Project Planning for Small and
Medium Scale Industries No.15

Husk Fired Thermal Power Plant

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JAPAN CONSULTING INSTITUTE

This technical brochure was compiled to help in the drafting of a suitable plan for the construction of a Husk Fired Thermal Power Plant.

The production scale and manufacturing process have been described in this brochure on the basis of a typical instance.

The profitability was estimated by fixing certain required conditions, which may differ from country to country.

We hope that the data contained in the brochure will help you to draw up the most suitable plan for the industrialization of your project.

In case a government or public organization requests the Japan Consulting Institute to conduct a feasibility study of the above industry for the purpose of establishing the most suitable plan, it is possible for us to carry this out free of charge.

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1. Introduction

This brochure explains how to construct a power plant using, as fuel, rice husk, one of the so-called industrial wastes. In order to give information necessary for the construction of said plant, description will briefly made on the construction process of power plant, required machinery and equipment, construction cost and profitability of a model plant.

For the purpose of conserving fossil fuel, efforts are being made worldwide to effectively utilize the husk at rice mills, and the wood chips and sawdust at sawmills and plywood factories, by way of energy sources for power generation in place of petroleum. In recent years, power supply using, as fuel, such flammable materials that had been disposed of as industrial waste, have been developed and are now being put to practical use.

It is reported that 470 million tons of paddy are produced in the world a year (see Table 1), and the quantity of husk being generated in the rice milling is estimated to be 94 million tons. Most of the husk are discarded as a sort of waste, for which rice mills are obliged to spend money, and the disposal of husk sometimes causes environmental pollution. Approximately 90% of paddy are produced in the developing countries, a majority of these nations are short of electricity.

One-kg rice husk have the calorific value of over 3,000 kcal, and 94 million tons of husk are equivalent to 28 million tons of fuel oil. Therefore, it is quite significant to effectively use the rice husk for electric power generation.

Table 1. Output of Paddy in Major Producing Countries in 1984

Unit: **1000 MT**

(Africa)	8,582	(Asia)	433,197	Malaysia	1,755
Egypt	* 2,230	China	F181,028	Laos	1,322
Madagascar	2,132	India	F 91,000	Kanpuchea DM	F 1,300
Nigeria	F 1,100	Indonesia	* 37,500	Iran	F 1,230
		Bangladesh	F 21,500		
(North and Central America)	8;521	Thailand	F 19,200	(Europe)	1,959
U.S.A.	6,216	Viet Nam	15,416	Italy	1,027
Mexico	635	Japan	14,848		
Cuba	555	Burma	F 14,500	(Oceania)	658
		Philippines	* 8,280	Australia	635
(South America)	14,542	Korea Rep.	7,970		
Brazil	9,023	Korea Dpr.	F 5,400	U.S.S.R.	2,500
Colombia	1,696	Pakistan	5,009		
Peru	1,134	Nepal	F 2,760	(Whole world)	469,959
		Sri Lanka	* 2,270		

Note: 1. Based on FAO's statistics for 1984.
*: indicates unofficial data.
F: shows FAO's estimated data.
2. Parenthesis indicates a region.

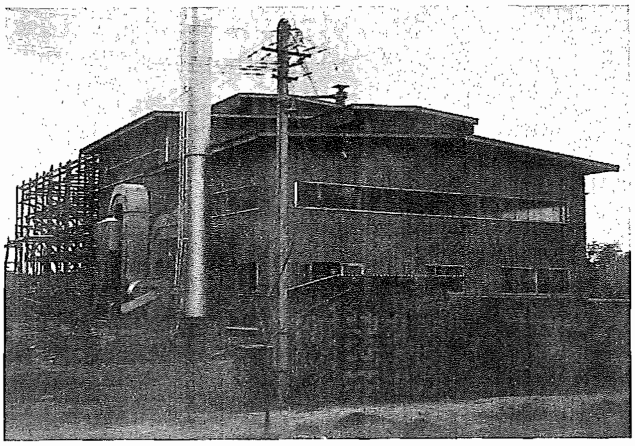


Photo 1. Outside View of Power Plant

2. Rice Husk

Rice husk are produced when paddy is cleaned. The properties of husk differ according to the kind of paddy and the harvest seasons. The calorific value is 2,900 to 3,600 kcal/kg. In this brochure the calorific value of 3,000 kcal/kg was adopted.

The characteristics of rice husk are as follows:

① 14 to 17% of total carbon are contained as the fixed carbon, which shows a slow combustion speed.

② Apparent specific gravity being as low as 0.1, the volume required as fuel becomes very large. Hence, to acquire husk from a distant place will cause its transportation cost to become higher, which will have an adverse effect on profitability.

