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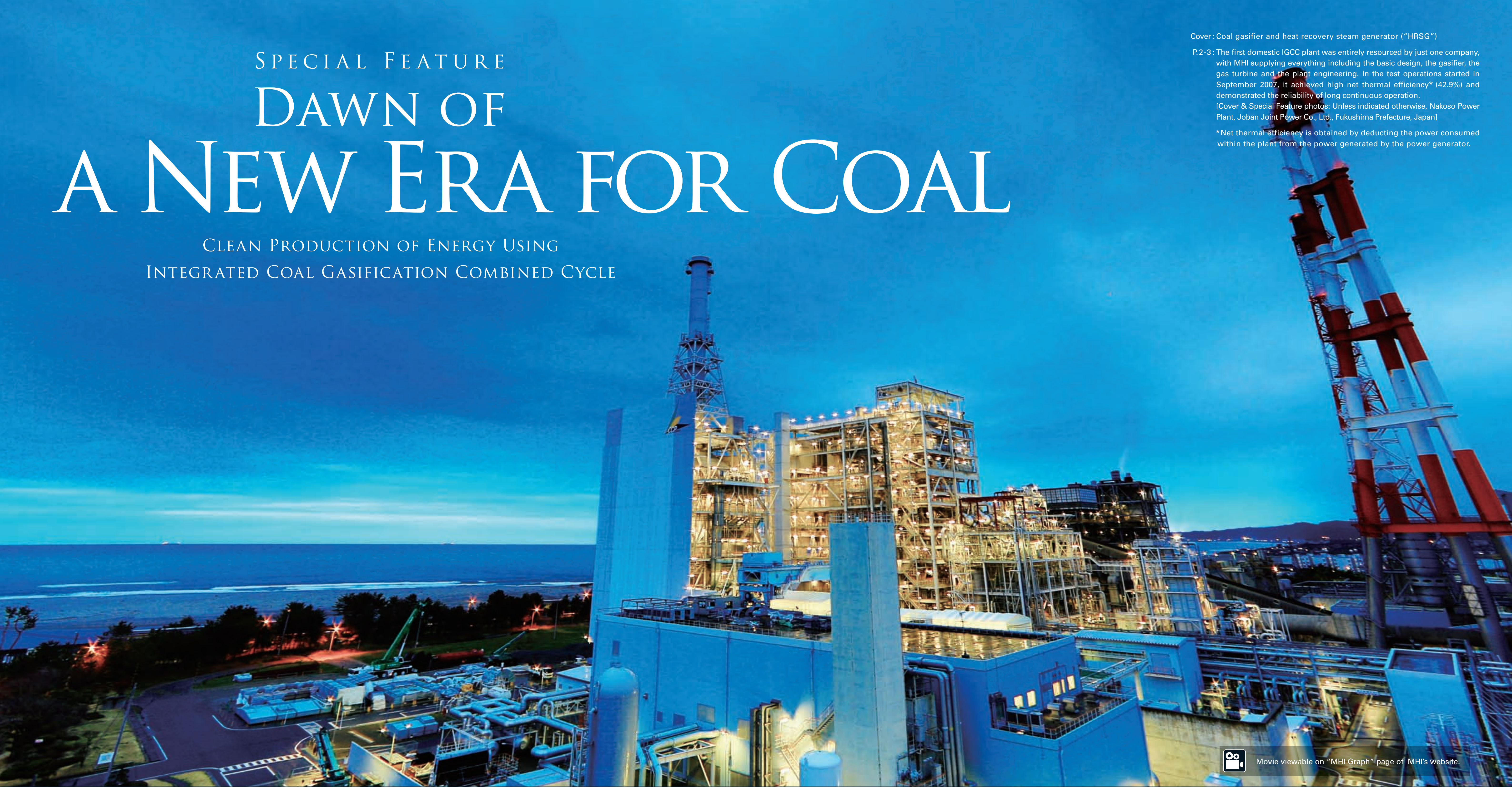
No.172

MITSUBISHI HEAVY INDUSTRIES 2013

Special Feature

Dawn of A New Era for Coal

Clean Production of Energy Using Integrated Coal Gasification Combined Cycle



Cover : Coal gasifier and heat recovery steam generator (“HRSG”)

