

Appendix 5.A10: Algorithm for the calculation of cooling loads by means of the admittance method

5.A10.1 Introduction

This appendix describes the way room cooling loads are calculated using the CIBSE admittance method. The solar position and transmission algorithms are those used to produce the cooling load tables in the 1999 and earlier editions of CIBSE Guide A. Other calculations follow the equations presented in Appendix 5.A2 which, although different in appearance, are identical to those in editions of Guide A preceding the 1999 edition.

The solar cooling load tables are based upon a particular space and rules related to the use of blinds. Details are given in section 5.A10.17.

An example of the implementation of this method is given by White et al. and currently a software tool can be downloaded via <http://www.arup.com> and searching for PDA. Note that the CIBSE does not endorse software. The tool should simply be seen as an example of the implementation of the admittance method.

5.A10.2 Input data

The input data required are:

- Latitude of the building: the calculations here are carried out for Local Apparent Time (solar time) and so longitude is not required. Information on how to correct to clock time is given in the annex to chapter 2 of this Guide, which may be downloaded from the CIBSE website*.
- Internal design temperature: operative temperature, see chapter 1, Table 1.5.
- Hourly dry bulb temperatures: design values can be found in chapter 2, Tables 2.14(a) to 2.14(n), which may be downloaded from the CIBSE website*.
- Hourly values of direct and diffuse solar radiation: design values can be found in chapter 2, Tables 2.13(a) to 2.13(n), which may be downloaded from the CIBSE website*.
- Dimensions of the space.
- Material properties: these are the dimensions and thermal properties of the fabric elements bounding the space. For glazing the data must be sufficient to determine the transmission, absorption and reflection for each pane of glass as a function of the solar angle of incidence.
- Internal heat gains: the hourly profile of use and the radiant/convective split are required.
- Infiltration rate/ventilation rate: this is for outside air only and it is assumed here to be constant throughout the day. The calculation of cooling loads when the ventilation rate varies is described in section 5.A2.7.

- Boundary conditions for internal surfaces: this algorithm assumes that internal surfaces are adiabatic. If the temperature in adjacent spaces is known then they can be treated in the same way as external spaces. If not an iterative procedure is required.
- Time plant is switched on and off.

5.A10.3 Overview

The basic process is as follows, for each hour of the day. Note that if measured climatic data are used the solar radiation at any given hour is, usually, the average over the preceding hour and so calculations should be made on the half hour. Measured temperatures are usually reported on the hour and so interpolation may be required in order to obtain the half hour value.

- (1) Calculate the U -value, thermal admittance, decrement and surface factor for all fabric elements (see chapter 3).
- (2) Calculate the factors required by the method.

The following preliminary calculations are carried out for each hour of the day:

- (3) Calculate the position of the sun.
- (4) Generate the direct and diffuse radiation normal to the sun (or obtain from tabulated or measured data).
- (5) Obtain appropriate hourly dry bulb temperatures.
- (6) Calculate the sol-air temperature for all external surfaces.
- (7) Calculate the radiation transmitted through and absorbed within the glazing. If necessary allowing for external shading devices and the raising or lowering of blinds. It is assumed here that blinds are lowered because of external conditions (level of solar radiation) and not internal space temperature. Iteration will be necessary if internal temperature control is required.

This completes the preliminary calculations.

- (8) The following loads at the environmental and air node are needed (see 5.A2.3 and 5.A2.4). Note that in the case of the solar cooling load tables only the solar and infiltration loads are required.
 - solar
 - infiltration/ventilation
 - fabric
 - internal gains.
- (9) Sum the gains and determine the cooling load for 24-hour plant operation.
- (10) Apply correction for intermittent plant operation.

The method of calculation is given in the following sections.

* <http://www.cibse.org/Guide-A/pdfs>

5.A10.4 Correction factors

The calculation requires the following input data for each surface:

VOL	Room volume (m ³)
AWALL	Opaque area (m ²)
AGLASS	Glazed area (m ²)
U	Thermal transmittance (<i>U</i> -value)
Y	Thermal admittance (<i>Y</i> -value)
YL	Time lead associated with thermal admittance
D	Decrement factor
DL	Time delay associated with the decrement factor
SF	The surface factor
SFD	The time delay associated with the surface factor
AIRCH	The air change rate
PLNTON	Time plant switched on
PLNTOFF	Time plant switched off

The following summations are necessary, the derived *U*-values etc. are those appropriate to an individual surface.

