HITACHI REVIEW

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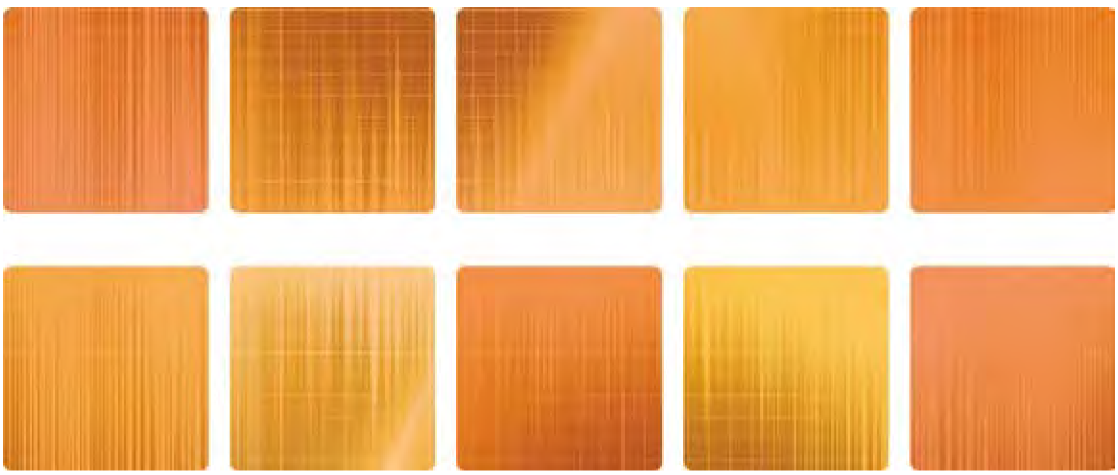
HITACHI
Inspire the Next

Role of Construction Machinery in Building Prosperous and Comfortable Society



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Construction Machinery for Diverse Global Markets

Yuichi Tsujimoto
President, Chief Executive Officer and Director
Hitachi Construction Machinery Co., Ltd.

THE market for construction machinery is growing in response to vigorous demand from emerging economies. While fluctuations in demand such as those that accompanied the global financial crisis are likely to recur in the future, demand for construction machinery is anticipated to continue increasing with the ongoing economic development of emerging economies such as China and India.

As a result, our business is rapidly expanding throughout the world, from developed to emerging economies, to the extent that the proportion of our business outside Japan has increased from about 50% 10 years ago to around 80% now.

Meanwhile, the business environment in the global marketplace is undergoing major changes, including the growing diversity of regional needs, the strengthening of environmental regulations, and intensifying competition, not only from existing competitors, but also from new manufacturers based in China or South Korea. In response to these increasingly diverse needs of the global market, our role is to deliver products that suit each region in a timely manner.

This issue describes what the Hitachi Construction Machinery Group is doing to meet the diverse needs of the global market.

Environmental measures will feature strongly in future construction machinery. Developed economies are taking active steps to strengthen exhaust emission laws for construction machinery, and energy efficiency improvement represents a central pillar for environmental measures because of its role in helping prevent global warming. In addition to complying with the world's most stringent exhaust emission laws in Japan, the USA, and Europe, the latest ZAXIS-5 Series of hydraulic excavators also feature excellent energy efficiency. As in automobiles, electric and hybrid drives are effective technologies for improving the energy efficiency of construction machines. We see trolley-assisted dump trucks, electric-hydraulic excavators, and hybrid hydraulic excavators equipped with the latest technology as representing a pioneering approach to reducing emissions of carbon dioxide (CO_2). Furthermore, we were the first in Japan to implement carbon offsetting for construction machines, and we believe this to be a valuable activity for raising wider awareness of CO_2 emissions reduction.

The articles in this issue cover a range of other measures that the Hitachi Construction Machinery Group is undertaking, including the use of information and communication technology (ICT) in construction machinery, preparing for the future through greater use of robotics in construction machines, and assistance with earthquake recovery and landmine clearance that we are undertaking as part of our corporate social responsibility (CSR) activities. I hope that this issue will help you understand the many different roles of construction machines, and prove beneficial to your business.

Technotalk

Business Operations in Global Markets Based On Life Cycle Support

Yukio Arima
Vice President, Executive Officer and Director
President, Life Cycle Support Operations Group
Hitachi Construction Machinery Co., Ltd.

The global market for construction machinery is expected to sustain double-digit growth for many years to come, with a major shift in relative demand away from developed economies and toward emerging economies. This has created a need for further improvements in support infrastructure across the entire product life cycle, including maintenance, parts, and services. Recognizing these major changes in the business environment and the outlook for the future, Hitachi Construction Machinery Co., Ltd. established a new Life Cycle Support Operations Group in April 2011 along with the release of its Go Together 2013 medium-term management plan. Yukio Arima, a Vice President and Executive Officer at Hitachi Construction Machinery Co., Ltd. explains the important role of life cycle support in the future, the development of service staff who can underpin this work, and its global deployment with an eye to the expanding mining industry market.

Importance of Life Cycle Support in Construction Machinery Business

——While many Japanese manufacturers have been struggling against adverse conditions over the last few years, including the strong yen and a depressed economy, what developments are taking place in the construction machinery business?

Arima: In terms of our financial results, they went into decline due to the global financial crisis after peaking in 2007, but the subsequent growth in international demand for construction machinery means they have now recovered back to 2007 levels in terms of the number of machines sold. The structure of global demand has changed notably since the start of the global financial crisis, with the growth in demand from emerging economies having a major impact. In Japan and other developed economies, the proportion of new entrants to the market for earthmoving machinery has been very low. This contrasts with the situation in emerging economies such as those in Asia and Africa where a large number of players have started new earthmoving machinery businesses.

Our Go Together 2013 medium-term management plan formulated in response to these changes in the business environment identified six strategic themes, one of which is life cycle support for which we established the Life Cycle Support Operations Group in 2011, the first year of the medium-term management plan.

——What are the reasons behind identifying life cycle support as one of the strategic themes of the medium-term management plan?

Arima: While we have always provided support across the entire product life cycle, from the initial sale of new construction machines through to maintenance, parts, repair, and sales of used machinery, we decided to explicitly designate life cycle support as one of the pillars of our business because our aftermarket business will become more important in the future in terms of both size and income.

When purchasing a car, for example, how to deal with servicing and maintenance is a major consideration when trading up to a new model. In the case of construction machinery, aftermarket services are even more important than they are for a car, and I believe one of the reasons why we have the leading share of the Japanese market is because our aftermarket services are so highly regarded by customers. In fact, the profit contribution of parts and services grew in our financial results for the 2011 fiscal year, indicating

Yukio Arima

**Vice President, Executive Officer and Director
President, Life Cycle Support Operations Group
Hitachi Construction Machinery Co., Ltd.**

Joined Hitachi Construction Machinery Co., Ltd. in 1974. Prior to appointment to his current position in 2010, his previous positions have included General Manager of the FA Business Division, and Executive Officer and Deputy General Manager of the Development and Production Division.

that building up the quality and quantity of our parts supply systems and service personnel is slowly but steadily paying off.

It is also clear that aftermarket services have been growing in importance from this business structure perspective. When looking at the global situation including emerging economies, awareness of the importance of services differs from place to place, and we have identified life cycle support as one of our strategic themes with the aim of raising the level of aftermarket services for Hitachi construction machinery, both in Japan and overseas.

——How are you going about implementing specific measures for life cycle support?

Arima: The Life Cycle Support Operations Group was formed in 2011 by combining the existing Customer Support Division, Spare Parts Division, and Life Cycle Support Office (previously the Spare Parts Business Strategy Office). However, the initiative wasn't limited to just headquarters, with local subsidiaries and independent agencies also coming together like beads on a string and all working toward the common goal of enhancing Hitachi's brand value.

In practice, maintenance of our products overseas is performed by service staff employed by local subsidiaries and agents. Headquarters staff are also posted around the world to interface with the local staff who work on the front line.

Naturally, the Life Cycle Support Operations Group, in addition to deciding overall strategy, also investigates how to maintain new products in order to improve customer satisfaction. The Group provides leadership in relation to boosting the individual skills of local staff and empowering the organization. Along with seeking to raise minimum standards for local companies and increase the level of customer-first awareness, we also seek to foster mutual exchanges whereby we share the things that each region is good at.

——In addition to improving service staff skills, I understand you are also adopting technical measures for making life cycle support more comprehensive.

Arima: The prime example would be Global e-Service. This is a system based on information from sensors installed on construction machinery and uses satellite communications for realtime remote monitoring of machine operational status. Similar to a health check, the system facilitates timely repairs and preventive maintenance.

While the system is also useful for small to medium-

Voices from Africa 1

The Lumwana Mine in the Republic of Zambia is said to be the largest copper mine in Africa, and the mining company is currently investing heavily in a major expansion in production. Hydraulic excavators, dump trucks, and other machines from Hitachi Construction Machinery Co., Ltd. are used at the mine, delivering high reliability to support 24-hour-a-day operation. This is made possible by machine maintenance carried out by staff from Hitachi Construction Machinery Southern Africa Co., Ltd., who are stationed permanently at the mine.

"Mining machines are required to operate in harsh conditions, and my job is to do my best to keep them in top condition. This has included, for example, working out ways of improving staging at the mine site and suggesting this to the customer. My job also includes supervision of maintenance staff and I work in cooperation with staff from the headquarters of Hitachi Construction Machinery on things like improving staff shift schedules or skills training."—Ockie Barnard

Ockie Barnard
Hitachi Construction Machinery Southern Africa Co., Ltd.

Hydraulic excavator and dump trucks in operation at Lumwana Mine sized construction machines, equipment used in the mining industry suffer harsh operating conditions and Global e-Service is particularly valuable for determining when these machines are due for an overhaul (a full inspection and servicing of the machine including items not covered by routine inspection), as well as for identifying signs of potential faults.

Working in collaboration with the Research & Development Group at Hitachi, Ltd., our aim is to help boost machine utilization by customers by making further advances in information and communication technology (ICT).

Building Infrastructure Required to Service Mining Industry

——The mining industry business is identified as an important strategic theme in the medium-term management plan.

Arima: It is seen as a strategic theme because demand for mining machinery is less affected by changing economic conditions than ordinary construction machinery, and because our business volumes are increasing against a backdrop of rising international demand.

Mines are a type of industrial plant where 24-hour operation is taken for granted, and mining machinery needs to operate under these harsh conditions. This makes after-market services even more important for mining than for our ordinary construction machinery business.

The profits of the mining company are greatly affected if machinery is out of service, whether for an hour or a whole day. Given this situation, we utilize Global e-Service and also locate parts remanufacturing facilities close to large mines to allow us to provide operational guarantees. Although conventional earthmoving machines also use remanufactured parts, the high cost of routinely replaced parts means that their use is much more widespread among mining machinery. Obviously services and parts are an important part of our mining industry business, but remanufacturing, too, has come to play a particularly significant role in helping reduce maintenance costs.

——What specific initiatives are you undertaking?

Arima: To meet customer needs and provide timely support, we have established parts remanufacturing facilities in different parts of the world, including the Republic of Indonesia, Australia, and Europe. Locating comprehensive support services close to the customer site is important in the

Voices from Africa 2

The Moatize Mine project in the Republic of Mozambique is attracting attention against a background of growing demand for steel around the world. It is Africa's largest coking coal mine. In the past, production of coking coal, which is used in steelmaking, has basically been limited to only four countries, the Russian Federation, China, the USA, and Australia. Production from this mine only started in September 2011 and it is currently at the initial stage of development. Coinciding with the supply of hydraulic excavators to Moatize Mine, Hitachi Construction Machinery Co., Ltd. formed Hitachi Construction Machinery (Mozambique), Ltd., making it the first Japanese corporation to establish a local subsidiary. The company currently has a 24-hour operation in which permanently stationed staff perform excavator maintenance to maintain a high level of utilization. While the customer has always had great confidence in machines from Hitachi Construction Machinery Co., Ltd., they are particularly impressed by this comprehensive support infrastructure, which also includes operator training and education programs.

With Mozambique having endured a long civil war, many young people lack adequate education and work opportunities. Also, Moatize Mine is known as a particularly harsh environment even by African standards, with summer temperatures in excess of 50°C.

Staff, including Brazilians of Japanese descent and locally recruited Japanese staff, engaged in maintenance services at the Moatize Mine site office of Hitachi Construction Machinery (Mozambique), Ltd.

To add further strength to our support activities despite these adverse conditions, we are working to develop the local staff who will support the business in the future, including through the recruitment of Brazilians of Japanese descent who have received training in Japan.

mining business, and we seek to provide ourselves with the ability to deal with customers in ways that closely suit their needs, including employing skilled service staff, determining when to perform overhauls, and stocking spare parts in case of unanticipated problems. In addition to building a relationship of trust with customers, we also take steps to minimize life cycle costs, such as proposing maintenance plans that tie in with production schedules.

Global Approach to Human Resource Development

——Africa is becoming increasingly important to the mining business. I understand you have embarked on human resource development initiatives there.

Arima: While it is commonly agreed that Africa will grow economically in the future, it is also clear that they lack the human resources to underpin this economic progress. Human resource development is also important to the construction machinery sector, and we anticipate that the initiatives we are taking will strengthen life cycle support and increase customer satisfaction, thereby increasing sales of new construction machines.

In one example of human resource development in Africa, we have since 2011 been planning to offer assistance in the form of practical training at our factories or through the supply of education programs. This is in response to a request from the Zambian government to pass on Hitachi technology to help develop the economy. In addition to Africa, we are also undertaking these human resource development initiatives in Asia. We have opened a training school for mining mechanics in Indonesia, and we accept young people from the Republic of the Philippines as trainees at our Tsuchiura Works where they study Hitachi technology and how we go about our work. We are proceeding with human resource development in accordance with the characteristics of each region, taking account of factors such as the ability to recruit large numbers of people from heavily populated Indonesia if good education programs are adopted, and that English is the national language of the Philippines, which makes communications easier, even in Japan.

We already have technicians working for us in Africa from the Philippines and the Federative Republic of Brazil who have studied in Japan. Meanwhile we are also using a training center located close to mines in Australia as a finishing school for people who have studied in other regions.

Voices from Africa 3

Hitachi Construction Machinery Southern Africa Co., Ltd. started conducting market surveys in the early 2000s in recognition of the expanding potential for mining in southern Africa. Along with supplying mining machinery to growing markets in the Republic of Zambia and Republic of Mozambique, the company has been building strong relationships of trust with our customers. A large number of products from Hitachi Construction Machinery Co., Ltd. are now in use in the region.

In the future, the company aims to extend its business to target not only mining companies, but also the mining contractors responsible for actual machine operation.

"Manufacturers from countries such as China and South Korea have recently been making steady improvements in their quality. Nevertheless, we boast an ability to deliver a very high level of maintenance services. Our ability to maintain a high market share to date can be seen as evidence of this. It is natural that people from different countries will have differences in their attitudes and cultural background, and I believe it is important that we are uncritically accepting of this. I want our company to be one that understands people's diversity and turns it into a strength." —Allen Brinkley

Allen Brinkley
President, Hitachi Construction Machinery Southern Africa Co., Ltd.

Premises and local staff of Hitachi Construction Machinery Southern Africa Co., Ltd.

This is because of its proximity to advanced mine sites.

——Are you doing anything else to develop overseas service staff?

Arima: We hold International Skills Competition events, a competition for manufacturing skills such as welding, painting, and assembly, and also run an annual skills competition for services. Service staff who have come through regional preliminary rounds in different parts of the world come together in one venue to demonstrate their abilities and compete to be number one. Some recent winners have been overseas service staff.

In addition to providing a very important motivational boost for service staff, another advantage of competitions like these is that they give staff a chance to assess their own skills in global terms. I hope these can continue to be a useful part of future human resource development.

——Finally, please tell us what role life cycle support should play in terms of making a contribution to the global market.

Arima: The construction machinery business will not continue to grow forever, even in emerging economies. Accordingly, how to obtain repeat orders will be an important challenge, and life cycle support will play a major role in increasing customer satisfaction, which is the key to success in this endeavor.

The Life Cycle Support Operations Group has the task of being the "power behind the scenes." How to support the customer's business is one aspect of this, another is the support of our company colleagues and the local service staff who work on the front line. In terms of our role in providing support for both of these areas, we need to be aware of our own job.

In addition to our fellow people, we also need to ensure that the machines themselves are maintained properly. Using machines appropriately reduces negative impacts on the environment. This should also lead to making a social contribution. While keeping an awareness of this important role, my aim is to take advantage of the comprehensive capabilities of the Hitachi Group and establish a comprehensive service infrastructure in the global market.

Voices from Africa 4

Amid a thriving mining industry market, Hitachi Construction Machinery Africa Pty. Ltd. was established in October 2010 to be the regional supervisory company for Hitachi Construction Machinery Group operations in southern Africa. Its aim was to establish the business infrastructure to meet expanding demand for mining machinery. Mining machinery demands a level of reliability able to sustain continuous operation, and customers expect to be provided with full maintenance services from closer sites.

"A business structure that allows the customer to have direct contact with the manufacturer gives mining companies a sense of confidence. In the case of ultra-large mining machinery, customers already have a good appreciation of the reliability of our products because of our past experience in places like Australia and the Republic of Indonesia. As the number of machines in use grows in the future, the number of the people who care for them will likewise need to increase. Collaboration with local schools is a prospect for the future, and I want to encourage even more human resource development."—Hironori Okajima

Hironori Okajima
President, Hitachi Construction Machinery Africa Pty. Ltd.

Premises and local staff of Hitachi Construction Machinery Africa Pty. Ltd.

Global Business Plan of Construction Machinery Solutions

Hidekazu Nakakuro
Manabu Arami
Hongjuan Wang

GLOBALIZATION OF MANAGEMENT BASE

HITACHI Construction Machinery Co., Ltd. was established in October 1970 and since then has contributed to its customers' businesses through two different types of creativity, namely, the development of innovative technologies that satisfy customer needs and the creation of demand by supplying those customers with new value.

Meanwhile, driven by infrastructure investment and the associated expansion in resource development, the construction machinery market for both construction and mining machinery has experienced growth in demand in recent years from emerging economies. Since the global financial crisis (Lehman Shock), demand for construction machinery has changed to a 25%/75% split between developed and emerging markets respectively, with competition in emerging economies becoming stronger by the day. In terms of technology, growing environmental awareness is providing an impetus behind measures such as energy efficiency improvements and stricter exhaust gas regulations.

To respond flexibly to these changes in the business environment and achieve sustainable growth, it is necessary to make progress toward a more global business management base.

Looking ahead to 2020, Hitachi Construction Machinery has formulated its 2020 Vision that sets out where it wants to be in a decade's time, expressing its aim to be a "Close and Reliable Partner anywhere on the Earth with Best Solutions through Kenkijin Spirit[(a)]." To achieve this, the company has embarked on a three-year medium-term management plan running from 2011 to 2013 and entitled Go Together 2013.

The company's aim is to establish an overwhelming presence for itself in the global market for construction machinery by offering solutions and services that are one step ahead and based on superior technologies cultivated over many years.

(a) Kenkijin Spirit
An expression of the underlying values and standards of conduct that constitute the approach taken by employees of the Hitachi Construction Machinery ("Kenki") group.

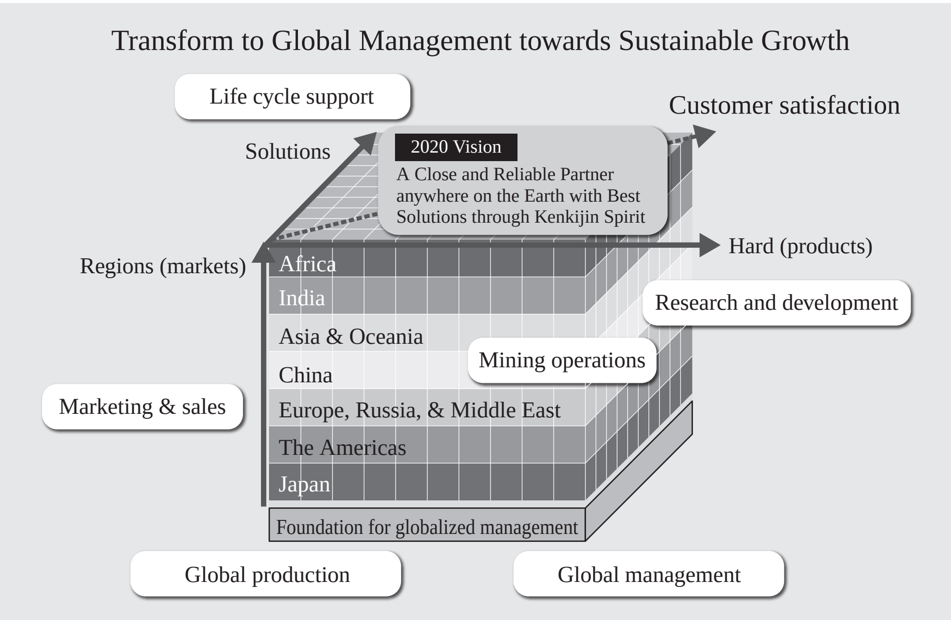

Fig. 1—2020 Vision and Six Imperatives to be Tackled in Medium to Long Term.
Hitachi Construction Machinery Co., Ltd. has identified six imperatives to strengthen along three key axes.

TRANSFORMATION OF BUSINESS MODEL

The Go Together 2013 medium-term management plan is a growth strategy based around the three axes of products, solutions, and regions (markets). It seeks to strengthen the following six imperatives of the company's strategy (see Fig. 1).

(1) Research and development
(2) Life cycle support
(3) Marketing and sales
(4) Global production
(5) Global management
(6) Mining operation

Product Strategy: Becoming a Comprehensive Broad-based Manufacturer of Construction Machinery

Hitachi Construction Machinery developed the UH03 hydraulic excavator in 1965 to be a model based on entirely Japanese technology, and now supplies products to suit various customer needs, ranging from small to medium-sized hydraulic excavators to ultra-large excavators with a machine weight of over 800 t. The company has become a broad-based manufacturer of construction machinery, with a product range that also includes mini excavators, dump trucks, wheel loaders, environmental recycling machinery, and tired rollers (see Fig. 2).

On the technical side, the company has followed a strategy of focusing investment on technology developments, such as hydraulic efficiency or performance improvements, that target economics, advanced features, and reliability. A feature of Hitachi Construction Machinery products is their enhanced total fuel efficiency achieved by adopting engines that suit the different circumstances in each country or region and matching them to the hydraulic systems. The company is also preparing itself for future electrification technologies, with power source innovations that include the development of hybrid and battery-powered excavators that consolidate technologies from the wider Hitachi Group.

For emerging markets, meanwhile, where operating conditions are mostly harsh, Hitachi Construction Machinery is earning a strong reputation by developing models designed for cost performance that are tough and easy to maintain while also being able to handle a heavy workload.

The company is pursuing value engineering practices for product development with the aim of maximizing the true value to the customer and minimizing costs across the entire life cycle, from the initial cost of purchase to the running costs of use and disposal (see Fig. 3).

Solution Strategy: Strengthening Solution Businesses

To satisfy customers around the world, the Hitachi Construction Machinery group supplies total solutions that combine all of its capabilities. These include contract service packages that deliver low after-sales running costs in the form of a fixed fee, an anti-theft service that utilizes mobile communications, support

Fig. 2—Main Products of Hitachi Construction Machinery Group.
Hitachi Construction Machinery is a broad-based manufacturer of construction machinery with an involvement in a wide variety of products that dates back to the development of the UH03 hydraulic excavator in 1965.

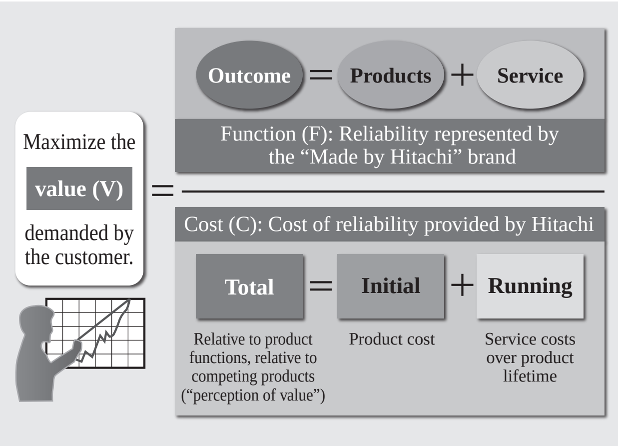

Fig. 3—Use of Value Engineering.
In 2003, Hitachi Construction Machinery won a Miles-Supreme Corporate Award from the Society of Japanese Value Engineering.

for staff to acquire licences for construction machinery operation, and financial services. Furthermore, Hitachi Construction Machinery Japan Co., Ltd. was established in April 2012 to further enhance value to customers by supplying sales, service, and rental products.

In Africa, Hitachi Construction Machinery was the first Japanese company to establish and operate a re-manufacturing factory of hydraulic components for hydraulic excavators. The facility is located in the Republic of Zambia and utilizes know-how from Japan.

