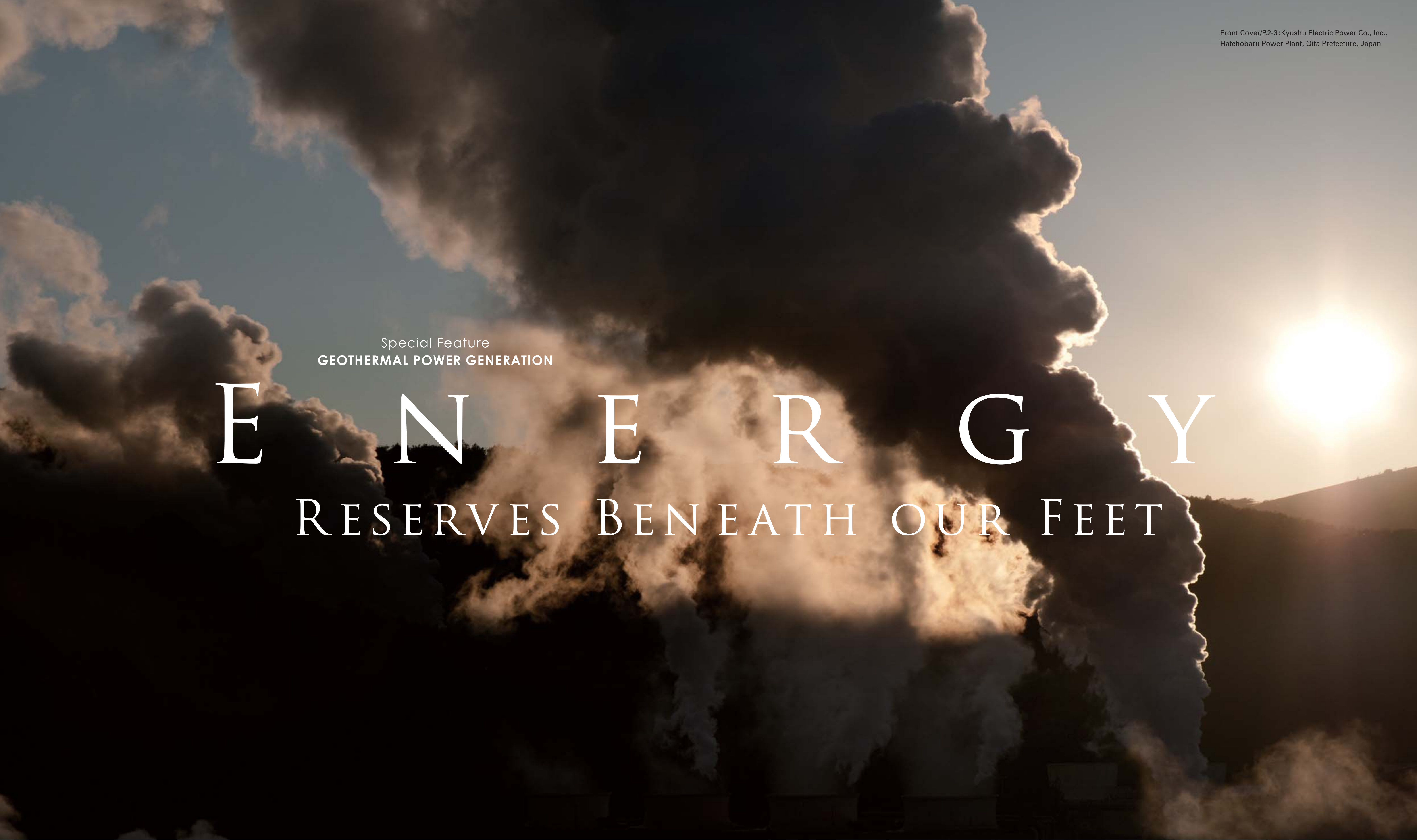

Front Cover/P.2-3: Kyushu Electric Power Co., Inc., Hatchobaru Power Plant, Oita Prefecture, Japan

Special Feature

GEOTHERMAL POWER GENERATION

ENERGY

Reserves Beneath our Feet

Tapping Earth's vast power to generate electricity — The geothermal option

The Earth's hot mantle accounts for more than 80% of the planet's volume. From steam and hot water heated to high temperatures by the thermal energy stored beneath the Earth's crust, geothermal power can be used to generate the supply of electricity. The Earth acts as a boiler, providing steam to spin turbines that generate power. Therefore, there is no need to consume limited resources or to emit CO_2 while generating power. Since the process is not weather-dependent, it has the additional merit of being able to provide a stable power supply. Geothermal power generation ranks alongside wind and photovoltaic power generation as renewable energy, and its use is spreading all around the world.

