Modeling Breathing Buildings Units in TAS

NVHR Units

Draft 5
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This document details how to model Breathable buildings' NVHR units using TAS software, for the purposes of overheating analysis; specifically, priority schools TM52.

Contents

1   The Breathing Buildings Wall Units

NVHR units are high level wall units which are designed to supplement low level windows in order to provide an enhanced natural ventilation strategy. These units have a fan boosted mode of operation that operates on hot days and during the night to provide effective night cooling. A typical installation will see a pair of units installed in each room.

The NVHR units have the following modes of operation, based on the **time of day**:

- Day Mode   (Depending on occupancy schedule)
- Night Mode   (between 9pm and 6am)

The NVHR units also have **seasonal modes** of operation, based on external air temperature:

- Summer Mode (ext. temp >= 16°C)
- Winter Mode   (ext. temp < 16°C)

As the winter mode depends on external temperature, the winter mode of operation can come into operation at any time of year depending on the weather. It is therefore important to model the winter mode of operation for overheating analysis.

1.1   Description of the modes of operation

1.1.1   Day mode: Summer

If the external temperature $\geq$ 16°C and the time is between 9am and 6pm[1], the units are in the daytime summer mode of operation.

In this mode, the apertures on the NVHR units start to open at 19°C and are fully open at 24°C. If the internal temperature exceeds 24°C, the fans provide boosted ventilation at the rate of 150 l/s per unit.

In this mode, the aperture on the NVHR unit will also open if CO2 in the zone exceeds 600ppmv. If CO2 continues to rise and exceeds 800ppmv, the unit will provide fan assistance at 80l/s per unit. If the CO2 in the zone exceeds 950ppm, the unit will switch to fan boost mode, providing fresh air at 150l/s per unit.

1.1.2   Day mode: Winter

When the external temperature is < 16°C and the time is between 9am and 6pm[1], the units are in the daytime winter mode of operation.

In this mode, the aperture on NVHR unit only opens if the concentration of CO_2 in the zone exceeds 600ppmv. The fans provide ventilation in the 'winter-mixing' mode at a rate of 80l/s per unit.

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[1] This is a typical occupancy schedule. Exact schedule may vary.

1.1.3 Night mode (Summer & Winter)

Between the hours of 9pm and 6am, the unit is in the night mode of operation.

In this mode, if the internal temperature is above 18°C, (and external temperature is less than room temperature), the apertures on the units are fully open. If the internal temperature is not less than 18°C by midnight, the fan provides boosted ventilation at a rate of 200 l/s per unit.

2 Modelling in Tas overview

The process of modelling these units is as follows:

3D Modeller:

- Create the NVHR units as windows

Building Simulator:

- Create and assign constructions for the NVHR units
- Create and assign apertures for the NVHR units
- Create and assign apertures for the openable windows[2]
- Create/modify the zones daytime internal condition (mech vent function)
- Create/modify the zones night time internal condition (mech vent function)

For the purposes of this guide, a simple building (Figure 1) has been created in TAS. The files may be available upon request. This simple one-story building has two rooms; the rooms will be identical wherever possible with the exception that one of the rooms will be modelled with a pair of NVHR units.

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[2] For more information about why the aperture functions of the windows may need altering, please see section **Error! Reference source not found.**.
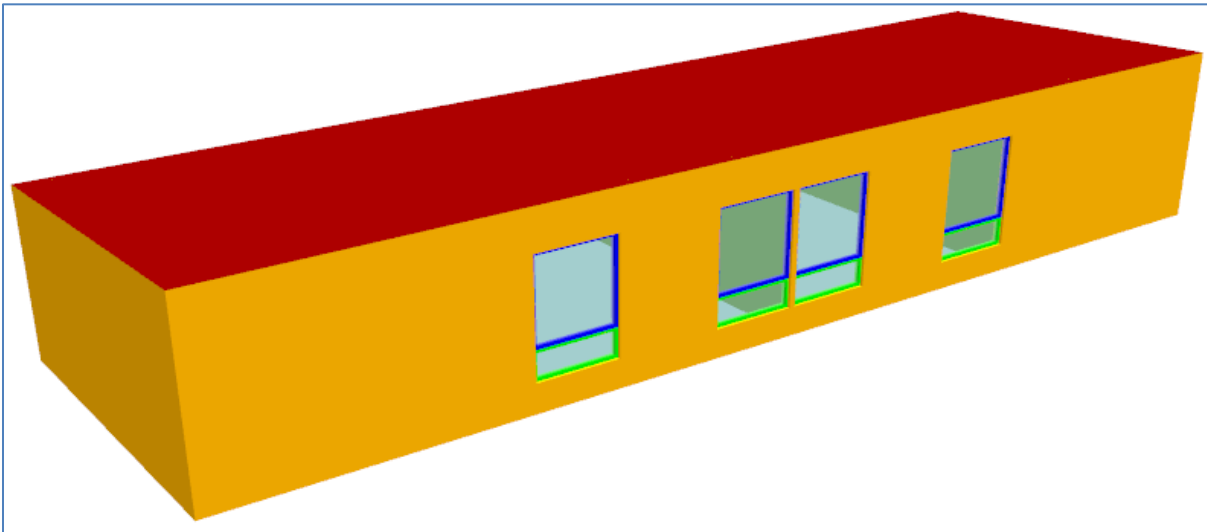
3   3D Modeller