SIGA	Sum of all AWALL and AGLASS
SIGAU	Sum of all AWALL* <i>U</i> and AGLASS* <i>U</i>
SIGAY	Sum of all AWALL* <i>Y</i> and AGLASS* <i>Y</i>
SIGAYL	Sum of all AWALL* <i>YL</i> and AGLASS* <i>YL</i>
SIGASF	Sum of all AWALL* <i>SF</i> and AGLASS* <i>SF</i>
SIGASFD	Sum of all AWALL* <i>SFD</i> and AGLASS* <i>SFD</i>

Ventilation conductance:

$$CV = AIRCH * VOL / 3$$

Response factor:

$$RFACT = (SIGAY + CV) / (SIGAU + CV)$$

Non-dimensional factors:

$$FU = 18 * SIGA / (18 * SIGA + SIGAU)$$

$$FY = 18 * SIGA / (18 * SIGA + SIGAY)$$

$$FV = 6 * SIGA / (6 * SIGA + CV)$$

$$F1A = 4.5 * SIGA / ((1 - 1.5R) * SIGAU + 4.5 * SIGA)$$

$$F2A = (SIGAU + 4.5 * SIGA) / ((1 - 1.5R) * SIGAU + 4.5 * SIGA)$$

$$F1AY = 4.5 * SIGA / ((1 - 1.5R) * SIGAY + 4.5 * SIGA)$$

$$F2AY = (SIGAY + 4.5 * SIGA) / ((1 - 1.5R) * SIGAY + 4.5 * SIGA)$$

$$F1C = 3.0 * (CV + 6 * SIGA) / ((SIGAU + 18.0 * SIGA + 1.5 * R * (3.0 * CV - SIGAU))$$

$$F2C = (SIGAU + 18.0 * SIGA) / (SIGAU + 18.0 * SIGA + 1.5 * R * (3.0 * CV - SIGAU))$$

$$F1CY = 3.0 * (CV + 6.0 * SIGA) / (SIGAY + 18.0 * SIGA + 1.5 * R * (3.0 * CV - SIGAY))$$

$$F2CY = (SIGAY + 18.0 * SIGA) / (SIGAY + 18.0 * SIGA + 1.5 * R * (3.0 * CV - SIGAY))$$

Factor for correction for intermittent operation:

$$PRUN = PLTOFF - PLTON + 1$$

$$DOUTPT = (FY * SIGAY - FU * SIGAU) / (24 - PRUN) * FU * SIGAU + PRUN * FY * SIGAY + 24 * CV * FV$$

Admittance and the associated factors are vector quantities and so all delays and leads should be handled separately. This simple method assumes that the overall response to solar radiation can be represented by a mean value for the surface factor as follows.

Mean surface factor:

$$SFBAR = SIGASF / SIGA$$

Mean surface factor delay:

$$SFDEL = SIGASFD / SIGA$$

The delay is rounded to the nearest hour, but if zero set to 1 hour.

5.A10.5 Calculation of solar position.

The calculation requires the following input data:

RLAT	Latitude (radians)
NUMDAY	Day of year (January 1st = 1, December 31st = 365)
HOUR	Sun time (sun will be overhead at 12.00)

The calculated data are:

DECANG	Declination angle (radians)
SUNALT	Solar altitude (radians)
SUNAZI	Solar azimuth (radians)
SUNRIS	Time sun rises (decimal hours)
SUNSET	Time sun sets (decimal hours)

5.A10.5.1 Declination angle

This the latitude at which the sun is overhead at solar noon.

$$SINDEC = (0.398 * \text{Sine}(0.01721 * \text{NUMDAY} + 0.03347 * \text{Sine}(0.01721 * \text{NUMDAY}) - 1.4096))$$

$$DECANG = \text{Arcsine}(SINDEC)$$

$$COSDEC = \text{Cosine}(DECANG)$$

$$TANDEC = \text{Tangent}(DECANG)$$

5.A10.5.2 Solar altitude and azimuth

$$COSLAT = \text{Cosine}(RLAT)$$

$$SINLAT = \text{Sine}(RLAT)$$

$$TANLAT = \text{Tangent}(RLAT)$$

Check if TANLAT is not equal to zero then:

$$\text{TANRAT} = \text{TANDEC} / \text{TANLAT}$$

Otherwise TANRAT is equal to a large number (10E32) and given the sign of TANDEC.

Hour angle:

HANG = Absolute value (sign ignored so taken as positive) of $((\pi * 15 / 180) * (12 - \text{HOUR}))$

COSHAG = Cosine (HANG)

SINALT = $\text{COSLAT} * \text{COSDEC} * \text{COSHAG} + \text{SINLAT} * \text{SINDEC}$

SUNALT = Arcsine (SINALT)

COSALT = Cosine (SUNALT)

TANALT = Tangent (SUNALT)

If the solar altitude (SUNALT) is negative the sun is below the horizon, otherwise it is necessary to carry out some checks.

$$\text{TV0} = \text{COSDEC} * \text{Sine}(\text{HANG}) / \text{COSALT}$$

If TV0 is greater than 1 then it is set to 1, if it is less than -1 then it is set to -1.

C = Arcsine (TV0)

TV1 = COSHAG

TV2 = TANRAT

Northern hemisphere

If the sine of the latitude (SINLAT) is greater than zero (Northern hemisphere) then if the hour is before 12 the following conditional checks are necessary.

