Kawasaki Heavy Industries, Ltd.

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Scope
Kawasaki Heavy Industries Quarterly Newsletter
No. 118 Winter 2019
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Special Feature

Gears Are at the Core of Aircraft Technology

The Aircraft Gear Business at Kawasaki Heavy Industries

カワる、サキへ。
Changing forward

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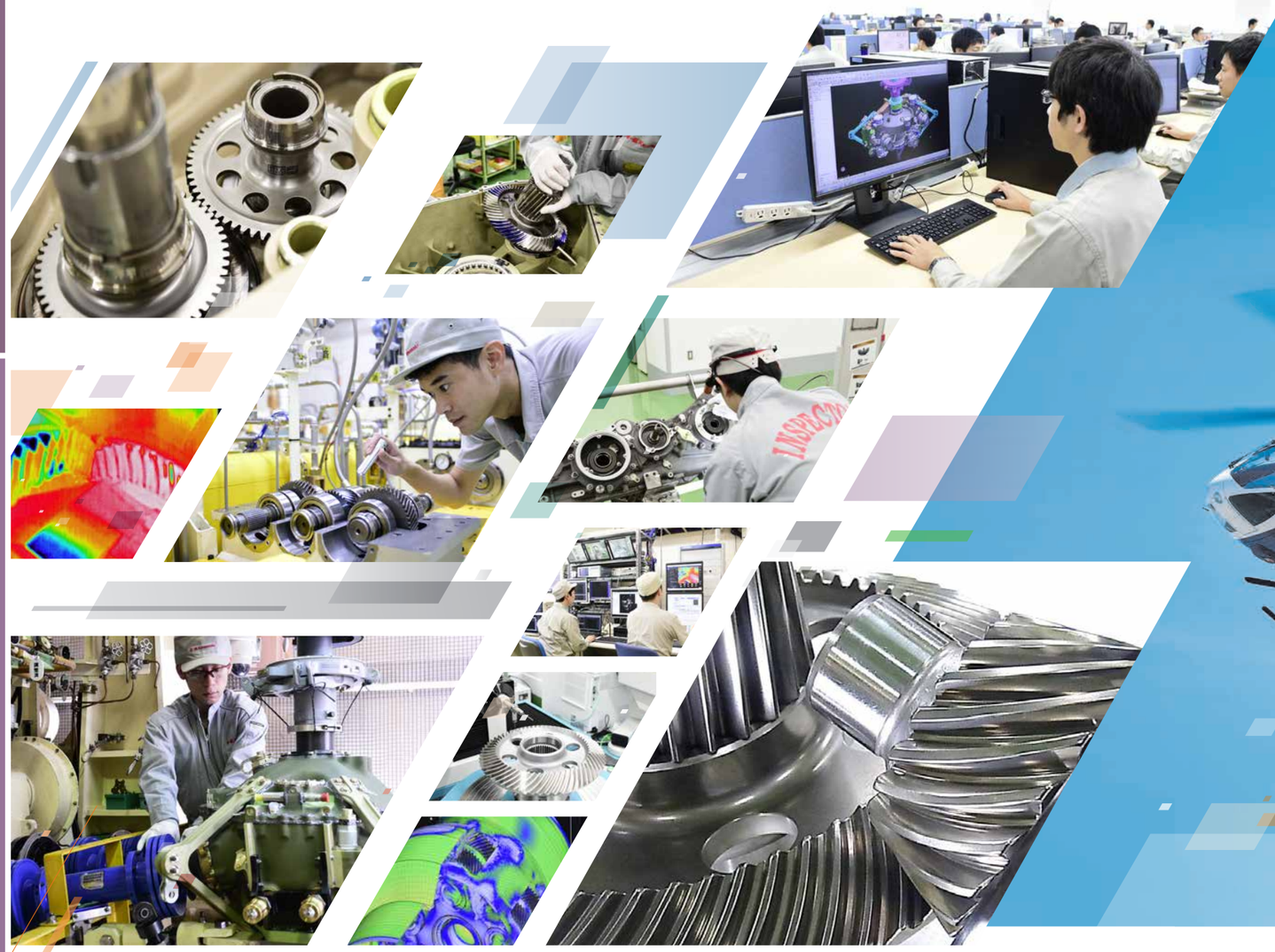
A scene from attitude testing for the accessory gearbox (AGB), conducted by simulating various attitudes during flight (up/down/left/right). For details, see *Special Feature* (page 2).



Gears Are at the Core of Aircraft Technology

The Aircraft Gear Business at Kawasaki Heavy Industries

One business in particular at Kawasaki Heavy Industries is gaining momentum—the aircraft gear business. Aspiring to be an excellent company in this sector, Kawasaki offers an impressive array of products, including transmission systems for helicopters, accessory gearboxes, and aircraft power generation systems. In this issue, we bring you a story featuring the core technology behind aircraft gears, for which Kawasaki is known as a vital provider in the aircraft business.

