Tons/hour to 4 @ 125 Tons/hour	$ 575,300
C. Input conveyor from 24" to 36"	$ 381,400
D. Ball Mills - keep same size mills, quantity from 6 mills to 20	$31,568,300
E. Conveyor from hammer mill to ball mills Increase length by 20% to handle additional mills and change from 24" wide to 36".	$ 429,300
F. Ball Mill Feeder - keep same size, one for each mill	$ 600,000
G. Ball Mill Output Cooler - 4 heat exchangers work with cooling tower under agglomerate system	$ 583,200
(135 Ton/Hour Plant - $11,159,900)	$34,703,900

VI. COAL PROCESSING PLANT CAPITAL COSTS

C. Capital Cost Estimate for a 450 Ton/Hour Plant

(As derived from the design of a 135 Ton/Hour Plant)

	450 Ton/ Hour Cost
3. Powdered Coal Clean-up & Waste Solid Removal	
A. Pump - 2 @ 7000 gallons/minute; monel	$ 164,100
B. Surge Tank - Sized to hold 10 minutes of flow or 140,000 gallons in two tanks, one for each pump.	$ 231,600
C. Two 625 HP high shear mixers (in proportion to fluid flow)	$ 79,200
D. Separator - 6 enclosed tanks, 1.6 times the volume of the 150-ton plant. Each tank has special rust proof coating and conveyors; 24" wide, not 18".	$ 2,587,800
E. Clarifiers - Approx. 6 clarifiers with motors	$ 1,000,000
F. Sludge Pump, Piping System	$ 307,100
G. Tailing Pond, cleaning, grading, excavating 200 acres	$ 5,298,200
Total Product Clean-up (135 Ton/Hour $3,519,690)	$ 9,668,000
4. Agglomerate Recovery & Storage	
A. Evaporator & Regenerator needs 3.33 times the capacity of 135 ton/hour plant.	$ 8,134,000
B. Agglomerate Storage Tank - sized to hold 40 minutes of plant capacity (200,000 gallons)	$ 198,800
C. Product coal conveyor from evaporator to slurry mixer, 3 required.	$ 91,200
D. Cooling Tower - Two 19000 GPM units	$ 1,296,000
Total (135 Ton/Hour $3,530,800)	$ 9,720,000

VI. COAL PROCESSING PLANT CAPITAL COSTS

C. Capital Cost Estimate for a 450 Ton/Hour Plant

(As derived from the design of a 135 Ton/Hour Plant)

5. Product Coal Slurry Mixing, Storing & Delivery	450 Ton/ Hour Cost
A. Mixing Tank - High Shear Mixer - Mixing tank included in 135 Ton plant has near five times the capacity required.	$ 61,600
B. Pump must handle 4200 gallons per minute at 75 PSI; split into two pumps.	$ 248,100
C. Rust Protected Steel Storage Tanks - (142 ft. dia. x 50 ft. high) Sufficient for 5 days of production, (the 135 Ton plant has 10 days). Five tanks	$8,030,000
D. Rail Siding - Three times more than 135 Ton plant. This allows trains on all sides of the tank form.	$ 990,000
E. Locomotive Fueling Facilities - Three times that for 135 Ton plant.	$ 90,000
Total (135 Ton/Hour $6,012,000)	$9,419,700

VI. COAL PROCESSING PLANT CAPITAL COSTS

C. Capital Cost Estimate for a 450 Ton/Hour Plant

(As derived from the design of a 135 Ton/Hour Plant)

6. Buildings, Utilities, Roadways, etc.	450 Ton/ Hour Cost
A. Process Building - Assume that the process machinery for a 135 Ton plant occupies 50% of the total area. The 450 Ton plant utilizes approximately 2.5 times the machinery area and 2 times the dead space. Plant square feet for 450 Ton plant is then 2.25 times the 135 Ton.	$ 5,523,100
B. Office and Quality Lab - No change between 135 Ton and 450 Ton plant.	$ 344,000
C. Roadways and Parking Lots - Roadways are related to the square root of process building square footage size increase or 1.5 times.	$ 347,000
D. Power requirements directly related to capacity; 70,000KVA Station.	$ 2,066,400
E. Fencing varies by the square root of equipment plant size increase between 135 Ton and 450 Tons per hour or 1.5.	$ 216,900
F. Land Preparation varies directly with the process building size increase - 2.25.	$ 364,700
G. Process water conditioner (4 units).	$ 2,756,000
Total (135 Ton/Hour $4,644,900)	$11,618,100

7. External Fueling Stations	
A. Storage tanks and pumps, 3.333 x 135 Ton plant	$13,164,200
Total (135 Ton/Hour $3,949,660)	$13,164,200

VI. COAL PROCESSING PLANT CAPITAL COSTS

D. Capital Cost Summary

1. 135 Ton/Hour and 450 Ton/Hour Plants

	Plant Size Cost in 1,000's	
	135T/Hour	450T/Hour
a. Raw Coal Unloading & Storage	$ 5,589	$ 10,750
b. Coal Pulverizing	$11,160	$ 34,704
c. Coal Clean-up & Solid Waste Removal	$ 3,520	$ 9,668
d. Agglomerate Recovery & Storage	$ 3,531	$ 9,720
e. Product Coal Slurry Mixing & Storing	$ 6,012	$ 9,420
f. Buildings, etc.	$ 4,645	$ 11,618
g. External Fueling Stations	$ 3,950	$ 13,165
Direct Costs	$38,407	$ 99,045
h. Indirect Costs (25%)[1] + Contingency (15%)	$15,363	$ 39,618
i. In-process Material Inventory		
- Coal - 78,000 tons x $33/ton	$ 1,311	$ 4,370
- Agglomerate 52,500 gallons x $1.5/gal.	$ 79	$ 266
- Additives - @ $6.00/ton	$ 136	$ 449
Total Wet Start-up	$ 1,526	$ 5,085
Grand Total	$55,296	$143,748

Size Exponential Factor = 0.80

[1] Indirect Costs include Sales Tax, Plant and Process Design, Supervision, etc.

VI. COAL PROCESSING PLANT CAPITAL COSTS

D. Capital Cost Summary (continued)

2. Plants designed to be expanded to twice the initial capacity as the need increases.

	Cost in 1,000's	
	68T/Hour Expandable 135T/Hour	225T/Hour Expandable 450T/Hour
a. Raw Coal Unloading & Storage		
reduce storage silos in 1/2	$ 3,564	$ 6,700
(add to get back to full capacity)	($ 2,025)	($ 4,050)
b. Coal Pulverizing		
reduce hammer mills and ball mills by 1/2	$ 6,242	$ 18,690
(add to get back to full capacity)	($ 4,918)	($ 16,014)
c. Coal Cleaning & Waste Removal		
reduce separators by 1/2 and all else divisible by 2	$ 2,694	$ 7,637
(add to get back to full capacity)	($ 826)	($ 2,031)
d. Agglomerate Recovery & Storage		
reduce evaporator & regenerator by 1/2	$ 2,074	$ 5,005
(add to get back to full capacity)	($ 1,457)	($ 4,715)
e. Product Coal Slurry Mixing & Storing		
reduce storage capacity by 1/2	$ 3,215	$ 5,281
(add to get back to full capacity)	($ 2,797)	($ 4,139)
f. Buildings, etc.	$ 4,645	$ 10,240
(to get back to full capacity, add water conditioners)		($ 1,378)
g. External Fueling Stations		
A. For 1/2 plant capacity	$ 1,975	$ 6,583
B. For full capacity	$ 3,950	$ 13,165
Totals		
A. Total direct costs for 1/2 plant capacity	$24,409	$ 60,136
B. For full capacity	$38,407	$ 99,045

VI. COAL PROCESSING PLANT CAPITAL COSTS

D. Capital Cost Summary

2. Plants designed to be expanded to twice the initial capacity as the need increases.

	Cost in 1,000's	
	68T/Hour Expandable 135T/Hour	225T/Hour Expandable 450T/Hour
h. Indirect (25%) + Contingency (15%)		
A. 1/2 plant capacity	$ 9,764	$ 24,054
B. Indirect + contingency for return to full capacity	$15,363	$ 39,618
i. Inprocess Material Inventory		
A. 1/2 capacity	$ 764	$ 2,543
B. Full capacity	$ 1,526	$ 5,085
Total		
A. 1/2 Capacity	$34,937	$ 86,733
B. Full Capacity	$55,296	$143,748

Size Exponential Factor = .80

Full capacity plant capital cost $= 1093\ (\text{Tons/hr})^{.8}$

or $= 141.1\ (\text{BTU required/year}/10^{10})^{.8}$

1st half size of expandable plant = 61.4% of full capacity cost

2nd invest to full capacity = 38.6%

VI. COAL PROCESSING PLANT CAPITAL COSTS

E. Appendix - Coal Processing Capital Costs

1. Raw Coal Unloading & Storage

A. Storage Silos - Sized for 45,000 tons coal or 1.8×10^6 ft.^{3}. Cost based on budgetary estimate from silo manufacturer, installer.

B. Railroad Siding - 8500 feet of track, and seven turnouts.

Per Unit Track Cost = $26.25/ft. (Ref. 1, p. 136)
Per Unit Grading Ballast = $ 6.25/ft. (Ref. 1, p. 136)
Per Unit Turnout Cost = $2800 (Ref. 1, p. 136)
Inflation Factor = 3 (Ref. 2)

C. Unloading Feeder to Conveyor - Sized to handle 459 tons per hour. Allows unloading a twenty-hour day of coal from a unit train in less than seven hours (Ref. 5, p. 161). Installation costs estimated at 2.5 times unit cost.

D. Unloading Conveyor - 1100 ft., 36" wide conveyor.

Per Unit Cost = $620 (Ref. 1, p. 132)
Size Exponent = 0.65 (Ref. 1, p. 132)
Field Installation Factor = 1.64 (Ref. 1, p. 132)
Factor Covered Conveyor = 2.1 (Ref. 1, p. 133)
Inflation Factor = 2.793 (Ref. 2)

2. Raw Coal Crushing & Pulverizing

A. Input Conveyor - 1100 ft. of 24" wide conveyor, from bottom of storage silos to bottom of hammer mills.

Conveyors:

Per Unit Cost = $540 (Ref. 1, p. 132)
Size Exponent - 0.65 (Ref. 1, p. 132)
Field Installation Factor = 1.69 (Ref. 1, p. 132)
Factor Covered Conveyor = 2.1 (Ref. 1, p. 133)
Inflation Factor = 2.793 (Ref. 2)

B. Hammer Mills - Energy requirement size reduction - 75 ton/hour; 175 HP (Ref. 2, p. 41).

Per Unit Cost = $500/ton/hour (Ref. 1, p. 133)
Number tons/hour = 75
Size exponent = .85 (Ref. 1, p. 133)
Installation = 70% (Ref. 1, p. 133)
Inflation Factor = 2.793 (Ref. 2)

VI. COAL PROCESSING PLANT CAPITAL COSTS

E. Appendix - Coal Processing Capital Costs

2. Raw Coal Crushing & Pulverizing (continued)

C. Input Conveyor to Hammer Mill - 600 ft. of 24" wide covered conveyor from the bottom of the hammer mills to top of hammer mills.

Conveyors:

Per Unit Cost = $540 (Ref. 1, p. 132)
Size Exponent = 0.65 (Ref. 1, p. 132)
Field Installation Factor = 1.69 (Ref. 1, p. 132)
Factor Covered Conveyor = 2.1 (Ref. 1, p. 133)
Inflation Factor = 2.793

D. Ball Mill Feeder - Grezley feeders to the ball mills, 24" wide and 15 feet long, $17,000 unit cost and 80% ($13,000) installation (Ref. 3, p. 162 for unit cost).

E. Ball Mill - Energy requirements (HP) for grinding median particle size to five microns is 90 KWH/ton. Conservative estimate from (Ref. 4, p. 19) (p. 576 of proceedings).

Cost: 90 KWH/ton requires a 3000 HP drive motor for a 25-ton/hour ball mill. Because this is a custom mill, budgetary estimates were sought from mill manufacturers and drive motor manufacturers.

F. Conveyor Hammer Mills to Ball Mills - 600 ft. of 24" wide covered conveyor from the bottom of the hammer mills to top of ball mill.

Conveyors:

Per Unit Cost = $540 (Ref. 1, p. 132)
Size Exponent = 0.65 (Ref. 1, p. 132)
Field Installation Factor = 1.69 (Ref. 1, p. 132)
Factor Covered Conveyor = 2.1 (Ref. 1, p. 133)
Inflation Factor = 2.793

G. Heat Exchanger, Ball Mill Output Cooling - Water-slurry heat exchanger to cool ball mill slurry, 60°F based on 3000 HP/ball mill = 46 x 10^6 BTU/Hr.

Overall Heat Transfer Coefficient, U = 375 BTU/hr. ft.^{2} °F (Ref. 4, Table 6).
Heat Exchanger Area, A = 4835 ft.^{2} (Ref. 6, Chapter 14)
Cost/ft.^{2} = $18 (Ref. 6, Fig. 14-18)
Installation Cost Factor = .15 (Assumed)

VI. COAL PROCESSING PLANT CAPITAL COSTS

E. Appendix - Coal Processing Capital Costs (continued)

3. Powdered Coal Clean-Up & Waste Solid Removal

A. Pump - Based on 4200 GPM @ 20 PSI. (2200 GPM for Ball Mill & water for mixing = 2000 GPM).

Monel Factor = 3.23 (Ref. 1, p. 126)
Installation Factor, incl. piping = 1.41 (Ref. 1, p. 126)
Inflation Factor = 2.793 (Ref. 2)

B. Surge & Mixing Tank - Sized for 4200 GPM, to yield 15% slurry solids by weight.

Factor for Costing = 1.48 (Ref. 1, p. 140)
Installation Factor = 1.47 (Ref. 1, p. 140)
Add Install Factor, Pumping System = 1.7 (Assumed)
Inflation Factor = 2.793 (Ref. 2)

C. High Shear Mixer - Sized for 4200 GPM of slurry; 75 HP cost x 2 for stainless steel (Ref. 5, p. 111). Installation costs estimated at 62% of unit cost in line with (Ref. 1).

D. Separators - Sized for slurry 85% water, 10% coal, 5% agglomerate. Four tanks, 64 ft. x 64 ft. x 8 ft. high with 18" built-in conveyors.

Tanks:

Factor for Costing = 1.48 (Ref. 1, p. 140)
Installation Factor = 1.85 (Ref. 1, p. 140)
Inflation Factor = 2.793 (Ref. 2)

Conveyors:

Per Unit Cost = $450 (Ref. 1, p. 132)
Size Exponent = 0.65 (Ref. 1, p. 132)
Field Installation Factor = 1.69 (Ref. 1, p. 132)
Inflation Factor = 2.793 (Ref. 2)

E. Clarifiers - Settling area required for proper operation estimated to be 21 sq. ft. per ton per day of solid wastes processed. Estimate falls between copper concentrate (specific gravity, 3.5) and nickel concentrate (specific gravity, 2.5); solid waste (specific gravity, approximately 3.0). Each clarifier designed to handle 7.5 tons per hour (coal with 10% mineral matter) or 150 tons per 20-hour day (Ref. 5, p. 137).

VI. COAL PROCESSING PLANT CAPITAL COSTS

E. Appendix - Coal Processing Capital Costs

3. Powdered Coal Clean-Up & Waste Solid Removal (continued)

F. Solid Waste Sludge Pumping System - Use five pumps over tailing pond, to handle 15 tons/hour, which has 40% water. Each pump then sized for 65 GPM @ 20 PSI. Conduits used for transporting materials.

Pumps:

Monel Factor = 3.23 (Ref. 1, p. 126)
Installation Factor w/o piping = 1.11 (Ref. 1, p. 126)
Inflation Factor = 2.793 (Ref. 2)

Conduit:

Cost Factor = $10/ft. (Assumed, 1985)
Length of Conduit = 3500 ft. (Based on dimensions of tailing pond)

G. Tailing Pond - Landfill 61 acres, 20 ft. x 1650 ft. x 1280 ft.

	Field Installation	$M&L
Clearing, Grading, Leveling, yd.^{2}	$0.90	$1.04 (Ref. 1, Table VI)
Excavation, 6 ft. yd.^{2}	$0.56	$0.63 (Ref. 1, Table VI)

Inflation Factor = 3.0 (Ref. 2)

4. Agglomerate Recovery & Storage

A. Evaporator, Condenser (Heat Pump) - Combined water and agglomerate heat to vaporize agglomerate for recovery and reuse.

Latent Heat of Vaporization Agglomerate, $\frac{1000\#}{\text{Ton Coal}}$ = 25×10^6 BTU/hr.

Sensible Heat Increase, Slurry + Agglomerate = 12.3×10^6 BTU/hr.

Total 37.3×10^6 BTU/hr.

Total 37.3×10^6 BTU/hr. = 3112 Equivalent Refrigeration Tons

Heat Pump Cost:

20°F Evaporator Factor = 1.95 (Ref. 1, p. 142)
Field Installation Factor = 1.31 (Ref. 1, p. 142)
Inflation Factor = 2.793 (Ref. 2)

VI. COAL PROCESSING PLANT CAPITAL COSTS

E. Appendix - Coal Processing Capital Costs

4. Agglomerate Recovery & Storage (continued)

B. Cooling Tower - Total heat to be handled generated by the ball mills (13,500 KW or 46.1 BTU/Hr. x 10^6) plus 10% for mechanical refrigeration in agglomerate recovery. To keep the cooling tower working on a 15°F temperature drop for the chilled water, 50.0 x 10 ÷ 15°F lbs. of water must be circulated or 7,000 gallons/min.

Curve for Unit Cost = (Ref. 1, p. 137, Fig. 13)
Inflation Factor = 2.793 (Ref. 2)

C. Agglomerate Storage Tank - Tank sized for 90,000 gallons and must have rustproof coating.

Base Cost Field Erected = $17,000 (Ref. 1, p. 140)
Factor, Rubber Lined = 1.48
Total M&L Factor = 1.85
Inflation Factor = 2.793 (Ref. 2)

D. Product Coal Conveyor, Evaporator to Slurry Mixture - Two required, 64 ft. each, 18" wide.

Per Unit Cost = $450 (Ref. 1, p. 132)
Size Exponent = 0.65 (Ref. 1, p. 132)
Field Installation Factor = 1.69
Inflation Factor = 2.793 (Ref. 2)

5. Product Coal Slurry Mixing, Storing, Delivery to User Locomotive

A. Mixing Tank - Same as High Shear Mixer Cost Basis (Sec. III.C.).

B. Pump - 625 GPM @ 50 PSI (2 pumps).

Monel Factor = 3.23 (Ref. 1, p. 126)
Installation Factor = 1.41 (Ref. 1, p. 126)
Inflation Factor = 2.793 (Ref. 2)

C. Storage Tanks - Ten days (2 weeks) of output storage for 18 x 10^6 gallons; four tanks, 4.5 x 10^6 gallons, 123 ft. dia., 50 ft. high.

Cone Roof Factor, Fd = 1.0 (Ref. 1, Fig. 15)
Rubber Lined Factor, Fm = 0.48 (Ref. 1, Fig. 15)
Inflation Factor = 2.793 (Ref. 2)

D. Rail Siding - 3000 feet, 5 turnouts.

Track Per Unit Cost = $26.25/ft. (Ref. 1, p. 136)
Turnout Unit = $2800 each (Ref. 1, p. 136)
Inflation Factor = 3 (Ref. 2)

VI. COAL PROCESSING PLANT CAPITAL COSTS

E. Appendix - Coal Processing Capital Costs (continued)

5. Product Coal Slurry Mixing, Storing, Delivery to User Locomotive (continued)

E. Locomotive Fueling Facilities - Costed as Locomotive Shipping Facility (2).

Per Unit Cost = $4,800 (Ref. 1, p. 136)
Inflation Factor = 2.793 (Ref. 2)

6. Buildings, Power, Heat & Land Preparation

A. Process Building - Building includes housing ball mills to coal water slurry output pump, 120,000 ft.² with steel roof, concrete floor and including heating, ventilation, plumbing and lighting.

Bare Building	$2.58/ft.²	(Ref. 1, p.	137)
Steel Truss Roof Factor, 0.1	0.26	"	"
Lighting	1.50	"	"
Plumbing	1.21	"	"
Heating, Ventilation	1.00	"	"
Fire Prevention, 2/3 area	0.64	"	"
Total	$7.18/ft.²		

Inflation Factor = 2.845 (Ref. 2)

B. Office, Quality Lab - 6400 ft.² with furniture, lab equipment and A/C.

Bare Building	$ 4.26/ft.²	(Ref. 1, p. 137)
A/C	3.75	
Lighting	2.25	
Plumbing	1.21	
Heating, Ventilation	1.00	
Fire Prevention	0.90	
Office Lab Equipment	5.50	
Total	$18.87/ft.²	

Inflation Factor = 2.845 (Ref. 2)

C. Roadways, Parking Lots - Approximately 5800 ft. of roadways, 16 ft. wide, 6" thick, concrete construction with a 6" base. Parking lot, 4000 ft.², 4" thick concrete, 6" base.

Roadways:
Area = 10310 yd.²
Per Unit Roadway Cost = $7.61/yd.² (Ref. 1, p. 135)
Inflation Factor = 3 (Ref. 2)

Parking Lot:
Area = 444 yd.²
Per Unit Parking Lot Cost = $6.35/yd.² (Ref. 1, p. 135)
Inflation Factor = 3 (Ref. 2)

VI. COAL PROCESSING PLANT CAPITAL COSTS

E. Appendix - Coal Processing Capital Costs

6. Buildings, Power, Heat & Land Preparation (continued)

D. Process Power - Total Load = 19508 KW @ .93 P.F. = 20,980 KVA.

Per Unit Total Cost = $12/KVA (Ref. 1, p. 136)
Inflation Factor = 2.46 (Ref. 2)

E. Fencing - Approximately 9000 feet of chain link fencing, 8 corner posts and 9 gates.

Per Unit Cost Fencing = $5.48/ft. (Ref. 1, p. 135)
Per Unit Cost Corner Posts = $31.50 (Ref. 1, p. 135)
Per Unit Gate Cost = $105.65 (Ref. 1, p. 135)
Inflation Factor = 3.0

F. Land Preparation - 1280 ft. x 1600 ft. on 1/4 area (excluding tailing pond).

Use only clearing, grading:

Area = 72,500 yd.^{2}
Per Unit Cost = $0.76/yd.^{2} (Ref. 1, p. 135)
Inflation Factor = 3.0

G. Process Water Deionizer, Demineralizer - Based on 1600 GPM. Budgetary estimate supplied from water processing vendor = $689,000.

VI. COAL PROCESSING PLANT CAPITAL COSTS

F. Appendix - Process Power Utilization

(Reference Cost Appendix, Sec. VI.D.)

1. Coal Grinding and Transport (Sized for 135T/Hour)

A. 6 Ball Mills 135T/hour x 90 KW/T = 13,500 KW

B. 2 Hammer Mills 175 HP x 2 = 350 HP

Conveyor HP from Ref. 7, pp. 10-75.

1100 ft. conveyor (item I.D.)
- 36" wide, 400T/hour, 500 ft/min. and 160' rise = 75 HP.

1100 ft. conveyor (item II)
- 24" wide, 150T/hour, 500 ft./min. and no rise = 20 HP.

600 ft. conveyor (item II)
- 24" wide, 150T/hour, 50 ft./min. and 70' rise = 27.5 HP.

600 ft. conveyor (item II)
- 24" wide, 150T/hour, 50 ft./min. and no rise = 17.5 HP.

Total input conveyor HP - 140 HP

Total HP 490 HP

Total KW 483 KW

2. Clarifier & Process Solid Waste Handling - Item 3.

A. 4, Pumps from Separators
800 GPM @ 20 PSI
22 HP each 88 HP

B. 2, Pumps clarified water
1400 GPM @ 50 PSI
90 HP each 180 HP

C. 5, Pumps, sludge to pond
15T per hr./40% water
4 HP each 20 HP

D. 2, Stirring Drives for Clarifiers
10 HP each 20 HP

Total 308 HP

Total KW 250 KW

VI. COAL PROCESSING PLANT CAPITAL COSTS

F. Appendix - Process Power Utilization (continued)

3. Slurry & Process Pumps

A. Pump - Item III.A.		
4200 GPM @ 20 PSI	90 HP	
B. Cooling Tower Pump - Item IV.B.		
7000 GPM @ 20 PSI	125 HP	
C. 2 Slurry Pumps - Item V.B.		
1250 GPM @ 75 PSI	220 HP	
Total	435 HP	
Total KW		360 KW

4. Remaining Process Motors

A. Conveyors on 4 Separators - Item III.D.		
Three on each (12); 10 HP		120 HP
B. Mixer - Item III.C.	75 HP	
C. 2 Mixers - Item V.A.		
Two, 5 HP each	10 HP	
Total	205 HP	
D. Fans, Lighting & Contingency - 410 KW		
Total KW		585 KW

5. Agglomerate Recovery

37.3×10^6 BTU/Hour x 2.929×10^{-4} KW/BTU/Hour = 10900 KW

with a conservative 60% efficiency for the heat pump, the input KW is	4330 KW
Total KW	19508 KW

VI. COAL PROCESSING PLANT CAPITAL COSTS

G. Appendix - References

REFERENCES

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2. BUREAU OF LABOR STATISTICS, FACTORS.