③ Husk ash being contained, 87 to 97% SiO_2 exist therein, and SiO_2 is the hard material.

Having such characteristics as that, husk has been disposed of as industrial waste. Nevertheless, husk has such calorific value as was cited above and contains plenty of SiO_2 in its ash. Hence, husk should be effectively utilized.

The moisture contained in paddy varies according to the harvest seasons, and it sometimes reaches 30%. When the paddy contains much moisture, the quality of rice gets worse, so the paddy is dried before being cleaned. Therefore, the husk produced in the cleaning process usually contains less than 10% moisture, and the husk directly coming from a rice mill can be put into a boiler as it is. However, once the husk is left outdoors, it comes to contain much moisture, worsening the combustion efficiency. In this case, the husk must be dried before being used as fuel.

3. Outline of a Model Plant

A power plant using husk as fuel is commonly set up near a rice mill. Consequently, the model plant in this brochure is to be constructed adjacent to a rice mill and the husk to be used as fuel is sent by air from the mill. The electric energy thus generated is used for the operation of the rice mill and a surplus will effectively be utilized for the modernization of a rural community.

Also, the ash coming from a boiler contains much SiO_2, which can be used effectively for asphalt filler, brick, heat insulator, etc.

The capacity of a rice mill is generally represented by the weight of paddy that the mill can process per hour.

The power necessary for the operation of a rice mill differs according to the type of equipment installed. Data from many rice mills show the following relationship between the power P (kW) necessary for the operation of a rice mill and it's capacity M (ton/hr):

$$P = 18 \left\{ (1 \sim 5) + M \right\}$$

Note: In $(1 \sim 5)$, 1 indicates an old-fashioned rice mill. As it is modernized, it gradually approaches 5.

3.1 Scale of Power Plant Output

The model plant in this brochure has a generation capacity of 600 kW. When the consumption of power in the plant is considered, the output at the sending end will become 530 kW.

In case the power plant is operated 24 hours a day, with a six-day working per week and a 30-day maintenance period, the annual number of operating days will be 280 days. Hence, the annual sales of electric energy will become as below.

530 kW x 24 hrs x 280 days ≒ 3,561,600 kWh.

In Southeast Asia there are various scales of rice mills. Of which a capacity of 5 to 15 ton/hr is most common, and a 10 ton/hr capacity is being generally employed there. In this case, two tons husk is produced per hour. In case the model plant in this brochure uses 90% of the said husk as fuel and applying condensing turbine, the plant output capacity will be able to 600 kW.

