Optimization of Energy Parameters in Buildings

By

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Submitted to the Department of Mechanical Engineering
In Partial Fulfillment of the Requirements for the Degree of
Bachelor of Science

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Abstract

When designing buildings, energy analysis is typically done after construction has been completed, but making the design decisions while keeping energy efficiency in mind, is one way to make energy-efficient buildings. The conscious design of building parameters could decrease or completely eliminate the need for Heating, Ventilation and Air Conditioning systems, and thus, optimizing building parameters could help conserve a great amount of energy.

This work focuses on two buildings – a passive solar house and an apartment in Beijing. The Beijing apartment is used to study natural ventilation in a space. Both buildings are modeled using EnergyPlus, and analyzed using VBA in Excel. The Genetic Algorithm Optimization Toolbox (GAOT) is used to optimize the parameters for the solar house. The program was run for 150 generations, with there being 20 individuals in each population. The optimized parameters for the solar house resulted in a mean internal temperature of 20.1 C, 7 C lower than that for randomly chosen parameters. The extreme temperatures in both cases were also markedly different, with the optimized parameters providing a more comfortable atmosphere in the house.

The apartment parameters were not optimized due to the inherent difficulty in quantifying an objective function. Through the simulation however, it was determined that each window has mass inflow and outflow occurring at the same time. In order to check that mass was conserved through the flow of air in and out of the apartment, the net flow in or out through each window had to be considered. This comparison did show the conservation of mass, which provided confidence in the EnergyPlus model used.

Thesis Supervisor: Prof. Leslie K. Norford
Title: Professor of Building Technology

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CHAPTER ONE
INTRODUCTION

1.1 Background

Energy is an expensive and scarce resource and the world will soon face an energy crisis if our dependence on the limited supply of fossil fuels continues. According to 2004 data from the US Energy Information Administration[1], about 40% of energy usage is devoted to buildings (residential and commercial) as seen in Figure 1. While some of this energy goes towards the use of electronic appliances used in these buildings, a significant amount (approximately 55% of total energy use[2] for each sector) goes towards space conditioning (heating and cooling) and lighting.

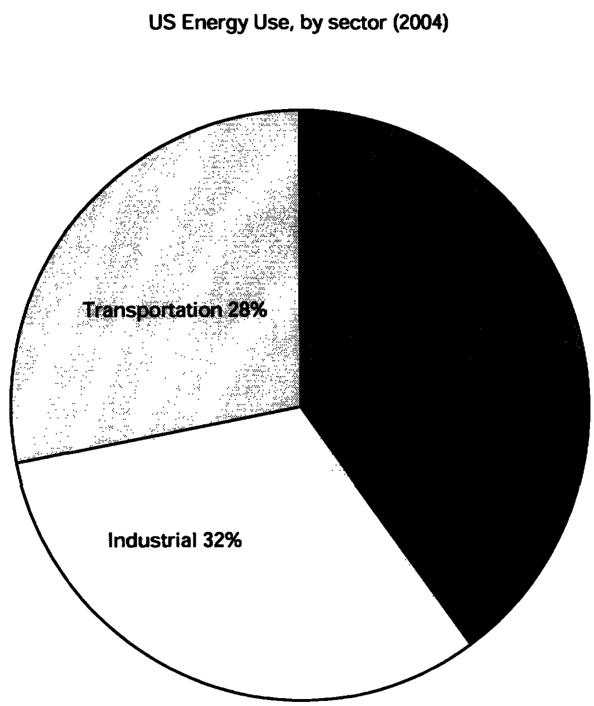

Figure 1: Pie-chart showing energy consumption by sector, for the year 2004, using data from the US Energy Information Administration.

When designing buildings, design decisions need to be made, and these decisions impact the energy consumption of the structure. Typically, energy analysis is done after construction has been completed, but making the design decisions while keeping energy efficiency in mind, is one way to make 'green' buildings. The conscious design of building parameters (such as window dimensions, doors, etc.) could decrease or completely eliminate the need for Heating, Ventilation and Air Conditioning (HVAC) systems. The energy analysis for a building can be done manually, but this approach is severely time consuming and expensive. Instead, one can use optimization programs to automate this process. The Genetic Algorithm Optimization Toolbox (GAOT) is used in this thesis to optimize the parameters for the buildings.

1.2 Overview

This chapter has briefly introduced the relevance of the optimization of energy parameters in buildings. Chapter 2 will physically describe the two buildings studied in this text – a passive solar house (referred to as an Elf House) and an apartment in Beijing, which was modeled to study wind-driven ventilation. Both buildings are studied in the course Building Technology Laboratory (course 4.411), taught by Professor Norford, and insight into these buildings could help future students optimize their models, thus gaining a better understanding of building physics. Chapter 3 will provide an in-depth explanation of the analysis structure of the programs used, and their linking mechanisms. The Genetic Algorithm Optimization Toolbox and the files used with it will be detailed. The chapter will also give a background on EnergyPlus, which is the software used to model the buildings.

The latter half of the thesis will focus on the simulations and results. Chapter 4 will focus on the Elf House. It will go over how to set up the EnergyPlus (E+) file, simulation, and genetic algorithm optimization results. Chapter 5 will be concentrated on the Beijing apartment, its EnergyPlus code, and simulation. Finally, Chapter 6 will present a conclusion to the thesis and offer possible courses of future study. There are several appendices at the end, which provide the code used for the models; they can be referred to for further information.

CHAPTER TWO
MODELS OF BUILDINGS

This chapter will provide a physical description of the two buildings analyzed in this thesis. Later chapters will go through the simulation and analysis of each of the buildings.

2.1 Elf House Specifications

The Elf House is a passive solar building, used in the course, Building Technology Laboratory (course number 4.411). Students build their houses to certain specifications and aim to design the house in such a way as to keep the internal temperature at 20 C around the clock. Performance is evaluated on the basis of deviation from this target.

Based on the specifications[3] used in the class, the elf house used in this thesis had the following specifications, as seen in Figure 2:

- Wall dimensions: 0.5 m x 0.5 m
- Floor dimension: 0.5 m x 0.5 m
- Construction material: rigid foam insulation, with a thermal absorptance of 0.9, a solar absorptance of 0.7, and a visible absorptance of 0.7. The R-value of the material (which depends on the thickness) was one of the variables optimized by the Genetic Algorithm (GA) with bounds between 2 and 5 m^2-K/W, though for the initial simulation, the value was taken to be 3 m^2-K/W.
- One window made of clear glass, on the east façade of the building. (For the characteristics of clear glass used, please see the text file in Appendix A). The height and width of the window was optimized by the GA, with bounds between 0.05 and 0.3 m each, though for the initial simulation, the value for each was taken to be 0.3m.
- Water as the internal thermal mass. The model assumed that the water was a layer of the construction above the floor, occupying the entire floor area. The height of the water was optimized by the GA, with bounds between 0.05 and 0.25 m, though for the initial simulation, the value was taken to be 0.25 m.

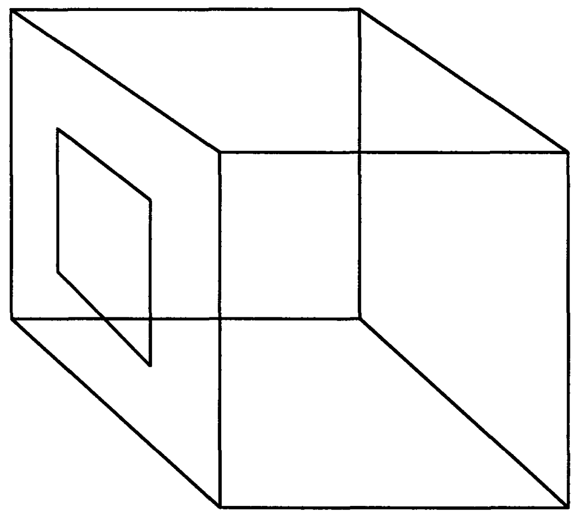

Figure 2: Model of Elf House used in initial simulation

The building was oriented due north, and the weather used for the simulation was that of Boston, MA.

2.2 Beijing Apartment Specifications

The Beijing apartment was another building modeled in the course, Building Technology Laboratory (course number 4.411). Students design their own balconies to append to a pre-built Beijing apartment model in order to maximize the natural ventilation through the house.

Based on the specifications[4] used in the class, the apartment used in this thesis as seen in Figure 3, had the following specifications:

- The apartment had a balcony at one end, connected to a living room, which then connected to two rooms, an east zone and a west zone. The balcony and the two rooms had one window each. A door connected the living room to the balcony, and the two back rooms to the living room.
- The height of the apartment was 3 m.
- Each room was 5 x 5 m.

- The living room was 4 x 10 m.
- The balcony was 3 x 10 m.
- The windows in the rooms were 2 x 1 m each.
- The balcony window was 4 x 2 m.
- The door connecting the living room to the balcony was 2 x 3 m.
- The doors connecting the living rooms to the back rooms were each 1 x 2 m.

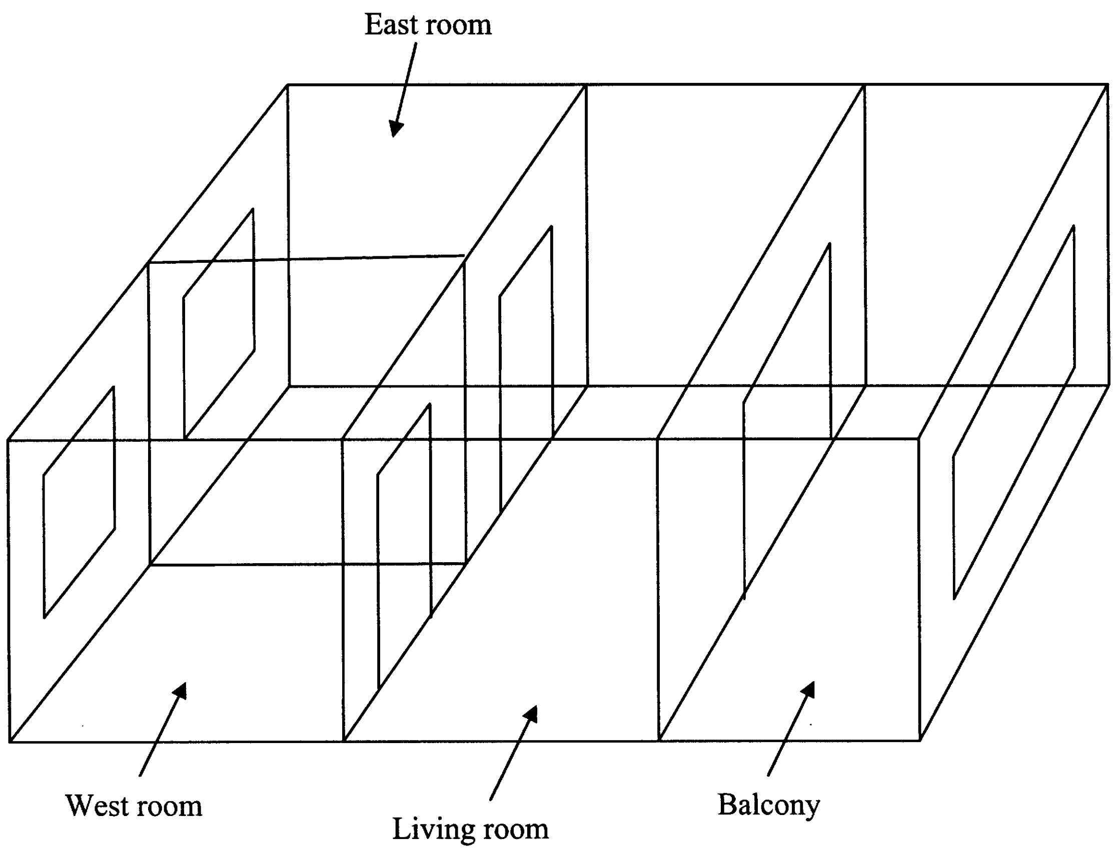

Figure 3: Model of Beijing apartment used for simulation.

CHAPTER THREE
ANALYSIS STRUCTURE

The optimizer used in this thesis is the Genetic Algorithm Optimization Toolbox (GAOT), which allows simulation in Matlab. There are several advantages of using genetic algorithms – they are generally applicable, require no function derivatives, and tend to avoid local minima. Hai-Yun Helen Xing, whose thesis,[5] focusing on building load control was used as a reference, also used a GA optimizer. The buildings were modeled using EnergyPlus (E+), and Excel was used to analyze the results of the GAOT simulation. All three programs in conjunction with one another were used to determine the optimal sizing of building parameters in order to decrease dependence on HVAC systems.

3.1 Genetic Algorithm Optimization Toolbox

The Genetic Algorithm Optimization Toolbox (GAOT) is a genetic algorithm implemented in Matlab, which uses a "survival of the fittest" strategy in determining better solutions. Starting with an initial population consisting of a certain number of individuals (either random or specified by the user), GAOT runs a simulation, and then determines the next population. Subsequent populations are generated by evaluating the current population using specified genetic operators that make up the reproduction function. The simulation is terminated after it has run for a particular number of generations that is specified by the user. Figure 4 summarizes a typical genetic algorithm[6]:

(1) Supply a population P_0 of N individuals and respective function values
(2) i ← 1
(3) P_i' ← selection_function (P_i – 1)
(4) P_i ← reproduction_function (P_i')
(5) evaluate (P_i)
(6) i ← i + 1
(7) Repeat step 3 until termination
(8) Print out best solution found

Figure 4: A simple genetic algorithm

For the Elf House, the deviation from a comfortable temperature was to be minimized, and so a Matlab file modified by Xing 'ga_min.m' was used. The flow chart in Figure 5 shows the way files linked to each other in the final model.

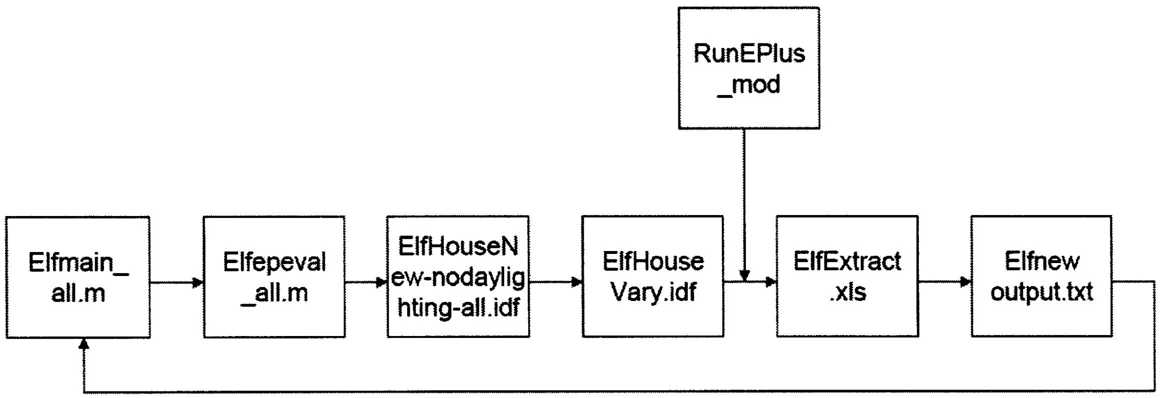

Figure 5: Flow chart showing how the different files refer and call on each other.

There were three files that needed to be modified for any changes in the model: Elfmain, Elfepeval and the EnergyPlus IDF file corresponding to them. In this Chapter, Elfmain and Elfepeval will be discussed, while the E+ IDF file will be explained in the next chapter.

3.1.1. Elfmain

This section is mainly a summary of the paper[7] on GAOT by Houck et al. For more information on the parameters, please refer to the paper. The file used in the Elf House simulation can be seen in Appendix B.

To set up the GA, the number of individuals in each population, and the number of generations in the simulation need to be specified, along with the operator functions. Operators provide the search mechanism of the GA, and are used to create new individuals based on existing individuals in the population. Each operator calls on a Matlab function in the GAOT folder. The use of the operators depends on the chromosome representation used. For binary representations, only binary mutation and simple crossover can be used, while for real-valued representations, any of the different operators defined below (except binary mutation) can be chosen. The specific commands are:

- num_of_gen

This specifies the number of generations that the software will run for.

- num_in_pop

    This specifies the number of individuals in each population.

- xFns

    This specifies the Crossover Operator. A Crossover takes two individuals from a population and produces two new individuals. The operators that can be chosen are arithXover, heuristicXover and simpleXover. arithXover refers to an arithmetic crossover which produces two complimentary linear combinations of the parents; heuristicXover refers to a heuristic crossover which produces a linear extrapolation of two individuals (and is the only operator that utilizes fitness information); and simpleXover refers to a simple crossover which creates two new individuals by generating a random number from a uniform distribution depending on the dimensions of the vectors denoting the parents.

- xOpts

    Each crossover operator needs an options matrix. For arithmetic crossovers, the options matrix is a row vector consisting of the number of the current generation and the number of arithmetic crossovers; for simple crossovers, the matrix is a row vector consisting of the number of the current generation and the number of simple crossovers; and for heuristic crossovers, the matrix is a row vector consisting of the number of the current generation, the number of heuristic crossovers, and the number of retries. The number of retries refers to the number of times the function tries to create a feasible solution.

- mFns

    This specifies the Mutation Operators for the algorithm. A Mutation alters one individual to produce a single new individual. The operators that can be chosen are boundaryMutation, multiNonUnifMutation, nonUnifMutation, unifMutation, and binaryMutation. boundaryMutation refers to a boundary mutation which changes one of the parameters of the parent randomly either to its upper or lower bound; multiNonUnifMutation refers to a multi-non-uniform mutation which changes all of the parameters of the parent based on a non-uniform probability distribution; nonUnifMutation refers to a non-uniform mutation which changes one of the parameters of the parent based on a non-uniform probability distribution; unifMutation refers to a uniform mutation which changes one of the parameters of the parent based on a uniform probability distribution; and binaryMutation refers to a binary mutation which changes each of the bits of the parent based on the probability of mutation.

- mOpts

Similar to the crossover operators, each mutation operator also needs an options matrix. For boundary mutations, the options matrix is a row vector consisting of the number of the current generation and the number of boundary mutations; for multi-non-uniform mutation crossovers, the matrix is a row vector consisting of the number of the current generation, the number of multi-non-uniform mutations, the maximum number of generations and the shape parameter, b; for non-uniform mutations, the options matrix is a row vector consisting of the number of the current generation, the number of non-uniform mutations, the maximum number of generations and the shape parameter, b; for uniform mutations, the options matrix is a row vector consisting of the number of the current generation and the number of uniform mutations; and for binary mutations, the options matrix is a row vector consisting of the number of the current generation and the probability of mutation.

- SelectFn

This refers to the selection function which determines what individuals survive and continue to the next generation. The ga function calls the selection function each generation after all the new children have been evaluated to create the new population from the old one. The different types of functions available are roulette, normGeomSelect and tournSelect. Roulette refers to the roulette wheel selection function with the probability of surviving equal to the fitness of the individual divided by the sum of the fitness of all individuals; normGeomSelect is a is a ranking selection function based on the normalized geometric distribution; and tournSelect refers to the tournament selection function which selects j individuals randomly, with replacement, from the population, and inserts the best of the j into the new population.

- selectOps

Each section function needs an options matrix. For roulette, the options matrix is a vector consisting of the number of the current generation; for normGeomSelect, the matrix is a row vector consisting of the number of the current generation and the probability of selecting the best individual; and for tournSelect, the matrix is a row vector consisting of the number of the current generation, and the number of tournaments.

- gaOpts

This is a vector of options, [**epsilon prob_param disp_param**]. **epsilon** is the change required to consider two solutions different; **prob_param** should be 0 if the binary version of the algorithm is being used, or 1 if the float version is being used; and **disp_param** controls the display of the progress of the algorithm, such that 1 displays the current generation and the value of the best solution in the population, while 0 prevents any output during the run.

- bounds

This row vector specifies the upper and lower bounds on the variables being changed by the GA during the simulation. For each variable, a lower bound must be specified followed by an upper bound; a semi-colon should separate the upper bound of one variable from the lower bound of the next variable. In the Elfmain_all file, the first bound refers to the R-value of the construction material (rigid foam), the second to the height of the water at the base of the Elf House, the third to the height of the window, and the fourth to the width.

- evalFn

This represents the evaluation function used by the GA, subject to the minimal requirement that the function can map the population into a partially ordered set. In the case of the Elf house, this function is the Elfepeval function which is discussed in Section 2.1.2.

- evalOps

This represents the row matrix of any parameters to the evaluation function.

- bounds

This specifies the bounds on the parameters to be optimized. In the Elfmain file, the R-value of rigid foam is bounded between 2 – 5 m^2-K/W (corresponding to a thickness of between 5.8 – 14.5 cm for a conductivity of 0.029 W/m-K), the height of the water is between 0.05 – 0.4 m, and the height and width of the window are between 0.05-0.3 m.

3.1.2. Elfepeval

This is the evaluation function that is called on by the Elfmain m-file. It evaluates the fitness of each solution, and must be changed each time the GA is used to optimize another problem. The specific commands that are typically changed are discussed below. To see the file used in the simulation, please refer to Appendix C.

- cd C:\EnergyPLusV1-3-0\ExampleFiles

  This changes the current Matlab directory to the directory where the E+ file is saved.

- dos('copy ElfHouseNew-nodaylighting-all.idf ElfHouseVary.idf');

  This copies the file specified first (ElfHouseNew-nodaylighting-all.idf) to the second file (ElfHouseVary.idf).

- file_id=fopen('ElfHouseVary.idf','A');

  This opens the ElfHouseVary.idf file and 'renames' it file_id for the purposes of reference in Matlab.

- fprintf(file_id,'\n %s ', 'Material:Regular-R, R-15 Pink Foam, Rough');

  This creates an entry in the text file for the rigid foam. Each new line in the text file is separated in the Matlab code by a comma, and there should be as many parameters as spaces in the IDF editor. When the parameter to be optimized is the next parameter that needs to be inserted in this string, a new command is used, and the string is resumed after. The \n in the command denotes linefeed, and the %s denotes a string of a characters. For more information on the fprintf command, please refer to the Matlab help menu.

