# DEVELOPMENT OF CONDENSING BOILERS FOR GAS CENTRAL HEATING SYSTEM

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## 1. INTRODUCTION

The Kyoto Protocol, adopted in December 1997 at the Third Conference of the Parties to the United Nations Framework Convention on Climate Change (COP3) to cut emissions of greenhouse gases by developed countries, set Japan the extremely tough target of cutting emissions by 6% compared with 1990. In order to achieve this target, the Japanese government revised the “Guideline of Measures to Prevent Global Warming” and put together a package of concrete measures for its attainment. One means of them is to establish standards for improvements in the efficiency of gas water heaters (based on the “Top Runner” method) and also to provide support to bring condensing water heaters, which offer the potential for especially substantial improvements in efficiency, into the market. So, improving the efficiency of gas water heaters is consequently attracting even more attention than in the past, particularly with regard to condensing water heaters.

## 2. WATER HEATERS IN JAPAN

### 2.1. Demands

Japanese consumers habitually bathe every day, filling a bath full of hot water and soaking in it. As a result, residential water heaters are expected 1) to be capable of providing large amounts of hot water, 2) to be capable of providing hot water instantly whenever required, and 3) to provide hot water at a steady temperature. Due to residential design circumstances, they are also expected 4) to be small and compact. These factors have given a competitive advantage to systems that heat water instantaneously without a hot water storage tank. In 2001, sales of gas water heaters reached approximately 1,900,000 units.

Most of the gas water heaters sold today incorporate microprocessors to provide electronic control. In addition to fine control of gas, air and water flow, they also have a large variety of safety devices such as self-diagnostic function to monitor the state of combustion. There has also been an increase in multifunctionality such as automatic bath operation (automated filling and temperature maintenance of hot water in a bathtub), and highly integrated communication system between boilers and other appliances (Gas central heating intelligent network communication). The development work to achieve these improvements in usability, safety and compactness have enabled gas water heaters to remain competitive with other energies.

### 2.2. Structure and Efficiency

The structure of a typical gas water heater is shown in Figure 1. When a shower or other water tap is turned on, water begins to flow in the water heater, and in conjunction, the burner starts combustion. When the water passes through the copper heat exchanger, it is warmed through heat exchanger with the combustion exhaust gases. The water temperature can be set by remote controller in 1°C increments. Gas control and water flow control by the microprocessor enables variations in water delivery temperature to be kept within 3°C either side of the setting, even with intermittent use such as showering. This provides users pleasant and comfortable shower bathing.

Heat exchangers are designed to have their thermal efficiency of about 80% (HHV). This level is selected because if the heat transfer area is too enlarged to raise the efficiency, that results in the production of acidic condensates, which erode the copper heat exchanger.

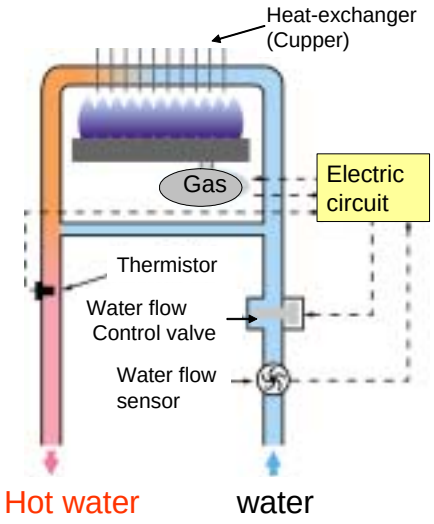



Figure 1: The structure of a typical gas water heater

**2.3. Boilers for Gas Central Heating System**

An example of a gas central heating system is shown in Figure 2. In this system, a single boiler provides hot water to all the taps and the bath, and also produces hot water (60°C and 80°C) for heating appliances such as floor heating mat, air conditioner, bath-dryer and so on. The boiler of this system consists of two combustion and heat exchanger sections, one for supplying sanitary hot water and one for generating hot water for heating appliances (please refer to Figure 4). Gas central heating system is now increasing in, especially in newly-built apartment houses.

