History of electric vehicles

-Providing support as a drive system pioneer

History of Meidensha's automobile-related business

Meidensha has greatly contributed to the development of automobile technology, such as by delivering Japan's first electric dynamometer in 1920, delivering Japan's first chassis dynamometer in 1927, and developing the roller dynamometer, which received the OHM Technology Award in 1985.

Meidensha has delivered numerous testing systems that have contributed to global automobile environmental strategies (fuel consumption reform, gas emission, noise reduction, etc.) focusing on the Ministry of Land, Infrastructure, Transport and Tourism and the Ministry of Economy, Trade and Industry, etc., research institutions, and Japanese automobile and parts manufacturers. According to the ever-changing needs of the times, Meidensha has conducted joint development with various automobile manufacturers to evaluate the functions of new automobiles, and has a record of delivering over 3,500 systems, placing it among the leaders of the industry. Furthermore, as a range of regulations concerning fuel consumption efficiency and exhaust gas have been implemented, Meidensha has been developing and delivering testing equipment in line with these regulations.

At present, labor hours for design and development have been increasing for power trains that have been diversifying due to more advanced functionality of automobiles (electronic control, safety driving support systems, connectivity, etc.) and tightening environmental regulations around the world. Against this backdrop, it has become even more important to shorten development periods while maintaining quality, and in order to deal with this issue, importance has been placed on model-based development (MBD) as an automobile development and evaluation method. MBD is a method to reduce the testing and trial frequency of testing vehicles and parts components and conducting development in an efficient manner, by evaluating functions, etc., through simulations that utilize CAE, etc. By integrating models created with CAE, etc., into the MBD process, Meidensha is working to develop efficient testing systems.

Technologies and strengths developed since Meidensha's foundation

• Motor/Inverter technology and EV drive systems

Meidensha's industrial motors and inverters have been adopted for a number of purposes in various locations and environments, and Meidensha has accumulated a range of technologies in the process. Based on these technologies, Meidensha started developing motors and inverters for EVs in the 1990s. Meidensha's motors and inverters have been adopted for a number of concept cars, such as the EV, "IZA," which was jointly developed by Tokyo Electric Power Company, Inc. (now Tokyo Electric Power Company Holdings, Inc.) in 1991. Meidensha currently provides products for the i-MiEV and OUTLANDER PHEV, which are vehicles on the market produced by Mitsubishi Motors Corporation, and has an extensive record of producing over 230 thousand vehicles in total. In addition, incorporating the knowledge gained from this record in our products is the most important source of improved reliability.

From a development perspective, in addition to continuous basic development, which is constantly focused on the future, Meidensha also has a system to develop products that are most appropriate for vehicles under development, by being involved with design from the early stages of the customer's vehicle development. From a production perspective, Meidensha is constantly working towards automation of production lines and quality control, and providing highly reliable products.

• Dynamometer systems

Meidensha is able to provide products, systems, and engineering for automobile development, from subcontracting of testing equipment such as for engines, transmission, and completed automobiles, and research and development, through to coordination of products and systems, and construction such as testing buildings, laboratories, and incidental equipment. Furthermore, Meidensha has an integrated production process at its domestic location (Dynamometer System Factory, Ohta City, Gunma Prefecture) that encompasses research, development, and design, through to manufacturing (machinery, control systems, and operation and design equipment, etc.), and it is able to provide customers with high-quality, highly functional products in collaboration with Group companies and partner companies.

Meidensha has testing buildings in two locations: Japan (Ohta, Gunma) and the US (Michigan), where various tests are carried out on commission and research and development of next-generation products is conducted. Through the use of these testing buildings, Meidensha not only conducts joint verification, which contributes to the research and development of customers, but also creates new technologies and new value together with customers and partner companies according to the needs and issues uncovered through testing.

