Clean Production of Energy Using Integrated Coal Gasification Combined Cycle

Dawn of a New Era for Coal

Highly efficient technology with low environmental impact expands the potential of coal

Previously referred to as the “black diamond” in Japan, coal was a vital component of the nation’s industrial development. Although its role as a primary source of energy was usurped by oil after World War II, the oil shocks starting in the 1970s led to coal’s resurgence. Now used as industrial fuel and power generation fuel, it has become an important energy source and provides about 40% of the world’s power.

Compared to oil and natural gas, coal has plentiful reserves, with coal fields evenly distributed around the world. Extremely economical and with a stable supply available, coal is therefore indispensable to the achievement of energy security by resource poor Japan.

Since the Great East Japan Earthquake, demand for thermal power generation has increased. However, traditional coal-fired thermal power plants are relatively inefficient at converting thermal energy to electrical energy, because they use only the steam produced in order to generate the power to rotate the plant’s turbines. Coal also has a harmful effect on global warming because it releases more CO2 emissions than other fossil fuels. In order to achieve “3E” sustainability, Japan must increase power plant efficiency, while minimizing the nation’s environmental load, and develop “clean coal technology” that makes smart use of coal.

Integrated coal Gasification Combined Cycle (IGCC) is a coal-based power generation technology that achieves the twin objectives of reduced CO2 emissions and increased efficiency by “gasifying” the coal and then using a gas turbine and a steam turbine in a two-stage generation process. MHI has been researching and developing this technology since the 1980s. It has accumulated numerous proprietary technologies and demonstrated their reliability primarily with test operations at an enormous IGCC demonstration plant. The demonstration plant quite successfully finished the test operations, satisfying all targets. With its capabilities highly evaluated through the series of test operations, the decision was made to convert it to a commercial plant owned by a utility company and to commence commercial operations in June 2013. This marks the long awaited practical application of a pioneering technology that will open a new era for the effective use of coal.

* The 3E’s are energy security, environmental protection, and economic growth.
Concentration of Proprietary Technology That Stems from Years of R&D

The IGCC plant first roasts the coal in a gasifier at a high temperature in order to create inflammable gas. This gas is used to drive the gas turbine. The heat discharged from the gas turbine produces steam, which is then used to rotate a steam turbine. The coal gasification and combined cycle of two stage power generation are the main characteristics of IGCC technology.

Prompted by the oil shocks, MHI began its R&D of coal gasification in 1983. It gathered researchers and designers from across different divisions, built its own demonstration facility, and cultivated its original and advanced technological expertise. Among these is the "air blown" technology that uses air as the oxidizer in gasification. While all other companies have adopted oxygen blown gasification, MHI is the only company in the world to successfully commercialize "air blown" technology. This achievement has dramatically increased the plant's thermal efficiency.

The plant also distills MHI's numerous progressive technologies, such as "two stage dry feed" for sending the coal to the gasifier in a stream of nitrogen with high concentration of pulverized coal powder and the expansion of the types of coal that can be used.

Pioneering R&D sets MHI ahead in gasification technology

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A-D. This coal pulverizer converts coal into minute particles smaller than 0.1 mm. (Photo A) A mixed coal has a larger surface area, resulting in more efficient burning. (Photo B)

C-D. The gasifier creates fuel gas called "syngas" from the coal. Coal particles and air are blown into the gasifier, which then heats the coal syngas. The heat discharged from this process is converted into steam using a heat exchanger and used to generate power for a second time with a steam turbine. The burnt coal ash melts and falls into water at the bottom of the gasifier, where it is cooled rapidly into a glassy solid before being discharged.

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Energy and cost savings generated by the pursuit of efficiency

MHI has committed every possible technology towards the pursuit of the IGCC plant’s efficiency. As well as combining gas and steam turbines with a highly efficient energy converting gasifier, MHI also makes use of the discharged heat to avoid waste. This mechanism delivers 10–15% better thermal efficiency than a state-of-the-art coal-fired conventional thermal power plant (ultra-supercritical coal-fired thermal power plant: USC). Because it can provide the same amount of power as a USC but using less fuel, it also cuts CO₂ emissions by about 10–15%. This puts it on a par with oil-fired thermal power plants in terms of emissions.

Moreover, the coal ash generated by gasification is discharged as glassy slag, thereby reducing the required capacity of the ash disposal area as well as ash handling facilities. Environmental impact is also lowered by the reduction of emissions and discharged water that cause air pollution and sea water warming, such as SOₓ, NOₓ, particulate matter and wasted hot water. IGCC is therefore widely expected to support a sustainable future by achieving energy and cost savings with high thermal efficiency.

* A solid material that is formed when ash is melted at high temperatures.
Opening New Horizons for Power Generation

IGCC pioneer focused on proving more solutions for the world’s energy and environmental problems

The IGCC plant is a complex system that combines a gasifier, a gas turbine, a steam turbine and other interconnected equipment. It is a testimony to MHI’s advanced design and engineering skills that the plant succeeds in harnessing them together into an efficient and reliable working unit. Within just a year of its start, the Nakoso demonstration plant had racked up 2,238 hours of continuous operation. This unparalleled achievement owes its speedy progress to the smooth interaction of the plant’s various equipment.