- for i=1
fprintf(file_id, '%s%f', ',', sol(i));
end

  This loop generates the first solution for the parameter to be optimized, in this case the R-value of rigid foam. The %f denotes a form feed.

- fprintf(file_id,'\n %s ', '0.9, 0.7, 0.7;');

  This completes the insertion of parameters into the object for the E+ text file. The end of an object must be denoted by a semi-colon.

- fclose(file_id);

  This closes the current file.

Similarly, each object that has a parameter to be optimized is defined in this way so that the text file has all the relevant parameters. Appendix C shows the Elfepeval file, and has optimizations for the R-value of the foam, height and width of the window, and thickness of the thermal mass.

- cd C:\EnergyPlusV1-3-0

This changes the directory back to the EnergyPlus directory.

- dos('runeplus_mod ElfHouseVary Boston');

This runs the ElfHouseVary file with the weather data being used from Boston. This can be done since all the missing objects (that have optimizable parameters) have been previously defined in the m-file.

3.2 EnergyPlus

EnergyPlus is a building energy simulation program for modeling building heating, cooling, lighting, ventilating, and other energy flows. It is being developed by the government based on its predecessors, BLAST and DOE-2, and has undergone extensive testing to ensure that the internal models are reliable. E+ uses text-based inputs and outputs, which make it easier to analyze the data using Excel.[8] Figure 6 shows the IDF editor for E+ which uses text inputs but has a more user-friendly, organized interface.

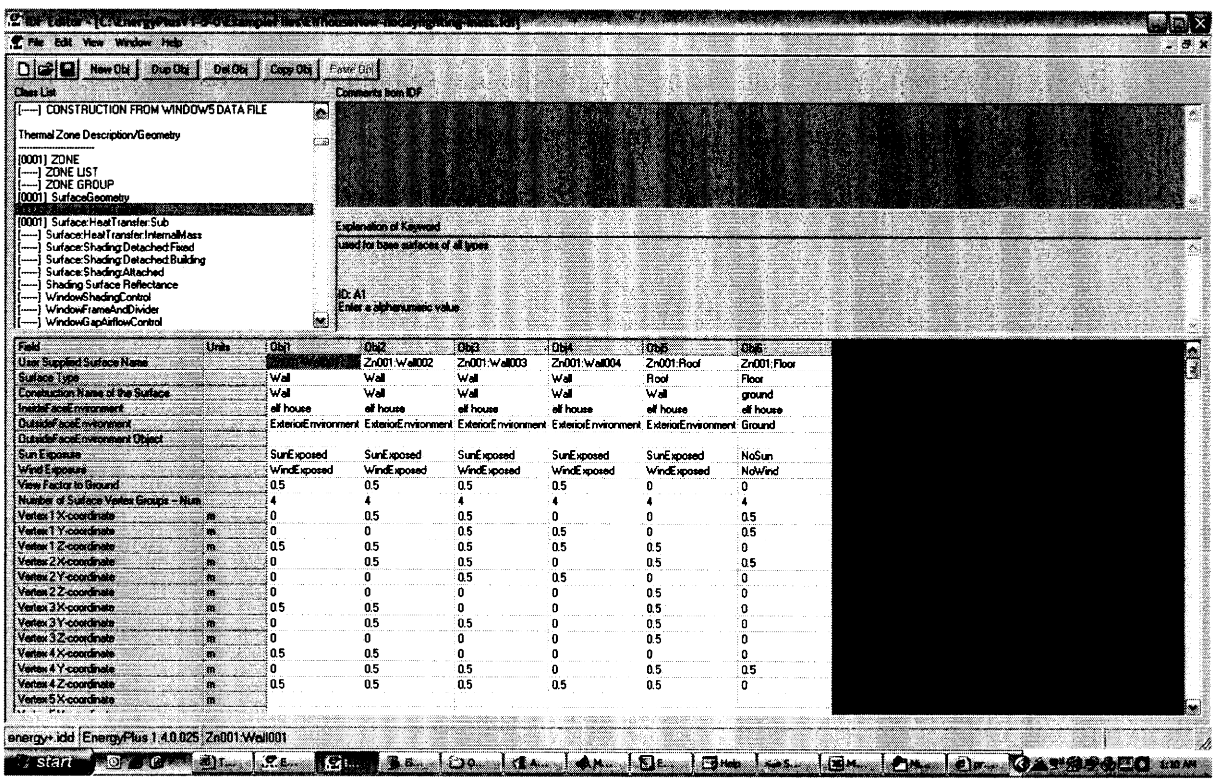

Figure 6: A screen image of the IDF file in E+.

To model a building in E+, certain conventions must be followed. Zones must be defined, corresponding to spaces defined by surfaces. Materials and material properties can be specified or looked up from the E+ database for each surface. The normal for each surface should be pointing outwards, and the coordinate system for each surface must be consistent throughout the model. HVAC equipment and schedules for equipment, occupancy, etc. can also be specified. Weather data for the desired location can be downloaded from the EnergyPlus website, and should be used for the simulation. The general organization of E+ can be seen in Appendix D, which shows each main field, followed by the sub-fields used in the two models in this thesis.

3.3 Excel

Excel was used to analyze the data, by calculating the mean temperature and the sum of the squares of the deviances for each individual of the population from the desired temperature of 20C. The GA tried to minimize the sum of the squares of the deviances. Macros were written using Visual Basic for Applications (VBA) so that Excel could perform these calculations by itself, and the programs could iterate towards the best solution without requiring any instructions. The Macro file is in Appendix E for further reference.

CHAPTER FOUR
ANALYSIS OF THE ELF HOUSE

4.1 Creating an EnergyPlus model

In order to check that EnergyPlus was simulating the model satisfactorily, the temperature output was compared with that of SolarCalculator, a file used by Professor Norford in his class, Building Technology Laboratory.[9] SolarCalculator is a spreadsheet that performs a transient thermal analysis of a single thermal zone represented as a lumped-parameter model. Shauna Jin's notes and examples on EnergyPlus were used to understand the fundamentals of the software, and a working model of the 0.5m x 0.5m x 0.5m Elf House was created as seen in Figure 2. This house had one window (dimensions 0.3m x 0.3m on the south-facing wall), and the eventual goal was to optimize this building's parameters, while keeping the interior temperature as close to 20 C as possible.

The mean air temperature for a week in October was simulated and compared for both cases. The results of both models can be seen in Figures 7 and 8. The two models did not give similar internal temperatures, but there are several reasons as to why this might have occurred. While the external temperature in SolarCalculator was changed to mimic the E+ external temperature, the solar heat gain factors were not, and neither was it determined what the cloud cover in the E+ weather file was. Due to these factors, the two results were dissimilar.

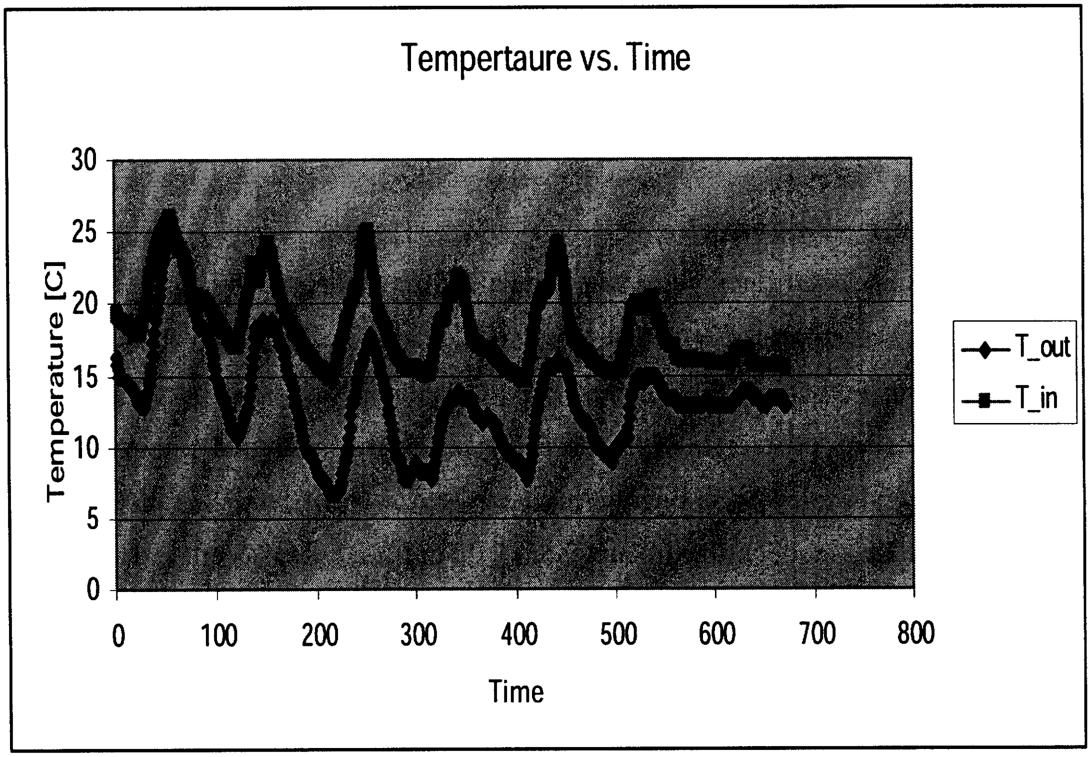

Figure 7: Graph showing the internal and external temperatures after simulation in E+.

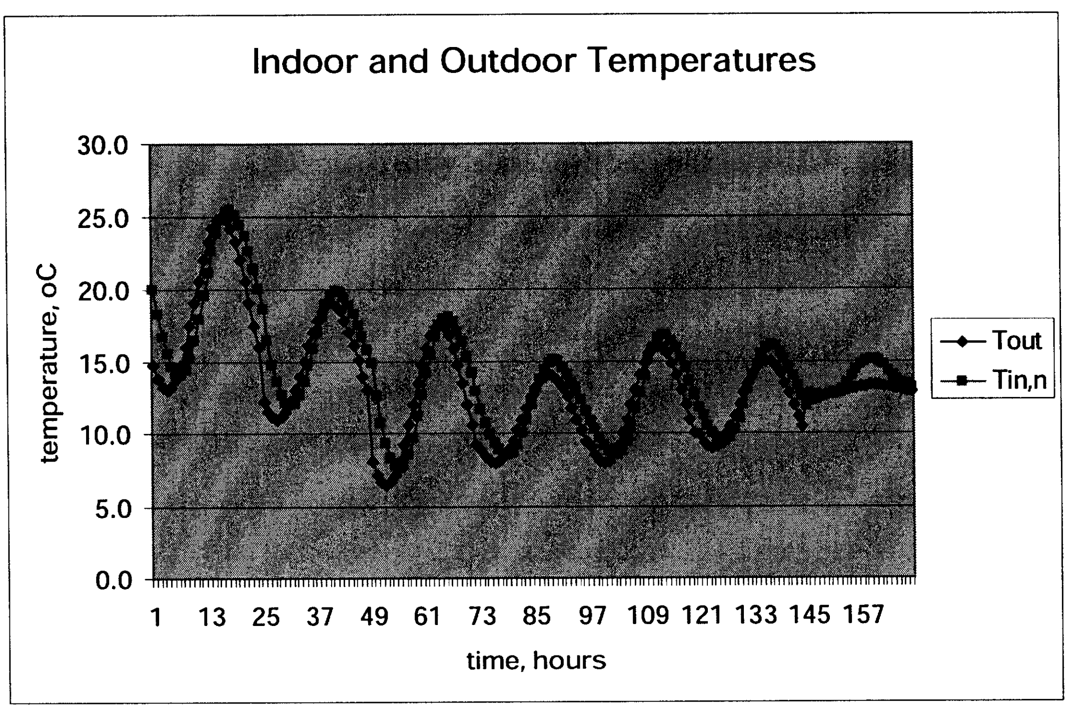

Figure 8: Graph showing the indoor and outdoor temperature from simulation in SolarCalculator.

However, the results from E+ were not absurd either. It seemed that the large amounts of thermal mass (water) in the model might have caused the offset between the internal temperature and the external temperature in the E+ file. Therefore, having obtained some confidence in the E+ program, we used the Genetic Algorithm Optimization Toolbox to determine the optimal parameters of the window, the thickness of the insulation and the height of the thermal mass in the building.

Something interesting to note here is that though the optimization did not focus on the location of the window, the model showed that the façade that the window is on, also makes a significant difference in the internal temperature. Figure 9 shows the indoor and outdoor temperature for the same week with the window on the east façade. Comparing this figure with figure 7, it is seen that the east façade window has a higher mean and a higher variance.

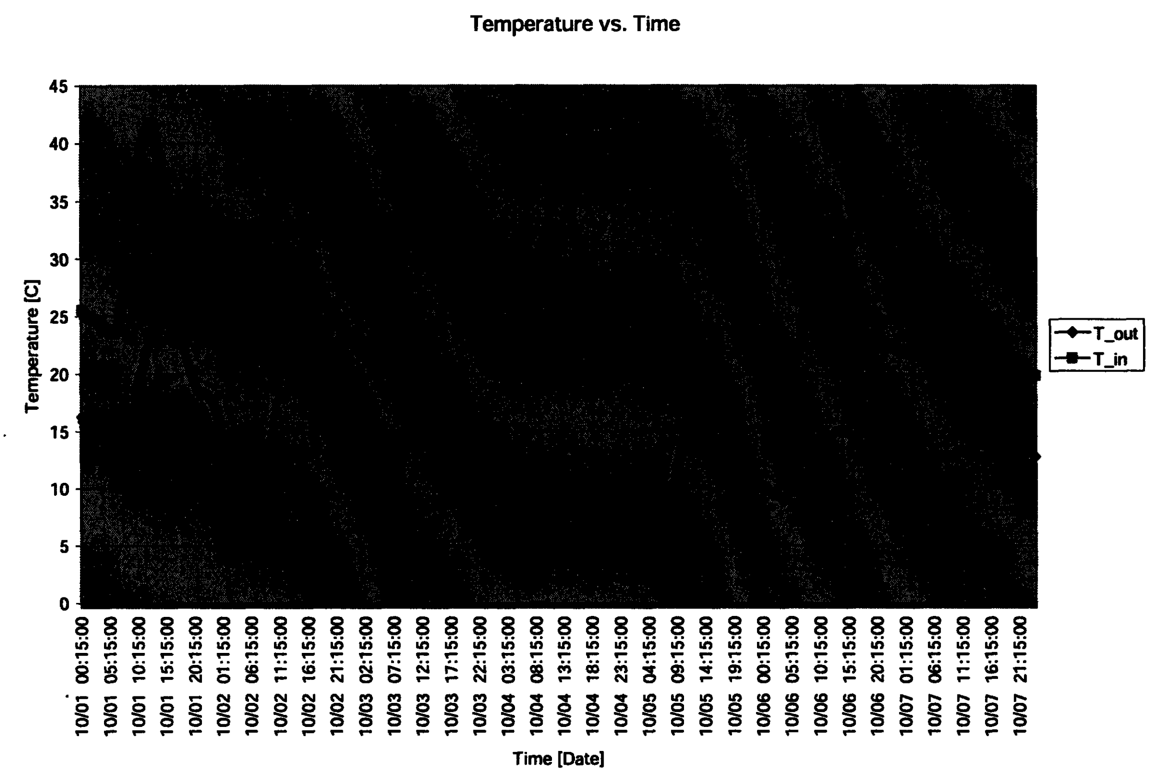

Figure 9: Graph showing temperature versus time for a window on the east façade. The mean internal temperature is much higher than that for the case of the window on the south façade, and has a much higher variance as well. This shows that it is not the dimensions and material of the window that matters, but also its location.

4.2 EnergyPlus IDF file

Some of the parameters that were modified most often for each file are explained below. The explanations are summaries of the Input Output reference[10] documentation that can be downloaded with E+. For further information on a particular command, please refer to the documentation. Please refer to Appendix A for the text file used in E+ to model the Elf House.

<u>Simulation Parameters</u>

- Run Control

  This specifies what simulations and calculations will be performed by E+. Design day simulation refers to the design days that can be specified under 'DesignDay' in "Location – Climate – Weather File Access" while weather file simulation refers to the dates specified under 'RunPeriod' in "Location – Climate – Weather File Access".

<u>Location – Climate – Weather File Access</u>

- RunPeriod

  This is used to specify what dates E+ should run the simulation for. Under 'Day of Week for Start Day', it is recommended to 'UseWeatherFile' since that will give the most accurate results.

- DesignDay

  This is used for any specific design days that you want E+ to run. It is most frequently used to calculate load sizes and size equipment.

- GroundTemperatures

  These are typically from the weather file, but can be changed depending on the particular location of the building.

<u>Surface Construction Elements</u>

This specifies the different materials used to construct the various layers for the walls, windows, roof and floor of the building.

- Material:Regular

This specifies opaque materials and is used when the four main thermal properties (thickness, conductivity, specific heat, and density) are known. Since water was used as thermal mass in the Elf House, and modeled as a layer of the floor, its properties were input. The thickness of the layer of water however, was one of the parameters that was to be optimized, and hence, this parameter was 'commented out' in the E+ text file, but was used in the Elfepeval file, which is discussed in the next section. (To comment out a parameter, exclamation points '!' are inserted before the value in the text file.) The properties of water that were used were: 0.61 W/m-K for conductivity, 1000 kg/m^3 for density, 4186 J/kg-K for specific heat, 0.9 for thermal absorptance, 0.7 for solar absorptance and 0.7 for visible absorptance.

- Material:Regular-R

Also used for opaque material, this object is used when only the thermal resistance (R-value with units m^2-K/W) of the material is known. Since the Elf House was constructed of rigid foam, for which the thermal resistance was known, its properties were inserted. The thickness of the walls (which affected the thermal resistance) however, was a parameter to be optimized, and hence, this parameter was commented out in the E+ text file. The other properties of the foam that were used were: 0.9 for thermal absorptance, 0.7 for solar absorptance and 0.7 for visible absorptance. The properties of different materials, used in the construction (say for a multi-layered wall, or the floor), can be entered by clicking on New Object towards the top of the screen. For the same material in series, the thermal resistance values can just be added.

- Material:WindowGlass

This specifies the material for the window. Data on different window materials can be obtained from the Windows5 program[11]. For a multi-layered window (for example, 3 mm clear glass – air gap – 6 mm clear glass, the properties for the different types of glass would be input under different objects here, and 'Material:WindowGas' would be used for the properties of air (or the gas between the panes of glass). For the Elf House, the properties of clear_glass can be found in the E+ text file in Appendix A.

- Construction

This defines the different layers that make up the walls of the house. In the Elf House, the wall is just made of 1 layer of rigid foam, but in case of more than one layer, the outside layer is specified first, and then the inner layers. The ground and window layers are also defined as seen in Appendix A.

Thermal Zone Description/Geometry

- Zone

This defines each thermal zone of the building, along with the relative north for the Elf House, and its origin. Though counter-intuitive, it is easier to leave the 'ceiling' and 'volume' values as zero, since if the value is zero, E+ will automatically calculate the value from the coordinates of the surfaces that will be entered later.

- SurfaceGeometry

This defines the coordinate system being used. The Elf House has all its surfaces starting at the upper left corner with the normal pointing outwards, and subsequent vertices defined in a counterclockwise direction. These settings could be changed, but care must be taken to redefine all surfaces (walls, roof, floor and windows) using the specified coordinate system. The WorldCoordinateSystem requires all values to be absolute.

- Surface:HeatTransfer

All the surfaces of the building are defined here, as shown in Appendix A where the four walls, roof and floor are defined to create a 0.5m x 0.5m x 0.5m elf house. The 'View Factor to Ground' is zero for the roof and floor since the ground is not seen from either of the surfaces (if one was lying back down on them). For the walls, a value of 0.5 is chosen.

- Surface:HeatTransfer:Sub

Any windows in the elf house need to be specified here. The example has one window on the east facade, but the height and width of the window are optimized, which is why this category is commented out in the text file. The window is specified to have the lower left coordinate at (0.125m, 0.125m).

- Surface:HeatTransfer:InternalMass

This specifies the surface area that the internal thermal mass sees. If the water is on the floor of the house, simply enter the floor surface area, which is 0.25 in the example.

Report

- Report Variable

Changes to the output variables can be made here. To change a variable, click on an existing object, and the available variables can be selected from the list.

4.3 Results

The model was run through GAOT for each population in 150 generations. Each population consisted of 20 individuals, and the model was simulated from October 1 to October 7. Figures 10 and 11 show the sum of the square of the deviation from the desired 20 C temperature in the house. Simply adding the deviations was not an ideal fitness function since a large variation above and below 20 C could end up having no net effect on the fitness value. However, squaring the deviations caused the value to always be positive, and therefore, minimizing this function would give the optimal solution. The best population was with R = 2.5288 m^2-K/W, thickness of water = 0.2131 m, height of window = 0.0877 m, and width of window = 0.1426 m. These parameters gave the lowest sum of the squares, 2572.43.

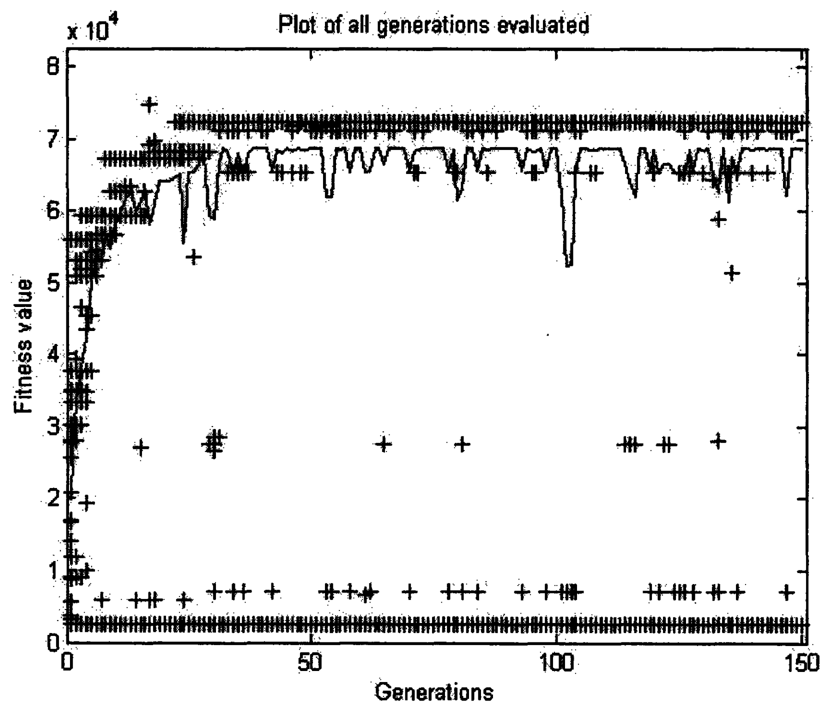

Figure 10: Graph showing the output from the simulation with each population over 150 generations.

