

Scope

Kawasaki Heavy Industries Quarterly Newsletter

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Quarterly Newsletter

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Special Feature
Leading Innovation for Wastewater
Treatment Around the World:
Kawasaki's Aeration Blower,
"Mega MAG Turbo"

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Changing forward

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Mikasagawa Sewage Treatment Plant, operated by the Fukuoka Prefectural Water and Sewage Control Center, where the Mega MAG Turbo is undergoing an actual load test.

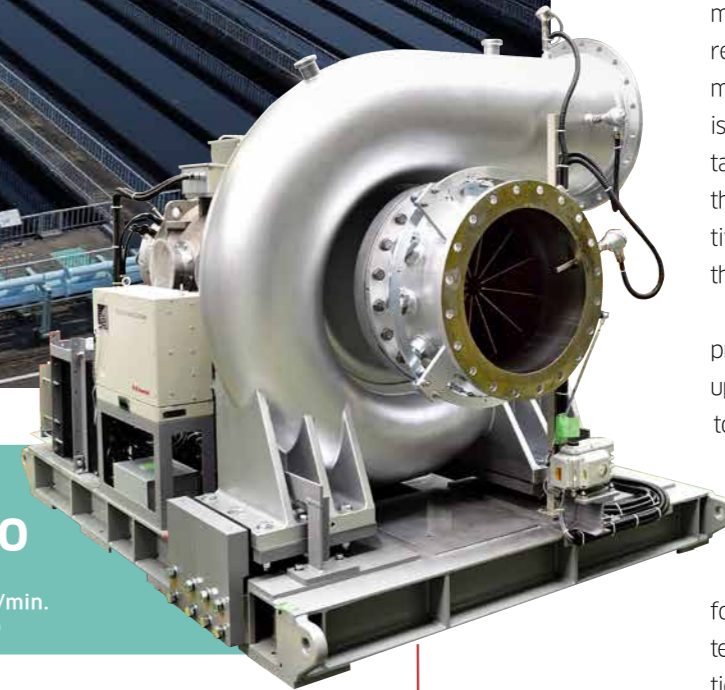
Leading Innovation for Wastewater Treatment Around the World: Kawasaki's Aeration Blower, "Mega MAG Turbo"

Preserving a clean environment and passing it on to future generations is what every global citizen hopes for, and wastewater treatment is considered one of the key contributors to fulfilling this hope. At sewage treatment facilities, the aeration blower is regarded as the real hero behind a wastewater purification process using microorganisms. Kawasaki is the leading manufacturer in Japan of a highly efficient aeration blower using magnetic bearings called the "MAG Turbo" (named by Kawasaki by combining "Magnetic bearing" and "Turbo Blower").

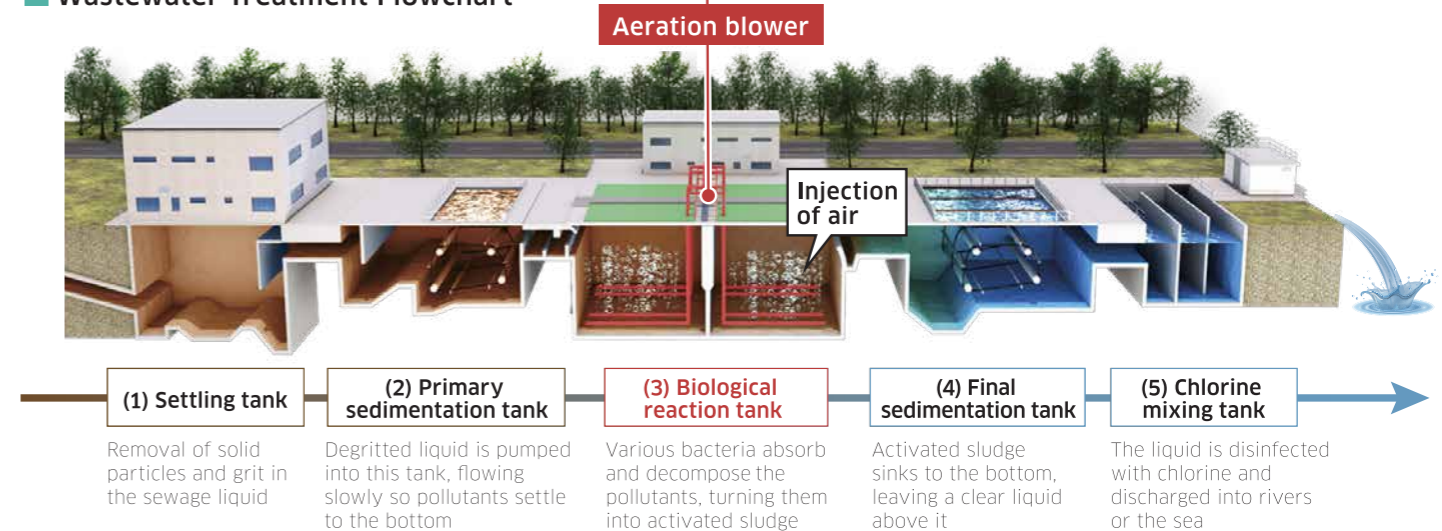
Kawasaki has always been the industry's innovator. With the development of MAG Turbo's "Mega MAG Turbo," which accommodates the needs of larger facilities, the Company has reached new heights in technological advancement.

Mega MAG TURBO

- Output: 1,300 kW
- Air flow rate: 900 m³/min.
- Pressure: 100 kPa (G)



Wastewater Treatment Flowchart



Blowers that Support the "Activated Sludge Process" — A History-Making Innovation

In 1914, the year WWI began, the world's first sewage treatment plant employing an "activated sludge process" was completed in the United Kingdom. Used for treating domestic sewage and rainwater, this process was so innovative and significant that it is considered an epoch-making invention.

In this process, activated sludge, which contains microorganisms, is mixed with sewage. The microbes digest the organic material, and as they increase in numbers, clean water is the result. At a sewage treatment plant, the microbes are in a biological reaction tank, and what takes place there makes up the "heart" of sewage treatment. It is the air provided to the biological reaction tank by the aeration blower which activates these microbes. Seen from another perspective, the blower is the real hero that makes this process work.