Unrivaled Reliability of Kawasaki Gear Products

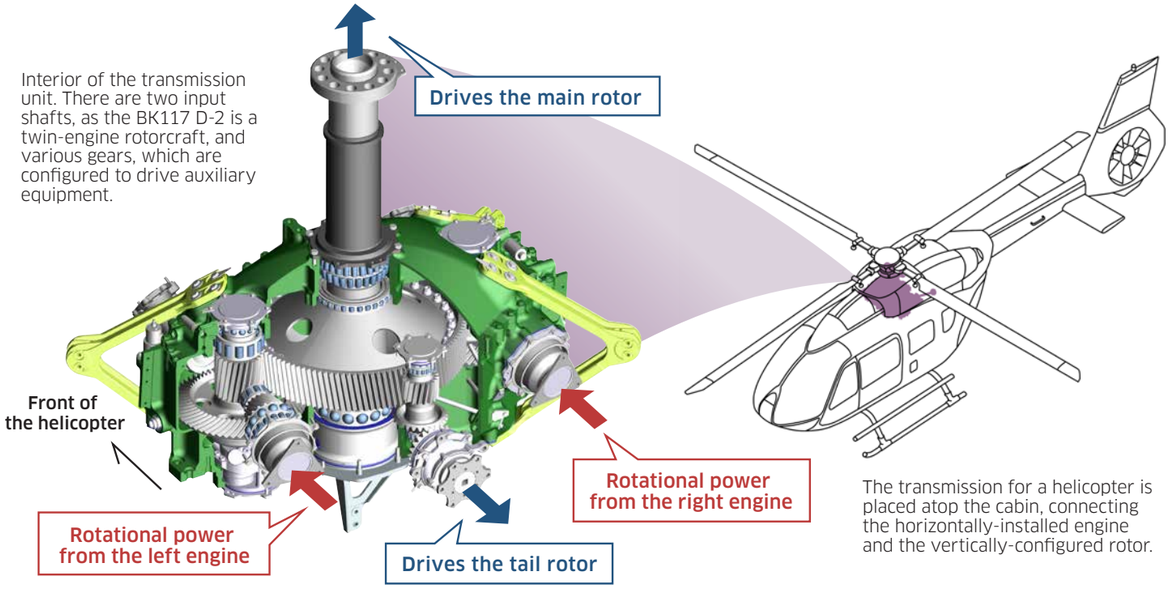
The Aerospace Systems Company of Kawasaki has been steadily increasing its gear-related product portfolio. Starting with the development of helicopter transmission systems, it expanded into accessory gearboxes (AGB) that drive auxiliary hydraulic, electric, and air-conditioning equipment, and proprietary traction-drive integrated drive generators (T-IDG™), a power generation system for aircraft. Kawasaki now boasts the industry's most extensive lineup of aircraft gear products.

Most aircraft engine manufacturers work collaboratively with gear manufacturers in developing engine systems. In this regard, Pratt & Whitney has been partnering with Kawasaki in developing advanced systems.

In the 1960s, Kawasaki embarked on the development of helicopter transmission systems as part of its larger project to develop helicopters in-house, which later became one of the mainstays of its aircraft business. In a joint development project with Messerschmitt-Bölkow-Blohm (present-day AIRBUS) that began in 1977 for the BK117 helicopter, Kawasaki was tasked with the development of the most critical component—the transmission system. Thanks to its reliability and durability, this system contributed to making the BK117 one of the best-selling helicopters in the world and helped establish the foundation for Kawasaki's growth in the aircraft business.

A helicopter transmission is installed atop the cabin and performs the following operations: 1) transfers power from the engine to the main rotor (rotor blade) and the tail rotor after stepping down the speed; 2) drives accessories; and 3) transfers the lift generated by the main rotor to the helicopter body, and receives the thrust force as well as the drag force that acts in opposition to the direction of movement.

In the BK117 D-2, the transmission steps down an engine speed of 6,000 rpm to 380 rpm (a reduction ratio of about 16:1), and at the same time increases the torque to 19,600 N·m to drive the main rotor. This is a remarkable torque capacity, sufficient to lift two passenger cars attached to the end of a 1-meter-long bar.



The transmission for a helicopter is placed atop the cabin, connecting the horizontally-installed engine and the vertically-configured rotor.

To be more specific, the rotary shafts from a pair of engines that generate a total of 1,000 horsepower are coupled to spiral bevel gears that change the direction of rotary motion by 90 degrees, and simultaneously reduce the engine output speed. After the directional change, the rotational speed is reduced by a helical gear on the second stage, resulting in an optimal rotor speed. Other Kawasaki designs use planetary gears to make them more compact, which can achieve a weight-to-horsepower ratio (weight divided by net horsepower) of less than half of an automobile transmission.

From Machining to Final Inspection: The World's Top Provider of One-Stop Gear Manufacturing

Achieving lightweight gears demands the utmost effort at thinning without compromising durability. The gears can be as thin as 2 mm, and yet transfer a tremendous amount of power. Gears with lightening holes are inevitably prone to deformation, and yet their tooth shape requires an accuracy at the level of micrometers (μm, which equals 1/1000 millimeter).

Masahiro Gouhashi of the Production Engineering Division comments: "The way gears deform varies, depending on their shape and type of machining process. Therefore, the key to producing accurate gears is minimizing deformation, so that the complex, delicate shapes the designers had first envisioned can be achieved."

In gear production, the first step is to cut a round gear blank using special machining equipment with a cutter exactly the same shape as the desired teeth. The gear then undergoes a carburizing and quenching process, through which the gear surface absorbs carbon and hardens, followed by a grinding process whereby the teeth are ground to a μm level of precision. The skillful operation of this special equipment is another key expertise required by the manufacturer. Finally, to improve resistance to fatigue, small steel beads are blasted against the surface—a process called "shot peening."

In the inspection process, nondestructive tests are performed repeatedly. These include "nital etch testing," which uses a special chemical solution to ensure that the strength of the gear has not decreased due to excessive temperature rise during the machining and grinding processes, and "magnetic particle inspection," which, by magnetizing the gears, detects micro-cracks at the surface that cannot be found in a conventional visual inspection.

Speaking of the comprehensive capabilities Kawasaki exhibits, Gouhashi says, "The most notable feature of our aircraft gear manufacturing is that we are in possession of expertise encompassing the entire process of gear manufacturing—from machining and heat treatment to final inspection—to make sure that no defects in hidden areas go undetected. In the aircraft gear sector, this comprehensive expertise is what gives us a competitive edge in the global arena."


1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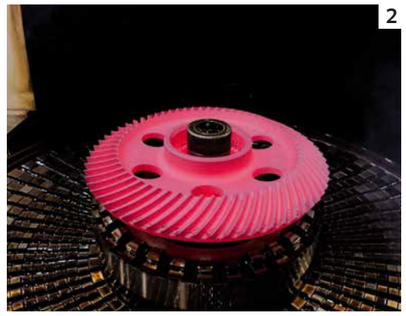
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4

Gear-manufacturing process: 1) Gear is machined from a gear blank, 2) undergoes carburization and quenching processes for surface hardening, 3) is ground to an accuracy of 1 μm, and 4) is inspected for finishing accuracy using special equipment.

Masahiro Gouhashi
Assistant Manager
Engine Production Engineering Section 1
Engine Production Engineering Department
Production Engineering Division
Aerospace Systems Company
Kawasaki Heavy Industries, Ltd.

