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DOWNSIZING GAS ENGINE MICRO-CHP'S FOR THE JAPANESE HOUSING MARKET

M.Yagi

Osaka Gas Co., Ltd.

Japan

1. ABSTRACT

Many dwellings in Japan, particularly in urban areas, are built on small plots and the lack of sufficient space for installation can be an obstacle to the sale of micro-CHP systems. This paper describes the results of a survey on space available for the installation of hot water supply systems in urban housing in Japan, considers the dimensional requirements on micro-CHP systems and introduces technologies used to achieve the target dimensions for the waste heat-powered hot water supply and space heating units.

TABLE OF CONTENTS

2. INTRODUCTION

Osaka Gas introduced the ECOWILL, a micro-CHP system based on an internal combustion-type gas engine, to the Japanese market in 2003, as the world's first mass-produced model of its kind, and succeeded in establishing a new market of micro-CHP systems for household use.

The ECOWILL uses gas as its primary energy source and is able to make efficient use of both waste heat and electrical power within the home, as shown in Figure 1. The system consists of a 1kW gas engine-powered generator unit developed by Honda and a waste heat-powered hot water supply/space heating unit co-developed by Osaka Gas, Tokyo Gas, Toho Gas, Saibu Gas, Chofu Seisakusho and Noritz. Combining energy savings with ease of use and convenience (usually mutually exclusive characteristics), the ECOWILL was very well received by the market and, as shown in Figure 2, had sold a total of 100,000 systems nationwide as of 2010.