3. COAL CLEANING TECHNOLOGY, edited by D.L. Khaura, Noyes Data Corporation, 1981.

4. DIRECT WET-GRINDING AND DISPERSION OF COAL PREPARATION OF COAL-WATER MIXTURES by Gispert Schalloy, Draiswerke, Inc.; presented 1983 Coal Slurry Combustion and Technology Meetings, Tampa, Florida.

5. MINING & MINERAL PROCESSING EQUIPMENT CHARTS & PRELIMINARY CAPITAL COST ESTIMATIONS by A.L. Mulary, The Canadian Institute of Mining & Metallurgy, 1982, Quebec.

6. PLANT DESIGN & ECONOMICS FOR CHEMICAL ENGINEERS by Peters & Timmerhaus, 3rd Edition.

7. STANDARD HANDBOOK FOR MECHANICAL ENGINEERS, 7th Edition, Baumeister & Marks.

	From 1979 To 1985	From 1969 To 1985
Building Materials	1.335	2.845
Electrical Machinery	1.483	2.46
Non-Electrical Machinery	1.457	2.793
Steel Products		3.42
Non-Metallic Products	1.356	3.03
Average Labor		3.00

VI. COAL PROCESSING PLANT CAPITAL COSTS

H. ROM Coal Fueling Stations

Independent of fleet size or fuel usage, a ROM coal burning locomotive will need a means of loading its hoppers with coal that is fast, taking no more time than refueling a diesel. This plan includes:

1. Coal train unloading facility. Equipment is sized to store one half coal unit train (30 cars - 100 tons each). Unloading facility is sized to accomplish the unloading in one 8-hour shift. Coal is dropped from cars into a pit. A covered conveyor carries the coal to the top of the storage silo.

   Cost derived from slurry plant estimate study. Unloading facility need be half the capacity; cost varies with the .8 power.

   Unloading cost = $1,539,000 X $(.5)^{.8}$ = $884,000.

2. Coal Storage and Unloader. A silo is provided that the locomotives drive through, stopping to have the coal directly dumped into the coal storage. Storage for 3000 tons allowing 20% additional capacity for variation in resupply means a silo with 144,000 cu. ft. storage. This is one-half the size of the silos employed for raw coal storage in the slurry plants. Using that estimate as a base, a cost variation with size for silos as the .9 power and a complexity factor of 1.2 for the drive-through feature.

   Total Cost = $675,000 X $(.5)^{.9}$ X 1.2 = $434,000

   Total Fuel Station Cost = $434,000 + 884,000 = $1,318,000

3. Total fueling needs for ROM coal burning locomotives will be a minimum of two fueling stations (one on each end of the line). Each fueling station can handle approximately 67 locomotives (See Item 4 below) a pair 134 locomotives.

   Total Fueling Station Costs = $2,636,000, 0 - 134 locomotives

   For 134 to 200, 8000 HP locomotives, add $1,318,000

   For 200 to 267, 8000 HP locomotives, add $1,318,000

VI. COAL PROCESSING PLANT CAPITAL COSTS

H. ROM Coal Fueling Stations (continued)

4. A ROM coal burning locomotive will consume approximately 23×10^{10} BTU/year at 8000 HP duty. Assuming 10^4 BTU per lb of coal.

$$\text{Lbs of coal} = \frac{23 \times 10^{10} \text{ BTU/year}}{10^4 \text{ BTU/Lb}} = 23 \times 10^6 \text{ lbs/year}$$

$$\text{Tons/Year} = 23 \times 10^6 = \frac{11.5 \times 10^6}{2 \times 10^2} \text{ Tons} = 11{,}500 \text{ Tons}$$

Fueling station holds. 3000 tons, refueling 5 days a week allows it to handle 780,000 tons/year or 67.8 locomotives/year. For locomotives less than 67.8, the resupply frequency of the station is reduced.

VII. PROBABLE MARKET

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VII. PROBABLE MARKET

A. Forward

The market any locomotive, independent of technology, will compete in is the same as long as the design intent is high utilization applications in mainline service. That market for highly utilized, mainline service locomotives is properly covered in Section VII of Task I report under contract DEAC 21-85MC22181, Coal Burning Diesel Locomotives. The basic data derived for that specific locomotive coal technology report is repeated in this report as the maximum probable market for any coal technology locomotive.

The coal burning diesel locomotive exactly duplicates the performance and features of the oil burning locomotives presently competing in this described market. As long as the coal burning diesel is equal in performance and features, it competes head on for the total market. All else being the same, net expense savings (fuel minus increased maintenance) can be applied directly as the financial leverage to the railroads to buy coal burning diesel locomotives.

Some of the technologies for burning coal on a locomotive do not produce a locomotive whose performance and features are exact duplicates of what is presently satisfying the market, oil burning diesel locomotives. As long as there are differences, the market's ability to accept the performance and feature differences must be examined and quantified. This section on Probable Market sets its objective as an analysis of the market as a function of the various coal technologies covered in this report. The results of this market study is in a definitive number of units and a measure of expected utilization, fuel consumed, such that the relative value of the locomotive can be determined elsewhere in this report.

B. Rationale for Analysis of Probable Market

Although it is understood that specific railroads have specific needs for features different from all else, it is known that fundamentally, all railroads use or can use the basic performance and basic features of locomotives equally in the application of power to trains. As the total productivity of the railroads improve, the similarity of application of power across railroads becomes even more obvious, tending to strengthen those trends for maximizing the economics of freight transportation.

The basic performance and features employed in this study for market derivation by technology are:

VII. PROBABLE MARKET

B. Rationale for Analysis of Probable Market (continued)

1. Horsepower per Locomotive Unit.

   a. Today's average horsepower applied to the average train is approximately 10,000. This is made up of three locomotive units. This average has been growing and will grow to the 11 to 12,000 hp range.

      Therefore, to enjoy full market potential, the coal burning technology must produce locomotives which are an even multiple of approximately 12,000 hp.

   b. Maximum normal hp applied as a block to train is 1600 hp. As time has progressed, train speed and revenue tons per train have and continue to increase; 18,000 hp might well be seen.

   c. Minimum assigned horsepower, 7 to 8000 hp in two units.

      For the purpose of this study, today's single locomotive mainline service is not considered large enough for consideration, although, there has been some interest in single locomotive; short, high priority trains as a means of enjoying point to point freight business with small crews and no switching yard activities. If the trends of "Just In Time" manufacturing process control continue, this type of service could become more prevalent.

2. Tractive Effort per Unit

   The tractive effort per locomotive unit compared to horsepower must be close to today's ratio or higher if the technology is to enjoy total market penetration. Today and in the future, some trains will be assigned locomotives based on climbing the ruling grade on the run. If the locomotive consist is made up of coal burning units to meet this tractive effort limitation and the resulting horsepower exceeds that now applied with oil burning diesel units, then the train cannot run at top efficiency. The basic thrust of utilization is to keep the locomotives in the highest horsepower notches for highest efficiency. Over horsepowering to meet a tractive effort requirement will force the throttling of total horsepower (lower notch) more frequently, especially to maintain set top train speeds while not on the ruling grade.

   Naturally, more tractive effort per unit horsepower is advantageous. This allows, assuming reduced speeds are allowable on grades, reduced total horsepower for the particular train and hence greater full power utilization.

VII. PROBABLE MARKET

B. Rationale for Analysis of Probable Market

2. Tractive Effort per Unit (continued)

The tractive effort to enjoy full market penetration is 25 lbs per horsepower when the locomotive is geared for 70 miles per hour.

3. Locomotive Unit Length, Weight

It is assumed that all coal burning locomotives can be designed to fit the AAR Clearance Diagram, Plate'C' profile, Track curvature and axle weight for any mainline service in the United States and therefore, no market restrictions can be quantitatively applied. It should be remembered that if a single locomotive appears within a number of married units, its length may be sufficient to limit its ability to be turned and, hence, it would need to be double-ended (operator cab on both ends).

4. Reliability

In today's market, railroads have taken advantage of the growth in unit locomotive reliability to increase the train's power productivity. As the locomotive reliability has improved, the railroads have dropped the extra unit in the consist employed to assure the train could complete its trip on time with a single locomotive failure. Reducing the number of locomotives works the locomotives left even harder, making them perform overall more efficiently.

Using today's oil diesel technology's reliability as a standard, the market available to a particular technology was linearly adjusted to its estimated reliability.

It could be argued that this is a severe limitation and it is. Reliability problems lead to road failures; sufficient road failures could cause a technology to be unacceptable completely to the railroad industry. By default, the market available would be reduced to zero, even though it may have excellent expense savings even after including the maintenance cost to fix the failures.

C. Locomotive Probable Market and Fuel Consumption by Technology

Table VII-1 below summarizes the total market available to each coal burning locomotive technology in number of units, rated horsepower, tractive effort and the energy consumed as though they were powered by oil burning diesel engines. Because reliability affects available market, it is also included.

COAL BURNING LOCOMOTIVE STUDY

LOCOMOTIVE COAL BURNING TECHNOLOGY	TOTAL MARKET[1] NO. OF UNITS OPTION SERVES	RATED UNIT HP FOR TRACTION	RATED UNIT TRACTIVE EFFORT IN LBS.	EQUIV DF2 USED/UNIT IN GALLONS	TOT. FLEET DF2 USED IN GALLONS	EXPECTED RELIABILITY IN F/LY
DIESEL (CWS)	6068	3800	103,500	308,140	1,869,800,000	3.09
GAS TURBINE (CWS)	3908	5900	142,000	478,450	1,869,800,000	3.09
GAS TURBINE WITH STEAM INJ. (CWS)	652[2]	8000	207,000	740,500	482,806,000	4.64
GAS TURBINE WITH ROM GASIFIER	551[2]	8000	207,000	740,500	408,016,000	5.49
STEAM TURBINE (ROM)	381[2]	8000	207,000	740,500	282,213,000	7.91

[1]MARKET ASSUMED EQUAL TO TODAY'S MAINLINE RAILROAD FLEET OF 3000 HP AND UP LOCOMOTIVES (7,329 UNITS, AVERAGE HORSEPOWER EQUALS 3146). NUMBER SHOWN FOR EACH TECHNOLOGY KEEPS THE UNITS TIMES HORSEPOWER CONSTANT.

[2]TECHNOLOGIES PRODUCING 8000 HP HAVE THEIR MARKET REDUCED BECAUSE THEIR PHYSICAL SIZE LIMITS VERSATILITY AND BECAUSE COMPLEXITY REDUCES RELIABILITY.

TABLE VII-1

PROBABLE MARKET AND FUEL CONSUMPTION
OF VARIOUS COAL BURNING LOCOMOTIVES

VII. PROBABLE MARKET

C. Locomotive Probable Market and Fuel Consumption by Technology

1. Coal Burning Diesel Locomotive

The diesel coal burning locomotive essentially duplicates the present oil burning locomotives and hence, are capable of direct competition with very little change on the part of railroad operations. The market for mainline locomotives was developed and defined first in an Economic Analysis exclusively for coal burning diesel locomotives. That market analysis was reported in Task I, Contract No.: DEAC21-85MC22181 and is reproduced in this report in Chapter VII.D.

2. Coal Slurry Burning Gas Turbine Locomotive

The coal slurry burning gas turbine powered locomotive represents a product competitive with coal burning diesels. The horsepower available for traction when the GE27 turbine is utilized is 5900. This allows the future average train to be powered by two gas turbine locomotives to make up the 11 to 12,000 horsepower instead of three diesels. Only three locomotives would be needed for maximum, 18,000 horsepower.

The tractive effort available from an eight-axle, 5900 HP, meets the minimum needed for drag service. Because the locomotive is simple and reliable, it would be an excellent candidate for the next generation propulsion system employing a-c traction motors and proportionally higher tractive effort per axle than available with d-c.

The gas turbine reliability is as good as an oil burning diesel but at 50% more horsepower. The gas turbine locomotive can compete in 100% of the available mainline locomotive.

Table VII-2,& -3 converts the basic marketing data and fuel consumption for each major railroad the coal burning diesels at 3800 HP into units assuming 5900 HP gas turbine locomotives displaced the total diesel fleet. Also included is the market represented by the most highly utilized, highest fuel burning locomotives - 10% of the total fleet.

ANALYSIS OF U.S. RAILROAD DOMESTIC FLEETS DESCRIBING THE POTENTIAL MARKET FOR 5900 HP COAL BURNING GAS TURBINE LOCOMOTIVE. (DERIVED FROM CHAP. VII OF REPORT UNDER TASK 1, CONTRACT NO. DEAC 21-85MC22181).

		PRESENT DIESEL		WITH 5900 HP COAL UNITS (TOTAL HP x UNITS = DIESEL)	
		NO. OF UNITS	AVERAGE HORSEPOWER	NO. OF UNITS	FUEL CONSUMPTION GAL/YEAR/LOCO
EASTERN ROADS	3000 HP < 15 YEARS OLD ≈ 33% TOTAL FLEET				
CONRAIL		589	3178	317	422,300
NORFOLK SOUTHERN		673	3189	364	472,300
CSX		1073	3128	569	479,800
WESTERN ROADS	3000 HP < 15 YEARS OLD ≈ 66% TOTAL FLEET				
BURLINGTON NORTHERN		1551	3041	800	556,300
UNION PACIFIC & MOPAC		1580	3078	824	477,700
SANTA FE & SOUTHERN PACIFIC		1863	3279	1034	437,400
			TOTAL	3908	

TABLE VII-2

PROBABLE TOTAL MARKET FOR 5900 HP GAS TURBINE POWERED LOCOMOTIVES

ANALYSIS OF U.S. RAILROAD DOMESTIC FLEETS DESCRIBING THE POTENTIAL FOR REPLACING ONLY THE HIGHEST 10% UTILIZED DIESEL LOCOMOTIVES WITH 5900 HP COAL BURNING GAS TURBINES. PROVIDES MAXIMUM FUEL USE PER UNIT AND MAXIMUM FUEL SAVINGS.

	PRESENT DIESEL		WITH 5900 HP COAL UNITS (TOTAL HP x UNITS = DIESEL)	
	NO. OF UNITS	AVERAGE HORSEPOWER	NO. OF UNITS	FUEL CONSUMPTION GALLONS PER YEAR
EASTERN ROADS 3000 HP < 15 YEARS OLD 10% TOTAL FLEET				
CONRAIL	245	3429	147	489,500
NORFOLK SOUTHERN	220	3566	133	561,300
CSX	322	3427	187	593,100
WESTERN ROADS 3000 HP < 15 YEARS OLD 10% TOTAL FLEET				
BURLINGTON NORTHERN	247	3270	137	650,480
UNION PACIFIC & MOPAC	260	3473	153	525,900
SANTA FE & SOUTHERN PACIFIC	395	3602	241	469,400
		TOTAL	992	

TABLE VII-3

HIGHEST UTILIZED FLEET FOR 5900 HP
GAS TURBINE LOCOMOTIVES

VII. PROBABLE MARKET

C. Locomotive Probable Market and Fuel Consumption by Technology

3. Multi-Unit, 8000 Horsepower Coal Burning Locomotives

. Gas Turbine with Heat Recovery, Steam Injection

. Gas Turbine Burning ROM Coal Gasified

. Steam Turbine Burning ROM Coal in Fluidized Bed Boiler

General

The three technologies analyzed here produce locomotives which have 8000 horsepower available for traction. The market these locomotives would compete in are fundamentally the same. Each results in locomotives made up of multiple, married sections that are relatively complicated machines. None have a predicted reliability proportional to their need.

An 8000 horsepower locomotive is a size that does not work well into the total locomotive market. The 12,000 horsepower average needed for the average train does not effectively use 8000 horsepower units. To maintain utilization, a single 8000 horsepower locomotive would have to be teamed with a different technology. Although mixed locomotive consists may happen, this study considers only reviewing the market where the technology competes and wins its market totally. 8000 horsepower would compete very favorably, functionally, in the 16,000 horsepower bulk train requirements (two units) which, according to AAR statistics, makes up approximately one third of the total ton miles. This study assumes the market available for 8000 HP is a maximum of one third dedicated to very specific bulk commodity haulage runs. Single unit assignments are out of the question with the reliability expected of these units. (See Sec. V).

Table VII-4 expands the market information developed for the diesel locomotive into three technologies:

. Gas Turbine Burning CWS and Steam Injection

. Gas Turbine Supplied from Gasifier

. Steam Turbine

All start with a potential of one third of the maximum market and are assumed to compete successfully (all else being equal) for only that portion proportional to their relative reliability. The reliability estimates are from Section V of this report.

RAILROAD	PRESENT DIESEL NO. OF UNITS	PRESENT DIESEL AVERAGE HP	NO. OF UNITS OF 8000 HP LOCOMOTIVES: GT W/STEAM INJECTION RELIABILITY 4.64 F/LY	GT W/GASIFIER RELIABILITY 5.49 F/LY	STEAM TURBINE RELIABILITY 7.9 F/LY	EQUIV. DF2 CONSUMED/ LOCOMOTIVE at 8000 HP
EASTERN ROADS			$1/3 \text{ TOTAL} \times \frac{3.09}{4.64}$	$1/3 \text{ TOTAL} \times \frac{3.09}{5.49}$	$1/3 \text{ TOTAL} \times \frac{3.09}{7.91}$	
CR	589	3178	53	45	31	663,790
N-S	673	3189	61	51	35	761,050
CSX	1073	3128	95	80	56	804,210
WESTERN ROADS						
BN	1551	3041	133	113	78	881,890
UP& MOPAC	1580	3078	137	116	80	713,050
SFE & SP	1863	3279	172	146	101	636,210
TOTAL NO. OF LOCOMOTIVES			652	551	381	

TABLE VII-4

PROBABLE MARKET FOR 8000 HP LOCOMOTIVES

VII. PROBABLE MARKET

D. Probable Market Analysis for Coal Burning Locomotives

1. Derivation
2. Summary of Results - Total Market
3. Summary of Results - Highest Utilized Fleet
4. Fleet Analysis

Note: This chapter has been extracted from the report on Coal Buring Diesel Locomotives Contract No.: DEAC21-85MC22181 in total. The only changes made are to the page numbers and subject numbering to conform and flow within this analysis report on all coal burning locomotive options.

VII. PROBABLE MARKET

D. Probable Market Analysis for Coal Burning Locomotives (continued)

1. Derivation

a. Forward

A coal burning locomotive's value is in its ability to provide the railroads with lower operating expenses by reducing fuel costs. Therefore, the market within the railroads for a low cost fuel locomotive will be in those applications burning large amounts of fuel or highly utilized locomotives.

The objective of this derivation is to analyze the various railroad fleets, determining numbers of units, horsepower and the amount of fuel consumed per unit.

b. Method

Ordering the typical railroad's locomotive fleet into those accumulating the highest yearly mileage to the lowest causes some obvious standards to become very clear.

The highest mileage locomotives generally are:

- The newest and most efficient (provides minimum total fuel consumption)
- Have the lowest average maintenance per mile requirement
- Are the highest horsepower per single unit

As the list proceeds to units with lower yearly mileage:

- The locomotives get older
- The per unit horsepower drops

This is not a surprising trend. Over the years, the per unit horsepower, efficiency and reliability of oil burning diesel locomotives has constantly increased making it an industry-driven economic selection to assign new locomotives to the most demanding applications.

With the locomotives ordered in descending miles, it is relatively easy to assign approximate fuel usage via weighted averaging of Horsepower Miles per unit per year. Total fuel consumed is available from Transportation Statistics for Railroads published by ICC. For a typical Western railroad, the allocation of locomotive and fuel consumption varies as follows:

. Top 10% - Burns 17% of total fuel
  - Highest mileage, highest horsepower trains

. Top 33.3% - Burns 50% of total fuel

VII. PROBABLE MARKET

D. Probable Market Analysis for Coal Burning Locomotives

1. Derivation (continued)

b. Method (continued)

. Top 66.6% - Burns 90% of total fuel

- Most locomotives are 3000 HP and up

. Bottom 33.3% - Burns 10% of total fuel

- Switchers and old low horsepower locomotives

For a typical Eastern Railroad, the results show a little more concentration of utilization in the high horsepower units.

. Top 10% - Burns 24% of total fuel

. Top 33% - Burns 59% of total fuel

- Eastern Roads 3000 HP and up are all contained in top one third

. Bottom 33% - Burns 15% of total fuel

- Eastern Roads use more fuel in switching than Western

This allows any railroad fleet to be examined determining approximate quantities of locomotives and their fuel consumption using only the fleet log.

It should be understood that assigning fuel consumption by HP miles assumes both a constant duty cycle and constant efficiency for all units in the fleet, which is incorrect. On test cases with actual fuel consumption and unit miles, the allocation by HP miles works reasonably well with the highly used, high horsepower locomotives where this study's interest lies. The allocation to the low horsepower, low miles bottom 33% is in considerable error. Because the fuel usage is so low for the bottom end, resulting under/over allocation of fuel will have but a minor impact on the high horsepower areas of interest.

For the coal burning locomotive, the potential market was limited to 3000 HP and up (top 1/3 of Eastern Roads and top 2/3 of Western Roads).

Figures VII.D.2 & 3 are the results of analyzing the biggest six U.S. railroads. Figures VII.D.4.a. through f. detail each railroad fleet examined. 3000 HP and up locomotives older than 15 years were excluded from the study as it is believed that most are in the lowest utilization category.

D. Probable Market Analysis for Coal Burning Locomotives (continued)

2. Summary of Results - Total Market

ANALYSIS OF U.S. RAILROAD DOMESTIC FLEETS DESCRIBING THE POTENTIAL MARKET FOR 3800 HP COAL BURNING LOCOMOTIVE.

		PRESENT DIESEL		WITH 3800 HP COAL UNITS (TOTAL HP x UNITS = DIESEL)	
		NO. OF UNITS	AVERAGE HORSEPOWER	NO. OF UNITS	FUEL CONSUMPTION GAL/YEAR/LOCO
EASTERN ROADS	3000 HP < 15 YEARS OLD ≈33% TOTAL FLEET				
CONRAIL		589	3178	492	272,000
NORFOLK SOUTHERN		673	3189	565	304,200
CSX		1073	3128	883	309,000
WESTERN ROADS	3000 HP < 15 YEARS OLD ≈66% TOTAL FLEET				
BURLINGTON NORTHERN		1551	3041	1242	358,300
UNION PACIFIC & MOPAC		1580	3078	1280	307,000
SANTA FE & SOUTHERN PACIFIC		1863	3279	1606	281,700
			TOTAL	6068	

D. Probable Market Analysis for Coal Burning Locomotives (continued)

3. SUMMARY OF RESULTS - HIGHEST UTILIZED FLEET

10% OF TOTAL LOCOMOTIVES

ANALYSIS OF U.S. RAILROAD DOMESTIC FLEETS DESCRIBING THE POTENTIAL FOR REPLACING ONLY THE HIGHEST 10% UTILIZED DIESEL LOCOMOTIVES WITH 3800 HP COAL BURNERS. PROVIDES MAXIMUM FUEL USE PER UNIT AND MAXIMUM FUEL SAVINGS.

