OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

This document has been produced without formal United Nations editing. The designations employed and the presentation of the material in this document do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations Industrial Development Organization (UNIDO) concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries, or its economic system or degree of development. Designations such as "developed", "industrialized" and "developing" are intended for statistical convenience and do not necessarily express a judgment about the stage reached by a particular country or area in the development process. Mention of firm names or commercial products does not constitute an endorsement by UNIDO.

FAIR USE POLICY

Any part of this publication may be quoted and referenced for educational and research purposes without additional permission from UNIDO. However, those who make use of quoting and referencing this publication are requested to follow the Fair Use Policy of giving due credit to UNIDO.

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

16096

RESTRICTED

26 October 1986

English

INDUSTRIAL ENERGY MANAGEMENT CONSULTANCY AND TRAINING

DP/PHI/82/002/11-54/31.4.2

Technical Report: COAL COMBUSTION

Prepared for the Government of the Republic of Philippines by the United Nations Industrial Development Organization acting as executing agency for the United Nations Development Programme

Based on the work of Waclaw Szulakowski
expert in coal extraction, beneficiation and combustion

United Nations Industrial Development Organization
Vienna

288

This report has not been cleared with the United Nations Industrial Development Organization, which does not, therefore, necessarily share the views presented

TABLE OF CONTENTS

	page
I. Abstract	2
Main Conclusions and Recomendations	2
II. Introduction	5
A. Job description	7
B. The work	9
1. The Philippines industry development	9
2. Philippine coal	11
3. Observations and analysis of coal-related problems on NPC coal thermal plants	19
C. Problems encountered with the use of local coals as fuel in power plants and cement industry	24
I. Power plants	24
II. Fluidized-bed combustion	25
III. Cement industry	25
IV. Problems encountered with the starage of coal in stocks	27
V. The utilization of the Batangas Coal Fired Thermal Power Plant pulverised-fuel ash	32
D. Recommended methods to be used in coal sampling and analysis in the Philippine chemical laboratories	35
I. Brief summary catalog of coal tests	38
II. Recommended apparatus and equipment to be used in a power plant chemical laboratory	42

I. Abstract

Title: Industrial Energy Management Consultancy and Training

Number: DP/PH/82/002/11-04/31.4.Z

Objective: To establish the necessary services and capacities in order to achieve better energy utilization in industry, and to improve the respective performance

Duration: Two months

Main Conclusions and Recommendations

1. The programme proves valuable and its results should be advantageous to the Philippines' industry in reducing the dependence on energy imports with the highest rate of utilization of domestic coals and by-products.

2. The Philippines are in possession of rich fuel resources with relatively favourable mining and geological conditions. Hence, indigenous hard coal and to a certain extent brown coal, ought to constitute the main source of primary energy in the Philippines. There exist a real possibility of reducing the dependence of the Philippines on imported sources of energy. The industrial progress in the Philippines may be soundly based on energy provided by the expanding own coal mining and power generation.

3. Philippine run-of-mine coals are low quality. Coal mines should make immediate changes in applied extraction methods which would in the short term bring the coal quality to guaranteed minimum specifications required by cement and power generation industries. They ought to apply the

selective mining methods for the purpose to remove much of shales from coal output as it is possible only. Contaminated coals with shales, alkalis and sulphur should be washed for purpose to satisfy energy demand on high rank coals of the developing industry. It is very possible that using washed coal at power plants and cement plants will eliminate the use of imported ones.

4. In the stockyard coals with high ash-fouling properties are mixed with coal with low ash-fouling properties and power plants burn blended coal as fuel with moderate ash-fouling properties and calorific value about 9000 BTU/lb. The power plants should continue this coal blending programme. Should be analyzed every coal delivered to power plant with particular focus on alkalis, sulphur and phosphorus for purpose of preventing boilers from high ash-fouling of external heating surfaces.

In order to minimize coal handling problems and deterioration of coal property at the stockyard, the following may be adopted:

- Reduction of coal inventory in plant stockyard to about 2-4 weeks of its normal operation.
- Reduce moisture content of coal before sending it to the boiler by storing it in a concrete paved and covered stockyard for a period of two weeks before sending to the boiler.

5. The best way to preserve stocks of coal from the impact of all kinds of tropical weather and to minimise deterioration of coal properties is to attempt at preventing the air. This is carried out by building the stock in layers and

consolidating it by rolling or by covering the heap completely with an impervious layer.

6. The problems encountered with the storage and the utilization of pulverized-fuel ash have become very important and urgent in the Batangas Power Plant. The greatest potential markets for PFA are found in building and civil engineering. The reaction with lime makes it an outstanding additive in a concrete mix, producing cheaper and more durable concrete. It is used in large quantities to produce aerated concrete blocks which appear load-bearing, low in density and thermally insulating. An aggregate, half the density of gravel, used for the production of lightweight concrete, can be readily produced by sintering processes. PFA also finds extensive use as a fill as a cement-bound material for floors and road basis as well as a very effective grout.

II. INTRODUCTION

The duration of the UNIDO consultant, Dr. Wacław Szulakowski, was two months (12 January - 12 March, 1986).

Duties: The consultant has been attached to the Ministry of Energy of the Philippines and has worked under close supervision of Dr. P.R. Srinivasan, UNIDO Chief Technical Adviser.

The expert has provided the following technical assistance:

1. Conduct seminars for coal users and coal producers such as coal mines, thermal power plants and cement plants on coal technology, classification, ph sical and chemical structure, coal sampling and analyses, preparation and utilisation, prevention of the external fouling and corrosion of boiler heating surfaces, relationship between coal constituents and boiler fouling, selection of coals for power generation and cement industry and prevention of deposit rings formation in rotary kilns. The seminars have been held in Manila (4): Bureau of Energy Utilization, National Power Corporation, Engineering and Development Corporation of the Philippines and Cemtecs-Cement Technology Services and beyond Manila (4): in power plants and coal mines: Batangas Coal - Direct Thermal Power Plant, Cebu Coal - Fired Thermal Power Plant, ACMDC - Fluidized Bed Combustion Plant, Semirara Coal Corporation, Semirara Coal Mine.
2. Train engineers of:

   Bureau of Energy Utilization

   National Power Corporation

   Philippine National Oil Corporation

Engineering and Development Corporation of the Philippines

PNOC - Engineering Research and Development Centre

PNOC - Malangas Coal Corporation

Atlas Consolidated Mining and Development Corporation

NPC - Visayas Regional Centre

Semirara Coal Mine

Uling Coal Mine

Cemtecs - Cement Technology Services

APO - Cement Corporation

Island Cement Corporation, Island Cement Plant.