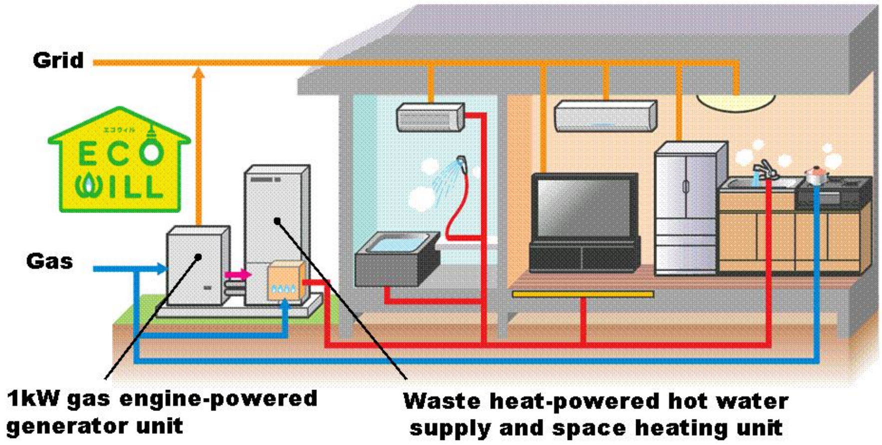

Fig. 1: Schematic view of the system as installed in a dwelling

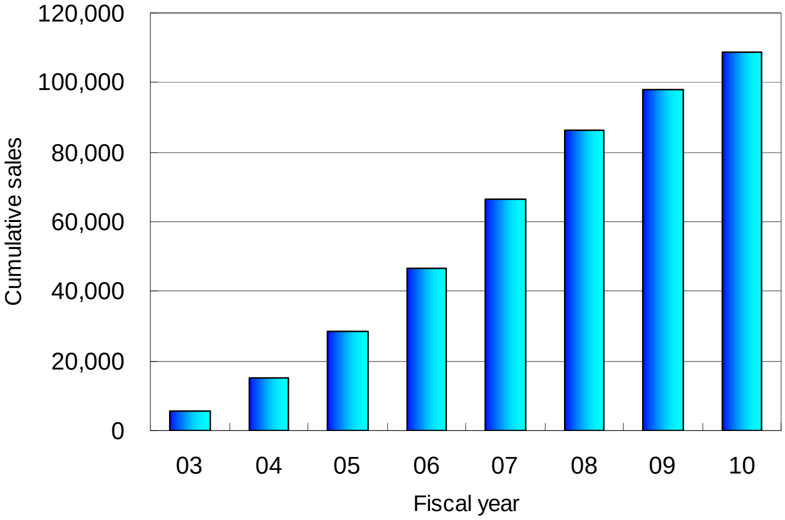

Fig. 2: Cumulative sales of the ECOWILL system in Japan

However, as more ECOWILL systems were sold, a considerable number of cases arose in which installation was not possible owing to lack of space, and this came to be seen as a serious obstacle to business. Osaka Gas's sales area covers many urban areas including Osaka City (population 2.67 million), Kyoto City (1.46 million) and Kobe City (1.54 million), and we reached the conclusion that downsizing the units to suit Japan's typically small urban dwellings would be important for further growth in sales of micro-CHPs.

3. SURVEY OF INSTALLATION SPACE

3.1 Installation conditions for hot water supply systems in Japan

Figure 3 shows the typical conditions for the installation of a hot water supply system in urban areas in Japan. The system is usually fixed to the outer wall of the house using a "PF" exhaust system. If sales of micro-CHP systems are to increase, it is essential that they should target not only installation in new-build dwellings, but also the replacement of existing hot water supply systems and that they should be suitable for installation in locations where instantaneous water heaters are installed. Some products are high priced, but there have never been any reports of theft. For reference, in cold regions where there is a risk of freezing and snowfall, the system may be installed indoors, using an "FF" exhaust system.

Urban dwellings are built close together and hot water supply systems need to be installed within the property boundary, but also in a location that allows space for maintenance.

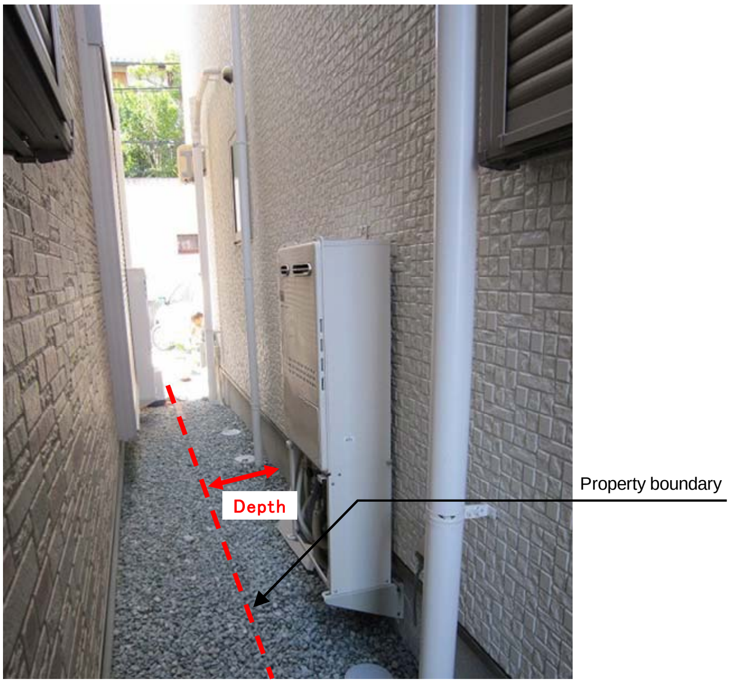

Fig. 3: Typical hot water supply system installation conditions in Japan

3.2 Results of installation space survey

Figure 4 shows the distribution of the depth of the spaces where hot water supply systems were installed, in 100 small urban dwellings selected at random within Osaka Gas's sales area. The previous model of ECOWILL required an installation space 950 mm deep, and the results of the survey showed that it could be installed in only around 30% of small urban dwellings. The most frequently available size of space was 400-500 mm deep, and the survey suggested that reducing the installation depth of the ECOWILL units to within this range would greatly improve ease of installation.

