

Scope

Kawasaki Heavy Industries Quarterly Newsletter

Special Feature

The Power of Heat:

Behind-the-Scenes Stars
Supporting the Comforts of
Everyday Life

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Changing forward

Summer 2018

No. **116**

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Osaka Medical College Hospital
serves as a core community
medical institution for the
Hokusetsu area (northern Osaka
Prefecture).



The KF-A compact once-through boiler. The green LED light on the front panel indicates that the boiler is in operation.

The Power of Heat: Behind-the-Scenes Stars Supporting the Comforts of Everyday Life

Kawasaki Thermal Engineering Co., Ltd. (KTE) is a pioneer in the manufacturing of boilers and absorption chiller-heaters which support the comforts of our daily lives. This issue of Special Feature focuses on how the "power of heat" is demonstrated in thermal products manufactured by KTE—a heat technology specialist celebrating its 120th anniversary in the boiler business in 2019.

Boilers and Absorption Chiller-Heaters at the Frontline of Life-Saving Work

Osaka Medical College Hospital is located adjacent to Takatsuki-shi Station on the Hankyu Railway Kyoto Line, and is a five-minute walk from Takatsuki Station on the Japan Railway Line. With 29 clinical departments and 14 specialized centers (such as pathology, laboratories, surgery, radiology, etc.), the 1,800-staff hospital serves about 2,000 outpatients per day and has 882 beds. It is positioned as a core community medical institution in the Hokusetsu district (in the northern part of Osaka Prefecture).

In March 2016, a six-story Central Surgery Building was completed at the hospital. One of the largest surgery

buildings in western Japan, it has 20 operating rooms, including a robotic surgery room and one for "hybrid" surgeries (a combination of catheter intervention under X-ray guidance and conventional surgical procedures), equipped with coronary and cerebral angiography.

KTE boilers and absorption chiller-heaters are working behind the scenes to support healthcare. Steam generated by the boilers is used in a variety of ways, including sterilization of medical equipment, and the cooling/heating and humidification of the hospital using heat exchangers. Absorption chiller-heaters provide cold and hot water, which are also used for cooling and heating the entire hospital.

Katsuhiko Tsutsumi, head of the Facility Section of the General Administrative Department at Osaka Medical College, which manages all facilities of Osaka Medical College and its hospital, comments, "Boilers and absorption chiller-heaters are energy sources that drive all medical activities at the hospital and are a lifeline for its 24-7 operations. That is why high stability and reliability are expected of them."

Three units of the KF-A multi-tube once-through boilers are in operation at the hospital. This compact boiler, measuring 110 cm wide, 210 cm high, and 170 cm deep, generates a ton of steam per hour. Also in operation are two Efficio absorption chiller-heater units, each capable of 180-ton refrigeration (equivalent to 265 units of

About the Cover

A WILLHEAT compact once-through boiler undergoes an in-service inspection. See Special Feature for details.

household air-conditioners capable of cooling/heating a room with a floor space of 10 m²).

As for the reason why multi-tube, once-through boilers were originally adopted at the hospital, Tsutsumi says, decisively, "Because of KTE's high standard of manufacturing and a maintenance system that allows expeditious servicing." He adds, "Boilers can last longer than 20 years if maintained properly. I support KTE's approach to product development, which is based on its conviction that products should serve the users for a long time and should never be designed as disposable equipment."

The speed with which service personnel can respond to equipment malfunctions can affect and sometimes jeopardize the mission of a hospital. On KTE's quickness, Tsutsumi comments, "Absorption chiller-heaters have been the main products we have had business with at KTE, and their responses to malfunctions have been extremely swift. The company also doesn't change service personnel frequently, and the same staff are assigned each time, so that we can work as a team with the shared goal of protecting hospital operations. KTE has a sense of mission in supporting the frontline of life-saving interventions. This is the biggest reason why our business relationship has lasted for half a century."



Standing with **Katsuhiko Tsutsumi** (center), who supervises the management of all facilities at Osaka Medical College and its hospital, are officials of KTE's Osaka Branch: **Keigo Ikeda** (left), boiler group leader, and **Kanehisa Hayashida** (right), administration group leader.

A History Lasting 120 Years, and the Industry's Longest Warranty Provided with Confidence

Kisha Seizo Co., Ltd., the predecessor of KTE, was the first private company to manufacture a locomotive in Japan. It then launched a smoke tube boiler in 1899, which means that KTE will be celebrating the 120th anniversary of its boiler business in 2019. Boilers evolved as a family of steam-driven types of equipment which led the Industrial Revolution. Presently, once-through boilers account for 90% of the steam boiler market in Japan.

A once-through boiler has a cylindrical body consisting of many heat-transfer tubes connected together by steel plates called "fins," which are welded in between the tubes. A burner at the top of the cylindrical body burns the gas to heat the water in the tubes, supplied from the bottom section (water circulates continuously), and the heated water rises upward as steam.

Because the volume of water in the tubes is small and therefore the energy stored in the water is also small, this type of boiler is less likely to explode due to pressure and therefore safer. This type is also characterized by a short steam-start-up time

after the boiler is activated. In terms of implementation, it is not mandatory in Japan for entities adopting compact boilers to employ a licensed boiler engineer. In recent years, many entities have chosen to adopt compact once-through boilers instead of one large system, in order to obtain the amount of steam needed.

Because of its simple structure, technologies associated with once-through boilers are considered to be already mature. However, Takahide Yanagida, Senior Manager of KTE's Boiler Engineering Department, says, "We are pursuing further advancement of these technologies in four areas: firing, heat-exchange, control, and welding."

For example, by reusing exhaust gas and using fins with high heat-transfer performance, boiler efficiency (the ratio of the energy absorbed by the water and steam in the boiler against total energy input) as high as 98% can be attained. Efficient boiler operations are also attributable to KTE's control technology, which stabilizes fluctuations in the load and in steam pressure.

