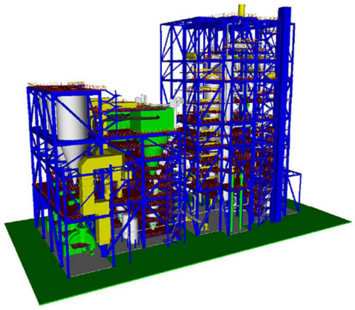
Development of Coal Gasification System for Producing Chemical Synthesis Source Gas



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Mitsubishi Heavy Industries, Ltd. (MHI) has developed its own air-blown gasification technology and has been smoothly operating an IGCC demonstration plant. On the basis of this 2-stage, 2-chamber gasification method, MHI continues to develop an oxygen-blown gasifier system for chemical synthesis by applying the basic gasifier structure of the IGCC demonstration plant to that of the oxygen-blown gasifier. The current status of oxygen-blown gasifier development for chemical synthesis is presented in this paper.

1. Introduction

In view of energy issues, since coal reserves are abundant all over the world and the price of coal is stable, the effective and clean use of coal should be promoted as an alternative to the heavy dependence on natural gas and oil. With this in mind, coal-gasification technologies which produce liquefied fuels from solid coal as feed materials or synthesize chemical products are spotlighted. For liquefied fuels and chemical products, a reduction in the amount of nitrogen (N_2) gas, which is an inert component in syngas generated in a downstream process, is desired. Therefore, an oxygen-blown method is the mainly applied for chemical synthesis. MHI has already developed its own air-blown gasification technology for power generation and has been smoothly operating an IGCC demonstration plant. We are now committed to developing a commercial IGCC plant with the world's highest efficiency using an air-blown gasification method. On the basis of this 2-stage, 2-chamber entrained bed gasification method, MHI has been continuing to develop an oxygen-blown gasifier system for chemical synthesis by applying the basic gasifier structure of the IGCC demonstration plant to that of the oxygen-blown gasifier.

2. Features of Mitsubishi oxygen-blown coal gasifier

2.1 Principle of Mitsubishi 2-stage, 2-chamber entrained bed gasifier

Figure 1 shows the principle of the Mitsubishi 2-stage, 2-chamber entrained bed gasifier. This gasifier includes a combustor (combustion section), where high temperature combustion with stable discharge of melting ash is conducted, as well as a reductor, where the gasification reaction is conducted with the high temperature gas from the combustor. By separating functions, the gas temperature required for coal ash melting and the stable discharge of slag (even in the case of an air-blown system), as well as the syngas heating value resulting in stable combustion in a gas turbine in the case of power generation, are all compatible. Moreover, melting ash particles contained in the syngas can be effectively quenched by the endothermic reaction of coal gasification, so that a quenching system using a large radiant exchanger or low temperature syngas is not required. It provides the advantage of being able to manufacture the gasifier compactly. The sensible heat of the syngas from the gasifier and char containing unreacted carbon can be cooled to the predetermined temperature and recovered as high pressure steam by exchangers in the downstream of the gasifier.

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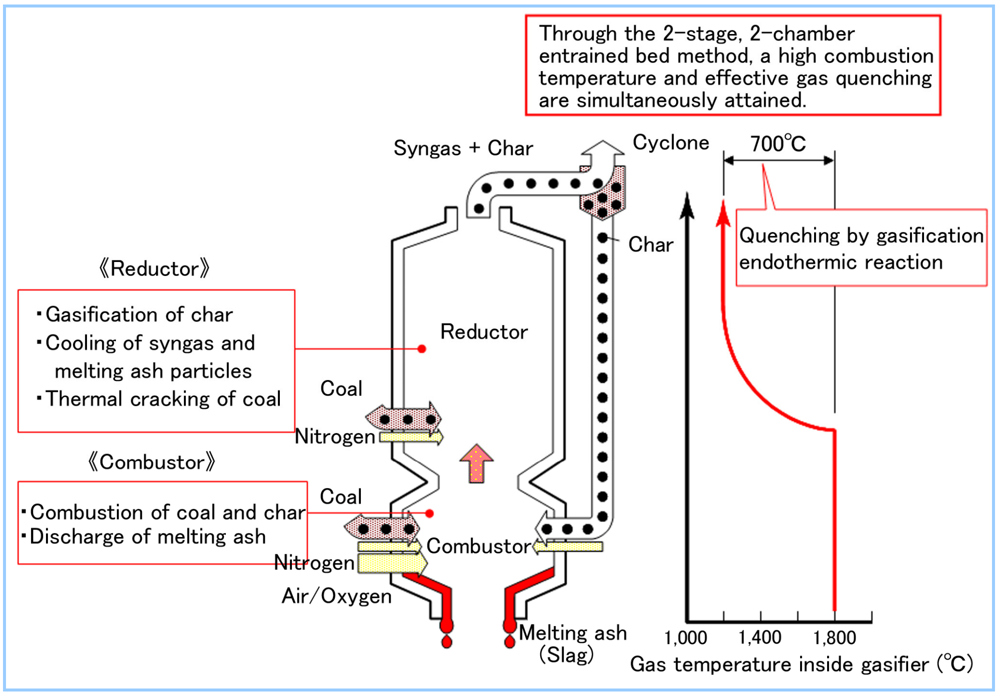