P.2-3 : The first domestic IGCC plant was entirely resourced by just one company, with MHI supplying everything including the basic design, the gasifier, the gas turbine and the plant engineering. In the test operations started in September 2007, it achieved high net thermal efficiency* (42.9%) and demonstrated the reliability of long continuous operation.
[Cover & Special Feature photos: Unless indicated otherwise, Nakoso Power Plant, Joban Joint Power Co., Ltd., Fukushima Prefecture, Japan]

*Net thermal efficiency is obtained by deducting the power consumed within the plant from the power generated by the power generator.

Movie viewable on “MHI Graph” page of MHI’s website.

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 lead to coal’s reemergence. 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 CO_2 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 CO_2 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 set. 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

Coal storage yard where coal imported from around the world is collected. Low-grade coal (lignite) with a very high water content (more than 50% of its mass) can also be used as fuel by MHI's gasification technology.

The air separation unit creates the nitrogen that will carry the coal particles. This equipment is a lot smaller than that used in oxygen-blown coal gasification. This leads to a lower power consumption and therefore a higher thermal efficiency for the whole plant.

Pioneering R&D sets MHI ahead in gasification technology

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.

A

B

A・B: This coal pulverizer smashes coal into minute particles smaller than 0.1mm (Photo A). Pulverized coal has a larger surface area, enabling more efficient burning (Photo B).

C

D

C・D: The gasifier creates fuel gas called “syngas” from coal. Coal particles and air are blown into the gasifier, which then emits 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.

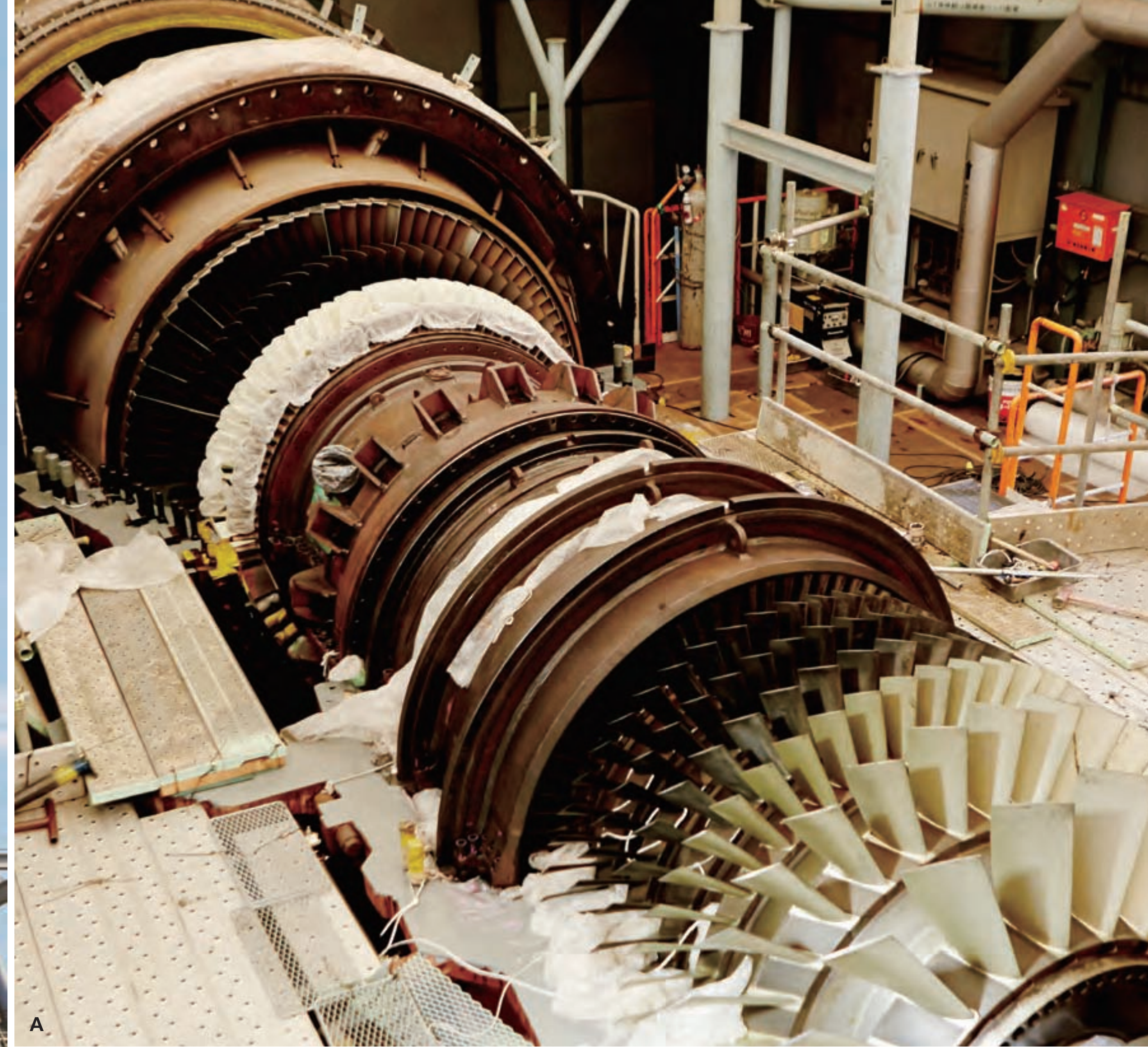
E: The burnt coal ash melts and falls into water at the bottom of the gasifier, where it is cooled rapidly into a glassy solid before being discharged.

