Scope

Kawasaki Heavy Industries Quarterly Newsletter

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Kawasaki

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About the Cover
The cover photo shows a close-up of the first Boeing 787, for which Kawasaki has designed and manufactured key components. See Frontline for more.

KAWASAKI HEAVY INDUSTRIES, LTD.

Scope

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The Future of Flight Has Arrived: Boeing 787 Ready for Take-off

Forward Fuselage, Key Engine Parts Designed and Manufactured by Kawasaki

On September 26, a long-awaited dream finally came true with the delivery of the first 787 Dreamliner to launch customer All Nippon Airways (ANA). A vision of "working together" has been the driving force behind the development of this state-of-the-art midsize commercial airplane, which was completed with the cooperation of Boeing's partners around the globe. Kawasaki has been a partner since the beginning, undertaking the development and manufacturing of key components such as the forward fuselage, main landing gear wheel well, and fixed trailing edge.

Kawasaki is also a partner in the development of the Rolls-Royce Trent 1000, one of two engine options available on the 787 Dreamliner. As part of the Trent 1000 development team, Kawasaki is in charge of the design, production and assembly of the core engine component known as the intermediate pressure compressor (IPC) module.

This issue's *Frontline* takes you behind the scenes for an up-close look at the delivery of the first 787 Dreamliner, as well as the Kawasaki production site that contributed to making the dream a reality.

787 forward fuselages on the 787 North Plant's assembly stage (Nagoya Works 1).

Boeing 787 Dreamliner Sets the Pace

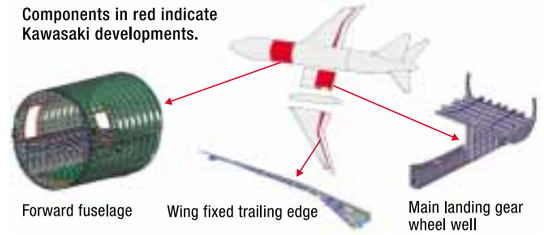
Better Fuel Economy and Longer Range Lead to Over 820 Orders

At 57 m long with a wingspan of 60 m, the 787 is a midsize airplane that can carry 210 to 250 passengers. What makes it so revolutionary is the groundbreaking use of lightweight, highly durable carbon-fiber composite materials for its primary structure, including the fuselage and wings. Composite materials make up about 50% of the 787 airframe by weight. The plane's onboard components have also been made lighter than those found on any other commercial jet. All this weight reduction adds up to about a 20% cut in fuel consumption and about a 30% longer range compared with airplanes of the same class in the air today. The 787 is a midsize plane enabling nonstop flights from Japan to as far as the East Coast of the U.S. or Europe.

The interior features indirect LED lighting, which gives the cabin a more open, spacious feel. It also has roomy seats and nice wide aisles. Use of high-strength, corrosion-proof composites has enabled the 787 to be fitted with larger windows, providing passengers with a better view. It also makes it possible to maintain a closer-to-sea-level cabin pressure regardless of altitude, alleviating the discomfort sometimes associated with air travel, such as the ear popping passengers may experience during flight. The use of composite materials also enables higher cabin humidity for increased passenger comfort.

The popularity of this innovative aircraft continues to soar around the globe. As of October 2011, more than 820 airplanes were on order. That figure is quite an impressive feat for the aviation industry, where an airplane is considered a bestseller when sales hit 500. What's even more astonishing is the fact that the 787 surpassed the 500-unit milestone while it was still in development.

A 787 test plane on view at the Central Japan International Airport (Centrair).



Industry's First One-Piece Barrel

Kawasaki is responsible for the development and manufacture of the 787's primary components, such as the forward fuselage, main landing gear wheel well and fixed trailing edge (see illustration).

The manufacturing technologies applied to build the 787 are as unique and innovative as the airplane itself. To get an idea of just how unique, we need only look at how Kawasaki put together the plane's forward fuselage. The 7 m long fuselage, with a diameter of approximately 6 m, is the first ever to employ a one-piece composite structure. Rather than following conventional airplane fuselage production methods, a revolutionary, one-piece barrel design was employed which completely eliminates the steps taken to assemble a number of panels with joints and fasteners, drastically reducing the weight and manufacturing processes.

