# Industrial Machinery and Manufacturing Equipment that Support Hitachi's Social Innovation Business

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## MARKET TRENDS AND HITACHI'S INDUSTRIAL MACHINERY AND MANUFACTURING EQUIPMENT BUSINESS

EMERGING from the difficult economic conditions that followed the international financial crisis (Lehman shock), the Japanese economy began a slow recovery in 2010 financial year. Exports grew in response to stimulus measures enacted by developed economies and economic recovery, particularly in emerging economies. The Japanese economy, meanwhile, was underpinned by a variety of government policies and also benefited from an extremely hot summer. However, given the continuing strength of the yen and concerns about a slowing of the global economy combined with the withdrawal or expiry of stimulus measures, it seems increasingly likely that the economic recovery will enter a period of stagnation.

Amid this uncertain future for global markets, Hitachi's Mid-term Management Plan highlights growth of its Social Innovation Business and the establishment of a stable management framework (see Fig. 1). Industrial machinery and manufacturing equipment support the industries that play a central role in these plans and are core competencies that symbolize Japan's strength in manufacturing.

According to statistics from The Japan Machinery Federation, the global economic recession saw the total value of machinery production in Japan in 2009 fall by 18.6% compared to the previous year, to about 61,548.8 billion yen. In 2010 financial year, however, in response to the slow recovery, the forecast is that the value of machinery production will have risen again by 9.4% to about 67,353.5 billion yen. Domestically, manufacturers who are the main source of demand

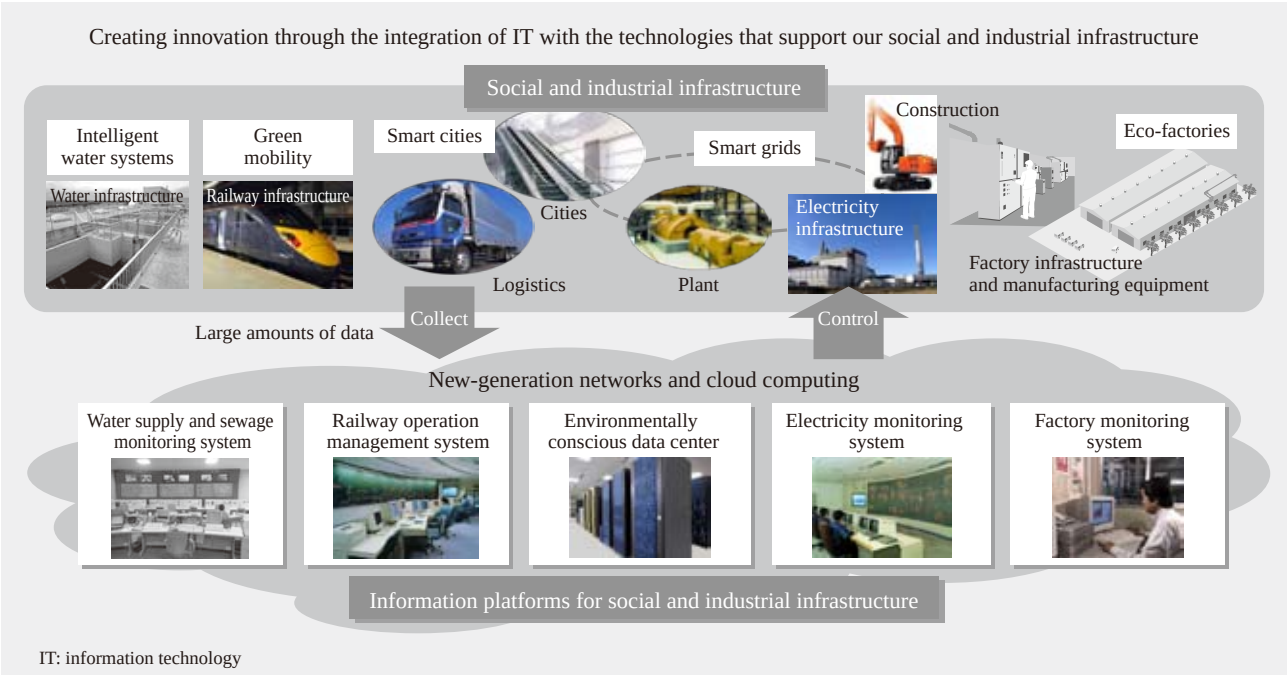


*Fig. 1—Integration of IT with Social and Industrial Infrastructure.*
*Hitachi supplies total solutions for social and industrial infrastructure such as smart grids and eco-factories that combine IT with core products, technologies, and systems.*


