Demonstration of Upgraded Brown Coal (UBC®) Process by 600 tonnes/day Plant

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Utilization of low rank coal has been limited so far, due to its high moisture content, low calorific value and spontaneous combustibility. In Indonesia, more than half of the minable coal is low rank coal such as lignite or brown coal. Some lignite in Indonesia has the feature of low sulfur and low ash content. Therefore, it can be turned into an attractive fuel coal if it is upgraded using an economical dewatering method. Kobe Steel has been developing upgraded brown coal (UBC) technology since the early 1990s. Currently, a UBC demonstration plant project is underway in Indonesia, and operation of the plant has already commenced.

Introduction

Bituminous coal with a high calorific value is the fuel coal mainly used in Japan for the sake of efficiency in power generation, cost, and safety in logistics such as transportation and storage. In recent years, however, supplies of it have become tight on a global scale because of the economic growth of rising nations such as China and India. Low rank coal, including lignite, has a high moisture content, low calorific value, and spontaneously combusts, characteristics that make it difficult for Japanese consumers to utilize.

In Indonesia, a main producer of the coal imported by Japan, only 15% of the coal deposits consist of bituminous coal, while brown coal and subbituminous coal, both categorized as low rank coal, account for 58% and 27% respectively. The country has vast deposits of low rank coal with a low content of ash and sulfur. Upgrading (dewatering) low rank coal will enable the supplying of upgraded coal with a high calorific value and low ash and sulfur content, which is expected to secure a source of coal for consumers in Japan and to decrease the environmental burden of treating ash and sulfur.

Kobe Steel has been working on the technological development of upgrading low rank coal since the early 1990s. The process, called the upgraded brown coal (UBC) process, is based on the principle of "tempura (Japanese battered deep-fried food)" and efficiently removes the water contained in low rank coal in heated light oil.[1)] This technical development involves a pilot plant operation in Indonesia (production base capacity, 3 tonnes/day), whose operation has lasted for four years since FY 2001[1), 2)], and a demonstration project in the same country. The demonstration has been an ongoing project since 2006, subsidized by the Ministry of Economy, Trade and Industry (METI) and Japan Coal Energy Center (JCOAL). This paper introduces the outline of the project.

1. Process for dewatering low rank coal

1.1 Conventional process for dewatering low rank coal[3)]

Among conventional processes for dewatering low rank coal, the heating of low rank coal above the boiling point of water to vaporize fluid does not accompany thermal reforming at a high temperature. Thus, the process is characterized by having little of the thermal loss associated with thermal cracking and partial oxidation. Various dryers, such as steam tube dryers, are used for the process. However, the process has problems because the large latent heat of water vaporization increases its energy consumption and the product is spontaneously combustible. A process that can solve these issues would be more feasible.

1.2 Features of UBC process

The UBC process includes crushing low rank coal, dispersing the crushed coal in light oil containing a heavy oil such as asphalt, and dewatering the dispersion at a temperature of 130 to 160℃ under a pressure of 400 to 450 kPa. This process, whose conditions are rather mild, is expected to resolve the issues associated with the conventional processes for dewatering low rank coal. The following describes the features of the UBC process.

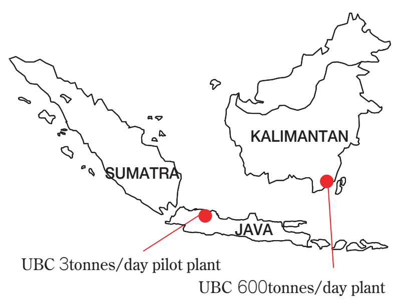
1) Essentially no chemical reaction occurs under the rather mild conditions of the dewatering, which minimizes the heat loss of the product and decreases the burden of waste water treatment.
2) The coal contains water that is vaporized into steam and separated from the coal during the dewatering in hot oil. The water steam is compressed and reused as a heat source, which makes it possible to decrease energy consumption.
3) The pores that remain in the low rank coal during the dewatering in oil absorb heavy oil such as

asphalt, which stabilizes the characteristics of the coal and prevents spontaneous combustion.