Another component that demonstrates the technological prowess of KTE is a steam-water separator. Once-through boilers manufactured by other companies are designed such that the feedwater is supplied directly to the heat-transfer tubes. KTE's model, however, heats the feedwater first, using waste heat from the boiler, and then guides the water through the steam-water separator before it is supplied to the tubes.

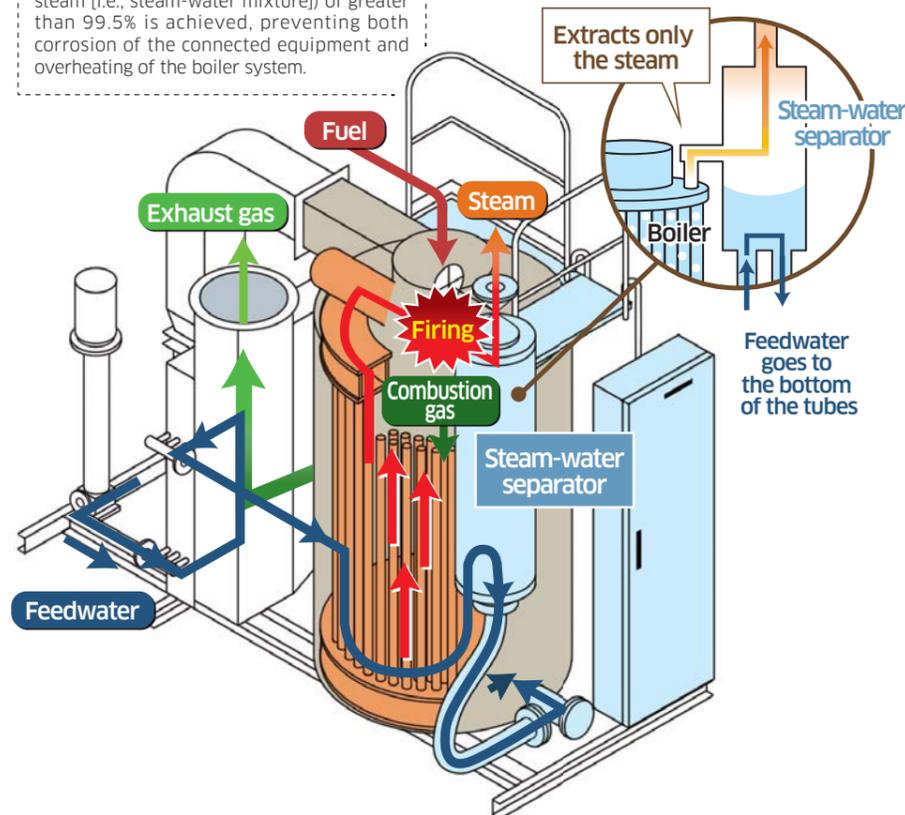
Yanagida comments, "If the feedwater is supplied directly to the heat transfer tubes, warm and cold waters are mixed abruptly inside the tube, causing thermal shock and releasing dissolved oxygen into the water, which results in increased corrosion of the tubes. However, by having the feedwater pass through the steam-water separator in order to keep the water level at consistent level, thermal shock can be avoided, minimizing corrosion of the tubes and fluctuations in steam pressure. This may not appear to be an eye-opening design, but many such ingenuities are packed into the boilers to prolong their lives."

KTE provides a 15-year warranty with its boilers — the longest in the Japanese market. (Certain conditions apply, such as establishing an annual maintenance contract with KTE.) Yanagida says, "Offering the longest warranty (in the market) reflects our confidence in our products."



Takahide Yanagida
Senior Manager, Boiler Engineering Department
Engineering Office, Kawasaki Thermal
Engineering Co., Ltd.

A steam-water separator of the once-through boiler manufactured by KTE achieves highly-dry steam even when faced with fluctuations of running load. Because the feedwater passes through the steam-water separator before entering the boiler tubes, thermal shocks are avoided, resulting in a reduced level of dissolved oxygen in the water and reduction of tube corrosion. The dryness of the steam-water mixture that enters the separator (indicated by red arrows in the diagram) can be enhanced by accelerating the speed of centrifugation using swirl fins, combined with another separation mechanism—the inversion of the flow of the mixture. As a result, a dryness fraction (a ratio of dry steam contained in the wet steam [i.e., steam-water mixture]) of greater than 99.5% is achieved, preventing both corrosion of the connected equipment and overheating of the boiler system.



Developer of a Number of World's Firsts; One of the Largest Market Share Holders for Absorption Chiller-Heaters in Japan

In recent years, more compact and highly efficient absorption chiller-heaters have been developed. An absorption chiller-heater is a piece of equipment used to cool or heat, using the principle of heat extraction through water evaporation—the same mechanism as *uchimizu*, the Japanese custom of sprinkling water in streets and gardens to cool the surrounding area. Water is used in this system instead of fluorocarbons with high global warming potential, or chloro-fluorocarbon substitutes, so as to achieve a large, centralized, eco-friendly heating and cooling system. KTE successfully commercialized the double-effect direct-fired absorption chiller-heater in 1968, and the triple-effect direct-fired absorption chiller-heater in 2005—both of which were first in the world of their kind.

How a KTE Boiler Is Made



For the once-through boiler's casing, tubes and steel plates (fins) are used. This compact boiler with a steam output of 2,000 kg/h requires 51 tubes.



Welding is the key to constructing effective boilers. Tubes and fins are welded to produce the boiler's cylindrical body. At KTE's manufacturing plant, welding robots are widely used for this process.



After welding leak tests are conducted, the entire boiler goes through an annealing process to eliminate residual stress, so as to make it capable of withstanding high pressure and achieve prolonged product life.