Regional Strategy: Transformation from Japanese to Global Company

Hitachi Construction Machinery has been transforming its business from one based on exports from Japan toward expansion of local production. Production in countries such as China and the Republic of Indonesia commenced during the 1990s. The company has increased the proportion of overseas sales year by year to the point where they now account for about 80% of total sales. This was achieved by expanding its network of dealers, particularly in Asia and Oceania, and by establishing its own sales companies in mining regions (see Fig. 4).

The company has also adopted an organizational structure that divides itself into seven regional business divisions to ensure a prompt response to the pace of growth in emerging markets. This includes adopting diversity management and accelerating a shift to global management that combines business delegation to locally based management and governance of its operation (see Fig. 5)

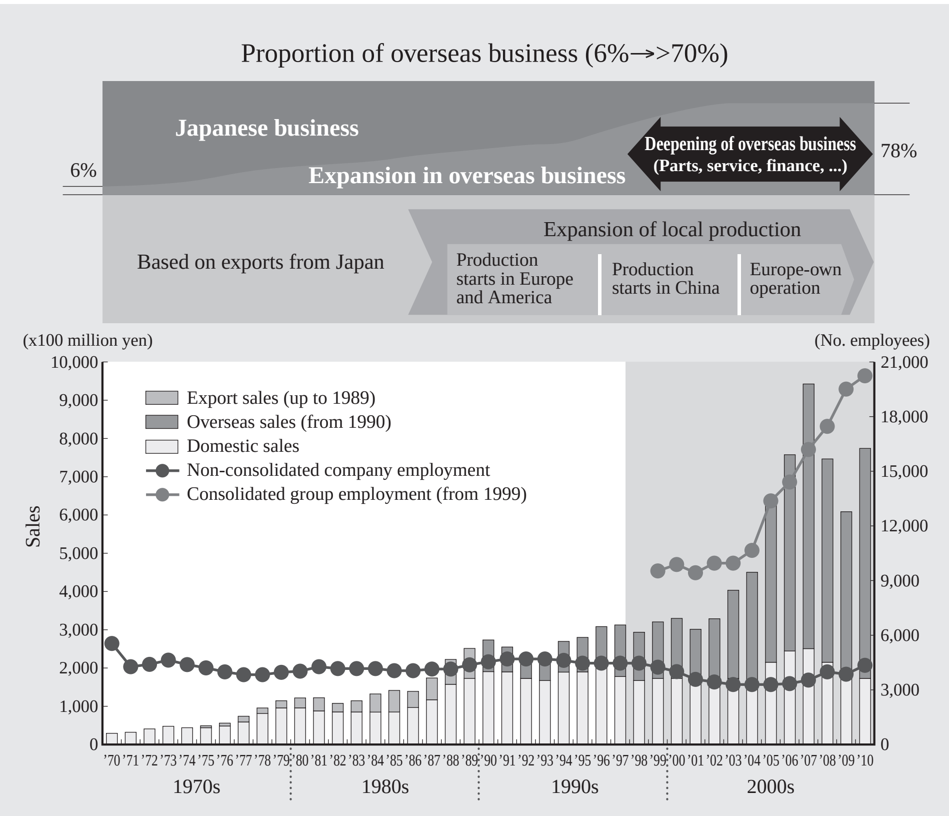

Fig. 4—Expansion of Overseas Operations of Hitachi Construction Machinery.
Hitachi Construction Machinery seeks to transform itself from a Japanese to a global corporation.

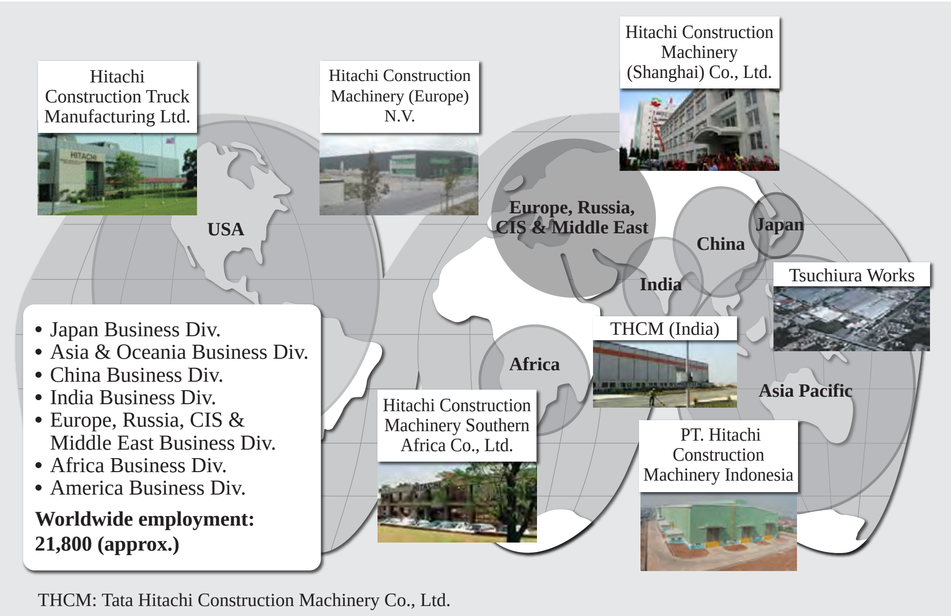

Fig. 5—Hitachi Construction Machinery's Seven Regional Business Divisions.
The organizational structure has been divided into seven regional business divisions to accelerate the transition to global management.

As global competition continues to intensify, the company is also strengthening its management base by pursuing both monozukuri innovation to achieve industry-leading cost-competitiveness and optimum procurement and production.

Hitachi Construction Machinery (China) Co., Ltd. in Hefei City, Anhui Province, China boasts world-top class scale and is making progress on a shift to local production to achieve the volumes needed to satisfy vigorous demand in China. To achieve a world-class level of quality, the company has established a staff training system in collaboration with a vocational training institution in Hefei.

Hitachi Construction Machinery (China) is also undertaking joint research on construction machinery with Zhejiang University through a three-way partnership that also includes Hitachi (China) Research & Development Corporation.

In India, Hitachi Construction Machinery established a technical collaboration more than 25 years ago with Tata Motors Limited, one of the core businesses in the Tata Group, the nation's largest conglomerate. Since then, Tata Hitachi Construction Machinery Co., Ltd. (THCM) has had a strong presence in the Indian market under the Tata Hitachi brand, with the leading position of the market for hydraulic excavators. This was achieved through a combination of the leading-edge technology and high quality of Hitachi Construction Machinery with Tata's unparalleled brand presence and sales network.

In the future, Hitachi Construction Machinery intends to continue building its global production system and expanding its sales network so that it can respond flexibly to changes in the business environment.

ONGOING GLOBAL GROWTH IN MINING MARKET

For the mining market, Hitachi Construction Machinery has developed ultra-large excavators boasting excellent reliability and dump trucks that incorporate large alternating current (AC) motor drives augmented by Shinkansen technology from Hitachi, Ltd. These machines are in use in mines around the world.

Trolley-assisted dump trucks[b] help reduce the load on the environment and combine dump truck technology from Hitachi Construction Machinery with AC motor technology from Hitachi, Ltd. and pantograph technology from Hitachi Engineering & Services Co., Ltd. The Hitachi Group combines to supply these dump trucks as a package that includes the overhead contact lines (see Fig. 6).

In the future, Hitachi aims to further enhance customer satisfaction with its mining machinery by drawing on its strengths in fields such as electrical technology and vehicle stability control systems to

(b) Trolley-assisted Dump Truck
A dump truck driven by electric power supplied via a pantograph from overhead contact lines. Trolley-assisted dump trucks improve production volume and utilization compared to diesel trucks due to advantages such as superior hill-climbing speed and because the reduced load on the engine reduces the frequency of overhauls. Because they are powered by electricity rather than diesel, they help reduce the load on the environment by reducing carbon dioxide (CO_2) emissions as well as operating costs.

Fig. 6—Trolley-assisted Dump Truck Incorporating Technology from Hitachi Group.
This trolley-assisted dump truck was developed using technology from across the Hitachi Group and is being sold as a package that includes the overhead contact lines.

enhance performance and reliability while minimizing life cycle costs per unit of material excavated.

UTILIZATION OF ICT DESIGNED FOR GLOBALIZATION

Currently, approximately 120,000 construction machines fitted with communications equipment are in use around the world. Hitachi Construction Machinery is using information and communication technology (ICT) to track the location of these machines and other operational information so that it can be used in the next generation of product development and to strengthen service and support.

At a mine that operates 24 hours a day, for example, even very short machine downtime can result in major losses to the customer. The ultra-large excavators used at such mines are fitted with sensors at approximately 50 locations to perform detailed monitoring of the machine's working condition. The company is also working on research and development of techniques that analyze the large quantities of collected data to predict when to replace parts and to facilitate preventive maintenance.

RESPONSE TO ENVIRONMENTAL CONCERNS

As part of Hitachi's Environmental Vision 2025, Hitachi Construction Machinery is seeking to cut carbon dioxide (CO_2) emissions by 3.5 million tons.

In addition to compliance with the world's most stringent exhaust gas regulations in Japan, Europe, and America, Hitachi's latest ZAXIS-5* Series hydraulic excavator also features excellent energy efficiency. Also, the company led the construction machinery industry in Japan by being the first to use carbon offsets to offset the emission of CO_2 in manufacturing, something it has been doing since 2008.

As it is anticipated that regulations and other environmental requirements will become even stricter in the future, the company is seeking to combine technologies from all Hitachi group to reduce the load on the environment with a focus that extends from manufacturing to the rest of the product life cycle (see Fig. 7).

CSR

Construction machinery also has an essential role to play in disaster recovery.

Double-arm working machines have a primary arm for crushing and cutting work and a secondary arm for assisting in these tasks. Able to manipulate both arms simultaneously using intuitive controls, one of these machines can accomplish work efficiently that would normally require two heavy machines, such as

Fig. 7—ZH200 Hybrid Hydraulic Excavator.
Progress is also being made toward the adoption of electric and hybrid drives for construction machinery. Hitachi Construction Machinery released the 20-metric-ton ZH200 hybrid hydraulic excavator in July 2011.

* ZAXIS is a trademark of Hitachi Construction Machinery Co., Ltd.

Fig. 8—Double-arm Working Machine (Left) and Demining Machine (Right).
Machines such as the double-arm working machine and demining machines help with disaster recovery and with restoring the land to peace and prosperity.

supporting and cutting or dismantling and separating. In recovery work following the Great East Japan Earthquake, double-arm working machines were able to deal quickly with complex rubble that would otherwise have been difficult to deal with.

Demining (landmine clearance) equipment developed by Yamanashi Hitachi Construction Machinery Co., Ltd. has earned a reputation for reliability, and 86 machines have been supplied to a total of nine countries (as of April 2012). Each machine is customized to suit specific conditions such as the soil and how the landmines are deployed. Many years of localization and rigorous research went into ensuring that the machines will restore the land to peace and prosperity in a way that combines safety with efficient landmine clearance. Maintenance costs have been reduced by building up know-how and designing parts that local technicians can replace quickly. In brush-covered or flat terrain, the machine can, in addition to clearing mines, also act as a cultivator to help rehabilitate the land for agricultural use by plowing the soil using nine large rippers.

In China, Hitachi Construction Machinery (China) Co., Ltd. donated a hydraulic excavator after the Great Sichuan Earthquake. Hitachi Construction Machinery has also been involved in a 10-year tree planting program (that started in 2005) to prevent desertification in the Horqin Desert in the Inner Mongolia Autonomous Region. In the Kingdom of Cambodia, the company is working through Good Earth Japan, a non-profit organization, to help people become self-sufficient.

The Hitachi Construction Machinery Group engages in corporate social responsibility activities around the world to continue its growth into a truly global corporation (see Fig. 8 and Fig. 9).

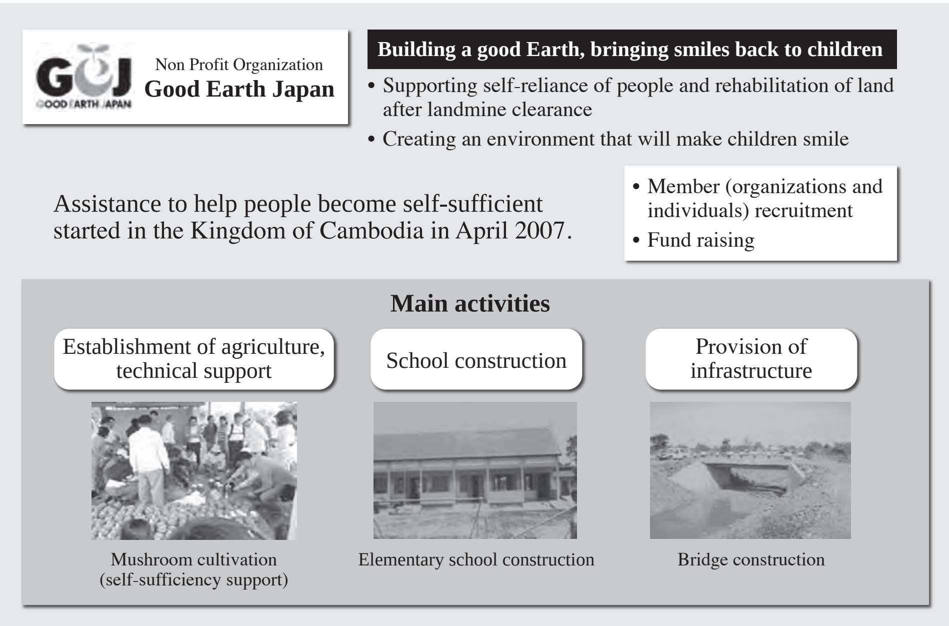

Fig. 9—Helping People in Kingdom of Cambodia Become Self-sufficient.
In the Kingdom of Cambodia, the company is working through Good Earth Japan, a non-profit organization, to help people become self-sufficient.

ACHIEVING SUSTAINABLE GROWTH

Hitachi Construction Machinery Co., Ltd. will continue to respond flexibly to various changes in the business environment and strive to deliver new value to customers through the development of technology. To achieve sustainable growth as a truly global corporation, the company is working to reform its management from the perspectives of strengthening its management base and the three axes of products, solutions, and regions (markets), with the aim of being a company that always looks one step ahead.

ABOUT THE AUTHORS

Hidekazu Nakakuro

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Development of Mining Machinery and Future Outlook for Electrification

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OVERVIEW: Accompanying the rapid industrialization of emerging economies, particularly the heavily populated nations of China and India, the 21st century has seen ongoing growth in demand for mined resources such as coal and iron ore. It is generally recognized that increasing demand for resources will remain as long as this growth in emerging economies continues. Against this background, Hitachi Construction Machinery Co., Ltd. has developed and released a series of mining machines, including working jointly with Hitachi, Ltd. on the development of dump trucks with AC drives based on the latest technology. Hitachi Construction Machinery is also committed to the planned development and release of environmentally conscious trolley-assisted dump trucks, autonomous dump trucks, and electric excavators.

INTRODUCTION

HITACHI Construction Machinery Co., Ltd. first entered the mining market in earnest in 1979 with the release in the North America of the ultra-large UH801 hydraulic excavator (operating mass: 157 t) designed for the mining industry. Since then, as the mining industry has grown in scale, Hitachi Construction Machinery has established a comprehensive range of ultra-large hydraulic excavators that extends all the way up to the EX8000-6 (operating mass: 811 t). The company has retained a large share of the market for ultra-large hydraulic excavators of 200 t or more, the category that forms the mainstay of the mining market.

In the market for dump trucks, meanwhile, Hitachi Construction Machinery was a late arrival, first entering the market in earnest in 2008 with the release of the EH3500ACII, which featured a Hitachi alternating current (AC) drive and freight mass in the 190-t class. With a pressing need to differentiate its technology from that of its competitors in order to establish itself in the truck market, Hitachi Construction Machinery is developing advanced vehicle control systems incorporating the latest insulated-gate bipolar transistor (IGBT) inverter technology, with plans to release a series of new models onto the market from 2012.

With the growth in international resource demand having now resulted in a chronic shortage of machine operators, and with a strong emphasis being placed on safety measures to prevent accidents due to inexperience, a growing need is emerging for autonomous (driverless) dump trucks. Various companies are seeking to develop these vehicles, including Hitachi Construction Machinery working in collaboration with Hitachi, Ltd. Regarding environmental protection, Hitachi Construction Machinery has also commercialized trolley-assisted dump trucks and released a series of electric excavators that help reduce carbon dioxide (CO_2) emissions.

This article recounts the history of mining machinery made by Hitachi Construction Machinery, and describes both recent developments and future mining machinery.

TRENDS IN MINING MARKET

North America is a major resource consumer, and use of opencast mining spread from the North American continent to the rest of the world from the 1960s onwards, replacing the underground mining (tunneling) that had predominated in the past. The total market for opencast mining equipment was approximately 1 trillion yen in the 2011 fiscal year. It is also predicted that global resource production will double over the next decade (see Fig. 1).

History of Opencast Mining

Many opencast mines have been developed since the advent of large digging machines required for efficient opencast mining, such as draglines and mechanical excavators. Nowadays, production from opencast mining represents about 45% of total resource extraction (according to a survey by The Freedonia Group, Inc.). Along with the demand for mining techniques, most large mining machinery

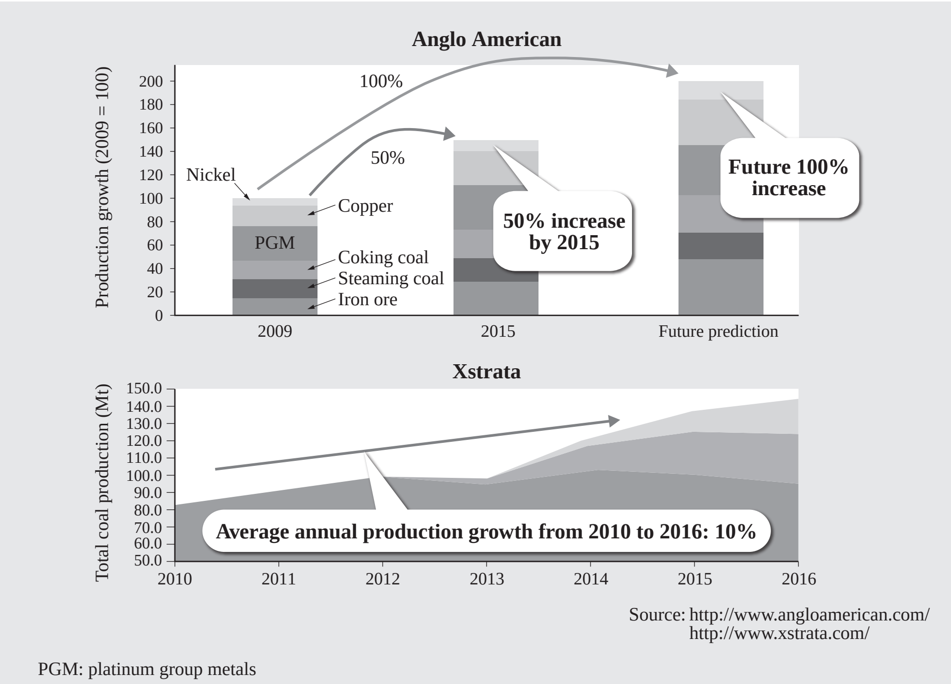

Fig. 1—Planned Production Growth by Major Resource Companies.
The graphs show the planned expansion in production by two major resource companies, Anglo American and Xstrata.

was developed in the USA, and the large hydraulic excavators that arrived on the scene in the 1970s led to innovations in mining practices, to the point where the most common method now involves use of these machines in combination with dump trucks (excavator/dump truck mining). As expensive machinery such as draglines that are amortized over 20 years or more are unable to respond flexibly to the fluctuations of resource markets, it is anticipated that market demand for excavator/dump truck mining will continue to grow in order to cope with factors such as short-term (yearly) purchase contracts, global competition in resource prices (cost of production), and the speed of new mine development (see Fig. 2).

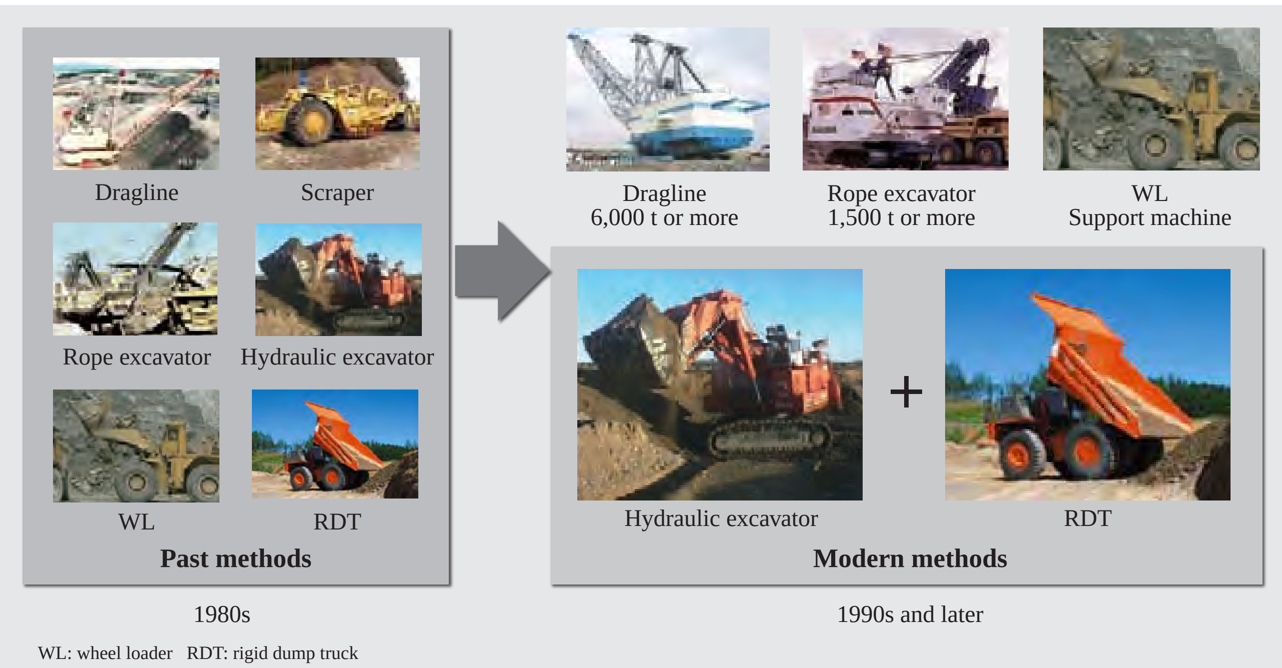

Fig. 2—Changes in Mining Practices.
As a result of improvements in the performance and reliability of hydraulic excavators, the most common form of opencast mining now involves use of these machines in combination with dump trucks (excavator/dump truck mining).

Resource Boom and Changes at Mining Companies

Faced with difficult business conditions, the mining industry underwent a period of consolidation, involving mergers between mining companies, during the mining slump that ran from the 1990s to the early 2000s. Prices subsequently rose rapidly in response to a sharp increase in demand for resources from China and other emerging economies, allowing mining companies to reap large profits and leading to a further burst of investment and new mine development around the world. This resulted in an international shortage of personnel that prompted mining companies to involve equipment manufacturers and suppliers in the joint operation of mines, and led to demand for solutions such as for machinery operation and maintenance.

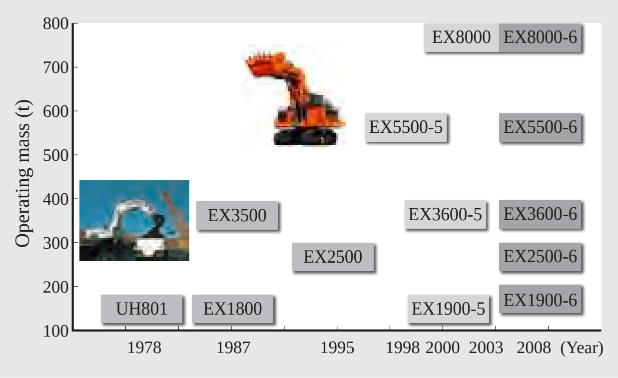

Fig. 4—Hydraulic Excavator Product Range and Development History.
Starting with the UH801 developed in the 1970s, Hitachi Construction Machinery has established a range of hydraulic excavators for the mining industry that extends up to the EX8000 with an operating weight in the 800-t class.

HISTORY OF MINING MACHINERY

Hydraulic Excavators

Hydraulic excavators were first developed in Europe in the 1950s. In Japan, Hitachi released the first hydraulic excavator based entirely on Japanese technology in 1965. Called the UH03, it had a gross weight of 8.7 t and a bucket capacity of 0.35 m^3 (see Fig. 3).

Following on from the UH801 released in 1979 (operating mass: 157 t, loading bucket capacity: 8.4 m^3), Hitachi Construction Machinery released a series of progressively larger machines over the next 25 years, culminating in the EX8000-6 in 2005 (operating mass: 811 t, loading bucket capacity: 40 m^3). Not only were the machines designed from the outset to deliver work performance and reliability, Hitachi Construction Machinery also placed an emphasis during this period on incorporating feedback from the market. The numerous improvements that resulted gave the machines a strong reputation for reliability in particular and gained a large market share. Fig. 4 shows a history of hydraulic excavator development for the mining industry together with the Hitachi product range.