3. The author visited the biggest open pit coal mine in the Philippines - Semirara Coal Mine and the biggest coal fired thermal power plants: Batangas Power Plant and Cebu Power Plant, and analyzed those enterprises' problems and drew up expert opinions and recommendations.

4. The author drew samples of coal in Cebu Power Plant and samples of deposits from external heating surfaces of the boiler in Batangas Power Plant for chemical analyses. The results of these analyses were needed for the elaboration of expert opinions.

5. The author became acquainted with the country's fuel problems and tried to address these in the specific reports.

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

UNIDO

3 June 1985

A. JOB DESCRIPTION

DP/PHI/82/002/11-54/31.4.Z

Post title Short-Term Expert/Coal Combustion Technology

Duration Two months

Date required As soon as possible

Duty station Manila, Philippines

Purpose of project To establish the necessary services and capacities in order to achieve better energy utilization in industry, and to improve the performacne of the sector.

Duties The expert will be attached to the Ministry of Energy and will work under close supervision of Chief of Energy Conservation Division, Bureau of Energy Utilization and Chief Technical Adviser of the project. In particular the expert shall provide the following technical assistance:

1. Conduct selective survey of Philippines plants presently utilizing coal or are in the process of converting to coal to determine and recommend measures to improve efficiency of coal utilization.

2. Conduct seminars for coal users such as cement plants and power plants on coal combustion technologies which shall include proper handling and utilization of coal in cement kilns, boilers and furnances.

3. Train engineers of BEU and the PNOC coal corporation on conducting energy audits of coal combustion systems.

..../..

Applications and communications regarding this Job Description should be sent to:

Project Personnel Recruitment Section, Industrial Operations Division
UNIDO, VIENNA INTERNATIONAL CENTRE, P.O. Box 300, Vienna, Austria

Qualifications A degree in Mechanical, Electrical or Chemical Engineering with extensive experience in operation and maintenance of coal-fired thermal preventions, cement plants and/or experience of a reputed Engineering consultancy organization specializing in design, construction, operation of coal-fired thermal stations and/or coal-fired cement plants.

Language English

Background Information Research and development undertaken within the last decade in various countries has produced many new technological and non-technological techniques for the conservation and economical usage of energy in industry. Although information regarding such schemes is generally available, it has not yet been greatly extended to developing countries, partly because it has not been adequately disseminated to them and partly because these countries generally lack sufficient expertise to avail themselves of it. Technical assistance is therefore a valuable vehicule for imparting new knowledge to the recipient countries and for creating both the expertise and the facilities where they are needed.

Energy conservation is a relatively new area in the Government's programme to reduce its dependence on imported oil. In addition to its aggressive development of domestic energy resources, the Government now wishes to embark on an energy-saving programme through the improvement of efficiency in the use of fuels in major industrial enterprises.

A practical way of achieving this goal is the creation of an institution which would gradually acquire a knowledge of energy management and conservation techniques and the skill of applying them to energy users. To this end, it is proposed to establish an Energy Management Consultancy Service (EMCS) in the country with UNDP/UNIDO assistance.

The principal objective of the EMCS will be to implement energy-saving measures among industrial and non-industrial users. It will work towards that objective by developing a core of 15 specialists trained by a team of international experts to carry out energy audits and consultancies with local staff. This will entail the elaboration of a general system for the development, application and implementation of energy-saving measures and technology and the preparation of working manuals with methodologies. Local specialists will be trained by the EMCS and in factories. Furthermore, a laboratory will be established for the purpose of testing the efficiency of fuel utilization by energy-consuming equipment. Group training and fellowships will be organized by the EMCS for officials and managers to observe how other countries and selected industries deal with their energy problem.

B. The work

1. The Philippines industry development

In my opinion, any development of national economy should base upon rational energy policy with the highest possible rate of utilization of the domestic resources. The Philippines are fortunate in possessing rich resources with relatively favourable mining and geological conditions. Hence, hard coal, and to certain extent, brown coal, ought to constitute the main source of primary energy in the Philippines. The industrial progress of the country should be soundly based on energy provided by the expanding coal mining industry.

The traditional objectives of energy policy have stated that there should be adequate and secure energy supplies; that they should be efficiently used; and that these two objectives should be achieved at the lowest cost to the nation. The objectives for an integrated energy policy for the nation can never be pursued in isolation. Every energy policy decision is likely to involve some or all of a wide number of other considerations. It is not possible to find a general formula to express the proper balance to strike in each individual decision. What is important is that the difference in cost in resources between alternative courses of action should be determined as precisely as possible and borne prominently in mind when decisions are being taken. This is the first essential step in achieving reasonable consistency of a policy.

The reduction of dependence on imported energy is often put forward as an objective of energy policy. Self-sufficiency, however, is desirable only in so far as indigenous sources may offer supplies which have a lower resource cost, and are more secure, or both, as compared with imports, it is not an objective in its own right. In present circumstances, with very expensive energy supplies from world markets and with indigenous resources in many countries capable of exploitation, it is reasonable to measure progress towards their underlying objectives of low cost and security in terms of reduction of the dependence on imports.

2. PHILIPPINE COAL

It is common practice in countries with a variety of high and low rank coals, to reserve the higher ranking coals for industrial and domestic use and export whilst lower ranking coals are used for power generation and for firing cement kilns. In the Philippines much of the coal burning plants have been converted or designed to use coal with calorific value of 9000-10000 BTu/lb, whereas it was realised that most of the country's future coal output would have a calorific value 7200-8000 BTu/lb. The problem in marketing Philippines' coal lies therefore in how to satisfy best the present and future demand on high rank coals. There are two possibilities: by importing high rank coals and blending them with local low value coal to bring them to the minimum specifications required by the cement and power generation industries, or by upgrading in quality domestic coals in washing plants.