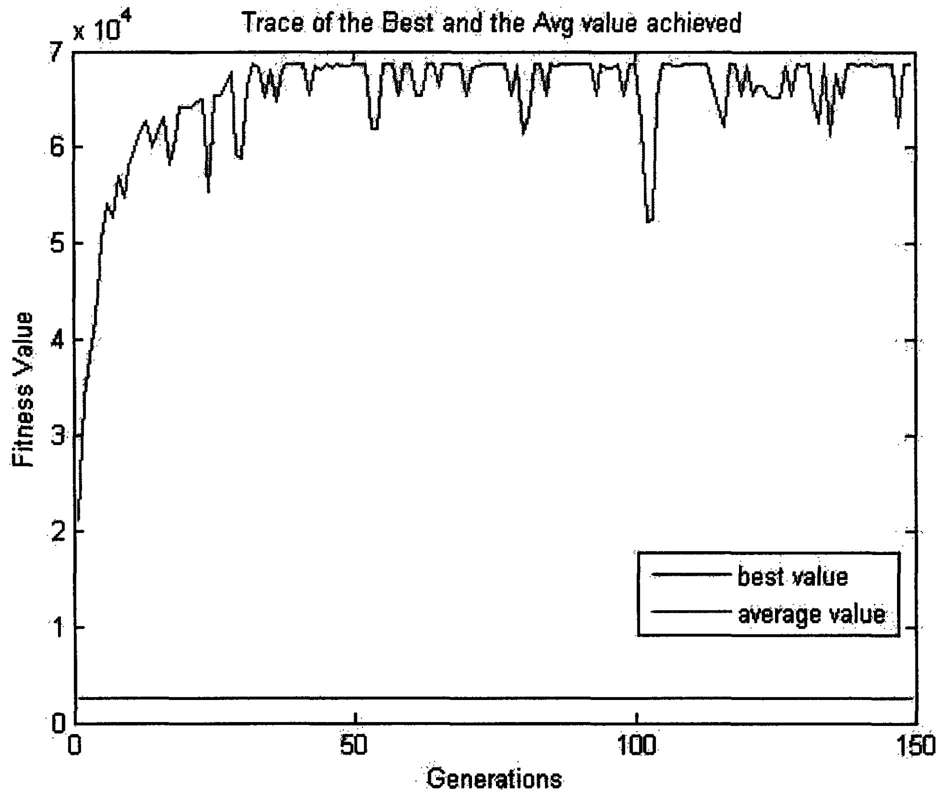

Figure 11: Graph showing the best value in each generation, and the average value in each generation.

The range in the fitness value due to varying parameters shows that optimizing the parameters before construction can lead to desired temperatures in the building. It is seen by comparing the best population for the Elf House with the other individuals in the GA, that the optimized parameters can make a significant difference in the fitness value. Figure 12 shows the temperature versus time graph for the best parameter model:

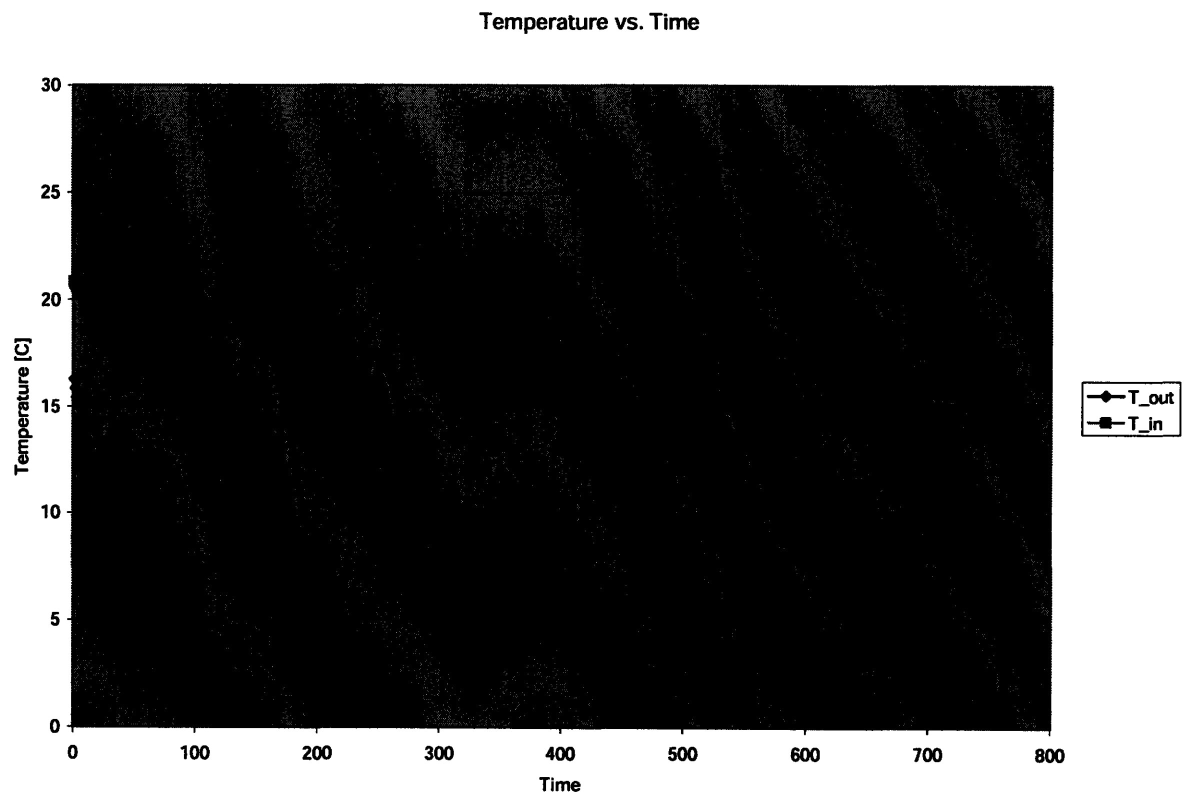

Figure 12: Results for the best parameters in the Elf House.

This was simulated for an east-facing window, and comparing this graph to that in Figure 9 shows a remarkable difference. The optimized result had a mean internal temperature of 20.1 C while the result of the randomly picked parameters had a mean internal temperature of 27.0 C. 21 C can be considered pleasant while an average of 27 C is bordering on warm. The extreme temperatures in the two cases are also remarkably different – the optimized case has a high of 27.4 C and a low of 16.4 C, while the case with the randomly chosen parameters has a high of 41.8 C and a low of 19.9 C.

CHAPTER FIVE
ANALYSIS OF THE BEIJING APARTMENT

5.1 EnergyPlus IDF file

Some of the parameters that were modified most often for each file are explained below. The explanations are summaries of the Input Output reference[12] documentation that can be downloaded with E+. For further information on a particular command, please refer to the documentation. (The parameters already explained in Section 3.2.1 will not be documented again.) The text file used for the Beijing apartment can be seen in Appendix F.

Surface Construction Elements

- Material:Regular

  This specifies opaque materials and is used when the four main thermal properties (thickness, conductivity, specific heat, and density) are known. Several different materials were specified and their values were obtained from the E+ example file, AirflowNetwork3zVent.idf. For a list of the materials defined and their properties, please refer to Appendix F.

- Material:WindowGlass

  This specifies the material for the window. A single layer window was used for the Beijing apartment, whose properties can be looked up in Appendix F.

- Construction

  This defines the different layers that make up the walls of the house. Each surface in the apartment is made up of different layers, defined from the outside towards the inside. The doors were made of 1.375" solid core; the exterior walls consisted of 1" stucco, 4" common brick, and 1.75" plaster or gyp board; the partitions consisted of 1.75" plaster or gyp board, 8" clay tile, and 1.75" plaster or gyp board; the floor slab was made of 8" concrete; the roof consisted of 2.5" slag or stone, 3.375" felt and membrane, 1" dense insulation, and 2" concrete; and the window consisted of the glass defined earlier.

Schedules

- ScheduleType

This is used to validate portions of other schedules. The field 'range' specifies the bounds for the schedule values. The 'numeric type' field indicates how the range values are validated – they are either 'continuous' where any numbers (including fractions) within the range can be inserted, or they are 'discrete' which only allows for integers. In the case of the Beijing apartment, the objects were Any Number, Fraction, Temperature and Control Type. Any Number meant the user could specify any number, Fraction meant that the value needed to be between 0 and 1, Temperature defined a range within which the value could be chosen, and Control Type allows for integer values between 1 and 4.

- Schedule:Compact

This incorporates all the schedule components, but values must be specified for every day in a year. The ScheduleType field refers to the ScheduleType objects defined earlier (Any Number, Fraction, Temperature, or Control Type). There is a sequence associated with the complex fields, since each compact schedule must include the date until which the schedule applies ('Through'), the number of days the schedule applies for ('For'), the time of day the schedule applies to ("Until") and the value associated with the schedule ("Value"). Each of these fields in the sequence is entered on a new Complex Field line. For example, a multiple value schedule might look like (semi-colons signify a new line): "Office occupancy; Fraction; Through: 12/31; For: AllDays; Until: 9:00; 1; Until 18:00; 0.5". For the specific schedules related to the Beijing apartment, please refer to Appendix F.

Internal Gains (People, Lights, Other internal zone equipment)

- People

This models the occupant's affect on the conditions inside the space. The number of people and their different schedules (AirVelocity, Clothing Schedule, etc.) can be specified.

- Lights

This specifies what the thermal effects of lights in the space are. A zone and a schedule are defined along with the design level (maximum electrical power input in Watts). The fraction of long-wave (thermal) radiation heat given off by the lights, and the short-wave (visible) radiation given off is also inserted.

- Electric Equipment

This specifies what the electrical equipment in the space is. A zone and a schedule are defined along with the design level (maximum electrical power input in Watts). The fraction of latent heat given off, the radiant heat given off and the heat lost by the electrical equipment is also inserted.

Airflow Network System

- AirflowNetwork:Multizone:Surface

This specifies the opening, and associates an opening factor with it. A value of 0 denotes that the opening is closed, and 1 implies that the window is fully open. For the Beijing apartment, each opening factor was set to 0.5, which means that the 'open' area of the window or door was half the total area.

- AirflowNetwork:Multizone:Site Wind Conditions

This specifies the properties of the wind close to the building. Separate wind conditions should be used for wind in different directions.

- AirflowNetwork:Multizone:External Node

This specifies the name of the external node, and the height which it is located at.

- AirflowNetwork:Multizone:Wind Pressure Coefficient Array

This specifies the reference height and wind directions.

- AirflowNetwork:Multizone:Wind Pressure Coefficient Values

This specifies the values associated with the wind pressure coefficient array defined earlier. Each node has its own wind pressure coefficient values corresponding to the wind pressure coefficient array.

5.2 Results of Simulation in E+

The simulation showed that the mass of the air flowing into the apartment is always equal to the mass flowing out. This was reassuring since mass must always be conserved, and there could not be an accumulation of air inside the apartment. There was however, an interesting discovery. At a given point in time, there is air flowing in and out of the window. Hence, when we compared the mass flow rates in the output file, we could not just compare, for instance, mass flow from Node 1 to 2 through the balcony with the sum of the mass flows from Node 2 to 1 through the east and west windows. The net mass flow through each window had to be calculated and then used for purposes of a comparison. An Excel file showing the partial results (for October 1st) and analysis of the simulation of the Beijing apartment can be seen in Appendix G.

5.3 Problems with Optimization

The Beijing apartment was not optimized with GAOT due to several reasons. First, natural ventilation is trickier than passive solar heating, in that it is hard to come up with an objective function that is to be maximized or minimized. In the case of the Elf House, it was desired that the temperature be as close to 20 C as possible, no matter what the external temperature was; in the case of the Beijing apartment however, wanting to maximize the airflow through the space did not seem to be a satisfactory objective function. The desire to maximize airflow through a space could be satisfied by having as large windows as possible, and that was intuitively obvious. A more interesting objective function could have been to find the optimal schedule for the windows i.e., when they should be opened and when they should be closed. However, E+ has inbuilt control algorithms to perform this venting of the space on the basis of temperature. If the internal temperature was below a certain value, or if the external temperature was above a certain value, the ventilation would be turned off, and in the case of it being too hot in the apartment, or 'cool' outside, the windows would be opened. This night ventilation is commonly used by people, who leave their windows open at night when it is cool, and close them during the day to keep the hot air out. However, one way of using an optimization on the apartment would be to help consumers weigh the different costs of the building: a bigger balcony might mean a higher construction cost, but this could be offset by the lower operating costs of HVAC systems. Costs, however, are very complex, and this problem could be taken up by interested parties. This thesis provides a test bed for future work in this area, by providing a successful model of air flow through a space.

CHAPTER SIX
CONCLUSIONS

This chapter will present a summary of the work and provide some thoughts on future work that could be done, using GAs and E+.

6.1 Conclusions

Optimized parameters can be very useful in designing energy-efficient buildings as they decrease dependence on HVAC systems, keeping the internal conditions pleasant. The location of the window on a particular façade has a significant effect on the internal temperature of the building. As is seen in the comparison between Fig 11 and Fig 5, the optimized parameters make a significant difference in the temperature within the house. With the optimized parameters, the mean internal temperature was 20.1 C, while the randomly chosen parameters gave a mean internal temperature of 27.0 C. 21 C can be considered pleasant while an average of 27 C is bordering on warm. The extreme temperatures in the two cases are also remarkably different – the optimized case has a high of 27.4 C and a low of 16.4 C both of which sound bearable, while the case with the randomly chosen parameters has a low of 19.9 C and a high of 41.8 C, which is undoubtedly worse.

Optimizing natural ventilation parameters was more challenging due to the problems associated with generating an objective function to maximize or minimize. However, the simulation helped conclude that at a given point in time, each window had mass flowing in and out of it, and it was the net mass flow in and out that needed to compared. This comparison showed that the total mass in the system was always conserved, which built confidence in our model.

6.2 Future Work

The Elf House model is a very simple model; future work could include modeling a full-scale house, with several windows. A longer or different design period could also be chosen to give a broader sense of what happens through the year, rather than just during a week. The methodology of replacing chunks of E+ code in Matlab with parameters generated by the GA is a good one, because E+ is text based. Even with more complicated models, as long as this methodology is followed, the GA should work, and output optimized energy parameters.

While it seems obvious that larger windows would imply a greater flow rate through the space, it would be more beneficial to be able to schedule the opening of the windows with respect to the indoor and outdoor temperature. E+ has inbuilt control algorithms for this, and it would be interesting to do some more work on it, and maybe determine the optimal temperature at which the scheduling would take place. Another factor that could be considered is the cost associated with a larger window opening as opposed to lower operating costs of HVAC systems.

REFERENCES

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[8] http://www.eere.energy.gov/buildings/energyplus/ <viewed on May 08, 2007>

[9] Professor L. Norford, Building Technology Laboratory assignments, Fall 2004.

[10] Input Output Reference, EnergyPlus

[11] The Windows5 program can be downloaded from
http://windows.lbl.gov/software/window/window.html .