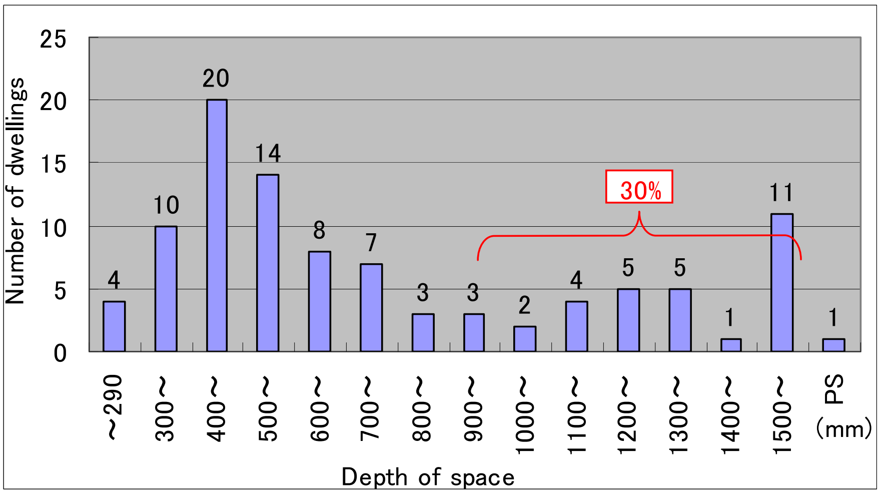

Fig. 4: Distribution of depth of spaces where hot water supply systems are installed

4. STUDY OF PRODUCT STRUCTURE

4.1 Study of unit structure with a view to creating models with reduced depth

The survey of installation space suggested that reducing the depth of the units would make them easier to install. A study was therefore undertaken to determine the most suitable structure for the units. One target for depth was the depth of a typical hot water supply system, which is 250 mm. As a condition for the study, it was decided that the capacity of the hot water tank should remain the same. It would have been relatively easy to reduce the size of the units by reducing the capacity of the tank, but because reducing the capacity of the tank would reduce the proportion of the demand for heat fulfilled using waste heat and could have reduced the energy savings, and because it would have required technological breakthroughs to expand the range of applications for which waste heat can be used, it was provisionally decided to specify the same heat use applications as for the previous model (it should be possible to use waste stored in the hot water tank to supply hot water, it should be possible to use waste heat produced during the power generation process for space heating in real time).

Since major structural changes are not frequently undertaken, the study looked at ways to cut costs and to ease the constraints on installation, as well as reducing the depth of the units. Figure 5 shows examples of the different models considered.

