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INDIGENOUS ENERGY UTILIZATION

(COAL & BIOMASS)

UC/PHI/88/024/11-01

Republic of Philippines

Report*on: The Visit to Manila, Cebu & Semirara/Philippines

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

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0. Summary

The author stayed in the Pilippines from November 8th to 24th, 1968 for drafting proposals for further proceeding with respect to the following questions:

- Central coal preparation plant on Cebu island.
- fluidized-bed gasification of coal for direct heat application.

In 1983 the question of a central coal preparation plant on Cebu island was given detailed consideration by Messrs. Norwest Resource Consultants Inc. This study needs thorough revision because the conditions changed substantially. This revision needs to comprise assessment of the cost-effectiveness as well as selection of site and of the technology to be used. The cost-effectiveness assessment may be based on an updated cost analysis contained in the Norwest study. The points of main efforts must be the investigation of the possibly higher proceeds for cleaned coal. In this case, the quality stipulations contained in existing supply contracts as well as the transport costs must be considered.

When examining the question of site, consideration is to be given to the fact that Central and Southern Cebu are strongly favourised in comparison to Northern Cebu with respect to present and future production and with respect to the mineable reserves. The question arises, therefore, whether Northern Cebu should still be considered for the question of site at all.

The Norwest study proposes a coal preparation plant with a jig as main cleaning system. When looking at the conditions prevailing on Cebu island, however, the question

should be examined whether the presently available preparation plants in modular design (running dense medium separation) are to be preferred. The question of site and of the machinery to be used, however, should not be investigated unless it is evident that cost-effectiveness can be arrived at.

The Philippine National Oil Company, Energy Research & Development Center proposes to set-up a pilot plant for fluidized-bed gasification for firing furnaces and kilns in industrial plants.

In view of the fact that British Coal almost completed the development of a fluidized-bed gasification system for industrial use, and in view of the fact that BC runs a pilot plant of such a design, it does not seem useful to start a parallel development in the Philippines. However, it seems logical to find out how far - under the conditions prevailing in the Philippines - the use of gasifiers for producing gas for industrial plants is economically justifyable. When examining this question, however, consideration should not be given to fluidized-bed gasification only, but also to the large variety of available fixed-bed gasification processes. It may be pointed that, in the past, exclusively fixed-bed gasifiers have been used for such cases of application in industrial scale.

In a first step, therefore, the worldwide available gasification processes should be examined with respect to their suitability for Philippine coals. In a second step, the gasification process which seems to be the best suited one should be investigated in detail. In this phase, the question of cost-effectiveness should be investigated for a given favourably situated site (in an industrial plant). A demonstration unit, then, should be the logical third step.

The autor remits his thanks to Mrs. Mildred N. Cadoc and her staff and also to the staff of the Department Coal & Nuclear Minerals for friendly support and cooperative attitude to the author throughout his work.

1. Preface

The author stayed in the Philippines from November 8th to November 24th, 1988, and visited the following authorities, institutes, and companies:

Office of Energy Affairs
- Conventional Resources Division
- Coal & Nuclear Minerals Division

Board of Investments
Philippine National Oil Company
- Coal Corporation
- C.C., Central Cebu Coal Mines
- Energy Research & Development Center

Semirara Coal Corporation
- Main Office Manila
- Unong-Mine

The Philippine Chamber of Coal Mines

I.D. Almendras Agro-Industrial Corporation

Phil-Hispano Ceramics, Inc.

Rizal Cement
National Power Corporation, Naga Power Station

Atlas Consolidated Mining & Development Corporation.

The glass works of Republic Glass Corp. could not be visited due to fludding in the region.

The purpose of the visit was consulting of the government of the Philippines in view of decisions on the use of indigenous energy, in particular coal.

The considerations were mainly centered on two projects:

1. Central preparation plant Cebu
2. Fluidized-bed gasification of coal

2. General remarks

The mineable reserves of coal in the Philippines are of round about 300 Mio t, and the mining industry of that country produces at present 1,2 Mio t/a. It seems logical to increase production and utilization of domestic coal in order to reduce the need for imported coal as well as the oil demand. This would allow foreign currency becoming available for other urgently needed importations.

An increase of domestic coal use depends largely on the price of domestic coal compared to the one for imported coal and for imported oil. This applies to the extent that the government does not intervene in favour of domestic coal by import limitations, customs duties, or subsidies. The influence of the prices for imported coal is reflected e.g. in the conditions of a supply contract concluded between the Semirara Coal Corporation and the National Power Corporation. Said contract specifies adjustment of payments between the contracting partners as a function of the guaranteed price and the reference price.