Fig. 3—First Hydraulic Excavator Based Entirely on Japanese Technology (UH03).
Developed in 1965, the UH03 was the first hydraulic excavator based entirely on Japanese technology. An example is on display at the Tsuchiura Works of Hitachi Construction Machinery Co., Ltd.

Including the UH801, the models in the figure are used in a total of 72 countries around the world, with cumulative shipments of approximately 1,500 machines. The electric excavator described below was developed by Hitachi Construction Machinery in the 1970s, with the number of machines shipped getting a boost in 2001 thanks to a large order from the Kingdom of Thailand. Total shipments to date have now reached 45 excavators.

Dump Trucks

Hitachi has developed various series of dump trucks, dating back to the development in 1971 of a truck with freight mass in the 190-t class by Euclid (now Hitachi Construction Truck Manufacturing Ltd.) in Canada. The base for dump truck development was subsequently shifted to Hitachi Construction Machinery. The EH3500ACII dump truck released in 2008 had freight mass in the 190-t class and featured the latest IGBT AC drive made by Hitachi, Ltd. This was followed in 2010 by the 220-t EH4000ACII series of dump trucks (see Fig. 5).

While other companies have been selling mining dump trucks since the 1970s, most models used either mechanical drive systems with automatic gearboxes or direct current (DC) electrical drive systems in

Fig. 5—EX5500-6 and EH4000ACII in Operation.
The EX5500-6 and EH4000ACII shown here are at a coal mine in eastern Australia.

which the engine drives a generator to produce an alternating current that is then rectified to drive the electric traction motors. Hitachi, Ltd. has a long and successful experience in the development of electric drive systems for trains and other vehicles, so although Hitachi Construction Machinery was a late arrival to the dump truck market, it was able to achieve an ideal match between chassis and electric drive through their joint development of an AC drive system for dump trucks. The result was a high level of both driving and operational performance.

More than a hundred EH3500ACII and EH4000ACII trucks are already in use in 11 different countries where they have a high level of utilization, including some that have already clocked up more than 20,000 hours of operation.

Having a range of hydraulic excavators and dump trucks for the mining industry allows Hitachi Construction Machinery to sell these as a package, and it will be necessary in the future to provide more comprehensive support so that customers can operate their mines even more efficiently.

DUMP TRUCK DEVELOPMENT

The EH3500ACII and EH4000ACII models that emerged out of a joint development with Hitachi, Ltd. use an AC drive system in which the engine drives a generator that supplies power to latest IGBT inverter from Hitachi, Ltd. The inverter in turn controls the AC electric motors that drive the vehicle. Table 1 lists the specifications and Fig. 6 shows the configuration of the AC drive system used by the vehicles.

The objectives of the joint development with Hitachi, Ltd. of the chassis and electric drive system were as follows.

(1) A high level of driving and operational performance achieved by matching the chassis and electric drive system.
(2) Improve quality by moving production to Japan.
(3) Enhance truck capabilities by using technology from ultra-large hydraulic excavators.

In addition to utilizing technology from Euclid, a company with a long history of dump truck manufacturing, and adopting reliability design techniques honed on ultra-large excavators, Hitachi Construction Machinery also offered performance guarantees. Regarding the specific technologies that play a core role in dump trucks, Hitachi Construction Machinery established proprietary technologies by working with Hitachi, Ltd. on joint development through all stages from initial design through to final testing. They also developed machines based on the same concepts by sharing these technologies across

TABLE 1. Specifications of EH3500ACII and EH4000ACII.
The table below lists the specifications of the EH3500ACII and EH4000ACII dump trucks.

	EH3500ACII	EH4000ACII
Nominal payload (t)	168	222
Capacity (m^3)	111	153
Net machine mass (t)	141	162
Target vehicle mass (t)	309	384
Engine	Cummins QSKTA-50CE	Cummins QSKTA-60CE
Engine output (kW)	1,491	1,864
Length (m)	13.51	14.28
Width (m)	8.99	9.54
Height (m)	6.77	7.36
Maximum speed (km/h)	56	56
Tire size	37.00R57	46/90R57

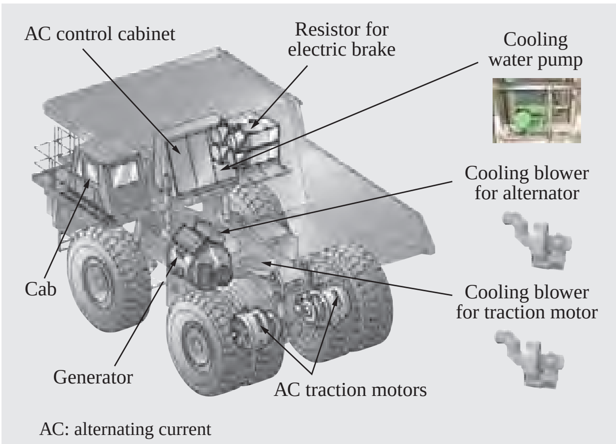

Fig. 6—Configuration of Dump Truck with AC Electric Drive.
The diagram shows the component parts of the AC electric drive system on the EH3500ACII dump truck.

other classes of dump truck. Designing most of the key components used in the trucks themselves and bringing production in-house allowed feedback from the field to be incorporated, sped up parts supply, and facilitated sharing of parts across models.

An indication of how good the vehicles are is that they achieve brake and hill-climbing performance among the best in their class by using the same high-voltage IGBT modules from Hitachi, Ltd. that are used in railway control systems. Similarly, because the vehicle control and AC drive control systems were jointly developed by Hitachi, Ltd. and Hitachi Construction Machinery, they are able to take advantage of sensor technology and the high-speed control characteristics of the AC drive to perform detailed vehicle control. Developed for vehicle stability control, this control technology can be used to assist with the driving safety of the dump trucks, to reduce the driver's workload, and to reduce the load on the vehicle.

The aspect of development that took the longest time was tuning the vehicle and AC drive control. By combining desktop simulations with field trials, Hitachi Construction Machinery was able to establish a pattern for this tuning work, which is expected to improve significantly the efficiency of future development. Performing the work on the overall control of the vehicle within Hitachi enhanced their ability to respond to future development requirements such as optional enhancements or the next generation of models. Working together with Hitachi, Ltd. also made development faster.

The frame was modified to use bolts to fasten the cab support instead of the welds used previously. This was done to eliminate the need for on-site welding as well as to improve the reliability of the fastening and to simplify local assembly (see Fig. 7).

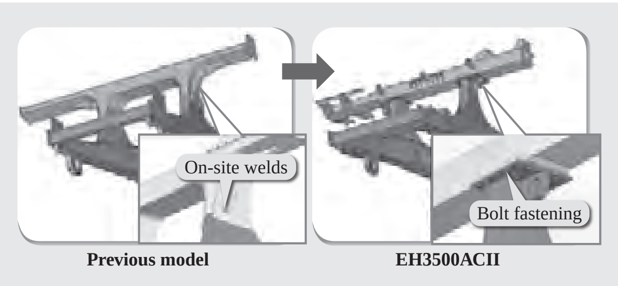

Fig. 7—Split Frame Configuration (Bolt Fastening Structure).
The figure shows the frame structure on the EH3500ACII dump truck that can be split apart. This was done to improve reliability and reduce the amount of local assembly work.

FUTURE MINING MACHINES

The rapid rise in the price of oil is behind demand for better productivity (cost/t), and the electrification of mining machinery is seen as one way of achieving this. Electrification is also important for environmental reasons and active steps are being taken toward adopting trolley-assist for dump trucks and electric drive for hydraulic excavators.

Trolley-assisted dump trucks only receive electric power from overhead contact lines when they are loaded and driving uphill, at which time they are powered by AC motors instead of their diesel engine. This provides significant fuel savings and improves productivity by allowing the trucks to drive uphill faster than they could using their diesel engines.

Electric-hydraulic excavators, in contrast, by substituting an electric motor for the diesel engine with which they are normally fitted and by receiving electric power from a cable, use this electric motor to drive all operations. As most mines already have electric power infrastructure, the major benefits of electric-hydraulic excavators are that they can significantly reduce running costs and cut CO_2 emissions.

Trolley-assisted Dump Trucks

Trolley-assisted dump trucks use a pantograph fitted to the top of the vehicle to receive electric power from overhead contact lines installed on uphill sections. Because this power is used to drive the AC motors, the engine can be idled during those times when a power supply is available. The trolley box fitted on the right side of the vehicle is used to control switching between trolley mode and engine mode. At locations where no overhead lines are installed, such as at loading and unloading sites or downhill sections, the vehicle powers itself using its engine to generate electric power in the same way as a conventional dump truck (see Fig. 8).

To date, trolley-assisted dump trucks have been most widely used in southern Africa (see Fig. 9).

Because most trolley-assisted dump trucks in the past have used electric motors and other key electrical components made by companies like Siemens AG or General Electric Company, together with pantographs produced by local suppliers, there has been a limit to how well systems could be put together to provide the best reliability for the vehicle. In response, Hitachi Construction Machinery has been able to deliver highly reliable trolley-assisted dump trucks by jointly developing all parts of its products in collaboration with other companies in the Hitachi Group. Other

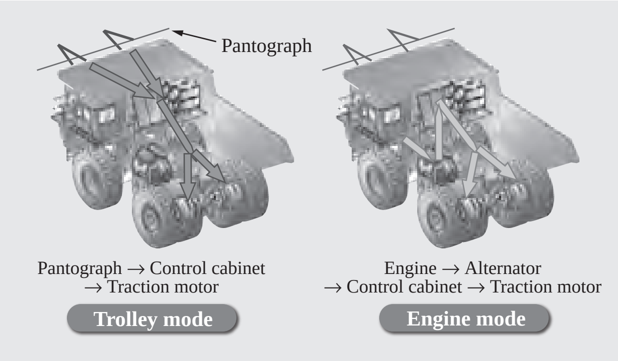

Fig. 8—Power Flow in Trolley-assisted Dump Truck.
The diagrams show the flow of power in an EH3500ACII trolley-assisted dump truck during trolley mode and engine mode respectively.

Fig. 9—EH3500ACII Trolley-assisted Dump Truck.
This EH3500ACII trolley-assisted dump truck was supplied to a copper mine in the Republic of Zambia in Africa.

advantages include being able to conduct on-site tuning as appropriate, and being able to respond quickly by providing a single point of contact for service and support.

By consolidating these group synergies, Hitachi has won an order for 24 trolley-assisted dump trucks from the Republic of Zambia and is currently preparing the first truck for operation at the customer's site.

Trolley-assisted dump trucks have the following advantages over conventional models.

(1) Lower fuel consumption
(2) Better hill-climbing performance
(3) Lower engine maintenance costs
(4) Lower CO_2 emissions

In the case of fuel consumption, for example, assuming the vehicles are making round trips on a road with a 10% gradient, trolley-assisted dump trucks use roughly half as much fuel as conventional dump trucks. Furthermore, while the speed of an engine-powered dump truck traveling fully loaded up this 10% gradient would be about 11 km/h, trolley-assisted dump trucks can travel at approximately twice that speed. This shortens the travel time between loading and unloading sites, resulting in higher production per truck than for conventional dump trucks.

Regarding maintenance costs, because the engine can be idled while the dump truck is operating in trolley mode, the load on the engine is reduced. Assuming a typical case of 60,000 operating hours, an engine-powered dump truck would require three engine overhauls during this time compared to only two for a trolley-assisted dump truck. Considering the load on the environment, the reduced load on the engine also limits the CO_2 emissions from the trucks themselves.

In other words, adopting trolley-assisted dump trucks has major benefits for both production and the environment.

Electric-hydraulic Excavator

Although electric-hydraulic excavators currently make up less than 10% of hydraulic excavator shipments to the mining industry, the number of electric machines has roughly doubled in the last two to three years and it is anticipated that demand for this configuration will continue to grow in the future.

Electric-hydraulic excavators have the following advantages over engine-powered models.

(1) The electric power they use costs less than diesel.
(2) Lower overhaul costs
(3) No CO_2 emissions from excavator itself
(4) Does not require consumables such as engine oil and filters.
(5) Low noise and vibration

In particular, because their total running costs are about one-half those of engine-powered models, electric excavators can help cut costs for customers in countries or regions where the price of fuel is high. Fig. 10 shows an example worksite that uses an electric excavator.

Electric-hydraulic excavators required a continuous supply of electric power.

The disadvantages of this configuration include a requirement for electric transmission equipment, and the difficulty of moving from place to place, depending on the availability of cables.

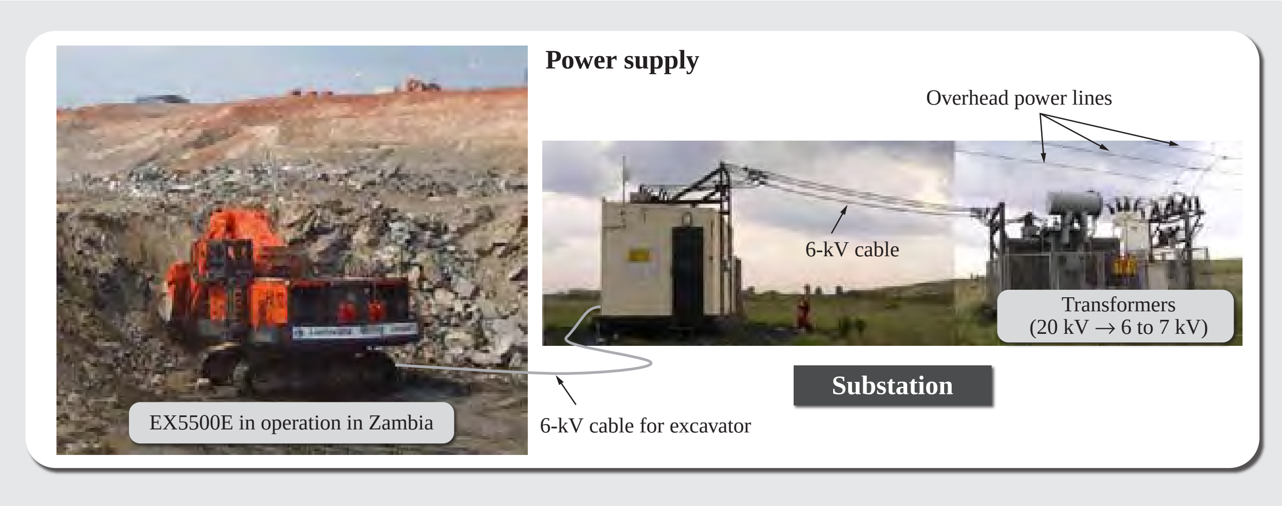

Fig. 10—Electric Excavator Worksite.
Electric power from a generation plant is stepped down by transformers to 6 to 7 kV and supplied to the electric-hydraulic excavator.

Nevertheless, for mining developments that face a tradeoff against environmental problems, electric-hydraulic excavators have superior environmental performance (place less of a load on the environment), and their running costs deliver great benefits to customers in mines where the power supply infrastructure is already in place.

As of the end of 2011, most deliveries of electric-hydraulic excavators had been to Asia, Africa, the Russian Federation, and the Commonwealth of Independent States (CIS) region. However, it is anticipated that demand from the Americas will also grow in the future as exhaust emission laws become more stringent.

While factors such as temperature and altitude mean that many mines around the world present hydraulic excavators with a harsh operating environment, Hitachi Construction Machinery aims to achieve even greater results by overcoming the problems associated with selling into many different regions.

CONCLUSIONS

This article has recounted the history of mining machinery made by Hitachi Construction Machinery, and described both recent developments and future mining machinery.

Meanwhile, there is strong demand from the market for improvements in mine production efficiency, including a need to maintain high levels of utilization, not only through machine reliability, but also through the establishment of a robust post-sales support system.

In addition to the conventional approach of making further improvements in machinery quality, Hitachi Construction Machinery is also taking active steps to strengthen its support system for machinery operating at mines. The aims include use of mining information and communication technology (ICT) to reduce machine downtime and to implement preventive maintenance by obtaining timely information from sensors embedded in the machines and detecting faults preemptively.

In the future, Hitachi Construction Machinery Co., Ltd. intends to advance beyond being a supplier of individual machines so that it can offer solutions that help achieve efficient operation across all aspects of mining.

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Application of ICT to Lifecycle Support for Construction Machinery

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OVERVIEW: In its 2020 Vision, Hitachi Construction Machinery Co., Ltd. has expressed its aim of being a "Close and Reliable Partner anywhere on the Earth with Best Solutions through Kenkijin Spirit," and all parts of the company are working to ensure that they can satisfy increasingly diverse customer needs in a timely manner. ICT is a particularly effective tool for achieving this objective, and a wide range of technologies have been adopted in the construction machinery industry to provide the infrastructure for easy access to large quantities of data. Global e-Service is a support service that offers a diverse range of options for providing information on machine operation, while also making this information available for use in the lifecycle support of these machines.

INTRODUCTION

OUTSIDE the developing economies, the market for construction machinery is a mature one in which it has become difficult to differentiate products on the basis of performance alone. This makes aftermarket service particularly important.

What customers are looking for in aftermarket service is an improvement in machine utilization and a reduction in maintenance costs. Each construction machinery manufacturer has responded to this by using information and communication technology (ICT) to introduce techniques for managing machinery remotely.

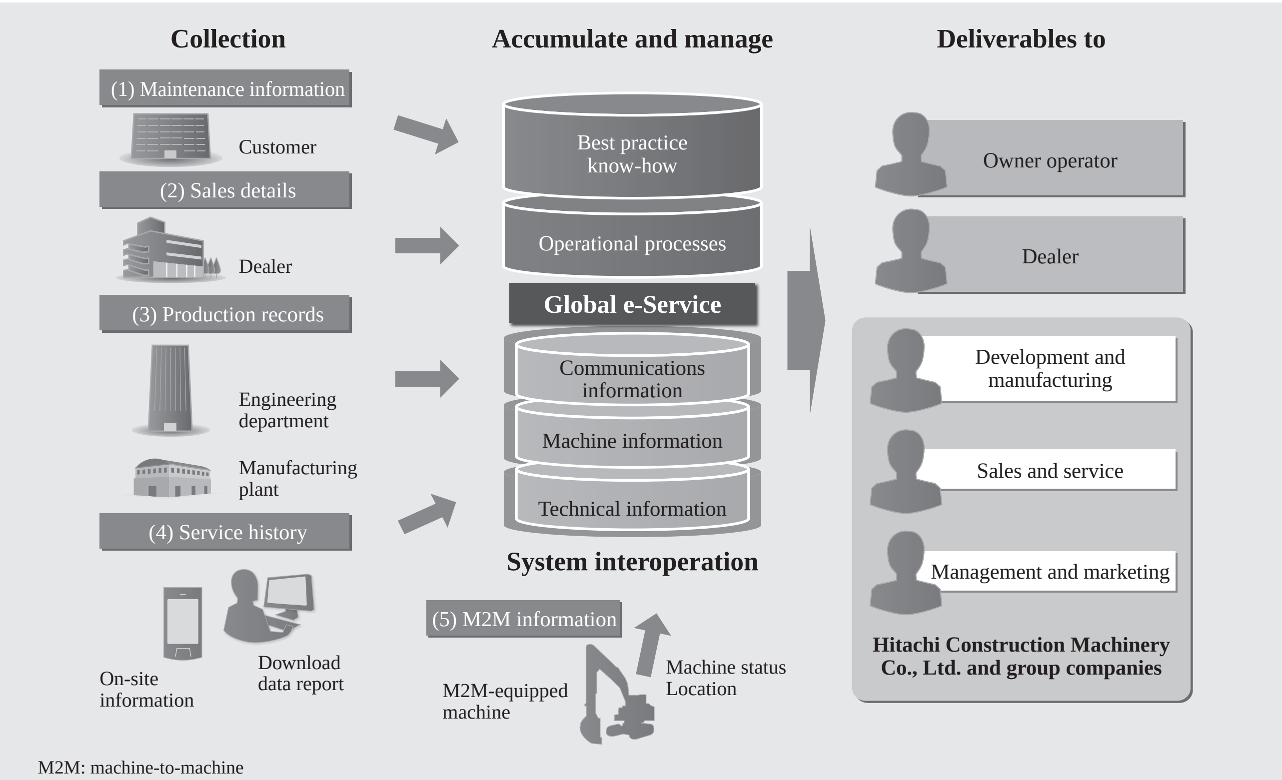

Fig. 1—Overview of Global e-Service Support Service for Construction Machinery.
The service performs integrated management of information that includes production records, service history, technical information, and sales details as well as operational data, supplying this data in ways that suit different users.

Hitachi Construction Machinery Co., Ltd. led the market in June 2000 by offering a satellite communications device as an option in its ZAXIS* Series 1 hydraulic excavators, releasing it on the market as an "information excavator" capable of remotely collecting operational information[1]. The function was subsequently made a standard feature on the ZAXIS-3 Series released in April 2006.

Hitachi Construction Machinery has also been operating its Global e-Service since October 2005. This system performs integrated management of operational information together with associated machine and technical information. It seeks to improve work efficiency by supplying everyone involved in supporting the machinery with the information they require, including the customer.

This article gives an overview of how Global e-Service uses ICT to support the lifecycle of construction machinery, and describes examples of aftermarket use of operational information for lifecycle support.

OVERVIEW OF GLOBAL E-SERVICE

Global e-Service can be broadly divided into the following three functions.

(1) Collect production, quality, operational, technical, sales, and service history information from the time of manufacture to the end of the machine's life (see Fig. 1).

(2) Store the collected information and perform integrated management.

(3) Provide a range of options for making the accumulated information available to the parties involved with the machine.

Including those used by administrators, the system offers approximately 80 functions. Different combinations of functions are made available to suit different users, such as dealers or customers.

Global e-Service currently manages document information for all Hitachi Construction Machinery Group products, and supplies useful information to approximately 24,000 registered companies and 60,000 users. As indicated by its name, the system supports 20 languages and operates globally with users in 82 countries or regions.

Global e-Service monitors operational information from machines via mobile phone or satellite communication networks, which is called machine-to-machine (M2M) services. It currently collects and stores large amounts of information from approximately 110,000 machines internationally and supplies this information for use in a variety of applications, including overlaying on maps, for example.

Fig. 2—Example Daily Report Screen.
This report presents the daily operational status of each machine in the form of graphs and data for use in machine management.

Based on data acquired from these M2M systems, the service can display information about the operation of each machine in the form of a daily report. The information in this report can be used to view details such as engine operating conditions, daily operating hours, the amount of fuel in the tank, and cumulative operating hours (see Fig. 2).

The system also includes a link function that allows various information from the machine to be accessed from this screen. Access to details such as the machine's maintenance history or technical data allows a quick response when responding to a customer inquiry, for example.

The communications device includes a global positioning system (GPS) function, and position information is sent together with operational data. Displaying the latest machine position on a map helps service personnel to work more efficiently (see Fig. 3).

EXAMPLE APPLICATIONS

Use for Service and Parts Sales

The departments responsible for service and parts sales are working on the development and utilization of a system for generating service reports for customers that uses the daily operational data sent from general-purpose hydraulic excavators and other mining equipment fitted with communications

* ZAXIS is a trademark of Hitachi Construction Machinery Co., Ltd.

*1 Zenrin is a product name, trademark or registered trademark of Zenrin Co., Ltd.
*2 Google and the Google Logo are registered trademarks of Google Inc.

Fig. 3—Managing Machines on Map.
Displaying the latest positions from all of the machines belonging to a customer on a map improved the efficiency of field servicing.

Fig. 4—Example Repair Proposal Screen.
Convincing proposals can be produced by combining operational data with the results of a visual inspection.

devices to collect information such as advice on when to perform maintenance or repairs, suggestions for preventive maintenance, and guidance on operating practices. To provide timely services and sales of spare parts, they also conduct field servicing and other work at appropriate times based on data such as the cumulative engine running time (“hour meter”) and position information. The following sections describe the functions of the report system based on machine operating data and provide examples of how it is used and of proposals presented to customers.

(1) Service report support system

In the past, most reporting has been done by hand using printed forms or on a personal computer using software such as Microsoft Excel* or Microsoft Word*. Accordingly, in certain ways, the quality of the reports and the time taken to produce them depended on the abilities of the people doing the work. The service report support system establishes the procedures (“flow”) for consistent reporting processes and methods, improving report quality, reducing the work required to produce them, and enhancing the ability to present proposals to customers.

In Japan, Hitachi Construction Machinery provides a free inspection service (special field servicing) as part of its marketing of services, using the results of the inspections as feedback to gain orders for repair work or to produce proposals for services such as preventive maintenance. Along with machine inspection results, the service report support system collects operational information recorded by the machine, such as temperatures and loads, and also provides an easy way to present it in a graphical format. This makes it possible to explicitly determine the required timing for repairs or other maintenance by presenting not only external damage or deterioration, but also the load on the engine and hydraulics, and to compile convincing repair proposals (see Fig. 4).