Morning:

If TV1 is greater than TV2 then $\text{SUNAZI} = \pi - C$

If TV1 is equal to TV2 then $\text{SUNAZI} = \pi / 2$

If TV1 is less than TV2 then $\text{SUNAZI} = C$

Southern hemisphere

Switch values:

TV3 = TV1

TV1 = TV2

TV2 = TV3

The checks are now made for the afternoon:

If TV1 is greater than TV2 then $\text{SUNAZI} = \pi + C$

If TV1 is equal to TV2 then $\text{SUNAZI} = 1.5 * \pi$

If TV1 is less than TV2 then $\text{SUNAZI} = 2\pi - C$

5.A10.5.3 Sunrise and sunset times

$$\text{COSANG} = \text{TANDEC} * \text{TANLAT}$$

Normal situation

Some checks:

TV4 = the absolute value of (COSANG-1)

If TV4 is negative then the time of sunrise = $12 - \text{Arccosine}(\text{COSANG}) / \pi$; the time of sunset = $24 - \text{the time of sunrise}$.

Other cases

If COSANG is less than unity the sun never rises.

If COSANG is equal to or greater than unity the sun never sets.

5.A10.6 Calculation of the solar radiation incident upon a surface and the angle of incidence

This calculation requires the following input data where it is assumed that any corrections for sky clarity and altitude have been applied if theoretical solar data is used.

SUNAZI	Solar azimuth (radians)
SUNALT	Solar altitude (radians)
ORIEN	Surface orientation (radians, North 0 or 2π)
SLOPE	Angle of surface to horizontal (radians, flat roof 0, vertical wall $\pi/2$)
DIRAD	Direct radiation normal to the sun ($\text{W} \cdot \text{m}^{-2}$)
DIFRAD	Diffuse radiation on the horizontal ($\text{W} \cdot \text{m}^{-2}$)
GREF	Solar albedo (Ground reflectance)
Calculated values:	
DIRECT	Direct radiation incident upon an exposed surface ($\text{W} \cdot \text{m}^{-2}$)
SKYDIF	Sky diffuse radiation incident on a surface ($\text{W} \cdot \text{m}^{-2}$)
GRDREF	Ground reflected radiation incident on a surface ($\text{W} \cdot \text{m}^{-2}$)
ANGINC	Solar angle of incidence (radians)

5.A10.6.1 Solar angle of incidence

Default this to $\pi/2$ (i.e. the sun's rays are parallel to the surface).

The solar azimuth relative to the surface is:

$$\text{WALSUN} = \text{SUNAZI} - \text{ORIEN}$$

$$\text{COSSLO} = \text{Cosine (SLOPE)}$$

$$\text{SINSLO} = \text{Sine (SLOPE)}$$

$$\text{COSINC} = \text{Cosine (SUNALT)} * \text{SINSLO} * \text{Cosine (WALSUN)} + \text{Sine (SUNALT)} * \text{COSSLO}$$

If COSINC is positive the solar angle of incidence (ANGINC) is equal to Arccosine (COSINC).

5.A10.6.2 Incident radiation

Direct radiation incident on surface, first check if surface is facing the sun, for this the angle of incidence must be less than 90 degrees; that is the cosine of the angle of incidence (COSINC) is greater than zero. The intensity of the direct radiation (beam) is:

$$\text{DIRECT} = \text{DIRAD} * \text{COSINC}$$

The diffuse radiation falling on the surface depends on the orientation of the surface. The simple correction given here was used in the original calculation of the cooling load tables.

$$\text{AZCOR} = 0.9 - 0.1 * \text{Cosine (ORIEN)}$$

$$\text{AZCOR} = 1. - \text{SINSLO} * (1. - \text{AZCOR})$$

$$\text{SKYDIF} = \text{DIFRAD} * \text{AZCOR} * (1. + \text{COSSLO}) / 2.0$$

$$\text{GRDREF} = \text{GREF} * ((\text{BASRAD} * \text{Sine (SUNALT)} + \text{DIFBAS}) / 2.) * (1. - \text{COSSLO})$$

5.A10.7 Dry bulb temperature

Where measured values are used combined with measured solar radiation data, it is necessary to ensure consistent timing. For example, measured solar data are usually the average over the preceding hour and referenced to local apparent time (LAT) (although in the latest CIBSE hourly weather data sets solar data is referenced to GMT). Dry bulb data are usually with reference to the local time zone time.

In this case calculations should be made on the half hour. In theory, the dry-bulb time should be corrected to LAT using the 'equation of time' (see the annex to chapter 2 of this Guide, which may be downloaded from the CIBSE website*). Bearing in mind the approximations involved in the admittance method, this is considered unnecessary for use of the method in the UK. The same may not be true where time zones span greater distances. It is therefore considered sufficient to use the average of the dry-bulb over the hour.

It is important to be consistent in timing and the convention of 'hour 1' being representative of the period midnight to 01:00 is recommended.