[12] Input Output Reference, EnergyPlus

Appendix A   ElfHouse Code

```
!-Generator IDFEditor 1.27 'current version of IDFEditor - less than 1 is a
beta

!-NOTE: All comments with '!-' are ignored by the IDFEditor and are generated
automatically.
!-      Use '!' comments if they need to be retained when using the
IDFEditor.


!-   ===========  ALL OBJECTS IN CLASS: VERSION ===========

VERSION,
    1.4;                     !- Version Identifier


!-   ===========  ALL OBJECTS IN CLASS: BUILDING ===========

BUILDING,
    ELF HOUSE DEMO,          !- Building Name
    0,                       !- North Axis {deg}
    Suburbs,                 !- Terrain
    0.039999999,             !- Loads Convergence Tolerance Value
    0.0040000002,            !- Temperature Convergence Tolerance Value
{deltaC}
    MinimalShadowing,        !- Solar Distribution
    25;                      !- Maximum Number of Warmup Days


!-   ===========  ALL OBJECTS IN CLASS: TIMESTEP IN HOUR ===========

TIMESTEP IN HOUR,
    4;                       !- Time Step in Hour


!-   ===========  ALL OBJECTS IN CLASS: INSIDE CONVECTION ALGORITHM
===========

INSIDE CONVECTION ALGORITHM,
    Detailed;                !- Algorithm


!-   ===========  ALL OBJECTS IN CLASS: OUTSIDE CONVECTION ALGORITHM
===========

OUTSIDE CONVECTION ALGORITHM,
    Detailed;                !- Algorithm


!-   ===========  ALL OBJECTS IN CLASS: SOLUTION ALGORITHM ===========

SOLUTION ALGORITHM,
    CTF;                     !- SolutionAlgo
```

```
!-   ===========  ALL OBJECTS IN CLASS: RUN CONTROL ===========

RUN CONTROL,
    No,                      !- Do the zone sizing calculation
    No,                      !- Do the system sizing calculation
    No,                      !- Do the plant sizing calculation
    No,                      !- Do the design day simulations
    Yes;                     !- Do the weather file simulation


!-   ===========  ALL OBJECTS IN CLASS: RUNPERIOD ===========

RunPeriod,
    10,                      !- Begin Month
    1,                       !- Begin Day Of Month
    10,                      !- End Month
    7,                       !- End Day Of Month
    UseWeatherFile,          !- Day Of Week For Start Day
    Yes,                     !- Use WeatherFile Holidays/Special Days
    Yes,                     !- Use WeatherFile DaylightSavingPeriod
    No,                      !- Apply Weekend Holiday Rule
    Yes,                     !- Use WeatherFile Rain Indicators
    Yes;                     !- Use WeatherFile Snow Indicators


!-   ===========  ALL OBJECTS IN CLASS: LOCATION ===========

Location,
    Boston,                  !- LocationName
    42.37,                   !- Latitude {deg}
    -71.03,                  !- Longitude {deg}
    -5,                      !- TimeZone {hr}
    40;                      !- Elevation {m}


!-   ===========  ALL OBJECTS IN CLASS: GROUNDTEMPERATURES ===========

GroundTemperatures,
    18.89,                   !- January Ground Temperature {C}
    18.92,                   !- February Ground Temperature {C}
    19.02,                   !- March Ground Temperature {C}
    19.12,                   !- April Ground Temperature {C}
    19.21,                   !- May Ground Temperature {C}
    19.23,                   !- June Ground Temperature {C}
    19.07,                   !- July Ground Temperature {C}
    19.32,                   !- August Ground Temperature {C}
    19.09,                   !- September Ground Temperature {C}
    19.21,                   !- October Ground Temperature {C}
    19.13,                   !- November Ground Temperature {C}
    18.96;                   !- December Ground Temperature {C}


!-   ===========  ALL OBJECTS IN CLASS: MATERIAL:WINDOWGLASS ===========

!MATERIAL:REGULAR,
!water,
!Smooth,
```

```
!0.25,
!0.61,
!1000,
!4186,
!0.9,
!0.7,
!0.7;
!MATERIAL:REGULAR-R,
!R-15 pink foam,
!Rough,
!3,
!0.9,
!0.7,
!0.7;
MATERIAL:WINDOWGLASS,
    clear_glass,            !- Name
    SpectralAverage,        !- Optical Data Type
    ,                       !- Name of Window Glass Spectral Data Set
    0.003,                  !- Thickness {m}
    0.771,                  !- Solar Transmittance at Normal Incidence
    0.07,                   !- Solar Reflectance at Normal Incidence: Front
Side
    0.07,                   !- Solar Reflectance at Normal Incidence: Back
Side
    0.884,                  !- Visible Transmittance at Normal Incidence
    0.08,                   !- Visible Reflectance at Normal Incidence:
Front Side
    0.08,                   !- Visible Reflectance at Normal Incidence: Back
Side
    0,                      !- IR Transmittance at Normal Incidence
    0.84,                   !- IR Hemispherical Emissivity: Front Side
    0.84,                   !- IR Hemispherical Emissivity: Back Side
    1,                      !- Conductivity {W/m-K}
    1,                      !- Dirt Correction Factor for Solar and Visible
Transmittance
    No;                     !- Solar Diffusing

!-   ===========  ALL OBJECTS IN CLASS: CONSTRUCTION ===========

!CONSTRUCTION,
!Wall,
!R-15 pink foam;
!CONSTRUCTION,
!ground,
!R-15 pink foam,
!water;
CONSTRUCTION,
    window,                 !- Name
    clear_glass;            !- Outside Layer


!-   ===========  ALL OBJECTS IN CLASS: ZONE ===========

ZONE,
    elf house,              !- Zone Name
    0,                      !- Relative North (to building) {deg}
```

```
    0,                          !- X Origin {m}
    0,                          !- Y Origin {m}
    0,                          !- Z Origin {m}
    1,                          !- Type
    1,                          !- Multiplier
    0,                          !- Ceiling Height {m}
    0;                          !- Volume {m3}


!-   ===========  ALL OBJECTS IN CLASS: SURFACEGEOMETRY ===========

SurfaceGeometry,
    UpperLeftCorner,            !- SurfaceStartingPosition
    CounterClockWise,           !- VertexEntry
    WorldCoordinateSystem;      !- CoordinateSystem


!-   ===========  ALL OBJECTS IN CLASS: SURFACE:HEATTRANSFER ===========

Surface:HeatTransfer,
    Zn001:Wall001,              !- User Supplied Surface Name
    Wall,                       !- Surface Type
    Wall,                       !- Construction Name of the Surface
    elf house,                  !- InsideFaceEnvironment
    ExteriorEnvironment,        !- OutsideFaceEnvironment
    ,                           !- OutsideFaceEnvironment Object
    SunExposed,                 !- Sun Exposure
    WindExposed,                !- Wind Exposure
    0.5,                        !- View Factor to Ground
    4,                          !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    0,                          !- Vertex 1 X-coordinate {m}
    0,                          !- Vertex 1 Y-coordinate {m}
    0.5,                        !- Vertex 1 Z-coordinate {m}
    0,                          !- Vertex 2 X-coordinate {m}
    0,                          !- Vertex 2 Y-coordinate {m}
    0,                          !- Vertex 2 Z-coordinate {m}
    0.5,                        !- Vertex 3 X-coordinate {m}
    0,                          !- Vertex 3 Y-coordinate {m}
    0,                          !- Vertex 3 Z-coordinate {m}
    0.5,                        !- Vertex 4 X-coordinate {m}
    0,                          !- Vertex 4 Y-coordinate {m}
    0.5;                        !- Vertex 4 Z-coordinate {m}

Surface:HeatTransfer,
    Zn001:Wall002,              !- User Supplied Surface Name
    Wall,                       !- Surface Type
    Wall,                       !- Construction Name of the Surface
    elf house,                  !- InsideFaceEnvironment
    ExteriorEnvironment,        !- OutsideFaceEnvironment
    ,                           !- OutsideFaceEnvironment Object
    SunExposed,                 !- Sun Exposure
    WindExposed,                !- Wind Exposure
    0.5,                        !- View Factor to Ground
    4,                          !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    0.5,                        !- Vertex 1 X-coordinate {m}
```

```
    0,                          !- Vertex 1 Y-coordinate {m}
    0.5,                        !- Vertex 1 Z-coordinate {m}
    0.5,                        !- Vertex 2 X-coordinate {m}
    0,                          !- Vertex 2 Y-coordinate {m}
    0,                          !- Vertex 2 Z-coordinate {m}
    0.5,                        !- Vertex 3 X-coordinate {m}
    0.5,                        !- Vertex 3 Y-coordinate {m}
    0,                          !- Vertex 3 Z-coordinate {m}
    0.5,                        !- Vertex 4 X-coordinate {m}
    0.5,                        !- Vertex 4 Y-coordinate {m}
    0.5;                        !- Vertex 4 Z-coordinate {m}

Surface:HeatTransfer,
    Zn001:Wall003,              !- User Supplied Surface Name
    Wall,                       !- Surface Type
    Wall,                       !- Construction Name of the Surface
    elf house,                  !- InsideFaceEnvironment
    ExteriorEnvironment,        !- OutsideFaceEnvironment
    ,                           !- OutsideFaceEnvironment Object
    SunExposed,                 !- Sun Exposure
    WindExposed,                !- Wind Exposure
    0.5,                        !- View Factor to Ground
    4,                          !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    0.5,                        !- Vertex 1 X-coordinate {m}
    0.5,                        !- Vertex 1 Y-coordinate {m}
    0.5,                        !- Vertex 1 Z-coordinate {m}
    0.5,                        !- Vertex 2 X-coordinate {m}
    0.5,                        !- Vertex 2 Y-coordinate {m}
    0,                          !- Vertex 2 Z-coordinate {m}
    0,                          !- Vertex 3 X-coordinate {m}
    0.5,                        !- Vertex 3 Y-coordinate {m}
    0,                          !- Vertex 3 Z-coordinate {m}
    0,                          !- Vertex 4 X-coordinate {m}
    0.5,                        !- Vertex 4 Y-coordinate {m}
    0.5;                        !- Vertex 4 Z-coordinate {m}

Surface:HeatTransfer,
    Zn001:Wall004,              !- User Supplied Surface Name
    Wall,                       !- Surface Type
    Wall,                       !- Construction Name of the Surface
    elf house,                  !- InsideFaceEnvironment
    ExteriorEnvironment,        !- OutsideFaceEnvironment
    ,                           !- OutsideFaceEnvironment Object
    SunExposed,                 !- Sun Exposure
    WindExposed,                !- Wind Exposure
    0.5,                        !- View Factor to Ground
    4,                          !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    0,                          !- Vertex 1 X-coordinate {m}
    0.5,                        !- Vertex 1 Y-coordinate {m}
    0.5,                        !- Vertex 1 Z-coordinate {m}
    0,                          !- Vertex 2 X-coordinate {m}
    0.5,                        !- Vertex 2 Y-coordinate {m}
    0,                          !- Vertex 2 Z-coordinate {m}
    0,                          !- Vertex 3 X-coordinate {m}
    0,                          !- Vertex 3 Y-coordinate {m}
```

```
    0,                          !- Vertex 3 Z-coordinate {m}
    0,                          !- Vertex 4 X-coordinate {m}
    0,                          !- Vertex 4 Y-coordinate {m}
    0.5;                        !- Vertex 4 Z-coordinate {m}

Surface:HeatTransfer,
    Zn001:Roof,                 !- User Supplied Surface Name
    Roof,                       !- Surface Type
    Wall,                       !- Construction Name of the Surface
    elf house,                  !- InsideFaceEnvironment
    ExteriorEnvironment,        !- OutsideFaceEnvironment
    ,                           !- OutsideFaceEnvironment Object
    SunExposed,                 !- Sun Exposure
    WindExposed,                !- Wind Exposure
    0,                          !- View Factor to Ground
    4,                          !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    0,                          !- Vertex 1 X-coordinate {m}
    0,                          !- Vertex 1 Y-coordinate {m}
    0.5,                        !- Vertex 1 Z-coordinate {m}
    0.5,                        !- Vertex 2 X-coordinate {m}
    0,                          !- Vertex 2 Y-coordinate {m}
    0.5,                        !- Vertex 2 Z-coordinate {m}
    0.5,                        !- Vertex 3 X-coordinate {m}
    0.5,                        !- Vertex 3 Y-coordinate {m}
    0.5,                        !- Vertex 3 Z-coordinate {m}
    0,                          !- Vertex 4 X-coordinate {m}
    0.5,                        !- Vertex 4 Y-coordinate {m}
    0.5;                        !- Vertex 4 Z-coordinate {m}

Surface:HeatTransfer,
    Zn001:Floor,                !- User Supplied Surface Name
    Floor,                      !- Surface Type
    ground,                     !- Construction Name of the Surface
    elf house,                  !- InsideFaceEnvironment
    Ground,                     !- OutsideFaceEnvironment
    ,                           !- OutsideFaceEnvironment Object
    NoSun,                      !- Sun Exposure
    NoWind,                     !- Wind Exposure
    0,                          !- View Factor to Ground
    4,                          !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    0.5,                        !- Vertex 1 X-coordinate {m}
    0.5,                        !- Vertex 1 Y-coordinate {m}
    0,                          !- Vertex 1 Z-coordinate {m}
    0.5,                        !- Vertex 2 X-coordinate {m}
    0,                          !- Vertex 2 Y-coordinate {m}
    0,                          !- Vertex 2 Z-coordinate {m}
    0,                          !- Vertex 3 X-coordinate {m}
    0,                          !- Vertex 3 Y-coordinate {m}
    0,                          !- Vertex 3 Z-coordinate {m}
    0,                          !- Vertex 4 X-coordinate {m}
    0.5,                        !- Vertex 4 Y-coordinate {m}
    0;                          !- Vertex 4 Z-coordinate {m}


!-   ===========  ALL OBJECTS IN CLASS: SURFACE:HEATTRANSFER:SUB ===========
```

```
!Surface:HeatTransfer:Sub,
    !Zn001:Wall001:Win001,    !- User Supplied Surface Name
    !WINDOW,                  !- Surface Type
    !window,                  !- Construction Name of the Surface
    !Zn001:Wall001,           !- Base Surface Name
    !,                        !- OutsideFaceEnvironment Object
    !0.5,                     !- View Factor to Ground
    !,                        !- Name of shading control
    !,                        !- WindowFrameAndDivider Name
    !1,                       !- Multiplier
    !4,                       !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    !0.125,                   !- Vertex 1 X-coordinate {m}
    !0,                       !- Vertex 1 Y-coordinate {m}
    !0.425,                   !- Vertex 1 Z-coordinate {m}
    !0.125,                   !- Vertex 2 X-coordinate {m}
    !0,                       !- Vertex 2 Y-coordinate {m}
    !0.125,                   !- Vertex 2 Z-coordinate {m}
    !0.425,                   !- Vertex 3 X-coordinate {m}
    !0,                       !- Vertex 3 Y-coordinate {m}
    !0.125,                   !- Vertex 3 Z-coordinate {m}
    !0.425,                   !- Vertex 4 X-coordinate {m}
    !0,                       !- Vertex 4 Y-coordinate {m}
    !0.425;                   !- Vertex 4 Z-coordinate {m}


!-   ===========  ALL OBJECTS IN CLASS: SCHEDULETYPE ===========

!Surface:HeatTransfer:InternalMass,
!internal thermal mass,
!ground,
!elf house,
!0.25;
ScheduleType,
    Fraction,                !- ScheduleType Name
    0.0:1.0,                 !- range
    CONTINUOUS;              !- Numeric Type


!-   ===========  ALL OBJECTS IN CLASS: REPORT VARIABLE ===========

Report Variable,
    *,                       !- Key_Value
    Outdoor Dry Bulb,        !- Variable_Name
    timestep;                !- Reporting_Frequency

Report Variable,
    *,                       !- Key_Value
    Zone Mean Air Temperature,  !- Variable_Name
    timestep;                !- Reporting_Frequency

Report Variable,
    *,                       !- Key_Value
    Zone Mean Radiant Temperature,  !- Variable_Name
    timestep;                !- Reporting_Frequency
```

```
Report Variable,
    *,                          !- Key_Value
    Surface Inside Temperature,  !- Variable_Name
    timestep;                   !- Reporting_Frequency

Report Variable,
    *,                          !- Key_Value
    Surface Outside Temperature;  !- Variable_Name


!-   ===========  ALL OBJECTS IN CLASS: REPORT ===========

Report,
    Variable Dictionary;        !- Type_of_Report

Report,
    Surfaces,                   !- Type_of_Report
    DXF;                        !- Name_of_Report

Report,
    Construction;               !- Type_of_Report
```

Appendix B Elfmain.m code

```
clear all
close all
%load nextPop.mat
global history_array_new  array_temp
global evaluation_ctr epEval_ctr simsave_ctr

num_of_gen=150;
num_in_pop=20;

% Crossover Operators
xFns = 'arithXover';
xOpts = [1 0];

% Mutation Operators
mFns = 'boundaryMutation';
mOpts = [2 0 0];

% Termination Operators
termFns = 'maxGenTerm';
termOps = [num_of_gen]; % number of generations before program terminates

% Selection Function
selectFn = 'normGeomSelect'; %could be 'roulette' too
selectOps = [0.08];

% Evaluation Function
evalFn = 'Elfepeval_all';
evalOps = [];

% GA Options [epsilon float/binar display]
gaOpts=[1e-3 1 1];

%bounds on the thickness of material, height of thermal mass and dimensions
of window - height and width.
%%%% SPECIFY BOUNDS AS DESIRED %%%%
bounds=[2 5; 0.05 0.4; 0.05 0.3; 0.05 0.3];

% Generate an intialize population
startPop = initializega(num_in_pop, bounds, evalFn, evalOps, [1e-3 1])

history_array_new=[startPop(:,1:end)] %put into array
save history_array_new history_array_new;
array_temp = history_array_new;

%run the GA - conduct selection, crossover and mutation to create next
generation
%end of GA when the criteria are satisfied or limit is reached
start_time=cputime;

[x,endPop,bestPop,trace]=ga_min(bounds,evalFn,evalOps,startPop,gaOpts,...
    termFns,termOps,selectFn,selectOps,xFns,xOpts,mFns,mOpts);

 % x is the best solution found
x;
```

```
% endPop is the ending population
endPop;
% bestPop is the best solution tracked over generations
bestPop;
% trace is a trace of the best value and average value of generations
trace;

% Plot the best over time
% clf
plot(trace(:,1),trace(:,2));
hold on
plot(trace(:,1),trace(:,3));

num_of_epEval =  epEval_ctr
num_of_simSave = simsave_ctr
%num_of_epEval_GA = evaluation_ctr
timeuse_in_min=(cputime-start_time)/60
time_per_Eval = timeuse_in_min / num_of_epEval

save history_array_new history_array_new;
```

Appendix C Elfepeval.m code

```
function [sol, val]= Elfepeval_all(sol,options)
   %[sol, val]= Elfepeval(sol,options)

   global epEval_ctr

cd C:\EnergyPLusV1-3-0\ExampleFiles
dos('copy ElfHouseNew-nodaylighting-all.idf ElfHouseVary.idf');

%for R-value:
file_id=fopen('ElfHouseVary.idf','A');
fprintf(file_id,'\n %s ', 'Material:Regular-R, R-15 Pink Foam, Rough');
for i=1
fprintf(file_id, '%s%f', ',', sol(i));
end
fprintf(file_id,'\n %s ', '0.9, 0.7, 0.7;');
fclose(file_id);

file_id=fopen('ElfHouseVary.idf','A');
fprintf(file_id,'\n %s ', 'Construction, Wall, R-15 pink foam;');
fclose(file_id);

%for mass:
file_id=fopen('ElfHouseVary.idf','A');
fprintf(file_id,'\n %s ', 'Material:Regular, water, Smooth');
for i=2
fprintf(file_id, '%s%f', ',', sol(i));
end
fprintf(file_id,'\n %s ', '0.61, 1000, 4186, 0.9, 0.7, 0.7;');
fclose(file_id);

file_id=fopen('ElfHouseVary.idf','A');
fprintf(file_id,'\n %s ', 'Construction, ground, R-15 pink foam, water;');
fclose(file_id);

file_id=fopen('ElfHouseVary.idf','A');
fprintf(file_id,'\n %s ', 'Surface:HeatTransfer:InternalMass,
internalthermalmass, ground, elf house, 0.25;');
fclose(file_id);

%for window:
file_id=fopen('ElfHouseVary.idf','A');
initx = 0.125;
inity = 0;
initz = 0.425;
for i=3
    h = sol(i);
  end
for i=4
    w=sol(i);
  end
fprintf(file_id,'\n %s ', 'Surface:HeatTransfer:Sub, Zn001:Wall001:Win001,
Window, window, Zn001:Wall001, , 0.5, , , 1, 4, 0.125, 0, 0.425, 0.125, 0');%
fprintf(file_id, '%s%f', ',', initz-h);
fprintf(file_id, '%s%f', ',', initx+w);
fprintf(file_id, '%s%f', ',', inity);
```

```
fprintf(file_id, '%s%f', ',', initz-h);
fprintf(file_id, '%s%f', ',', initx+w);
fprintf(file_id, '%s%f', ',', inity);
fprintf(file_id, '%s%f', ',', initz);
fprintf(file_id, '%s%f', ';');
fclose(file_id);

cd C:\EnergyPlusV1-3-0
dos('runeplus_mod ElfHouseVary Boston');

cd C:\
    file_out=fopen('Elfnewoutput.txt','r');
    val=fscanf(file_out, '%f');

cd C:\gaot
```

Appendix D: Structure of E+

This will provide a list of the E+ fields used in the two models with their sub-headings, to help the reader get a better sense of the organization of E+.

Simulation Parameters

- Version
- Building
- Timestep in Hour
- Inside Convection Algorithm
- Outside Convection Algorithm
- Solution Algorithm
- Zone Volume Capacitance Multiplier
- Run Control

Location - Climate - Weather File Access

- RunPeriod
- Location
- DesignDay
- GroundTemperatures

Surface Construction Elements

- Material:Regular
- Material:Regular-R
- Material:WindowGlass
- Construction

Thermal Zone Description/Geometry

- Zone
- SurfaceGeometry
- Surface:HeatTransfer
- Surface:HeatTransfer:Sub

Schedules

- ScheduleType
- Schedule:Compact

Internal Gains (People, Lights, Other internal zone equipment)

- People
- Lights
- Electric Equipment

Airflow Networks System

- AirflowNetwork Simulation
- AirflowNetwork:MultiZone:Zone
- AirflowNetwork:MultiZone:Surface
- AirflowNetwork:MultiZone:Component Detailed Opening
- AirflowNetwork:MultiZone:Site Wind Conditions
- AirflowNetwork:MultiZone:External Node
- AirflowNetwork:MultiZone: Wind Pressure Coefficient Array
- AirflowNetwork:MultiZone: Wind Pressure Coefficient Values

Report

- Report Variable
- Report

APPENDIX E   Macros in Excel-VBA

Auto_open:

```
Public Sub Auto_open()

Dim title As String
Dim page As String

title = "C:\EnergyPlusV1-3-0\ExampleFiles\Outputs\ElfHouseVary.csv"

Workbooks.Open Filename:=title
Cells.Select
Selection.Copy
Windows("ElfExtract.xls").Activate
Sheets.Add
Cells.Select
ActiveSheet.Paste

'column t - avg temp

    Range("U2").Select
    ActiveCell.FormulaR1C1 = "=(RC[-1]-20)^2"
    Range("U2").Select
    Selection.AutoFill Destination:=Range("U2:U673"), Type:=xlFillDefault
    Range("U2:U673").Select
    ActiveWindow.ScrollRow = 637
    ActiveWindow.ScrollRow = 623
    ActiveWindow.ScrollRow = 603
    ActiveWindow.ScrollRow = 544
    ActiveWindow.ScrollRow = 511
    ActiveWindow.ScrollRow = 481
    ActiveWindow.ScrollRow = 430
    ActiveWindow.ScrollRow = 400
    ActiveWindow.ScrollRow = 367
    ActiveWindow.ScrollRow = 334
    ActiveWindow.ScrollRow = 233
    ActiveWindow.ScrollRow = 200
    ActiveWindow.ScrollRow = 180
    ActiveWindow.ScrollRow = 132
    ActiveWindow.ScrollRow = 118
    ActiveWindow.ScrollRow = 105
    ActiveWindow.ScrollRow = 98
    ActiveWindow.ScrollRow = 95
    ActiveWindow.ScrollRow = 91
    ActiveWindow.ScrollRow = 71
    ActiveWindow.ScrollRow = 59
    ActiveWindow.ScrollRow = 44
    ActiveWindow.ScrollRow = 8
    ActiveWindow.ScrollRow = 1
    Range("V2").Select
    ActiveCell.FormulaR1C1 = "=SUM(RC[-1]:R[671]C[-1])"
    Range("V3").Select

Range("V2").Select
```

```
    Selection.Copy
    Sheets("avg").Select
    Range("A2").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone,
SkipBlanks _
        :=False, Transpose:=False

fr = FreeFile
Open "C:\Elfnewoutput.txt" For Output As #fr
 Print #fr, Sheets("avg").Range("A2").Value
Close #fr

Sheets("Sheet1").Activate
DeleteWorksheet

ChDir "C:\EnergyPlusV1-3-0\ExampleFiles"
Workbooks("ElfHouseVary.csv").Close

ChDir "C:\"
Workbooks("ElfExtract.xls").Save
Workbooks("ElfExtract.xls").Close

End Sub
```

<u>Macro1:</u>

```
Sub Macro1()


'Open the file for output
'Filename = "c:\Temp\selection.txt"
Filename = "C:\Elfnewoutput.txt"
filenumber = FreeFile
Open Filename For Output As #filenumber


Range("Elfextract.xls").Select
Range("Elfxtract.xls").Activate


'Loop over all the choices
colOffset = 1
While (ActiveCell.Offset(0, colOffset).Value <> "")
    'Start the output string
    outputStr = ActiveCell.Offset(0, colOffset).Value & "(" 'eg Choice1(
    'Walk down each row and include it in the string if the cell is not empty
    rowOffset = 1
    While (ActiveCell.Offset(rowOffset, 0).Value <> "")
        If (ActiveCell.Offset(rowOffset, colOffset).Value <> "") Then
          'This is selected, add it to the string
          outputStr = outputStr & ActiveCell.Offset(rowOffset, 0).Value & ","
        End If
        rowOffset = rowOffset + 1
    Wend
    'Each row checked, close off the string
    If (Right(outputStr, 1) = ",") Then
        outputStr = Left(outputStr, Len(outputStr) - 1)
```

```
    End If
    outputStr = outputStr & ")"
    'Add the output string to the file
    Print #filenumber, outputStr
    'OR WRITE USING THIS CODE IF YOU DONT WANT TO PRINT OUT AN EMPTY SET, eg
Choice1()
    'If (Right(outputStr, 2) <> "()") Then
    '    'Add the output string to the file
    '    Print #filenumber, outputStr
    'End If


    'Try the next column
    colOffset = colOffset + 1
Wend


'Close the file
Close #filenumber


End Sub
```

<u>DeleteWorksheet:</u>

```
Sub DeleteWorksheet()

Application.DisplayAlerts = False
ActiveWindow.SelectedSheets.Delete
Application.DisplayAlerts = True

End Sub
```

<u>Copy:</u>

```
Sub Copy()
'
' Copy Macro
' Macro recorded 7/17/2006 by Ruchi Jain
'

'
    Range("U2").Select
    Selection.Copy
    Sheets("avg").Select
    Range("A2").Select
    Selection.PasteSpecial Paste:=xlPasteValues, Operation:=xlNone,
SkipBlanks _
        :=False, Transpose:=False
End Sub
```

