Ⅷ. 付 属 資 料

1. 4TH INTERNATIONAL SYMPOSIUM AGGLOMERATION

2. COMBUSTION CHARACTERISTICS OF BIOCOAL

3. SCOPE OF WORK

4. MINUTES

付属資料 1.

4TH INTERNATIONAL SYMPOSIUM ON AGGLOMERATION

June 2-5, 1985
Royal York Hotel
Toronto, Ontario, Canada

Co-Sponsors:
Iron and Steel Society • Canadian Institute of Mining and Metallurgy
In Cooperation with - Society of Mining Engineers

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BRIQUETTING AND COMBUSTION CHARACTERISTICS OF COAL-WOOD COMPOSITE FUEL (BIO-COAL)

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INTRODUCTION

Lying in the northernmost part of Japan, Hokkaido is a cold, snowy area where a vast volume of oil is consumed as fuel for domestic heating and for medium and small boilers for the heating of offices, commercial and industrial buildings, etc. For instance, kerosene accounts for about 90% of the total consumption of fuel for domestic use, with annual consumption amounting to about 3.5 million kiloliters.

Stimulated by the second oil crisis, the substitution of coal, coke, woody pellets and other solid fuels for such oil fuels has been pursued, and the greatest hopes have been entertained for coal. However, coal has many inconveniences. For example, suppression of sooty smoke emission, control of combustion rate and disposal of ash are very difficult in conventional combustion equipment. Even if such difficulties could be eliminated by development of a new type of combustion equipment, usable qualities and brands of coal are extremely limited because low-ash and non-caking coal is required. In these circumstances, it is difficult for coal or other solid fuel with a coal base to find general acceptance as an alternative fuel for oil, though the price of such solid fuel is lower than that of oil.

With a view to stable supply of an improved solid fuel that is free of the inconveniences of coal, the Hokkaido Industrial Research Institute is developing a new composite solid fuel called "Bio-Coal", which can be made from a wide range of ranks of coal in combination with wood wastes, such as sawdust, bark, etc. Special burning equipment for Bio-Coal is also being developed. In this study, Bio-Coal production is embodied in a roll press method in cooperation with Otsuka Iron Works Co., Ltd.

Briquettability of Coal-wood Particles Mixture

Coal and wood waste, used as raw materials for Bio-Coal, are typical solid fuel sources, long employed as fuels for heating. However, their direct use as fuel for heating involves various difficulties. As already mentioned, coal has many inconveniences, including liability to emission of sooty smoke. As compared with coal, woody fuel has favorable characteristics, such as low ash content, low nitrogen content, reduced emission of smoke and good combustibility, but it has also a serious drawback. Woody fuel is low in calorific value, which is an essential property required for fuel.

The object of this study is therefore to blend coal with wood waste so as to obtain a solid fuel that combines the advantageous characteristics of both raw materials - a sort of composite fuel. With a view to developement of this composite fuel, its production by a roll press is studied.

In the roll press technique, powder-briquetting technique excellent for mass production, is now widely adopted in various sectors of industry, such as the ceramics industry, mining industry, metallurgical industry and chemical industry. In this technique, briquetting is carried out by any one of the following three methods according to the powder properties of raw material used, purpose of briquetting, use of briquettes obtained and other conditions: briquetting method with compression only, briquetting method with addition of binder, and hot-briquetting method.

For Bio-Coal, briquetting is carried out by compression only, without addition of binder. However, since its raw material is a sort of natural high polymer, properties of the raw material as a viscoelastic body must be taken into consideration for briquetting of Bio-Coal. The rheological properties of its raw material depend on the rank of coal[1], on one hand, and on the species of tree, portion in tree, moisture content[2], etc. of woody material, on the other hand. Its briquettability is greatly affected by such rheological properties. In particular, in the process of roll press briquetting of Bio-Coal, where the woody material serves as binder, the springback on decompression may greatly affect the breaking strength, density and other properties of Bio-Coal. Therefore, to determine the conditions for production of Bio-Coal, it is necessary to study, in addition to such briquetting conditions as temperature and pressure, the springback on decompression which reflects directly the rheological properties of the raw material. Such springback must be studied in terms of raw material compositions, nature of coal and woody material, coal blends, etc.

Basic tests (tablet tests)

Tableting tests were carried out on coal-wood particles mixtures for basic study of their briquettability from the relation of briquetting temperature and pressure to springback, breaking strength and density of tablet obtained.

(1) Testing procedure:

Samples used for tests were selected from the materials given in Table I: two kinds of coal, Sunagawa coal and Horonai coal, were used as coal samples, while two types of wood dust, A and B, were used as woody material samples. Petroleum coke was also used as test sample. Tableting was carried out with a small cylindrical mold (d = 25 mm), where 3 g of each mixture sample of coal and wood dust was placed. The tableting conditions were as follows: 20°C, 50°C and 80°C for tableting temperature, 0.8 t/cm^2, 1.5 t/cm^2 and 2.4 t/cm^2 for tableting pressure and 10 sec for holding time. On each coal-wood tablet obtained, breaking strength*, density and springback ratio** were measured.

(2) Test results:

From the tableting tests, the following results were obtained (Table II):

(a) The breaking strength of coal-wood tablets increased with increasing wood content, while it decreased with increasing grain size of coal. In these tablets, it was their woody constituent that served as binder[3].

(b) The breaking strength of tablets showed a tendency toward increase with increasing tableting pressure. Tablets obtained at a temperature of 20°C had a relatively low breaking strength for all of three tableting pressures, while tablets consisting of 75 wt.% of coal and 25 wt.% of wood dust A, obtained at tableting temperatures of 50°C and 80°C, presented a breaking strength of about 100 kg for both Sunagawa coal and Horonai coal. The variation of breaking strength according to the rank of coal was remarkable in the case of tableting at 20°C (Fig. 1).

* Breaking strength (kg): forced breaking load as measured by test with a steel ball 20 mm in diameter.

** Springback ratio (%): [(Thickness of tablet immediately after decompression) - (Thickness of tablet being molded)]/[Thickness of tablet being molded] × 100

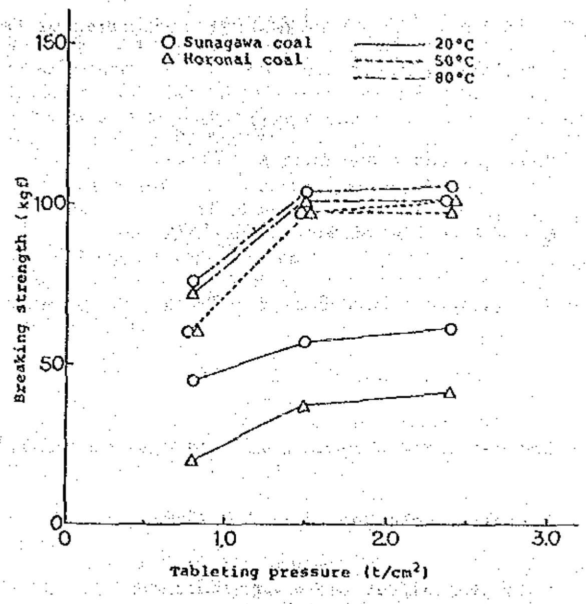


Fig. 1 Relation of Tableting Pressure and Temperature with Breaking Strength of Coal-wood Tablets

(c) The density of tablets increased in proportion to the increase of tableting pressure, while no remarkable difference in density between tableting temperatures was found. However, the difference in density of tablets between ranks of coal was considerable: in general, the tablets made from Sunagawa coal were of higher density than those made from Horonai coal (Fig. 2).

(d) The springback ratio of tablets showed a tendency toward increase with increasing tableting pressure. At a tableting temperature of 20°C, the springback ratio on decompression was very high. In the case of Horonai coal, little difference in springback ratio between tableting temperatures of 50°C and 80°C was observed, and the springback ratio for Horonai coal was found obviously high as compared with that observed for a tableting temperature of 80°C for Sunagawa coal (Fig. 3).

Table I Analytical Properties of Test Samples

		Sunagawa coal	Horonai coal	Obira coal	Tenpoku coal	Wood dust A	Wood dust B	Petroleum coke
Moisture content	(%)	2.6	3.3	8.0	11.5	5.5	4.8	1.2
Ash content	(%)	8.4	5.2	14.5	16.1	2.0	1.4	0.6
Volatile matter	(%)	39.5	49.5	37.0	41.8	78.2	72.3	13.1
Fixed carbon	(%)	49.5	42.0	40.0	30.6	14.3	21.5	85.1
Calorific value	(kcal/kg)	7,330	7,420	5,720	4,660	4,480	4,530	8,570

Wood dust A: sawdust, building timber waste, etc.
Wood dust B: larch bark

Table II Properties of Coal/Petroleum Coke/Wood Tablets

Ratio (wt.%)	Tableting temperature (°C)	Springback ratio (%)	Density (g/cm³)	Breaking strength (kgf)
Sunagawa coal/Wood dust A - 75:25	50	26.7	1.11	106
	80	24.3	1.10	127
Horonai coal/Wood dust A - 75:25	50	30.5	1.07	98
	80	30.6	1.05	111
Sunagawa coal/Wood dust B - 75:25	50	20.0	1.17	100
	80	19.0	1.16	105
Horonai coal/Wood dust B - 75:25	50	24.0	1.10	75
	80	21.0	1.09	98
Horonai coal/Sunagawa coal/Wood dust A - 37.5:37.5:25	50	26.2	1.10	98
	80	24.4	1.12	128
Petroleum coke/Wood dust A - 75:25	50	24.8	1.14	107
	80	24.5	1.15	130
Horonai coal/Petroleum coke/Wood dust A - 50:25:25	80	26.5	1.11	93

(e) Mixtures with wood dust of larch bark (wood dust A) presented a lower springback ratio than those with wood dust of timber waste (wood dust B) and gave tablets of higher density. For mixtures where Horonai coal was blended with Sunagawa coal or petroleum coke, their springback ratio was lower in all cases than that of mixtures where Horonai coal was used neat (Table II).

(f) The springback ratio of tablets made only of coal fines depended on the rank of coal. In the case of Sunagawa coal, it was low for all grain size ranges. On the other hand, the springback ratio of wood tablets depended largely on the grain size of raw material, but for grain sizes of a 25 mm and over, it was higher than that of tablets of Horonai coal (Fig. 4).