For increase in consumption of indigenous coals various possibilities exist:

a) The simplest possibility exists, when new industries are constructed. In that case it should be strived for firing these plants exclusively with domestic coal. This applies above all to the forthcoming erection of power stations. For electricity generating the coal needs not necessarily to undergo a preparation step. Coal combustors for plants of any capacity can be designed for coal high in inerts either as stoker or as fluidized-bed combustors or pulverized fuel furnaces. However, the homogenety of the supplied coal's quality is of decisive importance for the user so that not necessarily a coal preparation, but in any case measures for product homogenisation seem logical.

b) Substitution of presently imported coal by domestic coal constitutes another large potential in the market. For 1988, coal importations are expected to amount to more than 1 Mio t. In some cases imported coal is necessary because for certain users the calorific value of domestic coal is insufficient. The imported coal is partly blended with domestic coal and partly used as supplied. For conquering this share in the market, domestic coal must undergo preparation in order to place at the customer's disposal a product whose calorific value corresponds to the one of imported coal.

In the view of the Philippine Chamber of Coal Mines preference should always given to domestic coal if the price for said coal is not by more than 10 to 15 % higher than the price for comparable imported coal.

c) Replacement of oil-fired plants by coal-fired ones

In this case it is the general rule that direct combustion of coal, whenever possible, is more cost-effective than gasification processes. There are cases, however, in which direct combustion of coal is impossible so that only gasification is possible. Since the gasification efficiency is to be assumed to be of approx. 75 % there must be a substantial difference in price between coal and oil in order to justify gasification. A particularly favourable solution is to replace oil-fired equipment at the end of its useful life, but: replacement by a coal firing is the option to be considered first. Only in case of more recent and by far not yet depreciated plants, gasification should be looked at first.

3. Central coal preparation plant Cebu

3.1 Technical features

The high inert content is reported to be the most important factor for the limited sales of domestic coal. It is expected that the coal sales may increase considerably if the coal's gross calorific value can be boosted to more than 23 MJ/kg (10,000 Btu/lb).

For the coal producer a coal preparation plant is advantageous in that with guaranteed product quality long term supply contracts can be concluded. Furthermore, improved product quality means higher net profits.

For the customer, an improved and consistent quality of the coal means advantages in operation. Less ashes are produced, and the tranport costs are kept substantially lower.

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The fact, however, that production comes from a variety of relatively small privatly owned mines is a drawback for Cebu.

In 1983 Messrs. Norwest Resource Consultatnts Inc. carried out a feasibility study for a central coal preparation plant on Cebu island[1)] for the Bureau of Energy Development. The study was published in March 1984, and consists of 3 volumes.

Vol. 1: Summary and coal preparation study
Vol. 2: Coal supply study
Vol. 3: Coal utilization study

The study is focussed on the coal mines of Northern Cebu which, in 1982, recorded a production of 150,000 t. It was assumed that the main obstacle for a coal production increase is the lacking demand for high-inert coal. The ash content of the run-of-mine production varies between 7 and 35 % (air dried) and the gross calorific value ranges between 19 and 23 MJ/kg (8,000 - 10,000 Btu/lb) for the air dried substance.

A central coal preparation plant should produce a coal with a minimum gross calorific value of at least 23 MJ/kg (10,000 Btu/lb) and with an ash content of less than 12 %. The plant should be rated for 325,000 t/a of raw feed coal.

A 180 kg bulk sample was taken from the raw production of 15 mines, and, additionally, 31 2 kg spot samples were taken from other mines. A composite bulk sample was made up of the 15 above-mentioned samples. The shares of each of these 15 samples in the composite sample corresponded to the expected contribution of the individual mines' production. The properties of this composite bulk sample are shown in tables 1 and 2. On the basis of these data, 4 different preparation processes were investigated. A jig was recommended as the best option for the separation step. Thus, the best suited flow sheet looks as follows (fig. 1): The run of mine coal (< 250mm) supplied by truck is first crushed to < 35 mm prior to homogenisation in a raw coal stockpile of 5,000 t capacity. The particle size < 35 mm is fed to the jig. The separation should be run at a density of approx. 1.6 kg/dm^3. The clean coal fraction is then dewatered and screened. The fraction 35 - 13 mm is cycled to the large coal bunker while the fraction 13 - 0.6 mm undergoes prior dewatering in a centrifuge. The < 0.6 mm fraction is cycled to a classifying cyclone whose underflow is cycled to a Derrick-screen. The 0.6 - 0.15 mm fraction thus obtained undergoes further dewatering by centrifuge, and is added to the washed smalls. The fines < 0.15 mm are cycled through a thickener, are then dewatered in refuse belt press and discarded, together with the refuse from the jig. Another flow sheet provides the first centrifuge for the dewatering of the 35 - 15 mm fraction. Norwest calculated for this flow sheet an 80 % yield of coal with the required properties.