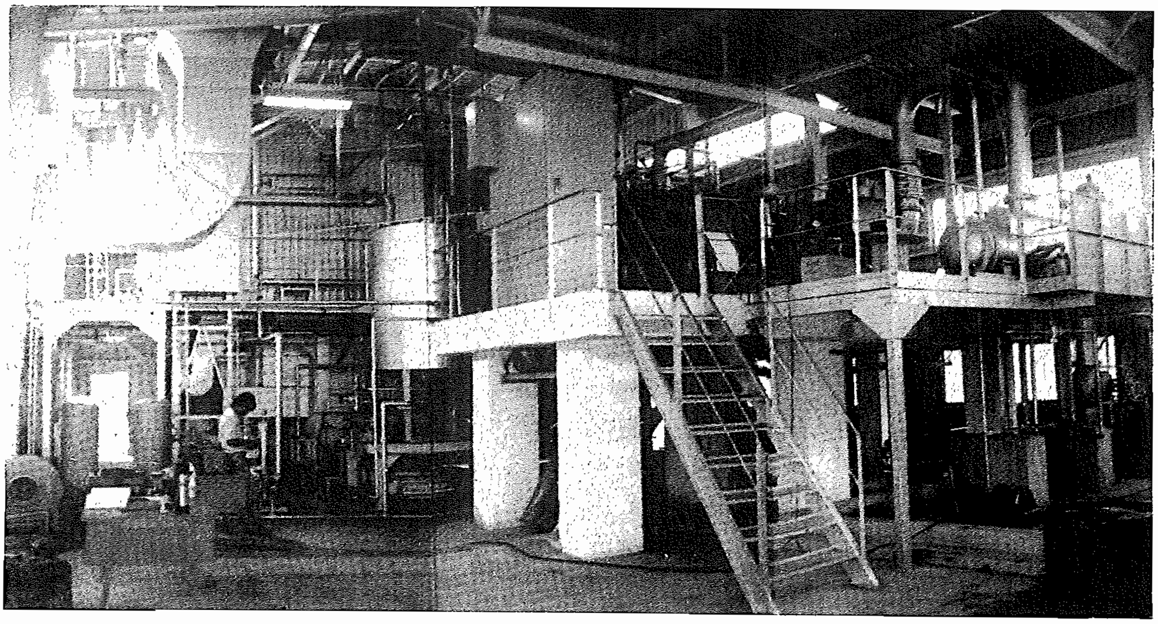


Photo 2. Interior Part of Power Plant

3.2 Required Quantity of Raw Material

(1) Raw material

① Husk 1,730 kg/hr
1,730 kg/hr x 24 hrs x 280 days
= 11,625,600 kg/year

② Chemical 0.34 kg/hr*1
0.34 kg/hr x 24 hrs x 280 days
= 2,285 kg/year

(2) Utilities

① Boiler feed water 285 ℓ/hr*1
285 ℓ/hr x 24 hrs x 280 days
= 1,915,200 ℓ/year

② Cooling water 250 m^3/hr
250 m^3/hr x 24 hrs x 280 days
= 1,680,000 m^3/year

③ Fuel oil 110 ℓ/time*2
110 ℓ/time x 40 times
= 4,400 ℓ/year

*1: Differs according to the quality of boiler feed water, but in this brochure the standard quality of water was taken into consideration, and the continuous blow of a boiler was fixed as 5%, and three kinds of chemicals are dosed at a rate of 20 ppm each.
*2: Fuel oil is burned for about 30 minutes when the power plant starts its operation.

3.3 Power Generation Process

Fig. 1 shows the flow diagram of the power generation facilities which use husk as fuel. A starting diesel engine generator is included for the start up of the plant when external power supply from the power grid is not available. Although a husk hopper is included, it will be unnecessary when a power plant is constructed close to the rice mill. They are therefore omitted in this brochure. An outline of each process will be described below.

(1) Fuel feeder

The husk from a rice mill is conveyed to the service hopper silo from the husk storage yard by pneumatic conveyor and then sent to the fuel feeder with a feeder fan, and the husk is fed automatically to the boiler.

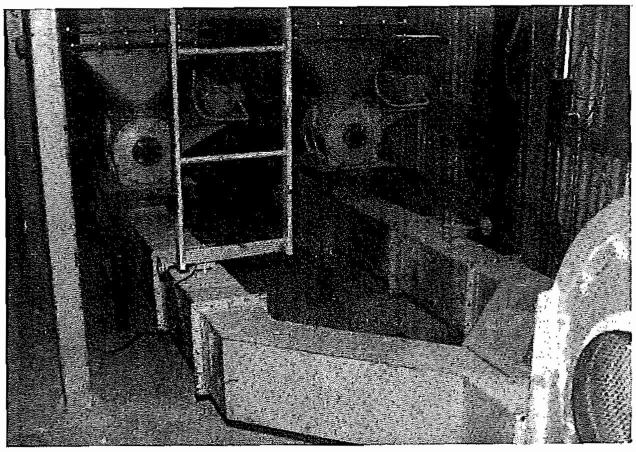


Photo 3. Husk Feeder

(2) Boiler and draft system

① The advantages of a fire tube and a water wall tube are optimally applied in the boiler for the burning of husk. The high pressure steam produced in the boiler is super heated and feed to the steam turbine.

② Boiler combustion air is caused to flow through the boiler by a forced draft fan and an induced draft fan, and the airflow is controlled at the optimum rate for combustion.

③ Boiler combustion gas is deprived of dust and soot as it passes through a dust collector