2. UBC demonstration project

2.1 Outline

This project is subsidized by the Ministry of Economy, Trade and Industry (METI) and Japan Coal Energy Center (JCOAL) and includes building a plant (production base capacity, 600 tonnes/day) at Satui, South Kalimantan, Indonesia, and running the plant to establish and demonstrate the technologies for commercialization during the period between FY 2006 and 2009. **Fig. 1** shows the outline and **Fig. 2** shows the schedule of the project.



Item	Detail
Project structure	By "JCOAL" jointed by Kobe Steel Ltd with the partnership of Arutmin & Bumi Resources. Indonesian government also supports the project.
Period	2006-2009
Budget	80M$
Scale	600tonnes/day (Product base), 1,000tonnes/day (Feed base)
Place	Satui area in South Kalimantan, Indonesia
Coal	Several lignites (4,000-5,000kcal/kg as received base)
Product evaluation	By several companies (Kobe Steel Ltd, Power companies)

Fig. 1 Outline of demonstration project

2.2 Purposes of demonstration

The demonstration purposes of the project are:

1) to evaluate the stability and reliability of the UBC process through long-term continuous operation and to obtain scale-up data for building a commercial plant
2) to evaluate the applicability of UBC by conducting a combustion experiment at a coal-fired power station using a large-scale sample of UBC transferred to Japan
3) to evaluate the economic feasibility of the process with accuracy improved by the experience of procuring the raw materials, producing, maintaining the plant and shipping the product

2.3 Process

As shown in **Fig. 3**, a UBC process comprises five steps: coal crushing, slurry dewatering, solid/liquid separation, oil recovery, and briquetting. **Fig. 4** is a full view of a UBC plant. The following outlines each step in the process.

1) Coal crushing

This step includes taking in raw coal, preliminarily rough-crushed to 50 mm or smaller in size, and crushing the raw coal to 5 mm or smaller using a grinding mill.

2) Slurry dewatering

This step includes mixing the crushed coal with light oil containing a heavy oil, such as asphalt, in a slurry preparation tank to prepare the coal slurry. This is followed by putting the coal slurry into a slurry dewatering tank, and

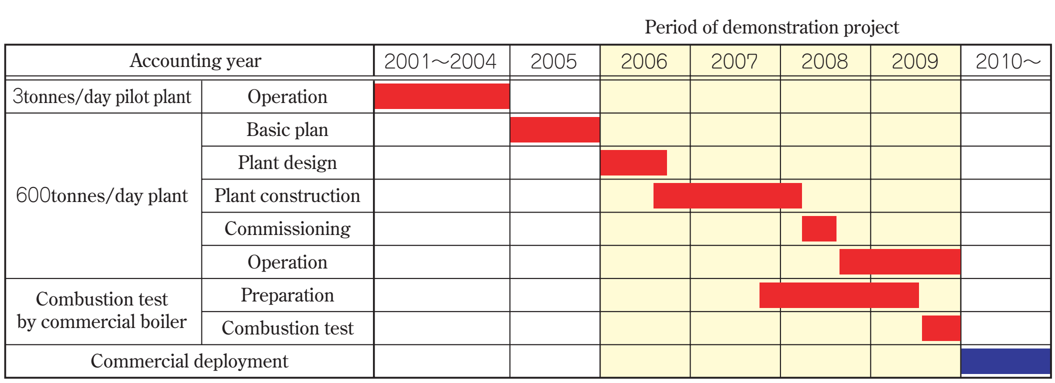


Fig. 2 Master schedule of UBC demonstration project

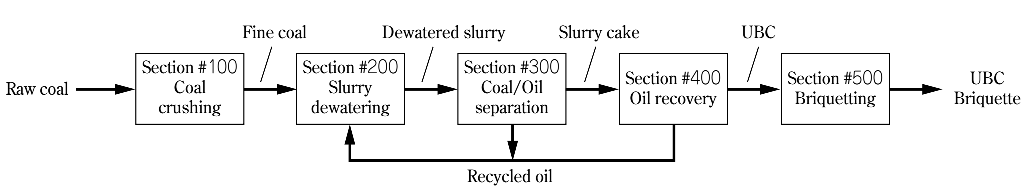


Fig. 3 Block flow diagram of UBC process

Fig. 4 Full view of UBC 600 tonnes/day plant

dewatering the slurry at a temperature from 130 to 160℃ and under a pressure of 400 to 450 kPa. The slurry dewatering generates mixed vapor (hereinafter referred to as "process vapor") consisting of water and light oil. The process vapor is compressed by a compressor to be reused as a heat source for coal slurry dewatering.

