Building Serv. Eng. Res. Technol. 9(1) 39–40 (1988) Printed in Great Britain

Technical Note

Summary The inappropriateness of modelling ventilation in a building as a conductance is demonstrated. A correct formulation in terms of a quasi heat source is given.

Modelling ventilation—Source, not conductance

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Received 23 April 1987, in final form 29 July 1987

Heat may move around a building by the mechanisms of conduction, convection or radiation. It is also transferred by the action of air movement—air infiltration from outside a room, or from a ducted hot air supply. If the rate of air movement is $V\,\mathrm{m^3\,s^{-1}}$, and the volumetric specific heat of air is denoted by s (equal to about $1200\,\mathrm{J\,m^3\,K^{-1}}$), the quantity Vs has units $\mathrm{W\,K^{-1}}$ and in thermal circuits is often treated as a conductance, on the same footing as the product of wall area and U-value. This is inappropriate however as will be shown below.

Consider the enclosure illustrated in Figure 1. The air temperature is T_1 and is supposed to be uniform. For convenience, we will take its six surfaces to be perfectly reflecting so that there is no radiant transfer and we will further take five of the surfaces to adiabatic. The sixth surface, area A, is in contact with air maintained in some way at T_0. It permits heat conduction and its U-value, (the transmittance between T_0 and T_1), is U. Air infiltrates from outside to the room with a thermal flow rate of Vs. A convective source inputs a heat flow of Q into the room.

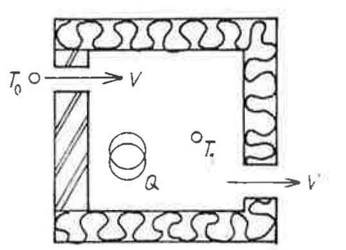

Figure 1 An enclosure allowing conductive heat exchange with the enclosure through one wall. It experiences a throughput of air of $V\,\mathrm{m^3\,s^{-1}}$ and has an internal convective heat input of Q W.

If the heat input to the room is equated to the heat flow from it, we have

$$Q + VsT_0 = VsT_1 + AU(T_1 - T_0)$$

There are two ways of handling this equation: It can be written as

$$(AU + Vs)(T_1 - T_0) = Q$$

This implies the thermal circuit shown in Figure 2. T_0 is modelled as a pure temperature source, Q as a pure heat source and the conduction and ventilation mechanisms provide parallel paths of equal status between T_1 and T_0.

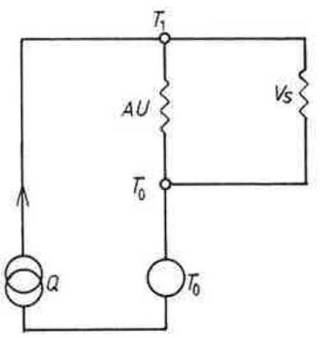

Figure 2 The throughput of air incorrectly modelled as a conductance Vs

This is inappropriate however. AU correctly describes a heat flow from T_1 to T_0 should T_1 exceed T_0, and conversely. (Q could be negative.) However, there is no way in which any heat can be transferred from T_1 to T_0 through the 'ventilation' conductance. A flow of air from T_0 to T_1 can only convey internal energy from T_0 to T_1 and not conversely.

Instead we have to rewrite the continuity equation as

$$AU(T_1 - T_0) = Q + Vs(T_0 - T_1)$$

This implies the thermal circuit of Figure 3. The infiltration mechanism is now represented by a quasi heat source, $Vs(T_0 - T_1)$, with an arrow to denote the direction in which it acts. It is of comparable status to the pure heat source Q, but acts between the two temperatures T_0 and T_1. The source could equally model the heat supplied by a ducted hot air system.

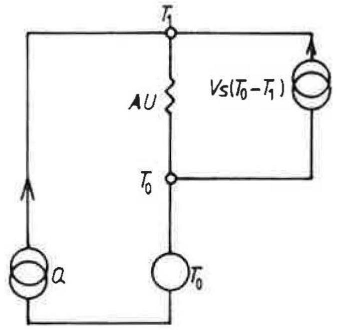

Figure 3 The throughput of air correctly modelled as a quasi heat source $Vs\,(T_0 - T_1)$

The air flow V which enters the room must of course leave it, and if it passed to an adjoining room with air temperature at T_2, the flow would impose a quasi heat source of strength $Vs(T_1 - T_2)$ on the second room.

The *CIBSE Guide*[1] models ventilation as a conductance similar to that illustrated in Figure 2. It is notated as $C\rho v$ and lies between t_{ai} (in room A say) and t_{ao}. See Reference 1, Figure A5.1. Infiltration should appear as a quasi heat source, not a conductance, between these nodes. In fact, this misrepresentation does not matter here, since t_{ao} is an independent variable, not one to be calculated. If, however, t_{ao} had denoted the air temperature in an adjoining room (room B say), to be calculated using heat continuity relations in the usual way, $C\rho v$ would be providing a heat flow path which illegally allowed conditions in room A to influence those in room B. Room A can affect conditions in room B via the AU conductance, but not via $C\rho v$.

AU and $C\rho v$ do not have equal status. It is suggested that the *Guide* be amended in due course to provide different symbols for their actions.

Reference

1 CIBSE Guide Section A5: Thermal Response of Buildings (London Chartered Institution of Building Services Engineer) (1979)