Figure 1 Principle of Mitsubishi 2-stage, 2-chamber entrained bed gasifier

2.2 Feature of Mitsubishi oxygen-blown coal gasifier

On the basis of our differentiated air-blown coal gasification technology as stated above, we began to develop an oxygen-blown coal gasifier, aiming to apply it to chemical synthesis such as CTL (Coal to Liquid), DME, SNG and ammonia, etc.

The development concepts are: (1) to minimize the development items associated with oxygen-blown technologies, with maximum sharing of the construction, equipment and component technologies of the air-blown gasifier, which has already been developed and verified, and (2) to develop a commercial plant by making the best use of the findings from the IGCC demonstration plant.

Figure 2 shows the features of the Mitsubishi oxygen-blown gasifier. By applying the basic design criteria of the Mitsubishi 2-stage, 2-chamber entrained bed gasifier to the oxygen-blown gasifier, the structure of the oxygen-blown gasifier may be similar to that of the IGCC demonstration plant. Although the change of the oxidizing agent from air to oxygen affects the flow characteristics, heat transfer and reaction conditions inside gasifier, an appropriate risk study was conducted through component research, combustion simulation and verification of the test equipment.

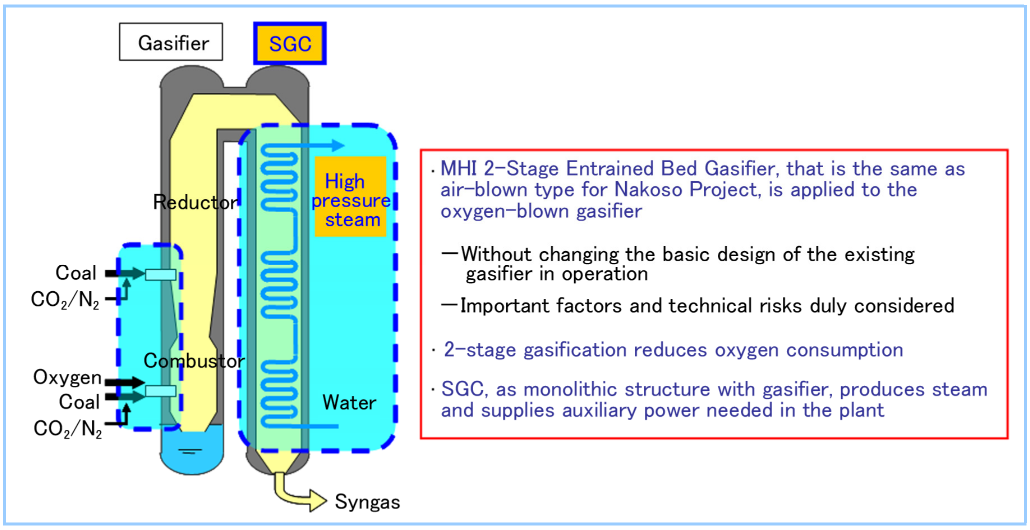

Figure 2 Features of Mitsubishi oxygen-blown gasifier

Since the dry-feed method shows low latent heat loss of water compared with slurry feed method, dry feed is adopted in the air-blown gasifier. By combining the dry-feed method with the 2-stage, 2-chamber entrained bed method, the Mitsubishi oxygen-blown coal gasifier can reduce oxygen consumption by 15-25% compared with the oxygen-blown gasifiers of other companies as shown in **Figure 3** and can contribute to the power reduction of oxygen-production units, realizing high cold-gas efficiency.

The sensible heat of the syngas and char from the SGC (Syn Gas Cooler) may be recovered as steam for other uses, so that it may be used in a wide range of steam conditions in response to user needs.