History of Automobiles

Meidensha's History with Automobiles

Dynamometers

EV

1900

1904 First automobile in Japan

1908 Model T Ford (mass production)

1897 Establishment of Meidensha
One horse power three-phase induction motor

1920

1934 Establishment of Nissan Motor Company Ltd.

1937 Establishment of Toyota Motor Corporation

1920 10 horse power DC dynamometer - Tokyo Technical School (first dynamometer in Japan)

1940

1948 Establishment of Honda Motor Co., Ltd.

1958 ECDY series (first ECDY*1 in Japan)

1960

1965— Profusion of automobiles

1970 Regulation of gas emissions

1979 Formulation of fuel-efficiency standards

1978 Ministry of Transport NTSEL CHDY*2 for automobile certification testing

1980

1991 TEPCO - IZA in-wheel motor (176 km/h)

2003 Keio University - Eliica in-wheel motor (370 km/h)

1996 Dynamometer for FWD vehicles - PM dynamometer (world first)

2000

2005 ZEV*3 regulations (California, USA)

2002— Contingent valuation system (VRS) virtual reality simulation technology

2009 Mitsubishi i-MiEV

2018

2018 Tightening of ZEV regulations

2019 NEV*4 regulations (China)

2018 Model-based development - Japan Automobile Research Institute - Environmental automobile and EV testing system

First mass-produced EV in the world

First mass-produced PHEV in the world

2013 Mitsubishi OUTLANDER PHEV

*1 Eddy Current Dynamometer
*2 Chassis Dynamometer
*3 Zero Emission Vehicle
*4 New Energy Vehicle

The proliferation of EVs presents a business opportunity

Tackling challenges presented by the accelerating new age of automobiles head on

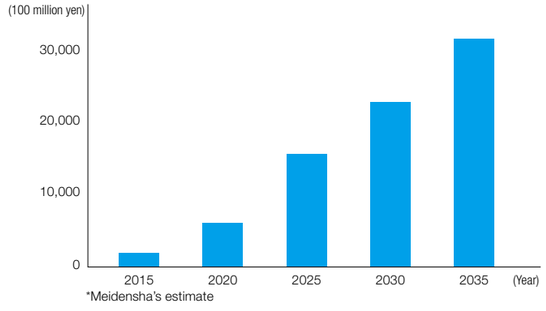
OUTLANDER PHEV (Mitsubishi Motors Corporation)

The environment surrounding the automobile industry and future technological trends

The accelerating shift from gasoline and diesel vehicles to EVs has been labeled a once in a hundred-year upheaval. The tide of electrification of automobiles is rising around the world, such as the future prohibition of sales of gasoline and diesel vehicles in Europe, and China promoting EVs/PHEVs on a national level. From a technological perspective, there have been improvements in battery performance, and we are gradually creating the foundation for the rapidly expanding electric vehicle market.

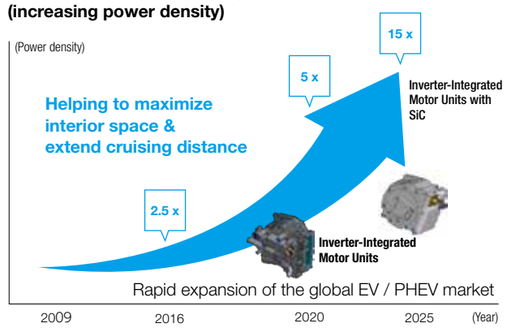
In this environment, (1) miniaturization, (2) improved output density, and (3) reduced cost are required for future EV drive systems. It is important to work towards miniaturizing and lightening components and minimizing loss in order to extend the range per charge. Furthermore, because the cost of electric vehicles is higher than gasoline-powered vehicles, the national government is providing subsidies. In order to make the cost of electric vehicles on par with gasoline-powered vehicles, it is necessary to work to reduce the cost of EV drive systems.

