Modelling A-500 e-stacks in Dynamic Thermal Modelling Software

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Introduction

This document is to allow our clients to model the e-stack ventilation system in commercial dynamic thermal modelling software such as IES or TAS.

The main advantage of the e-stack system over other natural ventilation systems is that in the winter, we do not bring in air via opening windows, as this requires a large amount of preheating energy. Instead we operate in 'mixing mode' where we bring in air at high level and mix it with warm room air to create a tempered air stream which is comfortable for occupants.

Building regulations do not take account of thermal comfort, this significant energy saving is difficult to model in commercially available tools. The e-stack system will look the same as any other natural ventilation system in terms of heating energy consumption, because the need for preheating is disregarded by most thermal modelling tools which just takes into account the bulk air temperature.

To accurately model conventional natural ventilation systems, a preheat at the low level windows would have to be incorporated which is almost never done by modellers, thereby giving results which are too optimistic. By contrast, the results for modelling an e-stack using the method below will be far more accurate, as in the winter the incoming air is treated as part of the energy balance, accurately representing our mixing strategy.

Summary of the Strategy

External Temperature	Internal Temperature	Strategy
< 16 degC	-	Winter Mixing Mode Minimum ventilation on CO_2
> 16 degC	<24 degC	Upwards Displacement Mode No Fans
> 16 degC	>24 degC	Upwards Displacement Mode Fan Assistance
>25degC	-	Nightcooling operates that night

Modelling the Winter Mixing Mode

The atrium systems saves energy by tempering the fresh air in the atrium and exchanging that air with the classroom using low powered fans, instead of heating the air. The casual gains produced inside the space keep it warm on all but the coldest days (<5-10degC).

High level openings at the top of the atrium are actuated and controlled by the e-stack control panel to target a CO_2 level of 1000ppm. No fans are used to do this, instead wind and buoyancy are used to maintain this level. The openings can be modelled as windows which open and close on CO_2 as follows:

Atrium CO_2	Opening (%)
800ppm	0
1200ppm	100

Each space off the atrium has two A-series units that sit between the atrium and the space. Each unit can be modelled as a mechanical flow rate, set at 10l/s/person, one bringing air into the space from the atrium and the other extracting to the atrium. The specific fan power should be set at 0.15 W/l/s for each unit.

The simplest way to define the flow rate is to specify an air exchange to provide an equivalent of 10l/s/person from the atrium to the room and create a variation profile which operates in the same way for each occupied day of the year, when **External Temperature<16**, during all occupied hours. A second flow rate should also be defined in the opposing direction.

No preheating should be applied to the supply air. All casual gains present in the space and atrium should be included in the model as these are what keep the space warm. The atrium heating setpoint should be set below the classroom heating setpoint. Typically this is set to 18degC.

Modelling the Upwards Displacement Mode

This mode relies on natural buoyancy and wind to drive air through the space and the fans are not required. In this mode, the unit consumes minimal power. The units can be simply modelled as a 2 holes or opening doors in the wall between each classroom and the atrium. It is important that the windows and other openings in the space and atrium are in the correct position as this will affect the rate of natural ventilation. The hole size should take account of the free area of the A-500 unit and therefore should be specified as below:

Unit	Aerodynamic Free Area (m^2)	Suggested Hole Dimension
A-500	0.154	0.5m x 0.497m

It is assumed that modelling tools take a C_d of 0.62 for each hole, therefore achieving the aerodynamic area specified above.

It is also important that all the windows and other openings are positioned correctly in the space and the atrium as this will affect the natural ventilation flow. The windows at the top of the atrium and in the spaces should be based on a modulating profile that varies linearly on the average of all of the adjacent room temperatures between the following values:

Average of room T	Opening (%)
19degC	0
24degC	100

Two profiles should be created separately for the low level openings and the high level atrium openings. The low level openings should operate in the same way all year round for each occupied day, and should open when **External Temperature>16**, **Internal Temperature>21** and **Internal Temperature>External Temperature**, during all occupied hours.

The daily profile for the atrium openings will be more complicated but should begin with the same formula as above put in for all occupied hours.

Modelling the Upwards Displacement Mode with Fan Assistance

The system is still driven predominantly by buoyancy and wind, but assistance is given to the flow by the fans that are also used in winter. To model this, the natural mode should be used at the same time as an additional mechanical extract from the classroom to the atrium. The maximum effect of this fan assistance on top of the natural rate is as follows for each A-500 pair (i.e. for each room):

Unit	Fan Assistance (l/s)
A-500 pair	200

In this mode the fan in each unit runs assist the air transfer from the room to the atrium, with a specific fan power of 0.45W/l/s for the pair of units.

The simplest was to define the flow rate is to specify an air exchange with the correct flow rate from each room to the atrium, which operates in the same way for each occupied day of the year, whenever **Internal Temperature>24** and **Internal Temperature>External Temperature** during all occupied hours.

Modelling the Nightcool Mode

If the day before has been particularly hot, a night cooling strategy is used that night. This is operated between the hours of 21.00 and 06.00. During this time the high level atrium openings are fully open.

It is often difficult, in software, to control the nightcool based on temperatures the previous day, so a simplified profile can be applied when **Internal Temperature>18** and **Internal Temperature >External Temperature** from 21.00 to 06.00 during the summer months (1st May-30th August), to the atrium opening profile which was partially created earlier. For the other months of the year the simple low level opening profile can be applied.

If the average of all of the room temperatures has not dropped below 18degC by 03.00, the fans are switched (one to supply air from the atrium and one to extract air to the atrium) on and provide assisted ventilation at the rate described in the last table until 6am.

The simplest way to define the flow rate is to specify an air exchange with the correct flow rate, when **Internal Temperature>18** and **Internal Temperature>External Temperature**, **from** 03.00 to 6.00 during the summer months (1st May-30th August). A second flow rate should also be defined in the opposing direction.