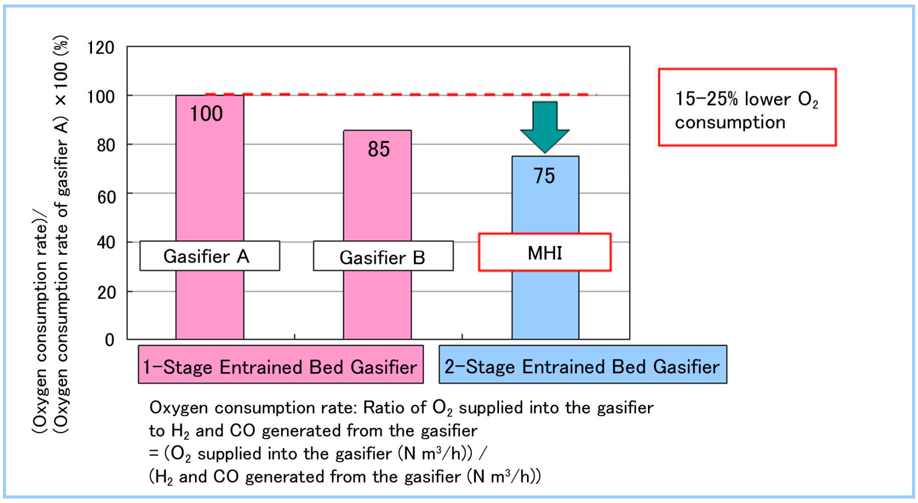

Figure 3　Comparison of oxygen consumption rate

3. Coal gasification test results

3.1 Coal gasification test results

In order to verify the application feasibility of the oxygen-blown gasifier, a coal-gasification test was planned using our existing coal-gasification testing facilities. Prior to the oxygen-blown gasification test, only minor changes were made in the utility system of the testing facilities – which had been used as air-blown gasification testing facilities – and were used without modifying the gasifier itself.

After the coal feeding rate for the testing gasifier was increased to the maximum level of the gasifier under oxygen-blown conditions, while stable slag discharge from the bottom of the gasifier was checked, the amount of syngas for stable gasification, the syngas property and other necessary data was examined. As a result, it was confirmed from the above test data that continuous operation will be feasible. In addition, internal inspection after completion of the tests proved that the interior of the combustor was in a sound condition. This means that our air-blown gasifier design may be applicable to the oxygen-blown gasifier design without major equipment modifications. The test results are shown in **Figure 4** and the slag discharge conditions are shown in **Figure 5**.

■Operation pressure	1 MPa
■Coal	
Ash	28wt%
Moisture	18wt%
■Oxidizing agent	Oxygen
■Syngas property	
CO	48vol%
H_2	22vol%
HHV (dry)	9.6 MJ/m^{3}N
	(2,300 kcal/ m^{3}N)

Figure 4　Test results of oxygen-blown gasification test in MHI testing facilities

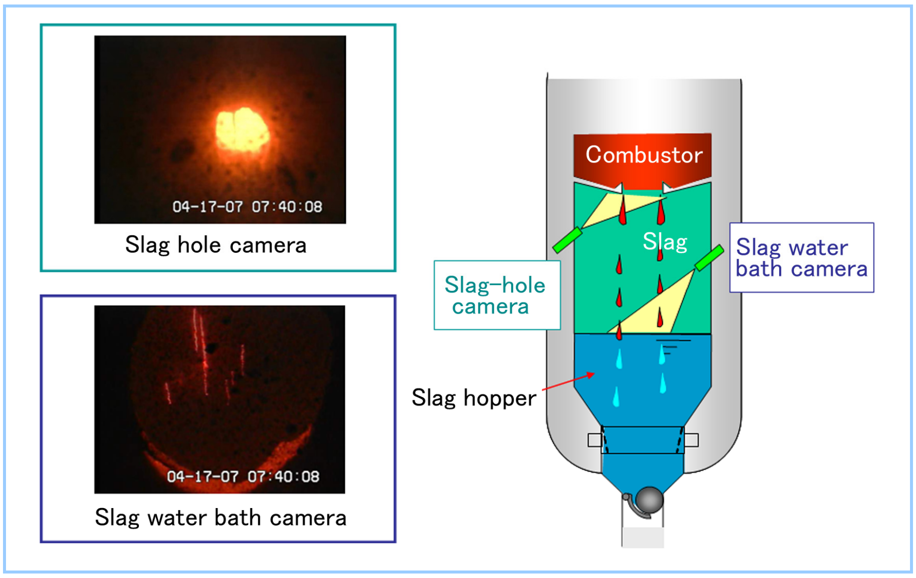

Figure 5 Slag discharge conditions during oxygen-blown gasification test

3.2 Commercial plant plan

In developing a commercial plant, it is common to proceed with due consideration of scale-up risk, from pilot scale to demonstration plant. As the structure of air-blown gasification was proven to be applied to that of oxygen-blown gasification, as stated above, it was confirmed that the commercial gasification plant could be implemented by reflecting the newly developed components. This was confirmed in these tests.