Customer concerns about cost continue to grow in the global market for construction machinery, and the service departments are currently transferring to overseas dealers the know-how in acquiring orders for services that they have built up through their own experience with services in Japan.

In overseas markets, meanwhile, the favorable conditions enjoyed by mining businesses in recent times are making support for mining machinery even more important. In countries such as Australia or the Republic of Indonesia that have a large number of mines, customers are increasingly using operational data themselves to ensure that machine maintenance is efficient and economical, and are expressing strong interest in the reports from dealers. Significant numbers of mining machines have full maintenance service contracts (FMCs) and dealers provide periodic reports on these machines. Utilizing this information, Hitachi Construction Machinery is working to deepen communication with customers and to improve machine utilization (see Fig. 5).

A reporting system is also under development to generate operating data reports for hybrid models

* Microsoft Excel and Microsoft Word are either registered trademarks or trademarks of Microsoft Corporation in the United States and/or other countries.

Fig. 5—Example FMC Report Screen.
Regular detailed operational data reports are sent to customers who have mining machinery covered by a full maintenance contract (FMC).

released in 2011 and to show the superiority of hybrid models by comparing these with conventional models, particularly in terms of operational and fuel consumption data. Recent price increases have further raised customer concern about fuel consumption. Because whether or not hybrid models deliver adequate fuel savings and environmental benefits depends on how they are driven by the operator and on other operational conditions, Hitachi Construction Machinery sees these reports as becoming an effective tool for contact with customers in the future. Reports are already being distributed on a trial basis and the ultimate plan is to integrate this reporting into the service report support system.

(2) Use of event monitoring system

Steps are being taken around the world to reduce emissions of greenhouse gases, and industry is obliged to comply with exhaust gas laws that also apply to construction machinery fitted with large engines. Under the schedule for implementation of these laws, key models are currently covered by Stage III B (in Europe) and Interim Tier 4 (in the USA). The technology used to achieve compliance involves fitting muffler filters (DPF, catalyst-based diesel particulate filter).

Muffler filters work by extracting and burning particulate matter (PM), and maintaining this PM scavenging ability is a mandatory requirement for reaching the levels stipulated in the regulations. To achieve this, Hitachi Construction Machinery developed an event monitoring system that uses the communication function for efficient status monitoring. The system collects relevant events that indicate the engine status and passes this information to Global e-Service. Service departments remotely monitor the machines in their territories and respond to each event depending on its status. Guidelines have been compiled specifying how to respond to each event, providing instructions on what to do when events occur and improving the speed of response (see Fig. 6).

(3) Example proposal to customer on how to improve work practices

This example describes how analysis of operational information helped improve machine fuel consumption.

When the basic performance of the machine in question was first studied, it was found to have no problems itself and to be delivering its rated performance. Next, operational information was collected from other machinery from the same industry to provide a comparison (see Fig. 7).

When the pump load of the machine in question was compared against the average pump load from the other machines, it was found to be frequently operating in the maximum load range. The customer was questioned about the nature of the work being performed by the machine and suggestions for improving operating practices were made to reduce actual fuel consumption.

Marketing Example

In contrast to servicing work that deals with individual machines, sales departments take a macro

Fig. 6—Example Screens for Event Monitoring System.
The screens present engine status information together with guidance on what to do next based on events from the machine.

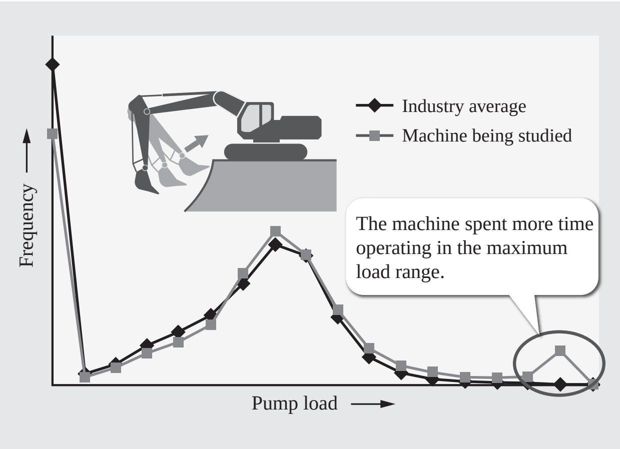

Fig. 7—Analysis of Pump Load.
Based on a comparison with average loads in the same industry that indicated the machine was frequently operating in the maximum range, improvements were made to operating practices to reduce fuel consumption.

approach to analyzing operational data. A system has been implemented that provides an overview of operational data from machines around the world and displays the trend in operating times in each region (see Fig. 8).

This system can be used to compare changes in relevant time-series information (such as total operating time, mean operating time, and number of machines) over any time period between one day and three years. The system also allows different comparison variables to be selected for display, including customer-related information such as industry type, demand information, or economic indicators.

Currently, the system is mainly used for reference when formulating sales strategy and to issue reports to senior management and the respective country managers, accompanied by comments from local managers.

CONCLUSIONS

This article has given an overview of how Global e-Service uses ICT to support the lifecycle of construction machinery, and described examples of aftermarket use of operational information for lifecycle support.

Other ways in which Hitachi Construction Machinery is using this technology include in new machine development and to help make further quality improvements. For example, centralized management of operational data from around the world provides an understanding of how machines are used in each country or region, allowing the development of machines that suit actual conditions.

Putting operational information to good use throughout the product lifecycle, including development, allows Hitachi Construction Machinery Co., Ltd. to deliver machines and services that customers can use with confidence, and to seek to be a “Close and Reliable Partner anywhere on the Earth with Best Solutions through Kenkijin Spirit.”

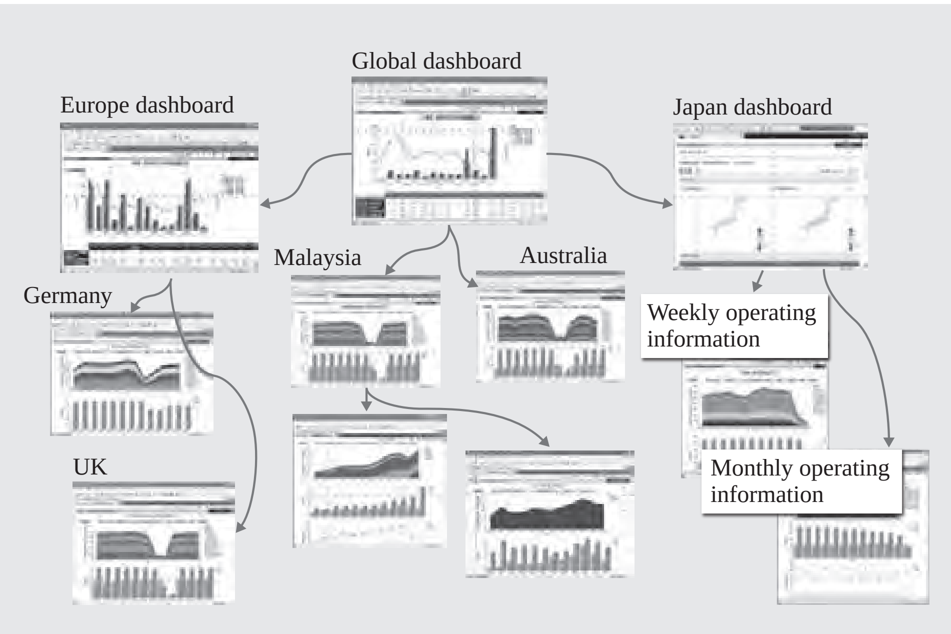

Fig. 8—Screens from Operation Visualization System.
The system can be used to view operational information from around the world by shifting the focus from the global dashboard to specific regions or models.

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ZAXIS-5 Hydraulic Excavator Series Compliant with New Emissions Law

Toshiaki Nishida
Tsuyoshi Nakamura
Yasushi Arai
Kazuhiro Shibamori

OVERVIEW: Exhaust emission laws are becoming stricter, with new laws being introduced progressively in Japan, Europe, and North America, starting in 2011. Designed to reduce the load on the environment, these laws also apply to the engines used in construction machinery. To comply with these requirements, Hitachi Construction Machinery Co., Ltd. is proceeding with a full revamp of its range of hydraulic excavator models to incorporate the numerous requests gleaned from surveys of user needs in Japan and elsewhere. The new models will be called the ZAXIS-5 Series. In addition to compliance with the new emissions laws, the ZAXIS-5 Series aims to provide even better fuel consumption, a safer and more comfortable operator's cab, and more advanced information technology functions. Models have already been released in Europe and North America.*

INTRODUCTION

RECENT years have seen progress on measures aimed at reducing the load on the environment in various ways, and construction machinery also faces stricter exhaust emission laws around the world. In response, Hitachi Construction Machinery Co., Ltd. has developed the ZAXIS-5 Series of hydraulic excavators that are compliant with the new emissions laws and has released them on the European and North American markets.

In addition to having an engine that complies with the new emissions laws, Hitachi Construction Machinery has built a system for the ZAXIS-5 Series that achieves both better fuel consumption and improved digging performance. Along with the durability of the front attachment and crawler unit, lifecycle costs have been reduced through easier maintenance, including the addition of the fault diagnosis equipment to the cab monitor. The operator's environment has also been considered with a more spacious and comfortable cab, and the excavator is full of new technology that operators will find easy to use, including multi-function switches to provide centralized controls in easy reach. Further enhancements have been made to the information technology functions that earned a strong reputation in previous models, including a rear-view camera that displays on a wide monitor and an upgrade to the Global e-Service function that operates as a mobile communications device.

* ZAXIS is a trademark of Hitachi Construction Machinery Co., Ltd.

This article describes the energy efficiency technologies on the ZAXIS-5 Series, its clean engine technology, safe and comfortable cab, and advanced information technology (see Fig. 1).

CLEAN ENGINE TECHNOLOGY AND PURSUIT OF ENERGY-EFFICIENT PERFORMANCE

New Hydraulic System

The ZAXIS-5 Series uses the three-pump/three-valve hydraulic system in place of two-pump/two-valve systems used in the past. The objectives of the system are to further reduce fuel consumption and

Fig. 1—ZAXIS-5 Series.
The photograph shows a ZAXIS 250LC-5 hydraulic excavator.

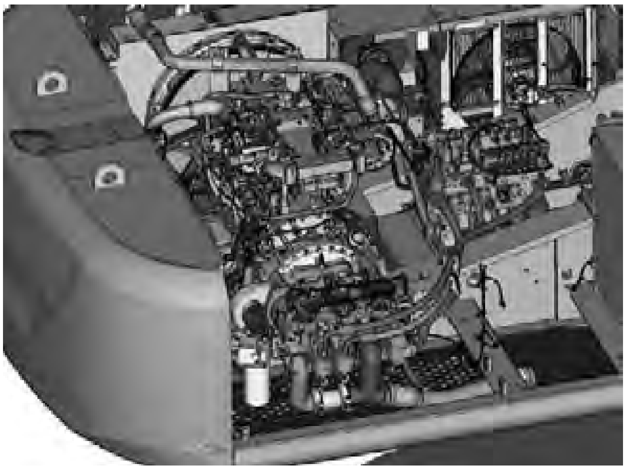

Fig. 2—Hydraulics.
The hydraulics makes the excavator easier to operate and provides a significant reduction in fuel consumption.

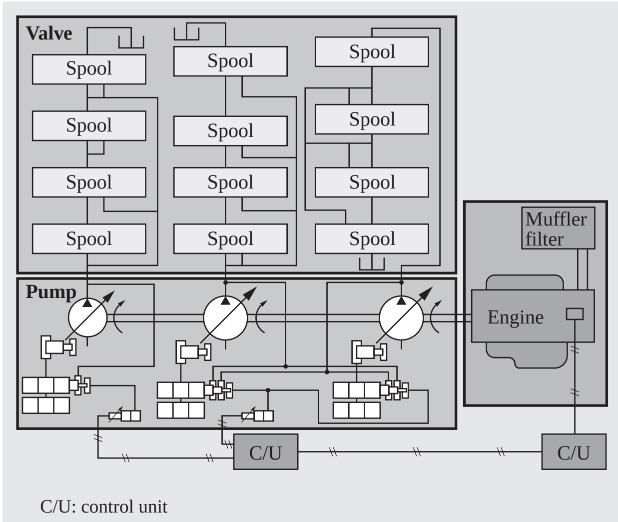

Fig. 3—Three-pump/three-valve Hydraulic System Configuration.
Pressure losses in the hydraulic circuit were significantly reduced by maintaining a more appropriate level of pump output.

improve operation by making the excavator easier to drive (see Fig. 2).

In particular, to reduce fuel consumption, the system uses precise electronic control to achieve more appropriate pump output as well as paying close attention to reducing pressure losses in the hydraulic circuits, which is achieved through both software and hardware (see Fig. 3).

Specifically, the system combines different techniques, including reducing power losses during simultaneous operations by selecting optimal power settings for each pump, reducing pump power by adjusting the efficiency of each actuator, reducing throttling losses for energy regeneration by increasing the pump discharge volume, and reducing pressure losses by adding additional circuits and switching valves. These result in a significant improvement in fuel consumption.

The result when using the new ECO operating mode is an 18% saving in fuel consumption (on the ZAXIS 250LC-5, compared to a previous model).

Clean Engine Technology for Hydraulic Excavators

The new emission laws require particulate matter (PM) to be reduced to one-tenth the level required by the previous law, and nitrogen oxides (NO_x) to one-half. In addition to the common rail fuel injection system from the previous engine, newly developed technologies adopted on the new engine include a muffler filter to reduce PM, a variable geometry system (VGS) turbo (variable turbo) to reduce NO_x, and a larger capacity exhaust gas recirculation (EGR) cooler (see Fig. 4).

Fig. 4—Engine for ZAXIS 250-5 Class.
The engine complies with the new emissions laws in Europe, North America, and Japan.

The catalyst used in the muffler filter becomes active when the engine is heavily loaded and the temperature of the exhaust gas is high. However, because hydraulic excavators are used for a wide range of tasks, including digging, leveling, lifting, and loading, and are fitted with various different attachments, such as breakers or fork grapples, there are times when most of their operation takes place under light loads with low exhaust gas temperature. During development, Hitachi Construction Machinery tested different engine running patterns associated with the various different types of hydraulic excavator operation to fine-tune the engine control to suit its use in hydraulic excavators, including working on the fuel injection timing and EGR valve open/close control to optimize the level of PM removal by the muffler filter, the savings on fuel consumption, and the level of exhaust gas.

CAB

Pursuit of Safety and Improved Comfort

The safety and comfort of the cab are important elements in improving the working environment for the operator and preventing accidental damage at the worksite.

For safety, the hydraulic excavators comply with roll-over protective structures (ROPS) requirements to maintain a minimum safe area that prevents the operator from being crushed even if the machine were to fall over and rotate through 360°. The performance requirements that ROPS must satisfy and the associated test methods have been stipulated in International Organization for Standardization (ISO) standards. The cab design also uses irregular-profile pipe for the pillars to optimize the ROPS, and maximizes the area of glass to improve the field of view and allow the operator to check the safety of the region around the excavator.

A rear-view monitor is also included as a standard feature, with the monitor conveniently located where the operator can see it without turning his or her head. Frequently used switches such as those that control the wipers and lights are located close to the operator, with the layout designed to prevent misoperation (see Fig. 5).

For operator comfort, in addition to a seat designed to allow extended use without tiring, the automatic air conditioning system (a standard feature) has been optimized so as to surround the operator with vents (see Fig. 6). Improvements to the air tightness of the cab have also improved thermal insulation and reduced interior noise levels.

Fig. 5—ZAXIS-5 Series Cab Interior.
The spacious and comfortable cab improves monitor visibility and the right-hand-side field of view.

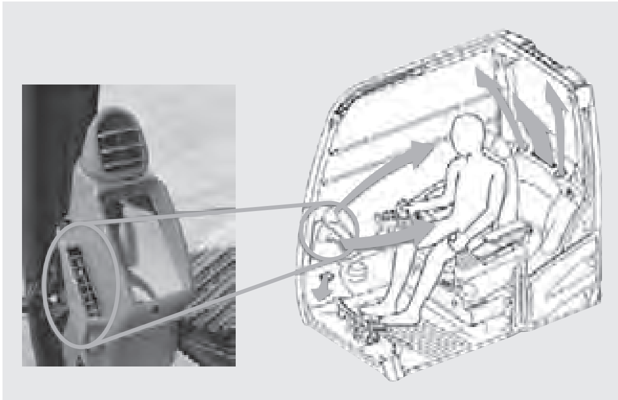

Fig. 6—Location of Air Conditioning Vents on ZAXIS-5 Series.
The air conditioning vents surround the operator.

Multi-function Monitor Operator Controls

Multi-function monitors that use full-dot color liquid-crystal displays have been used since earlier models where they were well regarded. On the new models, these have been upgraded to provide additional functions and easier monitor operation.

In addition to basic functions such as the water temperature gauge, fuel gauge, and machine information display, features such as the radio and air conditioning have been consolidated into the monitor along with existing functions that used the multi-function monitors, such as those for maintenance and hydraulics adjustment (see Fig. 7). These functions are available in 32 different languages.

Fig. 7—Multi-function Monitor and Controls.
The photographs show the main screen of the multi-function monitor (left) and the multi-function switch and air conditioning and radio switches (right).

The multi-function monitor is also used for machine adjustment. Previous models also used a monitor for fault diagnostics and other simple servicing tasks. To these, the new models have added a selection of sensor and engine data monitoring functions as well as machine adjustment and other setup functions, these being the bare minimum of functions required for servicing. While servicing of previous models required a special external device, these devices are not available in some countries or regions and therefore these functions are used as a workaround for this problem. In addition to providing additional functions of value to both the customer and service staff, the new models have been localized to suit different markets.

Feedback on previous models indicated that their large number of switches made them confusing to operate. To simplify the operation of the new excavator models, Hitachi Construction Machinery responded by undertaking considerable testing of their ease-of-operation. Based on this, the controls on the multi-function monitor were limited to “turn” or “press” only, and multi-function switches were developed specifically for use in construction machinery. While dedicated switches were still provided for the air conditioning and radio because of their frequency of use, the switches were consolidated into a single location and restricted to the same turn and press operations as other functions to ensure that the multi-function monitor would be easy to use.

ENHANCEMENTS TO INFORMATION TECHNOLOGY

On the previous models, it was difficult to determine what condition the machine was in when a fault occurred in the marketplace. Even after service staff had carried out an inspection, identifying the cause of the fault sometimes took a long time, if it could be identified at all. Because of the enhancements to the engines used in the new models required for compliance with exhaust emission laws, Hitachi Construction Machinery built the following three systems to minimize downtime and make faults easier to diagnose.

Recording of Machine Information when Fault Occurs

Hitachi Construction Machinery has simplified problem analysis and fault finding by recording sensor readings, digital signals, and other data from around the time a fault occurs. All of this recorded machine data can be retrieved remotely by issuing commands from the office.

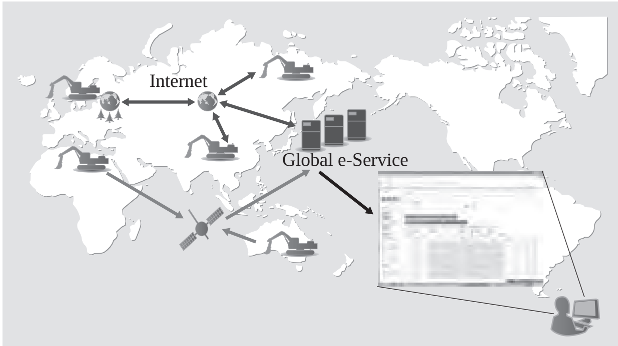

Fig. 8—Overview of Remote Monitoring System.
Operating data from machines located throughout the world can be viewed from the office.

Building of Remote Monitoring Function

The ZAXIS-5 Series collects data from the various sensors fitted to the machine and uses a built-in communications device to send this data to the Global e-Service monitoring server. The aim is to reduce downtime by building a system capable of monitoring machines in use around the world from the office (see Fig. 8).

Enhancements to Fault Diagnostics System

The growing use of electronics and more complex control in construction machinery is increasing the number of data points for monitoring of the machine’s sensors. In the past, a special-purpose fault diagnostics system was used during maintenance to select from approximately 100 different data points. For the new models, functions have been added to the device

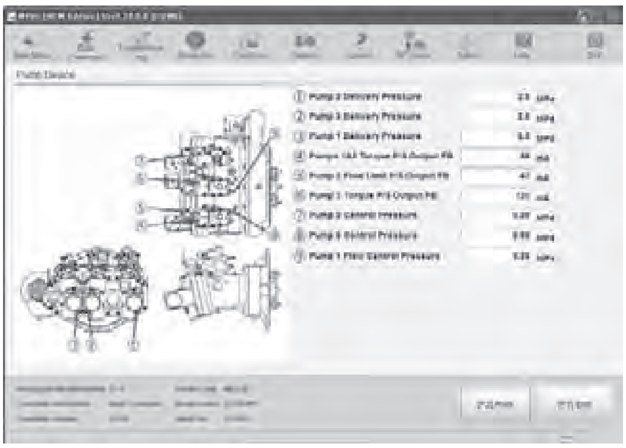

Fig. 9—Example Screen on Fault Diagnostics System.
The example screen from the fault diagnostics system shows the main pump pressure.

to make it easier for staff to perform servicing, simplifying the task of checking the machine's condition by displaying a diagram of the relevant control system as they go (see Fig. 9).

CONCLUSIONS

This article has described the energy efficiency technologies on the ZAXIS-5 Series, its clean engine technology, safe and comfortable cab, and advanced information technology.

The ZAXIS-5 Series is being adopted by users in all parts of the world where its performance is earning a strong reputation.

In the future, Hitachi Construction Machinery Co., Ltd. intends to continue working on developments aimed at increasing customer satisfaction, strengthening the "made by Hitachi" brand, and supplying products that will be in demand from a larger number of users.

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Adoption of Electrification and Hybrid Drive for More Energy-efficient Construction Machinery

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OVERVIEW: As for automobiles, electric and hybrid drives are effective technologies for improving the energy efficiency of construction machinery. In July 2011, Hitachi Construction Machinery Co., Ltd. released the 20-metric-ton ZH200 hybrid hydraulic excavator. Having overcome the cost, reliability, durability, and safety challenges associated with the adoption of hybrid drive, the number of ZH200 machines in service is steadily growing thanks to the strong reputation it has earned for ease of use and work performance as well as for energy efficiency. In the future, Hitachi Construction Machinery intends to continue incorporating its device and electronic control technologies for electric drives into construction machinery to deliver products that match customer needs while also providing excellent energy-efficient performance.

INTRODUCTION

FACTORS such as rapid rises in the price of oil and moves to reduce carbon dioxide (CO_2) emissions to help prevent global warming in recent years are behind growing demand for construction machinery to be made more energy efficient. A number of government policies have been introduced in response to this, including giving points for use of energy-efficient construction machinery in bidding for public works projects, and subsidies for purchases of hybrid models.

As in the automotive sector, electric and hybrid drives are effective technologies for improving the energy efficiency of construction machinery. Hitachi Construction Machinery Co., Ltd. has been engaged in the development of electrically driven construction machinery for some time, and has already released an electric-hydraulic excavator that operates using commercial electric power supplied by electric companies via transmission lines, an electric powered excavator fitted with lithium-ion batteries, and a large wheel loader with a series hybrid drive. Hitachi Construction Machinery also released the 20-metric-ton ZH200 hybrid hydraulic excavator in July 2011.

This article describes key aspects of energy efficiency improvement for hydraulic excavators and the issues associated with adopting hybrid drive, and also gives an overview of the ZH200 hybrid hydraulic excavator.

ENERGY EFFICIENCY IMPROVEMENT FOR HYDRAULIC EXCAVATORS

Whereas the motive force for an automobile is achieved by transmitting the torque produced by the engine to the wheels, a hydraulic excavator uses

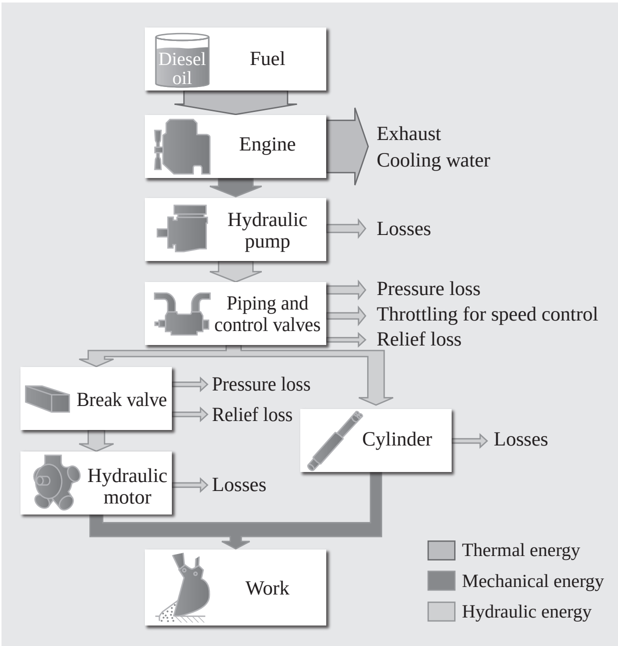

Fig. 1—Energy Losses in Hydraulic Excavators.
Because of the various losses that occur in the engine and hydraulic system, less than 10% of the energy contained in the fuel ends up being converted into work.

its engine to turn a hydraulic pump, which in turn drives the hydraulic actuators that perform the work. Accordingly, the operation and concept behind the use of hybrid systems to save energy is different to that for automobiles, even though both use electric motors and electrical storage devices. Similarly, while it is possible to assess automobile fuel consumption based on the fuel consumed per unit of distance traveled, the diverse range of tasks and uses to which hydraulic excavators are put makes defining fuel consumption difficult.