State-of-the-Art Production

Joint International Development

Working with Boeing for over half a century has provided Kawasaki with a wealth of experience and technological expertise. Developing the 787's carbon-fiber composite one-piece barrel proved to be an epoch-making venture for Kawasaki, made possible by this joint development project that has really strengthened ties with Boeing.

Kawasaki has continually worked to improve operational efficiency to ensure 100% on-time deliveries and production increases of top-quality products every step of the way. That hard work earned appreciation from Boeing, which named the Kawasaki Aerospace Company its Supplier of the Year in the Major Structures category in 2010. This was the second time Kawasaki was honored with this award following its first in 1997.

The forward fuselage produced by Kawasaki is transported to the U.S. by the Dreamlifter, Boeing's large cargo freighter.

Automatic Fiber Placement, Curing, Machining/Drilling and Non-Destructive Inspection

The production process for the one-piece barrel jointly developed by Kawasaki and Boeing begins with laying prepreg tape via an automatic fiber-placement machine. The machine wraps flexible, uncured composite tape in specified widths around a large cylindrical mold measuring 6 m in diameter. This composite "lay-up" is then put into an autoclave, where it is cured through a chemical reaction at a high temperature and pressure. Once cured, the composite undergoes the machining process, in which openings for windows, doors and holes are trimmed and drilled. It is then inspected for any small foreign particles and micro air bubbles by use of ultrasonic non-destructive inspection equipment before the barebones forward fuselage is ready to be installed with a frame and floor structure, as well as tubes and wiring.

Taking Aircraft Production to New Heights

In 2006, Kawasaki expanded its production facilities with an eye to boosting its 787 forward fuselage production capability. The newly built 787 North Plant — boasting a total floor area of 16,000 m^2 — was an extension to the 777 North Plant at its Nagoya Works 1, where fuselage panels for the Boeing 777 are manufactured. Then in 2010, Kawasaki finished construction on another new facility with a total floor area of 31,000 m^2. Located adjacent to the 787 North Plant, the new plant was dubbed the 787 South Plant. Both of these twin plants provide state-of-the-art equipment for aircraft production.

The autoclave used to cure laid-up composites was designed and manufactured by the Kawasaki Group. With an internal diameter of 8 m and a length of 17 m, it's one of the biggest in the world. The door alone on this super-size autoclave weighs about 120 tons. It is a monster of a machine, capable of heating a composite lay-up weighing over 100 tons (mold included) up to 200°C in just a few hours. The autoclave and mold are specially engineered so the forward fuselage's cross-section forms a perfect circle when the cured composite material comes out of the autoclave oven.

The inside of the forward fuselage still looks quite bare. The top half will be the passenger cabin while the bottom half will be used as cargo space.

Overview of the Nagoya Works 1. The gray-roofed building (upper right) is the 787 North Plant. In the foreground is the 787 South Plant, with a rooftop solar-power system that generates 750 kW and can supply approximately 5% of the electricity consumed at the Nagoya Works 1.

Team Spirit Soars at Plant Aiming to Be No. 1

Making the first one-piece forward fuselage for the 787 test airplane seemed to entail all the artistry of a fine traditional craft, only the skilled artisans here were using the most cutting-edge techniques the world has ever seen. Producing a large number of uniform forward fuselages with the exact same precision and quality requires a standardized manufacturing process. Therefore, Kawasaki built two new plants equipped with some of the biggest and most advanced machines in the industry, some of them like no others in the world. Now it is ready to begin commercial production.

At the moment, Kawasaki is fully equipped and ready to do its part to produce the 787 airframe.

A sample of the carbon-fiber composite prepreg that, by weight, constitutes about 50% of the 787 airframe.

The state-of-the-art automatic fiber placement machine lays carbon-fiber composite material around a large cylindrical mold measuring 6 m in diameter.

A forward fuselage cured in one of the largest autoclaves in the world.

A forward fuselage undergoes rigid inspection using ultrasonic non-destructive inspection equipment exclusively developed for the one-piece composite barrel.

A fastening machine automatically installs frames to a fuselage.

