P-23: Experimental Study on Transient Heating of the Glass Panel in the Infrared Heating Chamber

Kong Hoon Lee, Ook Joong Kim, and Suseok Ha
Thermo-fluid System Dept., Korea Institute of Machinery and Materials, Daejeon, Korea

Abstract

The temperature distribution of a glass plate heated in the infrared heating chamber has been investigated. Temperature of the glass panel is measured using a set of thermocouples and the optical pyrometer. Temperatures measured by thermocouples have good agreement with those by the pyrometer. The temperature uniformity of the panel is improved with wall reflectivity, which is one of the important factors to uniformly heat the panel

1. Introduction

Recently, the development of the flat panel display (FPD) is rapid and the demand of the FPD also increases rapidly so the glass plate is widely used. In the fabrication process of the FPD, the glass plate flows through many heating process such drying, baking, and so on after the surface treatments such as the formations of electrodes, barrier ribs, dielectric layers, etc. The fabrication process of the PDP requests the baking, vacuum pumping, and sealing under the relatively high temperature in comparison to the LCD process, and then the improvement of such high temperature processes is necessary. Since the heat treatment by the conventional convection oven is stable but needs long process time, it is very important to reduce the process time for the curtailment of the production cost[1,2].

In order to develop the technique to reduce the process time for the heat treatment, the researches have been carried out to introduce the Rapid Thermal Processing (RTP) into the PDP process[2-4]. When the RTP is used in the PDP process it is important to improve the temperature uniformity of the glass panel since the large temperature difference results in the large thermal stress and then the fracture or deformation of the panel. Besides, the uniform heating of the panel is needed to improve the performance of sealing and vacuum pumping.

When the material semitransparent to radiation such as glass[5] is heated by radiant heating, heat transfer mechanism differs from that for a opaque material. The part of the radiation energy incident on the semitransparent material is absorbed and reflected on the surface, some of the energy is absorbed inside the material, and the rest is transmitted through the material[5-7]. For example, soda-lime glass is semitransparent to radiation in the range of wavelength less than 5 μm and opaque in the other range of wavelength[8]. Thus heating characteristics varies with the spectrum of the radiant heating source.

The present work has been carried out to develop the technique for the uniform heating and the temperature measurement as the part of the research to develop the vacuum sealing furnace for the PDP in the Korea Institute of Machinery and Materials[3,4] The object is to investigate the characteristic for the radiant heating of the panel and the variation of the panel temperature with time. The thermocouples and the optical pyrometer are utilized to measure the temperatures of the panel. The temperatures measured by both devices are compared and the effect of wall reflectivity on the temperature distribution of the panel has been investigated.

2. Experiments

The experimental apparatus is composed of the model chamber to heat the panel and the data acquisition system shown in Figure 1. The model chamber is a cube of 340 mm length and its wall is 20 mm thick and is shown in Figure 2. The model chamber is made of an aluminum plate and its inner surface is polished to retain the high reflectivity. The glass panel is composed of two sheets of soda-lime glass plates and each glass plate is 200 mm square and 2.8 mm thick. The panel is lying on the center of the chamber and is supported by the aluminum bars fixed to the chamber wall. Twelve halogen lamps are used to heat the panel as radiant heaters. The effective heating length of each lamp is 300 mm, and six lamps are installed near the top and others near the bottom. The power of lamps is controlled using the variable transformer with the maximum output power of 20 kW.

The water jacket is installed inside the top and bottom walls to prevent the over-heating of the chamber walls and to ensure the safety during experiments. The bottom wall has five view ports through which the temperature of the panel is measured by the pyrometer.

K-type thermocouple (Marlin Mfg. Corp., Insulation temperature of 871°C) is used to measure the temperature of the panel and its covering material is a kind of ceramic fiber

