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PROJECT TO ESTABLISH HEAT RECOVERY-TYPE GAS HOT-WATER HEATERS AS THE DE FACT STANDARD

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1. ABSTRACT

A variety of high efficiency type home use hot water heaters capable of contributing to the reduction of CO_2 emissions by home use hot water heating equipment are now coming into wide use. One of these is "Eco-JOES", a latent heat recovery type gas hot water heater. This hot water heater is, in addition to the conventional primary heat exchanger, also equipped with a secondary heat exchanger which uses latent heat in combustion exhaust gas. This can improve energy consumption efficiency from 80% to 95%, cutting CO_2 emissions by about 13% from conventional hot water heaters.

The Government of Japan has set an ambitious intermediate target for greenhouse effect gas emission reductions in 2020 at less than 25% of the quantity emitted in 1990, and in response, the Japan Industrial Association of Gas and Kerosene Appliances and the Japan Gas Energy Promotion Council have made a decision to replace all gas hot water heaters which gas equipment makers manufacture with Eco-JOES (de facto standardization of Eco-JOES) by April 2013.

In order to replace conventional hot water heaters with the latent heat recovery type hot water heaters, the following technologies were developed in order to adapt them to conditions in Japanese homes.

1. Compact size: Realizing a device size equal to the conventional type, even with the secondary heat exchange installed.
2. Drainage water treatment technologies: Developing a device with a function that transports drainage water produced during heat recovery to bathrooms.
3. Combustion exhaust gas treatment technology: Development of a device to cause the combustion exhaust gas to flow more rapidly in order to prevent retention of the combustion exhaust gas.
4. CO sensor: Development of a CO sensor to sustain service lifetime equivalent to 10 years, even in a high humidity environment.

In the future, total costs including the cost of installation work will be reduced, energy visualization promoted, high value added, and other technology development carried out in order that 20 million units are installed by 2020.

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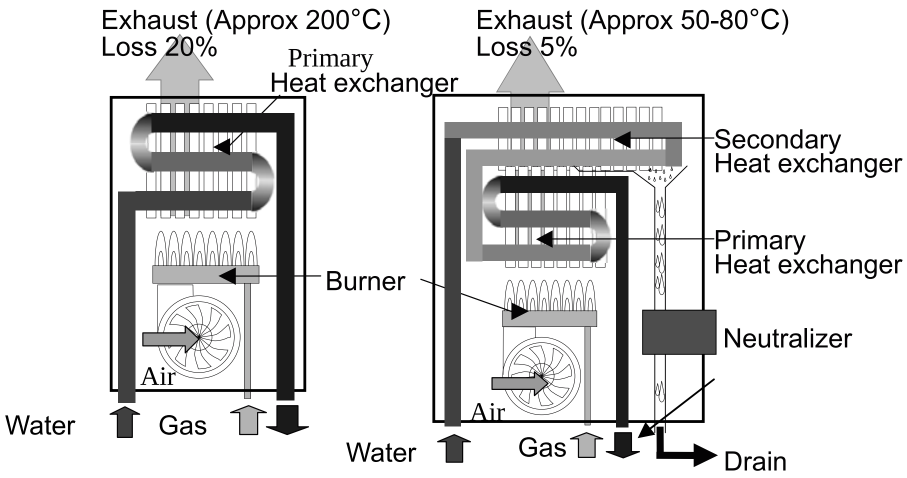
2. INTRODUCTION

At present, in the residential hot-water equipment market, various kinds of high-efficiency hot-water supply devices which contribute to reduction of CO_2 emissions have become more popular. One of such device is the latent heat recovery-type gas hot-water supply device, which is usually called the condensing boiler, and our product name is "Eco-JOES". In addition to the conventional primary heat exchanger, the device has a secondary heat exchanger which uses latent heat from combustion gas as shown in Figure 1. In this way, it achieves water heating efficiency of approximately 95%, a significant improvement compared to the conventional water heaters whose efficiency is limited to around 80%. Better efficiency not only reduces CO_2 emissions but also dramatically cuts running costs.