Outlook Bright on Achieving 60-Minute "LOL (Loss of Lubrication)" Operation

The development divisions experience different challenges in helicopter transmissions than those faced by the manufacturing divisions. This is because the design engineers are tasked not only with improving the precision and performance of individual gears, but also with upgrading the entire transmission into a high-precision, high-performance component of the helicopter, all of which requires a variety of technological innovations. This includes development of bevel gears that can handle faster rotational speeds and greater horsepower, and mechanisms to minimize the vibration that light, thin gears are prone to generate.

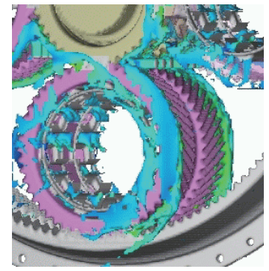
Scenes from the transmission assembly. A shaft in the upper part drives the rotor (left). Gear meshing and cleanliness are rigorously checked during an inspection conducted before assembly of the accessory gearbox. The inspection process is recorded by a camera attached to the cap of the inspector (below).

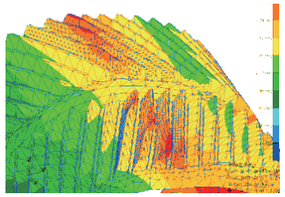
In recent years, demand has been on the rise for improved LOL performance, which is the capability of continuing to fly after loss of lubricant in the transmission. This was originally required for military helicopters, to enable them to reach a safe location in the event that they experienced ballistic damage and were faced with a sudden loss of lubricating oil. However, this safety measure is now vital for media and emergency helicopters as well, as they often fly in urban areas where landing space may not be readily available. Commercial aircraft are required to have a 30-minute LOL capability, but an even longer operation is called for to ensure the safety of aircraft flying between offshore oil fields and onshore terminals. According to Kenta Ogasawara of the Commercial Engine Project Division, "Improved technology is providing a good outlook for Kawasaki to achieve a 60- to 70-minute LOL capability, and a demonstration test is planned for the end of fiscal 2018."

Kenta Ogasawara
Assistant Manager
Drive System Engineering Section 1
Drive System Engineering Department
Commercial Engine Project Division
Aerospace Systems Company
Kawasaki Heavy Industries, Ltd.

Key to achieving such duration is cooling. A transmission configuration and structure which will preclude the overheating and seizing of gears and bearings is being developed. In addition, materials with greater seizure resistance are being selected. At Kawasaki, it is now possible to optimize gear shape and bearing configuration by means of computer simulation, which allows the simulation of temperature changes in transmission gears in the event of LOL.

"We hope that this technology will lead to future transmission development with innovative concepts," adds Ogasawara.





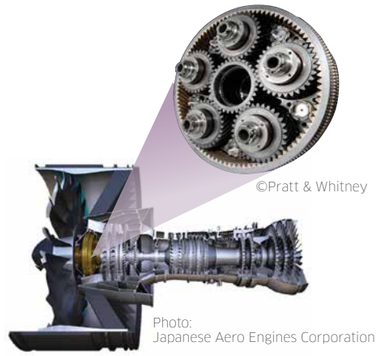
Improvement in computer simulation technology directly enhances the company's competitiveness. The shapes of the transmission's interior components, the flow of lubricants, deformation of gear teeth, and other factors are simulated to achieve optimal design of the transmission.

Fan Drive Gear System (FDGS) Is "Heart" of New Engine

At Kawasaki, proactive strategies are being implemented to tap into a promising market involving an FDGS for a geared turbofan (GTF) engine that was developed by Kawasaki's partner, Pratt & Whitney.

Fans for passenger aircraft turbofan engines have been increasing in size in order to attain higher fuel efficiency. However, due to differences in the rotational speeds of the fans and the optimal rotational speeds for the turbines and compressors which drive them, further enhancements in engine performance were deemed challenging. A breakthrough in this stalemate was the GTF engine, which inserts a gearbox between the fan and the turbine, allowing each component to achieve optimal rotational speeds.

In the GTF engine, the FDGS uses planetary gears to accommodate its coaxial input and output shaft design, and to make it more compact and lightweight. The engine is also designed to produce 20,000 horsepower (hp), which far exceeds the engine output of helicopters, and to attain longer than the required 30,000 hours of reliable operation.



©Pratt & Whitney

An FDGS (a gear system for a geared turbofan, right) for a next-generation open rotor engine will be driving more complex counter-rotating propellers (left).

Photo: Japanese Aero Engines Corporation

Kazuhiro Sato, who leads the development project, comments, "With such huge horsepower, even a 1% loss of energy, about 200 hp, will generate 150 kW of heat. This not only compromises the most important factor—fuel efficiency—but also poses serious challenges involving the oil for cooling and the weight and size of heat exchangers."

This is why, in addition to being lightweight and compact, the FDGS must be designed to minimize losses from gear friction and oil churning. According to Sato, oil and gas mix and flow in a very complex way inside the FDGS, and Kawasaki possesses the world's most sophisticated technology to computer-simulate this flow. Moreover, the company has developed a proprietary technique that not only optimizes the flow, but also maximizes the lubrication and cooling effects. As a result, an energy efficiency of 99.6% has been achieved.