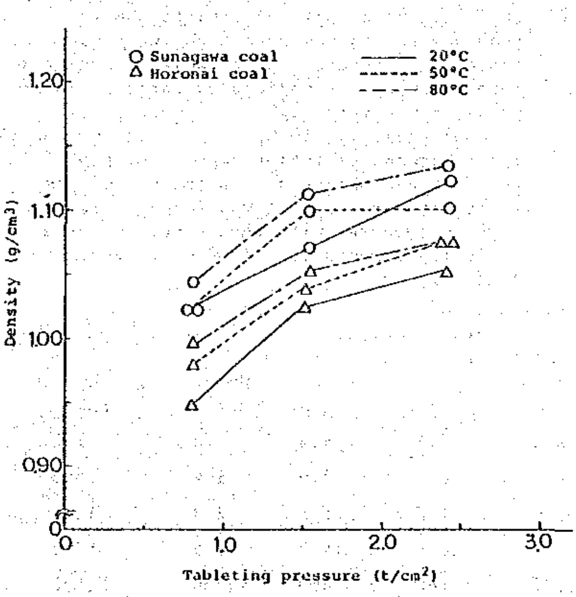


Fig. 2 Relation of Tableting Pressure and Temperature with Density of Coal-wood Tablets

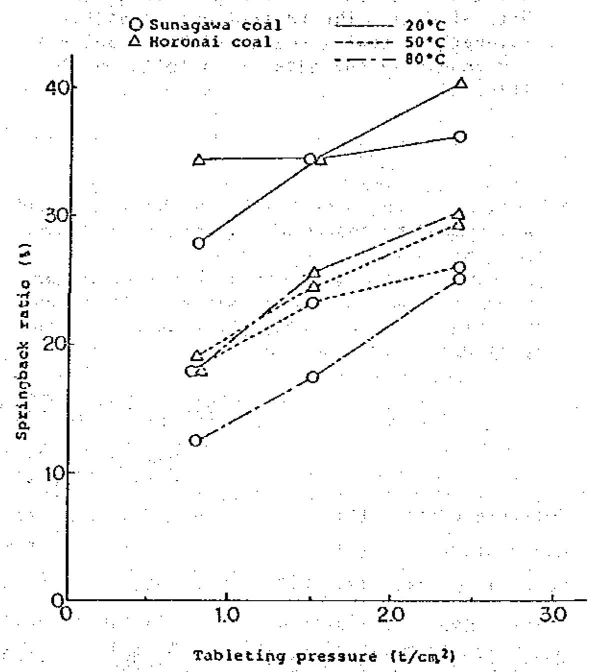


Fig. 3 Relation of Tableting Pressure and Temperature with Springback Ratio of Coal-wood Tablets

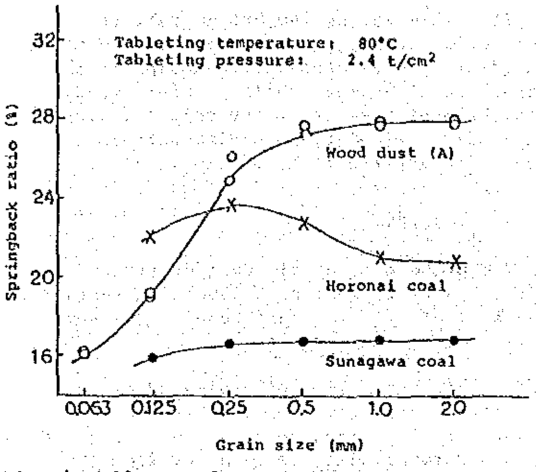


Fig. 4 Effects of Grain Size on Springback Ratio of Coal Tablet and Wood Tablet

According to these test results, tablets having a satisfactory strength are obtained from a mixture of 75 wt.% of coal and 25 wt.% of wood, without addition of any special binder, under the tableting at a temperature of 80°C and pressure of 2.4 t/cm^2. The tabletability of such coal-wood mixture depends on the kind of coal or of woody material used, in addition to the tableting temperature and pressure. In terms of properties of tablets, especially springback ratio, it may be considered that Sunagawa coal belongs to the group of coals of high briquettability, while Horonai coal falls under the group of coals of low briquettability. For wood, larch bark may be a woody raw material excellent in briquettability. If the briquettability of coal-wood mixture is to be further improved, blending the raw material coal with highly briquettable coal fines or petroleum coke fines may be an effective approach.

Bio-Coal Briquetting Tests

On the basis of the tableting test results so far obtained, process and optimal equipment for actual production of Bio-Coal were studied and briquetting tests were conducted by using a small test equipment to study the feasibility of mass production of Bio-Coal in terms of raw material compositions, coal brands, possibility of coal blending and other conditions.

General types of actual production equipment based on the high-compression molding process include reciprocating piston press, rotary tableting machine and briquetting machine. For Bio-Coal production equipment, the following conditions are desired: the equipment should permit mass production and continuous operation for long period and, at the same time, it should be capable of giving products which are little susceptible to breaking during transportation and which have a form contributing to their good combustion quality. The equipment best adapted to these conditions is a briquetting machine.

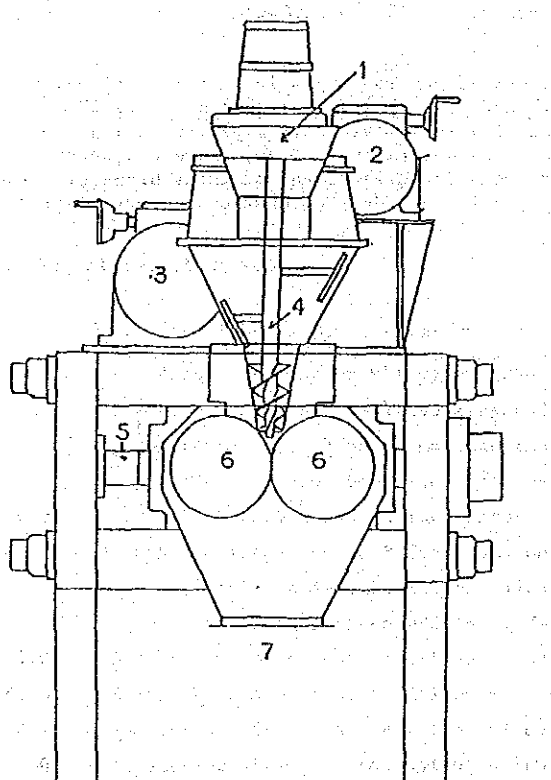
In Japan, briquetting is widely employed in various sectors of industry, such as iron and steel industry, ceramic industry and chemical industry. Large machine with briquetting pressure of 0.5 to 5 t/cm^2 and capacity of tens of tons per hour is put to practical use.

For briquetting tests, it was decided to make briquettes of about 6 cc or more in size since briquettes made by a small test equipment would be used also for combustion tests. And, a small briquetting machine with a roll size permitting the briquetting to such size was manufactured for trial.

In this test machine, the raw material is fed forcedly into between rolls by a vertical screw. The test machine has a function of stepless control of screw rotation speed, roll rotation speed and roll pressure.

(1) Test samples:

Samples used for briquetting tests are given in Table I. Their grain sizes were 3 mm and under for coal and petroleum coke, and 2 mm and under for woody materials. Petroleum coke was used to condition the calorific value or combustion properties of Bio-Coal.



1: Charging hopper
2: Feeder drive motor
3: Roll drive motor
4: Screw
5: Load cell
6: Roll tyre
7: Product outlet

Fig. 5 Outline of Test Briquetting Machine

(2) Testing procedure:

The small-size roll press manufactured for trial is outlined in Fig. 5. With this roll press, briquetting tests were carried out in accordance with the following procedure:

Fifteen kilograms (15 kg) of starting raw material consisting of determined proportions of coal, petroleum coke breeze and wood dust were charged into a ribbon-type heating agitator, where the raw material was mixed while being heated to a temperature of 70 ± 5°C. Then, the hot mixture was briquetted under the conditions given in Table III. For each sample mix, this operation cycle was repeated 5 to 10 times and 75 to 150 kg in total of starting raw material was continuously briquetted. The pressure applied on the roll by the mixture being briquetted was read by a load cell. Briquettes obtained were passed through a seive of 10-mm mesh size to remove their fins, and the product yield was determined. Then, these briquettes were used for measurement of their properties and for testing of their combustion characteristics.

Table III Roll-press Briquetting Conditions

Roll size: φ 300 mm × 55 mm

Roll pocket: 1 line, almond-shaped, approx. 6 cc

Roll clearance, rotation speed and separating force: 1.0 mm, 6 to 7 rpm, 30 t

Roll line pressure: 4,000 to 6,000 kg/cm

Capacity: 150 to 200 kg/h

For mixes having low briquettability, a double briquetting test was performed to study the effect of preliminary briquetting on the improvement of briquettability. For certain mixes, briquetting test using only the fins removed from briquettes was also performed, to study the briquettability of fins.

(3) Test results:

The properties of Bio-Coal determined from the results of roll-press briquetting tests are given in Table IV. The test results are summarized below.

(a) The btiquettability of coal-wood mixture varied distinctly from one brand coal to another. Sunagawa coal gave better Bio-Coal than Horonai coal, as expected from the above-mentioned results of tableting tests.

(b) To obtain good Bio-Coal from coal of low briquettability, it is necessary either to adopt the double briquetting method as in case of Obira coal and Tenpoku coal or to blend, as in case of Horonai coal, a highly briquettable woody material (for example, larch bark) or weakly caking to caking coals (for example, Sunagawa coal) with the poorly briquettable coal.

(c) The briquetting yield had a value of 85% or more whenever good Bio-Coal was obtained. In addition, all briquetting tests using only the fins removed from briquettes gave good Bio-Coal as in the case of double briquetting mentioned above. Accordingly, in the mass-

Table IV Properties of Bio-Coal Briquette Made by Roll Press

Ratio (wt.%)	Surface condition**	Density (g/cm^3)	Breaking strength (kgf)	Yield (%)
Sunagawa coal/Wood dust A - 75:25	◎	1.17	101	88.0
Sunagawa coal/Petroleum coke/Wood dust A - 37.5:37.5:25	◎	1.07	92	90.5
Horonai coal/Wood dust A - 75:25	×	1.07	42	75.0
Horonai coal/Wood dust B - 75:25	o	1.14	52	94.2
Horonai coal/Sunagawa coal/Wood dust A - 50:25:25	◎	1.13	94	85.6
Horonai coal/Sunagawa coal/Wood dust B - 50:25:25	◎	1.10	74	88.7
Obira coal/Wood dust A - 75:25	×	1.16	27	71.8
*Obira coal/Wood dust A - 75:25	o	1.18	74	89.5
Obira coal/Petroleum coke/Wood dust A - 50:25:25	×	1.08	43	76.3
*Obira coal/Petroleum coke/Wood dust B - 50:25:25	◎	1.20	108	85.6
Obira coal/Sunagawa coal/Wood dust A - 37.5:37.5:25	◎	1.18	77	88.5
Obira coal/Sunagawa coal/Wood dust A - 50:25:25	◎	1.19	71	89.3
Tenpoku coal/Wood dust A - 75:25	o	1.03	67	80.2
*Tenpoku coal/Wood dust A - 75:25	◎	1.20	109	90.2
Tenpoku coal/Sunagawa coal/Wood dust A - 50:25:25	◎	1.17	60	85.3
Petroleum coke/Wood dust A - 75:25	◎	1.16	70	87.0

*Double briquetting of the same sample. **◎: Good, o: Passable, ×: Bad production process, it may be expected that the blending of removed fins with the starting raw material will improve its briquettability.

(d) Petroleum coke breeze showed a briquettability similar to that of Sunagawa coal, and its blending with coal-wood mixes gave good Bio-Coal in all cases. This possibility of blending of petroleum coke* with high calorific value and low ash content implies that the calorific value of Bio-Coal using low-grade coal as raw material can be made higher and that a blend of different kinds of coal will make it possible to produce a composite solid fuel having better combustion properties than those obtained from a coal-wood mix system.