(1) Conventional type (2) Latent heat recovery type

Figure 1: Design principle of a Latent Heat Recovery-Type Gas Hot-water Heater

Since the launch of Eco-JOES in June 2000, its cumulative shipments reached approximately 1.6 million units by the end of March 2010, with estimated CO_2 emissions reduction of 350,000 tons per year.

The Japanese Government has, as one of the policies intended to prevent global warming, set an ambitious 2020 climate target which aims to cut greenhouse effect gas emissions by 25% from the 1990 levels.

In response to the policy, the Japan Gas Energy Promotion Council (commonly known as COLLABO in Japan), dedicated to making high-efficiency gas hot-water heaters the de facto standard, has set a target of integrating hot-water heater production lines exclusively with Eco-JOES by 2013, and has set a 2020 market penetration goal of 20 million units and predicted CO_2 emissions reduction of about 4.45 million tons per year.

But in order to replace the conventional hot-water heaters with the latent heat recovery type gas hot-water heaters, it is essential to make them suitable for Japanese houses, which are characterized by stringent limiting conditions for installation.

This paper reports the development of technology to manage drainage water produced during latent heat recovery, the development of exhaust gas treatment technology, and the development of CO sensors and other technologies needed to support the de facto standardization of Eco-JOES.

3. COMPACT DESIGN OF THE DEVICES

The Eco-JOES differs from a conventional hot water heater in that it is equipped with a secondary heat exchanger and neutralizer. When considering replacing a conventional type or installing pipe shaft equipment in apartment buildings, device sizes must be based on those of a conventional type, and the first step in converting to Eco-JOES, was to reduce the size, modularize, and revise the layout of each component of the hot water heater. In particular, waste space was reduced through optimizing the design and revising the layout of the components and the piping of the combustion chamber. As a result, inside a hot water heater with dimensions of 450mm(width)× 750mm(height)×250mm (depth), space was ensured to install a secondary heat exchanger with dimensions of 370mm(width) × 100mm(height)×220mm(depth) and a neutralizer containing about 2.5kg of calcium carbonate.

4. DEVELOPMENT OF DRAINAGE MANAGEMENT TECHNOLOGY

4.1 Newly constructed apartment building

One serious challenge to installing Eco-JOES is treating the drainage water produced by condensation of water vapor in the combustion exhaust gas during latent heat recovery. The drainage water is highly acidic because NOx is mixed into the combustion exhaust gas. Therefore, because the water cannot be drained in such acidic condition, the acidic drainage water is discharged outside the heater after it has been neutralized by the calcium carbonate packed inside the hot water heater.

In single-family dwellings, the water is drained to an outside house inlet, but at an apartment building, there are few place where drainage is possible, so drainage has been done by, for example, installing a specialized pipe for drainage water. But to apply this method, is it essential to execute the specialized drainage water pipe after making advance arrangements with the builder, which entails greater expense and is more time-consuming than applying the conventional method. This is one obstacle to popularizing the widespread use of Eco-JOES.

So a device housing a drain tank and a drainage discharge pump installed downstream from the neutralizer of the hot water heater as shown in Figure 2 was developed (called “Drain Up Eco-JOES” in Japan). The acidic drainage water produced during heat recovery is neutralized by the neutralizer, then temporarily stored in the drain tank. The water level in the drain tank is constantly monitored, and when the collection of a stipulated quantity is detected, the drainage pump starts up. The drainage water is forcibly transported outside of the device by the drainage pump. A pipe combining a reheating pipe and a drainage water discharge pipe connected to the device as shown in Figure 3 transports the drainage water to the bathroom. The drainage water which has been transported outside the device by the discharge pump passes through this discharge pipe to the bathroom where it is discharged from the bathroom's drainage water outlet.