The forward fuselage is turned clockwise as its internal structure is assembled to boost work efficiency. Kawasaki earned high marks from Boeing for outstanding productivity.

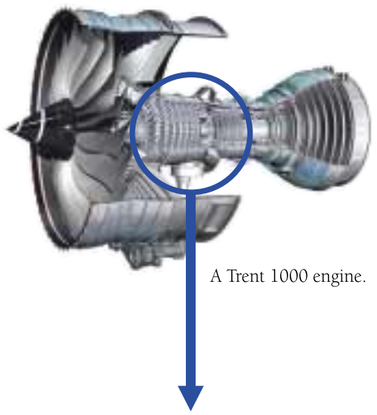
Kawasaki Components at the Core of the Trent 1000 Super Jet Engine

Working Together to Build the First 787 to Go Into Service

Airlines purchasing the 787 can choose between two different engines from two different manufacturers. The Trent 1000, the state-of-the-art passenger aircraft engine developed by Britain's Rolls-Royce, is the engine of choice for launch customer ANA.

Kawasaki has been participating in the development and production of the Trent 1000 engine from the very beginning. A risk- and revenue-sharing partner (RRSP) with Rolls-Royce, Kawasaki is responsible for the design, production and assembly of the intermediate pressure compressor (IPC) module, the engine's core component. It has also conducted operational tests at its Akashi Works in Hyogo Prefecture as part of the engine development program since 2008.

When the first 787 took to the skies on ANA's domestic routes this fall, Kawasaki's advanced airframe and engine technology played a big part in making it soar.



A Trent 1000 engine.

An intermediate pressure compressor (IPC) module.

Production Facility for IPC Modules at Seishin Works

The IPC module is one of the Trent 1000's primary components. It increases the pressure of compressed air drawn into the engine fan from approximately 1.5 atm to approximately 10 atm before sending it on to the high-pressure compressor.

Measuring 1,240 mm long and 350 mm in diameter, and weighing approximately 600 kg, the IPC module is made almost entirely of an extremely lightweight titanium alloy. The welded drum features eight stages of rotating titanium blades, or rotors, and a number of fixed stator blades. During takeoff, air is compressed as the rotating blades spin inside the casing at speeds up to 9,000 rpm. It's an ultraprecision product using parts machined with pinpoint accuracy to within two- to five-hundredths of a millimeter.

The IPC module was designed, manufactured and assembled entirely in Plant 2, a dedicated facility opened in 2006 at Kawasaki's Seishin Works in Kobe.

Assembling on the Cutting Edge

The Plant 2 machining shop is equipped with a variety of machining tools, including state-of-the-art NC (numerically-controlled) machining centers.

The facility houses the world's only high-speed electrical discharge holing machine, used to drill a 1.25 mm diameter hole through component walls that are 80 mm thick or more. It is also home to one of the world's few electron-beam welding machines, used to weld the IPC module's front bearing housing, located near the engine fan.

Every precision component manufactured with these cutting-edge machines gets assembled into an IPC module according to the Trent 1000 assembly system — a unique Kawasaki system developed completely in house that has garnered high praise from Rolls-Royce.

At Plant 2 all the parts of the manufacturing process are arranged and ready for mass production.

The world's only high-speed electrical discharge holing machine drills holes to exact specifications.

The Seishin Works machining shop, built exclusively for the Trent 1000. The facility is home to state-of-the-art machining tools, including the latest NC machining centers, as well as a number of one-of-a-kind or unique machines.

Assembly of the intermediate pressure compressor (IPC) module consists mostly of ultraprecision parts machined with micrometer accuracy.

First 787 Flight Takes Off in November

After much anticipation, watching the first Boeing 787 Dreamliner touch down on the runway at Tokyo's Haneda Airport on September 28 was an extremely moving experience. As the 787 launch customer, ANA has ordered a total of 55 Boeing 787 Dreamliners and participated in Boeing's Working Together program, enabling us to provide a great deal of input from the airplane operator's point of view.

