Scope

Kawasaki Heavy Industries Quarterly Newsletter

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Kawasaki
Powering your potential

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in this issue...

About the Cover
The cover photograph shows the front end of the fairing Kawasaki developed for the Epsilon Launch Vehicle. The fairing is located at the tip. Read this issue's *Frontline* for details.

Kawasaki Heavy Industries, Ltd.

Scope

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Developing the Fairing for the Epsilon Launch Vehicle

The Epsilon Launch Vehicle is a small solid-propellant rocket developed by the Japan Aerospace Exploration Agency (JAXA).

A payload fairing is a structure mounted at the front end of the launch vehicle to house a satellite and the launch vehicle body, protecting them from the severe acoustic and vibration loads, high temperatures and other environmental factors experienced at lift-off and during flight. Outside the earth's atmosphere, the fairing must be safely separated and jettisoned to place the satellite securely into orbit.

To date, Kawasaki has developed and manufactured a variety of payload fairings for the H-II A/B launch vehicles—Japan's leading launch vehicles—and has delivered over 30 of them. This extensive track record, as well as its constant pursuit of new technologies, earned Kawasaki the contract to develop the Epsilon fairing.

On September 14, JAXA launched the first of its new-generation Epsilon rockets into space. Kawasaki was a development partner in this landmark event, and our story is on the following pages.

The fairing separation test is carried out successfully.

Structural Strength Testing of Prototype Model

In mid-December 2012, a prototype model of the fairing was installed in the testing tower at Kawasaki's Harima Works to undergo a strength test.

The fairing for the Epsilon is approximately 9 m long, with a diameter of 2.6 m and a cone-shaped tip.

Because it must protect satellites and other instruments mounted at the front end of a launch vehicle from the severe environment of lift-off and flight through the atmosphere, the fairing requires sufficient strength and rigidity to withstand the load experienced by the launch vehicle in flight, as well as high thermal and acoustic insulation performance to protect the satellite and other payloads from the extreme heat and acoustics during the flight—the temperature on the surface of the fairing reaches as high as 800°C due to air friction, and the exhaust noise generated by a launch vehicle at lift-off can create vibrations strong enough to break glass.

In a strength test, the prototype model is subjected to loads applied both vertically and horizontally, and is then measured for any distortion to evaluate its strength and rigidity.

In a strength test, loads are applied to the prototype model from all directions, and distortion is measured to evaluate strength and rigidity.

The strength test conducted this day did not produce any plastic deformation under the limit load (the load predicted to be borne by a launch vehicle in flight). Durability under the ultimate load (1.25 times the limit load) was also confirmed, demonstrating that the design and analysis of each structure were valid.

Cost and Processes Reduced with Clamshell Panels

Kawasaki has designed and manufactured more than 30 payload fairings for the large H-II A/B launch vehicles, including those used for tests. Every fairing that was lifted into space has performed as it was designed to.

Building on the foundation of its core technologies, Kawasaki moved forward with the development of the Epsilon's fairing, which incorporates new technologies. Fairings are designed to split in half once their launch vehicle is out in space. The panel that separates like a clamshell consists of a honeycomb sandwich structure, with two aluminum plates bonded to either side of a honeycomb core. In the past, the cylindrical portion of the panel and the conical portion were manufactured separately and then combined later. With the Epsilon's fairing, however, a two-piece clamshell panel produced by molding the two portions as one was used.

For the insulation of the outer surface of the fairing, Kawasaki developed new adhesive insulation sheets, which erase the need for a large dedicated booth. And for the soundproof material, resin blankets that can be processed to fit a curved surface were used. These new technologies enabled Kawasaki to reduce the number of production processes and manufacturing costs, while improving performance.

Payload Access Door Fastens in 20 minutes

The fairing is provided with an access door for the engineers to conduct a final check of the satellite and other payload immediately before launch. The process of closing and fastening this door with bolts after the final check used to take about an hour. One of the goals with the Epsilon was to reduce the amount of time it took from assembly of the launch vehicle on the launching pad to inspection and lift-off (described later). To this end, Kawasaki worked to reduce the access door fastening time as much as possible.