Using this Drain Up Eco-JOES and the triple-tube permits the execution of a drainage water discharge pipe simply by executing a normal bath reheating pipe. Therefore, it is no longer necessary to execute a specialized drainage water pipe, contributing to a sharp reduction of the execution cost.

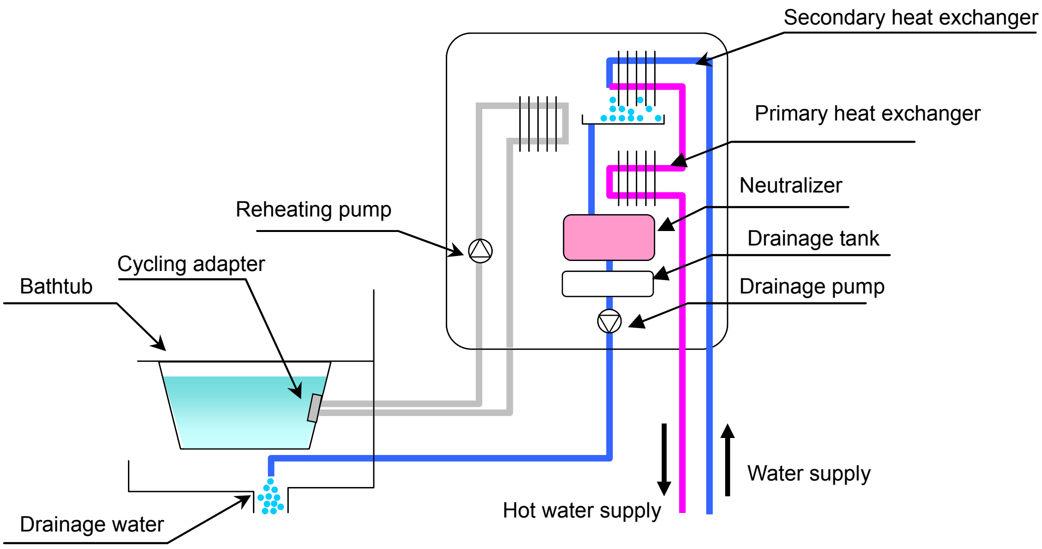


Figure 2: Principle of the Eco-JOES with Built-in Drainage Water Discharge Pump

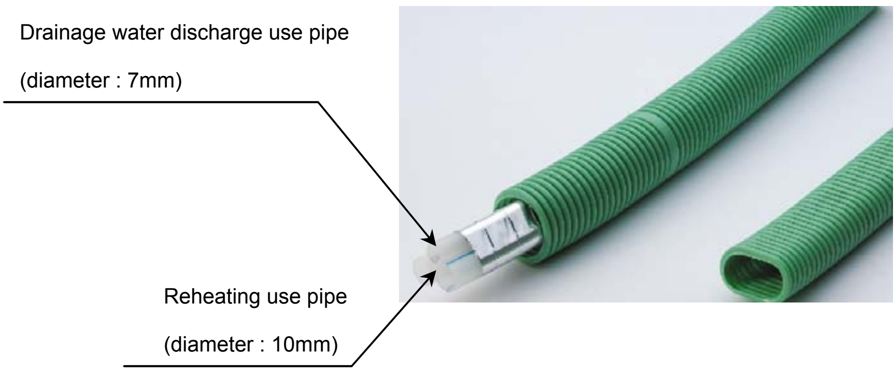
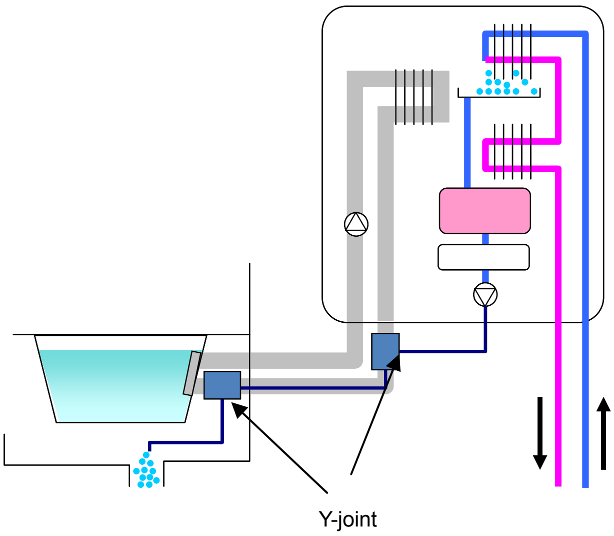