3) Solid/liquid separation
This step includes transferring the dewatered coal slurry to a continuous centrifugal separator (decanter) to separate slurry cake from the light oil. The separated light oil is returned to an oil re-circulating tank and is reused as the light oil for slurry preparation.

4) Oil recovery
This includes feeding the slurry cake, separated from liquid, to a dryer (steam tube dryer), vaporizing and drying the oil contained in the slurry cake through indirect heat exchange with high temperature steam to recover UBC in powder form (UBC powder). The oil vapor, contained in the circulating gas (mainly consisting of nitrogen) passing through the dryer, is condensed in a cooling tower and is separated from the nitrogen. The separated light oil is fed back to a circulating oil tank and is reused as the light oil for slurry preparation.

5) Briquetting
In this step, the UBC powder is fed into a briquetting machine of the double roll type. The apparatus comprises a pair of rolls, rotating in opposite directions, each roll having a roll surface provided with pockets, whereby the UBC powder is formed into the product, pea-coal-shaped briquettes.

2.4 Ancillary equipment

The plant has utility equipment for treating raw water, a boiler (steam generation), equipment for cooling water, equipment for producing nitrogen, for compressing air, and for treating wastewater. Also provided are a tank yard for storing light oil and heavy oil and fire-fighting equipment. An analysis lab and workshop, established in parallel, support the demonstration operation.

2.5 Items of technical evaluation

This project is aimed at technically evaluating the UBC process, as shown in **Fig. 5**.

1) Coal crushing
To be evaluated are the coal crushing performance of the crushing mill and its material characteristics (durability and wear resistance).

2) Slurry dewatering
To be demonstrated is the stability of the slurry re-circulating operation, exploiting slurry handling techniques for preventing slurry sedimentation and the plugging of the slurry-distribution pipes and the like, the techniques for which are based on know-how accumulated through the operation of the pilot plant and other activities. Also to be demonstrated is the stability of compressor operation achieved by controlling slurry entrainment in the process steam. The thermal recovery performance of the compressor is yet to be evaluated.

3) Solid/liquid separation
To be evaluated is solid/liquid separation performance in accordance with the operating conditions of the decanter (the supply volume of dewatered slurry, the revolution of the decanter, etc.).

4) Oil recovery
Items to be evaluated include oil recovery performance as it relates to the operating conditions of the dryer (steam pressure, UBC residence time, etc.) and pressure loss in the gas circulation system.

5) Briquetting
To be evaluated is the quality of the UBC briquettes in relation to the operating conditions of the briquetting machine (roll revolution, roll pressure, UBC temperature, etc.).

6) Combustion test
To be evaluated are the handing properties and combustibility of the UBC briquettes