The Philippines industry development based chiefly upon own primary raw materials will be possible only if the state has adequately large own back-up potential energy facilities as fossil, liquid fuels and other energy sources. The state has to get enough big power industry completely satisfying the quickly growing energy demand of the developing industry and towns and villages. The Philippines have sufficient resources of bituminous and lignitous coals and other power resources in order to be able to satisfy the current and the future power requirements of the state.

The estimation of quality of Philippine coals taken from 37 coal mines and areas as a fuel for power and cement industry is difficult at present because the delivered chemical analyses of coals and coal ashes are not complete. Very often it was not known from where and how samples of coal for analysis were taken. The chemical analyses of coal have not contained chlorine, phosphorus, alkalis, which are belived to be a factor of fireside fouling problems. Deficiency of coal ash fusibility made in a mildly reducing and oxidizing atmosphere. These data are essential for the estimation of coal quality.

The delivered chemical analyses of coals were made by different laboratories in the Philippines and abroad. These laboratories used different standard methods: British Standard, DIN Standard and ASTM Standard. If these chemical analyses were made in accord with ASTM Standard methods only, the most universal used methods in the Philippines, it would have been much easier to compare them and draw conclusions about the analysed coal quality. The quality of run-of-mine coals from different coal mines is various. Coal mines use only sizing of coal, they do not use cleaning coal. Some coals are strongly contaminated with shale or with sulphur and alkalis. For the purpose to improve the quality of coal they blend it on stockyards. We must conclude that these coals cannot satisfy the demand of power and cement plants because of coal quality constraints and that the coals mut be cleaned.

The Philippines have underground and opencast coal mines. Undergrou d coal mines are small and of low mechanization rate. There are a number of small-scale opencast prospects and opencast mines.

Semirara Coal Mine is the biggest modern opencast coal mine in the Philippines. Coal from this mine is burned in Philippine coal fired thermal power plants, Batangas Power Plant being the biggest receiver of Semirara coal. The Semirara coal is recognized as a fuel leading to high, fouling of boiler external heating surfaces. The reason for high ash fouling properties of the coal is its high content of alkalis: Na_2O and K_2O. Samples of this coal taken in 1985 were analyzed for content of sodium oxides and potassium oxides. Some samples of the coal were found to contain from 6 to above 10 % of sodium oxide in the ash. Unfortunately, we do not possess information on where these samples were taken from.

In Semirara, coal mined from different ledges, seams has different properties as steam fuel. The output from the mine is stacked on two piles: the first pile has selected high quality coal with low ash contents and calorific value about 9,000 BTU/lb, and the second pile has low quality coal with high contents of ash and low calorific value: 7,500 BTU/lb. In these two piles, the Semirara coal is blended. The chemical analyses of blended coals, at present have made in the country and abroad, showed that this coals as a fuel for boilers has moderate ash fouling properties. This conclusion is confirmed by the experience of Semirara's own power plant.

Semirara Coal Mine has a nominal rated capacity of 1.0 million MT pa and a number of smaller scale opencast prospects and opencast mines using conventional earthmoving equipment for overburden removal and coal extraction. The present Unong opencast belongs to the Semirara Coal Corporation.

Four SR400 Voest Alpine Ab.Bucket Wheel Excavators (BWE's) are employed in cutting 30 m high benches. Total daily output is some 20,000 bank m^3. Coal and overburden are loaded directly on to belt conveyors via hopper cars. Run of mine coal is transported to the coal stockpiles for direct shipping. Overburden is directed to a dumping site which is located northeast of the pit, where land is being reclaimed from the sea. Attempts are currently being made to mine the Main Seam and its wider seams more selectively to exclude, where possible, the thin shale bands within the Main Seam and generally improve the quality of mine product. The total thickness of the Seam is 24.5 m. Total coal: 18.6 m (76 %) and total shale 5.9 m (24 %). The final remnants of overburden are cleared off the top of the seam using a combination of a D7 or D8 Caterpillar bulldozer and a Caterpillar backhoe, in conjunction with D.J.B. articulated dump trucks. During excavation of the seam by the BWE' the shale partings are nearly all selectively mined. Mine officials report that the BWE's can excavate selectively down to 0.3 m and much of total shale is therefore selectively removed. The more contaminated coal is directed to the stockpile and for the mine's own captive power station. The power plant is rated at 15 MW and takes about 50,000 MT pa of low grade coal, equivalent to 5 % of the nominal total coal output. Relatively uncontaminated coal is directed to the coal stockpile, and placed in a pre-determined location accoridng to its quality.

However, selective miningy by BWE's can only provide a minor safeguard against producing an exeptionally low quality product.

Chemical analyses of Semirara coals

(Proximate analysis)

	Run-of-mine coal	High selected coal	Low selected coal	Washed coal
Total moisture, %	25.87	16.5	17.5	7.0
Ash, %	17.63	9.9	17.5	8.1
Volatile m., %	29.60	37.4	37.5	37.6
F.Carbon, %	26.90	36.2	27.5	47.3
Calorific value, gross, BTU/lb	6900	9100	7200	11500
Sulphur, %	0.59	0.70	0.78	0.60
Na_2O in coal, %	0.43	0,32	0.56	0.23
K_2O in coal, %	0.17	0.15	0.16	0.06
$Na_2O + K_2O$ in coal, %	0.60	0.47	0.72	0.29
Grain size, mm			0–40	

Ash content in the so-called selected coal ranges between 10 % and 12 % and is about 50 % higher than in coal samples taken directly from the seam. Probably the bulk of higher quality stocked coal for shipment car have an ash content close to 17 % with an inherent moisture of 17 %. Such ash and moisture contents would produce air dried calorific value of 8,200 BTU/lb. If we take into consideration the calorific value of low grade coal in the stock pile: 7,200 BTU/lb, and that in the Philippines much of the coal burning plants have been converted or designed to use coal with calorific value of 9000 to 10,000 BTU/lb we must conclude that Semirara coal cannot satisfy the demand of these plants because of coal quality constraints and that selective mining by BWE's is not sufficient and does not give the minimum specifications required by the cement and power generation industries.