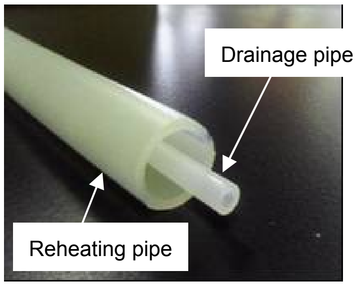
Figure 3: External Appearance of the Reheating pipe and Drainage Water Discharge Pipe (called : Triple-tube).

4-2. Introduction to an existing apartment building

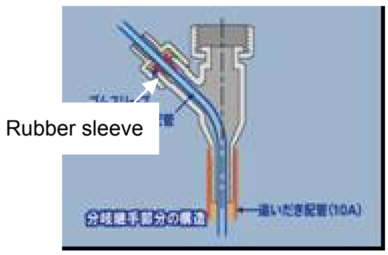
The three-way Valve Type Eco-JOES was developed to replace conventional hot water heaters in existing apartment buildings. The major obstacle encountered when planning the introduction of Eco-JOES to an existing apartment building is ensuring a place to discharge the drainage water. In Japan, discharging drainage water of the Eco-JOES into the rainwater system is prohibited in principle, so it must either be fed into the domestic wastewater pipe system or a specialized drainage water discharge pipe must be provided. In the case of an existing apartment building, it is difficult to execute a vertical pipe specialized for drainage, as is now done in a new apartment building described above, so it was in fact, impossible to actually replace the existing system with Eco-JOES. Therefore, construction methods to discharge drainage water into the bathroom using an existing reheating pipe were developed. One is the double pipe method, and the other is the triple-tube replacement method.

The double pipe method is, as shown in Figure 4, executed by inserting a resin pipe with external and internal diameters of 4mm and 2.5mm respectively into the existing reheating pipe (internal diameter 10mm). This method involves inserting the drainage water discharge use resin pipe inside the reheating pipe in one direction, then installing Y-joints near the connection port of the device and near the drainage port in the bathroom, then sealing both ends. The Drain Up Eco-JOES introduced in part 3-1 can be used as the replacement use Eco-JOES. But there are various problems with using this method. For example, if the existing reheating pipe is a copper pipe, there is a possibility that the interior surface of the copper pipe will be scratched when a super fine pipe is inserted, so it cannot be used. And when this method is used, the pipe resistance of the reheating pipe increases, prolonging the time required to draw a bath and time needed for reheating.





The drainage pipe inserted into the reheating pipe



Structure of a Y-joint

Figure 4: Schematic Diagram of the double pipe Method

The triple-tube replacement method is executed by pulling the existing reheating pipe (2 tubes) inside the CD tube, and at the same time, pulling in a triple-tube including the drainage tube (1 drainage tube + 2 reheating pipes). This method is also executed using the Drain Up Eco-JOES as the device. The shortcomings of this method are, not only that it cannot be executed when the existing reheating pipe is a copper pipe, but that even if the existing tube is a resin pipe, it may be impossible to pull it out because of the tube length and number of bends.

The three-way valve Eco-JOES was developed to supplement for the shortcomings of these two methods. It achieves both drain water discharge and reheating with the existing reheating pipe by executing a three-way valve unit midway on the existing reheating pipe to replace its valve as shown in Figure 5.

