SCOPE21 The Future of Cokemaking

(Super Coke Oven for Productivity and Environmental enhancement toward the 21st century)

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SUMMARY

Coke ovens in Japan have 29 years of service on the average and the supply of coke is foreseen to come to shortage at the early years of this century. Furthermore, the existing cokemaking process entails a lot of issues such as an effective use of coal resources, an adverse effect on environment. Thus, the Japan Iron and Steel Federation has launched an 9 years research program called SCOPE 21 in collaboration with the Center for Coal Utilization, Japan in 1994.

The program pursues the following targets;

1) To increase the ratio of using poor coking coal from 20% to 50%.
2) To treble productivity for reducing the construction costs.
3) To reduce NOx by 30% and to achieve no smoke and no dust.
4) To reduce the energy by 20% which contributes to reducing CO_2.

After two years of preliminary feasible study, the program has advanced to basic research and to a bench scale test. It is in a stage of the construction of a pilot plant. This report describes the outline of the program and the results obtained through the basic research and the bench scale plant tests.

Keywords: coal, coke, rapid heating, coke oven, fluidized bed, briqetting

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1. INTRODUCTION

Coke is an indispensable material to sustain blast furnace-based ironmaking which may still play the dominant role in the coming few decades. Coke ovens in Japan, however, have 29 years in the average working life and the supply of coke is foreseen to come to shortage because of the superannuation of the coke ovens at the early years of this century. Furthermore, the existing cokemaking process entails a lot of issues to be addressed such as an effective use of coal resources, an adverse effect on environment, and the like.

An innovative cokemaking process solving global issues of environmental protection and energy saving is strongly desired to be developed. Thus, the Japan Iron and Steel Federation JISF has launched an 9 years research program called SCOPE21(Super Coke Oven for Productivity and Environmental enhancement toward the 21st century) in collaboration with the Center for Coal Utilization, Japan(CCUJ) in 1994. This program has advanced to basic research and to a bench scale test. Now a pilot plant is under construction.

This report describes the outline of the program and the results obtained through basic research and the bench scale plant tests.[1)-2)]

2. OUTLINE OF THE SCOPE21 PROCESS

The SCOPE21 process is classified into three divisional processes according to the manufacturing flow of the existing cokemaking process, that is, the rapid heating of coal, the rapid carbonization of coal, and the refining of coke at a medium temperature, and it aims to pursue the function of each process to the utmost and to develop an innovative cokemaking process which is wholly harmonized.

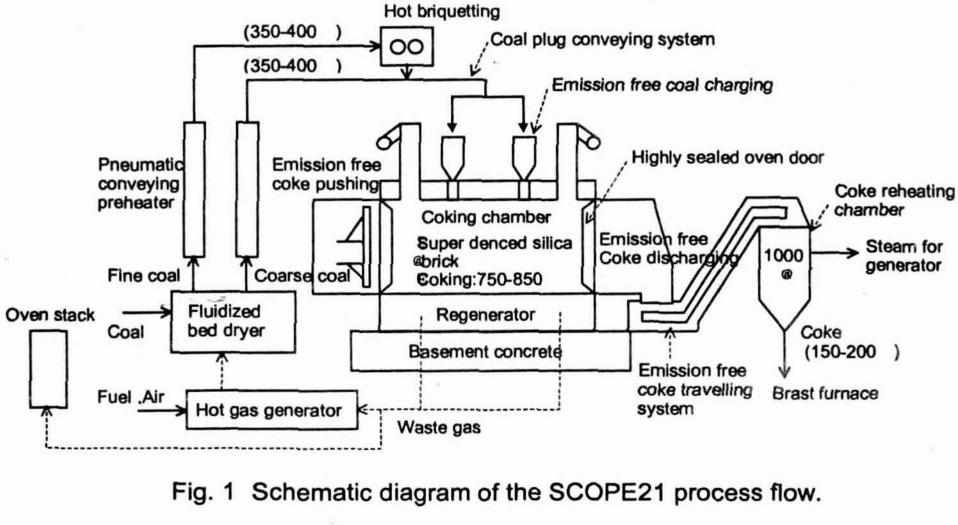


Fig. 1 Schematic diagram of the SCOPE21 process flow.