Appendix F: Beijing Apartment code

```
VERSION,
    1.4;                         !- Version Identifier

!-   ===========  ALL OBJECTS IN CLASS: BUILDING ===========

  BUILDING,
    3 Zone COMIS Building,   !- Building Name
    0,                       !- North Axis {deg}
    Suburbs,                 !- Terrain
    3.9999999E-02,           !- Loads Convergence Tolerance Value
    0.4000000,               !- Temperature Convergence Tolerance Value
{deltaC}
    MinimalShadowing,        !- Solar Distribution
    25;                      !- Maximum Number of Warmup Days

!-   ===========  ALL OBJECTS IN CLASS: TIMESTEP IN HOUR ===========

  TIMESTEP IN HOUR,
    6;                       !- Time Step in Hour

!-   ===========  ALL OBJECTS IN CLASS: INSIDE CONVECTION ALGORITHM
===========

  INSIDE CONVECTION ALGORITHM,
    Simple;                  !- Algorithm

!-   ===========  ALL OBJECTS IN CLASS: OUTSIDE CONVECTION ALGORITHM
===========

  OUTSIDE CONVECTION ALGORITHM,
    Simple;                  !- Algorithm

!-   ===========  ALL OBJECTS IN CLASS: SOLUTION ALGORITHM ===========

  SOLUTION ALGORITHM,
    CTF;                     !- SolutionAlgo

!-   ===========  ALL OBJECTS IN CLASS: ZONE VOLUME CAPACITANCE MULTIPLIER
===========

  ZONE VOLUME CAPACITANCE MULTIPLIER,
    1.0;                     !- Capacitance Multiplier

!-   ===========  ALL OBJECTS IN CLASS: RUN CONTROL ===========

  RUN CONTROL,
    No,                      !- Do the zone sizing calculation
    No,                      !- Do the system sizing calculation
    No,                      !- Do the plant sizing calculation
    No,                      !- Do the design day simulations
    Yes;                     !- Do the weather file simulation

!-   ===========  ALL OBJECTS IN CLASS: RUNPERIOD ===========
```

```
  RunPeriod,
    7,                        !- Begin Month
    1,                        !- Begin Day Of Month
    7,                        !- End Month
    7,                        !- End Day Of Month
    UseWeatherFile,           !- Day Of Week For Start Day
    Yes,                      !- Use WeatherFile Holidays/Special Days
    Yes,                      !- Use WeatherFile DaylightSavingPeriod
    No,                       !- Apply Weekend Holiday Rule
    Yes,                      !- Use WeatherFile Rain Indicators
    Yes;                      !- Use WeatherFile Snow Indicators

!-   ===========  ALL OBJECTS IN CLASS: LOCATION ===========

  Location,
    Beijing,                  !- LocationName
    39.55,                    !- Latitude {deg}
    116.25,                   !- Longitude {deg}
    8,                        !- TimeZone {hr}
    43.5;                     !- Elevation {m}

!-   ===========  ALL OBJECTS IN CLASS: DESIGNDAY ===========
! CHICAGO_IL_USA Annual Heating 99% Design Conditions DB, MaxDB= -17.3°C

  DesignDay,
    CHICAGO_IL_USA Annual Heating 99% Design Conditions DB,  !- DesignDayName
    -17.3,                    !- Maximum Dry-Bulb Temperature {C}
    0.0,                      !- Daily Temperature Range {deltaC}
    -17.3,                    !- Humidity Indicating Conditions at Max Dry-
Bulb
    99063.,                   !- Barometric Pressure {Pa}
    4.9,                      !- Wind Speed {m/s}
    270,                      !- Wind Direction {deg}
    0.0,                      !- Sky Clearness
    0,                        !- Rain Indicator
    0,                        !- Snow Indicator
    21,                       !- Day Of Month
    1,                        !- Month
    WinterDesignDay,          !- Day Type
    0,                        !- Daylight Saving Time Indicator
    Wet-Bulb;                 !- Humidity Indicating Type

! CHICAGO_IL_USA Annual Cooling 1% Design Conditions, MaxDB=  31.5°C MCWB=
23.0°C

  DesignDay,
    CHICAGO_IL_USA Annual Cooling 1% Design Conditions DB/MCWB,  !-
DesignDayName
    31.5,                     !- Maximum Dry-Bulb Temperature {C}
    10.7,                     !- Daily Temperature Range {deltaC}
    23.0,                     !- Humidity Indicating Conditions at Max Dry-
Bulb
    99063.,                   !- Barometric Pressure {Pa}
    5.3,                      !- Wind Speed {m/s}
    230,                      !- Wind Direction {deg}
    1.0,                      !- Sky Clearness
```

```
    0,                          !- Rain Indicator
    0,                          !- Snow Indicator
    21,                         !- Day Of Month
    7,                          !- Month
    SummerDesignDay,            !- Day Type
    0,                          !- Daylight Saving Time Indicator
    Wet-Bulb;                   !- Humidity Indicating Type

!-   ===========  ALL OBJECTS IN CLASS: GROUNDTEMPERATURES ===========

  GroundTemperatures,
    20.03,                      !- January Ground Temperature {C}
    20.03,                      !- February Ground Temperature {C}
    20.13,                      !- March Ground Temperature {C}
    20.30,                      !- April Ground Temperature {C}
    20.43,                      !- May Ground Temperature {C}
    20.52,                      !- June Ground Temperature {C}
    20.62,                      !- July Ground Temperature {C}
    20.77,                      !- August Ground Temperature {C}
    20.78,                      !- September Ground Temperature {C}
    20.55,                      !- October Ground Temperature {C}
    20.44,                      !- November Ground Temperature {C}
    20.20;                      !- December Ground Temperature {C}

!-   ===========  ALL OBJECTS IN CLASS: MATERIAL:REGULAR ===========

  MATERIAL:REGULAR,
    A1 - 1 IN STUCCO,           !- Name
    Smooth,                     !- Roughness
    2.5389841E-02,              !- Thickness {m}
    0.6918309,                  !- Conductivity {W/m-K}
    1858.142,                   !- Density {kg/m3}
    836.8000,                   !- Specific Heat {J/kg-K}
    0.9000000,                  !- Absorptance:Thermal
    0.9200000,                  !- Absorptance:Solar
    0.9200000;                  !- Absorptance:Visible

  MATERIAL:REGULAR,
    C4 - 4 IN COMMON BRICK,     !- Name
    Rough,                      !- Roughness
    0.1014984,                  !- Thickness {m}
    0.7264224,                  !- Conductivity {W/m-K}
    1922.216,                   !- Density {kg/m3}
    836.8000,                   !- Specific Heat {J/kg-K}
    0.9000000,                  !- Absorptance:Thermal
    0.7600000,                  !- Absorptance:Solar
    0.7600000;                  !- Absorptance:Visible

  MATERIAL:REGULAR,
    E1 - 3 / 4 IN PLASTER OR GYP BOARD,  !- Name
    Smooth,                     !- Roughness
    1.905E-02,                  !- Thickness {m}
    0.7264224,                  !- Conductivity {W/m-K}
    1601.846,                   !- Density {kg/m3}
    836.8000,                   !- Specific Heat {J/kg-K}
    0.9000000,                  !- Absorptance:Thermal
    0.9200000,                  !- Absorptance:Solar
```

```
  0.9200000;               !- Absorptance:Visible

MATERIAL:REGULAR,
  C6 - 8 IN CLAY TILE,     !- Name
  Smooth,                  !- Roughness
  0.2033016,               !- Thickness {m}
  0.5707605,               !- Conductivity {W/m-K}
  1121.292,                !- Density {kg/m3}
  836.8000,                !- Specific Heat {J/kg-K}
  0.9000000,               !- Absorptance:Thermal
  0.8200000,               !- Absorptance:Solar
  0.8200000;               !- Absorptance:Visible

MATERIAL:REGULAR,
  C10 - 8 IN HW CONCRETE,  !- Name
  MediumRough,             !- Roughness
  0.2033016,               !- Thickness {m}
  1.729577,                !- Conductivity {W/m-K}
  2242.585,                !- Density {kg/m3}
  836.8000,                !- Specific Heat {J/kg-K}
  0.9000000,               !- Absorptance:Thermal
  0.6500000,               !- Absorptance:Solar
  0.6500000;               !- Absorptance:Visible

MATERIAL:REGULAR,
  E2 - 1 / 2 IN SLAG OR STONE,  !- Name
  Rough,                   !- Roughness
  1.2710161E-02,           !- Thickness {m}
  1.435549,                !- Conductivity {W/m-K}
  881.0155,                !- Density {kg/m3}
  1673.600,                !- Specific Heat {J/kg-K}
  0.9000000,               !- Absorptance:Thermal
  0.5500000,               !- Absorptance:Solar
  0.5500000;               !- Absorptance:Visible

MATERIAL:REGULAR,
  E3 - 3 / 8 IN FELT AND MEMBRANE,  !- Name
  Rough,                   !- Roughness
  9.5402403E-03,           !- Thickness {m}
  0.1902535,               !- Conductivity {W/m-K}
  1121.292,                !- Density {kg/m3}
  1673.600,                !- Specific Heat {J/kg-K}
  0.9000000,               !- Absorptance:Thermal
  0.7500000,               !- Absorptance:Solar
  0.7500000;               !- Absorptance:Visible

MATERIAL:REGULAR,
  B5 - 1 IN DENSE INSULATION,  !- Name
  VeryRough,               !- Roughness
  2.5389841E-02,           !- Thickness {m}
  4.3239430E-02,           !- Conductivity {W/m-K}
  91.30524,                !- Density {kg/m3}
  836.8000,                !- Specific Heat {J/kg-K}
  0.9000000,               !- Absorptance:Thermal
  0.5000000,               !- Absorptance:Solar
  0.5000000;               !- Absorptance:Visible
```

```
  MATERIAL:REGULAR,
    C12 - 2 IN HW CONCRETE,  !- Name
    MediumRough,             !- Roughness
    5.0901599E-02,           !- Thickness {m}
    1.729577,                !- Conductivity {W/m-K}
    2242.585,                !- Density {kg/m3}
    836.8000,                !- Specific Heat {J/kg-K}
    0.9000000,               !- Absorptance:Thermal
    0.6500000,               !- Absorptance:Solar
    0.6500000;               !- Absorptance:Visible

  MATERIAL:REGULAR,
    1.375in-Solid-Core,      !- Name
    Smooth,                  !- Roughness
    3.4925E-02,              !- Thickness {m}
    0.1525000,               !- Conductivity {W/m-K}
    614.5000,                !- Density {kg/m3}
    1630.0000,               !- Specific Heat {J/kg-K}
    0.9000000,               !- Absorptance:Thermal
    0.9200000,               !- Absorptance:Solar
    0.9200000;               !- Absorptance:Visible

!-   ===========  ALL OBJECTS IN CLASS: MATERIAL:WINDOWGLASS ===========

  MATERIAL:WINDOWGLASS,
    WIN-LAY-GLASS-LIGHT,     !- Name
    SpectralAverage,         !- Optical Data Type
    ,                        !- Name of Window Glass Spectral Data Set
    0.0025,                  !- Thickness {m}
    0.850,                   !- Solar Transmittance at Normal Incidence
    0.075,                   !- Solar Reflectance at Normal Incidence: Front
Side
    0.075,                   !- Solar Reflectance at Normal Incidence: Back
Side
    0.901,                   !- Visible Transmittance at Normal Incidence
    0.081,                   !- Visible Reflectance at Normal Incidence:
Front Side
    0.081,                   !- Visible Reflectance at Normal Incidence: Back
Side
    0.0,                     !- IR Transmittance at Normal Incidence
    0.84,                    !- IR Hemispherical Emissivity: Front Side
    0.84,                    !- IR Hemispherical Emissivity: Back Side
    0.9;                     !- Conductivity {W/m-K}

!-   ===========  ALL OBJECTS IN CLASS: CONSTRUCTION ===========

  CONSTRUCTION,
    DOOR-CON,                !- Name
    1.375in-Solid-Core;      !- Outside Layer

  CONSTRUCTION,
    EXTWALL80,               !- Name
    A1 - 1 IN STUCCO,        !- Outside Layer
    C4 - 4 IN COMMON BRICK,  !- Layer #2
    E1 - 3 / 4 IN PLASTER OR GYP BOARD;  !- Layer #3

  CONSTRUCTION,
```

```
    PARTITION06,                !- Name
    E1 - 3 / 4 IN PLASTER OR GYP BOARD,  !- Outside Layer
    C6 - 8 IN CLAY TILE,        !- Layer #2
    E1 - 3 / 4 IN PLASTER OR GYP BOARD;  !- Layer #3

  CONSTRUCTION,
    FLOOR SLAB 8 IN,            !- Name
    C10 - 8 IN HW CONCRETE;     !- Outside Layer

  CONSTRUCTION,
    ROOF34,                     !- Name
    E2 - 1 / 2 IN SLAG OR STONE,  !- Outside Layer
    E3 - 3 / 8 IN FELT AND MEMBRANE,  !- Layer #2
    B5 - 1 IN DENSE INSULATION,  !- Layer #3
    C12 - 2 IN HW CONCRETE;     !- Layer #4

  CONSTRUCTION,
    WIN-CON-LIGHT,              !- Name
    WIN-LAY-GLASS-LIGHT;        !- Outside Layer

!-   ===========  ALL OBJECTS IN CLASS: ZONE ===========

  ZONE,
    East_ZONE,                  !- Zone Name
    90,                         !- Relative North (to building) {deg}
    0,                          !- X Origin {m}
    0,                          !- Y Origin {m}
    0,                          !- Z Origin {m}
    1,                          !- Type
    1,                          !- Multiplier
    0;                          !- Ceiling Height {m}

  ZONE,
    West_ZONE,                  !- Zone Name
    90,                         !- Relative North (to building) {deg}
    5,                          !- X Origin {m}
    0,                          !- Y Origin {m}
    0,                          !- Z Origin {m}
    1,                          !- Type
    1,                          !- Multiplier
    0;                          !- Ceiling Height {m}

  ZONE,
    Balcony_ZONE,               !- Zone Name
    90,                         !- Relative North (to building) {deg}
    0,                          !- X Origin {m}
    9,                          !- Y Origin {m}
    0,                          !- Z Origin {m}
    1,                          !- Type
    1,                          !- Multiplier
    0;                          !- Ceiling Height {m}

  ZONE,
    Living_ZONE,                !- Zone Name
    90,                         !- Relative North (to building) {deg}
    0,                          !- X Origin {m}
    5,                          !- Y Origin {m}
```

```
    0,                          !- Z Origin {m}
    1,                          !- Type
    1,                          !- Multiplier
    0;                          !- Ceiling Height {m}

!-   ===========  ALL OBJECTS IN CLASS: SURFACEGEOMETRY ===========

  SurfaceGeometry,
    UpperLeftCorner,            !- SurfaceStartingPosition
    CounterClockWise,           !- VertexEntry
    relative;                   !- CoordinateSystem

!-   ===========  ALL OBJECTS IN CLASS: SURFACE:HEATTRANSFER ===========

  Surface:HeatTransfer,
    East_ExtWall1,              !- User Supplied Surface Name
    WALL,                       !- Surface Type
    EXTWALL80,                  !- Construction Name of the Surface
    East_ZONE,                  !- InsideFaceEnvironment
    ExteriorEnvironment,        !- OutsideFaceEnvironment
    ,                           !- OutsideFaceEnvironment Object
    SunExposed,                 !- Sun Exposure
    WindExposed,                !- Wind Exposure
    0.5000000,                  !- View Factor to Ground
    4,                          !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    0,0,3,  !- X,Y,Z ==> Vertex 1
    0,0,0,  !- X,Y,Z ==> Vertex 2
    5,0,0,  !- X,Y,Z ==> Vertex 3
    5,0,3;  !- X,Y,Z ==> Vertex 4

  Surface:HeatTransfer,
    East_ExtWall2,              !- User Supplied Surface Name
    WALL,                       !- Surface Type
    EXTWALL80,                  !- Construction Name of the Surface
    East_ZONE,                  !- InsideFaceEnvironment
    ExteriorEnvironment,        !- OutsideFaceEnvironment
    ,                           !- OutsideFaceEnvironment Object
    SunExposed,                 !- Sun Exposure
    WindExposed,                !- Wind Exposure
    0.5000000,                  !- View Factor to Ground
    4,                          !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    0,5,3,  !- X,Y,Z ==> Vertex 1
    0,5,0,  !- X,Y,Z ==> Vertex 2
    0,0,0,  !- X,Y,Z ==> Vertex 3
    0,0,3;  !- X,Y,Z ==> Vertex 4

  Surface:HeatTransfer,
    East_Part1,                 !- User Supplied Surface Name
    WALL,                       !- Surface Type
    PARTITION06,                !- Construction Name of the Surface
    East_ZONE,                  !- InsideFaceEnvironment
    OtherZoneSurface,           !- OutsideFaceEnvironment
    Living_Part1,               !- OutsideFaceEnvironment Object
    NoSun,                      !- Sun Exposure
    NoWind,                     !- Wind Exposure
```

```
    0.5000000,                !- View Factor to Ground
    4,                        !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    5,5,3,  !- X,Y,Z ==> Vertex 1
    5,5,0,  !- X,Y,Z ==> Vertex 2
    0,5,0,  !- X,Y,Z ==> Vertex 3
    0,5,3;  !- X,Y,Z ==> Vertex 4

  Surface:HeatTransfer,
    East_Part2,               !- User Supplied Surface Name
    WALL,                     !- Surface Type
    PARTITION06,              !- Construction Name of the Surface
    East_ZONE,                !- InsideFaceEnvironment
    OtherZoneSurface,         !- OutsideFaceEnvironment
    West_Part1,               !- OutsideFaceEnvironment Object
    NoSun,                    !- Sun Exposure
    NoWind,                   !- Wind Exposure
    0.5000000,                !- View Factor to Ground
    4,                        !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    5,0,3,  !- X,Y,Z ==> Vertex 1
    5,0,0,  !- X,Y,Z ==> Vertex 2
    5,5,0,  !- X,Y,Z ==> Vertex 3
    5,5,3;  !- X,Y,Z ==> Vertex 4

  Surface:HeatTransfer,
    East_Floor,               !- User Supplied Surface Name
    FLOOR,                    !- Surface Type
    FLOOR SLAB 8 IN,          !- Construction Name of the Surface
    East_ZONE,                !- InsideFaceEnvironment
    OtherZoneSurface,         !- OutsideFaceEnvironment
    East_Floor,               !- OutsideFaceEnvironment Object
    NoSun,                    !- Sun Exposure
    NoWind,                   !- Wind Exposure
    1.000000,                 !- View Factor to Ground
    4,                        !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    5,5,0,  !- X,Y,Z ==> Vertex 1
    5,0,0,  !- X,Y,Z ==> Vertex 2
    0,0,0,  !- X,Y,Z ==> Vertex 3
    0,5,0;  !- X,Y,Z ==> Vertex 4

  Surface:HeatTransfer,
    East_Roof,                !- User Supplied Surface Name
    ROOF,                     !- Surface Type
    ROOF34,                   !- Construction Name of the Surface
    East_ZONE,                !- InsideFaceEnvironment
    ExteriorEnvironment,      !- OutsideFaceEnvironment
    ,                         !- OutsideFaceEnvironment Object
    SunExposed,               !- Sun Exposure
    WindExposed,              !- Wind Exposure
    0,                        !- View Factor to Ground
    4,                        !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    0,0,3,  !- X,Y,Z ==> Vertex 1
    5,0,3,  !- X,Y,Z ==> Vertex 2
    5,5,3,  !- X,Y,Z ==> Vertex 3
```

```
    0,5,3;  !- X,Y,Z ==> Vertex 4

  Surface:HeatTransfer,
    West_ExtWall1,            !- User Supplied Surface Name
    WALL,                     !- Surface Type
    EXTWALL80,                !- Construction Name of the Surface
    West_ZONE,                !- InsideFaceEnvironment
    ExteriorEnvironment,      !- OutsideFaceEnvironment
    ,                         !- OutsideFaceEnvironment Object
    SunExposed,               !- Sun Exposure
    WindExposed,              !- Wind Exposure
    0.5000000,                !- View Factor to Ground
    4,                        !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    5,0,3,  !- X,Y,Z ==> Vertex 1
    5,0,0,  !- X,Y,Z ==> Vertex 2
    10,0,0,  !- X,Y,Z ==> Vertex 3
    10,0,3;  !- X,Y,Z ==> Vertex 4

  Surface:HeatTransfer,
    West_ExtWall2,            !- User Supplied Surface Name
    WALL,                     !- Surface Type
    EXTWALL80,                !- Construction Name of the Surface
    West_ZONE,                !- InsideFaceEnvironment
    ExteriorEnvironment,      !- OutsideFaceEnvironment
    ,                         !- OutsideFaceEnvironment Object
    SunExposed,               !- Sun Exposure
    WindExposed,              !- Wind Exposure
    0.5000000,                !- View Factor to Ground
    4,                        !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    10,0,3,  !- X,Y,Z ==> Vertex 1
    10,0,0,  !- X,Y,Z ==> Vertex 2
    10,5,0,  !- X,Y,Z ==> Vertex 3
    10,5,3;  !- X,Y,Z ==> Vertex 4

  Surface:HeatTransfer,
    West_Part1,               !- User Supplied Surface Name
    WALL,                     !- Surface Type
    PARTITION06,              !- Construction Name of the Surface
    West_ZONE,                !- InsideFaceEnvironment
    OtherZoneSurface,         !- OutsideFaceEnvironment
    East_Part2,               !- OutsideFaceEnvironment Object
    NoSun,                    !- Sun Exposure
    NoWind,                   !- Wind Exposure
    0.5000000,                !- View Factor to Ground
    4,                        !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    5,5,3,  !- X,Y,Z ==> Vertex 1
    5,5,0,  !- X,Y,Z ==> Vertex 2
    5,0,0,  !- X,Y,Z ==> Vertex 3
    5,0,3;  !- X,Y,Z ==> Vertex 4

  Surface:HeatTransfer,
    West_Part2,               !- User Supplied Surface Name
    WALL,                     !- Surface Type
    PARTITION06,              !- Construction Name of the Surface
```

```
    West_ZONE,                !- InsideFaceEnvironment
    OtherZoneSurface,         !- OutsideFaceEnvironment
    Living_Part2,             !- OutsideFaceEnvironment Object
    NoSun,                    !- Sun Exposure
    NoWind,                   !- Wind Exposure
    0.5000000,                !- View Factor to Ground
    4,                        !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    10,5,3,  !- X,Y,Z ==> Vertex 1
    10,5,0,  !- X,Y,Z ==> Vertex 2
    5,5,0,  !- X,Y,Z ==> Vertex 3
    5,5,3;  !- X,Y,Z ==> Vertex 4

  Surface:HeatTransfer,
    West_Floor,               !- User Supplied Surface Name
    FLOOR,                    !- Surface Type
    FLOOR SLAB 8 IN,          !- Construction Name of the Surface
    West_ZONE,                !- InsideFaceEnvironment
    OtherZoneSurface,         !- OutsideFaceEnvironment
    West_Floor,               !- OutsideFaceEnvironment Object
    NoSun,                    !- Sun Exposure
    NoWind,                   !- Wind Exposure
    1.000000,                 !- View Factor to Ground
    4,                        !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    10,5,0,  !- X,Y,Z ==> Vertex 1
    10,0,0,  !- X,Y,Z ==> Vertex 2
    5,0,0,  !- X,Y,Z ==> Vertex 3
    5,5,0;  !- X,Y,Z ==> Vertex 4

  Surface:HeatTransfer,
    West_Roof,                !- User Supplied Surface Name
    ROOF,                     !- Surface Type
    ROOF34,                   !- Construction Name of the Surface
    West_ZONE,                !- InsideFaceEnvironment
    ExteriorEnvironment,      !- OutsideFaceEnvironment
    ,                         !- OutsideFaceEnvironment Object
    SunExposed,               !- Sun Exposure
    WindExposed,              !- Wind Exposure
    0,                        !- View Factor to Ground
    4,                        !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    5,0,3,  !- X,Y,Z ==> Vertex 1
    10,0,3,  !- X,Y,Z ==> Vertex 2
    10,5,3,  !- X,Y,Z ==> Vertex 3
    5,5,3;  !- X,Y,Z ==> Vertex 4

  Surface:HeatTransfer,
    Living_Ext1,              !- User Supplied Surface Name
    WALL,                     !- Surface Type
    EXTWALL80,                !- Construction Name of the Surface
    Living_ZONE,              !- InsideFaceEnvironment
    ExteriorEnvironment,      !- OutsideFaceEnvironment
    ,                         !- OutsideFaceEnvironment Object
    SunExposed,               !- Sun Exposure
    WindExposed,              !- Wind Exposure
    0.5000000,                !- View Factor to Ground
```

```
    4,                          !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    0,9,3,  !- X,Y,Z ==> Vertex 1