Market size prediction for motor inverters for EV drive system (EV and PHEV)



*Meidensha's estimate

Future technological developments (increasing power density)



Aiming to further miniaturize motors and inverters

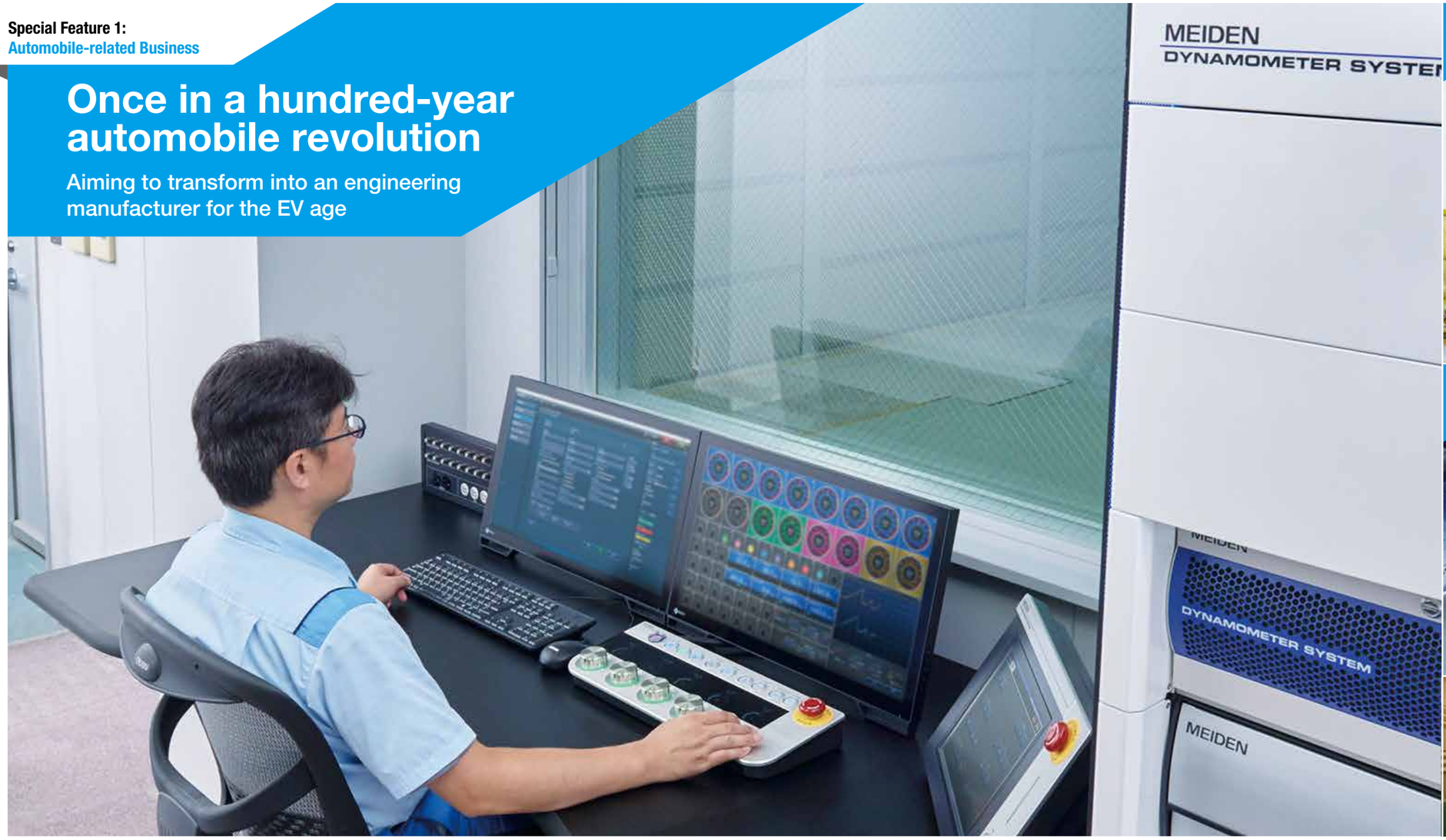
Motors and inverters are integral components of EVs. In order to achieve higher efficiency and lighter weight, as well as achieve vehicles with a flat floor and a roomy interior, there is strong demand for further miniaturization of components.