*Fig. 2—Industrial Machinery and Manufacturing Equipment that Support Social Innovation Business.*
*The industrial machinery and manufacturing equipment that support Hitachi's Social Innovation Business are managed through an operational structure that is split into "Social Infrastructure & Industrial Systems," "Electronic Systems & Equipment," and "Construction Machinery" divisions.*

are experiencing a recovery while overseas there is growing demand for industrial machinery and machine tools, particularly in emerging economies, along with a willingness to invest in manufacturing equipment. While the market for industrial machinery and manufacturing equipment is strongly influenced by companies' appetite for capital investment, it can be concluded that Japan continues to exhibit strength in this field that has underpinned its success in manufacturing.

Hitachi's Social Innovation Business, which is a major theme in its Mid-term Management Plan, consists of the "fusion of social infrastructure and IT (information technology)" and "materials and key devices." Hitachi's industrial machinery and manufacturing equipment that support this business are managed through an operational structure that is split into "Social Infrastructure & Industrial Systems," "Electronic Systems & Equipment," and "Construction Machinery" divisions (see Fig. 2).

Industrial machinery relates to a wide range of different fields that extend into many of the areas that support our society from construction to electric power and various other industries. Using the articles in this issue as an example, they include plastic injection molding machines (Toyo Machinery & Metal Co., Ltd.), compressors and transformers (Hitachi Industrial Equipment Systems Co., Ltd.), continuous flow ultracentrifuges (Hitachi Koki Co., Ltd.), and construction machinery (Hitachi Construction Machinery Co., Ltd.). Hitachi products feature high performance in terms of parameters such as speed and efficiency, are flexible, are equipped with superior technologies including technologies for better environmental performance and energy efficiency, and include many global niche products that suit a wide range of user needs.

An important category in the field of industrial machinery is that of equipment for producing electronic devices and products. Hitachi High-Technologies Corporation, Hitachi Kokusai Electric Inc., Hitachi Via Mechanics, Ltd., and Hitachi Plant Technologies, Ltd. all supply equipment for this purpose. The markets for semiconductors and LCDs (liquid crystal displays) are characterized by rapid change and the industry is marked by intense global competition between manufacturers. It is in this environment that Hitachi supplies products and technologies that meet customer needs for larger sizes, higher performance, and environmental protection.

## ELECTRONIC DEVICE AND PRODUCT MANUFACTURING EQUIPMENT THAT SUPPORT IT INFRASTRUCTURE

### Production and Inspection Equipment for Semiconductors and Hard Disks

Electronic devices such as semiconductors and hard disks have overcome any number of technical hurdles to achieve higher levels of performance through miniaturization (see Fig. 3). In recent years,

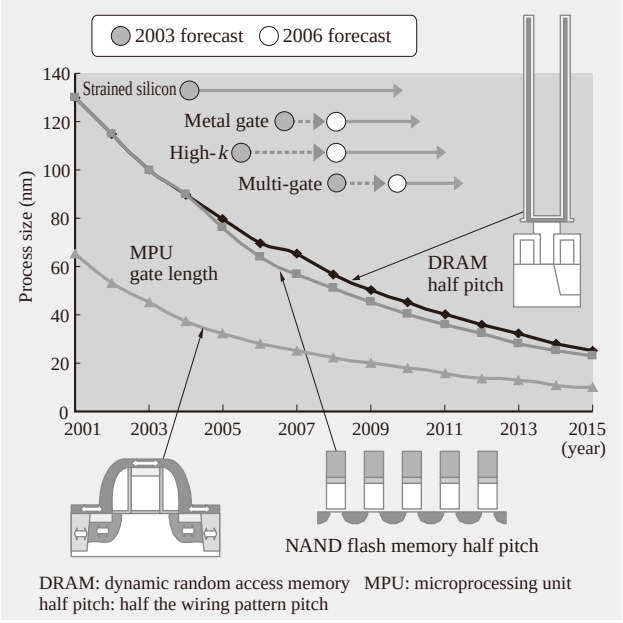


*Fig. 3—Microfabrication Technology Forecast in International Technology Roadmap for Semiconductors (ITRS).*
*Use of shrink technology achieves process dimensions for MPU gates that are even smaller than the half-pitch value used to indicate the fabrication technology generation. Also, since 2005, the driver behind microfabrication technology has been shifting away from DRAM and toward NAND flash memory.*

miniaturization has reached the vicinity of about 10 nm that has been seen as representing a physical limit and the development of various types of manufacturing equipment has made a major contribution to this success.