The study also contains the result of a float-and-sink analysis for various size categories (table 2). This float-and-sink analysis shows a coal of good washability. The 80 % yield assumed by Norwest is on the safe side. However, operation problems could arise if, with an upper particle size of 35 mm, the coal is fed to the jig without previous desliming. This question should in any case be looked at if further consideration is given to the use of a jig.

Table 1

Analytical Results for Composite Sample

Raw coal quality

		adb	db
Residual moisture	%	12.17	
Ash	%	21.11	24.0
Volatile matter	%	25.11	40.0
Fixed Carbon	%	31.61	36.0
Sulphur	%	1.05	1.2
Gross Calorific value	Btu/lb	8464	9637
Hardgrove index		50	

Size distribution in weight %

	mean	max fines	max coarse
38 - 13 mm	32		55
13 - 6 mm	11		18
6 - 0.6 mm	42	45	
0.6 - 0.15 mm	6	10	
< 0.15 mm	9	16	

Ash distribution

38 - 12 mm	18 %
12 - 6 mm	18.4 %
6 - 0.6 mm	14.9 %
0.6 - 0.15 mm	20 %
< 0.15 mm	61 %

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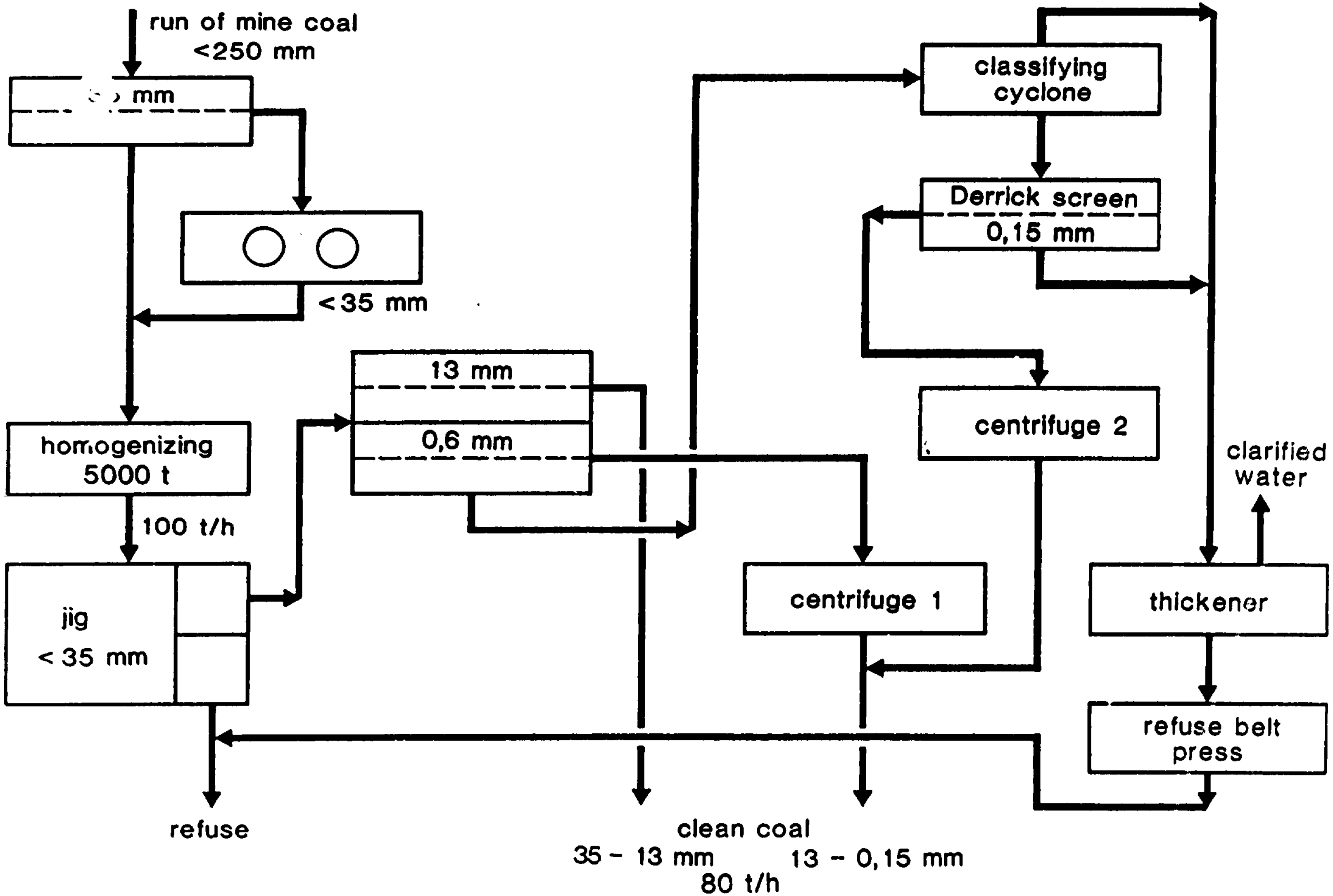
Composite Sample Washability Data