E

Source of Power for a Sustainable Community

Photo Center～Right:
The syngas generated by the gasifier is sent to a gas cleanup system that removes the sulphur compounds from the syngas. These compounds can cause air pollution and provoke corrosion and erosion in the gas turbine and other downstream equipment.

Photo Left:
This is a Heat Recovery Steam Generator (HRSG) that uses the hot exhaust gas discharged from the gas turbine to generate steam. This steam is then sent to the steam turbine for a second cycle of power generation.



A

B

A : MHI's proven gas turbines support high efficiency. The plant (former demonstration plant) currently uses the 1,200°C-class turbine, but new commercial plants are planned to further increase efficiency by using turbines that can withstand even higher temperatures.

B : Staff in the central control room totally control and regulate safe operation of the entire power plant.

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 CO_2 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 SO_x, NO_x, 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.

C

D

E

C : The glassy slag is temporarily stored in a slag hopper.

D・E : The water-insoluble "no-leaching" glassy slag can be used as a high quality material for mixtures with cement and asphalt.

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 65% 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)
Much is expected of the triple-combined cycle that combines durable and long-life SOFC with an IGCC to deliver extremely high thermal efficiency.

A New Hope for Energy Issues

Introducing a Seismic Vessel with a Unique Hull Form

A Special Hull Designed for More Efficient Surveys of Oil and Natural Gas below the Seabed — Realized Using MHI Technology.

Ms. Hege Renshus of PGS wearing a Norwegian folk costume at the christening ceremony where cutting of support cables was conducted.

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 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 Geo-Services 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 echoes. These echoes 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.

Although the unique shape and concept for this seismic vessel were devised by PGS, the vessel was realized using MHI technology, from basic design to completion.

3D design played a particularly important role. The new vessel had to comply with the rules and regulations stipulated for this kind of vessel despite its unusual shape, requiring many pipes, wires and other equipment to be installed in flat, subdivided sections. This complex design had to be implemented in a short time frame, and 3D design was used to create a high-density plan in which an array of equipment could be positioned close together while avoiding interference between pipes or between pipes and structural elements of the hull.

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 at Technology & Innovation Headquarters worked closely with the design team from the outset. The synergy produced by specialists from each field working across divisions resulted in vessel performance that not only met but surpassed PGS's requested specifications. This outstanding cooperation between the design and manufacturing departments and the in-house research facilities played a vital role in the successful completion of this unique vessel.

*A design method that allows drafting of 3D plans, in contrast to 2D plans drawn on a flat surface.

