Building occupant thermal loads representation in ESP-r

Introduction

Buildings are used and occupied by people, where they spend most of their time indoor. Consequently, the presence of people inside building affects the performance of the building in term of energy consumption and the indoor environment quality. The important thing is to maintain thermal comfort in such environment.

Building simulation tools generally use fixed heat flux to represent occupant thermal load. The fixed representation of building occupants in building simulation tools is often rudimentary leading to inaccurate predictions of both thermal comfort and indoor conditions. For these reasons, a more detailed representation of people is presented in ESP-r.

Method

In order to investigate the effect of dynamic heat load from occupant on building performance, firstly we developed and implemented a simple polynomial equation for both sensible (radiation and convection) and latent heat load (evaporation) function of operative zone temperature.

The Polynomial equation is a correlation of data provided by (Clark H. et al. 1967) and from (ASHREA 2013) table for various metabolic rate and temperature. Energy Plus provides a polynomial equation to calculate the sensible heat load of occupant considering the thermal body always at steady-state.

In contrast, this approach does not take clothing factor and humidity of zone in consideration. Accordingly, a two-node model was developed. The model based on energy balance equations derived from the Gagge model taking into account the thermoregulatory process as sweating, shivering and blood flow, vasoconstriction, and vasodilation. We also consider clothing insulation and activity level. Age and gender are considered as a percentage of metabolic rate as stated in ASHRAE.

Three steps approach toward better occupant representation

•The first was by changing casual gains of the occupant from constant values to be variable with its surrounding condition.

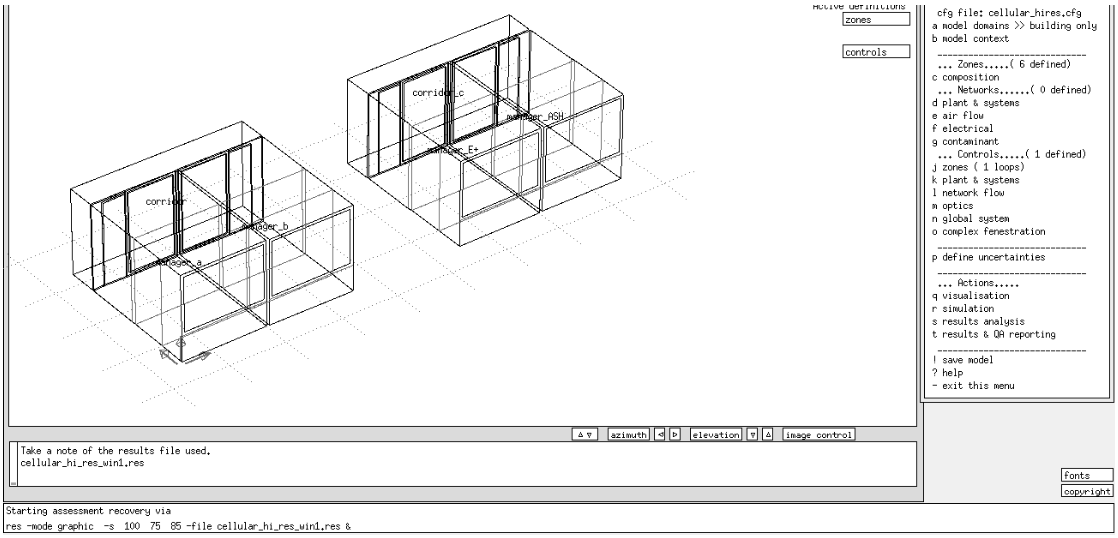
•The second step was by implementing a two-node model based on the model of Gagge, where energy balance equations of the two nodes skin and core capable of predicting skin and core temperature, the comfort of the occupant and all heat losses from the body each time steps.

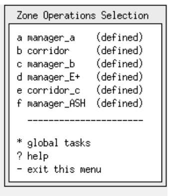
•The third approach was by representing the occupant body geometrically in a CFD simulation studies.