We're pleased with the spacious 787 cabin. We chose the Rolls-Royce engine for its overall superior performance, including the fact that it's so quiet. The 787 is the only midsize airplane that enables passengers to fly from Japan to the East Coast of the U.S. or Europe non-stop. It provides all the comforts passengers need for a long-haul flight and more.

At ANA, we see the 787 as part of our strategic fleet. Its excellent fuel economy and long range will make it the backbone of our fleet. We decided to kick off our domestic 787 service on November 1 with the Haneda-Okayama and Haneda-Hiroshima routes. International 787 services will begin with our existing Haneda-Beijing route in December and our new Haneda-Frankfurt route next January. When it comes to the role we see the 787 playing in both our domestic and international operations, the sky's the limit.

Yuichi Murakoshi
Assistant Manager, Public Relations
All Nippon Airways Co., Ltd.

Inside the New Jet Mill: Grinding Things Down to Micron Size

Pulverizing Jet Air Collisions

Many of us are familiar with the toner used in photocopiers and laser printers, but very few of us know that each toner particle measures a mere 5μm*. Toner is composed of a mixture of pigments and resins, which are first blended, melted together, rolled and then cooled. The cooled material is then broken into small flakes via a pre-crushing process, after which it must be ground into even finer particles—and this is where the jet mill comes into play.

Kawasaki subsidiary EarthTechnica recently developed a cutting-edge jet mill with a simple design that belies the complex mechanism at work. The new machine employs three separate nozzles to deliver jet streams of compressed air, with a pressure of approximately 7 atm, into the lower section of the mill, where it generates pulverizing particle-to-particle collisions that result in an ultrafine powder.