(air-dry basis)

Sink	Float	38 - 12 mm weight %	ash	sulphur	12 - 6 mm weight %	ash	sulphur	6 - 0.6 mm weight %	ash	sulphur	0.6 - 0.15 mm weight %	ash	sulphur
1.2	- 1.35	59.69	4.5	0.69	55.79	4.78	0.79	55.42	3.6	0.75	41.46	2.43	0.72
1.35	- 1.4	6.73	9.0	2.13	7.31	7.98	1.63	11.35	6.91	1.77	13.55	4.43	1.2
1.4	- 1.5	9.06	15.51	1.05	14.29	13.23	1.83	10.15	10.72	2.0	11.65	7.75	1.26
1.5	- 1.55	3.51	24.11	1.76	1.94	24.28	1.25	2.39	18.5	1.67	4.2	12.9	1.39
1.55	- 1.6	1.34	29.52	1.44	1.63	29.98	1.18	0.34	20.38	1.45	2.58	19.38	1.31
1.6	- 1.8	3.67	42.88	0.76	3.08	39.29	0.64	5.09	23.10	1.36	7.18	43.35	1.28
1.8	- 2.0	2.25	54.38	0.71	2.22	49.34	1.1	2.49	34.01	1.06	4.07	60.66	0.86
2.0		13.75	67.56	0.66	13.74	72.98	1.55	12.77	66.43	1.20	15.31	71.02	1.49


run of mine coal
<250 mm
< 35 mm
homogenizing
5000 t
100 t/h
jig
< 35 mm
13 mm
0,6 mm
classifying
cyclone
Derrick screen
0,15 mm
centrifuge 2
centrifuge 1
clarified
water
thickener
refuse belt
press
refuse
clean coal
35 - 13 mm
13 - 0,15 mm
80 t/h

However, other considerations can be made as well:

A study prepared by Wardell-Armstrong[2)] provides a dense-medium washing plant in modular design. This proposal is justified in so far as the design of a coal preparation plant must be looked at with consideration of the operational status of the producing coalfaces. The room and pillar mining with pillar recovery predominantly practised in Cebu (a method with limited efficiency) is reason enough to prefer plants of modular design which, due to their design features, can repeatedly be disassembled and reassembled in another place, if necessary.

The transition to long-wall caving will imply changes of the ROM quality and a longer useful life of the shafts. Then, the use of jigs characterized by low operation costs and high throughput rates becomes interesting. The float- and sink analyses run by Norwest show that the coal is most probably suited for jigs. It should be checked, however, whether the coals produced in Central or Southern Cebu exhibit similarly good features with respect to their washability.

Coal preparation plants in modular design are supplied in form of pre-assembled steel elements, and finally assembled on site. Machinery and other equipment is fitted after assembly. The preparation system is protected against influences of weather only by steel sheets. Such systems logically seem appropriate for places where up to present no coal preparation plants exists, but where coal winning capacities of limited operation life is intended to be jointly catered for. Low investment and short construction times as well as a certain mobility are the particular advantages of such plants in modular design.

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If dense-medium washing systems are used, the raw feed coal, as proposed by Norwest, is to be crushed to < 35 mm, and subsequently homogenized. The separation density is always to be kept at 1.6 kg/dm^3. In contrast to jig operation, the raw feed coal can be cycled without preliminary desliming. The throughput of 100 t/h should be kept to.

Summary:

The above statements show that the technology proposed in the Norwest study should be re-examined because the prerequisites changed sustantially. The determination of the best-suited separation technology under the prevailing conditions should be made by Philippine engineers. Furthermore, the coals produced in Central Cebu and Southern Cebu should be checked for their washability. The equipment for running float-and-sink-analyses might by provided within the framework of the planned mining technolgy training center in Cebu.