3. BASIC TECHNOLOGIES OF THE SCOPE21 PROCESS

3.1 Effective utilization of coal resources

Quality of coke could be improved by the effect of upgrading the coking property of coal through the rapid heating, together with the effect of increasing bulk density of charged coal due to drying and briquetting of its fine part. As shown in Figure 2, it is anticipated from the above effects that the effective use of poor coking coal, of which only 20 percent can be used in the conventional process, can be raised to as high as 50 percent.

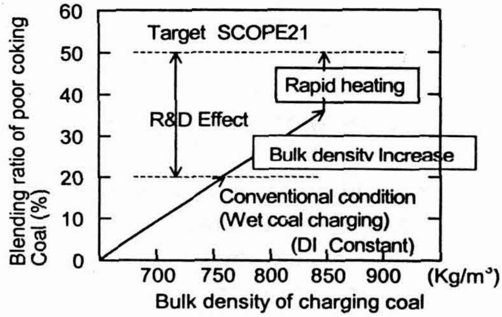


Fig. 2 Technologies to be developed and the expanded utilization of poor coking coal.

3.2 Technologies for high productivity cokemaking

Preheating the charging coal, employing the high heat conductive brick, and lowering the coke discharging temperature also have the effect of reducing cokemaking time. Figure 3 shows a schematic diagram of the heating time for cokemaking with the conventional process and with the SCOPE21. Gross coking time is usually about 18 hours in the conventional process. The SCOPE21 process consists of three stages to control the heating. Specifically, 350 to 400 in the coal pretreatment facility, 800 at the coke oven, and 1000 by reheating in CDQ. By this heating method it seems probable that productivity of the SCOPE21 process is as much as three times, compared to the conventional process.

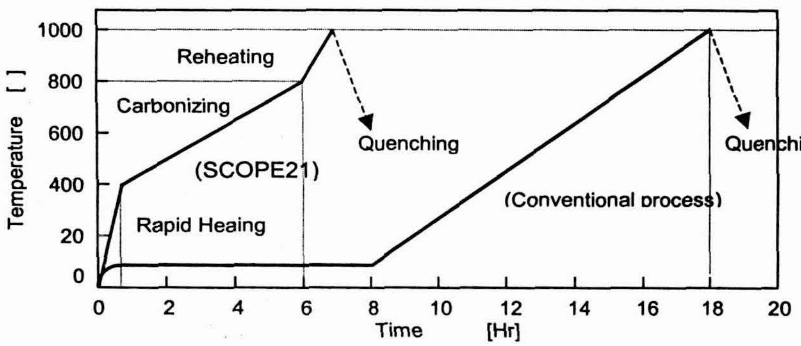


Fig. 3 Schematic diagram for comparing carbonizing temperatures in the new process and the conventional process.

3.3 Energy saving technologies

The aim is to decrease the heat quantity for carbonization by increasing the starting temperature of carbonization through preheating the coal at a high temperature and by decreasing the coke discharging temperature through carbonization at medium temperature. Further, energy saving is also aimed at, by recovering the latent heat of the generated gas during the carbonization and the exhausted waste gas from the stack.

3.4 Environmental conservation technologies

Environmental conservation will be improved by conveying the coal and coke in sealed structure, by preventing gas leakage from the coke oven and by reducing NOx (nitrogen oxides) by improving the heating system of the coke oven.

4. SUMMARY OF BASIC TEST RESULTS

4.1 Rapid heating test

Since there is a possibility that fine particle of coal would be overheated and adhere to the inner wall of the pneumatic preheater when it is heated rapidly, within the SCOPE21 process it is planned to install a fluidized bed dryer 'for separating the coal into coarse particle and fine particle before rapid heating.

For the coal rapid heating test, equipment of 90 kg per hour in scale was employed. With this test equipment, coal heated slowly (2 per minute) by fluidized bed dryer and the coal heated rapidly (10000 per minute) by a pneumatic preheater was carbonized in a test oven. The obtained coke was evaluated based on the JIS drum index of coke (DI150/15).