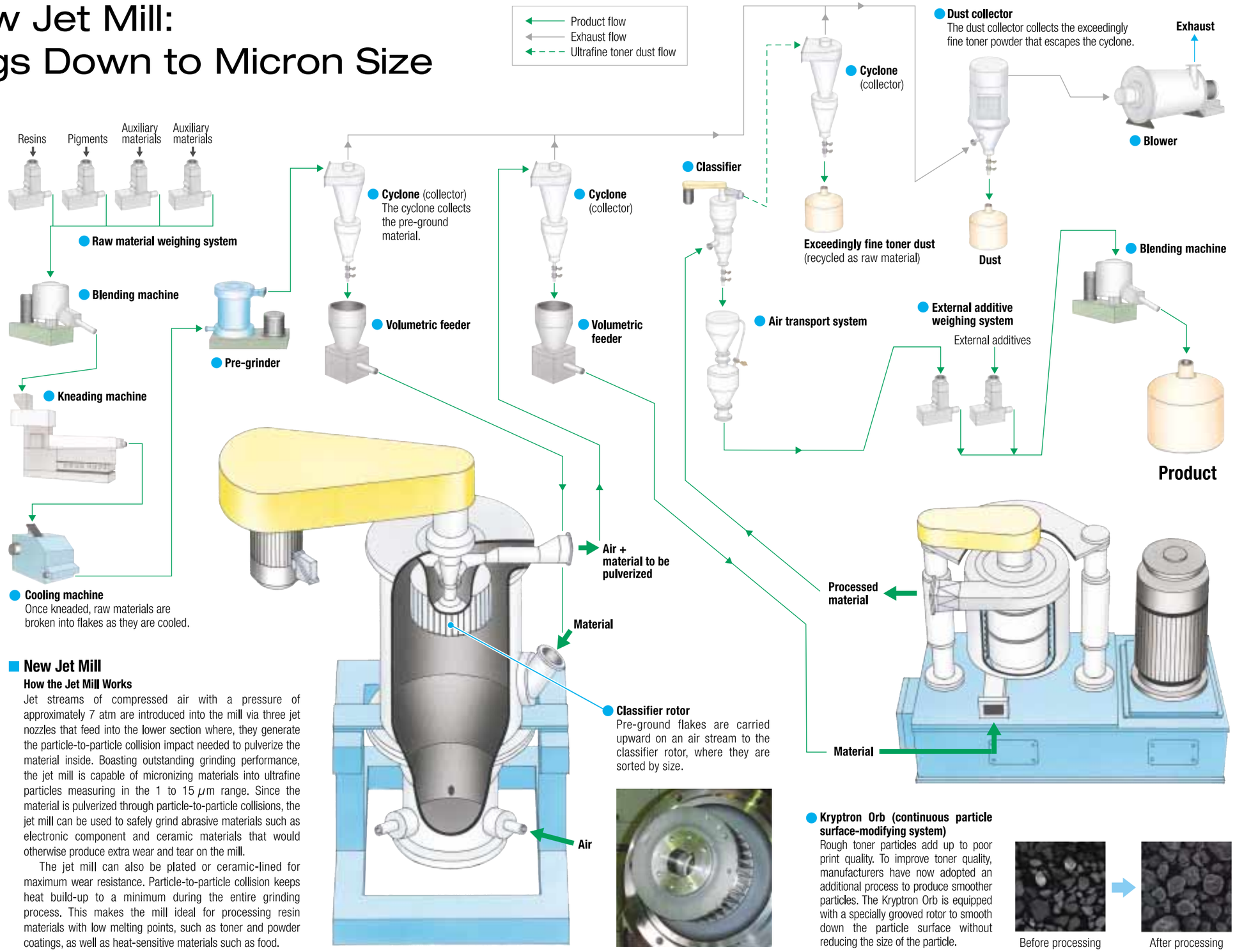
Wide Range of Applications

Use of the new jet mill goes well beyond toner production. You can find it employed in a wide range of applications: it is used to make battery materials, to grind carbon steel and other metals, and to process food products such as tea leaves, rice and more.

The illustration here shows a typical toner production system with a jet mill.

* Micrometer (μm) is a unit of length used in the International System of Units. A micrometer is one-millionth of a meter or 0.001 mm. While a micrometer is also known as a micron, the International System of Units does not use the term micron.

New Jet Mill JEDI EJM20



New Jet Mill

How the Jet Mill Works

Jet streams of compressed air with a pressure of approximately 7 atm are introduced into the mill via three jet nozzles that feed into the lower section where, they generate the particle-to-particle collision impact needed to pulverize the material inside. Boasting outstanding grinding performance, the jet mill is capable of micronizing materials into ultrafine particles measuring in the 1 to 15 μm range. Since the material is pulverized through particle-to-particle collisions, the jet mill can be used to safely grind abrasive materials such as electronic component and ceramic materials that would otherwise produce extra wear and tear on the mill.

The jet mill can also be plated or ceramic-lined for maximum wear resistance. Particle-to-particle collision keeps heat build-up to a minimum during the entire grinding process. This makes the mill ideal for processing resin materials with low melting points, such as toner and powder coatings, as well as heat-sensitive materials such as food.

Kryptron Orb (continuous particle surface-modifying system)

Rough toner particles add up to poor print quality. To improve toner quality, manufacturers have now adopted an additional process to produce smoother particles. The Kryptron Orb is equipped with a specially grooved rotor to smooth down the particle surface without reducing the size of the particle.

Before processing | After processing

Steam Turbine Generators Shipped to Korea

Kawasaki recently shipped two 24.2 MW steam turbine generator (STG) units to Hyundai Energy Co., Ltd. in Yeosu, Korea, fulfilling a 2009 order from Korea's Hyundai Engineering & Construction. The STGs will be installed in a cogeneration plant currently being constructed by Hyundai Engineering & Construction at the Yeosu National Industrial Complex. The cogeneration plant, consisting of a coal-fired boiler and two STG units, will supply electricity and steam to the industrial complex. The plant is scheduled to go into operation in February 2012.

The STG is equipped with both a back-pressure turbine and a double-extraction steam system (ESS). Exhaust steam is employed by the turbine as process steam while the ESS makes use of steam extracted at the turbine's intermediate stage. These STGs can provide the industrial complex with steam that meets a wide range of requirements.

Kawasaki has a proven track record in the field, having delivered 345 steam turbine units worldwide. This latest delivery brings to 40 the number of steam turbine units it has delivered to Korea for power generation applications. The order is a testament to the outstanding reliability of Kawasaki steam turbines as well as their superior performance and lifecycle cost.

Today's growing demand for distributed power generation systems continues to fuel sales at Kawasaki, as it moves forward to expand its energy and environmental business.