Energy Losses in Hydraulic Excavators

A hydraulic excavator can be thought of as a machine that converts the energy in fuel (typically diesel oil) into useful work by driving various hydraulic actuators.

Fig. 1 shows the energy losses in a hydraulic excavator.

When the thermal energy in the fuel is converted to the output from the engine's driveshaft, approximately 60% escapes as heat. The driveshaft energy of the engine is then used to turn a hydraulic pump, converting it into hydraulic energy that is distributed via pipes and control valves to the various hydraulic actuators. In addition to the direct pressure losses, each of the actuators has different characteristics and a considerable amount of energy is also lost in the hydraulic system to provide the controllability needed to operate them as required. Similarly, positional and inertial energy generated during operation is also lost in the hydraulic system through conversion to heat. While it varies depending on operating conditions, the proportion of useful energy available for performing work is less than 10% of the energy in the fuel[1].

Operation of Hybrid Systems

Over time, numerous enhancements have been made to different parts of hydraulic excavators to reduce the different losses that affect them, including the hydraulic equipment and systems, engine, structure, and mechanical components.

Hybrid excavators seek to achieve even better energy efficiency by combining the excellent characteristics of electrical drive components to boost overall system efficiency.

The most important of these characteristics are listed below.

(1) High level of control responsiveness (compared to engines and hydraulics)

(2) High level of drive and transmission efficiency (compared to hydraulics)

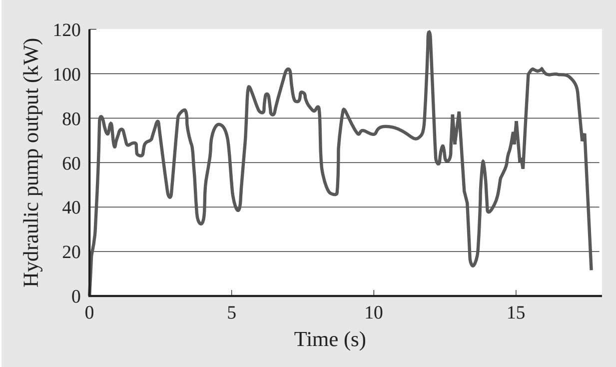

Fig. 2—Example of Variation in Pump Output during Excavation by 20-metric-ton Hydraulic Excavator.
The pump output varies from near zero to close to maximum engine output.

(3) Potential for use of regenerative energy (compared to hydraulics)

Fig. 2 shows data on the variation in hydraulic pump output on a hydraulic excavator during excavation work[2]. The engine load is roughly equivalent to this output. This shows one of the characteristics of hydraulic excavators, namely that their output varies from near zero to close to maximum engine output.

Being subject to this sort of variation in load means that the engine and pump are not necessarily working at an efficient operating point. While it makes sense to operate the engine at a speed that provides high efficiency, the slow control response of the engine represents a bottleneck. When hybrid drive is used, it is possible to take advantage of the control responsiveness [characteristic (1) above] to use the electric motor to assist when changing the engine speed, thereby keeping the engine and hydraulic pump at more efficient operating points (see Fig. 3). Similarly, characteristics (2) and (3) can also be used to save energy by converting some of the hydraulic actuators, such as the swing device, to electric operation, thereby increasing overall system efficiency and allowing regeneration to be used during deceleration. Scope for reducing other energy losses, particularly in the hydraulics system, also lies in making skillful use of these three characteristics.

Issues Associated with Adopting Hybrid Drive

While the adoption of hybrid drive clearly represents an effective means for making hydraulic excavators more energy efficient, the key problems are cost, reliability, and durability.

For example, while the Toyota Motor Corporation sold about 300,000 of its Prius hybrids in Japan alone

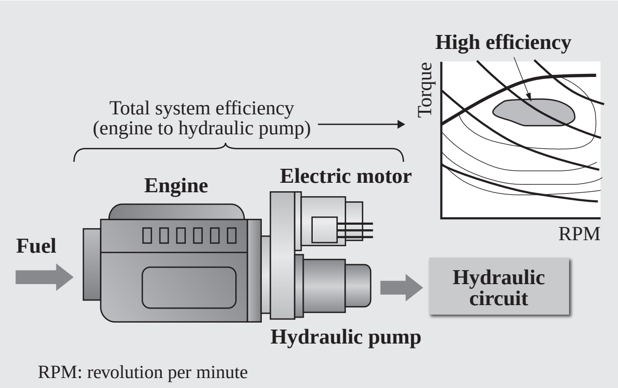

Fig. 3—Example of High Efficiency Operation of System Comprising Engine, Electric Motor, and Hydraulic Pump.
Energy savings are achieved by controlling overall operation to remain within an operating range with high total system efficiency.

Fig. 4—ZH200 Hybrid Hydraulic Excavator.
The ZH200 was awarded a Good Design Award 2011 from the Japan Institute of Design Promotion.

during 2010 (source: Japan Automobile Dealers Association), total international demand for hydraulic excavators of all classes does not exceed 150,000 machines a year (excluding very large excavators and mini excavators)(3). Because the cost savings of mass production are considerable for electrical components, reducing the cost of hybrid systems requires not only the wider adoption of hybrid excavators but also other cost cutting measures such as standardization of parts across different models and the use of automotive parts(4).

Furthermore, because it is not uncommon for hydraulic excavators to remain in use for 20 years or more in harsh environments, the reliability and durability of electrical drive components, particularly energy storage devices, is a major issue. There is no advantage for customers in machines that fail due to faulty electrical drive components or that cannot be repaired due to obsolescence.

Adequate account also needs to be taken of safety. Hybrid excavators need not only to be kept safe from high voltages, they must also be able to be operated safely even if electronic control becomes unavailable.

ZH200 HYBRID HYDRAULIC EXCAVATOR

Hitachi Construction Machinery's technology and many years of experience with electric construction machinery have culminated in the release of the ZH200 20-metric-ton hybrid hydraulic excavator. It was developed based on extensive market research into customer needs and achieves a high degree of balance between its initial cost and excellent fuel consumption performance, as well as the practicality to be able to be used for any sort of work or at any site (see Fig. 4).

ZH200 Hybrid System

The ZH200 features a newly developed system that combines hybrid technology with the newly developed fuel-efficient, three-pump hydraulics system. Fig. 5 shows an overview of the system.

In contrast to previous two-pump/two-valve hydraulics systems, it has a three-pump/three-valve configuration that includes an additional heavy-duty pump and valve. The availability of three hydraulic power sources improves system efficiency by limiting throttling losses when performing complex operations.

The ZH200 is also equipped with an electric-hydraulic swing mechanism with an electric motor that can produce regenerative energy during swing deceleration and assist with swing acceleration.

In addition to using the hybrid system, features such as advanced engine control, an idling stop function, and reduced pressure losses in the hydraulic piping also help the ZH200 deliver 20% better fuel consumption than the standard model (ZX200-3).

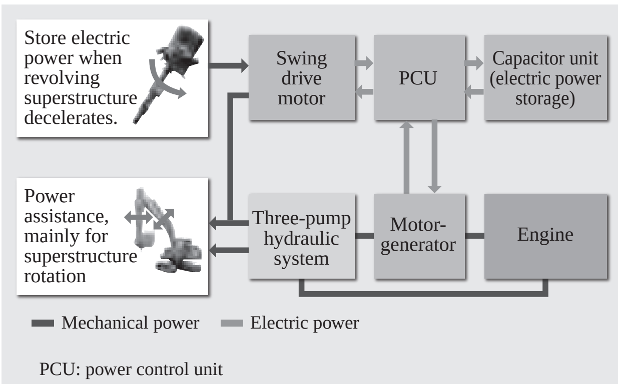

Fig. 5—ZH200 Hybrid System.
The ZH200 combines a newly developed three-pump/three-valve hydraulic system with a hybrid system to achieve excellent basic performance together with energy efficiency.

Fig. 6—ZH200 Swing Device.
The swing hydraulic motor is visible at the top while the swing electric motor has three-phase cable connections.

ZH200 Electrical Drive Components

The electrical drive components used in the ZH200 include two motors, a power control unit (PCU), and a capacitor unit.

The swing electric motor is located between the swing device's hydraulic motor and the swing reduction gear (see Fig. 6). The swing electric motor is a water-cooled, permanent magnet synchronous motor, and its torque is controlled by commands from the PCU. This includes producing regenerative electric power when the revolving superstructure of the excavator is decelerating and assisting the swing hydraulic motor during acceleration.

The motor-generator is a permanent magnet synchronous motor connected to the driveshaft that runs from the engine to the hydraulic pump and its primary role is to control charging of the capacitor unit.

The PCU incorporates the electrical circuit for the power system comprising the motor drive inverter and chopper, and drives the two motors at the specified torques based on commands from the supervisory controller.

The capacitor unit includes large-capacity, electric double-layer capacitors, control circuits, and a main relay. It stores regenerative electric power from the swing drive motor and generated electric power from the motor-generator.

ZH200 Objectives and Features

Before the ZH200 could be released, it needed to overcome the aforementioned challenges of cost, reliability, and durability.

To reduce the cost of the hybrid system, the ZH200 uses automotive products for its power system electric components, and the maximum current and output requirements have been reduced by sharing energy delivery with the hydraulic system. The electric drive components, including the capacitor unit, have a design life that exceeds the life of the excavator chassis. Furthermore, the system is designed so that, even if these components were to fail, the machine can continue to operate as far as possible by switching over to hydraulics-only mode.

For safety, the electrical design follows those for hybrid or electric vehicles, while the mechanical design is such that the hydraulics system keeps the excavator in a safe condition even if an electrical fault occurs.

Hitachi Construction Machinery hydraulic excavators need to combine appropriate levels of both basic performance and ease-of-use. The energy efficiency of vehicles can be measured in terms of how much fuel they consume for each unit of distance traveled. In the case of hydraulic excavators, on the other hand, while fuel consumption relative to work done might be more suitable, measuring fuel consumption relative to operating time is more practical. Some caution is required, however, because an excavator that does not operate the way its operator wants it to is not necessarily very energy efficient, even if its hourly fuel consumption is low. For example, a task that can be done in a single operation by an easy-to-use machine might take two or even more inefficient operations to complete on a less useful machine. In the case of the ZH200, the control algorithms were developed using a model-based design method(5) with a seamless transition between simulation and live testing to ensure that, despite its being a hybrid, its operation would feel no different to that of a conventional excavator.

CONCLUSIONS

This article has described key aspects of energy efficiency improvement for hydraulic excavators and the issues associated with adopting hybrid drive, and also given an overview of the ZH200 hybrid hydraulic excavator.

Making a major contribution to minimizing global warming will require widespread market adoption of energy-efficient construction machinery like the ZH200. In addition to incorporating Hitachi Construction Machinery's electric drive device technology and electronic control technology into its construction machinery products, Hitachi Construction Machinery Co., Ltd. also intends to continue developing the core technologies for construction machinery, specifically engines, hydraulics systems, structures, and mechanical components, so that it can continue to satisfy customer needs and supply construction machinery products with even greater energy efficiency.

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Use of Emission Rights for Construction Machinery to Help Prevent Global Warming

Shuji Ohira
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Kensuke Kawamura

OVERVIEW: With measures being adopted around the world to reduce emissions of CO_2, use of carbon offsets has grown rapidly in recent years as a means of offsetting one's own emissions with the aim of complying with international commitments made through the United Nations Framework Convention on Climate Change. Against this background, Hitachi Construction Machinery Co., Ltd. has added environmental value to its products by using carbon offsetting for its construction machines that deliver a higher level of energy efficiency than previous models. Hitachi Construction Machinery is also contributing to the use of construction machinery to prevent global warming in the forestry industry, with emission rights able to be generated for highly energy-efficient electric-hydraulic excavators (domestic credit projects).

INTRODUCTION

AT the Third Conference of the Parties to the United Nations Framework Convention on Climate Change (COP3) in 1997, Japan made an international commitment to reduce its carbon dioxide (CO_2) emissions by 6% relative to 1990 levels. FY2012 is the final year of the first Kyoto Protocol period. The policy of the Japanese government was that, of that 6% reduction, 3.8% should be achieved by increasing CO_2 removal units from forests, and the Forestry Agency has managed forests as a resource for CO_2 removal through its *Kizukai-Undou* (wood products use campaign) program[1].

Hitachi Construction Machinery Co., Ltd. also supplies forestry machinery that is used for forest management work such as thinning and the removal of thinned material. Participants in the forestry industry have a strong awareness of the environment, and Hitachi Construction Machinery has since 2008 been operating a joint program of carbon offsets for forestry machinery with customers that is aimed at preventing global warming.

Carbon offsets were first proposed by private businesses in the UK in 1997 and their use in Japan has grown rapidly since about 2008. As carbon offsets were originally intended as way for organizations to offset their own CO_2 emissions, organizations could choose for themselves which emissions to offset. Hitachi Construction Machinery has established a carbon offset policy that it applies to machines that significantly reduce or minimize emissions of CO_2. The carbon offsets work as follows[2] (see Fig. 1).

(1) Identify how the activities being studied result in carbon emissions.

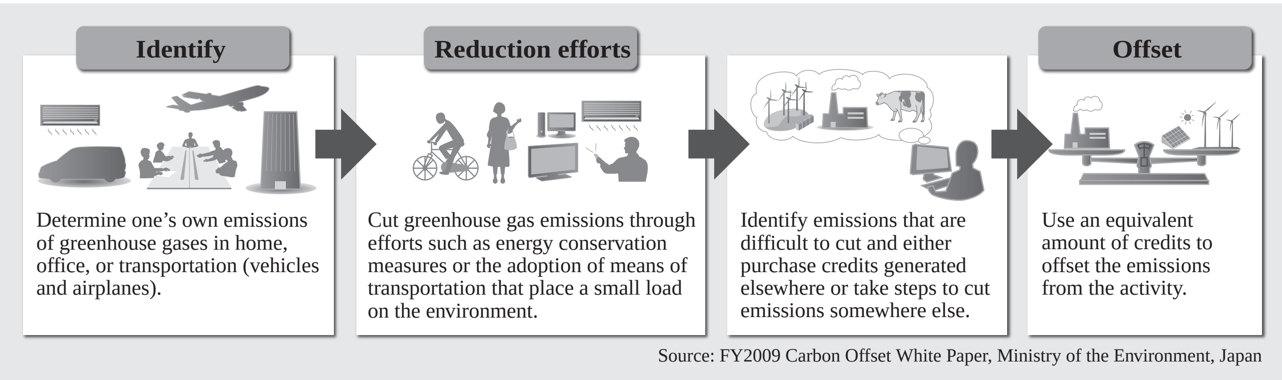

Fig. 1—Operation of Carbon Offsets.
The flowchart shows how carbon offsets work.

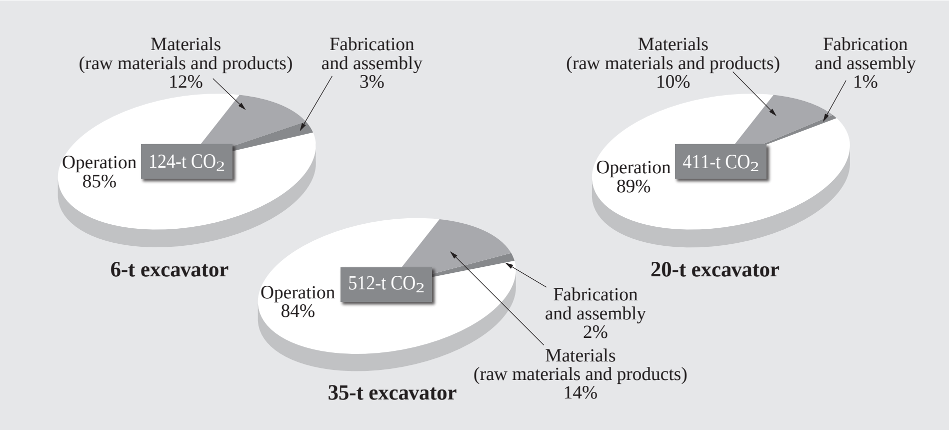

Fig. 2—Comparison of CO_2 Emissions over Hydraulic Excavator Lifecycles(3).
Between 85 and 90% of CO_2 emissions occur during operation, with materials accounting for 10 to 14%, and manufacturing only about 1 to 3%.

(2) Take steps to reduce emissions.
(3) Use credits to offset emissions that cannot be eliminated.

Use of carbon offsets starts with an awareness of CO_2 reduction. Using (redeeming) credits to offset emissions provides a means to collaborate with and support projects aimed at reducing greenhouse gas emissions.

The Clean Development Mechanism*1 (CDM) is one way of generating credits. CDM credits are a recognized mechanism under the Kyoto Protocol (to the United Nations Framework Convention on Climate Change) and grant credit for the CO_2 reductions that result from the use of advanced technology from developed economies in projects in emerging economies. This acts as an incentive for emerging economies to adopt energy-efficient technology.

The Ministry of Economy, Trade and Industry of Japanese government introduced a domestic credit system [CDM (based on a rule in Japan), domestic CDM hereafter]*2 in October 2008. The domestic CDM is a scheme for helping small and medium-sized companies in Japan to reduce greenhouse gas emissions, and it has greater energy saving benefits in Japan than CDMs that support overseas reduction projects as it makes a direct contribution to Japan's 6% reduction commitment under the Kyoto Protocol. Hitachi Construction Machinery has been participating in the domestic CDM since 2010.

*1 The Clean Development Mechanism is a scheme for awarding credits under the Kyoto Protocol (to the United Nations Framework Convention on Climate Change). For projects in which developed economies supply energy efficiency technology to emerging economies, it provides a mechanism for the managers of these projects to receive credit for the resulting reductions in CO_2 emissions.

*2 The domestic CDM is a scheme run by the Ministry of Economy, Trade and Industry whereby large corporations help small and medium-sized companies to reduce emissions. The credits generated by the scheme are called "domestic credits" and can be used for carbon offsets in Japan and to achieve voluntary reduction targets.

This article describes what Hitachi Construction Machinery is doing to use emissions rights to prevent global warming through construction machinery.

ACTIVITIES OF HITACHI CONSTRUCTION MACHINERY

Fig. 2 shows the CO_2 emissions over the lifecycles of hydraulic excavators. Between 85 and 90% of emissions occur during operation, with materials (raw materials and products) accounting for 10 to 14%, and manufacturing only about 1 to 3%(3). Similarly, Fig. 3 shows a breakdown of the relative CO_2 emissions from construction machinery during operation in Japan. Total emissions are about 10-million-t CO_2, with hydraulic excavators responsible for approximately half of these. This means that developing energy-efficient construction machinery

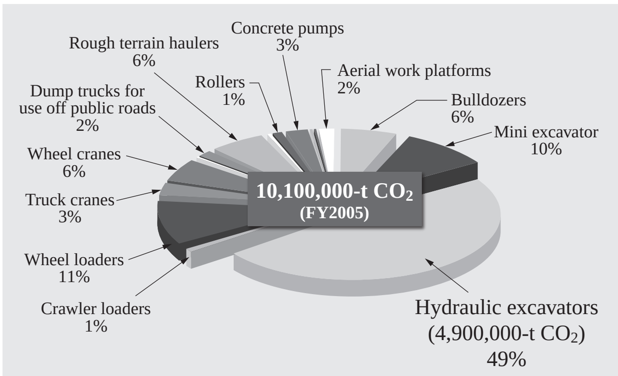

Fig. 3—Breakdown of CO_2 Emissions from Construction Machinery.
The figure shows a breakdown of the relative CO_2 emissions from construction machinery during operation in Japan.
The figures were calculated based on data from surveys of construction machinery market trends and ownership costs conducted by the Ministry of Land, Infrastructure, Transport and Tourism.

capable of minimizing CO_2 emissions, particularly those associated with the operation of hydraulic excavators, will make a major contribution to preventing global warming.

While its conventional construction machines already feature a high level of energy efficiency, Hitachi Construction Machinery has also been working on the research and development of leading-edge, clean, and energy-efficient machines. These have included the development of an industry-first hybrid wheel loader in 2002, and also the release of a battery excavator powered by lithium-ion batteries in 2005, a hybrid rubber-tired gantry crane (RTG) in 2007, and a hybrid excavator that uses an electrolytic double layer capacitor, also in 2007. Hitachi Construction Machinery has also developed energy-efficient construction systems based on information-integrated construction that uses the Hitachi on-site screening & solution business for efficient operation of machinery at construction sites, and the global positioning system (GPS) and Global e-Service construction information management service for greater work efficiency. To encourage the wider adoption of these machines and systems, and to contribute to the prevention of global warming in conjunction with customers, their clients, and other stakeholders, Hitachi Construction Machinery has been promoting the use of carbon offsets and the domestic CDM. The domestic CDM provides the mechanism for generating credits, carbon offsets provide a way to use (redeem) these credits[*3], and construction machinery provides the model for utilizing credits through a product's lifecycle (see Fig. 4).

*3 Transferring carbon credits to a national management account at no cost prevents the credits from being subsequently onsold or transferred, and ensures that they count toward Japan's CO_2 emission reductions.

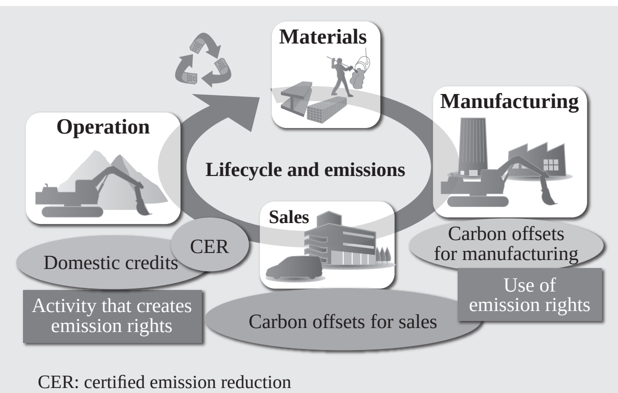

Fig. 4—Emission Rights over Construction Machine Lifecycle.
The figure shows the model for the creation and use of credits in the case of a hydraulic excavator.

The forestry industry makes a major contribution to reducing CO_2 in its own right. Carbon offsets apply to machines used in forestry and for machines with significantly better fuel efficiency than conventional models.

The domestic CDM applies to electric excavators used in industry that have significant benefits for minimizing CO_2 emissions. Credits created through the domestic CDM are called "domestic credits," which means they are local credits that can only be used in Japan. Under this arrangement, Hitachi Capital Corporation is a provider of credits.

EXAMPLES OF CARBON OFFSETTING

Carbon Offset Policy

Hitachi Construction Machinery developed a joint carbon offset scheme with the Total Solutions Division (as it was then known) of Hitachi, Ltd. that has been operating since October 2008. Hitachi Construction Machinery carbon offsets are divided into three types: product offsets, event offsets, and voluntary action offsets[(4)]. These carbon offsets are marketable and mainly use certified emission reductions (CERs)[*4] to offset emissions.

The following section describes carbon offsets for products.

Applicable Machines for Carbon Offsets

The fact that carbon offsetting is voluntary makes its scope and applicability difficult to ascertain. Accordingly, Hitachi Construction Machinery set the following policies when starting the scheme.

(1) Seek to encourage wider use of environmentally conscious machines and systems.

(2) Actively support government programs, such as *Kizukai-Undou* and Challenge 25[(5)], as well as the −6% target.

(3) Help boost business activities and environmental branding of customers.

In accordance with these action policies, Hitachi Construction Machinery embarked on the progressive implementation of carbon offsetting on the basis that it would apply to the following four types of machines (the dates in brackets are the dates when carbon offsetting started).

(1) Forestry machinery (October 2008)

(2) Information-integrated construction machinery (October 2010)

(3) Electric excavators (April 2011)

*4 Credits created under the Clean Development Mechanism and recognized under the Kyoto Protocol.

Fig. 5—Forestry Machinery.
Carbon offsets can be used for forestry machines ranging from thinning machines designed for use in forestry to wood chippers used after thinning.

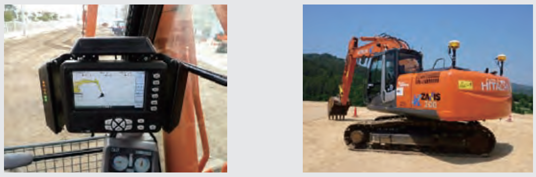

Fig. 6—Information-integrated Construction Machinery.
The photographs show a construction information display unit (left) and an information-integrated construction machine (right). The two masts are GPS receivers.

Fig. 7—Electric and Hybrid Excavators.
The ZX225USR (left) is an electric excavator and the ZH200-A (right) is a hybrid excavator.