The Semirara coal is recognized as a fuel leading to high fouling of boiler external heating surfaces. The reason for high ash fouling properties of the coal is its high content of alkalis: Na_2O and K_2O. Samples of this coal taken in 1985 were analyzed for content of sodium oxides and potassium oxides. Some samples of the coal were found to contain from 6 % to above 10 % of sodium oxide in the ash. Unfortunately we do not possess information on where these samples were taken from. The chemical analyses of blended coals both in this country and abroad show that this coal as a fuel for boilers has moderate ash fouling properties. Based on the Semirara coal chemical analyses quoted above, the conclusion is that washed Semirara coal will not only meet the required calorific value, but will also result in low or moderate ash fouling properties.

The quality of Semirara coal depends, above all, on how much it is contaminated by coal shale associated with the seam being mined. The shales and mudstone, the common non-coal impurities, exhibit high brittle but when moist are highly plastic. When wet, the shale swells rapidly slakes to form a smooth putty-like mass. On kneading and further wetting the shales produces a smooth oily textured suspension. During the wet season this clayish shales covers the surfaces of coal grains, agglomerates, and adheres to the surfaces of the coal handling system causing coal supply interruption to the thermal plant.

It has been decided to build a Coal Washing Plant at Semirara of output 250 MT/hr, which has to bring Semirara coal to the quality level required by the cement and power generation industries. However, commissioning of such a plant will take a relatively long time. In my opinion the Semirara Coal Corporation should make immediate changes in applied extraction methods which would in the short term bring the coal quality up to the guaranteed minimum specifications required by industry.

One proposed way of achieving this might be as follows: to recruit a team of workers (crafstmen/technicians) and equip them with pneumatic drills, shovelling machines and additional conveying equipment and deploy them to work together with the BWE's excavators. This group of miners could achieve almost totally selective mining of coal. When the coal washing plant in Semirara is put in operation and Semirara Coal Mine returns to the present system this team of miners can be retrained and employed at the washing plant.

The coal reserves at Semirara island when properly mined are generally suitable for pulverized-coal and /or stocker firing boilers. Continuous mining system using bucket-wheel-excavator conveyor system is appropriate. However, the cut-off seam thickness of 0,50 m currently being practiced by the miners may have to be increased to minimize on impurities like shales and mudstone from being mined with coal. In case of thinner coal seams it is necessary to employ manually-operated pneumatic drills together with shovel machine to selectively mine of coal.

With regards to alkalis content in ash, the final direction of the Semirara coal is to undergo coal beneficiation at the mine site before shipping to coal users. A review of the CWM studies conducted by USAID using Semirara coal indicated that significant amount of these alkalis can be removed by washing, thus, utilization of purely Semirara as fuel at Calaca Plant (washed) is highly achievable.

. Semirara coal preparation plant facilities are designed to clean raw coal from opencast coal mines. The clean coal produced is usually of consistent quality, but its proportion of marketable product is about 20 to 40 % less than the raw coal received from the mines. Mining costs per ton of clean coal are therefore increased accordingly. Furthermore, the capital costs of a modern coal preparation plant and facilities designed to treat 1,000,000 tons of raw coal per year are $15 to $30 million, to which must be added the cost of operating the plant and the cost of disposing of the large quantities of waste products of coal preparation.

3. OBSERVATIONS AND ANALYSIS OF COAL - RELATED PROBLEMS ON NPC COAL THERMAL PLANTS

I. GENERAL INFORMATION

This report is prepared to outline observations and analysis of coal related problems at the Batangas and the Cebu Coal Thermal Plants.

The mission was carried out from January 22 to February 14, 1986. It covered visits to Batangas and Cebu Coal Thermal Plants, Atlas Consolidated Mining and Development Corporation's (ACMDC) Fluidized-Bed Combustion (FBC) system as well as series of lectures in each plant and seminar on coal combustion technology.

It was gathered that the primary concern of the Batangas Plant is the ash fouling effects if the Semirara coal whereas in Cebu Coal Thermal Plant problems like coal handling, grinding and deterioration of coal property at the stockyard were observed.

II. BATANGAS COAL-FIRED THERMAL PLANT

A. Observations and Findings

Visual inspection of the superheaters (primary and secondary), preheaters and economizers confirmed a relatively clean convective surfaces. This is the result of a continued firing of a successful blend of local with imported coal which has a neutralizing impact on the high alkali Semirara coal.

In the event that the Philippine Government should stop importing coal in the future, however, NPC should be prepared to switch to firing straight local coal. This may be accomplished by investigating at this stage local coal, other than Semirara, with neutralizing property on the fouling alkalis of the Semirara coal.

Sodium compounds which Semirara coal has high content in ash are the most active consituents in promoting hot zone fouling. By beneficiating this coal a high percentage of fouling alkalis can be removed resulting in moderate ash fouling when used as feul. It is very likely tha using washed coal at the Batangas Plant will eliminate the use of the imported ones.

Weekly checking of the pulverizers performance currently practiced by the Batangas Laboratory should be made daily to ensure that coal is ground to specifications.

B. Recommendations

To minimize ash fouling to acceptable level, the following suggestions arranged to their importance should be carried out.

1. Continue the present coal blending programme. This may be accomplished by undertaking laboratory analysis of every coal delivery with particular focussed on alkali's concentration. A report highlighting the fouling characteristics and the recommended ratio of blending of coals should be submitted to the Plant Manager.
2. Apply soot blowing as often as possible.
3. Check and keep excess air as low as possible.
4. Keep grain size of pulverized coal to specifications.
5. If the above suggestions are not enough to prevent ash

a) Paint the superheaters, preheaters and economizers with three (3) coatings using calcium hydroxide ($Ca(OH)_2$).

b) Apply humidification at the secondary air using waste steam approximately 7 psig, from 10 to 20 lb steam/1,000 lb.air.

c) Apply additives to the fuel supply line before the pulverizer or at the secondary air using any of the following additives ground to 200 mesh.:Limestone, dolomite, magnesium oxide (MgO) and aluminium oxide (Al_2O_3).

6. Expand laboratory capability to be able to undertake complete coal analyses.

III. CEBU COAL THERMAL PLANT

A. Observations and Findings

The Cebu Coal Fired Thermal Plant receives coal from eight (8) different coal mines. These coals were mined using bulldozer at the stockyard (uncovered) before being sent into the boilers. At the stockyard, coal piled to about 10 m high is estimated at 180,000 MT enough to sustain the plant 300 days operation.