These activities, however, should logically not start unless the questions under 3.2 and 3.3 are answered positively.

3.2 The location for the Cebu coal preparation plant

The study carried out by Norwest gives preference to a site near Danao, Northern Cebu. This proposal is based on the assumption that the North Cebu production of 146,000 t in 1983 would be boosted to 425,000 t in 1987. Actually, in 1987, the total production of Cebu Island was of 238,000 t only. For this reason the question of site needs to be reconsidered. The new consideration should not disregard the following facts:

1. In the north of Cebu only 1.03 Mio t of mineable reserves are on hand while 1,24 Mio t for the Center of the island and 3,32 Mio t for the southern part of Cebu have been confirmed.

2. The 1988 production (evaluated for a calorific value of 23 MJ/kg) reads: Northern Cebu 52,000 t, Central Cebu 74,000 t, and Southern Cebu 122,000 t. The planned figures for 1993 read: Northern Cebu 144,000 t, Central Cebu 101,000 t, and Southern Cebu 273,000 t.

This leads to the conclusion that a central processing plant should rather be set up in Central or Southern Cebu. This question, however, is to be examined in more detail.

3.3 Economic consideration

The Norwest study contains data on the economic feasibility of a central preparation plant. The necessary investments as well as the operation costs were determined on the price level prevailing in the fourth quarter of 1983.

The results of the economic consideration were laid down in the following formula:

$$\text{Selling price} \times \frac{\%\ \text{clean coal yield}}{100} - \text{buying price} > 64\ \text{₱/t} \qquad (1)$$

If the difference is greater than 64 ₱/t, an internal rate of return of 15 % is exceeded. However, Norwest stresses the strong influence of buying and selling prices on the economics of the preparation plant. If the selling price decreases by 10 % only there is no longer an adequate return on investment. Therefore, selling and buying prices need to be determined quite carefully. As to the buying price, Norwest assumed as a basis the supply contracts with Unicemco, the largest coal buyer in Northern Cebu. A value of 438 ₱/t was assumed as selling price. No reason for the figure is given anywhere in the study, and thus a careful examination based on present-day conditions is to be carried in this context.

The question whether at all and, if yes, to which extent, run-of-mine coal is to undergo preparation cannot be given a general answer. If e.g. the mining company and the coal user (e.g. a power station) belong to the same group of companies, an optimization calculation may be set up considering coal preparation costs against higher costs of transport and higher operation costs. According to the conditions prevailing in each case the results will vary.[8)]

Such a situation, however, is not given in Cebu. Optimization calculations may be carried out, however, are not economically relevant. In such case the cost effectiveness of a coal preparation plant will largely depend on existing supply constracts and agreements with respect to the coal price being possibly ajusted as a function of the coal's properties, such as calorific value, moisture content, ash content, and sulphur content. Only if the properties of the run-of- mine coal are so bad that the coal is rejected by the customer, a coal preparation plant is absolutely necessary. In all other cases, however, the possibly higher sales proceeds need to be compared with the costs for coal preparation.

It makes sence, therefore, to check, on the basis of existing supply contracts, the influence of the coal quality on the possible proceeds.

In the individual supply contracts the gross calorific value is considered quite differently. NPC-Naga stipulates a lower limit of 16 MJ/kg (7,000 Btu/lb). Supply batches with lower calorific value are not accepted. With the Asian Alcohol Corporation (AAC) the lower limit is of 17 MJ/kg. In the supply contracts a basic price bound to a specified calorific value is provided. With NPC-Naga e.g. this value reads 19,8 MJ/kg. According to deviations of the actual calorific value from the reference value either credits or penalties are applied. With NPC-Naga as well as with Atlas Consolidated Mining and Development Corporation (Atlas) and AAC the accounting is controlled by the calorific value supply, i.e. the energy supply is payed for in the end.

The contract between Semirara Coal Corporation and NPC-Calaca is somewhat different. The basic calorific value is fixed to 20.3 MJ/kg. Up to 19.8 MJ/kg linear penalisation is practised which, below 19.8 MJ/kg is doubled. Apparently, credits for higher calorific values than 20.3 MJ/kg are not provided.

Apart from the particular Semirara practice, accounting therefore is proportional to the calorific value supplied. Such accounting practice is not favourable to the options including coal preparation plants because, during preparation, always carbonaceous substance is lost so that the possible proceeds are affected. A synopsis on the quality features of Cebu coal shows that the minimum calorific value of 16 MJ/kg (7000 Btu/lb) as stipulated in the NPC-contract is - on average - exceeded. In some cases only individual supply batches are out of standard. In this respect, a homogenisation plant could bring about some improvement.