Over the years, as the activated sludge process underwent a series of technological upgrades, the blowers' features were tailored to sewage treatment. These advancements included technologies for adjusting the amount of air being injected based on the volume of sewage, and for operating the equipment stably, without interruption, for many years. Even with the maturing of technologies, however, high power consumption remained the hardest challenge. Power used by sewage treatment plants accounts

About the Cover
A Mega MAG Turbo M55 going through a final pre-shipping test at Kobe Works in Hyogo Prefecture, Japan. For details, see Special Feature (this page).

for approximately 1% (10 billion kWh/year) of total power consumption in Japan, 60% of which is utilized by the blowers.

To solve this problem, Kawasaki developed its innovative high-efficiency aeration blower with magnetic bearings — the “MAG Turbo” — and made its first delivery in 2004. With the MAG Turbo, an impeller is attached to the end of the rotor shaft of a high-speed, inverter-controlled motor*. The rotor is levitated by the magnetic force exerted by the magnetic bearings, rotating the impeller at high speed, which compresses air entering through the inlet and discharges it from the outlet. Due to the absence of mechanical contact, the levitated rotor requires no bearings to protect it while running at high speed, nor a lubrication system or other auxiliary equipment.

By minimizing mechanical losses, power consumption in the treatment process, overall, was reduced by 15 to 30% compared to previous models. Since delivery of the first unit, Kawasaki has received orders for more than 200 units, and in FY2019 achieved a 70% share in the domestic aeration blower market. Based on the number of deliveries, it is estimated that 50,000 tons per year of CO₂ emissions are being reduced by the MAG Turbo.

Moreover, Kawasaki took on the challenge of developing a model for large sewage treatment plants — the “Mega MAG Turbo” — which boasts of being the magnetic-bearing aeration blower with the highest output in the world. In Japan, 14 billion m³ of sewage is treated annually, but because of limited land area, most of

the treatment plants are small or medium-sized and are dispersed across the country. Outside Japan, however, treatment of sewage from multiple urban areas is often done collectively at a single, much larger facility. For example, there are more than 100 plants in the United States capable of treating 300,000 m³ of sewage per day, while only 43 in Japan have the same capacity, and regardless of size, all plants are aging rapidly.

The aging of facilities is also seen outside Japan, which makes a reduction in renewal

costs and operational expenses by utilizing highly-efficient equipment a common imperative for sewage treatment plants around the world. The Mega MAG Turbo was developed as one solution to that challenge.

Mega-Output Motor Runs the Rotor to Generate Massive Airflow

In the summer of 2020, a final pre-shipping test for the Mega MAG Turbo M55 was conducted at Kawasaki's Kobe Works. This powerful blower achieves an unprecedentedly

high output considering its surprisingly compact size.

The prefix “Mega” reflects the much greater output of the motor compared to the original MAG Turbo. While the motor output of the largest MAG Turbo is only 400 kW, that of the M55 is 1,300 kW (i.e., 1.3 megawatts — hence the appellation, “Mega MAG”). In terms of discharge air volume and discharge pressure, the M55 is rated at 900 m³/min. and 100 kPa (G), respectively, compared to the 300 m³/min. and 80 kPa (G) of the largest MAG Turbo.

Its weight, however, is significantly greater — the rotor alone weighs 700 kg, or more than five times that of the MAG Turbo. This rotor is levitated by 10 electromagnets installed in three bearings, with a shaft vibration displacement of a mere 20 μm.

Soichiro Takemura, Assistant Manager at the Aero-Dynamic Machinery Department of the Energy System & Plant Engineering Company, comments, “To stably levitate such a heavy shaft, which rotates 11,500 times per minute with only 20 μm of vibration displacement, we were compelled to improve not only the electromagnets' magnetic attraction performance but also to develop new technologies for the controller and control systems for the magnetic bearings.”

The controller uses position sensors installed at several places in the magnetic bearings to accurately determine the rotor's position relative to the X, Y, and Z axes at all times. The rotor is maintained in its reference position by controlling the amount of electric current provided to the magnetic bearings. This technology, called “High Frequency Feedback Control,” enables high speed control by receiving positional information 10,000 times per second. Kawasaki developed this innovative technology and applied it in controlling the high-speed, high-output motor.

High-Output Model Made Possible by the Fusion of Machine and Electrical Engineering Technologies

Along with developing needed technologies, Kawasaki also reviewed the design of the impeller — a vital component in compressing the air. Since the first model was developed by



(Above) The M55 sits to the rear of the photo. The equipment in the foreground is the M25. In 2007, Kawasaki introduced the MAG Turbo, the components and parts of which are all Kawasaki-made. Since that model is considered the “second-generation” blower, the Mega MAG Turbo is technically the third generation. (Left) The Mega MAG Turbo being assembled. The fan-shaped objects inside the intake opening are inlet guide vanes.

Kawasaki half a century ago, the design of the impeller's shape and airflow path has undergone a series of upgrades using cutting-edge technologies. The resulting impeller is also a core part of the supercharged Ninja H2, Kawasaki's flagship series of motorcycles, which boasts outstanding power.

Akio Hashimoto, Senior Staff Officer at the Aero-Dynamic Machinery Department of the Energy System & Plant Engineering Company, says, “For the development of the M55, we've used an analytic method called ‘Genetic Algorithms’ to identify the optimal shape for the impeller, achieving both high pressure and high efficiency at a relatively low rpm.” In addition, a special aluminum alloy was used to ensure the impeller's strength when it experiences high temperatures due to compression heat as the discharge pressure approaches 100 kPa (G).

Moreover, the inlet guide vanes placed at the suction port open and close to cause the air to swirl, and coupled with the motor, which is controlled by the inverter to optimize rotor speed, they make highly-efficient control of a wide range of airflow volume possible. Thanks to this feature, the blower demonstrates

excellent partial-load efficiency when it is not operating at full capacity.