Figure 1 - The test building used throughout this guide, as seen in the 3D modeller

The test building (Figure 1) being used in this guide consists of two rooms with identical dimensions. These rooms are adjacent to one another and are situated in the middle of the building. Their surrounding spaces are un-zoned, so there is no heat transfer between them. The floor plan of the test building is shown in Figure 2.
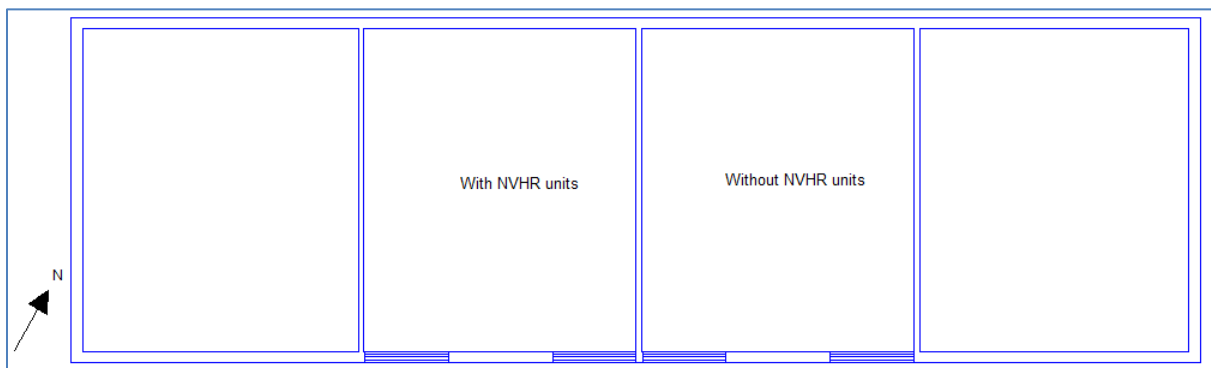

Figure 2- Floor plan of the test building before the NVHR units are added. Note that adjacent spaces are unzoned so are adiabatically linked with the zones of interest. The dimensions of each zone are (5.8x4.9) m.

3.1   Create the NVHR Units as windows

The NVHR units have physical dimensions of $(900\ w \times 300\ h)mm$. These units are typically placed at a high level on the façade, but their exact positions may vary. Create a new window in TAS as shown in Figure 3. Enter the level to represent the level on the façade that the unit will be placed.

Colour	Name	Placement	Width	Height	Level	Transparent	Internal Shadows	Frame Width	% Frame	Frame Percent...	Frame Depth	Used
🟩	NVHR Unit	Wall	0.9m	0.3m	2.5m	☐	☐	0.063m	☑	50.0%	0.1m	☑
🟦	Window 1	Wall	1.5m	1.5m	1.0m	☑	☑	0.05m	☐	12.89%	0.1m	▣
🟩	Window 2 (openable)	Wall	1.5m	0.5m	0.5m	☑	☑	0.05m	☐	25.33%	0.1m	▣

Figure 3 - NVHR Unit properties as shown in the window dialogue box of the 3D modeller