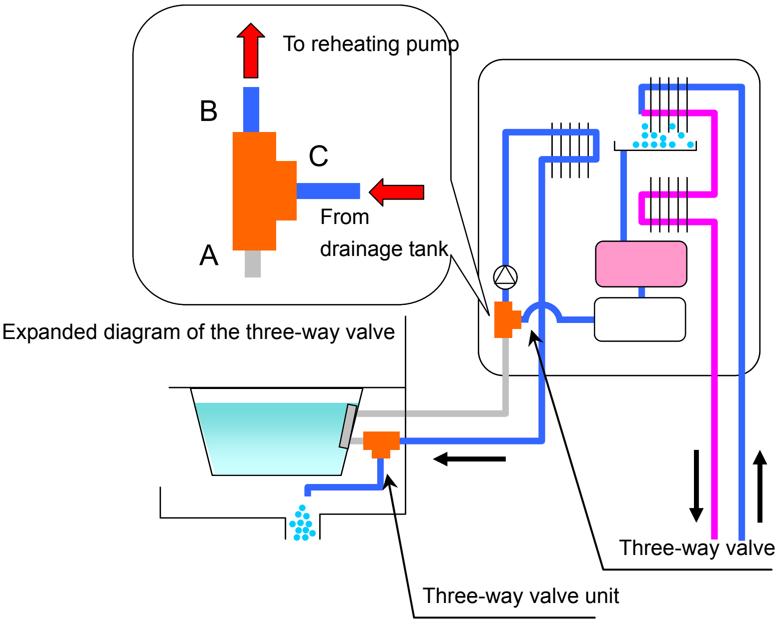


Figure 5: Principle of the Three-way Valve Type Eco-JOES

Inside the three-way valve unit, flow channel switching use three-way valves are installed, and the electrical part is covered by a resin case finished to water-proofing specifications. As stated earlier, this device was developed assuming its installation in an existing apartment building. In the case of an existing apartment building, it is impossible to install a new power source to power the three-way valve inside bathrooms, so a power output port is installed on the bathroom remote control, and this ensures electric power to drive the three-way valve unit.

And three-way valves are installed inside the device as shown in Figure 5. During reheating, the flow route is changed to the A-B side by the three-way valve. When reheating was performed by an operation by the user, the bath pump was driven, drawing hot water from the bathtub into the hot water heater side. The hot water drawn in is fed to the heat exchanger through the reheating return tube, three-way valve A-B, and the reheating pump, then heated to the stipulated temperature. After heating, it is returned unchanged to the bathtub through the reheating return tube.

The drainage water created during combustion is temporarily collected in the drainage tank of the device. When the collection of a stipulated quantity of drainage water has been detected, drainage water discharge operation begins. During drainage water discharge, the three-way valve switches the flow route to C-B. When the reheating pump operates, the drainage water inside the drainage tank is fed to the three-way valve unit through the three-way valve C-B, the reheating pump, heat exchanger, and reheating return tube. During drainage water discharge, the three-way valve inside the three-way valve unit switches to the drainage side, discharging the drainage water into the discharge outlet of the bathroom.

The three-way valve type Eco-JOES can be applied regardless of the material of the existing reheating pipe or tube length, so it will presumably be applicable to meet most of the apartment building replacement demand.

