Development of Leading Technology for a Low-BTU Gas-firing Gas-turbine Combined-cycle Plant at a Steelworks

TOYOAKI KOMORI*1 NOBUYUKI YAMAGAMI*2

YUTAKA SHIMAMURA*2

Mitsubishi Heavy Industries, Ltd. (MHI) has recently received a variety of customer requests in regard to the blast-furnace gas (BFG) firing gas turbine plants at steelworks. Many of these are related to decreasing the nitrogen gas levels or reducing the amount of coke-oven gas (COG) used to adjust for the calorific value of BFG. In response to these requests, we have used existing power plants in China for test operations: M701S (DA) operating on low-calorie fuel gas due to reduced COG, M251S operating under zero-pilot conditions, and M251S operating on fuel gas with a high calorific value. No problematic outcomes occurred during the no-load, rated-load, or load-rejection tests. The operability was improved to satisfy the requirements of our customers. We are also suggesting possible operability improvements to other customers. This report describes the improvements that have been made.

1. Introduction

The worldwide environmental reduction movement has placed significant pressure on the steel industry to reduce CO_2 emissions as a measure against global warming. A BFG-firing gas turbine can make effective use of the low-BTU by-product gases at steelworks. Accordingly, this type of gas turbine provides a power-generation plant that not only helps decrease the use of primary energy sources such as fossil fuels, but also contributes toward lessened global environmental impact.

We have long been engaged in the development of BFG-firing gas turbines, and have served customers with a variety of needs. A request that we often receive nowadays is to reduce the COG for the power-generation plants built in steelworks. The reasons include the common use of COG in other steelmaking processes because of its relatively high calorific value. In China, COG is occasionally sold preferentially to neighboring residents as fuel for home heating. COG is also useful for industries in which hydrogen is needed in large quantities, since it will be easy to obtain the pure hydrogen by refining COG. The raw COG contains higher levels of the impurities, which often results in failure to comply with usage requirements. This is another area in which we have received requests for improvement. We have also had requests that nitrogen not be used to decrease the calorific value, since it is often in short supply at the M251S power generation plant in China.

In response to these requests, we have tested in the existing plants as follows: M701S (DA) with a low-calorie fuel gas to reduce COG, M251S under zero-pilot conditions, and M251S with a high-calorie to reduce nitrogen. The test operations could be completed without any problematic outcomes; the details are given below.

*1 Engineering Manager, Power Systems Plant Engineering & Construction Division
*2 Power Systems Plant Engineering & Construction Division

2. Operation of M701S (DA) with a Low-calorie Fuel Gas Due to Reduced COG

BFG has a low calorific value. In a typical BFG-firing gas turbine, shown in **Figure 1**, COG is mixed with BFG to increase a calorific value of 4,400 kJ/m^{3}N-dry (lower heating value, LHV), and the mixed gas is used as fuel. In June of 2009, the M701S (DA) gas turbine designed for power generation at a steelworks in China was test-operated on fuel gas with a calorific value lower than the specified level by reducing the amount of COG in the mixture (**Figure 2**).