New Hydraulic Pump Facility Goes into Full Operation

Kawasaki's Nishi-Kobe Works, the company's hydraulic production hub, recently started full-scale production of hydraulic pumps for construction machinery at its new facility.

The new facility was built to meet the increasing worldwide demand for hydraulic construction machinery equipment. Completed in December 2008, full operation of the plant had been temporarily halted in the wake of the global financial crisis. However, demand in the Chinese market continued to surge over the last year, so Kawasaki gradually outfitted it with new production equipment needed to boost capacity.

After an investment totaling 8 billion yen, Kawasaki's new facility boasts the latest hydraulic pump production equipment for parts processing, assembly, operation and painting, in addition to hydraulic pump production lines transferred from an older facility. The plant has raised Nishi-Kobe Works' annual hydraulic pump production capacity by 20%, bringing the total from 110,000 units to 130,000.

The construction machinery market is expanding across the globe. China, which is aggressively investing in infrastructure, urban and natural resources development, is hardly the only place where demand is on the rise. Soaring prices for natural resources continues to fuel demand in resource-rich nations throughout South America and elsewhere as well.

Kawasaki will leverage its enhanced production capacity to meet this increasing demand with a keen focus on providing highly reliable, high-performance products to the ever-expanding global hydraulic equipment market. Driven by a deep commitment to improve aftersales and service capabilities, Kawasaki is taking customer satisfaction to new levels.

About the New Facility

Address: 234 Matsumoto, Hazetani-cho, Nishi-ku, Kobe, Japan
Products: Hydraulic pumps
Production capacity: 48,000 units/year
Total floor area: Approx. 10,000 m² (bi-level structure)
Employees: 120 (as of May 2011)

Three Shield Machines Ordered for Abu Dhabi Sewage Tunnel Project

Kawasaki recently received an order for three shield machines to be used in a sewage tunnel project in Abu Dhabi, the United Arab Emirates (UAE). The order, which came from Samsung C&T Corporation of South Korea, is Kawasaki's first for shield machines bound for the Middle East. The machines are scheduled for delivery by March 2012.

These earth-pressure balanced shield machines have a diameter of 5.22 m, and will be used to excavate a 16.2 km leg of the 42 km long Strategic Tunnel Enhancement Program (STEP) being undertaken by the Abu Dhabi Sewerage Service Company (ADSSC). Samsung C&T was awarded a contract to build the 16.2 km tunnel, which will link the industrial satellite town of Mussafah with central Abu Dhabi. The project is scheduled to be completed by the end of 2014.

Engineered to tunnel through soft ground as well as hard rock and gravel layers, the shield machine can dig through virtually any geological composition. All three shield machines have been designed to provide the superior durability and high speed needed to construct long tunnel distances stretching approximately 5 km.

Kawasaki's lengthy list of achievements includes the delivery of approximately 1,400 shield machines to customers around the world. This latest order is a testament to its outstanding technological capabilities as well as the proven track record and reliability of its shield machines.

Kawasaki expects to see additional orders for the machines coming from the Middle East, where plans for more underground construction work are on the drawing board, including ongoing subway projects in Abu Dhabi, Dubai and Cairo. The outlook for the medium to long term looks bright throughout the Middle East as well as Asia, with subway construction projects scheduled to break ground in the major Indian cities of Mumbai, Delhi, Calcutta, Chennai and Bangalore, as well as in China, Singapore, Thailand, Malaysia and Indonesia. Kawasaki is moving steadily ahead to expand shield machine and tunnel boring machine sales across the globe.

Some of the outstanding features of the shield machines to be used in the Abu Dhabi sewage tunnel construction project are summarized below.

Project operator: Abu Dhabi Sewerage Service Company (ADSSC)
Project contractor: Samsung C&T Corporation (Korea)
Shield machine model: 3 articulated earth-pressure balanced shield machines with a diameter of 5.22 m
Contract: Design and production of shield machines, on-site technical services

Chinese Joint Venture to Build Facilities for Cement Plant Components

Kawasaki recently announced plans to build new production facilities for cement plant components at Anhui Conch Kawasaki Equipment Manufacturing Co., Ltd. (CKE). CKE is a joint venture between Kawasaki and Anhui Conch Cement Co., Ltd., one of China's biggest and the world's fourth-largest cement maker.