Growing Hopes for the Resolution of Energy Issues

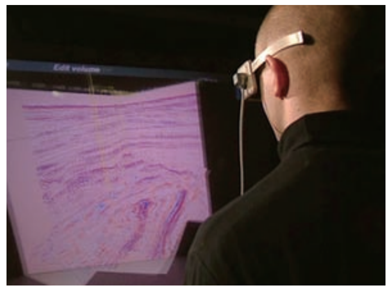
The economic development of emerging nations has meant growing demand for such resources as oil and natural gas. However, the limited onshore resources could eventually become exhausted, and their uneven distribution in just a few regions, including some areas considered politically unstable, is problematic. In an attempt to resolve these issues, more effort is now being focused on searching for, discovering and excavating offshore resources. This trend has created rising demand for seismic vessels. For example, the number of vessel exploring the seabed using acoustic waves increased from 156 in 2010 to 163 in 2011, and the market is steadily expanding.

As needs change and the demand for seismic vessels increases, MHI will leverage the experience gained in this project, seeking orders and promoting sales of 3D seismic and other specialized vessels. As more of these ships survey the world's oceans, there are high expectations that they will contribute to resolving the energy problems we face.

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

■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.

Stern of the *RAMFORM TITAN*. The streamer deck at the vessel's stern can house 24 streamer cables.

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 around the forward vicinity of the propellers that had to be rethought— 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 verification, 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.

Engineering Manager
Development & Initial Designing Section
Nagasaki Ship & Ocean Engineering Department
Ship & Ocean Engineering Division
Shipbuilding & Ocean Development
Noriyuki Manabe

*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.

Enthusiastic People

Yamashita competing at the 50th Japan National Skills competition

National Skills Gold Medalist Bound for International Competition

Long Days of Hard Work and Refining Skills pay off

In October 2012, thirty MHI contestants participated in the 50th Japan National Skills competition, an event where young technicians compete using skills honed on a daily basis. Daisuke Yamashita, in his third year at MHI, took home gold in the Construction Steel Work category of the competition, marking MHI's first gold medal win in 47 years. The technical skills Yamashita displayed in the competition were developed in an environment conducive to skill transmission, where the joy of creation and the fun of refining skills are continuously passed on.

Nuclear Energy Systems
Kobe Shipyard & Machinery Works, Kinki General Affairs Department

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 according to plans and specifications and complete the assigned small steel structure within the time limit of 10 hours. The finished item is judged on dimensional accuracy and cross sections, the aesthetics of welded portions, and how smoothly movable parts operate. Each contestant must read the plans carefully and determine a process to create the item; there is no single correct answer. They need highly developed skills as well as a deep understanding of the equipment, tools and materials involved.

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 Matsuno, 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 Matsuno's.

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 out 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."

The winning steel structure produced by Yamashita in capturing gold at the 50th Japan National Skills competition.

From left photo: Nuclear Energy Systems, Nuclear Plant Production Division, Nuclear Plant Manufacturing Department,Heavy Component Shop, Kunitoshi Horike, Coach / Containment Vessel & Piping Shop, Daisuke Yamashita / Containment Vessel & Piping Shop, Masahiro Nishikawa, Coach / Kobe Shipyard & Machinery Works, Kinki General Affairs Department, Labor Section, Seiichi Morimoto, Manager

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 leeway 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 Matsuno 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 Akinori 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 technical employees and halted its participation in the competition . However, MHI returned in 2002 when Kobe Shipyard & Machinery Works decided to strengthen the *monozukuri* skills and leverage the training of its young technical employees.

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 no 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.

Yamashita after the medal ceremony, being cheered as he secures a place at WorldSkills International.

MITSUBISHI HEAVY INDUSTRIES graph 2013 No.172

Published & Edited by: Mitsubishi Heavy Industries, Ltd. Presidential Administration Office Corporate Communication Dept.© General Manager: Akihiko Nakayama 2-16-5 Konan, Minato-ku, Tokyo 108-8215 Japan **Phone:** +81-3-6716-3111 **URL:** http://www.mhi.co.jp/en/ **Produced by:** DAIYA PR Co.,Ltd., rco Co., Ltd. **Printed by:** Bishodo Co.,Ltd.