Appendix 5.A9: Comparison of thermal steady-state models

Although the methods described in this appendix are presented as steady state methods they can be, and are, the basis of a room model in a transient calculation, Of these methods the only one suited to hand calculation is the 'simple model'. The 'basic model' can easily be implemented within a spreadsheet but the 'reference model' is best used within a software package. The CIBSE recognises that, although many users will not have the luxury of choice of method, users should understand the limitations of the methodology employed within any software application.

The significant difference between the methods lies in the way heat transfer by longwave radiation is treated with the consequence that, assuming a uniform distribution of air temperature within the space, simplification results in errors in the calculation of surface temperature. In the case of the simple model all surfaces with the same U-value and adjacent to the same bounding temperature will be predicted to have the same internal surface temperature; for the basic model surfaces with identical areas and U-values will have identical surface temperatures. Thus these models may not be appropriate for studies associated with prediction of surface mould growth or condensation*. Predictions of heating and cooling load will also differ. However, in most cases differences will be a few percent and virtually zero with well insulated buildings. This is demonstrated in Example 5.A9.1, below, where the highlighted surfaces are of identical areas. The calculation is for a convective heating system.

Example 5.A9.1: Enclosure with multiple surfaces; varying U-values, uniform emissivities

See Figure 5.A9.1 and Tables 5.A9.1 and 5.A9.2. In this example, the calculation methods are applied to multiple surfaces. It is intended to assist in checking computer programs to determine the accuracy with which surface temperatures are calculated.

Operative temperature: 21 °C
Outside air temperature: –1 °C
Infiltration rate: 1.0 h^{-1}

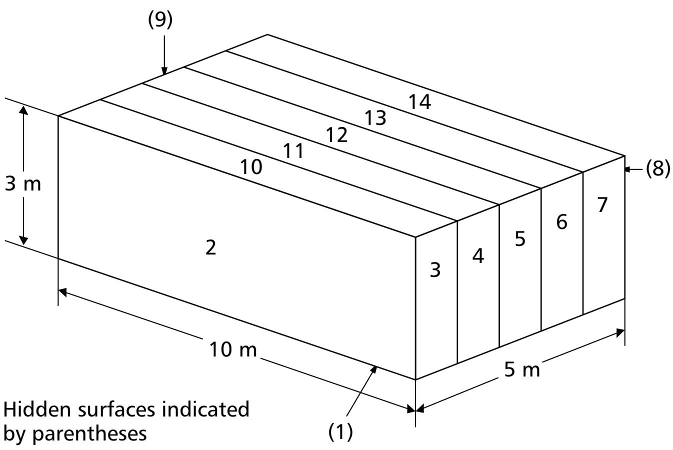

Figure 5.A9.1 Example 5.A9.1: Geometry for enclosure with multiple surfaces

Table 5.A9.1 Example 5.A9.1: surface data

Surface number	Area / m^2	U-value / W·m^{-2}·K^{-1}	Emissivity of surface, ε_n	Convective heat transfer coefficient, h_c	Inside surface resistance, R_{si} / m^2·K·W^{-1}	Temperature on outer side of surface / °C
1	50.0	1.0	0.8	1.5	0.14	–1.0
2	30.0	5.6	0.8	3.0	0.12	–1.0
3	3.0	1.0	0.8	3.0	0.12	–1.0
4	3.0	1.0	0.8	3.0	0.12	–1.0
5	3.0	1.0	0.8	3.0	0.12	–1.0
6	3.0	1.0	0.8	3.0	0.12	–1.0
7	3.0	1.0	0.8	3.0	0.12	–1.0
8	30.0	1.0	0.8	3.0	0.12	–1.0
9	15.0	1.0	0.8	3.0	0.12	–1.0
10	10.0	1.0	0.8	4.3	0.10	–1.0
11	10.0	1.0	0.8	4.3	0.10	–1.0
12	10.0	1.0	0.8	4.3	0.10	–1.0
13	10.0	1.0	0.8	4.3	0.10	–1.0
14	10.0	1.0	0.8	4.3	0.10	–1.0

* In many cases, these three-dimensional heat transfer models will be required to understand the implications of thermal bridges. However, the reference model can provide a good indication of the potential for condensation

Figure 5.A9.2 Example 5.A9.1: Comparison of results of example calculation using the reference, basic and simple models

Property	Calculation method		
	Reference	Basic	Simple
Air temperature (°C)	27.03	27.05	26.78
Mean radiant temp. (°C)	14.97	14.95	15.22
Surface temp. (°C):			
— surface no. 1	15.07	14.82	16.2
— surface no. 2	5.74	5.72	5.81
— surface no. 3	16.06	16.98	16.71
— surface no. 4	16.71	16.98	16.71
— surface no. 5	17.07	16.98	16.71
— surface no. 6	17.3	16.98	16.71
— surface no. 7	17.46	16.98	16.71
— surface no. 8	16.94	16.85	16.71
— surface no. 9	16.92	16.93	16.71
— surface no. 10	17.26	18.29	17.02
— surface no. 11	17.81	18.29	17.02
— surface no. 13	18.18	18.29	17.02
— surface no. 13	18.42	18.29	17.02
— surface no. 14	18.61	18.29	17.02
Heat input (W)	7962	7949	7973
Fabric loss (W)	6560	6547	6585
Air loss (W)	1402	1402	1389