Table shows the characteristics of the tested coal and Table shows the testing conditions. As shown in Figure 5, the rapid heating increase the DI^{150}_{15} of coke, and the poor coking coal has a greater effect than the coking coal.

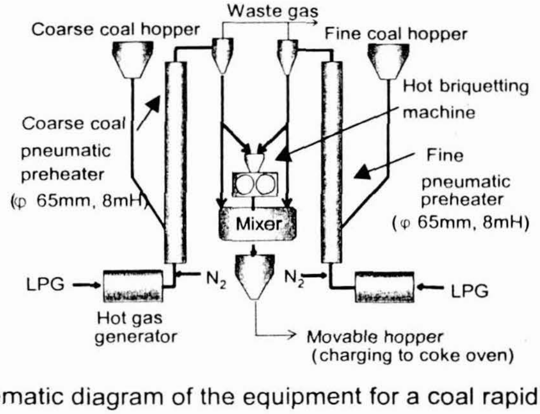


Fig.4 Schematic diagram of the equipment for a coal rapid heating test.

Table Characteristics of the tested coal

	Proximate analysis (%,dry)		Ultimate analysis (%,daf)					Fluidity index (LogMF)
	VM	Ash						
CoalA (Coking coal)	24.6	8.72	90.17	5.19	1.88	0.55	2.21	3.14
CoalB (Poor coking coal)	32.7	7.54	85.38	5.19	2.04	0.48	6.91	0.85

Table Testing conditions

	Treating method for coal heating
CASE	Non heating
CASE	Preheating to 200 in the fluidized bed, and briquetting the fine coal
CASE	Rapid heating both of the coal and coal to 380
CASE	Rapid heating only coal to 380
CASE	Rapid heating only coal to 380

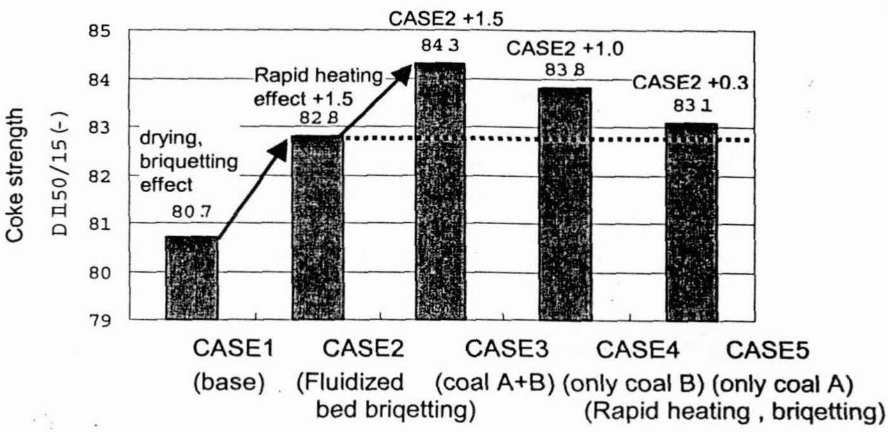


Fig. 5 Effects of improvements in the DI_{15}^{150} due to the rapid heating types.

4.2 Hot briquetting test

A double roll briquetting machine was employed for compacting of hot fine coal which is under 0.3mm. As shown in Figure 6, it was confirmed that the hot fine coal, of which poor coking coal content is 50 percent, could be molded without a binder. And it was found that the briquette strength was better when the coal temperature was higher.

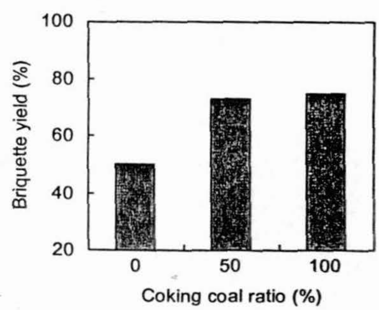


Fig. 6 Relationship between coking coal ratio

4.3 Plug flow conveying test

Although pipe transportation method of hot coal was developed in the past, it was uneconomical because of the large amount of carrier gas and electric power. In the SCOPE21 process, plug flow conveying system has been developed to transport preheated coal at a high density and at a low speed with a smaller amount of carrier gas. Figure 7 shows the test result obtained with an ordinary temperature coal (moisture content 1 2 percent). A transporting rate over 50 tons per hour has been attained in the case of 45°pipe By means of this method, it might be possible to charge the preheated coal into the coke oven cleanly and safely.