(4) Hybrid excavators (April 2011)

Carbon offsetting for forestry machinery extends from thinning machines designed for use in forestry, such as harvesters, processors, and swing yarders (which are based on Hitachi Construction Machinery excavators), to wood chippers used after thinning (see Fig. 5).

Carbon offsetting for information-integrated construction machinery covers road rollers and excavators fitted with machine guidance systems. Machine guidance systems display work drawings (input previously) and the position of the machine or bucket on a monitor located in the cab. A 24% improvement in work time has been reported(6), which indicates that the system also helps reduce CO_2 emissions (see Fig. 6).

Fig. 7 shows an electric and a hybrid excavator. These clean and energy-efficient construction machines utilize Hitachi's electrification technology. An electric excavator uses an electric motor instead of a diesel engine to drive the hydraulic pump using the commercial electricity supply. Up until 2010, nuclear power generation supplied approximately one-third of Japan's electric power. The amount of CO_2 emitted per unit of electric energy is low (0.36 kg-CO_2/kWh), and CO_2 emissions are reduced by around 60 to 80% compared to conventional machines(7). The ZH200 hybrid excavator uses an electric motor and capacitor to boost system efficiency by capturing energy from swing braking and using it to assist with swing acceleration, for example. This provides energy savings of about 20% compared to conventional machines.

Carbon Offsetting in Practice

For the four types of machines referred to above that are more effective than conventional machines for countering global warming, the total number covered by product carbon offsets reached a cumulative total of 253 in March 2012, with offsets exceeding 300 t (see Fig. 8).

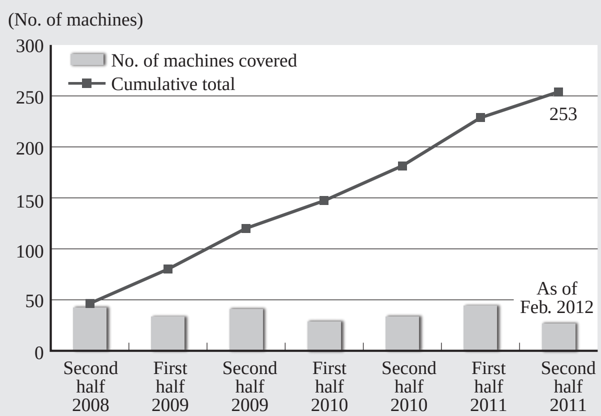

Fig. 8—Trend in Number of Machines with Carbon Offsets.
Carbon offsetting is used for four types of machinery: forestry machinery, information-integrated construction machinery, electric excavators, and hybrid excavators. The offsets range between 1 and 2 t per machine.

Product carbon offsets offset the CO_2 emitted during manufacturing (fabrication and assembly). The amount of CO_2 emitted during manufacturing is calculated from the production line electric power and fuel consumption for each model based on the "guidelines for calculating greenhouse gas (GHG)*5 emissions of activities to be offsets." Offsetting is performed in 1 t increments for excavators of 7 t or more and 0.5 t increments for mini-excavators, with any remainder rounded up to the nearest increment. For example, if the calculated CO_2 emission for manufacturing are 1.1 t, application is made for 2 t of offset credits.

Fig. 9 shows an example of a carbon offset scheme for electric excavators. After a machine is delivered to the customer, Hitachi Construction Machinery requests Hitachi Capital Corporation (the credit provider) to provide carbon offsetting. Hitachi Capital Corporation then transfers the required amount of credits to the Japanese government at no charge in accordance with the written instructions (nullification). To verify the transaction, Hitachi Capital Corporation also produces a carbon offset certificate specifying the numbers of the nullified credits and details of the carbon offsetting (see Fig. 10). Hitachi Construction Machinery then forwards this certificate and a carbon offset sticker to the customer.

The main motors in electric excavators are alternating current (AC) induction motors from Hitachi Industrial Equipment Systems Co., Ltd. As Hitachi Industrial Equipment Systems performs carbon offsetting for the motors supplied for electric excavators, the above certificates contain details of two different offsets.

*5 Greenhouse gases. Six different gases are subject to government emission controls, including CO_2, methane (CH_4), and nitrous oxide (N_2O).

Benefits of Carbon Offsets

By using the machines covered by offsetting in their businesses, customers are contributing to preventing global warming and helping Japan achieve its

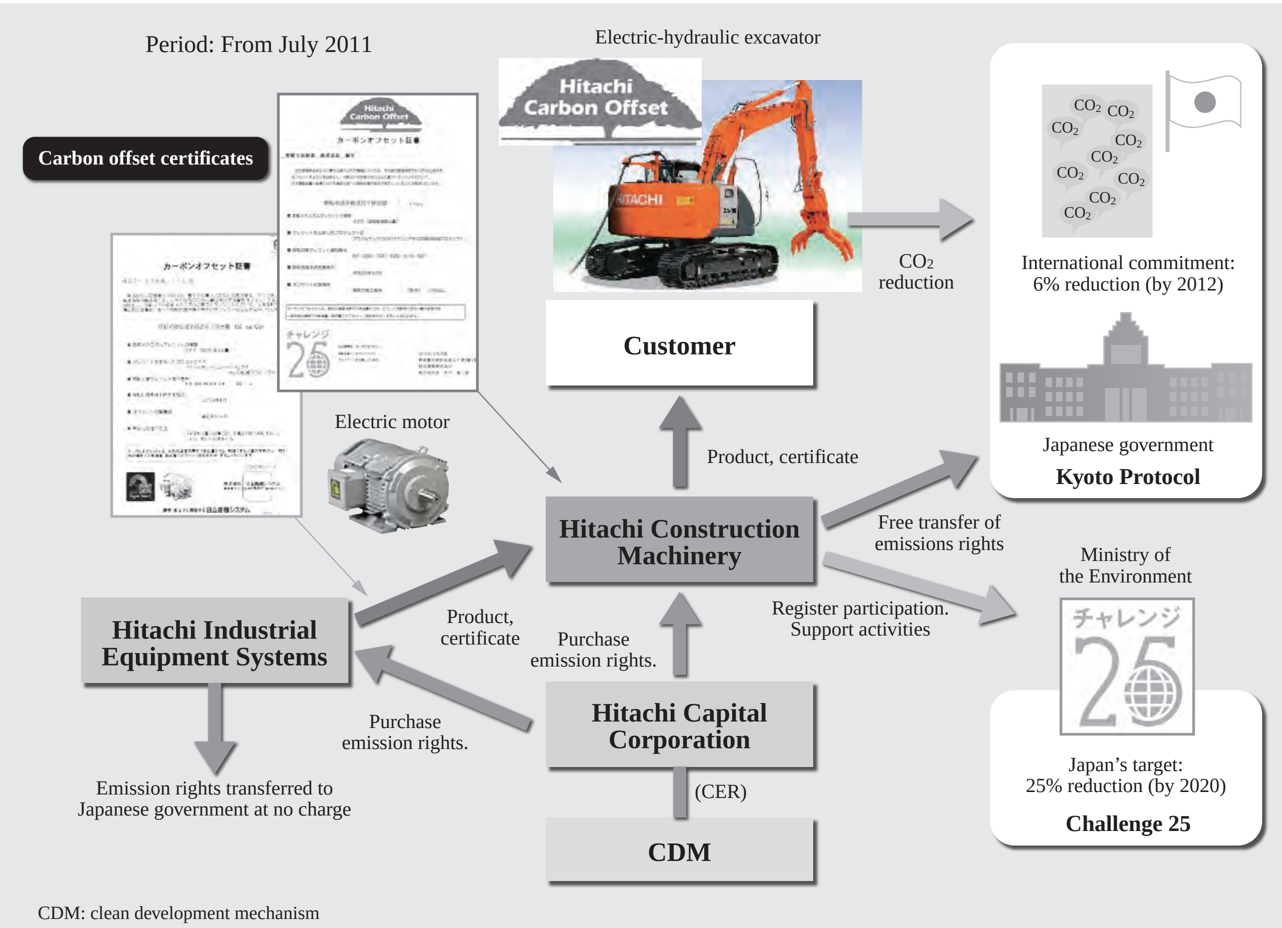

Fig. 9—Carbon Offset Scheme.
The figure shows the CO_2 offset scheme used for electric excavators and their main motors. Main motors are a major component of electric excavators.

Fig. 10—Carbon Offset Certificate and Carbon Offset Sticker.
The form on the left is a double carbon offset certificate covering both the electric motor and excavator. The carbon offset sticker on the right is affixed to the machine itself.

international commitment for the period of the Kyoto Protocol (a 6% reduction in emissions relative to 1990 levels) and the greenhouse gas reduction project. Carbon offsets raise awareness of environmental protection, not only among customers but also among staff and suppliers of Hitachi Construction Machinery, and provide an opportunity to make further progress on measures for preventing global warming.

In 2010, Hitachi Construction Machinery received a certificate of thanks from the Japan Wood-Products Information & Research Center that administers the *Kizukai-Undou* program, acknowledging the company's actions in promoting forestry machinery with carbon offsets. Together with the Total Solutions Division (as it was then known) of Hitachi, Ltd. and Hitachi Capital Corporation, Hitachi Construction Machinery was also awarded the special centenary prize as part of Hitachi's Inspiration of the Year 2010.

DOMESTIC CREDIT PROJECTS (DOMESTIC CDM)

Involvement with Domestic CDM

The domestic CDM program promoted by Japan Ministry of Economy, Trade and Industry is a CDM recognized by the Kyoto Protocol that has been revised to operate in Japan. It provides incentives for small and medium-sized companies making energy efficiency improvements by creating carbon credits that can only be used in Japan from the CO_2 emission reductions that result from large companies providing technical support to help small and medium-sized companies save energy (see Fig. 11). Adopting electric operation in the excavators used at factories and other plants not only significantly reduces CO_2 emissions, it also helps improve the workplace environment by reducing exhaust gas and heat generation.

The domestic CDM required a revision of the project design for use of construction machinery to reduce CO_2 emissions. Accordingly, Hitachi Construction Machinery worked with the Total Solutions Division (as it was then known) of Hitachi, Ltd. to create a project design for domestic credits for the replacement of engine-driven hydraulic excavators with electric excavators that was subsequently certified as an emissions reduction project design by the Domestic Credit Certification Committee in December

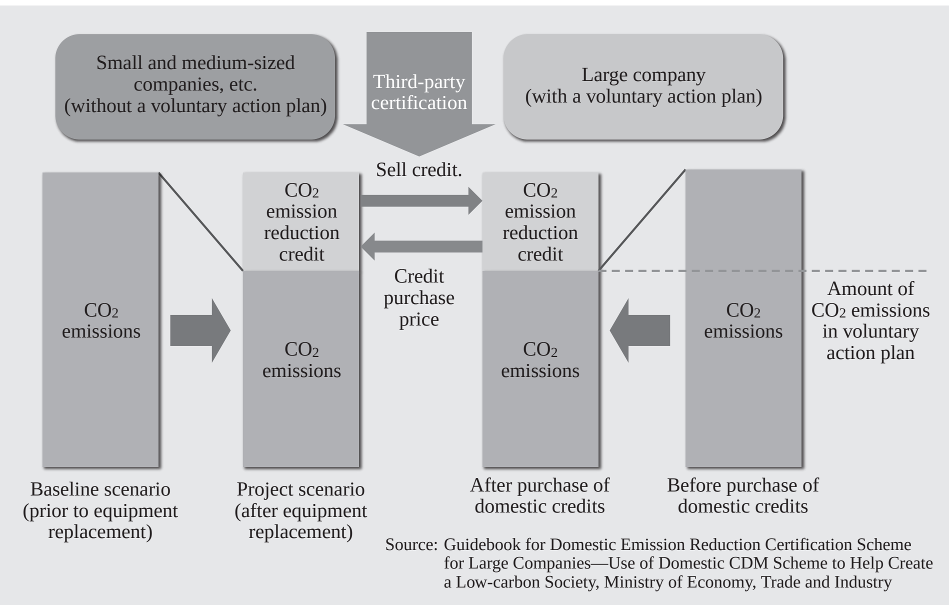

Fig. 11—Overview of Domestic CDM.
The domestic CDM turns CO_2 emission reductions into carbon credits that can only be used in Japan.

2010 under the title, "Replacement of Construction Machinery and Industrial Vehicles with Electrically Driven Machines" (Project Design Number 026). This was the first example anywhere in the world of a project design for using construction machinery to reduce CO_2 emissions.

Operation of Domestic Credit Projects

The initial emissions reduction project based on the project design described above was commissioned by Ishizaka-Group who operates a highly specialized recycling business for construction waste in Miyoshi in the Iruma District of Saitama Prefecture. An environmental leader with a strong awareness of environmental problems, Ishizaka-Group is already involved in numerous environmental protection activities, and factors such as the timing of its excavator replacements made it a suitable partner for collaboration.

The procedure for certifying domestic credits consists of (1) auditing and approval of a reduction project plan and (2) auditing and approval of reported reductions. The reduction project plan (1) requires auditing and approval of the size of CO_2 emission reductions, how the reductions are to be verified, and potential problems such as the project's economics and scope for expansion. The auditing of reported reductions (2) determines whether appropriate monitoring indicates that the level of emissions is in line with the plan. This involves auditing and approval of monitoring methods and of reported quantities such as emission volumes. Only after these two processes have been completed are the domestic credits created.

The principal in this emissions reduction project was Ishizaka-Group, with Hitachi Capital Corporation acting as co-principal. The resulting emission rights formed part of the scheme run by Hitachi Capital Corporation (see Fig. 12). The details of the plan were formulated into a plan document by Ishizaka-Group and Hitachi Construction Machinery with support from the Total Solutions Division of Hitachi, Ltd.

Ishizaka-Group's emissions reduction project plan involved replacing a 20-t engine-driven hydraulic excavator used for sorting industrial waste with an equivalent electric excavator. This was estimated to reduce the annual CO_2 emissions of the engine-driven hydraulic excavator (approximately 137 t) by 64% (87 t). Other potential benefits included improving the workplace environment, eliminating exhaust gas from indoor work areas, reducing waste heat, and cutting running costs for fuel and engine maintenance.

An emissions reduction report approved in October 2011 stated that Ishizaka-Group had reduced emissions by 52 t over seven months, which was roughly in line with the plan.

Domestic credits created by the reduction project are to be used as carbon offsets by Hitachi Construction Machinery from FY2012 onward.

CONCLUSIONS

This article has described what Hitachi Construction Machinery is doing to use emissions rights to prevent global warming through construction machinery.

At COP17 held in Durban in December 2011, Japan decided it would not participate in the Kyoto Protocol post the Kyoto Protocol period.

With the falling price of CERs and the increasing volume of assigned amount unit*6 trading since the onset of the global financial crisis, credit trading and the CDM are facing difficult conditions and the enthusiasm of a few years ago has disappeared(8). Nevertheless, levels of greenhouse gases continue to

*6 Emission quotas assigned to countries with reduction obligations that have signed the Kyoto Protocol. Trading involves emission quotas from countries that have significantly reduced their CO_2 emissions relative to the base year, such as the Russian Federation and the nations of Eastern Europe.

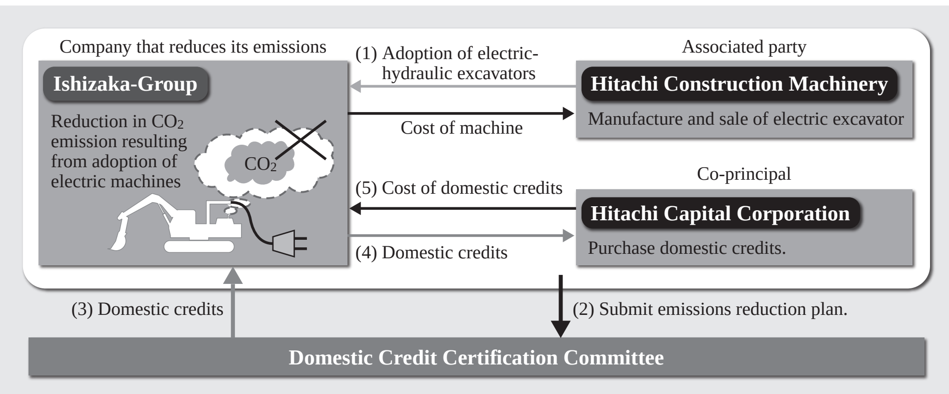

Fig. 12—Ishizaka-Group's Emission Reduction Plan.
The figure shows an outline of the Ishizaka-Group's emission reduction plan.

rise and there is a growing need for energy-efficient and clean machinery.

How to engage with carbon offset policies, CDM policies, and other mechanisms is an important factor in encouraging the wider adoption of the leading-edge, energy-efficient machines developed by Hitachi Construction Machinery to help prevent global warming. Hitachi Construction Machinery would like to believe that this is a good opportunity for everyone to consider how the use of machines with excellent fuel efficiency can affect the level of carbon emissions, and how best to reduce these emissions.

Although the offset amount for a single machine is small, the total quantity of offsets to date is equivalent to 22,000 trees[9]. Hitachi Construction Machinery Co., Ltd. believes that patient environmental protection measures like this will help create a sustainable society and prevent global warming.

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Advances in Robotics for Construction Machinery

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Mariko Mizuochi

OVERVIEW: With robotics being increasingly adopted in a variety of products, such as cars and home appliances, Hitachi Construction Machinery Co., Ltd. is proceeding with greater use of robotics in construction machinery, its major objectives being to expand the scope of its application and to enhance the underlying competitiveness of the company's products. Hitachi Construction Machinery is developing robotics for construction machinery with a focus on three technologies: (1) operator assistance whereby the intelligence and control functions of a construction machine are used to assist its operator, (2) H/Is that provide smooth interaction between human and machine, and (3) improvements to the body functions of construction machines, including the front and crawler mechanisms. Hitachi Construction Machinery is also working on the fusion with external information networks, this being another important factor in introducing robotics to construction machinery.

INTRODUCTION

AS computers have become more widely used and more sophisticated in recent years, progress has also been made on applying robotics in common products such as cars and home appliances. Recognizing this trend, Hitachi Construction Machinery Co., Ltd. is proceeding with greater use of robotics in construction machinery, its major objectives being to expand the scope of application of these machines and to enhance the underlying competitiveness of its products. Robotics is an "integration technology" with a wide range of applications. Three key concepts for the use of robotics in construction machinery are intelligence and control, human interface (H/I), and body functions. Hitachi Construction Machinery is developing technology in each of these fields.

This article gives an overview of intelligence and control, H/I, and body functions for robotics in construction machinery, describes the technologies under development, and uses information integrated construction as an example of integration with external networks.

INTELLIGENCE AND CONTROL

Operator Assistance

Intelligence and control refers to the part of a machine that is analogous to a brain. Reference to intelligence in the context of robotics brings to mind images of automation and autonomous operation, and machines that function without human intervention. However, because construction machines are frequently used for work in unstructured environments where the materials change shape from moment to moment depending on the conditions, moving directly to automatic and autonomous operation is impractical. Instead, Hitachi Construction Machinery is undertaking research and development of intelligence functions that can be used for operator assistance, which means having a construction machine being driven by an operator provide support for itself. In particular, current research topics focus on support for non-operational factors, such as safety and ride comfort, so as to free up the operator to concentrate on the actual work to be done.

Dynamic Center of Gravity Measurement

To improve the safety of construction machines and make them easier to use, Hitachi Construction Machinery is developing a system for measuring dynamic stability in realtime in a way that takes account of the inertial forces that occur during operation. Conventionally, the stability of construction machines has been assessed for static tasks such as operating as a crane. However, construction machines are used for a wide range of tasks and large inertial forces can affect their stability, such as when a machine is required to perform a large movement quickly. Japanese Industrial Standards (JIS) only specify rudimentary methods for assessing dynamic stability and no development has previously been done on quantitative assessment techniques.

The system being developed has adopted zero moment point (ZMP) as an indicator for assessing stability that can take account of the dynamic aspects of machine operation. The system calculates ZMP in realtime. The same indicator has been used for walking robots in the past, and it can be interpreted as a point projection of the center of gravity that considers the dynamics of the machine.

Using ZMP as an indicator for assessing stability has the following two advantages.

(1) It allows the assessment to take account of the dynamics of the machine (inertial forces).

(2) Instability corresponds to machine lift, demonstrating that the indicator has a direct correlation with machine behavior.

The system calculates the ZMP from sensor measurements that detect the orientation of the construction machine, the acceleration of the center of gravity of major components, and the load on the attachment. Use of the system provides an accurate indication of changes in stability that would not be caught by a static stability assessment (see Fig. 1).

H/I

Smooth Interaction

As described above, the field of H/I technology is specific to construction machinery, which is characterized by the presence of an on-board operator. The interfaces can be broadly divided into information input systems that the operator uses to specify instructions to the machine, and information output systems used to present information about the machine and its surroundings to the operator. In particular, the amount of data handled by operating machines is increasing in step with the improving performance of the computers installed in the machines, so the ability to present this information to operators clearly is a major issue.

Similarly, making machine operation as simple as possible is important for more complex machine systems such as the double-arm working machines. That is, achieving a smooth interaction between human and machine is critical, and Hitachi Construction Machinery is working on research and development aimed at achieving this.

Periphery Monitoring

With the aim of enhancing the systems that output information to the operator, Hitachi Construction Machinery is developing an overhead view monitor that provides visibility over a large area and minimizes blind spots around the machine. Images from a number of cameras mounted on the machine are converted (shifted in viewpoint) and combined to generate an overhead (bird's-eye) view centered on the machine that is displayed on a screen in the cab as a periphery monitoring image. This system has the following features (see Fig. 2).

(1) The machine is fitted with a number of wide-angle cameras (160° horizontal field of view). Images from each of the cameras are converted (shifted in viewpoint) and then combined to produce images that cover a wide area (up to 360°). This allows the operator to see the situation around the machine at a single glance (the distance and direction of people or other obstacles).

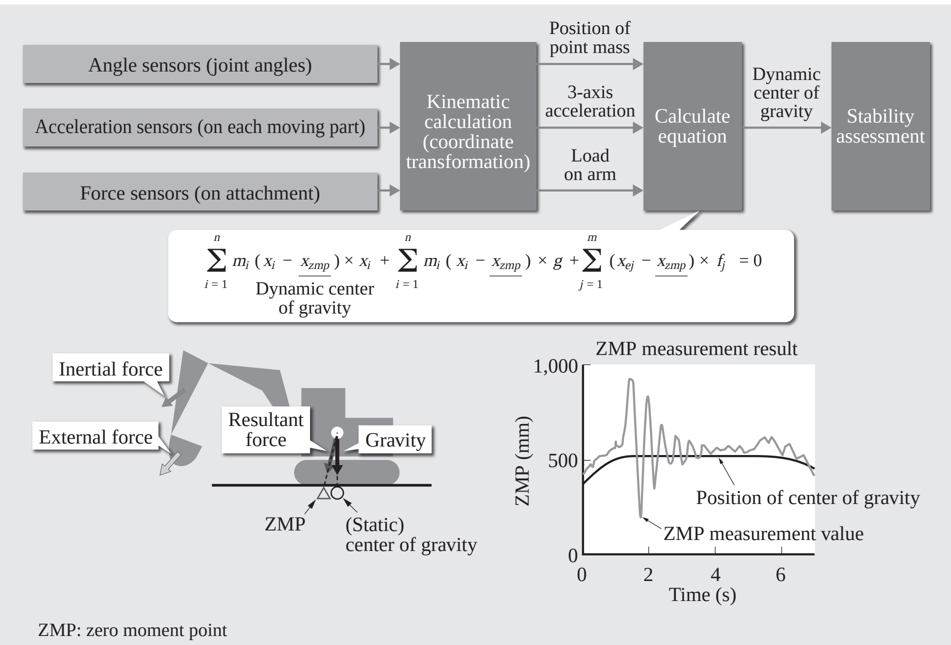


Fig. 1—System for Dynamic Measurement of Construction Machinery Center of Gravity.
The system calculates the ZMP from sensor measurements that detect the orientation of the construction machine, the acceleration of the center of gravity of major components, and the load on the attachment.

(2) The system allows the operator to select from a number of display options that show different areas or have different screen formats. Displaying the overhead image and rear-view camera image at the same time is one of the options.

BODY FUNCTIONS

Improvements to Body Functions of Construction Machines

As indicated by the name, body functions relate to the body of a construction machine. Of the two main objectives, body functions involve, in particular, technology that aims to expand the scope of application of construction machinery by increasing the range of tasks and activities they can be used for through research aimed at improving the functions of the arm (front) and undercarriage (crawler). Also, the concept of "embodiment" includes sensors and other sensing functions. Rather than developing the sensors themselves, the research is primarily concerned with how to make use of sensor information and how to utilize information from multiple sensors (sensor fusion).

Double-arm Working Machine

To provide more advanced arm functions, Hitachi Construction Machinery has developed a double-arm working machine with an enhanced capability for performing complex operations. Because it is equipped with two arms at the front like a human being, the machine can perform complex tasks such as holding and cutting at the same time. The features of the machine are listed below (see Fig. 3).

