Performance Test of a Forced-Circulation Solar Water Collector during Winter in the Cold Region*

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Last winter 1976–1977, in Kitami City, the northern part of Japan (N 43° 49′, E 143°55′), the feasibility test was made on a small scale forced-circulation solar water collector made by ourselves and the expected results are obtained.

1. Introduction

In accordance with the weather survey for past ten years [1], Kitami District has the climate characteristics of a high transperent rate of atmosphere. It yields the long insolation time of 2355 hours and the high insolation rate of 53 per cent through a year. In spite of being in the high latitude on the northern hemisphere there is a high intensity of solar radiation, also there is a large temperature difference from over 30°C in the summer to under −30°C in the winter. At the same time, the precipitation for a year, 750 mm, is less than one half of the average throughout Japan, therefore, it seems that this area is one of the optimum region to utilize the solar energy in spite of low temperature in the winter [2].

To use solar energy effectively under these favorable climate characteristics a solar water collector peculiar to the cold district made by ourselves and the performance test was carried out especially during the winter.

2. Experimental Instrument

The schematic diagram of the total system of the forced-circulation solar water collector used in this experiment is shown in Fig. 1. Water warmed while it flows through the small tubes of collector panel is returned into the storage tank by a circulation pump. The total area of two parallel collectors is 2.38 m² and the volume of water is 260 liters. Each of two thermostat sensors is fixed on the panel surface and inserted into the storage tank. The circulation pump runs and the water begins to flow when the temperature of panel goes up by 5°C higher than that of water within the tank when receiving sunshine. On the other hand, the heat loss from the panel during continuous water circulation is prevented by pump stopping automatically when the temperature of panel surface goes down by 2°C higher than that of water when clouds shade the sunshine. The temperature was measured by C–A thermocouples (0.32 mm) and recorded on the

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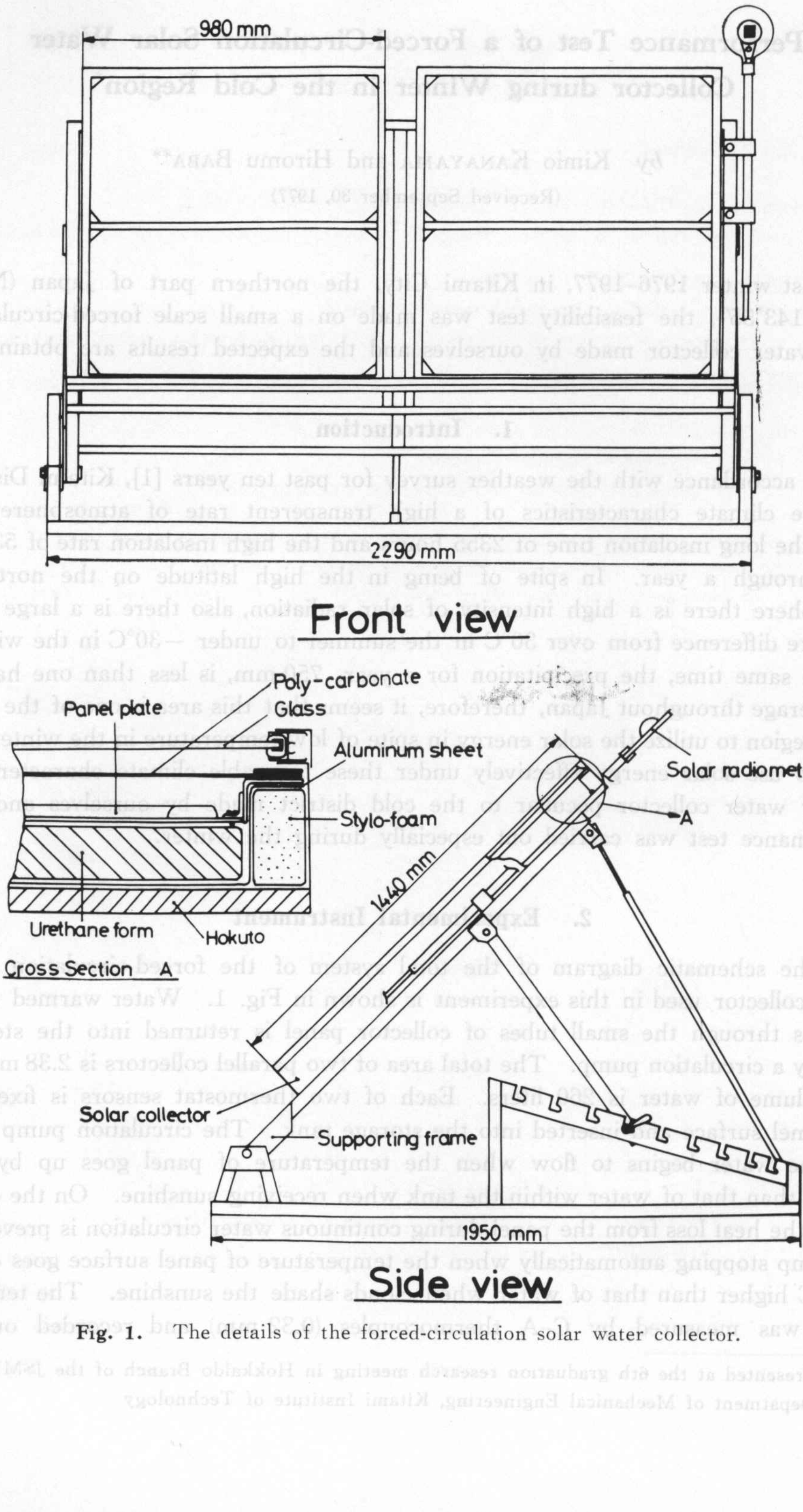

