Observation of Liquid-filled Window without Presence of Liquid in Test Chamber

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Abstract

This article deals with progressive glass unit in glazing systems of building facades. Main aim of this research is reduction of heat gain in interior achieved by water added into Basic Insulation Glass Unit (hereinafter as IGU) which thereby becomes a transparent collector. Concerning heat gain reduction, this system provides a variety of positive characteristics. In relation to outdoor conditions, however, the system has its limitations, due to which each glass unit needs to be designed with regard to the climate condition it is intended for. These special properties have been described in previous articles. Currently, the model in scale 1:1 is prepared and provided for measurements in test chamber. Observation of liquid-filled window in summer weather simulation has brought valuable results for temperature, radiation and humidity. Temperature has been observed on surfaces, and exterior and interior sides of cavities.

Key words: progressive glass unit, building façade, Insulation Glass Unit, heat gain, radiation, humidity, liquid-filled cavity, heat barrier, renewable energy sources

1 Introduction

Heat transfer is considered as a very complex process that occurs continuously in nature. Façade design and construction aim to take an advantage of those physical laws. Basically, there are two types of façades, transient and non-transient and they are used as a heat barrier. This research deals with the transient construction that is improved with liquid layer inserted between two glass panes in order to direct the heat flow more efficiently at the liquid, in this case. As a result, IGU is changed to solar collector.

Incident solar energy may be utilized in three possible ways. First, energy is passively utilized in the accumulation processes of incident energy in building facades. Second method uses incident solar energy actively and takes advantage of the most effective way energy is collected, transported and transferred. Third method is a combination of the first two and

distinguishes between primary and secondary circuit. The former absorbs heat that is transferred to the later one by means of heat exchanger, where it is stored for further usage. Currently, this method is highly required in building facades designing.

The liquid-filled window takes advantage from this combination of active and passive processes and represents south facing vertical transient collector. Figure 1 shows section of the window. Glazing consists of three glass panes A, B, and C separated by two cavities. The cavity closer to exterior is filled with water and the cavity closer to interior with air. Liquid-filled cavity represents active primary circuit that is connected to the passive secondary circuit by a heat exchanger.

Figure 1: Detail of glass panes A, B, and C in liquid-filled window (author)

2 Radiation through liquid-filled window

Sun, as a biggest source of energy, shines on Earth almost equally and its energy is transferred by radiation. The solar constant includes all types of solar radiation, not just the visible light. It is measured by satellite as being 1.361 kW per square meter (kW/m^2) at solar minimum and approximately 0.1% greater (roughly 1.362 kW/m^2) at solar maximum [1]. In the process when Earth receives solar energy the following happens:

- Part of incident radiation is reflected by atmosphere, by clouds, by Earth spaces
- Part of incident radiation is absorbed by atmosphere, by land and oceans
- Part of incident radiation is converted and radiated, conducted and convected to the environment.

Figure 2: Heat flow processes in window (author)

Very similar processes occur in the liquid-filled window, as shown in Figure 2. An incident radiation is partly reflected to outside surroundings, partly absorbed by glass panes, liquid layer, and air layer and partly transported to interior and results in heat gain in the room. Near the surface of each glass pane, a heat convection occurs as a result of temperature differences and natural convection.

2.1 Construction of prototype liquid-filled window in scale 1:1

Liquid-filled cavity contains clean deionized stream of water circulating within the entire space between the glass panes A and B (see Fig. 1). Due to its position near the external wall this works as an advanced window device that is able to reduce solar transmission. This process results not only in absorption of excessive solar heat by the circulating liquid stream itself, but also in effective reduction of solar heat gain in interior.

Figure 3: Inlet pipe with measuring conductors (author)

3 Measured quantities

3.1 Temperature

The most important issue is establishing the temperature difference between exterior and interior side of IGU. For window, the temperature difference is most visible at low exterior temperature, at winter conditions for example.

Heat transfer coefficient is calculated from the calculation of partial quantities according to properties of the material used on the frame, glass and spacer profiles. Values are expressed by the following equation:

The following formula is used to determine the heat transfer coefficient [2]:

$$U_w = \frac{(A_g \cdot U_g + A_f \cdot U_f + I_g \cdot \Psi_g)}{(A_g + A_f)} \quad (1)$$

U_g = heat transfer coefficient of the glazing, W/m².K

U_f = heat transfer coefficient of the frame, W/m².K

Ψ_g = linear heat transfer coefficient of the insulated glazing edge seal, W/m².K

A_g = glass area, m²

A_f = frame area, m²

$A_w = A_g + A_f$, m²

l_g = length of inside edge of frame profile (or visible periphery of the glass sheet), m

Digital temperature sensors located at exterior and interior side of the glazing bring precise values of temperature differences which enter into further calculations. This sensor is recording also air velocity. Detail position of the sensor is shown in Figure 4, overall view is shown in Figure 5.