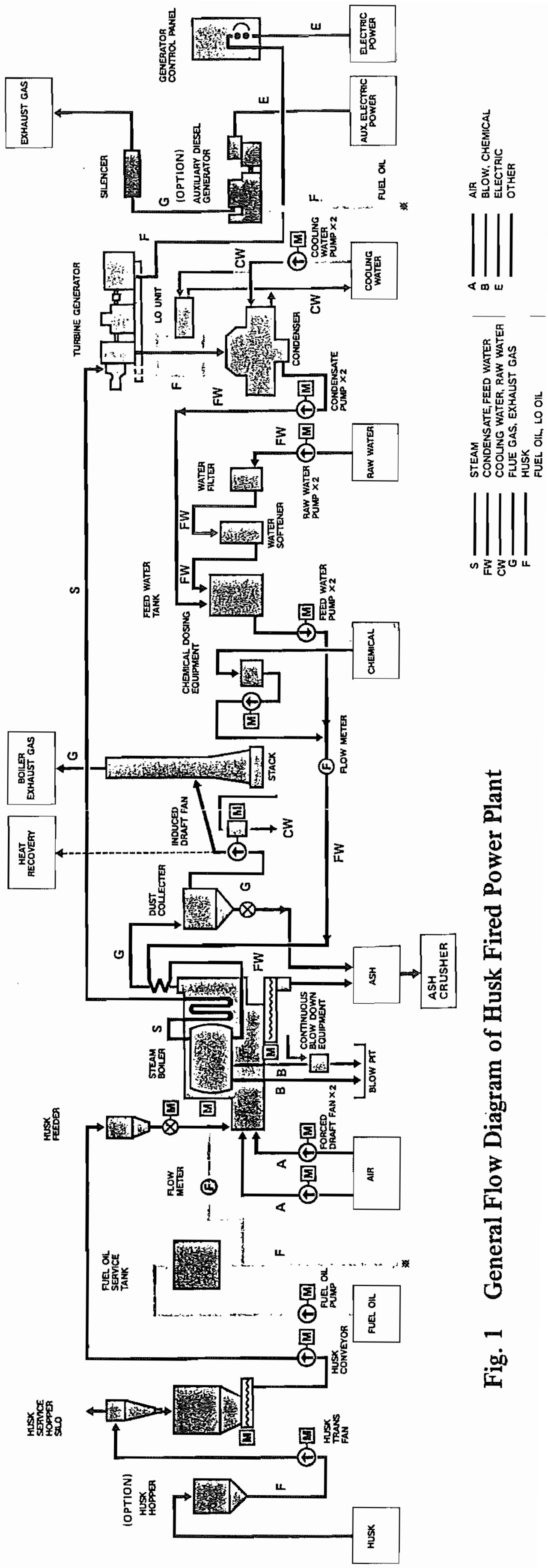


Fig. 1 General Flow Diagram of Husk Fired Power Plant

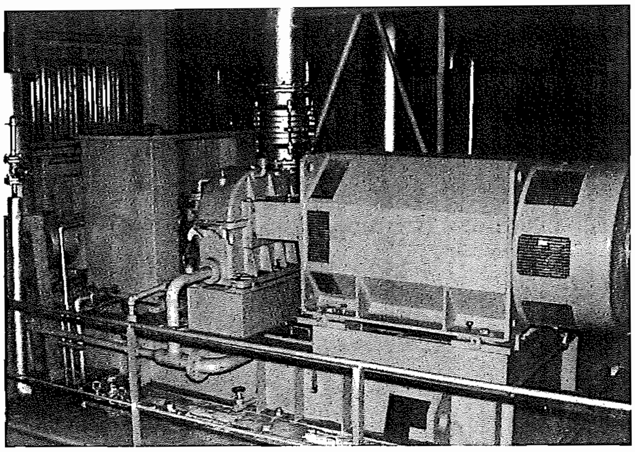


Photo 4. Steam Turbine Generator

and is sent to a stack by an induced draft fan and discharged into air.

④ Heavy oil in a storage tank is used as a supplemental boiler fuel. It is pumped into a fuel service tank by a fuel transfer pump and is burned by a fuel burner at boiler starting.

(3) Steam turbine generator

① The steam turbine is a simple, single-stage or multi-stage condensing turbine, which drives the generator through reduction gears.

② The turbine, reduction gears and generator are mounted on the common base.

③ The exhaust steam from the steam turbine condenses into condensate in a condenser and returns to the boiler feed water tank.

(4) Boiler feed water

① The recirculating condensate is the source of boiler feed water.

② The condensate obtained in the turbine condenser is extracted by a condensate pump into a feed water tank and is fed into the boiler by a boiler feed water pump.

③ To supplement the boiler water (recirculating water) raw water is used after being treated in a water filter and a water softener.

④ A small amount of chemical is put into the boiler water for the protection of boiler tubes and turbine blades.

(5) Condenser cooling water

Condenser cooling water is pumped from a pond or river by a cooling water pump into the condenser, part of which is used for the cooling of lube oil.

In case a proper water source is not available in the plant site, cooling water may be recirculated, using a cooling tower.

(6) Post ash treatment

The ash from a boiler is crushed and atomized so that it can easily be used again.