Fig. 1. The details of the forced-circulation solar water collector.

chart of an automatic recorder.

Following points are measured ; 1. room temperature, 2. outlet water temp. from panel, 3. inlet water temp. to panel, 4. surface temp. of panel, 5. outside ambient temp., 6. water temp. within tank, 7. inclined solar energy on the collector surface, and 8. horizontal total solar energy.

Symmetric relation between the two parallel panels is confirmed by measuring both the inlet and outlet water temperature. Two solar radiometers are used, one is for the inclined radiation incidence on the panel surface and another is for total horizontal incidence. Figure 1 shows the solar collector settled on the supporting frame as well as the details of collector cross section. To make the panel surface at right angle with sunshine, an elevation angle of collector can be controled by the setting stay adjusting to seasons. The panel plate is made of aluminum by roll-bond method, coated with normal black paint on the upper surface and has 14 water flow tubes. The bottom and side parts of panel are insulated by two layers of insulators with aluminum sheet between them, the upper part is covered by two transparent plates of glass (3 mm thick) and polycarbonate (0.6 mm thick). All of them are put into a case made of zinc-shees. Hard type polychloride-vinyle pipe (20 mm dia.) is used as a hot water circulation pipe and kept warm by double layers of urethanefoam and glass wool with aluminum-sheet outside of it. Figure 2 showes the schematic diagram of the all instrument.