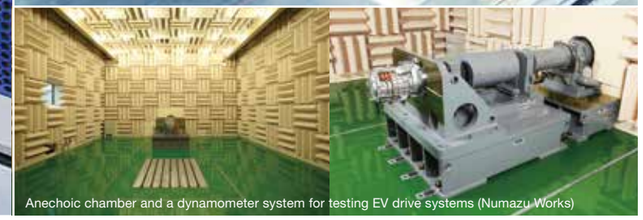
In order to achieve miniaturization, for motors, we are working to improve the performance of permanent magnets and limit energy loss (iron loss) in the motor core. For inverters, we are working to miniaturize capacitors, which are one of the components used to improve cooling technology. To achieve further miniaturization, units that integrate motors and inverters are under development. By including motors and inverters in a single case, cabling is reduced, required installation space is reduced by 30%, and weight is reduced by 15% in comparison to motors and inverters being installed separately. From 2017, we will be able to display prototypes at exhibitions and commence mass production at will. There are instances in which it is better to install motors and inverters separately; however, if the structure is optimized for integration, the merits of integration are considerable.

Through these measures, we plan to increase the output volume of inverters to five times the level of 2009 by 2020. By 2025, we aim to increase the output volume to 15 times that of 2009 by replacing the current silicone (Si) power semiconductors used for inverters with silicone carbide (SiC).

Once in a hundred-year automobile revolution

Aiming to transform into an engineering manufacturer for the EV age





Anechoic chamber and a dynamometer system for testing EV drive systems (Numazu Works)

What testing systems are required in the electric and digital age?

The automobile is undergoing a once in a hundred-year upheaval, and we are increasing investment in next-generation technology with a focus on CASE*1, in medium to long-term preparation for the electric and digital age. With this in mind, research and development initiatives are also necessary for testing equipment, in order to respond to new needs.

The first of these initiatives is “model-based development.” Model-based development is a method that shortens development lead time and increases efficiency by conducting development through simulations, without manufacturing actual prototypes if possible. The second is “improving the performance of high-speed dynamometers, battery simulators that mimic batteries, and testing equipment for electric vehicles, such as charge-discharge devices to evaluate batteries, etc.,” as electrification accelerates. The third is “enhancing engineering capabilities.”

Speed is becoming even more important in order to respond to an environment in which these kinds of technology and products are becoming more widespread and complex. Therefore, we will enhance our business partnership strategy, which includes companies in the same industry as well as those in other industries.

*1 CASE: Connected Autonomous Shared Electric

Creating new value through the merger of products and testing equipment

Meidensha is the only company in the world that has both a product business and testing equipment system business for EV/ PHEV motors and inverters, making us a pioneer in the field. Medium-term Management Plan 2020 designates automobile-related businesses as growth businesses, and aims to ensure the expansion of both businesses by proactively investing resources.

In the future, the global market for automobile electrification is expected to grow rapidly, and Meidensha considers automobile electrification to be important for global environmental conservation, safety measures such as reducing road deaths to zero, and solving social issues to achieve a mobile society where all people can move freely.

The history of EV/PHEV-related testing devices is approximately 10 years. In 2009, sales commenced for the EV and HEV testing system EVREVO. In 2011, Meidensha installed an anechoic chamber and a dynamometer system for testing EV drive systems (Numazu Works, Shizuoka), and in 2013, Meidensha added a testing building at Kofu Meidensha Electric Mfg. Co., Ltd.

In addition, in 2011, Meidensha announced testing technology that used the Mitsubishi Motors i-MiEV (joint announcement with Ono Sokki Co., Ltd. at the Society of Automotive Engineers of Japan, Inc.), and we are working on measurement and testing of sound and vibration, etc., to further improve the quality of motor and inverter products for EVs and PHEVs.

In 2018, Meidensha delivered EV testing systems that can test whether electric vehicles and environmental automobiles that have undergone the WLTP*2 for the Japan Automobile Research Institute meet environmental standards. Going forward, we aim to expand the scale of our businesses by speeding up research and development at Meidensha’s product businesses and further improving quality and mass-production technology capabilities, through improved performance and enhanced engineering, centered on simulation and analysis.