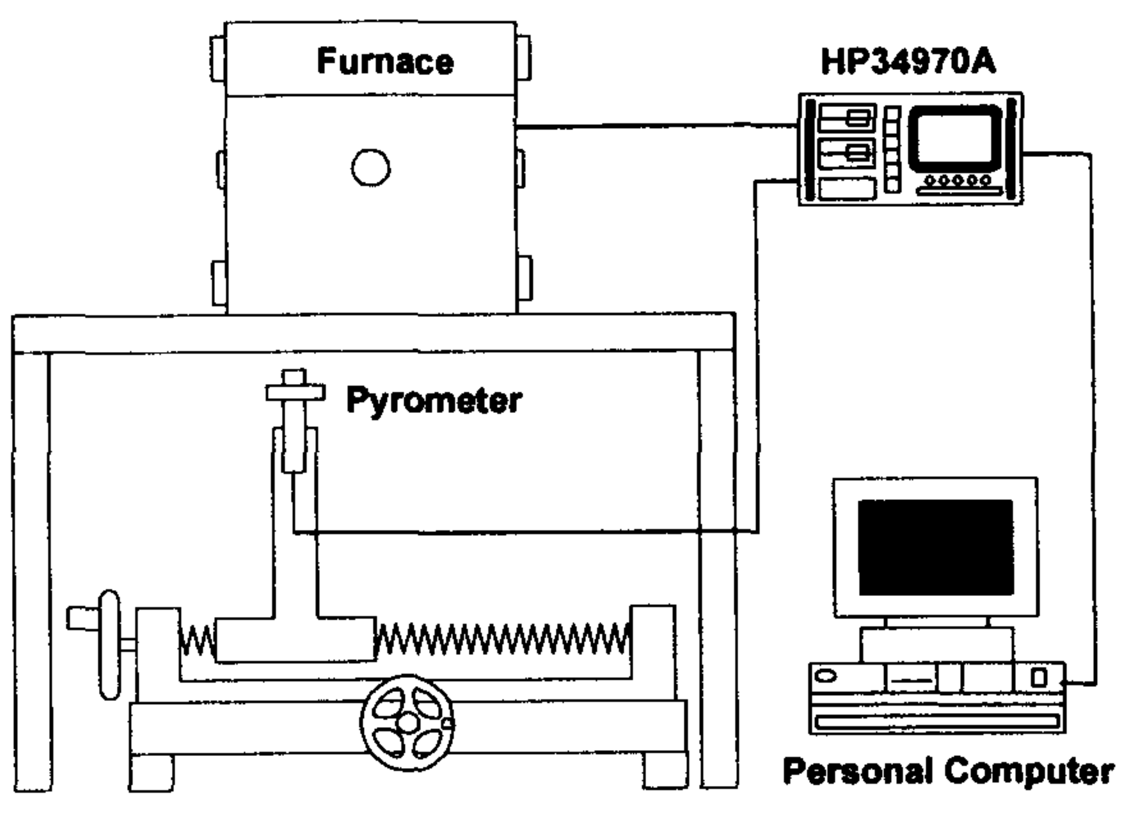

Figure 1 Schematic of the experimental apparatus

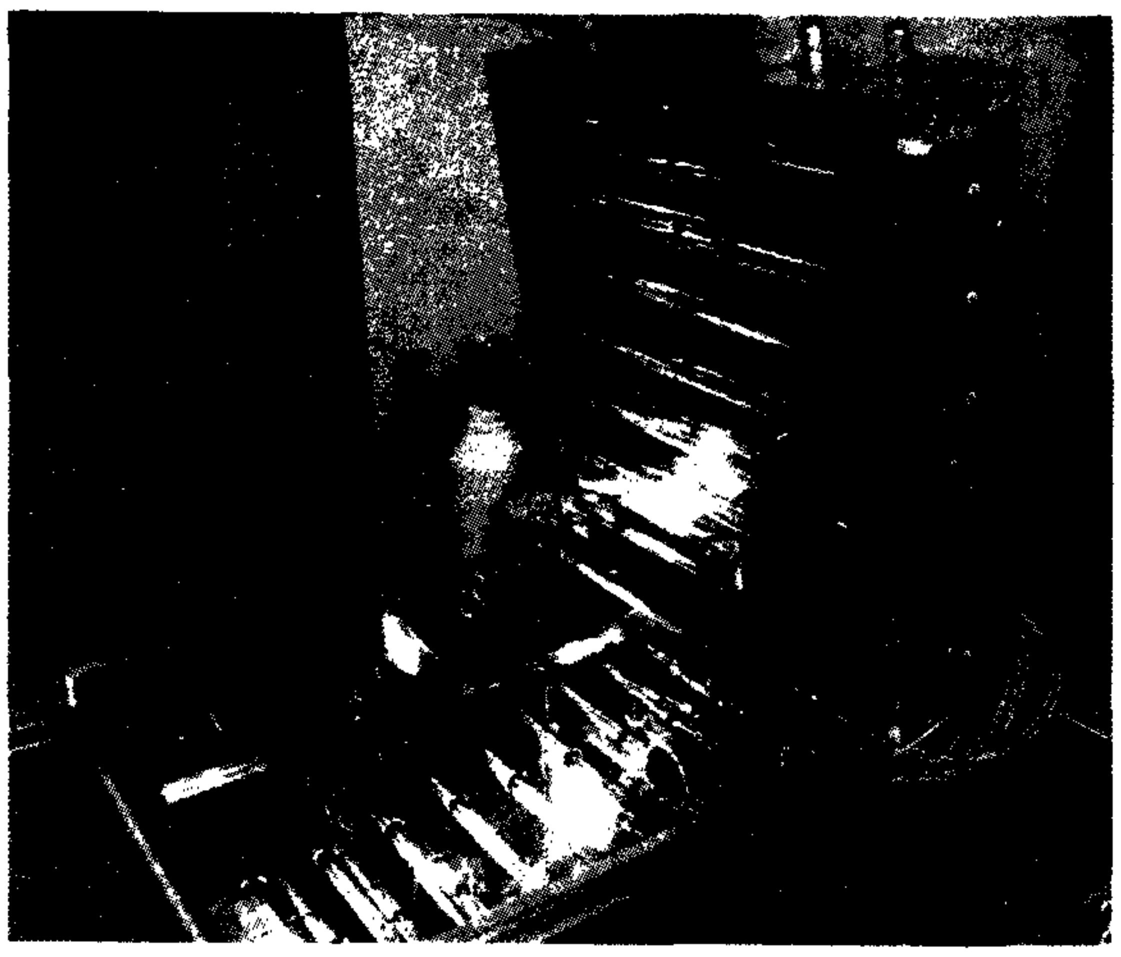

Figure 2 Model chamber used in the experiment

to prevent the covering to be fired in the high temperature environment. Thermocouples are located in the center and four positions (50 mm, 50 mm) away from the corners of the panel. The optical pyrometer (Infrapoint Co.) operates at the wavelength of 5.14 μm in which glass is opaque to radiation and it can measure the temperature ranging from 100 to 1200°C. Data logger (Agilent HP34970A) is used to collect the temperatures from thermocouples and the pyrometer and to send them to the personal computer. The power input to lamps is measured with the digital power meter (Yokogawa WT-130).

3. Results and Discussion

Figure 3 shows the temperature variation at the different positions of the panel. Before the measurement, the surface of the chamber wall is well polished and its reflectivity is relatively high. The temperature measured by the pyrometer is valid over 100 °C because it operates over 100 °C. The temperatures by thermocouples are slightly higher that those by the pyrometer before the steady state. The differences might be caused by errors due to the usage of the ceramic bond, the uncertainty of thermocouple, the accuracy of the pyrometer, and so on. In addition, the pyrometer is located about 5 mm away from the point measured by the thermocouple to avoid the interference with each other.