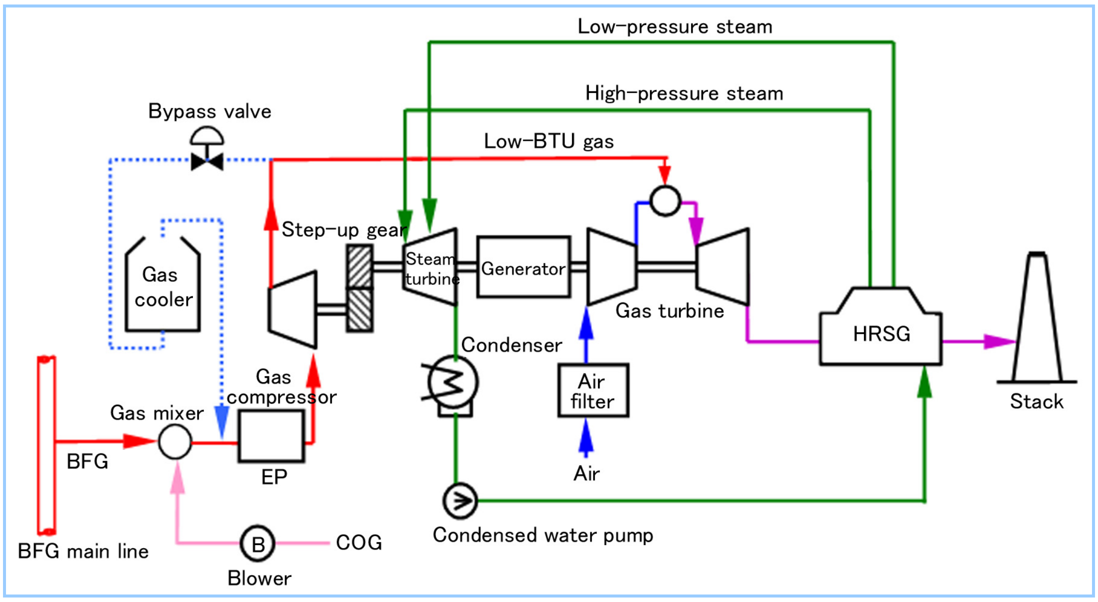

Figure 1 Outline of the BFG firing gas turbine plant system

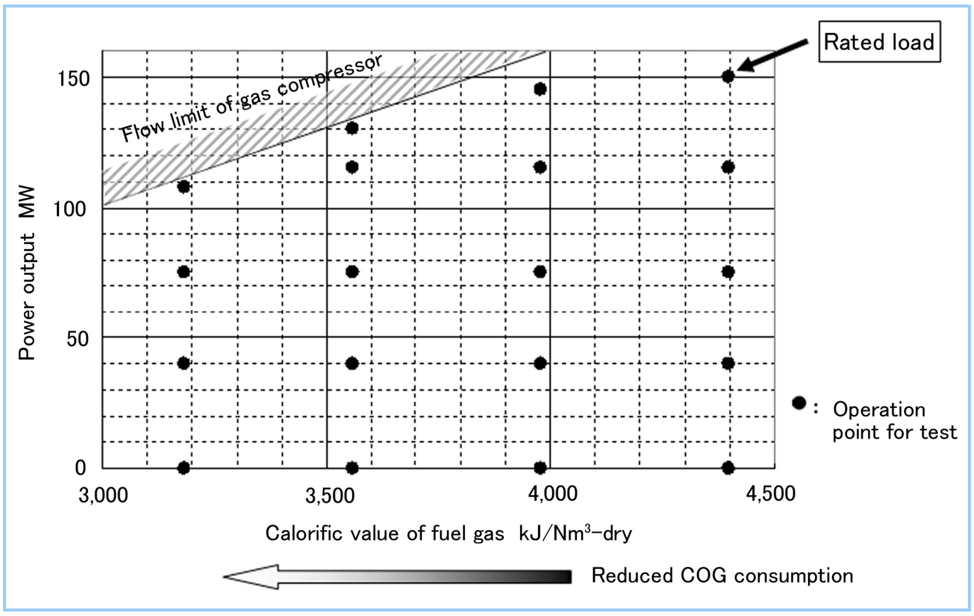

Figure 2 Relationship between the calorific value of fuel gas and the power output of M701S (DA)

The advantages of operation with low-calorie fuel gases include: 1) the calorie setting could be adjusted within the normal operating loads (i.e., no need to reduce the load for changeover), and 2) operation could be maintained even when COG does not be supplied properly (for example, because of tar clogging the control valve in the COG system). On the other hand, operation with low-calorie fuel gases causes the power output reduction as the calorific value decreases owing to the limited capacity of the gas compressor (**Figure 3**). Any COG failure due to dysfunction of the COG system has customarily been regarded as a shut-down. However, it has become possible to continue operation, even when the supply of COG is interrupted, by changing the operational settings.