(1) The ability to perform complex tasks such as holding and cutting at the same time or folding a long piece of material

(2) A hydraulic system capable of driving multiple actuators from a single pump that allows both arms to operate simultaneously

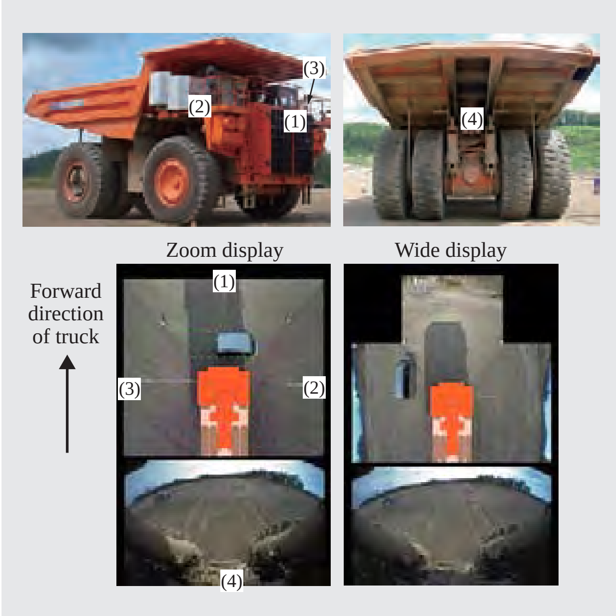
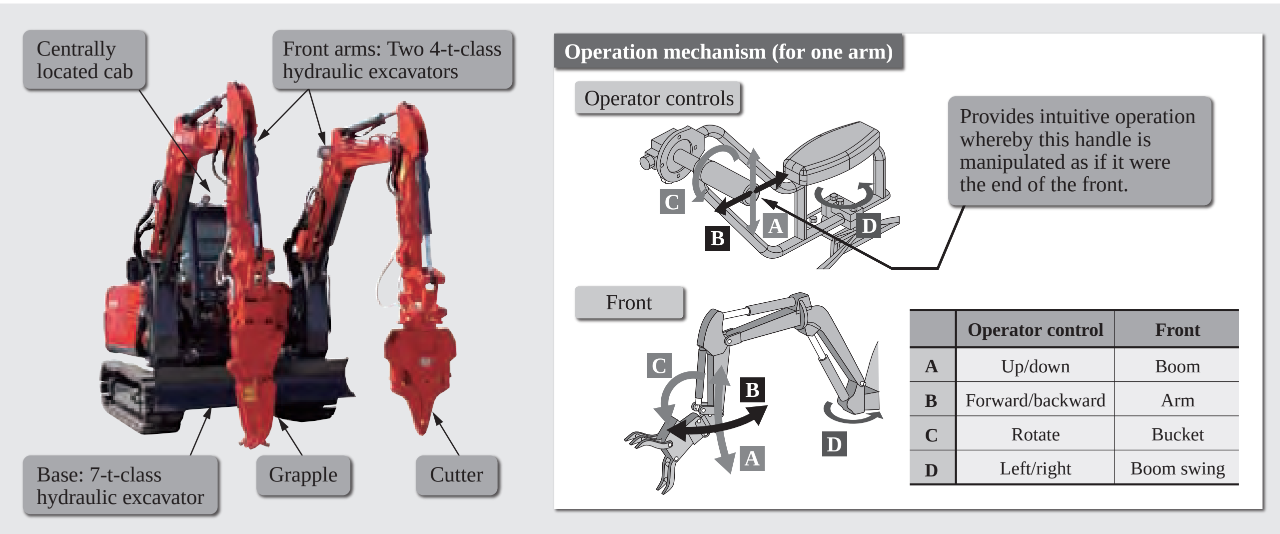


Fig. 2—Overhead View Monitor System.
An overhead (bird's-eye) view of the region around the machine (periphery monitoring image) is generated by converting and combining images from multiple cameras.



	Operator control	Front
A	Up/down	Boom
B	Forward/backward	Arm
C	Rotate	Bucket
D	Left/right	Boom swing

Fig. 3—Double-arm Working Machine (Left) and Operation Mechanisms (Right).
The photograph shows one of the custom-built 7-t-class double-arm working machines supplied to the fire department for routine use. The operation mechanisms use the velocity directive one lever method for intuitive control of both arms at the same time.

(3) A design that allows the operator to control both arms at the same time, with the right arm controlled by the operator's right hand and the left arm controlled by the operator's left hand
(4) The use of the velocity directive one lever method for the operator controls to provide intuitive operation and reduce operator fatigue
(5) A three-dimensional arm position calculation that prevents arms from colliding

A 7-t-class prototype model was supplied to a fire department in October 2008 so that its use for rescue work at disaster sites could be trialed. Based on their evaluation, two new custom-built machines fitted with special-purpose equipment were supplied for routine use in March 2011.

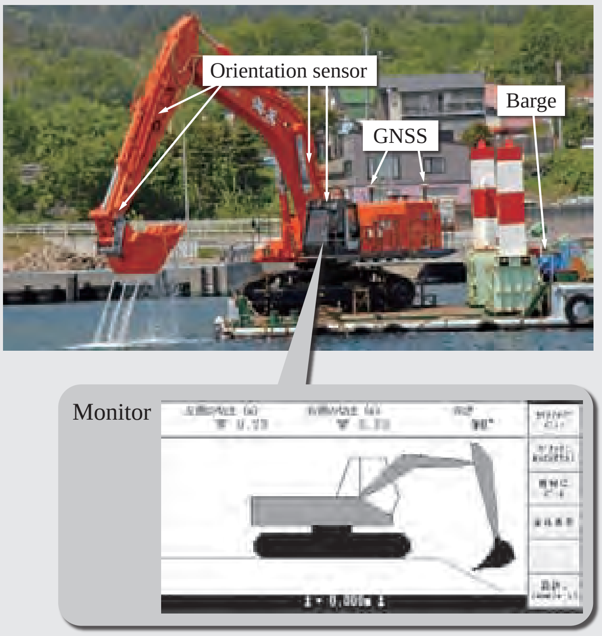
INTEGRATION WITH EXTERNAL NETWORKS

Rather than just considering the machine in isolation, an important part of the integration of robotics into construction machines is their fusion with external information networks. This section describes one example of integration with external networks, namely, information integrated construction.

Business of construction and fabrication can be thought of as consisting of surveying, design, construction, maintenance, and refurbishment processes. Information integrated construction focuses on the construction process in particular, and is a way of ensuring that this work is done efficiently and accurately based on electronic information collected from each process using information and communication technology (ICT). It is also a system for improving productivity and maintaining quality across all construction and fabrication processes by taking electronic information collected from the construction process and using it in other processes. Construction machinery is used in the actual fabrication of the facility being constructed. Accordingly, construction machines can both use information to perform their work and be a source of information about the progress of construction work.

The functions provided by information integrated construction can be divided into two categories. The first are the functions that use ICT to automate construction machines or to assist operators to perform work. A guidance system for hydraulic excavators is one example (see Fig. 4). The system uses a global navigation satellite system (GNSS) and total stations (TS) to determine the position of a machine and simplifies the job of its operator by displaying design drawings or work movement patterns. With Japan's aging population contributing to a shortage of experienced operators, examples of this sort of operator assistance technology being adopted are slowly starting to increase. Currently, design drawings are input into the cab computer manually via a memory card. In the future, it is anticipated that it will be necessary to provide construction machines with the ability to connect to the Internet and access the latest drawings remotely from the site office, both to improve work efficiency and to ensure that any changes to the drawings are passed on promptly to the machine.

The second category functions are those that use information collected during machine operation to help engineers working at the site to make better decisions. A fleet management system for dump trucks used at mining sites is one example (see Fig. 5). To ensure appropriate assignment of dump trucks across a mine site that might extend over several square kilometers, each dump truck is fitted with a GNSS that transmits its position to the mine site office in realtime. The mine site office tracks the location of each truck and formulates dump truck assignment plans based on the target production volume and the operational status of the dump trucks, loaders, and other plants. Based



GNSS: global navigation satellite system

Fig. 4—Guidance System for Hydraulic Excavator.
The system supports the operator by measuring the position and orientation of the machine and presenting information on work drawings and movement patterns.

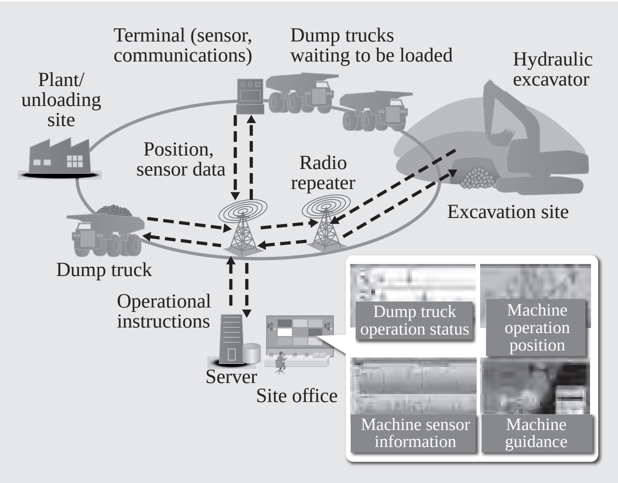


Fig. 5—Fleet Management System for Mining Dump Trucks.
Located at the mine site office, the system formulates dump truck assignment plans based on position information sent from each dump truck, and then sends instructions to the computer in each dump truck instructing it where to go next.

on this plan, the mine site office transmits information to the computer in each dump truck instructing it where to go next. Use of this fleet management system requires the installation of a wireless network at the site. Currently, a 2.4-GHz-band wireless local area network (LAN) with mesh topography is used. In addition to communications between machines and the site office, it is anticipated that the transmission of information between machines will also be required in the future to provide accurate, realtime updates about mechanical status, work volume, and other machine information.

CONCLUSIONS

This article has given an overview of intelligence and control, H/I, and body functions for robotics in construction machinery, described the technologies under development, and used information integrated construction as an example of integration with external networks.

In addition to reducing fuel consumption as a response to environmental problems, the growing market for construction machinery also has an increasing need for the use of robotics to provide more advanced functions for demolition and other work. In the future, Hitachi Construction Machinery intends to continue actively developing new construction machinery by bringing together its strengths in fields such as electrification and control technologies.

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Use of Construction Machinery in Earthquake Recovery Work

Eiji Egawa
Kensuke Kawamura
Masaharu Ikuta
Takayuki Eguchi

OVERVIEW: In addition to use in conventional civil engineering work, the power of construction machines and the range of uses to which they can be put make them vital to disaster recovery work. The Great East Japan Earthquake resulted in unprecedented damage, and the role being played by construction machinery is large, starting with reopening roads to emergency vehicle traffic and extending to recovery work such as removing large quantities of rubble, as well as the reconstruction that has yet to get fully underway. Unmanned construction techniques developed during and after work on recovery from the damage caused by the Mount Unzen-Fugen eruption in Japan have proved effective in dealing with the nuclear power plant accident triggered by the earthquake, and Hitachi Construction Machinery Co., Ltd. has contributed to the cleanup work at the site through the supply of approximately 20 machines. The company is preparing for ongoing disaster recovery work with a product range that includes advanced double-arm working machines and disassemblable hydraulic excavators capable of remote operation.

INTRODUCTION

IN recent years, hydraulic excavator and other construction machines have become an essential part of recovery and reconstruction work after major disasters. With demand for construction machinery in Japan in FY2012 anticipated to increase by 11.3% over the previous year to 605.8 billion yen as a consequence of the Great East Japan Earthquake in March 2011, all the factories of Hitachi Construction Machinery Co., Ltd. are making an effort to increase production.

This article describes conventional construction machinery used in post-earthquake reconstruction along with the assistance provided using advanced double-arm working machines, emergency assistance for Fukushima Daiichi Nuclear Power Station, and disassemblable hydraulic excavators suitable for disaster recovery work.

INVOLVEMENT IN EARTHQUAKE RECONSTRUCTION

Role of Construction Machinery

When television screens showed the huge amount of rubble resulting from the Great East Japan Earthquake, far too much to move using manual labor, the cameras also captured a variety of construction machines at work. It can be thought of as a real demonstration of what construction machinery can do. This section recounts the time since the earthquake and tsunami and describes what is expected from construction machinery in the post-disaster reconstruction.

Fig. 1 shows the progress over time of reconstruction carried out since the earthquake. In practice, the

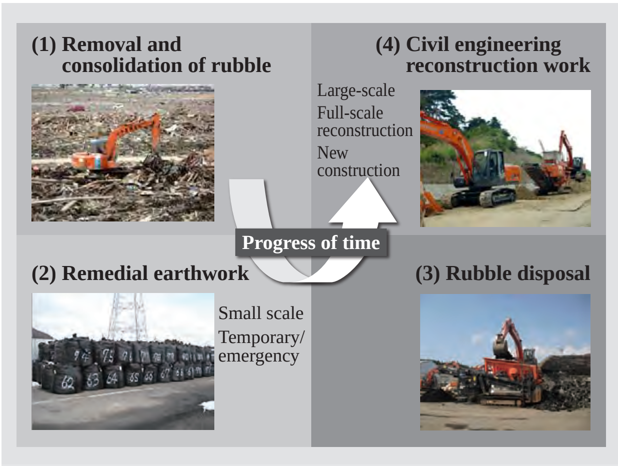

Fig. 1—Progress over Time of Recovery and Reconstruction Work.
First hydraulic excavators are used to remove and consolidate rubble and complete temporary remedial earthworks, then hydraulic excavators and recycling machinery undertake rubble disposal and embark on full-scale civil engineering reconstruction work.

removal and consolidation of rubble was mostly done in parallel with remedial earthworks. Amid horrific scenes, periods when construction machinery was operated to allow for the rescue of survivors was the time for removal and consolidation of rubble. The Tohoku branch of Hitachi Construction Machinery also suffered tsunami damage, and although staff were themselves victims of the devastation, they did their utmost to meet the requests of customers who were pouring their efforts into disaster recovery.

Rubble Disposal Plant

While there have been delays in dealing with the huge quantities of rubble, plants for disposing of this rubble are currently being constructed at various sites, or are already in operation. Although the methods vary between locations and in accordance with other circumstantial factors, recycling machinery are used for some of this work. For example, hydraulic excavators are used to feed concrete demolition material into track mounted crushers that break it up to produce recycled aggregate.

One example of a rubble disposal plant is the “Tagajo City Project for Interim Disposal of Rubble and Other Waste Material from the Great East Japan Earthquake” that Tagajo City in Miyagi Prefecture contracted to the Tohoku branch of Konoike Construction Co., Ltd. (see Fig. 2). The plant helps provide employment in the wake of the worsening of the job market after the earthquake. It also went

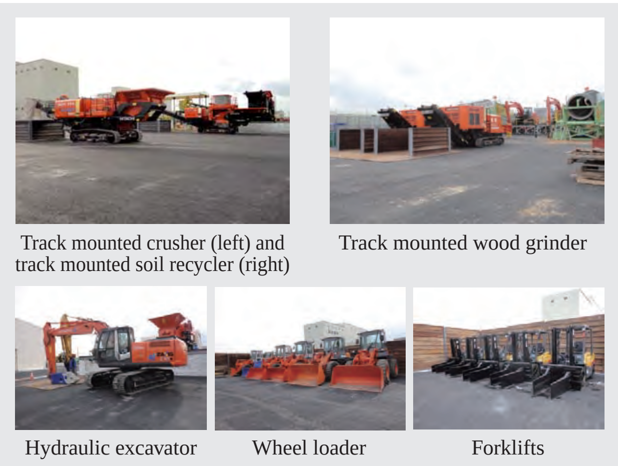

Fig. 2—Tagajo City Project for Interim Disposal of Rubble and Other Waste Material from the Great East Japan Earthquake.
The work utilizes all types of recycling machinery, such as track mounted wood grinders and track mounted screens, as well as hydraulic excavators, wheel loaders, and also forklifts made by TCM Corporation, a subsidiary of Hitachi Construction Machinery Co., Ltd.

Fig. 3—Track Mounted Soil Recycler and Other Construction Machinery Used for Civil Engineering Reconstruction Work.
It is anticipated that the track mounted soil recycler and other machines will be used for tasks such as stabilization of soft ground, roadbed construction, and repairing of washed-away riverside embankments.

through a variety of startup problems, not only because some staff had little experience and was unfamiliar with the operation, but also because the rubble was non-uniform. Despite facing many uncertainties about how to get the machinery operating smoothly, the company is taking steps to achieve a high level of plant utilization.

Civil Engineering Reconstruction Work

Plans for civil engineering reconstruction work include the construction of embankments and new expressways or highways for which funding has been allocated in the government’s supplementary budget. In particular, it is expected that considerable use will be made of machines such as track mounted crushers able to recycle destroyed coastal embankments and other concrete structures into construction material, and track mounted soil recyclers that can be used for stabilization of soft ground, building roadbeds for new roads, and repairing washed-away riverside embankments (see Fig. 3).

PROVISION OF ASSISTANCE USING DOUBLE-ARM WORKING MACHINES

Deployment of Double-arm Working Machines

Following the Great East Japan Earthquake, double-arm working machines were twice (in May and June of 2011) brought to the disaster zone to support rubble clearance. This machine was developed under a contract with the New Energy and Industrial Technology Development Organization (NEDO) as part of a project to develop strategic and advanced robotics technologies. Equipped with a small auxiliary

Fig. 4—Removal of Refrigerated Vehicle Containers (Ishinomaki City).
The machine's arms were used to separate out the different materials used in the containers, which included steel frames, aluminum, and wood.

Fig. 5—Rubble Clearance (at Minamisanriku-cho).
The main arm holds up steel framing and pulls it away from building foundations so that the cutter attached to the auxiliary arm can cut it free.

arm as well as its conventional main arm, the machine is able to perform complex operations that would not be possible using a conventional hydraulic excavator, such as using the main arm to hold material while the auxiliary arm cuts it(1).

Container Removal

The first site was Ishinomaki City in Miyagi Prefecture. Fig. 4 shows the machine in action clearing refrigerated vehicle containers washed into shops by the tsunami. The site was close to Ishinomaki Port and a number of containers of processed seafood had been carried to the shops by the flooding. The work involved using the two arms to separate out the different materials used in the containers, which included steel frames, aluminum, and wood. To allow the material to be removed from the site, it was also broken up into pieces small enough to be loaded onto a trailer.

Cutting and Removal of Steel Framing

Fig. 5 shows the clearance of rubble and scrap in Minamisanriku-cho in Miyagi Prefecture. This harbor-side town suffered enormous damage in the tsunami, with steel framing from factory buildings left scattered about in a complex tangle. The nature of the debris made clearance using just a grapple or other grasping machinery impractical. As steel framing and building foundations had been left fused together in many places after the damage from the tsunami, the work was conducted by using the main arm to hold up steel framing while a cutter attached to the auxiliary arm was used to cut it.

EMERGENCY ASSISTANCE FOR FUKUSHIMA DAIICHI NUCLEAR POWER STATION

System Proposal for Recovery

While achieving a cold shutdown was an urgent task on the recovery roadmap for the Fukushima Daiichi Nuclear Power Station, there was also an urgent need to clear the debris left scattered around the site and to remove as soon as possible the exploded reactor building so that the state of the containment vessel and other internal parts could be ascertained. Hitachi Construction Machinery worked with other Hitachi Group companies to directly or indirectly offer Tokyo Electric Power Co., Inc. the associated materials and systems needed for the recovery.

To begin with, working through the Unmanned Construction System Association (a society for unmanned construction with 18 member companies, including construction companies), it was decided that emergency cleanup of the debris around the site would require use of radio-controlled hydraulic excavators and radio-controlled carriers for removing rubble and other material. Accordingly, Hitachi Construction Machinery modified a crawler carrier for radio-controlled operation and brought it to the site (see Fig. 6).

Next, as the details became clearer, it was determined that the exploded building contained a large amount of scattered debris and structural material (including steel H beams), and that removal work would need to be carried out at heights of 30 m or more and under high levels of radiation.

Fig. 6—Radio-controlled Crawler Carrier.
This EG110R crawler carrier was modified for radio control and supplied to the site together with the remote controller (specified low-power 429-MHz band).

Table 1. Main Technical and Commercial Aspects of Emergency Response
The table lists the main challenges in the way of achieving a resolution by the in-house Fukushima Nuclear Power Station Project established by Hitachi Construction Machinery.

Challenge	Response
Confirm ability of electronic equipment to tolerate radiation.	Conducted durability testing of actual electronic equipment (at JAEA).
Prepare radio control components.	Emergency component stockpiling and procurement
Establish video transmission system for remote control.	Collaborate with construction companies and experts (build a system using commercially available parts).
Construct automatic fuel supply system.	Generate ideas and develop rapidly (outsource manufacturing to specialist companies).
Develop lead-lined protective cab (for manned operation).	Build local ventilation system for radioactive fumes based on in-house design.
Build suspended steel frame demolition system.	Proceed with in-house development based on prior testing of cutter capabilities.

JAEA: Japan Atomic Energy Agency

In response, because of its strengths in fields such as demolition machines and large cranes, Hitachi Construction Machinery embarked on the development of machinery and radio control systems in cooperation with related parties (see Fig. 7).

Technical Development and Emergency Response

To ensure a rapid response to the accident at Fukushima Daiichi Nuclear Power Station, Hitachi Construction Machinery established its own in-house Fukushima Nuclear Power Station Project and included sales departments in its activities. Table 1 lists the main challenges in the way of achieving a resolution.

As many aspects of these challenges could not be overcome by the company on its own, Hitachi Construction Machinery actively sought to cooperate with specialist agencies and suppliers. To assess the radiation tolerance of electronic equipment, Hitachi Construction Machinery conducted testing at the Takasaki test facility of the Japan Atomic Energy Agency (JAEA) to determine suitable standards for cumulative exposure. Machinery such as the remotely operated demolition machine and large crane that Hitachi Construction Machinery offered the site is being used for removal of debris from reactor No. 3 (see Fig. 8).

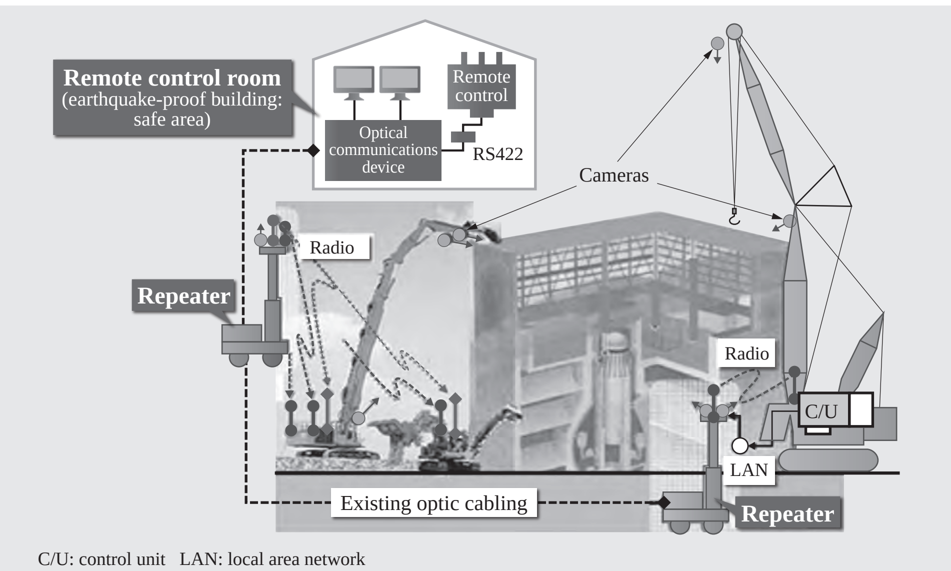

Fig. 7—Proposed Remote Control System for Large Machinery.
Hitachi Construction Machinery was quick to propose a remote control system using equipment such as demolition machines and large cranes to the relevant authorities, and started work on preparing the machinery and radio control system.

Fig. 8—Remotely Operated Upright Demolition Machine.
Hitachi Construction Machinery's remotely operated demolition machine (center rear of photograph) in action at reactor No. 3 where it is used for tasks such as removing beams from the collapsed building.

DISASSEMBLABLE HYDRAULIC EXCAVATORS

Previous disassemblable hydraulic excavators were developed for small-scale civil engineering work in mountainous locations that lack access roads for heavy equipment, such as the construction of power pylons. In recent years, however, demand has emerged for the development of large disassemblable hydraulic excavators capable of performing conventional-scale earthworks to prevent further damage, and able to be helicoptered into the site in the initial stages of the response to a major disaster without waiting for heavy equipment access roads to be opened up (see Table 2).

Based on experience with use of a 0.45-m^3-class disassemblable hydraulic excavator in recovery work after the 2008 Iwate-Miyagi Nairiku Earthquake, Hitachi Construction Machinery received an order from the Tohoku Regional Bureau of the Ministry of Land, Infrastructure, Transport and Tourism of Japan to develop a larger 1.0-m^3-class model in 2010 (see Fig. 9 and Table 3).

The Tohoku Regional Bureau trialed the excavator in six prefectures of Tohoku to confirm that it was suitable for use in disaster recovery work.