Also for the ash content, stipulations are made in the supply contracts. NPC-Naga provides an upper threshold of 30 % of ash on dry basis (air dried substance). In case of calorific values of more than 21 MJ/kg, even 33 % of ashes are admitted. Accounting is done for a reference ash content of 15 %. Ash contents above that 15 % threshold result in linearly determined deductions from the weight considered for accounting.

Atlas, too, strives for an ash content of 15 %, however, does not provide penalties. The not clearly defined upper threshold is of about 25 % ash. With AAC, the reference ash content is of 20 %. Ash contents beyond that threshold are subjected to a 50 % reduction of the weight accounted. The supply contract Semirara/Calaca provides a penalty for ash contents beyond 18 % which is doubled in case of inert contents beyond 21 %.

For the Cebu conditions this means that generally coal qualities with ash contents below 30 % are saleable so that generally there is no absolute need for coal preparation. How far the penalties, if applicable, and the additional transport costs exceed the costs for coal preparation is to be checked for each particular case.

With respect to the moisture content of the coal supplied, there is no possibility foreseen for rejection. The Naga power station specifies a reference moisture of 16 % as supplied. Higher moisture contents result in a correction of the weight. With AAC penalties become applicable from an internal moisture of more than 20 % onwards. Of course, in no case credits are granted for lower moisture contents. The Semirara/Calaca contract specifies, with the total moisture content range of 24 to 29 %, a simple correction of the weight to be accounted and a doubled correction for moisture contents greater than 29 %.

When considering cleaning of the run-of-mine coal it should be borne in mined that, process-inherently, the moisture content could rise and thus be the reason for additional penalties.

Naga power station sets an upper limit of 2 % for sulphur, however, neither rejection nor penalties are provided. With AAB, penalisation starts from an upper threshold of 3 % sulphur onwards, and above 3.3 % the batches supplied can be rejected. For the Semirara-coal, simple penalties are applied for sulphur contents between 1 and 1.3 %; these penalties are doubled for contents between 1.3 and 3 %, and quadrupled for sulphur contents of more than 3 %.

Apart from the data discussed up to present, such as calorific value, ash, moisture and sulphur content, further features are stipulated, however, not subjected to penalties or rejection of batches supplied. Naga power station e.g. stipulates a volatile matter content of at least 40 % (air dried), a particle size of max. 100 mm, a Hardgrove- Index of > 40, and a softening point of the ashes > 1250° C.

For making quite clear how far assessment and penalty systems affect the cost-effectiveness of coal preparation plants we quote here as example the accounting system of Naga power station and its effect on the conditions ruling the cleaning of coal from Northern Cebu as determined by Norwest. For this example it is assumed that neither the total moisture content of the run-of-mine coal nor the one of the cleaned coal exceeds 16 % so that no weight corrections due to increased moisture content are made.

As to be seen from table 1, the run-of-mine coal exhibits an ash content of 21.11 % so that, accordingly, a weight correction is to be made. The calorific value of the run-of-mine coal corresponds approx. to the reference value so that only minimal changes are made. Weight correction of the cleaned coal is not necessary because the reference ash content of 15 % is not reached. The higher calorific value of 23 MJ/kg results in proceeds which are by approx. 12 % higher.

As stated above, Norwest assumes a buying price for the coal preparation plant of 284 ₱/t. The selling price was assumed to be of 438 ₱/t. On the basis of a 284 ₱/t buying price and with consideration of possible credits for the cleaned coal according to the NPC-system (no correction by weight and higher proceeds due to higher calorific value) a selling price of 358/₱t for the clean smalls is calculated (price level of 1983).

If these values are integrated into formula (1), we may recognize quite readily that under these circumstances a preparation plant will not be cost-effective. Consideration, however, should be given to the fact that also transport costs will be reduced because the mass to be transported is reduced by 20 %.

This situation may also be taken as a basis for future power stations if these are designed for higher inert contents and if the accounting system remains unchanged.

For cement industries the situation looks different. Due to the present-day structure of cement works, coal with a calorific value of substentially less than 21 MJ/kg cannot be used. In some cases even higher minimum calcrific values (23 MJ/kg, Rizal-Cement) are quoted. It should be pointed out, however, that also in Cebu there are mines whose supplies to Atlas in 1987 did not fall short of a calorific value of 23 MJ/kg (e.g. Luvimin and Manguerra).

Summary:

From the above statements the urgent necessity to check in considerably more detail than in the Norwest study the cost effectiveness of a central coal preparation plant in Cebu arises. The existing supply contracts between the collieries and the customers should be given particular consideration. Furthermore, it should be examined to which extent the penalty system is realistic, i.e. how far the penalties provided correspond to the actual operation costs increase of the consumers.