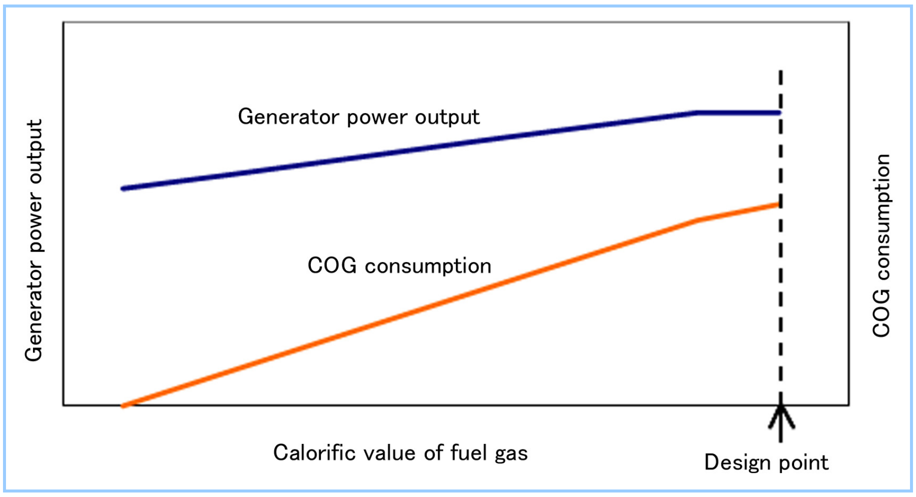

Figure 3 Fuel gas calorific value versus generator power output

The calorie setting could be adjusted anytime during normal-load operation if only a low-calorie fuel gas is available due to a shortage of COG. This flexibility in the calorific value range of fuel gas has improved the operability of gas-turbine for power generation.

3. Zero-pilot Operation of M251S with a Low-calorie Fuel Gas

The M251S gas turbine for power generation in China was test-operated under conditions in which only the main fuel (BFG) was burned and no pilot fuel (COG) was used (zero-pilot operation). Conventionally, in the M251S gas turbine, COG is fired through the pilot nozzle in the combustor along with the BFG main fuel, to maintain the flames. However, failure to comply with the usage requirements of the COG pilot fuel system frequently leads to discontinuation of plant operations. The supply of COG available for power generation may become short as a result of direct sales to customers. Accordingly, zero-pilot operation was tested on the M251S gas turbine under load operation. **Figure 4** shows the outline of the fuel system. COG (pilot fuel) was fired during the start-up of the gas turbine, but was stopped under low-load operation. A sweep system, which enables BFG (main fuel) to flow in place of COG, was added to prevent the reverse flow of fuel gas.

