TYPE 715: ASHRAE METHOD FOR CALCULATING BASEMENT HEAT TRANSFER

General Description

In 2001 ASHRAE Fundamentals Chapter 31, the American Society of Heating and Refrigeration Engineers proposes a simplified method for calculating the energy transfer through a rectangular aspect ratio basement with various insulation schemes (back insulation, side insulation, no insulation, etc.). The same chapter also presents the simplified method as it applies to calculating energy transfer through slabs. This Type should be used for basements while Type714 is available for calculating energy transfer through slabs. Because of the methodology used, this model is not appropriate for use with Type56 but can be used with simplified building models such as standard TRNSYS Type12, or 88, or the TESS simplified multizone building model (Type660).

Nomenclature

$\dot{q}_{slab}$	[kJ/hr]	The rate at which energy is transferred through the basement (positive is defined as energy exiting the basement)
$\dot{q}_{mean}$	[kJ/hr]	The average annual rate at which energy is transferred through the basement
$\dot{q}_{amp}$	[kJ/hr]	The amplitude of the sinusoidal rate at which energy is transferred through the basement.
ω	[radians/hr]	The annual angular frequency (7.17×10^{-4} rad/hr)
$time$	[hr]	The hour of the year
ϕ	[hr]	The phase lag between the hottest hour of the year and the hour in which the maximum energy transfer through the basement is experienced.
B	[m]	The basement depth
$U_o, G, H_{mean}, H_{amp}, D_{mean}, D_{amp}$	[various]	Model fitting parameters.
k_{soil}	[kJ/hr.m.K]	The thermal conductivity of the soil.
A_{slab}	[m^2]	The area of the basement floor and walls
P_{slab}	[m]	The perimeter of the basement. SEE NOTE IN TEXT BELOW!
$R_{equivalent}$	[$hr.m^2.K/kJ$]	The equivalent thermal resistance of the basement
α_{soil}	[m^2/hr]	The thermal diffusivity of the soil
R_{insul}	[$hr.m^2.K/kJ$]	The thermal resistance of the insulation material
R_{slab}	[$hr.m^2.K/kJ$]	The thermal resistance of the basement walls and floor material
L_{insul}	[m]	The length of the basement
ρ_{soil}	[kg/m^3]	The density of the soil
Cp_{soil}	[kJ/kg.K]	The specific heat of the soil
$U_{eff,mean}$	[$kJ/hr.m^2.K$]	The mean heat loss coefficient for the basement
$U_{eff,amp}$	[$kJ/hr.m^2.K$]	The difference between the maximum heat loss coefficient for the basement and the average heat loss coefficient for the basement
$T_{mean,indoor}$	[ºC]	The average indoor temperature.
$T_{mean,ambient}$	[ºC]	The average outdoor temperature

T_{amp}	[ºC]	The difference between the maximum outdoor temperature and the average outdoor temperature.

Detailed Description

The 2001 ASHRAE Fundamentals Handbook, Chapter 31 presents a simplified method for estimating energy transfer through slabs and basements. The configuration modeled by this Type is that of a rectangular basement that may or may not be insulated beneath its floor and that may or may not be insulated around its perimeter. A schematic drawing of such a basement is shown in Figure 1.