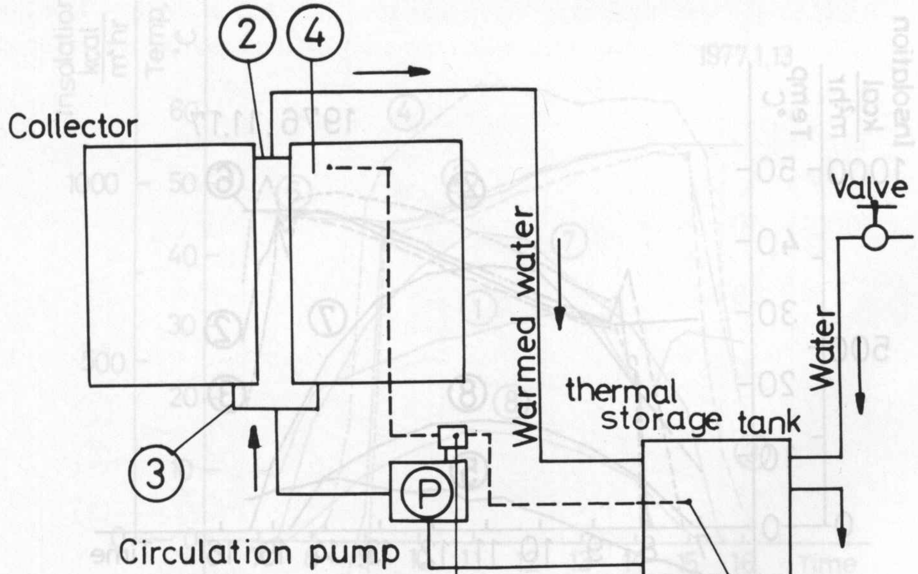

Fig. 2. Schematic diagram of the instrument.

3. Results and Discussion

The experiment was begun from September 1976, however, one month at the beginning was spent to improve and to adjust the measuring apparatus. Thus the results obtained for three months from October 22, 1976 to January 23, 1977 are discussed in this paper. Data gathered during on the cloudy day for this period were not analyzed.

The change of all measured temperatures and the insolation energy on November 17, 1976 is shown in Fig. 3. The inclination angle of panel plate equals 45 deg. and the collector faces nearly to the south. When the temperature on the panel surface is 5°C higher than that of water within the tank by receiving an incidence of sunshine at 8 : 10 a. m., the water is circulated by a pump through the instrument by means of a thermostat switching on. However, because the insolation energy is not enough in the early morning the temperature of panel surface goes down and the circulation of water is stopped by means of a thermostat switching off. Receiving continuous sunshine during this time, the pump runs continuously and water temperature gradually goes up due to the increment of incident energy which is usually highest for two hours from 10 : 00 to 12 : 00 a. m. and goes down after 1 : 00 p. m. Around 2 : 30 p. m., the insolation energy decreases due to the falling of elevation of the sun, the difference between the panel temperature and tank water temperature is less than 2°C, consequently

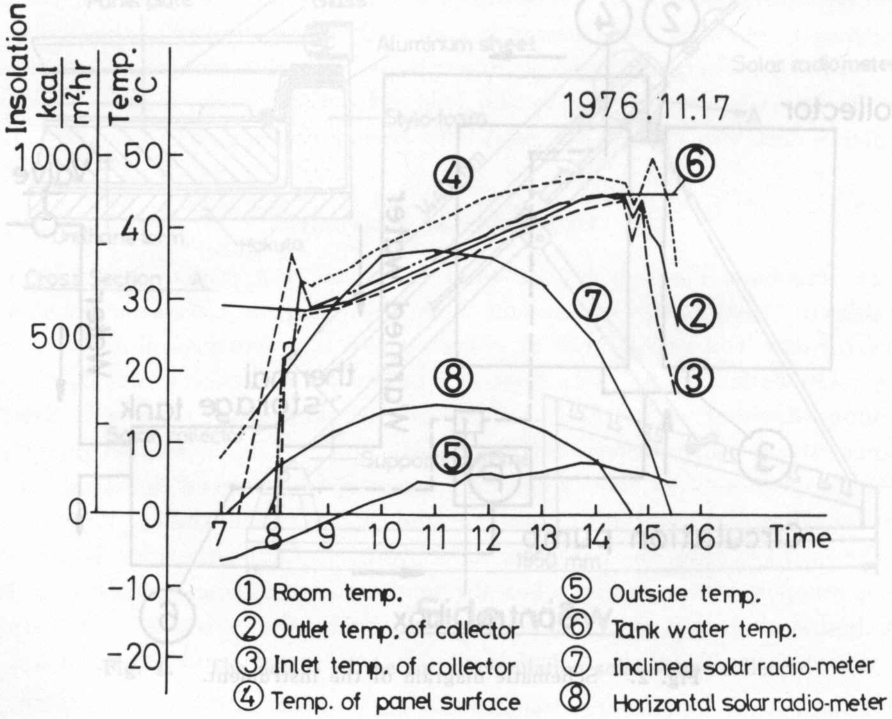

Fig. 3. Experimental results on Nov. 17, '76.

