
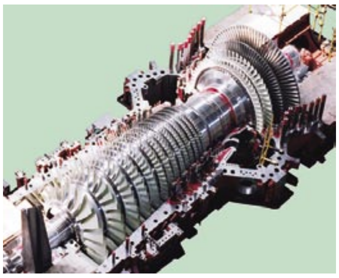

Approach to Highly Efficient Power Generation

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With elaborate countermeasures against global warming becoming a major issue, highly efficient thermal power plants with huge CO_2 emissions are an important problem calling for an immediate solution. This paper outlines an approach toward highly efficient, super critical-pressure, coal-fired boiler plants, IGCC and GTCC, capable of effective utilization of coal and natural gas, the main energy sources for thermal power.

1. Introduction

With elaborate countermeasures against global warming getting important, the reduction of CO_2 emissions from thermal power plants using fossil fuels is strongly demanded. The industrial sector, including power plants, like the transportation and civilian sectors, consumes a huge amount of fossil energy, equivalent to about one third of the world's total fossil energy consumption. It is estimated that the total value of power generation will increase continuously for the next 20 - 30 years, keeping that ratio intact. Highly efficient thermal power plants are an extremely important issue as countermeasure against CO_2 emissions.

As the increase in world energy demand causes an increase in CO_2 emissions, the countermeasures against CO_2 emissions always involve the problem of cost performance. The adequate technical verification of highly efficient power plants may prove an excellent and effective means in terms of the general cost (economic) performance in spite of its initial cost. With the present and future world power generation as a background, this paper outlines the approach to highly efficient coal and natural-gas firing plants, which are the main thermal power plants.

2. Change in power generation by thermal power plants

(1) Change in fuel power generation

Figure 1 shows the change in fuel power generation[1] of the world. Power generation is increasing around the world and will increase further. It is considered that natural gas thermal power generation will have the highest increase rate (4.2%) until 2030 followed by coal thermal power generation (2.6%). These two are selected for environmental performance (CO_2 emissions from natural gas is 40% less than from coal) and economic performance (the price of coal is less than half that of natural gas).

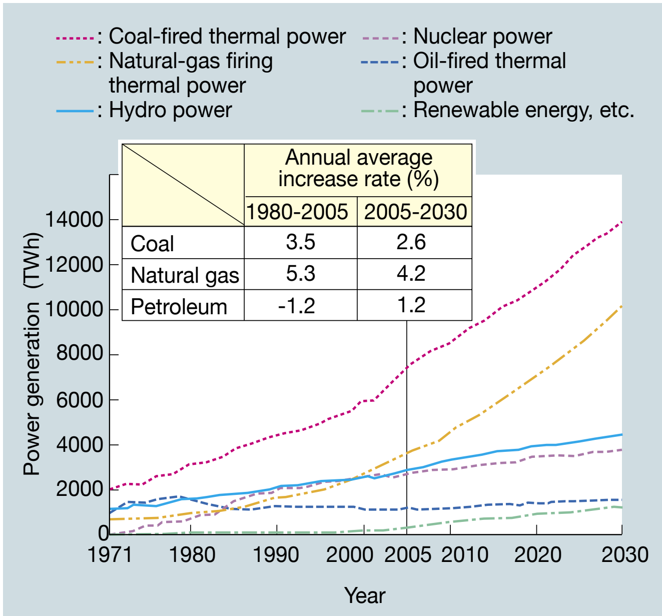

Fig. 1 Change in fuel power generation in the world
The world power generation shows a sharp increase, with the main plants using coal and natural gas.

(2) Change in fuel consumption for power generation by region

Figure 2 shows the change in fuel consumption for power generation in regions around the world.[1] Approximately 80% of the increase in fuel consumption in the future will be in developing countries, with Asia alone accounting for approximately 50% (with China and India accounting for about 40%). This indicates that countermeasure against CO_2 emissions in developing countries is an urgent need.

(3) Transition of fuel prices

Figure 3 shows the change in fossil fuel prices over the last ten years.[2] With the world power generation showing an upward trend from 2000, fuel prices other

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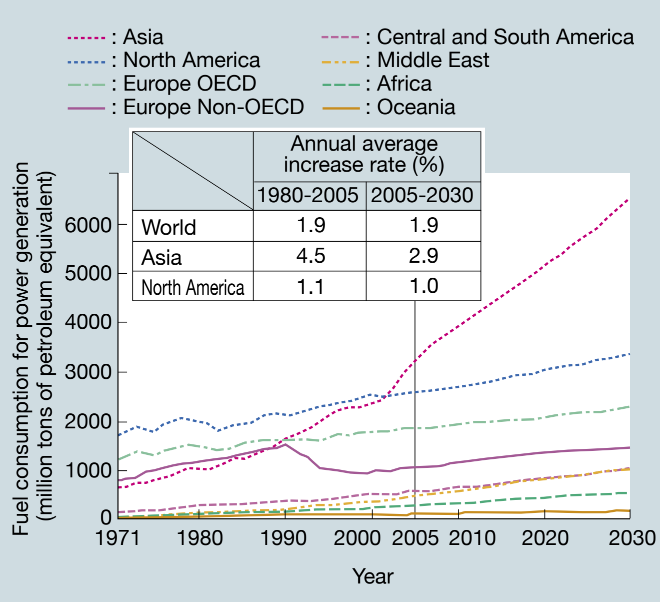