Figure 4 compares the temperatures at the center of the panel for two different reflectivities of the chamber wall. For low reflectivity the temperature increases faster than that for high reflectivity. As the reflectivity decreases, the radiation absorption on the wall increases and then heat loss through the wall increases. Therefore, when the reflectivity is low, the rapid heating of the panel is possible but the electric power is required more to compensate the large heat loss through the wall. The wall reflectivity is initially set to a certain value for the experiment by polishing the surfaces, but the reflectivity decreases due to the contamination by out-gassing from the covering of thermocouples, etc. during the repetition of experiments. While the reflectivity is high, the heating time becomes longer but the temperature uniformity of the panel is improved and the heat loss becomes smaller. When the reflectivity is low, the power input increases since the temperature of the panel reaches the desired value during the short time as shown in Figure 4 and the heat loss is relatively large. When the reflectivity is high, the desired temperature (390°C) at the center is reached with the power input of 1.48kW but when the reflectivity is low, the desired temperature could be obtained with about 3.8 kW. In the latter case, the temperature difference between the center and the corner of the panel is large and then the temperature uniformity is also poor. Therefore, if the temperature uniformity is the only requirement, the high reflectivity is a good choice for the radiant heating but the rapid heating is impossible. For the rapid heating, the low reflectivity is desired and the limit of the temperature uniformity is needed to be set.