However, the plant is using dual-firing (oil/coal) because the required volume of coal to sustain the boiler requirements cannot be supplied due to coal handling problems. These problems were experienced starting at the crushers, conveyors, down to silos, screens , hoppers, etc. Another significant problem is the deterioration of coal property while at the stockyard. Coal handling problems are to a large extent cause by clayey property in coal, high percentage of coal fines and high moisture content which when combined together agglomerates and adheres to the surfaces of the coal handling system causing coal supply interruption and a shift to oil burning. The dominant factor that contribute to the handling problems, however, is moisture content.

The large variance of coal property when delivered to the stockyard: 10,000 BTU/ // and 12 % of ash; and when fired in the boiler: 8,000 BTU/ // and 28 % of ash, in my opinion is due primarily to improper stocking at the stockyard for exceptionally long period of time before being reclaimed for use.

It must be kept in mind that in tropical countries, like the Philippines, excessively high piled coal exposed to all kinds of weather will release heat when moisture is added therefore losing volatile matter, reduce calorific value; at the same time ash content increases. If the temperature of coal inside the piles reaches the critical point of 140°F, the spontaneous combustion of coal occurs.

B. Recommendations

In order to minimize coal handling problems and deterioration of coal property at the stockyard, the following may be adopted:

1. Reduction of coal inventory in the stockyard to about 2-4 weeks plant normal operation.
2. Reduce moisture content of coal before sending it to the boiler.

This may be done by storing coal in a concrete paved and covered (roofed) stockyard for a period of two (2) weeks before sending it to the boiler.

C. PROBLEMS ENCOUNTERED WITH THE USE OF LOCAL COAL AS FUEL IN POWER PLANTS AND CEMENT INDUSTRY

I. POWER PLANTS

Low quality of local coals used as fuel for power plants results in low output and efficiency. The steam boilers have high ash fouling of heating surfaces and corrosion. In order to improve the efficiency of boilers coal is burned blended with imported coals which have neutralizing impact on local coals.

Some power plants have coal handling problems and another significant problem is the deterioration of coal property while at the stockyard. Coal handling problems are to a large extent caused by clayey property in coal, high percentage of coal fines and shales as well as moisture content which when combined together agglomerate and adhere to the surfaces of the coal handling system causing coal supply interruption. Another significant problem is the deterioration of coal property while at the stockyard. The large variance of coal property when delivered to the stockyard and when fired in the boiler is due primarily to improper stocking at the stockyard for an exceptionally long period of time (6-12 months) before being reclaimed for use.

The power industry also encounters problems with the utilization and storage of pulverized-fuel ash.

II. FLUIDIZED-BED COMBUSTION

A review of the Philippine coal reserves indicated that future coal output would range from 7,200 to 8,000 BTU/lb. It also contained sulphur and fouling alkalis and high ash content. Coal cleaning is an expensive method of improving coal quality and not every coal can be successfully cleaned. High percentage of coal fines which contribute to coal handling problems will always be experienced even with the mechanization of the coal mining industry.

In view of the varying types of coal that the coal mining industry has to offer in the future, fluidized-bed combustion system may yet offer the best alternative to the pulverized coal burning plant.

Fluidized-bed combustion is reliable, and efficient method of producing steam from low grade coals. The usé of limestone as bed material ensures very low sulphur emission, while the low operating temperature in the bed ensures low NOx emission.

High ash, low calorific coal can be successfully burned in this type of boiler at high thermal efficiency - 85 %.

The industrial development program based on indigenous raw materials will be possible only is the state has adequate back-up potential energy reserves and enough power supply to successfully meet the growing energy demand.

III. CEMENT INDUSTRY

Until 1985 nearly all cement plants in the country have converted to coal. The planned annual consumption of all cement plants will reach 1.459.000 metric tons by 1986. They burn high calorific coal, which is a mixture of local and imported coals. The author explained to them the reasons of formation of ash-rings, deposit rings at the beginning and at the end of dintering and calcination zones of burning kiln and provided methods how to prevent their information.

Lectures were given on the properties of coal as fuel, coal sampling and analysis, cleaning and utilization, and on the fouling properties of coal mineral matter. Also considered was the ash fouling of cement kilns and some recommendations were provided on how to prevent ash fouling of them.

The author also acquainted the listeners with the technology of applying pulverized-fuel ash and coal wastes in cement production. The author has visited the Island Cement Plant where the wet method of cement production is applied.

IV. PROBLEMS ENCOUNTERED WITH THE STORAGE OF COAL IN STOCKS

During my visits to the coal mines and the thermal plants I have seen large stocks of coal which were not protected from heavy tropical rains and from oxidation at high temperature. Coal was often maintained at the stockyards for period of some months. It must be kept in mind that in tropical countries like the Philippines, excessively high piled coal exposed to all kinds of weather will release heat when moisture is added therefore losing volatile matter, reduce calorific value at the same time increases ash content. If the temperature of coal inside the piles reaches the critical point of 140°F (60°C), spontaneous combustion of coal occurs. For example in Semirara Coal Mine the output is stocked on two large piles and spontaneous combustion of coal is occasionally experienced.

At the Cebu Coal Fired Thermal Plant coal from eight different local coal mines is utilized. The coal was piled to about 30 ft high at the stockyard and was estimated at 180000 MT - enough to sustain 300 days operation of the plant. Because of this large inventory, the coal that remained in the stockyard for exceptionally long period of time under any weather conditions gradually/continuously deteriorates, i.e.: the large variance of coal property when delivered to the stockyard: 10.000 BTU/lb and 12 % of ash and when fired in the boiler: 8000 BTU/lb and 28 % of ash.

As soon as coal has been mined and is exposed to the air it begins to oxidize slowly, the rapidity of the process being related to rank and surface area (i.e.fineness). The actual conditions of storage and the precautions taken in laying down a stock play an overriding part in determining whether heating actually takes place, but there is always some loss of calorific value and coking properties when coal is exposed to the air. If there is coal in stock at any time which is likely to remain unused for a year or more, the loss due to slow oxidation, even if no heating occurred, would be considerable; but it is well known that many stocks heat up (and so have an increased rate of oxidation) even though they may not actually reach the stage of an active fire.