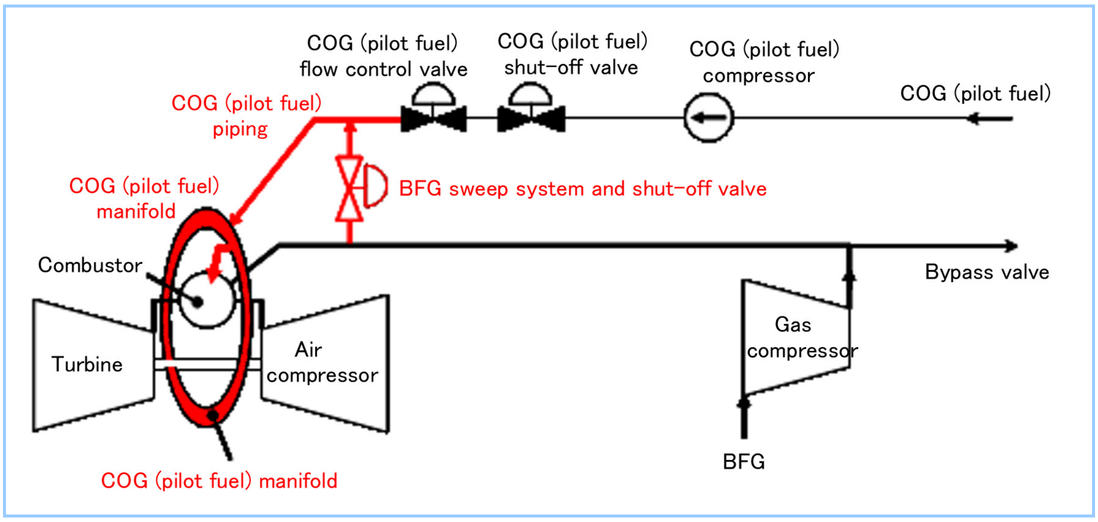

Figure 4 M251S fuel system operation when no pilot fuel (COG) is used

The test results indicate that combustion oscillations were sufficiently below the maximum permissible level during normal operation using BFG with a calorific value between 3,220 and 3,800 kJ/Nm^3-dry throughout the specified range of operating loads. Thus, the operations were completed without any problematic outcomes (**Figures 5** and **6**).

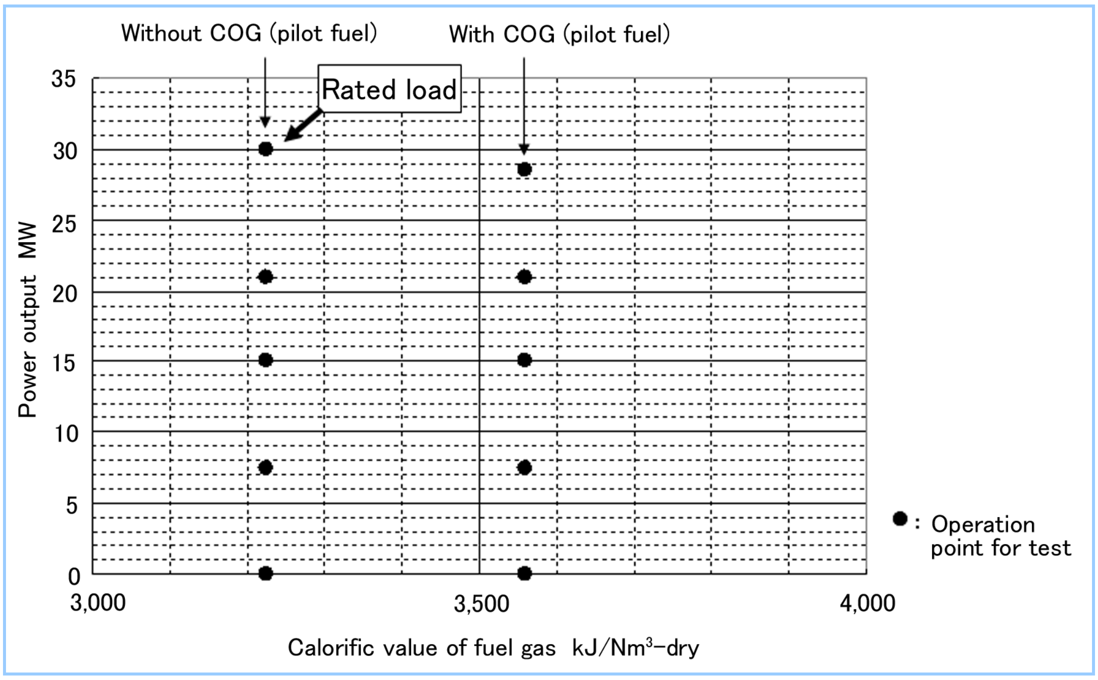

Figure 5 Relationship between the calorific value of fuel gas and the power output of M251S operated without COG (pilot fuel)

