Introducing Coal-Water-Mix Fuels to the Philippines

Assessment of Project Feasibility

Executive Summary and Overview

Report to the
National Economic and Development Authority
Republic of the Philippines
on behalf of the
National Power Corporation
Development Bank of the Philippines

Report by
U.S. Agency for International Development
Office of Energy
based on analyses by
Brookhaven National Laboratory
Burns and Roe, Inc.
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EXECUTIVE SUMMARY

Feasibility and attractiveness have been assessed for a project to introduce coal-water-mix (CWM) fuels to the Philippines. The 850 MW Sucat generating station, serving the Luzon Grid and depending entirely on imported fuel oil, would be retrofitted to burn a coal-water-mix fuel -- a suspension of finely-powdered coal in water that can be handled, stored, distributed and utilized like liquid fuel oil with relatively minor power-plant modification. CWM-fuels technology is considered commercial for high-rank coals in the United States and other developed countries. The results of this assessment are highly positive, and the nature of further work to adapt the technology to the Philippine low-rank coals is clear.

The coal would come from Semirara Island, where large-scale mining operations now exist. The CWM-fuel would be prepared from low-rank Semirara coal on the island and shipped by barge or tanker to an existing terminal on the Pasig River, in metro-Manila, where an existing oil pipeline connects with the Sucat Station. Compared to a retrofit to pulverized coal, capital investment is considerably lower. Moreover, a range of social and environmental problems surrounding the transport and storage of sized and pulverized coal in metro-Manila can be avoided.

To achieve the maximum practical output (634 MW) from the Station, the investments to cover total plant costs, including those for particulate emission control, are U.S.$ 109 million for the power station modifications and U.S.$ 101.4 million for the CWM fuel supply and delivery facilities -- a total of U.S.$ 210.4 million. Sixty to seventy percent of these investments would be expended in foreign exchange. A major structural modification to the steam generators can be eliminated and the investment in total plant costs reduced to U.S.$ 80.5 million from U.S.$ 109 million. The station output would be reduced from 634 MW to 523 MW, without reducing the capability to achieve nameplate rating with fuel oil. The schedule for completion of the entire conversion is estimated at seven years, but benefits can begin after three years.

By comparison, converting the station to use pulverized coal, including the rebuilding of the Batangas - Sucat railway and the provision of rolling stock, would be considerably more costly. If new steam generators are installed to achieve the full 850 MW capacity, the investment is estimated to be U.S.$ 675 million -- about three times higher than a CWM retrofit. If the existing steam generators were modified instead, and a derating to 655 MW accepted, the investment would be U.S.$ 445 million -- twice the cost of the CWM retrofit. In the case of new pulverized-coal steam generators, the schedule for completion is estimated to be 13 years, almost twice that for a retrofit to CWM fuel. The longer schedule significantly lowers the present value of prospective savings in foreign exchange through eliminating imported fuel oil.

In all three cases of conversion to coal -- use of CWM fuels, new pulverized-coal fired steam generators, and existing steam generators retrofitted to pulverized coal -- mining operations on Semirara Island would need to be expanded from less than 1 million tonnes annually to 3-4 million tonnes. The investment to cover the costs of opening and equipping a new mine is estimated to be U.S.$ 173.3 million. The mineable reserves on Semirara Island are adequate to support this expansion over the remaining life of the Sucat Station.

The project offers the nation impressive and needed benefits. The present value of foreign exchange savings from imported oil elimination, adjusted for foreign exchange costs to repay initial investments, is approximately U.S.$ 383 million. The corresponding cumulative value of the net savings is about U.S.$ 1.4 billion. Additional benefits accrue from the generation of new jobs and from the certainty that the use of CWM-fuels in the Sucat Station can be extended to other oil-fueled installations in industry and in the National Power Corporation system.

Moreover, the project is likely to stand high in comparison with other investment projects in the Philippines that may offer comparable foreign exchange savings. Its economic return on investment is estimated to be 54 percent. If one-third of the investment is financed by equity and the rest by loan, the economic return on equity could be as high as 133 percent.

The calculations of the benefits and returns on investment are based on realistic and conservative assumptions of costs and prices. Sensitivity analyses of the results, based on more conservative assumptions, show sustained attractiveness for the national benefits. Such parameters as a decreased world price for imported oil, reduced plant capacity, and delays in construction were explored.

At the same time, the project could offer attractive private-sector investment opportunities. For the same investment figures and the same conservative basis for costs and prices, returns on the power station investment range from 30 to 37 percent over the prevailing range of selling prices for Semirara coal to the National Power Corporation. These rates apply to the higher investment level, the level which achieves a 634 MW output for the station. For the lower investment level, which achieves a 523 MW output, the range of returns is 33 to 40 percent.

Estimates of net present value of future cash flows show a reverse result. Higher station output is more attractive than the lower station output. The values are U.S.$ 122 to 176 million for the higher output and U.S.$ 107 to 157 million for the lower output.

If the project is publicly financed 33 percent by equity and 66 percent by loan, the rate of return on equity is estimated to range, for the 634 MW output, from 80 to 94 percent under prevailing Semirara coal prices. For the 523 MW output, the range is 85 to 101 percent.

As before, the calculations of the financial rates of return and net present values are based on realistic and conservative assumptions of costs and prices that are considered. Sensitivity analysis of the results, based on more conservative assumptions, show potential attractiveness for the private-sector investment opportunities. Such parameters as station loading, price paid for busbar electricity, and cost of capital were explored.

The project requires adaptation and transfer of technology which has been accepted in the United States and other countries. The adaptation involves the extrapolation of results obtained for the use of high-rank eastern-U.S. bituminous coals in CWM-fuel formulation to the use of Philippine low-rank Semirara sub-bituminous coal. The significant technical difference is the high (25 percent) inherent moisture in the Semirara coal compared to the very low (2-3 percent) inherent moisture in high-rank coals. Inherent moisture affects the slurryability of the coal and the CWM fuels produced contain lowered contents of coal measured on a bone-dry basis. Heating values of the CWM-fuels are correspondingly lower.

Experimental work performed with samples of Semirara coal showed that a CWM fuel could be prepared containing up to 57 percent dry coal weight. The baseline fuel on which the assessment results were obtained contained 50 weight percent dry coal. On a pilot scale, such a fuel has manageable properties of stability, flow, and combustion; and experiments identified the parameters that can increase the heating value of a Semirara CWM fuel significantly without materially altering the flow properties. Moreover, work performed in parallel by commercial CWM-fuel manufacturers on samples of the same Semirara coal confirmed these findings.

Study of the sensitivity of the financial rates of return to a 10 percent increase in the heating value of the CWM fuel -- about a 5 percent increase in dry coal weight -- showed that the return on investment increases for the higher level of station capacity from 26 to 35 percent. The corresponding increase in return on equity is from 71 to 90 percent. The increase in net present value is from U.S.$ 91 million to U.S.$ 160 million.

The incentive to undertake further efforts to increase the coal loading is a powerful one. Increases in coal loading, however, will not come free of cost. The amount of increase will have to be optimized through evaluating trade-offs between performance and costs. A fuel optimization activity should be a key principle in any implementation plan considered for the project.

Other key implementation principles are

- The performance of flow and combustion tests on the scale of the tests that have already been performed by others for high rank coals.

- The development of mine plans and the estimation of capital costs for increasing the production level of Semirara coal from the present and from future pits.

- Organization of the implementation schedule for parallel efforts to avoid delays that can reduce the national benefits.

- Periodic reconfirmation of project attractiveness as new, firmer, data are developed.

- Adoption of an investment schedule that avoids premature expenditure of funds.

- Addressing such institutional aspects as timely training of Philippine managers, engineers, and technicians to support the technology transfer and a review of the basis upon which generation planning is performed for the Luzon Grid.

Further details elaborating the assessment results are presented later in this volume in the section entitled OVERVIEW. These details are based on work performed by the participants in the project assessment. Their work and results are reported in five volumes as follows:

Volume I, The Philippine Coal Resource
United States Geological Survey

Volume II, Formulation of Coal-Water-Mix Fuels from Philippine Coals
Brookhaven National Laboratory

Volume III, Power Plant Retrofit and Performance
Burns and Roe, Inc.

Volume IV, The CWM-Fuel Supply System
Burns and Roe, Inc., and Development Sciences, Inc.

Volume V, Financial and Economic Analysis
Development Sciences, Inc.

BACKGROUND

In March 1984, the U.S. Agency for International Development (A.I.D.), through its Mission to the Philippines, entered into an agreement with the Government of the Philippines to fund and manage a comprehensive assessment of the attractiveness of a project to introduce coal-water-mix (CWM) fuels to the Philippines. The Project Agreement provided for the Philippine Government to delegate its responsibilities to its Development Bank of the Philippines and to its National Power Corporation. The Development Bank, in turn, delegated its collaborative responsibilities to the Economic Development Foundation, Inc. of Manila. A.I.D. delegated its responsibilities to its central Office of Energy, located in Washington.

Philippine interest in the subject of CWM-fuel utilization began in February 1983 at the time the Symposium to Accelerate Philippine Coal Development through U.S. Technology, organized by the Philippine Ministry of Energy and the United States Trade Development Program, was conducted in Manila. Philippine interest arose from efforts then underway to develop indigenous coal resources to help reduce the country's dependence on imported petroleum. Interest intensifed when, in August 1983, the A.I.D. Office of Energy sponsored an exploratory identification of technical assistance opportunities in the Philippine coal sector. The results led to the Project Agreement, and to the provision of funds and services to undertake the assessment of CWM potential in the Philippines.

A.I.D.'s interest in CWM-fuel utilization began in 1980/81 when Florida Power and Light conducted a large-scale trial of coal-oil-mix fuel utilization in a 400-MW unit in Sanford, Florida. When later development work in the United States and elsewhere focused on replacing the oil in the fuel mix with water, total independence from oil become feasible and electric utilities switched their interest accordingly. For example, even though for the past three years the Florida Power Corporation has been operating its 120 MW Bartow No. 1 Unit on coal-oil-mixture fuel, this utility recently has been considering conversion to a coal-water-mix fuel. The Florida Power and Light Company perspective in this respect is presented in Appendix A.

The emergence of an industry in the U.S. and elsewhere for preparing commercially saleable formulations of CWM fuels, the growing body of experience (see listing in Appendix B) to apply these fuels to industrial and utility steam generators, and the clear indications of technical acceptance by important oil-consuming electrical utilities in the United States supported A.I.D.'s interest in providing the funds and services to undertake a project assessment for the Philippines. Another reason is the totally different economic scene in a developing country compared to that in the United States.

Developing countries do not receive the benefits of falling world oil prices. They purchase oil in U.S. dollars, and the U.S. dollar is strong against practically all currencies. For example, early in 1983 at the time Philippine interest began, a barrel of imported oil cost about 250 pesos. Today, this same barrel costs about 560 pesos, more than double in a two-year period. More than doubling the local cost of oil has contributed in large measure to the more than doubling of the wholesale price index in the Philippines over the same period. Whether or not oil prices resume their rise, the negative impact of imported oil on economic growth in the developing countries probably will continue.

Three important considerations guided the identification of work efforts, their planning, and their accomplishment:

- High-rank bituminous coals have been the basis for development programs in the United States and elsewhere to formulate and utilize coal-water-mix fuels. Coals in indigenous deposits of most developing countries are most often low-rank, lignitic or sub-bituminous. The question arose of the impact of the high equilibrium moisture contents of low rank coals. Therefore, work should begin with air shipments to the United States of carefully identified samples of various Philippine coals for experimental evaluation of their behavior in coal-water-mix fuel formulation.

- Technology transfer should begin with the cooperation of firms in the United States experienced in the preparation and utilization of coal-water-mix fuels. After a background briefing in September 1984, firms willing to cooperate were provided with samples of Philippine coals.

- Selecting the scope for the project assessment should be given careful thought. The scope for an assessment of technical feasibility is relatively narrow. It can be limited to judging the practicability of preparing and handling coal-water-mix fuel mixtures, burning them, and modifying the boiler equipment affected. The scope for an assessment of economic and financial attractiveness, however, is much broader. It should involve a total system of facilities, institutions, and infrastructure within which preparation and utilization of coal-water-mix fuels can function. A cost saving or cost increase in the operation of one facility in the system can affect costs in the operation of another facility. Cost trade-off situations arise that should be evaluated from a system point of view. For Philippine context, a total system should contain the extraction of coal from a Philippine mining operation, the preparation of the CWM fuel, its transport to the steam generator, the effect on steam-generator performance from its combustion, and the net environmental impact of conversion to coal from fuel oil.

Work began in the Philippines in April 1984. Coal samples were prepared and shipped to the United States. These arrived in June 1984. Upon clear indication that these samples could be used to prepare CWM-fuel formulations of acceptable properties, remaining efforts began in August 1984. Field work occurred in the Philippines during October and November 1984, while experimental work on the coals continued in the United States. Evaluations were completed in late February 1985, when results were presented in a U.S. workshop of participants from the United States and the Philippines. Participants were selected to enable a critical review of the work and results, for use in the formal presentation of the results in Manila in April 1985.

PROJECT DESCRIPTION

The project goal is to convert the Sucat Station of the Philippine National Power Corporation from total reliance on residual fuel oil from imported petroleum to total reliance on coal from indigenous sources. This station serves the Luzon Grid, and comprises four large generating units having an aggregate nameplate capacity of 850 MW. The station location is south of Manila in a crowded metropolitan area on the western shore of the Laguna Lake. The station receives its fuel oil from adjacent tankage, fed by pipeline from the petroleum refineries located at Batangas about 70 miles south. Except for cyclone dust separators for each steam generator, no environmental emission controls are installed.

Coal from Semirara Island, off the southern coast of Mindoro, is selected as the coal upon which to base the assessment of the project. The mineable reserves are adequately large. Commercial mining operations already exist on the island, and transport infrastructure handling solid coal is already in place. The total recoverable resource is likely to be extracted ultimately in three open-pit mining operations. The first pit, Unong, is already developed and in operation, and coal samples for experimentation were taken from this pit. The sites for the remaining two pits, Himalian and Panian, have been explored, and mining plans established in a preliminary fashion. Adequate detail is available for the Himalian site to make a preliminary estimate of costs of extraction suited for present purposes. The quantity of coal that will be consumed in a full conversion of the four units of the Sucat Station will be larger than the Unong pit is able to produce, even without supplying the present customers. After the conversion of the first unit, a second mine will be needed.

This coal is transferred at the mine site to the CWM-fuel preparation plant. The plant is located on Semirara Island to avoid, wherever practical, handling coal in solid form.

Bringing the level of knowledge and experience for utilizing Semirara-based CWM fuels to the level that exists for U.S. eastern bituminous coals clearly is not feasible in the time available for the assessment. The approach taken, therefore, is to formulate a fuel with minimum additives containing the highest dry-coal weight that still permitted flow in pipelines and atomization in burner nozzles. CWM-fuel properties, measured on samples formulated and supplied by the commercial firms collaborating in the assessment, are compared with this baseline fuel. The objective is to demonstrate that further work at a later stage on a larger scale, based on commercial fuel formulations, can only enhance the attractiveness of a project employing the baseline fuel. Further work clearly involves the beneficiation of Semirara coal to reduce its variability and reject non-coal materials in the as-mined product.

The CWM-fuel preparation plant, for the present, does not incorporate coal beneficiation. As-mined coal is pulverized to specification and dispersed in water to assure a homogeneous and predictable product. The CWM fuel is stored in agitated tanks awaiting loading onto barges for transport. The barge terminus is upstream on the Pasig River, entered from Manila Harbor, at the location of the terminus of an existing pipeline connecting the now-idled Rockwell generating station with the Sucat Station.

CWM-fuel, delivered to the Sucat Station, is stored in existing tankage, now used to store fuel oil, fitted with agitation devices. The fuel is metered and distributed to the steam generator burners.

The steam generators are modified to accept CWM fuel in place of fuel oil. Modifications occur at two levels: major modifications that result in a minimum derating of nameplate capacity at a higher capital cost; and minor modifications that produce a reasonable derating of nameplate capacity at minimum capital cost. At either level, emission control is installed through electrostatic precipitation of particulates in the flue gases. Also, for either level of modification, equipment is installed to remove ash deposits from heat transfer surfaces and to manage and dispose of ash accumulations.

PARTICIPANTS IN THE ASSESSMENT

The A.I.D. Office of Energy delegated its responsibilities to four organizations in the United States and coordinated its efforts with one organization in the Philippines. It retained for itself the responsibility for the technical management of the various efforts to achieve the objective of the assessment. Periodic workshops and a number of ad-hoc meetings of the participating teams permitted the necessary coordination and harmonization of the efforts. The participating organizations and their responsibilities are

Brookhaven National Laboratory, Upton, New York

> Establish the technical feasibility of preparing and burning CWM fuels from Philippine coals; and act as an objective monitor in collaborating with U.S. firms engaged in commercial CWM fuel supply. Their work and results are reported in Volume II.

Burns and Roe, Inc., Oradell, New Jersey

> Establish the engineering feasibility of retrofitting Philippine steam-generator equipment to utilize CWM fuels; estimate expected performances in terms of attainable output; establish the feasibility of CWM-fuel transport by pipeline; estimate costs involved; and set realistic retrofit schedules. Their work and results are reported in Volumes III and IV.

Development Sciences, Inc., Sagamore, Massachusetts

Establish the source of the CWM fuel and the transportation modes; estimate the fuel preparation and fuel-transport costs; integrate the associated costs to reflect system operation; assess benefits in relation to costs in economic and financial terms; and identify the implementation principles. Their work and results are reported in Volumes IV and V.

Economic Development Foundation, Inc., Manila, Philippines

In terms of participating in the assessment efforts, facilitate and assist in the collection, compilation, and analysis of Philippine data; obtain, prepare, and ship coal samples; provide advice and otherwise assist in the identification of the implementation principles. Their efforts are reflected throughout the five report volumes.

In terms of its responsibilities to the Development Bank of the Philippines, receive the results of the assessment, recognize the Philippine national and business context, arrange for formal presentation of the assessment results in Manila, and identify possible financing plans. The report volumes will provide a basis for these efforts.