Thus, the results of these roll-press briquetting tests are well correlated with the results of the tableting tests described above. In particular, the springback ratio determined by the tableting tests is considered to serve as an indicator of briquettability when solid fuel briquettes are produced by the roll press, using as raw material such visco-elastic material as a mixture of coal and wood waste. Furthermore, from the results of briquetting tests of coal-wood mixes, coupled with the results of tableting tests of coal particles only and wood particles only, it can be deduced that the consolidation of coal-wood mixture in a roll press takes place under compressive force with shearing strain. This implies that coal particles, while being partially broken, are subject to plastic deformation together with woody particles and that, in the end, the woody particles having received a larger plastic deformation act as the binder of Bio-Coal at the decompression stage.

Combustion Properties of Bio-Coal

According to the results of basic burning tests so far conducted on coal-wood tablet specimens[4], it was expected that the combustion properties of Bio-Coal would be excellent in ignitability, combustibility and smoke suppression as compared with those of coal. To confirm this point, burning tests using a coal stove available on the market were carried out, together with monitor burning tests. In addition, with a view to development of special Bio-Coal burning equipment, two types of small-size combustion equipment now under development were manufactured for trial use and combustion tests in this equipment were conducted.

*Petroleum coke, if used neat, is excellent in calorific value and ash content, but it has high sulfur content (which is a source of sulfur oxides) and high vanadium content (which causes corrosion and scaling in fuel-burning equipment). However, these drawbacks of petroleum coke can be eliminated if it is used in the form of composite solid fuel.

Tests on Bio-Coal Combustion in Coal Stove

Figs. 6 and 7 show smoke density values, which are among the results of tests conducted in a coal stove with coal storage (Fig. 8) available on the market to check the combustion properties of Bio-Coal shown in Fig. 9. Horonai coal and Taiheiyo coal tested for comparison with Bio-Coal are typical brands of coal used for heating in Hokkaido. Burning tests were conducted by firing wood to form a fire bed on the fire grate and then by charging the test fuel into the coal storage barrel. Thereafter, no special operation, such as poking, was carried out. Bio-Coal easily caught fire from the wood. Its combusti-

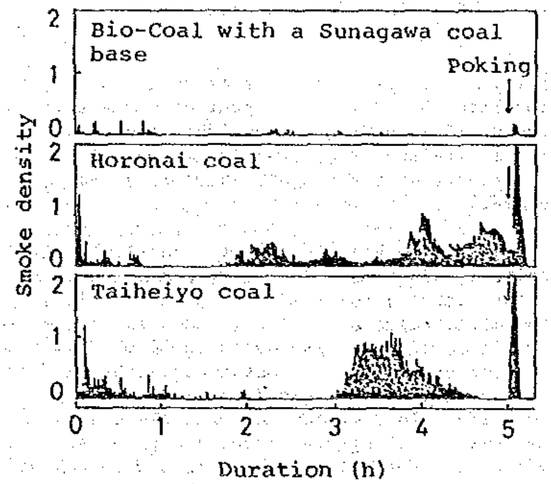


Fig. 6 Combustion Patterns during Test

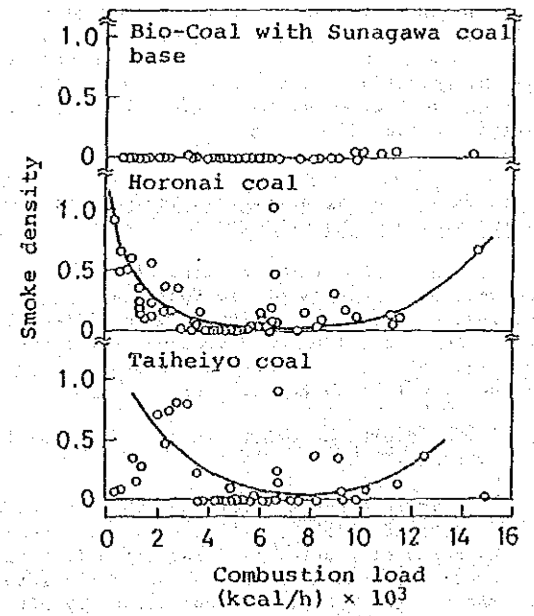


Fig. 7 Relation between Combustion Load and Smoke Density

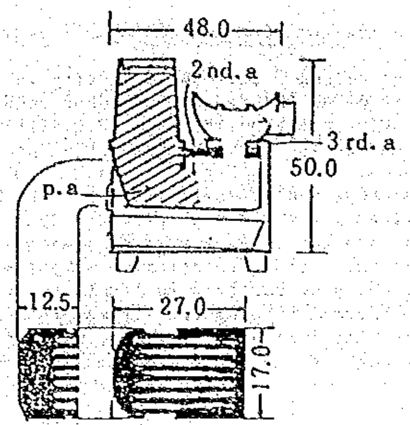


Fig. 8 Coal Stove with Storage

bility was better than that of coal. As is clear from Figs. 6 and 7, the amount of smoke emitted from Bio-Coal during combustion was very small over a wide load range. This characteristic is very important for combustion rate control and automatic combustion.

Thus, Bio-Coal is a little-smoking fuel. In addition, since wood dust with low nitrogen and sulfur contents is blended, a reduction in generation of nitrogen and sulfur oxides is also expected. In particular, for sulfur oxides, a part of the combustible sulfur contained in the raw material is fixed in the ash in the form of gypsum anhydride. In addition, even in the case of Bio-Coal with a caking-coal base, the phenomenon of melting and deposition, which is a drawback of coal, does not occur during combustion and, as is shown in Fig. 9, the ash is not liable to clinkering. Therefore, ash disposal is easy.

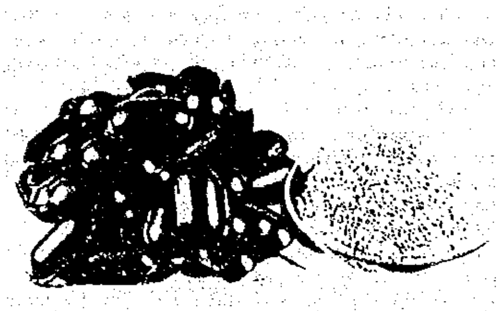
As described above, Bio-Coal is a composite solid fuel having better combustion properties than coal. Such better properties were verified also by domestic monitor tests conducted in various types of coal stoves for a long or short period of time.

Trial Manufacturing of Small-size Combustion Equipment and Combustion Tests

On the basis of the results of the study of combustion properties of Bio-Coal, two types of small-size combustion equipment with different combustion mechanisms were designed and manufactured for trial. Combustion tests in this equipment were also carried out.

(a) Forced-draft, automatic fuel feed combustion system:

In this system, the fuel is automatically dropped into a pot-type combustion chamber by means of a screw feed mechanism (spiral steel bar) and is burned with air fed into the pot through primary and secondary air inlets provided in the pot bottom and side wall. The heating power is done by dial control of fuel feed rate. The ash is removed from the combustion chamber by automatic operation of the grate at regular time intervals.



Bio-Coal
Sunagawa coal 75 wt.%, Larch bark dust 25 wt.%
Moisture content: 3.8%
Ash content: 6.1%
Carolific value: 6,700 kcal/kg

Fig. 9 Bio-Coal and Its Ash

(b) Traveling-grate automatic combustion type hot-air heating system:

In this system, Bio-Coal is automatically burned in the primary combustion chamber on a traveling grate and in the arch-type secondary combustion chamber. The combustion rate control is done by control of travel speed of the grate.

Table V gives the results of combustion tests conducted in this equipment.

According to the results of combustion tests so far obtained, the amount of smoke is very small in both types of combustion equipment. In both cases, the combustion can be kept good and, in a high-load combustion range, the air ratio can be reduced to about 1.5. Thus, both types of combustion equipment are considered to offer a system that makes the best use of the combustion properties of Bio-Coal. Therefore, it is planned to make further improvements to this equipment so as to put both types into practical use.

Conclusion

The purpose of this study is to develop a new regional energy system by supplying Bio-Coal, a coal-wood composite solid fuel having novel combustion properties, in combination with special burning equipment for it, while incorporating also an ash recovery system.

For the Bio-Coal production technique, briquetting tests by long-term operation are continuing in accordance with the flow sheet given in Fig. 10. However, from the roll-press test

Table V Results of Combustion Tests

Briquette		Bio-Coal (Horonai coal 75 : Wood dust 25)	
Test duration	(h)	5.5	6.5
Combustion rate	(kg/h)	2.2	0.8
Grate travel speed	(cm/h)	5.5	3.0
Primary air flow rate	(m^3/h)	9.5	1.2
Secondary air flow rate	(m^3/h)	6.0	3.2
Smoke density	(OD/20 cm)	0	0
Flue gas composition			
CO	(%)	0.13	0.33
CO_2	(%)	8.8	4.5
O_2	(%)	9.0	14.7
NOx (as 6% O_2)	(ppm)	215	181
Air ratio m	(-)	1.7	3.3

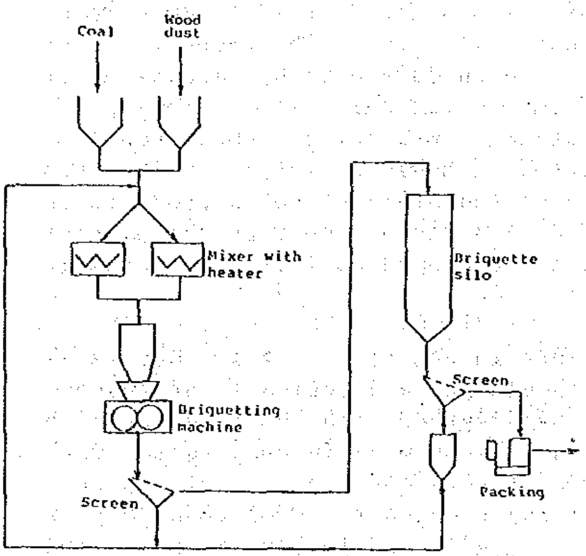


Fig. 10 Bio-Coal Production Flow Sheet

results so far obtained, it was judged that the mass production of Bio-Coal by the roll-press technique is quite feasible.

As for the combustion properties of Bio-Coal, it was confirmed that Bio-Coal was excellent, as compared with coal, in smoke suppression, combustion rate control, ease of ash disposal and other points. The development of special Bio-Coal burning equipment is still in the stage of trial manufacture, but further improvements to combustion equipment manufactured for trial, as well as improvements to conventional combustion equipment, will be pursued to develop a new combustion system matching the combustion properties of Bio-Coal.

As for the construction of Bio-Coal production plants in Hokkaido, it is desirable from an economic viewpoint (collection of raw materials, especially wood wastes, and delivery of products, etc.) to locate such plants on a regional or block-wise basis. It is important for greater economy, such as reduced transport cost, to establish a system where Bio-Coal produced from raw materials available in a region or block is consumed in that immediate region or block. For this purpose, a study of a Bio-Coal production system compatible with local conditions in each region is now being made in cooperation with a certain enterprise on the assumption of future construction of Bio-Coal plants in a few regions.

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付属資料 2.

COMBUSTION CHARACTERISTICS OF BIOCOAL (COAL-WOOD BRIQUETTES)

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Hokkaido Industrial Research Institute, Sapporo, Japan

INTRODUCTION

Biocoal is a sort of composite fuel and is consisted of 70 to 80 percent of coal and 20 to 30 percent of wood waste by weight. The technology for mass production of Biocoal has already been developed by adoption of high pressure briquetting method with compression only in the roll press technique, and the practical plant annually producing 6,000 tons of Biocoal (called "Hotcoal") was constructed in November 1985 at Obira town of Hokkaido. The materials used for production are some coals produced in Hokkaido and bark discarded from the wood chip factory near by the site of plant. The Biocoal produced now is mainly consumed as fuel for domestic heating.

