Room Air Conditions for Preventing Water Mist Formationin in Roofed Skating Facilities

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ABSTRACT

It is known that water mist occasionally fonns near ice surfaces in roofed skating facilities depending on the indoor environmental conditions. The mist can lead to problems such as decreased visibility during skating competitions. The objective of the present paper is to clarify the relationship between indoor air conditions and water mist formation and to provide a useful design method for preventing mist formation in roofed skating facilities.

In the first section, studies concerning the indoor air conditions for preventing water mist formation near the ice surface are described. The boundary layer theory is used to determine the criteria of mist formation. The criteria can be expressed by a psychrometric chart. This paper also describes the results of measurements made in an existing skating facility. According to visual observation, water mists were formed when the indoor relative humidity was high.

The measured air temperatures and relative humidities prove that the proposed criteria for mist formation are useful for designing HVAC systems in skating facilities.

KEYWORDS

Skating facility , Mist formation , Room air condition

INTRODUCTION

It is generally known that in indoor ice-skating rinks water mists may develop and persist over the ice, depending on the indoor environmental conditions. Thick mist may pose a problem because it reduces visibility.

In the present study, indoor environmental conditions required for preventing the occurrence of such mists were formulated, and field investigations were carried out at an indoor ice-skating rink to verify the formulated conditions. This paper reports the results.

PREVIOUS STUDIES ON MIST DEVELOPMENT

Previous studies on mist generation include Mori and Hijikata's[3] analysis assuming saturation and Hayashi, Takimoto, and Kawahara's[4] analysis assuming oversaturation. These studies deal with problems involving mist generation in the direction of flow along or in a relatively simple surface or surfaces, such as along a plate or in a duct. Fujii, Ota, and Hijikata[5] conducted a numerical analysis considering the particle-size distribution of heteronuclear particles and the gravity settling of mist particles.

Though based on these studies, the present study does not treat the mechanism of mist generation. Instead, it tries to define the conditions of mist generation, with the aim of preventing the occurrence of mist over ice-skating rinks by keeping the indoor environmental conditions within specified limits.

CONDITIONS OF MIST GENERATION

Usually, a considerable amount of dust is suspended over an indoor ice-skating rink. Mist is thought to develop as water vapor condenses on these fine particles of dust under "conditions of saturation."

The conditions for mist generation near a skating rink surface can be expressed as follows(see Fig.1):

$$\left(\frac{dX}{dy}\right)_{y=0} \geq \left(\frac{dX_{sat}}{dy}\right)_{y=0} \quad (1)$$

The right-hand side of the above equation can be related, using the Clausius-Clapeyron equation, to temperature distribution:

$$\frac{dX_{sat}}{dy} = \frac{dX_{sat}}{dT} \cdot \frac{dT}{dy} = \frac{H_L X_{sat}}{RT^2} \cdot \frac{dT}{dy} \quad (2)$$

The conditions of Eq. (1), therefore, can be expressed as

$$\left(\frac{dX/dy}{dT/dy}\right)_{y=0} \geq \frac{H_L X_{sat}(T_W)}{RT_W^{\,2}} \quad (3)$$

If similarity between the diffusion of heat and the deffusion of mass in the boundary layer is assumed in the case where the conditions of mist generation are not satisfied, the left-hand side of equation can be approximated, using the temperatures and absolute humidities outside the boundary layer and at the skating rink (ice) surface, as

$$\left(\frac{dX/dy}{dT/dy}\right)_{y=0} = \frac{\lambda}{D} \cdot \frac{h_D}{\alpha_c} \cdot \frac{X_R - X_W}{T_R - T_W} \quad (4)$$

Substituting this in Eq. (3) gives

$$\frac{X_R - X_W}{T_R - T_W} \geq C \cdot \frac{H_L X_{sat}(T_W)}{RT_W^{\,2}}$$

where、 $C = (D \cdot \alpha_c)/(\lambda \cdot h_D)$ (5)

Nomenclature

- y : height from rink surface
- T : air temperature at height y
- T_R : air temperature outside the boundary layer
- T_W : ice surface temperature
- X : absolute humidity at height y
- X_{sat}: saturate absolute humidity at temperature T
- X_R : absolute humidity outside the boundary layer
- X_W : absolute humidity at ice surface
- R : gas constant of water vapor
- H_L : latent heat of vaporization
- D : diffusion coefficient of water vapor
- h_D : moisture conductivity
- λ : thermal conductivity of humid air
- a_c : convective heat conductivity

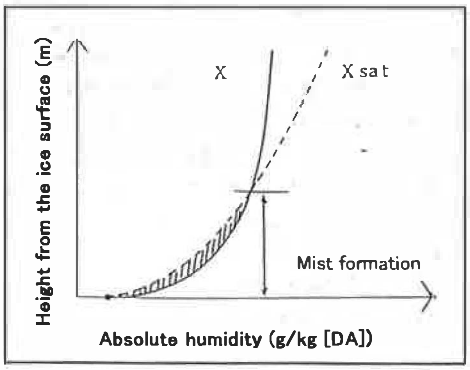

Figure.1 Water mist formation near an ice-rink

If C is a constant, Eq. (5) plots as a straight line on a psychrometric chart.