United States Geological Survey, Reston, Virginia

> Review overall the national Philippine coal resource in terms of occurrence, quantity, and quality; and describe as far as present knowledge permits the coal resources in the areas appearing to be the likely sources of coal for formulating CWM fuels. Their work and results are reported in Volume I.

Seven firms agreed to receive samples of Philippine coals and provide information, either through submitting samples or through offering opinions concerning the amenability of these samples to formulation of CWM-fuels of acceptable physical properties. These firms are the following:

Atlantic Research Corporation
Babcock and Wilcox Company
Coaliquid, Inc.
Foster Wheeler Energy Corporation (with Carbogel, Inc.)
Methacoal Corporation
Morrison-Knudsen Company, Inc. (with Snamprogetti)
OXCE Fuel Company.

Three of these firms provided samples of fuel formulations large enough in quantity to permit testing flow properties in a laboratory pipeline loop and demonstrating combustion characteristics in a water-cooled furnace. They are the following:

Babcock and Wilcox Company

Coaliquid, Inc.

Methacoal Corporation.

Results from the tests on the large samples are presented in Volume II, but the source of each sample is disguised.

Economic Development Foundation retained the services of Fuel Supply Services, Inc. in the Florida Power and Light Group to provide a basis for comparing technically the efforts for the Philippine project assessment with the efforts expended so far by Florida Power and Light to assess the applicability of coal-water-mix fuels to replace oil in its generating system.

OVERVIEW

RETROFIT ALTERNATIVES

Conversion of Sucat Station steam generators to use a coal-water-mix fuel is only one of the three alternatives that may be considered to allow operation of the station solely on coal rather than on imported fuel oil. The remaining two alternatives are either the erection of new pulverized-coal fired steam generators or the conversion of the existing steam generators to use pulverized coal fuel. These two alternatives have been considered by the National Power Corporation in the past, but have never been implemented.

Both pulverized-coal alternatives are technically feasible. They are based on technologies that have long been in commercial practice and are ready to apply immediately. In fact, the new 300-MW generation unit at the National Power Corporation Calaca Station is already based on pulverized-coal fuel combustion technology and designed to burn 100% Semirara coal. For the CWM-fuel alternative, the technical feasibility of this alternative for Philippine coal is established in Volume II of this report. However, because of the low-rank of the Philippine coal source, implementation of CWM fuel preparation and combustion technologies in the Philippines will require a specific effort to optimize fuel formulation and to prepare and burn CWM-fuels on a larger scale.

For high-rank U.S. coals, coal-water-mix fuel preparation and combustion technologies are considered by prominent U.S. utilities as technically feasible and ready to implement without an optimization step. These utilities are held back from implementation for the present by unfavorable country-specific financial, economic, and institutional conditions prevailing in the United States.

The application of pulverized-coal combustion to the Sucat Station was reviewed. The review was based on field observations made during the present investigation and on previous work reported to the National Power Corporation. The recommendation at the time was the construction of a new boiler house and installation of new steam generators west of the present station, and scrapping the existing station. Today, implementation of this recommendation would require the condemnation of residential areas that have been built up since the original study was made.

Two variations of the recommendation were investigated: in one, the new boiler house would be constructed to the east of the station on land reclaimed from the Laguna and from the area occupied by an existing water discharge channel; in the other, the existing steam generators would be replaced, one by one, by extending the present boiler house to accommodate the first replacement, avoiding loss of capacity and replacing each of the other units one by one in the new spaces sequentially made available by the initial boiler house extension. For the latter variation, substantial reconstruction would be required for auxiliary piping systems and associated equipment, and for the boiler-house structural steel and stacks.

Retrofit of the existing steam generators to pulverized-coal firing was also investigated. New coal-pulverizer burner trains would be installed as best as they can be fitted in limited space, since the equipment layout originally did not anticipate coal-firing. For this retrofit mode, steam generators would be derated almost to the extent for coal-water-mix fuel firing -- the difference attributable to the greater water content of the CWM fuel, 50 percent compared to 25 percent.

In all cases, real estate would be built for the coal storage pile and the stacking and reclaiming equipment. Environment would be adversely impacted from fugitive dust, visual pollution, and water run-off to the Laguna -- a fishing lake. Run-off water would be caught and treated except for the excess during torrential downpours.

In all cases, too, the coal delivery should occur by railroad from Batangas. A 100-km long railroad formerly operated, has been abandoned, would have to be reconstructed, and needs to be provided with rolling stock acquired solely for the coal traffic. Port unloading facilities would require expansion, and unloading facilities at Sucat would be built. The transport of a coal slurry through the existing Batangas-Sucat pipeline is a possible alternative. Investments would be required for slurrying facilities upstream and for dewatering facilities downstream. Disposal of excess water would remain a problem, if deterioration of the Laguna is to be avoided.

Conversion to pulverized coal firing by any mode would have an adverse environmental impact. Noise levels for a residential area would become high;

fugitive dust emissions would occur; water contamination, particularly in the Laguna, is certain; nitrogen-oxide emissions are higher with pulverized than with CWM fuels, and railway crossings create traffic impediments.

Costs are higher and schedules are longer. Costs for installation of new steam generators, including railway rehabilitation, may be as high as U.S.$ 675 million, requiring about 13 years to accomplish the retrofit. Full station output of 850 MW could be achieved. For retrofitting the existing boilers, costs may be as high as U.S.$ 445 million, with a somewhat shorter schedule. Station capacity would be derated to 655 MW. As is shown later, costs for retrofit to firing with CWM fuel are considerably lower, and schedules are about half as long. Thus, benefits from foreign exchange savings are higher and are achieved sooner. Environmental impact for CWM-fuel firing can be about the same as now prevails with the use of fuel oil.

METHODOLOGY

The methodology addresses the CWM-fuel alternative and the limitation of the relatively short time available to complete a comprehensive assessment of feasibility. The time limitation particularly impacts on the scope of the experimental program for establishing the fuel formulation that is optimum for the system, and on the scale of the experimental program because of the need to ship coal samples by air. To accommodate the time limitation, a conservative basis is adopted, such that it becomes clear that the financial attractiveness and economic benefits calculated can only be improved, or enhanced, when additional work is undertaken as part of an implementation of the project.

The financial attractiveness of the CWM alternative and the economic benefits this generates for the nation are analyzed for a total system extending from coal extraction to transfer of busbar electricity to the Luzon grid. Four different scenarios for analysis are defined.

- Scenario A. Only the No. 2 Unit steam generator is retrofitted. Only selected modifications, of all that are practical to make, are made to the unit. This is a minor modification and results in a derating of nameplate capacity.

- Scenario B. Only the No. 2 Unit steam generator is retrofitted. All modifications that are practical to make are made to the unit. This is a major modification and results in a lesser derating of the nameplate capacity, i.e., a higher unit output.

- Scenario C. All four steam generators are retrofitted under conditions corresponding to scenario A (minor modification).

- Scenario D. All four steam generators are retrofitted under conditions corresponding to scenario D (major modification).

Financial analysis for each scenario employs as a basis costs in three different categories to produce a delivered price of CWM-fuel in the tanks at the Sucat Station.

CWM-Fuel Production. Costs are estimated for a plant on Semirara Island to produce the baseline specification fuel defined later below. The production cost includes the price of the as-mined coal. A range of prices is considered which appears to reflect a reasonable production cost for coal on Semirara Island, particularly if a new pit is opened and dedicated to the supply of the Sucat Station.

Water Transport. A single cost is used, r[illegible]

tariff to transport CWM fuel from the preparation plant to the pipeline terminal on the Pasig River.

Pipeline Transport. An average cost is used for each scenario to cover transport of CWM-fuel over the existing pipeline from the Rockwell Station to the Sucat Station. Costs are estimated to reflect recovery of new capital investment as a public rather than private enterprise.

Summation of appropriate costs in the three categories produces a cost of CWM fuel in the tankage at the Sucat Station.

The financial analyses calculate rates of return on total investment, the same on the investor's equity, net present values of cash flows at a fixed discount rate on both equity and total investment, and debt service. These analyses employ the delivered cost of CWM-fuel in the tankage of the Sucat Station and a transfer price per kwh for busbar electricity.

The financial analyses are intended primarily to measure the attractiveness to the National Power Corporation to undertake the conversion of the station to CWM fuel for the basic input data employed. They may also indicate attractiveness to other investors.

The financial results are analyzed further for their sensitivity to specific items in the input data, should their values vary from those employed. These data items are:

- <u>Busbar electricity transfer price.</u> The basic price is taken at a level of 1.20 pesos (6 cents) per kwh and at a level of 1.30 pesos.

- <u>Capital Investment.</u> The total capital requirement for the major or minor retrofit scenarios is taken as 20 percent higher to account for contingencies.

- <u>Station Loading.</u> The base case station loading is assumed to be a constant 75 percent over the remaining life of the station, and reduced to 65 percent and 55 percent.

- <u>Dry-Coal Weight in Fuel.</u> The baseline fuel as defined below contains a bone-dry coal weight of 50 percent. Loading is increased to correspond with a 10 percent increase in heating value.

- <u>Cost of Capital.</u> The weighted (equity and debt) cost of capital in the public sector is taken as 13 percent. This cost of capital is reduced to 10.7 percent and increased to 16 percent.

For purposes of economic analysis, two shadow factor values are postulated as generally fitting current and near term economic conditions in the Philippines The shadow factor on foreign exchange is taken as 1.2; that is, 20 percent more pesos are required for the purchase of one U.S. dollar than current exchange rates suggest. The shadow factor on unskilled labor wages is taken as 0.6; that is, the value of the output to the Philippine national economy of unskilled labor that will be employed in the total system for conversion to coal, if they were to be employed otherwise instead, will drop to 60 percent. Economic internal rates of return in investment and equity are calculated by making appropriate adjustments to the financial cost factors entering into the analysis. For example, all taxes are eliminated.

Implementation of either Scenario C or Scenario D (all four units) requires the output of the mining operations on Semirara Island to be more than tripled. New coal output of approximately 3 million metric tons annually is needed. Semirara Coal Company has already explored the potential for opening a new pit at either the Himalian or the Panian sites on Semirara Island. The obvious precondition for new investment by the coal company is to receive the commitment of the new market offered by Sucat conversion to coal with a price offered for the coal justifying the investment. This is a matter for negotiation between principals and is outside the scope of this assessment.

The coal quantities required for implementation of either Scenario A or Scenario B (Unit No. 2 only) are likely to be available for some time from the present open-pit operations at the Unong site. The price of coal on this basis is also a subject for commercial negotiation, but in a different context

Whichever scenario is adopted, localized economic benefits from intensified coal mining on Semirara Island would be generated. Evaluation of these benefits is outside the scope of the present assessment. Nevertheless, their potential existence should be recognized.

THE PHILIPPINE COAL RESOURCE

Known or reported coal areas in the Philipppines are shown in Figure 1. The noteworthy areas are those of Semirara, Cebu, and Malangas (on the Sibuguey Peninsula of Mindanao). They are the presently significant coal-producing areas of the country. Also noteworthy are the potential coal-producing areas of South Mindoro to the north of Semirara Island, and the region around Bagacay on Samar. Coal has also been produced at Bislig on Mindanao and on Polillo Island, off eastern Luzon.

The estimated coal resource potential of the Philippines is 1,600 to 1,700 million metric tons, with nearly 200 million tonnes estimated and classified as mineable reserves. Because of detailed exploration in the past, which was undertaken in preparation for present and potential future open-pit mining, more than 40 percent of these estimated mineable reserves are located on the island of Semirara. In contrast, the combined estimated mineable reserves of

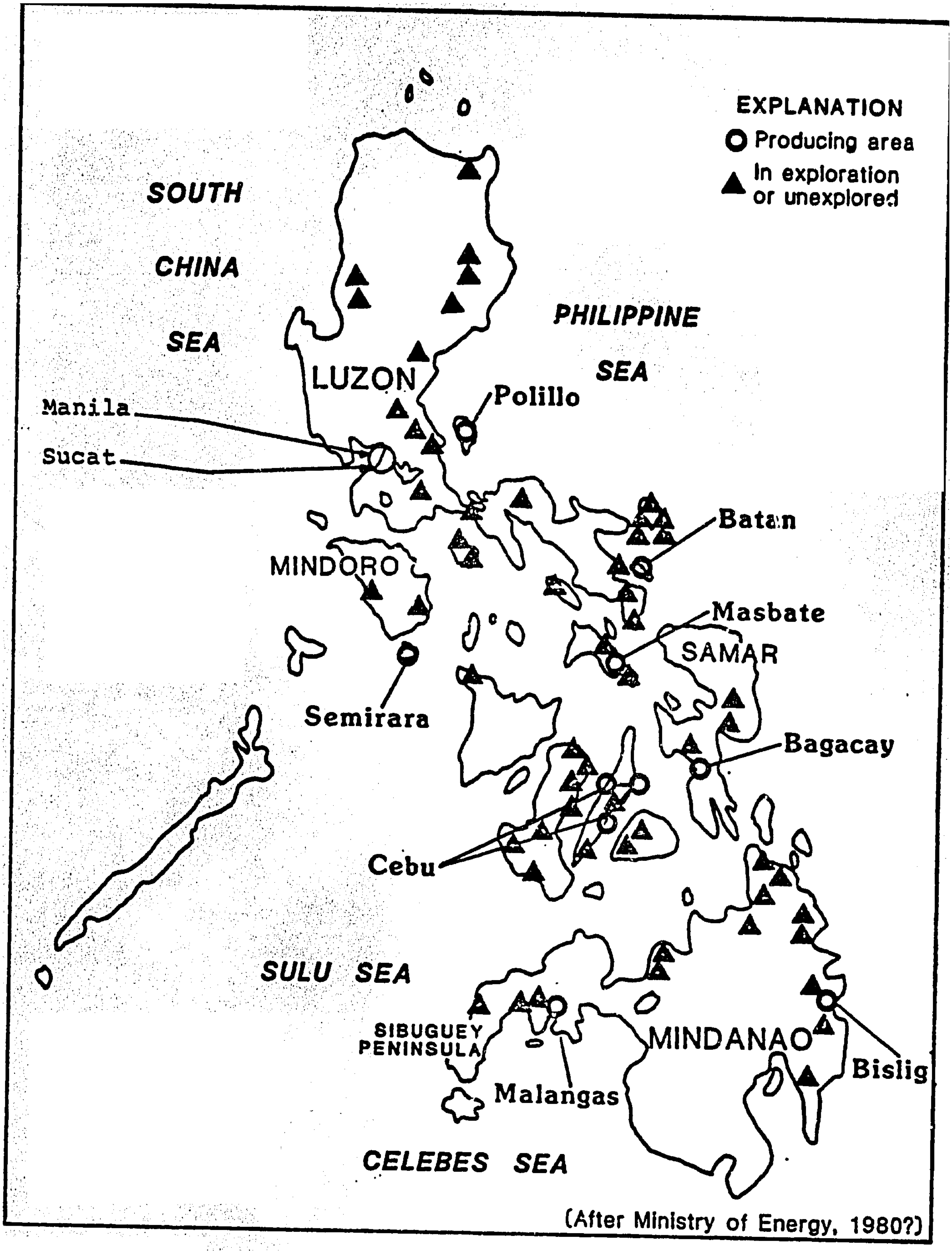

Figure 1. Known and reported coal areas.
(Producing areas updated to 1984)

South Mindoro, the Sibuguey Peninsula (Lalat and Malangas areas), and Samar-Leyte are less than 15 percent of the total. Compared to the attention given Semirara, these three regions range from partially explored -- the Sibuguey Peninsula -- to essentially unexplored -- South Mindoro and Samar. Evaluation of existing available resource information and data and observations during site visits to mining and exploration operations show these four regions could be primary candidates to supply the coal requirement for an initial project to introduce coal-water-mix fuels to the Philippines.

The resource potential for the Semirara, Sibuguey Peninsula, South Mindoro, and Samar regions may be estimated as follows. Where information and data were of doubtful value, conservative assumptions were made.

Area	Resource Potential Million Metric Tons	Mineable Reserves Million Metric Tons
Semirara	550	79
Sibuguey Peninsula	45 or 50	10 or 11
South Mindoro	100	2.4
Samar	27	6.3

Other estimates of reserves for Semirara are available, but whether or not they are mineable is not clear. The two estimates for the Sibuguey Peninsula are based on recent data. However, neither estimate probably includes even more recent estimates for the Lalat area, which could increase the mineable reserve figure by about 7 million tonnes. The estimate for Samar may not include recent estimates for the Carbon Creek area, which could increase mineable reserve estimates as much as 5 million tonnes.

For the coals included in the estimates of resource potential, the variations in quality are uncertain. Philippine coals range in rank from lignitic to bituminous, with the bulk of the coal categorized as sub-bituminous C and B. Sulfur ranges from low (1% or less) to high (more than 3%). Ash content ranges from low (less than 8%) to high (more than 15%). Coal quality variations for the Semirara deposit are the best known, since the exploration programs and mining operations for this deposit are the most advanced, and currently, the most extensive in the country.

Recent shipments of Semirara coal to Luzon for power generation, and for other uses, such as cement manufacture, show the following quality characteristics. Units are weight percent except as noted.

	As-received		Air-Dried	
	Mean	Range	Mean	Range
Moisture	25.7	23-29	17.6	15-20
Ash	16.4	12-21	17.5	14-22
Volatile Matter	29.3	24-31	33.7	31-36
Fixed Carbon	27.8	24-31	31.2	27-35
Sulfur	0.5	0.4-0.6	0.6	0.5-0.7
Heat Value (Btu/lb)	7138	6627-7630	7981	7232-8679

Other analyses for 22 specific shipments of Semirara coal, received by the National Power Corporation in 1984 for use in its Calaca Station, show variations similar to those in the table above.

Two samples of Semirara coal show considerably less ash and higher heat values than is indicated by the analyses in the table above. One of the samples was collected in April 1984 in the Unong open-pit mine by a standard mine-face vertical-cut sampling technique. The other sample was taken from a 1,000 tonne shipment of a "selected Semirara coal" sent to the Calaca generating plant in February 1984. These two samples show 9 and 6% ash and 8,209 and 8,547 Btu/lb. respectively. Both have 26% moisture on an as-received basis.