As for the construction of Biocoal plants in Hokkaido, it is desirable from economic view point to locate such plants on a regional or block-wise basis. For this purpose, a study of a production system compatible with local conditions in each region is now being made in cooperation with a certain enterprise on the assumption of future construction of plants in few regions. And also the feasibility studies for construction of plants in the foreign countries such as Australia and Turkey are now being carried out in cooperation with Hokkaido Industrial Research Institute.

At this paper, the Biocoal production process is briefly described and furthermore, with a view to suppression of environmental emissions, combustion characteristics of Biocoal is chiefly discussed from the results of burning test conducted using coal stove available on market.

This paper was made in cooperation with Otsuka Iron works Co.,Ltd., Japan Environment Assessment Center Co.,Ltd. and San'ei Kogyo Co.,Ltd.

PRODUCTION PROCESS OF BIOCOAL

(1) Practical plant of Biocoal used Hokkaido coal

The production flow sheet of Biocoal plant is outlined in Figure 1. Each coal and bark materials prepared in the fixed moisture content and particle size is stocked in the bins separately. Then, the material fines consisting of coal 75 wt.% and bark 25 wt.% is charged into the mixer with heater, where it is mixed while being heated to a temperature of around

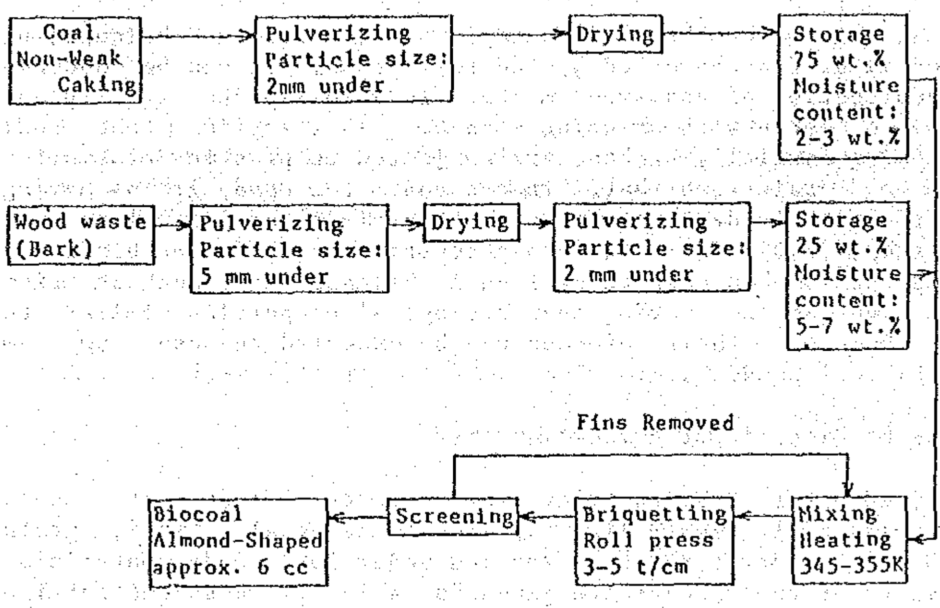

FIGURE 1. Outline of Biocoal Production Flow-Sheet

353K, and the hot mixture is briquetted under around 3000 kg/cm of roll line pressure. The fins of briquettes obtained are removed through the screening process and their fins are backed into the mixing process. The Biocoal produced through such the process gives around 120 kg of breaking strength bearable under its usual stock and handling.

Thus, Biocoal has a satisfactory strength without addition of any special binder and an internal texture intimately relating to its properties is shown in Fig.2. These were obtained from a polished and a thin sectioned specimens. As is clear in these microphotographs, both coal and wood grains are oriented in a direction and coal grains in the surface part of Biocoal are finer in its sizes. And the voids among coal grains are more compact with the wood ones, where seem to be plastic-deformed in briquetting process.

Coal Grains (bright parts)
Wood Grains (dark parts)
(polished surface , x20)

Coal Grains (dark parts)
Wood Grains (bright parts)
(polished surface , x20)

FIGURE 2. Internal Texture of Biocoal

According to the results of these microscopic observations and briquetting tests of Biocoal so far conducted by the roll press, it can be deduced that the consolidation of coal-wood mixture in a roll press take place under compressive force with shearing strain. This implies that coal grains, while being partially broken, are subjected to plastic deformation together with wood grains and that, in the end, the woody grains having received a large plastic deformation act as the binder of Biocoal at the compression stage.(1,2,3) Thus, the woody constituent serves as binder in Biocoal. This action has been recognized in biomass fines such as rice husk, bagasse and so on, having the rheological properties similar to woody fines, therefore their biomass can be expected to use as raw materials for Biocoal production.

(2) Briquetting of Biocoal for combustion test

Raw coals used for briquetting were three kinds of coal, Hokkaido(Sunagawa) coal, Australian coal and Turkey coal. Their grain sizes were 3mm and under for coal, 2mm and under for woody materials. Analytical results of their coals are given in Table 1. Both the foreign coals have highly combustible sulphur content, as compared with that of Hokkaido coal, especially Turkey coal contains high sulphur content more than 2 percent by weight. Therefore, in the case of these coals some

TABLE 1. Analytical Results of Raw Coals and Biocoal

	Hokkaido coal		Australian coal		Turkey coal	
	Raw coal (Sunagawa)	Biocoal (a)	Raw coal	Biocoal (b)	Raw coal	Biocoal (c)
Moisture(%)	2.6	4.0	13.8	12.3	16.3	9.7
Ash(%)	8.4	7.1	11.8	9.6	20.4	18.2
Volatile matter(%)	39.5	48.2	41.0	49.0	30.8	44.8
Fixed carbon(%)	49.5	40.7	33.4	29.1	32.5	27.3
Calorific value(MJ/kg)	30.7	27.6	22.3	20.6	20.0	20.2
Total sulphur(%) (d.b)	0.6	0.5	1.1	0.7	2.6	1.9
Incombustible sulphur(%)(d.b)	0.1	0.2	0.1	0.6	0.3	1.5
Combustible sulphur(%)(d.b)	0.5	0.3	1.0	0.1	2.3	0.4

a)Hokkaido biocoal :Bituminous coal 75 wt.% , Wood 25 wt.%
b)Australian biocoal:Subbituminous coal 71.25 wt.% , Wood 23.75 wt.%,
Slaked lime 5 wt.%
c)Turkey biocoal :Brown coal 68.2 wt.% , 22.7wt.% ,
Slaked lime 9.1 wt.%

desulphuration agents such as slaked lime were added, together with wood dust.

Briquetting test were carried out using the small-size roll press manufactured for trial. Each the hot mixture heated to a temperature of around 343 K was briquetted under the conditions given in Table 2 and around 50kg of the Biocoal without fins obtained was used for each a burning test. All of the samples gave more than 100kg of breaking strength.

TABLE 2. Roll-Press Briquetting Conditions

Roll size	:	Ø300 mm x 55 mm
Roll pocket	:	1 line , almond-shaped , approx. 6 cc
Roll clearance, rotation speed and separating		
Force	:	1.0 mm , 6 to 8 rpm , 30 t
Roll line pressure	:	3,000 to 5,000 kg/cm
Capacity	:	150 to 200 kg/h

COMBUSTION PROPERTIES OF BIOCOAL

(1) Qualities of Biocoal

Analytical results of Biocoal used three kinds of coal are given in Table 1. The woody material used here are consisted of saw dust, building timber waste, etc. and it contains 0.1percent of sulphur content and 0.3 percent of nitrogen content by weight (d.a.f). Qualities of Biocoal are different in proximate, ultimate analyses, and calorific values from those of raw coals. In terms of its properties ,especially combustible sulphur content, it is largely reduced in Biocoal using foreign coals by addition of desulphuration agent. Thus, in the case of Biocoal, since wood dust with low sulphur, nitrogen content and desulphuration agent are blended, a reduction in environmental emissions, in particular, for sulphur oxides can be expected.

(2) Burning tests of Biocoal

As for Biocoal("Hot coal") consumed now as fuel for domestic heating in Hokkaido, it has been recognized that its combustion properties are excellent in ignitability, combustibility and smoke suppression as compared with those of coal.(3,4) To confirm those points on Biocoal used low rank coal having high sulphur content such as Australian and Turkey coals, some burning tests were carried out using two types of coal stoves available on market.

Figure 3 shows smoke density values, which are among the results of tests conducted in a coal stove with storage (Fig.4). Taiheiyo coal (lumpy size) tested for comparison with Biocoal is a typical bland of coal used for heating in Hokkaido. Burning tests were conducted by firing wood to form a fire bed on the fire grate and then by charging test fuel (Sunagawa and Australian Biocoal) into a storage barrel. Both Biocoal easily caught fire from the wood and continued to be burned from a stage of its volatile matter combustion to that of coke and charcoal grains combustion, to the end. Such a combustion process can be estimated from an internal texture of Sunagawa Biocoal (Fig.2) and one burning out of its volatile matter (Fig.5). As is clear from this figure, the amount of smoke emitted from both Biocoal samples during combustion were very small over a wide load range. This characteristics is very important for combustion rate control and automatic combustion, especially in the case of small size combustion equipments.

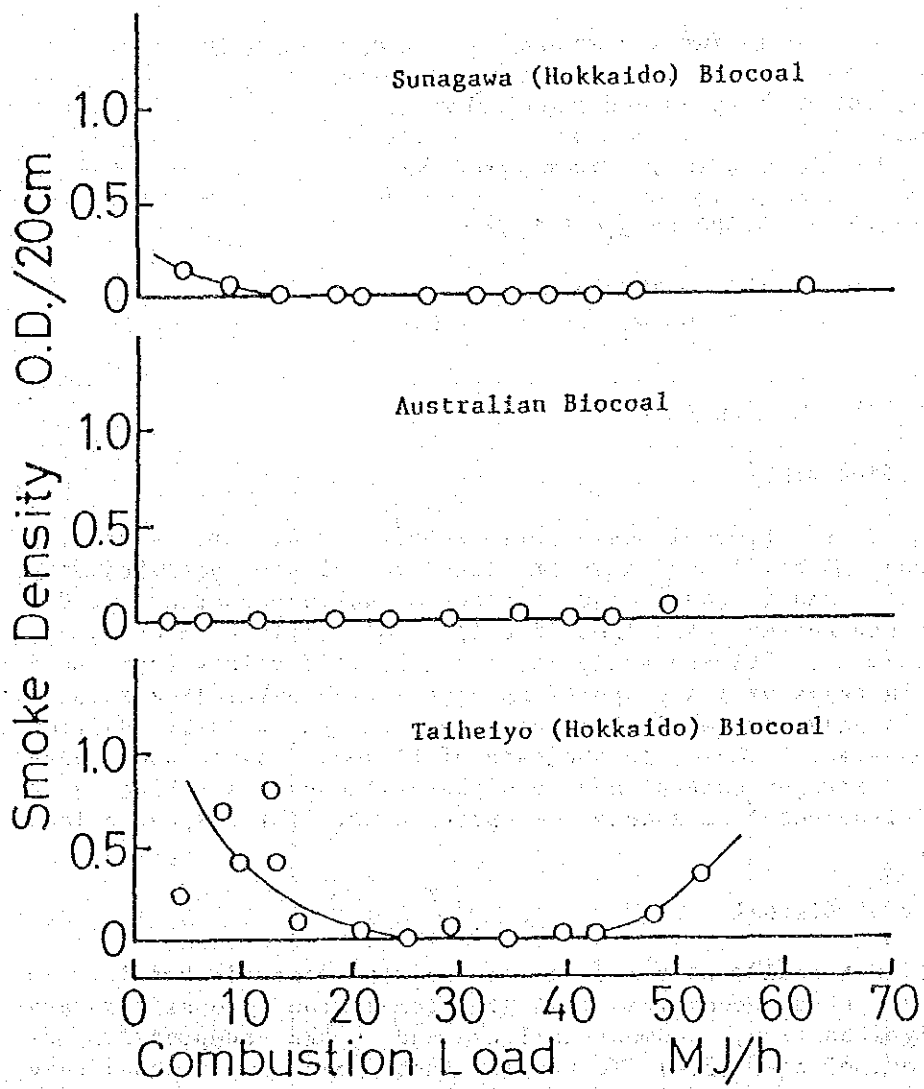

FIGURE 3. Relation between Combustion Load and Smoke Density

Table 3 shows environmental emissions from Biocoal and its raw coals during combustion. In the case of every Biocoal, dust emission was largely reduced, as compared with that of its raw coal. In particular, its tendency is remarkable in Australian Biocoal. For sulphur emissions,