Fig. 2 Change in fuel consumption for power generation by region
Most of the increase in power generation is in developing countries, with Asia alone accounting for approximately 50%.

than coal began to rise, and since the middle of 2004, when the dependency on energy of the developing countries in Asia increased, a sharp rise has been seen in the prices of all fuels including coal. Since it is thought that prices will keep rising in the future, highly efficient plants are also important to reduce power generation costs.

(4) Change in CO_2 emissions

Figure 4 shows the change in world CO_2 emission levels.[1] It is said that as a result of the use of fossil fuels CO_2 emissions will increase from 7.5 billion tons of carbon equivalent in 2005 to 11.7 billion tons, approximately

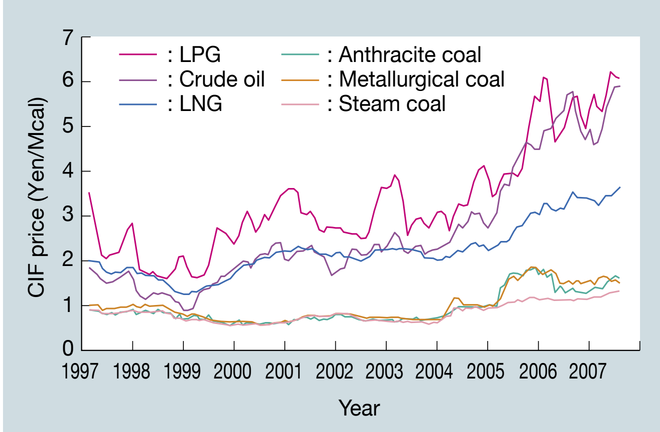

Fig. 3 Change in fuel prices
Prices of fuel including coal rose sharply from the middle of 2004, when dependency of developing countries in Asia on energy increased, with the prices estimated to keep rising in the future.

1.6 times larger, in 2030. More than half of the increase will be in Asia, followed by North America and Europe. One measure for reducing CO_2 emissions is to improve the efficiency of existing and newly built thermal power plants, calling for the urgent development of effective technology in this field.

3. Approach to high-efficiency plants

The main fuels used in thermal power plants are coal and natural gas, and the high-efficiency use of these two is indispensable for CO_2 reductions.

In coal-fired power plants, with plant capacity increasing, the use of high-temperature, high-pressure steam conditions is expected to improve the thermal energy efficiency. The efficiency of the state-of-the-art thermal power with ultra super critical (USC) conditions is 43% (gross power plant efficiency, HHV base), capable of reducing CO_2 emission

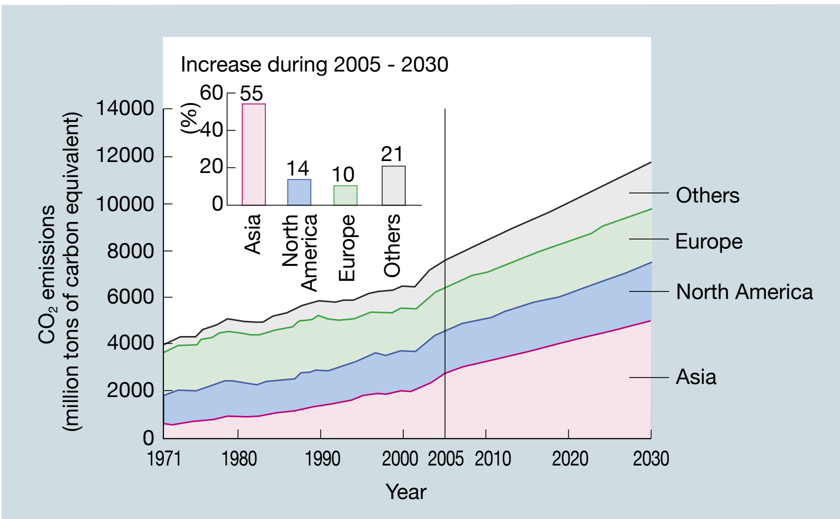

Fig. 4 Change in world CO_2 emissions
Emission to increase in 2030 to 1.6 times of the level in 2005, with more than half of the increase attributed to Asia.