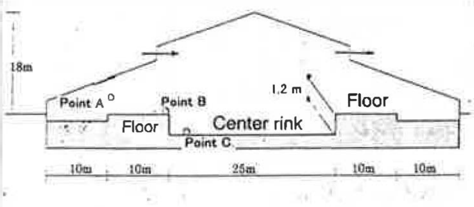

Figure.2 Main measuring points

For an ice surface temperature of - 7℃, which was actually measured at the skating rink described below , the straight line is as shown in Fig. 5.

MEASUREMENT AT AN INDOOR SKATING RINK

Measurements were taken at an indoor ice-skating rink, as shown in Fig. 2, to investigate the relationship between indoor environmental conditions and mist generation.

Air temperature and relative humidity measurements taken in a building naturally ventilated through louvers are shown in Figs. 3 and 4. Measurements of ice surface were not taken at night because ice-making operations were performed during night hours. When the daytime measurements were taken, ice was being maintained, but there were no skaters. The primary source of moisture which causes mist formation was the outside air introduced through louvers

On September 28, indoor air humidity was high during the morning hours and thickmist were observed. In the afternoon,air temperature rose,resulting in a decrease in indoor relative humidity and therefore disappearance of the mist. After 16:00,mists were formed again .

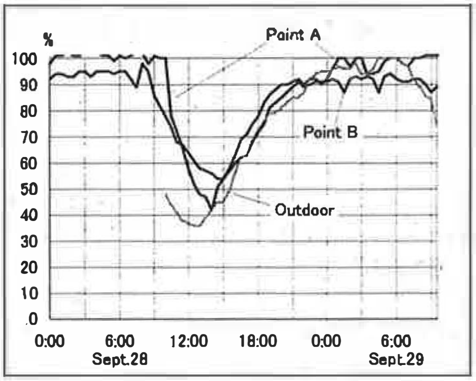

Figure. 3 Air temperatures and surface temperatures

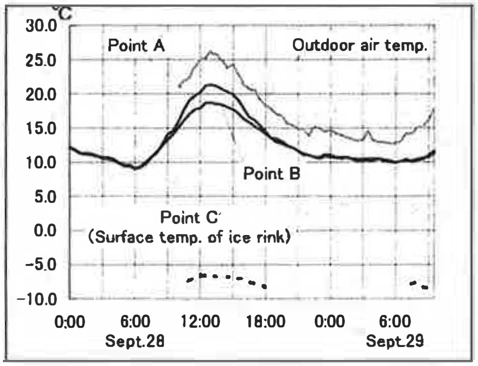

Figure. 4 Relative humidities

Fig. 5 is a plot of this result on a psychrometric chart. Data measured at point A are used in Fig. 5.

Fig. 6 shows the vertical air temperature distribution near the ice surface. Air temperatres measured at 3.2 m above the floor(point A) are assumed to be outside the boundary layer.

The result confirms that mist generation does not occur unless the above-mentioned conditions are satisfied.

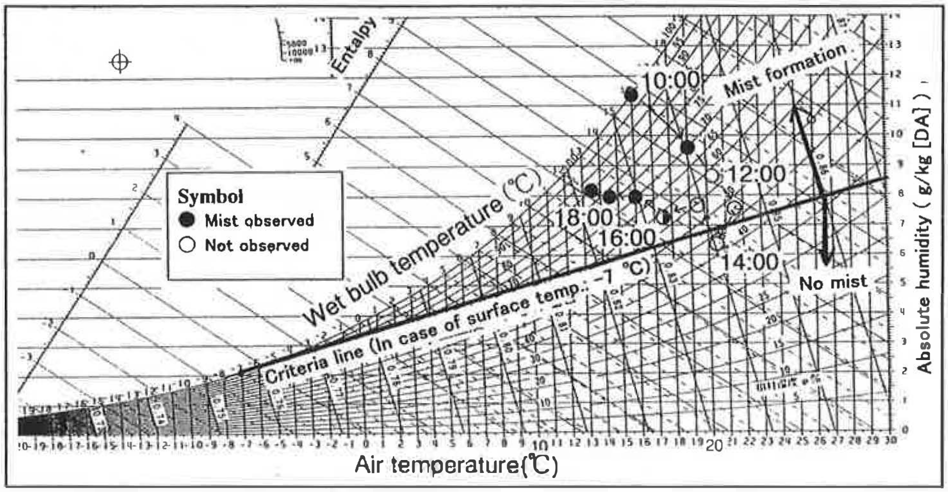

Figure. 5 Criteria line for preventing mist formation and measurement results at an indoor scating rink

DISCUSSION

These findings were all obtained through visual observation(see Photo.1), and therefore it is quite likely that there were some cases in which mist was present but not observed.

The authors nevertheless believe that the conditions described above as a reasonable goal for indoor environment control.

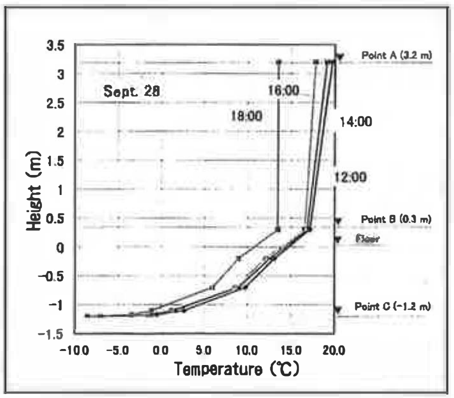

Figure.6 Vertical air temperature distributions near the ice surface.

Photo.1 An example of mist observation

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