The boiler is then fitted with sensors and "clothed" with insulation sheets. This is the semi-final stage of boiler construction.



Finally, a cover casing is installed. The door's front panel is equipped with a controller used for remote monitoring of the boiler via communication lines.



The Efficio absorption chiller-heater in operation at Osaka Medical College Hospital. Two Efficio units cool and heat the entire Surgery Building. With dual lines—one dedicated to cooling and another to heating—the hospital can control both temperature and humidity to optimize the surgical environment of each operating room according to its needs.

Regarding the features of this equipment, Koichi Someya, Senior Manager of KTE's Research & Development Department, explains, "The triple-effect absorption chiller-heater achieves a COP* of 1.74. Compared to the double-effect models, it achieves 35% fewer carbon dioxide emissions and reduces annual running cost by about 3.5 million yen. For its high-temperature regenerator, the same cylindrical body design as the once-through boiler was adopted, which was achievable by KTE alone because we are in possession of both boiler and absorption technologies."

Another feature contributing to the advantages of absorption chiller-heater is the versatility that allows the use of diverse heat sources for its regeneration process, including gas, oil, waste heat from the co-generation system, cooling water heated by the large engines of the same system, etc. Moreover, KTE's Efficio absorption chiller-heater series includes a model which uses gas or oil interchangeably as an energy source,

making it a preferred model of medical institutions and other entities in need of such versatility. On the significance of this feature, Someya comments, "Operations at a hospital designated as a 'Disaster Relief Core Hospital,' which serves as a medical hub in the event of large-scale disasters, will not be interrupted if it has the option of switching to oil if the gas supply is shut down. This means that this model could be positioned as a critical component of business continuity planning."

Kawasaki holds a 25% market share in Japan (in terms of equipment capacity), making it one of the largest market share holders in the country's absorption chiller-heater market. This is attributable to KTE's capabilities for developing a number of the world's first technologies, and to its maintenance system and other services accommodating users' diverse needs.

The WILLHEAT Compact Once-Through Boiler Was Launched to Meet Diverse Customer Needs

In 2000, KTE launched the Ifrit series (large once-through boilers), and 16 years later, the WILLHEAT series made its debut to better accommodate diverse customer needs.

In April 2018, the Boiler Development Division — dedicated to developing next-generation once-through boilers — was established to strengthen KTE's product offerings geared toward Southeast Asian markets and other regions where growth in boiler demand is seen. The division is focused especially on selling



Koichi Someya
Senior Manager, Research & Development Department, Kawasaki Thermal Engineering Co., Ltd.

boilers with maintenance contracts and supplies of corrosion-prevention chemicals. Presently, the division is based in Malaysia, at Kawasaki Gas Turbine Asia Sdn. Bhd. (KGA). In addition, KTE plans to establish a subsidiary in Thailand in the future to bolster its marketing capabilities. Yanagida adds, "We are hoping to develop compact boilers with a maximum steam output that is 1.5 times greater than current models. We will be exploring improved water flow, flow rate, circulation, and other functions to improve overall efficiency."

Absorption chiller-heaters are also the subject of KTE's improvement efforts. These include enhancement of operating procedures and compatibility with various heat sources. Expounding on KTE's approach, Someya explains, "Our technological enhancements are focused on how we can flexibly accommodate customer needs, such as the leveling of running loads that change seasonally, which is essentially an improvement on so-called 'seasonal efficiency,' or the development of a technology to utilize low-temperature waste heat of 60 degrees Celsius or lower."

Maximizing the potential of the power of heat in order to realize a more comfortable present and an optimal future—that is what KTE is pursuing. Its products may not be in the foreground of attention, but they certainly support our lives behind the scenes.

* "Coefficient of performance" (COP) denotes the energy consumption efficiency of refrigerating equipment such as a freezer. It is the ratio of the cooling or heating capacity of the system divided by the fuel consumption. The higher the ratio, the more efficient the energy consumption under the rated conditions.



A WILLHEAT compact once-through boiler



From Top Management

Shin-ichiro Noumi

President*
Kawasaki Thermal Engineering, Co., Ltd.



A waste heat boiler for a co-generation system — the fruit of synergy between KHI and KTE

Our Ever-Evolving Endeavor as "Heat Specialists"

In 2019, KTE will be marking 120 years in the boiler business, during which time we also developed the world's first double-effect and triple-effect absorption chiller-heaters. In both sectors, KTE has been serving as a "heat specialist," providing superior thermal technology.

In a network of three offices and 13 branches dedicated to product maintenance, one-third of the 500-member KTE team is working hard to ensure uninterrupted operation of their products at customer sites. We are also upgrading our remote monitoring system called "Tele-Mente-Advance," through which our monitoring center collects operating data and evaluates equipment status in order to support optimal operations. The next version of this system currently being developed is compatible with the IoT (Internet of Things) platform being developed by Kawasaki Heavy Industries (KHI).

With respect to boilers, after we launched the WILLHEAT compact once-through boiler in 2016, we received a great deal of feedback from our customers, expressing high expectations for our compact products. However, we acknowledge that there are many markets we have not been able to tap into which could benefit from equipment like WILLHEAT. For the Japanese market, we offer the industry's longest 15-year warranty, in a package deal including the equipment, a maintenance contract, and supplies of anti-corrosion

chemicals, so as to ensure that our products operate safely for a long time.

KTE is also bolstering its efforts to market waste heat boilers to be used in co-generation systems, utilizing the waste heat from gas turbines and gas engines manufactured by KHI, in order to capitalize further on synergy between the two companies.

Regarding absorption chiller-heaters, we will be exploring the application of underutilized waste heat in order to improve the products' versatility in accommodating diverse heat sources. Equipment which can be driven by multiple heat sources is an essential component of business continuity in the event of major disasters, and offers benefits that are not achievable by electricity-driven heating/cooling systems.