In addition to the development of new materials, stable yet highly efficient thin film formation and wiring processes have also been essential to the semiconductor production process. As well as facilitating the early adoption of high-*k* (high dielectric constant) dielectric films and resolving problems with uniformity that arise as wafers become larger, Hitachi Kokusai Electric's thin film formation and annealing furnaces[(a)] for semiconductors also make a major contribution to improvements in batch processing productivity by allowing more than 100 wafers to be processed in each batch. Also, the benefits of Hitachi High-Technologies' etching machines used in fine pattern formation include not only greater precision in patterning dimensions but also uniform processing of large wafer sizes (300 mm) and better three-dimensional fabrication including the formation of through holes used for interconnection between multiple wiring layers (consisting of as many as 10 layers). Hitachi High-Technologies also intends further upgrades to these machines including support for 450-mm wafers and expanding their scope of application to include new materials.

Status monitoring plays an important role in maintaining the production process. In the case of semiconductors, this management is done through measurement of the wiring patterns. Hitachi High-Technologies' CD-SEMs (critical dimension measurement scanning electron microscopes) were developed to measure pattern dimensions and the technology was turned into a viable product by transforming what was originally a device for making observations into an industrial instrument equipped with the repeatability and calibration functions suitable for a measurement instrument. Current CD-SEMs can achieve resolutions of 1.8 nm and repeatable accuracy of 0.3 nm. They play an essential role both in production where they are used as quality management tools for the microfabrication process and in the development of new technology where they are used as measurement instruments. A Hitachi High-Technologies SEM won the 54th (2007) Okochi Memorial Production Prize for establishing this technical standard. Hitachi High-Technologies is also working on system-based improvements including more efficient measurement and allowing faster feedback of measurement results to the process. It has commercialized models with features such as enhanced configuration functions and measurement systems that can work from design drawings.

In the hard disk field, further technical innovations are being made to meet the demand for higher density both in the storage medium and data read/write heads with positioning accuracy in production having reached the nanometer range in recent years resulting in recording densities of 600 Gbit/in$^2$. In addition to optical inspection techniques such as those for detecting microprotrusions on the recording medium, Hitachi High-Technologies has also developed systems for measuring electrical characteristics, head shape, and other properties. For example, the head shape measurement system has a measurement repeatability of 1 nm (standard deviation) which makes a major contribution to maintaining high-precision fabrication processes.

It is not only the underlying performance of these

(a) Annealing furnace
Annealing is a form of heat treatment used to improve ductility, release stress, or otherwise stabilize the properties of a material by raising its temperature so that its atomic lattice can recrystallize. The implantation of oxygen ions or other impurities into substrates made of silicon or similar materials is performed in semiconductor manufacturing to control conductivity. This ion implantation disrupts the crystal structure of the substrate and annealing is used to restore it.

production and inspection machines that has been an important factor in recent years but also their merits as environmentally friendly products (including their support for "green" practices) and in addition to complying with environmental standards they also deliver top class performance in areas such as making efficient use of resources and requiring less space for installation (smaller footprint).

## LCD Manufacturing and Inspection Equipment

Since first appearing on the market in the late 1980s, LCD use has expanded from the small displays used in early notebook PCs (personal computers) to encompass desktop PC screens and televisions to the point where it has now become the mainstream display device. In addition to image quality improvement and other technical innovations, the reasons for this include the comprehensive cost reductions achieved through more efficient production. In terms of production technology, the adoption of larger mother glass substrates has recently reached its 10th generation that uses glass substrates that are roughly 3 m square (see Fig. 4).