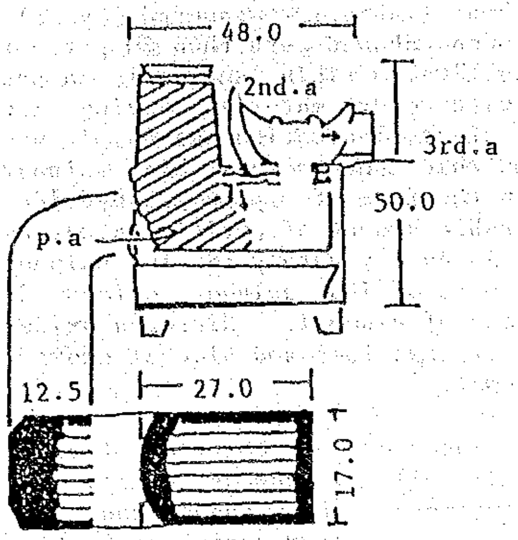

FIGURE 4. Coal Stove with Storage

FIGURE 5. Internal Texture of Biocoal after devolatilized

TABLE 3. Environmental emissions from Biocoal and coals

	Dust (g/kg,fuel)	Sulphur + (g/kg,fuel(d.b.))	Nitrogen oxides ++ (ppm/Nm^3 , as 6% O_2)
Sunagawa Biocoal	0.17	3.5	273
Taiheiyo coal (lumpy size)	2.61	0.5	227
Australian Biocoal	0.09	1.8	175
Its raw coal (lumpy size)	2.34	10.3	245
Turkey Biocoal +++	0.35	5.8	—
Its raw coal ++ (lumpy size)	2.53	23.0	—

\+ Sulphur emissions was calculated from sulphur content in combustion residues and total sulphur in test fuel.

++ Emitted volume at medium load in combustion by a coal stove with storage.

+++ A coal stove used for these fuel was a cartridge-type (called "Rumpen-type"). Burning tests were conducted by charging 5.500g of fuel into combustion chamber and then by firing 500g of wood charged on test fuel.

its values were somewhat higher than those (Table 1) measured by JIS method, but both Australian and Turkey Biocoal showed more than 70 percent of its reduction ratio to raw coal, respectively. This is clearly caused by addition of slaked lime, together with woody material having low sulphur content. As for addition effect of desulphuration agents, it was confirmed by X-ray diffraction analysis that the combustible sulphur contained in Biocoal was fixed in ash in the form of gypsum anhydride. And since two raw coals contain a considerable amount of pyritic matter as a combustible sulphur constituent, it is easily pyrolyzed in sulphur oxides and iron oxides (hematite) and a part of its sulphur oxides is fixed in the form of gypsum anhydride in ash of Biocoal. Nitrogen oxides emissions are related to nitrogen content of test fuel and Biocoal shows a tendency to be less than that of its raw coal.

Thus, Biocoal is a little-smoking and sulphur oxides emitting fuel. In addition, Biocoal is excellent in ignitability, combustibility and combustion rate control, and furthermore the phenomenon of clinkering, which is a drawback of coal, does not occur during combustion and ash disposal is easy.

CONCLUSION

Biocoal is a solid composite fuel that combines the advantageous characteristics of both coal and woody materials. According to the results of burning test so far conducted using conventional coal stoves, it was confirmed that Biocoal had better combustion properties than coal and that, in the case of raw coal having high sulphur content, it could be largely reduced in its sulphur oxides emission by addition of desulphuration agents. In addition, the development of special Biocoal burning equipments must be promoted in terms of its combustion characteristics and the properties such as calorific value, ash content, size and so on, of Biocoal.
As for the development of special Biocoal burning equipment, up to date, two types of small-size combustion equipments with different combustion mechanism and a special Biocoal burning stove were designed and manufactured for trial.(5) Combustion tests in these equipments have been also carried out. The development of special equipment is still in stage of trial manufacture, but further improvements to these equipment manufactured for trial, as well as improvements to conventional ones, will be pursed to develop a new combustion system matching the combustion properties of Biocoal.

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SCOPE OF WORK
FOR
THE FEASIBILITY STUDY
ON
THE SMOKELESS COAL BRIQUETTES DEVELOPMENT PROJECT
IN
THE ISLAMIC REPUBLIC OF PAKISTAN

AGREED UPON BETWEEN

PAKISTAN MINERAL DEVELOPMENT CORPORATION

AND

THE JAPAN INTERNATIONAL COOPERATION AGENCY

Islamabad, December,7,1987

Mr. Viqar Rustam Bakhshi
Chairman
Pakistan Mineral Development
Corporation

Mr. Masahito YAMADA
Leader of the Preliminary
Survey Team
The Japan International
Cooperation Agency

Mr. Sajid Hassan
Deputy Secretary
Ministry of Petroleum and
Natural Resources

I . Introduction

In response to the request of the Government of the Islamic Republic of Pakistan (hereinafter referred to as "Pakistan"), the Government of Japan has decided to implement the feasibility study on the smokeless coal briquettes development project (Hereinafter referred to as "the Study") in accordance with the relevant laws and regulations in force in Japan.

Accordingly, the Japan International Cooperation Agency (hereinafter referred to as "JICA"), the official agency responsible for the implementation of the technical cooperation programs of the Government of Japan, will undertake the Study, in close cooperation with the authorities of Pakistan.

The present document sets forth the scope of work with regard to the Study.

II . Objective of the Study

The objective of the Study is to investigate the technical and economic feasibility of the smokeless coal briquettes development project to substitute kerosene oil and fuel wood in Pakistan.

III . Scope of the Study

The study will be carried out in the following two (2) stages :

1st stage : Market study

2nd stage : Techno-economic feasibility study and overall conclusion

The 1st stage study consists of the market survey for the coal briquettes and for the competitive substitutes. Before the commencement of the 2nd stage the interim report will be offered to justify the implementation of the 2nd stage study.

The 2nd stage study consists of the technical and economic evaluation of the coal briquettes production and overall conclusion.

The details at the respective stages are as follows :

1st stage :

1. Survey on the background of the Project
   - 1-1 National policy on, and present situation of, the energy in Pakistan
   - 1-2 National policy on, and present situation of, coal industry in Pakistan

2. Survey on the energy consumption
   - 2-1 Classification of energy use by industrial sectors and household sectors
   - 2-2 Trend of energy consumption by sectors
   - 2-3 Acts and regulations governing usage of fuels

3. Survey on the coal briquettes market and its distribution system
   - 3-1 Review of reports available on the above and the studies carried out so far
   - 3-2 Price trends of coal briquettes and its alternatives
   - 3-3 Quality and quantity demand for the coal briquettes by sectors
   - 3-4 Reasonable price structure for the consumer side by sectors
   - 3-5 Consumers' response to different types of fuels
   - 3-6 Present and potential distribution system of coal briquettes and other fuels

4. Overall evaluation on the market feasibility

2nd stage :

1. Resources and materials for producing the coal briquettes
   - 1-1 Volume and quality of lignite at the Lakhra coal mine
   - 1-2 Quality and supply of other materials for briquettes production
2. Production technology of briquettes
   - 2-1 Review of coal briquettes production technology and its combustion technology developed by Pakistan Council for Scientific & Industrial Research
   - 2-2 Review and evaluation of available data/reports

2-3 Test and analysis of production of smokeless briquettes made from Lakhra coal

2-4 Test and analysis of combustion of smokeless briquettes

2-5 Preparation of production process flow diagram

2-6 Transportation and supply scheme of coals and other relevant raw material

3. Construction study of the briquettes manufacturing plant

3-1 Site selection

3-2 Conceptual design and cost estimation of the plant

3-3 Supply methods of resources and material

3-4 Utilities (water, sewerage, electricity, etc)

3-5 Construction schedule

4. Operation plan

4-1 Operation schedule

4-2 Operation and management organization of the project

5. Economic evaluation of the project

5-1 Economic comparison between coal briquettes and other existing fuels

5-2 Financial analysis of the project

5-3 Economic and social evaluation

6. Conclusion and recommendations

IV. Steps and Schedule of the Study

1. Steps

Step 1: Preparatory work in Japan

Step 2: Field work (1) in Pakistan

Step 3: Home office work (1) in Japan

Step 4: Presentation of and discussion on the Interim Report

Step 5: Field work (2) in Pakistan

Step 6: Home office work (2) in Japan

Step 7: Presentation of and discussion on the Draft Final Report

2. Schedule

Schedule of the Study is shown in Annex.

V. Reports

JICA shall prepare and submit the following reports written in English to the Government of Pakistan within the time period indicated below :

1. Inception Report: at the commencement of the Step 2: 10 copies
2. Progress Report(1st stage): at the end of the Step 2: 10 copies
3. Interim Report: within four(4) months after the end of Step 2: 10 copies
4. Progress Report(2nd stage): at the end of the Step 5: 10 copies
5. Draft Final Report and its summary within four(4) months after the end of the Step 5: 15 copies
6. Final Report and its summary within two(2) months after the receipt of comments on the Draft Final Report from Government of Pakistan 30 copies

VI. Undertaking of the Government of Pakistan

1. To facilitate the smooth implementation of the Study, the Government of Pakistan shall take necessary measures:

   1-1 To secure the safety of the Japanese study team (hereinafter referred to as "the Team")

   1-2 To permit the members of the Team to enter, leave and sojourn in Pakistan for the duration of their assignment therein, and exempt them from alien registration requirements and consular fees

   1-3 To exempt the members of the Team from taxes, duties and other charges on equipment, machinery and other materials brought into Pakistan for the implementation of the Study

   1-4 To exempt the members of the Team from income taxes and other charges of any kinds imposed on or in connection with any emoluments or allowances paid to the members of the Team for their services in connection with the implementation of the Study

   1-5 To provide the necessary facilities to the Team for the remittance as well as utilization of fund introduced in Pakistan from Japan in connection with the implementation of the Study

   1-6 To provide medical services as needed and its expenses will be chargeable on the members of the Team

   1-7 To secure permission for entry into private properties or restricted areas for the conduct of the Study

   1-8 To secure permission to take all data and documents related to the Study (including unrestricted photographs) out of Pakistan to Japan by the Team

2. The Government of Pakistan shall bear claims, if any arises against the members of the Team resulting from, occurring in the course of, or otherwise connected with the discharge of their duties in the implementation of the Study, except when such claims arise from gross negligence or wilful misconduct on the part of the Japanese members of the Team.