The coal deposit on Semirara Island can be extracted at the three sites shown in Figure 2. All are suited for open-pit mining. Present production occurs in the Unong pit, which is fully developed and employs European bucket-wheel excavating machines. The Himalian and Panian areas have already been explored as potential future open-pit mining sites. Preliminary studies of mine plans exist. The quantity of coal required for a complete retrofit of the Sucat Station to the use of coal-water-mix fuels would require the opening of a second pit, either at the Himalian or at the Panian site.

There are seven coal beds in the Unong deposit -- one major bed or zone, now being mined, ranges up to 29 meters in thickness, with minor beds above and below. The thickness of the beds ranges from 3.5 to 29 meters with an aggregate average of 18 meters. The Himalian area includes 13 main coal beds and 29 non-coal splits. The aggregate thickness of the coal beds average about 39 meters. The Panian area contains seven continuous coal beds -- with three to four major beds. The aggregate thickness averages approximately 38 meters.

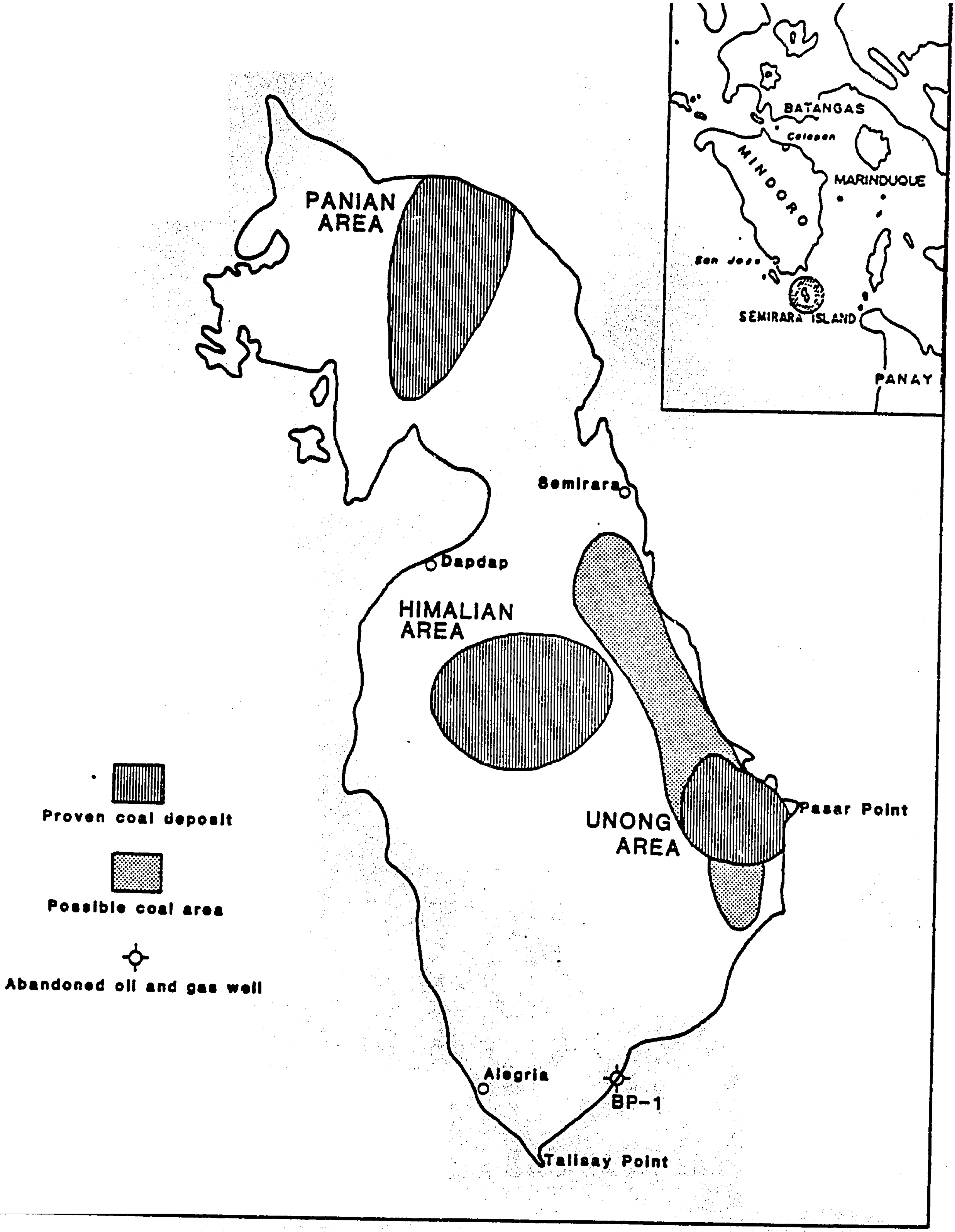

Figure 2. Location map showing proven and possible coal mine areas on Semirara.

The estimated mineable reserve for Semirara coal of 79 million tons applies to mining coal of quality that falls within the variability ranges in the table above; for example, 24% moisture, 14% ash, 33% volatile matter, and 7,507 Btu/lb. heating value. If production from the sites were to be restricted to coal of the quality of the "selected Semirara coal" received recently at the Calaca Station, the mine life -- in essence, the mineable reserves -- would be decreased by some unknown factor.

Ash analyses were performed on all coal samples collected for use in the coal-water-mix fuel formulation studies in the United States. The results indicate that the samples of Semirara coal, as a group, contain more silica, more sodium and potassium, and less iron and calcium than most of the samples from deposits in the other regions. Many more samples are needed for a better characterization of the ash compositions.

The coal in the southern region of Mindoro Island is of sub-bituminous B rank. Few analyses exist and most of these indicate that this coal is high in sulfur and low in ash. However, a few analyses indicate that some of the coal in southern Mindoro may be of low to medium sulfur content. More exploration is needed to characterize this coal.

The analyses of samples of the coal of the Carbon Creek area of southeastern Samar show it to be of sub-bituminous C rank, high in ash, and low in sulfur.

The highest rank coal in the Philippines occurs in the deposits of the Sibuguey Peninsula. This coal is bituminous in rank, low in moisture, and has low to medium sulfur and ash content. This coal is the best quality available in the Philippines and probably also in most of southeast Asia. It is in demand for fueling cement plants and for potential use in a metallurgical coal blend for a future Philippine steel industry.

Evaluation of the available information on the quantity and quality of Philippine coals shows that Semirara is the only region in the Philippines with the estimated mineable reserves of coal large enough to supply the market that a conversion to coal-water-mix fuels use would immediately generate. Two of the other three regions that were studied -- southern Mindoro and southeastern Samar -- have coal of similar quality to the Semirara coal, but exploration is not yet advanced sufficiently to allow meaningful evaluation. The existing mine at Malangas and the planned mine at Lalat on the Sibuguey Peninsula of Mindanao cannot supply sufficient coal. Moreover, at this time, all present and future production for these mines is presumably committed to cement manufacture and to metallurgical uses.

The review and evaluation of available information and data on the Philippine coal resource show that general and specific deficiencies in their completeness abound. A new national coal quantity and quality assessment appears to be needed. To assist such an effort, a program of standardization of coal sampling, handling, storage, preparation, and comprehensive analysis should be begun. To preserve the results of such an effort, a management system for the geological, resource, chemical, and physical information and data needs to be established. Other more-specific needs are obvious. They are

-- A comprehensive program to produce precise and accurate ınformation about the quality and quantity of the coal of Semirara so that the ultimate potential of this deposit can be assessed.

-- An investigation of beneficiation techniques for Semirara co can reduce variations in quality and possibly generally impr quality.

-- A geological and resource synthesis of the whole of the Sibuguey Peninsula, including a study of the feasibility of mining the coal of the Lalat area, to establish the ultimate size of the deposit.

-- A regional reconnaissance study of the coal-bearing areas in southern Mindoro, including a study of the feasibility of mining in the Napisian area and in the Siay area, to obtain better information about resource potential and coal quality, particularly sulfur content.

-- A similar reconnaissance study of the coal resources of southeastern Samar for similar purposes.

COAL-WATER-MIX FUEL FORMULATION

The geological investigation has shown that the only known coal resource in the Philippines that has a quality approaching the high-rank eastern U.S. bituminous coals used in the United States and elsewhere as the basis for coal-water-mix fuels is the resource on the Sibuguey Peninsula of Mindanao. The properties of coals from this region are essentially identical with those of eastern U.S. bituminous, except for their somewhat lower volatile material content that could cause unstable combustion and poor combustion efficiency. A current mining operation at Malangas and a proposed mining operation at Lalat, together with a limited resource base and an already established demand, preclude the use of this resource as a sole supply for the needs of an generating station as large as the Sucat Station, when retrofitted to depend entirely on coal. The best to be expected is a prospect of small quantities becoming available for blending with coals from other Philippine sources.

The geological investigation has also shown that the only presently-known coal resource in the Philippines that is large enough to supply the needs of a coal-fired Sucat Station is the resource on Semirara Island. This resource is presently being exploited in a single open-pit mine (Unong), and operations can be expanded to increase output as coal requirements rise. Coal quality is variable, and selective mining to reduce ash content seems practical. A reasonable conservative assumption of as-received quality, suitable for design purposes and estimation of costs, is that of an inherent moisture content of 24%, an ash content of 14%, a volatile material content of 33%, and a heating value of 7,507 Btu/lb. However, the two samples received at the Brookhaven National Laboratory for experimental work show ash content of 4 and 9%. Ash contents this low are likely to be the result of selective mining or the sampling of a seam without interbedded non-coal material.

The objective of the experimental work at the Brookhaven National Laboratory was to establish a baseline coal-water-mix fuel formulation, using Semirara coal, for use in evaluating the performance of the four steam generators of the Sucat Station. The work was to demonstrate the technical feasibility of formulating a coal-water-mix fuel from the lower-rank Semirara coal that produces acceptable properties for storage, flow, handling, and combustion. The experimental work comprised four different categories of effort.

-- Evaluation of the relative slurryability of five samples of Philippine coals from different deposits, in order to permit the selection of a candidate coal for further investigation. This work led to the selection of Semirara coal for the reasons stated above.

-- Performance of detailed studies on the formulation of coal-water-mix fuels from Semirara coal.

-- Coordination and collaboration with the efforts of U.S. commercial coal-water-mix fuel manufacturers willing to accept and evaluate the behavior of Semirara coal under their particular formulation techniques.

-- For all coal-water-mix fuel formulations, comparative experimental evaluations on a pilot scale of rheological properties, stability, flow characteristics in pipe loops, and combustibility in a furnace simulating commercial operating conditions.

The analysis of the five coal samples shipped to the United States in June 1984 are shown in Table 1. The inherent moisture content (equilibrium moisture in the table) is only 2.1% for the Malangas sample and is as high as 25.96% for the Semirara sample. Volatile material content in the Malangas sample was 19.63%, while it was 32.08% in the Semirara sample. Another significant property, initial deformation temperature of the ash content under reducing conditions, was 2600°F for Malangas -- a high value, -- and from 1900°F to 2300°F for the Semirara coal -- a lower range of values. Low values require careful attention in the steam generator furnace retrofit to manage the tendency to deposit slag on furnace tubes.

Inherent moisture content in coal does not aid in its slurryability. Bone-dry, weight-percentage coal loadings in coal-water-mix fuels, when made from low rank, high inherent-moisture coals, will be low. High rank, low inherent-moisture coals, conventionally used in the United States, consistently produce fuels with high coal loadings, 70% weight or higher. Thus, for Malangas coal, the laboratory work showed that a fuel formulation containing a coal loading in the 65-70% range is reasonable. For the Semirara coal, the range becomes 45-55%.

Detailed formulation studies of coal-water-mix fuels performed at the Laboratory for the Semirara and Malangas coal samples considered the effects of:

Table 1

COAL ANALYSES
(USGS, 1984)

	South Cebu	Malangas	Bislig	Semirara	Bagacay
Proximate					
As Received:					
Ash %	4.43	15.18	14.49	8.86	11.78
Moisture %	9.93	1.94	18.92	25.66	33.11
Volatiles %	42.35	19.63	30.73	32.08	28.23
Fixed Carbon %	43.29	63.25	35.86	33.40	26.88
Higher Heating Value (btu/lb)	12,212	12,909	8,209	8,209	6,662
Equilibrium Moisture %	5.57	2.10	18.96	25.96	32.27
Free Swelling Index	1.0	5.0	0	0	0
Hardgrove Grindability	46	101	43	42	47
Sulfur:					
Total	1.74	0.49	0.57	0.58	5.44
Sulfate	0.04	0.00	0.01	0.03	0.04
Pyritic	0.77	0.02	0.20	0.25	1.91
Organic	0.93	0.47	0.36	0.40	3.49
Ash Fusion Temperature (°F) (reducing atmosphere)					
Initial Deformation	2050	2600	2530	2300	2250
Softening	2130	2680	2620	2370	2360
Fluid	2160	2720	2660	2410	2400

-- coal concentration

-- coal particle size distribution

-- additives

-- methanol to replace water as a carrier

-- coal cleaning

-- coal blending.

The detailed laboratory studies, including comparisons with coal-water-mix fuel samples received from the commercial fuel manufacturers, show the following:

1. A Semirara-based fuel will contain 49-51% coal on a dry weight basis. This loading potential is expected to increase somewhat as fuel manufacturers gain experience with Semirara coal. Because, as a low-rank coal, Semirara coal is hydrophilic in nature, it is not practical to increase its concentration in a fuel through a use of dispersant additives.

2. Several prospective formulation techniques promise increases in the dry-coal loading of a Semirara coal-water-mix fuel. Further detailed investigation and study are required, but the indications so far are the following:

A sink-float beneficiation test of the first Semirara sample received (June 1984), at a specific gravity of 1.5, reduced the inherent moisture content of the coal product and permitted a dry-coal loading of 55% weight. A large reduction of the soluble sodium content occurred. These results were not achieved on the second sample received (September 1984). Nevertheless, some form of coal pretreatment is desirable, and should be identified, to enable the reported variations in quality of Semirara coal to be managed.

Using Malangas coal in a 25% blend with Semirara increased the dry-coal loading to 57%. One commercial fuel manufacturer reported a 60% loading when the blend contained 30% of Malangas coal. Since Malangas coal is naturally hydrophobic in nature, a dispersant was used. The Laboratory used 0.1% of sodium lignosulfonate.

An attempt to reduce the inherent moisture content of Semirara coal through a high-pressure, hot-water drying process, now under development at the Energy Research Center of the University of North Dakota, shows a reduction of the inherent moisture content to 11.5% and an increase in the dry-coal loading to 57%.

An acid flush of Semirara coal before formulation, using a 1 normal sulfuric acid solution, showed a 5% increase in coal loading for both batches of the coal. This effect is thought to result from removal of minerals from the coal which hold water aggressively and add to the inherent moisture content.

The replacement of some of the water with methanol (or presumably with a similar alcohol) did not increase the coal loading potential. The methanol, however, is beneficial in terms of increasing fuel heating value and flame stability.

Accordingly, the following fuel specification is reasonable and should be adopted as the baseline for fuel handling properties and pressure drop calculations. For estimating performance of the steam generators of the Sucat Station, when firing a CWM fuel, this specification with increased ash content was used. With clear favorable prospects of increasing dry-coal loading and heating value that can come from further investigation, this baseline specification is clearly conservative.

- Dry Coal Loading - 50 percent
- Grind analysis - greater than 75% below 200 mesh,
  greater than 99% below 50 mesh
- Stabilizer Additives - 3 percent ammonia and 1000 ppm formaldehyde
- Viscosity - 875 centipoise at 100 sec^{-1}

Tests in fuel formulation using a number of different grinds showed no marked effect on coal loading.

Flow tests were performed on two of the large samples received from the participating commercial coal-water-mix fuel manufacturers. The equipment is shown in Figure 3. For each run, shear rate and velocity ranged as follows. Flow was strictly in the laminar regime, and the Reynolds numbers ranged from 1 to 750.