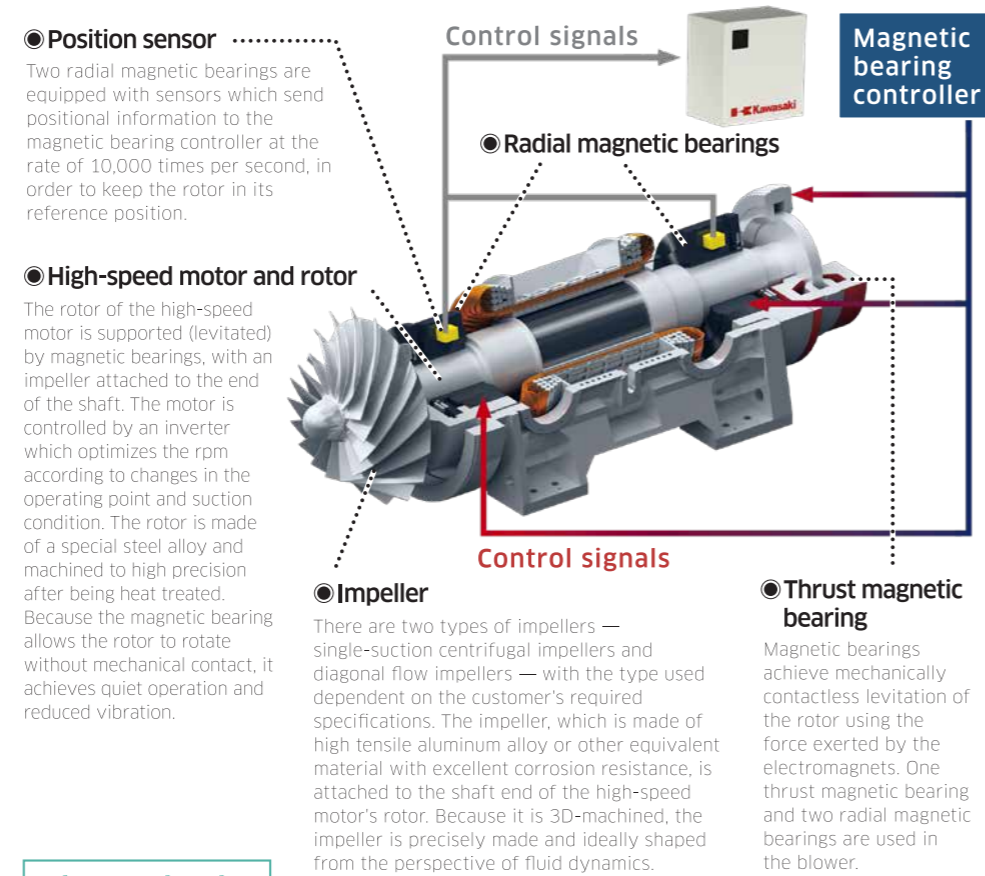
For example, compared to a conventional high-output blower, the power required by the M55 to raise the pressure to 60 kPa (G) of a volumetric airflow unit of 1 m³ is 20% lower. In addition, while producing the same amount of compressed air, the M55 achieves a 50% reduction in installation footprint, proving that it is a high-output model with energy- and space-saving advantages.

Hashimoto adds, “The same principle of levitating the rotor utilizing magnetic bearings is applied to all MAG Turbo models,

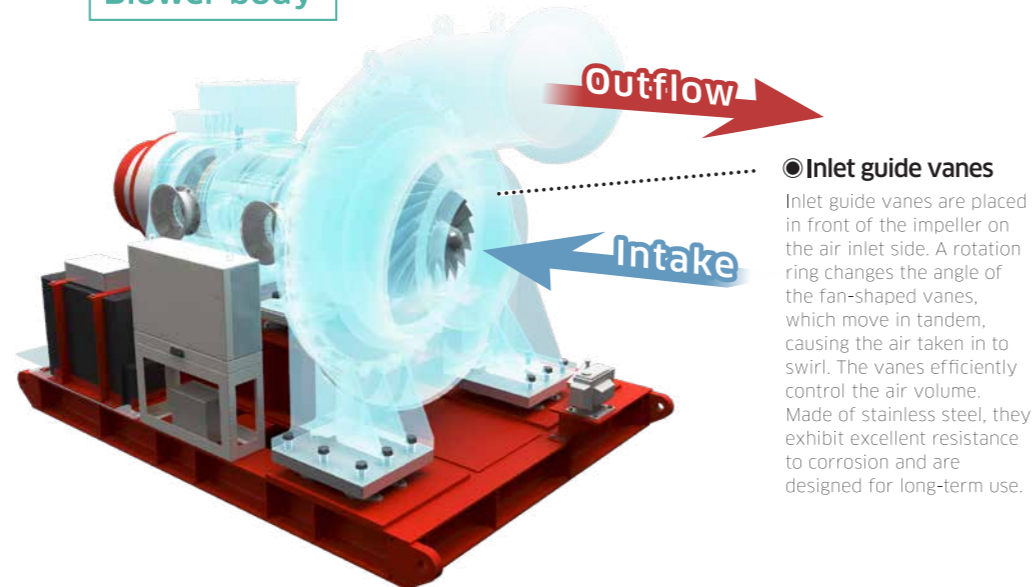


Akio Hashimoto
Senior Staff Officer, Engineering and Development Section, Aero-Dynamic Machinery Department, Energy System Group, Energy Solution Business Division, Energy System & Plant Engineering Company

Structure of Aeration Blower



Blower body



* An inverter alters the frequency and voltage of supplied power to control the rotation speed of a motor.



Soichiro Takemura
Assistant Manager, Blower Engineering Section, Aero-Dynamic Machinery Department, Energy System Division, Energy System & Plant Engineering Company



A Mega MAG Turbo M55 going through a final pre-shipping test at Kawasaki's Kobe Works. This unit is for a sewage treatment plant in Russia.

but in order to accommodate a motor with an output that far exceeds what we have been producing, our machinery and electrical engineering departments had to put their heads together to develop a new model from scratch. We also couldn't let the price go too high or it won't sell, so we tried to achieve both high output and reduced cost by reviewing the design and production method of the magnetic bearings and other core parts."

Evolution from Stand-alone Blower "MAG Turbo" to MAG ENERGY MANAGEMENT SYSTEM — the "MAG E2"

Since November 2019, a Mega MAG Turbo has been undergoing an actual load test at Mikasagawa Sewage Treatment Plant in Fukuoka Prefecture. This facility is one of the largest sewage treatment plants in the Kyushu region, processing up to about 300,000 m³ of wastewater per day. Replacing two medium-sized blowers, the M55 is currently operating under actual load conditions and has shown a reduction in power consumption. Its construction cost was also lower than that of the previous equipment, because of its smaller installation footprint.