3. PMDC shall act as counterpart agency to the Team and also as coordinating body in relation with other governmental and non-governmental organizations concerned for the smooth implementation of the Study.

4. PMDC shall, at its own expense, provide the Team with the following, in cooperation with other relevant organization:

4-1 Available data and information related to the Study

4-2 Counterpart personnel

4-3 Suitable air-conditioned office with necessary equipment and furniture

4-4 Credentials and identification cards

VII. Undertaking of JICA

For the implementation of the Study, JICA shall take the following measures:

1. To dispatch, at its own expenses, the Team to Pakistan
2. To pursue technology transfer to Pakistani counterpart personnel in the course of the Study

VIII. CONSULTATION

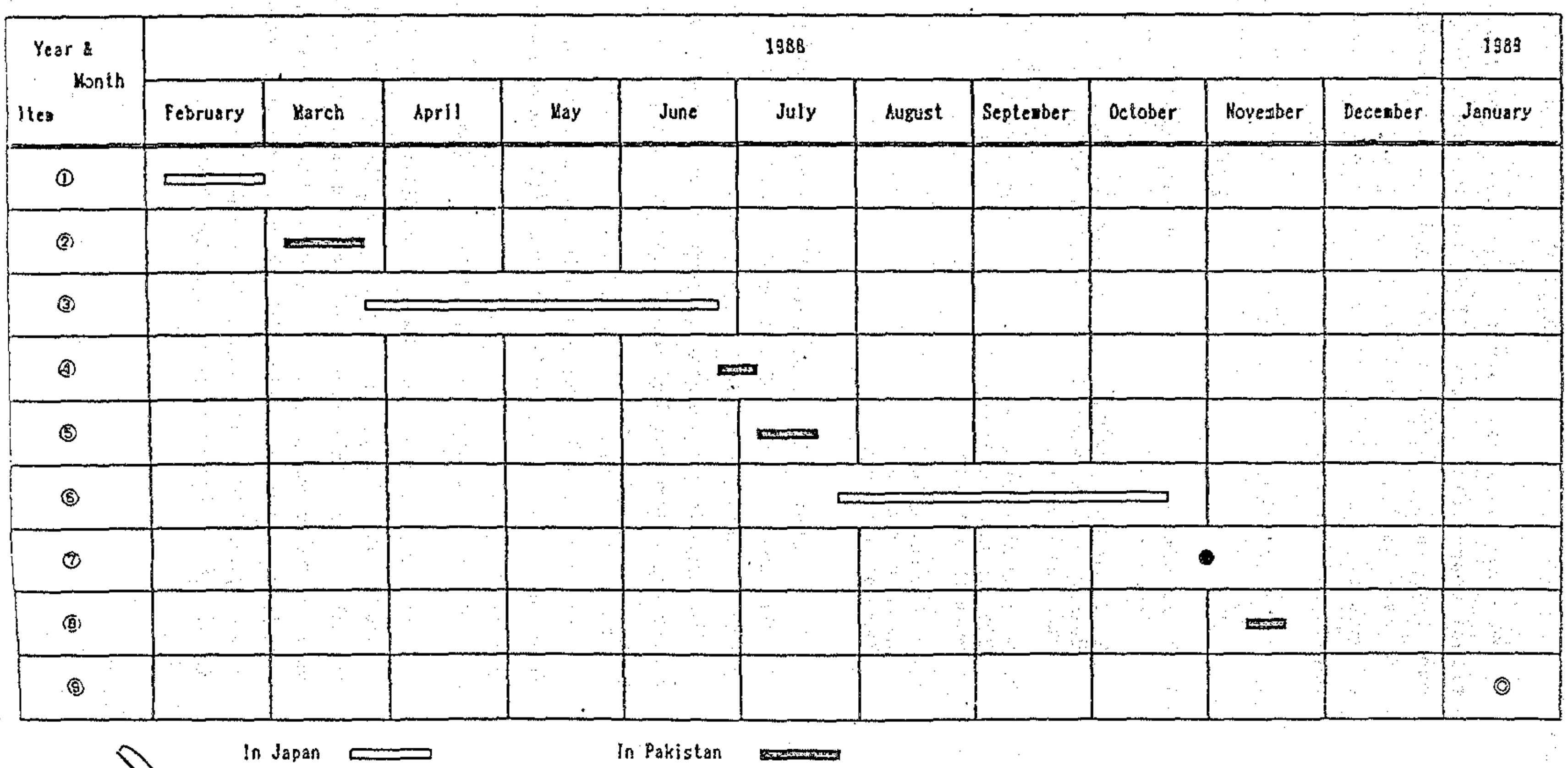
JICA and PMDC shall consult with each other in respect of any matter that may arise from or in connection with the Study.

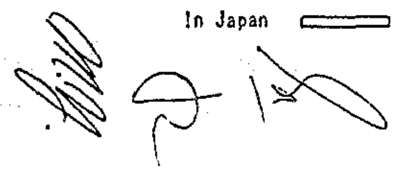
Tentative Schedule of the Study

<Annex>

Item:

① Preparatory Office Work
② Field Work(1)
③ Home Office Work
④ Presentation of Interim Report and Preparatory Work for Field Work(2)
⑤ Field Work(2)
⑥ Home Office Work
⑦ Submission of Draft Final Report
⑧ Presentation of Draft Final Report
⑨ Submission of Final Report





付属資料 4.

MINUTES

Meetings were held between the Mission of Japan International Cooperation Agency (JICA) and Pakistan Mineral Development Corporation (PMDC) on 2nd, 3rd and 6th December, 1987 in PMDC Head Office at Islamabad to discuss and finalize the scope of work for feasibility study on the Smokeless Coal Briquettes Development Project.

The follwoing were present:-

JICA

1. Mr. Masahito Yamada, Leader, JICA Mission.
2. Mr. Terutoshi Noghuchi, Ministry of International Trade and Industry.
3. Mr. Toshihiko Maruyama, Hokkaido Industrial Research Institute.
4. Mr. Masahoshi Juro, Japan International Cooperation Agency.

PMDC

1. Khawaja Asifullah, Director (Technical).
2. Mr. K.A. Siddiqui, Chief (P&D).
3. Mr. A. Sattar Memon, Chief Geologist(Coordination).

The Chairman, PMDC welcomed the JICA Mission and had brief discussions with them about the scope of work of the feasibility study. Later on meetings were held with the Director (Technical) in a cordial atmosphere. Both the JICA and PMDC had prepared the scope of work separately (Annexure-I and Annexure-II). Both the drafts were discussed in depth and the concerned parties agreed as under:-

1. The scope of work proposed by JICA shall be modified by adding the following as a sub-clause under the Item-2 "production technology of briquettes":-

"Review and evaluation of available data/reports."

2. The scope of work shows that the feasibility study will cover only conceptual designing and the cost estimates thereof. The Director(Technical) verbally requested that PMDC would not be able to proceed to implementation stage unless detailed designing is carried out. JICA was however, of the view that it was not in conformity with the policy of JICA. After lenghty discussions, the JICA Mission agreed to consider the request of PMDC separately in view of its importance as stressed by PMDC.

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3. The study will be carried out in two stages. Under the first stage Market Study will be conducted while the second stage will include Techno-economic Feasibility Study and over all conclusion and recommendations.

4. The item 3.7 of PMDC draft (consumers survey in possible consuming centres with a view to checking the data generated) and item 3.8 (Recommend appropriate sale strategy for briquettes and sale price taking into consideration their quality, the price of competing fuels, other costs, sale revenue etc.) shall be deleted as these are covered under the following items of JICA's draft:-

4.1. Price trends of coal briquettes and its alternatives.

4.2. Quality and quantity demand for coal briquettes by sectors.

4.3. Economic evaluation of the project.

5. The following items included in PMDC's draft will form a part of the terms of reference for the Consultants:-

5.1. Review and evaluation of available data/report.

5.2. Specify and control the collection at site of a required quantity of bulk sample of coal and limestone for pilot plant tests.

5.3. Conduct pilot plant tests to determine the washing characteristics of coal and evolve a flow diagram.

5.4. Conduct studies on pilot plant scale for production of smokeless coal briquettes with/without binder suitable for domestic consumption.

5.5. Test and analysis of smokeless coal briquettes produced from Lakhra coal.

5.6. Technical description of various washing and briquetting routes with comparative economics of all the available options.

5.7. Select a most suitable and economic process of washing and briquetting on the basis of pilot plant test results.

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5.8. Computation of material flow quantities for the suggested flow sheet.

5.9. <u>Site selection</u>

- Location with regard to distance from the coal mines, existing infrastructure etc.
- Local conditions including topography, soil properties, water and power supply, waste disposal etc.
- Estimated cost of site preparation.

5.10. <u>Plant design and capacity</u>

- Determine minimum economic size of the plant and preparation of design with provision of expansion to 300,000 tonnes of coal briquettes per annum.
- Preparation of technical specifications of plant and machinery.

5.11. <u>Plant layout proposals</u>

- Drawing of functional layout including arrangement of equipment and positioning of operational components and provisions for plant expansion.
- Determination of total space requirements for the plant, storage area and waste dump.

5.12. <u>Operational requirements</u>

- Qualitative and quantitative determination of inputs for operation of the plant such as water, electricity, fuels etc.
- Determination of auxiliary requirements including spare parts.
- Supply methods of resources and materials.

5.13. <u>Civil engineering</u>

- Site preparation and development cost.
- Design of building and other related structures with estimates.

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6. Financial and Economic Evaluation

6.1. Investment cost

- Estimates of capital investment required for land, site preparation, civil works, plant and machinery in local and foreign currency separately.
- Estimates of pre-production expenses.
- Estimates of working capital required for operation of the plant.

6.2. Production cost

- Calculation of production cost.
- Computation of unit cost.

6.3. Project financing

- Elaboration of financial model.
- Preparation of cash flow chart showing timing of financial inflow and outflow.
- Preparation of profit/loss statement.
- Estimate of annual financial cost.

6.4. Financial evaluation

Financial and economic evaluation of the project by computing net present day value, internal rate of return, break even point, pay back period and sensivity analysis.

6.5. Feasibility study

The proposal of PMDC regarding design and specification of stove was discussed. The JICA Mission stated that PMDC's proposal is covered under item 2.3. of JICA's draft i.e. "test and analysis of combustion of smokeless briquettes". Director (Technical),PMDC however, emphasized the need for designing of the stove keeping in view the results of analysis of combustion. After detailed discussions it was decided that the following proposals of PMDC shall be included in the Terms of Reference for the Consultants.

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"The detailed feasibility report will also include the design and specifications of a stove adopted to the characteristics of the briquettes and local conditions in Pakistan. The following parameters will particularly be considered for the design:-

- Geometry of the stove grate configuration, volume of the fuel and ash compartments.
- Ignition.
- Disposal of combustion gases and ash.
- Material to be used for fabrication."