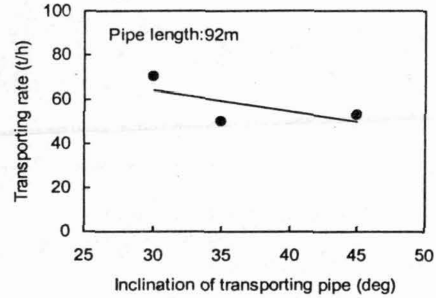


Fig. 7 *Influence of pipe inclination on transporting rate.*

5. TESTS ON THE BENCH SCALE PLANT

The bench scale plant shown in Photo. 1 is the combined one of elemental technologies of coal pre-treating processes, that is, drying/classifying rapid heating hot briquetting conveying of high temperature coal, which are the important processes of SCOPE21. The object of those apparatus is to confirm their functions and to collect the scale-up data for designing a pilot plant.

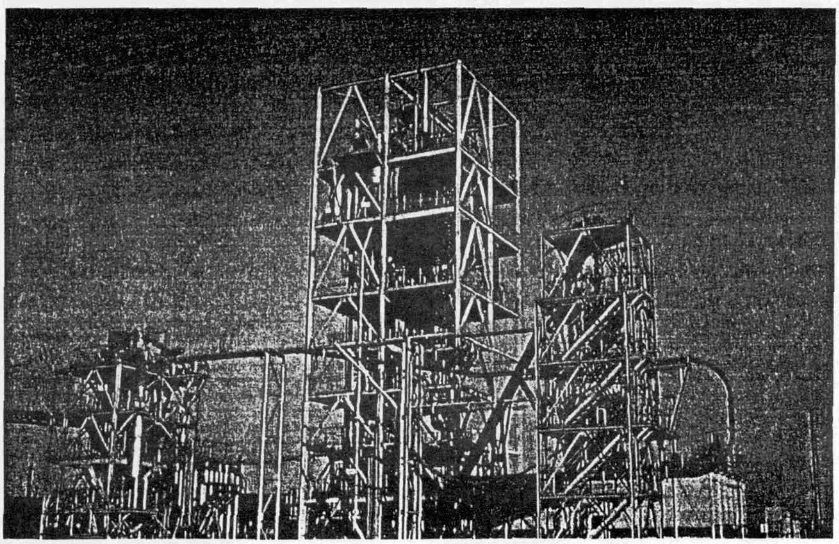


Photo. 1 Bench scale test plant

5.1 Outline of the bench scale plant

The main specifications of the equipment for the bench scale test plant are shown in Table and the process flows of the plant in Figure 8.

Further, the assumed commercial plant is arranged on the assumption that it will be capable of producing the coke of approximately 4,000 tons per day, which is necessary to produce the pig iron of 10,000 tons per day from a blast furnace with a capacity of approx. 4,000 cubic meters.

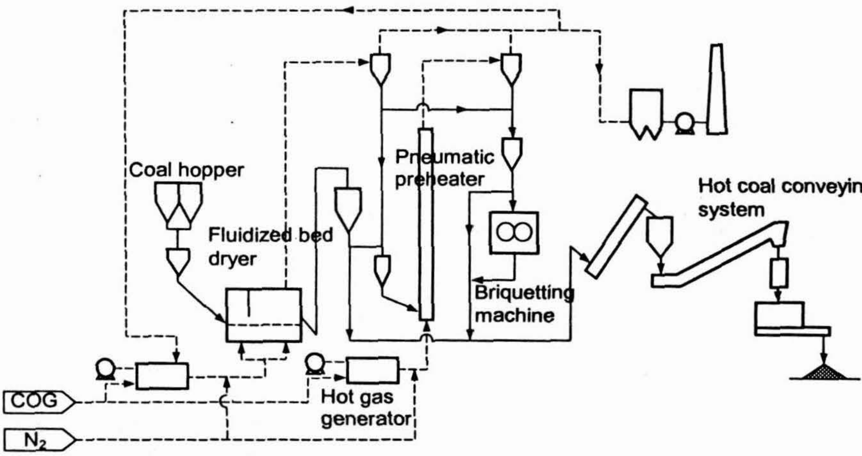


Fig. 8 Process flows of the equipment for the bench scale plant.