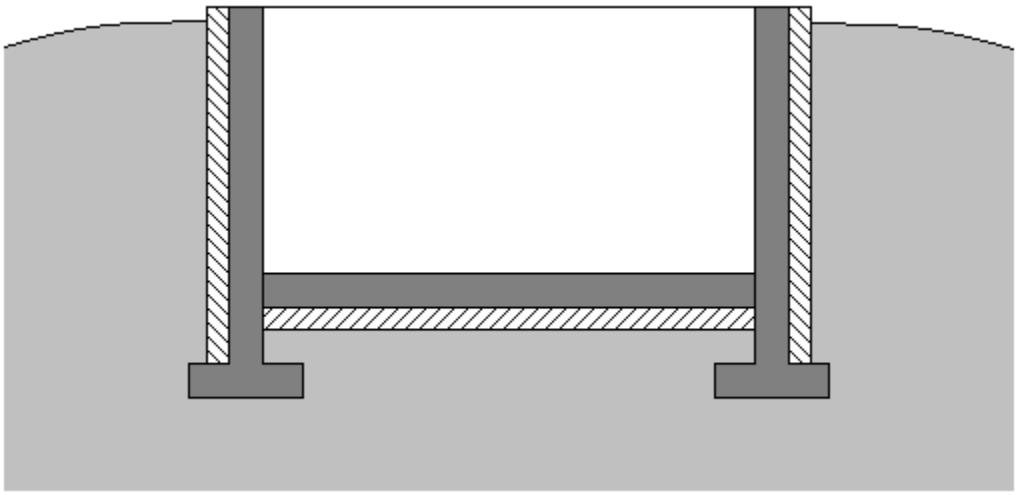


Figure 1: Basement Configuration

The basement model is employed in TRNSYS as though it were a slab in contact with the ground. It does not require the definition of any sort of below grade zone. A user might employ the model by defining a the basement in Type715, then connecting the energy transferred through the basement (output 1) as an additional energy gain / loss in a Type660 simplified building model.

The energy transferred through the basement at any point in time is given by Equation 715.1 (ASHRAE equation 5).

$$\dot{q}_{slab} = \dot{q}_{mean} + \dot{q}_{amp} \sin(\omega\, time + \phi) \qquad \text{(Eq. 715.1)}$$

In which ω is the annual angular frequency (expressed in radians / hour) and ϕ is the phase lag (in hours) between the maximum annual temperature and the maximum annual energy transfer through the basement. In essence, equation 715.1 indicates that the energy transfer through the basement follows a sinusoidal function about the mean energy transfer rate and with a certain amplitude.

The mean energy transfer and the amplitude of the energy transfer are calculated as follows. First, the soil conductivity is normalized to form four parameters U_o, G, H and D. The first, U_o, requires only the soil conductivity, the area and the perimeter of the basement.

$$U_o = \frac{k_{soil}}{\left(\frac{A_{slab}}{P_{slab}}\right)} \qquad \text{(Eq. 714.2)}$$

The perimeter of the basement in this case is the total edge length if the basement walls are folded down to form the shape shown in Figure 2.

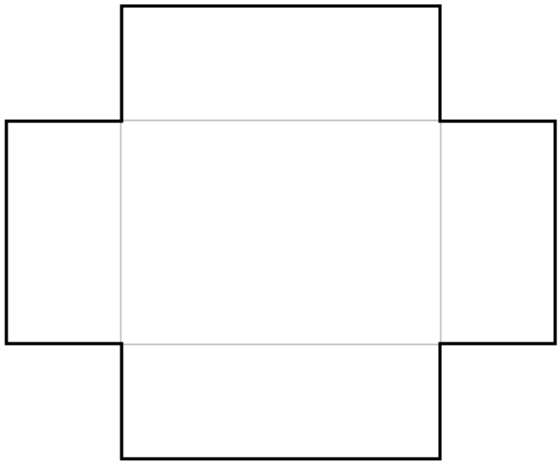


Figure 2: Basement Perimeter Definition

In the second parameter, G, an equivalent thermal resistance of the insulation and the annual angular frequency are introduced. The equivalent resistance is calculated using equation 715.6 (ASHRAE equation 14) while the annual angular frequency is given by equation 715.7. Equation 715.3 (ASHRAE equation 12) also requires the thermal diffusivity of the soil, a value that is calculated from the models parameters using equation 715.8.

$$G = k_{soil}\ R_{equivalent}\ \sqrt{\frac{\omega}{\alpha_{soil}}} \qquad \text{(Eq. 715.3)}$$