*2 WLTP (Worldwide harmonized Light vehicles Test Procedure): International standard for testing methods to calculate gas emissions and fuel efficiency

Towards enhanced development of the social infrastructure business and creation of new businesses

The Medium-term Management Plan 2020, designates the overseas business as a growth business, and aims for expansion of the scale of businesses in the fields of railways, electric power companies, and the private sector, in accordance with the growth of the respective markets. Demand for infrastructure such as power plants, railways, water supply, and sewage treatment continues to grow in emerging countries, mainly in Asia, due to population growth and urbanization. In addition, new social demands are appearing, such as heightened environmental awareness around the globe, and accelerated innovation due to new technologies such as the IoT and AI technology.

In response to this situation, Meidensha is accelerating implementation of its global strategies to strengthen partnerships with its subsidiaries based in 13 countries around the world and local companies in Southeast Asia, to participate in urban transit projects and high speed rail projects which are rapidly increasing, and to enter new markets and new businesses.

We will introduce these strategies below, along with our fiscal 2017 results.

Policies by region

- Strengthen expansion of social infrastructure businesses, taking advantage of increased demand for infrastructure due to population increase and urbanization, etc., in emerging countries, particularly in Southeast Asia.
- Create new businesses that address new social trends such as heightened environmental awareness around the globe, and accelerated innovation due to new technologies such as the IoT and AI technology.

China:
Stable growth of an enormous market

Expand the industrial systems business, by responding to demand for electrification and labor-saving solutions.

North America:
Environment and innovation

Acquire environmental and cutting-edge technologies and create new business fields.

India:
High economic growth

Strengthen the business expansion of PRIME MEIDEN LIMITED. by responding to vigorous infrastructure investment against a backdrop of high economic growth.

ASEAN:
Advancing population growth and urbanization

Strengthen the social infrastructure business focusing on electric power and railways by responding to increasing demand for infrastructure due to advancing urbanization.

Development of new businesses

Establishment of the Silicon Valley Office

In August 2017, Meidensha established the Silicon Valley Office in San Jose, California, as a business site for its subsidiary, MEIDEN AMERICA INC., in order to expand its business in the North American market. To date, MEIDEN AMERICA INC. has mainly been selling dynamometer systems for automobile-related companies, semiconductor-related products such as vacuum capacitors, and ceramic membranes for water supply, wastewater, and industrial wastewater treatment, etc., primarily in Michigan. By establishing an office in the Silicon Valley region, where there are many semiconductor-related customers, many leading companies, universities, and research institutes from around the world, Meidensha aims to collect cutting-edge information about rapidly advancing ICT and environmental technology, etc., and create new business models based on its unique social infrastructure technology developed over many years.

Strengthening partnerships

First delivery of a 400kV transformer to an Indian state power company

In July 2017, PRIME MEIDEN LIMITED., a transformer manufacturer and engineering company, delivered a 400kV 315MVA transformer to India's Transmission Corporation of Andhra Pradesh Limited (APTRANSCO). This product is the highest voltage transformer manufactured by the Meiden Group. Meidensha expects further business expansion into the Indian electric power market.

PRIME MEIDEN LIMITED., which had previously focused on the production of medium-size transformers, has shifted toward the production of large-size 400kV transformers to expand business in India, where demand for substations is expected to increase rapidly. The 400kV transformer for APTRANSCO represents the first supply to a state-owned power company for PRIME MEIDEN LIMITED. and the second supply of large-size transformers in India, following a 270MVA transformer that had been supplied to a power generating company in March 2017, which has opened the way for further orders of ultra-high voltage transformers.

Currently, major international as well as local manufacturers are dominating the global transformer market. Meanwhile, Meidensha has increased its share capital in PRIME MEIDEN LIMITED. and taken over the control of the company to make the best use of the company's geographical advantage and accelerate its business expansion. Meidensha expects sustainable growth in the substation business in India as well as potential opportunities for export to Africa and ASEAN countries through the Meiden Group's network.