		PRESENT DIESEL		WITH 3800 HP COAL UNITS (TOTAL HP x UNITS = DIESEL)	
		NO. OF UNITS	AVERAGE HORSEPOWER	NO. OF UNITS	FUEL CONSUMPTION GALLONS PER YEAR
EASTERN ROADS	3000 HP < 15 YEARS OLD 10% TOTAL FLEET				
CONRAIL		245	3429	219	315,300
NORFOLK SOUTHERN		220	3566	206	361,500
CSX		322	3427	290	382,700
WESTERN ROADS	3000 HP < 15 YEARS OLD 10% TOTAL FLEET				
BURLINGTON NORTHERN		247	3270	137	418,900
UNION PACIFIC & MOPAC		260	3473	238	338,700
SANTA FE & SOUTHERN PACIFIC		395	3602	374	302,200
			TOTAL	1542	

VII. PROBABLE MARKET

D. Probable Market Analysis for Coal Burning Locomotives

4. Fleet Analysis

a. CONRAIL

Fleet Data (GE Listing dated 1/1/84 updated to 1/1/85)

HP	NO.	COMMENTS
3600	105	Some 15 years old
3500	80	
3200	10	
3000	394	Some 15 years old
2300	227	

Analysis

Top 10% - 245 Locomotives

Burns 24% of total fuel

- Average HP - 3429
- Total Fuel Consumed - 69,690,400 Gallons/Year
- If changed to 3800 HP coal burning locomotives:
  - 221 Locos Needed
  - 315,300 Gallons/Year/Loco

Top 33.3% - 816 Locomotives (589 Locomotives - 3000 HP and up)

Burns 59% of total fuel

- Average HP - 3178
- Total Fuel Consumed - 133,947,000 Gallons/Year (3000 HP & up locos)
- If changed to 3800 HP coal burning locomotives:
  - 492 Locomotives Needed
  - 272,000 Gallons/Year/Loco

VII. PROBABLE MARKET

D. Probable Market Analysis for Coal Burning Locomotives

4. Fleet Analysis

b. NORFOLK SOUTHERN

Fleet Data (GE Listing dated 1/1/84 updated to 1/1/85)

HP	NO.	COMMENTS
3900	14	
3600	89	Eliminated 135 over 15 years old
3500	116	
3300	10	All 15 years old
3000	444	Eliminated all over 15 years old
2300	61	All under 10 years old

Analysis

Top 10% - 220 Locomotives

Burns 24% of total fuel

- Average HP - 3566
- Total Fuel Consumed - 74,463,190 Gallons/Year
- If changed to 3800 HP coal burning locomotives:
  - 206 Locos Needed (same work done)
  - 361,500 Gallons/Year/Loco

Top 33.3% - 734 Locomotives (673 Locomotives - 3000 HP and up)

Burns 59% of total fuel

- Average HP - 3189 (3000 HP and up)
- Total Fuel Consumed - 171,838,000 Gallons/Year
- If changed to 3800 HP coal burning locomotives:
  - 565 Locos Needed
  - 304,200 Gallons/Year/Loco

VII. PROBABLE MARKET

D. Probable Market Analysis for Coal Burning Locomotives

4. Fleet Analysis

c. CSX

Fleet Data (GE Listing dated 1/1/84 updated to 1/1/85)

HP	NO.	COMMENTS
3600	160	Some 15 years old
3500	83	All SD50's 2 years old
3000	830	Up to 13 years old

Analysis

Top 10% - 322 Locomotives

Burns 24% of total fuel

- Average HP - 3427
- Total Fuel Consumed - 110,980,300 Gallons/Year
- If changed to 3800 HP coal burning locomotives:
  - 270 Locos Needed
  - 382,700 Gallons/Year/Loco

Top 33.3% - 1073 Locomotives (all 3000 HP or above)

Burns 59% of total fuel

- Average HP - 3128
- Total Fuel Consumed - 272,826,600 Gallons/Year
- If changed to 3800 HP coal burning locomotives:
  - 883 Locomotives Needed
  - 309,000 Gallons/Year/Loco

VII. PROBABLE MARKET

D. Probable Market Analysis for Coal Burning Locomotives

4. Fleet Analysis

d. BURLINGTON NORTHERN

Fleet Data (GE Listing dated 1/1/84 updated to 1/1/85)

HP	NO.	COMMENTS
3600	120	All 15 years old
3500	10	GP50's
3200	3	Dash 8's
3000	1418	Up to 15 years old
2500	46	
2000	51	

Analysis

Top 10% - 247 Locomotives

Burns 17% of total fuel

. Average HP - 3270

. Total Fuel Consumed - 89,222,727 Gallons/Year

. If changed to 3800 HP coal burning locomotives:

- 213 Locos Needed

- 418,900 Gallons/Year/Loco

Top 66.6% - 1648 Locomotives (1551 Locomotives - 3000 HP & up)

Burns 90% of total fuel

. Average HP - 3041

. Total Fuel Consumed - 445,008,600 Gallons/Year (by 3000 HP and up)

. If changed to 3800 HP coal burning locomotives:

- 1242 Locomotives Needed

- 358,300 Gallons/Year/Loco

VII. PROBABLE MARKET

D. Probable Market Analysis for Coal Burning Locomotives

4. Fleet Analysis

e. UNION PACIFIC

Fleet Data (GE Listing dated 1/1/84 updated to 1/1/85)

HP	NO.	COMMENTS
6000	20	15 years old
3600	0	UP has some 17 years old
3500	90	MoPac GP50's
3000	1470	Up to 15 years old
2500	40	
2300	120	

Analysis

Top 10% - 260 Locomotives

Burns 17% of total fuel

- Average HP - 3473
- Total Fuel Consumed - 80,603,000 Gallons/Year
- If changed to 3800 HP coal burning locomotives:
  - 238 Locos Needed
  - 338,700 Gallons/Year/Loco

Top 66.6% - 1740 Locomotives (1580 Locomotives - 3000 HP & up)

Burns 90% of total fuel

- Average HP - 3078
- Total Fuel Consumed - 393,810,000 Gallons/Year (by 3000 HP and up)
- If changed to 3800 HP coal burning locomotives:
  - 1280 Locomotives Needed
  - 307,000 Gallons/Year/Loco

VII. PROBABLE MARKET

D. Probable Market Analysis for Coal Burning Locomotives

4. Fleet Analysis

f. SANTA FE & SOUTHERN PACIFIC

Fleet Data (GE Listing dated 1/1/84 updated to 1/1/85)

HP	NO.	COMMENTS
3900	3	Dash 8's
3600	780	Up to 15 years old
3300	150	Up to 15 years old
3000	930	
2500	320	
2300	420	
2000	30	

Analysis

Top 10% - 395 Locomotives

Burns 17% of total fuel

- Average HP - 3602
- Total Fuel Consumed - 113,054,300 Gallons/Year
- If changed to 3800 HP coal burning locomotives:
  - 374 Locos Needed
  - 302,200 Gallons/Year/Loco

Top 66.6% - 2633 Locomotives (1863 Locomotives - 3000 HP & up)

Burns 90% of total fuel

- Average HP - 3279
- Total Fuel Consumed - 452,407,200 Gallons/Year
- If changed to 3800 HP coal burning locomotives:
  - 1606 Locomotives Needed
  - 281,700 Gallons/Year/Loco

VIII. ECONOMIC ANALYSIS

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G. ROM Coal Gasifier Gas Turbine Locomotive	VIII-49
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VIII. ECONOMIC ANALYSIS

A. Forward

1. Analysis Methodology

The economic analysis is developed from the viewpoint of the railroads investing their money in an apparent optimum way in the purchase of new locomotives. As the railroads present fleet ages, they have a choice of buying new, modern diesel electric locomotives or rebuilding existing locomotives. This analysis assumes the railroads have decided to buy new locomotives to gain expense savings. This section examines the economic viability of a new option, coal burning locomotives over oil burning locomotives.

Coal burning locomotives offer an incremental additional fuel savings over and above that offered by the latest oil burning diesels. This incremental fuel savings (from Chapter II) is offset by an increase in maintenance costs (Chapter III) providing a net expense savings to the operation of the railroad.

For a railroad to purchase and utilize a coal burning locomotive fleet, their investment in capital must not only include the additional or incremental increase in the price paid for the coal burning locomotive but also they must invest monies in a new coal fuel infrastructure (Section VI).

The analysis adjusts the incremental purchase price increase over oil diesel locomotives of each coal burning locomotive option such that the total investment (locomotives and required infrastructure) meets a discounted rate of return of 15% considering the specific net expense savings (fuel minus maintenance increase). If the resulting incremental increase in purchase price appears to be a value at which the locomotive could be manufactured profitably, a second analysis was undertaken readjusting the purchase price such that the total investment increase and expense saving produce a 20% DCRR.

The analysis assumes the specified fleet is changed to a coal option linearly over a 10-year period with the infrastructure being added as required for their support.

2. DCRR Spreadsheet Description

For each railroad case, the size of the fleet to be purchased is determined (Section VII) along with the average fuel consumed based on standard diesels. See attached example. These are input in cursor cells, G7 and G13. Based on the latter, fuel savings per year based on average fuel costs in Table II.A.3-2 (G17) and maintenance costs premium per year based on maintenance costs of oil burning and coal burning diesel locomotives in Section III (G19) are automatically calculated, using the formulas shown in the listing.

VIII. ECONOMIC ANALYSIS

A. Forward

2. DCRR Spreadsheet Description (continued)

Next, the fleet purchases are spread over a 10-year period resulting in a locomotive capital cost investment difference derived from the Allowable Capital Cost Adder/Locomotive (H3).

The infrastructure capital investments for the coal processing plants and fueling stations are added as follows:

a. Those options utilizing coal water slurry (CWS):

Stage 1 - One-half of the first fuel processing plant and associated fueling stations

Stage 2 - The second half of the first processing plant and associated fueling stations

Stage 3 - One-half of the second fuel processing plant and associated fueling stations

Stage 4 - The remaining half of the second fuel processing plant and its fueling stations

b. For those options utilizing coal directly, only fueling stations are included.

Coal processing infrastructure investment costs are entered (Column D) in years 1, 3, 6 and 8 of the 10-year locomotive buying cycle for those options utilizing CWS. For those options using ROM coal, fueling stations are in accordance with Sec. V.H. Column F shows the total investment by year, with the negative value indicating direction of cash flow.

Columns G and H show the fuel savings and maintenance premiums expected over diesel oil locomotives as coal burning locomotives are added to the fleet.

Column I shows the net impact on cash flow from the 10% investment tax credit and from the depreciation schedule applied to purchases. Both locomotives and infrastructure investments are depreciated in accordance with the schedule shown. Column J shows the net expense savings which result from fuel and maintenance savings with tax factors included.

Column K sums up the annual cash flows from capital outflow, net expense savings and investment and depreciation impacts. In Column L, present value of these cash flows is determined. The discounted cumulative cash flow is shown in Column M.

It should be noted that locomotives are assumed to have a 15-year life and they are therefore retired in sequence, just as they were added (Cells B44 through B53).

VIII. ECONOMIC ANALYSIS

A. Forward

2. DCRR Spreadsheet Description (continued)

The spreadsheet is then used in the interactive mode. First, a value of Allowable Capital Cost Adder is assumed. If the discounted cumulative cash flow (DCCF) is negative after calculation (cursor cell, M53), a lower value of Allowable Capital Cost Adder is substituted. If the DCCF is positive, the value is increased. By this technique, the final Allowable Capital Cost Adder is obtained which results in a zero value after 25 years.

When a 20% DCRR hurdle rate is desired, cell (G9) is changed to 20% and the procedure repeated.

VIII. ECONOMIC ANALYSIS

B. Spreadsheet Road Map

1. Economic Analysis Spreadsheet Explanation

The cells, Columns and rows referred to below are shown on Fig. VIII.C.

Cell	Title	Function	Source or Data
B1	Railroad Initials	Informative	BN,CR,CSX,NS,SF,UP
E1	Run Number	Informative	1,2,3 etc.
F1 to M1	Analyzed Fleet Description	Informative	Title, Words
H3	Allowable Adder Per Loco	Input/Output	See VIII.A.2.
G5	Railroad Total Fleet Size	Informative	See VIII.B.2
G7	Case Locomotive Fleet Size	Input at 3800 hp Equivalent	See VII.
G9	DCRR vs Standard Diesel	Input	.15 for 15% .20 for 20%
G11	Total Fleet Diesel Fuel Used (Gal)	Informative	See VIII.B.2.
G13	Diesel (Fuel) Used per Loco (1000 Gal)	Input at 3800 hp	Corresponds to the fleet analyzed, (G7). See VII.
G15	BTU/Loco (10) 10	Converts G13 to required options fuel input for coal only.	See VIII.B.3.
G17	Fuel Savings/year/loco ($000)	Provides direct input to analysis.	Relationship between fuel savings and fuel consumed (G13). See VIII.B.4.
G19	Maintenance Cost Adder/Year	Another expense for direct input to analysis.	Relationship between maintenance cost adder and fuel consumed (G13). See VIII.B.5.

VIII. ECONOMIC ANALYSIS

B. Spreadsheet Road Map

1. Economic Analysis Spreadsheet Explanation (continued)

Cell	Title	Function	Source or Data
G21	Plant Capital Cost	Capital expenditure for CWS production infrastructure and refueling stations.	Relationship between the number of fleet BTU's consumed and investment required. See VIII.B.6.
A29 A53	Year	Represents the individual years over which the analysis is run.	Start with 1, run to 25.
B29 to B53	Locomotives added and later retired	Depicts the plan for fleet build-up and build-down.	The plan calls for the fleet shown in Cell G7 to be purchased evenly over 10 years and then to be retired after 15 years of age.
C29 to C38	Locomotive investment difference	Provides the coal burning locomotive portion of the total investment.	B29 to B38 X H3 the quantity of locomotives purchased times the allowable price increase per locomotive.
D29 to D38	Infrastructure Capital Investment plan	Distributes the capital investment in line with program need.	See VIII.B.7.
F29 to F38	Total Investment	Totals the two pieces of investment, coal fired locos and infrastructure.	Add columns C & D respectively.
G29 to G53	Fuel Savings	The expense savings offsetting maintenance cost increases and capital investment.	Individual locomotive savings (G17) times total locomotives in service.
H29 to H52	Maintenance cost adder	Detracts from fuel savings	Yearly savings per locomotive (G19) times the number of locomotives in service.

VIII. ECONOMIC ANALYSIS

B. Spreadsheet Road Map

1. Economic Analysis Spreadsheet Explanation (continued)

Cell	Title	Function	Source or Data
I29 to I52	Investment Tax Credit and Depreciation	Incorporates tax savings into the analysis.	See VIII.B.8.
J29 to J52	Net Expense Savings	Effective savings after taxes.	Fuel savings plus maintenance increase times .54. (Col. G + Col. H) X .54
K29 to K52	Annual Simple Cash Flow	Investment outflow yearly dollars minus year expense savings.	Investment (Col. D) minus fuel savings (Col. G) plus maintenance increase (Col. H).
L29 to L52	Present Value Cash Flow	Simple cash flow above converted into dollars necessary today to support that future flow at the given discount or hurdle rate established (15% or 20%).	The individual simple annual cash flows are brought back to today's dollars by the yearly compounding of the hurdle rate. Col. K÷(1+G9) (Col. A-1)
M29 to M53	Discounted cumulative cash flow	Accumulates the years and past years present value cash flow. When year 25 arrives, the cumulative discounted cash flow should be 0. (This says the expense savings just balanced the investment at the desired hurdle rate).	Col. M accumulates Col. L. By changing the allowable selling price adder per loco (H3), the program will recalculate with new investment cash flows and finally cumulative discounted cash flow. Successive tries allows the 25th year (program end) to be 0.

VIII. ECONOMIC ANALYSIS

B. Spreadsheet Road Map

2. Railroad Total Fleet Data

Data for the individual railroads was obtained from General Electric files for 1984, the latest year with complete information.

Railroad	Total Active Fleet No. Units	Total Fuel Consumed Gallons
Burlington Northern - BN	2593	514,750,379
Conrail-CR	2447	290,376,555
CSX	3218	462,417,920
Norfolk Southern - NS	2148	310,263,302
Santa Fe & Southern Pacific - SFE	3950	652,249,114
Union Pacific & Missouri Pacific - UP	2569	465,106,829

3. Conversion of DF2 (Cell G13) to Coal Fuel (G15)

To convert the input fuel, DF2, to an oil burning diesel of 3800 hp to the input BTU's required from coal fuel for a 3800 hp coal burning locomotive, a conversion factor is made up.

a. Convert gallons of DF2 X 10^3 to BTU's X 10^3, multiply by 150,000 BTU's/gallon, a standard. (This produces the BTU input required for an OBD locomotive).

b. To convert input BTU's to that required for a coal burning locomotive, multiply by the ratio of cycle efficiencies (Chapter I). For the coal burning diesel, an additional factor is employed to remove from the BTU's supplied by DF2 pilot fuel. This allows the calculation to result in BTU's to be supplied by coal fuel. The input coal fuel BTU's is used in calculating the coal fuel processing plant size/cost in cell G21.

VIII. ECONOMIC ANALYSIS

B. Spreadsheet Road Map

3. Conversion of DF2 (Cell G13) to Coal Fuel (G15) (continued)

For Coal Burning Option	Ratio of Cycle Eff	Results
Coal Burning Diesel	$\frac{39.2\ OBD}{35.9\ CBD} \times .84^*$	= .9172
* Accounts for the 16% DF2 Pilot Fuel		
Gas Turbine	$\frac{39.2\ OBD}{28.9GT}$	= 1.3564
Gas Turbine w/Steam Injection	$\frac{39.2\ OBD}{34,4\ GT\&I}$	= 1.1395
Gas Turbine w/Gasifier	$\frac{39.2\ OBD}{25.6\ GT/Gas.}$	= 1.5313
Steam Turbine	$\frac{39.2\ OBD}{18.1\ ST}$	= 2.1657

c. Combining a. and b. above with a scale factor of 10^-7, Cell G13 converts to G15 in BTU^10 by multiplying G13 by:

For Option	Combined Factor
. Coal Burning Diesel	.01378
. Gas Turbine	.02035
. Gas Turbine w/Steam Injection	.01711
. Gas Turbine w/Gasifier	.02295
. Steam Turbine	.03242

VIII. ECONOMIC ANALYSIS

B. Spreadsheet Road Map (continued)

4. Fuel Savings Calculation

Chapter II derives the fuel cost savings for all of the coal burning locomotive options. From II.A.4, the following equations are summarized relating the savings in $(000) to fuel consumed as shown in Cell G13 for coal water slurry burning locomotives:

- Coal Burning Diesel ($60,871+.257x(G13x1000-$160,000))/1000
- Gas Turbine ($58,663+.2 059x(G13x1000-$160,000))/1000
- Gas Turbine w/Steam Injection ($73,980+.2905x(G13x1000-$160,000))/1000

For classified ROM coal burning locomotives, the equations are derived in Section II.B.8 and are summarized as follows:

- Gas Turbine w/Gasifier (-$16239+.7739x(G13x1000-$160,000))/1000
- Steam Turbine (-$551+.8515(G13x1000-$160,000))/1000

5. Maintenance Cost Adder

Section III develops the maintenance cost adder for the respective options. The equation relating maintenance cost increase (decrease) to fuel consumed (Cell G13) are from Table III-2 to Table III-6 and are summarized below:

- Coal Burning Diesel ($.0079/Gal.xG13x1000+$25,070) x $\frac{-1}{1000}$
- Gas Turbine ($.07375/Gal.xG13x1000-$17,750) x $\frac{-1}{1000}$
- Gas Turbine w/Steam Injection ($.087/Gal.xG13x1000+$6,290) x $\frac{-1}{1000}$
- Gas Turbine w/Gasifier ($.13/Gal.xG13X1000+$40,000) x $\frac{-1}{1000}$
- Steam Turbine ($.052/Gal.xG13x1000+$54,530) x $\frac{-1}{1000}$

VIII. ECONOMIC ANALYSIS

B. Spreadsheet Road Map (continued)

6. Plant Capital Cost

Section VI develops the plant capital cost relationship to the total energy output required. For coal water slurry burning locomotives this relationship is:

Capital Costs = 2x141.1x(G15/2 x G7)∧.8

Where Cells G15 x G7 equals the total fleet energy required. Dividing by 2 provides the cost of a half size plant. Multiplying the result by two provides capital funds for two half size plants located at convenient places on the railroad, Chapter II.

For classified ROM coal burning locomotives, only refueling stations are required. Chapter VI also covers the capital cost for these refueling stations. Summarized from VI.H.3.

a. Year one - $2,636,000/1000

b. After 134 locos at 8000 HP (282 @ 3800 HP)
   - Add $1,318,000/1000

c. After 199 locos at 8000 HP (419 @ 3800 HP)
   - Add $1,318,000/1000

7. Total Infrastructure Investment in Capital

This column of numbers represents the plan necessary to accommodate the locomotives purchased yearly as shown in column B.

For CWS burning locomotives, the two plants described above under VIII.B.6 are installed in four parts. The first plant is built at half capacity in year 1 at 61.4% of a plant cost. The second half is added in year 3 at 38.6% of the cost. The second plant comes on stream with the second half of the locomotives in the years 6 and 8. The spreadsheet needs to have in Cells D29 and D34, the statement -G21x.614x.5 to put the proper investment into these years and in cells D31 and D36; -G21x.366x.5.

For the 8000 HP options, an additional infrastructure investment is required. All of these large locomotives are complicated which reflects in locomotive unavailabiltiy. Chapter IV covers the derivation of the individual coal burning option availability. Because these locomotives are not as available as the oil fired diesel locomotive, coal fired diesel or the direct fired gas turbine locomotive, additional motive power must be added to keep the fleet functional. Additional motive power is added here as investment per year in oil fired diesel locomotives with a selling price of $1,325,000 per 3800 hp unit (today's selling price). The amount of additional investment needed is:

VIII. ECONOMIC ANALYSIS

B. Spreadsheet Road Map

7. Total Infrastructure Investment in Capital (continued)

Investment Dollars =

$$\$1,325,000 \times \frac{\text{Avail of OFD - Avail Coal Option}}{\text{Avail of OFD}} \times Z$$

Where Z is the Number of Coal Fired Locomotives purchased in equivalent 3800 hp units. The spreadsheet employs this relationship in the following manner:

$$\text{D29 to D38} = \text{B29 to B38} \times \frac{.929-Q}{.929} \times 1.325$$

Where Q is (from IV.C.) the availability of the coal burning option. Only 8000 hp units need be considered:

Gas Turbine w/Steam Injection	Q = .852
Gas Turbine w/Gasifier	Q = .660
Steam Turbine	Q = .781

For ROM Coal Burning Options the plant and equipment capital investment is only in refueling stations. As explained under VIII.B.6 above, the investment is proportional to the total locomotive fleet (Cell G7). Therefore, this investment varies with the railroad. All railroads are satisfied with the initial investment in year one for up to 282 locomotives at 3800 hp. Only Santa Fe has more requiring an additional investment in the seventh year of $1,318,000.

8. Investment Tax Credit and Depreciation

Accumulated year by year in Column I (Cells I29 to I53) is the investment tax credit and depreciation. The yearly investment is depreciated:

1st year of investment	15.0%
2nd year	22.0%
3rd year	21.0%
4th year	21.0%
5th year	21.0%

A tax credit of 10% is taken during the first year and added to the 15% depreciation allowance. All these individual deductions are converted to credit dollars assuming a corporate tax rate of 46% with the exception of the first year tax credit.

VIII. ECONOMIC ANALYSIS

C. Sample Analysis Spreadsheet

	A	B	C	D	E	F	G	H	I	J	K	L	M
1		BN	RAILROAD FIG. NO. 1					* 66% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD					
2													
3		ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO =						426.291					
4													
5			RAILROAD - TOTAL LOCO FLEET =				2593	(Ref)					
6													
7			CASE - LOCOMOTIVE FLEET SIZE =				1242						
8													
9			DCRR VERSUS STANDARD DIESEL =				15.00%						
10													
11			TOTAL FLEET DF2 USED (gal) =				514750379	(Ref)					
12													
13			CASE - DF2 / LOCO (000 gal) =				358.30						
14													
15			BTU / LOCO (10)^10 =				4.94				INVESTMENT DEPRECIATION SCHEDULE		
16													
17		FUEL SAVINGS (000) /YEAR /LOCOMOTIVE =					111.891				YEAR 1	15.00%	
18											2	22.00%	
19		MAINT COST ADDER(000), AVE/YR OVER LIFE =					22.219				3	21.00%	
20											4	21.00%	
21			PLANT CAPITAL COST (000) =				86841				5	21.00%	
22													
23													
24								NOTE: ALL $ IN THOUSANDS					
25		LOCOS	LOCO	COAL PROC		TOTAL					ANNUAL		DISCOUNTED
26		PRCHSD	INVESTMNT	INFRASTR.		YEAR	FUEL	MAINT.CST	^INV. TAX	NET EXP.	SIMPLE	PRES.VAL	CUMULATIVE
27	YEAR	OR RET	DIFFRENCE	INVESTMNT		INVESTMN	SAVINGS	SAVINGS	CR.+ DEPR	^SAVINGS	CASH FLOW	CASH FLOW	CASH FLOW
28													
29	1	124	-52860	-53321		-106181	13874	-2755	17945	6004	-82232	-82232	-82232
30	2	124	-52860			-52860	27749	-5510	19679	12009	-21172	-18411	-100643
31	3	124	-82860	-33321		-86381	41623	-8266	30205	18013	-38163	-28857	-129499
32	4	124	-52860			-52860	55498	-11021	33038	24018	4196	2759	-126740
33	5	124	-52860			-52860	69372	-13776	37991	30022	15152	8663	-118077
34	6	124	-52860	-53321		-106181	83247	-16531	41851	36026	-28303	-14072	-132149
35	7	124	-52860			-52860	97121	-19286	38236	42031	27406	11849	-120300
36	8	124	-52860	-33521		-86381	110995	-22042	40417	48035	2072	779	-119521
37	9	124	-52860			-52860	124870	-24797	38145	54039	39324	12855	-106666
38	10	126	-53713			-53713	138968	-27597	38135	60141	44563	12667	-93999
39	11	0					138968	-27597	23993	60141	84133	20796	-73202
40	12	0					138968	-27597	18639	60141	78780	16933	-56269
41	13	0					138968	-27597	10295	60141	70436	13165	-43104
42	14	0					138968	-27597	5189	60141	65329	10618	-32486
43	15	0					138968	-27597	0	60141	60141	8500	-23987
44	16	-124					125094	-24841	0	54136	54136	6653	-17334
45	17	-124					111219	-22086	0	48132	48132	5144	-12190
46	18	-124					97345	-19331	0	42128	42128	3915	-8275
47	19	-124					83470	-16576	0	36123	36123	2919	-5356
48	20	-124					69596	-13820	0	30119	30119	2116	-3240
49	21	-124					55722	-11065	0	24114	24114	1473	-1767
50	22	-124					41847	-8310	0	18110	18110	962	-805
51	23	-124					27973	-5555	0	12106	12106	559	-245
52	24	-124					14098	-2800	0	6101	6101	245	0
53	25	-126					0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

D. CWS Burning Diesel Locomotive

SFe RAILROAD FIG. NO. 1 * 66% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = 327.907

RAILROAD - TOTAL LOCO FLEET = 3950 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 1606

DCRR VERSUS STANDARD DIESEL = 15.00%

TOTAL FLEET DF2 USED (gal) = 652249114 (Ref)