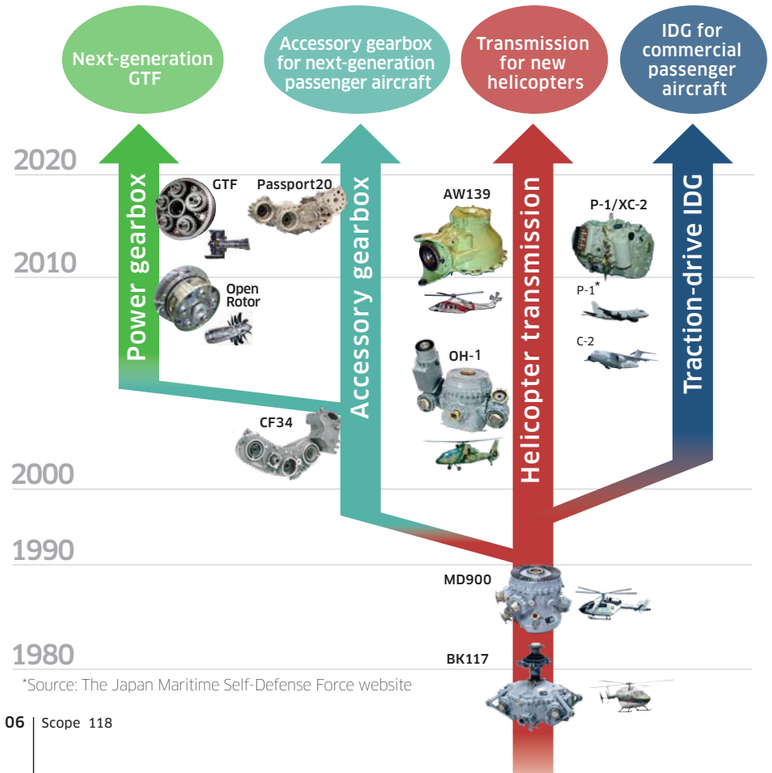
"Kawasaki's proprietary technologies were all developed in conjunction with the Corporate Technology Division in the course of a research project to develop a gear system for open rotor engines whose commercialization is expected to take place after 2030: in other words, in an engine development project already focused on the next generation after GTF engines. Based on the expertise gained, we would like to continue to upgrade our technological prowess and propose further innovations," adds Sato.

Transmissions and FDGS are behind-the-scenes systems. However, without them, the safe flight of aircraft is impossible. Gears are, indeed, at the core of aircraft technology.

Kazuhiro Sato
Drive System Engineering Section 1
Drive System Engineering Department
Commercial Engine Project Division
Aerospace Systems Company
Kawasaki Heavy Industries, Ltd.

Aircraft Gear Development Chronology for Kawasaki Heavy Industries

Cumulative shipments: 12,869 units (as of September 30, 2018)



*Source: The Japan Maritime Self-Defense Force website

From the Project Team

Dr. Tatsuhiko Goi
Fellow, Gear System Technology, Aerospace Systems Company, Kawasaki Heavy Industries, Ltd.

Aiming to Become the Dominant Player in the Global Aviation Market by Leveraging Our Aircraft Gear Technologies

Fundamentally, gears are used for efficient transfer of energy. The more we try to enhance that efficiency, the more important the roles of gears become. They are parts that demonstrate great potential for innovative technologies.

The aircraft gear business at Kawasaki was launched with the licensed production of helicopter transmissions. After that, in conjunction with the Corporate Technology Division, the Aerospace Company tackled various challenges to develop unbeatably high-performing and reliable products based on proprietary technologies. These achievements are attributable to our integrated manufacturing process, covering all phases from development to manufacturing, and allowing the sharing and solving of problems that arise in between phases. A proactive corporate culture that has encouraged engineers to take on new challenges was another contributor.

As a result, technologies originally associated with helicopter transmissions have evolved to a level that is now applicable to the accessory gearboxes that drive auxiliary equipment, the traction-drive integrated drive generator (T-IDG™) that is driven by the aircraft engine to generate electrical power, and now, future technology—the FDGS. These technologies are indispensable to the operation of aircraft, and, considering the future growth of the aviation industry and the expansion of gear applications ("gearification"*), our gear business has great potential for growth and is expected to become one of the pillars of the Aerospace Systems Company.

In the aircraft sector, continuous efforts are being made to reduce fuel consumption and emissions, and eventually there will come a time when more advanced GTFs, open rotor engines, and other next-generation engines are the only options. Even when such trends become prevalent, gears will still be pivotal parts. Without gears, there would be no next-generation engines.

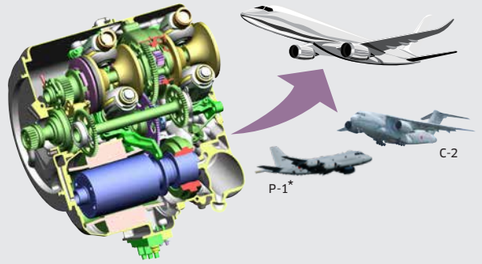
The drivers of new aircraft industry trends are prominent U.S. and European manufacturers. However, in terms of gear technology that can turn these trends into reality, or which serves as the backbone of innovation and demonstrates great potential in creating technological breakthroughs, Kawasaki is the world leader. In my opinion, it is not an overstatement to say that Kawasaki's technological innovations drive forward the new trends. Indeed, those who rule the gears, rule the world.

* "Gearification" is a term coined to mean "using gears to drive fans."

Looking Forward to Tomorrow

T-IDG™ Supports Progressive Electrification of Aircraft

In an aircraft, electricity for flight equipment and facilities is supplied from a generator driven by the engine. The generator, which is installed on the accessory gearbox of the engine, is an integrated drive generator (IDG) which houses a constant-speed drive unit: in other words, a CVT (continuously variable transmission). Being integrated with the CVT, the generator always rotates at a constant speed and provides the aircraft with constant-frequency power even if the engine speed changes.



*Source: The Japan Maritime Self-Defense Force website

A hydro-mechanical CTV is commonly used for IDGs. However, Kawasaki's newly-developed T-IDG™ has a high-speed traction-drive CVT, which is the first in the world to be applied as a constant-speed drive unit for aircraft. T-IDG™ was selected as the main generator for the P-1 maritime patrol aircraft and the C-2 transport aircraft of the Japan Ministry of Defense. To transmit power, a traction-drive CVT utilizes the viscous resistance of oil film, reducing losses as compared with conventional hydraulic CVTs. It also offers better durability because no contact friction occurs between parts. To meet the increasing demand for "more electric aircraft" (MEA), Kawasaki is accelerating its efforts to develop T-IDG™ with greater capacity, in order to introduce products to the commercial aircraft market.

Kawasaki LPG Carriers:

An Innovation-Studded History Demonstrating Expertise in Shipbuilding Technologies

Liquefied petroleum gas (LPG) carriers transport LPG composed primarily of propane and natural gas processing. Looking at the history of LPG carriers, one can tell that Kawasaki has always been a pioneer in innovation.