Executing large-scale overseas railway projects

Orders received for power supply systems for Singapore's MRT* North-South and East-West lines

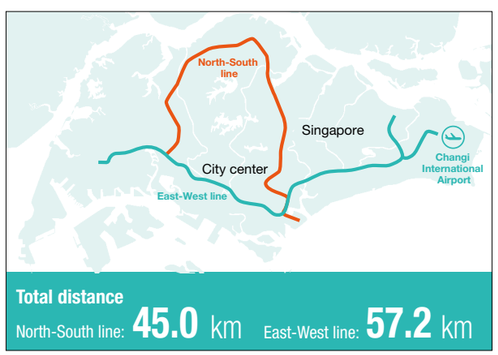
In February 2018, MEIDEN SINGAPORE PTE. LTD., a Singapore subsidiary of Meidensha, received an order for power supply systems for Singapore's MRT North-South and East-West lines from Singapore's Land Transport Authority.

The MRT North–South and East–West lines are extensions of the first urban railway opened in Singapore. Since Meidensha supplied the power supply system for the line opened in 1987, the company has been renewing feeding substations to deal with increasing train traffic. This time, MEIDEN SINGAPORE PTE. LTD. received a package contract for electrical system design, supply of equipment (feeding transformers, railway distribution panels, AC circuit breakers, surge arresters, etc.), renovation of existing equipment, and on-site installation and testing, for the 75 existing substations on the MRT North-South and East-West lines.

Since the initial construction was completed in 1988, the MRT has progressively been extended, and it has become an important means of transport for residents, connecting downtown residential areas, industrial areas, and the airport, from north to south, east to west. The Meiden Group has continuously been conducting maintenance and replacement for the North-South line and the East-West line since the MRT commenced operation.

Just like thirty years or so ago, there was fierce competition for this project from other bidders from Europe, the US, etc. However, MEIDEN SINGAPORE PTE. LTD. received the order due to the Meiden Group's highly-evaluated track-record and engineering capabilities. The Meiden Group has delivered electrical power equipment for many projects both in Japan and overseas. We will leverage our track-record and knowhow accumulated over many years to respond to the growing demand for railway infrastructure, particularly in the ASEAN region, and contribute to the growth and development of various countries and regions by providing safe and reliable equipment and facilities.

* MRT: Mass Rapid Transit



Enhancing profitability through increased productivity and changes to the business model

Social infrastructure businesses — Enhancing product competitiveness through a new production strategy

Designing and manufacturing products efficiently is important to solidify the market dominance of our social infrastructure business, which mainly undertakes production of order-made products.

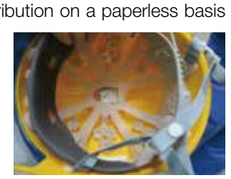
Under the Medium-term Management Plan 2020, the Meiden Group aims to conduct capital investment for increases in business scale and production, improve production efficiency, such as by automating production and automating inspection processes for mass produced products, and thereby increase profitability. We will now showcase enhancements to product competitiveness through production strategies such as smart factories that utilize IoT and AI technology and automation of design.

Aiming for enhanced product competitiveness through the introduction of the IoT to create smart factories

Meiden Plant Systems Corporation aims to reduce estimate costs by 50% by the end of 2020, through greatly reduced lead times and increased production due to revisions to production mechanisms, through improvement and transparency of production processes, such as through utilization of the IoT.

Target:
Estimate costs
50% reduction

Although Meiden Plant Systems Corporation carries the Meiden brand, it is responsible for the manufacture and sale of low-cost high and low voltage control boards. In terms of improvements to production processes through the introduction of the IoT, we have increased efficiency by discovering and eliminating unnecessary tasks by introducing a real-time positional detection system that is capable of checking flow and work status by fitting ID tags to workers' helmets and products. Through this system, we have achieved improved work efficiency by increasing transparency of the history of workers and conducting improvements, by applying the system to component defects, design flaws, and tasks other than assembly, to which distribution of parts cannot keep up. We have achieved distribution on a paperless basis for each engineering code and each level, and thereby increased work efficiency, through the introduction of distribution trolleys, kit boxes, and parts distribution tablets on a per engineering code basis.