Jun Ichikawa, Manager of the Blower Sales Section at the Energy System & Plant Engineering Company, comments, "Thanks to its high efficiency energy-saving feature and small footprint, the Mega MAG Turbo boasts an overwhelming competitive edge. Our sales department can proudly recommend the product to customers for their renewal projects."

He adds, "The Mega MAG Turbo has transformed the landscape of Kawasaki's blower

business." What he means is that the Company can now offer not only an extensive lineup of blowers — from compact to large — but also an "Energy Management System."

The system allows for the control of more than one blower and for collaborating with the manufacturers of air diffusers (equipment that diffuses the air injected by the blower into the biological reaction tank) in designing an aeration system that offers reduced power consumption as a whole. In addition, Kawasaki is planning to propose new ways to operate the system based on analyses of the data collected through remote monitoring of the blowers.

A unit of the Mega MAG Turbo M55 which went through a pre-shipping test at Kobe Works in August 2020 will soon be delivered to a large underground sewage treatment plant in Russia. This plant is one of the largest in Europe, capable of treating 3 million m³ of wastewater per day. (In Tokyo, the largest plant is Morigasaki Water Reclamation Center which treats 1.14 million m³ per day.) The first unit is scheduled to start operations in January 2021, followed by seven more units in the future. Ichikawa says, "This is a huge project to modernize sewage treatment facilities in Russia. I believe that the larger the facility, the greater the efficiency offered by the Mega MAG Turbo."

The evolution of the Mega MAG Turbo is ongoing. Together with the New Energy and Industrial Technology Development Organization (NEDO) of Japan, Kawasaki has launched a feasibility study for an

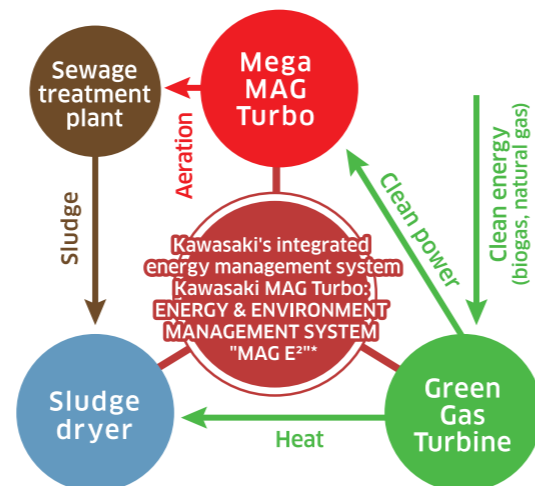
international demonstration project on cogeneration systems, the "MAG E2," involving the Mega MAG Turbo, the Green Gas Turbine, and a sludge dryer. This system utilizes a gas turbine power generator powered by "clean" natural gas and biogas harvested from sewage treatment facilities. The electricity generated by the gas turbine will be used to power the blower, while the heat generated will be used to dry the sludge. In summary, Kawasaki is building an "eco system" that generates electricity, heat, and air.

Hashimoto explains, "The project is an initiative to build a system with the Mega MAG Turbo as its key element to optimize energy use and thereby achieve a sustainable sewage treatment model." Goal 6 of the Sustainable Development Goals (SDGs) endorsed by the United Nations is to "ensure availability and sustainable management of water and sanitation for all." Kawasaki's blower business has become one of the drivers that moves forward the fulfillment of the SDGs.



Jun Ichikawa
Manager, Blower Sales Section, Land Machinery Sales Department, Marketing & Sales Division, Energy System & Plant Engineering Company

Kawasaki MAG Turbo Energy Management System in Sewage Treatment Plant



* Using innovation from a sanitation facility [sewage plant] to enable economical coexistence with a local wastewater energy center by realizing an "integrated control system for sewage energy" through combining the Kawasaki Mega MAG Turbo and its Gas Turbine.



A Supporter's Voice

Yasuhiro Kasai

Director, International Affairs Office and Office for Promotion of International Project, Infrastructure System and Water Industry Manufacturing Industries Bureau, Ministry of Economy, Trade and Industry

High-Quality Water Infrastructure for the World: Strategy for Selling the First MAG Turbo in North America in FY2021

In 2013, the Japanese government formulated an "Export Strategy for Infrastructure Systems," with the goal of winning approximately 30 trillion-yen worth of overseas infrastructure projects in 2020. The Strategy's four pillars for meeting this goal were to: 1. Strengthen competitiveness through collaborative efforts between public and private sectors; 2. Implement strategic initiatives for winning orders; 3. Promote high-quality infrastructure; and 4. Expand the range of infrastructure to be developed. Due to these measures, the Strategy has yielded certain results, such as orders totaling 25 trillion yen in 2018.

To further increase exports by improving recognition among Japan's trading partners of its sophisticated technologies, the Ministry of Economy, Trade and Industry (METI) has been actively implementing various policy tools, including top-to-top sales meetings, intergovernmental negotiations, feasibility studies, and human resource development.

As one such endeavor, METI has been conducting a series of studies called "Project on Feasibility Study Toward Overseas Expansion of High Quality Energy Infrastructures," and in FY2019 and FY2020, it made Kawasaki's high-output MAG Turbo subject to this study, focused on entry into the US market. To be more specific, the study provides marketing analyses, a select list of local after-sales service partners, and plans for actual operation of the blowers in North America under the presumption that more than 100 wastewater treatment plants are potential Kawasaki customers. In short, the study provides an infrastructure export strategy for Kawasaki to close deals in FY2021 and onwards.

Although Japanese companies' share in the water business market in North America (valued at 18 trillion yen in 2016) — the second largest after Europe — is 0.1%* and still limited, we think market entry opportunities are expanding, as the number of renewal projects for aging sewage treatment plants is rising, and the need for reclaimed water for drinking due to water resource shortages is increasing.

To promote market entry, METI will continue its efforts to increase the presence of Japanese companies using the results of the feasibility studies, and by broadly communicating their technological prowess at international events and other opportunities in cooperation with the private sector.

Today, with the global spread of COVID-19, new strategies are called for in meeting infrastructure needs that previously did not exist. In this age of digitization, in which social paradigm shifts are accelerating, strategies for water infrastructure must focus on a fundamental improvement in public sanitation and include the development of new technologies that allow for remote monitoring and contactless maintenance. METI plans to pro-actively support Japanese companies in expanding their business opportunities, and to improve competitiveness in these new segments as well.