Probably the best way to preserve stocks is to try to prevent access of air, and this is normally carried out by building the stock in layers and consolidating it by rolling.

Some years ago it seemed that this process of air exclusion could be improved by covering the heap completely with an impervious layer, and road tar proved an efficient and economical method of carrying out this operation. In addition this method could be used on heated heaps which in the absence of air would then cool off and stop oxidizing.

The sealing of a stock with tar has added some advantages, such as protection against wind losses and reduction of channelling due to heavy tropical rain; a secondary effect, therefore, is to reduce atmospheric and river pollution to a minimum. By reducing oxidation and stopping the percolation of water through the heap an effluent problem of acidic drainage which often occurs from stored coal can be completely eliminated. The tar covering also keeps the coal much dryer, which improves the handling capabilities of the material on recovery. These handling problems were experienced starting at the crushers, conveyors, down to silos, screens, hoppers, etc. at the Cebu Power Station and at the Batangas Coal Fired Thermal Plant.

The use of road tar has some unique advantages. Road tar is produced in large quantities and used in all countries; equipment for applying it and personnel skilled in its application are available everywhere. Road tar is produced in such quantities that the amount that might be required for treating heaps of coal will share only a very small part of the amount used for road dressing.

In my opinion the most suitable tar is the "A" type, defined in B.S.S.76, with a viscosity 80 to 100 sec. Tar skin satisfactory for all purposes can be formed with the tar put on at the rate of one gallon to two square yards giving a layer approximately 0.10 in thickness. Actually the tar will soak in to at least one quarter of an inch binding the coal particles together. The tar should be applied at a temperature of about 212°F (100°C) It is essential that, if the tar skin becomes broken, it should be patched as quickly as possible to maintain the seal. To seal a dump effectively with tar, certain requirements must be met. The dump should be accessible from all sides and all over its surface for the tar-spraying equipment and its operators. It should be built in such a way, or have stood for so long enough, so that it is not likely to settle unevenly. The shape of the heap matters little, as long as its outline is free from promontories and re-entrants and its top does not undulate or form troughs and ridges, but it is an advantage to have as small an exposed surface as possible for a given quantity of coal. This may be most conveniently achieved with round, square, or only slightly elongated dumps, which should in any case be as deep as possible consistent with a limited slope on the sides. Further, for a given shape, the bigger the heap, the less tar per ton of coal will be needed. The slope of the sides of the heap should be well below the angle of repose of the coal, so that subsidence at the sides, and the segregation of lumps, does not occur. In order to form a complete seal the interstices between the particles of coal on the surface of the dump must be blinded by the tar, and it will be impossible to do this if the surface layer consists of coarse coal. The surface layer should be as smooth as possible, which means that it shall consist of fine coal, or contain a substantial proportion of it; thus any coarse coal will be embedded in a matrix of fine coal. It may be necessary to trim the edges and sides of the dump, or even alter the shape of the whole dump, with a bulldozer, and also to remove irregularities throughout the top surface. An ideal finish may be not obtainable with a bulldozer, and rolling is desirable to smooth the surface and to push lumps of coal into the fine to ensure the required surface texture.

Tar can be used either to prevent spontaneous combustion or to remedy it. It is probable that the expense of tar as a preventive measure is justified only when a heap of coal is built in such a way and of such coal that spontaneous heating or a dust problem is anticipated. If tarring has been delayed and fringe fires have started, they must be quenched before tar can be applied to the place where they have occurred, but it does not matter if the coal is still hot just below the surface. Spraying with water for a while after tarring in such circumstances may be desirable to prevent the heated coal from melting the tar and thus breaking the continuity of the newly formed skin; but it should not be necessary if the heap is prepared properly.

Practically the cost of tarring depends directly on the area to be covered; the deeper the heap the more coal there is under unit area and the lower the cost per ton of coal; a square yard of surface covers approximately a ton of coal in a heap 5 ft deep. In average cases, therefore, a heap 10 ft high will take approximately a quarter of a gallon of tar per ton of coal for a layer of average thickness of about 0.10 m. In Poland it appears that, on average, this process would cost about 3 % of the cost of the coal for moderately sized heaps, but would be much cheaper for large dumps. On the credit side there is a recovery of approximately 10 % of the cost in the heating value of the tar, the need for much less attention during the life of the heap in order to avoid and control spontaneous combustion, and the elimination of loss and troubles due to dust borne away by the wind. In addition, when tar is used successfully to prevent any spontaneous heating there is also the saving in the heat value and coking properties of the coal. A secondary advantage is that rain runs off the heap without causing channelling or passing through the heap and thus effluent problems are reduced to a minimum.

V. THE UTILIZATION OF THE BATANGAS COAL FIRED THERMAL POWER PLANT PULVERIZED-FUEL ASH

The problems encountered with the storage and the utilization of PFA have become very important and urgent in the Batangas Power Plant.

The effective use of by-products is intimately associated with industrial economics. Many industries could not survive if their by-products were not economically viable and a considerable proportion of research effort has always been channelled towards this goal. In addition to the inherent adventure aspect of discovering new applications for the known materials, the effective use of a by-product is a reflection on the economic efficiency and cost consciousness of an industry. One of the most remarkable by-product stories of recent times must be that of the utilization of pulverized-fuel ash PFA. Large modern coal-burning furnaces are usually fired by pulverized fuel and produce most of the ash in the form of a fine powder. Every potential use for PFA is necessarily related to its physical and chemical properties and its most significant property is certainly that of size. Its high specific surface enhances reactivity and it differs chemically from ash produced by the combustion of lump coal. Substances which are vaporized during combustion condense on the fine suspended ash particles in the cooler parts of the furnace and flues; therefore PFA contains substances not found in clinker ash.

Potential uses fall into two main categories - the extraction of valuable substances present in the ash, and the development of uses of the ash itself. A considerable amount of research work has been performed on the former aspect which has scientific interest but has not so far been of much practical importance.

In contrast, great success has been achieved in making use of the properties of ash: its physical properties and self-hardening characteristics (load-bearing fill), pozzolanic characteristics (stabilization with lime and cement, use as a component in structural and aerated concrete mixes) and its ability to produce a lightweight aggregate after pelleting and sintering.