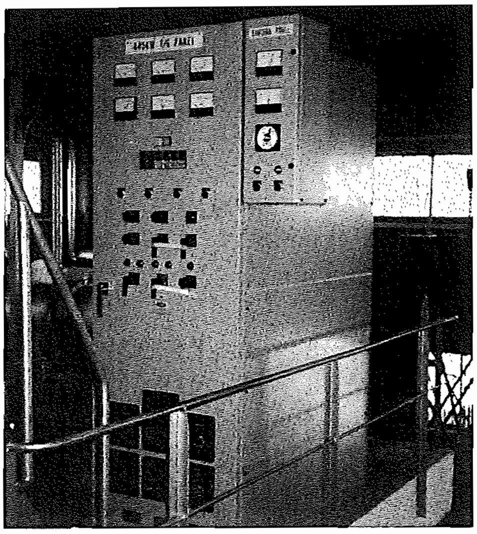


Photo 5. Generator Panel

3.4 Required Machinery and Equipment

The following shows the required machinery and equipment for the model plant.

< Husk feeder >			
Husk transfer fan		3.7 kW	1 set
Rotary valve		0.4 kW	4 sets
Husk service silo			1 set
< Starting fuel feeder >			
Service tank			1 set
Fuel oil pump			1 set
< Boiler >			
Furnace	husk	1,730 kg/hr	1 set
Boiler	evapo. capa.	6,000 kg/hr	1 set
Burner		5.5 kW	1 set
Induced draft fan		30 kW	1 set
Primary draft fan		7.5 kW	1 set
Secondary draft fan		5.5 kW	1 set
Superheater			1 set
Economizer			1 set

Ash pusher	0.75 kW	1 set
Ash paddle wheel	0.75 kW	1 set
Ash conveyor	0.4 kW	2 sets
Boiler auxiliary panel		1 set
Dust collector		1 set
Stack		1 set
< Turbine generator >		
Turbine	315°C, 16 Bar	1 set
Reduction gear		1 set
Generator	600 kW	1 set
Generator panel		1 set
< Boiler water feeder >		
Raw water pump	0.75 kW	2 sets
Water treatment equipment		1 set
Feed water tank		1 set
Feed water pump	11 kW	2 sets
Chemical dosing equipment	0.2 kW	1 set
< Cooling water equipment, condenser >		
Cooling water pump	15 kW	2 sets
Condenser		1 set
Condensate pump	1.5 kW	2 sets
Vaccum pump	1 kW	2 sets
< Post ash treatment equipment >		
Crusher	1 ton/hr	1 set

3.5 Cost of Machinery and Equipment

The cost of machinery and equipment of a power plant with a output of 600 kW is almost as follows:

Cost of machinery and equipment	¥189,000,000 (US$1,050,000)

Note
1. FOB Japanese port.
2. Starting diesel generator and husk storage are not included.
3. Water piping from a water source to the plant is not included.
4. Power feeder from the power plant to the adjacent power grid is not included.
5. US$1 = ¥180

3.6 Layout of Plant and Construction of Buildings

(1)	Area of plant site	1,200 m²
(2)	Floor space of power plant	600 m²
	Floor space of office	100 m²

(3) Layout of plant

The plant layout is shown in Fig. 2.

3.7 Personnel Required

Factory manager	1
Engineer	3
Skilled worker	3
Unskilled worker	6
Odd-job man	9
Total	22

Note: 24 hrs/day operation with a 3-shift system

3.8 Use of Ash

The ash generated by the combustion of husk may be used for the following purposes:

(1) Asphalt filler

Asphalt uses cement and crushed stone as its fillers. If ash is utilized in place of these fillers, the softening temperature and elongation will be improved.