7. The following items of JICA draft will remain unchanged. However, it was clarified by PMDC that regarding the undertaking of the Government of Pakistan, the Economic Aaffairs Division will obtain clearance from the concerned quarters:-

iv) Steps and schedule of study.

v) Reports.

vi) Undertaking of the Government of Pakistan and PMDC.

vii) Undertaking of JICA.

viii) Consultation.

(MASAHITO YAMADA)
Leader,
JICA Mission.

(KHAWAJA ASIFULLAH)
Director (Technical),
PMDC.

SCOPE OF WORK

FOR

THE FEASIBILITY STUDY

ON

THE SMOKELESS COAL BRIQUETTES DEVELOPMENT PROJECT

IN

THE ISRAMIC REPUBLIC OF PAKISTAN

AGREED UPON BETWEEN

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Islamabad, December,7,1987

Mr.	Mr.Masahito YAMADA
Chairman	Leader of the Preliminary
Pakistan Mineral Development	Survey Team
Corporation	The Japan International
	Cooperation Agency

Mr.

Ministry of Petroleum and Natural

Resources

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2nd stage: Techno-economic feasibility study and overall conclusion

The 1st stage study consists of the market survey for the coal briquettes and for the competitive substitutes. Before the commencement of the 2nd stage the interim report will be offered to justify the implementation of the 2nd stage study.

The 2nd stage study consists of the technical and economic evaluation of the coal briquettes production and overall conclusion.

The details at the respective stages are as follows:

1st stage:

1. Survey on the background of the Project

   1-1 National policy on, and present situation of, the energy in Pakistan

   1-2 National policy on, and present situation of, coal industry in Pakistan

2. Survey on the energy consumption

   2-1 Classification of energy use by industrial sectors and household sectors

   2-2 Trend of energy consumption by sectors

   2-3 Acts and regulations governing usage of fuels

3. Survey on the coal briquettes market and its distribution system

   3-1 Review of reports available on the above and the studies carried out so far

   3-2 Price trends of coal briquettes and its alternatives

   3-3 Quality and quantity demand for the coal briquettes by sectors

   3-4 Reasonable price structure for the consumer side by sectors

   3-5 Consumers' response to different types of fuels

   3-6 Present and potential distribution system of coal briquettes and other fuels

4. Overall evaluation on the market feasibility

2nd stage:

1. Resources and materials for producing the coal briquettes

   1-1 Volume and quality of lignite at the Lakhra coal mine

   1-2 Quality and supply of other materials for briquettes production

2. Production technology of briquettes

   2-1 Review of coal briquettes production technology and its combustion technology developed by Pakistan Council for Scientific & Industrial Research

2-2 Test and analysis of production of smokeless briquettes made from Lakhra coal

2-3 Test and analysis of combustion of smokeless briquettes

2-4 Preparation of production process flow diagram

2-5 Transportation and supply scheme of coals and other relevant raw materials

3. Construction study of the briquettes manufacturing plant

3-1 Site selection

3-2 Conceptural design and cost estimation of the plant

3-3 Supply methods of resources and material

3-4 Utilities (water,sewerage, electricity,etc)

3-5 Construction schedule

4. Operation plan

4-1 Operation schedule

4-2 Operation and management organization of the project

5. Economic evaluation of the project

5-1 Economic comparison between coal briquettes and other existing fuels

5-2 Financial analysis of the project

5-3 Economic and social evaluation

6. Conclusion and recommendations

IV. Steps and Schedule of the Study

1. Steps

Step 1: Preparatory work in Japan

Step 2: Field work(1) in Pakistan

Step 3: Home office work(1) in Japan

Step 4: Presentation of and discussion on the Interim Report

Step 5: Field work(2) in Pakistan

Step 6: Home office work(2) in Japan

Step 7: Presentation of and discussion on the Draft Final Report

2. Schedule

Schedule of the Study is shown in Annex.

V. Reports

JICA shall prepare and submit the following reports written in English to the Government of Pakistan within the time periods indicated below:

1. Inception Report: at the commencement of the Step 2: 10 copies
2. Progress Report(1st stage): at the end of the Step 2: 10 copies
3. Interim Report: within four(4) months after the end of Step 2: 10 copies
4. Progress Report(2nd stage): at the end of the Step 5: 10 copies
5. Draft Final Report and its summary within four(4) months ater the end of the Step 5: 15 copies
6. Final Report and its summary within two(2) months after the receipt of comments on the Draft Final Report from the Government of Pakistan: 30 copies

VI. Undertaking of the Government of Pakistan

1. To facilitate the smooth implementation of the Study, the Government of Pakistan shall take necessary measures:

   1-1 To secure the safety of the Japanese study team (hereinafter referred to as "the Team")

   1-2 To permit the members of the Team to enter, leave and sojourn in Pakistan for the duration of their assignment therein, and exempt them from alien registration requirements and consular fees

   1-3 To exempt the members of the Team from taxes, duties and other charges on equipment, machinery and other materials brought into Pakistan for the implementation of the Study

   1-4 To exempt the members of the Team from income taxes and other charges of any kinds imposed on or in connection with any emoluments or allowances paid to the members of the Team for their services in connection with the implementation of the Study

   1-5 To provide the necessary facilities to the Team for the remittance as well as utilization of fund introduced in Pakistan from Japan in connection with the implementation of the Study

   1-6 To provide medical services as needed and its expenses will be chargeable on the members of the Team

   1-7 To secure permission for entry into private properties or restricted areas for the conduct of the Study

   1-8 To secure permission to take all data and documents related to the Study(including unrestricted photographs) out of Pakistan to Japan by the Team

2. The Government of Pakistan shall bear claims, if any arises against the members of the Team resulting from, occurring in the course of, or otherwise connected with the discharge of their duties in the implementation of the Study, except when such claims arise from gross negligence or willful misconduct on the part of the Japanese members of the Team.

3. PMDC shall act as counterpart agency to the Team and also as coordinating body in relation with other governmental and non-governmental organizations concerned for the smooth implementation of the Study.

4. PMDC shall, at its own expense, provide the Team with the following, in cooperation with other relevant organization:

4-1 Available data and information related to the Study

4-2 Counterpart personnel

4-3 Suitable air-conditioned office with necessary equipment and furniture

4-4 Credentials and identification cards

VII. Undertaking of JICA

For the implementation of the Study, JICA shall take the following measures:

1. To dispatch, at its own expense, the Team to Pakistan

2. To pursue technology transfer to Pakistani counterpart personnel in the course of the Study

VIII. Consultation

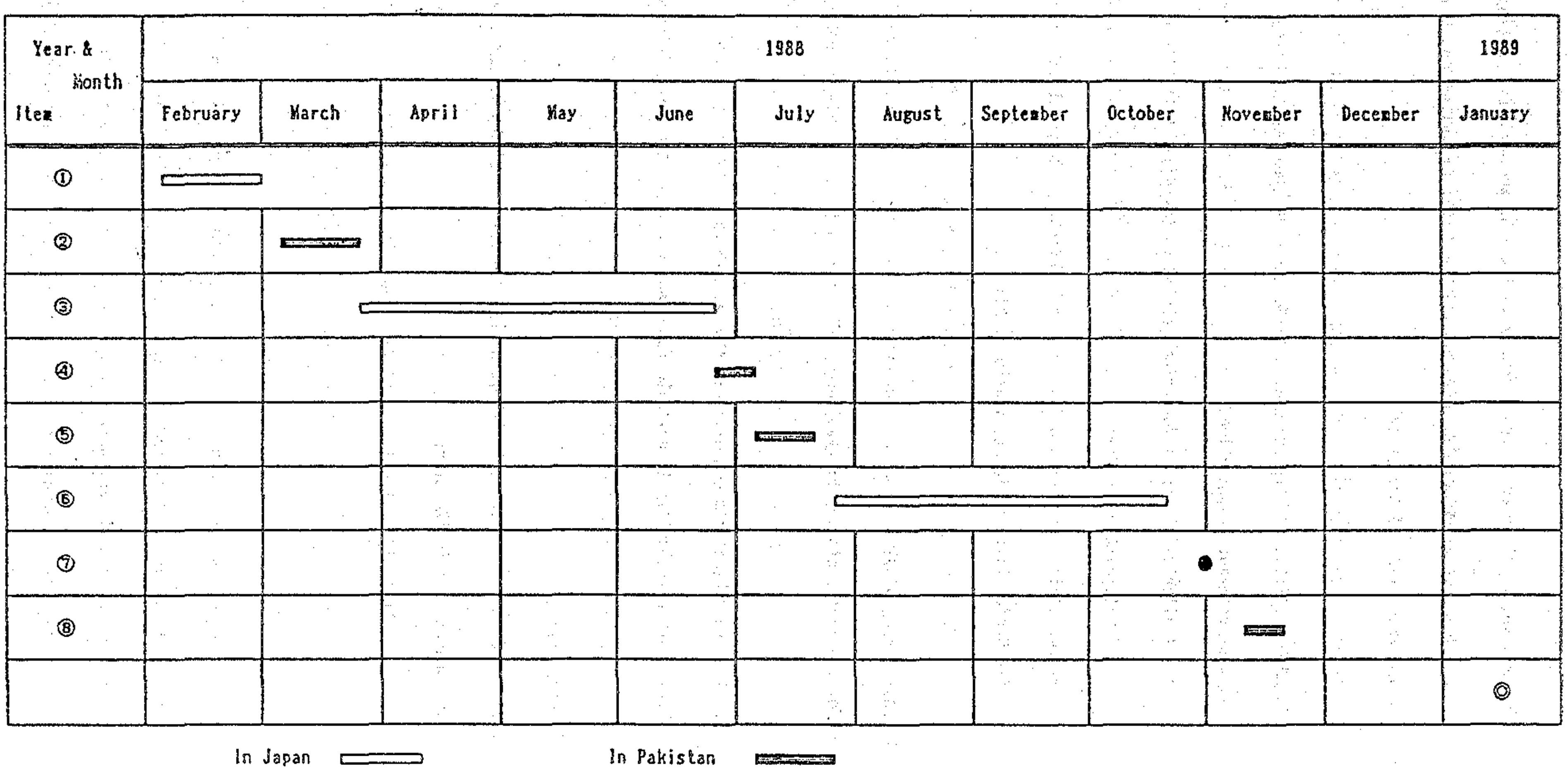
JICA and PMDC shall consult with each other in respect of any matter that may arise from or in connection with the Study.

<Annex>

Tentative Schedule of the Study

Item:

① Preparatory Office Work
② Field Work(1)
③ Home Office Work
④ Presentation of Interim Report and Preparatory Work for Field Work(2)
⑤ Field Work(2)
⑥ Home Office Work
⑦ Submission of Draft Final Report
⑧ Presentation of Draft Final Report
⑨ Submission of Final Report



ANNEXURE-II

SCOPE OF WORK
FOR
THE FEASIBILITY STUDY
ON
THE SMOKELESS COAL BRIQUETTES DEVELOPMENT PROJECT
IN
THE ISLAMIC REPUBLIC OF PAKISTAN

AGREED UPON BETWEEN

PAKISTAN MINERAL DEVELOPMENT CORPORATION

AND

THE JAPAN INTERNATIONAL COOPERATION AGENCY

Islamabad, December, 7, 1987

Mr. Chairman Pakistan Mineral Development Corporation	Mr. Masahito YAMADA Leader of the Preliminary Survey Team The Japan International Cooperation Agency
Mr. Ministry of Petroleum and Natural Resources	Mr. Economic Affairs Division

I- INTRODUCTION

In response to the request of the Government of the Islamic Republic of Pakistan(hereinafter referred to as "Pakistan") the Government of Japan has decided to implement the feasibility study on the smokeless coal briquettes development project (hereinafter referred to as"the Study") in accordance with the relevant laws and regulations in force in Japan.