This was accomplished by simplifying the structure of the door and reducing the number of bolts used without taking away from the strength, reducing the time to less than 20 minutes.

Development engineers gaze intently at data in the fairing measurement room.

An Epsilon fairing is transported to the workbench (left), where workers can access it (right).

Separated Fairing Sinks Below Waves

Fairings separated from the launch vehicle after lift-off fall into the ocean. It is necessary to prevent them from becoming large floating debris and interfering with the operation of ships. For the Epsilon's fairing, small slots were created in the panel's honeycomb to form a new structure that makes it easier for water to pass inside the panel. The Epsilon fairing would thus be able to sink below the waves within a few hours.

Acoustic Test Conducted at JAXA's Tsukuba Space Center

In mid-February 2013, an acoustic test was conducted on the prototype model following the strength test at the test facility at JAXA's Tsukuba Space Center.

This facility, which was constructed and delivered by Kawasaki, simulates the acoustic environment of a rocket at launch and during flight to examine how the equipment under testing will function in that environment. A high-pressure flow of nitrogen gas is created by the acoustic generator to produce up to about 151 decibels (dB) of acoustic power.

An acoustic test is conducted under the direction of JAXA engineers.

The Epsilon fairing prototype model installed in the acoustic test facility. Acoustic power is applied from the bottom left.

The small, high-performance, low-cost, solid-propellant launch vehicle Epsilon. ©JAXA

A prototype model fitted with the same acoustic insulation as the actual equipment is fixed to the floor of the facility's reverberation chamber. The same acoustic level to be experienced in flight is applied to the prototype model, and measurements are taken of acoustic pressure levels inside and outside the fairing to study the impact, among other measurements.

The acoustic test was conducted over a period of three days, and it confirmed that the vibration response and acoustic damping of the structure performed as designed. Further, no damage or loosening was seen in the structural members, and no separation of the inside of the sandwich panel or insulating material was observed. Consequently, the design and analysis were deemed valid.

Aiming for Higher Performance at a Lower Cost

The Epsilon is the successor of the M-V launch vehicle (retired in 2006). The M-V was developed using Japan's home-grown technology and is said to have attained the pinnacle of solid-propellant rocket technology. Developers of the Epsilon aimed to carry on the tradition, and to create a solid-propellant launch vehicle that had evolved even further.

It is a three-stage launch vehicle measuring approximately 24.4 m in length and 2.6 m in diameter, and weighing about 91 tons. The launch capability (low-earth orbit) is 1.2 tons (compared to 1.8 tons for the M-V).

Epsilon development was initiated in response to the technological advances that are producing smaller satellites (weighing less than 500 kg). Solid-propellant launch vehicles are easier to operate than their liquid-propellant counterparts, making them more suitable for launching small satellites. To make the most of this, development of the Epsilon was pursued with the goal of achieving higher performance at a lower cost.

First Launch Vehicle that Conducts Self-Inspection

The Epsilon combines pre-existing technologies established with the M-V launch vehicle and the large H-II A launch vehicle with new improvements, as well as an innovative launching system.

In particular, an autonomous inspection system enabled by the introduction of artificial intelligence represents a major technological advance.

All onboard instruments must be inspected up until immediately before launch. With the M-V launch vehicle, this pre-launch inspection required as many as 100 engineers to perform. These engineers would use tens of inspection machines lined up in the control room to examine the main launch vehicle and onboard instruments.

With the Epsilon, however, artificial intelligence was built into each stage of the three-stage launch vehicle. Responding to commands issued by a computer, the launch vehicle inspects itself as well as its onboard instruments. The results of each inspection are then transmitted to the computer, where engineers can view them. The Epsilon is the first-ever launch vehicle to be equipped with artificial intelligence to conduct pre-launch self-inspections in this manner.