Figure 5 shows the variations of temperatures measured by thermocouples for low wall reflectivity. The temperature measured by thermocouple agrees well with that by the pyrometer. The figure shows that the temperature increases more quickly than

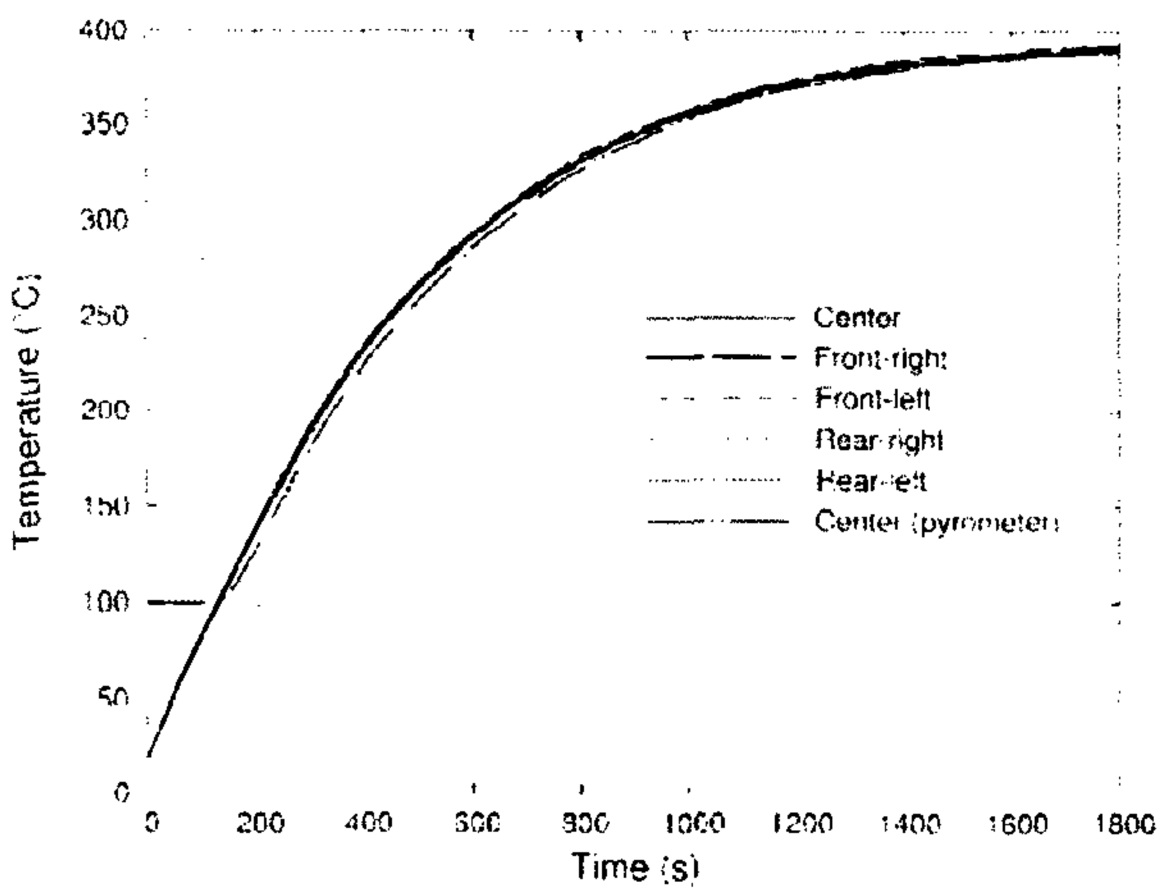

Figure 3 Temperature variation of the panel for high reflectivity

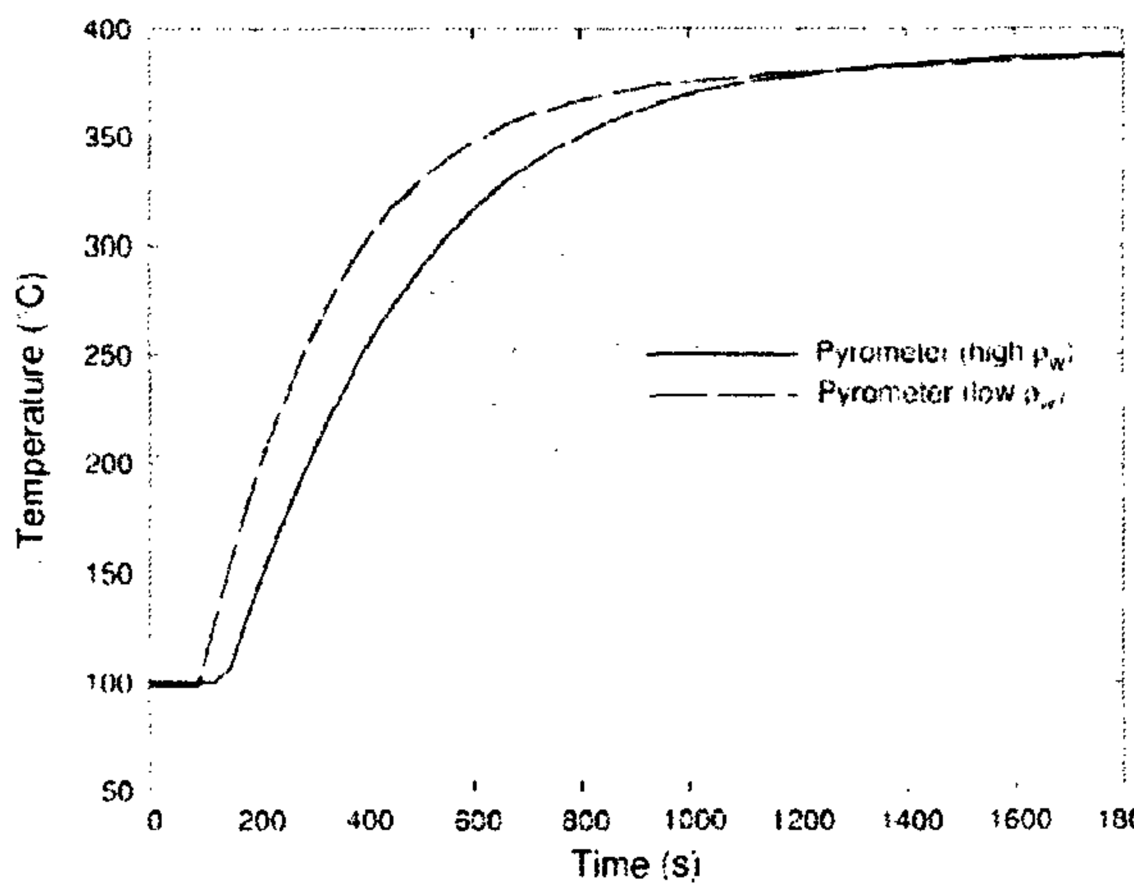

