Executive Summary

The Phase Change Material wall layer component (Type1270) is implemented in the thermal model of a generic sky scraper floor. The addition of a PCM layer above the suspended ceiling covering approximately 36% of the floor's area resulted in a 15% reduction in annual cooling energy and a 1% reduction in annual heating energy for the entire floor based on the assumptions in the model. The model and these modeling notes are intended to provide an example of how to implement the PCM layer in an existing building simulation.

Building

The representative floor of a high-rise building is modeled as seven conditioned thermal zones: WEST, EAST, NORTH, SOUTH, SOUTHSUN, CONF, and ELEVBLOCK. An eighth (unconditioned) thermal zone called "PLENUM" sits over all seven. The seven conditioned zones are held between a cooling temperature of 26C (78.8F) and a heating set point of 21.1C (70F) during occupied hours. The space is set up to 30C (86F) and back to 18.3C (65F) at night. The floor of the conditioned zone is adjacent to a plenum temperature below while the ceiling of the unconditioned PLENUM zone is adjacent to a conditioned temperature above. The conditioned zones are separated from the plenum by a suspended ceiling made of acoustic tile in the base case. In the design case, three conditioned zones (WEST, EAST, and SOUTHSUN) have a PCM layer above the acoustic tile. Because of the way the PCM component is modeled, it must be sandwiched between two wall layers. As a result, the PCM in the design case is backed by an inconsequentially thin, low R-value material. The external walls of the building are almost entirely glass, having a 95% glazing fraction.

The capacity of the heating and cooling system is limited in each zone so that when the zone returns from a setback temperature, it does not experience an unrealistically high zone load. The capacities were determined by running the model once with heating and cooling setpoints that do not set back at night, recording the maximum load experienced in each zone, multiplying that load by a safety factor of 1.1, and setting that value as the maximum capacity of the system.

The floor plan of the model is shown in Figure 1 below.

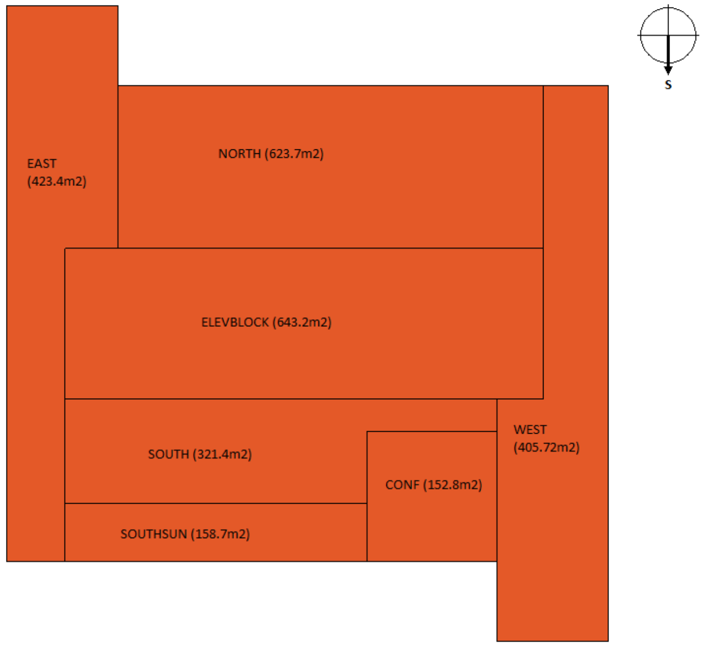

Figure 1: Building Floor Plan

Energy Gains

The conditioned spaces are subject to lighting, occupancy, and equipment gains. Schedules for these gains (fractions of the peak value) are taken from the ASHRAE Standard 90.1-2007 User's Guide as representative of high-rise office buildings. The peak occupant density is taken to be one person per 21m^2 (225ft^2) of floor area. Equipment gains were taken to have a peak value of 21.5 W/m^2 (2 W/ft^2) and lighting gains were taken to have a peak value of 12 W/m^2 (1.1 W/ft^2). It is assumed that 60% of the heat gains from lighting go into the plenum while 40% affect the conditioned space below. Peak values are again taken from the ASHRAE Standard 90.1-2007 User's Guide. The plenum is also subject to a 21.5 W/m^2 equipment gain.

Fresh Air

Fresh (outside) air is provided to the conditioned spaces according to ASRHAE Standard 62.1-2004. As such 0.304 lps/m^2 (0.06 cfm/ft^2) and 2.36 lps/occupant (5 cfm/occupant) is provided whenever the building is occupied. The building is occupied between 6AM and 7PM Monday through Friday.

Modifying the Building Model to Accommodate the PCM

Three zones contain PCMs above their suspended ceiling: WEST, EAST, and SOUTHSUN. In each of these zones, the ADJACENT ceiling that separates the zone from the plenum above is replaced by a BOUNDARY wall with a userdefined input boundary temperature on its back side. The wall areas remain unchanged. The boundary temperatures are called TPCM_PLENWEST, TPCM_PLENEAST, and TPCM_PLENSTHSUN. The ceiling, which was a single layer construction made up of acoustic tile and called "ADJ_CEILING" is set to a new wall construction called "BND_CEILING(1)." Only the name changes; its construction remains a single layer of acoustic tile. The back side convection coefficient of each of the three new BOUNDARY walls is set to 0.0001 indicating direct thermal contact with a temperature (the temperature that will be used is the temperature of the PCM layer.