5.A10.8 Sol-air temperature

The following input data are required:

TDRY	External dry bulb temperature
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HSO	External surface heat transfer coefficient (see chapter 3, section 3.3.9)
ALPHA	External surface absorption coefficient
EMISS	External surface emissivity
SLOPE	Angle of surface to horizontal (radians: flat roof 0, vertical wall $\pi/2$)
RAD	Incident solar radiation = sum of direct, ground reflected and sky diffuse solar radiation, as appropriate.
RRLM	Longwave radiation loss; standard value for an emissivity of 1 is $100 \text{ W} \cdot \text{m}^{-2}$.

Calculated value:

TSOL	Sol-air temperature ($^{\circ}\text{C}$)
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The following allows for a reduction in longwave loss dependant on the angle between the surface and the sky. For the surface to see the sky the slope must be less than π . In which case the reduction factor is zero (COR=0), otherwise:

$$\text{Let } X = \text{SURANG} / \pi$$

The correction factor is:

$$\text{COR} = 1. - X * (2. - X)$$

The longwave loss is then:

$$\text{RLONG} = \text{COR} * \text{RRLM}$$

and the sol-air temperature is:

$$\text{TSOL} = \text{TDRY} + (\text{ALPHA} * \text{RAD} - \text{EMISS} * \text{RLONG}) / \text{HSO}$$

5.A10.9 Solar load imposed by the glazing

Appendix 5.A11 describes the way the admittance method calculates the transmission and absorption of solar radiation within a glazing system. That appendix includes the calculation of the mean and alternating solar gain factors. These factors are only intended to be used in 'hand' calculations; the cooling load calculation makes use of the appropriate value for each hour of the day. That is, the glazing system properties are determined as a function of the solar angle of incidence (section 5.A10.6.2).

Appendix 5.A11, section 5.A11.3, describes how to determine the transmitted and absorbed radiation and calculate the gain to the environmental node and, where internal blinds are used, the air node. The admittance method requires the following to be done at each hour of the day (only between sunrise and sunset, see section 5.A10.5.3).

The following input data are required:

Glass and blind properties including cavity, internal and external thermal resistances (see chapter 3, section 3.6).

Dimensions of the glazed surface (window).

* <http://www.cibse.org/Guide-A/pdfs>

Dimensions and position of any shading device relative to the window.

ORIEN	Window orientation (radians: North 0 or 2π)
SLOPE	Angle of window to horizontal (radians: flat roof 0, vertical wall $\pi/2$)
DIRECT	Direct radiation incident upon an exposed surface ($\text{W}\cdot\text{m}^{-2}$)
SKYDIF	Sky diffuse radiation incident on a surface ($\text{W}\cdot\text{m}^{-2}$)
GRDREF	Ground reflected radiation incident on a surface ($\text{W}\cdot\text{m}^{-2}$)
ANGINC	Solar angle of incidence (radians)

Calculated values (hourly):

QTRANS	Total transmitted solar radiation
QGE	Solar gain to the environmental node
QGA	Solar gain to the air node

For each glazed surface:

— If there are external shading devices other than blinds, determine the amount of shadow created by the device. The calculation of shade is not given here. The calculation of the effect of shade on the performance of a window can be treated at many levels ranging from the simplistic (and probably conservative) approach described here to taking full account of the relationship between the shade, window and sky vault, the reflections of solar radiation within the shading system and the temperature of the shades. The approach here is to assume that the whole window is exposed to diffuse radiation with the direct intensity reduced by the shade fraction.

— Where blinds are fitted determine if they are lowered. This may be a simple schedule or at a particular solar intensity. The cooling load tables assume the blinds are lowered if the intensity of direct radiation on the façade was greater than $200 \text{ W}\cdot\text{m}^{-2}$.

— From the solar angle of incidence and the properties of the glazing calculate the transmission coefficient for direct (TAUD) and diffuse radiation (TAUd) and the absorption coefficient for each element in the glazing system.

AGLASS = total window area

AS = area of the window that is in shade

$QTRANS = DIRECT * TAUD * (AGLASS - AS) + AGLASS * (SKYDIF + GRDREF) * TAUD$

— If QGED and QGE_d are the loads at the environmental node for direct and diffuse radiation respectively (determined following section 5.A11.3), and similarly for the air point loads QGAD and QGAd, the load at the environmental node is:

$QGE = (AGLASS - AS) * QGED + AGLASS * QGE_d$

$QGA = (AGLASS - AS) * QGAD + AGLASS * QGAd$

5.A10.10 Calculation of the solar component of the gain

The following data are required.

Surface areas:

SFBAR	Mean surface factor
SFDEL	Mean surface factor delay

The solar loads imposed by the glazing (5.A10.9):

QTRANS	Total transmitted solar radiation for each hour of the day
QGE	Solar gain to the environmental node for each hour of the day.
QGA	Solar gain to the air node for each hour of the day.

Calculated values:

QSESW	The swing in solar cooling load at the environmental node at each hour of the day
QSEBAR	The daily mean solar cooling load at the environmental node
QSASW	The swing in solar cooling load at the air node at each hour of the day
QSABAR	The daily mean solar cooling load at the air node

Carry out the following summations over the day.

