Appendix Q for solar preheat Positive Input Ventilation systems (SAP 2009)

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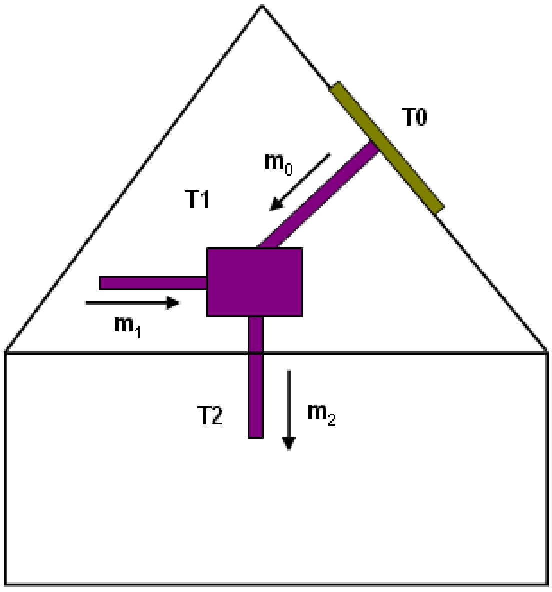
1. Introduction

This document notes a procedure implemented in the Appendix Q (2009) for solar preheat Positive Input Ventilation systems, which comprise a solar air heat collectors linked to a positive input ventilation system. A general four zone (house, loft, air collector volume and outside) model is illustrated below and was set-up for this purpose.

2. Four zone steady state energy model



A_p is the aperture area

m_0 and m_1 is air mass flow rate drawn through the collector and the loft

m_2 is the outlet air mass into the dwelling flow rate

T_3 is the room temperature;

T_0 is the outside air temperature;

T_1 is the loft air temperature;

T_2 is the outlet air temperature;

UA_{rf} , UA_{lw} , and UA_{lt} is the product of exposed area and U-value of the roof, loft walls and loft floor in W/K.

Q_i is incidence solar heat kWh/month

η is the collector efficiency

The model assumes that there is no heat flow between inside and outside the dwelling. This is because the temperature in the house will be determined by the heating system; internal heat gains and fabric losses. The heat transfer by conduction between the ceiling and loft is modelled.

Assuming no heat loss is lossed from the ductwork:

The energy balance of the loft space gives:

$$(T_1 - T_0)(UA_{rf} + UA_{lw}) + m_1 C_p (T_1 - T_0) = UA_{lf} (T_3 - T_1) \quad 1$$

The energy balance of air through the ventilator gives:

$$m_0 (T_0 + \eta Q_i / m_0 C_p) + m_1 T_1 = m_2 T_2 \quad 2$$

The power delivered is: 3

$$Q_{del} = m_2 C_p (T_2 - T_0)$$

Rearranging equation (1) to make T_1 the subject gives:

$$T_1 = \frac{UA_{lf} T_3 + m_1 C_p T_0 + (UA_{rf} + UA_{lw}) T_0}{(UA_{rf} + UA_{lw} + UA_{lf} + m_1 C_p)} \quad 4$$

Rearranging equation (2) to make T_2 the subject gives:

$$T_2 = \frac{m_0 T_0 C_p + \eta Q_i}{m_2 C_p} + \frac{T_1 m_1}{m_2} \qquad 5$$

Provided the right hand parameters of 4 and 5 are known; first solve for T_1 and then T_2 using (4) and (5) respectively and then calculate the delivered power from (3).

3. Application of model to SAP AQ

The solar collector operates into two modes depending on the incident solar radiation.

A) Loft mode – air is pre-heated via the loft only (m_0 = 0)

B) Solar collector mode – air is pre-heated by in the collector by drawing air through the loft near the collector.

Theoretically 'B' can be separated into warming by the loft and by the sun leaving the three modes to consider are:

A) Times when in loft mode – air is pre-heated via the loft only

B_1) Times when in solar mode - loft heating part – outside air is pre-heated by the loft and not collector.

B_2) Times when in solar mode - solar heating part – outside air is pre-heated by collector

When both 'A' and 'B_1' modes are combined this is equivalent to the standard assumptions for positive input ventilation (PIV) within SAP. In SAP 2009 (2.6.1), mode 'A' is represented as follows.

Positive input ventilation (PIV)
Positive input ventilation is a fan driven ventilation system, which often provides ventilation to the dwelling from the loft space. The SAP calculation procedure for systems which use the loft to pre-heat the ventilation air is the same as for natural ventilation, including 20 m³/h ventilation rate equivalent to two extract fans or passive vents. (The energy used by the fan is taken as counterbalancing the effect of using slightly warmer air from the loft space compared with outside).

Some positive input ventilation systems supply the air directly from the outside and the procedure for these systems is the same as for mechanical extract ventilation.

Therefore, assuming the PIV aspect is modelled sufficiently in SAP, this leaves only mode 'B_2' to be modelled in SAP Appendix Q. The effect of the loft gain was found to be small in previous studies at BRE and does not warrant a separate treatment in Appendix Q. Utilising only a single mode for Appendix Q, mode 'B_2', also has the advantage of requiring fewer data inputs within the model, making it easier to implement and less prone to data entry errors by the SAP assessor. Therefore, modelling mode 'B_2' only was considered optimal; the favoured approach assumes air from the solar collector is drawn from outside only, so m_1 =0.