1st Generation
(1969 - 1983)

BRIDGESTONE MARU NO.5

This vessel was the first to apply the semi-membrane tank system which was jointly developed by Kawasaki and Bridgestone Liquefied Gas Co., Ltd. (the company's name at that time). In this tank system, the tank is self-supporting when empty, but when fully loaded, it expands as a result of hydraulic pressure and its load becomes supported by the ship's hull—a unique design which became one of the world's leading tank systems. Eight ships have been built by Kawasaki.

2nd Generation
(1990 - 2003)

PACIFIC HARMONY

Improvements in materials used for cargo tanks and in accuracy of stress analysis made the development of the independent tank system possible. This tank system allows the tank itself to support the cargo's liquid load. Adoption of the new tank system also proved effective in shortening the shipbuilding period, and the first vessel equipped with the system, *Pacific Harmony*, was completed in just 19 months. The vessel also achieved an impressive cargo capacity of 84,000 m^3. Kawasaki has built 23 ships in the past dozen or so years.

3rd Generation
(2003 - 2019)

CRYSTAL MARINE

The next innovation added to the independent tank system, and which resulted in our next-generation LPG carrier, was a new bow shape called the SEA-Arrow. SEA-Arrow halved the bow wave resistance and decreased the main engine horsepower by 6-10% compared to conventional LPG carriers moving at the same speed. Characterized by the replacement of the mainstream bulbous shape with an innovative design, SEA-Arrow achieved outstanding propulsive performance. The number of LPG carriers built with SEA-Arrow has reached 24 and is still increasing.

New Generation
(2019 -)

LPG-powered LPG carrier

The next-generation LPG carrier will be designed to achieve large-capacity transport using LPG as fuel, while fulfilling various marine transport environmental rules and regulations. It should also be able to enter LPG terminals used by existing carriers. Kawasaki has already developed the specifications and basic design, and when completed, the ship will be a showcase of Kawasaki's shipbuilding expertise. Robust marketing activities for the new ship are already underway.

Building a vessel for transporting LPG or liquefied natural gas (LNG) requires sophisticated cryogenic technologies, which include material selection for the tanks, structural considerations, thermal insulation, and treatment of boil-off gas. Such expertise is considered one of the barometers for judging the level of a manufacturer's shipbuilding technology.

The first Kawasaki-developed LPG carrier, *BRIDGESTONE MARU NO.5*, was built in 1969 with a structurally novel tank called a "semi-membrane tank." Installed in the insulated double hull, this cubic tank was made of thin (8-10 mm) low-temperature-service steel plates and had no structural members. This ingenious design resulted in Kawasaki winning The Okochi Memorial Prize, which is considered the highest honor in manufacturing. Since then, the semi-membrane tank has become one of the global standards of cargo tanks.

Moving further, Kawasaki embarked on another innovative challenge in the 1990s. With an eye toward improvements in safety, analytical accuracy for stress on tank materials was improved, and to shorten shipbuilding time, the company switched its design approach to that of an independent tank system. With this tank system, independent cargo tanks are installed in the hold and the load of the cargo is supported by the tank itself.

In 2003, Kawasaki adopted a new bow shape, the "SEA-Arrow (Sharp Entrance Angle bow as an Arrow)," and led its LPG carriers into the third generation. The new bow shape reduced wave resistance by half and significantly improved the ship's propulsive performance.

Today, Kawasaki is going even further, having developed the next-generation LPG-powered LPG carrier, and implemented robust new marketing strategies. The ship was designed to reduce emissions of nitrogen oxides (NO_x) and sulphur oxides (SO_x) in marine transport and complies with updated international transport rules and regulations that demand a higher level of safety. In addition, despite the installation of larger tanks, it can enter the same LPG terminals as existing carriers without compromising on capacity—a feature that shippers expected of the new vessel. Kawasaki stays ahead of its competitors by pioneering innovation. This fundamental approach defines our strength in shipbuilding.

Techno Box 18

The 3000 Series Debuts on Kobe New Transit's

"Rokko Liner"

Commentary by

Masaru Tachibana (left)
Senior Staff officer, Domestic Bogie Engineering Section
Domestic Engineering Department, Domestic Project Division
Rolling Stock Company, Kawasaki Heavy Industries, Ltd.

Junji Kamatani (middle)
Assistant Manager, Domestic Bogie Engineering Section
Domestic Engineering Department, Domestic Project Division
Rolling Stock Company, Kawasaki Heavy Industries, Ltd.

Daichi Kosuge (right)
Assistant Manager, Design Section
Engineering Planning Department, Domestic Project Division
Rolling Stock Company, Kawasaki Heavy Industries, Ltd.

Designed to Foster a Feeling That the Rokko Liner is Part of Everyday Life

On August 31, 2018, Kobe New Transit inaugurated the use of the 3000 Series train cars on the Rokko Island Line (commonly known as "Rokko Liner"), connecting Sumiyoshi in Kobe City and Marine Park Station on Rokko Island, a man-made island with a population of about 20,000. This was the first time since this automated guideway transit (AGT) system opened in 1990 that the cars had had a model changeover. By the end of fiscal 2023, a total of 44 cars (11 sets of four-car trains) will be replaced by the 3000 Series model.

The development of the new train was entrusted to Kawasaki, which had developed the preceding 1000 Series. As a starting point in formulating the design concept, Kawasaki's project team conducted a fact-finding study on the perceived benefits of living on Rokko Island and using the Rokko Liner. This was done by organizing a web-based survey of 121 users, and holding "Co-creation Conferences" with an additional four users representing different age groups.

Based on the survey results, the team came to the conclusion that the new trains needed to foster a feeling in the users that the Rokko Liner is as much a part of everyday life as watching the beautiful dawns and sunsets from their seaside homes, or the sense of relief they experience when crossing the bridge on the way home.

As a result, the train was designed to resemble a smart-looking ship, as passengers "sail" to and from Rokko Island across the sea aboard the Rokko Liner, and as a theme color, a subdued blue-green inspired by Kobe's iconic oldest gaslamp was selected.

Also, to make the ride more comfortable and pleasant, many ideas were incorporated, such as increasing the width of the train by 14 cm on the aisle side to make it roomier, and introducing seats with openings in the backrests to allow more light to come in from the windows.

