

## Heat Flow Calculations

Application Note TSI-124

The VELOCICALC<sup>®</sup> Multi-function Ventilation Meter calculates heat flow by making temperature, humidity, and flow measurements upstream and downstream of the coil in the duct. The following steps and calculations are utilized to make the heat flow measurement:

- Select **HEATFLOW** under the applications menu.
- The current upstream measurements of temperature, humidity, and flow are displayed. Highlight the desired measurement and hit the measurement key. This will update the reading. The flow rate will be calculated using either the thermal anemometer or pitot tube depending if the TA probe is attached.
- Select **Downstream** to make readings downstream of the coil.
- The unit will display real time values based on the temperature and humidity readings from the probe.

The Equations used for the calculations are described below.

### Sensible Heat Flow

Sensible heat is dry heat. It causes a change in temperature in a substance, but not a change in the moisture content of that substance.

$$Q_s = 60c_p\rho q\Delta t \text{ (English units)} \quad \text{OR} \quad Q_s = c_p\rho q\Delta t/3600 \text{ (metric units)}$$

where  $Q_s$  = sensible heat flow in Btu/hr (kW)

$c_p$  = specific heat in Btu/lb °F = 0.2388 Btu/lb °F (1.0048 kJ/kg K)

$\rho$  = air density at standard conditions = 0.075 lb/ft<sup>3</sup> (1.202 kg/m<sup>3</sup>)

$q$  = measured air flow in ft<sup>3</sup>/min (m<sup>3</sup>/hr) (assuming flow is the same at first and second measurement location)

$\Delta t$  = temperature difference in °F (°C) (difference between first and second measurement location)

Replacing constant values gives:

$$Q_s = 1.0746q\Delta t \text{ (English units)} \quad \text{OR} \quad Q_s = 1.21q\Delta t/3600 \text{ (metric units)}$$

## Latent Heat Flow

Latent heat is the heat that when supplied to, or removed from, a substance there is a change in the moisture content of the substance (change in state), but the temperature of that substance does not change.

$$Q_L = 60h_{fg}\rho q\Delta W \text{ (English units)} \quad \text{OR} \quad Q_L = h_{fg}\rho q\Delta W/3600 \text{ (metric units)}$$

where  $Q_L$  = latent heat flow in Btu/hr (kW)

$h_{fg}$  = latent heat of vaporization of water in Btu/lb = 1060 Btu/lb (2,465.56 kJ/kg)

$\rho$  = air density at standard conditions = 0.075 lb/ft<sup>3</sup> (1.202 kg/m<sup>3</sup>)

$q$  = measured air flow in ft<sup>3</sup>/min (m<sup>3</sup>/hr)

$\Delta W$  = humidity ratio difference in lb water/lb dry air (kg water/kg dry air)  
(difference in water content of air between first and second measurement location)

Replacing constant values gives:

$$Q_L = 4770q\Delta W \text{ (English units)} \quad \text{OR} \quad Q_L = 0.8287q\Delta W \text{ (metric units)}$$

## Total Heat Flow

Total heat is the sum of latent heat and sensible heat.

$$Q_T = Q_S + Q_L$$

where  $Q_T$  = total heat flow in Btu/hr (kW)

$Q_S$  = sensible heat flow in Btu/hr (kW)

$Q_L$  = latent heat flow in Btu/hr (kW)

## Sensible Heat Factor

The sensible heat factor equals sensible heat divided by total heat in the air.

### Given at measurement location 1 (conditions inside room):

dry bulb temperature  $t_1 = 76$  °F

%RH<sub>1</sub> = 49.0% ( $\phi_1 = .490$ )

barometric pressure = 29.921 in. Hg

### Given at measurement location 2 (conditions of supply air entering room):

dry bulb temperature  $t_2 = 53$  °F

%RH<sub>2</sub> = 88.0% ( $\phi_2 = .880$ )

flow rate  $q = 15,000$  std ft<sup>3</sup>/min

**Find:** sensible heat flow  $Q_S$ , latent heat flow  $Q_L$ , total heat flow  $Q_T$ , and sensible heat factor SHF.

### Sensible heat flow $Q_S$

$$Q_S = 1.0746q\Delta t = 1.0746 (15000)(|53-76|) = 370,737 \text{ Btu/h of heat removal}$$

**Latent heat flow  $Q_L$** 

$Q_L = 4770q\Delta W$ , so we need to find  $W_1$  and  $W_2$ .

$$W = 0.62198p_{ws}(t_d)/(29.921 - p_{ws}(t_d))$$

$$p_{ws}(t_d) = (\phi_1)(p_{ws}(t))$$

Definitions of terms used to calculate  $W$ :

$p_{ws}(t_d)$  = saturation pressure of the air stream at the dew point temperature (inches Hg)

$p_{ws}(t)$  = saturation pressure of the air stream at ambient temperature (inches Hg)

$\phi$  = humidity (expresses as a value between 0 -1, not as %RH)

To find  $W_1$ :

