Development of condensing boiler, a high-efficiency condensing water heater

Noritz Corporation

Takagi Industrial Co., Ltd.

Rinnai Corporation

1. Background of the development

Following the revision of Japan's Law Concerning the Promotion of the Measures to Cope with Global Warming in March 2002, standards were established (based on the "top runner") for improvement of the efficiency of gas water heaters. Thereafter, assistance was furnished for the marketing of high-efficiency equipment (such as models with CO2 heat pumps and others of the latent heat recovery type). February this year saw the official effectuation of the Kyoto Protocol, which requires Japan to reduce its greenhouse gas (GHG) emissions by 6 percent relative to 1990. These developments added further impetus to the movement to make equipment more energy-saving.

Water heating and space heating account for about 60 percent of the energy consumption in the home. Furthermore, in recent years, the expansion of the demand for floor heating systems and bathroom heaters (including mist sauna systems) is being paralleled by one for heaters. This has made it essential to promote the early marketing and diffusion of combination water and space heaters of the latent heat recovery type, which have a very high energy-saving effect. Nevertheless, the initial models (manufactured by Takagi Industrial) were aimed solely at detached housing, and their widespread diffusion was impeded by the following factors.

* Depth of 300 mm (as compared to 250 mm for the conventional type without latent heat recovery)
* Standard exhaust only
* Limitations on construction of the installation platform

Besides a reduction in size to a par with the conventional models (without latent heat recovery), expanded diffusion of the subject heaters demanded a full assortment of exhaust variations to enable proposal of installation in multiple dwelling houses. Implemented in this situation, the project described here was one of technology development for such expanded diffusion, undertaken with certain equipment manufacturers.

Figure 1 shows the principle of the latent heat recovery system. It can be seen that, as compared to the conventional type, the heater brings a great reduction in the exhaust temperature and recovery of latent heat by installation of a secondary heat exchanger for recovery of latent heat. Because of the condensation of dew (pH 2 - 3) during recovery of latent heat, the heat exchanger had to be equipped with a good resistance to corrosion. In addition, the need for pH adjustment in venting outdoors led to installation of a neutralizer within the heater. The heater is capable of attaining an overall heat exchange rate of 95 percent.

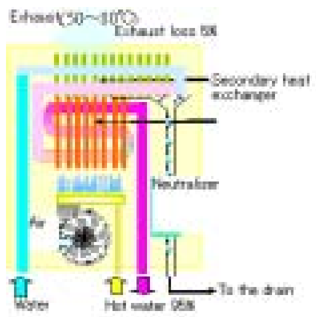


Figure 1: Principle of the latent heat recovery system

2. Profile of the development

(1) Compact constituent components

To reduce the size of the heater required the development of constituent components that were more compact. This section profiles the efforts made by the manufacturers in various fields to this end.

1) Development of the heat exchanger for latent heat recovery

As shown in Figure 2, the heat exchanger for latent heat recovery in the initial model manufactured by Takagi Industrial Co., Ltd. had a continuous curvature structure using flexible titanium pipe. The material was costly and presented some difficulties in processing. Another issue was the increase in volume accompanying the use of flexible pipe.

In contrast, the heat exchanger developed by Noritz Corporation is of the stack type and was designed to optimize the shape based on automotive oil coolers. Because the exchanger is made of stainless steel, it is superior to the former type in respect of both cost and processability. Moreover, thanks to the stack-plate structure, the volume is about one-third as large as the former model.

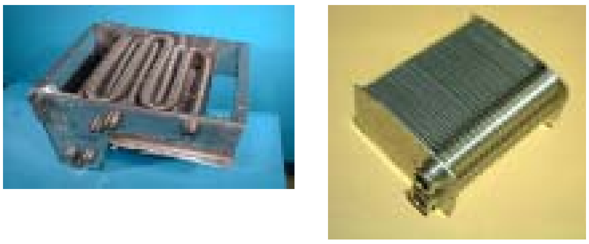
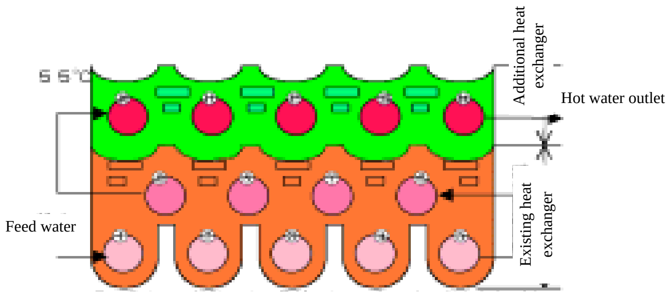


Figure 2: Conventional model (manufactured by Takagi Industrial) and new model (manufactured by Noritz)

2) Development of the primary heat exchanger

Rinnai Corporation succeeded in greatly increasing the efficiency of the primary heat exchanger. More specifically, it raised the efficiency to 87 percent with a three-stage pipe as opposed to about 80 percent in the conventional model which utilized a two-stage water pipe. The use of a copper fin on the primary heat exchanger, however, caused apprehensions of dew condensation and accompanying outbreak of corrosion due to a decline in the exhaust temperature along with the increase in efficiency. The heat exchanger development also improved the water heater system control so that the exhaust temperature would not fall below 55 degrees (centigrade) when the heat exchanger was in operation, to prevent condensation of dew.