Soft-beam Lighting Illuminates Kobe at Night

To express the warm feeling of going home where your family awaits you, the cars are outfitted with a row of lights above the front window, inspired by torch light. The lights are also intended to enhance visibility from afar and give a different look from the cars' daytime appearance, to make the railway line look more attractive.

Individual Seats Permit More Light to Enter

Seats of the 3000 Series are separated individually, with openings under the backrest to let more light from the windows come through.

Seats are wide enough for large individuals

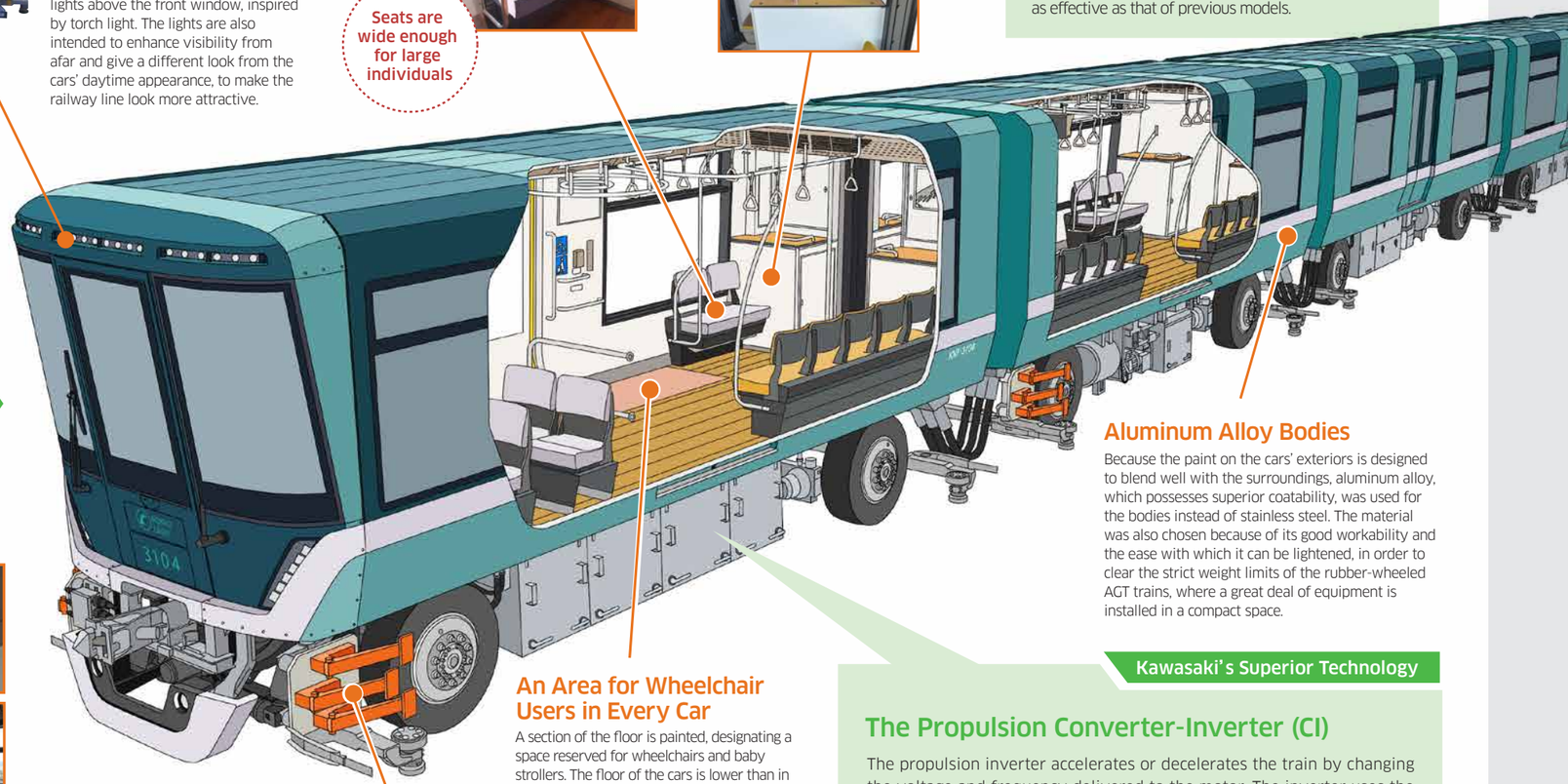
The Secret of the Luggage Holders

The luggage holders in the corners are covered with wood and have handrails. Inside this cubical space, a variety of control equipment is installed—an ingenious way to squeeze equipment into a compact area without compromising the usability of the car.

Kawasaki's Superior Technology

A Compact Space Packed with State-of-the-art Technology

Because the 3000 Series has higher ceilings, increased width, and a lowered floor to make the train roomier, space allocated to train equipment was greatly reduced. Also, the same lineup of equipment as that for the typical 18- to 20-meter long car needed to be squeezed into this eight-meter long car. Therefore, the shapes of the equipment and their layout were re-designed, resulting in more compact and higher-performing equipment that is as effective as that of previous models.



Aluminum Alloy Bodies

Because the paint on the cars' exteriors is designed to blend well with the surroundings, aluminum alloy, which possesses superior coatability, was used for the bodies instead of stainless steel. The material was also chosen because of its good workability and the ease with which it can be lightened, in order to clear the strict weight limits of the rubber-wheeled AGT trains, where a great deal of equipment is installed in a compact space.

An Area for Wheelchair Users in Every Car

A section of the floor is painted, designating a space reserved for wheelchairs and baby strollers. The floor of the cars is lower than in the 1000 Series to create barrier-free accessibility from the platform to the train.

Instant privacy glass: On (left) and Off (right)

New Levels of Safety and Comfort Attained

The new cars have large windows that allow passengers to view beautiful scenery and to enjoy a brighter ambiance. Windows facing private residences along the railway are instantly switchable to privacy (frosted) glass. Moreover, in order to ensure both safety and comfort, security cameras are installed on each end of the cars, and plasma-cluster ion air purifiers help to create a hygienic environment.