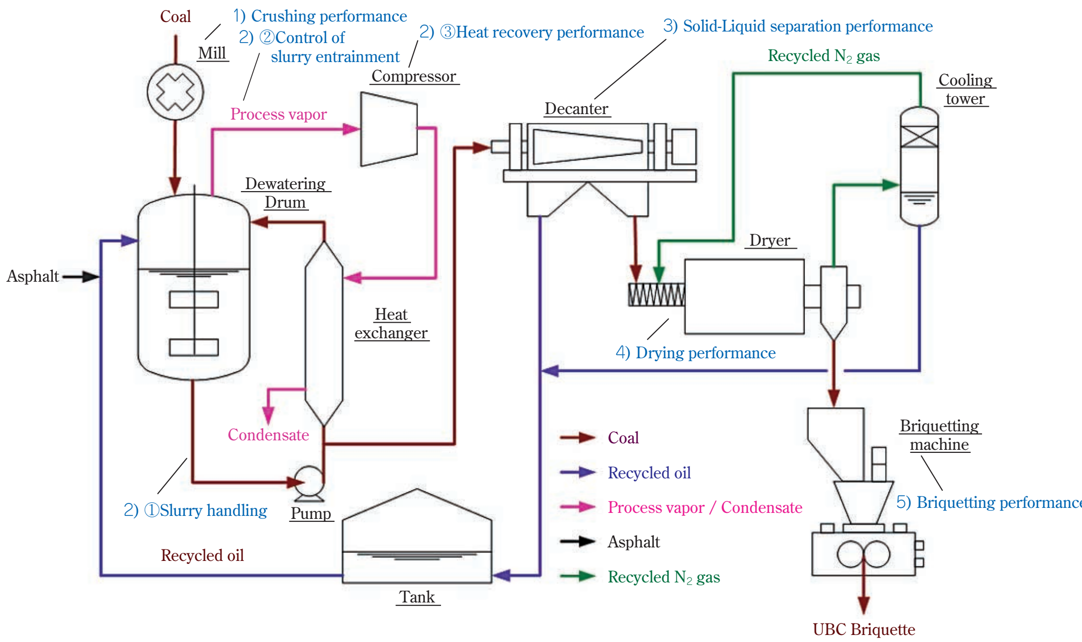


Fig. 5 Items of technical evaluation in UBC process

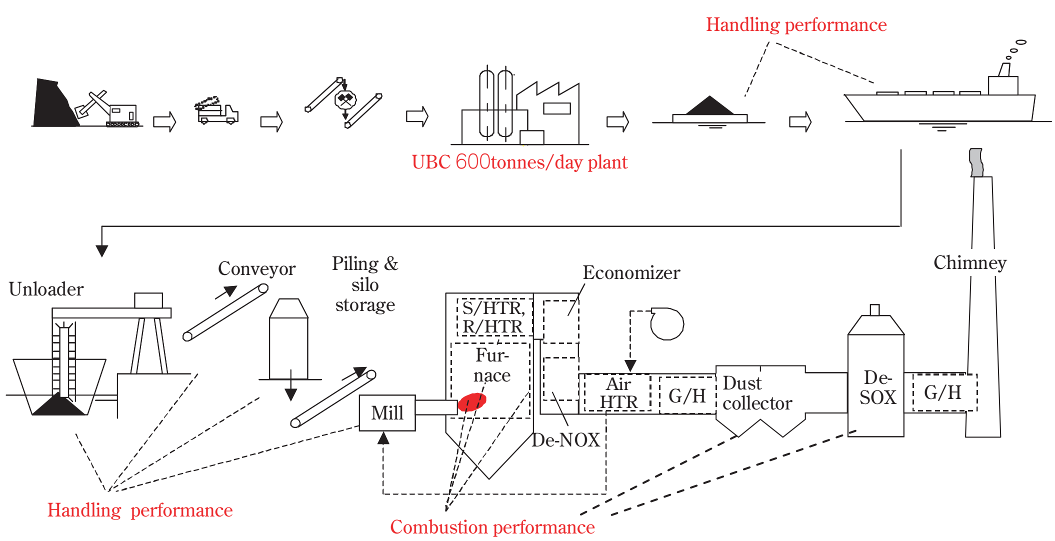


Fig. 6 Items of technical evaluation in combustion test

transferred to a coal-fired power plant in Japan. **Fig. 6** shows the items to be technically evaluated in the combustion test. The evaluation of the handing properties of UBC briquettes includes a drop test, pile test, crushing test (performed on coal mixed with bituminous coal), spontaneous combustibility test and hopper discharge test. The combustion performance to be evaluated includes the heat amount of the UBC, exhaust characteristics (NOx, SOx, residual coal, fly ash), furnace soiling (slagging and fouling), corrosion of the furnace interior and the exhaust treatment (dust-collection, desulfurization, gypsum quality, denitrification, trace element behavior, etc.).