Only Two Engineers Required to Launch Via Mobile Control

Artificial intelligence is not the only feature that sets the Epsilon apart from the rest of the pack. Previously, it required nearly two months to assemble a launch vehicle on the launch pad and complete the full inspection prior to lift-off. The Epsilon, however, can be readied for launch just one week after the start of the assembly process. No other launch vehicle in the world is capable of being ready for launch this fast. This advance was made possible by simplifying the assembly work: the number of components was reduced and the launch vehicle is now transported to the launch site in near-complete form.

Further, the realization of computer-based mobile launch control has enabled launch control to be performed by just two engineers. The Epsilon is completely redefining the conventional wisdom of requiring hordes of engineers on standby in the control room to keep watch during launch.

With demand for small satellites expected to grow, getting a head start on mobile launch control over the rest of the world is extremely meaningful. The cost of launching a test vehicle is estimated to be approximately half that for an M-V launch vehicle, and Kawasaki is pursuing further cost reductions in the next stage. Epsilon is expected to contribute greatly to Japan's rocket-launching business in the future.

Kawasaki provided technical support for a dry run of the assembly process using the prototype model.

The fairing separation test is carried out successfully. The two panels are split in half with the detonation of the explosives built into the separation mechanism.

Fairing Separation Test Carried Out Successfully

In early April, a fairing separation test was conducted using a prototype model at Kawasaki's Harima Works.

After installing the prototype in the fairing test tower, the explosive terminal for a separation mechanism built into the connecting portions between the two panels was triggered to activate the detonating device.

When the test was ready to be conducted, countdown began, and an explosion was set off. With a huge blast, the prototype model split in half like a clamshell, with each half falling to either side. The explosives were detonated, and the bolts connecting the panels were instantly broken, vertically separating the panels into two halves.

The test confirmed the performance of the separation mechanism. It also evaluated the impact of the fairing separation on the satellite and launch vehicle, and the design and analysis were considered valid for both.

With this series of tests, development of the Epsilon's fairing was virtually complete.

Launching of the SPRINT-A

As with previous fairings, the fairing for the Epsilon was assembled in a fairing assembly plant at the Harima Works, using parts and components manufactured at the Gifu Works.

The completed fairing was shipped from the Harima Works at the end of May and delivered to JAXA's Uchinoura Space Center, where the launch site is located.

In mid-May, JAXA conducted a dry run of the assembly process at Uchinoura, using a prototype model for which Kawasaki provided technical assistance.

Test Flight Model Launched

A test model of the Epsilon, carrying the Spectroscopic Planet Observatory for Recognition of Interaction of Atmosphere (SPRINT-A), which will observe Venus, Mars and other planets from an orbit around the Earth, was successfully launched from the Uchinoura Space Center on September 14.

An Air Conditioner that Cools by Heating? Efficio Is the World's Highest Efficiency Double-Effect Absorption Chiller

Eco-Friendly Water Chiller for Air Conditioning

Absorption chillers are environmentally friendly air conditioning systems that use water as a refrigerant and gas or oil as fuel. They are widely used in hotels, commercial buildings, schools, hospitals and factories around the world, as well as in such applications as district heating and cooling (DHC) systems. They boast outstanding energy efficiency, ease of operation and stable performance, and do not use global-warming CFCs or CFC alternatives.

Kawasaki Thermal Engineering Co., Ltd., a leading company in this field and the first ever to commercialize an absorption chiller 45 years ago, recently released a new model in its Efficio series that has achieved the world's highest efficiency (COP* 1.51) in double-effect absorption chillers (see the "Generator" section in the illustration).

It may seem counterintuitive to burn fuel even when using absorption chillers for air conditioning. Why is it necessary to produce heat in order to cool? The structure of the newest Efficio (NZ type) is illustrated here to reveal the principle of cooling.

* COP stands for Coefficient of Performance and is obtained by dividing cooling capacity by heat input. The larger the number, the higher the efficiency.

NZ type (COP 1.51)

Efficio

Control panel
A touch panel allows for easy operation.

Low-temperature regenerator

Condenser
The refrigerant vapor is condensed and sent on to the evaporator.

Evaporator
Refrigerant (water) is evaporated in a vacuum state and the water passing through the pipe is cooled with vaporization heat. The vapor is sent on to the absorber.