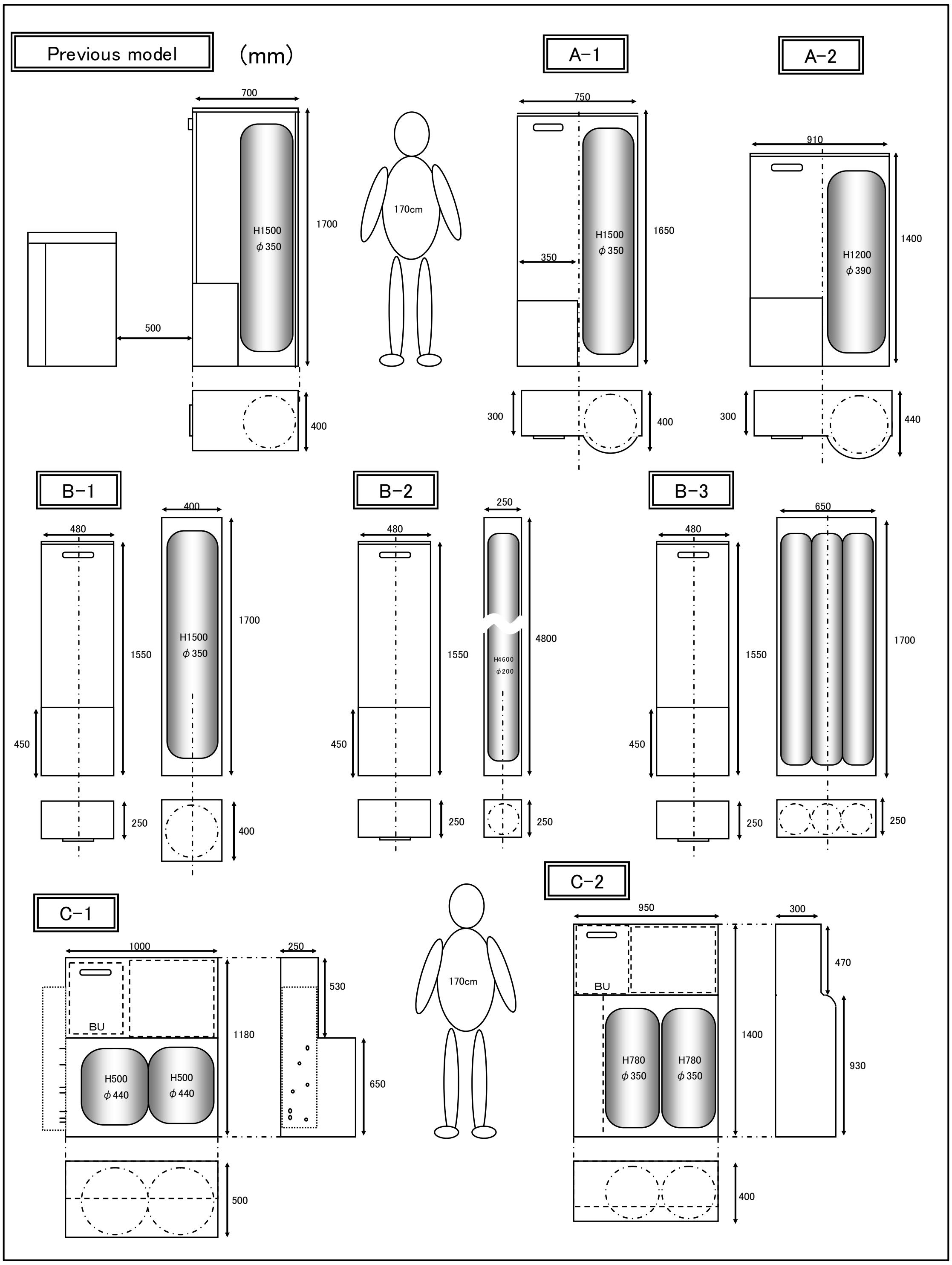

Fig. 5: Examples of models considered during the structural study

The backup boiler in the previous model faced sideways and the width of its burner and heat exchanger also restricted the depth of the waste heat-using water/space heating unit. For this reason, it was decided to rotate the backup boiler through 90°. This made it possible to keep the backup boiler and the mechanical assembly, containing the pump, solenoid valve, plate heat exchanger, etc. to a depth equivalent to those found in ordinary water heaters. Next, the shape of the tank was considered. As mentioned earlier, the capacity of the tank was to be 140L, as in the previous model.

Model A-1 had a tank of the same dimensions as the previous model. To allow the depth of the tank to remain the same, the unit had the form of the letter P when seen from above. Model A-2 was a modified version of Model A-1, with the height reduced to allow its installation under a bay window. As hot water storage tanks almost never break down, maintenance space is required only for the backup boiler and the mechanical assembly and this shape would have made it possible to reduce the depth of installation space required. However, it would also have required the housing of the unit to be curved. This would have looked good in design terms, but would have raised the cost and would also have been difficult to make earthquake-resistant, and was therefore rejected.

Models B-1, B-2 and B-3 divided the mechanical assembly and the tank into smaller units. In Model B-1 the shape of the tank was the same as in the previous model. This layout initially seemed highly practical. However, since removing and replacing the gas engine generator unit could involve carrying it past the tank, and in this respect Model B-1 would effectively have the same depth as the existing model, it was felt desirable that the tank should be made slimmer. Model B-2 was a modified version of Model B-1 with a slimmer tank. To maintain capacity while reducing the depth 250 mm, the height of the tank would have to be 4800 mm, which was unrealistic. Model B-3 achieved a depth of 250 mm while keeping to a realistic height, by using three tanks of the same height. The three tanks were capable of stratified hot water storage when linked in series or in parallel, but in view of internal pressure loss, parallel connection was preferable. This structure was highly desirable from the viewpoint of ease of installation, but the fact that it required three tanks was thought likely to increase costs significantly.