A: Heat sources from underground are separated into steam and hot water by a steam separator (photo right); the steam is then sent to the turbine and used as power to drive the generator. That power holds enough energy to rotate the nearly 25-ton turbine rotor at 3,600 rpm to produce 55,000kW of electricity. (The photograph was taken while the power generation plant was shut down for maintenance and shows the steam that would normally be delivered to the turbine being discharged from the silencer. Ordinarily, this steam is used to generate power.)〔Kyushu Electric Power Co., Inc., Hatchobaru Power Plant, Oita Prefecture, Japan〕

B: Transportation pipes carry steam from a production well in the mountains to the power generation plant. A symbolic landscape as geothermal power generation plants tend to be located mostly in mountainous area. 〔Kyushu Electric Power Co., Inc., Otake Power Plant, Oita Prefecture, Japan〕

A B

Ecological Plant Solutions for Earth's Water

Power plants in coexistence with nature: a beneficial cycle

In geothermal power generation plants, steam and hot water are extracted from production wells dug to geothermal aquifers anywhere from 300 to 3,000 meters underground.* Care is taken during this process to protect precious underground resources. After use, the hot water is sent back underground through several reinjection wells. After powering the turbines, the exhaust steam is cooled, turning it back into water, and is used as cooling water, while another portion is discharged from cooling towers as water vapor. The mist eventually becomes rain and returns to earth; over time, it soaks deep into the ground, once again becoming a geothermal resource. These are truly ecological plants that perform beneficial cycles modeled on Mother Nature.

*In the Kyushu Electric Power Co., Inc. Hachobaru Power Plant, steam and hot water are extracted from geothermal aquifers located from 2,000 to 3,000 meters underground.

C D

E

C: Two-phase flow transmission pipe economically uses one pipe to transport steam and hot water (two-phase fluid) extracted from a production well to a power generation plant. MHI adopted this style of transmission in combination with the world's first double-flash cycle (described on page 8 of this article) in its operations, and it has now become a global standard.

D: Hot water separated from steam in the steam separator (photo left) is sent to the flasher (photo right). In the flasher, the pressure is reduced, turning some of hot water into steam, which is used to power the turbines. The residual warm water separated in the flasher is returned to the ground through reinjection wells.

E: Hot steam exhausted from the turbine is cooled in a condenser, converted to warm water, and sent to a cooling tower. Here, it comes into contact with the atmosphere, and after being cooled further, it is returned to the condenser and reused as cooling water. Accordingly, there is no need for external sources of cooling water during operation at a geothermal power plant.
〔C～E: Kyushu Electric Power Co., Inc., Hatchobaru Power Plant, Oita Prefecture, Japan〕

A〜C: A geothermal power generation steam turbine on which maintenance and inspection have been completed. The turbine has been adjusted to within 1/100th of a millimeter, and then covered with the upper casing. MHI was the first manufacturer of steam turbines in Japan. Since then, the company has developed and manufactured steam turbines for thermal, nuclear, and other types of power generation plants. Moreover, MHI also boasts an abundant maintenance record and continues to use the knowledge it acquires in the process to refine its turbine development techniques. 〔A〜C: Hatchobaru Power Plant, Oita Prefecture, Japan〕

Advancing the Pioneering Spirit

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Harnessing Earth's riches through sustained endeavors

In order to use geothermal energy – natural heat – at a power generation plant, high-level facility design and careful materials selection are indispensible. Natural subterranean steam and hot water contain large amounts of impurities and non-condensible gas that can get into plant piping, equipment and turbines, resulting in corrosion and erosion damage of metals and in lowered facility production. What's more, the elements in the steam and water vary by region, compounding the challenge.

Here, extensive knowledge accumulated from local material testing and field operations in 13 countries worldwide is put to use. This knowledge facilitates precise and flexible designs and materials selection suited to each environment and its diverse needs, and is poised to lead the way to the next challenge: rates of operation and reliability surpassing those of thermal power generation.

D: A corrosion test by electrochemical method, conducted on raw materials considered for use in turbine rotors and blades. The harsh corrosive environment to which geothermal turbines are exposed is artificially created; the candidate materials are then put inside, and their corrosive properties observed and tested. In this way materials are narrowed down to those that stand up best in corrosive environments.

E: Performing an endurance inspection under dynamic stress in a corrosive environment for candidate materials, in order to design high-reliability turbines. This is a "rotary bending corrosion fatigue test," used to inspect fatigue strength of a material repeatedly subjected to a load. In the test, candidate material 6mm in diameter is exposed to natural geothermal steam and then inspected by repeatedly applying a load more than a million times. The enormous amount of data from materials research makes it possible to design geothermal power generation steam turbines suited to steam from any part of the world.

F, G: The casting process in a foundry. Of the equipment and components used in geothermal power generation plants, machinery such as the steam turbine and equipment unique to geothermal generation is manufactured in-house. This includes the casting of components. The highlight of the process is when molten metal at approximately 1,600°C is poured into casting molds made of artificial ceramic sand.