Hitachi High-Technologies has been involved in the development of production machinery since the early days of LCD commercialization having developed and commercialized products for the upstream stages of the production process (such as glass substrate inspection machines, cleaning machines, and color filter exposure machines) as well as assembly systems such as module mounting machines for finishing processes. With the achievement of low-cost production being the key challenge in LCD manufacturing, these machines require high throughput. Taking exposure machines as an example, Hitachi High-Technologies has been able to keep up with the needs of the industry and in recent years has produced high-speed machines capable of processing 3-m-square glass substrates in 30 s or less through the commercialization of technologies such as precise high-speed mechanical control, temperature uniformity of 0.2°C or better over a wide area, high-brightness optics, and XY step exposure(b), a technique in which Hitachi High-Technologies leads the industry. The growth in equipment size has also been remarkable. With a 10th-generation exposure machine being about 8 m high and having a footprint of 100 m$^2$, ensuring temperature uniformity and a clean environment inside the machine are major challenges. Also, Hitachi Plant Technologies uses its constant-temperature cleanroom technology to manage the environment inside exposure machines and other large machines and has achieved significant results through initiatives such as identifying sources of particle contamination inside equipment with large transport mechanisms and taking appropriate countermeasures. Hitachi has also contributed to the stable operation of semiconductor equipment through a control system that can keep temperature fluctuations to within the ±0.001°C range. In future, Hitachi High-Technologies intends to expand the scope of these technologies to include the production of new device types such as organic EL (electroluminescent) displays and photovoltaic cells.

| Generation | G4 | G5 | G6 | G7 | G8 | G10 |
|---|---|---|---|---|---|---|
| Time (year) | 1999– | 2002– | 2004– | 2005– | 2006– | 2010– |
| System layout | Single stage | Single stage | Single stage<br>Double stage | Single stage<br>Double stage | Double stage | Double stage |
| Glass substrate size (mm) | 730 × 920 | 1,100 × 1,300 | 1,500 × 1,850 | 1,950 × 2,250 | 2,200 × 2,500 | 2,880 × 3,130 |
| Equipment footprint (mm) | 7,260 × 5,040 | 6,400 × 6,650 | S:7,550 × 10,000<br>D:9,100 × 10,000 | S:8,400 × 11,000<br>D:11,000 × 11,000 | 14,100 × 12,200 | 15,400 × 17,200 |

S: single D: double

*Fig. 4—Trend in Size of LCD Substrates and Manufacturing Equipment Footprint (Exposure Machine).*
*Manufacturing costs are reduced by producing multiple LCD (liquid crystal display) panels from a single mother glass substrate. The increasing panel sizes in demand for products such as televisions is also accelerating the trend to larger mother glass substrate sizes. Meanwhile, Hitachi High-Technologies is drawing on a range of methods to shorten production cycle times and reduce the floor space (footprint) required for the machinery. In the case of exposure machines, for example, although these have grown in size from approximately 37 m$^2$ (in G4) to 264 m$^2$ (in G10), in relative terms this is only about half the increase in the size of the substrates.*

## Electronics Manufacturing Equipment

Mounting technology has made a significant

(b) XY step exposure
In the color filter exposure process, a quartz mask is used to form a pattern on the glass substrate. As glass substrate sizes increase, the very high cost of the quartz masks means that continuing to use masks the same size as the glass substrate would increase production costs. Instead, a technique using multiple exposures of smaller masks is adopted. XY step exposure is a technique for the efficient exposure of large glass substrates using steps in both the X and Y directions.

contribution to reducing the size and improving the performance of electronic equipment, with portable devices being a typical example.

Enhancements to the functionality of manufacturing equipment have played an important role. These include smaller and thinner semiconductor packages with high-density mounting, precision machining and high density in printed circuit boards, and precise high-speed component mounting on circuit boards. Hitachi High-Tech Instruments Co., Ltd. is developing techniques for high-density mounting of semiconductor chips and giving component mounting machines for printed circuit boards the ability to handle extremely small components. Hitachi Via Mechanics leads the industry in commercializing high-density machine tools for printed circuit boards. For example, micro SD (secure digital) cards achieve their large memory capacity by layering a large number of memory boards that have been machined to be only about 15 μm thick. Hitachi Via Mechanics has also played a major role in the creation of advanced mobile phones by providing the capability to drill holes of 0.15 mm or less in circuit boards and mount components as small as 0.4 × 0.2 mm. While achieving higher densities results in a significant increase in the number of processing steps which creates an inevitable demand for higher processing speed, in addition to technologies that increase speed through the use of precise mechanism design and mechanical control techniques, the development of products that seek to improve total productivity by reducing the amount of preparation work and other downtime is another major feature.