Next, approaching the issue from a different angle, Model C-1 was considered as a means of lowering the center of gravity of the system with a view to reducing the size of the concrete foundations needed to prevent the system from toppling. Earthquakes are frequent in Japan and for this reason the legal guidelines are that any equipment installed should be of earthquake-resistant design and should not topple in an earthquake with an acceleration of 0.4G. To conform to these guidelines, the ECOWILL system would have required concrete foundations wherever it was installed, but concrete takes time to set and this would have prolonged the installation time. Foundations based on prefabricated concrete blocks have been developed, but these would represent an increased cost and it was therefore decided to design the equipment itself to withstand a 0.4G earthquake. Model C-2 was a modified version of Model C-1 in which the depth of the units had been reduced. However, Model C-2 was also rejected, since having two tanks increased the cost and it did not achieve the necessary saving in the depth of installation space required.

As design is also an important factor in the commercialization of products, the study included making actual-size models using expanded polystyrene as well as drawings, and the specific appearance of the product if it were commercialized was also considered.

4.2 Final specifications of the reduced-depth model

The final dimensions of the new model ECOWILL system were jointly considered by Noritz, Tokyo Gas, Toho Gas and Saibu Gas. The structural study described earlier was conducted on the assumption that the capacity of the hot water tank should remain unchanged, but the new model allows heat stored in the tank to be used for space heating (which was not possible with the previous model) and increases the range of applications in which waste heat can be used, and in this way makes it possible to maintain the energy savings even if the capacity of the tank is reduced. On the basis of field tests it was decided that the capacity of the hot water tank should be 90L, which would allow the same energy savings for the same load as the previous model. The final dimensions for the waste heat-using water/space heating unit were 1690 mm high by 720 mm wide and 300 mm deep.

Besides reducing the dimensions of the units themselves, reducing the minimum distance at which they can be installed from the external wall of the dwelling and reducing the maintenance space are also effective ways of reducing the depth of the installation space, and these issues were also addressed in the development of the new model.

With a view to fire prevention, the certifying body prescribes the minimum distance at which units must be installed from the outer wall of the dwelling. The previous model of waste heat-using water/space heating unit had to be installed at least 50 mm from the wall, but modifications to the structure of the exhaust have reduced the distance to 10 mm.

As the exhaust temperature of the gas engine power generator unit is low, Osaka Gas negotiated with the certifying body, which created a new standard that relaxes the clearance required for the prevention of fire.

To allow maintenance work to be carried out even in spaces with limited depth, the layout of the components was changed to allow the engineer to face diagonally towards the unit and work on it either from the front or from the side. This made it possible to reduce the maintenance space from 500 mm to 340 mm.

The new gas engine power generator unit developed by Honda is 298 mm deep, and the same measures regarding maintenance space have been taken as for the waste heat-using water/space heating unit. As shown in Figure 6, it was finally possible to reduce the installation space required for the ECOWILL system from 950 mm to 650 mm.