The units can then be placed on the external wall of the desired zone. This is visible in green, in Figure 4. Note that the location the unit is placed can affect the natural ventilation performance, so the unit should be placed in the location it is expected to be installed in the real building.
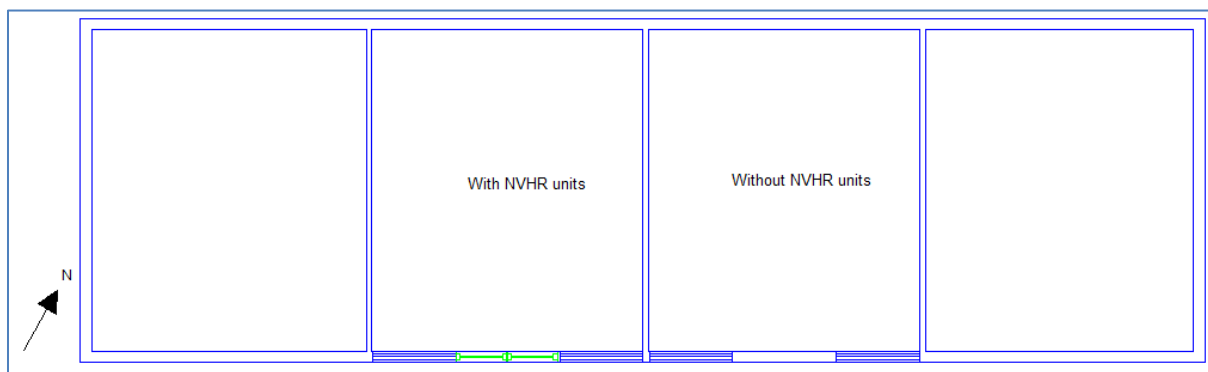

Figure 4 – A pair of NVHR Units placed in one of the zones.

3.2   Ensure sufficient openable windows are present

Breathing Buildings can advise on a minimum low level façade openable area, appropriate to your project, and if they do, it is important to that this requirement is met to ensure the e-stack units operate effectively.

To ensure sufficient minimum free area has been achieved, first determine the areas of each surface in Tas Building Simulator file that will have an aperture applied. This can be read directly from the surfaces information in the TBD file, or calculated from the 3D modeller file.

For the purposes of this test building, a minimum area of $1m^2$ is recommended; the test building has two sets of two windows in each zone. Each openable window in the test building has the following properties:

- Name ("Window 2 (openable)")
- Width (2.0m)
- Height (0.5m)
- Frame Width (24%)

If the aperture is applied to the building element called "Window 2 (openable) - pane" in the TBD, the area of this surface will be Width × height × Pane percentage/100 $= 2 \times 0.5 \times 0.76 = 0.76\text{m}^2$.

Often, windows have restrictors that prevent them being fully opened. If the windows of the test building can be opened to 80% of their free area, this gives a total openable area of 0.608m^2. As there are two windows, the total openable area of the windows in this zone would be 1.216m^2. This area is greater than the minimum requirement.

> **The windows in a room with a unit may be controlled differently to a room without.** If a window is present in a room with and without a unit, a copy of the window will need to be made in the 3D modeller. This is shown in Figure 5. When making a copy of the window, it is important to ensure that any windows that are already placed in the 3D modeller have their types changed accordingly.
>
>
>
> Windows
>
> | Colour | Name | Placement | Width | Height | Level | Transparent | Internal Shadows | Frame Width | % Frame | Frame Percent... | Frame Depth | Used |
> |---|---|---|---|---|---|---|---|---|---|---|---|---|
> | | R-Series Unit | Roof | 1.6m | 0.95m | | ☐ | ☐ | 0.172m | ☑ | 50.0% | 0.1m | ☑ |
> | | Window 1 | Wall | 2.0m | 1.5m | 0.5m | ☑ | ☑ | 0.05m | ☐ | 11.33% | 0.1m | ◉ |
> | | Window 2 (openable) | Wall | 2.0m | 0.5m | 2.0m | ☑ | ☑ | 0.05m | ☐ | 24.0% | 0.1m | ◉ |
> | | Window 2 (openable) (e-stack) | Wall | 2.0m | 0.5m | 2.0m | ☑ | ☑ | 0.05m | ☐ | 24.0% | 0.1m | ☐ |
>
> **Figure 5 - Each window in the window dialogue box can only have one aperture assigned to it in the building simulator.**

4   The Building Simulator

For the purposes of this guide, the building simulator file associated with the test building model has been setup as follows:

- Notional constructions.
- The weather file used is the CIBSE Norwich DSY.
- Occupancy schedule of 9:00 – 16:00
- Internal conditions as in Figure 6
- Openable windows which are openable to 80% of their free area, start to open at 20°C and are fully open at 21°C
- Standard calendar