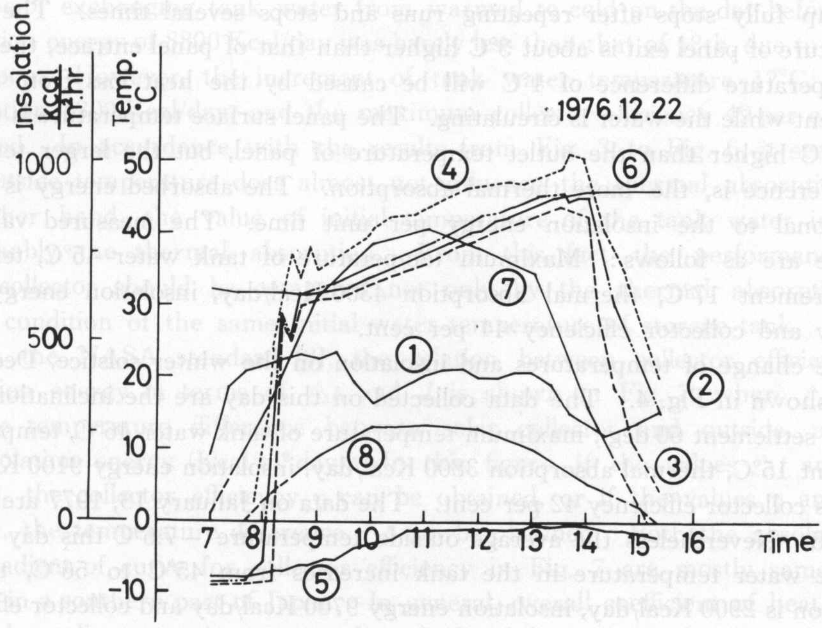

Fig. 4. Experimental results on Dec. 22, '76.