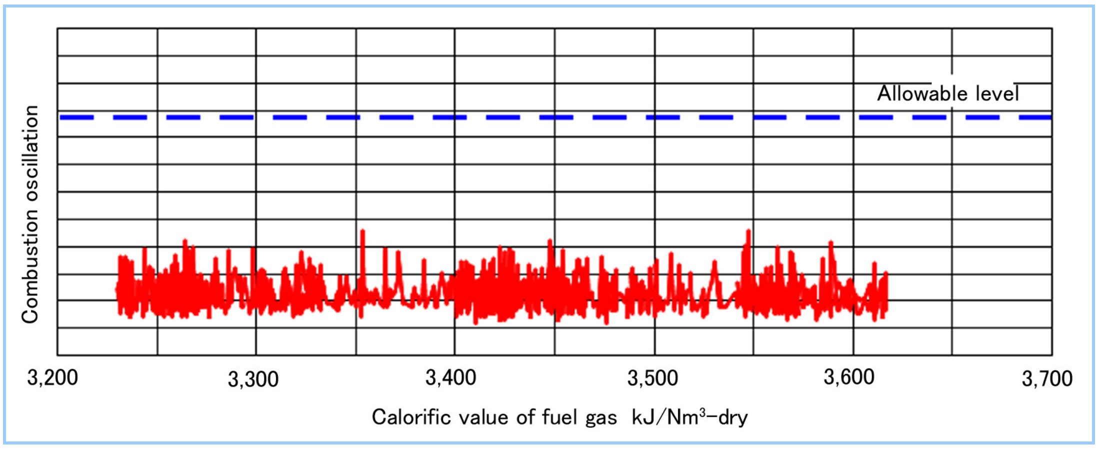

Figure 6 Test results (combustion oscillations) for M251S operated without COG (pilot fuel)

4. Operation of M251S with a High-calorie Gas Fuel Due to Reduced Nitrogen.

The M251S gas turbine is usually operated within a BFG calorific value range of 3,010 to 3,410 kJ/Nm^3-dry. If the BFG calorific value is too high, a nitrogen gas mixture is used for decreasing the calorific value. However, at Chinese steelworks, a sufficient quantity of nitrogen is often unavailable. Many of our customers have to purchase nitrogen from other companies, and hence have requested that the required amount of nitrogen should be decreased to reduce the nitrogen costs.

For the purpose of reducing the required amount of nitrogen gas used for decreasing the calorific value, we test-operated the M251S gas turbine in China to extend the upper limit of the calorific value range for operation. Load-rejection, trip, and load-change tests were conducted during operation with a high-calorie fuel gas, and no problematic outcomes occurred. It was therefore confirmed that this gas turbine could be stably operated, even on a BFG with a calorific value of 3,930 kJ/Nm^3-dry. Thus, the calorific value range for operation has been extended to 3,010-3,930 kJ/Nm^3-dry. Depending on the fluctuations of the BFG calorific value, the amount of nitrogen used for decreasing the calorific value can be reduced, especially during operation with a higher calorific BFG (**Figures 7** and **8**).