Generator
The absorbent is heated to evaporate the water, and condensed absorbent is returned to the absorber. Vapor is sent on to the condenser.

Absorber
Refrigerant (water) vaporized in the evaporator is recovered with the absorbent.

High-temperature regenerator

Burner

Adoption of energy-saving technologies

The Efficio has achieved improved efficiency by adopting various energy-saving technologies, such as a heat exchanger that uses newly developed plates offering as much as 40% performance improvement, and newly developed two-stage evaporation/absorption technology. In addition, high-performance heat exchanger tubes have been introduced, and the temperature of heat recovered by the exhaust gas heat exchanger has been reduced from around 200°C to 100°C.

Efficio lineup supports a wide range of applications

- NH type (COP 1.43)
- NU type (COP 1.39)
- NE type (COP 1.33)

*Model shown: NE type

The mechanism (cycle) by which heat is used to cool water for air conditioning

When liquid evaporates, it carries heat energy away from its surroundings. This principle is used to produce cold water for air conditioning. An absorption chiller works as an air conditioner by using a heat-driven concentration difference to move refrigerant vapor (water) from the evaporator to the condenser. Heat is used to convert the vaporized water back into water again, and then to repeat the cycle in an efficient manner.

Condenser

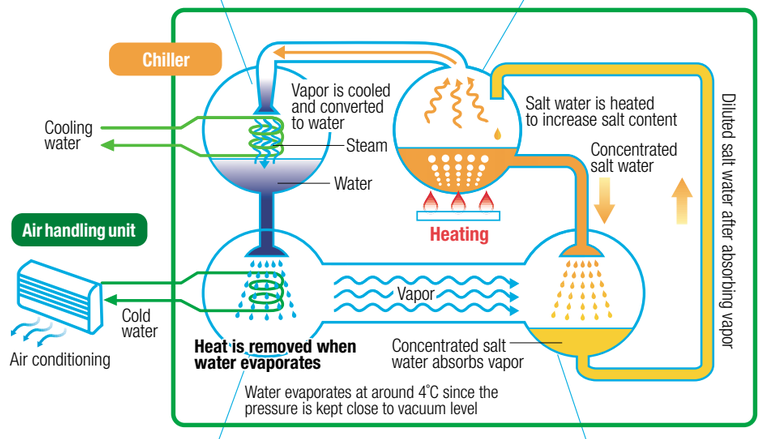
The refrigerant vapor is condensed and sent on to the evaporator.

The condenser cools the vapor produced by the regenerator using cooling water to convert it back into water. Cooling water is water cooled in cooling towers often placed on the roofs of buildings.

Generator

The absorbent is heated to evaporate the water, and condensed absorbent is returned to the absorber. Vapor is sent on to the condenser.

Heat produced by burning gas or kerosene is used to evaporate the water content of the absorbent (salt water) that had been diluted after absorbing vapor, and returns the absorbent to its original concentration level. The absorbent in the low-temperature generator is heated by the steam generated in the high-temperature generator—the reason this is called a "double-effect" absorption chiller—to increase efficiency.



Evaporator

Refrigerant (water) is evaporated in a vacuum state, and the water passing through the pipe is cooled with vaporization heat. The vapor is sent on to the absorber.

Under a pressure level close to a vacuum, water evaporates at around 4°C. The evaporator cools water this way. Inside the evaporator, the pressure is kept at a vacuum level so that refrigerant water will evaporate by being sprayed over tubes. The water flowing through tubes is cooled from 15°C to 7°C with vaporization heat and used for air conditioning.

Absorber

Refrigerant (water) vaporized in the evaporator is recovered with the absorbent.

Salt absorbs moisture. This property is used to induce a highly concentrated salt-water solution to absorb the vapor generated in the evaporator to recover the water—thus the name absorption chiller. Although the absorbent is referred to as salt water, it uses a compound called lithium bromide instead of common dietary salt, or sodium chloride. Lithium bromide has the same hygroscopic property as sodium chloride, and also has a briny taste.