Table Outline of the equipment for the bench scale test plant

Main equipment	Basic specifications
Fluidized bed dryer type unit	Coal throughput 0.6t-dry/h Classifying size 0.3mm Coal heating temperature 300 Fluidized bed size W 0.4m×L1.1m×H 5.6m Hot gas temperature 400
Pneumatic preheater type unit	Coal throughput 0.18t-dry/h (for both coarse coal and fine coal) Coal heating temperature 380 Preheater size φ100A×H 25m Hot gas 500Nm^3/h Hot gas temperature 450
Hot briquetting machine unit	Briquetting capacity 2.4t/h Double rolled briquetting machine φ1200mm×W 87mm Mold Massec type 18cc

Hot coal conveying system unit	Chain conveying and Plug conveying combined system Plug conveying system φ200A×11.9 degree inclined to horizontal direction conveying gas nitrogen

5.2 Drying and classifying test by fluidized bed dryer

The drying and classifying of coal tests were carried out. Property of heating in the fluidized bed is shown in Figure 9. It was confirmed that the coarse coal could be heated to 300 and there was no problem on the coal quality. This result corresponded with a calculated result by means of heat transfer model. Figure 10 shows a classifying property of coal. It was confirmed that the classifying point could be controlled by the heating gas velocity at the freeboard. This means that content of the fine coal under 0.3mm, which causes carrying-over at coal charging into coke oven, in the coarse coal is able to be controlled

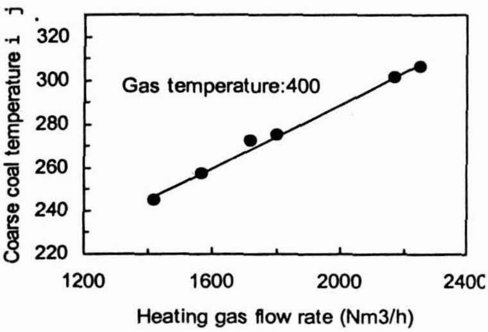


Fig.9 Relationship between heating gas flow rate and coarse coal temperature.

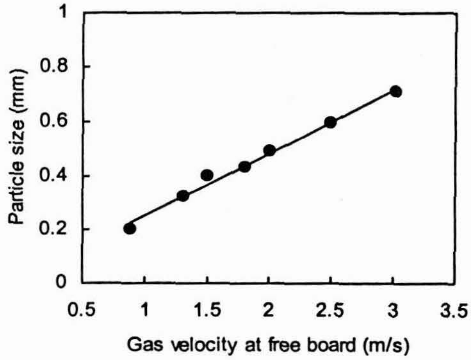


Fig.10 Relationship between gas velocity at free board and particle size at a classifying point.

5.3 Rapid heating test by the pneumatic preheater

Property and performance tests of the pneumatic preheater on rapid heating of the fine and coarse coal were carried out. Figure 11 shows the property of rapid heating by the pneumatic preheater. It was found that the fine coal could be heated to 380 without a problem on the coal quality. On the other hand, the coarse coal temperature had to be under 350 from a restriction of the heating gas velocity and the heating gas temperature, because it was also found that a higher

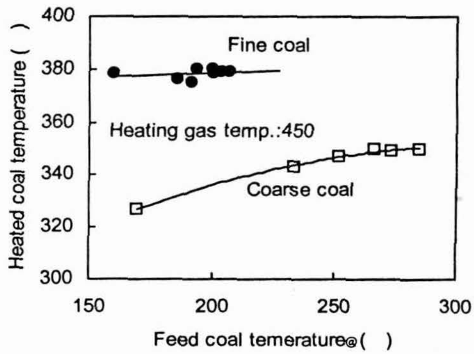


Fig.11 Relationship between feed coal temperature and heated coal

gas velocity caused mechanical breakage of coal and that a higher gas temperature caused debasement of coal quality.