$p_{ws}(t_1) = p_{ws}(76 \text{ }^\circ\text{F}) = 0.90532 \text{ in. Hg}$  (from lookup table – TA460 has this data programmed into its memory)

$$p_{ws}(t_{d1}) = (\phi_1)(p_{ws}(t_1)) = (0.490)(0.90532) = 0.4436068$$

$$W_1 = 0.62198p_{ws}(t_{d1})/(29.921 - p_{ws}(t_{d1})) = 0.62198(0.4436068)/(29.921 - 0.4436068) = 0.00936021 \text{ lb H}_2\text{O/lb dry air}$$

**SHF =  $Q_S/Q_T$** 

where SHF = sensible heat factor (ratio of sensible heat load to total heat load)

$Q_S$  = sensible heat flow in Btu/hr (kW)

$Q_T$  = total heat flow in Btu/hr (kW)

**EXAMPLE 1: (Imperial Units)**To find  $W_2$ :

$p_{ws}(t_2) = p_{ws}(53 \text{ }^\circ\text{F}) = 0.40516 \text{ in. Hg}$  (from lookup table – TA460 has this data programmed into its memory)

$$p_{ws}(t_{d2}) = (\phi_2)(p_{ws}(t_2)) = (0.880)(0.40516) = 0.3565408$$

$$W_2 = 0.62198p_{ws}(t_{d2})/(29.921 - p_{ws}(t_{d2})) = 0.62198(0.3565408)/(29.921 - 0.3565408) = 0.00750094 \text{ lb H}_2\text{O/lb dry air}$$

To find  $Q_L$ :

$$Q_L = 4770q\Delta W = 4770(15,000)(|0.00750094 - 0.00936021|) = 133,031 \text{ Btu/h heat removed}$$

**Total heat flow  $Q_T$** 

$$Q_T = Q_S + Q_L = 370,737 + 133,031 = 503,768 \text{ Btu/h heat removed}$$

**Sensible Heat Factor SHF**

$$\text{SHF} = Q_S/Q_T = 370,737/503,768 = 0.74$$

## EXAMPLE 2: (Metric Units)

### Given at measurement location 1 (conditions inside room):

dry bulb temperature  $t_1 = 24.4$  °C

%RH<sub>1</sub> = 49.0% ( $\phi_1 = .490$ )

barometric pressure = 760 mm Hg

### Given at measurement location 2 (conditions of supply air entering room):

dry bulb temperature  $t_2 = 11.7$  °C

%RH<sub>2</sub> = 88.0% ( $\phi_2 = .880$ )

flow rate  $q = 25486$  std m<sup>3</sup>/hr

**Find:** sensible heat flow  $Q_S$ , latent heat flow  $Q_L$ , total heat flow  $Q_T$ , and sensible heat factor SHF.

#### Sensible heat flow $Q_S$

$$Q_S = 1.21q\Delta t/3600 = 1.21 (25486)(24.4 - 11.7) = 108.79 \text{ kW of heat removal}$$

#### Latent heat flow $Q_L$

$Q_L = 0.8287q\Delta W$ , so we need to find  $W_1$  and  $W_2$ .

$$W = 0.62198p_{ws}(t_d)/(760 - p_{ws}(t_d))$$

$$p_{ws}(t_d) = (\phi_1)(p_{ws}(t))$$

Definitions of terms used to calculate  $W$ :

$p_{ws}(t_d)$  = saturation pressure of the air stream at the dew point temperature (mm Hg)

$p_{ws}(t)$  = saturation pressure of the air stream at ambient temperature (mm Hg)

$\phi$  = humidity (expresses as a value between 0 -1, not as %RH)

#### To find $W_1$ :

$$p_{ws}(t_1) = p_{ws}(24.4 \text{ °C}) = 22.922 \text{ mm Hg (from lookup table – TA460 has this data programmed into its memory)}$$

$$p_{ws}(t_{d1}) = (\phi_1)(p_{ws}(t_1)) = (0.490)(22.922) = 11.232 \text{ mm Hg}$$

$$W_1 = 0.62198p_{ws}(t_{d1})/(760 - p_{ws}(t_{d1})) = 0.62198(11.232)/(760 - 11.232) \\ = 0.00933 \text{ kg H}_2\text{O/kg dry air}$$

#### To find $W_2$ :

$$p_{ws}(t_2) = p_{ws}(11.7 \text{ °F}) = 10.312 \text{ mm Hg (from lookup table – TA460 has this data programmed into its memory)}$$

$$p_{ws}(t_{d2}) = (\phi_2)(p_{ws}(t_2)) = (0.880)(10.312) = 9.075 \text{ mm hg}$$

$$W_2 = 0.62198p_{ws}(t_{d2})/(760 - p_{ws}(t_{d2})) = 0.62198(9.075)/(760 - 9.075) \\ = 0.00752 \text{ kg H}_2\text{O/kg dry air}$$

To find  $Q_L$ :

$$Q_L = 0.8287q\Delta W = 0.8287(25486)(|0.00752 - 0.00933|) = 38.228 \text{ kW heat removed}$$

**Total heat flow  $Q_T$**

$$Q_T = Q_S + Q_L = 108.79 + 38.228 = 147.018 \text{ kW heat removed}$$

**Sensible Heat Factor SHF**

$$\text{SHF} = Q_S/Q_T = 108.79/147.018 = 0.74$$

The  $p_{ws}(t)$  and  $W$  that are being used in these equations are the same  $W$  that is calculated when finding the wet bulb temperature.

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