	Velocity Range ft/sec	Shear Rate Range sec^{-1}
Small Loop (3 GPM)		
1/2" section	1.2-2.7	190-415
1" section	.40-.95	20- 85
Large Loop (30 GPM)		
1" section	2.2-12.0	200-1100
2" section	.7- 3.6	35- 185

Viscometer tests with the baseline fuel show the relation between shear stress and shear rate to be as in Figure 4. The flow curve that best fits the data plotted is

$$\tau = k\dot{\gamma}^{n},$$

where τ = shear stress ($dynes/cm^2$)
$\dot{\gamma}$ = shear rate (1/sec)
k = consistency $\left(\frac{dynes\ sec^n}{cm^2}\right)$, 130.7
n = flow index (dimensionless), 0.413

The pressure drop relationship for pipeline flow, corresponding to the flow curve in Figure 4, is

$$\left(\frac{D\Delta P}{4L}\right) = (1.45 \times 10^{-5}) \left[\left(\frac{3n + 1}{n}\right)^{n} k \left(\frac{2V}{D}\right)^{n}\right]$$

where D = Pipe Diameter (ft)
L = Section Length (ft)
V = Velocity (ft/sec)
ΔP = Pressure Drop (lb/in^2)

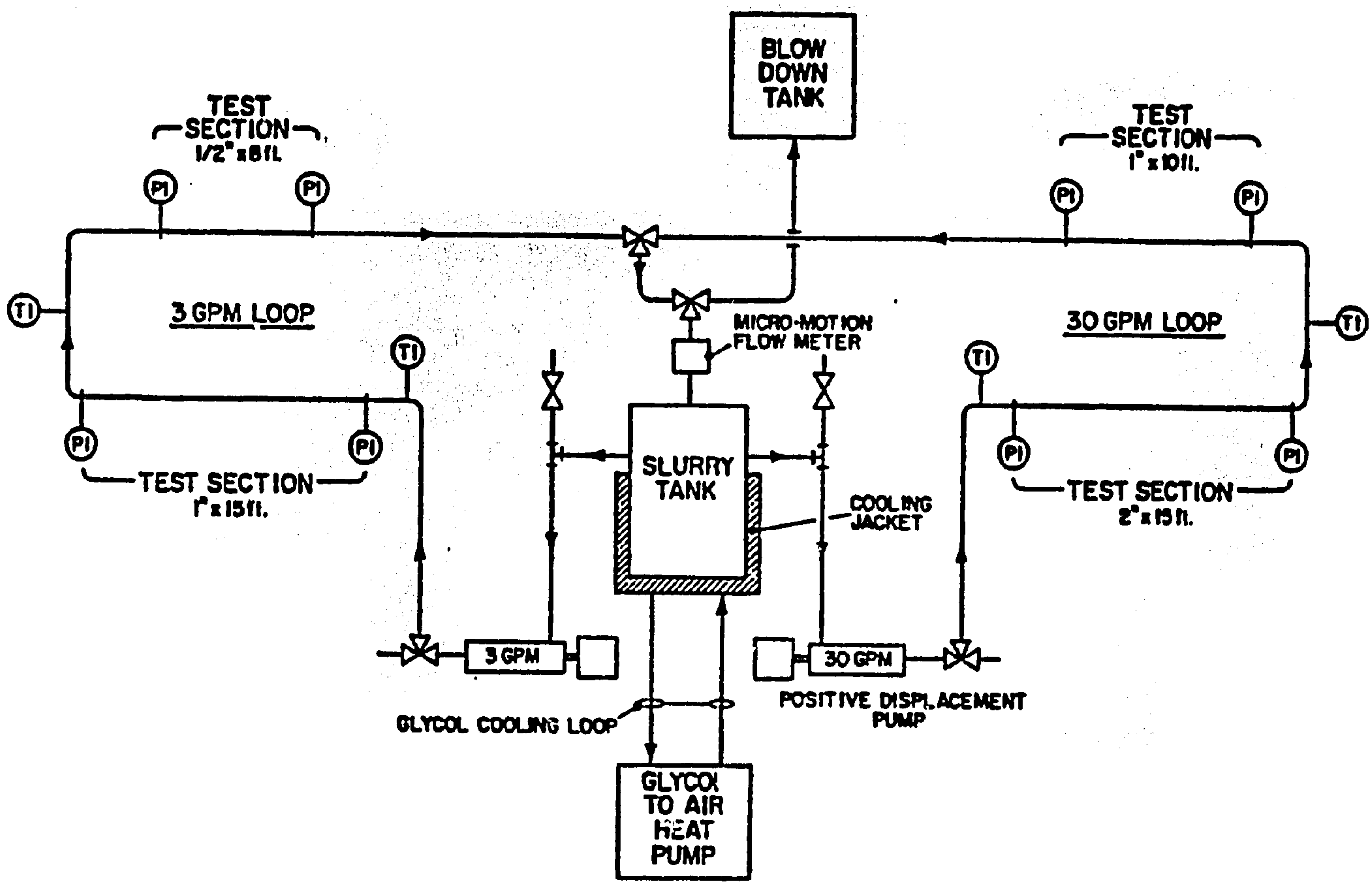

Figure 3. Pipe Loop Layout for Slurry Flow Testing

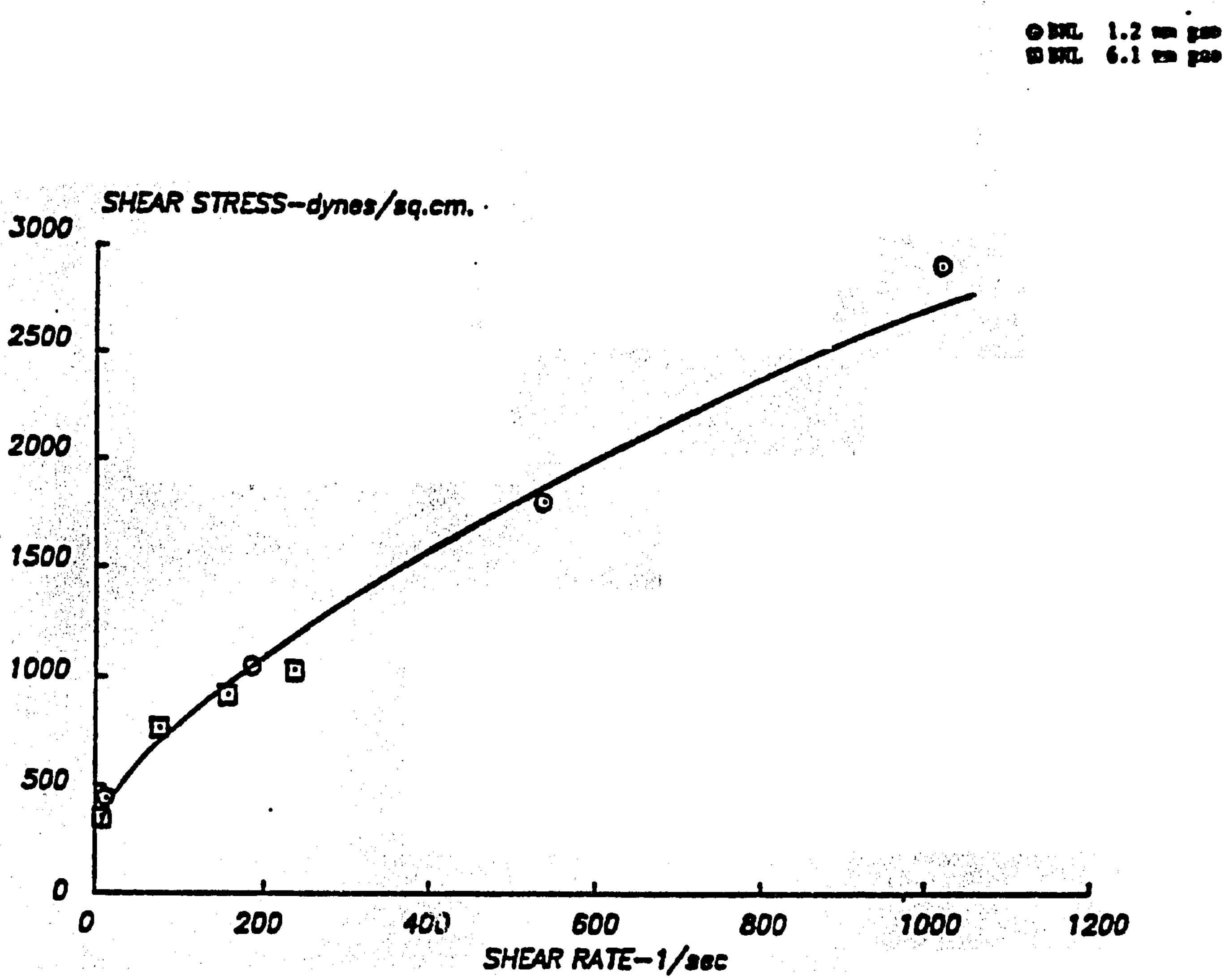

Figure 4. Shear-Stress/Shear-Rate Relationship for Baseline CWM-Fuel

Relationships of this type were prepared for all commercial fuels submitted to the Laboratory. For the two commercial fuels used in the loop tests, the agreement between viscometer-predicted and measured pressure drops was good. These results indicate that fuels prepared from Semirara coal can be stored and handled predictably. Similar tests to those described above should be repeated as the final coal-water-mix fuel formulation evolves.

Combustion tests were performed on large samples of the baseline fuel, and on the three large samples received from the participating commercial coal-water-mix fuel manufacturers. The combustion furnace is shown in Figure 5. The burner is equipped with an integral kerosene-fired direct contact air heater, which can produce air temperatures as high as 530^{O}F. at the expense of consuming about 2% of the oxygen in the combustion air. The burner register was designed for high air swirl. The burner nozzles either were of an axial-flow type with atomization occurring at the exit through a high-pressure drop swirling air blast, or were provided with an impact plate at the exit, hit by the internally-mixed fuel and air.

The atomization and combustion tests performed at Brookhaven National Laboratory showed that, on the pilot-scale (1 million Btu/hr liberation) of the equipment, the baseline fuel and the fuels provided by commercial formulators can be burned without support fuel. Combustion air preheat temperatures were about 500^{O}F. One commercial sample, containing methanol, burned without support fuel and without air preheat.

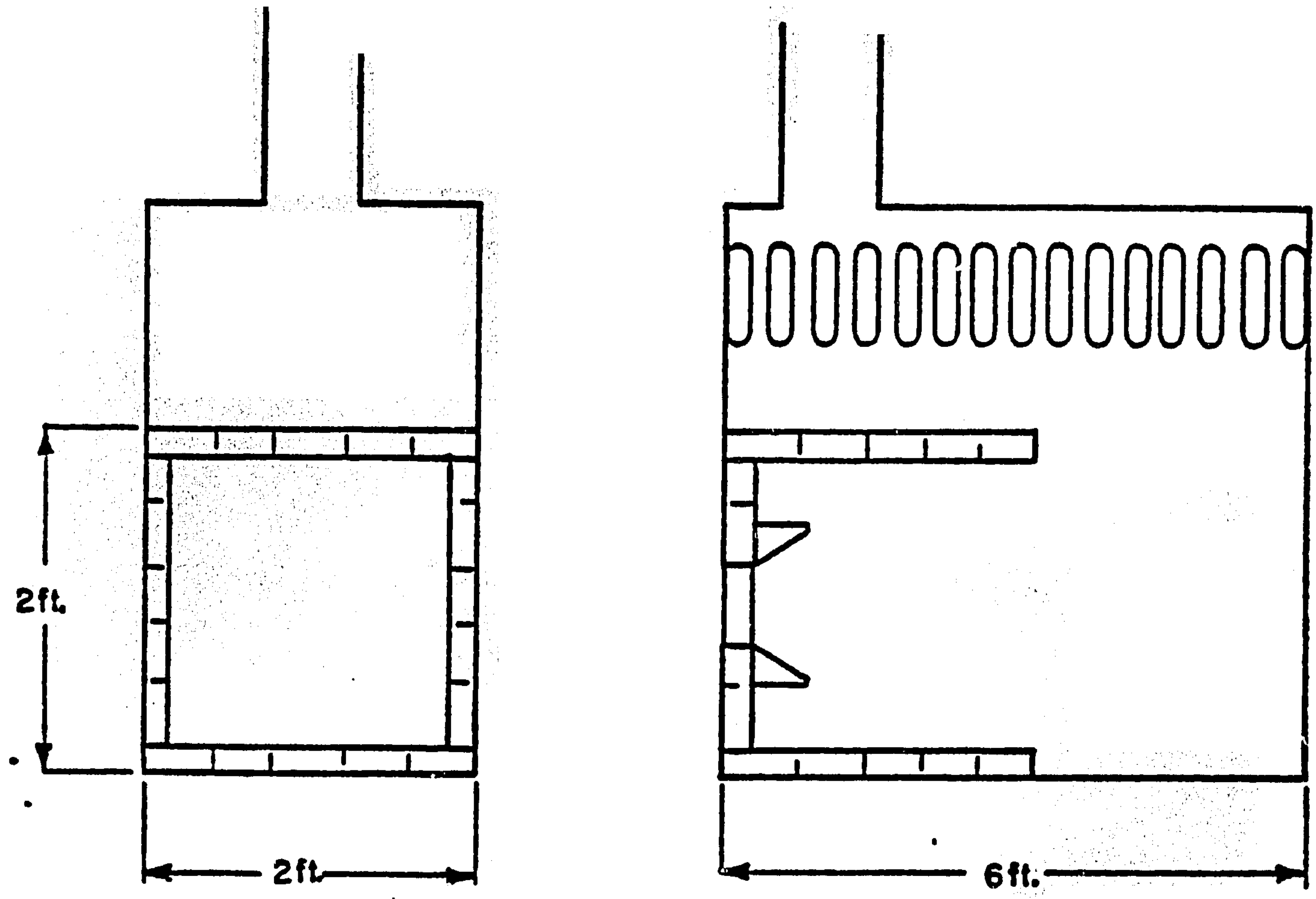

Figure 5. Outline and Dimensions for Combustion Test Furnace

As a project to introduce coal-water-mix fuels to the Philippines evolves, the atomization and combustion tests should be repeated on a larger scale to establish the design details for the commercial burner, the corresponding combustion conditions, and the appropriate operating practices.

POWER PLANT RETROFIT AND PERFORMANCE

The Sucat Thermal Power Station of the National Power Corporation is the largest generating plant in the Philippines, with a nameplate capacity of 850 MW, serving the Luzon Grid. The station is located in Muntinlupa, metro Manila, on the western shore of Laguna Lake. The station capacity comes from four generating units, whose steam generators have been designed only to fire a residual petroleum fuel oil. Individual unit nameplate capacities and commissioning dates are No. 1, 150 MW (1968); No. 2, 200 MW (1970); No. 3, 200 MW, (1971); and No. 4, 300 MW (1972). Station layout is shown in Figure 6.

The site is flat and at an elevation of 44 feet above sea level. The neighboring area is congested and residential. Access to the site is by truck or barge. The neighboring highway area is heavily traveled. The railway presently is inoperative. Lake barge traffic is restricted, and access to Manila Bay is via a narrow lock on the Pasig River purposely installed to restrict salt water intrusion.

Unit No. 1 turbo-generator is supplied with superheated steam at 1800 psig and 1000^{o}F. from a conventional natural-circulation, drum-type steam generator. Units No. 2 and No. 3 are duplicate design. Steam at 2700 psig and 1000^{o}F.

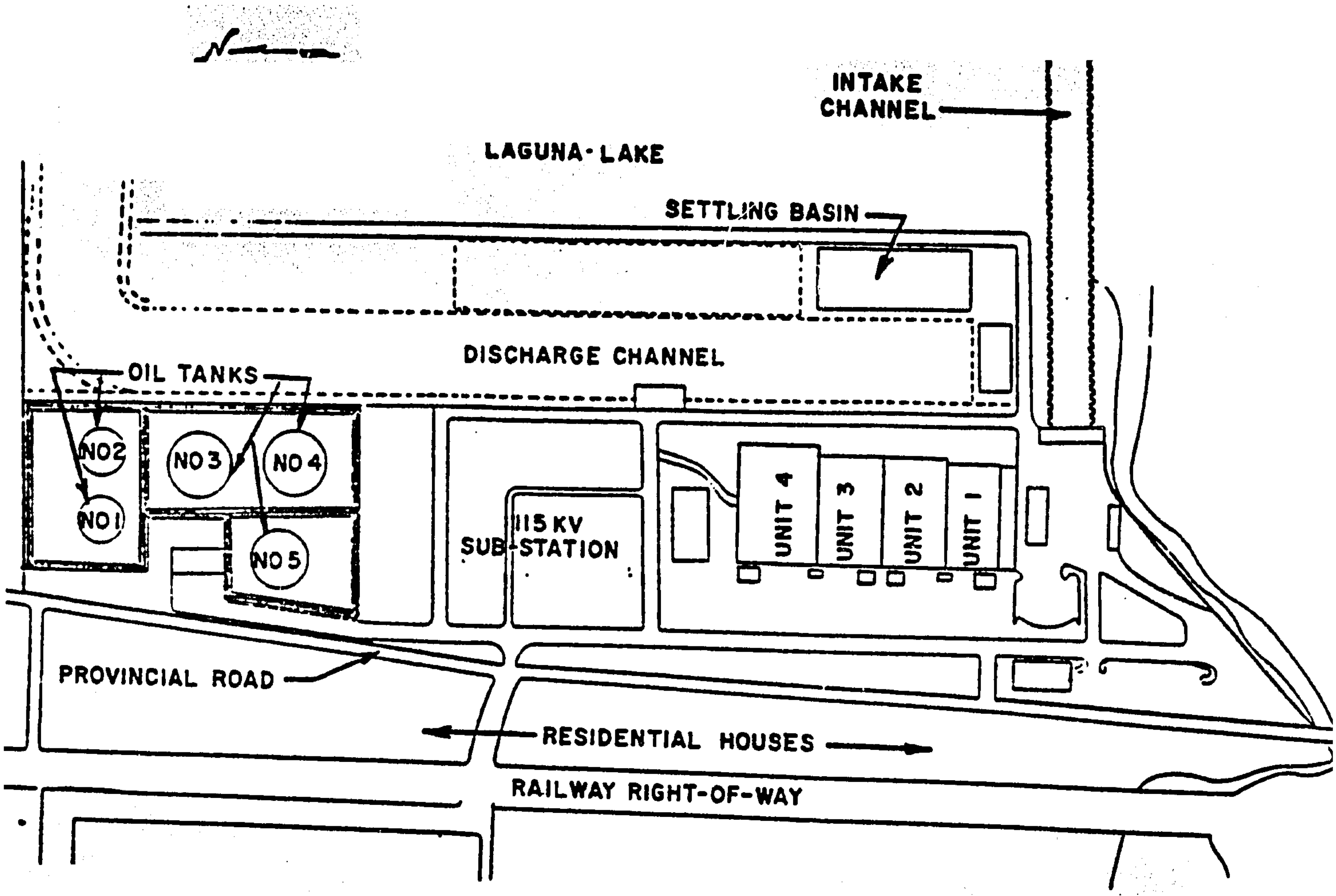

Figure 6. Plot Plan of the Sucat Station

is supplied from forced-circulation, drumless, once-through steam generators. No. 4 unit is similar to No. 2 and No. 3 units, except for its larger capacity. All steam generators were supplied by Babcock-Hitachi of Japan. All four units use single reheat at $1000^{0}F$.

Conversion of the steam generators to coal-water-mix fuel requires two types of modification: modifications that are mandatory, such as installations of new burners and equipment to manage ash and slag deposits; and modifications that are optional and selected on the basis of trading off the cost of modification with the improvement offered in increased capacity and reliability. Two particular schemes were selected involving the two types of modifications for each steam generating unit, and each scheme was evaluated in terms of cost and performance.