Figure 4 Comparison of temperatures measured by the pyrometer

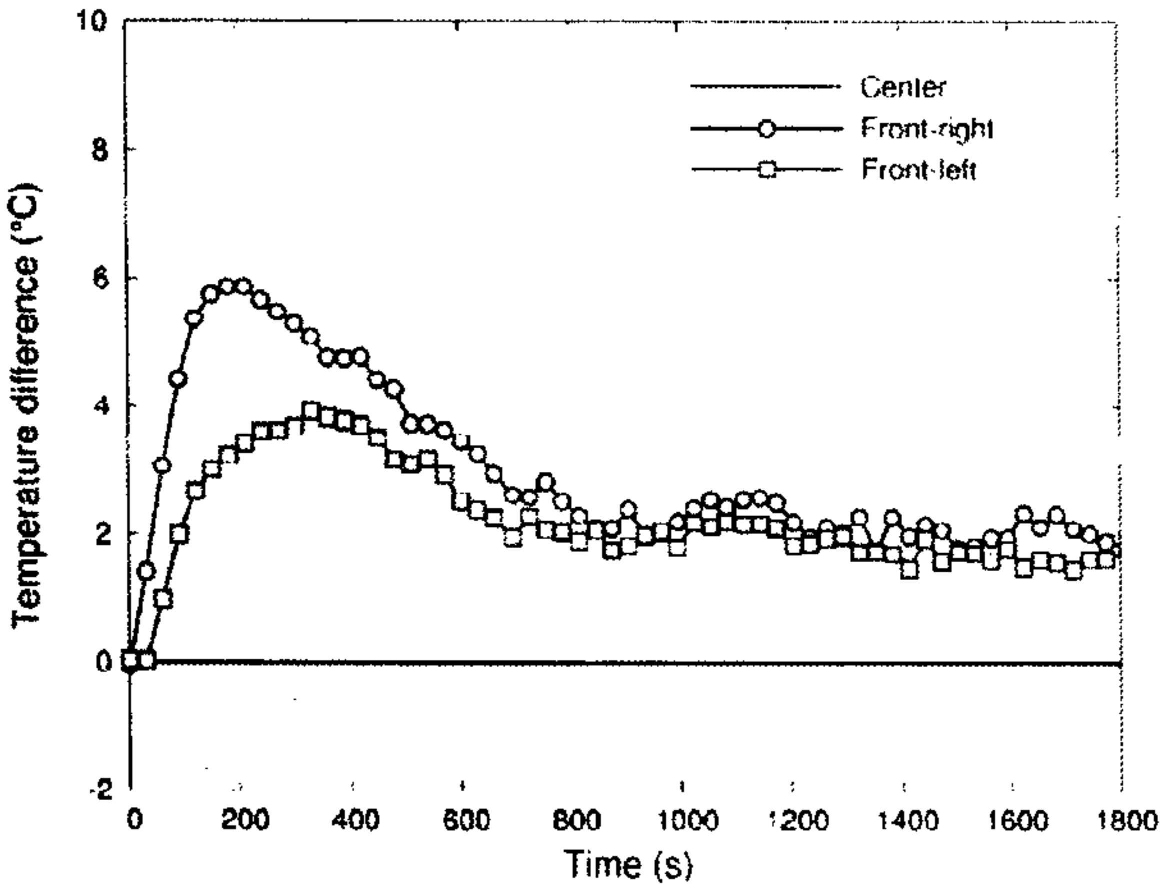

Figure 5 Temperature difference of the glass panel for low wall reflectivity

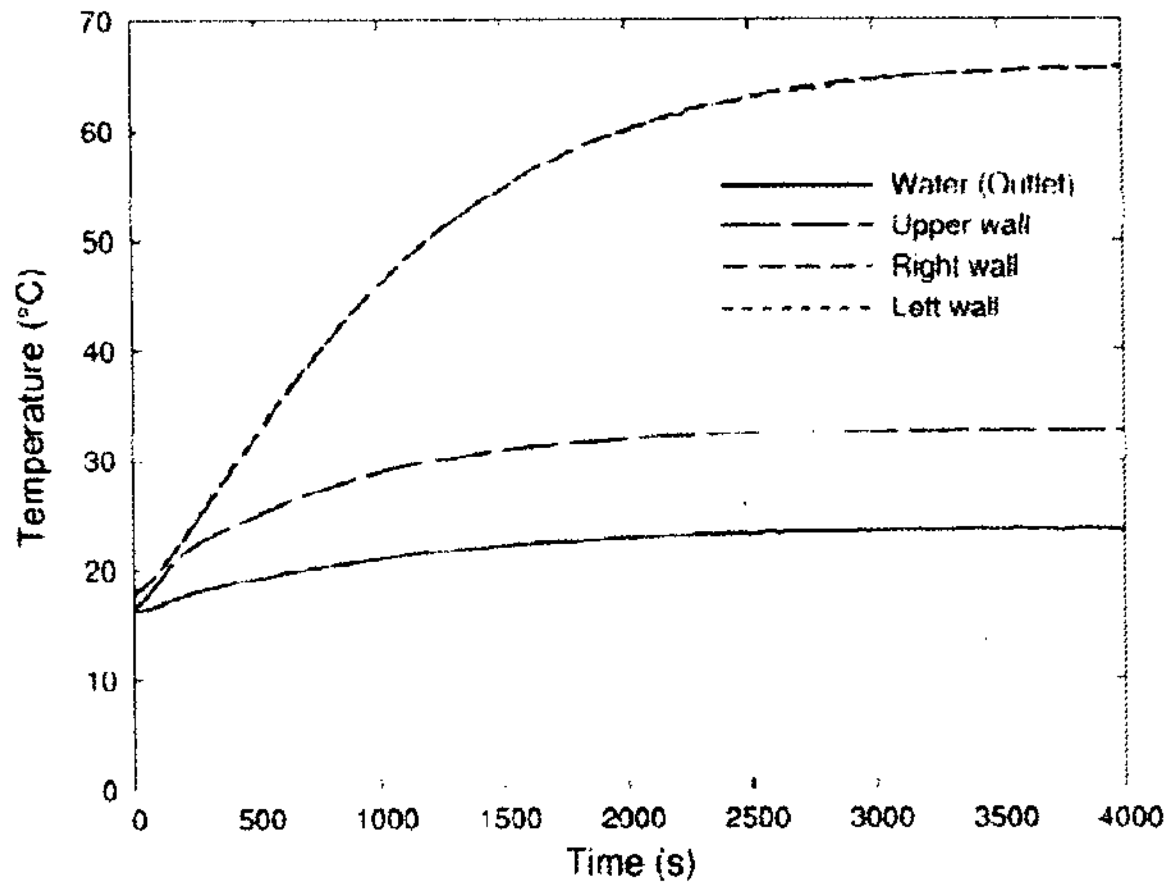

Figure 7 Temperature variations of the chamber wall and cooling water for high reflectivity

that for high wall reflectivity. The temperature difference between the center and the other positions is shown in Figure 6, and the difference is larger in comparison to that for high wall reflectivity. It has the maximum of 4 ~ 6 °C in the early stage of heating process and about 2 °C at the steady state. The reason that the maximum difference appears in the early stage is that the temperature near the corner is relatively small in comparison to that of the center since the thermal diffusion is slow due to the small conductivity of glass.