Given all this, we hope to win our first order for the MAG Turbo in the North American market in FY2021, and become one of the icons of infrastructure exports in the new era.

*Source: "Overseas Development Strategy of Water Industry" released by METI in July 2018



Kawasaki's Advanced Technology: Supporting the Transfer of Wastewater Treatment Expertise from Osaka City to St. Petersburg

Osaka City has a long history of operating sewage treatment plants and possesses time-tested know-how in the field. Using this expertise, the City has been expanding its international activities and signed a Memorandum of Understanding (MOU) in 2015 with its sister city, St. Petersburg, for a technical exchange of expertise in the field of water and sewage systems. Every year since then, Osaka has been supporting the improvement and modernization

projects of St. Petersburg's water supply and sewage through technical exchanges. Kawasaki is part of this program in the area of sewage treatment, and is gaining a high rating. Observing Kawasaki's efforts, an Osaka City official is quoted as saying, "The Company's sophisticated technology and passion for market development are strongly supporting our technical exchanges. I was quite impressed that the person in charge of plant operations in St. Petersburg was still asking questions of Kawasaki after an allotted time had ended."



The November 2015 MOU signing ceremony at State Unitary Enterprise (SUE) Vodokanal of St. Petersburg for a technical exchange between Osaka City and the City of St. Petersburg.



The fully-recovered MGWTP, with sedimentation tanks, a biological reaction tank, the blower/pump station building, and a discharge gate on the ocean side, and the sludge treatment facility and administration building on the land side.

SUPPORTING
LIFE WITH
TECHNOLOGY



MAG Turbo Is Driving Forward Recovery Efforts in Sendai



In the new blower/pump station building, six units of the MAG Turbo M25 are in operation.

Minami-Gamo Wastewater Treatment Plant (MGWTP) is a large sewage treatment facility that provides municipal wastewater services to 70% of Sendai City's population. It was severely damaged by the Great East Japan Earthquake. Shortly after the disaster, MGWTP staff undertook recovery activities under the conviction that Sendai had to be protected from sewage overflow and that wastewater should be cleaned before reaching the sea. Kawasaki's MAG Turbo played an integral part in supporting these efforts.

Sendai is a city rich in greenery, nicknamed "Mori No Miyako" (City of Trees). It is also a city known for its advanced sewage system, having achieved the third earliest installation of a modernized sewage system in Japan (1899), after Tokyo and Osaka. Beginning operations in 1964, MGWTP is located in the city's Miyagino Ward and is the largest such facility in the Tohoku region (Northern Honshu), treating 400,000 m³ of wastewater a day.

Located near Sendai Port on the Pacific Ocean, it was hit on March 11, 2011, by a 10-meter-tall tsunami caused by the giant earthquake, with the water covering the land area at a depth of more than four meters. The situation was so devastating that the only good news was the survival of all of the staff and workers, who fled to the roof of the administration building which is further from the coast.

The day after the earthquake, they were rescued by helicopters dispatched by the Japanese Self-Defense Force. However, they had no time to relax, as they had an urgent mission to fulfill — ensuring that the water-releasing functions were working, removing debris, restoring

electricity, treating wastewater, etc. Recalling the recovery effort, Shinya Igarashi, in charge of maintenance, says, "Our plant is a mission-critical facility, providing services to about 70% of Sendai's 1.08 million residents. Because most of the sewage flows down naturally from the city center, which is 30 meters higher in altitude than the plant's location, we knew we had to continue the sewage treatment to avoid an overflow."

In preparing for temporary recovery measures, finding blowers was one of the highest priorities, as all 11 existing blowers had failed. Since Kawasaki had been providing blowers to the plant, the Company fixed two of the 11 units that were comparatively less damaged, and quickly supplied the plant with a prototype of the MAG Turbo M35. Thanks to these temporary measures, the plant began to recover.

Concurrent actions were taken to achieve complete recovery, and by April 2016, the plant had resumed full-fledged operations, with six units of the MAG Turbo M25 supporting its sophisticated wastewater treatment program. Igarashi comments that because the plant's primary mission is to return cleaned water to the Pacific Ocean, the MAG Turbo continues to play a significant role. In addition to being energy efficient, space saving, and quiet, owing to its magnetic bearings, Igarashi cites stable operations backed by great durability and 24/7 monitoring as among the blower's valuable benefits.

Asked what he expects of the future, Igarashi replied, "Our declining population will compel us to achieve sewage treatment with even higher efficiency and reduced costs. On top of that, to meet environmental standards, reducing energy use will be a must. For blowers, it will be especially important to achieve reductions in operating time, quantity, and output, so I hope to see AI-based optimization and other innovations from future blowers."

Shinya Igarashi
Section Head
Minami-Gamo Wastewater
Treatment Plant Servicing Section
Sewage Operation Department
Construction Bureau, Sendai City



2011.3.11



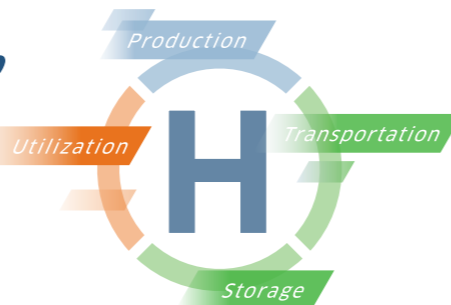
(Left) On March 11, 2011, the MGWTP was severely damaged by a giant earthquake and a tsunami which swept away much of its equipment and facilities. After the tsunami subsided, the blower bodies and pipes were found submerged in seawater inside the blower/pump station building, while floating debris had damaged various pieces of equipment. (Right) A temporary blower/pump station building was constructed in October 2012, housing two of 11 submerged blowers which had been disassembled, repaired, and reassembled, as well as a prototype of the MAG Turbo M35.



Hydrogen-Based Society Moving Forward!



GO! GO! Developers' Voices Hydrogen Road



That which drives forward Kawasaki's endeavors to realize a hydrogen-based society is a commitment to "pioneering the future," made by each employee involved in hydrogen projects. SCOPE's editorial team asked six employees who are at the forefront of various development projects to share their thoughts and aspirations regarding hydrogen as an energy source.