5.4 Hot briquetting test

A double roll briquetting machine, which is the same type of basic test, was applied. Since a scaling-up theory for the roll diameter of the briquetting machine has not been established, a roll diameter was set at 1200mm supposing a commercial plant. The poor coking coal content of raw coal was 50 percent in every case. Figure 12 shows a relationship between rotation speed of the roll and briquette yield with no binder. It was confirmed that the briquette yield was over 80 percent, which is a target value. Figure 13 shows a relationship between the briquette strength (drum index) and the classifying point of raw coal in fluidized bed dryer. It was found that the briquette strength was affected by the classifying point and by the brand of coal.

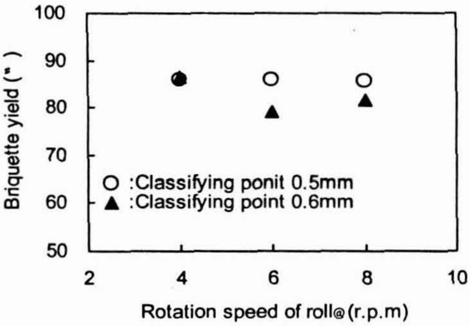


Fig.12 Relationship between rotation speed of roll

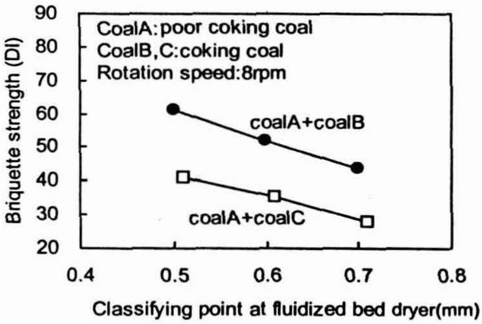


Fig.13 Influence of coal particle size and coal brand on briquette strength.

5.5 Transporting test of the hot coal

Both a chain conveyer and a plug flow conveyer were adopted for the transporting of the hot coal which was a mixture of the coarse coal and the briquette. Since the method of plug flow conveying for the hot coal had not been established, property and performance test of the plug flow conveyer was carried out. As shown in Figure 14, the transporting rate could be controlled by the pressure of the feed vessel. It was confirmed that the transporting rate, of which the target is 240t/h, was enough for the commercial plant. A relationship between the pressure of the feed vessel and the solid-gas ratio is shown in Figure 15. It shows that by heightening of the pressure, the solid-gas ratio raised and that the solid-gas ratio could be over 100kg-coal/kg-N_2 which is the target value. Concerning with the chain conveyer, it was confirmed that

heatproof ability was enough for long term running.
Mentioned above, the each basic technologies were evaluated and the specifications of the pilot plant were determined from the data obtained by the bench scale test.

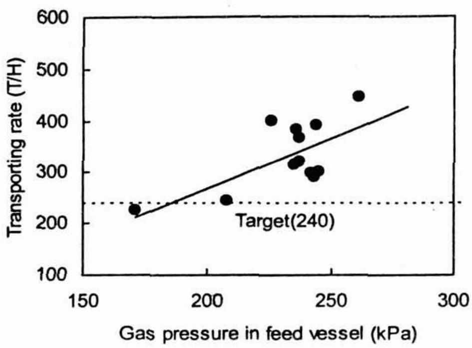


Fig.14 Relationship between gas pressure in feed vessel and transporting rate.

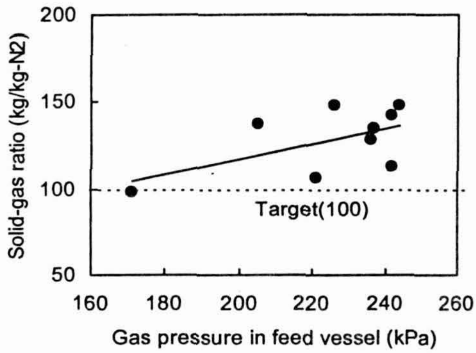


Fig.15 Relationship between gas pressure in feed and solid-gas ratio.