2.6 Operational status of demonstration plant

After the completion of the construction of a 600 tonnes/day plant in July 2008, utility apparatuses were launched one after another, and the independent test operation of each system unit began. The continuous operation of the utility apparatuses began in August. Operation charged with coal, began in early November after a commissioning operation of the process equipment. This was followed by a continuous operation charged with coal, going through the entire process to verify the basic performance. **Fig. 7** shows the UBC briquettes produced by this plant. From here on, samples of UBC briquettes are to be produced for the combustion test, which will be followed by high-

Fig. 7 UBC briquette

load operation and long-term continuous operation. The following introduces the operation status of major process steps.

1) Slurry dewatering

One of the features of this process is to reuse process steam generated in the slurry dewatering tank. The steam is compressed by a compressor to be reused as a heat source for dewatering coal slurry. The introduction of a compressor increases the calorific value, exchangeable with the slurry, by a factor of twenty in comparison with the unit workload of the compressor, according to calculations made under ideal conditions, assuming the mechanical efficiency of the compressor to be 100%. Thus, there is a significant merit to this process in comparison with a case in which no heat is recovered from the process steam. The compressor, a Kobe Steel product, introduced this time, is designed for steam compression. In this process, however, it is supplied with steam (a mixture of water and light oil) from the process. Solid matter and/or liquid droplets, if caught in the compressor, can cause mechanical troubles such as abnormal vibrations and sounds. Thus, one of the key points of long-term continuous operation is to prevent slurry entrainment and condensation of the process steam.

Fig. 8 shows process flow diagrams, each incorporating a compressor. A first attempt was made with the compressor disconnected from the process steam line, as shown in Fig. 8 (a), in which steam was supplied to the compressor. The result confirmed that the compression performance follows the compressor's performance curve and that the vibration displacement falls in a range of 20μm or less as shown in **Table 1**, which indicates no mechanical problem.

The process steam was next supplied to the compressor as shown in Fig. 8 (b). Despite the difference in molecular weight between water vapor and the process steam (average molecular weight), compression performed almost as expected. The vibration displacement of the compressor body was almost the same as in the case of the operation with steam, verifying the stability of the operation.

The operation has been running smoothly without trouble such as slurry sedimentation and the plugging of pipes in the slurry circulation system.

2) Oil recovery

A steam tube dryer is a unit comprising a rotary cylinder laid at an inclination, the cylinder constituting a shell and a plurality of heating

Table 1 Operation conditions of compressor

Operation	Molecular weight	Pressure (MPa)		Flow rate	Vibration displacement
		Suction	Discharge	(Nm^3/h)	(μm)
Steam	18	0.41	0.60	11,000	10～20
Process Vapor	27	0.36	0.68	12,000	10～20