In Poland pulverized-fuel ash has found an important application in the production of bricks, blocks and lightweight aggregates.

It is possible to make bricks containing 100 % PFA by means of pressing and sintering at temperatures of 1830°F (1000°C) and more. The "green" strength (i.e. strength before firing) of such materials is however very low and the important use of PFA in brickmaking is as an additive to brickmaking clays where it can account for as much as 80 % of the raw materials. Very high quality facing bricks are currently being manufactured from mixtures of PFA and brickmaking clay. The advantages are the greatest with the more plastic clays and improvements have been reported in power consumption, drying rates and saving in fuel.

Blocks can readily be made from pressed mixtures of PFA, cement and water. This process produces a strong dense block which like dense concrete, has poor thermal insulation properites

A much more satisfactory building material is the aerated concrete block made usually by the addition of aluminium powder to the wet mix of PFA, cement and water. The aluminium releases hydrogen from the alkaline mix and the aerated product is kept at an elevated temperature for some hours to be then autoclaved in saturated steam at 150 lb/in^2 (10.5 kg/cm^3), corresponding to a temperature of about 365°F (185°C). This produces a very stable product with low moisture movement and drying shrinkage. The density is approximately 50 lb/ft^3 (0.8 g/cm^3) and, with a crushing strength in excess of 600 lb/in^2 (42.2 kg/cm^2), good load bearing properties are achieved. Blocks of this type find extensive application as the inner leaf of cavity wall construction and, in addition to high thermal insulation, have the property of readily accepting nails and screws.

Much attention is devoted both in Poland and in other countries, to the production of a lightweight aggregate from PFA. Several different processes have been designed, but they all depend on sintering. The PFA, to which carbon in some form is added to bring the total amount up to about 5 %, is usually first pelleted with water to give round pellets of the size of marbels. An alternative method is to add clay and form pellets by extrusion. The sintering is accomplished by igniting the pellets in some form of furnace or kiln when the heat of combustion of the carbon present is sufficient to raise the temperature of the pellet to about 2200°F (1200°C).

The processes produce pellets of a hard cellular lightweight material with a bulk density of about 50 lb/ft^3 (0.8 g/cm^3) (approximately half the density of gravel) and with a very low sulphate content. Although the individual pellet is less strong than that of gravel, this does not preclude very high concrete strengths being obtained. T.e use of lightweight aggregates introduces a new technology of lightweight concrete construction. This allows lighter structures to be designed of more than adequate strength with a consequent saving of materials for both foundations and superstructure. To these advantages that of greater thermal insulation can be added.

D. Recommended methods to be used in coal sampling and analysis in the Philippine chemical laboratories

The Philippines have sufficient resources of bituminous and lignitous coals to satisfy the current and the future power requirements of the state. The rank and quality of the Philippine coals depends partly on their age and partly on the structural setting in which they are found. Older coals, deposited in structurally complex strata near the massifs of the magnetic belts or allochthonous masses are generally higher in rank (bituminous to high volatile bituminous and semi-anthracite).

Younger coals distant from the massifs are of lower rank (lignite to sub-bituminous). The estimation of quality of Philippine coals as fuels for power and cement industry based on the delivered chemical analyses of coals made by different laboratories in the Philippines and abroad has been difficult at present because these laboratories had applied different standards: British Standard, DIN Standard and ASTM Standard. If these chemical analyses were made in accordance with ASTM Standard methods only, the most universal used methods in the Philippines, it would have been much easier to compare them and take out conclusions about analysed coals quality.

In my opinion, the delivered chemical analyses of coals, sampled from different coal mines and boreholes, were not complete and representative. The analysed samples of coal had calorifc value of 9000-12000 BTU/lb and in the Philippines much of the coal burning plants have been converted or desifned to use coal with such calorific value whereas it was realized that most of the country's coal output has a calorific value of 7200-8000 BTU/lb only. For the reason of low quality of local coals as fuel, the power plants have achieved low output and efficiency. For this reason chemical laboratories of fuels should know how important their work is for the national economy and how high is the price the country pays for their mistakes. In my opinion, chemical laboratories of fuels and raw materials in the Philippines should be coordinated by the National Power Corporation in order to prevent such an incident, as for example, the biggest power plant in the Philippines - Batangas Power Plant which has been built for local coals and burns fuel blend (a mixture of imported and local coals).

For the purpose of credible estimation of the coal quality as fuel for power plants, it is necessary to consider the following:

1. Ledge analyses of coal.
2. Gauss' probability curves of coal quality (ash content, calorific value, sulphur, alkalis)

3. The results of tests of coal-grading and chemical analyses of every coal grade size
4. The feasibility of coal ash in mildly reducing and oxidizing atmosphere
5. The results of tests of coal cleaning in heavy liquids and chemical analyses of every coal fraction.

The following investigations of local coals should be carried out:

- which coals, either as mined or after beneficiation by conventional preparation, are suitable under present standards for industrial and domestic use,
- which coals require special and more intensive treatment in preparation than it is now practiced,
- which coals cannot be considered potential sources for power generation and cement industry regardless of preparation.

The ash content of these coals could generally be substantially reduced by removing the heavy impurities. Washability analyses of the coalbeds of the Philippines should be an effort to help establishing their physical characteristics. Owing to the present concern over emission of sulphur oxides released in burning coals, it is essential that the quality of the Philippines coals be known so that they can be used most efficiently.

I. BRIEF SUMMARY CATALOG OF COAL TESTS

Some of the principal variables in terms of which coal quality is expressed are measured by empirical tests that do not directly measure the variables themselves, but rather the behaviour of coal under fixed conditions. Standardization of these fixed conditions is essential for obtaining comparable results between determinations performed within a laboratory and between determination performed by different laboratories. The source of most of these standard methods in the commerce of coal is the American Society for Testing and Materials.

There follows a brief summary catalog of these tests, together with a few special tests.