5. DEVELOPMENT OF COMBUSTION EXHAUST TREATMENT TECHNOLOGY

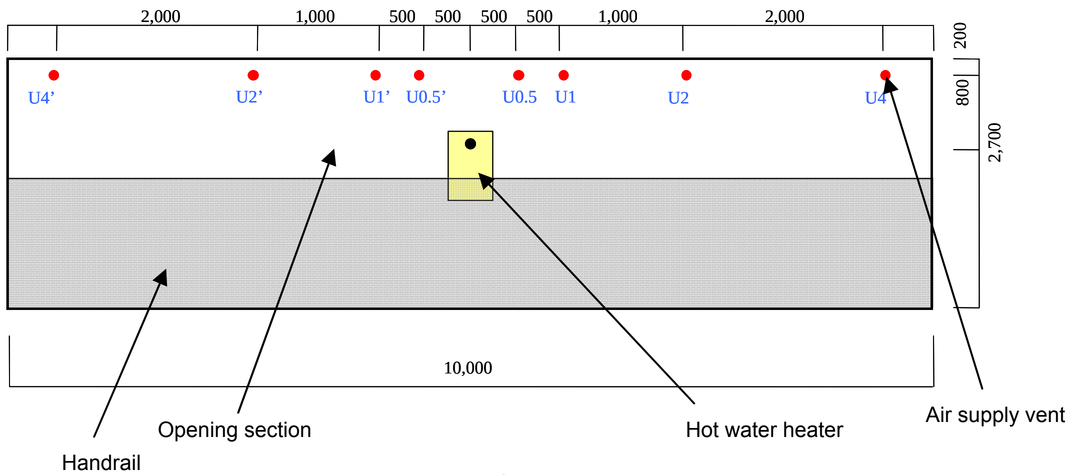
Another challenge facing Eco-JOES is the retention of combustion exhaust gas. The exhaust of Eco-JOES is extremely humid and its temperature is very low at between 50°C and 80°C, in contrast to the approximately 200°C of a conventional hot water heater. Thus, when the Eco-JOES is installed in an open corridor of an apartment building, etc., exhaust gas is easily retained. On the sides of open corridors of apartment buildings, air supply vents to the indoors are often installed, raising fear of the deterioration of the indoors environment, and the following stipulations are entered in the hot water heater execution guidelines.

- Do not install an air supply vent or ventilation vent etc. in the ceiling of an open corridor.
- Avoid installing an air supply vent or ventilation vent etc. within a range of 30cm from the wall or ceiling surface directly above the device.

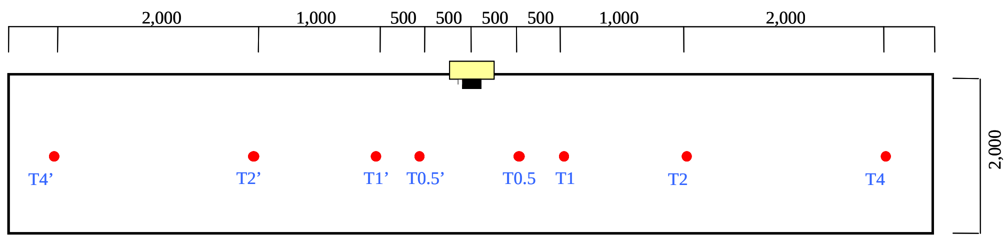
But considering the design of apartment buildings, it is impossible to avoid installing air supply vents or ventilation vents on the sides of open corridors, so to comply with the above guidelines, it is necessary to adopt a measure to extend the combustion exhaust gas of a hot water heater to the opening of an open corridor. Extending the distance that combustion exhaust gas is exhausted incurs the cost of installing an exhaust pipe, so it is possible that some collective building owners will hesitate to introduce Eco-JOES.

So we developed an Eco-JOES in which the combustion exhaust gas flows more rapidly in order to prevent the retention of exhaust gas in open corridors. Figure 6 shows a full-size model in the open corridor of an apartment building.

(a) External photo



(b) Front view of the open corridor



(c) Plane diagram of the open corridor

Figure 6: Full Size Model in an Open Corridor

A device with its hot water heater exhaust top opening surface area reduced so that the combustion exhaust gas flows more rapidly was installed on the model, and the carbon dioxide concentration near the air supply vent was measured to confirm whether or not combustion exhaust gas is retained.

Table 1 shows an example of confirmation results. The top are results for a conventional Eco-JOES and the bottom are results for the Eco-JOES with its flow rate increased. U1, U4, T1, and T4 etc. in the Table represent the locations of the air supply vents installed in Figure 6. This table shows that while the carbon dioxide concentration near the air supply vent of the Eco-JOES without its flow speed increased was more than 2,000ppm, while the increase of the flow speed cut this concentration to 1,000ppm.