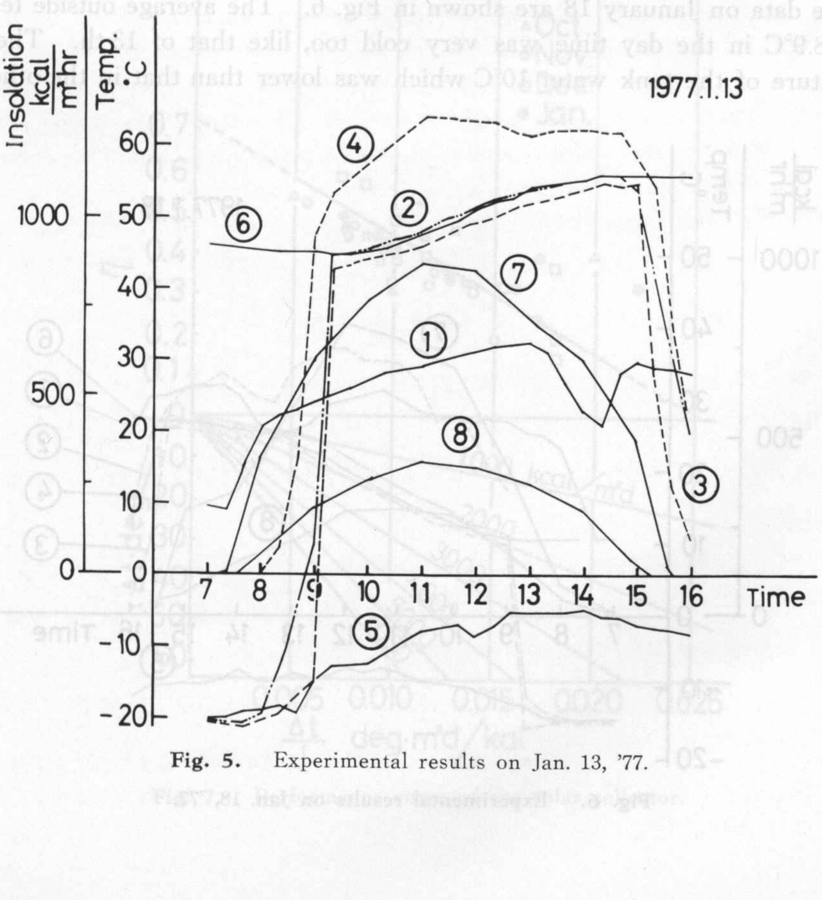

Fig. 5. Experimental results on Jan. 13, '77.

the pump fully stops after repeating runs and stops several times. The water temperature of panel exit is about 3°C higher than that of panel entrace, therefore, the temperature difference of 1°C will be caused by the heat loss from all the instrument while the water is circulating. The panel surface temperature is usually about 5°C higher than the outlet temperature of panel, but the larger temperature difference is, the more thermal absorption. The absorbed energy is nearly proportional to the insolation energy per unit time. The measured values in this case are as follows: Maximum temperature of tank water 45°C, temperature increment 17°C, thermal absorption 4300 Kcal/day, insolation energy 9700 Kcal/day and collector efficiency 44 per cent.

The change of temperatures and insolation on the winter solstice, December 22, are shown in Fig. 4. The data collected on this day are the inclination angle panel of settlement 60 deg., maximum temperature of tank water 46°C, temperature increment 15°C, thermal absorption 3800 Kcal/day, insolation energy 9100 Kcal/day and thus collector efficiency 42 per cent. The data on January 13, 1977 are shown in Fig. 5. Nevertheless the average outside temperature −7.6°C this day is very low, the water temperature in the tank increases from 45°C to 56°C, thermal absorption is 2900 Kcal/day, insolation energy 9700 Kcal/day and collector efficiency 30 per cent in spite of low outside temperature. According to this case, it is clarified that this facility is capable for use during the cold season.

The data on January 18 are shown in Fig. 6. The average outside temperature −8.9°C in the day time was very cold too, like that of 13 th. The initial temperature of the tank water 10°C which was lower than that in the other case

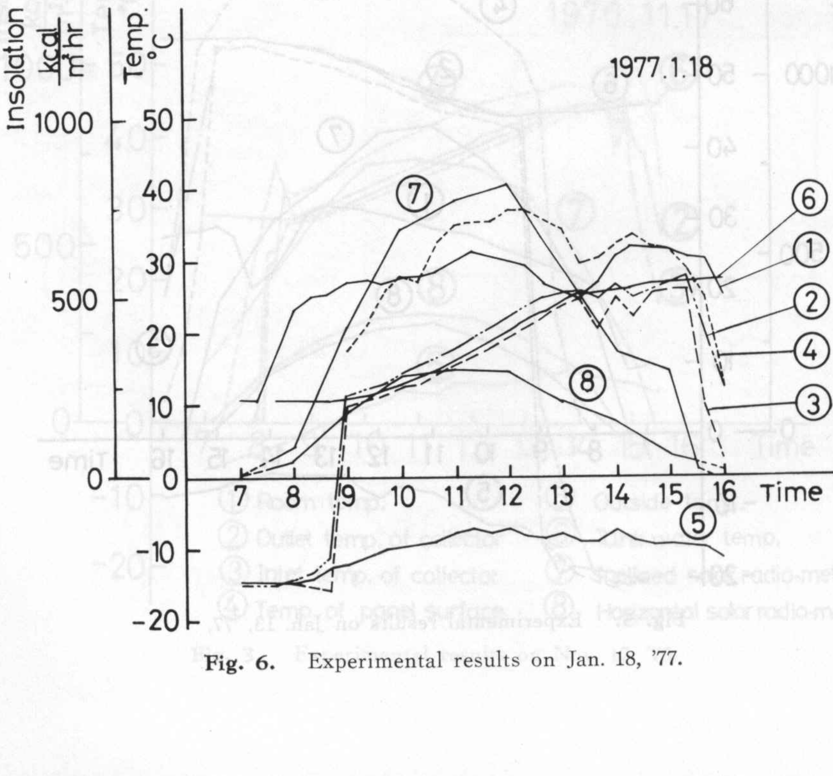

Fig. 6. Experimental results on Jan. 18, '77.