KTE plans to focus more on overseas markets, especially the Southeast Asian markets, where package deals inclusive of a maintenance contract are widely accepted. By collaborating with KHI and Kawasaki Gas Turbine Asia, we plan to implement aggressive marketing for both the once-through boilers and waste heat boilers.

Although the technologies for boilers and absorption chiller-heaters are considered to be in the mature stage, we at KTE, as heat specialists, are committed to advancing these technologies further, based on our long-standing expertise and the confidence our customers have placed in our products as "equipment that lasts for a long time."

* On June 28, 2018, Mr. Noumi's position changed. He is now adviser to KTE.

Looking Forward to Tomorrow



Verification Testing for Hydrogen-Fired Once-Through Boilers Begins

In March 2018, KTE commenced verification testing for once-through boilers which utilize hydrogen as fuel. Although hydrogen-based energy is expected to play a

critical role in realizing an energy-efficient society, there are many challenges to resolve. Ironworks and chemical plants, for example, have been challenged to utilize effectively the hydrogen byproduct which is generated in the production process. Verifying the functioning of the hydrogen-fired once-through boiler is KTE's endeavor to achieve effective use of eco-friendly hydrogen

resources, and thereby resolve various pressing environmental issues.

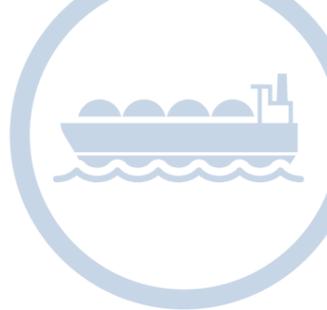
Because the flame temperature of hydrogen is high, burning it results in high emissions of nitrogen oxide (NOx). In the past, reduction of NOx emissions during hydrogen burning required the use of water or steam. For the verification test, however, KTE developed a technology to achieve NOx emission cuts not involving water or steam, using a newly-developed dry-type burner. This testing is an opportunity to verify the viability of the technology, which KTE plans to apply to the boiler and commercialize it in 2019, in cooperation with the Corporate Technology Division of Kawasaki Heavy Industries.



A hydrogen-fired once-through boiler used for the verification testing. The red tank contains the hydrogen.



35-Year History of the Rexpeller: King of Marine Propulsion Units that Provide 360-Degree Thrust



The Rexpeller is an azimuth thruster that enables marine vessels to have precise and agile maneuverability and accurate positioning capability, which are essential requirements for operation in severe nautical conditions. Thirty-five years after receiving its first order, Kawasaki is ready to make a further leap forward in the evolution of the Rexpeller.

maneuverability and accurate positioning capability, years after receiving its first order,

First order for the Rexpeller received

The first order was for a tugboat owned by a Japanese company. Production of Rexpellers started at Akashi Works (then Akashi Minami Works, in Akashi City, Hyogo Prefecture), and its all-in-one structure, arranging the clutch and hydraulic machinery on the platform (foundation), drew much public attention as the first such design in Japan.



1983

The Rexpeller is an azimuth thruster which rotates the propeller 360-degrees around the vertical axis so the unit generates thrust in any direction horizontally, to act as propulsor and rudder. Tugboats, offshore supply vessels, drill ships, and cable-layers are major beneficiaries, thanks to its superior maneuverability.

Since 1983, when Kawasaki commenced production of the Rexpeller, more than 1,000 units have been delivered. Culmination of Kawasaki's comprehensive technologies such as fluid-dynamics for marine propellers,

First delivery of the A-series Rexpeller made

Launch of the A-series dramatically extended the market share of Kawasaki, even though Kawasaki was the last to enter the market for azimuth thrusters in Japan. The A-series pulled a trigger that led to a variety of vessels equipping themselves with azimuth thrusters, other than tugboats.

1986

hydraulic technology for accurate control, and reduction gears technology for reliable torque transmission are fully incorporated in the design and are working all over the world.

Kawasaki has an excellent delivery record for the Rexpellers for vessels engaged in offshore oil and gas development, such as drillships that use them in the drilling of oil and gas wells, shuttle tankers that transport oil and gas mined from petroleum wells, and platform supply vessels that transport goods to offshore platforms. The growth in market share achieved by Kawasaki is attributable not

Six units of a Rexpeller model that was world's then-largest azimuth thrusters for the Chikyu, a deep-sea scientific drilling vessel

The Chikyu was the first vessel in history which could drill into the earth's mantle. Using six units of the coordinated Rexpellers, the Chikyu is able to remain in a specified position in the ocean while using an excavation drill to drill the seabed, without any anchors and/or mooring lines. Such stability of position is possible for as long as a year, even under challenging conditions where wind speeds of up to 23 m/s, waves 4.5 m-high, and currents moving at 3-4 knots are seen.

2001

only to its highly reliable equipment, which operates stably in harsh environments caused by strong winds and tidal currents, but also to Kawasaki's ability to accommodate the individual requirements of its clients, and achieve made-to-order customization.

In 2018, Kawasaki launched the E-series Rexpeller into the market, and has already been awarded orders for four units. Deemed a model with the potential to become a new international best-seller, high expectations are placed on the E-series as a driver of increased sales.

one of the were delivered vessel



2003

First order for the retractable Rexpeller for shuttle tankers received

A shuttle tanker is a vessel used for transportation of oil from an offshore production platform to an onshore oil stockpile base. The Rexpeller, which provides omnidirectional thrust, is instrumental in offshore operations, as they require accurate maintenance of positions.



The retractable Rexpeller can be retracted into the hull by hydraulic means, allowing the vessel to sail at high speed by reducing hull resistance during transportation.

New factory completed to increase production capability

For extended demand of azimuth thrusters in the growing oil and gas related offshore development market, a new factory was built at Harima Works (in Kako County, Hyogo Prefecture) and production commenced.