The new facilities will be designed for in-house production of cast parts and other consumables as well as main cement plant components, which Anhui Conch Cement currently procures from external suppliers. Two cast shops (with a combined floor area of 65,000 m²) and a plate-working facility (with a floor area of 19,000 m²) will be constructed on the premises of the company's existing factory in Wuhu City, Anhui Province. The cast shops will be used mainly for producing crushing machine hammers, air-quenching coolers (AQCs), grates and tube liners while the plate-working facility will produce roller presses, AQCs, kilns and tube mills. The total investment is estimated to amount to approximately 7.4 billion yen in property, buildings and production equipment for the three facilities.

China produces 1.8 billion tons of cement annually, more than half of the world's total (3.3 billion tons). The outlook for the future of the industry is bright, with growing domestic demand fueling production volume. Against this backdrop, large-scale, state-of-the-art facilities are being built to replace older, less efficient facilities. This development is expected to generate increased demand for cement plant components along with cast and other consumable parts. Kawasaki is leveraging CKE's in-house cement plant component manufacturing capabilities with its own expertise, to provide products that are superior in every way. Expanding its joint venture operations and revenue base, Kawasaki is on track to become the world's leading comprehensive cement plant supplier.

Kawasaki and Anhui Conch Cement are working together to make the most of their competitive edge as they supply products that will help China save energy while protecting the natural environment.

Overview of Joint Venture

Company name: Anhui Conch Kawasaki Equipment Manufacturing Co., Ltd.
Location: Wuhu City, Anhui Province, China
Capital: Approximately 150 million yuan (2.1 billion yen)
Capital ratio: 50% Kawasaki Heavy Industries, 50% Anhui Conch Cement
Description of business: Design, manufacture, sales and maintenance of cement production equipment, as well as provision of related technical services, and spare parts.

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Heizo Kanayama's World

The Peak of Autumn, 1945-1956, 45.3 x 60.5cm, oil on canvas, from the collection of the Hyogo Prefectural Museum of Art.

Fall's Vibrant Colors Highlight Our Connection with Nature

Shusaku Sagara, **Associate Curator, Hyogo Prefectural Museum of Art**

In 1966 Raku Kanayama, the wife of renowned painter Heizo Kanayama, donated 130 of his canvasses, which had been housed at Kawasaki Heavy Industries after his death, to Hyogo Prefecture. The Hyogo Prefectural Kobe Life Enhancement Center commemorated the bequest by holding the Heizo Kanayama Art Exhibition from May 21 to June 3, 1966.

The piece shown here, presumably painted in Towada, was among those on display at the exhibition. Kanayama's signature brush stroke is visible here in the radiant leaves. The foliage, rendered in a palette of autumn colors, makes the mountain path come to life.

What is especially intriguing about this painting is how the viewer's eye is drawn to the figure walking in the distance. This is a continually reappearing motif in Kanayama's works that turns up again here, only this time there is an unusual twist. Unlike his other paintings, in which we always see the person from the back, here the subject is walking toward us. Painted against the backdrop of an expansive landscape, the work depicts how man fits in with his ever-changing natural surroundings. It's almost as if the painter is inviting us down the path in the hopes that we will realize how deeply connected we are with nature.

Heizo Kanayama and Kawasaki

Heizo Kanayama (1883 -1964) went to Europe in 1912, after graduating at the top of his class from the Tokyo University of the Arts. He won the second prize at the Ministry of Education Art Exhibition in 1916, and went on to create many masterpieces in which nature is a recurring theme. Kanayama left an indelible imprint on the history of modern art in Japan.

The Shipyard, exhibited at the Ministry of Education Art Exhibition in 1917 (and featured in *Scope 83*), is the work that first brought Kawasaki and Kanayama together. Toward the end of Kanayama's life, Kawasaki agreed to the artist's request to permanently house 138 pieces of his artwork. Kawasaki has since donated a major portion of this collection to the Hyogo Prefectural Museum of Art.