"Hydrogen is a 'clean' form of energy that produces no CO₂ when used. It can be produced from many different resources around the world via a variety of methods, and can be transported and stored in various forms. Since Japan is a country with limited natural resources, the use of hydrogen could contribute to enhancing its national energy security."

Sayaka Yagi
Project Development Department
Hydrogen Project Development Center
Corporate Technology Division



Ms. Yagi is in charge of liaising mainly with the Hydrogen Council, a global initiative of private companies promoting hydrogen deployment. She comments, "Collaboration on a global scale is a prerequisite to increasing the deployment of hydrogen. While each country and corporation has its own interest and focus, I would like to drive forward our hydrogen business by communicating to others the Company's vision and approach."

"Nature is irreplaceable. To pass it on to the world's future generations, I'd like to establish technologies for hydrogen use to realize a world where clean energy can be used freely!"

Yuichi Emi
Project Control Department
Hydrogen Project Development Center
Corporate Technology Division



Mr. Emi is in charge of project management for demonstration testing at the liquid hydrogen loading/unloading terminal on Kobe Airport Island. He thinks that using hydrogen allows us to transport energy over longer distances and store it for a longer term than electricity. "Because my wife and I both love to travel, we'd like to see the natural sceneries we've encountered in the world preserved, using clean hydrogen energy."

"When hydrogen is combusted, it becomes water, and when water is decomposed, hydrogen is once again released. This reversibility of hydrogen that allows for repeated use as an energy carrier, as well as its sustainability, is a true gift for the future."

Keisuke Nakagawa
Industrial and Hydrogen Plant Department
Industrial Plant Engineering Group
Energy System & Plant Engineering Company



Mr. Nakagawa is designing a hydrogen liquefaction plant. As the world increasingly shifts from mass consumption to practicing the 3R's (reduce, reuse, and recycle), he is concerned that the energy sector overall is lagging behind in the development of technology that improves reversibility in energy. "Hydrogen is reusable, semi-permanently, so we are working to realize its use on an industrial scale."

"In considering the future of my own two children, who were born recently, the use of hydrogen energy has become a theme that is a lot more relevant to me than it was before!"

Takuto Naoe
R&D Department of Liquefied Hydrogen Carrier
Engineering Division
Ship & Offshore Structure Company



Mr. Naoe is designing the electrical portion of the hydrogen-related equipment for our pilot liquefied hydrogen carrier currently being built. He and his wife lived in Hokkaido until they graduated from university, and he comments, "My children were born close together, and their births reminded me of how precious it is to live in Hokkaido where the beauties of nature and clean air are preserved. My approach toward my work changed dramatically at that time, too, because I had an increased desire to preserve the environment for the sake of our children's future."

"Some consumers still feel hesitant or have misunderstandings about the transition to hydrogen energy. Establishment of a reliable hydrogen supply chain should convince such people that hydrogen is the energy of the future."

Chie Komori
Project Development Department
Hydrogen Project Development Center
Corporate Technology Division



Ms. Komori is responsible for negotiating with our project partners in commercializing a series of liquefied hydrogen supply chains, in which hydrogen is produced and liquefied overseas and then transported to Japan by a liquefied hydrogen carrier where it is unloaded and distributed. She says, "My father was a solar power engineer, and he was very happy to hear that I was going to be involved in the hydrogen business. He has been supportive of me, and to carry out his wishes, I'd like to contribute to establishing a stable supply of clean energy."



"I think hydrogen energy leads to a brighter future. Because hydrogen-related equipment uses a variety of innovative technologies, their effects need to be carefully checked from different angles. Our checks are therefore performed in the context of actual hydrogen usage, which we do to realize a safe and clean hydrogen-based society."

Tetsuya Taguchi
HSE & Standard Promotion Department
Hydrogen Project Development Center
Corporate Technology Division



Mr. Taguchi is responsible for evaluating the safety of liquefied hydrogen carriers. He collaborates cross-divisionally to develop processes for safety evaluations. He says, "In the future, I'd like to apply to other Kawasaki products the methods we are currently developing to ensure the safe use of hydrogen."

NOW UPLOADED!

"カワル、サキへ。* Changing forward" Check out our new video, "Hydrogen-Based Society"!



"We wish to remain as an innovative creator, always changing, seeing one step ahead and transforming fast enough to keep up."

A series of short movies — "カワル、サキへ。Changing forward" — is on Kawasaki's official YouTube channel. They express the Company's strong determination to lead the world in times of change. In the "Hydrogen-Based Society" episode, we feature efforts made by our employees to realize a society reliant on hydrogen energy. Please enjoy this short movie, which contains rare footage, such as scenes from the construction of our liquefied hydrogen carrier.



"カワル、サキへ。Changing forward" Special Site

<https://global.kawasaki.com/en/stories/articles/vol47/#hydrogen>

* Reads KAWA-ru, SAKI-e



High-Performance, Twin-Engine, Multipurpose Helicopter BK117 D-3



Commentary by
Dr. Kensaku Hazawa (left)
 Senior Staff Officer
 Future Helicopter Project Section
Tomoko Hattori (right)
 Future Helicopter Project Section
 Future Helicopter Project Planning Department
 Helicopter Project Group
 Aerospace Systems Company
 Kawasaki Heavy Industries, Ltd.

New Concept 1

Five-Blade Main Rotor Reduces Vibrations and Improves Flying Comfort

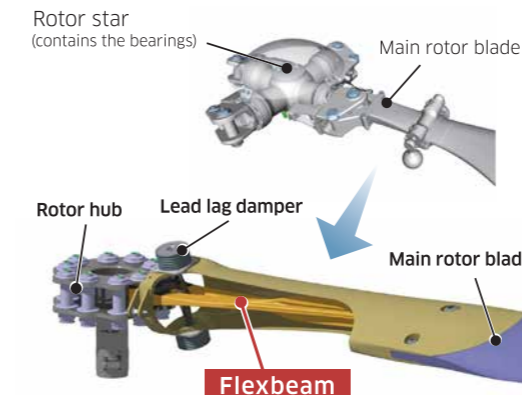
The revolution of rotor blades creates distinctive vibrations, with the principal vibration frequency of the helicopter per revolution determined by the number of blades. In addition to adopting a new rotor system, the increase in the number of blades from four to five — thus changing the vibration frequency — has optimized the helicopter's vibration and attained improved flying comfort. Pilots also give high ratings to its maneuverability. The five-blade feature, which comes from foundational research done by Airbus, contributes greatly to reducing total weight. Thanks to this feature, the D-3 is free of the anti-vibration device which is found under the cabin floor of the D-2.