When used as a heater (outline)

Water evaporates when the absorbent (salt water) is heated by the regenerator. The resulting steam is used to raise the temperature of the water flowing through the pipe. Water condensed during heating is mixed with the absorbent (salt water) and sent to the regenerator. This cycle is used to continuously obtain hot water for heating.

Hull Parts for Brazilian Drillship

Kawasaki recently announced that it will provide drillship hull parts to Estaleiro Enseada do Paraguaçu S.A. (EEP) of Bahia State, Brazil, a company in which Kawasaki holds a 30% stake. The parts will go into the hull of the first of six vessels ordered by Sete Brasil, an investment company in the oil and gas industry, which will be chartered by Petrobras, Brazil's state-owned oil company. After the 210 m drillship's hull parts are completed at Kawasaki's Sakaide Shipyard, they will be transported to EEP for installation of other segments, such as topside equipment, before delivery to the owner.

With the drillship owner's agreement, Kawasaki is working on the initial vessel's hull as part of a technical cooperation with EEP, with completion expected for the 1st quarter of 2015. The Brazilian minimum content of all the ordered vessels will remain as determined in the contract with Sete Brasil, as well as other contractual conditions.

Kawasaki plans to continue providing offshore vessels to meet the global demand for offshore drilling projects.

World's First Rolling Stock Bogie with a CFRP Frame and Suspension Function

Kawasaki has developed a world's first: the efWING* rolling stock bogie, which uses CFRP (carbon fiber-reinforced plastic) for the main structure of its framework. CFRP is a material that exhibits exceptional strength despite being lightweight, and is often used in aerospace applications.

For the next-generation efWING, Kawasaki replaced the original steel of the main structure, thus eliminating the need for coil springs. The bogie is also 40% lighter than the steel-frame type, with a simplified structure due to integration of the coil spring function and the bogie frame. The reduced weight roughly translates into a reduction of about 900 kg per train car. This significantly contributes to increased fuel economy (i.e. lower running costs) and reduced CO_2 emissions.

The efWING has already undergone about 4,500 km of operational tests conducted by the Transportation Technology Center, Inc. (TTCI), which confirmed its basic and safety performance in operation. The arch-shaped CFRP bogie frame with suspension functionality stabilizes the force transferred by each wheel onto the rail. This results in improved passenger comfort as well as greater protection against derailment, with wheel load reduction** due to rail irregularity reduced to less than half the previous rate.

The efWING has been designed according to the principles of Kansei Engineering, taking a holistic approach that achieves the ideal combination of performance, aesthetics and cost. The result is a new generation of rolling stock bogies manifesting a sophisticated harmony of function and aesthetics.

Kawasaki will continue to leverage its superior technology and reliability to provide rolling stock products that contribute to customers around the world.

* This stands for "environmentally friendly Weight-Saving Innovative New Generation Truck."
** Wheel load reduction refers to a reduction in vertical load transferred from the wheels onto the rails while passing through a curved section or running over irregular rails, and can cause the train to go off the track.

Development of Rolls-Royce Trent 1000-TEN and Trent XWB-97

Kawasaki recently reached an agreement with Rolls-Royce on contracts for its participation in the Trent 1000-TEN and Trent XWB-97 engine programs as a Risk-and-Revenue-Sharing Partner, including module design, development and production activities.

The Trent 1000-TEN is the latest version of the Trent 1000 engine, incorporating new technologies for improved fuel efficiency and higher thrust. The engine will power all versions of the Boeing 787 Dreamliner, including the third member of the 787 Dreamliner family, the 787-10, which was formally launched at the Paris Air Show in June 2013. The aircraft will have seating for 300-330 passengers.

The 97,000 lb thrust Trent XWB-97 is the exclusive powerplant for the Airbus A350-1000 aircraft, which has a 350-400 seating capacity and is part of the A350 XWB family.

Kawasaki will be responsible for the design and manufacture of the Intermediate Pressure Compressor (IPC) module on both engines, further extending its participation in Trent engine programs.