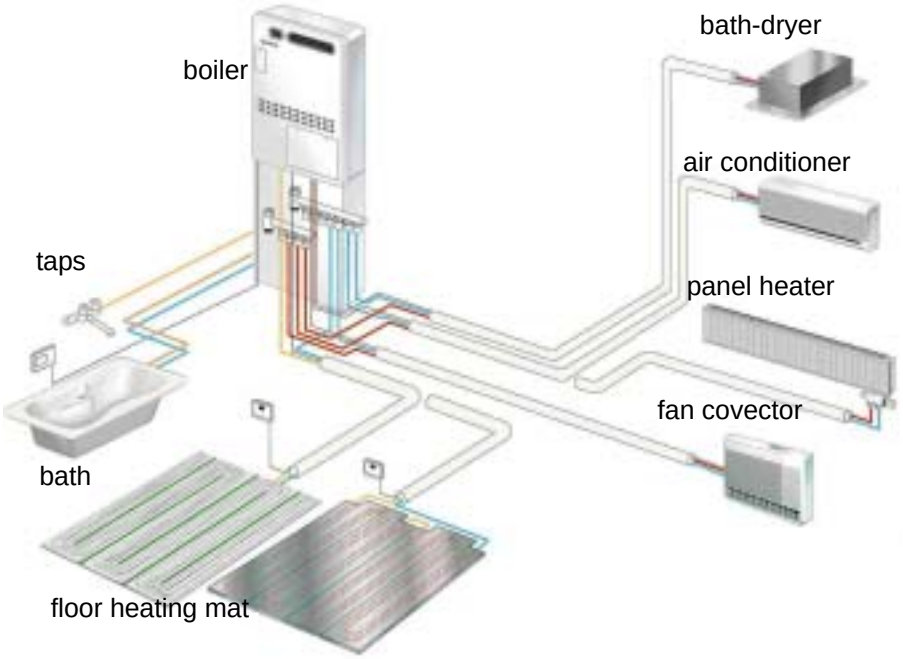



Figure 2: Example of a gas central heating system

### 2.4. Condensing Water Heater

Condensing water heaters were first put into practical service in Europe, particularly the Netherlands. Japan has also been involved in their development from an early stage, but in over 20 years of development, no condensing water heaters have reached the stage of being marketed. The reason is that since condensing water heaters have many more components than standard(=non condensing) water heaters, they were expected to cost substantially more, making it difficult to make a viable product. The fact that condensing appliances become larger was also a substantial disadvantage.

Despite these considerations, gas companies and appliance manufacturers responded to the increasing awareness of environmental issues described above and in 1999 started the commercial development of condensing water heaters, beginning with units for commercial applications where there are larger benefits in running cost cuts. Figure 3 compares the structure of a condensing water heater with that of a conventional water heater.