2013

First order received for the E-series Rexpeller — our newly-developed azimuth thruster

The E-series, which offers energy savings through improvements of propulsion efficiency, ease of onboard maintenance, and environmentally friendly performance, was launched. Four units were ordered, which will be installed onto tugboats to be operated by China's Port of Tianjin, and the operation will start from the latter half of 2018.



2018



The duAro:

A Dual-arm SCARA (Selective Compliance Assembly Robot Arm) Robot that Achieves Human-Robot Coexistence



Commentary by Kazunori Hirata
 Assistant Manager
 FA System Section 1
 FA System Department
 FA and Clean Group, Robot Division
 Precision Machinery and Robot Company
 Kawasaki Heavy Industries, Ltd.

Pioneering Robot Applications in Areas Previously Deemed Unfeasible

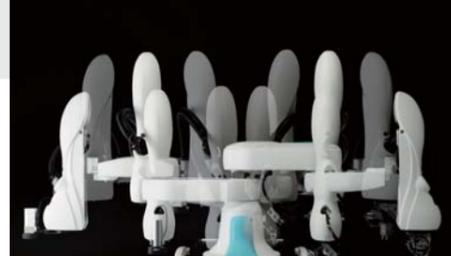
The duAro, a dual-arm SCARA robot that operates alongside humans, was launched in 2015, based on Kawasaki's experience as the first company to commercially manufacture robots in Japan. The debut of this robot marked the company's commitment to pioneering a new era of coexistence and collaboration between robots and humans.

As Japan faces an ever-shrinking workforce, manufacturing sites in dire need of replacing that vanishing manpower with industrial robots are increasing. However, introduction of robots at companies such as those in the electrical and electronics industries has been hampered by unjustifiably low cost-effectiveness, given the short life-cycle of their products and the lengthy preparation period required for their introduction.

Another negative factor contributing to reservations felt by small and mid-sized companies, which make up the majority of Japan's industry — the very groups most in need of robot applications — has been their lack of expertise in robotics.

The duAro was developed to resolve these challenges. Standing up to 170 cm tall, and weighing 200 kg, the duAro is installable in the working space of a single human worker. It can be taught easily by the simple means of step-by-step direct teaching, or by using a tablet. Its two arms can perform separate tasks, and with its collision detection features, the safety of collaborative operations with humans is assured. The duAro also comes with a price tag that is reasonable enough to make it a viable option for implementation, which has been contributing to its popularity more than any other factor.

Since its launch, these benefits have been expanding the horizon of duAro's applications. From the fastening of screws for printed circuit boards (PCBs), to the picking and placing of rice balls into food trays, the duAro is an innovation that is sure to become a key contributor to the future growth of the manufacturing and service industries in Japan.



Automated Smoothing of Horizontal and Vertical Movements

The arms of the duAro are movable in horizontal and also z-axis (up and down) directions, and each arm is capable of lifting a workpiece of up to 2 kg. The movement in the z-axis direction can be taught through direct teaching, and the smooth up/down movement of the arms is achieved by features such as measurement of the weight of the jigs attached to the end effectors.



The arm covers are made of urethane to soften the impact, should people come into contact with them.



Low-Power Motors Adopted for Operations Free of Safety-Fencing

The arms are driven by motors mounted on their "shoulders," "elbows," and "hands," and their movements are controlled by changing the number of the motors' revolutions. The arms, padded with soft material, can be configured to move at different speeds in different zones; setting the low-speed areas at either side of the robot, where human workers might approach, allows the robot to move slowly in those two areas while it operates at high speed in the center zone. The robot is also equipped with sophisticated safety measures, including a collision detection feature which instantly stops any arm movement when people come in contact with the robot and the impact is detected.

Kawasaki's Superior Technology

Flexible Direct Teaching Features

The controller for the robot arms is housed in a wheeled, box-shaped platform which is easily moved to a desired location, allowing the robot to perform tasks in any part of the production line. There are two simple ways to teach the duAro: direct teaching or via the Android-based tablet. In the former, the operator performs a task holding the robot arms to make it reproducible by duAro. In the tablet-based method, the operator configures the required movements by inputting numerical values. Both are very simple means, requiring no specialized knowledge.

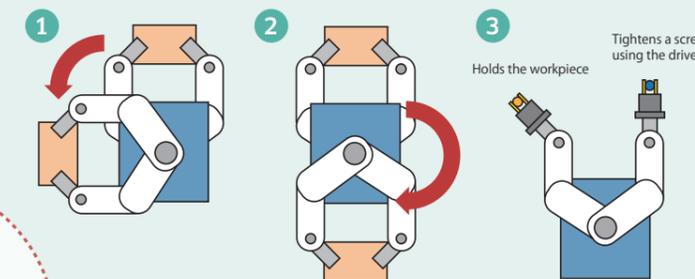
With its weight accounting for 75% (145 kg) of the entire robot, the platform provides needed stability for the duAro to move its arms.



Simple teaching by tablet.