CASE - DF2 / LOCO (000 gal) = 281.70

BTU / LOCO (10)^10 = 3.88

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 92.181

MAINT COST ADDER(000), AVE/YR OVER LIFE = 22.825

PLANT CAPITAL COST (000) = 87995

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	160	-52465	-54029	-106494	14749	-3652	17997	5992	-82504	-82504	-82504
2	160	-52465		-52465	29498	-7304	19644	11985	-20836	-18119	-100623
3	160	-52465	-33966	-86431	44247	-10956	30204	17977	-38250	-28923	-129545
4	160	-52465		-52465	58996	-14608	32969	23970	4473	2941	-126604
5	160	-52465		-52465	73745	-18260	37881	29962	15378	8792	-117812
6	160	-52465	-54029	-106494	88494	-21912	41792	35955	-28747	-14292	-132104
7	160	-52465		-52465	103243	-25564	38129	41947	27611	11937	-120167
8	160	-52465	-33966	-86431	117992	-29215	40340	47939	1848	695	-119472
9	160	-52465		-52465	132741	-32867	38037	53932	39504	12914	-106558
10	166	-54433		-54433	148043	-36656	38213	60149	43930	12488	-94071
11	0				148043	-36656	23994	60149	84143	20799	-73272
12	0				148043	-36656	18676	60149	78825	16943	-56329
13	0				148043	-36656	10326	60149	70475	13172	-43157
14	0				148043	-36656	5258	60149	65407	10631	-32526
15	0				148043	-36656	0	60149	60149	8501	-24025
16	-160				133294	-33004	0	54157	54157	6656	-17370
17	-160				118545	-29352	0	48164	48164	5147	-12223
18	-160				103796	-25700	0	42172	42172	3919	-8304
19	-160				89047	-22049	0	36179	36179	2923	-5380
20	-160				74298	-18397	0	30187	30187	2121	-3259
21	-160				59549	-14745	0	24194	24194	1478	-1781
22	-160				44800	-11093	0	18202	18202	967	-814
23	-160				30051	-7441	0	12210	12210	564	-250
24	-160				15302	-3789	0	6217	6217	250	0
25	-166				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

D. CWS Burning Diesel Locomotive

BN RAILROAD FIG. NO. 1 * 66% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = 426.291

RAILROAD - TOTAL LOCO FLEET = 2593 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 1242

DCRR VERSUS STANDARD DIESEL = 15.00%

TOTAL FLEET DF2 USED (gal) = 514750379 (Ref)

CASE - DF2 / LOCO (000 gal) = 358.30

BTU / LOCO (10)^10 = 4.94

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 111.891

MAINT COST ADDER(000), AVE/YR OVER LIFE = 22.219

PLANT CAPITAL COST (000) = 86841

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	124	-52860	-53321	-106181	13874	-2755	17945	6004	-82232	-82232	-82232
2	124	-52860		-52860	27749	-5510	19679	12009	-21172	-18411	-100643
3	124	-52860	-33521	-86381	41623	-8266	30205	18013	-38163	-28857	-129499
4	124	-52860		-52860	55498	-11021	33038	24018	4196	2759	-126740
5	124	-52860		-52860	69372	-13776	37991	30022	15152	8663	-118077
6	124	-52860	-53321	-106181	83247	-16531	41851	36026	-28303	-14072	-132149
7	124	-52860		-52860	97121	-19286	38236	42031	27406	11849	-120300
8	124	-52860	-33521	-86381	110995	-22042	40417	48035	2072	779	-119521
9	124	-52860		-52860	124870	-24797	38145	54039	39324	12855	-106666
10	126	-53713		-53713	138968	-27597	38135	60141	44563	12667	-93999
11	0				138968	-27597	23993	60141	84133	20796	-73202
12	0				138968	-27597	18639	60141	78780	16933	-56269
13	0				138968	-27597	10295	60141	70436	13165	-43104
14	0				138968	-27597	5189	60141	65329	10618	-32486
15	0				138968	-27597	0	60141	60141	8500	-23987
16	-124				125094	-24841	0	54136	54136	6653	-17334
17	-124				111219	-22086	0	48132	48132	5144	-12190
18	-124				97345	-19331	0	42128	42128	3915	-8275
19	-124				83470	-16576	0	36123	36123	2919	-5356
20	-124				69596	-13820	0	30119	30119	2116	-3240
21	-124				55722	-11065	0	24114	24114	1473	-1767
22	-124				41847	-8310	0	18110	18110	962	-805
23	-124				27973	-5555	0	12106	12106	559	-245
24	-124				14098	-2800	0	6101	6101	245	0
25	-126				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

D. CWS Burning Diesel Locomotive

CR RAILROAD FIG. NO. 1 * 33% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000) per LOCO = 281.020

RAILROAD - TOTAL LOCO FLEET = 2447 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 492

DCRR VERSUS STANDARD DIESEL = 15.00%

TOTAL FLEET DF2 USED (gal) = 290376333 (Ref)

CASE - DF2 / LOCO (000 gal) = 272.00

BTU / LOCO (10)^10 = 3.75

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 89.686

MAINT COST ADDER(000), AVE/YR OVER LIFE = 22.901

PLANT CAPITAL COST (000) = 33209

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	*INV. TAX CR.+ DEPR	NET EXP. *SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	49	-13770	-20390	-34160	4395	-1122	5773	1767	-26620	-26620	-26620
2	49	-13770		-13770	8789	-2244	5784	3534	-4452	-3871	-30491
3	49	-13770	-12819	-26589	13184	-3366	9187	5301	-12100	-9150	-39641
4	49	-13770		-13770	17578	-4489	9648	7068	2946	1937	-37704
5	49	-13770		-13770	21973	-5611	10919	8836	5985	3422	-34282
6	49	-13770	-20390	-34160	26368	-6733	12395	10603	-11162	-5550	-39831
7	49	-13770		-13770	30762	-7855	11013	12370	9613	4156	-35675
8	49	-13770	-12819	-26589	35157	-8977	11847	14137	-605	-227	-35903
9	49	-13770		-13770	39551	-10099	10978	15904	13112	4286	-31616
10	51	-14332		-14332	44125	-11267	11014	17743	14425	4101	-27516
11	0				44125	-11267	6679	17743	24423	6037	-21479
12	0				44125	-11267	5283	17743	23026	4949	-16529
13	0				44125	-11267	2715	17743	20458	3824	-12706
14	0				44125	-11267	1384	17743	19128	3109	-9597
15	0				44125	-11267	0	17743	17743	2508	-7089
16	-49				39731	-10145	0	15976	15976	1963	-5126
17	-49				35336	-9023	0	14209	14209	1518	-3607
18	-49				30942	-7901	0	12442	12442	1156	-2451
19	-49				26547	-6779	0	10675	10675	863	-1589
20	-49				22152	-5657	0	8908	8908	626	-963
21	-49				17758	-4534	0	7141	7141	436	-526
22	-49				13363	-3412	0	5373	5373	285	-241
23	-49				8969	-2290	0	3606	3606	167	-74
24	-49				4574	-1168	0	1839	1839	74	0
25	-51				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

D. CWS Burning Diesel Locomotive

CSX RAILROAD FIG. NO. 1 ^ 33% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = 348.068

RAILROAD - TOTAL LOCO FLEET = 3218 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 883

DCRR VERSUS STANDARD DIESEL = 15.00%

TOTAL FLEET DF2 USED (gal) = 462417920 (Ref)

CASE - DF2 / LOCO (000 gal) = 309.00

BTU / LOCO (10)^10 = 4.26

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 99.206

MAINT COST ADDER(000), AVE/YR OVER LIFE = 22.609

PLANT CAPITAL COST (000) = 58717

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL. CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	88	-30630	-36053	-66682	8730	-1990	11269	3640	-51773	-51773	-51773
2	88	-30630		-30630	17460	-3979	11925	7280	-11425	-9933	-61708
3	88	-30630	-22665	-53295	26190	-5969	18548	10920	-23827	-18017	-79725
4	88	-30630		-30630	34920	-7958	19970	14560	3900	2564	-77161
5	88	-30630		-30630	43651	-9948	22825	18199	10394	5943	-71218
6	88	-30630	-36053	-66682	52381	-11937	25435	21839	-19408	-9649	-80867
7	88	-30630		-30630	61111	-13927	22991	25479	17840	7713	-73155
8	88	-30630	-22665	-53295	69841	-15917	24466	29119	290	109	-73046
9	88	-30630		-30630	78571	-17906	22929	32759	25058	8192	-64854
10	91	-31674		-31674	87599	-19964	23001	36523	27850	7917	-56937
11	0				87599	-19964	14271	36523	50794	12556	-44382
12	0				87599	-19964	11167	36523	47690	10251	-34131
13	0				87599	-19964	6019	36523	42541	7951	-26180
14	0				87599	-19964	3060	36523	39583	6433	-19747
15	0				87599	-19964	0	36523	36523	5162	-14585
16	-88				78869	-17974	0	32883	32883	4041	-10544
17	-88				70138	-15984	0	29243	29243	3125	-7419
18	-88				61408	-13995	0	25603	25603	2379	-5039
19	-88				52678	-12005	0	21963	21963	1775	-3265
20	-88				43948	-10016	0	18323	18323	1288	-1977
21	-88				35218	-8026	0	14684	14684	897	-1080
22	-88				26488	-6037	0	11044	11044	587	-493
23	-88				17758	-4047	0	7404	7404	342	-151
24	-88				9028	-2057	0	3764	3764	151	0
25	-91				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

D. CWS Burning Diesel Locomotive

NS RAILROAD FIG. NO. 1 * 33% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000) per LOCO = 326.720

RAILROAD - TOTAL LOCO FLEET = 2148 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 565

DCRR VERSUS STANDARD DIESEL = 15.00%

TOTAL FLEET DF2 USED (gal) = 310263302 (Ref)

CASE - DF2 / LOCO (000 gal) = 304.20

BTU / LOCO (10)^10 = 4.19

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 97.971

MAINT COST ADDER(000), AVE/YR OVER LIFE = 22.647

PLANT CAPITAL COST (000) = 40569

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	*INV. TAX CR.+ DEPR	NET EXP. *SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	56	-18296	-24910	-43206	5486	-1268	7302	2278	-33626	-33626	-33626
2	56	-18296		-18296	10973	-2536	7465	4556	-6276	-5458	-39084
3	56	-18296	-15660	-33956	16459	-3805	11764	6833	-15339	-11613	-50697
4	56	-18296		-18296	21945	-5073	12470	9111	3284	2160	-48538
5	56	-18296		-18296	27432	-6341	14165	11389	7258	4150	-44388
6	56	-18296	-24910	-43206	32918	-7609	15968	13667	-13571	-6747	-51135
7	56	-18296		-18296	38404	-8878	14280	15945	11928	5157	-45979
8	56	-18296	-15660	-33956	43891	-10146	15299	18222	-435	-164	-46142
9	56	-18296		-18296	49377	-11414	14237	20500	16441	5375	-40768
10	61	-19930		-19930	55353	-12795	14441	22981	17492	4972	-35795
11	0				55353	-12795	8832	22981	31813	7864	-27932
12	0				55353	-12795	6973	22981	29954	6438	-21493
13	0				55353	-12795	3693	22981	26674	4986	-16508
14	0				55353	-12795	1925	22981	24907	4048	-12460
15	0				55353	-12795	0	22981	22981	3248	-9212
16	-56				49867	-11527	0	20704	20704	2544	-6667
17	-56				44381	-10259	0	18426	18426	1969	-4698
18	-56				38894	-8991	0	16148	16148	1501	-3198
19	-56				33408	-7723	0	13870	13870	1121	-2077
20	-56				27922	-6454	0	11592	11592	815	-1262
21	-56				22435	-5186	0	9315	9315	569	-693
22	-56				16949	-3918	0	7037	7037	374	-319
23	-56				11463	-2650	0	4759	4759	220	-99
24	-56				5976	-1381	0	2481	2481	100	0
25	-61				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

D. CWS Burning Diesel Locomotive

UP RAILROAD FIG. NO. 1 * 66% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000) per LOCO = 357.689

RAILROAD - TOTAL LOCO FLEET = 2569 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 1200

DCRR VERSUS STANDARD DIESEL = 15.00%

TOTAL FLEET DF2 USED (gal) = 465106829 (Ref)

CASE - DF2 / LOCO (000 gal) = 307.66

BTU / LOCO (10)^10 = 4.24

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 98.862

MAINT COST ADDER(000), AVE/YR OVER LIFE = 22.619

PLANT CAPITAL COST (000) = 78752

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	*INV. TAX CR.+ DEPR	NET EXP. *SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	120	-45784	-48354	-94138	12654	-2895	15909	5270	-72959	-72959	-72959
2	120	-45784		-45784	25309	-5791	17264	10540	-17980	-15635	-88594
3	120	-45784	-30398	-76182	37963	-8686	26602	15810	-33771	-25536	-114129
4	120	-45784		-45784	50617	-11581	28964	21080	4259	2800	-111329
5	120	-45784		-45784	63272	-14476	33247	26349	13812	7897	-103432
6	120	-45784	-48354	-94138	75926	-17372	36747	31619	-25771	-12813	-116245
7	120	-45784		-45784	88580	-20267	33449	36889	24574	10624	-105621
8	120	-45784	-30398	-76182	101235	-23162	35447	42159	1424	535	-105085
9	120	-45784		-45784	113889	-26058	33386	47429	35031	11452	-93634
10	120	-45784		-45784	126543	-28953	33247	52699	40161	11416	-82217
11	0				126543	-28953	20838	52699	73337	18177	-64040
12	0				126543	-28953	16205	52699	68904	14810	-49230
13	0				126543	-28953	8846	52699	61544	11503	-37727
14	0				126543	-28953	4423	52699	57122	9284	-28443
15	0				126543	-28953	0	52699	52699	7448	-20995
16	-120				113889	-26058	0	47429	47429	5829	-15166
17	-120				101235	-23162	0	42159	42159	4505	-10661
18	-120				88580	-20267	0	36889	36889	3428	-7233
19	-120				75926	-17372	0	31619	31619	2555	-4678
20	-120				63272	-14476	0	26349	26349	1851	-2827
21	-120				50617	-11581	0	21080	21080	1288	-1539
22	-120				37963	-8686	0	15810	15810	840	-699
23	-120				25309	-5791	0	10540	10540	487	-212
24	-120				12654	-2895	0	5270	5270	212	0
25	-120				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

D. CWS Burning Diesel Locomotive

SFe RAILROAD FIG. NO. 1 ` 66% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = 229.140

RAILROAD - TOTAL LOCO FLEET = 3950 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 1606

DCRR VERSUS STANDARD DIESEL = 20.00%

TOTAL FLEET DF2 USED (gal) = 652249114 (Ref)

CASE - DF2 / LOCO (000 gal) = 281.70

BTU / LOCO (10)^10 = 3.88

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 92.181

MAINT COST ADDER(000), AVE/YR OVER LIFE = 22.825

PLANT CAPITAL COST (000) = 87995

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	*INV.-TAX CR.+ DEPR	NET EXP. *SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	160	-36662	-54029	-90691	14749	-3652	15327	5992	-69372	-69372	-69372
2	160	-36662		-36662	29498	-7304	15374	11985	-9304	-7753	-77125
3	160	-36662	-33966	-70628	44247	-10956	24407	17977	-28244	-19614	-96739
4	160	-36662		-36662	58996	-14608	25646	23970	12953	7496	-89243
5	160	-36662		-36662	73745	-18260	29031	29962	22331	10769	-78474
6	160	-36662	-54029	-90691	88494	-21912	32943	35955	-21794	-8758	-87232
7	160	-36662		-36662	103243	-25564	29280	41947	34564	11576	-75656
8	160	-36662	-33966	-70628	117992	-29215	31490	47939	8801	2456	-73200
9	160	-36662		-36662	132741	-32867	29187	53932	46457	10804	-62396
10	166	-38037		-38037	148043	-36656	29264	60149	51375	9957	-52439
11	0				148043	-36656	17755	60149	77904	12582	-39857
12	0				148043	-36656	14039	60149	74188	9985	-29872
13	0				148043	-36656	7216	60149	67365	7555	-22317
14	0				148043	-36656	3674	60149	63823	5965	-16352
15	0				148043	-36656	0	60149	60149	4685	-11667
16	-160				133294	-33004	0	54157	54157	3515	-8152
17	-160				118545	-29352	0	48164	48164	2605	-5547
18	-160				103796	-25700	0	42172	42172	1901	-3646
19	-160				89047	-22049	0	36179	36179	1359	-2287
20	-160				74298	-18397	0	30187	30187	945	-1342
21	-160				59549	-14745	0	24194	24194	631	-711
22	-160				44800	-11093	0	18202	18202	396	-315
23	-160				30051	-7441	0	12210	12210	221	-94
24	-160				15302	-3789	0	6217	6217	94	0
25	-166				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

D. CWS Burning Diesel Locomotive

BN RAILROAD FIB. NO. 1 ^ 66% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = 298.743

RAILROAD - TOTAL LOCO FLEET = 2593 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 1242

DCRR VERSUS STANDARD DIESEL = 20.00%

TOTAL FLEET DF2 USED (gal) = 514750379 (Ref)

CASE - DF2 / LOCO (000 gal) = 358.30

BTU / LOCO (10)^10 = 4.94

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 111.891

MAINT COST ADDER(000), AVE/YR OVER LIFE = 22.219

PLANT CAPITAL COST (000) = 86841

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. CR.+ DEPR	TAX	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	124	-37044	-53321	-90365	13874	-2755	15272	6004	-69089	-69089		-69089
2	124	-37044		-37044	27749	-5510	15405	12009	-9630	-9025		-77114
3	124	-37044	-33521	-70565	41623	-8266	24404	18013	-28148	-19547		-96661
4	124	-37044		-37044	55498	-11021	25709	24018	12683	7340		-89322
5	124	-37044		-37044	69372	-13276	29134	30022	22111	10663		-78658
6	124	-37044	-53321	-90365	83247	-16531	32994	36026	-21344	-8578		-87236
7	124	-37044		-37044	97121	-19286	29379	42031	34363	11509		-75727
8	124	-37044	-33521	-70565	110995	-22042	31560	48035	9031	2520		-73207
9	124	-37044		-37044	124870	-24797	29288	54039	46283	10764		-62443
10	126	-37642		-37642	138968	-27597	29235	60141	51734	10026		-52417
11	0				138968	-27597	17783	60141	77923	12585		-39832
12	0				138968	-27597	14031	60141	74172	9983		-29849
13	0				138968	-27597	7215	60141	67355	7554		-22295
14	0				138968	-27597	3636	60141	63777	5961		-16334
15	0				138968	-27597	0	60141	60141	4684		-11650
16	-124				125094	-24841	0	54136	54136	3514		-8136
17	-124				111219	-22086	0	48132	48132	2603		-5532
18	-124				97345	-19331	0	42128	42128	1899		-3634
19	-124				83470	-16576	0	36123	36123	1357		-2277
20	-124				69596	-13820	0	30119	30119	943		-1334
21	-124				55722	-11065	0	24114	24114	629		-705
22	-124				41847	-8310	0	18110	18110	394		-311
23	-124				27973	-5555	0	12106	12106	219		-92
24	-124				14098	-2800	0	6101	6101	92		0
25	-126				0	0	0	0	0	0		0

VIII. ECONOMIC ANALYSIS

D. CWS Burning Diesel Locomotive

CR RAILROAD FIG. NO. 1 * 33% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = 184.300

RAILROAD - TOTAL LOCO FLEET = 2447 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 492

DCRR VERSUS STANDARD DIESEL = 20.00%

TOTAL FLEET DF2 USED (gal) = 290376555 (Ref)

CASE - DF2 / LOCO (000 gal) = 272.00

BTU / LOCO (10)^10 = 3.75

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 89.686

MAINT COST ADDER(000), AVE/YR OVER LIFE = 22.901

PLANT CAPITAL COST (000) = 33209

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	49	-9031	-20390	-29421	4395	-1122	4972	1767	-22682	-22682	-22682
2	49	-9031		-9031	8789	-2244	4504	3534	-993	-827	-23509
3	49	-9031	-12819	-21849	13184	-3366	7449	5301	-9100	-6319	-29828
4	49	-9031		-9031	17578	-4489	7452	7068	5490	3177	-26652
5	49	-9031		-9031	21973	-5611	8265	8836	8070	3892	-22760
6	49	-9031	-20390	-29421	26368	-6733	9741	10603	-9077	-3648	-26408
7	49	-9031		-9031	30762	-7855	8359	12370	11698	3918	-22490
8	49	-9031	-12819	-21849	35157	-8977	9193	14137	1481	413	-22077
9	49	-9031		-9031	39551	-10099	8324	15904	15198	3534	-18542
10	51	-9399		-9399	44125	-11267	8327	17743	16671	3231	-15311
11	0				44125	-11267	4807	17743	22550	3642	-11669
12	0				44125	-11267	3891	17743	21634	2912	-8758
13	0				44125	-11267	1780	17743	19524	2190	-6568
14	0				44125	-11267	908	17743	18651	1743	-4825
15	0				44125	-11267	0	17743	17743	1382	-3443
16	-49				39731	-10145	0	15976	15976	1037	-2406
17	-49				35336	-9023	0	14209	14209	769	-1637
18	-49				30942	-7901	0	12442	12442	561	-1076
19	-49				26547	-6779	0	10675	10675	401	-675
20	-49				22152	-5657	0	8908	8908	279	-397
21	-49				17758	-4534	0	7141	7141	186	-210
22	-49				13363	-3412	0	5373	5373	117	-94
23	-49				8969	-2290	0	3606	3606	65	-28
24	-49				4574	-1168	0	1839	1839	28	0
25	-51				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

D. CWS Burning Diesel Locomotive

CSX RAILROAD FIG. NO. 1 * 33% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000) per LOCO = 238.346

RAILROAD - TOTAL LOCO FLEET =	3218	(Ref)
CASE - LOCOMOTIVE FLEET SIZE =	883	
DCRR VERSUS STANDARD DIESEL =	20.00%	
TOTAL FLEET DF2 USED (gal) =	462417920	(Ref)
CASE - DF2 / LOCO (000 gal) =	309.00	
BTU / LOCO (10)^10 =	4.26	
FUEL SAVINGS (000) /YEAR /LOCOMOTIVE =	99.206	
MAINT COST ADDER(000), AVE/YR OVER LIFE =	22.609	
PLANT CAPITAL COST (000) =	58717	

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	*INV. TAX CR.+ DEPR	NET CIP. *SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	88	-20974	-36053	-57027	8730	-1990	9638	3640	-43750	-43750	-43750
2	88	-20974		-20974	17460	-3979	9316	7280	-4379	-3649	-47399
3	88	-20974	-22665	-43639	26190	-5969	15006	10920	-17713	-12301	-59699
4	88	-20974		-20974	34920	-7958	15496	14560	9081	5255	-54444
5	88	-20974		-20974	43651	-9948	17418	18199	14643	7062	-47383
6	88	-20974	-36053	-57027	52381	-11937	20028	21839	-15160	-6092	-53475
7	88	-20974		-20974	61111	-13927	17584	25479	22088	7397	-46078
8	88	-20974	-22665	-43639	69841	-15917	19059	29119	4538	1267	-44811
9	88	-20974		-20974	78571	-17906	17522	32759	29302	6816	-37995
10	91	-21689		-21689	87599	-19964	17539	36523	32372	6274	-31721
11	0				87599	-19964	10463	36523	46986	7588	-24133
12	0				87599	19964	8337	36523	44860	6038	-18095
13	0				87599	-19964	4121	36523	40644	4559	-13537
14	0				87599	-19964	2095	36523	38618	3609	-9928
15	0				87599	-19964	0	36523	36523	2845	-7083
16	-88				78869	-17974	0	32883	32883	2134	-4949
17	-88				70138	-15984	0	29243	29243	1582	-3367
18	-88				61408	-13995	0	25603	25603	1154	-2213
19	-88				52678	-12005	0	21963	21963	825	-1388
20	-88				43948	-10016	0	18323	18323	574	-814
21	-88				35218	-8026	0	14684	14684	383	-431
22	-88				26488	-6037	0	11044	11044	240	-191
23	-88				17758	-4047	0	7404	7404	134	-57
24	-88				9028	-2057	0	3764	3764	57	0
25	-91				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

D. CWS Burning Diesel Locomotive

NS RAILROAD FIG. NO. 1 ^ 33% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = 217.995

RAILROAD - TOTAL LOCO FLEET = 2148 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 565

DCRR VERSUS STANDARD DIESEL = 20.00%

TOTAL FLEET DF2 USED (gal) = 310263302 (Ref)

CASE - DF2 / LOCO (000 gal) = 304.20

BTU / LOCO (10)^10 = 4.19

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 97.971

MAINT COST ADDER(000), AVE/YR OVER LIFE = 22.647

PLANT CAPITAL COST (000) = 40569

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	56	-12208	-24910	-37117	5486	-1268	6273	2278	-28567	-28567	-28567
2	56	-12208		-12208	10973	-2536	5819	4556	-1833	-1527	-30094
3	56	-12208	-15660	-27867	16459	-3805	9531	6833	-11504	-7989	-38083
4	56	-12208		-12208	21945	-5073	9648	9111	6552	3791	-34291
5	56	-12208		-12208	27432	-6341	10755	11389	9937	4792	-29499
6	56	-12208	-24910	-37117	32918	-7609	12559	13667	-10892	-4377	-33876
7	56	-12208		-12208	38404	-8878	10870	15945	14607	4892	-28985
8	56	-12208	-15660	-27867	43891	-10146	11889	18222	2244	626	-28358
9	56	-12208		-12208	49377	-11414	10827	20500	19120	4447	-23912
10	61	-13298		-13298	55353	-12795	10940	22981	20623	3997	-19915
11	0				55353	-12795	6396	22981	29378	4745	-15170
12	0				55353	-12795	5156	22981	28137	3787	-11383
13	0				55353	-12795	2464	22981	25445	2854	-8529
14	0				55353	-12795	1285	22981	24266	2268	-6261
15	0				55353	-12795	0	22981	22981	1790	-4471
16	-56				49867	-11527	0	20704	20704	1344	-3128
17	-56				44381	-10259	0	18426	18426	997	-2131
18	-56				38894	-8991	0	16148	16148	728	-1403
19	-56				33408	-7723	0	13870	13870	521	-882
20	-56				27922	-6454	0	11592	11592	363	-519
21	-56				22435	-5186	0	9315	9315	243	-276
22	-56				16949	-3918	0	7037	7037	153	-124
23	-56				11463	-2650	0	4759	4759	86	-37
24	-56				5976	-1381	0	2481	2481	37	0
25	-61				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