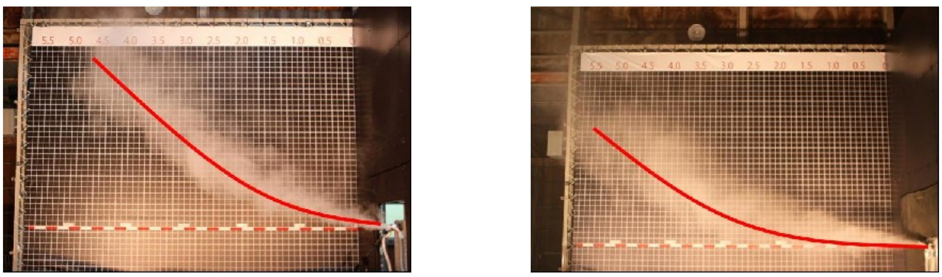
Table 1: Results of Measurements of Carbon Dioxide Concentration at the Air Supply Vent of an Open Corridor

	Hole conditions				Ceiling air supply vent			Wall surface air supply vent		
	Width	Height	Area	Hot water heater height	T1'	T1	T4	U1'	U1	U4
Before flow rate increased	2.0	1.3	2.6	1.8	1,867	2,594	2,228	1,949	2,279	2,278
After flow rate increased	↑	↑	↑	↑	925	699		801	766	

Figure 7 shows the external appearances of the exhaust opening shapes before and after the increase of the flow rate, and Figure 8 visualizes the combustion exhaust gas in each case. The shape of the exhaust opening is changed from its formerly round shape to a square shape, and its section area is cut to 65% of its former area. The result is, as shown in Figure 8, an increase in the straightness of the combustion exhaust gas, resulting in turn, in the elimination of the retention of combustion exhaust gas in the open corridor and the realization of a reduction of the carbon dioxide concentration near the air supply vent.

(a Conventional Exhaust Opening (b) New model of Exhaust Opening

Figure 7: Comparison of Combustion Exhaust Opening Shapes



(a) Before increase of flow rate (b) After increase of flow rate

Figure 8. Visualization of Combustion Exhaust Gas (Comparison Before and After Increase of the Flow Rate)

Based on the above results, devices to be installed in the open corridors of apartment buildings will be those with increased flow rate, permitting the relaxation of the guideline referred to above.

6. DEVELOPMENT OF THE CO SENSOR

In Japan, hot water heaters installed indoors must be equipped with CO sensors. Combustion exhaust gas from Eco-JOES contains a large quantity of water vapor, so the CO sensor is exposed to a high humidity environment and to an acidic drainage environment. A CO sensor able to survive for a service lifetime equivalent to about 10 years even under such a unique environment was developed.

The major change was the material. In the conventional type, copper-nickel alloy or brass were used, but it is known that these materials lack any acid-resistance. So a sample with its acid resistance boosted by the use of stainless steel was prepared and provided for durability testing. The results cleared durability testing of 10,000combustion hours and 100,000 cycles, ensuring durability equivalent to 10 years.

Future plans call for the Eco-JOES installation locations on exhaust routes to be optimized, and the development of the final marketable model will be completed aiming to begin sales in 2012.

7. CONCLUSION

This paper has introduced the development of the following technologies intended to make Eco-JOES a de facto standard in 2013.

1. Making the components inside the hot water heater compact and optimizing their layout has permitted the installation of a secondary heat exchanger and neutralizer in the same module as the conventional type.
2. A drainage water discharge technology which can be easily executed at low cost in both new and existing apartment buildings was developed.
3. The combustion exhaust gas flow rate was increased in order to prevent retention of combustion exhaust gas in the open corridor of an apartment building.
4. A CO sensor with durability equivalent to 10 years under a high humidity and highly acidic drainage environment was developed.

In the future, total costs including the cost of installation work will be reduced, energy visualization promoted, high value added, and other technology development carried out in order that 20 million units are installed by 2020.

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