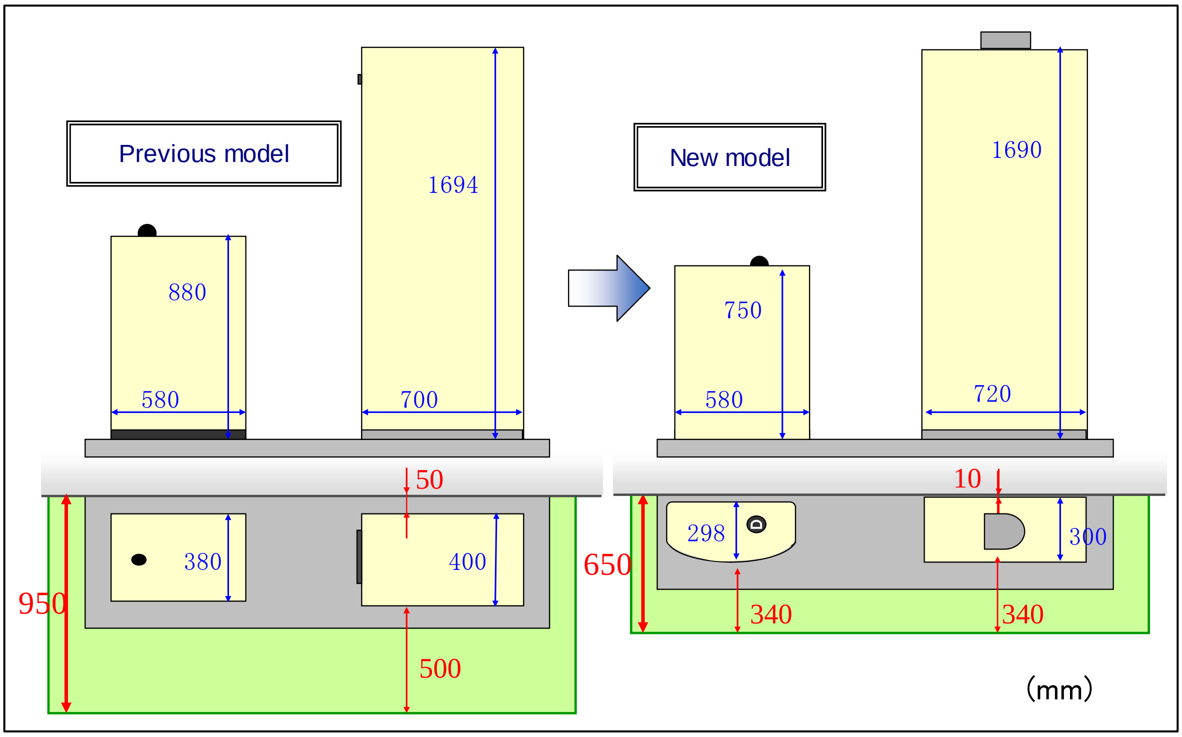

Fig. 6: Installation space required for the new model

5. SUMMARY

A variety of improvements were also made to reduce the depth and maintenance space required for the 1 kW gas engine-powered generator unit developed by Honda. The resulting full model change means that, as shown in Figure 7, the new system significantly eases installation space requirements, making it suitable for Japan's typically small urban dwellings and likely to help the further popularization of micro-CHPs.

Micro-CHP systems, of which the gas engine-based ECOWILL is representative, are likely to attract growing interest in the future for their combination of ecology and convenience. We are pursuing the development of technology that allows still more efficient use of energy and, by increasing the ECOWILL's commercial appeal, aim to make a positive contribution to the propagation of energy-saving micro-CHP technology, which will help to build a low-carbon society.

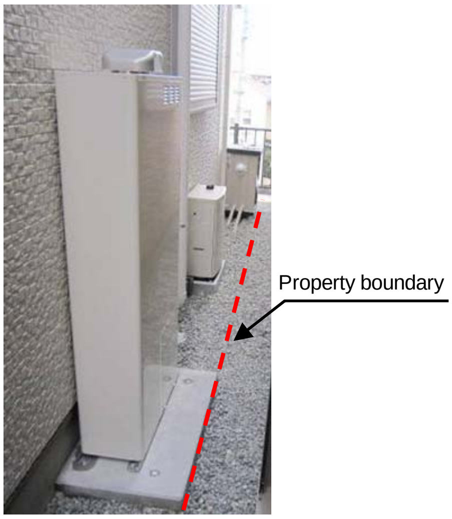

Fig. 7: The new system can be easily installed in Japan's typically small urban dwellings

6. REFERENCE

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