D. CWS Burning Diesel Locomotive

UP RAILROAD FIG. NO. 1 ^ 66% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = 249.050

RAILROAD - TOTAL LOCO FLEET = 2569 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 1280

DCRR VERSUS STANDARD DIESEL = 20.00%

TOTAL FLEET DF2 USED (gal) = 465106829 (Ref)

CASE - DF2 / LOCO (000 gal) = 307.66

BTU / LOCO (10)^10 = 4.24

FUEL SAVINGS (000) /YEAR-/LOCOMOTIVE = 98.862

MAINT COST ADDER(000), AVE/YR OVER LIFE = 22.619

PLANT CAPITAL COST (000) = 78752

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	128	-31878	-48354	-80232	12654	-2895	13559	5270	-61403	-61403	-61403
2	128	-31878		-31878	25309	-5791	13507	10540	-7832	-6526	-67929
3	128	-31878	-30398	-62277	37963	-8686	21501	15810	-24966	-17337	-85267
4	128	-31878		-31878	50617	-11581	22520	21080	11721	6783	-78484
5	128	-31878		-31878	63272	-14476	25459	26349	19930	9611	-68872
6	128	-31878	-48354	-80232	75926	-17372	28960	31619	-19653	-7898	-76770
7	128	-31878		-31878	88580	-20267	25682	36889	30693	10279	-66491
8	128	-31878	-30398	-62277	101235	-23162	27660	42159	7543	2105	-64386
9	128	-31878		-31878	113889	-26058	25599	47429	41150	9570	-54816
10	128	-31878		-31878	126543	-28953	25459	52699	46280	8969	-45847
11	0				126543	-28953	15401	52699	68100	10998	-34849
12	0				126543	-28953	12175	52699	64874	8731	-26117
13	0				126543	-28953	6159	52699	58858	6601	-19516
14	0				126543	-28953	3079	52699	55778	5213	-14303
15	0				126543	-28953	0	52699	52699	4105	-10198
16	-128				113889	-26058	0	47429	47429	3078	-7120
17	-128				101235	-23162	0	42159	42159	2280	-4840
18	-128				88580	-20267	0	36889	36889	1663	-3177
19	-128				75926	-17372	0	31619	31619	1188	-1989
20	-128				63272	-14476	0	26349	26349	825	-1164
21	-128				50617	-11581	0	21080	21080	550	-615
22	-128				37963	-8686	0	15810	15810	344	-271
23	-128				25309	-5791	0	10540	10540	191	-80
24	-128				12654	-2895	0	5270	5270	80	0
25	-128				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

E. CWS Burning Gas Turbine Locomotive

SFe RAILROAD FIG. NO. 1 * 66% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = 336.097

RAILROAD - TOTAL LOCO FLEET = 3950 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 1606

DCRR VERSUS STANDARD DIESEL = 15.00%

TOTAL FLEET DF2 USED (gal) = 652249114 (Ref)

CASE - DF2 / LOCO (000 gal) = 281.70

BTU / LOCO (10)^10 = 5.73

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 83.721

MAINT COST ADDER(000), AVE/YR OVER LIFE = 2.929

PLANT CAPITAL COST (000) = 120152

INVESTMENT DEPRECIATION SCHEDULE

YEAR	1	15.00%
	2	22.00%
	3	21.00%
	4	21.00%
	5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	160	-56976	-73773	-130749	13395	-469	22097	6980	-101672	-101672	-101672
2	160	-56976		-56976	26791	-937	22861	13961	-20154	-17525	-119197
3	160	-56976	-46379	-103354	40186	-1406	35863	20941	-46530	-35198	-154395
4	160	-56976		-56976	53581	-1875	38222	27922	9169	6029	-148367
5	160	-56976		-56976	66977	-2343	43513	34902	21440	12258	-136109
6	160	-56976	-73773	-130749	80372	-2812	48854	41883	-40012	-19893	-156002
7	160	-56976		-56976	93768	-3281	43852	48863	35740	15451	-140551
8	160	-56976	-46379	-103354	107163	-3749	46871	55843	-640	-241	-140791
9	160	-56976		-56976	120558	-4218	43726	62824	49575	16206	-124585
10	166	-59112		-59112	134456	-4704	43874	70066	54828	15586	-109000
11	0				134456	-4704	26974	70066	97040	23987	-85013
12	0				134456	-4704	21198	70066	91264	19617	-65396
13	0				134456	-4704	11214	70066	81280	15192	-50204
14	0				134456	-4704	5710	70066	75776	12316	-37889
15	0				134456	-4704	0	70066	70066	9902	-27986
16	-160				121061	-4235	0	63086	63086	7753	-20234
17	-160				107665	-3767	0	56105	56105	5996	-14238
18	-160				94270	-3298	0	49125	49125	4565	-9673
19	-160				80875	-2830	0	42144	42144	3405	-6267
20	-160				67479	-2361	0	35164	35164	2471	-3797
21	-160				54084	-1892	0	28183	28183	1722	-2075
22	-160				40688	-1424	0	21203	21203	1127	-948
23	-160				27293	-955	0	14223	14223	657	-291
24	-160				13898	-486	0	7242	7242	291	0
25	-166				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

E. CWS Burning Gas Turbine Locomotive

BN RAILROAD FIG. NO. 1 * 66% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000) per LOCO = 374.768

RAILROAD - TOTAL LOCO FLEET = 2593 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 1242

DCRR VERSUS STANDARD DIESEL = 15.00%

TOTAL FLEET DF2 USED (gal) = 514750379 (Ref)

CASE - DF2 / LOCO (000 gal) = 358.30

BTU / LOCO (10)^10 = 7.29

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 99.493

MAINT COST ADDER(000), AVE/YR OVER LIFE = 8.521

PLANT CAPITAL COST (000) = 118577

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	124	-46471	-72806	-119277	12337	-1057	20158	6091	-93028	-93028	-93028
2	124	-46471		-46471	24674	-2113	19925	12183	-14364	-12490	-105518
3	124	-46471	-45771	-92242	37011	-3170	31814	18274	-42153	-31874	-137392
4	124	-46471		-46471	49349	-4226	33200	24366	11095	7295	-130097
5	124	-46471		-46471	61686	-5283	37478	30457	21465	12272	-117825
6	124	-46471	-72806	-119277	74023	-6340	42750	36549	-39979	-19877	-137702
7	124	-46471		-46471	86360	-7396	37813	42640	33983	14692	-123010
8	124	-46471	-45771	-92242	98697	-8453	40792	48732	-2718	-1022	-124032
9	124	-46471		-46471	111034	-9509	37689	54823	46041	15051	-108981
10	126	-47221		-47221	123370	-10583	37605	61013	51397	14610	-94370
11	0				123370	-10583	22668	61013	83681	20685	-73686
12	0				123370	-10583	17961	61013	78974	16975	-56711
13	0				123370	-10583	9051	61013	70064	13095	-43615
14	0				123370	-10583	4562	61013	65575	10658	-32958
15	0				123370	-10583	0	61013	61013	8623	-24335
16	-124				111233	-9526	0	54922	54922	6750	-17585
17	-124				98896	-8470	0	48830	48830	5218	-12367
18	-124				86559	-7413	0	42739	42739	3972	-8395
19	-124				74222	-6357	0	36647	36647	2961	-5434
20	-124				61885	-5300	0	30556	30556	2147	-3287
21	-124				49547	-4243	0	24464	24464	1495	-1792
22	-124				37210	-3187	0	18373	18373	976	-816
23	-124				24873	-2130	0	12281	12281	567	-249
24	-124				12536	-1074	0	6190	6190	249	0
25	-126				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

E. CWS Burning Gas Turbine Locomotive

CR RAILROAD FIG. NO. 1 * 33% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = 306.720

RAILROAD - TOTAL LOCO FLEET = 2447 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 492

DCRR VERSUS STANDARD DIESEL = 15.00%

TOTAL FLEET DF2 USED (gal) = 290376333 (Ref)

CASE - DF2 / LOCO (000 gal) = 272.00

BTU / LOCO (10)^10 = 5.53

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 81.724

MAINT COST ADDER(000), AVE/YR OVER LIFE = 2.221

PLANT CAPITAL COST (000) = 45345

INVESTMENT DEPRECIATION SCHEDULE	
YEAR 1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	49	-15029	-27842	-42871	4004	-109	7245	2104	-33522	-33522	-33522
2	49	-15029		-15029	8009	-218	6879	4207	-3943	-3429	-36952
3	49	-15029	-17503	-32533	12013	-326	11160	6311	-15061	-11389	-48340
4	49	-15029		-15029	16018	-435	11425	8415	4811	3163	-45177
5	49	-15029		-15029	20022	-544	12797	10518	8286	4737	-40440
6	49	-15029	-27842	-42871	24027	-653	14813	12622	-15437	-7675	-48114
7	49	-15029		-15029	28031	-762	12925	14726	12621	5456	-42658
8	49	-15029	-17503	-32533	32036	-871	14064	16829	-1639	-616	-43274
9	49	-15029		-15029	36040	-979	12877	18933	16781	5486	-37789
10	51	-15643		-15643	40208	-1093	12900	21122	18380	5225	-32564
11	0				40208	-1093	7629	21122	28752	7107	-25457
12	0				40208	-1093	6106	21122	27228	5852	-19604
13	0				40208	-1093	2963	21122	24085	4502	-15103
14	0				40208	-1093	1511	21122	22633	3679	-11424
15	0				40208	-1093	0	21122	21122	2985	-8439
16	-49				36204	-984	0	19019	19019	2337	-6102
17	-49				32199	-875	0	16915	16915	1808	-4294
18	-49				28195	-766	0	14811	14811	1376	-2918
19	-49				24190	-657	0	12708	12708	1027	-1891
20	-49				20186	-549	0	10604	10604	745	-1146
21	-49				16181	-440	0	8500	8500	519	-626
22	-49				12177	-331	0	6397	6397	340	-287
23	-49				8172	-222	0	4293	4293	198	-88
24	-49				4168	-113	0	2190	2190	88	0
25	-51				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

E. CWS Burning Gas Turbine Locomotive

CSX RAILROAD FIG. NO. 1 ^ 33% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000) per LOCO = 342.402

RAILROAD - TOTAL LOCO FLEET =	3218	(Ref)
CASE - LOCOMOTIVE FLEET SIZE =	883	
DCRR VERSUS STANDARD DIESEL =	15.00%	
TOTAL FLEET DF2 USED (gal) =	462417920	(Ref)
CASE - DF2 / LOCO (000 gal) =	309.00	
BTU / LOCO (10)^10 =	6.28	
FUEL SAVINGS (000) /YEAR /LOCOMOTIVE =	89.342	
MAINT COST ADDER(000), AVE/YR OVER LIFE =	4.922	
PLANT CAPITAL COST (000) =	80175	

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	88	-30131	-49228	-79359	7862	-433	13412	4012	-61936	-61936	-61936
2	88	-30131		-30131	15724	-866	13123	8023	-8985	-7813	-69749
3	88	-30131	-30948	-61079	23586	-1299	21038	12035	-28006	-21177	-90925
4	88	-30131		-30131	31448	-1733	21850	16047	7765	5106	-85820
5	88	-30131		-30131	39311	-2166	24619	20058	14545	8316	-77503
6	88	-30131	-49228	-79359	47173	-2599	28183	24070	-27107	-13477	-90980
7	88	-30131		-30131	55035	-3032	24845	28082	22795	9855	-81125
8	88	-30131	-30948	-61079	62897	-3465	26859	32093	-2127	-800	-81925
9	88	-30131		-30131	70759	-3898	24761	36105	30734	10047	-71877
10	91	-31159		-31159	78889	-4346	24792	40253	33887	9633	-62245
11	0				78889	-4346	14875	40253	55128	13627	-48618
12	0				78889	-4346	11821	40253	52074	11193	-37425
13	0				78889	-4346	5921	40253	46174	8630	-28795
14	0				78889	-4346	3010	40253	43263	7031	-21763
15	0				78889	-4346	0	40253	40253	5689	-16074
16	-88				71027	-3913	0	36242	36242	4454	-11620
17	-88				63165	-3480	0	32230	32230	3444	-8176
18	-88				55303	-3047	0	28218	28218	2622	-5554
19	-88				47441	-2614	0	24207	24207	1956	-3598
20	-88				39579	-2180	0	20195	20195	1419	-2179
21	-88				31716	-1747	0	16183	16183	989	-1190
22	-88				23854	-1314	0	12172	12172	647	-543
23	-88				15992	-881	0	8160	8160	377	-166
24	-88				8130	-448	0	4148	4148	167	0
25	-91				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

E. CWS Burning Gas Turbine Locomotive

NS RAILROAD FIG. NO. 1 * 33% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000) per LOCO = 320.505

RAILROAD - TOTAL LOCO FLEET = 2148 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 565

DCRR VERSUS STANDARD DIESEL = 15.00%

TOTAL FLEET DF2 USED (gal) = 310263302 (Ref)

CASE - DF2 / LOCO (000 gal) = 304.20

BTU / LOCO (10)^10 = 6.19

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 88.354

MAINT COST ADDER(000), AVE/YR OVER LIFE = 4.572

PLANT CAPITAL COST (000) = 55395

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	56	-17948	-34013	-51961	4948	-256	8781	2534	-40646	-40646	-40646
2	56	-17948		-17948	9896	-512	8292	5067	-4589	-3991	-44637
3	56	-17948	-21383	-39331	14843	-768	13483	7601	-18247	-13798	-58434
4	56	-17948		-17948	19791	-1024	13767	10134	5953	3914	-54520
5	56	-17948		-17948	24739	-1280	15402	12668	10122	5787	-48733
6	56	-17948	-34013	-51961	29687	-1536	17865	15201	-18895	-9394	-58127
7	56	-17948		-17948	34635	-1792	15539	17735	15345	6634	-51493
8	56	-17948	-21383	-39331	39582	-2048	16950	20269	-2112	-794	-52287
9	56	-17948		-17948	44530	-2304	15501	22802	20354	6654	-45633
10	61	-19551		-19551	49920	-2583	15673	25562	21684	6164	-39469
11	0				49920	-2583	9246	25562	34807	8604	-30865
12	0				49920	-2583	7422	25562	32984	7090	-23775
13	0				49920	-2583	3622	25562	29184	5455	-18321
14	0				49920	-2583	1889	25562	27451	4461	-13859
15	0				49920	-2583	0	25562	25562	3613	-10247
16	-56				44972	-2327	0	23028	23028	2830	-7417
17	-56				40024	-2071	0	20495	20495	2190	-5226
18	-56				35076	-1815	0	17961	17961	1669	-3557
19	-56				30129	-1559	0	15428	15428	1247	-2311
20	-56				25181	-1303	0	12894	12894	906	-1405
21	-56				20233	-1047	0	10361	10361	633	-772
22	-56				15285	-791	0	7827	7827	416	-356
23	-56				10337	-535	0	5293	5293	245	-111
24	-56				5390	-279	0	2760	2760	111	0
25	-61				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

E. CWS Burning Gas Turbine Locomotive

UP RAILROAD FIB. NO. 1 ^ 66% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = 357.558

RAILROAD - TOTAL LOCO FLEET = 2569 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 1280

DCRR VERSUS STANDARD DIESEL = 15.00%

TOTAL FLEET DF2 USED (gal) = 465106829 (Ref)

CASE - DF2 / LOCO (000 gal) = 307.66

BTU / LOCO (10)^10 = 6.26

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 89.067

MAINT COST ADDER(000), AVE/YR OVER LIFE = 4.824

PLANT CAPITAL COST (000) = 107531

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	128	-45767	-66024	-111792	11401	-618	18893	5823	-87076	-87076	-87076
2	128	-45767		-45767	22801	-1235	19048	11646	-15074	-13108	-100184
3	128	-45767	-41507	-87274	34202	-1853	30180	17469	-39626	-29963	-130146
4	128	-45767		-45767	45602	-2470	31787	23291	9311	6122	-124024
5	128	-45767		-45767	57003	-3088	36017	29114	19364	11071	-112953
6	128	-45767	-66024	-111792	68403	-3705	40797	34937	-36057	-17927	-130879
7	128	-45767		-45767	79804	-4323	36321	40760	31313	13338	-117342
8	128	-45767	-41507	-87274	91205	-4940	39022	46583	-1669	-628	-117969
9	128	-45767		-45767	102605	-5558	36208	52406	42846	14007	-103963
10	128	-45767		-45767	114006	-6175	36017	58228	48478	13781	-90182
11	0				114006	-6175	21905	58228	80133	19808	-70375
12	0				114006	-6175	17273	58228	75501	16229	-54146
13	0				114006	-6175	8842	58228	67071	12536	-41610
14	0				114006	-6175	4421	58228	62650	10182	-31428
15	0				114006	-6175	0	58228	58228	8229	-23198
16	-128				102605	-5558	0	52406	52406	6440	-16758
17	-128				91205	-4940	0	46583	46583	4978	-11780
18	-128				79804	-4323	0	40760	40760	3788	-7992
19	-128				68403	-3705	0	34937	34937	2823	-5169
20	-128				57003	-3088	0	29114	29114	2046	-3124
21	-128				45602	-2470	0	23291	23291	1423	-1700
22	-128				34202	-1853	0	17469	17469	928	-772
23	-128				22801	-1235	0	11646	11646	538	-234
24	-128				11401	-618	0	5823	5823	234	0
25	-128				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

E. CWS Burning Gas Turbine Locomotive

SFe RAILROAD FIG. NO. 1 ^ 66% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = 239.845

RAILROAD - TOTAL LOCO FLEET = 3950 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 1606

DCRR VERSUS STANDARD DIESEL = 20.00%

TOTAL FLEET DF2 USED (gal) = 652249114 (Ref)

CASE - DF2 / LOCO (000 gal) = 281.70

BTU / LOCO (10)^10 = 5.73

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 83.721

MAINT COST ADDER(000), AVE/YR OVER LIFE = 2.929

PLANT CAPITAL COST (000) = 120152

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	160	-38375	-73773	-112149	13395	-469	18953	6980	-86215	-86215	-86215
2	160	-38375		-38375	26791	-937	17835	13961	-6580	-5483	-91698
3	160	-38375	-46379	-84754	40186	-1406	29041	20941	-34772	-24147	-115845
4	160	-38375		-38375	53581	-1875	29603	27922	19150	11082	-104763
5	160	-38375		-38375	66977	-2343	33097	34902	29624	14286	-90477
6	160	-38375	-73773	-112149	80372	-2812	38438	41883	-31828	-12791	-103268
7	160	-38375		-38375	93768	-3281	33436	48863	43924	14710	-88558
8	160	-38375	-46379	-84754	107163	-3749	36455	55843	7544	2105	-86453
9	160	-38375		-38375	120558	-4218	33310	62824	57759	13433	-73020
10	166	-39814		-39814	134456	-4704	33340	70066	63592	12325	-60695
11	0				134456	-4704	19631	70066	89697	14486	-46209
12	0				134456	-4704	15740	70066	85806	11548	-34660
13	0				134456	-4704	7553	70066	77619	8705	-25955
14	0				134456	-4704	3846	70066	73912	6908	-19047
15	0				134456	-4704	0	70066	70066	5457	-13590
16	-160				121061	-4235	0	63086	63086	4095	-9495
17	-160				107665	-3767	0	56105	56105	3035	-6460
18	-160				94270	-3298	0	49125	49125	2214	-4246
19	-160				80875	-2830	0	42144	42144	1583	-2663
20	-160				67479	-2361	0	35164	35164	1101	-1562
21	-160				54084	-1892	0	28183	28183	735	-827
22	-160				40688	-1424	0	21203	21203	461	-366
23	-160				27293	-955	0	14223	14223	258	-109
24	-160				13898	-486	0	7242	7242	109	0
25	-166				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

E. CWS Burning Gas Turbine Locomotive

BN RAILROAD FIG. NO. 1 ^ 66% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = 242.707

RAILROAD - TOTAL LOCO FLEET = 2593 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 1242

DCRR VERSUS STANDARD DIESEL = 20.00%

TOTAL FLEET DF2 USED (gal) = 514750379 (Ref)

CASE - DF2 / LOCO (000 gal) = 358.30

BTU / LOCO (10)^10 = 7.29

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 99.493

MAINT COST ADDER(000), AVE/YR OVER LIFE = 8.521

PLANT CAPITAL COST (000) = 118577

INVESTMENT DEPRECIATION SCHEDULE

YEAR	1	15.00%
	2	22.00%
	3	21.00%
	4	21.00%
	5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	124	-30096	-72806	-102902	12337	-1057	17390	6091	-79420	-79420	-79420
2	124	-30096		-30096	24674	-2113	15500	12183	-2413	-2011	-81431
3	124	-30096	-45771	-75866	37011	-3170	25807	18274	-31784	-22073	-103503
4	124	-30096		-30096	49349	-4226	25611	24366	19882	11506	-91998
5	124	-30096		-30096	61686	-5283	28308	30457	28670	13826	-78171
6	124	-30096	-72806	-102902	74023	-6340	33379	36549	-32774	-13171	-91342
7	124	-30096		-30096	86360	-7396	28643	42640	41188	13794	-77549
8	124	-30096	-45771	-75866	98697	-8453	31622	48732	4487	1252	-76296
9	124	-30096		-30096	111034	-9509	28519	54823	53246	12383	-63913
10	126	-30581		-30581	123570	-10583	28390	61013	58822	11400	-52513
11	0				123570	-10583	16238	61013	77251	12476	-40036
12	0				123570	-10583	13190	61013	74203	9987	-30049
13	0				123570	-10583	5861	61013	66875	7500	-22549
14	0				123570	-10583	2954	61013	63967	5979	-16570
15	0				123570	-10583	0	61013	61013	4752	-11818
16	-124				111233	-9526	0	54922	54922	3565	-8254
17	-124				98896	-8470	0	48830	48830	2641	-5612
18	-124				86559	-7413	0	42739	42739	1926	-3686
19	-124				74222	-6357	0	36647	36647	1377	-2310
20	-124				61885	-5300	0	30556	30556	956	-1353
21	-124				49547	-4243	0	24464	24464	638	-715
22	-124				37210	-3187	0	18373	18373	399	-316
23	-124				24873	-2130	0	12281	12281	222	-93
24	-124				12536	-1074	0	6190	6190	93	0
25	-126				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

E. CWS Burning Gas Turbine Locomotive

CR RAILROAD FIG. NO. 1 * 33% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = 190.290

RAILROAD - TOTAL LOCO FLEET = 2447 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 492

DCRR VERSUS STANDARD DIESEL = 20.00%

TOTAL FLEET DF2 USED (gal) = 290376555 (Ref)

CASE - DF2 / LOCO (000 gal) = 272.00

BTU / LOCO (10)^10 = 5.53

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 81.724

MAINT COST ADDER(000), AVE/YR OVER LIFE = 2.221

PLANT CAPITAL COST (000) = 45345

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	49	-9324	-27842	-37166	4004	-109	6281	2104	-28781	-28781	-28781
2	49	-9324		-9324	8009	-218	5337	4207	220	183	-28598
3	49	-9324	-17503	-26828	12013	-326	9068	6311	-11449	-7951	-36549
4	49	-9324		-9324	16018	-435	8782	8415	7872	4556	-31993
5	49	-9324		-9324	20022	-544	9602	10518	10796	5206	-26787
6	49	-9324	-27842	-37166	24027	-653	11618	12622	-12927	-5195	-31982
7	49	-9324		-9324	28031	-762	9730	14726	15131	5067	-26914
8	49	-9324	-17503	-26828	32036	-871	10869	16829	871	243	-26671
9	49	-9324		-9324	36040	-979	9682	18933	19291	4486	-22185
10	51	-9705		-9705	40208	-1093	9666	21122	21084	4086	-18099
11	0				40208	-1093	5375	21122	26497	4279	-13819
12	0				40208	-1093	4430	21122	25552	3439	-10380
13	0				40208	-1093	1838	21122	22961	2575	-7805
14	0				40208	-1093	937	21122	22060	2062	-5743
15	0				40208	-1093	0	21122	21122	1645	-4098
16	-49				36204	-984	0	19019	19019	1234	-2864
17	-49				32199	-875	0	16915	16915	915	-1949
18	-49				28195	-766	0	14811	14811	668	-1281
19	-49				24190	-657	0	12708	12708	477	-804
20	-49				20186	-549	0	10604	10604	332	-472
21	-49				16181	-440	0	8500	8500	222	-250
22	-49				12177	-331	0	6397	6397	139	-111
23	-49				8172	-222	0	4293	4293	78	-33
24	-49				4168	-113	0	2190	2190	33	0
25	-51				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