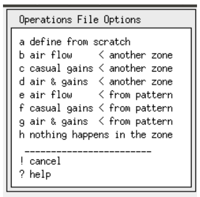
Four-office with different occupant heat load representation case study:

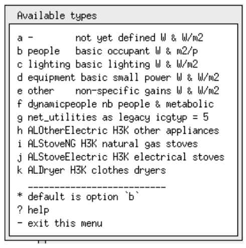
The model in the figure below shows four identical geometry and construction offices zones.

Each zone has a different occupant heat gain representation.

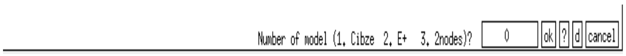


To define casual gains select your zone from zone operations selection 

Then choose to define from scratch 

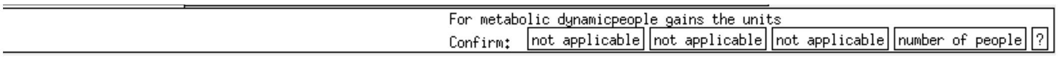
If you want to use the dynamic representation, choose option f. dynamicpeople 

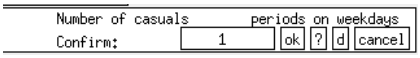
Then you will be asked to kindly choose between the three dynamic options as follow:

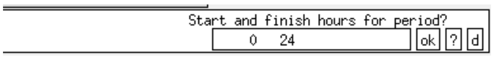


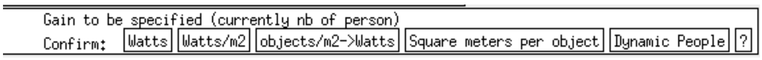
1. Is Cibze polynomial model to calculate sensible and latent, it is a regression line based on published data of sensible and latent loads from the occupant. Variables are operative temperature calculated in each zone and metabolic rate input.
2. The energy plus polynomial model similar to the previous approach but where the thermal body is always at steady-state.
3. The two-node model requires one more input which is the clothing insulation level in clo unit. It is based on energy balance equation.

Then you have to choose the unit which is a number of people, define the number of periods and start/finish hours as usual.



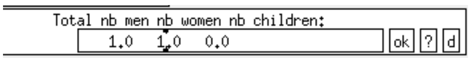




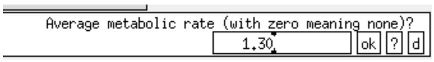


The gain type, in this case, will be Dynamic People. In the next stage, you will be asked to enter some inputs for each period defined as follow:

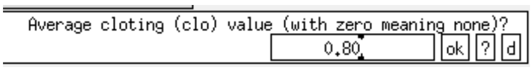
First, if there are people in the zone it is a real number gives flexibility in modelling, you can enter a number of men, women and children as required.



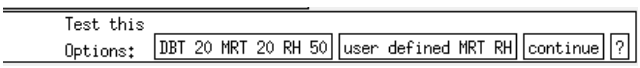
The second input is the metabolic rate/ activity level of the occupant for each period.



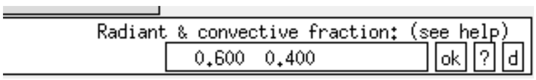
The third input is the clothing level it is only considered in the 2 nodes model.