Figure 6 shows the road map for the commercial development of the oxygen-blown gasifier plant. **Table 1** shows an example of the plans of the commercial plant.

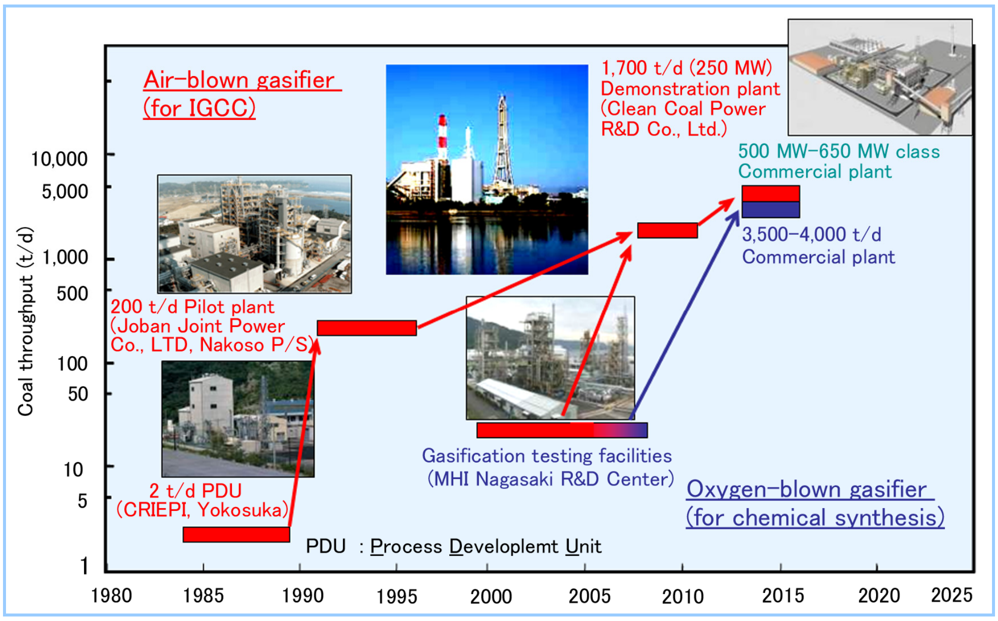

Figure 6 Road map for commercial development of oxygen-blown gasifier plant

Table 1 Commercial oxygen-blown gasifier plant

Coal throughput (as received)	3,500-4,000 t/d
Operation pressure	2.8-4.0 MPa (changeable by process request)
Oxidizing agent	Oxygen
Amount of syngas	270-330 t/h
Gross calorific value of syngas	2,500 kcal/Nm^3-dry
H_2/CO ratio	0.35 (- 0.6 at steam injection)
Gasifier SGC outlet high pressure steam conditions (example)	160-190 t/h 13 Mpa 430°C

4. Application of low-grade coal

As shown in **Figure 7**, low-grade coal such as brown coal and sub-bituminous coal, which is very common in Australia, Indonesia, the U.S., Europe and China, etc., accounts for about 50% of recoverable coal reserves. If this low-grade coal is put to effective use, the energy supply is expected to stabilize on a global basis.