TABLE 2. Deliveries of Disassemblable Hydraulic Excavators
The table lists the numbers of excavators delivered by Hitachi Construction Machinery between 1966 and 2011.

Bucket size	No. of excavators	Main uses
0.25-m^3 class	43	Small-scale civil engineering work in mountainous locations (such as construction of power pylons in locations lacking access roads)
0.45-m^3 class	15	
0.7-m^3 class	6	Conventional-scale civil engineering work (disaster response work when roads are closed)
1.0-m^3 class	1	
Total	65	

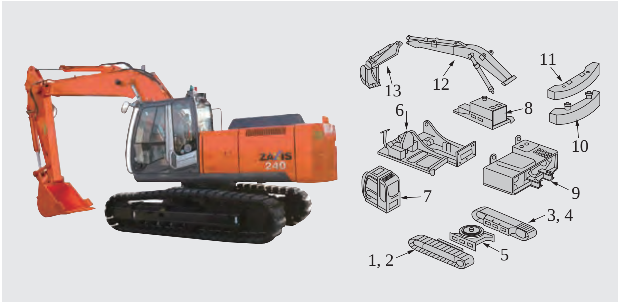

Fig. 9—1.0-m^3-class Disassemblable Hydraulic Excavator in Assembled and Disassembled Forms (Excluding Accessories).
The design includes use of flanges on detachable parts of structural components, one-touch hydraulic couplings, electrical connectors, and a weight that can be split into upper and lower halves.

TABLE 3. Specifications of 1.0-m^3-class Disassemblable Hydraulic Excavator
In addition to being operated by a driver, the excavator is also fitted with a radio system to allow remote operation.

Item	Specification	Remarks
Machine type	ZX240-3 2.7-t disassemblable excavator	Complies with regulation stage III for construction use. Splits into 14 units.
Bucket capacity	1.0 m^3	New JIS
Machine mass	25,800 kg	
Rated engine output	132 kW/2,000 min^{-1}	
Operation	Driver-operated	Also supports remote operation.

CONCLUSIONS

This article has described conventional construction machinery used in post-earthquake reconstruction along with the assistance provided using advanced double-arm working machines, emergency assistance for Fukushima Daiichi Nuclear Power Station, and disassemblable hydraulic excavators suitable for disaster recovery work.

Through its involvement in reconstruction assistance, Hitachi Construction Machinery has seen firsthand the state of the affected areas, right back to the immediate aftermath of the earthquake. While we have done what we could to assist, the effort made by the local people remains a humbling memory. We would also like to take this opportunity to extend our condolences to the families and associates of all those who fell victim to the disaster.

With reconstruction work set to begin in earnest, Hitachi Construction Machinery Co., Ltd. intends to adopt a more customer-oriented perspective and to share its operational know-how with the people on the ground as it takes steps to provide a one-stop shop for the required equipment and materials.

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report

Contributing to the International Community through Monozukuri
—Landmine Clearance for Restoring Land to Peace and Prosperity—

Kiyoshi Amemiya Masaharu Ikuta Shunya Hashimoto Shigeto Suzuki

The laying of landmines during the wars and civil conflicts of the 20th century has left somewhere between 60 and 110 million of these devices buried in the ground in different parts of the world (according to figures from a FY1998 U.S. Department of State report), and even now they result in injuries to around 20,000 people each year. It was against this background that Yamanashi Hitachi Construction Machinery Co., Ltd. established a project team to contribute to international peace through humanitarian aid, and in 1995 set about developing demining equipment based on functions from hydraulic excavators. This development got underway in earnest after the Japanese government signed the Ottawa Treaty in 1997. Currently 86 machines are being used for landmine clearance in nine different countries (as of April 2012), and the staff of Yamanashi Hitachi Construction Machinery are actively working to develop and supply demining equipment that is even more efficient and easy to use.

HUMANITARIAN INITIAL IMPETUS FOR DEVELOPMENT

ONE of the authors (Kiyoshi Amemiya of Yamanashi Hitachi Construction Machinery Co., Ltd.) made a sales trip to the Kingdom of Cambodia in 1994. During his stay, he was confronted with the suffering of people who had been injured by landmines, and this gave him the idea of using hydraulic excavators as the basis for developing an anti-personnel landmine removal machine. When he consulted staff from the Cambodian Mine Action Centre (CMAC), which is supported by the United Nations agency and the Cambodian government to undertake landmine clearance, he was told that the biggest problem was the clearance of reeds, bamboo, and other brush, and that this took up 70% of the time spent on landmine clearance. In response, he embarked on the development of a combined brush clearance and anti-personnel landmine removal machine that would be capable of dealing efficiently with this type of vegetation.

Although anti-personnel landmine removal machines were still subject to export controls at that time, Amemiya decided on humanitarian grounds to start the development anyway. Subsequently, development was spurred on by the Japanese government signing the Ottawa Treaty (officially known as the Convention on the Prohibition of the Use, Stockpiling, Production and Transfer of Anti-Personnel Mines and on their Destruction) in 1997, followed by the exclusion of anti-personnel landmine removal and detection machines from the “Three Principles on Arms Exports.”

DIFFERENT TECHNIQUES DEPENDING ON MINEFIELD CONDITIONS

At that time, approximately 54% of the world’s minefields were in the Middle East or North Africa, 21% in Asia, 18% in Central Africa, and 5% in Central or South America (see Fig. 1). The removal methods differ depending on circumstances in each region, including the soil type, how the mines have been laid, the types of mines, and the presence of other unexploded ordnance. Cambodia and other Southeast Asian nations have a high proportion of anti-personnel mines that can be difficult to locate because of the tendency for buried landmines to be carried to different positions during the rainy season. It is also common

Fig. 1—Anti-personnel Mine Embedded in the Ground.

for minefields to be overgrown with grass or brush, which impedes the removal of anti-personnel mines. In contrast, while minefields in places like the Middle East or North Africa commonly have little vegetation that needs to be cleared first, they often contain large numbers of anti-tank mines and unexploded ordnance. Mines can be broadly divided into anti-tank mines (containing 6 to 10 kg of explosive) designed to damage tanks, and anti-personnel mines (containing 50 to 250 g of explosive) designed to injure human beings. Some minefields also contain unexploded ordnance. Amid all these different considerations, the major issue was the development of a cutter able to deal with the brush that grows on Southeast Asian minefields.

PRODUCT DEVELOPMENT

The two types of anti-personnel landmine removal machines in current use are the swing type based on hydraulic excavators and the newly developed self-propelled push flail type based on past research and development. The removal methods are the rotary cutter type and the more explosion-resistant flail hammer type.

Swing Type Anti-personnel Landmine Removal Machine

In surveys of Cambodian minefields since 1995, what the people on the ground have requested has been machinery capable of efficiently clearing brush prior to mine removal, a task that consumes 70% of the time required for demining. Products on the market at that time included a Canadian-made brushcutter and locally produced grass cutters, but none had the capacity to cut the type of brush found in Cambodia. Hitachi decided that it needed to develop its own combined brush clearance and anti-personnel landmine removal machine to overcome this problem, and that it was also necessary to be able to clean up the brush after cutting. With operator safety and machine durability obviously being the overriding requirements, the first prototype anti-personnel landmine removal machine based on a hydraulic excavator was completed in 1998.

Minefields in Cambodia have reverted to jungle, with daytime temperatures ranging from 50°C to 60°C. In addition to the potential for landmine explosion, cutting and removing this jungle brush by hand also puts people at risk of poisonous snakes and mosquito-borne diseases such as malaria and dengue fever.

Rotary cutter machines are one solution to this problem. The cutters rotate at high speed to pull out brush by its roots, and these same cutters can be used to explode any mines in the soil. An advantage of swing type machines based on hydraulic excavators is that they can cope with the different terrains in which landmines are buried. In addition to the hill-climbing capabilities of a hydraulic excavator, the end of the arm can follow the topography in situations such as steep or rugged terrain with severe undulations. The machine can also be used for digging by changing the attachment at the end of the arm to a bucket, for example. A swing-type combined brush clearance and anti-personnel landmine removal machine was supplied in 2000 following explosion resistance testing in Cambodia that confirmed the safety and explosion resistance of the cabin, the durability and explosion resistance of the rotary cutter, and the blade strength. This machine is still in active service (see Fig. 2).

Fig. 2—Swing Type Anti-personnel Landmine Removal Machine Able to Deal with Brush Efficiently Using Rotary Cutter.

Push flail type anti-personnel landmine removal machines, on the other hand, prove effective in locations such as deserts or where the land is flat.

Flail Hammer Type Demining Equipment

The way landmines are buried in minefields varies widely, and these fields often also contain unexploded ordnance and anti-tank mines. Because of the risk of encountering these, it is essential that equipment development place a priority on maintaining the safety of the operator and machine. With the aim of developing demining equipment with better explosion resistance, and with support from the New Energy and Industrial Technology Development Organization (NEDO), Hitachi started developing flail hammer type demining equipment in 2002 based on research and development conducted between 1995 and 2000.

Fig. 3—Explosion Resistance Testing in the Islamic Republic of Afghanistan.

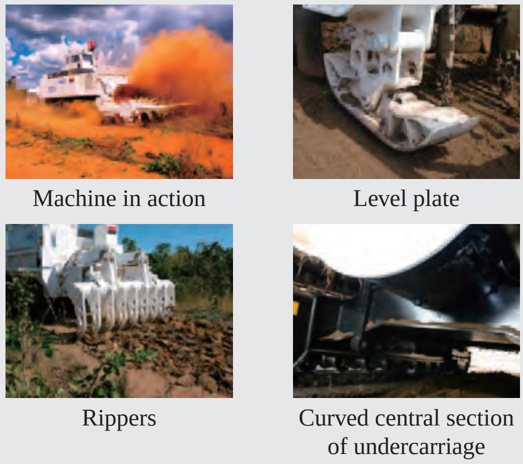

Fig. 4—Flail Hammer Type Demining Equipment.

Fig. 5—Slide Type Elevated Cab, and Hammer and Chain.

Unlike rotary cutter machines, flail hammer type demining equipment has a slimmer rotating shaft and works by rotating a chain with a hammer (weight) on the end at high speed to destroy the mines by blowing them up. The machines are more blast resistant because of the large number of gaps in the rotating flail.

This problematic explosion resistance testing was conducted in cooperation with the Japan Ministry of Defense. Hitachi also participated in practical trials in places such as the Islamic Republic of Afghanistan and Cambodia in cooperation with the Ministry of Foreign Affairs of Japan prior to the machine entering practical use in February 2007 (see Fig. 3). It is currently used in Cambodia and the Republic of Angola.

In 2006, Hitachi started developing new demining equipment that will be better suited to clearing flat land.

Equipped with a flail hammer at the front that covers a width of 3 m (twice that of the previous machine), the machine uses chains with 90 hammers attached to pummel the surface of the ground, and moves forward under its own power detonating mines as it goes. It is also fitted with nine large rippers at the rear of the machine that can plow the soil and help restore it to agricultural use. The machine provides an efficient way to clearing landmines with a capability of 1,700 m^2 per hour, which is more than 100 times faster than using manual labor.

The main features of the machine are as follows (see Fig. 4 and Fig. 5).

(1) Level plates (which function like sleds) fitted to the bottom of both flail hammer units provide an automatic control mechanism that can adjust the flail depth based on the terrain and detonates anti-personnel mines by reacting to uneven ground and keeping the excavation depth constant.

(2) Rippers are fitted to the rear of the machine to help rehabilitate the land for agricultural use.

(3) The undercarriage has a modular design that allows the crawler belt to be separated. This means that the crawler belt can be replaced on its own in the event of its being damaged by unexploded ordnance, an anti-tank mine, or some other large landmine.

(4) Even if the machine runs over a large landmine, the central part of the undercarriage is curved to deflect the blast wave and minimize damage.

(5) The cab is located at the rear of the machine to improve safety. Use of a slide type elevated cab also improves visibility.

(6) The shape and material of the hammers and chains were developed through repeated testing. To reduce maintenance costs, they are designed to allow refurbishment by local technicians.

LOCALLY BASED OPERATION AND MAINTENANCE

Before delivering machines, Yamanashi Hitachi Construction Machinery invites those involved,

Fig. 6—Maintenance Instruction in Progress.

Fig. 7—Presentation to Elementary School.

Fig. 8—International Exchange at Elementary School in the Republic of Mozambique.

including local operators, to Japan to receive between one and two months of training. A training range is available at Akeno-mura in Yamanashi where the company is located, and operational, technical, and classroom lessons are provided to ensure that the trainees have a thorough grasp of their job, including daily maintenance. Also, Hitachi staff travel from Japan to overseas sites to provide technical instruction at the time of delivery (see Fig. 6).

The machines are designed to be easy to use and maintain locally. For example, because visibility is obscured by dust thrown up at the front when used in desert regions, a cover is fitted over the flail hammer units to prevent scattering of debris. Features such as the split design used for the undercarriage referred to above were developed based on feedback from machine operators. This allows parts to be replaced efficiently if they are broken or damaged by landmines. The components most prone to damage include the flail hammers and chains, and these are designed in such a way that it only takes local workers one or two hours of work to refurbish them.

While training of local personnel presents some difficulties, the job is not complete until they can operate the machines on their own. It is necessary to be patient and repeat demonstrations over and over to ease their engrained fear of landmines and get them to accept that the demining equipment is safe. Our task is accomplished when the framework for local operation and maintenance has been established.

CSR ACTIVITIES

Through the development of demining equipment, Hitachi has been working actively to help eliminate the harm done by landmines in many countries around the world, to restore their land, and allow them to recover through their own efforts, seeing this as part of its corporate social responsibility (CSR).

While the development and supply of products is important, Hitachi also wants to express the value of life and the importance of understanding how other people feel by telling adults and children in Japan about the circumstances faced by the people who suffer from the world's minefields. To achieve this, Amemiya accepts around 70 to 80 invitations each year from schools and other social organizations to give presentations (see Fig. 7).

He also facilitates international exchanges between children, seeking to boost the morale of children living in the vicinity of minefields that are to be cleared by bringing them letters, pictures, and other artwork from children in Japan, and also by bringing letters and pictures from those children back to Japan (see Fig. 8).

SELF-RELIANCE AND INDEPENDENCE FOR LOCAL PEOPLE

Landmine clearing does not end when the mines are removed from the minefield. The actual benefits are realized when the land from which the mines have been removed is reused for a school or farm, for example, so that the local people can become more independent and self-reliant. In the Republic of Nicaragua, land from which mines had been cleared is now used to grow oranges, producing 600,000 cases a year and about 1.5 million dollars in exports. Other crops included coffee and highland vegetables (see Fig. 9).

In Cambodia, two schools have been built on former minefields to provide the infrastructure for children's education. Working through a non-profit organization, "Good Earth Japan," Hitachi is also actively participating in measures that support self-reliance, including providing local people with agricultural education, the construction of wells and reservoirs, and the provision of roads. The company's aim is to do what it can to make an international contribution by restoring land to peace and prosperity so that children can play barefoot (see Fig. 10).

Fig. 9—Magazine Article on Cultivation of Coffee after Landmine Clearance in the Republic of Nicaragua.

Fig. 10—Kiyoshi Amemiya with Children in the Kingdom of Cambodia.

RESTORING LAND TO PEACE AND PROSPERITY

The personal motto of Kiyoshi Amemiya, one of the authors, is that, "engineers are challenged by monozukuri, and the root of technology can be found in monozukuri and hitozukuri—making good products is equal to making good people." The falling birthrate in Japan means that the number of working engineers with a command of their craft is steadily diminishing. Japanese corporations have always placed a high value on their personnel, fostering engineers and supplying technologies that are recognized around the world. Perhaps now is the time to once more be fostering the forgotten "spirit of craftsmanship."

Our aim for the future is to continue our efforts to make an international contribution by developing, supplying, and supporting demining equipment, so that land can be restored to prosperity and be a place where children can play happily. Nevertheless, civil war, terrorism, and other conflict continue to occur around the world. Hitachi will keep up its desire to bring about a peaceful world in which demining equipment is not needed.

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topics

2011 Placement of UH03 in Japan's "Mechanical Engineering Heritage" by The Japan Society of Mechanical Engineers

—First Hydraulic Excavator Made from Entirely Japanese Technology—

Toshimasa Tanaka

In 1965, the division of Hitachi, Ltd. that manufactured construction machinery at that time developed the UH03, the first hydraulic excavator to be based entirely on Japanese technology. With features that included use of hydraulics and two boom cylinders, the configuration of the UH03 could be seen as the model for the hydraulic excavators of today. A combination of factors specific to Japan soon brought hydraulic excavators into widespread use, and Japan today remains a center for the development of these machines. In 2011, the UH03 was formally added to the "Mechanical Engineering Heritage" compiled by The Japan Society of Mechanical Engineers.

CONTINUED ROLE AS MODEL FOR MODERN HYDRAULIC EXCAVATORS

HYDRAULIC excavators are an archetypal construction machine. The first machines were built in Europe and it was through technical collaboration with Europe that they were introduced to Japan. In 1965, the division of Hitachi, Ltd. that manufactured construction machinery (which later became Hitachi Construction Machinery Co., Ltd.) released the first hydraulic excavator to be developed based entirely on Japanese technology. Called the UH03, the machine had a bucket capacity of 0.35 m^3 and a gross mass of 8.7 t (see Fig. 1).

Around the same time as the release of the UH03, a series of other hydraulic excavators produced through technical collaborations with European manufacturers were also appearing on the Japanese market. While models with a single-pump/single-valve hydraulics had previously been the mainstay of the market for these machines, the two-pump/two-valve hydraulics system on the UH03 is essentially the same configuration used today, and it gave the UH03 superior control of combined movements and allowed it to work faster. A catalog from that time lists the cycle time for digging as between 15 and 20 seconds, indicating its speed was not notably inferior to modern machines. Table 1 lists the main specifications of the UH03. With features that include a boom driven by two hydraulic cylinders, the design of the UH03 serves as a model for modern hydraulic excavators of this class.

Also, the small size of the cab that minimizes the space for the operator is evident at a glance. The cab contains an assortment of levers, the usual configuration consisting of six in total, of which four are used for swing (superstructure rotation) and front attachment operation, and two are used to operate the crawler (see the top photo of Fig. 2). As the four different operations used during conventional digging

Fig. 1—UH03 Hydraulic Excavator Now Designated Part of "Mechanical Engineering Heritage."

TABLE 1. UH03 Main Specifications

Gross mass	8,700 kg (approx.)	Hydraulics		Two pumps
Total width	2,340 mm (approx.)	Fuel tank capacity		125 L (approx.)
Total height	2,680 mm (approx.)	Engine	Name	Isuzu DA220
Track width	400 mm		Type	Water-cooled 4-stroke with precombustion chamber
Operation cycle time	15 to 20 s (approx.)		Displacement	4,084 cc (mL)
Speed	2.56 km/h (approx.)		Continuous rated output	50 ps/1,800 rpm

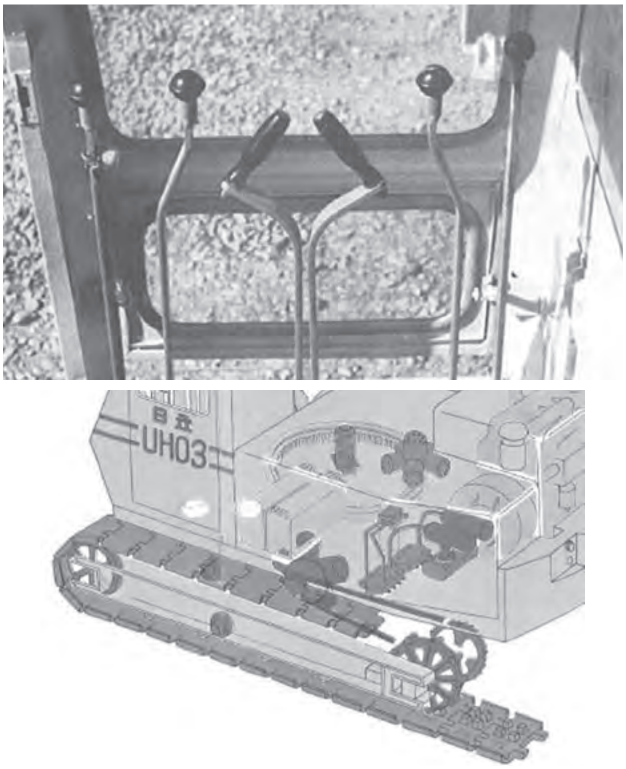

Fig. 2—UH03 Operator Controls (Top) and Crawler Design (Bottom).

involving the front attachment (consisting of a boom, arm, and bucket) and swing are too difficult to perform simultaneously by hand alone, the boom and swing are controlled by the left and right hands and the arm and bucket are controlled by foot using pedals attached to the bottoms of the levers.

While the crawler tracks are hydraulic-powered, they use a chain-driven sprocket configuration with the crawler itself having no track links, what is known as an excavator-type drive mechanism (see the bottom figure of Fig. 2). The engine and fans are visible through vents in the engine cover and other covers, indicating that the machine dates back to a time when noise was not a major consideration.

PROGRESS IN ADOPTION OF HYDRAULIC EXCAVATORS IN JAPAN

The catalog gives the impression that a strong emphasis was placed on crawler performance. Examples include, “if the tracks become stuck, the machine can be easily jacked up at the front so that it can free itself,” “spin turns and pivot turns can be performed at will,” and “the machine can cross a 1-m wide ditch.”

Prior to the arrival of hydraulic excavators, most digging and loading work was done by mechanical excavators equipped with a power shovel front attachment (see Fig. 3). These were widely used in the post-war recovery, and during the period of rapid economic growth, for tasks such as river improvement, dam construction, and mining development. However, their front attachments did not have the same flexibility of control as hydraulic excavators, making them much more difficult to operate. Moreover, the machine traction was mechanically driven using a mechanism in which power was transmitted via a shaft from the superstructure and transferred to the left and right crawlers via a clutch. In addition to being subject to numerous limitations, such as the steering not working on slopes or other difficult locations, the heavy weight of the vehicles and their high center of gravity meant that the machines were largely confined to use on easy sites with flat terrain.

Fig. 3—Mechanical Excavator.

The arrival of the hydraulic excavator onto this scene greatly expanded the scope for mechanized earthworks. The worksites shown in catalogs, manuals, and photographs tended to feature soft or uneven ground of the sort that a mechanical excavator would find difficult to cope with, indicating that not long after hydraulic excavators entered use, their applications had already expanded to encompass a level of use not dissimilar to the present day, such as the building of forestry roads or the shaping of sloped ground. The following three reasons can be suggested for why hydraulic excavators became so prevalent in Japan.

(1) No other types of earthmoving machinery were yet in widespread use.

(2) Topographical and soil characteristics meant that the machines were frequently used on soft or

uneven ground, and often in confined spaces. Their use of hydraulics not only gives hydraulic excavators a high level of traction, they can also use their front attachments to assist in their movement. This means that they can be used in locations that could not be reached using their traction capabilities alone.

(3) As unfavorable soil conditions mean that sand is used for backfilling in tasks such as ditch digging, the machines are frequently used for digging and filling up dump trucks. The backhoe loaders commonly used overseas are impractical for this work.

For these reasons, hydraulic excavators rapidly expanded their scope of use beyond merely being a replacement for mechanical excavators, with demand in Japan surpassing 20,000 machines in 1973 (see Fig. 4). Demand went on to exceed 50,000 machines in 1990, representing more than 50% of total international demand of about 100,000 machines. While Japan's share of the market shrunk after the bursting of the economic bubble, the country remained a center for the development of hydraulic excavators, including parts, and it is currently estimated that about 70% of the world's hydraulic excavators were developed in Japan. As the first hydraulic excavator to be based entirely on Japanese technology, the UH03 can be seen as one of the starting points for these Japanese hydraulic excavators.

Having been formally recognized as part of Japan's Mechanical Engineering Heritage, a UH03 is currently displayed at the Tsuchiura Works of Hitachi Construction Machinery Co., Ltd. along with Hitachi's first mechanical excavator, the U05. Anyone visiting Tsuchiura Works is encouraged to take a look.

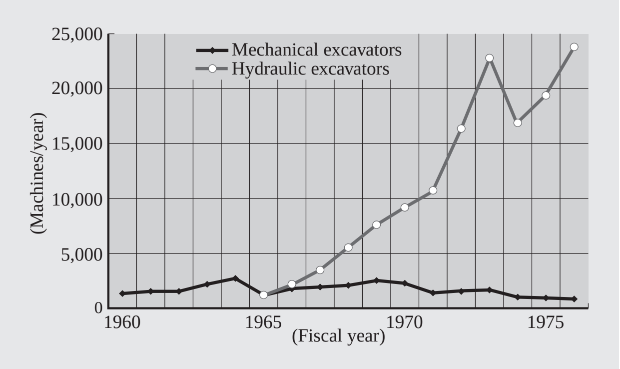

Fig. 4—Production of Mechanical and Hydraulic Excavators in Japan (Based on Statistics from the Former Ministry of International Trade and Industry).

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Joined Hitachi Construction Machinery Co., Ltd. in 1975, and now works at the Application, New Product & Construction Equipment Division. He is currently engaged in providing technical and commercial back-up to the sales staff and organization.