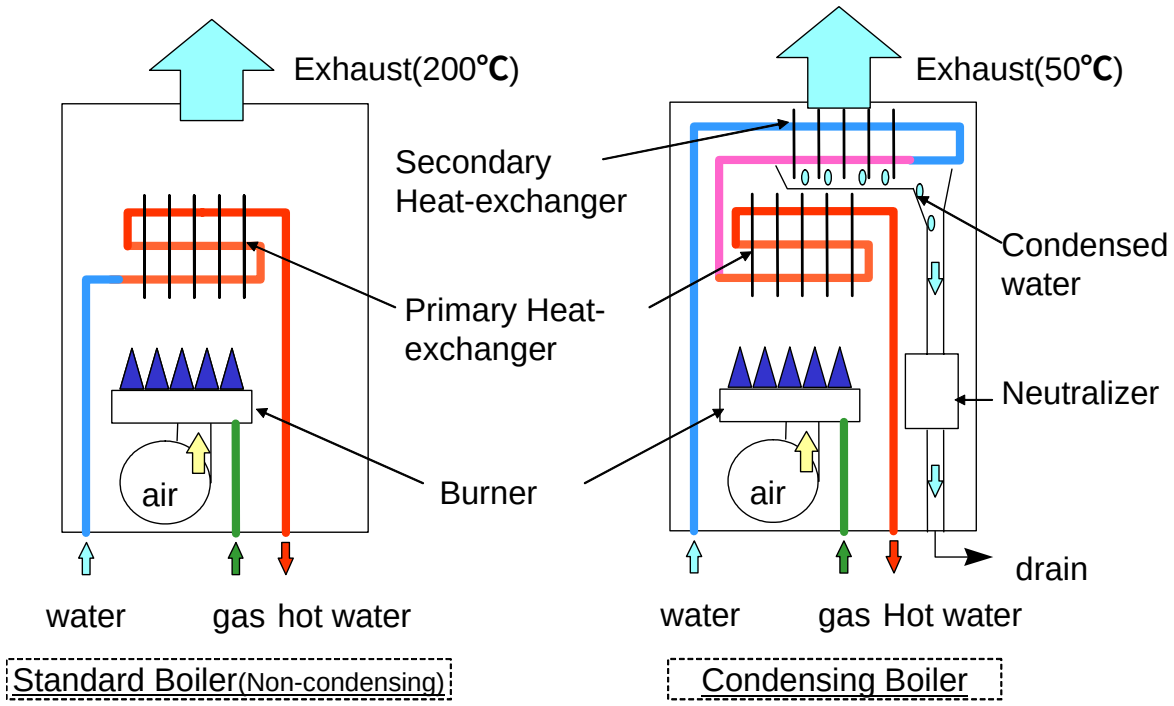



Figure 3: Structure of a standard boiler versus a condensing boiler

## 3. DESIGN CONCEPTS OF CONDENSING BOILER FOR GAS CENTRAL HEATING SYSTEM

The development of boilers for Gas central heating system was an urgent topic for promoting the widespread use of condensing water heaters in residential applications. We commenced development on the base of the expertise gained in the development of condensing water heaters for commercial applications.

### 3.1. Target Value of Efficiency

Our aim was to achieve water heating rating efficiency of 93~95% (HHV) ,when supplying sanitary hot water.

### 3.2. Structure

To share main parts with standard water heaters, we used conventional copper heat exchanger as a primary heat exchanger and started to develop secondary exchanger (condensing exchanger) to be set at the lower stream of conventional copper heat exchanger.

We also designed new secondary heat exchanger at another combustion - heat exchanger sections(hot water generator for heating appliances). Efficiency of hot water generator for heating appliances was increased to 88%, when 60°C hot water go to heating appliances and 40°C come back. (Efficiency of hot water generator for heating appliances in standard boilers is around 80%.)