Minor modification of a steam generator involves the minimum number of different modifications to maintain a low level of capital investment while still producing a reasonable rating of capacity. The specifications for this type are shown for Units No. 2, No. 3, and No. 4 steam generators in Figure 7, and for Unit No. 1 in Figure 8.

Major modification of a steam generator involves achieving the highest rating of capacity while involving a level of capital investment that is still considered reasonable. The specific modifications are shown for Units No. 2, No. 3, and No. 4 in Figure 9, and for Unit No. 1 in Figure 10. The major difference between the two types of modifications is the installation in the

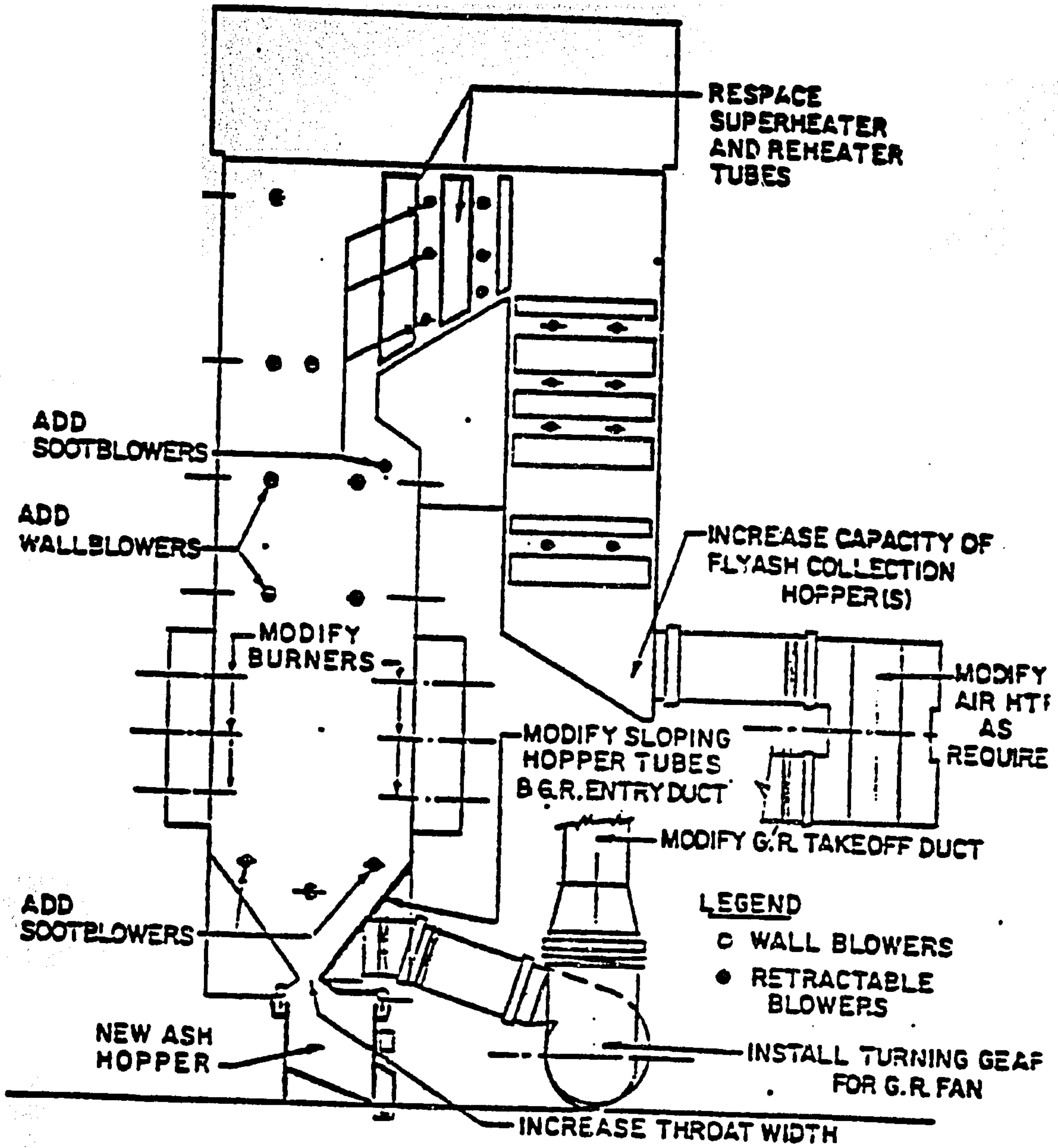

Figure 7. Minor Modifications for the Sucat Units 2, 3, and 4

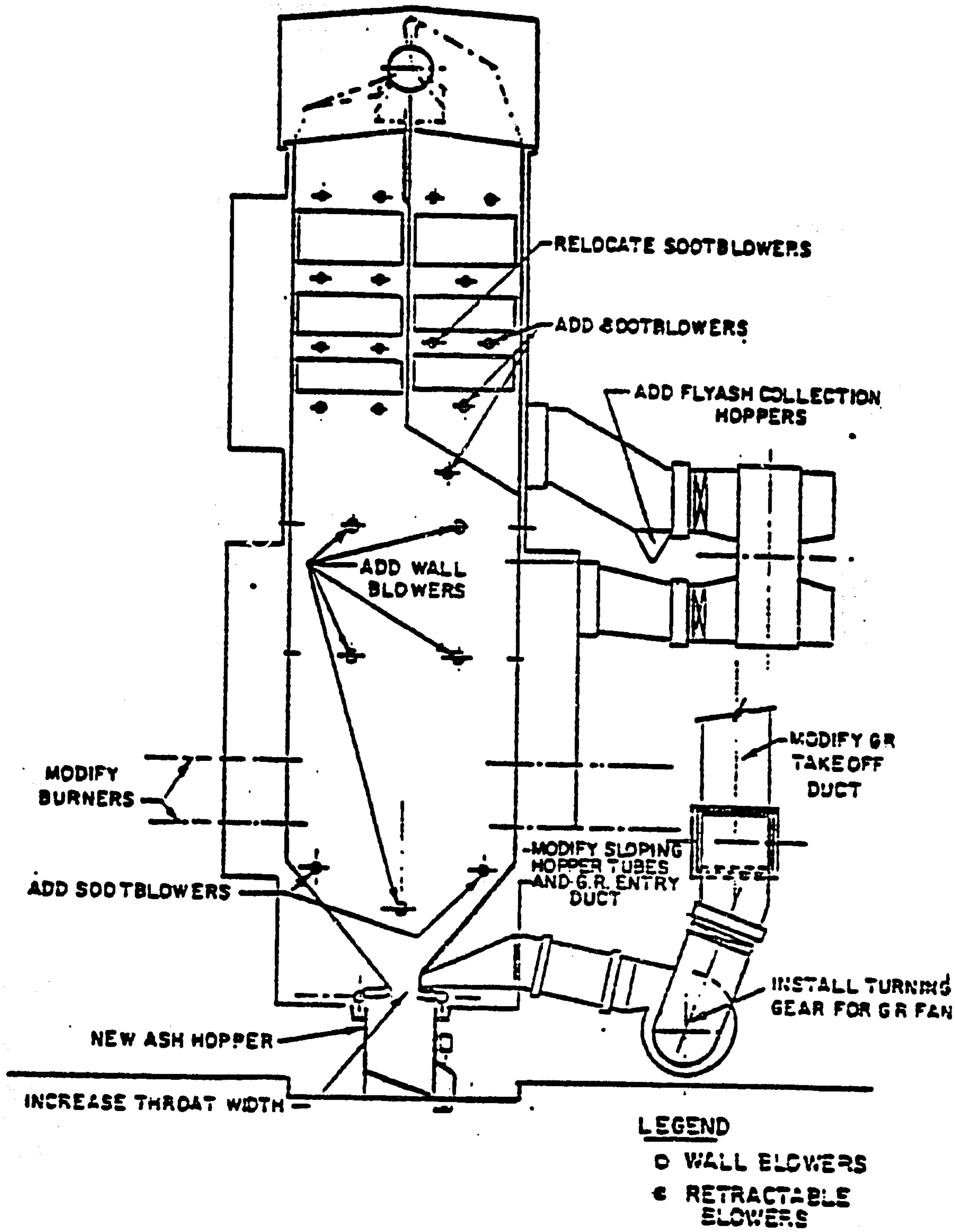

Figure 8. Minor Modifications to the Sucat Unit No. 1

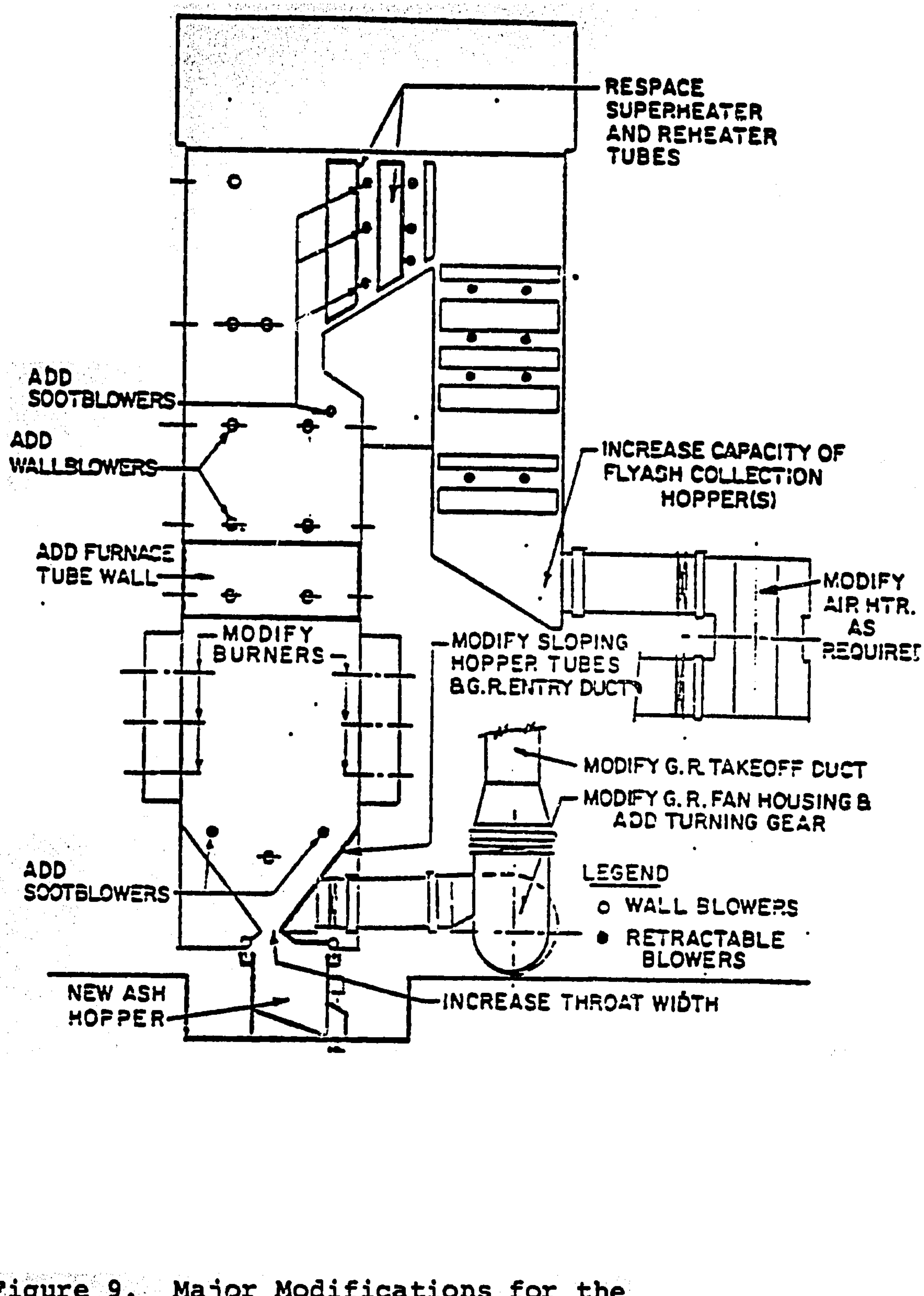

Figure 9. Major Modifications for the Sucat Units No. 2, 3, and 4

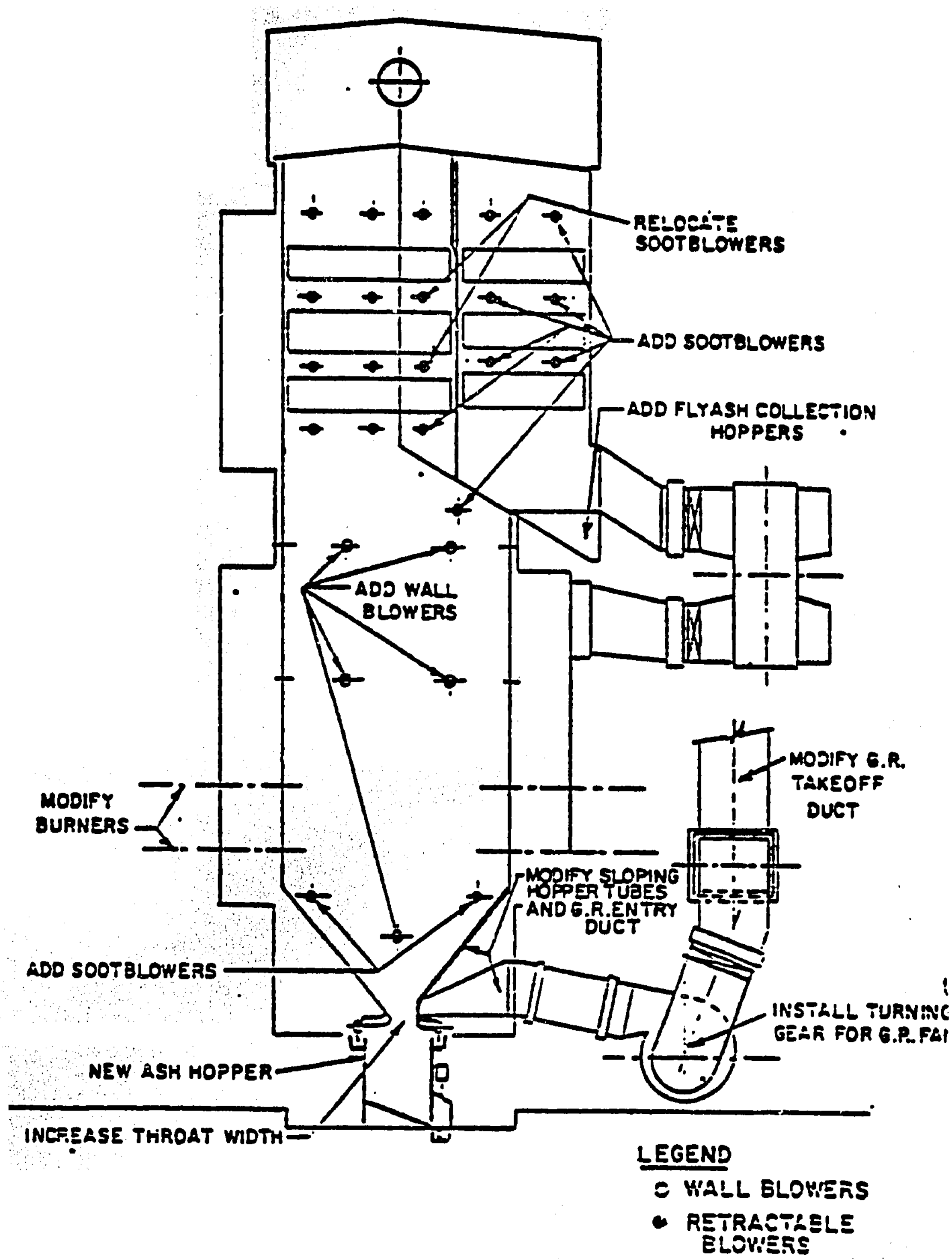

Figure 10. Major Modification to the Sucat Unit No. 1

major modification of additional furnace height in Units No. 2, No. 3, and No. 4, and the rebuilding of the economizer section in Unit No. 1.

Performance of the modified steam generators was estimated for three different CWM fuels: the baseline fuel at 50% dry Semirara coal weight; an improved fuel at 55% content; and a fuel at 60% content made from a blend of 75% Semirara coal and 25% Malangas coal. For the baseline fuel, performance estimates are the following

Unit	Sucat 2 (3)		Sucat 4		Sucat 1	
Modification	Minor	Major	Minor	Major	Minor	Major
Steam Flow, 10^3 lbs/hr	813.4	1,016.7	1,217.1	1,521.4	635.8	733.7
Rating, %	60	75	60	75	65	75
Gross Output, MW	128	156	195	238	97	113
Aux. Loads, MW	5	6	8	9	7	8
Net Output, MW	123	150	187	229	90	105
Boiler Efficiency, %	74.0	73.7	74.0	73.7	74.3	74.0
Net Plant Heat Rate, Btu/Kwhr	11,080	11,070	10,930	10,[illegible]80	11,960	11,900

With the Semirara/Malangas blend CWM-fuel, ratings increased by 5% of nameplate in each case.

New installations within the station itself are required, in addition to the steam-generator modifications. New installations are the CWM-fuel storage and distribution system, including modifications to existing storage tanks such that this new system can operate in parallel with the existing fuel-oil storage and distribution system; an electrostatic precipitator for each steam generator to control particulate emissions to suit local standards; a system to handle and dispose of ash and slag collected from within the furnace; and a system to handle and dispose of flyash collected from the electrostatic precipitators. Associated with these new installations are modifications to existing instruments and controls and the installation of new equipment; modification to the plant electrical supply and distribution system; new and altered foundations; and new civil-structural work.

Capital costs to achieve the modifications to the station for the baseline CWM fuel are shown below. The costs are in January 1985 dollars, and do not include contingencies, escalation of costs during construction, interest during construction, spare parts, and commissioning costs. About 75% of the costs shown are likely to be incurred in dollars and the rest in local currency.