E. CWS Burning Gas Turbine Locomotive

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = 219.364

RAILROAD - TOTAL LOCO FLEET = 3218 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 883

DCRR VERSUS STANDARD DIESEL = 20.00%

TOTAL FLEET DF2 USED (gal) = 462417920 (Ref)

CASE - DF2 / LOCO (000 gal) = 309.00

BTU / LOCO (10)^10 = 6.28

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 89.342

MAINT COST ADDER(000), AVE/YR OVER LIFE = 4.922

PLANT CAPITAL COST (000) = 80175

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	88	-19322	-49228	-68549	7862	-433	11585	4012	-52953	-52953	-52953
2	88	-19322		-19322	15724	-866	10203	8023	-1096	-913	-53866
3	88	-19322	-30948	-50269	23586	-1299	17073	12033	-21162	-14496	-68362
4	88	-19322		-19322	31448	-1733	16841	16047	13566	7851	-60711
5	88	-19322		-19322	39311	-2166	18565	20058	19302	9308	-51403
6	88	-19322	-49228	-68549	47173	-2599	22129	24070	-22350	-8982	-60385
7	88	-19322		-19322	55035	-3032	18791	28082	27351	9227	-51158
8	88	-19322	-30948	-50269	62897	-3465	20806	32093	2630	734	-50424
9	88	-19322		-19322	70759	-3898	18707	36105	33491	8254	-42170
10	91	-19980		-19980	78889	-4346	18676	40253	38949	7549	-34621
11	0				78889	-4346	10611	40253	50864	8215	-26407
12	0				78889	-4346	8653	40253	48906	6582	-19824
13	0				78889	-4346	3797	40253	44050	4940	-14884
14	0				78889	-4346	1930	40253	42183	3943	-10941
15	0				78889	-4346	0	40253	40253	3135	-7806
16	-88				71027	-3913	0	36242	36242	2352	-5454
17	-88				63165	-3480	0	32230	32230	1743	-3711
18	-88				55303	-3047	0	28218	28218	1272	-2439
19	-88				47441	-2614	0	24207	24207	909	-1530
20	-88				39579	-2180	0	20195	20195	632	-897
21	-88				31716	-1747	0	16183	16183	422	-475
22	-88				23854	-1314	0	12172	12172	265	-211
23	-88				15992	-881	0	8160	8160	148	-63
24	-88				8130	-448	0	4148	4148	63	0
25	-91				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

E. CWS Burning Gas Turbine Locomotive

ALLOWABLE CAPITAL COST ADDER ($,000) per LOCO = 197.555

RAILROAD - TOTAL LOCO FLEET = 2148 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 565

DCRR VERSUS STANDARD DIESEL = 20.00%

TOTAL FLEET DF2 USED (gal) = 310263302 (Ref)

CASE - DF2 / LOCO (000 gal) = 304.20

BTU / LOCO (10)^10 = 6.19

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 88.354

MAINT COST ADDER(000), AVE/YR OVER LIFE = 4.572

PLANT CAPITAL COST (000) = 55395

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	*INV. TAX CR.+ DEPR	NET EXP. *SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	56	-11063	-34013	-45076	4948	-256	7618	2534	-34924	-34924	-34924
2	56	-11063		-11063	9896	-512	6431	5067	433	363	-34561
3	56	-11063	-21383	-32446	14843	-768	10957	7601	-13888	-9644	-44206
4	56	-11063		-11063	19791	-1024	10576	10134	9647	5583	-38623
5	56	-11063		-11063	24739	-1280	11546	12668	13151	6342	-32280
6	56	-11063	-34013	-45076	29687	-1536	14009	15201	-15865	-6376	-38656
7	56	-11063		-11063	34635	-1792	11703	17733	18375	6154	-32503
8	56	-11063	-21383	-32446	39582	-2048	13095	20269	918	256	-32247
9	56	-11063		-11063	44530	-2304	11645	22802	23384	5438	-26808
10	61	-12051		-12051	49920	-2583	11713	25362	25225	4889	-21920
11	0				49920	-2583	6491	25362	32053	5177	-16743
12	0				49920	-2583	5367	25362	30929	4163	-12580
13	0				49920	-2583	2233	25362	27795	3117	-9463
14	0				49920	-2583	1164	25362	26726	2498	-6965
15	0				49920	-2583	0	25362	25362	1991	-4974
16	-56				44972	-2327	0	23028	23028	1495	-3479
17	-56				40024	-2071	0	20495	20495	1109	-2371
18	-56				35076	-1815	0	17961	17961	810	-1561
19	-56				30129	-1559	0	15428	15428	579	-982
20	-56				25181	-1303	0	12894	12894	404	-578
21	-56				20233	-1047	0	10361	10361	270	-308
22	-56				15285	-791	0	7827	7827	170	-138
23	-56				10337	-535	0	5293	5293	96	-42
24	-56				5390	-279	0	2760	2760	42	0
25	-61				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

E. CWS Burning Gas Turbine Locomotive

UP RAILROAD FIG. NO. 1 ^ 66% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = 235.788

RAILROAD - TOTAL LOCO FLEET = 2569 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 1280

DCRR VERSUS STANDARD DIESEL = 20.00%

TOTAL FLEET DF2 USED (gal) = 465106829 (Ref)

CASE - DF2 / LOCO (000 gal) = 307.66

BTU / LOCO (10)^10 = 6.26

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 89.067

MAINT COST ADDER(000), AVE/YR OVER LIFE = 4.824

PLANT CAPITAL COST (000) = 107531

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	128	-30181	-66024	-96205	11401	-618	16259	5823	-74124	-74124	-74124
2	128	-30181		-30181	22801	-1235	14837	11646	-3699	-3082	-77206
3	128	-30181	-41507	-71688	34202	-1853	24463	17469	-29756	-20664	-97870
4	128	-30181		-30181	45602	-2470	24564	23291	17675	10228	-87641
5	128	-30181		-30181	57003	-3088	27289	29114	26222	12646	-74996
6	128	-30181	-66024	-96205	68403	-3705	32069	34937	-29199	-11734	-86730
7	128	-30181		-30181	79804	-4323	27593	40760	38172	12784	-73947
8	128	-30181	-41507	-71688	91205	-4940	30294	46583	5189	1448	-72499
9	128	-30181		-30181	102605	-5558	27480	52406	49704	11560	-60939
10	128	-30181		-30181	114006	-6175	27289	58228	55336	10725	-50214
11	0				114006	-6175	15810	58228	74039	11958	-38257
12	0				114006	-6175	12756	58228	70984	9554	-28703
13	0				114006	-6175	5831	58228	64059	7185	-21518
14	0				114006	-6175	2915	58228	61144	5715	-15804
15	0				114006	-6175	0	58228	58228	4535	-11268
16	-128				102605	-5558	0	52406	52406	3401	-7867
17	-128				91205	-4940	0	46583	46583	2520	-5347
18	-128				79804	-4323	0	40760	40760	1837	-3510
19	-128				68403	-3705	0	34937	34937	1312	-2198
20	-128				57003	-3088	0	29114	29114	911	-1287
21	-128				45602	-2470	0	23291	23291	608	-679
22	-128				34202	-1853	0	17469	17469	380	-299
23	-128				22801	-1235	0	11646	11646	211	-88
24	-128				11401	-618	0	5823	5823	88	0
25	-128				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

F. CWS Burning Gas Turbine With Steam Injection

SFe RAILROAD FIG. NO. 1 ^15% OF TOTAL FLEET>3000 HP & <15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = 169.305

RAILROAD - TOTAL LOCO FLEET = 3950 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 363

DCRR VERSUS STANDARD DIESEL = 15.00%

TOTAL FLEET DF2 USED (gal) = 652249114 (Ref)

CASE - DF2 / LOCO (000 gal) = 302.20

BTU / LOCO (10)^10 = 5.17

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 115.289

MAINT COST ADDER(000), AVE/YR OVER LIFE = 34.512

PLANT CAPITAL COST (000) = 33684

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	36	-6095	-24642	-30737	4150	-1242	5195	1570	-23972	-23972	-23972
2	36	-6095	-3960	-10055	8	-2485	4810	-1338	-6583	-5724	-29696
3	36	-6095	-16962	-23057	12451	-3727	7883	4711	-10463	-7911	-37607
4	36	-6095	-3960	-10055	16602	-4970	7973	6281	4199	2761	-34846
5	36	-6095	-3960	-10055	20752	-6212	8885	7852	6681	3820	-31026
6	36	-6095	-24642	-30737	24902	-7455	10382	9422	-10933	-5436	-36462
7	36	-6095	-3960	-10055	29053	-8697	8980	10992	9917	4287	-32175
8	36	-6095	-16962	-23057	33203	-9939	9826	12562	-669	-251	-32426
9	36	-6095	-3960	-10055	37354	-11182	8944	14133	13022	4257	-28169
10	39	-6603	-4290	-10893	41850	-12528	9026	15834	13967	3970	-24198
11	0				41850	-12528	5272	15834	21106	5217	-18981
12	0				41850	-12528	4251	15834	20085	4317	-14664
13	0				41850	-12528	2024	15834	17857	3338	-11327
14	0				41850	-12528	1052	15834	16886	2744	-8582
15	0				41850	-12528	0	15834	15834	2238	-6344
16	-36				37700	-11285	0	14264	14264	1753	-4591
17	-36				33549	-10043	0	12693	12693	1356	-3235
18	-36				29399	-8801	0	11123	11123	1034	-2201
19	-36				25248	-7558	0	9553	9553	772	-1429
20	-36				21098	-6316	0	7982	7982	561	-868
21	-36				16947	-5073	0	6412	6412	392	-477
22	-36				12797	-3831	0	4842	4842	257	-219
23	-36				8647	-2588	0	3271	3271	151	-68
24	-36				4496	-1346	0	1701	1701	68	0
25	-39				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

F. CWS Burning Gas Turbine With Steam Injection

BN RAILROAD FIG. NO. 1 ^15% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = 273.870

RAILROAD - TOTAL LOCO FLEET = 2593 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 281

DCRR VERSUS STANDARD DIESEL = 15.00%

TOTAL FLEET DF2 USED (gal) = 514750379 (Ref)

CASE - DF2 / LOCO (000 gal) = 418.90

BTU / LOCO (10)^10 = 7.17

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 149.190

MAINT COST ADDER(000), AVE/YR OVER LIFE = 45.599

PLANT CAPITAL COST (000) = 35638

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	28	-7668	-24962	-32630	4177	-1277	5515	1566	-25549	-25549	-25549
2	28	-7668	-3080	-10748	8355	-2554	5119	3133	-2497	-2171	-27721
3	28	-7668	-16836	-24505	12532	-3830	8381	4699	-11425	-8639	-36359
4	28	-7668	-3080	-10748	16709	-5107	8487	6265	4004	2632	-33727
5	28	-7668	-3080	-10748	20887	-6384	9462	7832	6545	3742	-29985
6	28	-7668	-24962	-32630	25064	-7661	11046	9398	-12186	-6059	-36044
7	28	-7668	-3080	-10748	29241	-8937	9562	10964	9778	4227	-31816
8	28	-7668	-16836	-24505	33419	-10214	10458	12530	-1517	-570	-32386
9	28	-7668	-3080	-10748	37596	-11491	9525	14097	12873	4208	-28178
10	29	-7942	-3190	-11132	41923	-12813	9527	15719	14113	4012	-24166
11	0				41923	-12813	5570	15719	21289	5262	-18904
12	0				41923	-12813	4481	15719	20200	4342	-14562
13	0				41923	-12813	2114	15719	17833	3333	-11229
14	0				41923	-12813	1075	15719	16794	2730	-8499
15	0				41923	-12813	0	15719	15719	2222	-6278
16	-28				37745	-11536	0	14153	14153	1739	-4539
17	-28				33568	-10260	0	12586	12586	1345	-3193
18	-28				29391	-8983	0	11020	11020	1024	-2169
19	-28				25213	-7706	0	9454	9454	764	-1405
20	-28				21036	-6429	0	7887	7887	554	-851
21	-28				16859	-5153	0	6321	6321	386	-465
22	-28				12681	-3876	0	4755	4755	253	-212
23	-28				8504	-2599	0	3189	3189	147	-65
24	-28				4327	-1322	0	1622	1622	65	0
25	-29				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

F. CWS Burning Gas Turbine With Steam Injection

CR RAILROAD FIG. NO. 1 ^ 7% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = 151.800

RAILROAD - TOTAL LOCO FLEET = 2447 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 111

DCRR VERSUS STANDARD DIESEL = 15.00%

TOTAL FLEET DF2 USED (gal) = 290376555 (Ref)

CASE - DF2 / LOCO (000 gal) = 315.30

BTU / LOCO (10)^10 = 5.39

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 119.095

MAINT COST ADDER(000), AVE/YR OVER LIFE = 35.757

PLANT CAPITAL COST (000) = 13505

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV.. CR.+	TAX DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	11	-1670	-9502	-11172	1310	-393	1888	495	-8789	-8789	-8789	
2	11	-1670	-1210	-2880	2620	-787	1617	990	-272	-237	-9026	
3	11	-1670	-6423	-8093	3930	-1180	2738	1485	-3869	-2926	-11952	
4	11	-1670	-1210	-2880	5240	-1573	2663	1980	1763	1159	-10792	
5	11	-1670	-1210	-2880	6550	-1967	2917	2475	2513	1437	-9356	
6	11	-1670	-9502	-11172	7860	-2360	3518	2970	-4684	-2329	-11684	
7	11	-1670	-1210	-2880	9170	-2753	2955	3465	3541	1531	-10154	
8	11	-1670	-6423	-8093	10480	-3147	3295	3960	-838	-315	-10469	
9	11	-1670	-1210	-2880	11790	-3540	2941	4455	4517	1477	-8992	
10	12	-1822	-1320	-3142	13220	-3969	2962	4995	4815	1369	-7623	
11	0				13220	-3969	1656	4995	6651	1644	-5979	
12	0				13220	-3969	1363	4995	6359	1367	-4612	
13	0				13220	-3969	582	4995	5577	1042	-3570	
14	0				13220	-3969	303	4995	5299	861	-2709	
15	0				13220	-3969	0	4995	4995	706	-2003	
16	-11				11909	-3576	0	4500	4500	553	-1450	
17	-11				10599	-3182	0	4005	4005	428	-1022	
18	-11				9289	-2789	0	3510	3510	326	-696	
19	-11				7979	-2396	0	3015	3015	244	-452	
20	-11				6669	-2002	0	2520	2520	177	-275	
21	-11				5359	-1609	0	2025	2025	124	-151	
22	-11				4049	-1216	0	1530	1530	81	-70	
23	-11				2739	-822	0	1035	1035	48	-22	
24	-11				1429	-429	0	540	540	22	0	
25	-12				0	0	0	0	0	0	0	

VIII. ECONOMIC ANALYSIS

F. CWS Burning Gas Turbine With Steam Injection

CSX RAILROAD FIG. NO. 1 ^ 7% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = 228.600

RAILROAD - TOTAL LOCO FLEET = 3218 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 200

DCRR VERSUS STANDARD DIESEL = 15.00%

TOTAL FLEET DF2 USED (gal) = 462417920 (Ref)

CASE - DF2 / LOCO (000 gal) = 382.00

BTU / LOCO (10)^10 = 6.54

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 138.471

MAINT COST ADDER(000), AVE/YR OVER LIFE = 42.093

PLANT CAPITAL COST (000) = 25220

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. CR.+ DEPR	TAX NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	20	-4572	-17685	-22257	2769	-842	3761	1041	-17455	-17455	-17455
2	20	-4572	-2200	-6772	5539	-1684	3397	2082	-1293	-1125	-18579
3	20	-4572	-11935	-16507	8308	-2526	5625	3123	-7759	-5867	-24446
4	20	-4572	-2200	-6772	11078	-3367	5619	4164	3011	1980	-22467
5	20	-4572	-2200	-6772	13847	-4209	6229	5204	4661	2665	-19802
6	20	-4572	-17685	-22257	16617	-5051	7350	6245	-8662	-4306	-24108
7	20	-4572	-2200	-6772	19386	-5893	6300	7286	6814	2946	-21162
8	20	-4572	-11935	-16507	22155	-6735	6933	8327	-1246	-469	-21631
9	20	-4572	-2200	-6772	24925	-7577	6273	9368	8869	2899	-18732
10	20	-4572	-2200	-6772	27694	-8419	6229	10409	9865	2804	-15927
11	0				27694	-8419	3588	10409	13997	3460	-12467
12	0				27694	-8419	2903	10409	13312	2861	-9606
13	0				27694	-8419	1308	10409	11717	2190	-7416
14	0				27694	-8419	654	10409	11063	1798	-5618
15	0				27694	-8419	0	10409	10409	1471	-4147
16	-20				24925	-7577	0	9368	9368	1151	-2996
17	-20				22155	-6735	0	8327	8327	890	-2106
18	-20				19386	-5893	0	7286	7286	677	-1429
19	-20				16617	-5051	0	6245	6245	505	-924
20	-20				13847	-4209	0	5204	5204	366	-558
21	-20				11078	-3367	0	4164	4164	254	-304
22	-20				8308	-2526	0	3123	3123	166	-138
23	-20				5539	-1684	0	2082	2082	96	-42
24	-20				2769	-842	0	1041	1041	42	0
25	-20				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

F. CWS Burning Gas Turbine With Steam Injection

NS RAILROAD FIG. NO. 1 ^ 7% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = 178.370

RAILROAD - TOTAL LOCO FLEET = 2148 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 128

DCRR VERSUS STANDARD DIESEL = 15.00%

TOTAL FLEET DF2 USED (gal) = 310263302 (Ref)

CASE - DF2 / LOCO (000 gal) = 361.50

BTU / LOCO (10)^10 = 6.18

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 132.516

MAINT COST ADDER(000), AVE/YR OVER LIFE = 40.146

PLANT CAPITAL COST (000) = 16886

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	12	-2140	-11688	-13828	1590	-482	2337	599	-10893	-10893	-10893
2	12	-2140	-1320	-3460	3180	-963	1984	1197	-279	-243	-11135
3	12	-2140	-7838	-9978	4771	-1445	3372	1796	-4810	-3637	-14773
4	12	-2140	-1320	-3460	6361	-1927	3265	2394	2198	1446	-13327
5	12	-2140	-1320	-3460	7951	-2409	3569	2993	3101	1773	-11554
6	12	-2140	-11688	-13828	9541	-2890	4320	3591	-5917	-2942	-14496
7	12	-2140	-1320	-3460	11131	-3372	3617	4190	4346	1879	-12617
8	12	-2140	-7838	-9978	12722	-3854	4041	4788	-1149	-432	-13049
9	12	-2140	-1320	-3460	14312	-4336	3599	5387	5526	1806	-11242
10	20	-3367	-2200	-5767	16962	-5139	3959	6385	4576	1301	-9942
11	0				16962	-5139	2216	6385	8601	2126	-7816
12	0				16962	-5139	1855	6385	8240	1771	-6045
13	0				16962	-5139	891	6385	7276	1360	-4685
14	0				16962	-5139	557	6385	6942	1128	-3556
15	0				16962	-5139	0	6385	6385	902	-2654
16	-12				15372	-4657	0	5786	5786	711	-1943
17	-12				13782	-4175	0	5188	5188	554	-1389
18	-12				12191	-3693	0	4589	4589	426	-962
19	-12				10601	-3212	0	3990	3990	322	-640
20	-12				9011	-2730	0	3392	3392	238	-401
21	-12				7421	-2248	0	2793	2793	171	-231
22	-12				5831	-1766	0	2195	2195	117	-114
23	-12				4241	-1285	0	1596	1596	74	-40
24	-12				2650	-803	0	998	998	40	0
25	-20				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

F. CWS Burning Gas Turbine With Steam Injection

UP RAILROAD FIG. NO. 1 * 15% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = 215.105

RAILROAD - TOTAL LOCO FLEET = 2569 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 289

DCRR VERSUS STANDARD DIESEL = 15.00%

TOTAL FLEET DF2 USED (gal) = 465106829 (Ref)

CASE - DF2 / LOCO (000 gal) = 338.70

BTU / LOCO (10)^10 = 8.79

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 125.892

MAINT COST ADDER(000), AVE/YR OVER LIFE = 37.980

PLANT CAPITAL COST (000) = 30749

INVESTMENT DEPRECIATION SCHEDULE

YEAR	1	15.00%
	2	22.00%
	3	21.00%
	4	21.00%
	5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	28	-6023	-21960	-27983	3525	-1063	4729	1329	-21925	-21925	-21925
2	28	-6023	-3080	-9103	7050	-2127	4370	2658	-2074	-1804	-23728
3	28	-6023	-14949	-20972	10575	-3190	7169	3988	-9816	-7422	-31150
4	28	-6023	-3080	-9103	14100	-4254	7243	5317	3457	2273	-28877
5	28	-6023	-3080	-9103	17625	-5317	8068	6646	5611	3208	-25669
6	28	-6023	-21960	-27983	21150	-6381	9435	7975	-10573	-5256	-30925
7	28	-6023	-3080	-9103	24675	-7444	8135	9305	8357	3613	-27312
8	28	-6023	-14949	-20972	28200	-8507	8927	10634	-1411	-530	-27843
9	28	-6023	-3080	-9103	31725	-9571	8123	11963	10983	3590	-24252
10	37	-7959	-4070	-12029	36383	-10976	8562	13720	10253	2915	-21338
11	0				36383	-10976	5002	13720	18722	4628	-16710
12	0				36383	-10976	4067	13720	17787	3823	-12887
13	0				36383	-10976	2041	13720	15761	2946	-9941
14	0				36383	-10976	1162	13720	14882	2419	-7522
15	0				36383	-10976	0	13720	13720	1939	-5583
16	-28				32858	-9913	0	12390	12390	1523	-4061
17	-28				29333	-8849	0	11061	11061	1182	-2879
18	-28				25808	-7786	0	9732	9732	904	-1974
19	-28				22283	-6722	0	8403	8403	679	-1295
20	-28				18758	-5659	0	7073	7073	497	-798
21	-28				15233	-4596	0	5744	5744	351	-447
22	-28				11708	-3532	0	4415	4415	235	-213
23	-28				8183	-2469	0	3086	3086	143	-70
24	-28				4658	-1405	0	1756	1756	71	0
25	-37				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

F. CWS Burning Gas Turbine With Steam Injection

SFe RAILROAD FIG. NO. 1 ^ 15% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = 84.840

RAILROAD - TOTAL LOCO FLEET = 3950 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 363

DCRR VERSUS STANDARD DIESEL = 20.00%

TOTAL FLEET DF2 USED (gal) = 652249114 (Ref)

CASE - DF2 / LOCO (000 gal) = 302.20

BTU / LOCO (10)^10 = 5.17

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 115.289

MAINT COST ADDER(000), AVE/YR OVER LIFE = 34.512

PLANT CAPITAL COST (000) = 33684

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	36	-3054	-24642	-27696	4150	-1242	4681	1570	-21445	-21445	-21445
2	36	-3054	-3960	-7014	8301	-2485	3988	3141	115	96	-21350
3	36	-3054	-16962	-20016	12451	-3727	6768	4711	-8537	-5929	-27278
4	36	-3054	-3960	-7014	16602	-4970	6564	6281	5831	3374	-23904
5	36	-3054	-3960	-7014	20752	-6212	7182	7852	8019	3867	-20037
6	36	-3054	-24642	-27696	24902	-7455	8679	9422	-9595	-3856	-23893
7	36	-3054	-3960	-7014	29053	-8697	7277	10992	11255	3769	-20123
8	36	-3054	-16962	-20016	33203	-9939	8123	12562	669	187	-19937
9	36	-3054	-3960	-7014	37354	-11182	7242	14133	14360	3340	-16597
10	39	-3309	-4290	-7599	41850	-12528	7281	15834	15516	3007	-13590
11	0				41850	-12528	4058	15834	19892	3213	-10377
12	0				41850	-12528	3345	15834	19179	2581	-7796
13	0				41850	-12528	1412	15834	17246	1934	-5862
14	0				41850	-12528	734	15834	16568	1549	-4313
15	0				41850	-12528	0	15834	15834	1233	-3080
16	-36				37700	-11285	0	14264	14264	926	-2154
17	-36				33549	-10043	0	12693	12693	687	-1468
18	-36				29399	-8801	0	11123	11123	501	-966
19	-36				25248	-7558	0	9553	9553	359	-608
20	-36				21098	-6316	0	7982	7982	250	-358
21	-36				16947	-5073	0	6412	6412	167	-190
22	-36				12797	-3831	0	4842	4842	105	-85
23	-36				8647	-2588	0	3271	3271	59	-26
24	-36				4496	-1346	0	1701	1701	26	0
25	-39				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

F. CWS Burning Gas Turbine With Steam Injection

BN RAILROAD FIG. NO. 1 * 15% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = 121.450

RAILROAD - TOTAL LOCO FLEET = 2593 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 281

DCRR VERSUS STANDARD DIESEL = 20.00%

TOTAL FLEET DF2 USED (gal) = 514750379 (Ref)