Accordingly, the Japan International Cooperation Agency(hereinafter referred to as'JICA'), the official agency responsible for the implementation of the technical cooperation programmes of the Government of Japan, will undertake the study, in close cooperation with the authorities of Pakistan.

The present document sets forth the scope of work with regard to the study.

II- Objective of the Study:

The objective of the study is to investigate the technical and economic feasibility of the smokeless coal briquettes development project with an ultimate production capacity of 300,000 tonnes of briquettes per annum to substitute kerosene oil and fuel wood in Pakistan.

III- Scope of the Study:

The study will be carried out in the following three (3) stages:-

1st stage: Market study.
2nd stage: Techno-economic feasibility study.
3rd stage: Overall conclusion and recommendation.

The 1st stage consists of the market survey for the coal briquettes and for the competitive substitutes.

Before the commencement of the 2nd stage the interim report will be submitted.

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The 2nd stage consists of the technical and economic evaluation of the coal briquettes production.

The 3rd stage encompasses analysis and synthesis of collected information and data at the previous stages.

The details at the respective stages are as follows:

1st stage:

1. Survey on the background of the Project

1-1 National policy on and present situation of the energy in Pakistan.

1-2 National policy on and present situation of coal industry in Pakistan.

2. Survey on the energy consumption

2.1. Classification of energy use by industrial sectors and household sector.

2.2. Trend of energy consumption by sectors.

2.3. Acts and regulations governing usage of fuels.

3. Survey on the coal briquettes market and its distribution system:

3.1. Review of reports available on the above and the studies carried out so far.

3.2. Price trends of coal briquettes and its alternatives.

3.3. Potential demand for the coal briquettes by sectors.

3.4. Reasonable price structure for the consumer side by sectors.

3.5. Consumer' response to different types of fuels particularly to smokeless briquettes.

3.6. Present and potential distribution system of coal briquettes and other fuels.

..../3

3.7. Consumers survey in possible consuming centres with a view to checking the data generated.

3.8. Recommend appropriate sale strategy for briquettes and sale price taking into consideration their quality; the price of competing fuels, other costs, sales revenue etc.

4. Overall evalaution on the market feasibility:

<u>2nd stage:</u>

1. Resources and materials for producing the coal briquettes.

   1.1. Volume and qualities of lignite at the Lakhra coal mine.

   1.2. Qualities and supplies of briquettes binder.

   1.3. Others.

2. <u>PRODUCTION TECHNOLOGY OF BRIQUETTES</u>

2.1. Review of production technology developed by Fuel Research Centre, PCSIR.

2.2. Review and evaluation of available data/report.

2.3. Specify and control the collection at site of a required quantity of bulk samples of coal and lime-stone for pilot plant tests.

2.4. Conduct pilot plant tests to determine the washing characteristics of coal and evolve a flow diagram.

2.5. Conduct studies on pilot plant scale for production of smokeless coal briquettes with/without binder suitable for domestic consumption.

2.6. Test and analysis of smokeless coal briquettes produced from Lakhra coal.

2.7. Technical description of various washing and briquetting routes with comparative economic of all the available options.

..../4

2.8. Select a most suitable and economic process of washing and briquetting on the basis of pilot plant test results.

2.9. Computation of material flow quantities for the suggested flow sheet.

2.10. Conceptual design of the plant on the basis of the selected process.

2.11. Transportation and supply scheme of coal and other raw materials.

3. CONSTRUCTION STUDY OF THE BRIQUETTING MANUFACTURING PLANT

3.1. Site selection

- Location with regard to distance from the coal mines, existing infrastructure etc.
- Local conditions including topography, soil properties, water and power supply, waste disposal etc.
- Estimated cost of site preparation.

3.2. Plant design and capacity

- Determine minimum economic size of the plant and preparation of design with provision of expansion to 300,000 tonnes of coal briquettes per annum.
- Preparation of technical specifications of plant and machinery including operating data.

3.3. Plan layout proposals

- Drawing of functional layout including arrangement of equipment and positioning of operational component and provisions for plant expansion.
- Determination of total space requirements for the plant, storage area and waste dump.

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3.4. Operational requirements

- Qualitatives and quantitative determination of inputs for operation of the plant such as water,electricity,fuels etc.
- Determination of auxillary requirements including spare parts.
- Supply methods of resources and materials.

3.5. Civil Engineering

- Site preparation and development cost.
- Design of building and other related structures with cost estimates.

4. OPERATIONAL PLAN

- Operation schedule.
- Operation and management organization of the project.

5. FINANCIAL AND ECONOMIC EVALUATION

5.1. Investment cost;

- Estimates of capital investment required for land, site preparation, civil works,plant and machinery in local and foreign currency separately.
- Estimates of pre-production expenses.
- Estimates of working capital required for operation of the plant.

5.2. Production cost;

- Calculation of production cost.
- Computation of unit cost.

5.3. Project financing;

- Elaboration of financing model.
- Preparation of cash flow chart showing timing of financial inflow and outflow.

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- Preparation of profit/loss statement.
- Estimate of annual financial cost.

5.4. Financial Evaluation;

Financial and economic evaluation of the project by computing net present days value, internal rate of return, break even point, pay back period and sensivity analysis.

5.5. Feasibility Report;

The detailed feasibility report will also include the design and specification of a stove adopted to the characteristics of the briquettes and local conditions in Pakistan. The following parameters will particularly be considered for the design;

- Geometry of the stove grate configuration, volume of the fuel and ash compartments.
- Ignition.
- Disposal of combustion gases and ash.
- Material to be used for fabrication.

IV- STEPS AND SCHEDULE OF THE STUDY:

1. Steps:

Step 1: Preparatory work in Japan.
Step 2: Field work(I) in Pakistan.
Step 3: Home office work(I) in Japan.
Step 4: Presentation of and discussion on the Interim Report.
Step 5: Field work(2) in Pakistan.
Step 6: Home office work(2) in Japan.
Step 7: Presentation of and discussion on the Draft Final Report.

2. Schedule:

Schedule of the Study is shown in Annx.

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1.6. To provide medical services as needed and its expenses will be chargeable on the members of the Team.

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2. The Government of Pakistan shall bear claims,if any arises against the members of the Team resulting from, occurring in the course of, or otherwise connected with the discharge of their duties in the implementation of the Study,except when such claims arise from gross negligence or willful misconduct on the part of the Japanese members of the Team.

3. PMDC shall act as counterpart agency to the Team and also as coordinating body in relation with other governmental and non-governmental organizations concerned for the smooth implementation of the Study.

..../9

4. PMDC shall, at its own expense, provide the Team with the following, in cooperation with other relevant organization:

4.1. Available data and information related to the Study.

4.2. Counterpart personnel.

4.3. Suitable air-conditioned office with necessary equipment and furniture.

4.4. Credentials and identification cards.

VII- Undertaking of JICA

For the implementation of the Study, JICA shall take the following measures:

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VIII- Consultation

JICA and PMDC shall consult with each other in respect of any matter that may arise from or in connection with the Study.

Tentative Schedule of the Study

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Item:

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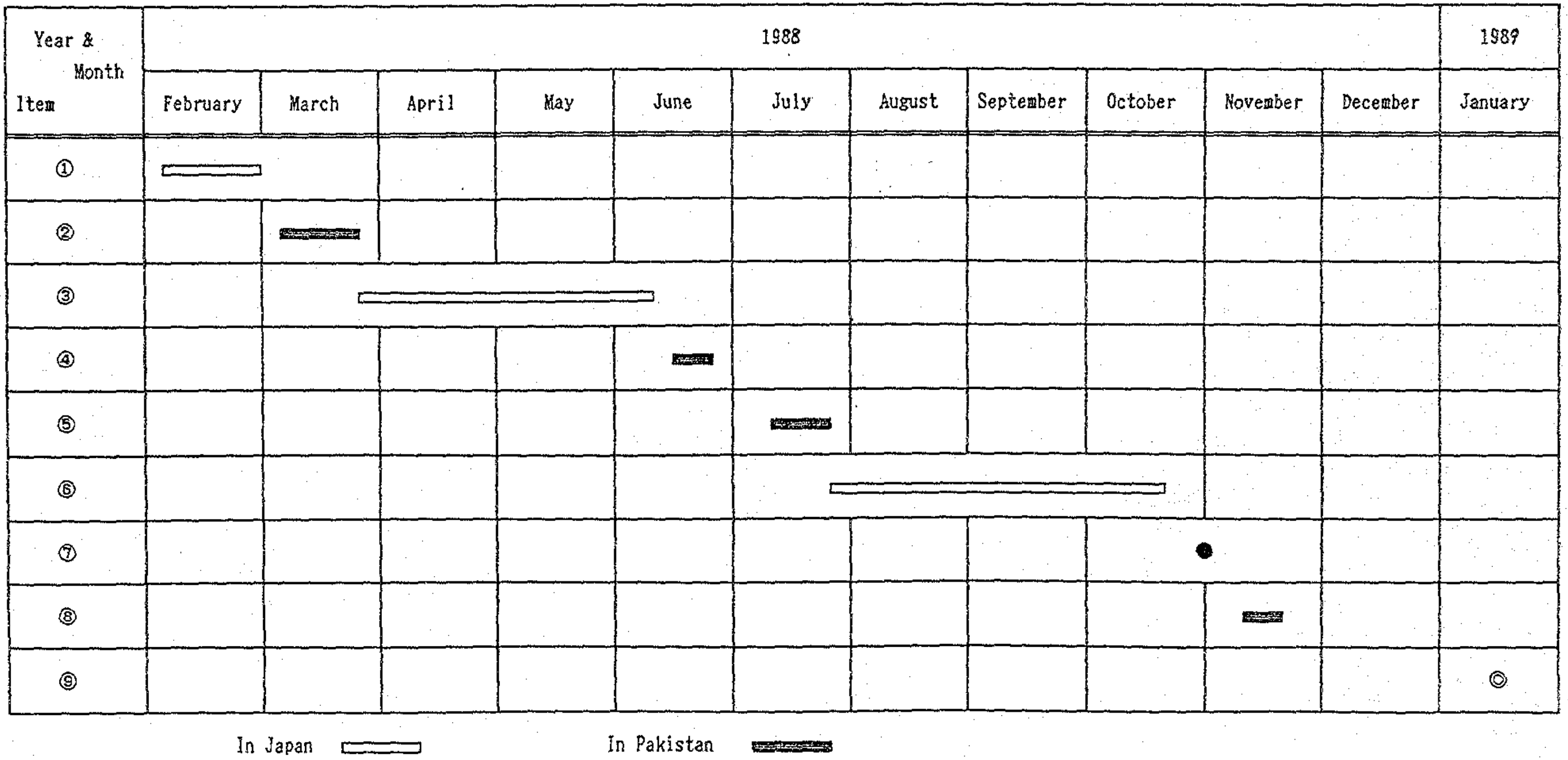

JICA