6. TESTS ON THE HEATING SYSTEM OF THE COKE OVEN

With regard to the heating system of the commercial coke oven for the next generation, the works of developing a new heating system for high productivity, uniform heating and low NOx were carried out.

The size of the heating chamber is that of the expected commercial plant as shown in Figure 16. Its chamber wall is made of super densed silica brick characterized by high heat conduction for attaining high cokemaking productivity. (see Table)

As shown in Figure 17, low NOx combustion have been attained.

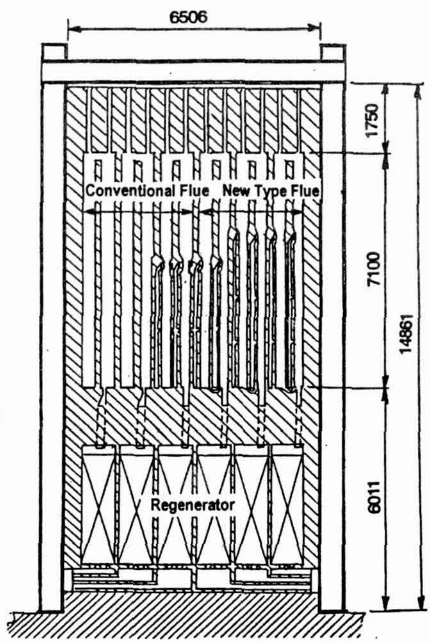
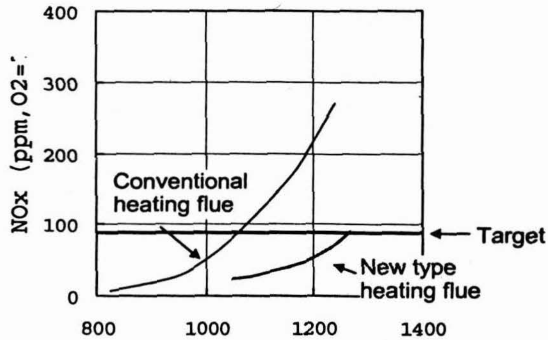


Table Characteristics of the super densed silica brick (SDB) compared to the conventional densed silica brick DE

	Temp. ( )	Heat conductivity (kcal/mhk)	Porosity ( )

SDB	750	2.1	9.7
	1000	2.3	
	1250	2.5	
DB	1000	1.7 2.0	18.6

Fig.16 Schematic drawing of the heating chamber for combustion testing.



Inner surface temperature of the heating flue ( )

Fig.17 Relationship between the flue temperature and NOx

7. CONSTRUCTION OF THE PILOT PLANT

The main specifications of the pilot plant are shown in Table . The specifications of the coal pretreating unit are based on the results of the bench scale test.

The specifications of the coke oven are determined by the results obtained from the above mentioned tests. The dimension of the coke oven has been established as follows; the chamber is 8m in length which is almost half the length of the expected commercial plant, its height is 7.5m and its width is 435/465mm. Both the height and the width are almost the same size as these of the commercial plant. Since the coke reheatment test has been carried out using an existing CDQ, the coke upgrading facilities are excepted from the pilot plant.

Table . Main specifications of the pilot plant

Main equipment	Basic specifications
Fluidized bed dryer	Coal throughput : 6.0dry-t/h Fluidized bed size : W0.5m×L7m×H5.5m
Pneumatic preheater	Coal throughput : 6.0dry-t/h(coarse), 2.4dryt/h(fine) Tower size :φ0.77m×H25m
Hot briquetting machine	Type : double roll, Mold : Massec type (18cc) Capacity : 2.4t/h Roll size :φ1200mm×W87mm

Hot coal conveying system	Chain conveyer Capacity : 8t/h, Inclination angle : 45° Plug conveying system Capacity : 350t/h, Pipe size :φ200A, Pipe length:29m
Coke oven	Height : 7.5m, Length : 8m, Width : 450mm Brick : super densed silica, Heat conductivity : 2.3kcal/mhk

8. CONCLUSION

In the SCOPE21 project, the basic technologies have been already completed. The construction of pilot plant has started from 1999.

The pilot plant test will be carried out in 2002 to confirm the aims of the R&D and to obtain data for designing the commercial plant constructed in the next generation.

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