IGCC is expected to spawn new technologies in the future. There is a real prospect of a MHI power plant achieving thermal efficiency of over 60% when it launches the J-Series gas turbine that delivers world high levels of efficiency and implements its triple combined cycle power plant (Integrated coal Gasification Fuel cell Combined cycle : IGFC) that uses Solid Oxide Fuel Cells (SOFC).

MHI has pioneered IGCC, the core technology for next generation use. It now intends to develop next generation power plant systems that deliver even higher efficiency with lower environmental impact. The paradigm shift created by the company’s innovative and original technological capabilities will hopefully open the door to a new energy era and beyond.

J-Series gas turbine
Developed using MHI’s proprietary technology, the J-Series gas turbine boasts the world’s highest efficiency with a gas turbine inlet temperature of 1,600°C class.

Integrated coal Gasification Fuel cell Combined cycle (IGFC)
MHI is expected to harness the triple-combined cycle that operates smoothly and has the IGFC with an IGFC to deliver extremely high thermal efficiency.
A Special Hull Designed for More Efficient Surveys of Oil and Natural Gas below the Seabed — Realized Using MHI Technology.

A New Hope for Energy Issues
Introducing a Seismic Vessel with a Unique Hull Form

A Seismic Vessel that Demands a Closer Look

On April 26, 2013, at the Nagasaki Shipyard & Machinery Works, a state-of-the-art seismic vessel was christened the "RAMFORM TITAN." The vessel’s distinctive triangular hull, called "Ramform," caught the attention of the large number of visitors at the christening ceremony. The vessel is 104 meters long with a breadth of 70 meters wide and is specially designed for more efficient 3D seismic surveys. Its completion drew upon all of MHI’s wealth of shipbuilding experience and advanced technologies, including 3D design.

The vessel was built for Petroleum Geoservices ASA (PGS), a major natural resource survey company in Norway specializing in offshore oil and gas fields that has supported seismic surveys for the Japanese government. The vessel is the first 5th generation Ramform fleet series vessel and will start seismic surveys in the North Sea in the summer of 2013.

Complex Hull Takes Shape through MHI Know-How and Synergies

This vessel will conduct seismic surveys using acoustic waves (also referred to as seismic waves). Air sources emit acoustic waves that strike the seabed and strata boundaries and bounce back as echos. These echos are detected by sensors inside multiple streamer cables several kilometers in length that are towed from the vessel’s stern. When the data from these cables is processed and analyzed by computer, it is possible to identify likely oil or natural gas below the seabed.

In the past, the main seismic survey method was single-cable 2D seismic survey, which could render only cross sections of underground structures. The method was improved by adding more cables to increase the amount of data that could be gathered, resulting in 3D seismic surveys, in which the cross sections are replaced by 3D images of underground structures.

Adding more cables also allows vessels to explore a wider area of the seabed, improving efficiency and safety. This vessel can be equipped with 24 cables, and its stern width has been increased from the 40 meters of PGS’s previous series of vessels to 70 meters.

When the speed of water flowing over the propeller surface changes, pressure on certain areas of the propeller drops. This difference between local and surrounding pressure results in faster vapor bubble formation and collapse.

Measures to counteract vibration and noise are very important when constructing this type of vessel. To that end, the Vibration Laboratory and the Fluid Dynamics Laboratory worked closely with the design team from the Development & Initial Designing Section to resolve the energy problems we face.

Overcoming Difficulties with Help from the Laboratories

MHI handled this project from basic design to completion, and the manufacturing process was challenging. The ship’s unique hull form was one of the reasons.

One of the biggest problems was propeller cavitation. To suppress noise emitted underwater, propellers that would not induce cavitation were necessary for this vessel. However, at a stage when the design had progressed substantially, it became apparent that cavitation could not be completely eliminated. To resolve the problem, it was not just the propeller design but the hull form and the sound field in the vicinity of the propellers that had to be thought about — even though it was very nearly time to begin construction. A new design proposal had to be developed right away, so help from the Fluid Dynamics Laboratory at Technology & Innovation Headquarters was requested. Several researchers started working together immediately, implementing everything from modified design proposals to effect vibration, and created a cavitation-free design. PGS told us we had solved their problem.

Seismic vessels are vital in opening up the sea floor frontier, and we believe they can contribute to the resolution of energy issues. This vessel, which required advanced design and manufacturing know-how, has enabled us to improve our shipbuilding technology. I would like to continue working hard so that MHI’s technologies can contribute to a prosperous future for all mankind.

Noriyuki Manabe
Engineering Manager

Me. Iega Hege of PGS wearing a Norwegian folk costume at the christening ceremony where cutting of export cables was conducted.

The vessel was built at the Kyugai Plant at Nagasaki Shipyard & Machinery Works.

Mr. Masahiro Kaneko of PGS wearing a Norwegian folk costume at the christening ceremony where cutting of export cables was conducted.