Gain	Value	Factor	Setback Value	Schedule
Infiltration	0.3 ach	1.0	0.0 ach	
Ventilation	Function	1.0	0.0 ach	NVHR Day
Lighting Gain	Function	1.0	0.0 W/m²	occupancy
Occupancy Sensible Gain	20.0 W/m²	1.0	0.0 W/m²	occupancy
Occupancy Latent Gain	10.0 W/m²	1.0	0.0 W/m²	occupancy
Equipment Sensible Gain	5.0 W/m²	1.0	0.0 W/m²	occupancy
Equipment Latent Gain	0.0 W/m²	1.0	0.0 W/m²	
Pollutant Generation	9.3 g/hr/m²	1.0	0.0 g/hr/m²	occupancy

Figure 6 - Summary of the internal conditions used in the test model, during occupied hours

The inputs stated here are for reference only.

Please note that Breathing Buildings advise that the heating set-point is kept below 19°C, so that it does not conflict with the summertime opening profile of the NVHR units

4.1   Create and assign NVHR Constructions

The construction used for the NVHR pane in the building simulator will have a relatively minor impact on the overall internal temperatures of the applied zones, as it represents a small proportion of the external wall area. For the purposes of this model, the construction given in Figure 7 has been used.

Layer	M-Code	Width (mm)	Conducti...	Convecti...	Vapour D...	Density (...	Specific ...
Inner	Aluminium sheet	5.0	160.0	0.001	9999.000	2800.0	880.0
2	Insulation 1	5.0	0.03	0.001	9999.000	40.0	1450.0
3	Aluminium sheet	5.0	160.0	0.001	9999.000	2800.0	880.0

Figure 7 - NVHR Construction used in the guide. This does not necessarily reflect the actual construction of the unit.

Once the construction has been created, it should be assigned to the building element called "NVHR Unit-pane". (Figure 8)

Building Elements			
Name	Description	Construction	Aperture Type
NVHR Unit-pane		NVHR Unit	
South facing upper window-pane		Notional Roof Lit Glazi...	

Figure 8 - Assigning the NVHR Construction

4.2   Create and assign NVHR Apertures

Two apertures will need to be created for the NVHR unit One should be called 'NVHR– Day', and the other NVHR –Night'.

NVHR – Day

The day aperture for each unit should be setup as in Figure 9; the openable proportion is the same for the Day and the Night aperture, and will be calculated in the next section.

Ensure that a schedule representing the occupied hours is setup for this aperture, and that it applies to all day types. In this guide, the occupied schedule is between 9am and 6pm. If your zone occupancy changes during lunch time, the schedule for the NVHR unit should **not** be modified to reflect this.

Once the aperture has been created, it should be applied to the "NVHR- Pane" building element.

NVHR – Night

The night aperture for each unit should be setup as in Figure 10; the openable proportion is the same for the Day and the Night aperture, and will be calculated in the next section.

The units' night aperture should apply to all day types and should have a schedule applied that includes the hours between 9pm and midnight.

Please note that in some cases it may be appropriate to alter the aperture opening temperatures, depending on the heating set-point selected in the model and also any window restrictors that may be present.

Once the aperture has been created, it should be applied to the "NVHR- Frame" building element.

Figure 9 – NVHR Day Aperture Settings

Figure 10 – NVHR Night Aperture Settings

4.2.1 Calculating the Openable Proportion

The NVHR units have an equivalent orifice area of $0.04 m^2$. If the NVHR window has been setup as described in section 3.1, the pane will have an area in TAS of $0.135 m^2$. This can be verified by viewing the surfaces of the zone containing the NVHR unit, as shown in Figure 11.

No.	Orientation	Inclination	Altitude (...	Altitude ...	Plan Peri...	Type	Area (m²)	Output S...	Building Element	Side facing ...
8	150.0 (SE)	90.0	2.65	0.175	0.0	Exposed	0.27		NVHR Unit-pane	Inner
7	150.0 (SE)	90.0	2.65	0.3	0.0	Exposed	0.27		NVHR Unit-frame	Inner
5	150.0 (SE)	90.0	0.75	0.5	0.0	Exposed	0.38		Window 2 (openable)-frame	Inner

Figure 11 - The surface associated with the NVHR Panes; NOTE: as there are two NVHR units in this zone, the area of each surface is 2x that of a single NVHR unit.