Use of the heat exchanger in the new model increases the amount of heat recovery on the primary side, and this made it possible to make the exchanger only about half as large in volume as in the former system.



Drainage does not flow into the water pipe array on the upper stage as long as the control temperature from 10 to 14 is at least 55 degrees.

Outline of the additional heat exchanger and fin

Figure 3: New primary heat exchanger (manufactured by Rinnai)

3) Development of the burner

The development had to reduce the size of the entire combustion chamber while maintaining or increasing the economic merit as regards levels of nitrogen oxides and other pollutants. Noritz succeeded in lowering the height of the combustion chamber to about two-thirds as high as in the former model and achieving a NOx emission level of only 30 parts per million (ppm), below the industry's voluntary standard, by adopting a new lean-rich burner.

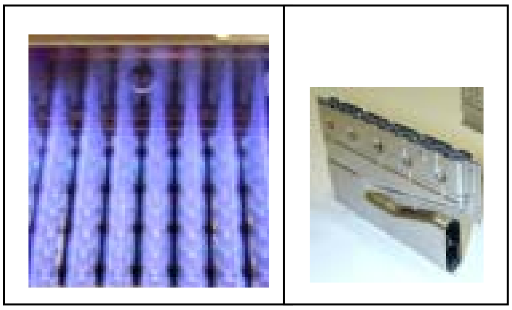


Figure 4: Development of a new burner (manufactured by Noritz)

4) Development of the neutralizer

Noritz optimized the shape of the neutralizer unit to make the most effective use of the small space left across the bottom of the entire heater. It also made the unit maintenance-free by giving it in advance the amount of neutralizing agent (calcium carbonate) sufficient to neutralize acidic drain water over a period equivalent to 15 years' worth of use. It also installed the unit with a safety device based on a water level electrode for the unlikely occurrence of clogging.

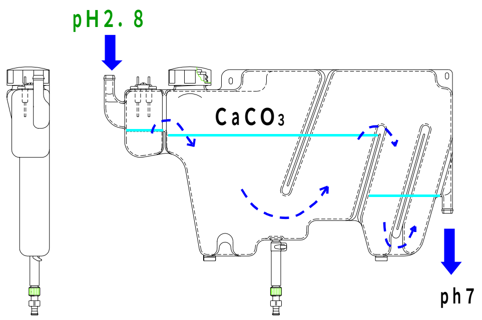


Figure 5: Newly developed neutralizer

Resting on the aforementioned fruits of this work, the newly developed heater of the latent heat recovery type covers all the classes of size covered by the conventional models and reached the highest levels of both water- and space-heating efficiency.

Type of equipment	Manufacturer	Water Heating	Space Heating
Conventional water and space heater		80.7%	80.2%
Initial water and space heater with latent heat recovery	Takagi Industrial	94.2%	87.6%
Newly developed heater - 1	Noritz	95.2%	89.2%
Newly developed heater - 2	Rinnai	95.2%	89.3%

(2) Development of the new system

The size reduction was achieved not only on the level of constituent components but also on that of the system. Figure 6 shows the newly developed water and space heater with a function for distribution of high-temperature water. Whereas the conventional models have two types of heat exchanger, one for heating water and the other for heating space, the newly developed system distributes hot water produced by the heat exchanger used for space heating as a source of thermal energy for bathing and water heating. The decrease in the number of heat exchangers as compared to the conventional model allowed the heater to be made much smaller.

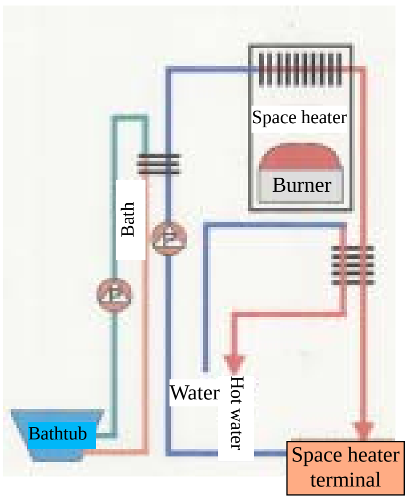


Figure 6: Newly developed system equipped for

distribution of high-temperature water
(manufactured by Takagi Industrial)

3. Data for environmental improvement

Tokyo Gas Co., Ltd. made trial calculations of the merits of the newly developed heater for saving energy and improving the environment based on data for those installed in 100 condominium units in the Greater Tokyo area. The results indicate that, relative to the conventional model, the newly developed one decreases annual CO_2 emissions by about 12.5 tons, or 13 percent, while also reducing the annual running cost per housing unit by about 9,500 yen.

4. Record of installation

The heater developed jointly by the three gas companies and Noritz was injected into the market in October 2002. Subsequently, a steady stream of other manufacturers came out with new models of their own based on the results of this project. That period coincided with the instatement of provisions for national subsidies for such equipment, and the resulting synergistic effect stimulated diffusion. As of the end of 2003, about 25,000 heaters had been installed in the service areas of city gas companies in Japan.

The national plans envision the installation of some 2.8 million heaters, including models that only heat water as well as combination of bathtub hot water supply and water heaters, across the country by the end of 2010. The project described above will therefore presumably be followed by others for additional development toward the end of expanded diffusion.

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