Geophysical exploration analysis

Air sources produce acoustic waves that bounce off the seabed and are picked up by sensors.

Data from multiple sensors is analyzed to visualize the structure of the seabed in 3D.

Stream of the RAMFORM TITAN. The streamer deck at the vessel’s stern can house 24 streamer cables.

A Special Hull Designed for More Efficient Surveys of Oil and Natural Gas below the Seabed — Realized Using MHI Technology.
Taking up the Challenge of Construction Steel Work — the Foundation of Monozukuri

In construction steel work, a single steel plate is transformed into a structure through processes such as marking, cutting, bending, welding and assembly. The techniques employed form the basis of monozukuri (manufacturing) and are used in everything from machinery and equipment manufacture to buildings, bridges, shipbuilding and even space engineering.

In the Construction Steel Work category at the Japan National Skills competition, entrants must process steel precisely and maintain smooth movement of parts and components. To be successful, contestants must have highly developed manual skills and an understanding of how pieces are put together.

MHI Dominates Rankings through Constant Competition

At first, there were several processes that Yamashita says he was not good at, including welding. However, he was helped by the more senior employees and Matsuno, who trained alongside him. Yamashita overcame his weaknesses by observing the others’ techniques, to the point where, in his words, “I stole almost all of them.”

His instructors were Masahiro Nishikawa (22 years with MHI) and Kunitoshi Horike (17 years with MHI), who channeled the contestants’ rivalry to make refining skills fun. According to Horike, “I thought it would be boring to just train, so I gave them problems they had to work on their own and had them compete. The rivalry between Yamashita and Matsuno grew fiercer every day. If Matsuno did better on one day’s problem, Yamashita would overtake him the next day. Before the competition, they were continually jockeying. I think maintaining motivation is part of an instructor’s job.”

Nishikawa says that, as he watched the two train, “I thought: ‘This is a rare sort of enthusiasm’, and I invested more and more in their instruction. We graded trainees and graphed the grades to foster rivalry. We weren’t just ‘instructing from on high,’ though; it felt as though we were creating right alongside them.”

At the MHI Kobe Shipyard & Machinery Works, technical employees who join the company hone their skills at an in-house training facility. After six months, some of these employees are selected to be National Skills contestants, and they concentrate on training specifically geared to the competition. Yamashita competed for the first time in 2011 during his second year with MHI, and won a bronze medal. “I trained really hard for the competition, and I just barely managed to win,” Yamashita remembers. “But my coworkers were very pleased, which made me happy, and I was glad I had put the work in.”

At the same event, Yamashita’s colleague, Yuzuru Matsumo, won a silver medal. “I had expected Matsuno to outperform me, so I wasn’t frustrated. At the time I wasn’t conscious of it, but looking back on the training that followed, I guess I did start seeing him as a rival.” From that point on, Yamashita dedicated himself to improving his skills beyond those of Matsumo’s.

By building upon the wisdom and skills that senior employees imparted, Yamashita and other trainees were able to develop the manual skills and understanding of construction steel work that were instrumental in his gold medal win. Yamashita’s victory was made possible by the more senior employees and Matsuno, who trained alongside him. Yamashita overcame his weaknesses by observing the others’ techniques, to the point where, in his words, “I stole almost all of them.”

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As Nishikawa always maintains, “If the beginning (pre-processing) is neat, the rest of the work goes easier.” According to Yamashita, as his weaker skills improved, he learned how to create things on his own and developed the keen eye to enjoy himself. A year later, his efforts paid off. At the 50th Japan National Skills competition, he won a gold medal in the Construction Steel Work category. With Matsumo and Yusuke Shiomoto (in his second year with MHI) both taking silver medals, MHI dominated the top slots.

Transferring Skills to the Next Generation Ensures Continuous Development

MHI’s success at the Skills competition go back to the 1962 international event, where Akinoi Honda of Nagasaki Shipyard & Machinery Works won a gold medal. Many more medalists followed that initial success until the oil shock and sluggish demand in the shipbuilding industry forced the company to stop hiring new technical employees. The company now have a policy of training employees to those who channeled the contestants’ rivalry to make refining skills fun.

Seiichi Morimoto, who supervises technical employee training, defines skill transmission this way: “If the first generation learns a skill in ten years, then passes that skill down to the next generation, that generation is able to learn it faster. And the faster they learn, the further they go. However, if this process of skill transmission stops, we have to start over again from scratch, and it takes a long time to relearn those skills. Unless skill transmission continues over a long period, it weakens.” National Skills training is no exception. Yamashita’s gold-medal win was made possible by building upon the wisdom and skills that senior workers had passed down to him. Morimoto continued, “There are many people at MHI who have instructor’s expertise and real, solid skills. By passing these skills on, our monozukuri organization can carry on indefinitely, and indeed, keep developing.”

This summer, Yamashita will represent Japan at WorldSkills International in Leipzig, Germany. At this competition, although contestants will be given new problems that differ from those at the National Skills competition, Yamashita will not doubt display his inherited monozukuri skills. His experiences will aid younger employees attempting National Skills competition and will be put to work in MHI’s many creations.