(2) Brick using ash which have sufficient strength

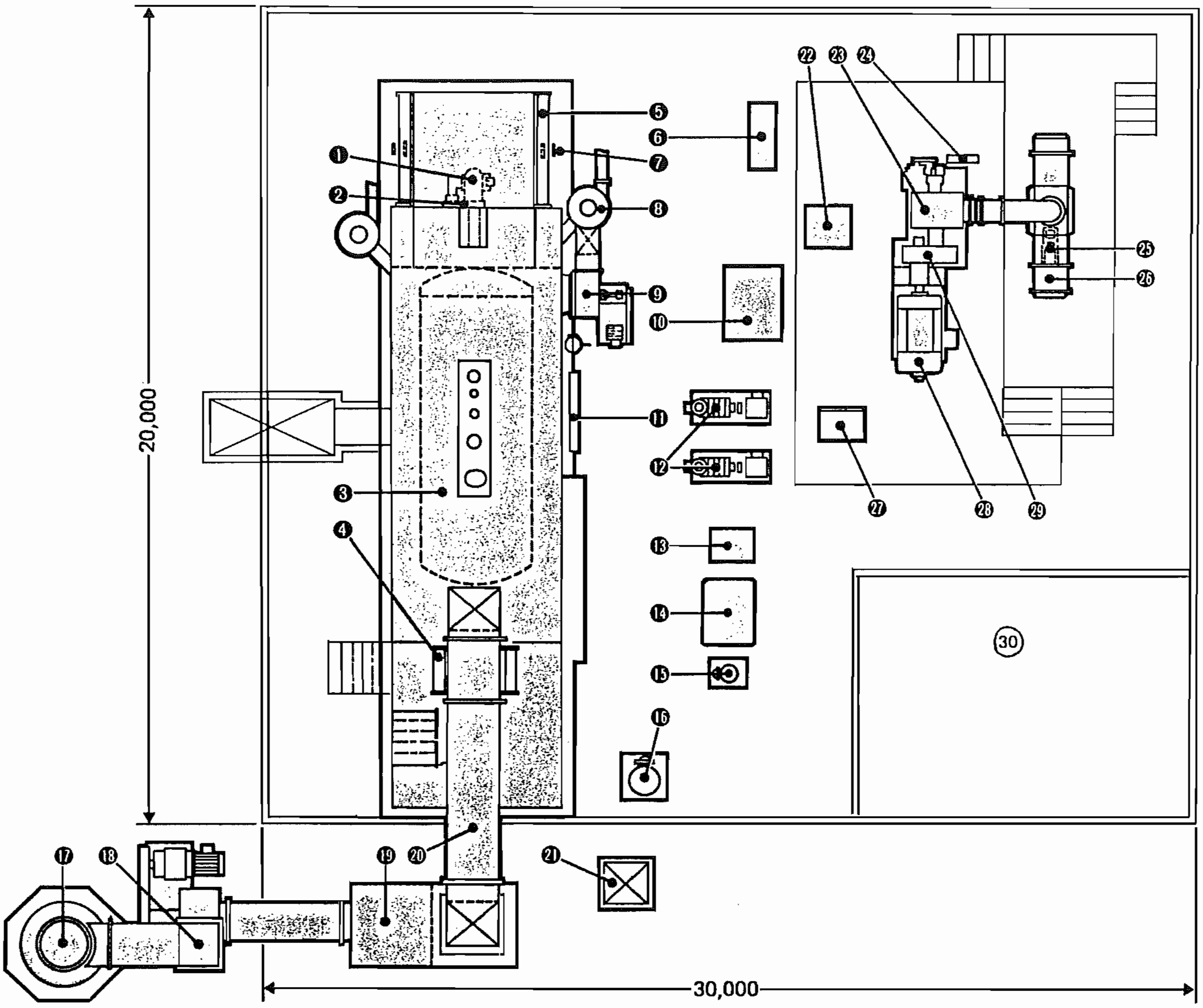
In case ash and quick lime (or cement) are kneaded and molded, it becomes a brick having sufficient strength for structural material.

(3) Heat insulator

If ash and quick lime are kneaded and superheated and cured under high pressure, it becomes a heat insulator of calcium silicate.

(4) Raw material of ceramics

Ash is a promising raw material of SiC which is drawing attention as new ceramics and raw material of amorphous silicone which are used for making semiconductor.



NO.	MACHINERY
1	OIL BURNER
2	BY-PASS DAMPER
3	BOILER
4	ECONOMIZER
5	SUPER HEATER
6	BOILER CONTROL PANEL
7	SOOT BLOWER
8	FUEL FEEDING EQUIPMENT
9	FORCED DRAFT FAN
10	FUEL OIL SERVICE TANK
11	FEED WATER REGULATOR
12	FEED WATER PUMP
13	CHEMICAL FEEDER
14	FEED WATER TANK
15	WATER SOFTENER
16	WATER FILTER
17	STEEL STACK

NO.	MACHINERY
18	INDUCED DRAFT FAN
19	DUST COLLECTOR
20	EXHAUST GAS FLUE
21	BLOW BOX
22	LUBRICATION UNIT
23	STEAM TURBINE
24	TURBINE GAUGE BOARD
25	CONDENSATE PUMP
26	CONDENSER
27	GENERATOR PANEL
28	SYNCHRONOUS GENERATOR
29	REDUCTION GEAR
30	CONTROL ROOM

Fig. 2 General Layout of Husk Fired Power Plant

4. Production Cost and Profitability

The production cost of a power plant must be calculated according to the conditions of each country concerned. However, it being difficult to make calculation for each different country, the calculation in this brochure was made on the following basis.

4.1 Basic Conditions for the Calculation of Fixed Capital, Working Capital and Production Cost

(1) Fixed capital

(a) Land price is not included.

(b) Unit construction cost of the power house and the office building is assumed to be US$200/m^2.