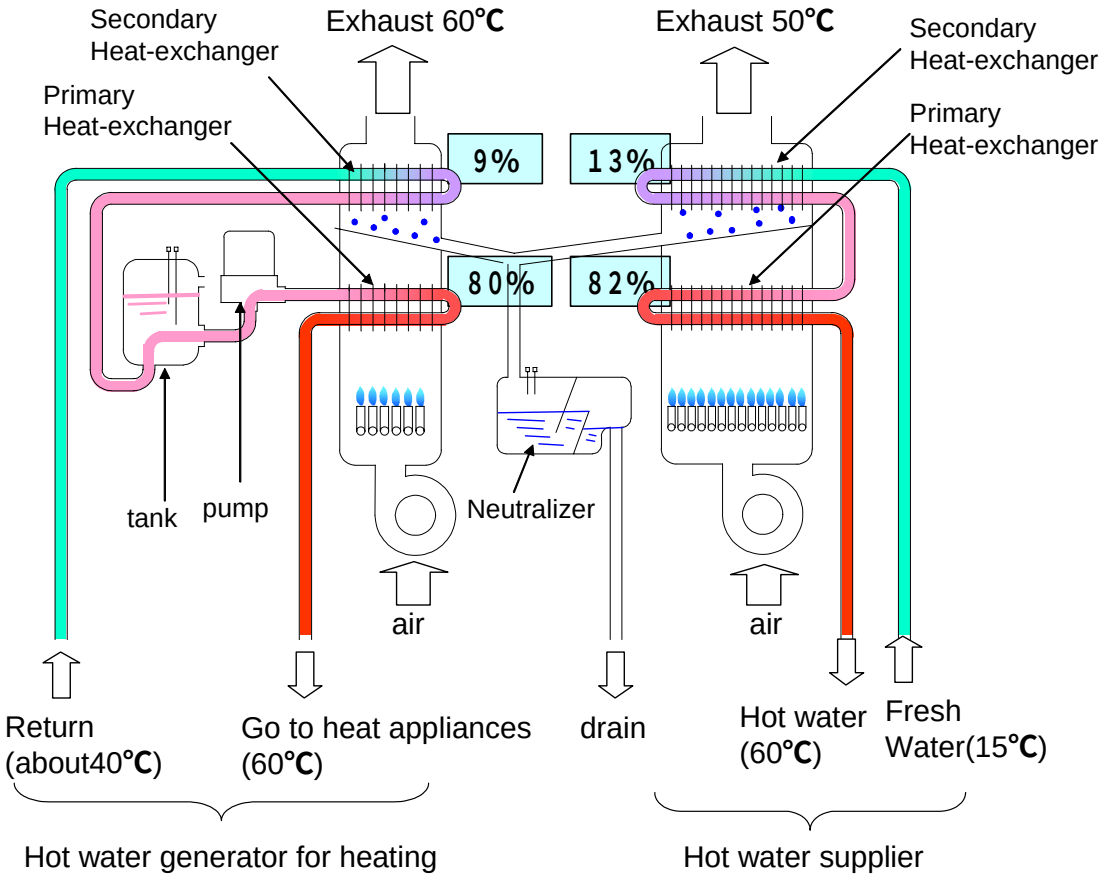


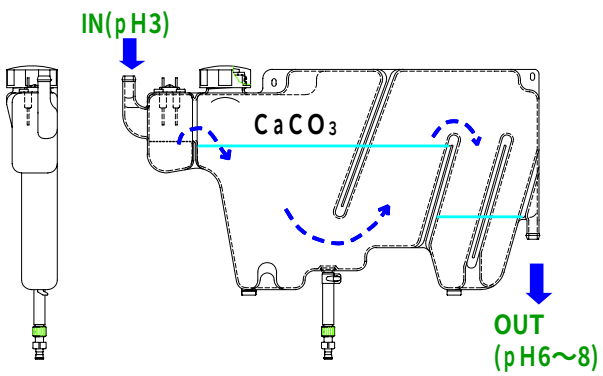

Figure 4: Principle of the condensing boiler for central heating

### 3.3. Durability

The equipment was designed to offer durability equal to that of standard gas water heaters, i.e. sufficient to withstand 10 years of use, during which regularly maintenance would not as a rule be required. New additional parts, such as the secondary heat exchanger and drainage channel, were required to withstand at least 10 years of use. The neutralizer described below was designed to be capable of neutralizing drainage for 15 years of use.

### 3.4. Neutralization

In Europe, gas water heaters are mainly installed indoors, but in Japan, except in particularly cold regions, it is more usual to install the gas water heater outdoors. The difference in installation location produces a difference in the piping used for drainage. In outdoor installations like those in Japan, all treatment of drainage must also be handled outdoors.



In Europe, especially in the Netherlands, builders and equipment companies cooperated in increasing the proliferation of condensing water heaters. In Japan, however, utilization of them is only in the very early stages, and the cooperation of builders and installers still needs to be acquired. Consequently, in order to minimize the impact on installers, a neutralization unit has been incorporated into the water heater to ensure the acidity of the drainage (Figure 5).

At this point, we consider that calcium carbonate is most suitable for neutralizing agent,

Figure 5: Neutralization unit

because of its easily use and cost.

### 3.5. Compact Design

Housing in Japan is not generally especially spacious, creating a need for water heaters to be made more compact to provide more living space. This is why instantaneous gas water heaters without hot water tanks have retained their popularity in Japan, and gas water heater sizes have in the main become standardized to allow their installation under a variety of conditions in condominiums and detached houses. As condensing water heaters are equipped with additional parts such as secondary heat exchangers and neutralizers, the challenge was to minimize as far as possible any consequent increase in size.