Kawasaki and Rolls-Royce have worked together on military, marine and civil aerospace engines in a relationship dating back to a licensing agreement on Orpheus engines in 1959. Kawasaki began its participation in Rolls-Royce civil engine programs on the RB211-524 and Trent 700 in 1988.

Motorcycle Sales Launched in China

Kawasaki Heavy Industries Management (Shanghai), Ltd., a new subsidiary, recently began importing and selling Kawasaki motorcycles and related products in China, the world's largest market for motorcycles. With the economic boom, the tastes and preferences of Chinese customers are becoming more diversified, a trend that will likely lead to a growth in recreational riders, the segment targeted by Kawasaki.

Kawasaki has entered the market with a number of popular models, mainly in the middle- and large-size classes: the Ninja ZX-14R, a flagship model with outstanding sport-riding performance, the Ninja 650 and ER-6n, midsize sport models popular for their stylish profiles, and the Ninja 250 and Z250, global strategy models with a quality and performance beyond their class.

Sales offices are being established mainly in large cities, including Shanghai, Beijing and Chengdu. The annual sales target for the first five years is 5,000 units.

Kawasaki will continue to provide products and services that further boost its brand appeal and bring greater satisfaction to customers around the world.

K-GET Waste-Heat Recovery System for Marine Diesel Engines

Kawasaki recently developed the K-GET (Kawasaki-Green Eco Turbine) waste-heat recovery system, which helps reduce CO_2 emissions in marine diesel engines.

Marine vessels plying international waters are required by the International Maritime Organization (IMO) to reduce CO_2 in stages starting this year. In response, Kawasaki has been developing a waste-heat recovery system that utilizes the surplus energy of exhaust gas emitted by marine diesel engines. Previously, all of this gas was sent to the turbocharger mounted on the engine, which provided energy to send in fresh air. Thanks to technological advances in recent years, however, turbochargers have become far more efficient, allowing sufficient air to be sent to the engine without using all the exhaust gas.

The K-GET system uses a portion of the exhaust gas to drive a power turbine, which generates power that helps rotate the crankshaft. Kawasaki has achieved high efficiency with its proprietary power turbine, and by simplifying the configuration of equipment, the impact on engine room layout is minimal. The energy obtained by recovering waste heat from the exhaust gas is used directly as part of the thrust power. This helps reduce CO_2 emissions and fuel consumption, as well as enabling application to a wide range of vessels, including bulk carriers, oil tankers and other types of ships that do not require much electricity on board during operation. In a test operation conducted at the Kobe Works, a reduction of up to 4% in CO_2 emissions and fuel consumption was confirmed.

The system will now be subjected to an in-service test to evaluate its performance and verify durability, in time for the scheduled launch in fiscal 2015.

Kawasaki will continue to develop technologies that help protect and improve the global environment.

Kawasaki's Dedication to Quality of Products

Fun to Ride for everyone around the world! Have fun riding Kawasaki's motorcycles.

Today, the motorcycle market is expanding globally,
from Japan, the United States, and Europe to Southeast Asia, Brazil, India, and China.
The Akashi Works here in Hyogo Prefecture, Japan is Kawasaki's global mother factory.
Notably, this factory is the embodiment of Kawasaki's technology, expertise,
and many years of commitment to quality manufacturing.
Each day, we mass-produce hundreds of motorcycles, but we always keep in mind
that every single motorcycle is dedicated to each customer.
That is why we manufacture our motorcycles with the utmost care.
Embodying the spirit of "Fun to Ride" and "Ease of Riding,"
Kawasaki guarantees excellent environmental performance.
With their attractive features, Kawasaki's motorcycles have enthralled riders.
Day after day, the latest Ninja motorcycles are shipped to customers worldwide,
delivering Kawasaki's aspirations.
The lime-green bodies represent their potential for speedy and dynamic driving.

Kawasaki, working as one for the good of the planet "Global Kawasaki"

http://www.khi.co.jp

Kawasaki
Powering your potential

"Diversified technological solutions that serve: opening up new possibilities for customers and communities"—this is the message of the Kawasaki brand, and the road to achieving our Group mission.

Kawasaki Heavy Industries, Ltd.