H: Scale formation on first-stage nozzle nearest the turbine inlet. Scale forms due to impurities in the geothermal steam, which leads to reduced generator output. A system that cleans the nozzle even while power is being generated has been developed and is now in operation.
〔D〜G: Nagasaki Research and Development Center, Nagasaki Shipyard and Machinery Works, Nagasaki Prefecture, Japan and other MHI facilities.〕

H

Into the future with Energy from the Earth

Ideal energy source attracting world attention

Geothermal development is currently expanding in countries all over the world, with the U.S.A. and Indonesia heading the list. It has been estimated that by 2015, the geothermal installed capacity around the world will reach 18.5 million kW, or approximately 1.8 times the current output. Geothermal power generation is considered promising for several reasons: it is not affected by the price of fuel; its operation is stable, not influenced by the weather, seasons, or the time of day, and fits a broad range of applications from several-hundred kilowatt in-house power generation to several hundred-thousand kilowatt power plants. The fact that geothermal energy can be used as a purely domestic energy source makes it particularly attractive to volcanic countries with abundant subterranean heat sources. This includes Japan, which boasts the third largest amount of geothermal resources in the world.

MHI — a pioneer in the geothermal business

The first geothermal power generation plant MHI delivered was for Otake Power Plant, which began operations in 1967. It was Japan's first commercial plant to use water-dominated geothermal wells and is operated by Kyushu Electric Power Co. At the time, a high level of technical skill was required to extract geothermal power from a production well in which steam and hot water were mixed. However, 'the flash cycle method' — in which geothermal fluid was separated into steam and hot water using a steam separator, after which the dehydrated steam was used to turn the turbine — elegantly overcame the problem.

In 1977, 'the double-flash cycle method' was put into operation at Hatchobaru Power Plant. In this method, additional steam is taken from the hot water via the steam separator and then injected into the turbine, increasing the efficiency of power generation. When this was applied in combination with two-phase flow transmission, it was the first technological solution of its kind in the world. Known as the 'Hatchobaru Type,' it became an opportunity to show the world MHI's geothermal power generation plant's capabilities. In that same year, MHI was involved at Otake Power Plant in the development of a plant that used the 'binary cycle method,' in which efficient power generation is possible even when the temperature of geothermal resources is low. With this and other projects, MHI continued to pioneer and drive the geothermal power generation into a new era, both in Japan and abroad.

The year 1975 marked the beginning of overseas development. Beginning with El Salvador in Central America, MHI received orders from 13 countries around the world, including Iceland, the Philippines, and North America. Now, MHI's combined output of geothermal power generation is the largest in the world, and it is making its presence as a geothermal power plant expert known both domestically and internationally.

Into the future: Boasting 100 plants' worth of geothermal achievements

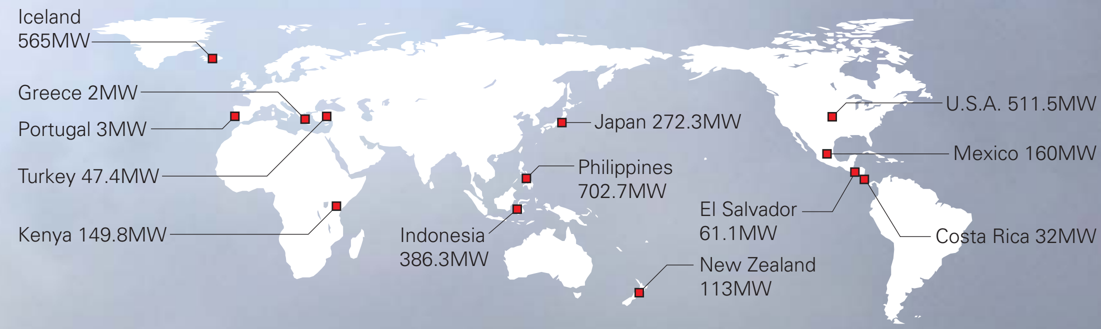
MHI has been involved in geothermal generation since the early days and has brought many ideas and technologies to fruition. MHI has created many technologies which are now geothermal power generation standards; in addition to anti-corrosion measures and the double-flash cycle introduced earlier and low-profile designs for plants to safeguard the beauty of the surrounding landscape.

At present, MHI has delivered a total of 100 geothermal power plants. Supporting this record is MHI's high level of technical expertise; the fact that customers can entrust the complete geothermal power generation project, from design through development, construction, operation management and maintenance, to the company; and the meticulous service unique to Japanese corporations, in which support is always performed from a user perspective.

A passion for geothermal work lives on in MHI's DNA, and our calling with regard to the expansion of this potential-filled energy will continue.

Geothermal power plants delivered
(as of December 2010, based on total capacity)

MW=1,000kW



P.8-9: Reykjavik Energy Co., Hellisheidi Geothermal Power Plant (Iceland)

Mindanao Power Plant (Philippines)

OlkariaⅡ Power Plant (Kenya)

MokaiⅡ Power Plant (New Zealand)

Germencik Power Plant (Turkey)