With m_1 =0 and hence $m_0 = m_2$ then (5) simplifies to:

$$m_2T_2 = m_2T_0 + \eta Q_i / C_p \qquad 6$$

Note that knowledge of T_1 (the temperature of the loft) is not required as there is only air flowing through the solar collector via the fan to the room.

The extra power delivered when in solar mode is therefore

$$Q_{del} = m_2C_p(T_2 - T_0) = \eta Q_i \qquad 7$$

Note for information only; to model the solar collector drawing air via the loft then $m_2 = m_1 = m_0$ and (4) and (5) reduce to (8) and (9) respectively.

$$T_1 = \frac{UA_{lf}T_3 + mC_pT_0 + (UA_{rf} + UA_{lw})T_0}{(UA_{rf} + UA_{lw} + UA_{lf} + mC_p)} \qquad 8$$

$$T_2 = T_0 + \eta Q_i / mC_p + T_1 \qquad 9$$

4. Collector efficiency η

The collector efficiency is reasonably independent of incident solar irradiance and outside temperature and can be considered constant. This is evident when $\Delta T = 0$ in the efficiency equation derived in the Fraunhofer Test Report (Air collector test adapted to EN 12975-1,2:2002, Test Report: KTB No. 2005-01). Note that the regression is valid at $\Delta T = 0$, because the measurements span this value.

5. SAP Calculation Method

1) In the SAP Calculator, enter option 'PIV sourced from loft' - This accounts for the loft preheating incoming air and the associated energy savings in loft mode (Mode 'A') and the loft part of the solar collector mode (Mode 'B_1').

2) The following are entered into the AQ by the assessor

- Make and model name
- Collector area (A_p)
- Tilt of solar collector (0º, 30º, 45º, 60º or 90º)
- Orientation of collector (N, NW, etc)
- Over shading (Heavy, significant, modest, none)
- Efficiency of main heating system η_{sp} (SAP 2009 - box 206)
- Monthly heating load of main system (SAP 2009 – box 211)
- Utilisation factor η_2 (SAP 2009 - box 89)
- Fuel of main heating system
- Dwelling volume (SAP 2009 - box 5)
- Mechanical throughput (SAP 2009 - box 23b) = 0.5 ACH

3) The following are provided in the AQ

- Solar irradiation tables H2 and H3 monthly figures.

4) The following measurements are retrieved from a database sheet by product brand and name

- Solar efficiency (η)
- Specific fan power (SFP) in W per l/s for a given number of wet rooms and manufacturers specified ducting. These are SFP varies when running in loft mode and solar collector mode.

5) The following are calculated in the AQ

Q_i is incident solar irradiance calculated from the angle of tilt, area and orientation of collector in kWh during the heating season by summing the data for the months October to May using table H2 (annual irradiance) and H3 (annual to monthly factor). Note Q_m units are kWh/month/m^2.

The monthly amount saved Q_{sav} off the main heating is

$$Q_{i,s} = \eta A_p . Q_m \eta_2 / \eta_{sp} \qquad 10$$

The utilisation factor (η_2) is introduced to account for the usefulness of the gains. The SAP calculation uses two utilisation factors, one for zone 1 with an assumed set point temperature of 21°C for living areas (a smaller proportion of total floor area (TFA)) and one for zone 2 (η_2) with an assumed set point temperature of 18°C for the remaining majority of the TFA. The utilisation factor for zone 2 (η_2) only is applied to this model, since it typically represents the majority of the TFA and simplifies the calculation process.

The monthly saving is limited to the space heating provided by the main heating system.

The fan power is slightly higher when drawing air through the solar collector and so needs to be taken into account. The additional fan consumption is:

$$Q_{fan,m} = SFP(N_{wrm}, D_{type}) \times h_m \qquad 11$$

- SFP is the additional specific fan power (a function of number of wet rooms and duct type)
- h is the annual running hours in solar collector mode.

(11) only applies if there is a space heating demand, otherwise it is zero.

The hours of running are difficult to estimate precisely, but the following approximates running hours as far as practicable, whilst retaining model simplicity.

Clearly the solar collector will not operate at night and approximately 0.5 hours either side of dusk and dawn. This would suggest approximately 9.6 operating hours per day between October and May (10.6 is average daylight hours in the heating season http://www.projectbritain.com/weather/sunshine.htm accessed 25/8/2010 at 17:47)

The number of hours of direct sunshine averaged 3 hours/day during Oct to May in the UK in 1971 to 2000 (see table 1). If the unit operates in direct sunshine it would operate for 3 hours per day during heating season.

Given that a moderate wind may increase heat loss significantly the lower figure of 3 hours seems a reasonable estimate of running hours. For the SAP 2009 application, the running hours are required monthly and therefore the monthly recorded hours of direct sunshine are used for calculation of the elevated electrical consumption from the PIV unit (fan) when drawing air through the solar collectors, see Table 1.

Table 1 UK Average sunshine hours 1971 to 2000

	Sunshine hours
Jan	44.6
Feb	65
Mar	97
Apr	141.3
May	184.6
Jun	169.4
Jul	174.3
Aug	166.5
Sep	123.6
Oct	91.6
Nov	58.7
Dec	38.4
Year	1354.9
Oct to May	3.0 hours/day

Source: http://www.metoffice.gov.uk/climate/uk/averages/19712000/areal/uk.html accessed 25/08/2010