4. Gasification of Philippine coal for direct heat application

4.1 Background

The Energy Research and Development Center of the Philippine National Oil Company (ERDC of PNOC) submitted a proposal to use the fluidized-bed gasification technology for gasifying domestic coal. The gas should be used firing such industrial plants which otherwise had to be oil fired. ERDC proposes to develop a fluidized bed gasification process - or to adopt an existing process - intended for application in industry to fire a range of high temperature furnaces and kilns. In addition, ERDC proposes to pilot test the fluidized bed gasifier in an appropriate industry and modify it to make it operate reliably with domestic coal. Subsequently, to initiate activities in developing a commercial fluidized-bed-gasifier based on the experience of the pilot installation.

4.2 Use of coal gasification plants in industries

As pointed out in chapter 2 above, there are cases in which the desired use of coal is impossible, except with prior gasification of that coal. Prior to the abundant supply of oil and gas in the highly industrialized countries it was standard practice to apply gasifiers in steel plants, in glass works, in ceramics and lime burning plants, in gas utilities, and metallurgical and chemical plants. In some parts of the world, in particular in South Africa, India, Chile where the economic conditions prevailing are favourable, such coal gasifiers are used still today.

In an industrial plant with own gas supply, the raw gas produced needs, as a general rule, to be purified, however, in some cases the hot and unpurified gas can be burnt directly, and this means, above all, without previous desulphurisation. As far as gas is produced in the own works difference should be made between low-Btu gas (LBG) and medium-Btu gas (MBG).

The simplest possibility of gas production is coal gasification with air as gasification agent. According to the operation mode and the feedstock used, the calorific value of the LBG produced in this way is of 4.6 to 6.7 MJ/m^3. The efficiency rates of the gasifiers (fixed-bed gasifiers) range between 75 and 80 %.

For industrial use of LBG the following criteria are to be considered:

- Flame properties such as flame temperature, air demand, and flue gas volume
- chemical composition
- plant size
- load factor
- partical-load operation behaviour and responsiveness with respect to load changes.

The capacity of individual gasifiers ranges between a minimum of 2 MW and the typical ratings of 7 to 20 MW. The use of LBG is frequently limited because of the flame temperature which, compared to the one of oil flames, is by some 100 K lower. When using pre-heaters, the maximum temperature which can be arrived at with LBG is of 1650°. Due to the high (approx. 50 %) nitrogen content the thermal efficiency is substantially lower than the one of oil firings.

These difficulties can be avoided by producing - instead of LBG - MBG with an average calorific value of approx. 11 MJ/m^3 or even 14 MJ/m^3. When using steam as gasification agent for MBG production the gasification efficiency rates, however, go down to values of 60 to 65 %. Furthermore, the water gas process is comparably complicated because of the discontinous operation, viz. gasification by steam interrupted by air injection for heating-up. Another possibility of increasing the calorific value is the use of oxygen as gasification agent. This, however, means a considerably more complex plant. Alternatively, LBG could be burnt with oxygen-enriched air to arrive at high flame temperatures and smaller flue gas volumes.

With MBG the possible flame temperature is higher than the one of natural gas. The flue gas volume is somewhat smaller so that, as to the flame properties, a broader range of application possibilities exists. Plants for production of MBG, however, are considerably more complex than LBG generators. If oxygen is used, the plant for oxygen recovery may be more expensive than the gasifier. Accordingly, the production of MBG makes sense only for larger units with a thermal output of at least 80 MW.

Other sources[4)] specify a lower limit for fixed-bed gasifiers with oxygen as gasification agent, viz. 20 MW of thermal output.

This means that for works with a heat demand of approx. 6 MW, as this is the case with Fil-Hispano Ceramics, everything else than a LBG generator is out of question. In these works, the kiln for the production of refractory and the rotary frid kiln with operation temperatures of 1400° C require the highest flame temperatures which, however, could be arrived at most probably with LBG as well.

The heat requirement of the Armco-Marsteel Alloy Corporation - approx. 12 MW at present - is considerably higher. If the production steps presently run in Quezon-City are moved to Taguig, and if the envisaged oxygen production plant is constructed anyhow, a gasifier run on oxygen could be considered. Therefore, it possibly makes sense to supply the two neighbouring production plants also with the MBG produced.