CASE - DF2 / LOCO (000 gal) = 418.90

BTU / LOCO (10)^10 = 7.17

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 149.190

MAINT COST ADDER(000), AVE/YR OVER LIFE = 45.599

PLANT CAPITAL COST (000) = 35638

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	28	-3401	-24962	-28362	4177	-1277	4793	1566	-22003	-22003	-22003
2	28	-3401	-3080	-6481	8355	-2554	3966	3133	618	515	-21488
3	28	-3401	-16836	-20237	12532	-3830	6816	4699	-8722	-6057	-27545
4	28	-3401	-3080	-6481	16709	-5107	6509	6265	6294	3642	-23903
5	28	-3401	-3080	-6481	20887	-6384	7072	7832	8423	4062	-19841
6	28	-3401	-24962	-28362	25064	-7661	8656	9398	-10309	-4143	-23984
7	28	-3401	-3080	-6481	29241	-8937	7172	10964	11656	3904	-20081
8	28	-3401	-16836	-20237	33419	-10214	8068	12530	361	101	-19980
9	28	-3401	-3080	-6481	37596	-11491	7135	14097	14751	3431	-16549
10	29	-3522	-3190	-6712	41923	-12813	7111	15719	16118	3124	-13425
11	0				41923	-12813	3886	15719	19605	3166	-10259
12	0				41923	-12813	3229	15719	18948	2550	-7709
13	0				41923	-12813	1274	15719	16993	1906	-5803
14	0				41923	-12813	648	15719	16367	1530	-4273
15	0				41923	-12813	0	15719	15719	1224	-3049
16	-28				37745	-11536	0	14153	14153	919	-2130
17	-28				33568	-10260	0	12586	12586	681	-1449
18	-28				29391	-8983	0	11020	11020	497	-953
19	-28				25213	-7706	0	9454	9454	355	-598
20	-28				21036	-6429	0	7887	7887	247	-351
21	-28				16859	-5153	0	6321	6321	165	-186
22	-28				12681	-3876	0	4755	4755	103	-82
23	-28				8504	-2599	0	3189	3189	58	-25
24	-28				4327	-1322	0	1622	1622	24	0
25	-29				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

F. CWS Burning Gas Turbine With Steam Injection

CR RAILROAD FIG. NO. 1 ^ 7% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = 26.800

RAILROAD - TOTAL LOCO FLEET = 2447 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 111

DCRR VERSUS STANDARD DIESEL = 20.00%

TOTAL FLEET DF2 USED (gal) = 290376555 (Ref)

CASE - DF2 / LOCO (000 gal) = 315.30

BTU / LOCO (10)^10 = 5.39

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 119.095

MAINT COST ADDER(000), AVE/YR OVER LIFE = 35.757

PLANT CAPITAL COST (000) = 13505

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	11	-295	-9502	-9797	1310	-393	1656	495	-7646	-7646	-7646
2	11	-295	-1210	-1505	2620	-787	1246	990	731	609	-7037
3	11	-295	-6423	-6718	3930	-1180	2234	1485	-2999	-2082	-9120
4	11	-295	-1210	-1505	5240	-1573	2026	1980	2501	1447	-7672
5	11	-295	-1210	-1505	6550	-1967	2147	2475	3118	1503	-6169
6	11	-295	-9502	-9797	7860	-2360	2748	2970	-4079	-1639	-7808
7	11	-295	-1210	-1505	9170	-2753	2185	3465	4146	1388	-6419
8	11	-295	-6423	-6718	10480	-3147	2525	3960	-233	-65	-6484
9	11	-295	-1210	-1505	11790	-3540	2171	4455	5122	1191	-5293
10	12	-322	-1320	-1642	13220	-3969	2170	4995	5524	1071	-4223
11	0				13220	-3969	1106	4995	6101	985	-3237
12	0				13220	-3969	953	4995	5948	801	-2437
13	0				13220	-3969	304	4995	5299	594	-1842
14	0				13220	-3969	159	4995	5154	482	-1361
15	0				13220	-3969	0	4995	4995	389	-972
16	-11				11909	-3576	0	4500	4500	292	-680
17	-11				10599	-3182	0	4005	4005	217	-463
18	-11				9289	-2789	0	3510	3510	158	-305
19	-11				7979	-2396	0	3015	3015	113	-191
20	-11				6669	-2002	0	2520	2520	79	-113
21	-11				5359	-1609	0	2025	2025	53	-60
22	-11				4049	-1216	0	1530	1530	33	-27
23	-11				2739	-822	0	1035	1035	19	-8
24	-11				1429	-429	0	540	540	8	0
25	-12				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

F. CWS Burning Gas Turbine With Steam Injection

CSX RAILROAD FIG. NO. 1 ^ 7% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = 86.050

RAILROAD - TOTAL LOCO FLEET = 3218 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 200

DCRR VERSUS STANDARD DIESEL = 20.00%

TOTAL FLEET DF2 USED (gal) = 462417920 (Ref)

CASE - DF2 / LOCO (000 gal) = 382.00

BTU / LOCO (10)^10 = 6.54

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 138.471

MAINT COST ADDER(000), AVE/YR OVER LIFE = 42.093

PLANT CAPITAL COST (000) = 25220

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	20	-1721	-17685	-19406	2769	-842	3280	1041	-15085	-15085	-15085
2	20	-1721	-2200	-3921	5539	-1684	2627	2082	787	656	-14429
3	20	-1721	-11935	-13656	8308	-2526	4579	3123	-5954	-4135	-18564
4	20	-1721	-2200	-3921	11078	-3367	4298	4164	4541	2628	-15936
5	20	-1721	-2200	-3921	13847	-4209	4632	5204	5915	2853	-13084
6	20	-1721	-17685	-19406	16617	-5051	5753	6245	-7407	-2977	-16060
7	20	-1721	-2200	-3921	19386	-5893	4703	7286	8068	2702	-13358
8	20	-1721	-11935	-13656	22155	-6735	5337	8327	8	2	-13356
9	20	-1721	-2200	-3921	24925	-7577	4677	9368	10124	2354	-11002
10	20	-1721	-2200	-3921	27694	-8419	4632	10409	11120	2155	-8847
11	0				27694	-8419	2473	10409	12882	2081	-6766
12	0				27694	-8419	2077	10409	12486	1680	-5086
13	0				27694	-8419	758	10409	11166	1252	-3833
14	0				27694	-8419	379	10409	10788	1008	-2825
15	0				27694	-8419	0	10409	10409	811	-2014
16	-20				24925	-7577	0	9368	9368	608	-1406
17	-20				22155	-6735	0	8327	8327	450	-956
18	-20				19386	-5893	0	7286	7286	328	-627
19	-20				16617	-5051	0	6245	6245	235	-393
20	-20				13847	-4209	0	5204	5204	163	-230
21	-20				11078	-3367	0	4164	4164	109	-121
22	-20				8308	-2526	0	3123	3123	68	-53
23	-20				5539	-1684	0	2082	2082	38	-16
24	-20				2769	-842	0	1041	1041	16	0
25	-20				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

F. CWS Burning Gas Turbine With Steam Injection

NS RAILROAD FIG. NO. 1 ~ 7% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = 37.740

RAILROAD - TOTAL LOCO FLEET = 2148 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 128

DCRR VERSUS STANDARD DIESEL = 20.00%

TOTAL FLEET DF2 USED (gal) = 310263302 (Ref)

CASE - DF2 / LOCO (000 gal) = 361.50

BTU / LOCO (10)^10 = 6.18

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 132.516

MAINT COST ADDER(000), AVE/YR OVER LIFE = 40.146

PLANT CAPITAL COST (000) = 16886

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	12	-453	-11688	-12141	1590	-482	2052	599	-9490	-9490	-9490
2	12	-453	-1320	-1773	3180	-963	1528	1197	952	794	-8697
3	12	-453	-7838	-8291	4771	-1445	2753	1796	-3742	-2598	-11295
4	12	-453	-1320	-1773	6361	-1927	2483	2394	3104	1796	-9499
5	12	-453	-1320	-1773	7951	-2409	2624	2993	3844	1854	-7645
6	12	-453	-11688	-12141	9541	-2890	3375	3591	-5175	-2080	-9725
7	12	-453	-1320	-1773	11131	-3372	2672	4190	5089	1704	-8020
8	12	-453	-7838	-8291	12722	-3854	3096	4788	-406	-113	-8134
9	12	-453	-1320	-1773	14312	-4336	2654	5387	6268	1458	-6676
10	20	-755	-2200	-2955	16962	-5139	2824	6385	6254	1212	-5464
11	0				16962	-5139	1442	6385	7827	1264	-4200
12	0				16962	-5139	1258	6385	7642	1029	-3171
13	0				16962	-5139	457	6385	6841	767	-2404
14	0				16962	-5139	285	6385	6670	623	-1781
15	0				16962	-5139	0	6385	6385	497	-1283
16	-12				15372	-4657	0	5786	5786	376	-908
17	-12				13782	-4175	0	5188	5188	281	-627
18	-12				12191	-3693	0	4589	4589	207	-420
19	-12				10601	-3212	0	3990	3990	150	-271
20	-12				9011	-2730	0	3392	3392	106	-164
21	-12				7421	-2248	0	2793	2793	73	-92
22	-12				5831	-1766	0	2195	2195	48	-44
23	-12				4241	-1285	0	1596	1596	29	-15
24	-12				2650	-803	0	998	998	15	0
25	-20				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

F. CWS Burning Gas Turbine With Steam Injection

UP RAILROAD FIG. NO. 1 ^ 15% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = 84.920

RAILROAD - TOTAL LOCO FLEET = 2569 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 289

DCRR VERSUS STANDARD DIESEL = 20.00%

TOTAL FLEET DF2 USED (gal) = 465106829 (Ref)

CASE - DF2 / LOCO (000 gal) = 338.70

BTU / LOCO (10)^10 = 5.79

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 125.892

MAINT COST ADDER(000), AVE/YR OVER LIFE = 37.980

PLANT CAPITAL COST (000) = 30749

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	28	-2378	-21960	-24338	3525	-1063	4113	1329	-18895	-18895	-18895
2	28	-2378	-3080	-5458	7050	-2127	3385	2658	586	488	-18407
3	28	-2378	-14949	-17327	10575	-3190	5832	3988	-7508	-5214	-23621
4	28	-2378	-3080	-5458	14100	-4254	5554	5317	5413	3133	-20488
5	28	-2378	-3080	-5458	17625	-5317	6027	6646	7215	3480	-17008
6	28	-2378	-21960	-24338	21150	-6381	7394	7975	-8969	-3604	-20613
7	28	-2378	-3080	-5458	24675	-7444	6114	9305	9960	3336	-17277
8	28	-2378	-14949	-17327	28200	-8507	6886	10634	193	54	-17223
9	28	-2378	-3080	-5458	31725	-9571	6081	11963	12587	2927	-14296
10	37	-3142	-4070	-7212	36383	-10976	6323	13720	12831	2487	-11809
11	0				36383	-10976	3458	13720	17178	2774	-9035
12	0				36383	-10976	2898	13720	16617	2236	-6798
13	0				36383	-10976	1224	13720	14944	1676	-5122
14	0				36383	-10976	697	13720	14416	1347	-3775
15	0				36383	-10976	0	13720	13720	1069	-2706
16	-28				32858	-9913	0	12390	12390	804	-1902
17	-28				29333	-8849	0	11061	11061	598	-1304
18	-28				25808	-7786	0	9732	9732	439	-865
19	-28				22283	-6722	0	8403	8403	316	-550
20	-28				18758	-5659	0	7073	7073	221	-328
21	-28				15233	-4596	0	5744	5744	150	-178
22	-28				11708	-3532	0	4415	4415	96	-82
23	-28				8183	-2469	0	3086	3086	56	-26
24	-28				4658	-1405	0	1756	1756	27	0
25	-37				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

G. ROM Coal Gasifier Gas Turbine

SFe RAILROAD FIG. NO. 1 ^ 13% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = -169.392

RAILROAD - TOTAL LOCO FLEET = 3950 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 307

DCRR VERSUS STANDARD DIESEL = 15.00%

TOTAL FLEET DF2 USED (gal) = 652249114 (Ref)

CASE - DF2 / LOCO (000 gal) = 302.20

BTU / LOCO (10)^10 = 6.53

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 115.461

MAINT COST ADDER(000), AVE/YR OVER LIFE = 80.225

PLANT CAPITAL COST (000) = 123160

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	30	5082	-14156	-9074	3464	-2407	1534	571	-6970	-6970	-6970
2	30	5082	-11520	-6438	6928	-4813	2006	1142	-3290	-2861	-9831
3	30	5082	-11520	-6438	10391	-7220	2616	1712	-2110	-1595	-11426
4	30	5082	-11520	-6438	13855	-9627	3238	2283	-917	-603	-12029
5	30	5082	-11520	-6438	17319	-12034	3860	2854	276	158	-11871
6	30	5082	-11520	-6438	20783	-14440	3605	3425	592	294	-11577
7	30	5082	-11520	-6438	24247	-16847	3605	3996	1163	503	-11074
8	30	5082	-11520	-6438	27711	-19254	3605	4567	1734	652	-10422
9	30	5082	-12838	-7756	31174	-21661	3828	5137	1209	395	-10027
10	37	6268	-14208	-7940	35446	-24629	3993	5841	1894	538	-9489
11	0				35446	-24629	2797	5841	8638	2135	-7353
12	0				35446	-24629	2138	5841	7980	1715	-5638
13	0				35446	-24629	1516	5841	7358	1375	-4263
14	0				35446	-24629	767	5841	6608	1074	-3189
15	0				35446	-24629	0	5841	5841	826	-2363
16	-30				31983	-22222	0	5271	5271	648	-1716
17	-30				28519	-19816	0	4700	4700	502	-1214
18	-30				25055	-17409	0	4129	4129	384	-830
19	-30				21591	-15002	0	3558	3558	288	-542
20	-30				18127	-12595	0	2987	2987	210	-332
21	-30				14663	-10189	0	2416	2416	148	-185
22	-30				11200	-7782	0	1846	1846	98	-87
23	-30				7736	-5375	0	1275	1275	59	-28
24	-30				4272	-2968	0	704	704	28	0
25	-37				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

G. ROM Coal Gasifier Gas Turbine

BN RAILROAD FIG. NO. 1 ^ 13% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = 189.125

RAILROAD - TOTAL LOCO FLEET = 2593 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 237

DCRR VERSUS STANDARD DIESEL = 15.00%

TOTAL FLEET DF2 USED (gal) = 514750379 (Ref)

CASE - DF2 / LOCO (000 gal) = 418.90

BTU / LOCO (10)^10 = 9.05

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 185.247

MAINT COST ADDER(000), AVE/YR OVER LIFE = 95.279

PLANT CAPITAL COST (000) = 93644

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	23	-4350	-11468	-15818	4261	-2191	2673	1117	-12027	-12027	-12027
2	23	-4350	-8832	-13182	8521	-4383	3829	2235	-7119	-6190	-18217
3	23	-4350	-8832	-13182	12782	-6574	5090	3352	-4740	-3584	-21801
4	23	-4350	-8832	-13182	17043	-8766	6363	4470	-2349	-1545	-23346
5	23	-4350	-8832	-13182	21303	-10957	7636	5587	42	24	-23322
6	23	-4350	-8832	-13182	25564	-13149	7382	6704	904	450	-22873
7	23	-4350	-8832	-13182	29825	-15340	7382	7822	2022	874	-21998
8	23	-4350	-8832	-13182	34085	-17531	7382	8939	3139	1180	-20818
9	23	-4350	-8832	-13182	38346	-19723	7382	10057	4257	1391	-19427
10	30	-5674	-11520	-17194	43904	-22581	8060	11514	2380	677	-18750
11	0				43904	-22581	5560	11514	17074	4220	-14530
12	0				43904	-22581	4208	11514	15722	3379	-11150
13	0				43904	-22581	2934	11514	14448	2701	-8450
14	0				43904	-22581	1661	11514	13175	2141	-6309
15	0				43904	-22581	0	11514	11514	1627	-4681
16	-23				39643	-20390	0	10397	10397	1278	-3404
17	-23				35382	-18198	0	9279	9279	992	-2412
18	-23				31122	-16007	0	8162	8162	758	-1654
19	-23				26861	-13815	0	7045	7045	569	-1084
20	-23				22600	-11624	0	5927	5927	416	-668
21	-23				18339	-9433	0	4810	4810	294	-374
22	-23				14079	-7241	0	3692	3692	196	-178
23	-23				9818	-5050	0	2575	2575	119	-59
24	-23				5557	-2858	0	1457	1457	59	0
25	-30				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

G. ROM Coal Gasifier Gas Turbine

CR RAILROAD FIG. NO. 1 ^ 6% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = -161.070

RAILROAD - TOTAL LOCO FLEET = 2447 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 94

DCRR VERSUS STANDARD DIESEL = 15.00%

TOTAL FLEET DF2 USED (gal) = 290376555 (Ref)

CASE - DF2 / LOCO (000 gal) = 315.30

BTU / LOCO (10)^10 = 6.81

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 123.294

MAINT COST ADDER(000), AVE/YR OVER LIFE = 81.915

PLANT CAPITAL COST (000) = 38732

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	9	1450	-6092	-4642	1110	-737	785	201	-3657	-3657	-3657
2	9	1450	-3456	-2006	2219	-1474	809	402	-795	-692	-4348
3	9	1450	-3456	-2006	3329	-2212	991	603	-412	-312	-4660
4	9	1450	-3456	-2006	4439	-2949	1184	804	-18	-12	-4672
5	9	1450	-3456	-2006	5548	-3686	1378	1006	377	216	-4456
6	9	1450	-3456	-2006	6658	-4423	1124	1207	324	161	-4295
7	9	1450	-3456	-2006	7768	-5161	1124	1408	525	227	-4068
8	9	1450	-3456	-2006	8877	-5898	1124	1609	726	273	-3795
9	9	1450	-3456	-2006	9987	-6635	1124	1810	927	303	-3492
10	13	2094	-4992	-2898	11590	-7700	1274	2100	477	135	-3356
11	0				11590	-7700	875	2100	2975	735	-2621
12	0				11590	-7700	668	2100	2768	595	-2026
13	0				11590	-7700	474	2100	2574	481	-1545
14	0				11590	-7700	280	2100	2380	387	-1158
15	0				11590	-7700	0	2100	2100	297	-861
16	-9				10480	-6963	0	1899	1899	233	-628
17	-9				9370	-6226	0	1698	1698	181	-446
18	-9				8261	-5488	0	1497	1497	139	-307
19	-9				7151	-4751	0	1296	1296	105	-202
20	-9				6041	-4014	0	1095	1095	77	-126
21	-9				4932	-3277	0	894	894	55	-71
22	-9				3822	-2539	0	693	693	37	-34
23	-9				2712	-1802	0	492	492	23	-11
24	-9				1603	-1065	0	290	290	12	0
25	-13				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

G. ROM Coal Gasifier Gas Turbine

CSX RAILROAD FIG. NO. 1 ~ 6% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = 66.900

RAILROAD - TOTAL LOCO FLEET = 3218 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 169

DCRR VERSUS STANDARD DIESEL = 15.00%

TOTAL FLEET DF2 USED (gal) = 462417920 (Ref)

CASE - DF2 / LOCO (000 gal) = 382.00

BTU / LOCO (10)^10 = 8.25

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 163.181

MAINT COST ADDER(000), AVE/YR OVER LIFE = 90.519

PLANT CAPITAL COST (000) = 67532

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	16	-1070	-8780	-9850	2611	-1448	1665	628	-7558	-7558	-7558
2	16	-1070	-6144	-7214	5222	-2897	2216	1256	-3743	-3255	-10812
3	16	-1070	-6144	-7214	7833	-4345	2901	1883	-2430	-1838	-12650
4	16	-1070	-6144	-7214	10444	-5793	3598	2511	-1105	-727	-13377
5	16	-1070	-6144	-7214	13054	-7242	4295	3139	219	125	-13251
6	16	-1070	-6144	-7214	15665	-8690	4040	3767	592	295	-12957
7	16	-1070	-6144	-7214	18276	-10138	4040	4395	1220	528	-12429
8	16	-1070	-6144	-7214	20887	-11586	4040	5022	1848	695	-11735
9	16	-1070	-6144	-7214	23498	-13035	4040	5650	2476	809	-10925
10	25	-1673	-9600	-11273	27578	-15298	4726	6631	85	24	-10901
11	0				27578	-15298	3232	6631	9863	2438	-8463
12	0				27578	-15298	2483	6631	9114	1959	-6504
13	0				27578	-15298	1786	6631	8417	1573	-4931
14	0				27578	-15298	1089	6631	7720	1255	-3676
15	0				27578	-15298	0	6631	6631	937	-2739
16	-16				24967	-13849	0	6003	6003	738	-2001
17	-16				22356	-12401	0	5376	5376	574	-1427
18	-16				19745	-10953	0	4748	4748	441	-986
19	-16				17134	-9504	0	4120	4120	333	-653
20	-16				14523	-8056	0	3492	3492	245	-407
21	-16				11912	-6608	0	2864	2864	175	-232
22	-16				9301	-5160	0	2237	2237	119	-114
23	-16				6690	-3711	0	1609	1609	74	-39
24	-16				4080	-2263	0	981	981	39	0
25	-25				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

G. ROM Coal Gasifier Gas Turbine

NS RAILROAD FIG. NO. 1 ^ 6% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = -12.610

RAILROAD - TOTAL LOCO FLEET = 2148 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 108

DCRR VERSUS STANDARD DIESEL = 15.00%

TOTAL FLEET DF2 USED (gal) = 310263302 (Ref)

CASE - DF2 / LOCO (000 gal) = 361.50

BTU / LOCO (10)^10 = 7.81

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 150.922

MAINT COST ADDER(000), AVE/YR OVER LIFE = 87.875

PLANT CAPITAL COST (000) = 44108

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	10	126	-6476	-6350	1509	-879	1073	340	-4936	-4936	-4936
2	10	126	-3840	-3714	3018	-1757	1270	681	-1763	-1533	-6469
3	10	126	-3840	-3714	4528	-2636	1617	1021	-1076	-813	-7282
4	10	126	-3840	-3714	6037	-3515	1976	1362	-376	-247	-7530
5	10	126	-3840	-3714	7546	-4394	2334	1702	323	185	-7345
6	10	126	-3840	-3714	9055	-5272	2080	2043	409	203	-7142
7	10	126	-3840	-3714	10565	-6151	2080	2383	749	324	-6818
8	10	126	-3840	-3714	12074	-7030	2080	2724	1090	410	-6409
9	10	126	-3840	-3714	13583	-7909	2080	3064	1430	467	-5941
10	18	227	-6912	-6685	16300	-9490	2582	3677	-426	-121	-6062
11	0				16300	-9490	1753	3677	5430	1342	-4720
12	0				16300	-9490	1363	3677	5040	1083	-3637
13	0				16300	-9490	1005	3677	4681	875	-2762
14	0				16300	-9490	646	3677	4323	703	-2059
15	0				16300	-9490	0	3677	3677	520	-1540
16	-10				14790	-8612	0	3336	3336	410	-1130
17	-10				13281	-7733	0	2996	2996	320	-810
18	-10				11772	-6854	0	2656	2656	247	-563
19	-10				10263	-5975	0	2315	2315	187	-376
20	-10				8753	-5097	0	1975	1975	139	-237
21	-10				7244	-4218	0	1634	1634	100	-137
22	-10				5735	-3339	0	1294	1294	69	-68
23	-10				4226	-2460	0	953	953	44	-24
24	-10				2717	-1582	0	613	613	25	0
25	-18				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

G. ROM Coal Gasifier Gas Turbine

UP RAILROAD FIG. NO. 1 ^ 13% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = -57.980

RAILROAD - TOTAL LOCO FLEET = 2569 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 244

DCRR VERSUS STANDARD DIESEL = 15.00%

TOTAL FLEET DF2 USED (gal) = 465106829 (Ref)

CASE - DF2 / LOCO (000 gal) = 338.70

BTU / LOCO (10)^10 = 7.32

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 137.288

MAINT COST ADDER(000), AVE/YR OVER LIFE = 84.933

PLANT CAPITAL COST (000) = 96332

INVESTMENT DEPRECIATION SCHEDULE

YEAR	1	15.00%
	2	22.00%
	3	21.00%
	4	21.00%
	5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	24	1392	-11852	-10460	3295	-2038	1768	679	-8014	-8014	-8014
2	24	1392	-9216	-7824	6590	-4077	2381	1357	-4087	-3553	-11568
3	24	1392	-9216	-7824	9885	-6115	3125	2036	-2664	-2015	-13582
4	24	1392	-9216	-7824	13180	-8154	3881	2714	-1230	-809	-14391
5	24	1392	-9216	-7824	16475	-10192	4636	3393	204	117	-14274
6	24	1392	-9216	-7824	19769	-12230	4382	4071	628	312	-13962
7	24	1392	-9216	-7824	23064	-14269	4382	4750	1307	565	-13397
8	24	1392	-9216	-7824	26359	-16307	4382	5428	1985	746	-12650
9	24	1392	-9216	-7824	29654	-18346	4382	6107	2664	871	-11780
10	28	1623	-10752	-9129	33498	-20724	4602	6898	2372	674	-11105
11	0				33498	-20724	3191	6898	10090	2494	-8611
12	0				33498	-20724	2394	6898	9292	1997	-6614
13	0				33498	-20724	1638	6898	8536	1595	-5019
14	0				33498	-20724	882	6898	7780	1264	-3754
15	0				33498	-20724	0	6898	6898	975	-2779
16	-24				30203	-18685	0	6220	6220	764	-2015
17	-24				26908	-16647	0	5541	5541	592	-1423
18	-24				23613	-14609	0	4863	4863	452	-971
19	-24				20319	-12570	0	4184	4184	338	-633
20	-24				17024	-10532	0	3506	3506	246	-387
21	-24				13729	-8493	0	2827	2827	173	-214
22	-24				10434	-6455	0	2149	2149	114	-100
23	-24				7139	-4417	0	1470	1470	68	-32
24	-24				3844	-2378	0	792	792	32	0
25	-28				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