## INDUSTRIAL MACHINES THAT SUPPORT SOCIAL INFRASTRUCTURE

### Electric Plastic Injection Molding Machines

Injection molders are the most commonly used machines for the production of plastic products. As a specialist producer of plastic injection molding machines and aluminum die-cast machines, Toyo Machinery & Metal supplies a wide range of injection molding machines to various industries in Japan and elsewhere, from the electrical and electronics industry through to home appliances, vehicles, food, and healthcare. Its products range from small machines for making precision miniature components up to large machines for automotive components.

Toyo Machinery & Metal has developed a new model in its latest Si-V (five) Series based on the "smart molding" concept which features a newly developed control system as well as other technologies that it has built up over time (see Fig. 5). The "smart molding" concept uses the machine itself to handle advanced condition settings that in the past depended on the skill of the operator and its aims include more uniform quality, shorter production times, and workload balancing. It also aims to improve environmental performance through features such as lower power consumption and materials-related improvements such as being lead-free.


*Fig. 5—Si-100V Electric Injection Molding Machine. The Si-100V is based on the "smart molding" concept in which the machine itself can handle advanced condition settings with capabilities that include workload balancing, shorter production times, and more uniform quality.*

### Air Compressors

Air compressors are an important source of compressed air for the assembly process, machine tools, and other applications in factories and elsewhere. However, the power consumed by air compressors and associated systems makes up 20 to 25% of total factory power consumption meaning there is also a need to improve their energy efficiency to help reduce $CO_2$ (carbon dioxide) emissions.

Hitachi has developed many different air compressors to meet customer needs since supplying its first 100-HP air compressor in 1911, just one year after the company was formed. Oil injection rotary screw compressors in particular are used in many areas of industry and Hitachi Industrial Equipment Systems is working on advances in the compressor unit at the heart of these machines to achieve better efficiency and quieter operation. Variable-speed controllers with capacities from 22 to 75 kW and equipped with

(c) DCBL
Abbreviation of "direct current brushless." A brushless DC (direct current) motor with a permanent magnet rotor. With low losses and the ability to operate with higher efficiency than an induction motor, the advantages of DCBL motors include lower power consumption and smaller motor size.

*Fig. 6—NEXT Series Oil Injection Rotary Screw Compressors. The variable-speed controller available with capacities from 22 to 75 kW is equipped with a DCBL permanent magnet motor and provides highly efficient operation. The units also feature excellent overall energy efficiency.*

*Fig. 7—Amorphous Transformer.*
*Highly efficient characteristics are achieved by using an amorphous alloy core. Hitachi is undertaking a comprehensive program of business expansion and technical development extending from the materials to the completed transformer.*

DCBL[c] permanent magnet motors that incorporate Hitachi's variable-speed drive technology provide a high level of energy efficiency. The compressors are also designed to reduce pressure loss within the unit, with energy efficiency being achieved throughout the total unit, not just in the compressor itself (see Fig. 6).

## Amorphous Transformers

With efforts to protect the global environment gaining momentum around the world, amorphous transformers are attracting attention for their ability to achieve dramatically higher efficiency than conventional transformers by significantly reducing the no-load loss (the power consumed by transformers when idle) (see Fig. 7).

Hitachi started research into amorphous transformers[d] at an early stage and released its first pole-top transformer in 1991 followed by a general industrial transformer in 1997. Hitachi has a comprehensive program of commercialization that extends from materials development to the technologies used in the transformers with ongoing developments including larger sizes and higher quality. Total shipments to date have reached about 150,000 units.

As an example of the benefits of installing amorphous transformers, Hitachi reduced electric losses by roughly one-third at Hitachi Industrial Equipment Systems' Nakajo Division by consolidating transformer numbers and adopting amorphous transformers, reducing $CO_2$ emissions by 900 t annually.

## Continuous Flow Ultracentrifuges

Continuous flow ultracentrifuges are a type of production machine used mainly in the production of vaccines for protecting against viral diseases to separate and recover the desired material from culture fluids in which large volumes of pathogenic viruses or other useful substances have been cultured. As these exist in the form of very small particles (18 to 300 nm), continuous flow ultracentrifuges play an important role in separating, purifying, and

*Fig. 8—CC40NX Continuous Flow Ultracentrifuge.*
*Features include improved sterilization of the separation process and electronic data management of pharmaceutical production records.*

(d) Amorphous transformer
A transformer in which the core around which the current-carrying coil is wound is made of amorphous alloy to significantly reduce the no-load loss (power consumption when idle). Amorphous alloys are alloys with a disordered non-crystalline internal structure and feature excellent strength and electrical characteristics.