Kawasaki's Superior Technology

Dual-Arm Feature that Mimics the Marvelous Dexterity of Human Hands and Arms



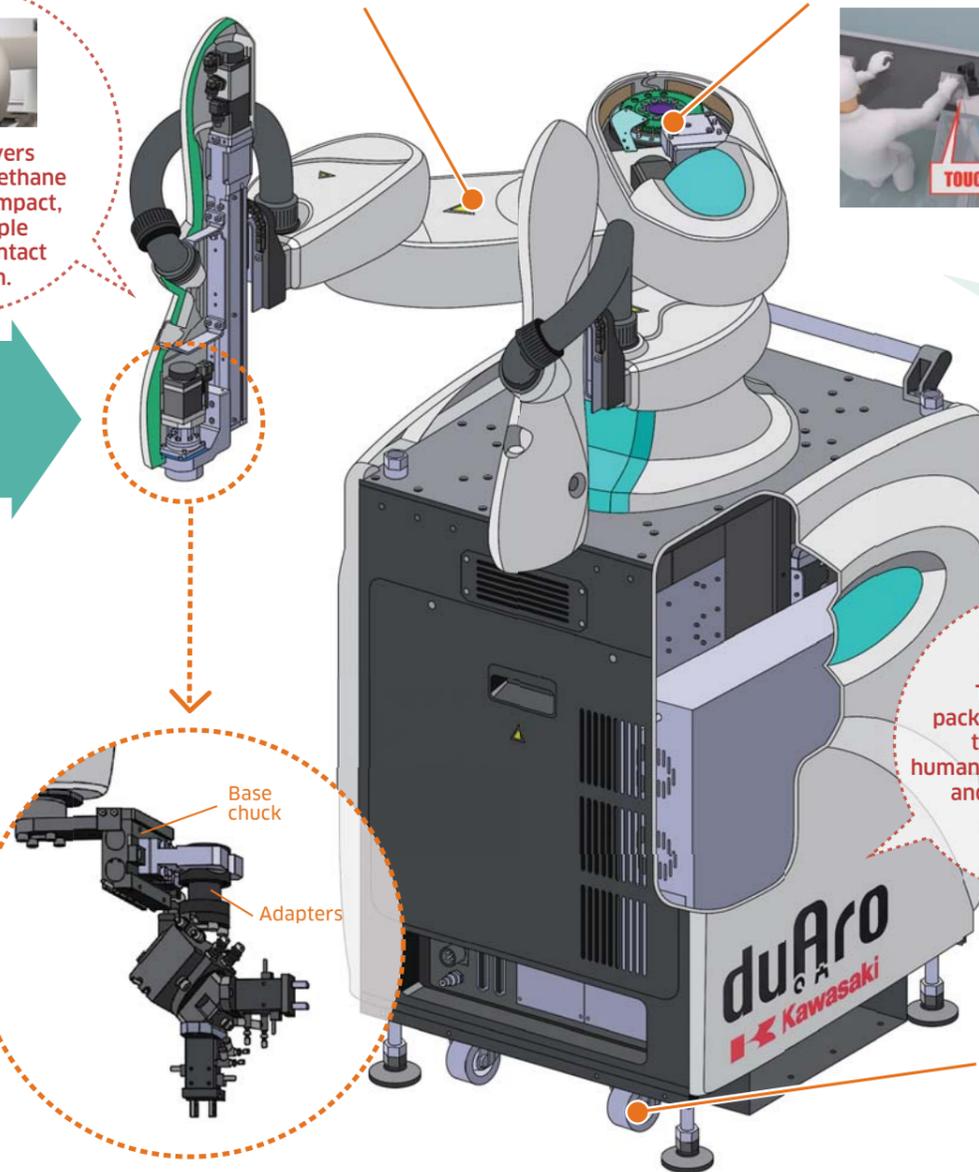
The duAro is capable of accurately reproducing human arm and body movements. Each arm, 76 cm long when fully extended (152 cm when both arms are extended), was designed based on the average working space of a human worker. By using simple "hands" (effectors) attached to the end of each arm, the duAro is able to grasp a large workpiece and move it (Fig. 1), and thanks to its coaxial configuration, the robot can also reach equipment at its back (Fig. 2). The arms can also perform separate tasks (Fig. 3). For example, when working on a PCB, the left arm can hold the PCB while the right arm tightens a screw. This results in shortened takt time (cycle time) and simplified production systems, because tools to hold the PCB are no longer necessary.



The duAro is packed with features that facilitate human-robot coexistence and collaboration.

Casters

The platform is equipped with casters and can be moved simply by pulling the handle, which allows for easy change of location by a single worker.



Existing Tools Are Also Usable

Tools that customers have been using are attachable to the duAro, using base chucks and adapters. An impressive lineup of accessories is additional proof that Kawasaki is committed to accommodating the needs of customers hoping to robotize human tasks expeditiously.

An impressive lineup of options is available for customization. The duAro can remedy increasing labor shortages.

Diverse Tasks Can be Robotized as Needed

Various tools are attachable to duAro's arms, enabling the robot to perform a wide range of tasks. Past applications include the mounting of parts on PCBs, the placing of rice balls in food trays, and inspections of functions and response capabilities of touch screens, to name a few, and many more are likely to be added.



Mounting of parts on a PCB



Placing of rice balls in food trays



Inspection of functions and response capabilities of a touch screen

Meet the Unknown, Think Hard,
and Decide for Yourself

Yoshiharu Habu

Shogi (Japanese Chess) Player

“A genius carries an air of coolness,” is a comment made by Kunio Naito, holder of the ninth dan (the highest shogi rank), on the character of Yoshiharu Habu—a shogi player who made a great achievement in his 33-year career: he became the first to hold an eisei (lifetime honor) in all of the then-seven major shogi titles, and, as a result, was given a People’s Honor Award by the Japanese government in 2018. Yet, Habu never ceases to seek new ventures. What aspirations does he hold today?

Win or Lose, Be Sure to Forget It

An ancient Indian board game called Chaturanga, which is believed to be the forerunner of shogi, was brought to Japan in the Heian period (794-1185/1192 CE) and evolved uniquely to become what shogi is today. During the Edo period (1603-1867 CE), a licensing system called *iemoto seido* (headmaster system), akin to the systems practiced in the tea ceremony, *ikebana* (flower arrangement), and other schools of traditional arts, was adopted by the guild of shogi players. This suggests that shogi included an aspect of mental training (a “way”) for people wishing to become more mature as a person.