because of exchanging tank water from warmed to cold on the day before. The insolation energy of 8800 Kcal/day was barely less than that of 13th, due to a cloudy afternoon. However, the increment of tank water temperature 17°C, thermal absorption 4300 Kcal/day, and the maximum collector efficiency 49 per cent were obtained. In accordance with the results from Fig. 3 to Fig. 6, it seems that the outside temperature does almost not influence the thermal absorption. On the other hand, the value of initial temperature of the tank water influences remarkably the thermal absorption. From this fact the performance of a solar collector should be compared not only by the thermal absorption, but under condition of the same initial water temperature of storage tank. According to the NASA standard [3], the relation between collector efficiency and insolation energy in terms of $\triangle t$ and J is shown in Fig. 7, where $\triangle t$ is the average temperature difference between solar collector and outside, and J is an insolation energy (Kcal/m^2 day). In this figure, if the values $\triangle t$ and J are known, the collector efficiency η can be obtained, or if the values η and J are known, the temperature difference $\triangle t$ can be obtained. Both the absolute value and gradient of curve for collector efficiency in Fig. 7 are mostly same as the results in a southern part of Japan. In general, overall coefficient of heat-transfer of a solar collector equipment can be calculated from the inclination of curve.

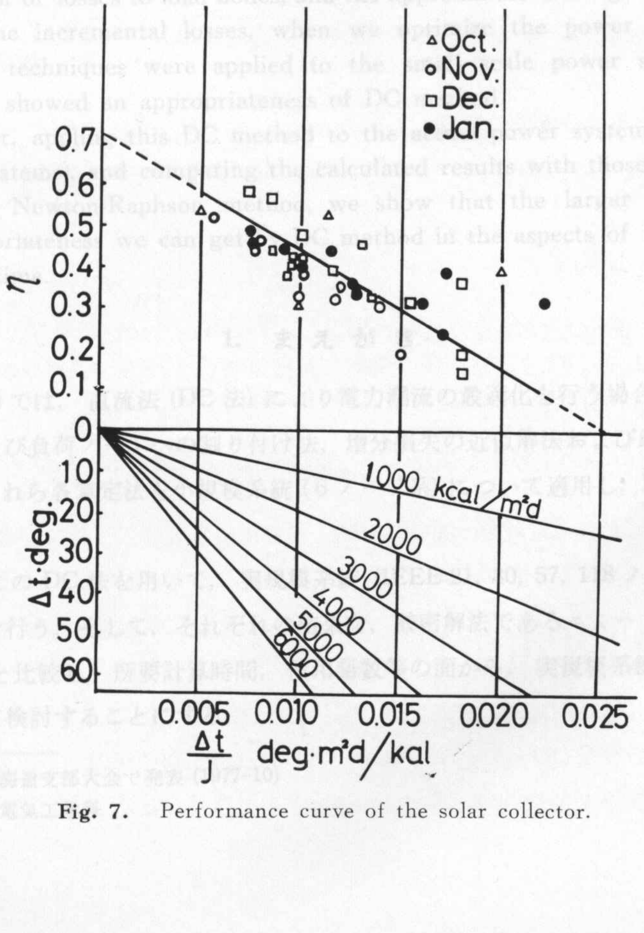

Fig. 7. Performance curve of the solar collector.

4. Conclusion

As the result of this performance test, it was clarified that the forced-circulation solar water collector made by ourselves is sufficiently applicable for the space heating and hot water feeding systems during the winter in the cold district. We can get the value of about 1.17 Kcal/m² h°C as overall coefficient of heat-transfer in this facility.

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