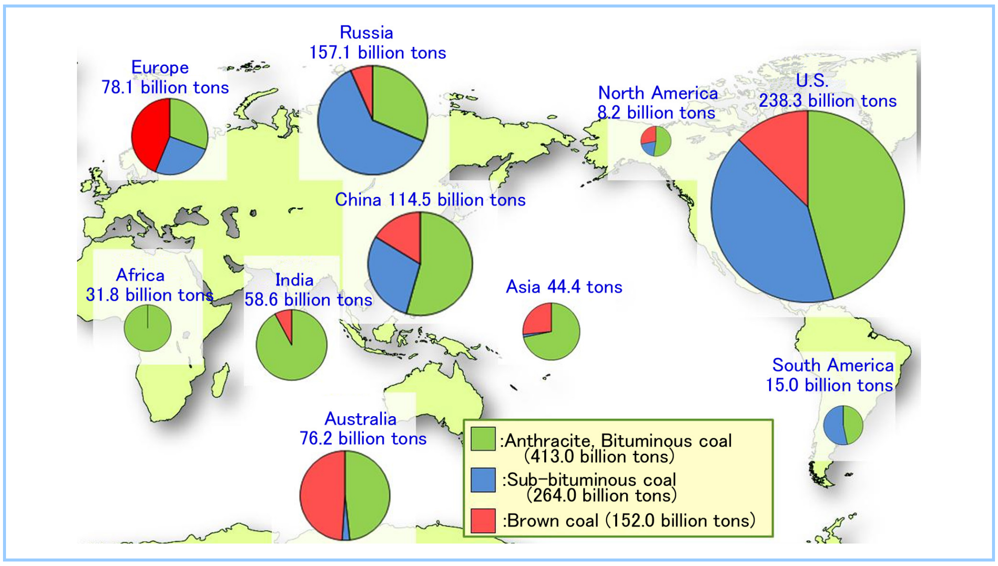

Figure 7 Global distribution of coal resources

Brown coal, a low-grade coal, can have moisture content in excess of 50%. Due to the latent heat loss caused by the moisture content in the coal, the efficiency of the power generation plant can be as low as about 30% and the CO_2 emissions rate as high as 1.2-1.6 kg-CO_2/kWh (about 1.5-2 times that of bituminous coal). This is a major challenge to be overcome in making efficient use of low-grade coal.

As a national subsidy project from fiscal 2010, MHI began to newly develop a pre-drying system that can dry high moisture-content coal with high efficiency by effectively recovering latent heat; that is, the heat associated with the vaporization of the water contained in coal.

After completion of the newly developed pre-drying system in this project, if brown coal is placed in the upstream of a boiler in a conventional brown-coal fired plant, the efficiency of the power generation may be greatly improved. To promote the effective use of brown coal, it is favorably applied to IGCC.

In a conventional thermal power plant, when low-grade coal such as brown coal, etc., is used, slagging is likely to occur compared with high-grade coal because the ash-melting temperature of the coal is generally lower. Therefore, the body structure of the boiler must be large to avoid problems, resulting in an economic disadvantage. In a coal gasifier, on the other hand, because the ash is drained in a melting condition, the structure of the gasifier even in the case of low-grade coal is almost equal compared with high-grade coal as shown in **Figure 8**. This means that the economies of scale in the case of low-grade coal compared with high-grade coal are also equal.

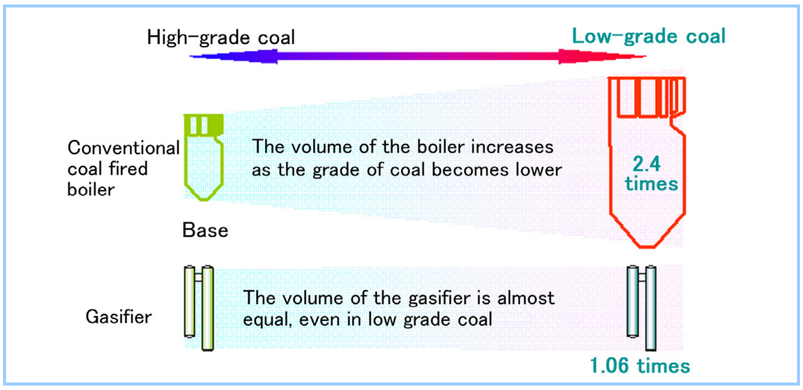

Figure 8 Comparison between brown-coal-fired boiler and gasifier

In addition, the technology of this pre-drying system can be applied to chemical synthesis. For example, given that synthesis fuels are produced by the combination of a brown-coal pre-drying system and oxygen-blown gasifier in brown-coal production regions, the production of highly value-added fuels, i.e., from low-grade coal to clean energy fuels, may contribute to the energy security of our country as new fuel sources.

5. Conclusion

From the viewpoint of the effective utilization of energy and CO_2 emissions reduction associated with global warming, coal-utilization technologies including low-grade coal will be of greater importance in the future.

MHI has developed an oxygen-blown gasifier for chemical synthesis and is now committed to developing a commercial gasifier plant. With the highest level of oxygen-blown gasifier technologies, along with air-blown technologies established for power generation, we will do our best for an effective response to customer needs and to make a contribution toward energy and global environmental issues.

Reference

1. Hashimoto, T. et al., Latest Technology of Clean Coal Power Production and CO_2 Recovery, Gas Turbine Society of Japan Vol. 38 No. 5 (2010)