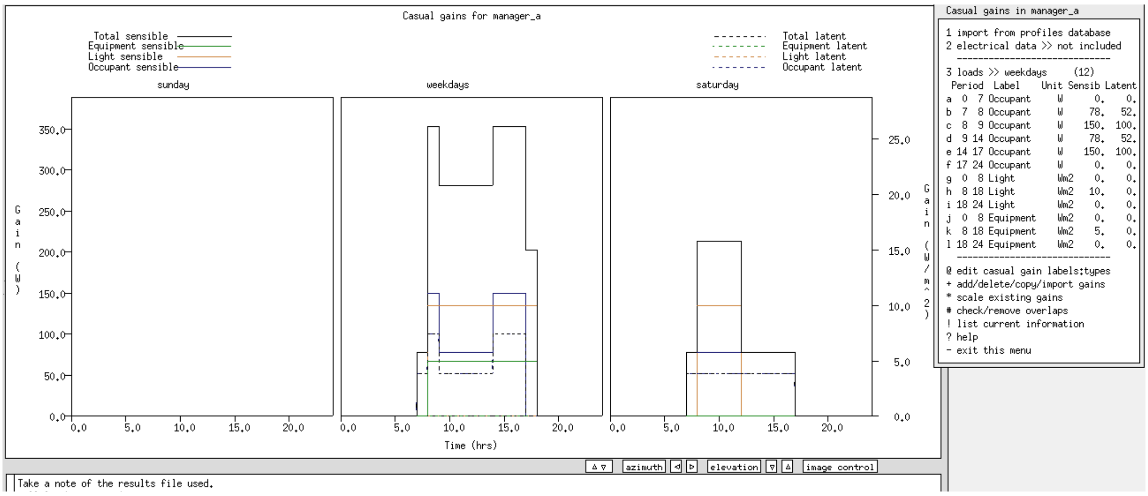
We can test occupant heat loads for specific temperatures before simulation start. The test is using the polynomial model only. Press continue if you do not want to test.



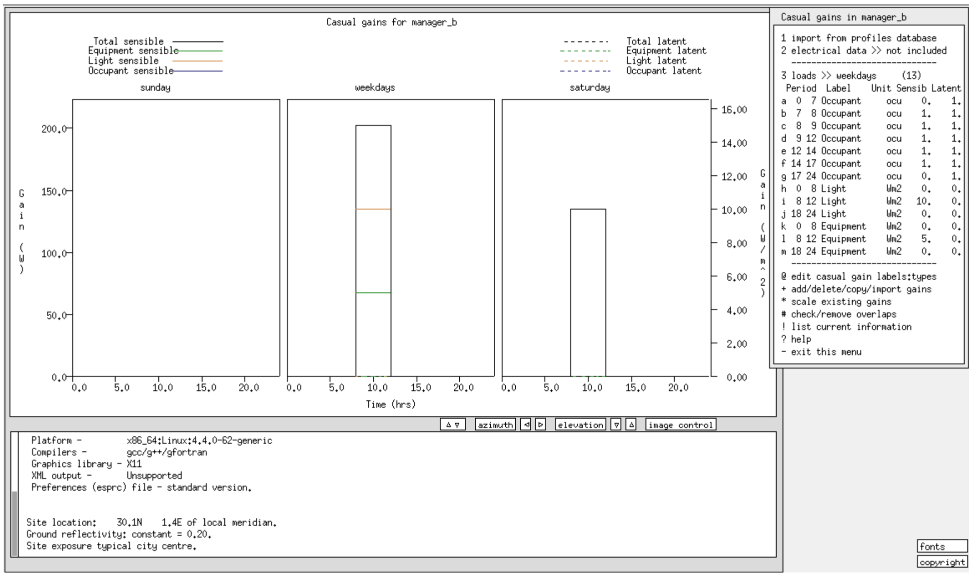
The fourth input is the radiative and convective fraction.