Figure 4: Heat flux sensor, temperature and wind velocity sensor at IGU (author)

3.2 Heat flux

Value of heat flux can be well observed at solid volumes of different materials, walls, insulations, plasters etc. Due to window (glazing) structure, whole process is complicated by inserting multiple cavities and panes of glass. The position of heat flux measurement unit is shown in Figure 4. The effect of the glass pane thickness on the heat flux passing through the glass-window is known. Increasing the thickness of the glass pane results in slight decrease of the heat flux through the window. [3]

Figure 5: Position of sensors in scale 1:1 on IGU (author)

Stabilization time of test chamber and measured unit was established under the following conditions:

- Exterior side: 0 °C, no humidity limitations
- Interior side: 20 °C, Relative humidity: 50%

Measurement points of temperature and heat flux were stabilized after 4 hours of test chamber operation. After 4 hours exterior temperature was changed from 0 °C to 5 °C. Measured units were stabilized after 1.5 hour of test chamber operation. Values of this measurement are listed in Table 1. Note, that temperatures of interior and exterior were established nearby glass surfaces without the liquid between the glass panes.

Table 1: Stabilization of temperature in IGU and heat flux

Time	Temperature Difference [°C]	Exterior Temperature [°C]	Interior Temperature [°C]	Heat flux M40 [W/m]	Heat flux M41 [W/m]	Heat Flux M42 [W/m]
12:53	0	23.8	23.8	-0.9	-1.2	-0.9
13:00	1.70	21.4	23.9	-1.4	-1.5	-1.2
14:00	15.40	5.8	20.7	-9.4	-14.3	-10.1
15:00	15.00	4.4	19.4	-20.1	-26.8	-19.7
16:00	15.40	4.0	19.4	-23.5	-31.4	-23.7
17:00	15.20	3.8	19.0	-26.0	-29.6	-23.7
18:00	11.2	8.0	19.2	-23.8	-25.6	-23.0
18:30	11.6	7.9	19.5	-20.7	-25.5	-21.4

3.3 Dew point

Dew point is the highest temperature at which airborne water vapor will condense to form liquid dew. Table 2 shows that minimum value of dew point is 10.0°C, the minimum measured surface temperature is 18.2 °C and temperature nearby glass pane is 19.0°C. These values will be compared with those measured on liquid-filled window planned in the next observation.

Table 2: Dew point establishment

Time	Surface Temperature point M97 [°C]	Interior Temperature [°C]	Relative Humidity RH [%]	Dewpoint Temperature DT [°C]	Atmospheric Pressure [mbar]
12:53	22.0	23.8	68.5	16.2	988.8
13:00	22.2	23.9	68.4	16.3	988.8
14:00	20.5	20.7	59.1	12.4	988.2
15:00	19.4	19.4	54.3	10.2	987.9
16:00	18.7	19.4	55.2	10.0	987.6
17:00	18.3	19.0	56.0	10.0	987.4
18:00	18.2	19.2	56.0	10.1	987.3
18:30	18.3	19.5	55.9	10.0	987.2

4 Discussion

Table 1 lists values measured with three heat flux sensors which were installed on the interior surface of glass pane (i.e. inside the test chamber). Recorded heat flux values in the table 1 shown differences between themselves. Sensor 41 in the lowest position as shown Figure 5 reaches values higher in average 5-35%. This effect can be caused by surface temperature gradient in the vertical direction. In the further measurements we will consider mean value of all sensors located in interior/exterior. Heat transfer through this structural glazing is very complex process dependent on material, therefore heat loss from interior through glass pane increase temperature heat gain gradient in circulating liquid. Observation of this process will continue in measurements with liquid present in window cavity.

Figure 6: Presence of liquid in the cavity of window

5 Conclusion

Measurement of IGU without liquid layer had established series of values for temperature (of surface and nearby surface, window cavity), humidity, heat flux, dew point, atmospheric pressure and air velocity. Calculations of those values provides overall picture of the window nature in comparison to the condition with the presence of liquid which is shown in Figure 6. It is assumed, that liquid present in the cavity will result in different values of measured physical units and also affect the optical properties of IGU. These issues are subject to the further observation of this research.

References

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