Shogi, however, was not immune to modernization. In the latter half of the 20th century, computers enabled widespread data-sharing of the moves and outcomes of shogi games, revealing the game’s real essence to be that of a “brain sport.” Against such a backdrop emerged 15-year-old shogi prodigy, Yoshiharu Habu.

At one point, his annual victory rate exceeded 80%, and he still maintains an average rate higher than 70%. Critics say that Habu’s unrivaled strength lies not only in tactics, but also in his flexibility in accommodating changing times and the tenacity to achieve continued victories.

Asked what the secret of remaining an undefeated player is, Habu says, “I feel that the life of a shogi player is like a marathon. It is vital that you stay in the lead group. As long as you are in that group, you can be the last runner (and still remain an active player).” He adds that for prolonging a shogi career, forgetting the past is essential.

“Win or lose, you must let go of the game quickly, because victories make you pompous and careless, and defeats undermine your aggressiveness. You should let go of those residual images of the games, and

after you review the results, it’s best to forget about the outcome—win or lose. Of course, I have feelings, but I think it’s important to learn how to channel the emotional ups and downs into motivation for improvement.”

Habu’s favorite description of a desirable state of mind is “*reiro*” (clear-minded, serene), but it is not difficult to imagine how challenging it is to stay *reiro* in a world where only victory counts. “I’m still exploring how to control my thoughts,” says Habu, scratching his head.

Competencies You Must Develop for the Future

With 81 squares on the board, and possible moves amounting to 10 to the power of 220, shogi is a very complex game—complex to the degree that no infallible strategy is known to date, even with the help of artificial intelligence (AI).

Speaking about his approach to competing, Habu comments, “Throughout the course of the game, I try predicting each move in detail, but 90% of my strategies prove ineffective. So, I’m not playing with a fully-working prediction most of the time, but with a hunch that this move might work better.” He does so, of course, after intensive data research on past games and after all possible predictive simulations.

“Failure to do data research results in immediate defeat. However, since such research is a prerequisite to playing any game nowadays, there is no chance of getting ahead of your opponent in that regard. Instead, generating something unique out of the data is critical,” explains Habu.

The emergence of AI and shogi apps has allowed the development of new moves or strategies on a weekly basis. Habu thinks, however, that although collective research may result in effective strategies, it also poses the risk that they will slide into uniformity.

“Collective thinking often outpowers that of an individual, but I still check out research results and ideas released by individuals and small groups, in search of something truly novel that might become an effective strategy. Cutting-edge developments are always in the trial-and-error stage, and you just have to try them to find out whether or not they work,” he adds.

Sectors threatened by the growing sophistication of AI are not limited to shogi. Regarding this trend, Habu comments, “It’s frightening that people so easily believe what AI suggests. AI can increase probabilities, but it is not error-free. You must be skeptical about the results AI produces, and verify them personally by thinking them through.”

In response to a question about how one can develop the sensibility, individuality, and capability of thinking hard that Habu has mentioned, he replies, “Put yourself in a new environment. It could be as simple as walking around a town that’s unknown to you. Routines tend to constrain your thinking, so go out and meet the unknown, think hard, and decide for yourself. As you repeat this process, you will naturally develop such capabilities.”



Photo courtesy of Japan Shogi Association

Yoshiharu Habu

Born in Saitama Prefecture, Japan, in 1970. In 1985, he became only the third junior high school student to turn professional shogi player. At age 19, he won his first championship in the Ryuo Tournament (one of the major shogi titles). In 1996, at age 24, he became the holder of all seven major titles for the first time in the history of shogi. Another first: in 2017, he became the holder of an *eisei* (lifetime honor) in those seven titles, which resulted in his being the first shogi player to receive the government’s People’s Honor Award. His hobby is to play chess, and he is the holder of second place in the World Chess Federation (FIDE) ranking for Japan.

Two Newly Developed LNG Transport Vessels Delivered

In February, Kawasaki delivered the *LNG SAKURA*, a 177,000 m³ capacity liquefied natural gas (LNG) transport vessel, for use by The Kansai Electric Power Company, Inc. (KEPCO) and Nippon Yusen Kabushiki Kaisha (NYK Line).

The first of Kawasaki's line of 177,000 m³ capacity LNG carriers to be commissioned, this ship is designed to enable passage through the newly expanded Panama Canal, which opened for full operations in 2016. The *LNG SAKURA* will be used by KEPCO to transport LNG from the Cove Point LNG Project in the U.S. The vessel features standard LNG carrier hull dimensions in order to enable docking at major LNG terminals around the world, while offering larger cargo tanks for increased transport capacity, thus cutting LNG transport costs and facilitating more flexible LNG trade operations by shipowners.

Kawasaki has optimized the hull structure to decrease overall ship weight, enhanced the hull-shape design, and adopted a

twin-propulsion motor, twin-screw propulsion system (the first of its kind in a large-size Kawasaki vessel), all of which help achieve the best propulsive performance possible. In addition, the company integrated a DFD electric propulsion system* for the first time in any Moss type LNG carrier worldwide, which increases fuel efficiency at all speeds.

Kawasaki has also delivered the *PACIFIC BREEZE*, a 182,000 m³ capacity LNG transport vessel for use by Kawasaki Kisen Kaisha, Ltd. ("K" Line), in March. The vessel is scheduled to transport LNG from the Ichthys LNG Project in Australia, which is operated by INPEX CORPORATION.

The *PACIFIC BREEZE* is the world's largest MOSS-type LNG carrier, with a cargo tank capacity of approximately 182,000 m³, and was based on the 177,000 m³ LNG carrier, previously the largest MOSS-type LNG carrier on offer from Kawasaki.

*The DFD (Dual Fuel Diesel) engine is capable of burning oil or gas, while a conventional generator engine can only use oil for fuel. The propulsion system is comprised of a number of generator diesel engines, variable speed propulsion motors and other components. Either gas or oil is supplied to the engines to generate electricity, which drives the propulsion motors that power the propeller.