The technology of decentralized gas production underwent improvement also in the periods of oversupply of oil and

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gas. The fixed-bed generators for LBG and water gas production could be successfully modified in a way that the plants produced no longer unwanted tar.[5)]

Obviously, more consideration is to be given nowadays to environmental protection. This applies above all to combustion of unpurified raw gas without downstream flue gas desulphurisation.

The decisive factor for answering the question: "gas production from coal, or use of oil" are of course the costs which are influenced by many parameters and which always depend on the specific conditions to which the plant in question is subjected. Therefore, there can be no simple or general solution to using coal gasification.

4.3 Fluidized-bed gasification

ERDC proposes to look particularly at fluidized-bed gasification processes. Eventhough fluidized-bed technology for coal gasification is known for more than 60 years, and eventhough this technology is applied still today in many cases, its application is up to present generally limited to larger units, in particular to gasification units run on oxygen. Fluidized-bed gasifiers run on air are operated - however, also in very large units - in the German Democratic Republic (Leuna).

More recently, a fluidized-bed gasifier (8 MW) run on air was constructed in San Benito, Texas, by Foster Wheeler for Central Power & Light. This plant, however, is to be regarded more as an experimental unit.

We should state that up to present no fluidized-bed gasifier for industrial LBG production to supply an industrial furnace exists. In 1974 British Coal started development work on a fluidized-bed gasifier for industrial gas production.[6] This development led to the construction and operation of a 12 t/d-pilot plant which is to remain operational at least until the end of 1989.

Messrs. Otto-Simon Carves Ltd. obtained a licence from British Coal and now try to commercialise the know-how obtained.[7] The development of this process is at the point of being completed, and certainly was not cheap. A competing development in the Philippines, therefore, does not seem justified.

In addition, the question is to be discussed whether for use in the Philippine industry, only fluidized-bed gasification should be given consideration. Without any doubt, fluidized-bed gasificatio . exhibits some advantages over the fixed-bed gasification almost exclusively used up to now for the purposes discussed. The main advantages of fluidized-bed gasification seem to be the following ones:

- Use of smalls instead of graded sizes (as necessary in case of fixed-bed gasification)
- production of a tar-free gas
- use of medium and strongly caking coals.

A drawback of fluidized-bed gasification is the high gas temperature of 900° C which normally necessitates waste heat recovery (steam raising). This makes the process more complicated. In many cases the steam produced in this way cannot be made good use of. The relatively high gas temperature limits the gasification efficiency to less than 60 % while 75 to 80 % of efficiency can be arrived at with fixed-bed gasifiers.

As far as the use of graded sizes is concerned we are still to state that even British Coal, in contrast to their previous intention, provide the use of graded sizes for fluidized-bed gasification in order to assure a sufficiently high carbon conversion rate.[6)]

Today, also fixed-bed gasifiers allow production of tar-free gas.[5)] Fixed-bed generators allow use of coal with a swelling index of up to 2 without stoking facilities, and this means that Philippine coal should be suited - except for very few qualities - for use in fixed-bed generators.

We are not to overlook either that fluidized-bed gasifiers partial-load operation behaviour is less favourable than the one of fixed-bed gasifiers.

The need for waste heat recovery - in case of fluidized-bed gasifiers - implies a complicated process engineering, so that, e.g. according to the opinion of British Coal, the fluidized-bed gasification for operating less than 10 MW is to capital-intensive. For this reason British Coal tries to develop a now gasification process for units of less than 10 MW which is based on cyclone technology with dry ash removal.

In literature[4)] information is found that fluidized-bed gasification run on air does only make sense in units of more than 100 MW. The development carried out by British Coal, however, was probably not yet considered in said

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literature. Actually, exclusively fixed-bed gasifiers with ratings of down to 3 MW have been used in the past for decentralized industrial gas production.

4.4 Further proceeding

From the points discussed above may be deduced that, for Philippine conditions, it does not make sense to look exclusively at fluidized-bed gasification.

Moreover, the application possibilities of fixed-bed gasifiers should be given the same consideration. As a first step, the gasification processes commercially available worldwide should be looked at for their suitability of being run on Philipine coal. Of course, the fluidized-bed gasification process developed by British Coal should be given consideration as well. All these investigations should include a general cost-effectiveness assessment whose results should identify one or possibly two gasification processes as the best suited ones.

As a next step, the suppliers of these gasification processes should be contacted, and for a life application case a site oriented detailed cost-effectiveness calculation should be carried out. The application case should be selected in a way that best-possible preliminary conditions are given. This means that the site should not necessarily be situated in or in the vicinity of Metro-Manila. Cebu should be given consideration as well.

The carrying out of the demonstration project should not be envisaged unless such a detailed cost-effectiveness assessment has been completed with positive results.

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