The openable proportion is given by the equivalent orifice area of the NVHR unit divided by the NVHR pane area in TAS. For the NHVR unit:

$$\text{openable proportion} = \frac{\text{Equivalent Orifice Area}}{\text{Area of NVHR Pane in TAS}} = \frac{0.04 m^2}{0.135 m^2} = 0.296$$

4.3 Create and assign apertures to the openable windows

Breathing Buildings recommend that the openable windows in the rooms with e-stack units reflect the operation of the NVHR units, and as such will generally start to open at 19°C and be fully open at 24°C.

If a window has a particularly small restrictor and therefore quite small openable proportion, the occupants may be more likely to fully open the window at a lower temperature and different opening profiles could be applied accordingly.

4.4 Modifying the NVHR zones' internal conditions: Occupied hours

The additional ventilation provided by the fan boost of the units is at a fixed rate, and is accounted for by including a mechanical ventilation function in the internal conditions for the zones that have an NVHR unit.

It is important to note that only one mechanical ventilation function can be assigned per internal condition; this may cause problems if a space already has mechanical ventilation; if a zone does have mechanical ventilation and an e-stack unit, the mechanical ventilation may have to be modelled using IZAMs.

In the test model, one zone has a unit and the other does not. There is one occupied internal condition for both of these zones, so a copy will be made for each such that one has the NVHR ventilation applied and the other does not.

To assign the appropriate function to the ventilation, click on the word "Ventilation" in the internal gain tab of the internal condition. In the resulting dialogue box, change the **type** from **value** to **function** and select 'tcbvc' and enter the values as in Figure 12.

Figure 12 - NVHR mechanical ventilation tcbvc settings for a single unit. Note that the day and night max flow rates depend on the number of units in the zone.

It is also imperative to change the schedule of the mechanical ventilation function (tcbvc) to match the occupied hours schedule applied to the NVHR apertures.

NOTE: Currently, the fan boost operation of the units is ignored at weekends. Ideally, a duplicate internal condition for each space with a unit needs to be created for the closed day types, and be identical with regards to ventilation function but having no internal gains.

4.4.1 Determining the flow rates

The day boosted flow rate of a single NVHR unit is 150 l/s, and the night flow rate is 200 l/s. If there are multiple units serving a zone, the flow rates of each unit should be summed together.

In the case of the test model, which has a pair of NVHR units serving it, the dialogue should reflect Figure 13.

Figure 13 - TCBVC function for a pair of NVHR units.

Figure 14 - The TCBVC function MUST be used in conjunction with a schedule.