The blade used for the five-blade design is packed with cutting-edge technologies

New Concept 2

Simple Yet Robust Bearingless Rotor Hub Structure Enables Easy Maintenance



In designing the BK117, bearings were adopted for the rotor hub mechanism, which rotates the main rotor by transmitting to it the power of the engine. The lubrication provided by these bearings allows the angle of the rotor blades to change, in order to generate aerodynamic lift. However, the D-3 adopted a bearingless rotor hub, reducing the number of parts while achieving reduced vibrations with its five-blade rotor design.

With this new design, a soft but high-strength structural element called the "composite flexbeam" is installed at the inner end of each rotor blade. This element allows the angle of the rotor blades to change as needed to generate aerodynamic lift.

With no bearings, the hub became structurally simpler, requiring no lubrication system or disassembly process for maintenance. This helps extend the intervals between inspections and maintenance, as well as reducing the helicopter's weight. Another Kawasaki helicopter which has already adopted the bearingless design is the OH-1.

Significantly Increased Useful Load and Reduced Vibration Achieved

The BK117 D-3 is the latest model of the BK117 Series of multipurpose helicopters, jointly developed by Kawasaki and Airbus Helicopters. The D-3 has recently been awarded a type certificate by the European Aviation Safety Agency (EASA) and the first domestically-produced helicopter is expected to be ready for delivery in the spring of 2021.

While the D-3 inherits excellent high-altitude hovering performance and state-of-the-art avionics (electronics) from the previous model, the D-2, the following functionality improvements have been made: 1) An increase in the number of main rotor blades from four to five, 2) Adoption of a bearingless design for the rotor hub, and 3) An increase of 150 kg in the useful load.

The five-blade main rotor achieves reduced vibration of the aircraft, and the simpler, bearingless hub structure allows for longer intervals between inspections/maintenance. This design has also reduced the aircraft weight by almost 50 kg, which, coupled with a 100 kg increase in the maximum take-off weight, has increased the helicopter's useful load by 150 kg. Such improvements translate into an increased capacity for transporting people and goods, resulting in significant benefits to operators and customers.

Since delivery of the first BK117 in 1983, the rotorcraft has undergone a series of upgrades, making it a product of high technological value and reliability that can be utilized in a wide range of missions, including emergency medical services (EMS), firefighting, and disaster relief. This medium-size, twin-engine BK117 Series has become a global best-seller, with deliveries made by Airbus and Kawasaki combined surpassing 1,600 units.

Under Development

Foldable Rotor Blades for Compact Storage

Currently under development is a new optional feature that allows for the five rotor blades to be folded, so that the helicopter's width and length can be reduced to fit in a small hanger.



Offers greater comfort and convenience

Kawasaki's Superior Technology

BK117 Series's Signature Roomy Cabin and Double Clamshell Doors

The optimized structure of the frame and skin panel allows for seamless configuration of the cabin and cargo room, realizing a fully-flat floor and a roomy passenger space. The electrical wiring, oil pipes, etc. are installed behind a thin wall — a prominent design technique of Kawasaki. Easy access to the cabin through the double clamshell doors at the rear is a feature highly rated by EMS helicopter operators.

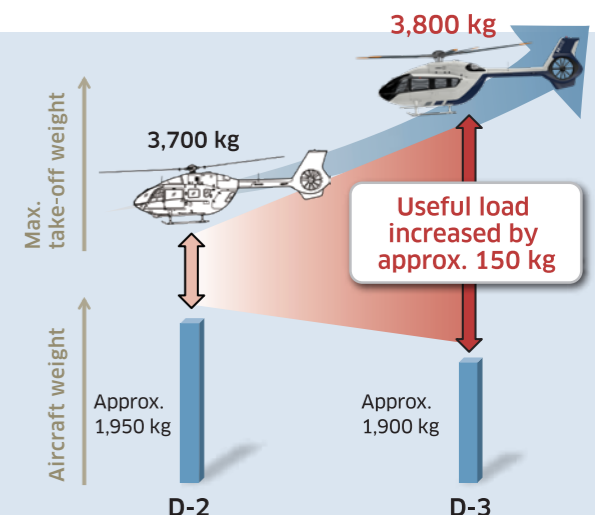


Offers Wider Operational Flexibility

Useful Load Increased by 150 kg

The D-3 has achieved an increased maximum take-off weight (the weight allowable for flying, including the aircraft itself, passengers, and other items) of about 100 kg. In addition, its total weight was reduced by about 50 kg, thanks to adoption of the new hub design, resulting in an overall increase of 150 kg in useful load. This improvement enables the D-3 to rescue more people during disaster relief, and to carry more medical equipment and healthcare professionals on EMS missions. It also allows for more fuel to be loaded, providing operators with greater operational flexibility.

Note: The weight of the D-2 in the diagram is inclusive of the LAVCS vibration control system.



Kawasaki Group Vision 2030

Trustworthy Solutions for the Future

Frontier

Pioneering the technology frontier with our challenger "DNA"

New Values

Providing innovative solutions to the problems facing the world

Cross Over

Becoming a creative challenger that continues to grow by breaking barriers

Kawasaki Announces "Group Vision 2030," Focused on Three Key Themes to Resolve Global Challenges

On November 2, 2020, Kawasaki held a public briefing regarding its new "Group Vision 2030: Trustworthy Solutions for the Future," which outlines what the Company aspires to be by the year 2030.

Group Vision 2030 delineates specific directions as to how we plan to achieve our corporate slogan "カワる、サキへ。" Changing forward." It represents our determination to make available, in a timely manner, innovative solutions which accommodate an ever-changing society, in order to create a hopeful future, and — with great agility — to take up challenges independent of organizational and divisional boundaries to expand the horizons of our potential for further growth.

In the Vision briefing on November 2, Kawasaki President Yasuhiro Hashimoto stated that "Frontier," "New Values," and "Cross Over" were the three key themes. Kawasaki will be focusing on to fulfill the Group Vision.