New Tire and Motor Achieve Lower Noise than the 1000 Series

Nitrogen-filled tubeless rubber tires equipped with safety cores are installed on the bogie for improved riding comfort and reduced noise. Also, the motor's cooling fan was redesigned, resulting in a 7 dB reduction in motor noise compared to the 1000 Series because of the fan's reduced aerodynamic noise.

Kawasaki's Superior Technology

The Propulsion Converter-Inverter (CI)

The propulsion inverter accelerates or decelerates the train by changing the voltage and frequency delivered to the motor. The inverter uses the cutting-edge silicon carbide (SiC) technology adopted by the most recent series of *Shinkansen* ("bullet trains"). Compared to conventional silicon (Si) power modules, the SiC power module is energy-saving because it requires no cooling fans. It also contributes to lowering noise, downsizing, reducing weight, and making maintenance easier. Our application of SiC in the inverter of an AGT system was the first in Japan.

Specifications Summary

	Series 1000		Series 3000
Width	2,370 mm	➡	2,510 mm
Height up to the ceiling	2,005 mm	➡	2,065 mm
Aisle width	1,070 mm	➡	1,250 mm (between long seats)
Capacity	176	➡	182

Ikuo Nakamura

My Journey on the Road Untraveled Has Been One of Trial and Error

When he was young, Ikuo Nakamura embarked on a career as an underwater photographer with zero experience in either diving or photography. Today, he is a first-rate specialist who records and reveals to the world previously unseen views. Even after reaching the age of 70, he is still diving and taking pictures, because, according to him, underwater stories never seem to run dry.

Self-taught Photography Entailed a Series of Trials and Errors

The goby thrives in the sludge-covered seabed of Tokyo Bay. Sea angels spread their wings and wander in the sea off Shiretoko Cape in Hokkaido. Columns of rock formed by layer upon layer of algae stand in Hamelin Pool on the west coast of Australia. The undersea worlds captured in Nakamura's photographs are always strikingly new, be they realistic or fantastic. It is scenery normally witnessed only by divers, and these pictures are capturable only at a certain place and time, and by a certain photographer.

Recalling the early years of his career, Nakamura comments, "Many underwater photographers start their career as divers or photographers, so it is rather unusual that someone like me who had no experience in diving or photography decided to do both at the same time."

He was only 19 then, and struggling to figure out what to do with his life. One day, he decided to visit Manazuru (a seaside town in Kanagawa Prefecture) and came across a group of divers who were taking underwater photos. He was not even a good swimmer and had no experience in photography, but it dawned on him, "This is it!" He emptied his small savings account and purchased skin-diving gear and underwater camera equipment.

As expected, it was not an easy start. "A snorkel mouthpiece has two protruding sections, and not knowing which went where, at first I stuck one in my nose." He was convinced, however, that even among thousands of aspiring young photographers, he could differentiate himself if he had a professional edge — the underwater world.

More than twenty years after that "inner nudge" at Manazuru, Nakamura won the prestigious Kimura Ihei Award for his works entitled *"Zen Tokyo Wan"* (All About Tokyo Bay) and *"Kaichu Ganmen Hakurankai"* (An Expo of Subsea Faces). Not only in the years up to this milestone, which he reached when he was 43, but throughout his career, Nakamura never studied photography professionally. That was his policy already before he joined an underwater photographic services company at age 24, during his years there, as well as after he became a freelance photographer at age 31. He has always taught himself and polished his artistry on his own.

Although Nakamura is best known for his underwater photography, he has also produced numerous "on land" works, including journalistic pieces, television and commercial film footage, and movies. The breadth of his technical skills and determination to master his craft are simply amazing.

"I have gotten involved in a variety of things because I love outwitting others by doing the opposite of what they expect of me. I also resented the idea of being defined only as an underwater photographer, so I organized shows and published books themed around things unrelated to the underwater world. I like to remain an unpredictable figure and let people wonder, 'What is Nakamura thinking?' or 'What is he going to do next?' rather than be labeled under one fixed category."

The Reason Why My Dream of Retirement Never Comes True

As his remarks imply, Nakamura has always tackled new challenges, and his success owes much to advancements in technology. For example, lighting equipment for underwater shooting has made significant progress in recent years, and Nakamura's approach to work changed as a result.

He comments, "Even if you dive on a sunny day, you still need the help of lighting equipment to shoot underwater because color, particularly red, fades. Before, I had power supplied from a ship via cables, but because the cables were 100 meters long, I had to hire electrical experts and large vehicles to carry the equipment. Now, I have a lighting system the size of a 500-ml bottle, and using its battery, I can shoot for one or two hours continuously. It has lightened the workload considerably."

However, the photographic equipment that Nakamura uses weighs at least 20 kg or so. Even with the weight reduced by being underwater it is burdensome, yet Nakamura is still an active photographer.

"During more than 50 years of diving, sea creatures have taught me so many valuable lessons," says Nakamura, "including the smallness of humans, or our arrogance. They helped me realize what we, as creatures who share planet Earth with them, must be doing to conserve the environment, and indeed, there is a great deal to do. I dream about becoming skipper of a fishing boat and enjoying pole-and-line fishing in my retirement in Okinawa, but that will have to wait a little longer," says Nakamura, laughingly.

Ikuo Nakamura

Born in 1945 in Akita Prefecture. In 1964, he began shooting photos underwater without any professional training. After working for a photographic services company, he became a freelance photographer in 1976. In 1988, he was awarded "The Kimura Ihei Photography Award" and in 2007, "The Domon Ken Award." In 2009, he appeared in a popular television program produced by NHK (national television), called "The Professionals." His scope of work encompasses a wide range of genres, including journalistic photography, television programs and movies, and lectures on environmental issues. He has authored *"Zen Tokyo Wan"* (All About Tokyo Bay), *"Kaichu Ganmen Hakurankai"* (An Expo of Subsea Faces), *"Kaichu 27,000 Jikan No Tabi"* (The 27,000 Hour Underwater Journey), *"Kyokuya"* (Polar Night), and many other books.

Kawasaki Delivers Cogeneration System with Newly Developed M5A Gas Turbine that Boosts World's Highest Energy Efficiency

Recently, Kawasaki delivered the first cogeneration (combined heat and power) system powered by Kawasaki's original 5 MW class M5A gas turbine to the IBIDEN Co., Ltd. Ogaki Plant in Ogaki City, Gifu Prefecture. IBIDEN started up the cogeneration system in July 2018 to provide both electricity and steam to the Ogaki Plant.