5   Results & Comments

Figure 15 shows the PSBP FOS overheating results for the test building when two NVHR units are installed. Compared to an identical adjacent room without NVHR units, the room is significantly cooler. In the test building modelled here, there will be a large amount of heat transfer from classroom 2 to classroom 1, yet the room is still able to remain cool.
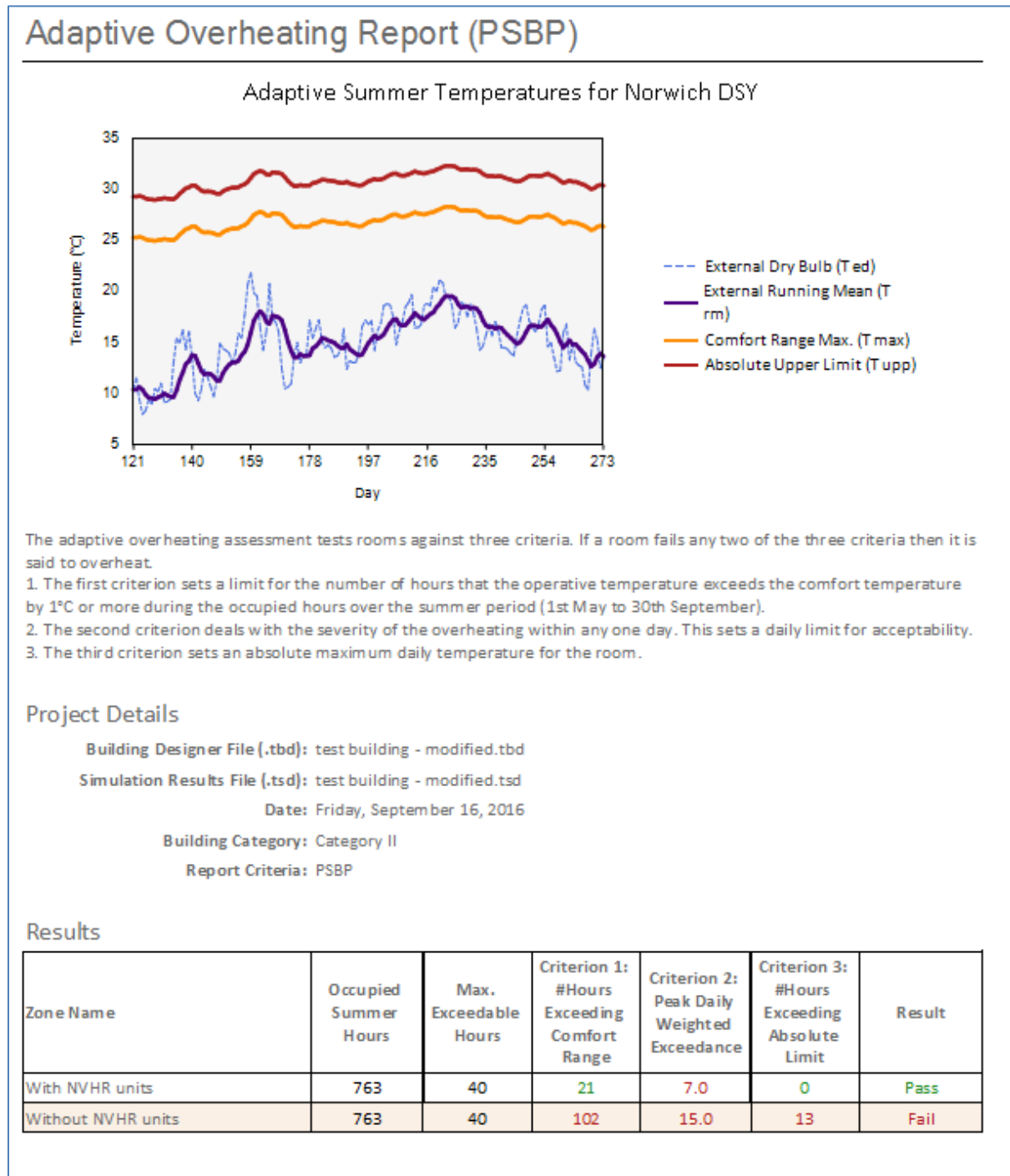
Adaptive Overheating Report (PSBP)

Adaptive Summer Temperatures for Norwich DSY

Legend:
- – – – External Dry Bulb (Ted)
- —— External Running Mean (Trm)
- —— Comfort Range Max. (Tmax)
- —— Absolute Upper Limit (Tupp)

The adaptive overheating assessment tests rooms against three criteria. If a room fails any two of the three criteria then it is said to overheat.
1. The first criterion sets a limit for the number of hours that the operative temperature exceeds the comfort temperature by 1°C or more during the occupied hours over the summer period (1st May to 30th September).
2. The second criterion deals with the severity of the overheating within any one day. This sets a daily limit for acceptability.
3. The third criterion sets an absolute maximum daily temperature for the room.

Project Details

Building Designer File (.tbd): test building - modified.tbd
Simulation Results File (.tsd): test building - modified.tsd
Date: Friday, September 16, 2016
Building Category: Category II
Report Criteria: PSBP

Results

Zone Name	Occupied Summer Hours	Max. Exceedable Hours	Criterion 1: #Hours Exceeding Comfort Range	Criterion 2: Peak Daily Weighted Exceedance	Criterion 3: #Hours Exceeding Absolute Limit	Result
With NVHR units	763	40	21	7.0	0	Pass
Without NVHR units	763	40	102	15.0	13	Fail

Figure 15- Priority school TM52 results for the test building.

5.1 Verifying the unit is modelled correctly

To ensure the operation of the unit is modelled correctly, the .tsd file produced when the building is simulated can be examined. Some things to look for:

During occupied hours (ext. temp > 16°C, low internal pollutant levels)

- There is no aperture flow through the NVHR-pane surface when the internal temperatures are > 24°C, but there is mechanical ventilation to the zone
- If the zone temperature is <24°C, there should be no mechanical ventilation
- If the zone temperature is >19°C but <24°C, there should be aperture flow through the NVHR pane and the openable windows.

During unoccupied hours

If the zone temperature is >18°C, there should be mechanical ventilation at a rate that is higher than any mechanical ventilation present during occupied hours.

- If the internal temperature is > external temperature, and internal temperature > 18°C at 1pm, there should be aperture flow through the unit but no mechanical ventilation. During hour midnight to 6am, if the internal temperature > 18°C there should be no aperture flow through the unit but there should be fan boosted ventilation.