$QTBAR = \sum QTRANS / 24$

$QSEBAR = \sum QGE / 24$

$QSABAR = \sum QSA / 24$

The direct solar gain must be absorbed by the room surfaces before it can contribute to the heat load in the room. Due to thermal storage within the surfaces of the room there will be a delay and 'smoothing out' of the direct gain. In the admittance method this is quantified by the 'surface factor' and the associated delay.

The swing in the transmitted load at hour H is that due to the radiation transmitted at:

$H_{del} = H - SFDEL$

The swing in the solar gain at the environmental node at hour, H is:

$QSESW(H) = (QGE(H) - QSEBAR) + SFBAR * (QTRANS(H_{del}) - QTBAR)$

The swing in the load at the air node at hour H is:

$QSASW(H) = QGA(H) - QSABAR$

5.A10.11 Calculation of the ventilation component of the gain

The following data are required:

TDRY	External dry bulb temperature
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TDES	Internal design temperature
CV	Ventilation conductance (5.A10.4)

FRG	Radiant fraction (0 = 100% convective)
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Calculated values:

QVENTSW	Swing in ventilation gain at the air node.
QVENTB	Mean ventilation load.

Calculated values:

QGASW	Swing in internal gain at the air node
QGAB	Mean internal gain at the air node
QGESW	Swing in internal gain at the environmental node
QGEB	Mean internal gain at the environmental node

The ventilation load at hour H is:

$$QVENT(H) = CV * (TDRY(H) - TDES)$$

$$QVENTB = \sum QVENT / 24$$

$$QVENTSW(H) = QVENT(H) - QVENTB$$

For each hour (H):

$$\text{Convective load: } QC = QGA(H) * (1 - FRG)$$

$$\text{Radiant load: } QR = QGA(H) * FRG$$

5.A10.12 Calculation of the conduction component of the gain

The following data are required.

For each surface:

A	Area (opaque and glazed)
U	U -value
D	Decrement factor
DL	Time delay associated with decrement factor
TSOL	Hourly sol-air temperature for each external surface
TSBAR	Daily mean sol-air temperature for each external surface
TDES	Internal design temperature

The load at the air node:

$$QGA(H) = QC - 0.5 * QR$$

The load at the environmental node is:

$$QGE(H) = 1.5 * QR$$

The mean loads are:

$$QGAB = \sum QGA / 24$$

$$QGEB = \sum QGE / 24$$

The swing in load is:

$$QGASW(H) = QGA(H) - QGABAR$$

$$QGESW(H) = QGE(H) - QGEBAR$$

Calculated values:

QCSW	The swing in conduction gain at the environmental node
QCSB	The mean conduction gain at the environmental node

Mean conduction gain

For each hour (H) of the day, calculate for each external surface (N) and sum:

$$QC(H) = U(N) * A(N) * (TSOL(H, N) - TDES)$$

$$QCSB = \sum QC / 24$$

The swing in gain is due to the gain that occurred DL hours before the current hour, that is:

$$HDEL = H - DL$$

$$QCSW(H) = U(N) * A(N) * D(N) * (TSOL(HDEL, N) - TSBAR(N))$$

5.A10.13 Calculation of the internal gain

The following data are required.

QGI	Hourly value of the internal gain (W)
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5.A10.14 Calculation of the total gain and the solar cooling load for 24-hour plant operation

The calculation here is for control by air temperature or operative temperature. In the case of the cooling load tables only the solar load is considered. The air change rate is used in the calculation of the non-dimensional parameters only.

The following data are required.

Daily mean values of loads at the environmental node:

QSEBAR	Daily mean solar cooling load (5.A10.10)
QCSB	Mean conduction gain (5.A10.12)
QGEB	Mean internal gain (5.A10.13)

Daily mean values at the air node:

QSABAR	Daily mean solar cooling load (5.A10.10)
QVENTB	Mean ventilation load (5.A10.11)
QGAB	Mean internal gain (5.A10.13)

Hourly swing in load at the environmental node:

QSESW	Swing in solar cooling load (5.A10.10)
QCSW	Swing in conduction gain (5.A10.12).
QGESW	Swing in internal gain (5.A10.13)

Hourly swing in load at the air node:

QSASW	Swing in solar cooling load (5.A10.10).
QVENTSW	Swing in ventilation gain (5.A10.11).
QGASW	The swing in internal gain (5.A10.13).

Non-dimensional parameters (5.A10.4):

FU	FY
F1C	F1AY
F2C	F2AY
F1A	F1CY
F2A	F2CY

Calculated values:

QPBARDaily mean plant load	
QPSWG	Hourly swing in the plant load
QPLANT	Hourly cooling load

The following sums are required:

QGENVB	Sum of all mean gains to the environmental node
QGAIRB	Sum of all mean gains to the air node
QGENVS	Sum of all swings in gain at the environmental node for each hour (H) of the day
QGAIRS	Sum of all swings in gain at air node for each hour (H) of the day.