Capital Cost Summary

Baseline CWM Fuel

	Millions of U.S. Dollars				Total
	Sucat 2	Sucat 3	Sucat 4	Sucat 1	Sucat 1-4
Minor Modification	21.0	18.5	26.0	15.0	80.5
Major Modification	28.5	25.5	34.0	21.0	109.0

The schedule for the construction period to retrofit all four units is based on retrofit and operation first for the No. 2 unit. Retrofit of the No. 3 and No. 4 units follow upon initial operation of the No. 2 unit. No. 1 unit retrofit follows with slight delay. The schedule is shown in Figure 11 for both the minor and major modification types. The period is 73 months for the minor modification and 81 months for the major modification. Variations are possible depending on whether or not the operation of an electrostatic precipitator for the No. 2 unit can be deferred until initial operation has been achieved.

The results of current work in the United States by several firms to develop and demonstrate a staged slagging combustor can affect whether or not the major modification type of retrofit is ever implemented. Staged slagging combustors would replace existing burners in a retrofitted unit. In operation, these combustors could retain up to 90% of the ash content in the fuel as a molten slag. This slag would be drained within the combustor and never enter the furnace. Operation of the steam generator with the cleaner combustion-gases that result is likely to produce ratings equal to, or perhaps higher than, those for the major modification. Capital costs could be lower at the same time. The prospects are that proven burners of this type could become available within the construction period. Their progress should, therefore, be monitored. Figure 12 illustrates how the Sucat No. 3 might be modified to accept staged-slagging combustors instead of conventional burners.

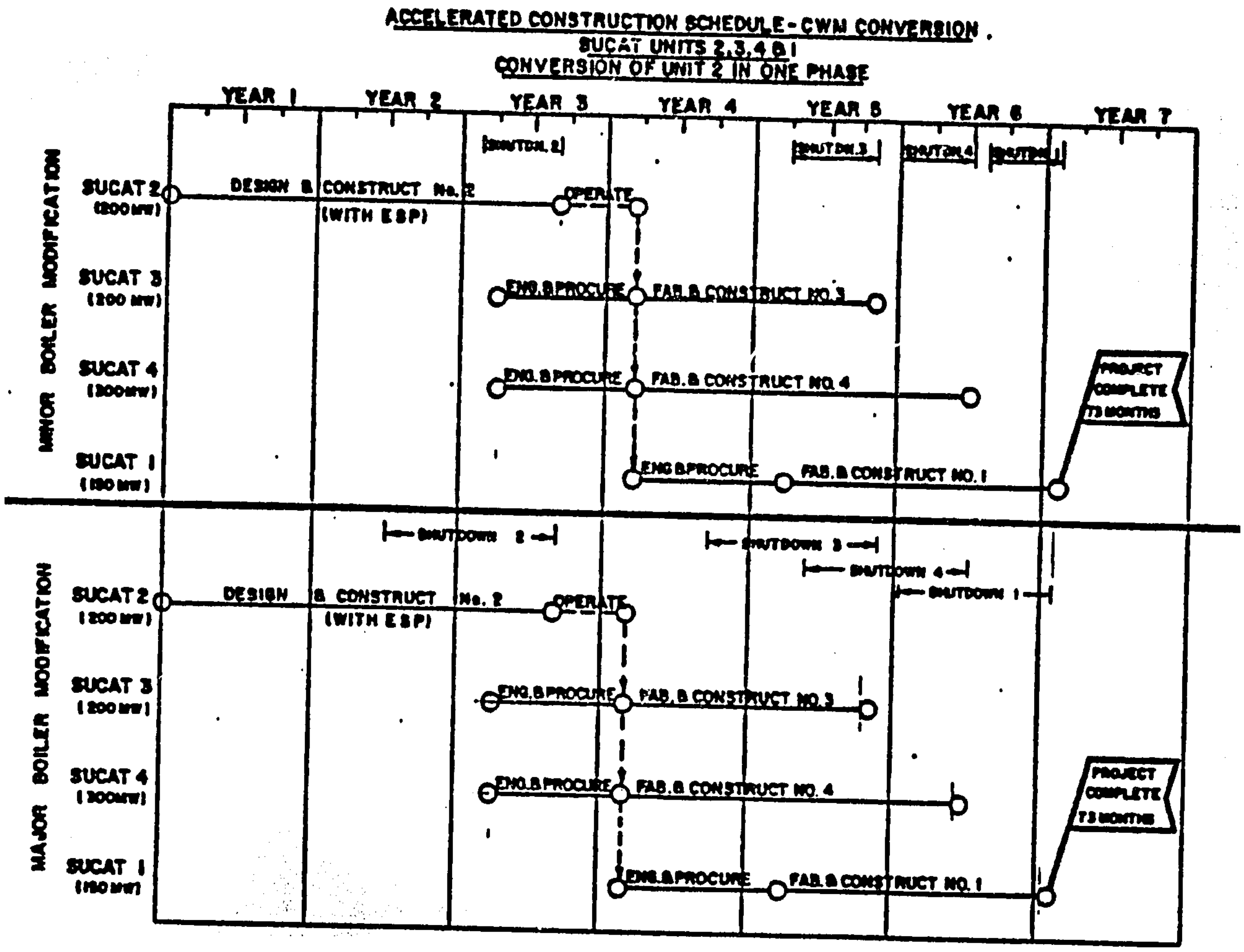

Figure 11. Projected Completion Schedules

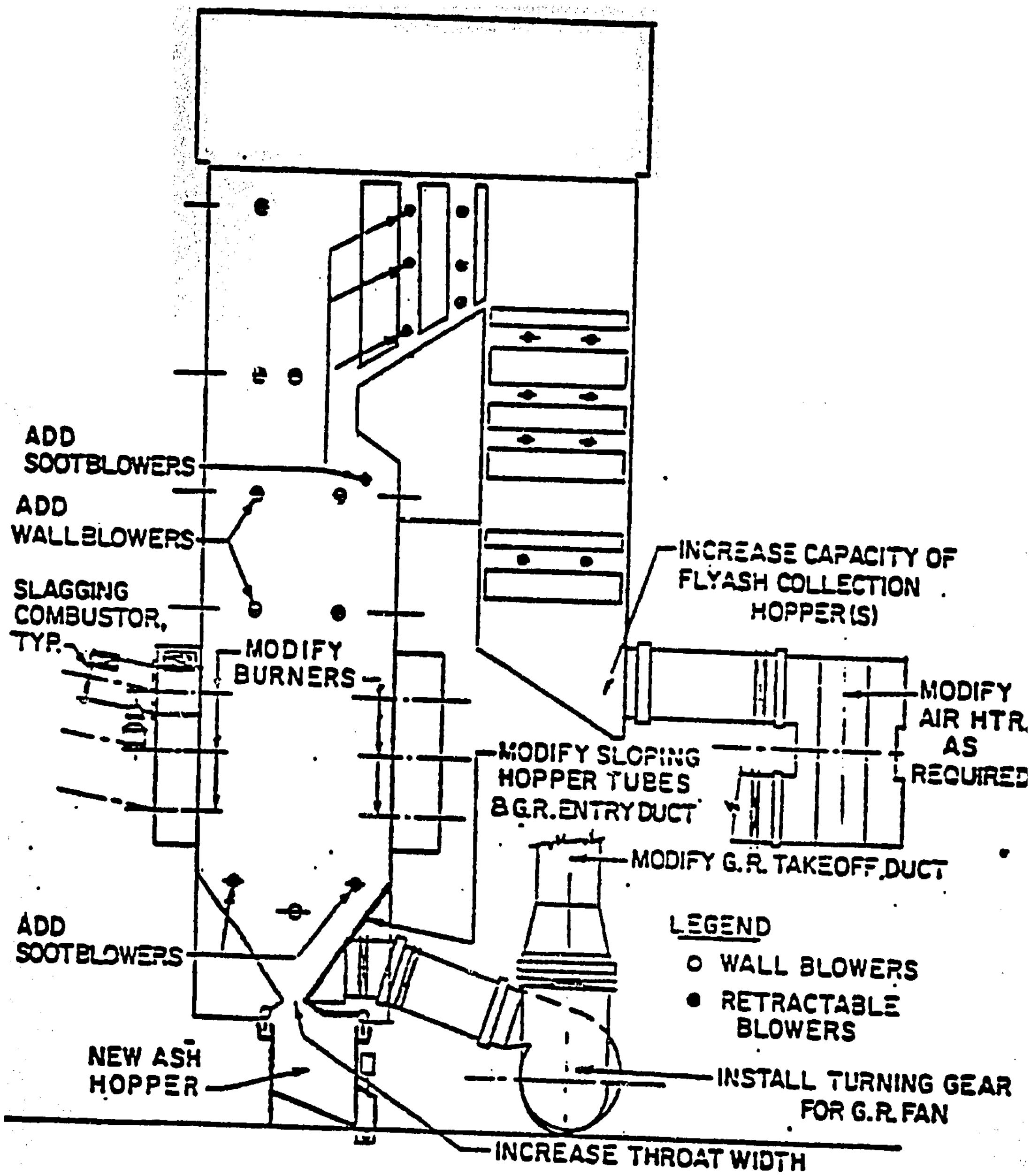

Figure 12. Modification of Sucat Unit No. 3 using Staged-Slagging Combustors

CWM-FUEL SUPPLY SYSTEM

The scope of the CWM-fuel supply system extends from the extraction of coal on Semirara Island through the delivery of the CWM-fuel in the tanks of the Sucat Station. It includes the expansion of the mining operations first in the Unong open pit to accommodate the coal requirements of the initial retrofit, and later through the opening of a new open-pit mine at the Himalian or Panian sites to provide the additional coal requirement for the retrofit of the remaining units of the Sucat Stations. It includes the construction and operation of a CWM-fuel preparation plant on Semirara Island for the initial retrofit and the expansion of this plant to accommodate the requirements for the retrofit of the remaining units. Also included are the shipment by sea going barge of the CWM-fuel to the site of the idle Rockwell Station on the Pasig River in the metro-Manila area, where an idle pipeline connects to the Sucat Station.

Investments will be required to expand coal production on Semirara Island. Expansion projects have already been studied: by Dames and Moore for the Himalian site; and by Austromineral for the Panian site. A study in 1980 for the Unong site by Austromineral shows an investment of U.S.$ 187.6 million including contingency and interest during construction. This study also showed a coal production cost of U.S.$ 21.17 (Pesos 423) per metric ton at an output level of 1 million tonnes annually.

Four bucket-wheel excavators remove overburden and produce the coal output in the Unong pit during about 40 percent of available time operation. The output could be increased another 700,000 tons annually to supply the initial operation of the Sucat Station, if the operations are extended to about 60 percent of available time. Operating history and maintenance practices would have to be reviewed to ascertain that such an extension of operating time is feasible. If so, the production cost of the total output of 1.7 million tons should decrease. According to the indication in Figure 2, the limits of the Unong pit may transcend the presently delineated boundaries. The present estimate of extractable reserves of 17.2 million tonnes should increase.

The reserves at the Himalian site are estimated to be about 37.5 million tonnes. A portion of the site is covered by a hard limestone cap. The capital cost of opening and commissioning an open-pit mine at Himalian was estimated by Dames and Moore in 1983 to be U.S.$ 118.7 million, including all the mine offsites, but excluding contingency and interest during construction. The output level would be two million tonnes annually. They estimated the coal production cost, during the first four years, while the hard limestone cap is worked, to be U.S.$ 22.42 (Pesos 448) per tonne. For the fifth year onward, the estimate reduces to U.S.$ 19.55 (Pesos 391) per tonne.

The reserves at the Panian site are estimated to be 45.8 million tonnes. The capital cost of opening and commissioning an open-pit mine at Panian was estimated by Austromineral in 1982 to be U.S.$ 211.2 million, including all the mine offsites, but excluding contingency and interest during construction. The output level would be 1.7 million tonnes annually. They estimated the coal production cost to be U.S.$ 24.93 (Pesos 499) per tonne.

For both studies the basic coal extraction equipment would be bucket-wheel excavators. For the Unong and Panian sites, all coal seams lie below sea level. The Himalian site is a hilltop, but the lower seams are likely to dip below sea level. All sites involve extensive dewatering equipment. Sea water infiltration is a likely problem at the Unong and Panian sites. Pumping systems would have to accommodate an annual rainfall of 3000 mm, which occurs over a consecutive 3-4 months of the year.

Since the data for the Himalian and Panian sites are developed by different organizations, they may not be entirely comparable. Nevertheless, it appears that the Himalian site could be developed more quickly and have a less serious problem of water control. This should be the site to focus on in an implementation of the project.

Washing tests on the coal obtained during the exploration programs show that the ash content of as-mined coal can be reduced significantly. (However, losses may be as high as 40 percent.) Since laboratory work at Brookhaven indicates, for samples from the Unong pit, that the rejected clays in a washing process are highly water-absorbent, the incorporation of washing in the CWM-fuel preparation step should raise the dry-coal content in the fuel significantly. Experience to date indicates that fresh water is plentiful on

Semirara Island, and available many times over the 981 gallons per minute maximum required to formulate the CWM-fuel.

The CWM-fuel preparation plant consists of multiple parallel trains of equipment of fixed size, based on the largest-capacity pulverizing equipment commercially available. Each train is fed from the coal storage area by front-end loaders. The as-mined coal is crushed, then fed to a wet grind ball mill. The slurry produced is held in deaeration tanks where necessary additives are introduced, and then stored in agitated tanks for shipment. Three such trains are required to supply the initial retrofit of the Sucat No. 2 unit. Plant area is about 740 feet by 165 feet, including the coal storage area. The power requirement to operate the plant is about 4 MW.

The CWM-fuel preparation plant to supply the full four-unit retrofit of the Sucat Station will comprise 11 trains of equipment. Plant area is about 740 feet by about 600 feet. The power requirement to operate the plant is about 15 MW.

The CWM fuel will be transported to the pipeline terminal on the Pasig River at the Rockwell Station in 5-6 thousand tonne capacity petroleum-type barges retrofitted to handle CWM fuel and provide agitation during the voyage. For the initial capacity, two trains of two barges each and a tug are required in dedicated service. The round trip voyage requires seven days. For the full retrofit of the Sucat Station, the number of barge trains in dedicated service rises to eight. At the site of the Rockwell Station, a 10-inch, 10-km idle pipeline exists that connects with the Sucat Station. This line is essentially level.

A potential alternative route exists to reach the Sucat Station from a water-born delivery point in the Batangas harbor. A 16-inch, 91-km operating pipeline connects Batangas to Sucat. It presently delivers the fuel oil supply to the Sucat Station. This line rises and falls as it traverses mountainous terrain between Batangas and Sucat. Converting this line to CWM-service poses flow management problems.

Calculations based on small-scale pipe loop testing and on rheological data developed at Brookhaven National Laboratory indicate that the existing Rockwell line cannot supply the full CWM fuel requirement for the major modification of all four of the Sucat units. An additional line would ultimately be laid in the same right-of-way. The Batangas line has adequate capacity when four intermediate pumping stations are installed at about 15-20 km intervals. The Rockwell line has no pumps, since the original direction of its flow would be reversed. All the new pumping stations and the pumping station at Batangas are provided with new electric-drive, positive-displacement piston pumps of the type currently in use in the United States for the Black Mesa coal slurry transport line. Sedimentation is controlled during flow by periodically launching cleaning augers (the PIG system) through the line.

Costs established for modifying the pipelines and for their operation are based on small-scale pipe loop tests and on rheological data developed by Brookhaven National Laboratory for the baseline fuel. These costs are conservatively estimated, and considered adequate for purposes of financial analysis. For purposes of ultimate pipeline retrofit and operation, pipeline loop testing on a larger scale with the CWM-fuel intended for ultimate use is needed.

The costs established for modifying and operating the pipelines are the following:

	Rockwell/Sucat U.S.$(000) equiv.	Batangas/Sucat (at full capacity) U.S.$(000) equiv.
Capital Investment		
Present Line	6,000	25,000
Additional Line	6,500	--
Total	12,500	25,000
Operating Cost		
Present Line	850	4,000
Additional Line	300	--
Total	1,150	4,000

Total costs for preparation and delivery of CWM fuel to the tanks at the Sucat Station are estimated below for the four retrofit scenarios, for the range of Semirara coal selling prices currently being paid or negotiated by the National Power Corporation, and from the data assembled above. These costs are averaged from costs estimated for each year of future operation throughout the life of the project.

ESTIMATED AVERAGED COSTS FOR

CWM-FUEL DELIVERY

($/MT of Baseline Fuel)

Sucat Scenario	Coal Price*	Coal in Fuel	Average Cost Range for CWM Preparation	CWM Barge Transport	Pipeline Transport	CWM Fuel Delivered at Sucat**
A. Sucat 2, Minor Retrofit	$26	12.70	$16.50	7.30	$2.80	$40.90
	35	17.20	18.02	7.30	2.80	43.80
B. Sucat 2, Major Retrofit	26	12.80	13.40	7.30	2.40	37.50
	35	17.30	14.90	7.30	2.40	40.40
C. All Units, Minor Retrofit	26	12.70	11.50	7.30	1.70	34.80
	35	17.01	13.01	7.30	1.70	37.60
D. All Units, Major Retrofit	26	12.70	11.05	7.30	1.50	34.60
	35	17.01	13.00	7.30	1.50	37.60

*expressed as $/MT of as-mined coal.

**based on a range of production costs, taxes, and profits, in addition to variations in coal prices. Therefore, numbers do not add horizontally.

FINANCIAL ATTRACTIVENESS

The total plant expenditures to cover the total project costs, i.e., costs for the facilities to increase the output of the mining operations on Semirara Island, to construct the CWM-fuel preparation facilities on Semirara Island, to convert barges to inland sea and river transport of CWM fuel, to retrofit the existing Rockwell/Sucat pipeline, and to convert the four steam generators in the Sucat Station to utilize CWM fuel, are summarized as follows in millions of U.S. dollar equivalents. Interest during construction and other financing costs are excluded.

Category	Scenario D All Four Units Major Modifications
Mine Construction and Commissioning	173.3
Fuel Supply System	
Preparation	80.4
Barge Conversion	6.0
Pipeline Conversion	15.0
Subtotal	101.4
Power Plant Conversion	109.0
Total Expenditures	383.7

The financial analysis is based on these capital requirements and the delivered CWM-fuel costs developed above.