(c) Machinery and equipment cost is shown by FOB Japanese port. The price is of July 1986, and import duties are exempted.

(d) Spare parts cost is assumed to be 5% of the FOB price of machinery and equipment.

(e) Freight and insurance cost is assumed to be 8% of the FOB price of machinery and equipment.

(f) Erection cost is assumed to be 5% of the FOB price of machinery and equipment.

(g) Civil engineering cost is assumed to be 8% of the FOB price of machinery and equipment. The bearing capacity of soil being unknown, the foundation work for machinery and equipment is not included.

(h) Supervision cost is assumed to be 10% of the FOB price of machinery and equipment.

(i) Commissioning cost is assumed to be 4% of the FOB price of machinery and equipment. Raw materials necessary for commissioning are not included.

(j) Training cost is assumed to be 4% of the FOB price of machinery and equipment.

(k) Contingency is assumed to be 10% of the FOB price of machinery and equipment.

(2) Working capital

(a) Raw material cost for one month operation.

(b) Utility cost for one month operation.

(c) A-half-month ash sales revenue.

(3) Production cost

(a) Raw material cost

① Husk
Husk being discarded as industrial waste, it is supposed to be obtained free of charge.

② Chemical
Average unit price of chemical is assumed to be US$14.44/kg.

US$14.44/kg x 2,285 kg
= US$33,000/year

(b) Utility cost

① Boiler feed water and cooling water
As boiler feed water and cooling water, rainwater or good river or well water is used. Hence, the water cost was omitted. The electric energy necessary for utilizing the water will be supplied from the house service energy of the plant.

② Fuel oil
Average unit price of fuel oil is assumed to be US$0.4/ℓ.

US\$0.4/ℓ x 4,400ℓ = US\$1,760/year

As the starting fuel, fuel oil was adopted in this brochure, but suitable waste wood can be utilized instead.

(c) Labor cost

Direct labor cost is shown in man/year.

Factory manager	US\$14,000
Engineer	US\$ 8,000
Skilled worker	US\$ 4,000
Unskilled worker	US\$ 2,000
Odd-job man	US\$ 500

(d) Maintenance cost

Maintenance cost is assumed to be 3% of the FOB price of machinery and equipment.

(e) Depreciation cost

Straight line method was adopted with residual value being 10%. Depreciation of machinery and equipment is done in 15 years and the buildings in 30 years as follows:

Machinery and equipment $\frac{1-0.10}{15} = 0.06$

Building $\frac{1-0.10}{30} = 0.03$

Machinery and equipment cost
= Fixed capital – Construction cost of buildings

(f) Insurance cost

Insurance cost is assumed to be 0.5% of the fixed capital.

(g) Selling and administration expenses

Selling and administration expenses are assumed to be 3% of the annual sales.

(h) Interest

One-second of the fixed capital is to be covered by equity capital and the remaining half by a long-term loan with an annual interest rate of 10%.

Note: The exchange rate of the US dollar to the Japanese yen is assumed to be US\$1 = ¥180.

4.2 Annual Sales

(a) Electric energy sales

If the unit price of electric energy to be supplied outside is assumed to be US\$0.08/kWh, the annual sales of electric energy will become as follows:

US\$0.08/kWh x 530 kW x 24 hrs x 280 days
= US\$284,928

(b) Ash sales

The ash from husk firing boiler contains 87 to 97% of SiO_2. Therefore, this kind of ash has the large possibility for the source material of SiO_2. If the ash supplied continuously and stably to the market, the ash will be saled with suitable price. Hence, US\$0.06/kg was adopted as the unit selling price of ash.

The quantity of ash corresponds to about 20% of the quantity of husk. The annual sales revenue of ash will become as below.

US\$0.06/kg x 1,730 kg/hr x 0.20 x 24 hrs
x 280 days = US\$139,507

(c) Total annual sales

The annual sales is a total of (a) + (b), that is US\$424,435.

4.3 Capital Required

(1) Fixed capital

	US$
Area of plant site: 1,200m²	–
Floor space of power plant and office: 700m²	140,000
Machinery and equipment (FOB Japanese port)	1,050,000
Spare parts	52,500
Freight and insurance	84,000
Erection cost	52,500
Civil engineering cost	84,000
Supervision cost	105,000
Commissioning cost	42,000
Training cost	42,000
Contingency	105,000
Sub-total	US$1,757,000