LNG SAKURA



PACIFIC BREEZE

100MW Class Gas Turbine Combined Cycle Power Plant Boasts the World's Highest Electrical Efficiency

In March, Kawasaki completed development of a combined cycle power plant (CCPP) with the world's highest level of electrical efficiency, and has commenced marketing activities. The CCPP employs the L30A, a 30 MW class made-in-Japan high-efficiency gas turbine featuring the highest output of all Kawasaki gas turbines.

A CCPP consists of two stages of power generation. A gas turbine generator provides the primary power generation, and the gas turbine exhaust is utilized as the heat source for a heat recovery steam generator (HRSG). Steam from the HRSG drives a steam turbine generator to provide secondary power. A CCPP has a shorter startup time than a conventional steam turbine power plant of the same output, and features excellent load response as well as

high electrical efficiency, meaning minimal thermal energy is wasted.

The newly developed CCPP is composed of two L30A gas turbines, two HRSGs, and one steam turbine, all produced by Kawasaki. This brings together Kawasaki's product technology and plant engineering capabilities cultivated over many years, to achieve high efficiency in the combined cycle as a whole, in addition to that of the gas turbines alone*. Total Electrical efficiency is 55.2% (reheat type**) in the 100 MW class and 54.4% in the 90 MW class systems, both among the world's highest levels of electrical efficiency.

*Some of the technologies for increasing efficiency and improving load responsiveness of L30A gas turbines were developed by the New Energy and Industrial Technology Development Organization's (NEDO) Program for Strategic Innovative Energy Saving Technology.

**This is a reheat-type CCPP, in which steam is extracted from the middle stage of a steam turbine and reheated in the reheater of an HRSG before being returned to the steam turbine in order to increase power output.



Kawasaki gas turbine CCPP

New AUTO CULTURE Automated Cell Processing System to Aid Regenerative Medicine

Kawasaki recently completed development of its new AUTO CULTURE* automated cell processing system. The system enables consistent-quality, low-cost cell culture operations at various scales, and is expected to help promote the adoption of regenerative medicine. Kawasaki will begin approaching companies seeking the commercialization of regenerative medicine to offer the system as an ideal solution for their business needs.

Kawasaki developed the AUTO CULTURE system by leveraging synergies between relevant technologies in areas such as plant engineering and clean robots for medical and drug discovery applications. This new system maintains the same high quality achieved through manual cell culture operations by experienced technicians, while fully automating all operations from seeding to harvesting. By automating

the entire cell culture process, the system achieves safe and consistent cultivation, lowers cell culture costs, enables more flexible response to changes in production volume, improves the work environment for technicians, and achieves other breakthroughs to solve a plethora of problems.

Compared with past Kawasaki systems, the new AUTO CULTURE system attains higher production efficiency through its ability to handle multiple flasks simultaneously. It also includes enhanced measures to prevent problems such as contamination and operator errors, and reduces costs while increasing safety and consistency in cell culture operations. Furthermore, incubator** units and reagent storage cabinets are detachable from the main system unit, allowing for seamless capacity increases from clinical trials to commercial production. The system is

capable of handling various flask sizes, and operators can adjust settings for cultivation operations, enabling cultivation of induced pluripotent stem cells (iPS cells), mesenchymal stem cells (MSCs) and a wide range of other cell types.

*"AUTO CULTURE" is a registered trademark of Kawasaki Heavy Industries, Ltd.

** A device used to cultivate cells. Internal environmental conditions are maintained at levels suited to cell proliferation.



Mercedes-Benz GLC F-CELL to use a New High-Pressure Hydrogen Regulator Developed for Daimler

In April, Kawasaki delivered a high-pressure hydrogen regulator to Daimler, a major German automobile manufacturer, to be used in a new model of fuel cell vehicle, the Mercedes-Benz GLC F-CELL.

This high-pressure hydrogen regulator is the fruit of joint development with NuCellSys, a subsidiary of Daimler. Fuel cell vehicles store hydrogen in a tank at extremely high pressure (approx. 700 atmospheres), and the regulator plays the important role of reducing the gas pressure to prepare it for use in the fuel cell stack*.

Exploiting the fluid control technology that Kawasaki has developed through its many years of developing and manufacturing hydraulic devices, together with NuCellSys' expert knowledge in fuel cell systems, we

have developed a regulator that takes up less space and contributes to increased range by improving fuel efficiency, while at the same time offering superior reliability, having cleared durability tests that suggest a product life of 20 years. This is all possible through the efficient pressure reduction

enabled by high precision gas control technology, and the stable hydrogen gas pressure it delivers during power generation.

* A device that generates power through the chemical reaction of hydrogen and oxygen.



Range: Approx. 500km (NEDC value)
Fuel filling time: 3 minutes
(Photo courtesy of Daimler)



High-Pressure Hydrogen Regulator

Please follow us on social media [f https://www.facebook.com/global.kawasaki/](https://www.facebook.com/global.kawasaki/) [in https://www.linkedin.com/company/83150/](https://www.linkedin.com/company/83150/)



1
800

Liquefaction shrinks the volume of hydrogen to 1/800, making mass transportation possible.

-253°C

Japan's first plant to produce liquefied hydrogen by cooling it to -253°C.

Produce

Transport

Kawasaki – Pioneering the Future of Hydrogen-Based Societies

With our technologies and products focused on transitioning to a decarbonized society, we aspire to achieve a future where people can enjoy an enhanced quality of life.



0%

Realization of pure hydrogen gas turbine emitting zero CO₂.

30,000
vehicles

Development of a huge hydrogen storage tank equivalent to the total volume of 30,000 fuel cell vehicles' fuel.

Store

Use