The results of the financial analysis for various prices paid for run-of-mine coal range from U.S.$ 26 to U.S.$ 45 equivalent per tonne. The likely range is from U.S.$ 26 to U.S.$ 35 per tonne. This is the range of prices being paid, or being negotiated, by the National Power Corporation to supply its new station at Calaca. The higher price is being negotiated for a selectively-mined coal of lower ash and less variation in ash content

Investment banks in their commercial operations have a minimum cut-off point on the rate of return on investment (ROI) for a project to be considered. Depending on local conditions, one could choose, say, 14.0 percent. The ROIs in Scenarios C and D exceed such a threshhold by a significant margin, particularly in the U.S.$ 26-35 coal price range. It is unlikely that a

TABLE 2

Results of Financial Analyses

Scenario	Coal Price ($/MT)	Return on Investment (%)	Return on Equity (%)	Net Present Value ($Million)	Net Present Value (PMillion)
A. Sucat 2, Minor Retrofit	$26	23	62	$27	P440
	35	16	46	7	140
	40	12	38	(2)	(40)
	42	10	34	(5)	(100)
	45	7	29	(10)	(200)
B. Sucat 2, Major Retrofit	26	27	73	42	840
	35	21	58	23	460
	40	18	50	13	260
	42	17	47	10	200
	45	14	42	3	60
C. All Units, Minor Retrofit	26	40	101	151	3,020
	35	33	85	107	2,140
	40	29	78	85	1,700
	42	26	72	70	1,400
	45	24	67	56	1,120
D. All Units, Major Retrofit	26	37	94	176	3,520
	35	30	80	122	2,440
	40	26	71	91	1,820
	42	24	67	77	1,550
	45	21	61	58	1,160

conversion of the Sucat Station would stop with only the No. 2 unit. Yet, even the conversion of only this unit shows the ROI exceeding the postulated threshhold.

The impact of the range of coal prices indicates that considerable attention and care should be given to the expansion of the mining capacity on Semirara Island to assure that the eventual coal prices can be the minimum while still offer an attractive profit level for investment in the mine facilities.

Sensitivity analyses on the results shown for Scenario D are shown in the following table for such parameters as capacity at which the station operates; price paid for bus-bar electricity; cost of acquiring the investment capital; the level of capital investment itself; reducing the scope of the conversion by omitting the least cost-effective unit Sucat 1; and increased heating value in the CWM-fuel resulting from increasing the coal content. Although not shown in the table, in all cases of sensitivity analysis, the ROIs remain above the postulated threshhold level noted above.

RESPONSE TO SENSITIVITY ANALYSIS

Sensitivity Variable	Change in Sensitivity Variable	Change from Return of Investment	Base Case in Net Present Value
Capacity Factor	-13%	-17%	-35%
Price of Electricity	+8% -8%	+46% -42%	+95% -95%
Cost of Capital	+25% -25%	-12% +15%	-54% +81%
Capital Investment	+20%	-23%	-38%
Omit Sucat No. 1	-	+23%	+20%
Fuel Heating Value	+10%	+35%	+76%

The financial analyses are performed from the point of view of the National Power Corporation as the investor. Thus, the prices estimated for the delivery of the CWM-fuel into the storage tanks at Sucat are considered to be costs. The transfer price of the generated electricity at the bus-bar produces revenues. The Corporation accordingly is responsible for financing and managing the retrofit. Rates paid for interest are those that are normally paid by a publicly-owned enterprise having the backing of the government.

NATIONAL ECONOMIC BENEFITS

National economic benefits are estimated as the net savings in foreign exchange achieved in the operation of the Sucat Station using CWM fuel through the year 2002, a period somewhat less than the Station's remaining life. Net savings are the yearly differences between the foreign exchange saved by eliminating the purchase of residual fuel oil and the total foreign exchange costs of the project that are required to repay debt, pay for services and spare parts, and repatriate profits. Based on preliminary analysis of future generation plans for the Luzon Grid, it is not clear at this time that the retrofit of Sucat Unit No. 1 will produce equivalent displacement of fuel oil in the system. This finding requires further investigation to confirm its validity, but its effect is reflected in the foreign exchange savings estimates.

A summary of net foreign exchange savings is presented for each retrofit scenario in the table below.

Scenario	Net Present Value ($ Million)	15-Year Cumulative Savings ($ Million)	15-Year Cumulative Savings (P Million)
A. Sucat 2, Minor Retrofit	152	434	8,680
B. Sucat 2, Major Retrofit	188	544	10,880
C. All Units, Minor Retrofit	363	1,260	25,200
D. All Units, Major Retrofit	383	1,390	27,800

Sensitivity analyses on the results shown for Scenario D for such parameters as oil price; reduced station capacity factors and delays in the construction schedule show sustained impressive savings in foreign exchange benefits.

Examples are given in the following table.

Variable	Options	Net Present Value ($ Million)	15-Year Cumulative Savings ($ Million)	15-Year Cumulative Savings (P Million)
Base Case	See footnote.	383	1,390	27,800
Oil Price	$22/BBL	223	954	19,000
Plant Capacity Factor	55%	293	1,132	22,640
Construction Schedule	1 year delay	340	1,190	23,800
Shadow Factors	Foreign Exchange 1.20 Unskilled Labor 0.60	431	1,488	29,760

Footnote: $28/BBL Oil Price, 75% Capacity Factor, Base Completion Schedule

The shadow factors are considered to be realistic for the present condition of the Philippine economy and show even higher foreign exchange savings than for the base case.

The project was analyzed in terms of its economic rate of return to the nation so that it can be compared with the rates of return for other projects of interest in the Philippines, offering similar high foreign exchange savings. Financial costs and prices were adjusted, accordingly, to eliminate national taxes, duties, and tax credits and to apply the shadow factors above to foreign exchange costs and wages of unskilled labor. For the base case a cost to the nation for the coal was taken at $20/tonne and the price paid for bus-bar electricity 6 cents/kwh.

Economic return on investment is estimated to be 54 percent and on equity, 133 percent. The net present value of future economic cash flows is estimated to be U.S.$ 366 million. For a coal price of U.S.$ 26/tonne, these rates decrease to 48 percent and 121 percent respectively, and the net present value drops to U.S.$ 314 million. If electricity price rises to 6.5 cents/kwh (reflecting the lifting of a current 0.5 cents subsidy), rates increase to 62 and 152 percent respectively; and present value to U.S.$ 454 million.

IMPLEMENTATION

Any number of implementation plans may be formulated and considered for financing. The choice is certainly sensitive to the interests and perceptions of those participating in the financing. Nevertheless, the results of the assessment point to a number of principles which any prudent implementation plan should follow. The purpose below is to present these principles and to develop them to the extent that the elements to be incorporated when applying these principles, are identified.

Fine Tune the Project

The principle is to fine tune the project design. The result should be significant enhancement of the financial attractiveness of the project. The major elements for addressing this principle should be the following:

Optimize the CWM fuel. Commercial firms who specialize in the formulation of CWM fuels should have the opportunity to determine the optimum dry-coal loading in the fuel based on acceptable stability, flow, and combustion properties. Some of the parameters to achieve such optimization that so far have been identified are incorporation of additives, use of a blend with higher-rank indigenous coal such as Malangas, ash rejection through coal beneficiation, or combinations. New costs identified to achieve optimization of fuel properties should be evaluated for impact elsewhere in the system so that the net effect is the enhancement of the financial attractiveness for the overall project.

Perform larger-scale tests. The fuel specification eventually adopted should be the basis for larger-scale fuel preparation and for transport-pipeline flow and combustion testing. The objectives would be to confirm the operating parameters and practices for the Rockwell-Sucat pipeline and to establish design of the burner equipment. This effort on the Philippine lower-rank coal essentially will duplicate larger-scale work already done in the United States on higher-rank coals.

Optimize the retrofit design. The engineering design for the steam generator retrofit should be reviewed and further investigation made of physical features that impact on practicality and costs of modification. Operations of the Calaca Station and other steam generators with Semirara coal should be monitored for lessons learned that are applicable to the Sucat retrofit.

- Establish the coal mine development plan. The developed and undeveloped sites for open-pit mining operations should be investigated to identify the mining technologies that can produce the coal requirement of the Sucat Station retrofit at the least production cost. At the same time, the coal quality pattern that may be expected should be identified. The present mining technology employed for the Unong pit should be reviewed for its appropriateness in providing controllable coal quality given the geometric, geological, and structural character of the coal deposit in the Unong area.

Retain the Schedule

The principle is to avoid introducing delays into the project completion schedule. The present value of the national economic benefits offered by the project is sensitive to delays in the schedule. Delays can occur to accommodate the time period during which the project is fine-tuned and because of the long lead and delivery times for the procurement and installation of an electrostatic precipitator. Decisions in these two respects are certainly subjective to the views of those participating in the financing. In the case of the precipitator, the views of Philippine environmental protection authorities are critical. The major elements for addressing this principle should be the following:

- Simultaneous Design of No. 2 Retrofit. Formal data collection and evaluation, engineering design work, preparation of equipment specifications, and solicitation of quotations for procurement can be undertaken in parallel with the efforts to fine tune the project. Committing the purchase of the long-lead major equipment items for coal preparation, pipeline retrofit, and No. 2 unit retrofit should occur at the time fine tuning the project is complete, the results known, and retrofit design and specification work rechecked for these results.

- Begin Environmental Licensing Process. The procedures and experiences from the 1980/81 test of coal-oil-mixture fuels by Florida Power and Light in its 400 MW unit in the Sanford, Florida station may be a model. Even though this station is located in a residential and resort area (Orlando), the Florida State Environmental Protection Agency granted a variance that permitted the test period without a precipitator. The utility, in turn, installed two small pilot precipitator sections in flue gas by-pass ducts to take data needed for precipitator design. Had the utility decided on permanent operation with coal-oil-mix fuels, they would have been required to install the precipitator.

Reconfirm Project Attractiveness

The principle is to provide a basis for selecting, scheduling, and guiding the efforts to fine tune the project and avoid schedule delays. The only element involves detecting the milestones in the schedule when the financial attractiveness and the national economic benefits for the project should be reevaluated for new input cost data and schedule changes, and the results of the reevaluations used to correct or guide the ongoing activities.

Establish Investment Schedule

The principle is to avoid incurring investments any earlier than the implementation activities require. The diagram will provide a basis upon which decisions can be taken to provide new funds based on the results obtained from previous funding. The only element involved to establish such a diagram at the outset of implementation and periodically review and revise it as appropriate.

Address Institutional Aspects

The principle is to address those institutional aspects that can facilitate the implementation activities. The major elements involved are the following:

Enhance personnel capabilities. The project involves the adaptation and transfer of technology and the conservation of foreign exchange. Implementation activities should, therefore, be organized and conducted to increase the capabilities of Philippine personnel to take over ultimately the new managerial, engineering, and technical positions that will be generated in the activities. New positions will arise from the expansion of coal mining operations, the construction and operation of fuel preparation and transport facilities, and the retrofit and operation of the Sucat Station with a different fuel.

<u>Generation planning for the Luzon Grid.</u> This grid is being supplied by generation from the existing Sucat oil-fired capacity, coal-fired capacity at Calaca, and geothermal capacity in Southern Luzon. Future generation needs can come from nuclear capacity now almost ready and from the retrofit of the Sucat Station to coal. Meanwhile the Philippine economy is in transition and growth of electricity demand is difficult to forecast. Existing generation planning methodology and the assumptions upon which it is based should be reviewed, revised as appropriate, and new input data compiled. The result should allow the nation to take maximum advantage of foreign exchange savings that reliance on indigenous sources of energy can produce.

APPENDIX A

COAL WATER MIXTURES
A UTILITY PERSPECTIVE

BY

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Why FPL is Considering CWM

FPL has traditionally been an oil based utility. Through conservation programs, the addition of nuclear units, and the acquisition of substantial amounts of coal-fired generation purchased as "coal-by-wire" from other utilities, FPL's oil consumption has been temporarily reduced. In spite of these conservation and fuel oil reduction measures, to meet normal load growth, the use of oil on the FPL system will increase throughout the second half of the 1980's. If no further action is taken, oil consumption by the early 1990's could again exceed 40 million barrels of oil.

FPL has followed and supported many efforts to develop alternative fuels which could be used in its oil-designed power plants. However, as work on these alternatives continued, it became increasingly clear that synthetic fuels for oil-designed power plants would not be available in significant quantities until at least the mid-1990's, except for coal slurry based fuels.

Both coal oil mixtures (COM) and coal water mixtures (CWM) appeared to offer an economically and technically acceptable alternative to residual fuel oil in 1979 when most of these investigations were conducted at FPL, but CWM technology was still in the laboratory stage of development. Thus, at that time, 1979, FPL concluded that the most likely substitute fuel which the Company could burn near-term in our power plants would be COM. Based on this, during 1981 and 1982 FPL conducted a one year COM demonstration at its Sanford Unit No. 4, a 400 MW unit, the results of which were technically encouraging but did not financially or strategically support a conversion decision.

Upon completion of the COM demonstration, FPL took another look at the technological developments in CWM. A lot of research, development and testing has been conducted over the past several years by individual companies who would like to be in the CWM business, equipment manufacturers, individual utilities including FPL, the Electric Power Research Institute, and the Department of Energy. The results are technically quite encouraging, and FPL is convinced that CWM conversion of existing plants is indeed feasible.

Status of CWM Technology

In order to further assess the technical and financial factors of CWM production and conversion, FPL conducted, in early 1983, an independent study of the various processes being developed, and assessed the scale-up of these processes. The results of this preliminary study were quite encouraging.

As a result of this study FPL received somewhat conflicting and at times incomplete information with respect to the performance and financial aspects of the various processes used to produce CWM. Any time one tries to scale up cost from the pilot plant stage to a large commercial facility there are considerable uncertainties with respect to capital costs, operating expenses and equipment reliability.

In addition to these uncertainties with respect to CWM production costs, a utility faces risks on the user side as well. How much will it really cost to modify plants to burn CWM? How will plant performance and reliability be affected? And most important, what will be the overall generating system financial benefit resulting from a conversion to CWM.

With these uncertainties in mind, FPL embarked, late in 1983, on a comprehensive program to try to minimize the technical and financial risks associated with the potential use of CWM on FPL's system.

FPL's Program

The purpose of FPL's program was to assess Coal Water Mixture as a boiler fuel. The program was designed to evaluate competitive technologies and business arrangements for a CWM supply, and use this information to see if the risks of CWM can be reduced to an acceptable level. If the costs can be covered through operating savings and other contributions, the next step will be the conversion of one 400 MW unit for an initial operation on CWM fuel that will last approximately one year. Finally, if the initial operating period is successful and the long term financial benefits can be reasonably assured, FPL could proceed with a staged conversion of a number of oil-fired plants to CWM.

Florida Power & Light Company budgeted $1.5 million to conduct this evaluation. Other utilities, engineering firms, coal companies and CWM producers participated (financially and otherwise) in this effort, and provided significant technical support.

The Scope of Work for the program is summarized in the following Objectives:

- Determine technical and financial potential for substituting coal water mixtures for oil in utility boilers, and compare with other currently available alternatives (continued oil use, and pulverized coal conversion).

- Evaluate the technical performance and commercial competitiveness of current coal water mixture preparation technologies, and select one or more for a full-scale initial operation on a 400 MW unit.

- Establish a framework of potential suppliers, including basic business arrangements, which could be used to implement the initial operation stage and a follow-on long term commercial supply of CWM.

To meet the program's objectives, the work was organized into several tasks which were designed to address the uncertainties and risks currently surrounding CWM fuels.

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These tasks are:

- Conduct controlled comparative tests of currently available CWM technologies using three (3) selected coals supplied by FPL with ash content ranging from 3% to 10%.

- Develop independent estimates of the production cost of CWM using a generic technology and also, each of the tested technologies.

- Develop engineering designs and cost estimates for the permanent conversion of utility boilers and fuel handling systems to use CWM.

- Select the CWM technologies which are most technically and financially attractive.

- Conduct a utility system economic analysis of the long term use of CWM vs. alternatives such as oil and pulverized coal.

- Discuss potential business arrangements with prospective CWM suppliers for the initial operation stage and a follow-on commercial fuel supply.

During 1984, detailed comparative tests were conducted among selected companies which have developed proprietary CWM preparation processes. FPL provided them with controlled samples of coal, observed them make the fuel, analyzed the technical and financial characteristics of their processes, and tested the resulting products. At the same time, detailed engineering studies were made of the scale-up costs of CWM production facilities employing various technologies. Engineers also developed detailed designs for the required conversion of FPL's fuel handling and power plant equipment. Detailed cost estimates of all aspects of CWM production and use were developed. These cost estimates, along with various price scenarios for future coal and oil prices, were used to assess the long term financial aspects of CWM use on the FPL system. FPL is currently working with state and federal regulatory agencies to clearly define the environmental, financial support and rate making considerations that will have to be factored into the overall decision on plant conversions.

Summary of Results

A summary of results from each of the tasks is presented below.

Controlled Comparative Test of CWM Production Technologies

The purpose of the comparative testing was to examine the slurriability of the various coals, the rheological properties of the slurries under various conditions, and the ease of atomization of the slurries. A non-proprietary, no-additive slurry is also being examined as a basis for comparison.

During this phase of the program, FPL worked with four proprietary CWM preparation processes. These processes generally included the use of additives such as dispersants, stabilizers, biocides, PH-control, etc. The three coals being used in the program were selected by FPL to represent a varied range of ash, grindability(HGI), heat content(BTU), as well as other key properties. The purpose was to try to identify how these parameters would affect the preparation process (in particular those that include beneficiation) and the properties of the slurries.

All slurry producers experienced difficulty with at least one coal. Some of the problems experienced during the processing were due to the HGI and moisture content. One specific coal required a longer holding or "aging" time than the others, before it became rheologically "stable" (i.e., the viscosity as a function of shear rate stabilized). In all but one specific case, however, the producers were able to prepare a slurry that met FPL's specifications. The out-of-spec slurry resulted from poor quality control due to faulty instrumentation.