Control by operative temperature

$$QPBAR = F1C * QGENVB + F2C * QGAIRB$$

$$QPSWG(H) = F1CY * QGENVS(H) + F2CY * QGAIRS(H)$$

Control by air temperature

$$QPBAR = F1A * QGENVB + F2A * QGAIRB$$

$$QPSWG(H) = F1AY * QGENVS(H) + F2AY * QGAIRS(H)$$

Hourly cooling load

$$QPLANT(H) = QPBAR + QPSWG(H)$$

5.A10.15 Calculation of total gain for intermittent plant operation

The following data are required:

QPLANT	Hourly cooling load for 24-hour plant operation (5.A10.14)
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PLNTON	Time plant switched on
PLNTOFF	Time plant switched off
DOUTPT	Intermittency correction factor (5.A10.4)

Sum the cooling load for all hours (H) for which the plant is off (QB). This is the sum of $QPLANT$ when H is less than $PLNTON$ or H is greater than $PLNTOFF$.

The cooling load for each hour for which the plant is switched on is:

$$QPLANTI(H) = QPLANT(H) + QB * DOUTPT$$

Otherwise:

$$QPLANTI(H) = 0.0$$

5.A10.16 Example calculation

This example uses an implementation of the algorithm described in this appendix to perform the manual cooling load calculation described in Appendix 5.A6.3. In both cases the space geometry, construction, internal gains and climatic data are the same (see Figure 5.A10.1 and Table 5.A10.1).

Because the algorithm determines the solar gain by the methodology described in Appendix 5.A11, it was necessary to devise a glazing system that would have a U -value of $2.2 \text{ W} \cdot \text{m}^{-2} \cdot \text{K}^{-1}$ and a G -value of 0.6. To do this the inner glazing element was assigned the optical properties of a typical low emissivity glass (transmission coefficient 0.6, reflectivity 0.27 and absorptivity 0.18).

The thermal resistance of the cavity was set to the value necessary to achieve a U -value of $2.2 \text{ W} \cdot \text{m}^{-2} \cdot \text{K}^{-1}$ and the outer pane was taken as clear glass, the transmission being adjusted to achieve a G -value close to 0.6. The calculation of cooling load for control to both operative and air temperature with 24-hour plant operation and 8-hour plant is described in Tables A5.10.2 to A5.10.4. The resulting design values, which all occur between hours of 15:00 and 16:00, are:

- *Control to operative temperature:* 2391 W for continuous operation and 3060 W for 8-hour plant operation.
- *Control to air temperature:* 1890 W for continuous operation and 2633 W for 8-hour plant operation.

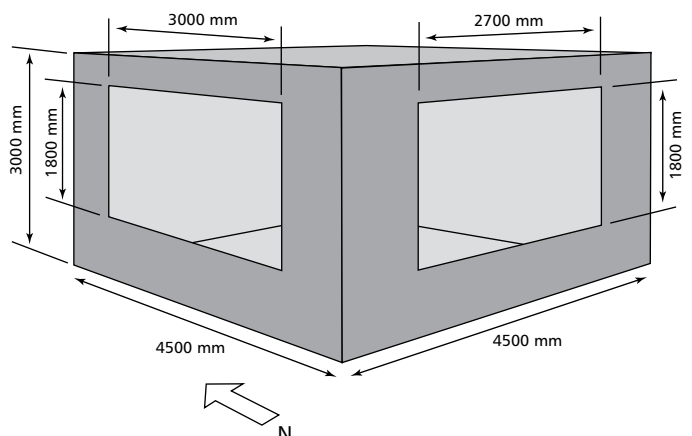


Figure 5.A10.1 Example calculation: south facing office module

Table 5.A10.1 Example calculation: dimensions and properties

Surface no.	Area / m ²	Orientation / degree	U-value / W·m ⁻² ·K ⁻¹	Admittance		Decrement factor		Surface factor		Solar absorptivity	G-value
				Y-value / W·m ⁻² ·K ⁻¹	Time lead / h	Value	Time lag / h	Value	Time lag / h		
Opaque surfaces											
1 (ext. wall)	8.6	180 (S)	0.35	0.94	4.02	0.99	1	0.95	1	0.6	—
2 (ext. wall)	8.6	270 (W)	0.35	4.4	1.79	0.3	9	0.588	2	0.6	—
3 (int. wall)	13.5	—	1	4.13	3	0.1	3	0.5	2	—	—
4 (int wall)	13.5	—	1	4.13	3	0.1	3	0.5	2	—	—
5 (ceiling)	20.3	—	1	2	3	0.1	3	0.5	2	—	—
6 (floor)	20.3	—	1	5.3	6	0.1	3	0.5	2	—	—
Windows											
1	4.37	180 (S)	2.2	2.2	0	1	0	0.9	0	—	0.6
2	4.86	270 (W)	2.2	2.2	0	1	0	0.9	0	—	0.6

Notes: window 1 is in surface 1 and window 2 in surface 2; there are no other external surfaces. The space volume is 60.75 m³.