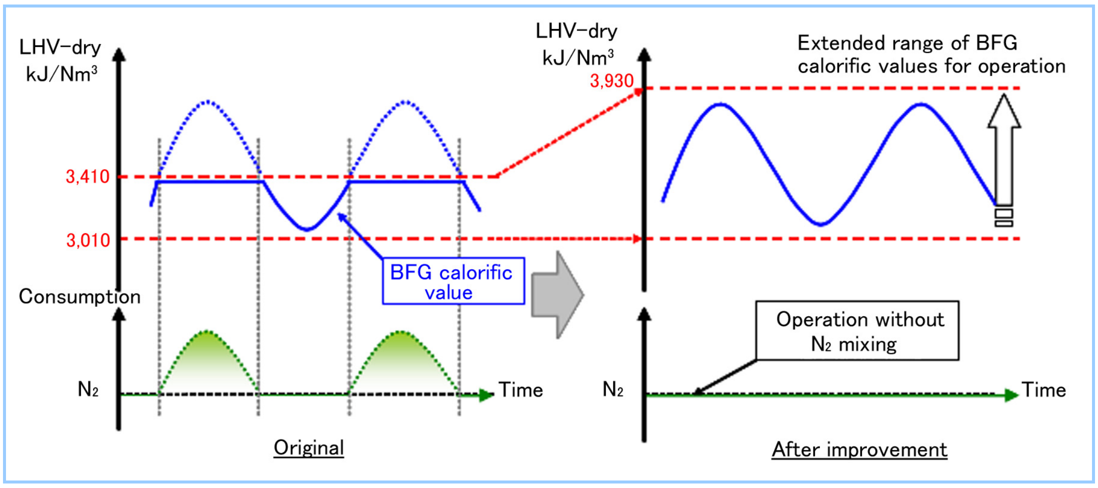

Figure 7 Reduction of the required nitrogen quantity owing to the extended BFG calorific value range for operation

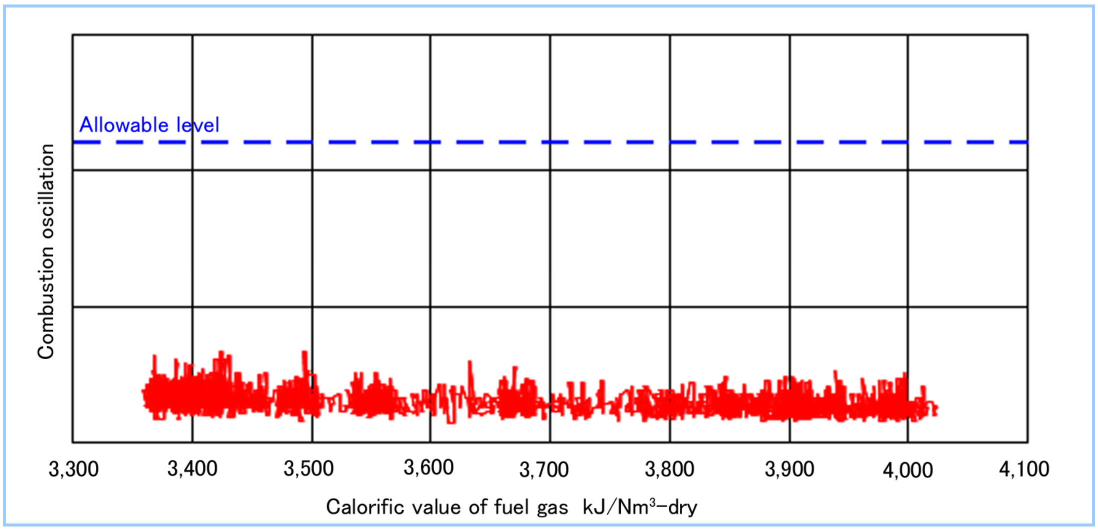

Figure 8 Test results (combustion oscillations) for operation within the extended range of BFG calorific values

5. Conclusion

Power-generation plants employing our BFG-firing gas turbine technologies are in the design process or under construction in Japan, as well as in other countries. More plants will be installed in the coming years. With the increasing worldwide demand for energy conservation, effective use of fossil fuels, and measures against global warming, we must meet the expectations of our stakeholders by achieving higher efficiency and higher power output for BFG-firing gas turbines (in which the low-BTU by-product gases in steelworks are used effectively). As an example of this, technologies enabling a wider range of fuel gas calorific values for operation (i.e., operation on a low-calorie fuel gas due to reduced COG or a high-calorie fuel gas due to reduced nitrogen) have been developed to satisfy customer needs and market demands, as described in this report. Further technological developments are expected. We will continue our efforts to develop technologies to fulfill our commitments as a pioneer in this field.

References

1. Komori, T. et al., BFG-firing Gas Turbine Combined Cycle Pants, Journal of the Gas Turbine Society of Japan Vol. 34 No. 5 (2006)
2. Hyakutake Y. et al., Low BTU Gas Firing Technologies for Gas Turbine, Power Gen India 2009