Once the slurries were prepared, they were shipped to a laboratory where various rheological properties were examined. The slurries, as received, ranged from 67.3 to 71.6% solids by weight. As received, some of the apparent viscosities were as high as 3100 cp (at 100 sec-1). A reduction of 2-3% in the solids loading through dilution lowered the viscosity to a more manageable range, on the order of 700 cp (at 100 sec-1). Some of the slurries showed great sensitivity to heating. In fact, some began to form a gel when heated beyond 40 deg. C. We feel that this was due to the particular additive package used in the formulation. Finally, we also examined the effects of a freeze/thaw cycle on stability and viscosity, and found, in most cases, very little effect on either.

Based on the results of the rheological analysis, several slurries were selected for atomization testing. One of the key parameters examined during atomization was the percent of droplets in the spray with a mass mean diameter greater than 226 microns. This relates directly to carbon burnout efficiency. Another parameter of interest is air to fuel ratio. This is related to parasitic losses due to requirements for atomizing media. Currently, the trade-offs between better carbon burnout and the expense of greater parasitic losses are being evaluated.

For comparison purposes, a quantity of non-proprietary slurry was prepared using one of the same coals used in the proprietary part of the program. This particular slurry has several advantages. First, it does not require expensive chemical additives (i.e., dispersants, stabilizers, etc.). It only requires some PH control, depending on the coal, in order to improve the rheological properties of the slurry. It is much easier to make and does not require the deaeration or "aging" which is characteristic of some of the proprietary processes. It has a lower apparent viscosity and is more easily atomized. The disadvantages are that it has a lower solids loading (approximately 54% for this particular coal; although loadings could be higher for other coals), and a faster settling rate. Since we have not run any combustion tests on this slurry, flame stability at low loads is yet to be determined.

Independent Estimate of CWM Production Cost

As a result of this effort, a generic CWM plant design was developed. This generic design does not duplicate any of the currently proposed CWM process plants being considered by the producers we are working with. Yet, the process equipment included in this generic plant, as well as the coal handling and CWM storage and handling facilities are similar to those proposed for use in their plants by the CWM producers. Therefore, we are confident that the economic data developed regarding fixed and variable costs as developed from this effort do provide a good yardstick with which to measure and evaluate each CWM producers' plant construction and expansion plans.

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The same three coals that were used in the comparative test program were assumed to be the feed coals to the large scale production plant. This provided us with the relative sensitivity of processing costs, throughput, etc., to the feed coal themselves.

We were also interested in the sensitivity of plant location to total delivered CWM price. Therefore, three "typical" geographic locations with different attributes were selected. These locations were mine-mouth, tide-water, and north Florida sites.

The "generic" process design for the CWM preparation plant had the various component systems arranged in modules and included integrated cleaning and benficiation circuits prior to the slurry preparation steps. These circuits were sized based on the actual washability data for the selected feed coals used in the comparative anaysis.

The analysis of approximately 40 coal sources that are considered potential candidates for CWM preparation, including bimodal transportation (i.e., rail from the mine to the preparation plant location and barge to the power plant), and 5 different process designs, results in the following CWM cost breakdown (in $/MBTU):

Coal and transportation to the preparation plant	:	1.86 - 2.57
Processing	:	0.90 - 1.99
(This includes the carrying charge on the preparation facility, levelized over 10 years, and including a 20% R.O.I.)		
Transportation to power plant (by barge)	:	0.20 - 0.45
Total CWM cost delivered to power plant	:	2.96 - 5.01

By eliminating some of the least likely combinations and only considering the most feasible, the cost range can be narrowed to:

3.03 - 4.09 $/MBTU

<u>Engineering and Cost Estimates of Utility Plant Conversions</u>

Our initial assumptions regarding the required boiler modifications for firing CWM fuel were gathered during the Sanford COM test in 1981. Based on this data, we had assumed that no internal boiler pressure part modifications would be required if a CWM with less than three (3) percent ash were used.

However, the detailed engineering review work done by Foster Wheeler as part of this CWM evaluation program showed that a metal temperature problem existed in the superheater area of the boiler which would require the changing out of some of the superheater loops in addition to the other anticipated boiler modifications. This change out of the superheater tube material is caused by the expected longer, slower burning coal fire allowing higher temperatures to reach the furnace outlet/superheater inlet area of the boiler. This higher temperature would exceed the temperature rating of the present superheater tubes.

These modifications will also allow FPL to re-space the loops and make other modifications such that the boiler will be able to fire CWM with up to six (6) percent ash without derating of the unit.

One area of concern is that of CWM burners. To date, no large size, reliable burners are readily available, and most of the testing and development work has been on burners of approximately one quarter to one half (50 to 100 MBTU/HR) the size we need. However due to the current work being done in this area by the burner manufacturers and EPRI with burners in the 100 MBTU/HR range, we expect that by early 1986, when we would be in need of a burner in the 200 million BTU per hour size, they will be available.

The results of the engineering work done on the balance of plant have shown that a new CWM unloading system would have to be installed, along with a new fuel transfer system and ash handling/storage system. None of these are considered to pose major problems as the equipment required is standard, off-the-shelf equipment.

To ensure maintaining the proper quality of the CWM while in storage, it appears that, regardless of CWM producer claims about product storage stability, it will be prudent to install agitation and/or recirculation equipment on the CWM storage tanks.

As a result of this task, we have confirmed our initial assumption that conversion to CWM is very boiler/unit/site specific and that a detailed engineering review must be done before any decision is made regarding the suitability of a particular boiler or unit for conversion to CWM fuels.

In the particular case of FPL's units, this detailed engineering study has shown that we can expect full capability, i.e., no derating on the 400 MW units when firing CWM. This expected performance certainly makes these units viable candidates for conversion to CWM fuels.

The estimated CWM conversion costs, in 1984 dollars, range from $110 to $130 million for two (2) 400 MW units. These conversion costs compare favorably with those associated with a conversion to pulverized coal, which are approximately double this amount.

Selection of CWM Technologies

The work covered in this task was recently completed. Four different CWM preparation technologies were evaluated. Two of the technologies include beneficiation and the other two do not. The rheological and atomization results have shown that all preparation technologies are capable of producing fuels that can be transported, pumped, stored, and burned. Therefore, any final selection of one producer over the rest would have to be based on financial, as opposed to technical, parameters. To date, this work has helped us identify which technical and financial parameters will be critical in any CWM selection process.

In addition, the technical data base developed as a result of this project will be used to define a fuel specification that will meet our needs.

System Economic Analysis of CWM Fuels

The system economic analysis is the task which finally combines the results of all the other tasks into one overall financial evaluation based on the expected performance and operation of the units on the owner's system.

The cost of the CWM fuel, the cost of the site modifications and the expected unit performance, were used along with a production costing model to determine the converted units operation and thus, the displaced fuel cost when compared against the model's base case. This analysis results in financial information related to the unit's expected greater operating capacity factor, and projected fuel savings.

The operating and financial data is then used to calculate whether a net positive savings will occur over the project life and if these savings are enough to pay back the cost of the conversion over the same period of time and still result in savings to the customer in the form of reduced fuel costs.

Naturally, this analysis is highly dependent on what the displaced fuel cost projection and the cost of other displaced energy will be over the life of the project. Based on current FPL fuel oil and other displaced energy cost projections, the initial analysis shows that the potential payback for the unit conversion costs will be approximately 6 years, with significant savings after 10 years.

Since a public utility would be hard pressed to purchase CWM at a premium over the cost of the displaced energy, even for a few years, the CWM producer and the customer must find a way to make sure the price paid for the CWM fuel by the utility is always below the equivalent displaced energy price. Thus, during the early years of CWM utilization, a producer may need to accept a lower return on investment to make the CWM fuel competitive, or may agree to employ a pricing formula to ensure that the price to the CWM fuel is always less than the equivalent displaced energy price.

Discussion of Potential Business Arrangements

As a result of this activity, FPL has identified the various terms and conditions which need to be included in a CWM procurement contract. A contract for the supply of CWM must have provisions different from those of a standard coal or oil contract. Due to the fact that the availability of CWM is limited as well as the fact that CWM from different suppliers may not have the same specifications, or be compatible, the contract for its supply must have provisions to address these facts, in case the production of CWM is interrupted.

On the other hand, since the market for CWM is rather limited at this time, the contract must also contain provisions for, and address the possibility that the customer may be incapable of using the fuel for any number of reasons. In the case of an extended outage of the converted unit, the CWM producer may find himself unable to find other customers for his product.

Conclusions

There are several key conclusions that have resulted from this program to evaluate CWM fuels as a commercially practical boiler fuel, and which should be carefully considered by anyone contemplating a conversion to CWM.

- Since the cost of the coal and its delivery comprise approximately 40 to 60% of the final delivered CWM cost, and the coal's characteristics and specifications have a significant effect on the quality of the CWM as well as in the operation of the boiler, great care must be taken by the utility in ascertaining that the proper coal source is selected for the CWM. This selection process should include not only technical considerations, but also financial and reliability of supply related considerations.

- The selection of the proper CWM preparation process for the selected coal is important to ensure satisfactory technical and financial performance of the unit.

- A specific engineering study of the units to be converted is absolutely essential. This study should be structured so as to compare degree of modification and, hence, cost of conversion, including expected operating parameters and derating, if any, vs. quality of the CWM purchased.

  - Depending on the particulars of each case, it may result in greater net savings if a cheaper coal can be purchased, beneficiated through the CWM processing into a clean, high quality fuel and thus economize on required unit modifications.

  - Conversely, in those cases where the unit requires a certain degree of minimum conversion work due to physical or material constraints, then it may not pay off to utilize a CWM process which includes beneficiation.

Environmental effects associated with the use of CWM are generally less of a problem than those related to use of coal. Thus, it is expected that permitting of conversions to CWM will be less difficult. Specifically, the need to obtain a high quality, low ash, high fusion temperature coal for production of the CWM usually results in procurement of a coal which is also low in sulfur. Additionally, there are no environmental considerations to worry about due to on site coal piles or coal handling equipment.

Contract terms and conditions to be included in a CWM procurement contract need to be innovative, using some coal contract related terms as well as some terms more usually associated with procurement of liquid fuels. Additionally, the development of an adequate CWM pricing formula is of great importance.

- A large-scale demonstration in a utility boiler is necessary prior to a permanent conversion for both technical and financial reasons. It would be necessary in order to:

  - Test burner/atomizer designs.
  - Identify any on-site fuel handling problems that may not be apparent in a test loop.
  - Evaluate the actual boiler performance and efficiency.
  - Determine the boiler operating range and turndown.
  - Verify that the CWM producer can deliver large quantities of fuel with consistent properties.
  - Test performance of particulate control equipment and define specifications for the permanent equipment design.
  - Evaluate CWM specification and modify, if necessary, based on the results of the demonstration.
  - Establish fuel delivery logistics for the permanent conversion.
  - Verify the financial aspects of large-scale CWM production and utilization.

  The results of the demonstration would also allow us to eliminate any remaining uncertainty and, thus, reduce the permanent conversion cost estimates for both boiler and balance of plant.

This study has shown CWM fuels to be technically feasible and a potential financially viable alternative to fuel oil. Therefore, FPL will continue to consider and evaluate the CWM option along with its other future energy options in order to develop an integrated energy strategy for the nineties.

In order to further develop this option as a viable alternative, FPL will begin the environmental licensing effort necessary to support a permanent conversion to CWM during 1985, and will continue to support research and development activities aimed at reducing the delivered price of CWM and any remaining uncertainty regarding the conversion of units in our system to CWM fuels.

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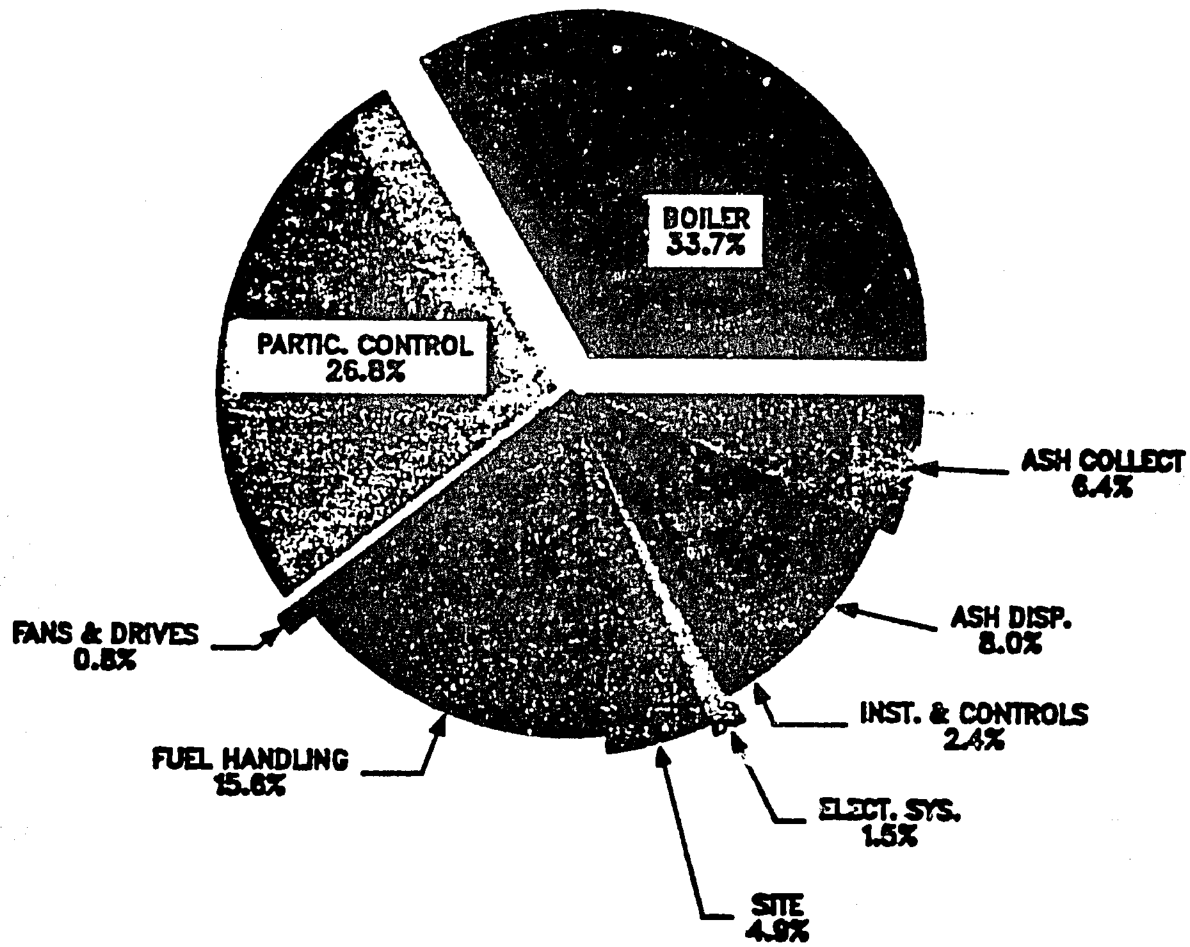
400 MW SANFORD 4 & 5 UNITS
CONVERSION COSTS
OIL TO CWM : $110 – $130

1984 $ MILLIONS



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APPENDIX B

Selected Worldwide Operating Installations Using Slurried Coal Fuels

Power-generation/utility-boilers with CWM fuel.

- New Brunswick Electric, Canada, Chatham Unit 1 (12 MWe) operated on/off approximately six months; Unit 2 (22 MWe) approximately three months, Carbogel fuel.
- Boston Edison, Mystic Unit 4 (140 MWe), fired CWM in 2 of 12 burners, approximately one week, Atlantic Research fuel.
- South Carolina Electric, Urquhart Unit 1, Beach Island, S.C., now fires 15 percent CWM in 75 MWe unit, Fluid-carbon fuel, operation started January 1985, planned to continue for at least six months.
- ENEL, S. Barbara Plant, Arezzo, Italy, 125 MWe, fired Snamprogetti CWM in two burners, about 20 hours.

Heating Boilers with CWM Fuel

- Upsala Kraftwarme, Sundbyberg, Sweden, 20 MW, uses two CE 25 million Btu burners, in operation since October 1983, presently undergoing 2000 hr. endurance run, NYCOL fuel.
- City of Lund, Sweden, 29 MW thermal, district heating boiler, operated on CWM during heating seasons in last two years, fluid-carbon fuel.
- Babcock-Wilcox, Barberton, Ohio, 60,000 lb/hr steam boiler, operated three months winter of 1984/85 on BW CWM fuel.
- Carbogel, Helsingborg, Sweden, 20,000 lb/hr steam, used 1984/85 heating season, Carbogel fuel.
- City of Stockholm, Sweden, 65,000 lb/hr Carbogel fuel, approximately two month operation.
- E.I.Dupont deNemours, Memphis, Tennessee, 65,000 lb/hr industrial steam generator, operated four weeks on Atlantic Research and one week on Slurry-tech (BW) fuel - EPRI sponsored test, summer 1983.

Process dryers and kilns with CWM Fuel

- Oxcegem, White Springs, Florida, 135,000 lb/hr steam, phosphate dryer, approximately two months, OXCE fuel.
- Aliquippa, Pennsylvania, blast furnace over several months burned about 25,000 barrels Atlantic Research CWM.
- Cincinnati, Ohio, asphalt heater, 125 million Btu/hr operated about 10 hrs/week several months summer 1984.

Power-Generation/Utility-Boilers with Coal-Oil-Mixture Fuel

- Florida Power Corp., Barton Unit 1, 120 MWe burned 2 million barrels over two years (1983/84) and continues to burn this fuel, COMCO fuel.
- Florida Power and Light, Sanford 4, 400 MWe, about six months 1980/81 with own COM preparation plant.
- New England Power, Salem Harbor, Salem, Massachusetts, 80 MWe, 1500 hrs on COM prepared on site, 1980/1981.

In addition many small boilers and kilns have operated in the United States, Europe, and Japan. An example is the phosphate-rock drying kiln at the Mulberry, Florida, plant of Agrico.