ID tag inside a worker's helmet

Other than the introduction of the IoT, we are conducting improvements such as by changing factory layout with awareness of the workflow of the manufacture of a single switchboard and the introduction of a *mizusumashi* (fixed-course pick-up) system, and creating transparency of work progress by changing assembly from the batch method to the cell method. Our target is to reduce the amount of time it takes to complete each product by 40% through these process improvements, including the introduction of the IoT. Going forward, we plan to successively convert our 8 main domestic factories to smart factories.


Display of work conditions


Introduction of a *mizusumashi* system

Target:
Time to completion of product
40% reduction

Optimization of the supply chain through creation of a design database

Meidensha is greatly improving efficiency of design tasks and optimizing the supply chain by centrally managing and creating a database of design information that is exchanged in vast quantities during the production process.

Until now, correspondence between design and manufacturing staff has mainly occurred by paper; however it is now possible to conduct digital correspondence through centralized management and creation of a database for design information. Furthermore, by creating a master of each component, linking those masters with design information, and centrally managing them, it is possible to reduce costs through bulk purchase of components, stay on top of the status of insufficient components such as if procurement of components is difficult due to a disaster, and consider replacements. Going forward, we will utilize product lifecycle management, which utilizes design databases even more effectively (utilization for operation and maintenance), as well as AI technology, to create design assistance mechanisms. We will also implement new design methods such as modular design, standardized design, automated design (design that follows patterns and rules), and cellular design.

Maintenance and servicing business — Expanding the business to include facility management to meet the needs of customers

As the environment undergoes dramatic changes, such as labor shortages as the working population declines, the aging workforce, and difficulties for local governments to implement fiscal policies, there are many private factories that are 30 to 40 years old, and dilapidation of facilities is becoming a more pressing issue. However, in the public sphere, inter-municipal projects and municipal amalgamation are increasing, and there is a trend to outsource maintenance, inspection, operation, and management to private companies as a package.

We provide preventative maintenance services that utilize sophisticated diagnostic technology that incorporated IoT and AI technology and labor-saving, low-cost operation in response to our customers' needs such as "wanting to use equipment for as long as possible," "wanting to manage symptoms and remaining life to prevent issues from occurring," and "wanting to know optimal operation conditions and operate equipment in an energy-efficient manner." Going forward, we aim to further enhance our one-stop service centered on lifecycle engineering, and expand the business to include facility management.

Improvement of maintenance utilizing AR (augmented reality)

In order to achieve efficient maintenance, we aim to increase efficiency and ensure accuracy through the introduction of AR. AR is mostly used in the three areas of "daily inspections," "periodic inspections," and "emergencies." By overlaying inspection locations, inspection history, and work procedures, etc., on an image of the equipment on a tablet, maintenance can easily be conducted by a worker who is not a specialist in the relevant equipment or by an inexperienced worker. In an emergency, it is expected that increasing accuracy and efficiency, such as by communicating with a remote maintenance specialist and sharing information written on the tablet screen, will lead to quick restoration of function.

Daily inspections:
An arrow indicates the locations to inspect


Periodic inspections:
Dismantling procedures are shown with a 3D animation


Emergencies:
The screen is shared with a remote maintenance specialist

Prediction of failures through remote monitoring and diagnostics of the equipment location through the IoT and AI

By sending data from existing monitoring devices installed by Meidensha and sensors affixed to equipment to Meidensha's cloud system, and gathering and analyzing that data, we are developing failure prediction technology to prevent emergency shutdowns of equipment.

We aim to visualize the status of the customer's equipment, run diagnostics on operational efficiency and failure risk, improve equipment availability, and reduce maintenance costs, etc., by collecting multiple forms of data in the cloud, such as electrical current, temperature, and vibration data collected by sensors, and analyzing it using AI. Furthermore, if we are able to understand past failures and abnormalities, we expect to be able to quickly dispatch maintenance staff to the site to minimize the impact of any abnormality.

As the number of veteran engineers declines, it is essential to rapidly establish high-precision equipment diagnostic technology. Going forward, we aim to proceed with the introduction of remote monitoring and diagnostic services for local governments, reduce costs and labor, create transparency of energy usage, and provide optimal solutions.

Diagram of Meidensha's remote monitoring and diagnostic services