G. ROM Coal Gasifier Gas Turbine

BN RAILROAD FIG. NO. 1 ^ 13% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = 65.810

RAILROAD - TOTAL LOCO FLEET = 2593 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 237

DCRR VERSUS STANDARD DIESEL = 20.00%

TOTAL FLEET DF2 USED (gal) = 514750379 (Ref)

CASE - DF2 / LOCO (000 gal) = 418.90

BTU / LOCO (10)^10 = 9.05

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 185.247

MAINT COST ADDER(000), AVE/YR OVER LIFE = 95.279

PLANT CAPITAL COST (000) = 93644

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	23	-1514	-11468	-12982	4261	-2191	2194	1117	-9670	-9670	-9670
2	23	-1514	-8832	-10346	8521	-4383	3062	2235	-5049	-4207	-13878
3	23	-1514	-8832	-10346	12782	-6574	4049	3352	-2944	-2044	-15922
4	23	-1514	-8832	-10346	17043	-8766	5049	4470	-827	-479	-16401
5	23	-1514	-8832	-10346	21303	-10957	6048	5587	1290	622	-15779
6	23	-1514	-8832	-10346	25564	-13149	5794	6704	2152	865	-14914
7	23	-1514	-8832	-10346	29825	-15340	5794	7822	3270	1095	-13819
8	23	-1514	-8832	-10346	34085	-17531	5794	8939	4387	1224	-12594
9	23	-1514	-8832	-10346	38346	-19723	5794	10057	5505	1280	-11314
10	30	-1974	-11520	-13494	43904	-22581	6326	11514	4345	842	-10472
11	0				43904	-22581	4364	11514	15878	2564	-7908
12	0				43904	-22581	3302	11514	14816	1994	-5914
13	0				43904	-22581	2303	11514	13817	1550	-4364
14	0				43904	-22581	1304	11514	12818	1198	-3166
15	0				43904	-22581	0	11514	11514	897	-2269
16	-23				39643	-20390	0	10397	10397	675	-1594
17	-23				35382	-18198	0	9279	9279	502	-1092
18	-23				31122	-16007	0	8162	8162	368	-725
19	-23				26861	-13815	0	7045	7045	265	-460
20	-23				22600	-11624	0	5927	5927	186	-274
21	-23				18339	-9433	0	4810	4810	125	-149
22	-23				14079	-7241	0	3692	3692	80	-69
23	-23				9818	-5050	0	2575	2575	47	-22
24	-23				5557	-2858	0	1457	1457	22	0
25	-30				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

G. ROM Coal Gasifier Gas Turbine

CSX RAILROAD FIG. NO. 1 ^ 6% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = -34.580

RAILROAD - TOTAL LOCO FLEET = 3218 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 169

DCRR VERSUS STANDARD DIESEL = 20.00%

TOTAL FLEET DF2 USED (gal) = 462417920 (Ref)

CASE - DF2 / LOCO (000 gal) = 382.00

BTU / LOCO (10)^10 = 8.25

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 163.181

MAINT COST ADDER(000), AVE/YR OVER LIFE = 90.519

PLANT CAPITAL COST (000) = 67532

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	16	553	-8780	-8227	2611	-1448	1390	628	-6209	-6209	-6209
2	16	553	-6144	-5591	5222	-2897	1777	1256	-2558	-2131	-8340
3	16	553	-6144	-5591	7833	-4345	2305	1883	-1402	-974	-9314
4	16	553	-6144	-5591	10444	-5793	2845	2511	-234	-136	-9449
5	16	553	-6144	-5591	13054	-7242	3385	3139	934	450	-8999
6	16	553	-6144	-5591	15665	-8690	3131	3767	1307	525	-8474
7	16	553	-6144	-5591	18276	-10138	3131	4395	1935	648	-7826
8	16	553	-6144	-5591	20887	-11586	3131	5022	2562	715	-7111
9	16	553	-6144	-5591	23498	-13035	3131	5650	3190	742	-6369
10	25	865	-9600	-8736	27578	-15298	3662	6631	1558	302	-6067
11	0				27578	-15298	2504	6631	9135	1475	-4591
12	0				27578	-15298	1924	6631	8555	1151	-3440
13	0				27578	-15298	1384	6631	8015	899	-2541
14	0				27578	-15298	844	6631	7475	699	-1842
15	0				27578	-15298	0	6631	6631	516	-1326
16	-16				24967	-13849	0	6003	6003	390	-936
17	-16				22356	-12401	0	5376	5376	291	-645
18	-16				19745	-10953	0	4748	4748	214	-431
19	-16				17134	-9504	0	4120	4120	155	-277
20	-16				14523	-8056	0	3492	3492	109	-167
21	-16				11912	-6608	0	2864	2864	75	-93
22	-16				9301	-5160	0	2237	2237	49	-44
23	-16				6690	-3711	0	1609	1609	29	-15
24	-16				4080	-2263	0	981	981	15	0
25	-25				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

H. Fluid Bed Steam Turbine

SFe RAILROAD FIG. NO. 1 * 9% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = -67.680

RAILROAD - TOTAL LOCO FLEET = 3950 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 212

DCRR VERSUS STANDARD DIESEL = 15.00%

TOTAL FLEET DF2 USED (gal) = 652249114 (Ref)

CASE - DF2 / LOCO (000 gal) = 302.20

BTU / LOCO (10)^10 = 9.80

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 93.810

MAINT COST ADDER(000), AVE/YR OVER LIFE = 68.769

PLANT CAPITAL COST (000) = 47368

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	21	1421	-7067	-5646	1970	-1444	954	284	-4408	-4408	-4408
2	21	1421	-4431	-3010	3940	-2888	1080	568	-1362	-1184	-5592
3	21	1421	-4431	-3010	5910	-4332	1359	852	-799	-604	-6196
4	21	1421	-4431	-3010	7880	-5777	1649	1136	-225	-148	-6344
5	21	1421	-4431	-3010	9850	-7221	1940	1420	350	200	-6144
6	21	1421	-4431	-3010	11820	-8665	1685	1704	379	189	-5955
7	21	1421	-4431	-3010	13790	-10109	1685	1988	663	287	-5668
8	21	1421	-4431	-3010	15760	-11553	1685	2272	947	356	-5312
9	21	1421	-4431	-3010	17730	-12997	1685	2556	1231	403	-4909
10	23	1557	-4853	-3296	19888	-14579	1734	2867	1304	371	-4539
11	0				19888	-14579	1206	2867	4072	1007	-3532
12	0				19888	-14579	900	2867	3767	810	-2722
13	0				19888	-14579	609	2867	3476	650	-2073
14	0				19888	-14579	318	2867	3185	518	-1555
15	0				19888	-14579	0	2867	2867	405	-1150
16	-21				17918	-13135	0	2583	2583	317	-832
17	-21				15948	-11691	0	2299	2299	246	-587
18	-21				13978	-10247	0	2015	2015	187	-400
19	-21				12008	-8802	0	1731	1731	140	-260
20	-21				10038	-7358	0	1447	1447	102	-158
21	-21				8068	-5914	0	1163	1163	71	-87
22	-21				6098	-4470	0	879	879	47	-40
23	-21				4128	-3026	0	595	595	27	-13
24	-21				2158	-1582	0	311	311	12	0
25	-23				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

H. Fluid Bed Steam Turbine

BN RAILROAD FIG. NO. 1 ^ 9% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = 486.900

RAILROAD - TOTAL LOCO FLEET = 2593 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 164

DCRR VERSUS STANDARD DIESEL = 15.00%

TOTAL FLEET DF2 USED (gal) = 514750379 (Ref)

CASE - DF2 / LOCO (000 gal) = 418.90

BTU / LOCO (10)^10 = 13.58

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 184.124

MAINT COST ADDER(000), AVE/YR OVER LIFE = 73.904

PLANT CAPITAL COST (000) = 37240

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	16	-7790	-6012	-13802	2946	-1182	2333	952	-10517	-10517	-10517
2	16	-7790	-3376	-11166	5892	-2365	3284	1905	-5978	-5198	-15716
3	16	-7790	-3376	-11166	8838	-3547	4350	2857	-3959	-2994	-18709
4	16	-7790	-3376	-11166	11784	-4730	5429	3809	-1928	-1268	-19977
5	16	-7790	-3376	-11166	14730	-5912	6508	4762	103	59	-19918
6	16	-7790	-3376	-11166	17676	-7095	6253	5714	801	398	-19520
7	16	-7790	-3376	-11166	20622	-8277	6253	6666	1753	758	-18762
8	16	-7790	-3376	-11166	23568	-9460	6253	7618	2705	1017	-17745
9	16	-7790	-3376	-11166	26514	-10642	6253	8571	3657	1196	-16550
10	20	-9738	-4220	-13958	30196	-12120	6725	9761	2528	719	-15831
11	0				30196	-12120	4649	9761	14410	3562	-12269
12	0				30196	-12120	3506	9761	13267	2852	-9418
13	0				30196	-12120	2427	9761	12188	2278	-7139
14	0				30196	-12120	1348	9761	11109	1806	-5334
15	0				30196	-12120	0	9761	9761	1380	-3954
16	-16				27250	-10938	0	8809	8809	1083	-2872
17	-16				24304	-9755	0	7856	7856	840	-2032
18	-16				21358	-8573	0	6904	6904	642	-1391
19	-16				18412	-7390	0	5952	5952	481	-910
20	-16				15466	-6208	0	5000	5000	351	-558
21	-16				12520	-5025	0	4047	4047	247	-311
22	-16				9574	-3843	0	3095	3095	164	-147
23	-16				6628	-2661	0	2143	2143	99	-48
24	-16				3682	-1478	0	1190	1190	48	0
25	-20				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

H. Fluid Bed Steam Turbine

CR RAILROAD FIG. NO. 1 * 9% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = -56.150

RAILROAD - TOTAL LOCO FLEET = 2447 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 65

DCRR VERSUS STANDARD DIESEL = 15.00%

TOTAL FLEET DF2 USED (gal) = 290376555 (Ref)

CASE - DF2 / LOCO (000 gal) = 315.30

BTU / LOCO (10)^10 = 10.22

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 103.948

MAINT COST ADDER(000), AVE/YR OVER LIFE = 69.345

PLANT CAPITAL COST (000) = 16351

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. CR.+ DEPR	TAX NET ^SAVINGS	EXP.	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	6	337	-3902	-3565	624	-416	603	112		-2850	-2850	-2850
2	6	337	-1266	-929	1247	-832	518	224		-187	-163	-3013
3	6	337	-1266	-929	1871	-1248	595	336		3	2	-3011
4	6	337	-1266	-929	2495	-1664	685	448		205	134	-2877
5	6	337	-1266	-929	3118	-2080	775	561		406	232	-2644
6	6	337	-1266	-929	3742	-2496	520	673		264	131	-2513
7	6	337	-1266	-929	4366	-2912	520	785		376	163	-2351
8	6	337	-1266	-929	4989	-3329	520	897		488	183	-2167
9	6	337	-1266	-929	5613	-3745	520	1009		600	196	-1971
10	11	618	-2321	-1703	6757	-4507	651	1215		162	46	-1925
11	0				6757	-4507	442	1215		1656	409	-1515
12	0				6757	-4507	344	1215		1559	335	-1180
13	0				6757	-4507	254	1215		1469	275	-906
14	0				6757	-4507	165	1215		1379	224	-682
15	0				6757	-4507	0	1215		1215	172	-510
16	-6				6133	-4091	0	1102		1102	135	-375
17	-6				5509	-3675	0	990		990	106	-269
18	-6				4886	-3259	0	878		878	82	-187
19	-6				4262	-2843	0	766		766	62	-125
20	-6				3638	-2427	0	654		654	46	-79
21	-6				3014	-2011	0	542		542	33	-46
22	-6				2391	-1595	0	430		430	23	-23
23	-6				1767	-1179	0	318		318	15	-9
24	-6				1143	-763	0	206		206	8	0
25	-11				0	0	0	0		0	0	0

VIII. ECONOMIC ANALYSIS

H. Fluid Bed Steam Turbine

CSX RAILROAD FIG. NO. 1 ~ 4% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = 297.400

RAILROAD - TOTAL LOCO FLEET = 3218 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 117

DCRR VERSUS STANDARD DIESEL = 15.00%

TOTAL FLEET DF2 USED (gal) = 462417920 (Ref)

CASE - DF2 / LOCO (000 gal) = 382.00

BTU / LOCO (10)^10 = 12.38

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 155.567

MAINT COST ADDER(000), AVE/YR OVER LIFE = 72.280

PLANT CAPITAL COST (000) = 27323

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	11	-3271	-4957	-8228	1711	-795	1391	495	-6343	-6343	-6343
2	11	-3271	-2321	-5592	3422	-1890	1778	989	-2825	-2457	-8800
3	11	-3271	-2321	-5592	5134	-2385	2306	1484	-1802	-1363	-10163
4	11	-3271	-2321	-5592	6845	-3180	2846	1979	-767	-505	-10667
5	11	-3271	-2321	-5592	8556	-3975	3386	2474	268	153	-10514
6	11	-3271	-2321	-5592	10267	-4770	3132	2968	508	252	-10262
7	11	-3271	-2321	-5592	11979	-5566	3132	3463	1002	433	-9828
8	11	-3271	-2321	-5592	13690	-6361	3132	3958	1497	563	-9265
9	11	-3271	-2321	-5592	15401	-7156	3132	4453	1992	651	-8614
10	18	-5353	-3798	-9151	18201	-8457	3733	5262	-156	-44	-8659
11	0				18201	-8457	2547	5262	7809	1930	-6728
12	0				18201	-8457	1964	5262	7227	1553	-5175
13	0				18201	-8457	1424	5262	6686	1250	-3925
14	0				18201	-8457	884	5262	6146	999	-2926
15	0				18201	-8457	0	5262	5262	744	-2183
16	-11				16490	-7662	0	4767	4767	586	-1597
17	-11				14779	-6867	0	4273	4273	457	-1140
18	-11				13068	-6072	0	3778	3778	351	-789
19	-11				11356	-5276	0	3283	3283	265	-524
20	-11				9645	-4481	0	2788	2788	196	-328
21	-11				7934	-3686	0	2294	2294	140	-188
22	-11				6223	-2891	0	1799	1799	96	-92
23	-11				4511	-2096	0	1304	1304	60	-32
24	-11				2800	-1301	0	810	810	33	0
25	-18				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

H. Fluid Bed Steam Turbine

MS RAILROAD FIG. NO. 1 ^ 4% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

`ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = 176.050

RAILROAD - TOTAL LOCO FLEET = 2148 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 75

DCRR VERSUS STANDARD DIESEL = 15.00%

TOTAL FLEET DF2 USED (gal) = 310263302 (Ref)

CASE - DF2 / LOCO (000 gal) = 361.50

BTU / LOCO (10)^10 = 11.72

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 139.702

MAINT COST ADDER(000), AVE/YR OVER LIFE = 71.378

PLANT CAPITAL COST (000) = 18461

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	7	-1232	-4113	-5345	978	-500	903	258	-4184	-4184	-4184
2	7	-1232	-1477	-2709	1956	-999	999	517	-1194	-1038	-5222
3	7	-1232	-1477	-2709	2934	-1499	1248	775	-686	-519	-5741
4	7	-1232	-1477	-2709	3912	-1999	1510	1033	-166	-109	-5850
5	7	-1232	-1477	-2709	4890	-2498	1772	1291	354	202	-5648
6	7	-1232	-1477	-2709	5867	-2998	1517	1550	357	178	-5470
7	7	-1232	-1477	-2709	6845	-3498	1517	1808	616	266	-5204
8	7	-1232	-1477	-2709	7823	-3997	1517	2066	874	329	-4875
9	7	-1232	-1477	-2709	8801	-4497	1517	2324	1132	370	-4505
10	12	-2113	-2532	-4645	10478	-5353	1844	2767	-33	-9	-4515
11	0				10478	-5353	1255	2767	4022	994	-3520
12	0				10478	-5353	972	2767	3739	804	-2717
13	0				10478	-5353	710	2767	3478	650	-2067
14	0				10478	-5353	449	2767	3216	523	-1544
15	0				10478	-5353	0	2767	2767	391	-1153
16	-7				9500	-4854	0	2509	2509	308	-845
17	-7				8522	-4354	0	2251	2251	241	-604
18	-7				7544	-3854	0	1992	1992	185	-419
19	-7				6566	-3355	0	1734	1734	140	-279
20	-7				5588	-2855	0	1476	1476	104	-175
21	-7				4610	-2355	0	1218	1218	74	-101
22	-7				3632	-1856	0	959	959	51	-50
23	-7				2654	-1356	0	701	701	32	-17
24	-7				1676	-857	0	443	443	18	0
25	-12				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

H. Fluid Bed Steam Turbine

UP RAILROAD FIG. NO. 1 * 9% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = 101.690

RAILROAD - TOTAL LOCO FLEET = 2569 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 169

DCRR VERSUS STANDARD DIESEL = 15.00%

TOTAL FLEET DF2 USED (gal) = 465106829 (Ref)

CASE - DF2 / LOCO (000 gal) = 338.70

BTU / LOCO (10)^10 = 10.98

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 122.057

MAINT COST ADDER(000), AVE/YR OVER LIFE = 70.375

PLANT CAPITAL COST (000) = 38295

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	16	-1627	-6012	-7639	1953	-1126	1291	447	-5902	-5902	-5902
2	16	-1627	-3376	-5003	3906	-2252	1619	893	-2491	-2166	-8068
3	16	-1627	-3376	-5003	5859	-3378	2090	1340	-1574	-1190	-9258
4	16	-1627	-3376	-5003	7812	-4504	2573	1786	-644	-423	-9681
5	16	-1627	-3376	-5003	9765	-5630	3056	2233	286	164	-9518
6	16	-1627	-3376	-5003	11717	-6756	2802	2679	478	238	-9280
7	16	-1627	-3376	-5003	13670	-7882	2802	3126	924	400	-8880
8	16	-1627	-3376	-5003	15623	-9008	2802	3572	1371	515	-8365
9	16	-1627	-3376	-5003	17576	-10134	2802	4019	1817	594	-7771
10	25	-2542	-5275	-7817	20628	-11893	3277	4717	177	50	-7721
11	0				20628	-11893	2241	4717	6957	1720	-6001
12	0				20628	-11893	1722	4717	6438	1384	-4617
13	0				20628	-11893	1238	4717	5955	1113	-3504
14	0				20628	-11893	755	4717	5472	889	-2615
15	0				20628	-11893	0	4717	4717	667	-1948
16	-16				18675	-10767	0	4270	4270	525	-1423
17	-16				16722	-9641	0	3823	3823	409	-1015
18	-16				14769	-8515	0	3377	3377	314	-701
19	-16				12816	-7389	0	2930	2930	237	-464
20	-16				10863	-6263	0	2484	2484	175	-290
21	-16				8910	-5137	0	2037	2037	124	-165
22	-16				6957	-4011	0	1591	1591	85	-81
23	-16				5004	-2885	0	1144	1144	53	-28
24	-16				3051	-1759	0	698	698	28	0
25	-25				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

H. Fluid Bed Steam Turbine

BN RAILROAD FIG. NO. 1 ^ 9% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = 335.220

RAILROAD - TOTAL LOCO FLEET = 2593 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 164

DCRR VERSUS STANDARD DIESEL = 20.00%

TOTAL FLEET DF2 USED (gal) = 514750379 (Ref)

CASE - DF2 / LOCO (000 gal) = 418.90

BTU / LOCO (10)^10 = 13.58

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 184.124

MAINT COST ADDER(000), AVE/YR OVER LIFE = 73.904

PLANT CAPITAL COST (000) = 37240

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	16	-5364	-6012	-11376	2946	-1182	1922	952	-8501	-8501	-8501
2	16	-5364	-3376	-8740	5892	-2365	2628	1905	-4207	-3506	-12006
3	16	-5364	-3376	-8740	8838	-3547	3460	2857	-2422	-1682	-13689
4	16	-5364	-3376	-8740	11784	-4730	4305	3809	-626	-362	-14051
5	16	-5364	-3376	-8740	14730	-5912	5149	4762	1171	565	-13486
6	16	-5364	-3376	-8740	17676	-7095	4894	5714	1868	751	-12735
7	16	-5364	-3376	-8740	20622	-8277	4894	6666	2821	945	-11791
8	16	-5364	-3376	-8740	23568	-9460	4894	7618	3773	1053	-10738
9	16	-5364	-3376	-8740	26514	-10642	4894	8571	4725	1099	-9639
10	20	-6704	-4220	-10924	30196	-12120	5263	9761	4100	795	-8844
11	0				30196	-12120	3638	9761	13399	2164	-6680
12	0				30196	-12120	2744	9761	12505	1683	-4997
13	0				30196	-12120	1900	9761	11661	1308	-3689
14	0				30196	-12120	1055	9761	10816	1011	-2678
15	0				30196	-12120	0	9761	9761	760	-1918
16	-16				27250	-10938	0	8809	8809	572	-1346
17	-16				24304	-9755	0	7856	7856	428	-921
18	-16				21358	-8573	0	6904	6904	311	-610
19	-16				18412	-7390	0	5952	5952	224	-386
20	-16				15466	-6208	0	5000	5000	156	-230
21	-16				12520	-5025	0	4047	4047	106	-124
22	-16				9574	-3843	0	3095	3095	67	-57
23	-16				6628	-2661	0	2143	2143	39	-18
24	-16				3682	-1478	0	1190	1190	18	0
25	-20				0	0	0	0	0	0	0

VIII. ECONOMIC ANALYSIS

H. Fluid Bed Steam Turbine

CSI RAILROAD FIG. NO. 1 ~ 4% OF TOTAL FLEET > 3000 HP & < 15 YRS OLD

ALLOWABLE CAPITAL COST ADDER ($,000)per LOCO = 179.750

RAILROAD - TOTAL LOCO FLEET = 3218 (Ref)

CASE - LOCOMOTIVE FLEET SIZE = 117

DCRR VERSUS STANDARD DIESEL = 20.00%

TOTAL FLEET DF2 USED (gal) = 462417920 (Ref)

CASE - DF2 / LOCO (000 gal) = 382.00

BTU / LOCO (10)^10 = 12.38

FUEL SAVINGS (000) /YEAR /LOCOMOTIVE = 155.567

MAINT COST ADDER(000), AVE/YR OVER LIFE = 72.280

PLANT CAPITAL COST (000) = 27323

INVESTMENT DEPRECIATION SCHEDULE

YEAR	
1	15.00%
2	22.00%
3	21.00%
4	21.00%
5	21.00%

NOTE: ALL $ IN THOUSANDS

YEAR	LOCOS PRCHSD OR RET	LOCO INVESTMNT DIFFRENCE	COAL PROC INFRASTR. INVESTMNT	TOTAL YEAR INVESTMN	FUEL SAVINGS	MAINT.CST SAVINGS	^INV. TAX CR.+ DEPR	NET EXP. ^SAVINGS	ANNUAL SIMPLE CASH FLOW	PRES.VAL CASH FLOW	DISCOUNTED CUMULATIVE CASH FLOW
1	11	-1977	-4957	-6934	1711	-795	1172	495	-5268	-5268	-5268
2	11	-1977	-2321	-4298	3422	-1590	1428	989	-1881	-1567	-6835
3	11	-1977	-2321	-4298	5134	-2385	1831	1484	-983	-683	-7517
4	11	-1977	-2321	-4298	6845	-3180	2246	1979	-73	-42	-7560
5	11	-1977	-2321	-4298	8556	-3975	2662	2474	837	404	-7156
6	11	-1977	-2321	-4298	10267	-4770	2407	2968	1077	433	-6723
7	11	-1977	-2321	-4298	11979	-5566	2407	3463	1572	526	-6197
8	11	-1977	-2321	-4298	13690	-6361	2407	3958	2067	577	-5620
9	11	-1977	-2321	-4298	15401	-7156	2407	4453	2561	596	-5024
10	18	-3236	-3798	-7034	18201	-8457	2869	5262	1098	213	-4811
11	0				18201	-8457	1957	5262	7219	1166	-3645
12	0				18201	-8457	1510	5262	6772	911	-2734
13	0				18201	-8457	1095	5262	6357	713	-2021
14	0				18201	-8457	679	5262	5941	555	-1466
15	0				18201	-8457	0	5262	5262	410	-1056
16	-11				16490	-7662	0	4767	4767	309	-747
17	-11				14779	-6867	0	4273	4273	231	-515
18	-11				13068	-6072	0	3778	3778	170	-345
19	-11				11356	-5276	0	3283	3283	123	-222
20	-11				9645	-4481	0	2788	2788	87	-135
21	-11				7934	-3686	0	2294	2294	60	-75
22	-11				6223	-2891	0	1799	1799	39	-36
23	-11				4511	-2096	0	1304	1304	24	-12
24	-11				2800	-1301	0	810	810	12	0
25	-18				0	0	0	0	0	0	0