Table 5.A10.2 Example calculation: dimensionless parameters

Name	Value	Name	Value	Name	Value
FU	0.985	F1AU	0.937	F1C	0.988
FY	0.839	F2AU	1	F2C	1
FV	0.996	F1AY	0.566	F1CY	0.842
FAU	0.941	F2AY	1	F2CY	1
FAY	0.566	F1A	0.941		
FCU	0.988	F2A	1		

Table 5.A10.3 Example calculation: calculated hourly values

Hour	TDRY	QHdir	QHdif	Ccover	Surface no. 1			Surface no.2		
					Qsnorm	Tsol	Qtrans	Qsnorm	Tsol	Qtrans
0 to 1	12.1	0	0	10	0	11.96	0	0	11.96	0
1 to 2	13.1	0	0	10	0	12.06	0	0	12.06	0
2 to 3	12.4	0	0	10	0	12.21	0	0	12.21	0
3 to 4	12.6	0	0	10	0	11.96	0	0	11.96	0
4 to 5	12.7	0	0	10	0	12.11	0	0	12.11	0
5 to 6	13.4	0	2	10	0	12.51	0	0	12.51	0
6 to 7	13.9	9	36	10	32.4	13.89	12.5	17.3	13.53	7.5
7 to 8	15.0	71	99	10	160.1	17.75	64.6	52.2	15.16	22.7
8 to 9	16.9	127	152	10	288	22.32	126.4	82	17.38	35.7
9 to 10	18.0	300	178	10	564.4	30.46	256	111.2	19.58	48.4
10 to 11	19.4	347	207	10	665.2	34.13	301.8	129.1	21.26	56.2
11 to 12	20.6	387	231	10	750	37.46	340.2	144	22.92	62.7
12 to 13	21.4	386	230	10	747.4	38.4	339.1	242.2	26.27	88.2
13 to 14	21.9	358	212	10	686.6	37.59	311.4	426.7	31.35	178.6
14 to 15	22.7	311	184	10	586.3	35.83	265.9	584.5	35.79	265.1
15 to 16	22.7	229	138	10	417.1	32.17	183.5	655.2	37.88	298.2
16 to 17	22.3	145	89	10	243	27.79	95.3	676.4	38.19	308.7
17 to 18	20.5	53	34	10	61.2	22.33	17.4	541.6	33.86	248.1
18 to 19	18.4	0	5	10	0	18.91	0	0	18.91	0
19 to 20	17.2	0	0	10	0	17.26	0	0	17.26	0
20 to 21	17.4	0	0	10	0	16.76	0	0	16.76	0
21 to 22	16.8	0	0	10	0	16.56	0	0	16.56	0
22 to 23	16.0	0	0	10	0	15.86	0	0	15.86	0
23 to 0	12.9	0	0	10	0	13.91	0	0	13.91	0
Mean	17.1	113	75	10	216.8	21.76	96.4	87.72	66.7	67.50