The M5A offers an electrical efficiency rating of 32.6%, the world's highest among 5 MW class models, and the GPB50D cogeneration system with the M5A enables a total energy efficiency rating of 84.5%—the highest in its class—for combined electricity and steam output. This outstanding energy efficiency contributes to reductions in both energy costs and CO_2 emissions. In the area of environmental performance, Kawasaki's latest combustion system with dry low emissions (DLE) technology achieves a 52.5 ppm (0% for O_2) nitrogen oxide (NOx) emission volume. In terms of maintenance, the M5A is designed to facilitate overhaul replacement work onsite and to enable simplified interim inspections (borescope inspections), which contribute to better annual operating rates (uptime).

The M5A gas turbine is the result of Kawasaki's small and medium-size gas turbine development technology cultivated over many years, and was released to the global market in November 2017. The integration of leading-edge technologies is the culmination of the company's experience in developing power-generation gas turbines, and boasts a track record of more than 11,000 units of this highly reliable product delivered to customers around the globe. Kawasaki's M5A gas turbine offers leading performance in the 5 MW class, for which global demand is particularly high.

Kawasaki's US Plant Completes First Commercial Aircraft Cargo Doors for Boeing

On September 17 Kawasaki completed its first cargo doors to be used in a commercial aircraft for The Boeing Company. The doors were manufactured by Kawasaki's US subsidiary Kawasaki Motors Manufacturing Corp., U.S.A. (KMM) at its Lincoln Plant in the State of Nebraska. On the same day, a ceremony was held at the plant to commemorate the shipping out of these first cargo doors, with about 80 in attendance, including representatives from Boeing and the governor of Nebraska.

The 777 cargo doors, measuring 2.6 meters tall by 3.0 meters wide, are made of an aluminum alloy. The doors will be sent to Boeing's Everett Factory in Washington State. The Lincoln Plant will continue producing cargo doors for Boeing's cutting-edge 777X commercial aircraft, and it plans to begin shipping out finished doors in February 2019.

In pursuit of greater automation, the Lincoln Plant's aerostructure production line features proprietary painting robots developed by Kawasaki that provide intricate, precise paint application, as well as an auto riveter with an expanded operating range, and other state-of-the-art equipment. The plant incorporates the unique KPS* (developed through mass-production activities over many years) into line operations to achieve high-quality, high-efficiency production, while utilizing U.S.-made, locally procured materials and parts to cut down on transport costs and reduce lead times. To prepare for a future upgrade to a smart factory, the company also plans to integrate Information and Communication Technologies (ICT), the Internet of Things (IoT) and other technologies and infrastructure like those seen in the 777X assembly plant at Nagoya Works 1.

* Kawasaki Production System: This proprietary Kawasaki production management approach aims to standardize operations in pursuit of consistent quality no matter who carries out operational tasks, thus ensuring reliable quality throughout. It also aims to establish workplace rules and regulations in order to ensure said standardized operations.

A scene from the ceremony.


Manufacturing a cargo door using an auto riveter.

First completed cargo doors.

Kawasaki Launches 2019 Ninja ZX-6R models with New Styling and Enhanced Performance for Both Street and Track

Kawasaki launched two upgraded 2019 models in the 600 cc supersport category: the Ninja ZX-6R ABS and Ninja ZX-6R. Both were released in selected markets in early October 2018.

The Ninja ZX-6R was designed to deliver the enjoyment and thrills unique to Kawasaki 600 cc class supersport models to a wide range of riders. Compared with most supersport models in their class, these new Ninja ZX-6R models have a 636 cm^3 engine which boasts a 37 cm^3 advantage, offering outstanding performance over the entire rpm range. Although its chassis was designed primarily for riding on winding roads, the highly versatile design offers a comfortable ride over a range of different situations, from track racing to street riding.

For the 2019 model, the gear ratio has been updated to provide a more powerful feel at low rpms. Sophisticated technologies for riding, such as KTRC*, KIBS** and the Power Mode Selector, are available on the new Ninja ZX-6R models, as well as on other recent sport models. An additional feature, KQS*** (which enables upshifting without operating the clutch), makes riding more fun on city streets and winding roads.

In terms of styling, various sections including the front and tail cowling have been updated. While the overall appearance matches that of other Ninja models, the unique look and feel make the ZX-6R stand out in its class. New LED bulbs in the head and tail lamps improve visibility during night riding and contribute to the bikes' high-grade appearance.

* Kawasaki Traction Control
** Kawasaki Intelligent anti-lock Brake System
*** Kawasaki Quick Shifter

First Order Received for New BK117 Firefighting and Disaster Relief Helicopter

Kawasaki has received an order for its leading-edge H145//BK117 D-2 helicopter (D-2) from Saga Prefecture. This is the first time Kawasaki has received a D-2 order for firefighting and disaster relief applications, and is the first such application of a helicopter by Saga Prefecture.

The D-2 was developed jointly with the European company Airbus SE, and is the latest model in the BK117 line. This new model retains the features offered by the previous BK117 C-2 that earned it high marks, such as the wide clamshell doors at the rear which enable easy loading and unloading of stretchers, and a design that is compact overall while offering a spacious interior cabin to facilitate medical procedures. The D-2 offers some novel features, including a new computer-controlled engine, cutting-edge integrated instruments, and a new ducted-fan design for the tail rotor, which boost high-altitude performance, reduce pilot workload, and enable the quietest operation in this helicopter's class.

The BK117 is a medium-sized, twin-engine helicopter used for various purposes, including emergency medical services, firefighting, disaster relief, law enforcement, broadcasting, and personnel and cargo transport. Following delivery of the first model in 1983, this domestically produced helicopter has been continually improved over the years, and thanks to the aircraft's outstanding technological strengths and high reliability, Kawasaki has successfully delivered 178 units as of November 22, 2018. Until today, a total of more than 1,500 BK117/EC145 helicopters have been delivered worldwide, combining deliveries made by Airbus, Kawasaki's development and manufacturing partner.

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