1. Proximate analysis - ASTM D 3172 covers the methods of analysis associated with the proximate analysis of coal and coke.
   1.1. ASTM D 1412 covers the method for the equilibrium moisture.
   1.2. ASTM D 2961 is a test method for Total Moisture in coal reduced to 8 mm top sieve size.
   1.3. ASTM D 3302 is the standard method for total moisture in coal as it exists at the site, at the time, and under the conditions that it is sampled.
   1.4. Residual moisture, ASTM D 3173 covers the method for moisture in the analysis sample of coal and coke.
   1.5. Ash. ASTM D 3174 covers the test method for ash in the analysis sample of coal and coke.
   1.6. Volatile matter. ASTM D 3175 covers the method for volatile matter in the analysis sample of coal and coke.

1.7. Total sulphur. ASTM D 3177 covers the test methods for total sulphur in the analysis sample of coal and coke.

1.8. BTU heating value. Either ASTM D 3286 or ASTM D 2015 can be used for determination of the heating value. D 3286 covers the test method for gross calorific value of solid fuel by the Isothermal-Jacket Bomb Calorimeter and D 2015 covers the test method for gross calorific value of solid fuel by the adiabatic Bomb Calorimeter.

2. Ultimate analysis - ASTM D 3176 covers the standard method for ultimate analysis of coal and coke.

2.1. Nitrogen. ASTM D 3179 covers the test for nitrogen in the analysis sample of coal and coke.

2.2. Softening temperature of ash. ASTM D 1857 covers the test method for fusibility of coal and coke ash.

2.3. Free swelling index. ASTM D 726 covers the test method for the free swelling index of coal.

2.4. Hardgrove grindability index. ASTM D 409 covers the test method for the grindability of coal by the Hardgrove Machine Method.

2.5. Forms of sulphur. ASTM D 2492 covers the test method for forms of sulphur in coal.

2.6. Chlorine. ASTM D 2361 covers the test method for chlorine in coal. Chlorine is believed to be a factor in fireside fouling problems. Although the validity of the values is uncertain, generally accepted fouling classification of coal, according to total chlorine content, is as follows:

Total percent chlorine in coal	Fouling type
0.2	low
0.2 - 0.3	medium
0.3 - 0.5	high
0.5	severe

Chlorine in coal is associated with sodium and sodium chloride. As such, the chlorine content of coal is a good indicator of the level of sodium - the principal ash-fouling element.

3. Elementary analysis of coal ash - ASTM D 1795 and ASTM 3682 cover the test methods for analysis of coal and coke ash.

The chemical composition of coal ash is recognized as an important factor in fouling and slagging problems and in the viscosity of coal ash in wet bottom and cyclone furnaces. Coals with high-iron ash, above 20 % Fe_2O_3, typically exhibit ash softening temperatures under 2200°F.

4. Coal sampling - Coal is one of the most difficult materials to sample, varying in composition from non-combustible particles to those which can be burned completely, with all gradations between. Its composition can vary substantially from the top to the bottom of the seam, from side to side, and from one end to the other, within an unmined bed. This variability is often bewilderingly increaced by mining, preparation and handling. The challenge is sampling coal, therefore is to collect a relatively small portion of a shipment or consignment that accurately enough represents the quality. Every sampling operation consists essentially of either extracting one sample from a given quantity of material or of extracting from different parts of

the lot series of small portions that are combined into one "gross sample" without prior analysis. The general purpose sampling procedure is intended for a precision such that if gross samples are taken repeatedly from a lot or consignment and one ash determination is made on the analysis sample from each gross sample, 95 out of 100 of these determinations will fall within plus or minus one tenth (1/10) of the average of all the determinations.

ASTM has been consolidating sampling specifications for many years, and most of the ASTM sampling procedures are now incorporated in the Standard Methods for Collection of a Gross Sample of Coal, Designation D 2234. The only other stand-alone sampling standard is the Standard Method of Sampling and Fineness Test of Pulverized Coal, Designation D 197.

II. RECOMMENDED APPARATUS AND EQUIPMENT TO BE USED IN A POWER PLANT CHEMICAL LABORATORY

1. List of analyses of coal, coal ash, fireside deposits, slag, fly ash and stack gas which should be made accordingly with ASTM Standards:

   A. Proximate analysis of coal - as received (%)

      Ash
      Moisture (total)
      Volatile
      Fixed Carbon
      Sulphur
      Heating value BTU/lbs
      Grindability Hardgrove

   B. Ultimate analysis of coal - as received (%)

      Ash
      Moisture
      Carbon
      Hydrogen
      Nitrogen
      Oxygen
      Chlorine
      Sulphur
      Sodium oxide[x]
      Potassium oxide[x]
      Phosphorus[x]

[x]Calculated values from coal ash analysis

C. <u>Coal-ash analysis</u> (The same determinations in fireside deposits slag and fly ash)

SiO_2	Na_2O
Al_2O_3	K_2O
Fe_2O_3	TiO_2
CaO	SO_3
MgO	P_2O_5

D. <u>Feasibility of coal ash - in reducing and oxidizing atmosphere</u>

Initial deformation

Hemispherical softening

Fluid softening

2. List of recommended apparatus:

2.1. Atomic absorption spectrophotometer and complete equipment

2.2. Flame photometer and complete equipment

2.3. Portable electronic analyzer for measuring stack gas components and complete equipment

2.4. Electric maffle furnace

2.5. Drying oven

2.6. Analytical balances with equipment

2.7. The equipment for sampling and fineness test of pulverized coal

2.8. The equipment for sieve analyses of coal (the complete sieves round-hole screens and wire-cloth sieves)

2.9. Hardgrove machine with equipment

2.10. A laboratory plate mill with equipment

2.11. The complete of round-hole screens and wire-cloth sieves with shatter test machine

2.12. Mechanical vacuum pump with equipment

2.13. A laboratory crusher or grinder: jaw, cone, rotary, hammer mill

2.14. The Gieseler Plastometer with equipment

2.15. Brass Cone mold with equipment

2.16. Mechanical sample divider and sample dividers (riffles) with equipment

2.17. The Adiabatic bomb calorimeter with complete equipment and reagents plus additive equipment and reagents for the determination of chlorine

2.18. The moisture oven with equipment

2.19. The vertical electric tube furnace with equipment for determining volatile matter

2.20. High temperature combustion tube furnace for the determination of total sulphur in coal with equipment

2.21. Laboratory pulvelizer for final reductions of laboratory sample to pass the No.60 (250 m) sieve.