*Fig. 9—EH3500ACII and EH4000ACII.*
*These dump trucks use an AC-IGBT (alternating current—insulated gate bipolar transistor) electric drive system jointly developed by Hitachi Construction Machinery Co., Ltd. and Hitachi, Ltd.*

concentrating them.

The requirements from producers of pharmaceuticals and vaccines are for manufacturing equipments that provide better sterilization of the separation process, electronic data management of pharmaceutical production records, and configurations and specifications that have the flexibility to work with other manufacturing equipment in order to achieve higher levels of product quality, greater production efficiency, and other benefits.

To meet these needs, Hitachi Koki released the CC40NX continuous flow ultracentrifuge in October 2009 (see Fig. 8). Its features include a top speed of 40,000 $min^{-1}$, steam sterilization of the sample flow path, and electronic recording of operational data.

### Super-large Hydraulic Excavators and Dump Trucks

Growing resource demand is also pushing up demand for mining equipment from the world's mines. At opencast mines in particular, large capacities and high reliability are required by the large hydraulic excavators and dump trucks used for the excavation and transport respectively of soil, ore, and other material.

The high performance and superlative capacity and reliability of Hitachi Construction Machinery's super-large hydraulic excavators have earned them the largest share of the international opencast mining market. Hitachi Construction Machinery has also developed 190-t and 220-t dump trucks that incorporate AC-IGBT(e) (alternating current—insulated gate bipolar transistor) electric drive systems that are the result of collaborative development drawing on Hitachi, Ltd.'s long experience in the development of electric drive systems for trains and other vehicles (see Fig. 9).

In addition to fault diagnosis systems that help Hitachi Construction Machinery mining equipment maintain high levels of utilization, Hitachi Construction Machinery is also helping boost productivity at the world's mines by developing models that take account of energy efficiency and compatibility with the environment, including electric drive and the adoption of engines with low exhaust emissions.

## CORE TECHNOLOGIES THAT SUPPORT INNOVATION IN INDUSTRIAL MACHINERY BUSINESS

The industrial machinery sector supports Social Innovation Business and in doing so it needs to respond to issues such as how to deal with environmental problems and the growing diversity of requirements resulting from market globalization. To accelerate the environmental performance and global suitability of its industrial machinery products, Hitachi is working on the development of innovative core technologies including analysis-based design techniques that utilize sophisticated numerical simulations and also technologies for reducing the burden on the environment and improving safety and comfort.

For example, the high-speed Class 395 trains designed specifically for markets outside Japan utilize a range of different analysis techniques created for Japanese trains but are built to suit the standards and infrastructure of the UK. Elsewhere, Hitachi is working to enhance and widen the scope of application of analysis techniques that allow optimum designs to be produced in a wide range of fields including accurate predictions of how dump trucks will handle in use and the application of unsteady flow analysis techniques to the design of impellers for large industrial pumps. Hitachi is also working on techniques for making hydraulic excavators quieter and on dynamic stability control technologies that can improve their safety and operational efficiency. It is developing microreactors that are seen as having the potential to build a new generation of chemical plants with a low impact on the environment.

Hitachi will continue to develop innovative technologies that support the industrial machinery at the core of its Social Innovation Business with aims that include higher productivity and imposing less of a burden on the environment.

(e) IGBT
Abbreviation of "insulated gate bipolar transistor." A semiconductor device used for switching in inverters and similar equipment. IGBTs combine high-speed switching performance with the ability to withstand high voltages and carry heavy currents.

## INDUSTRIAL MACHINERY AND MANUFACTURING EQUIPMENT THAT SUPPORT SOCIAL INNOVATION BUSINESS

Having celebrated the 100th anniversary of the company's founding last year, Hitachi is seeking to grow based on a global vision that has its Social Innovation Business at its core. The industrial machinery and manufacturing equipment described in this issue are the subject of high expectations for their potential to contribute in the fields of infrastructure as well as social and industrial systems in Japan and the rest of the world.

Through its industrial machinery and manufacturing equipment, Hitachi will continue to work toward building a sustainable society by directing its efforts at the development of new technologies, productivity improvements, energy efficiency, and reducing the burden on the environment.

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