Table 5.A10.4 Example calculation: calculated hourly values

Hour	Swings								Hourly values for control on stated temperature				
	QSESW	QCSW	QGESW	QGENVS	QSASW	QVENT	QSASW	QGAIRS	Operative temp.		Air temp.		
									QPLANT	QPLANTI	QPLANT	QPLANTI	
0 to 1	-620.2	-102.1	-90.6	-813	0	-9.3	-30.2	-40	-150.5	0	-333.8	0	
1 to 2	-620.2	-106	-90.6	-817	0	-9.1	-30.2	-39	-147.5	0	-331.8	0	
2 to 3	-620.2	-106.6	-90.6	-817	0	-8.8	-30.2	-39	-147.5	0	-331.8	0	
3 to 4	-620.2	-124.7	-90.6	-836	0	-9.3	-30.2	-40	-131.5	0	-321.8	0	
4 to 5	-620.2	-124	-90.6	-835	0	-9	-30.2	-39	-132.5	0	-321.8	0	
5 to 6	-620.2	-115.8	-90.6	-827	0	-8.2	-30.2	-38	-140.5	0	-327.8	0	
6 to 7	-600.6	-102.5	-90.6	-794	0	-7	-30.2	-37	-168.5	0	-347.8	0	
7 to 8	-533.6	-82.6	-90.6	-707	0	-5.4	-30.2	-36	-243.5	-882	-397.8	-1107	
8 to 9	-399.1	-41.7	181.3	-260	0	-2.3	60.4	58	-714.5	-1033	-744.8	-1209	
9 to 10	-85.9	1.5	181.3	97	0	0.7	60.4	61	-1017.5	-1655	-949.8	-1658	
10 to 11	167	52.7	181.3	401	0	3.2	60.4	64	-1275.5	-1914	-1124.8	-1833	
11 to 12	592.1	90.8	181.3	864	0	5.9	60.4	66	-1668.5	-2307	-1388.8	-2098	
12 to 13	757.9	121.5	181.3	1061	0	7.9	60.4	68	-1835.5	-2474	-1501.8	-2211	
13 to 14	976.8	137.8	181.3	1296	0	9.2	60.4	70	-2035.5	-2673	-1636.8	-2345	
14 to 15	1074.7	148.8	181.3	1405	0	10.5	60.4	71	-2128.5	-2766	-1699.8	-2408	
15 to 16	1236.2	152.3	181.3	1570	0	11.3	60.4	72	-2268.5	-2906	-1793.8	-2502	
16 to 17	1285.6	138.1	-90.6	1333	0	10.9	-30.2	-19	-1977.5	-2935	-1568.8	-2522	
17 to 18	1022	103.9	-90.6	1035	0	8.7	-30.2	-21	-1724.5	0	-1397.8	0	
18 to 19	549	49	-90.6	507	0	4.8	-30.2	-25	-1276.5	0	-1095.8	0	
19 to 20	160.1	6.2	-90.6	76	0	1.4	-30.2	-29	-909.5	0	-847.8	0	
20 to 21	-620.2	-7.6	-90.6	-718	0	0.4	-30.2	-30	-239.5	0	-397.8	0	
21 to 22	-620.2	-10.2	-90.6	-721	0	0	-30.2	-30	-237.5	0	-395.8	0	
22 to 23	-620.2	-20.5	-90.6	-731	0	-1.4	-30.2	-32	-227.5	0	-388.8	0	
23 to 0	-620.2	-58.3	-90.6	-769	0	-5.4	-30.2	-36	-191.5	0	-362.8	0	
Mean	937	-159	91	869	0	-14	30	16	-874.5	-897.708	-833.8	-828.875	
									Total:	-20990	-21545	-20010.2	-19893

5.A10.17 Solar cooling load tables

The UK cooling load tables (Tables 5.16(a) to (n) and 5.17(a) to (n)) and the similar tables for latitudes from 0–60° N/S available from the CIBSE website* were calculated using the algorithm described in this appendix with no internal, conduction or ventilation gains.

(a) For the tables relating to unshaded situations, values of parameters used for calculating the non-dimensional factors were as follows:

- *module location*: intermediate floor with one exposed surface
- *module dimensions*: (4.8 × 4.8 × 2.7) m
- *glazed percentage*: 40% of external wall
- *properties of surfaces of module*: see Table 5.A10.5.

For both cases (i.e. fast and slow thermal response), a relatively well-sealed facade was assumed, with an infiltration rate of 0.25 h⁻¹.

- (b) Glazing properties were as given in Table 5.A10.6.
- (c) Shading: the tables relating to shaded situations, a generic shading device having 20% transmission and 40% reflection was assumed, see Table 5.A10.6. The shading device was assumed to operate when direct radiation on the façade was greater than 200 W·m⁻².

References for Appendix 5.A10

CIBSE (2002) *Weather, solar and illuminance data* CIBSE Guide J (London: Chartered Institution of Building Services Engineers)

Harrington-Lynn J (1974) *The admittance procedure: variable ventilation* *Building Serv. Eng.* 42 199–200 (November 1974)

White AJ, Holmes MJ, Hacker JN, De Saulles T and Crawley N (2012) 'Passive Design Assistant — a tool to elucidate the principles of passive design' *Proc. CIBSE/ASHRAE Tech. Symp.*, 2012

* <http://www.cibse.org/Guide-A/pdfs>

Table 5.A10.5 Properties of surfaces for module used for determination of cooling load tables

Surface	Slow thermal response				Fast thermal response			
	U-value / W·m ⁻² ·K ⁻¹	Y-value / W·m ⁻² ·K ⁻¹	Surface factor, F	Time lag ψ / h	U-value / W·m ⁻² ·K ⁻¹	Y-value / W·m ⁻² ·K ⁻¹	Surface factor, F	Time lag ψ / h
Glass	3.0	3.0	—	—	3.0	3.0	—	—
Wall	0.45	5.5	0.5	2	0.45	2.0	0.8	1

Table 5.A10.6 Transmission, absorption and reflection components and emissivities for generic glass and blind combinations

Description	Shortwave radiation (proportions of total)			Longwave emissivity	
	Transmitted	Reflected 1	Reflected 2	Surface 1	Surface 2
Glass:					
— clear	0.789	0.072	0.072	0.837	0.837
— low emissivity*	0.678	0.091	0.108	0.837	0.17
— absorbing	0.46	0.053	0.053	0.837	0.837
— reflecting (high performance)*	0.39	0.31	0.45	0.837	0.025
Slatted blind†:					
— reflecting	0.0	0.60	0.40	0.80	0.80
— absorbing	0.0	0.80	0.20	0.80	0.80
‘Generic’ blind	0.20	0.40	0.40	0.80	0.80

* Asymmetric glass properties