Combined-Cycle Power Generation at Higashi-Niigata Thermal Power Station: In Search of the World's Highest Thermal Efficiency Level (Summary)

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Tohoku Electric Power Co., Inc. generates, transmits and supplies electricity to the northeastern (Tohoku) region of Honshu, the largest of Japan's four main islands. It supplies power to an area covering almost 20% of the total surface area of Japan and which is home to almost 10% of the total population of Japan. Tohoku Electric Power's gross output in 2001 was about ¥42.5 trillion, which accounts almost 9% of Japan's total industrial output.

Higashi Niigata Thermal Power Station (TPS) is located in Niigata Prefecture, where demand for electricity is the highest of all prefectures located within Tohoku Electric Power's supply area. Higashi Niigata TPS has a total power generation capacity of 3816 MW, making it the largest TPS in the Tohoku region. It has eight generating units, four of which are conventional thermal power plants (CTPP) that formerly used oil, but which have been converted to run on natural gas. Even now, if there was a shortage of natural gas, oil could still be used in these units. The remaining four units, which include one still under construction, are combined-cycle power plants (CCPP). CCPP is a combination of gas turbine and steam turbine power. In this method, high-temperature emissions from the gas turbine are used to generate steam, which facilitates steam turbine power generation.

In the 1980s, in the immediate aftermath of the oil crises and amid growing demand for energy conservation and greater energy efficiency, it became necessary for Tohoku Electric Power to respond to the growth in demand for power and build new power plants. Against this background, the spirit of inquiry of our engineers led them to direct their attention to CCPP, which has the advantages of being able to respond quickly to changes in power demand and not emitting pollutants such as sulfur oxides and soot. Another factor behind the decision to switch to CCPP was the fact that it achieved higher thermal efficiency by raising the combustion temperature.

In July 1980, we began a research and development project implemented in collaboration with the turbine manufacturers. The main goal was to build a system that could withstand the unprecedentedly high turbine inlet gas temperature of 1150°C. On 21st December 1984, Higashi-Niigata Thermal Power Station's Unit No.3 began to operate as the world's first combined-cycle power plant; not only was it the world's first such plant, it achieved the highest efficiency levels in the world and had greater capacity than any other power plant throughout the globe. The following year, we were awarded the Prime Minister's Prize and the Industrial Technology Grand Prize for this achievement.

The thermal efficiency of Unit No.3 is about 44% in HHV[1] terms or about 49% in LHV[2] terms, which is about 4% higher than the most advanced facilities available at the time it was built. The power factor of Unit No.3 is also more than 70% and the unit is still running well.

Following our success in developing Unit No.3, the use of CCPP quickly became widespread in power stations. In 1988, four years after Unit No.3 began operating, the turbine inlet gas temperature of the most advanced CCPP rose to 1300°C, higher than Unit No.3's capacity.

Adopting a long-term perspective, Tohoku Electric Power began a joint research and development project with turbine manufacturers, focusing on second generation CCPP and applying the technology cultivated in the development of Unit No.3. The main goal was to raise the turbine inlet gas temperature to 1500°C, i.e. 200°C higher than the most advanced CCPP facilities at that time, whose capacity was 1300°C; in addition, we sought to raise thermal efficiency to 50% (equal to about 55% in LHV terms). A technical challenge was posed by the fact that the target temperature was close to the melting point of iron (1536°C).

The joint research and development project started in May 1988 and finished in March 1995, with construction of Unit No.4-1 beginning in April 1996. Unit No.4-1 began to operate on 8th July 1999: Tohoku Electric Power had once more succeeded in developing a CCPP with the world's highest thermal efficiency level and power generation capacity (805 MW). This led to our being awarded the Prime Minister's Prize and the Industrial Technology Grand Prize again the following year. Winning this award twice was an exceptional achievement. Following some small-scale improvements in 2002, Unit No.4-1's annual average thermal efficiency exceeded 50% and Unit No. 4-2 is now being built.

The thermal efficiency of Unit No.4-1 is about 11% higher than CTPP, resulting in a saving of 190,000 tons of LNG, equivalent to around two years of consumption by Niigata City (based on its pre-merger population of 570,000[3]). The high thermal efficiency makes it possible to generate electricity using less fuel; as a result, CO_2 emissions from Unit No.4-1 are 22% lower than those from CTPP.

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[1] High Heat Value
[2] Low Heat Value; this is the standard in Europe and the USA.
[3] A new Niigata City was born after the municipal merger with 12 neighboring municipalities on March 21, 2005. His population as of March 31, 2005 is 773,911.