Figures 7 and 8 illustrate the temperature variations of the cooling water and outer wall surfaces for two different reflectivities. For low reflectivity (Figure 7), the temperatures of cooling water and wall surfaces are much higher than those for high reflectivity (Figure 8). It means that the heat loss increases as the reflectivity decreases as mentioned before. In two figures, the temperatures of the left and right walls are greater than that of the upper wall because the side walls are cooled only by the ambient air and the upper wall is cooled by the water. When the wall reflectivity is low, the absorptivity of the wall surface becomes large and then the radiation energy is absorbed much by the wall so that the wall temperature becomes high as shown in Figure 8. In this case, the temperature of the cooling water also increases due to the large heat loss through the wall. In Figure 8, the temperatures of the left and right wall vary differently, which means that the reflectivities of the two side walls also differ from each other.

4. Conclusions

The temperature distribution of a glass panel heated in the infrared heating chamber has been investigated and the results have been summarized as follows.

(1) Temperatures measured by thermocouples are good agreement with those by the optical pyrometer.

(2) When the wall reflectivity is high, the temperature uniformity of the panel is fairly good and the uniform heating of the glass panel is possible, but when the reflectivity is low, the

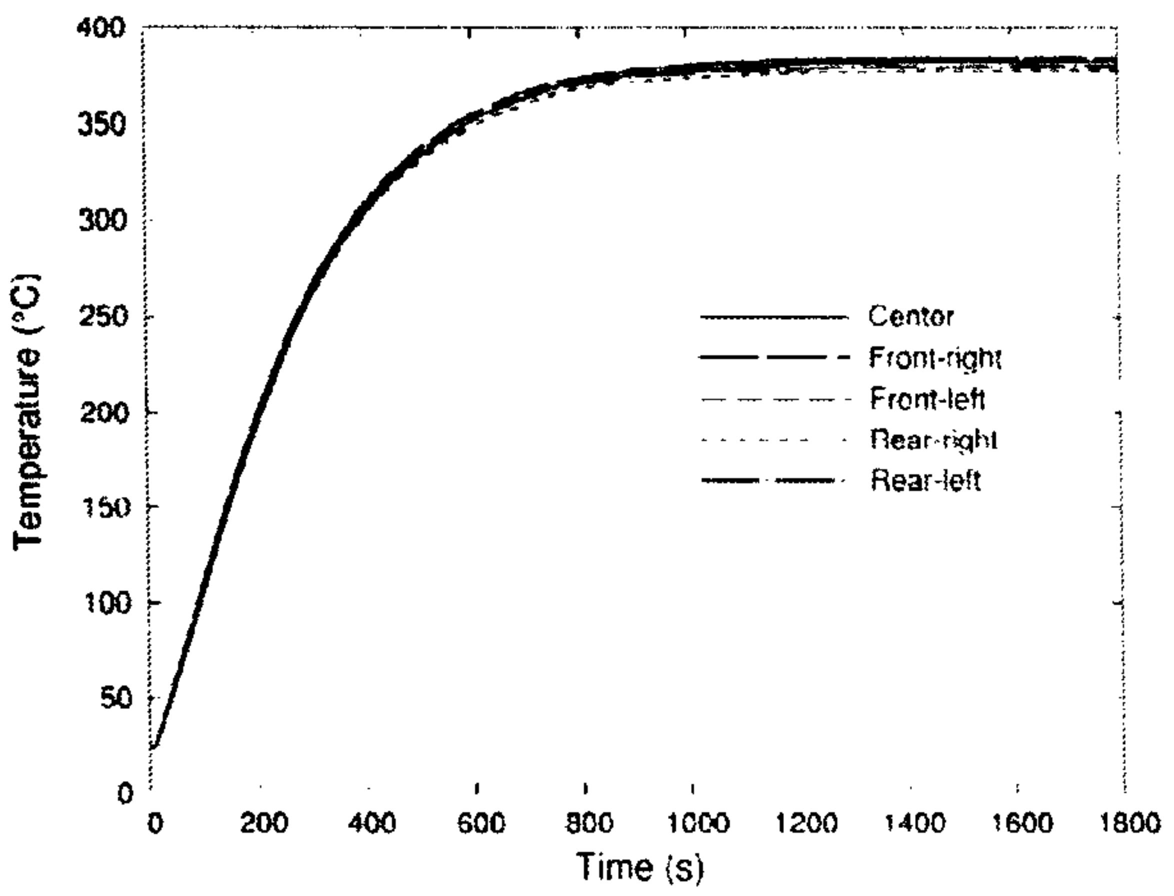

Figure 6 Temperature variation of the glass panel for low wall reflectivity

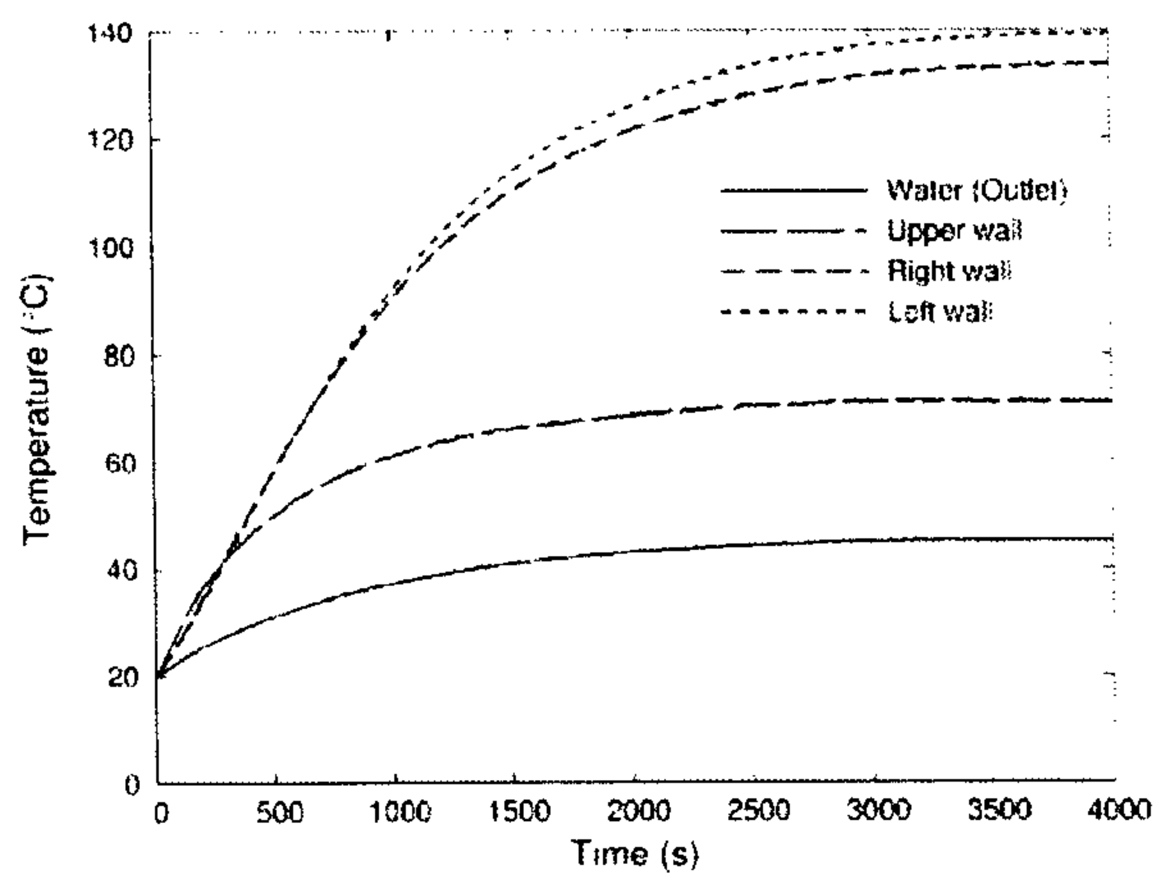

Figure 8 Temperature variations of the chamber wall and cooling water for low reflectivity

temperature uniformity is relatively poor.

(3) When the wall reflectivity is low, the rapid heating of the panel is possible, the temperature difference of the panel becomes large, and the electric power is required more to compensate the large heat loss through the chamber wall.

5. Acknowledgements

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6. References

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