LABORATORY SIMULATIONS OF AIR JET DYNAMICS ENCOUNTERED IN FORCED-AIR WARMING SYSTEMS

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INTRODUCTION

Bair Hugger® warming therapy is **used** on surgical patients to minimize physiologic complications due to inadvertent hypothermia. It **has** been reported that anesthetic-induced vasodilatation brings about a drop in the patient's body core temperature during surgery and is responsible for metabolic *stresses* during the recovery period **[1]**. Bair Hugger® warming therapy utilizes both convective and radiative modes of heat transfer to **transport** heat energy **from** a warming cover to the patient's cutaneous layer. In order to quantify the convective component of this heat transfer, a calorimetric heat flux gauge was designed and fabricated. This was accomplished by inputting the measured timewise varying gauge temperature into a **data** reduction program and calculating the desired convection heat transfer coefficient.

METHODS

The calorimetric heat flux gauge used a highly polished conductive metal disk that reflected more than 95 percent of **all** incident radiation. The convective heating was accomplished using nine impinging air jets similar in nature to the jets emerging from the Bair Hugger® cover. Each jet, with an initial diameter of 1 mm, impinges onto the gauge at a flow rate **equal** to 7.0 cm^3/sec. A guard heater was used to eliminate spurious heat loss errors. The timewise temperature variations of the metal disk given by an embedded thermocouple were recorded for two separate experiments. The first experiment involved vertical impinging jets normal to the gauge, while the second experiment implemented horizontal impinging jets normal to the gauge.

With the measured timewise disk and ambient temperatures, the total heat transfer coefficient $\bar{h}_{total}$ for simultaneously occurring forced convection, natural convection and radiation was deduced from the following formula.

$$P = \rho c V \frac{dT}{dt} + \bar{h}_{total} A (T - T_{\infty}) \qquad \text{Eq. 1}$$

Equation 1 represents an energy conservation equation with the following defined variables: P, power inflow *to* the calorimeter from the heater; ρ, **disk** density; c, disk specific heat; V, disk volume; T, disk temperature; T_{∞}, ambient air temperature; **A,** disk surface **area;** t, time. In words, Equation **1** states that the power inflow to the calorimeter disk from the embedded heater equals the sum of the timewise rise in the internal energy of the calorimeter **disk** and the power convected and radiated from the disk's surface.

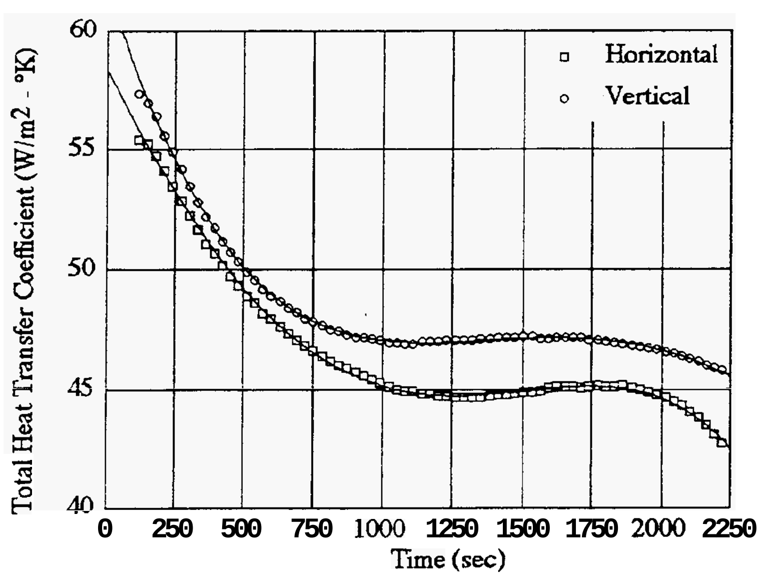

Fig. 1 **Heat Transfer Coefficient vs. Time for Normal Horizontal and Normal Vertical Jet Impingement Obtained Using Curve** Fitted **Temperatures**

RESULTS

The magnitudes of the timewise variation of the heat transfer coefficients for both jet orientations were determined from Equation 1 and plotted in Figure 1. For the numerical evaluation of Equation 1, the needed values of the calorimeter and ambient temperatures were imputed by means of curve fits. These temperatures were curve-fitted to minimize errors produced by ambient temperature fluctuations. For the vertical and horizontal impinging jet scenarios, the total quasi-steady-state convective heat transfer coefficients were determined from Figure 1 to be 46.8 W/m²-°K and 44.8 W/m²-°K respectively. When the slopes of the curves in Figure 1 approach a value of zero, quasi-steady-state conditions are achieved. This condition occurs as an equilibrium is attained between the conductive heat transfer across the metal disk and the convective heat transfer from the disk's surface.

Heat Transfer Coefficient	Vertical Jet	Horizontal Jet
Total	46.8 W/m²-°K	44.8 W/m²-°K
Natural Convection	6.86 W/m²-°K	5.13 W/m²-°K
Forced Convection	46.6 W/m²-°K	44.5 W/m²-°K
Radiation	0.30 W/m²-°K	0.30 W/m²-°K

Table 1 Summary of Heat Transfer Coefficients

CONCLUSIONS

The calorimetric heat flux gauge provided a means to measure the convective heat transfer coefficients for both vertical and horizontal jet impingement orientations. In comparing the magnitudes of the forced and natural convective components of the total heat transfer coefficient for the polished gauge, the results show that the Bair Hugger® warming therapy is dominated by forced convection heat transfer. Both the natural convection and radiation heat transfer effects were considered to be negligible.

REFERENCES

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