Casual gain will look like this in the case of constant heat loads



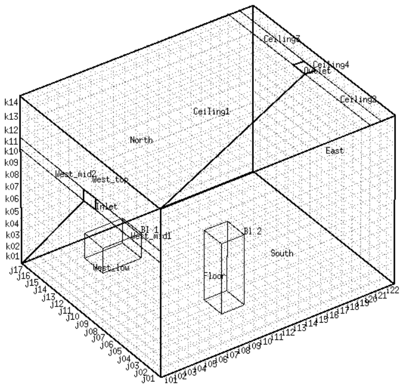
In case of dynamic people



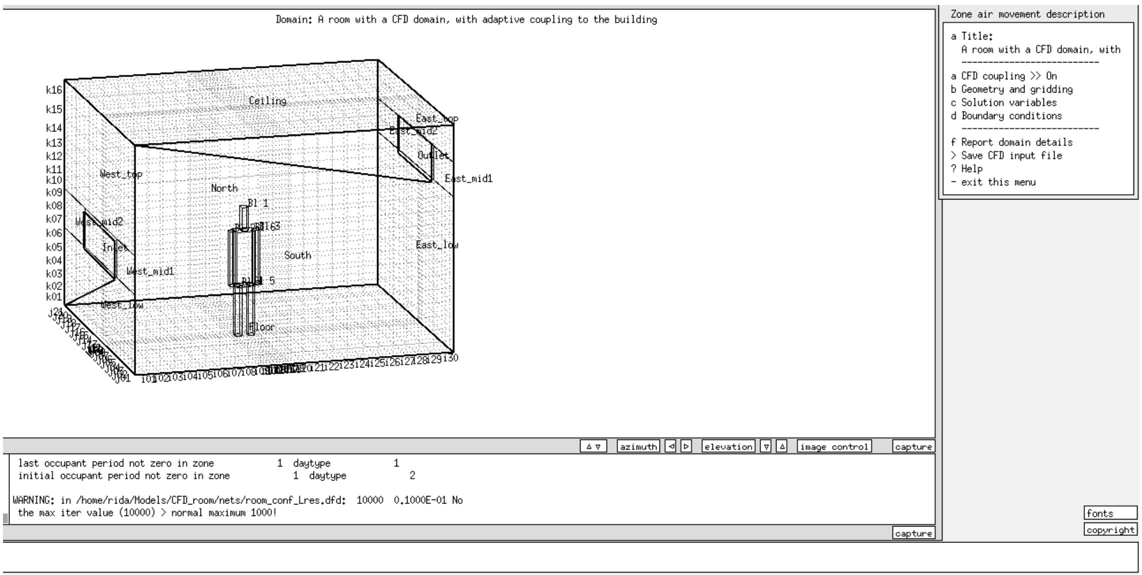
CFD Representation

An occupant in CFD could be represented simply as one blockage or as multiple one. ASHREA stated the average body surface area of an adult human body is 1.8m^2. Heat flux distribution on blockages will be calculated from the two-node model provided each iteration and updated each time-step.

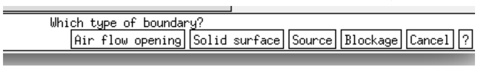
The figure below show a room with one blockage occupant.



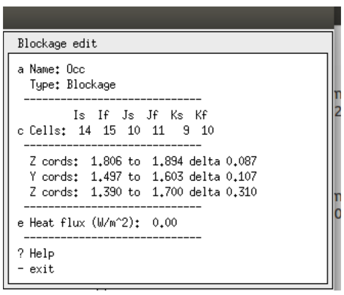
The model below represents the occupant body with six blockages representing the head, arms, trunk and legs.



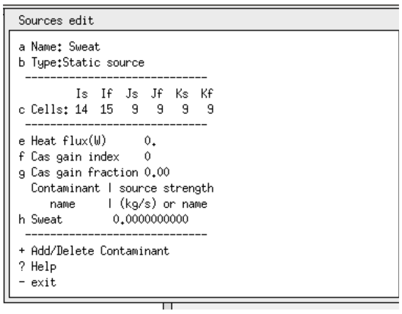
In order to have an occupant in a zone, we need to define a new Blockage the blockage name should have the letters 'Occ' followed by a number of multiple blockages.



Heat flux should remain zero as it values will be calculated directly from each time-step.

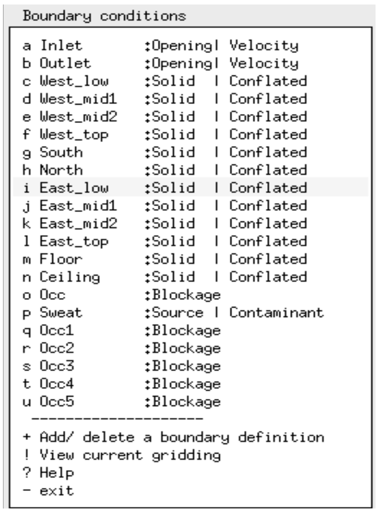


There is a capability to define the sweating emitted from the human body as a source of humidity. Simply define a new source name it 'Sweat' humidity source value will be calculated and linked to the cells defined.



```
Sources edit
a Name: Sweat
b Type:Static source
 -----------------------------
        Is  If  Js  Jf  Ks  Kf
c Cells: 14  15   9   9   9   9
 -----------------------------
e Heat flux(W)      0.
f Cas gain index    0
g Cas gain fraction 0.00
  Contaminant | source strength
     name     | (kg/s) or name
h Sweat        0.0000000000
 -----------------------------
+ Add/Delete Contaminant
? Help
- exit
```