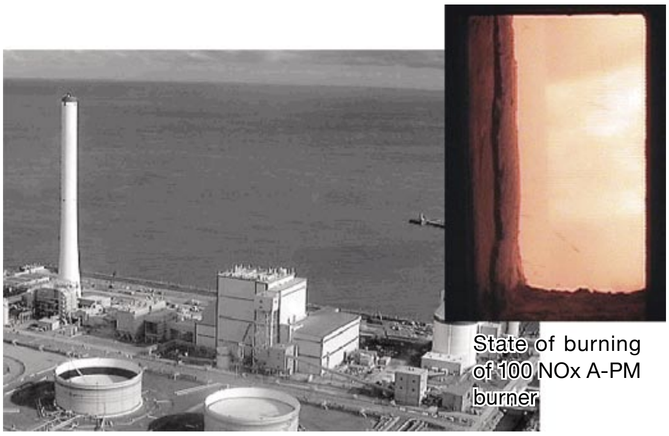

Fig. 5 USC coal-fired thermal power plant (600 MW Unit Hirono No. 5 Thermal Power Station of the Tokyo Electric Power Company.)
With the world's highest level steam condition of 24.5 MPa and 600°C, the unit ensures high efficiency power generation

Fig. 6 250 MW class air-fired IGCC demonstration unit (Built by Clean Coal Power R&D Co., Ltd.)
This is a promising new technology using highly efficient coal being currently high efficiency and high reliability are verified.

intensity by 3 - 4% compared with conventional plants. The Hirono No. 5 Thermal Power Station of the Tokyo Electric Power Company, which started operation in July 2004, shown in **Fig. 5**, has a main steam pressure of 24.5 MPa and a main steam temperature and reheated steam temperature of 600°C, the highest levels in the world, ensuring highly efficient power generation.[3] In order to withstand the high-pressure, high-temperature steam, the steam turbine uses high-temperature material and cooling technology in addition to a two casing turbine for the first time for a 600 MW turbine, and 48-inch steel ISB (integral shroud blade) blades. Further, the boiler has a vertical tube type furnace using high-temperature material and rifled tubes in addition to the latest, sophisticated technology such as low NOx combustion using an A-PM (advanced pollution-minimum) burner and an MRS (Mitsubishi rotary separator) pulverizer, and low unburned combustion technology. As improved steam conditions are the key to highly efficient coal-fired thermal power, there is a move in Japan to promote, as a national project, 700°C A-USC technology, similar to the drive for the next-generation advanced ultra super critical pressure plant in Europe and America, whose efficiency is estimated to be 46% (gross power plant efficiency, HHV base).

On the other hand, another highly efficient use of coal is the Integrated Coal Gasification Combined Cycle (IGCC) where the gasification of coal by partial combustion is used to produce combustible gas such as CO and H_2, for combustion in a gas turbine. Large-scale projects for 300 MW Class O_2-fired IGCC (for manufacturing chemical product raw materials) are already under way in some foreign countries. In Japan the development of air-fired IGCC for power generation with higher efficiency and higher reliability is being promoted. **Figure 6** shows an external view of the 250 MW class air-fired IGCC demonstration facility built by Clean Coal Power R&D Co., Ltd. established jointly by Japanese power companies under government subsidy.[4] The power generation efficiency of the IGCC using 1,500°C class G-type gas turbine is 48 - 50% (net power plant efficiency, LHV base), and its commercialization is eagerly awaited.

The generation efficiency of gas turbine combined cycle (GTCC) power generation using natural gas has been continuously improved by raising the gas turbine inlet temperature, such as 1,100°C (D-type), 1,350°C (F-type)

Fig. 7 1,500°C class GTCC plant (Kawasaki Thermal Power Station No. 1 Series of Tokyo Electric Power Company)
Highly efficient power plant employing state-of-the-art G-type gas turbine

and 1,500°C (G-type). The efficiency has reached the level of 58 - 60% (net power plant efficiency, LHV base) with a 1,500°C class GTCC. **Figure 7** shows an external view of the Kawasaki Thermal Power Station No.1 Series (single shaft combined plant × 3) of Tokyo Electric Power Company, where a 1,500°C class, 50 Hz M701G2 is installed.[5] A national development project is under way of a 1,700°C class gas turbine for further enhanced efficiency since the high-efficiency GTCC not only uses natural gas, but is also effective as a CO_2 countermeasure. Mitsubishi Heavy Industries, Ltd. (MHI) is taking part in this project, aiming at producing equipment with 62 - 65% efficiency (net power plant efficiency, LHV base).

4. Conclusion

As described above, because of the huge CO_2 emissions from thermal power plants and in view of the increasing world demand for energy in the future, it is utterly vital to make earnest and immediate efforts to reduce CO_2 emissions. MHI is taking positive steps towards improving the efficiency of coal-fired and natural gas burning plants which are closely related to the CO_2 problem, in order to contribute to environmental preservation. The status quo of the technical development of individual plants and their degree of contribution will be explained in the continued report for your reference.

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