In the PLENUM zone, there are three (now undefined) surfaces that had previously been adjacent to the respective conditioned zones below. These three surfaces are replaced by BOUNDARY walls. Again the areas remain unchanged. This time, the same boundary temperatures that were defined before are used again. The BOUNDARY walls are set to a construction called "BND_CEILING(2)" which is made up of a single massless layer with a low thermal resistance. Again the back side convection coefficient is set to 0.0001 in order to indicate direct thermal contact.

The Type56 output QCOMO (energy to the outside surface of a boundary wall – with positive defined as into the surface from the outside) is also added for each of the six surfaces (two surfaces per PCM layer)

Figure 2 shows a graphical representation of the changes.

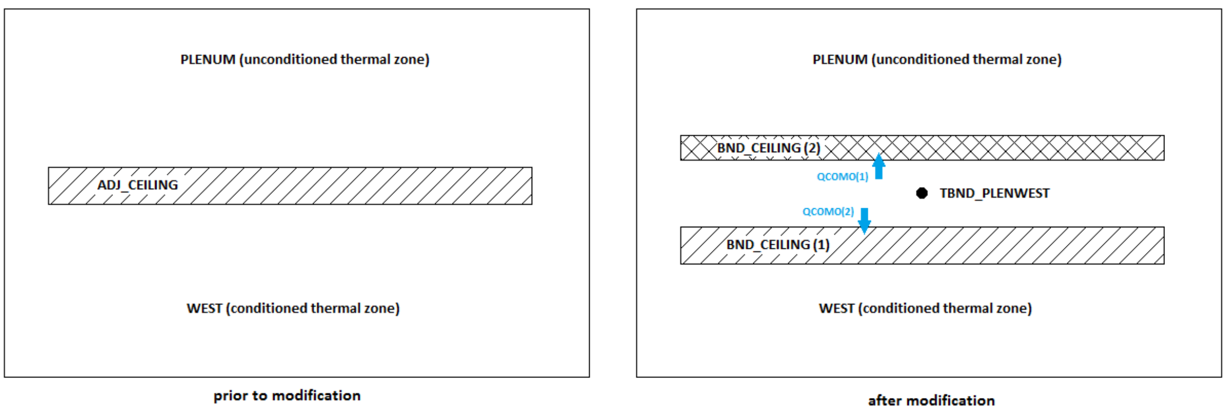

Figure 2: A Graphical Representation of the Changes Necessary in the Building Model in Order to Implement a PCM Layer

To summarize, thee inputs have been added to the building model: the temperature of the PCM above the west zone, the temperature of the PCM above the east zone, and the temperature of the PCM above the SOUTHSUN zone. Six new outputs have been added to the building model: QCOMO for each surface that is adjacent to a PCM layer. Lastly, the three ADJACENT ceilings separating conditioned zones from the plenum above have been split into six BOUNDARY ceilings, each having a userdefined input temperature on the back side.

Implementing the PCM

An equation block and an instance of Type1270 are added for each PCM layer. The purpose of the equation block is simply to change the sign of the two QCOMO outputs that pertain to the layer. Type56 defines QCOMO as the energy into the outer surface of a wall with positive defined as energy into the wall from the exterior. In this case, energy coming out of the surrounding wall layers and into the PCM would be negative. The PCM component (Type1270) defines energy entering the PCM as positive. As a result, the sign of QCOMO must be changed.

Setting up the PCM involves specifying the wall area (which should match the corresponding Type56 wall area exactly), setting the PCM initial temperature and setting the PCM product code. Type1270 can be used in either of two modes. In one mode, it automatically uses data provided by a PCM manufacturer (PhaseChange Energy Solutions: http://www.phasechange.com/) and the user enters a product code. In the other mode users may enter their own parameters. Please refer to the Type1270 Mathematical Description for additional information. Note that if the user enters the PCM's transition temperature as the initial temperature, the model will assume that the PCM starts completely solid (i.e. without any stored energy). For the purposes of the present example, product 901.25QFGM51 was implemented in all three PCM layers.

Once the equation and Type1270 are added, the Type56 QCOMO outputs are connected to the equation block inputs, the equation block outputs are connected to the respective Type1270 inputs and the Type1270 "PCM layer temperature output is connected back to the appropriate Type56 boundary temperature input (TBND_PLENWEST in the case of Figure 2.

Outputs

The model calculates the hourly heating and cooling (sensible only!) requirements of all the conditioned zones. These are printed to the file ***.hourly in which *** is the name of the input file. It is worth noting that the output devices in the example (the Type46 printer/integrator and various instances of the Type65 online plotter) are all contained on the "outputs" layer, which is hidden for clarity. To view the outputs layer, right click in the assembly panel and select "show layers: outputs" from the resulting context menu.