    0,9,0,  !- X,Y,Z ==> Vertex 2
    0,5,0,  !- X,Y,Z ==> Vertex 3
    0,5,3;  !- X,Y,Z ==> Vertex 4

  Surface:HeatTransfer,
    Living_Ext2,                !- User Supplied Surface Name
    WALL,                       !- Surface Type
    EXTWALL80,                  !- Construction Name of the Surface
    Living_ZONE,                !- InsideFaceEnvironment
    ExteriorEnvironment,        !- OutsideFaceEnvironment
    ,                           !- OutsideFaceEnvironment Object
    SunExposed,                 !- Sun Exposure
    WindExposed,                !- Wind Exposure
    0.5000000,                  !- View Factor to Ground
    4,                          !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    10,5,3,  !- X,Y,Z ==> Vertex 1
    10,5,0,  !- X,Y,Z ==> Vertex 2
    10,9,0,  !- X,Y,Z ==> Vertex 3
    10,9,3;  !- X,Y,Z ==> Vertex 4

  Surface:HeatTransfer,
    Living_Part1,               !- User Supplied Surface Name
    WALL,                       !- Surface Type
    PARTITION06,                !- Construction Name of the Surface
    Living_ZONE,                !- InsideFaceEnvironment
    OtherZoneSurface,           !- OutsideFaceEnvironment
    East_Part1,                 !- OutsideFaceEnvironment Object
    NoSun,                      !- Sun Exposure
    NoWind,                     !- Wind Exposure
    0.5000000,                  !- View Factor to Ground
    4,                          !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    0,5,3,  !- X,Y,Z ==> Vertex 1
    0,5,0,  !- X,Y,Z ==> Vertex 2
    5,5,0,  !- X,Y,Z ==> Vertex 3
    5,5,3;  !- X,Y,Z ==> Vertex 4

  Surface:HeatTransfer,
    Living_Part2,               !- User Supplied Surface Name
    WALL,                       !- Surface Type
    PARTITION06,                !- Construction Name of the Surface
    Living_ZONE,                !- InsideFaceEnvironment
    OtherZoneSurface,           !- OutsideFaceEnvironment
    West_Part2,                 !- OutsideFaceEnvironment Object
    NoSun,                      !- Sun Exposure
    NoWind,                     !- Wind Exposure
    0.5000000,                  !- View Factor to Ground
    4,                          !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    5,5,3,  !- X,Y,Z ==> Vertex 1
    5,5,0,  !- X,Y,Z ==> Vertex 2
    10,5,0,  !- X,Y,Z ==> Vertex 3
    10,5,3;  !- X,Y,Z ==> Vertex 4
```

```
  Surface:HeatTransfer,
    Living_Part3,            !- User Supplied Surface Name
    WALL,                    !- Surface Type
    PARTITION06,             !- Construction Name of the Surface
    Living_ZONE,             !- InsideFaceEnvironment
    OtherZoneSurface,        !- OutsideFaceEnvironment
    Balc_Part1,              !- OutsideFaceEnvironment Object
    NoSun,                   !- Sun Exposure
    NoWind,                  !- Wind Exposure
    0.5000000,               !- View Factor to Ground
    4,                       !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    10,9,3,  !- X,Y,Z ==> Vertex 1
    10,9,0,  !- X,Y,Z ==> Vertex 2
    0,9,0,  !- X,Y,Z ==> Vertex 3
    0,9,3;  !- X,Y,Z ==> Vertex 4

  Surface:HeatTransfer,
    Living_Floor,            !- User Supplied Surface Name
    FLOOR,                   !- Surface Type
    FLOOR SLAB 8 IN,         !- Construction Name of the Surface
    Living_ZONE,             !- InsideFaceEnvironment
    OtherZoneSurface,        !- OutsideFaceEnvironment
    Living_Floor,            !- OutsideFaceEnvironment Object
    NoSun,                   !- Sun Exposure
    NoWind,                  !- Wind Exposure
    1.000000,                !- View Factor to Ground
    4,                       !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    10,9,0,  !- X,Y,Z ==> Vertex 1
    10,5,0,  !- X,Y,Z ==> Vertex 2
    0,5,0,  !- X,Y,Z ==> Vertex 3
    0,9,0;  !- X,Y,Z ==> Vertex 4

  Surface:HeatTransfer,
    Living_Roof,             !- User Supplied Surface Name
    ROOF,                    !- Surface Type
    ROOF34,                  !- Construction Name of the Surface
    Living_ZONE,             !- InsideFaceEnvironment
    ExteriorEnvironment,     !- OutsideFaceEnvironment
    ,                        !- OutsideFaceEnvironment Object
    SunExposed,              !- Sun Exposure
    WindExposed,             !- Wind Exposure
    0,                       !- View Factor to Ground
    4,                       !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    0,5,3,  !- X,Y,Z ==> Vertex 1
    10,5,3,  !- X,Y,Z ==> Vertex 2
    10,9,3,  !- X,Y,Z ==> Vertex 3
    0,9,3;  !- X,Y,Z ==> Vertex 4

  Surface:HeatTransfer,
    Balc_Ext1,               !- User Supplied Surface Name
    WALL,                    !- Surface Type
    EXTWALL80,               !- Construction Name of the Surface
    Balcony_ZONE,            !- InsideFaceEnvironment
```

```
    ExteriorEnvironment,      !- OutsideFaceEnvironment
    ,                         !- OutsideFaceEnvironment Object
    SunExposed,               !- Sun Exposure
    WindExposed,              !- Wind Exposure
    0.5,                      !- View Factor to Ground
    4,                        !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    0,12,3,  !- X,Y,Z ==> Vertex 1
    0,12,0,  !- X,Y,Z ==> Vertex 2
    0,9,0,  !- X,Y,Z ==> Vertex 3
    0,9,3;  !- X,Y,Z ==> Vertex 4

  Surface:HeatTransfer,
    Balc_Ext2,                !- User Supplied Surface Name
    WALL,                     !- Surface Type
    EXTWALL80,                !- Construction Name of the Surface
    Balcony_ZONE,             !- InsideFaceEnvironment
    ExteriorEnvironment,      !- OutsideFaceEnvironment
    ,                         !- OutsideFaceEnvironment Object
    SunExposed,               !- Sun Exposure
    WindExposed,              !- Wind Exposure
    0.5,                      !- View Factor to Ground
    4,                        !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    10,12,3,  !- X,Y,Z ==> Vertex 1
    10,12,0,  !- X,Y,Z ==> Vertex 2
    0,12,0,  !- X,Y,Z ==> Vertex 3
    0,12,3;  !- X,Y,Z ==> Vertex 4

  Surface:HeatTransfer,
    Balc_Ext3,                !- User Supplied Surface Name
    WALL,                     !- Surface Type
    EXTWALL80,                !- Construction Name of the Surface
    Balcony_ZONE,             !- InsideFaceEnvironment
    ExteriorEnvironment,      !- OutsideFaceEnvironment
    ,                         !- OutsideFaceEnvironment Object
    SunExposed,               !- Sun Exposure
    WindExposed,              !- Wind Exposure
    0.5,                      !- View Factor to Ground
    4,                        !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    10,9,3,  !- X,Y,Z ==> Vertex 1
    10,9,0,  !- X,Y,Z ==> Vertex 2
    10,12,0,  !- X,Y,Z ==> Vertex 3
    10,12,3;  !- X,Y,Z ==> Vertex 4

  Surface:HeatTransfer,
    Balc_Part1,               !- User Supplied Surface Name
    WALL,                     !- Surface Type
    PARTITION06,              !- Construction Name of the Surface
    Balcony_ZONE,             !- InsideFaceEnvironment
    OtherZoneSurface,         !- OutsideFaceEnvironment
    Living_Part3,             !- OutsideFaceEnvironment Object
    NoSun,                    !- Sun Exposure
    NoWind,                   !- Wind Exposure
    0.5,                      !- View Factor to Ground
```

```
    4,                          !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    0,9,3,  !- X,Y,Z ==> Vertex 1
    0,9,0,  !- X,Y,Z ==> Vertex 2
    10,9,0,  !- X,Y,Z ==> Vertex 3
    10,9,3;  !- X,Y,Z ==> Vertex 4

  Surface:HeatTransfer,
    Balc_Floor,                 !- User Supplied Surface Name
    FLOOR,                      !- Surface Type
    FLOOR SLAB 8 IN,            !- Construction Name of the Surface
    Balcony_ZONE,               !- InsideFaceEnvironment
    OtherZoneSurface,           !- OutsideFaceEnvironment
    Balc_Floor,                 !- OutsideFaceEnvironment Object
    NoSun,                      !- Sun Exposure
    NoWind,                     !- Wind Exposure
    1,                          !- View Factor to Ground
    4,                          !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    10,12,0,  !- X,Y,Z ==> Vertex 1
    10,9,0,  !- X,Y,Z ==> Vertex 2
    0,9,0,  !- X,Y,Z ==> Vertex 3
    0,12,0;  !- X,Y,Z ==> Vertex 4

  Surface:HeatTransfer,
    Balc_Roof,                  !- User Supplied Surface Name
    ROOF,                       !- Surface Type
    ROOF34,                     !- Construction Name of the Surface
    Balcony_ZONE,               !- InsideFaceEnvironment
    ExteriorEnvironment,        !- OutsideFaceEnvironment
    ,                           !- OutsideFaceEnvironment Object
    SunExposed,                 !- Sun Exposure
    WindExposed,                !- Wind Exposure
    0,                          !- View Factor to Ground
    4,                          !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    0,9,3,  !- X,Y,Z ==> Vertex 1
    10,9,3,  !- X,Y,Z ==> Vertex 2
    10,12,3,  !- X,Y,Z ==> Vertex 3
    0,12,3;  !- X,Y,Z ==> Vertex 4

!-   ===========  ALL OBJECTS IN CLASS: SURFACE:HEATTRANSFER:SUB ===========

  Surface:HeatTransfer:Sub,
    Win_Balc,                   !- User Supplied Surface Name
    WINDOW,                     !- Surface Type
    WIN-CON-LIGHT,              !- Construction Name of the Surface
    Balc_Ext2,                  !- Base Surface Name
    ,                           !- OutsideFaceEnvironment Object
    0.5000000,                  !- View Factor to Ground
    ,                           !- Name of shading control
    ,                           !- WindowFrameAndDivider Name
    1.0,                        !- Multiplier
    4,                          !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    7,12,2.5,  !- X,Y,Z ==> Vertex 1
    7,12,0.5,  !- X,Y,Z ==> Vertex 2
```

```
    3,12,0.5,  !- X,Y,Z ==> Vertex 3
    3,12,2.5;  !- X,Y,Z ==> Vertex 4

  Surface:HeatTransfer:Sub,
    Door_Balc-Liv,             !- User Supplied Surface Name
    DOOR,                      !- Surface Type
    DOOR-CON,                  !- Construction Name of the Surface
    Balc_Part1,                !- Base Surface Name
    Door_Liv-Balc,             !- OutsideFaceEnvironment Object
    0.5000000,                 !- View Factor to Ground
    ,                          !- Name of shading control
    ,                          !- WindowFrameAndDivider Name
    1.0,                       !- Multiplier
    4,                         !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    3.500,9,2.0,  !- X,Y,Z ==> Vertex 1
    3.500,9,0,  !- X,Y,Z ==> Vertex 2
    6.5,9,0,  !- X,Y,Z ==> Vertex 3
    6.5,9,2.0;  !- X,Y,Z ==> Vertex 4

  Surface:HeatTransfer:Sub,
    Door_Liv-Balc,             !- User Supplied Surface Name
    DOOR,                      !- Surface Type
    DOOR-CON,                  !- Construction Name of the Surface
    Living_Part3,              !- Base Surface Name
    Door_Balc-Liv,             !- OutsideFaceEnvironment Object
    0.5000000,                 !- View Factor to Ground
    ,                          !- Name of shading control
    ,                          !- WindowFrameAndDivider Name
    1.0,                       !- Multiplier
    4,                         !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    6.5,9,2,  !- X,Y,Z ==> Vertex 1
    6.5,9,0,  !- X,Y,Z ==> Vertex 2
    3.5,9,0,  !- X,Y,Z ==> Vertex 3
    3.5,9,2;  !- X,Y,Z ==> Vertex 4

  Surface:HeatTransfer:Sub,
    Door_Liv-East,             !- User Supplied Surface Name
    DOOR,                      !- Surface Type
    DOOR-CON,                  !- Construction Name of the Surface
    Living_Part1,              !- Base Surface Name
    Door_East-Liv,             !- OutsideFaceEnvironment Object
    0.5000000,                 !- View Factor to Ground
    ,                          !- Name of shading control
    ,                          !- WindowFrameAndDivider Name
    1.0,                       !- Multiplier
    4,                         !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    2,5,2.0,  !- X,Y,Z ==> Vertex 1
    2,5,0,  !- X,Y,Z ==> Vertex 2
    3,5,0,  !- X,Y,Z ==> Vertex 3
    3,5,2.0;  !- X,Y,Z ==> Vertex 4

  Surface:HeatTransfer:Sub,
    Door_East-Liv,             !- User Supplied Surface Name
    DOOR,                      !- Surface Type
```

```
    DOOR-CON,                   !- Construction Name of the Surface
    East_Part1,                 !- Base Surface Name
    Door_Liv-East,              !- OutsideFaceEnvironment Object
    0.5,                        !- View Factor to Ground
    ,                           !- Name of shading control
    ,                           !- WindowFrameAndDivider Name
    1,                          !- Multiplier
    4,                          !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    3,5,2,  !- X,Y,Z ==> Vertex 1
    3,5,0,  !- X,Y,Z ==> Vertex 2
    2,5,0,  !- X,Y,Z ==> Vertex 3
    2,5,2;  !- X,Y,Z ==> Vertex 4

  Surface:HeatTransfer:Sub,
    Door_Liv-West,              !- User Supplied Surface Name
    DOOR,                       !- Surface Type
    DOOR-CON,                   !- Construction Name of the Surface
    Living_Part2,               !- Base Surface Name
    Door_West-Liv,              !- OutsideFaceEnvironment Object
    0.5,                        !- View Factor to Ground
    ,                           !- Name of shading control
    ,                           !- WindowFrameAndDivider Name
    1,                          !- Multiplier
    4,                          !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    7,5,2,  !- X,Y,Z ==> Vertex 1
    7,5,0,  !- X,Y,Z ==> Vertex 2
    8,5,0,  !- X,Y,Z ==> Vertex 3
    8,5,2;  !- X,Y,Z ==> Vertex 4

  Surface:HeatTransfer:Sub,
    Door_West-Liv,              !- User Supplied Surface Name
    DOOR,                       !- Surface Type
    DOOR-CON,                   !- Construction Name of the Surface
    West_Part2,                 !- Base Surface Name
    Door_Liv-West,              !- OutsideFaceEnvironment Object
    0.5,                        !- View Factor to Ground
    ,                           !- Name of shading control
    ,                           !- WindowFrameAndDivider Name
    1,                          !- Multiplier
    4,                          !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    8,5,2,  !- X,Y,Z ==> Vertex 1
    8,5,0,  !- X,Y,Z ==> Vertex 2
    7,5,0,  !- X,Y,Z ==> Vertex 3
    7,5,2;  !- X,Y,Z ==> Vertex 4

  Surface:HeatTransfer:Sub,
    Win_East,                   !- User Supplied Surface Name
    WINDOW,                     !- Surface Type
    WIN-CON-LIGHT,              !- Construction Name of the Surface
    East_ExtWall1,              !- Base Surface Name
    ,                           !- OutsideFaceEnvironment Object
    0.5,                        !- View Factor to Ground
    ,                           !- Name of shading control
    ,                           !- WindowFrameAndDivider Name
```

```
    1,                          !- Multiplier
    4,                          !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    2,0,2,  !- X,Y,Z ==> Vertex 1
    2,0,1,  !- X,Y,Z ==> Vertex 2
    3,0,1,  !- X,Y,Z ==> Vertex 3
    3,0,2;  !- X,Y,Z ==> Vertex 4

  Surface:HeatTransfer:Sub,
    Win_West,                   !- User Supplied Surface Name
    WINDOW,                     !- Surface Type
    WIN-CON-LIGHT,              !- Construction Name of the Surface
    West_ExtWall1,              !- Base Surface Name
    ,                           !- OutsideFaceEnvironment Object
    0.5,                        !- View Factor to Ground
    ,                           !- Name of shading control
    ,                           !- WindowFrameAndDivider Name
    1,                          !- Multiplier
    4,                          !- Number of Surface Vertex Groups -- Number of
(X,Y,Z) groups in this surface
    7,0,2,  !- X,Y,Z ==> Vertex 1
    7,0,1,  !- X,Y,Z ==> Vertex 2
    8,0,1,  !- X,Y,Z ==> Vertex 3
    8,0,2;  !- X,Y,Z ==> Vertex 4

!-   ===========  ALL OBJECTS IN CLASS: SCHEDULETYPE ===========

  ScheduleType,
    Any Number;                 !- ScheduleType Name

  ScheduleType,
    Fraction,                   !- ScheduleType Name
    0.0 : 1.0,                  !- range
    CONTINUOUS;                 !- Numeric Type

  ScheduleType,
    Temperature,                !- ScheduleType Name
    -60:200,                    !- range
    CONTINUOUS;                 !- Numeric Type

  ScheduleType,
    Control Type,               !- ScheduleType Name
    0:4,                        !- range
    DISCRETE;                   !- Numeric Type

!-   ===========  ALL OBJECTS IN CLASS: SCHEDULE:COMPACT ===========

  SCHEDULE:COMPACT,
    Activity Sch,               !- Name
    Any Number,                 !- ScheduleType
    Through: 12/31,             !- Complex Field #1
    For: AllDays,               !- Complex Field #2
    Until: 24:00,               !- Complex Field #3
    80;                         !- Complex Field #4

  SCHEDULE:COMPACT,
    Work Eff Sch,               !- Name
```

```
  Any Number,                !- ScheduleType
  Through: 12/31,            !- Complex Field #1
  For: AllDays,              !- Complex Field #2
  Until: 24:00,              !- Complex Field #3
  0.0;                       !- Complex Field #4

SCHEDULE:COMPACT,
  Clothing Sch,              !- Name
  Any Number,                !- ScheduleType
  Through: 12/31,            !- Complex Field #1
  For: AllDays,              !- Complex Field #2
  Until: 24:00,              !- Complex Field #3
  0.5;                       !- Complex Field #4

SCHEDULE:COMPACT,
  Air Velo Sch,              !- Name
  Any Number,                !- ScheduleType
  Through: 12/31,            !- Complex Field #1
  For: AllDays,              !- Complex Field #2
  Until: 24:00,              !- Complex Field #3
  0.137;                     !- Complex Field #4

SCHEDULE:COMPACT,
  Opening Factor Schedule, !- Name
  Fraction,                  !- ScheduleType
  Through: 12/31,            !- Complex Field #1
  For: AllDays,              !- Complex Field #2
  Until: 24:00,              !- Complex Field #3
  0.35;                      !- Complex Field #4

SCHEDULE:COMPACT,
  WindowVentSched,           !- Name
  Any Number,                !- ScheduleType
  Through: 12/31,            !- Complex Field #1
  For: Wednesday Thursday Friday Saturday,  !- Complex Field #2
  Until: 24:00,              !- Complex Field #3
  21.11,                     !- Complex Field #4
  For: Holiday SummerDesignDay,  !- Complex Field #5
  Until: 24:00,              !- Complex Field #6
  21.11,                     !- Complex Field #7
  For: Sunday Monday Tuesday,  !- Complex Field #8
  Until: 24:00,              !- Complex Field #9
  25.55,                     !- Complex Field #10
  For: WinterDesignDay CustomDay1 CustomDay2,  !- Complex Field #11
  Until: 24:00,              !- Complex Field #12
  25.55;                     !- Complex Field #13

SCHEDULE:COMPACT,
  OFFICE OCCUPANCY,          !- Name
  Fraction,                  !- ScheduleType
  Through: 12/31,            !- Complex Field #1
  For: AllDays,              !- Complex Field #2
  Until: 6:00,               !- Complex Field #3
  1.0,                       !- Complex Field #4
  Until: 7:00,               !- Complex Field #5
  1.0,                       !- Complex Field #6
  Until: 8:00,               !- Complex Field #7
```

```
    1.0,                     !- Complex Field #8
    Until: 12:00,            !- Complex Field #9
    0.50,                    !- Complex Field #10
    Until: 13:00,            !- Complex Field #11
    0.25,                    !- Complex Field #12
    Until: 16:00,            !- Complex Field #13
    0.5,                     !- Complex Field #14
    Until: 17:00,            !- Complex Field #15
    0.50,                    !- Complex Field #16
    Until: 18:00,            !- Complex Field #17
    0.5,                     !- Complex Field #18
    Until: 24:00,            !- Complex Field #19
    1.0;                     !- Complex Field #20

  SCHEDULE:COMPACT,
    INTERMITTENT,            !- Name
    Fraction,                !- ScheduleType
    Through: 12/31,          !- Complex Field #1
    For: AllDays,            !- Complex Field #2
    Until: 8:00,             !- Complex Field #3
    0.2,                     !- Complex Field #4
    Until: 18:00,            !- Complex Field #5
    0.8,                     !- Complex Field #6
    Until: 24:00,            !- Complex Field #7
    0.2,                     !- Complex Field #8
    For: AllOtherDays;       !- Complex Field #9

  SCHEDULE:COMPACT,
    OFFICE LIGHTING,         !- Name
    Fraction,                !- ScheduleType
    Through: 12/31,          !- Complex Field #1
    For: AllDays,            !- Complex Field #2
    Until: 6:00,             !- Complex Field #3
    0.05,                    !- Complex Field #4
    Until: 7:00,             !- Complex Field #5
    0.20,                    !- Complex Field #6
    Until: 18:00,            !- Complex Field #7
    0.3,                     !- Complex Field #8
    Until: 22:00,            !- Complex Field #9
    0.8,                     !- Complex Field #10
    Until: 24:00,            !- Complex Field #11
    0.1;                     !- Complex Field #12

!-   ===========  ALL OBJECTS IN CLASS: PEOPLE ===========

  PEOPLE,
    West_People,             !- Name
    West_ZONE,               !- Zone Name
    1,                       !- Number of People
    OFFICE OCCUPANCY,        !- Number of People SCHEDULE Name (real--
fraction)
    0.3,                     !- Fraction Radiant
    Activity Sch,            !- Activity level SCHEDULE Name (units W/person,
real)
    ZoneAveraged,            !- MRT Calculation Type
    ,                        !- Surface Name/Angle Factor List Name
    Work Eff Sch,            !- Work Efficiency SCHEDULE Name (0.0-1.0,real)
```

```
    Clothing Sch,              !- Clothing Insulation SCHEDULE Name (real)
    Air Velo Sch,              !- Air Velocity SCHEDULE Name (units m/s, real)
    Fanger;                    !- Thermal Comfort Report Type #1

  PEOPLE,
    East_People,               !- Name
    East_ZONE,                 !- Zone Name
    1,                         !- Number of People
    OFFICE OCCUPANCY,          !- Number of People SCHEDULE Name (real--
fraction)
    0.3,                       !- Fraction Radiant
    Activity Sch,              !- Activity level SCHEDULE Name (units W/person,
real)
    ZoneAveraged,              !- MRT Calculation Type
    ,                          !- Surface Name/Angle Factor List Name
    Work Eff Sch,              !- Work Efficiency SCHEDULE Name (0.0-1.0,real)
    Clothing Sch,              !- Clothing Insulation SCHEDULE Name (real)
    Air Velo Sch,              !- Air Velocity SCHEDULE Name (units m/s, real)
    Fanger;                    !- Thermal Comfort Report Type #1

  PEOPLE,
    Liv_People,                !- Name
    Living_ZONE,               !- Zone Name
    2,                         !- Number of People
    OFFICE OCCUPANCY,          !- Number of People SCHEDULE Name (real--
fraction)
    0.3,                       !- Fraction Radiant
    Activity Sch,              !- Activity level SCHEDULE Name (units W/person,
real)
    ZoneAveraged,              !- MRT Calculation Type
    ,                          !- Surface Name/Angle Factor List Name
    Work Eff Sch,              !- Work Efficiency SCHEDULE Name (0.0-1.0,real)
    Clothing Sch,              !- Clothing Insulation SCHEDULE Name (real)
    Air Velo Sch,              !- Air Velocity SCHEDULE Name (units m/s, real)
    Fanger;                    !- Thermal Comfort Report Type #1

!-   ===========  ALL OBJECTS IN CLASS: LIGHTS ===========