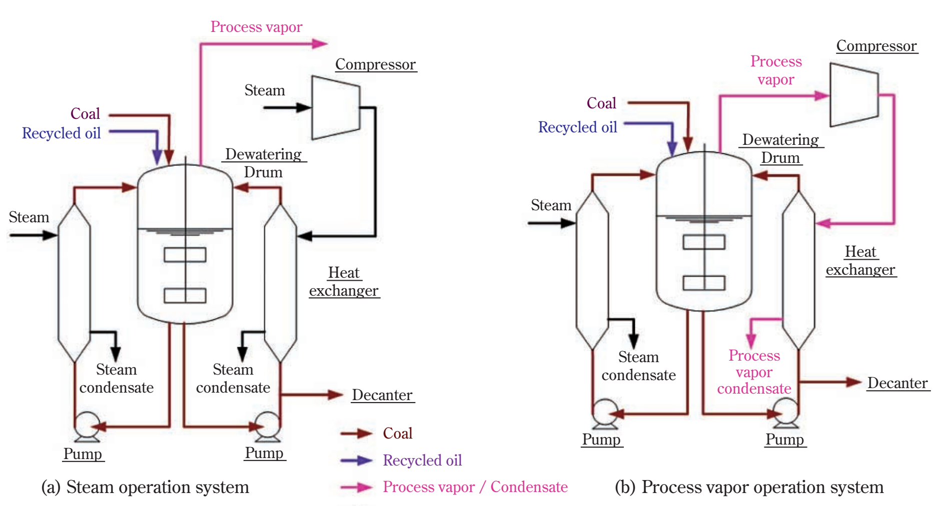


Fig. 8 Diagram of process flow around compressor

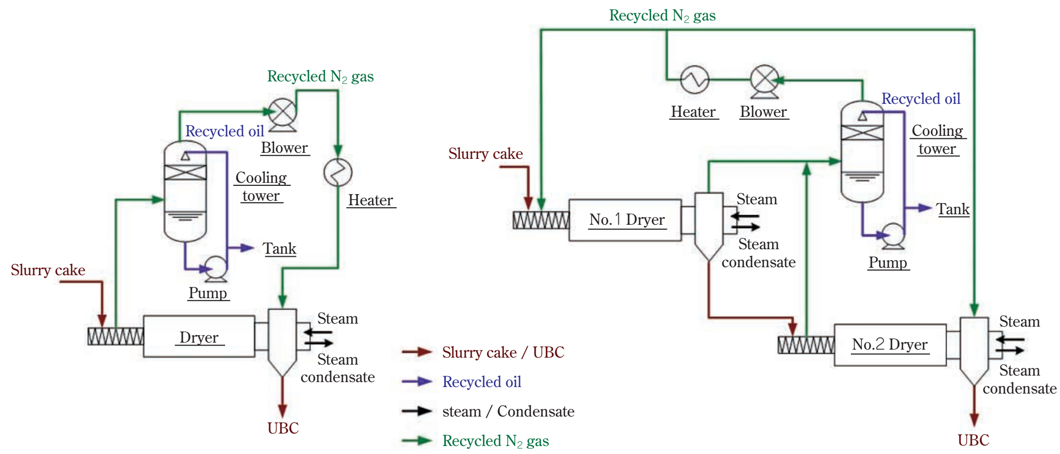


Fig. 9 Diagram of process flow around dryer

tubes housed in the shell of the cylinder, the tubes allowing the passage of a heating medium (e.g., steam), whereby the unit dries a subject moving in between the shell and the tubes. In order to discharge the volatile content transferred into the gas phase, a gas (nitrogen in this process) circulates on the shell side of the tubes. **Fig. 9** outlines the process flows, including the dryer(s). In a typical drying method using a steam tube dryer, circulating gas is caused to flow in a direction opposite to the flow of the subject to be dried as shown in Fig. 9(a), to ensure drying efficiency. In the pilot plant, which adopts this approach, however, a portion of the volatile oil component, contained in the circulating gas at a high temperature, was condensed by the slurry cake at a low temperature in the vicinity of the slurry cake inlet of the dryer as the gas passes out of the dryer, which increased the viscosity of the slurry cake. This caused the slurry cake to adhere to the steam tubes near said inlet of the dryer, deteriorating the dryer's heat transfer efficiency.

To resolve this issue, the demonstration plant has two steam tube dryers, disposed in series as shown in Fig. 9 (b), in which the circulating gas flows parallel with the flow of the slurry cake in the No. 1 dryer located in the upstream, while the gas flows in the direction opposing the flow of the slurry cake in the No. 2 dryer in the downstream. The following describes the features of this configuration[4].

a) At the inlet of the No. 1 dryer, the circulating gas with a low dew point suppresses the adhesion of slurry cake to the steam tube, despite the high oil content of the slurry cake.
b) At the outlet of the No. 2 dryer, the circulating gas with a low dew point is supplied in an opposite flow, increasing drying efficiency in the falling rate stage of drying.

Data, such as pressure loss, of the gas circulating system indicates that the operation has been stable so far, with neither obstruction caused by the slurry cake adhering to the steam tubes, nor a decrease in drying efficiency.

Conclusions

A plant with a capacity of 600 tonnes/year was constructed in Indonesia and has been running to demonstrate a process called the UBC process. In 2009, the basic performance of the entire process was verified through a continuous operation charged with coal. In 2010, samples of UBC briquettes are to be produced for a combustion test using a real combustor. This will be followed by loaded operation and long-term continuous operation, in accordance with the plan, to technically evaluate the stability and reliability of the UBC process, to obtain data for designing a scaled-up commercial plant, and to establish the quality and feasibility of the product as fuel.

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