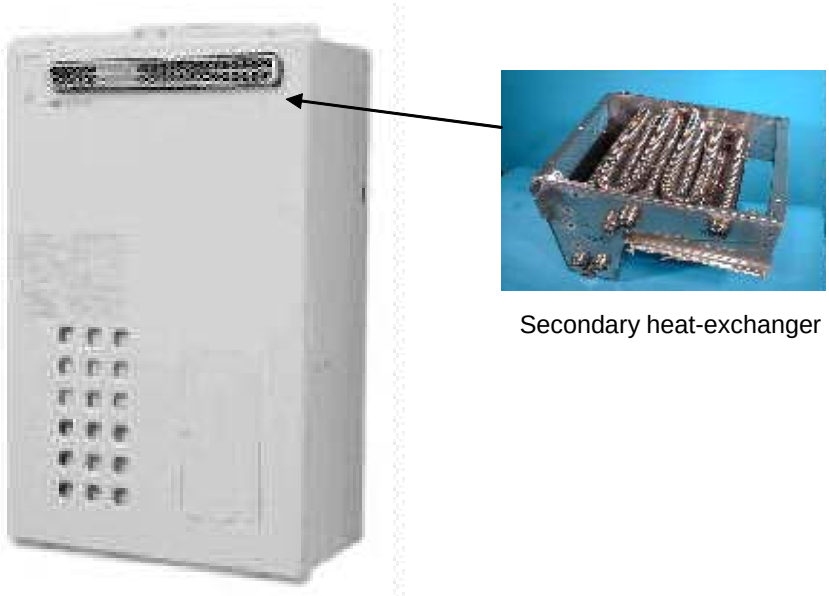
## 4. PRODUCTS

Figure 6 and 7 show the outward of boiler and Secondary heat-exchanger of Table 1 shows each specification of condensing boiler for Gas central heating Takagi Industrial Co. and those of Noritz Co.

### 4.1. Boiler of Takagi Industrial Co.

Launched in 2000, this was the first commercially available water/space heating unit in the Japanese market, and was designed as described above.

This unit uses a titanium pipe for the secondary heat exchanger. The pipe is shaped the same as a general-purpose flexible stainless steel pipe, and manufactured by the same method.



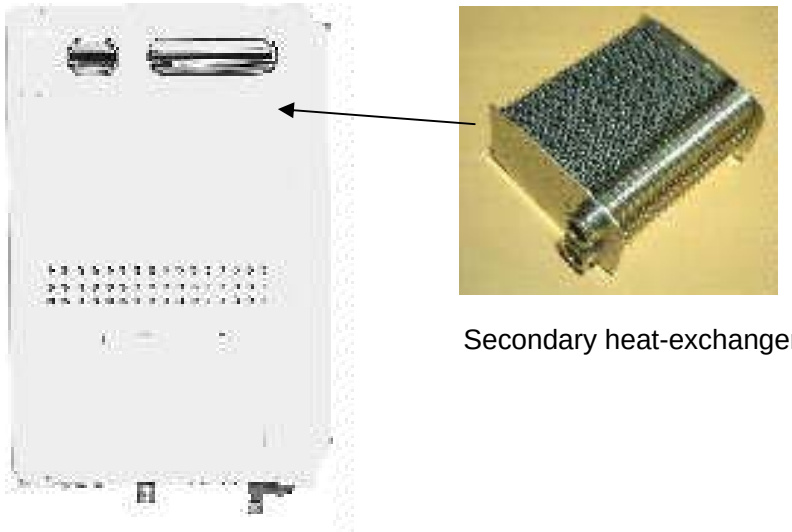
Secondary heat-exchanger

Figure 6 : Boiler (Takagi Industrial)

**4.2. Boiler of Noritz Co.**

This was marketed in 2002.

The design of the secondary heat exchanger incorporates technology from automobile radiators. It was made of stainless steel after first confirming that this would offer sufficient durability, thus keeping down costs. For the secondary heat exchanger, an ultra compact multi-layered heat exchanger was developed based on a liquid-liquid heat exchanger for automobiles, enabling the unit to be made more compact (the same size as that of a conventional non-condensing unit).



Secondary heat-exchanger

Figure 7: Boiler (Noritz)

| | Takagi Industrial Co. | Noritz Co. |
|---|---|---|
| Marketed in | 2000 | 2002 |
| Capacity (hot water) | 47kW | 42kW |
| Capacity (heating) | 14kW | 14kW |
| Size | H750×W480×D300mm | H750×W480×D240mm |
| Weight | 58kg | 54kg |

Table 1: Specification of condensing boiler for Gas central heating

## 5. PROSPECTS

Government support for the spread of condensing water heaters began in 2002. This is expected to accelerate the uptake of such heaters, and the Japan Gas Association estimates that the number in use when the Kyoto Protocol targets are scheduled to be achieved (2008~2012) will reach 800,000. In order to meet the growing demand for condensing water heaters, we plan to continue our collaboration on the development of such equipment.