"Frontier" expresses that, since our founding, we have been fostering a "DNA" characterized by a spirit of pioneering which draws on our unique perspective, and in light of this background, we will continue to respond to the frontier of this new era's social challenges, based on that unique perspective, in order to create a hopeful future.

"New Values" represents our commitment to provide innovative solutions for various challenges facing the world by consolidating the trustworthy technologies and knowledge that we have cultivated, and to offer additional value to our customers and other stakeholders by responding swiftly to societal change.

"Cross Over" describes our determination to provide innovative solutions to social challenges by continuing to be an open-minded, free-thinking, and creative team that goes beyond the boundaries of internal and external organizations and of product and service categories, leveraging our rich

diversity. Moreover, we will keep growing as an organization and as individuals by expanding our potential, through boldly taking up challenges in unfamiliar domains and learning from the experience.

To fulfill these key themes, President Hashimoto listed three business fields that the company will be focusing on: "A Safe and Secure Remotely-Connected Society," "Near-Future Mobility," and "Energy and Environmental Solutions." He also set forth plans for transforming Kawasaki's business structure, targets to work towards, and a growth scenario for achieving those targets.

Regarding a personnel training program which supports growth, he emphasized that the Company is committed to "introducing a new personnel system to promote the growth of young employees, and increasing cross-Company personnel transfers and interactions to help employees experience various businesses and to encourage further personal growth. By doing so, we will generate a synergy between various businesses and expand our comprehensive capabilities."

* Reads KAWA-ru, SAKI-e



A scene from the briefing

Please take a look at our "Group Vision 2030 Concept" video, by accessing the link or the QR code.

https://global.kawasaki.com/en/corp/newsroom/news/detail/?f=20201102_6625



HOT TOPICS

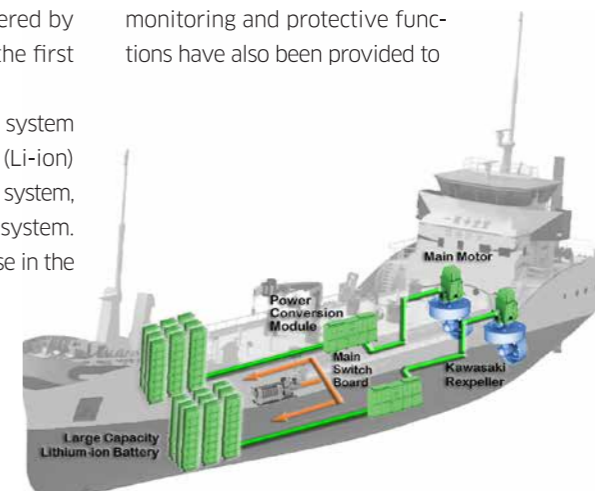
Kawasaki Receives First Order for Coastal Ship Large-capacity-battery Propulsion Systems

In October, Kawasaki received an order for large-capacity-battery propulsion systems designed for use in coastal vessels. The systems will be used on two zero-emission electrically propelled tankers*1 ordered by Asahi Tanker Co., Ltd., and will be the first ships of their kind worldwide.

Each Kawasaki battery propulsion system includes large-capacity lithium ion (Li-ion) marine batteries, a propulsion control system, and an electric power management system. Kawasaki made full use of its expertise in the

field of systems integration to realize a system that efficiently supplies power and electricity to the main propulsion system and auxiliary equipment. Irregularity monitoring and protective functions have also been provided to

safeguard the entire system, including the Li-ion batteries. In addition, Kawasaki utilized their electric power system experience in the generator field to make this system also usable as an emergency power supply source*2 in the event of a large-scale natural disaster, thus providing support for business and daily life continuity plans.



Large-capacity-battery propulsion system to be used on the world's first zero-emission electrically propelled tankers (major component diagram)

*1 Zero-emission electrically propelled tankers planned and designed by e5 Lab Inc. for purposes of developing similar ships and promoting their widespread use. These two vessels in particular are slated for use in ship refueling operations within Tokyo Bay. The ships will be built by KOA SANGYO CO., LTD. and IMURA SHIPYARD CO., LTD.
*2 This idea was originally proposed by e5 Lab and Asahi Tanker.

SEPERNA is Kawasaki's New Ventilation System Using Gas-Permeable Membrane Technology

Kawasaki has developed a new ventilation system, SEPERNA*, which uses gas-permeable membrane technology to create a comfortable indoor environment for office buildings and other similar areas. Through the use of a demonstration machine, the system has been shown to have excellent air purification performance.

Using a gas-permeable membrane with micropores several times larger than the diameter of gas molecules, SEPERNA succeeded in releasing indoor carbon dioxide outdoors without the use of the filters that are essential for conventional ventilation systems, and without allowing outside airborne particles to come indoors. In addition, by utilizing air with appropriate temperature and humidity, the power consumption required to control the temperature and humidity of the ventilated air can be reduced. It is also expected to be effective in eliminating aerosolized droplets.

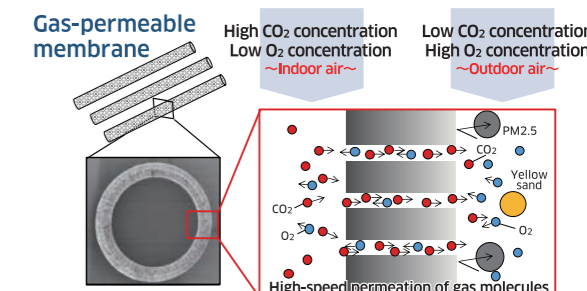
The effectiveness of the system will be verified by the SEPERNA demonstration machine. At the same time, Kawasaki will continue research and development to further improve the performance of this gas-permeable membrane. The goal is to miniaturize the equipment, in order to apply it not only in

office and commercial buildings, but also in a wide range of environments such as houses, hotels, and transportation facilities, including passenger ships.

* The system was named by combining the first letters of SEparation, PERmeation, and NATural, the words associated with the concept of advanced air cleaning using a gas-permeable membrane.



New ventilation system using a gas-permeable membrane (Demonstration machine)



Cross section of a gas permeable membrane (Outer diameter: approx. 2mm)
Membrane cross section (Enlarged view)
Mechanism of air purification using a gas-permeable membrane (Simplified images)

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