(2) Working capital

Raw material cost for one month operation:

$$US\$33,000/year \times \frac{1}{12} = US\$2,750$$

Utility cost for one month operation:

$$US\$1,760/year \times \frac{1}{12} = US\$150$$

A-half-month ash sales revenue:

$$US\$139,507/year \times \frac{1}{12} \times \frac{1}{2} = US\$5,810$$

Sub-total US$8,710

(3) Capital required total

(1) + (2) US$1,765,710

4.4 Production Cost

Annual production cost is as follows:

(a) Raw material cost (chemical) US$33,000

(b) Utility cost (fuel oil) US$ 1,760

(c) Labor cost

		US$
Factory manager	US$14,000 x 1	14,000
Engineer	US$ 8,000 x 3	24,000
Skilled worker	US$ 4,000 x 3	12,000
Unskilled worker	US$ 2,000 x 6	12,000
Odd-job man	US$ 500 x 9	4,500
	Sub-total	US$ 66,500

(d) Maintenance cost		US$ 31,500
(e) Depreciation cost		
(US$1,757,000 – US$140,000) x 0.06		US$ 97,020
US$140,000 x 0.03		US$ 4,200
	Sub-total	US$101,220
(f) Insurance cost		US$ 8,785
(g) Selling and administration expenses		US$ 12,730
(h) Interest		US$ 87,850
	Total for (a) to (h)	US$343,345

4.5 Profitability

When the power plant, which generates 600 kW electricity using husk as fuel, sales 530 kW x 24 hrs x 280 days energy and the ash of 346 kg/hr as the by-product, the annual sales revenue of the plant will be US$424,435.

The annual production cost being US$343,345, the annual profit will become US$81,090 which corresponds to 19.1% of the annual sales revenue.

The above calculation is for the initial year, and in and after the second year, the loan will be repaid. Hence, the interest payment burden will be alleviated, and profit will increase. Therefore, it can be said that the project has good profitability.

5. Others

(1) Collection of husk

It is advisable to construct a power plant adjacent to a rice mill. In case it is impossible to obtain enough quantity of husk from one mill, it needs to collect husk from nearby rice mills.

In case husk is transported by land, a truck may be used. If so, it is desirable to employ a truck with a high sidewall so that the loading capacity can be augmented. A 10-ton truck having a floor space of 10m x 2.3m and 2-meter high sidewall will be able to carry 4.6 tons of husk at a time.

(2) Advantages of a rice mill that receives electricity from the projected plant

In the developing countries, many rice mills have not so good power receiving condition, and meet with voltage drop and service interruption. This will cause the rice cleaning machine to stop and the rice quality will deteriorate, and time will be required for re-start of the machine, which will result in worsening the operation efficiency.

The power generated in the power plant surpasses the electricity required by a modernized rice mill, and the surplus power will make it possible to increase husk drier, parboil and rice-bran oil manufacturing facilities.

(3) Selection of machinery and equipment

It is important to select the machinery and equipment, they have various systems. In case the process steam is necessary, it needs to pay special attention.

In this brochure condensing turbine was adopted to increase the power output, and the whole steam is to be used for power generation. In selecting the machinery and equipment, consideration is given to the maintenance, life and productivity.

(4) Water

Water quality to be used will affect the life of a power plant. Of the water quality, attention must be paid to turbidity, hardness, pH, chlorine ion and iron ion. Particularly, the removal of chlorine ion will require expensive equipment.

Unless water quality and water amount are sufficient for turbine condenser, it needs to install a air cooling type condenser or a cooling tower.

(5) Products made from ash

It is desirable to construct a factory, which makes products from ash, near a power plant. In case of ash transportation is needed, vacuum car is utilized.

(6) Dust collector

The dust collector in this brochure is based on Japan's flue discharge criteria of less than 0.4 g/Nm^3. However, it is needed to select a dust collector that satisfies the environment condition of the country.

Project Planning for Small and Medium Scale Industries

No. 1 Rice Milling Plant and Rice Bran Oil Manufacturing Plant
No. 2 Plastic Woven Bag Manufacturing Plant
No. 3 Container Board Manufacturing Plant
No. 4 Plastic Blow Bottle Manufacturing Plant
No. 5 Concrete Block Manufacturing Plant
No. 6 Glassware Manufacturing Plant
No. 7 Galvanized Iron Sheet Manufacturing Plant
No. 8 Fishing Net Manufacturing Plant
No. 9 Ice Making, Refrigeration and Cold Storage Plant
No.10 Starch and Syrup Manufacturing Plant
No.11 Instant Noodle Manufacturing Plant
No.12 Surimi and Surimi-Based Food Manufacturing Plant
No.13 Polyethylene Shopping Bag Manufacturing Plant
No.14 Retreading Tire Manufacturing Plant
No.15 Husk Fired Thermal Power Plant

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