  LIGHTS,
    East_Lights,               !- Name
    East_ZONE,                 !- Zone Name
    OFFICE LIGHTING,           !- SCHEDULE Name
    250,                       !- Design Level {W}
    0,                         !- Return Air Fraction
    0.2,                       !- Fraction Radiant
    0.2,                       !- Fraction Visible
    0,                         !- Fraction Replaceable
    GeneralLights;             !- End-Use Subcategory

  LIGHTS,
    West_Lights,               !- Name
    West_ZONE,                 !- Zone Name
    OFFICE LIGHTING,           !- SCHEDULE Name
    250,                       !- Design Level {W}
    0,                         !- Return Air Fraction
    0.2,                       !- Fraction Radiant
    0.2,                       !- Fraction Visible
```

```
    0,                       !- Fraction Replaceable
    GeneralLights;           !- End-Use Subcategory

!-   ===========  ALL OBJECTS IN CLASS: ELECTRIC EQUIPMENT ===========

  ELECTRIC EQUIPMENT,
    East_Equip,              !- Name
    East_ZONE,               !- Zone Name
    INTERMITTENT,            !- SCHEDULE Name
    250,                     !- Design Level {W}
    0,                       !- Fraction Latent
    0.3,                     !- Fraction Radiant
    0;                       !- Fraction Lost

  ELECTRIC EQUIPMENT,
    West_Equip,              !- Name
    West_ZONE,               !- Zone Name
    INTERMITTENT,            !- SCHEDULE Name
    250,                     !- Design Level {W}
    0,                       !- Fraction Latent
    0.3,                     !- Fraction Radiant
    0;                       !- Fraction Lost

  ELECTRIC EQUIPMENT,
    Liv_Equip,               !- Name
    Living_ZONE,             !- Zone Name
    INTERMITTENT,            !- SCHEDULE Name
    250,                     !- Design Level {W}
    0,                       !- Fraction Latent
    0.3,                     !- Fraction Radiant
    0;                       !- Fraction Lost

!-   ===========  ALL OBJECTS IN CLASS: AIRFLOWNETWORK SIMULATION ===========

  AIRFLOWNETWORK SIMULATION,
    NaturalVentilation,      !- AirflowNetwork Simulation Name
    MULTIZONE WITHOUT DISTRIBUTION,  !- AirflowNetwork Control
    INPUT,                   !- Wind Pressure Coefficient Type
    Every 30 Degrees,        !- AirflowNetwork Wind Pressure Coefficient
Array Name
    LOWRISE,                 !- Building Type
    500,                     !- Maximum number of iterations {dimensionless}
    1,                       !- Initialization Type
    0.00001,                 !- Relative airflow convergence tolerance
{dimensionless}
    0.000001,                !- Absolute airflow convergence tolerance {kg/s}
    -0.5,                    !- Convergence acceleration limit
{dimensionless}
    10,                      !- Reference height for recorded wind data {m}
    0.14,                    !- Wind velocity profile exponent
{dimensionless}
    0,                       !- Azimuth Angle of Long Axis of Building {deg}
    1;                       !- Ratio of Building Width Along Short Axis to
Width Along Long Axis

!-   ===========  ALL OBJECTS IN CLASS: AIRFLOWNETWORK:MULTIZONE:ZONE
===========
```

```
  AIRFLOWNETWORK:MULTIZONE:ZONE,
    East_ZONE,               !- Name of Associated Thermal Zone
    CONSTANT,                !- Ventilation Control Mode
    ,                        !- Vent Temperature Schedule Name
    ,                        !- Limit Value on Multiplier for Modulating
Venting Open Factor {dimensionless}
    1,                       !- Lower Value on Inside/Outside Temperature
Difference for Modulating the Venting Open Factor {deltaC}
    ,                        !- Upper Value on Inside/Outside Temperature
Difference for Modulating the Venting Open Factor {deltaC}
    ,                        !- Lower Value on Inside/Outside Enthalpy
Difference for Modulating the Venting Open Factor {J/kg}
    ;                        !- Upper Value on Inside/Outside Enthalpy
Difference for Modulating the Venting Open Factor {J/kg}

  AIRFLOWNETWORK:MULTIZONE:ZONE,
    West_ZONE,               !- Name of Associated Thermal Zone
    CONSTANT,                !- Ventilation Control Mode
    ,                        !- Vent Temperature Schedule Name
    ,                        !- Limit Value on Multiplier for Modulating
Venting Open Factor {dimensionless}
    1,                       !- Lower Value on Inside/Outside Temperature
Difference for Modulating the Venting Open Factor {deltaC}
    ,                        !- Upper Value on Inside/Outside Temperature
Difference for Modulating the Venting Open Factor {deltaC}
    ,                        !- Lower Value on Inside/Outside Enthalpy
Difference for Modulating the Venting Open Factor {J/kg}
    ;                        !- Upper Value on Inside/Outside Enthalpy
Difference for Modulating the Venting Open Factor {J/kg}

  AIRFLOWNETWORK:MULTIZONE:ZONE,
    Balcony_ZONE,            !- Name of Associated Thermal Zone
    CONSTANT,                !- Ventilation Control Mode
    ,                        !- Vent Temperature Schedule Name
    ,                        !- Limit Value on Multiplier for Modulating
Venting Open Factor {dimensionless}
    1,                       !- Lower Value on Inside/Outside Temperature
Difference for Modulating the Venting Open Factor {deltaC}
    ,                        !- Upper Value on Inside/Outside Temperature
Difference for Modulating the Venting Open Factor {deltaC}
    ,                        !- Lower Value on Inside/Outside Enthalpy
Difference for Modulating the Venting Open Factor {J/kg}
    ;                        !- Upper Value on Inside/Outside Enthalpy
Difference for Modulating the Venting Open Factor {J/kg}

  AIRFLOWNETWORK:MULTIZONE:ZONE,
    Living_ZONE,             !- Name of Associated Thermal Zone
    CONSTANT,                !- Ventilation Control Mode
    ,                        !- Vent Temperature Schedule Name
    ,                        !- Limit Value on Multiplier for Modulating
Venting Open Factor {dimensionless}
    1,                       !- Lower Value on Inside/Outside Temperature
Difference for Modulating the Venting Open Factor {deltaC}
    ,                        !- Upper Value on Inside/Outside Temperature
Difference for Modulating the Venting Open Factor {deltaC}
```

```
    ,                          !- Lower Value on Inside/Outside Enthalpy
Difference for Modulating the Venting Open Factor {J/kg}
    ;                          !- Upper Value on Inside/Outside Enthalpy
Difference for Modulating the Venting Open Factor {J/kg}

!-   ===========  ALL OBJECTS IN CLASS: AIRFLOWNETWORK:MULTIZONE:SURFACE
===========

  AIRFLOWNETWORK:MULTIZONE:SURFACE,
    Win_Balc,                  !- Name of Associated Heat Transfer Surface
    WiOpen1,                   !- Leakage Component Name
    SFacade,                   !- External Node Name
    0.5;                       !- Window/Door Opening Factor, or Crack Factor
{dimensionless}

  AIRFLOWNETWORK:MULTIZONE:SURFACE,
    Win_East,                  !- Name of Associated Heat Transfer Surface
    WiOpen1,                   !- Leakage Component Name
    NFacade,                   !- External Node Name
    0.5;                       !- Window/Door Opening Factor, or Crack Factor
{dimensionless}

  AIRFLOWNETWORK:MULTIZONE:SURFACE,
    Win_West,                  !- Name of Associated Heat Transfer Surface
    WiOpen1,                   !- Leakage Component Name
    NFacade,                   !- External Node Name
    0.5;                       !- Window/Door Opening Factor, or Crack Factor
{dimensionless}

  AIRFLOWNETWORK:MULTIZONE:SURFACE,
    Door_Balc-Liv,             !- Name of Associated Heat Transfer Surface
    DrOpen,                    !- Leakage Component Name
    ,                          !- External Node Name
    0.5;                       !- Window/Door Opening Factor, or Crack Factor
{dimensionless}

  AIRFLOWNETWORK:MULTIZONE:SURFACE,
    Door_Liv-East,             !- Name of Associated Heat Transfer Surface
    DrOpen,                    !- Leakage Component Name
    ,                          !- External Node Name
    0.5;                       !- Window/Door Opening Factor, or Crack Factor
{dimensionless}

  AIRFLOWNETWORK:MULTIZONE:SURFACE,
    Door_Liv-West,             !- Name of Associated Heat Transfer Surface
    DrOpen,                    !- Leakage Component Name
    ,                          !- External Node Name
    0.5;                       !- Window/Door Opening Factor, or Crack Factor
{dimensionless}

!-   ===========  ALL OBJECTS IN CLASS: AIRFLOWNETWORK:MULTIZONE:COMPONENT
DETAILED OPENING ===========

  AIRFLOWNETWORK:MULTIZONE:COMPONENT DETAILED OPENING,
    WiOpen1,                   !- Detailed Opening Name
    0.001,                     !- Air Mass Flow Coefficient When Opening is
Closed {kg/s-m}
```

```
    0.667,                   !- Air Mass Flow Exponent When Opening is Closed
{dimensionless}
    1,                       !- Type of Rectanguler Large Vertical Opening
(LVO)
    0,                       !- Extra crack length or Height of pivoting axis
{m}
    2,                       !- Number of Sets of Opening Factor Data
    0,                       !- Opening factor #1 {dimensionless}
    0.5,                     !- Discharge coefficient for opening factor #1
{dimensionless}
    0,                       !- Width factor for opening factor #1
{dimensionless}
    1,                       !- Height factor for opening factor #1
{dimensionless}
    0,                       !- Start height factor for opening factor #1
{dimensionless}
    1,                       !- Opening factor #2 {dimensionless}
    0.6,                     !- Discharge coefficient for Opening factor #2
{dimensionless}
    1,                       !- Width factor for Opening factor #2
{dimensionless}
    1,                       !- Height factor for Opening factor #2
{dimensionless}
    0,                       !- Start height factor for Opening factor #2
{dimensionless}
    0,                       !- Opening factor #3 {dimensionless}
    0,                       !- Discharge coefficient for Opening factor #3
{dimensionless}
    0,                       !- Width factor for Opening factor #3
{dimensionless}
    0,                       !- Height factor for Opening factor #3
{dimensionless}
    0,                       !- Start height factor for Opening factor #3
{dimensionless}
    0,                       !- Opening factor #4 {dimensionless}
    0,                       !- Discharge coefficient for Opening factor #4
{dimensionless}
    0,                       !- Width factor for Opening factor #4
{dimensionless}
    0,                       !- Height factor for Opening factor #4
{dimensionless}
    0;                       !- Start height factor for Opening factor #4
{dimensionless}

  AIRFLOWNETWORK:MULTIZONE:COMPONENT DETAILED OPENING,
    DrOpen,                  !- Detailed Opening Name
    0.001,                   !- Air Mass Flow Coefficient When Opening is
Closed {kg/s-m}
    0.667,                   !- Air Mass Flow Exponent When Opening is Closed
{dimensionless}
    1,                       !- Type of Rectanguler Large Vertical Opening
(LVO)
    0,                       !- Extra crack length or Height of pivoting axis
{m}
    2,                       !- Number of Sets of Opening Factor Data
    0,                       !- Opening factor #1 {dimensionless}
```

```
    0.5,                        !- Discharge coefficient for opening factor #1
{dimensionless}
    0,                          !- Width factor for opening factor #1
{dimensionless}
    1,                          !- Height factor for opening factor #1
{dimensionless}
    0,                          !- Start height factor for opening factor #1
{dimensionless}
    1,                          !- Opening factor #2 {dimensionless}
    0.6,                        !- Discharge coefficient for Opening factor #2
{dimensionless}
    1,                          !- Width factor for Opening factor #2
{dimensionless}
    1,                          !- Height factor for Opening factor #2
{dimensionless}
    0,                          !- Start height factor for Opening factor #2
{dimensionless}
    0,                          !- Opening factor #3 {dimensionless}
    0,                          !- Discharge coefficient for Opening factor #3
{dimensionless}
    0,                          !- Width factor for Opening factor #3
{dimensionless}
    0,                          !- Height factor for Opening factor #3
{dimensionless}
    0,                          !- Start height factor for Opening factor #3
{dimensionless}
    0,                          !- Opening factor #4 {dimensionless}
    0,                          !- Discharge coefficient for Opening factor #4
{dimensionless}
    0,                          !- Width factor for Opening factor #4
{dimensionless}
    0,                          !- Height factor for Opening factor #4
{dimensionless}
    0;                          !- Start height factor for Opening factor #4
{dimensionless}

!-   ===========  ALL OBJECTS IN CLASS: AIRFLOWNETWORK:MULTIZONE:SITE WIND
CONDITIONS ===========

  AIRFLOWNETWORK:MULTIZONE:SITE WIND CONDITIONS,
    0,                          !- Wind Direction {deg}
    0.18;                       !- Exponent of Wind Velocity Profile
{dimensionless}

  AIRFLOWNETWORK:MULTIZONE:SITE WIND CONDITIONS,
    180,                        !- Wind Direction {deg}
    0.32;                       !- Exponent of Wind Velocity Profile
{dimensionless}

!-   ===========  ALL OBJECTS IN CLASS: AIRFLOWNETWORK:MULTIZONE:EXTERNAL
NODE ===========

  AIRFLOWNETWORK:MULTIZONE:EXTERNAL NODE,
    SFacade,                    !- Name of External Node
    1.524;                      !- External Node Height {m}

  AIRFLOWNETWORK:MULTIZONE:EXTERNAL NODE,
```

```
    NFacade,                  !- Name of External Node
    1.524;                    !- External Node Height {m}

  AIRFLOWNETWORK:MULTIZONE:EXTERNAL NODE,
    EFacade,                  !- Name of External Node
    1.524;                    !- External Node Height {m}

  AIRFLOWNETWORK:MULTIZONE:EXTERNAL NODE,
    WFacade,                  !- Name of External Node
    1.524;                    !- External Node Height {m}

!-   ===========  ALL OBJECTS IN CLASS: AIRFLOWNETWORK:MULTIZONE:WIND
PRESSURE COEFFICIENT ARRAY ===========

  AIRFLOWNETWORK:MULTIZONE:WIND PRESSURE COEFFICIENT ARRAY,
    Every 30 Degrees,         !- WPC Array Name
    10,                       !- Reference Height for WPC Data {m}
    0,                        !- Wind Direction #1 {deg}
    30,                       !- Wind Direction #2 {deg}
    60,                       !- Wind Direction #3 {deg}
    90,                       !- Wind Direction #4 {deg}
    120,                      !- Wind Direction #5 {deg}
    150,                      !- Wind Direction #6 {deg}
    180,                      !- Wind Direction #7 {deg}
    210,                      !- Wind Direction #8 {deg}
    240,                      !- Wind Direction #9 {deg}
    270,                      !- Wind Direction #10 {deg}
    300,                      !- Wind Direction #11 {deg}
    330;                      !- Wind Direction #12 {deg}

!-   ===========  ALL OBJECTS IN CLASS: AIRFLOWNETWORK:MULTIZONE:WIND
PRESSURE COEFFICIENT VALUES ===========

  AIRFLOWNETWORK:MULTIZONE:WIND PRESSURE COEFFICIENT VALUES,
    Every 30 Degrees,         !- AirflowNetwork WPC Array Name
    NFacade,                  !- External Node Name
    0.6,                      !- WPC Value #1 {dimensionless}
    0.48,                     !- WPC Value #2 {dimensionless}
    0.04,                     !- WPC Value #3 {dimensionless}
    -.56,                     !- WPC Value #4 {dimensionless}
    -.56,                     !- WPC Value #5 {dimensionless}
    -.42,                     !- WPC Value #6 {dimensionless}
    -.37,                     !- WPC Value #7 {dimensionless}
    -.42,                     !- WPC Value #8 {dimensionless}
    -.56,                     !- WPC Value #9 {dimensionless}
    0.04,                     !- WPC Value #10 {dimensionless}
    0.48;                     !- WPC Value #11 {dimensionless}

  AIRFLOWNETWORK:MULTIZONE:WIND PRESSURE COEFFICIENT VALUES,
    Every 30 Degrees,         !- AirflowNetwork WPC Array Name
    EFacade,                  !- External Node Name
    -.56,                     !- WPC Value #1 {dimensionless}
    0.04,                     !- WPC Value #2 {dimensionless}
    0.48,                     !- WPC Value #3 {dimensionless}
    0.6,                      !- WPC Value #4 {dimensionless}
    0.48,                     !- WPC Value #5 {dimensionless}
    0.04,                     !- WPC Value #6 {dimensionless}
```

```
    -.56,                    !- WPC Value #7 {dimensionless}
    -.56,                    !- WPC Value #8 {dimensionless}
    -.42,                    !- WPC Value #9 {dimensionless}
    -.37,                    !- WPC Value #10 {dimensionless}
    -.42,                    !- WPC Value #11 {dimensionless}
    -.56;                    !- WPC Value #12 {dimensionless}

  AIRFLOWNETWORK:MULTIZONE:WIND PRESSURE COEFFICIENT VALUES,
    Every 30 Degrees,        !- AirflowNetwork WPC Array Name
    SFacade,                 !- External Node Name
    -.37,                    !- WPC Value #1 {dimensionless}
    -.42,                    !- WPC Value #2 {dimensionless}
    -.56,                    !- WPC Value #3 {dimensionless}
    -.56,                    !- WPC Value #4 {dimensionless}
    0.04,                    !- WPC Value #5 {dimensionless}
    0.48,                    !- WPC Value #6 {dimensionless}
    0.6,                     !- WPC Value #7 {dimensionless}
    0.48,                    !- WPC Value #8 {dimensionless}
    0.04,                    !- WPC Value #9 {dimensionless}
    -.56,                    !- WPC Value #10 {dimensionless}
    -.56,                    !- WPC Value #11 {dimensionless}
    -.42;                    !- WPC Value #12 {dimensionless}

  AIRFLOWNETWORK:MULTIZONE:WIND PRESSURE COEFFICIENT VALUES,
    Every 30 Degrees,        !- AirflowNetwork WPC Array Name
    WFacade,                 !- External Node Name
    -.56,                    !- WPC Value #1 {dimensionless}
    -.56,                    !- WPC Value #2 {dimensionless}
    -.42,                    !- WPC Value #3 {dimensionless}
    -.37,                    !- WPC Value #4 {dimensionless}
    -.42,                    !- WPC Value #5 {dimensionless}
    -.56,                    !- WPC Value #6 {dimensionless}
    -.56,                    !- WPC Value #7 {dimensionless}
    0.04,                    !- WPC Value #8 {dimensionless}
    0.48,                    !- WPC Value #9 {dimensionless}
    0.6,                     !- WPC Value #10 {dimensionless}
    0.48,                    !- WPC Value #11 {dimensionless}
    0.04;                    !- WPC Value #12 {dimensionless}

!-   ===========  ALL OBJECTS IN CLASS: REPORT VARIABLE ===========

  Report Variable,
    *,                       !- Key_Value
    Zone Mean Air Temperature,  !- Variable_Name
    timestep;                !- Reporting_Frequency

  Report Variable,
    *,                       !- Key_Value
    Outdoor Dry Bulb,        !- Variable_Name
    timestep;                !- Reporting_Frequency

  Report Variable,
    *,                       !- Key_Value
    Wind Speed,              !- Variable_Name
    timestep;                !- Reporting_Frequency

  Report Variable,
```

```
    *,                          !- Key_Value
    Wind Direction,             !- Variable_Name
    timestep;                   !- Reporting_Frequency

  Report Variable,
    Win_Balc,                   !- Key_Value
    AirflowNetwork Volume Flow Rate from Node 1 to 2,  !- Variable_Name
    timestep;                   !- Reporting_Frequency

  Report Variable,
    Win_Balc,                   !- Key_Value
    AirflowNetwork Volume Flow Rate from Node 2 to 1,  !- Variable_Name
    timestep;                   !- Reporting_Frequency

  Report Variable,
    Win_East,                   !- Key_Value
    AirflowNetwork Volume Flow Rate from Node 1 to 2,  !- Variable_Name
    timestep;                   !- Reporting_Frequency

  Report Variable,
    Win_East,                   !- Key_Value
    AirflowNetwork Volume Flow Rate from Node 2 to 1,  !- Variable_Name
    timestep;                   !- Reporting_Frequency

  Report Variable,
    Win_West,                   !- Key_Value
    AirflowNetwork Volume Flow Rate from Node 1 to 2,  !- Variable_Name
    timestep;                   !- Reporting_Frequency

  Report Variable,
    Win_West,                   !- Key_Value
    AirflowNetwork Volume Flow Rate from Node 2 to 1,  !- Variable_Name
    timestep;                   !- Reporting_Frequency

  Report Variable,
    Door_Balc-Liv,              !- Key_Value
    AirflowNetwork Volume Flow Rate from Node 1 to 2,  !- Variable_Name
    timestep;                   !- Reporting_Frequency

  Report Variable,
    Door_Balc-Liv,              !- Key_Value
    AirflowNetwork Volume Flow Rate from Node 2 to 1,  !- Variable_Name
    timestep;                   !- Reporting_Frequency

  Report Variable,
    Door_Liv-East,              !- Key_Value
    AirflowNetwork Volume Flow Rate from Node 1 to 2,  !- Variable_Name
    timestep;                   !- Reporting_Frequency

  Report Variable,
    Door_Liv-East,              !- Key_Value
    AirflowNetwork Volume Flow Rate from Node 2 to 1,  !- Variable_Name
    timestep;                   !- Reporting_Frequency

  Report Variable,
    Door_Liv-West,              !- Key_Value
    AirflowNetwork Volume Flow Rate from Node 1 to 2,  !- Variable_Name
```

```
    timestep;                    !- Reporting_Frequency

  Report Variable,
    Door_Liv-West,               !- Key_Value
    AirflowNetwork Volume Flow Rate from Node 2 to 1,  !- Variable_Name
    timestep;                    !- Reporting_Frequency

  Report Variable,
    Win_Balc,                    !- Key_Value
    AirflowNetwork Mass Flow Rate from Node 2 to 1,  !- Variable_Name
    timestep;                    !- Reporting_Frequency

  Report Variable,
    Win_Balc,                    !- Key_Value
    AirflowNetwork Mass Flow Rate from Node 1 to 2,  !- Variable_Name
    timestep;                    !- Reporting_Frequency

  Report Variable,
    Door_Balc-Liv,               !- Key_Value
    AirflowNetwork Mass Flow Rate from Node 1 to 2,  !- Variable_Name
    timestep;                    !- Reporting_Frequency

  Report Variable,
    Door_Balc-Liv,               !- Key_Value
    AirflowNetwork Mass Flow Rate from Node 2 to 1,  !- Variable_Name
    timestep;                    !- Reporting_Frequency

  Report Variable,
    Win_East,                    !- Key_Value
    AirflowNetwork Mass Flow Rate from Node 2 to 1,  !- Variable_Name
    timestep;                    !- Reporting_Frequency

  Report Variable,
    Win_East,                    !- Key_Value
    AirflowNetwork Mass Flow Rate from Node 1 to 2,  !- Variable_Name
    timestep;                    !- Reporting_Frequency

  Report Variable,
    Win_West,                    !- Key_Value
    AirflowNetwork Mass Flow Rate from Node 1 to 2,  !- Variable_Name
    timestep;                    !- Reporting_Frequency

  Report Variable,
    Win_West,                    !- Key_Value
    AirflowNetwork Mass Flow Rate from Node 2 to 1,  !- Variable_Name
    timestep;                    !- Reporting_Frequency

!-   ===========  ALL OBJECTS IN CLASS: REPORT ===========

  Report,
    Variable Dictionary;         !- Type_of_Report

  Report,
    surfaces,                    !- Type_of_Report
    dxf;                         !- Name_of_Report
```