The list of boundary condition used in the model presented in the figure below.



```
Boundary conditions
a Inlet       :Opening| Velocity
b Outlet      :Opening| Velocity
c West_low    :Solid  | Conflated
d West_mid1   :Solid  | Conflated
e West_mid2   :Solid  | Conflated
f West_top    :Solid  | Conflated
g South       :Solid  | Conflated
h North       :Solid  | Conflated
i East_low    :Solid  | Conflated
j East_mid1   :Solid  | Conflated
k East_mid2   :Solid  | Conflated
l East_top    :Solid  | Conflated
m Floor       :Solid  | Conflated
n Ceiling     :Solid  | Conflated
o Occ         :Blockage
p Sweat       :Source | Contaminant
q Occ1        :Blockage
r Occ2        :Blockage
s Occ3        :Blockage
t Occ4        :Blockage
u Occ5        :Blockage
 ---------------------
+ Add/ delete a boundary definition
! View current gridding
? Help
- exit
```

Appendix

Help text to be added in ESP-r

*****************Polynomial Occupant heat load model******************

We use a polynomial function to calculate the total sensible and latent load from an average young man. The function is based on the metabolic rate of occupant and zone operative temperature.

*******************HELP TEXT NB OF OCCUPANT************************

Number of men, women and children in a zone represent the average number of people inside a zone. It could be a fraction for a defined period.

NB: Heat load from average adult women is 85% of average adult men.

Heat load from a Child is 75% of average adult men.

*******************HELP TEXT FOR METABOLIC RATE*************************

The metabolic rate or occupant activity level is in the unit 'met' where 1 met= 58 w/m2. And the total heat from relaxed seated person is 58 w/m2*1.8m2=104w.

Below some typical metabolic rate in met for some activity.

Activity	met
1.Sleeping	0.8
2.Seated relaxed	1.2
3.Office work	1.4
5.Light activity(teaching,shopping..)	1.6
6.Medium activity	
(Shop assistant)	2.0
(Washing dishes)	2.5
7.Gymnastics	4.0

**************HELP TEXT CLOTHING INSULATION*********************

Clothing insulation are measured in unit 'clo'

Below are value for some ensemble of clothing and their insulation value.

Ensemble Description	Icl (clo)
1.Walking shorts, short-sleeved shirt	0.36
2.Trousers, short-sleeved shirt	0.57
3.Trousers, long-sleeved shirt	0.61
4.Same as above, plus suit jacket	0.96
5.Same as above, plus vest and T-shirt	0.96
6.Trousers, long-sleeved shirt, long-sleeved sweater, T-shirt	1.01
7.Same as above, plus suit jacket and long underwear bottoms	1.30
8.Sweatpants, sweatshirt	0.74
9. Long-sleeved pyjama top, long pyjama trousers, short 3/4 sleeved robe, slippers (no socks)	0.96
10.Knee-length skirt, short-sleeved shirt, panty hose, sandals	0.54
11.Knee-length skirt, long-sleeved shirt, full slip, panty hose	0.67
12.Knee-length skirt, long-sleeved shirt, half slip, panty hose, long-sleeved sweater	1.10
13.Knee-length skirt, long-sleeved shirt, half slip, panty hose, suit jacket	1.04
14.Ankle-length skirt, long-sleeved shirt, suit jacket, panty hose	1.10
15.Long-sleeved coveralls, T-shirt	0.72
16.Overalls, long-sleeved shirt, T-shirt	0.89
17.Insulated coveralls, long-sleeved thermal underwear, long underwear bottoms	1.37

Values are taken from ASHREA