Development of the Duct / HRV Model for ESP-r

1.0 SUMMARY

This document provides non-source code information relating to the programming of the first HRV model for ESP'r Version xxx.x.x.x in January 2001. A new model was implemented previously in 1993, with further major revisions in this present version.

Major improvements are required in order to account for latent, and other effects in the calculations. The basis for the original model is documented in the HOT2000 Technical Manual (1).

3.0 HRV MODEL DEVELOPMENT

3.1 Basic Equations

Most HRV systems currently available have the supply and exhaust fans located on the "downstream" side of the air stream, as indicated in the figure shown in the accompanying file, HRVESPR1.gif. At least, these are the assumptions in the present model.

The first basic equation defines the HRV heat exchanger effectiveness. Chapter 2 of the ASHRAE HANDBOOK (3) gives a general definition of heat exchanger effectiveness, Eq. (16). In the current implementation, this is also taken as the sensible efficiency. The heat exchanger effectiveness, _ is given by

$$\varepsilon = \frac{T_s - T_7}{T_3 - T_7} \qquad (3.1)$$

where

T_7	=	temperature of supply air entering the heat exchanger (∘ C)
T_s	=	temperature of supply air leaving the heat exchanger (∘ C)
T_3	=	temperature of exhaust air entering the heat exchanger (∘ C)

A fundamental assumption of the HRV model as implemented here is that the heat exchanger effectiveness is a linear function of temperature. In the present model, it is assumed that _ is a linear function of the temperature of the air entering the heat exchanger, T_7, as indicated in the figure. This distinction is particularly important when there is a pre-heater, and when duct heat transfer is accounted for.

Temperatures of the air at various locations throughout the HRV system are calculated as follows. It is assumed that the mass capacity rates (mass flow rate x thermal capacity) are equal at all locations. Only sensible heat transfer is accounted for.

The outdoor air temperature, T_{od}, is the starting point for each set of calculations. The temperature at the entrance to the HRV heat exchanger, T_7 is given by

$$T_7 = T_{sd} + \frac{Q_{ph}}{\rho\, f\, C_p} \tag{3.2}$$

where

Q_{ph} = pre-heater power, watts.

Temperatures at other locations may be calculated when the HRV effectiveness is defined as a function of the air temperature at the inlet, i.e. _ = _ (T_7). The characteristics of the HRV will be developed in Section 3.2. With reference to the figure, the following equations may be developed.

$$\begin{aligned} \Delta T_h &= \varepsilon(T_7) * (T_3 - T_7) \\ T_s &= T_7 + \Delta T_h \\ T_2 &= T_s + \frac{Q_{sf}}{\rho\, C_p\, f} \\ T_e &= T_3 - \Delta T_h \\ T_x &= T_e + \frac{Q_{ef}}{\rho\, C_p\, f} \end{aligned} \tag{3.3}$$

where

Q_{sf} = supply fan power, watts.

Q_{ef} = exhaust fan power, watts.

These equations, along with the duct heat transfer equations developed in Sections 2.3 and 2.4 completely define the temperatures and heat transfers at all locations in the HRV. Note that it is assumed that the HRV supply and exhaust fan powers are equal.

3.2 HRV Sensible Heat Recovery Efficiency

The HRV characteristics developed in the preceding section are based on estimates of the temperature dependence of the heat recovery effectiveness _. The test data for sensible heat recovery efficiency are based on a particular configuration of the equipment as specified in CAN/CSA C439M. However, the HRV model for the house includes duct heat transfer. The overall HRV sensible efficiency, including the effects of duct heat transfer is given by

$$\eta = \frac{\rho C_p f (T_2 - T_{od}) - (Q_{ph} + Q_{sf} + Q_s + Q_e)}{\rho C_p f (T_3 - T_{od}) + Q_{sf}} \tag{3.4}$$

4.0 IMPLEMENTATION

5.0 INTERFACE

HOT2000 data inputs for the HRV have not changed as a result of these modifications, but an additional screen has been added to allow the user to describe the cold side ducts. The screen shown below appears after the HRV input screen {Editor: Refer users to present interface for most input elements}.

This section should also document, line-by-line, the inputs that are read from the .vnt file.

6.0 CONCLUSION

There remain several issues to be dealt with, as follows.

1) Latent Heat Transfer

HOT2000 considers only sensible heat transfer in all calculations. This may not be sufficiently accurate, particularly in humid climates. Some HRV manufacturers claim that this approximation unfairly penalizes some of their equipment.

2) HRV Defrost Cycles

The current model does not account for operation of the HRV during defrost cycles. This tends to underestimate the additional air heat loss which occurs during these periods.

3) HRV Configuration

The present implementation now assumes that the supply and exhaust fans are located "downstream" of the heat exchanger core. This is correct for most HRV's presently on the market. It is assumed that there is a separate motor driving the supply and exhaust fans (and that the motor heat is added to the respective air stream). This is not true for several of the single fan motor systems currently on the market.

No single assumption regarding fan motor location will be correct in all cases. The solution is to allow for all known cases. This could be done by enumerating all known HRV systems, and cataloguing their properties. Users specifying one of the known HRV types would then not need to enter any of the other HRV specifications (efficiency, fan power, etc.). A user defined type would be provided for systems not yet tested, but the inputs would include fan motor locations.

4) Model Improvements.

Bibliography

1. HOT2000 Version 6.0 Technical Manual, Canadian Home Builders Association, Ottawa, August, 1991.

2. Lubun, M. 1992. Private Communication.

3. ASHRAE Handbook, 1989 Fundamentals.

4. Canadian Standards Association, CSA Standard C439, "Standard Methods of Test for Rating the Performance of Heat Recovery Ventilators, Ottawa, 1988.

5. Dumont, R.S. 1988. "Energy Answers", SOL Magazine, #62, Jan-Feb 1988, pp.10.

6. Dumont, R.S. 1993. "The Effect of Heat Gains and Losses to Ducts Leading from an Air-to-Air Heat Exchanger to the Outside of a Building", Private Communication.

7. Bradley, B. 1993, "Development of the Duct / HRV Model for HOT2000", UNIES. Ltd. Report to NRCAN.