There are actually two H parameters, one for calculations involving mean conditions and one for calculations involving amplitudes. H_{mean} is given by equation 715.4 (ASHRAE equation 15 and 8 combined) and H_{amp} is given by equation 715.5 (ASHRAE equation 15 and 9 combined)

$$H_{mean} = \frac{\left(1 + \frac{B}{\frac{A_{basement}}{P_{basement}}}\left(-0.4 + e^{-\left(\frac{\frac{A_{basement}}{P_{basement}}}{k_{soil}\ R_{equivalent}}\right)}\right)\right)\left(\frac{A_{basement}}{P_{basement}}\right)}{k_{soil}\ R_{equivalent}} \qquad \text{(Eq. 714.4)}$$

$$H_{amp} = \frac{\left(1 + \frac{B}{\frac{A_{basement}}{P_{basement}}} e^{-\left(\frac{\frac{A_{basement}}{P_{basement}}}{k_{soil}\ R_{equivalent}}\right)}\right)\left(\frac{A_{basement}}{P_{basement}}\right)}{k_{soil}\ R_{equivalent}} \quad \text{(Eq. 714.5)}$$

The D parameter is given by equation 715.6 (ASHRAE equation 16) as a function of H. Again there are two versions of the D parameter, one for amplitude calculations and the other for mean calculations.

$$D_{mean} = \ln\left[\left(1 + H_{mean}\right)\left(1 + \frac{1}{H_{mean}}\right)^{H_{mean}}\right] \quad \text{(Eq. 715.6a)}$$

$$D_{amp} = \ln\left[\left(1 + H_{amp}\right)\left(1 + \frac{1}{H_{amp}}\right)^{H_{amp}}\right] \quad \text{(Eq. 715.6b)}$$

The equivalent resistance of the basement and insulation is given by equation 715.7 (ASHRAE equation 14).

$$R_{equivalent} = \frac{R_{slab}}{\left[1 - \left(\frac{L_{insul}}{\frac{A_{slab}}{P_{slab}}} \frac{R_{insul}}{R_{slab} + R_{insul}}\right)\right]} \quad \text{(Eq. 715.7)}$$

Since the period of the sinusoid that is used to describe energy transfer through the basement is one year, the frequency of that sinusoid, expressed in radians per hour is given by equation 715.8.

$$\omega = \frac{2\,\pi}{8760} \quad \text{(Eq. 715.8)}$$

The thermal diffusivity of the soil is given by 715.9.

$$\alpha_{soil} = \frac{k_{soil}}{\rho_{soil}\ Cp_{soil}} \quad \text{(Eq. 715.9)}$$

The Uo, G, D, and H parameters are next combined to find the effective mean loss coefficient as shown in equation 715.10 (ASHRAE equation 17) and the amplitude of the loss coefficient as given by equation 715.11 (ASHRAE equation 18).

$$U_{eff,mean} = 0.4\,U_o\ D_{mean} \quad \text{(Eq. 715.10)}$$

$$U_{eff,amp} = 0.25\,U_o\ D_{amp}^{0.16}\ G^{-0.6} \quad \text{(Eq. 715.11)}$$

The coefficients 0.4 and 0.25 are taken from ASHRAE Table 2 in chapter 31. In fact ASHRAE gives a number of different coefficient values for situations in which the basement is only partially insulated. Type715, however, assumes that the entire outside of the basement is insulated (provided that it is insulated at all)

With the loss coefficients in hand, the energy transferred through the basement can next be calculated using equations 715.12 and 715.13 (ASHRAE equations 19 and 20).

$$\dot{q}_{eff,mean} = U_{eff,mean}\ A_{slab}\ \left(T_{mean,indoor} - T_{mean,ambient}\right) \quad \text{(Eq. 715.12)}$$

$$\dot{q}_{eff,amp} = U_{eff,amp}\ A_{slab}\ T_{amp} \quad \text{(Eq. 715.13)}$$

Where T_{amp} is the amplitude of the annual ambient temperature.

References

[1] 2001 ASHRAE Handbook of Fundamentals, Chapter 31