APPENDIX G: PARTIAL RESULTS FROM SIMULATION OF BEIJING APARTMENT

Date/Time	Environm ent:Outdo or Dry Bulb [C](TimeS tep)	Environm ent:Wind Speed [m/s](Tim eStep)	Environm ent:Wind Direction [deg](Tim eStep)	WEST_Z ONE:Zone Mean Air Temperat ure [C](TimeS tep)	BALCONY _ZONE:Z one Mean Air Temperat ure [C](TimeS tep)	LIVING_Z ONE:Zone Mean Air Temperat ure [C](TimeS tep)	WIN_BAL C:AirflowN etwork Mass Flow Rate from Node 1 to 2 [kg/s](Tim eStep)	WIN_BAL C:AirflowN etwork Mass Flow Rate from Node 2 to 1 [kg/s](Tim eStep)	WIN_EAS T:AirflowN etwork Mass Flow Rate from Node 1 to 2 [kg/s](Tim eStep)	WIN_EAS T:AirflowN etwork Mass Flow Rate from Node 2 to 1 [kg/s](Tim eStep)	WIN_WE ST:Airflow Network Mass Flow Rate from Node 1 to 2 [kg/s](Tim eStep)	WIN_WE ST:Airflow Network Mass Flow Rate from Node 2 to 1 [kg/s](Tim eStep)	Balcony: Net Mass Flow Rate from Node 1 to 2	Win_East Net Mass Flow Rate from Node 2 to 1	Win_Wes t Net Mass Flow Rate from Node 2 to 1	Net Mass Flow Rates (through both windows) from Node 2 to 1	Differenc e between Net flow from Node 1 to 2 and Net flow from Node 2 to 1
07/01 00:	19.283	0.367	18.7	22.8	21.8	23.1	0.433	0.249	0.002	0.094	0.002	0.094	0.183	0.092	0.092	0.183	0.000
07/01 00:	19.767	0.733	37.3	22.6	22.2	23.1	0.507	0.179	0.000	0.164	0.000	0.164	0.328	0.164	0.164	0.328	0.000
07/01 00:	20.250	1.100	56.0	22.4	22.5	23.0	0.529	0.113	0.000	0.208	0.000	0.208	0.416	0.208	0.208	0.416	0.000
07/01 00:	20.733	1.467	74.7	22.5	22.7	23.0	0.478	0.104	0.000	0.187	0.000	0.187	0.375	0.187	0.187	0.375	0.000
07/01 00:	21.217	1.833	93.3	23.0	22.4	23.1	0.135	0.298	0.082	0.000	0.082	0.000	-0.163	-0.082	-0.082	-0.163	0.000
07/01 01:	21.700	2.200	112.0	23.4	22.1	22.8	0.000	0.619	0.310	0.000	0.310	0.000	-0.619	-0.310	-0.310	-0.619	0.000
07/01 01:	21.633	2.100	133.3	23.3	22.0	22.6	0.000	0.741	0.371	0.000	0.371	0.000	-0.741	-0.371	-0.371	-0.741	0.000
07/01 01:	21.567	2.000	154.7	23.1	22.0	22.5	0.000	0.764	0.382	0.000	0.382	0.000	-0.764	-0.382	-0.382	-0.764	0.000
07/01 01:	21.500	1.900	176.0	23.1	21.9	22.5	0.000	0.723	0.361	0.000	0.361	0.000	-0.723	-0.361	-0.361	-0.723	0.000
07/01 01:	21.433	1.800	197.3	23.0	21.9	22.5	0.000	0.686	0.343	0.000	0.343	0.000	-0.686	-0.343	-0.343	-0.686	0.000
07/01 01:	21.367	1.700	218.7	23.0	21.8	22.5	0.000	0.623	0.311	0.000	0.311	0.000	-0.623	-0.311	-0.311	-0.623	0.000
07/01 02:	21.300	1.600	240.0	23.1	21.8	22.5	0.000	0.516	0.258	0.000	0.258	0.000	-0.516	-0.258	-0.258	-0.516	0.000
07/01 02:	21.283	1.650	240.0	23.1	21.8	22.5	0.000	0.532	0.266	0.000	0.266	0.000	-0.532	-0.266	-0.266	-0.532	0.000
07/01 02:	21.267	1.700	240.0	23.1	21.8	22.5	0.000	0.549	0.275	0.000	0.275	0.000	-0.549	-0.275	-0.275	-0.549	0.000
07/01 02:	21.250	1.750	240.0	23.1	21.8	22.5	0.000	0.566	0.283	0.000	0.283	0.000	-0.566	-0.283	-0.283	-0.566	0.000
07/01 02:	21.233	1.800	240.0	23.0	21.7	22.4	0.000	0.583	0.291	0.000	0.291	0.000	-0.583	-0.291	-0.291	-0.583	0.000
07/01 02:	21.217	1.850	240.0	23.0	21.7	22.4	0.000	0.600	0.300	0.000	0.300	0.000	-0.600	-0.300	-0.300	-0.600	0.000
07/01 03:	21.200	1.900	240.0	23.0	21.7	22.4	0.000	0.616	0.308	0.000	0.308	0.000	-0.616	-0.308	-0.308	-0.616	0.000
07/01 03:	21.183	1.933	240.0	22.9	21.7	22.3	0.000	0.628	0.314	0.000	0.314	0.000	-0.628	-0.314	-0.314	-0.628	0.000
07/01 03:	21.167	1.967	240.0	22.9	21.6	22.3	0.000	0.639	0.319	0.000	0.319	0.000	-0.639	-0.319	-0.319	-0.639	0.000
07/01 03:	21.150	2.000	240.0	22.9	21.6	22.3	0.000	0.650	0.325	0.000	0.325	0.000	-0.650	-0.325	-0.325	-0.650	0.000
07/01 03:	21.133	2.033	240.0	22.8	21.6	22.2	0.000	0.661	0.331	0.000	0.331	0.000	-0.661	-0.331	-0.331	-0.661	0.000
07/01 03:	21.117	2.067	240.0	22.8	21.6	22.2	0.000	0.672	0.336	0.000	0.336	0.000	-0.672	-0.336	-0.336	-0.672	0.000
07/01 04:	21.100	2.100	240.0	22.8	21.5	22.2	0.000	0.684	0.342	0.000	0.342	0.000	-0.684	-0.342	-0.342	-0.684	0.000
07/01 04:	21.033	2.150	202.7	22.7	21.5	22.1	0.000	0.823	0.411	0.000	0.411	0.000	-0.823	-0.411	-0.411	-0.823	0.000
07/01 04:	20.967	2.200	165.3	22.7	21.4	22.0	0.000	0.842	0.421	0.000	0.421	0.000	-0.842	-0.421	-0.421	-0.842	0.000
07/01 04:	20.900	2.250	128.0	22.6	21.3	22.0	0.000	0.773	0.386	0.000	0.386	0.000	-0.773	-0.386	-0.386	-0.773	0.000
07/01 04:	20.833	2.300	90.7	22.9	21.7	22.4	0.164	0.197	0.036	0.019	0.036	0.019	-0.034	-0.017	-0.017	-0.034	0.000
07/01 04:	20.767	2.350	53.3	22.2	22.3	22.6	0.900	0.000	0.000	0.450	0.000	0.450	0.900	0.450	0.450	0.900	0.000
07/01 05:	20.700	2.400	16.0	21.7	22.4	22.3	1.143	0.000	0.000	0.572	0.000	0.572	1.143	0.572	0.572	1.143	0.000
07/01 05:	20.567	2.283	16.0	21.5	22.3	22.1	1.089	0.000	0.000	0.545	0.000	0.545	1.089	0.545	0.545	1.089	0.000
07/01 05:	20.433	2.167	16.0	21.5	22.2	22.0	1.035	0.000	0.000	0.517	0.000	0.517	1.035	0.517	0.517	1.035	0.000
07/01 05:	20.300	2.050	16.0	21.4	22.1	21.9	0.980	0.000	0.000	0.490	0.000	0.490	0.980	0.490	0.490	0.980	0.000
07/01 05:	20.167	1.933	16.0	21.3	22.0	21.9	0.925	0.000	0.000	0.463	0.000	0.463	0.925	0.463	0.463	0.925	0.000
07/01 05:	20.033	1.817	16.0	21.3	22.0	21.9	0.871	0.000	0.000	0.435	0.000	0.435	0.871	0.435	0.435	0.871	0.000
07/01 06:	19.900	1.700	16.0	21.2	22.0	21.9	0.829	0.013	0.000	0.408	0.000	0.408	0.816	0.408	0.408	0.816	0.000
07/01 06:	19.783	1.567	16.0	21.2	21.9	21.9	0.784	0.032	0.000	0.376	0.000	0.376	0.753	0.376	0.376	0.753	0.000
07/01 06:	19.667	1.433	16.0	21.3	21.9	21.9	0.742	0.052	0.000	0.345	0.000	0.345	0.689	0.345	0.345	0.689	0.000
07/01 06:	19.550	1.300	16.0	21.3	21.8	21.9	0.700	0.073	0.000	0.313	0.000	0.313	0.627	0.313	0.313	0.627	0.000

Date/Time	Environment:Outdoor Dry Bulb [C](TimeStep)	Environment:Wind Speed [m/s](TimeStep)	Environment:Wind Direction [deg](TimeStep)	WEST_ZONE:Zone Mean Air Temperature [C](TimeStep)	BALCONY_ZONE:Zone Mean Air Temperature [C](TimeStep)	LIVING_ZONE:Zone Mean Air Temperature [C](TimeStep)	WIN_BALC:AirflowNetwork Mass Flow Rate from Node 1 to 2 [kg/s](TimeStep)	WIN_BALC:AirflowNetwork Mass Flow Rate from Node 2 to 1 [kg/s](TimeStep)	WIN_EAST:AirflowNetwork Mass Flow Rate from Node 1 to 2 [kg/s](TimeStep)	WIN_EAST:AirflowNetwork Mass Flow Rate from Node 2 to 1 [kg/s](TimeStep)	WIN_WEST:Airflow Network Mass Flow Rate from Node 1 to 2 [kg/s](TimeStep)	WIN_WEST:Airflow Network Mass Flow Rate from Node 2 to 1 [kg/s](TimeStep)	Balcony: Net Mass Flow Rate from Node 1 to 2	Win_East Net Mass Flow Rate from Node 2 to 1	Win_West Net Mass Flow Rate from Node 2 to 1	Net Mass Flow Rates (through both windows) from Node 2 to 1	Difference between Net flow from Node 1 to 2 and Net flow from Node 2 to 1
07/01 06:	19.433	1.167	16.0	21.3	21.8	22.0	0.661	0.097	0.000	0.282	0.000	0.282	0.564	0.282	0.282	0.564	0.000
07/01 06:	19.317	1.033	16.0	21.3	21.7	22.0	0.627	0.125	0.000	0.251	0.000	0.251	0.502	0.251	0.251	0.502	0.000
07/01 07:	19.200	0.900	16.0	21.4	21.6	22.1	0.592	0.151	0.000	0.220	0.000	0.220	0.441	0.220	0.220	0.441	0.000
07/01 07:	19.083	0.750	13.3	21.5	21.5	22.2	0.553	0.178	0.000	0.187	0.000	0.187	0.375	0.187	0.187	0.375	0.000
07/01 07:	18.967	0.600	10.7	21.6	21.4	22.2	0.517	0.211	0.000	0.153	0.000	0.153	0.306	0.153	0.153	0.306	0.000
07/01 07:	18.850	0.450	8.0	21.7	21.2	22.3	0.477	0.241	0.000	0.118	0.000	0.118	0.236	0.118	0.118	0.236	0.000
07/01 07:	18.733	0.300	5.3	21.9	21.1	22.4	0.435	0.271	0.003	0.084	0.003	0.084	0.164	0.082	0.082	0.164	0.000
07/01 07:	18.617	0.150	2.7	22.1	21.0	22.4	0.406	0.300	0.013	0.066	0.013	0.066	0.106	0.053	0.053	0.106	0.000
07/01 08:	18.500	0.000	0.0	22.2	20.9	22.3	0.394	0.308	0.018	0.061	0.018	0.061	0.086	0.043	0.043	0.086	0.000
07/01 08:	18.400	0.167	0.0	22.3	20.8	22.4	0.408	0.297	0.014	0.070	0.014	0.070	0.111	0.055	0.056	0.111	0.000
07/01 08:	18.300	0.333	0.0	22.1	20.9	22.4	0.449	0.271	0.004	0.093	0.004	0.093	0.178	0.089	0.089	0.178	0.000
07/01 08:	18.200	0.500	0.0	21.9	21.0	22.4	0.507	0.246	0.000	0.131	0.000	0.131	0.262	0.131	0.131	0.262	0.000
07/01 08:	18.100	0.667	0.0	21.5	21.1	22.4	0.573	0.229	0.000	0.172	0.000	0.172	0.344	0.172	0.172	0.344	0.000
07/01 08:	18.000	0.833	0.0	21.1	21.2	22.2	0.627	0.200	0.000	0.214	0.000	0.214	0.427	0.214	0.214	0.427	0.000
07/01 09:	17.900	1.000	0.0	20.9	21.2	22.0	0.691	0.180	0.000	0.256	0.000	0.256	0.512	0.256	0.256	0.512	0.000
07/01 09:	17.883	1.167	0.0	20.5	21.3	21.7	0.744	0.150	0.000	0.297	0.000	0.297	0.594	0.297	0.297	0.594	0.000
07/01 09:	17.867	1.333	0.0	20.3	21.3	21.5	0.797	0.121	0.000	0.338	0.000	0.338	0.676	0.338	0.338	0.676	0.000
07/01 09:	17.850	1.500	0.0	20.1	21.3	21.3	0.859	0.100	0.000	0.379	0.000	0.379	0.759	0.379	0.379	0.759	0.000
07/01 09:	17.833	1.667	0.0	20.0	21.2	21.1	0.915	0.074	0.000	0.421	0.000	0.421	0.842	0.421	0.421	0.842	0.000
07/01 09:	17.817	1.833	0.0	19.8	21.1	20.9	0.970	0.046	0.000	0.462	0.000	0.462	0.925	0.462	0.462	0.925	0.000
07/01 10:	17.800	2.000	0.0	19.7	21.0	20.7	1.029	0.021	0.000	0.504	0.000	0.504	1.008	0.504	0.504	1.008	0.000
07/01 10:	17.917	2.167	2.7	19.6	21.0	20.6	1.084	0.000	0.000	0.542	0.000	0.542	1.084	0.542	0.542	1.084	0.000
07/01 10:	18.033	2.333	5.3	19.6	20.8	20.5	1.158	0.000	0.000	0.579	0.000	0.579	1.158	0.579	0.579	1.158	0.000
07/01 10:	18.150	2.500	8.0	19.6	20.7	20.4	1.230	0.000	0.000	0.615	0.000	0.615	1.230	0.615	0.615	1.230	0.000
07/01 10:	18.267	2.667	10.7	19.6	20.7	20.4	1.301	0.000	0.000	0.650	0.000	0.650	1.301	0.650	0.650	1.301	0.000
07/01 10:	18.383	2.833	13.3	19.7	20.6	20.3	1.371	0.000	0.000	0.685	0.000	0.685	1.371	0.685	0.685	1.371	0.000
07/01 11:	18.500	3.000	16.0	19.7	20.6	20.3	1.440	0.000	0.000	0.720	0.000	0.720	1.440	0.720	0.720	1.440	0.000
07/01 11:	18.750	3.000	16.0	19.8	20.6	20.3	1.438	0.000	0.000	0.719	0.000	0.719	1.438	0.719	0.719	1.438	0.000
07/01 11:	19.000	3.000	16.0	20.0	20.6	20.4	1.436	0.000	0.000	0.718	0.000	0.718	1.436	0.718	0.718	1.436	0.000
07/01 11:	19.250	3.000	16.0	20.2	20.7	20.6	1.434	0.000	0.000	0.717	0.000	0.717	1.434	0.717	0.717	1.434	0.000
07/01 11:	19.500	3.000	16.0	20.4	20.8	20.7	1.432	0.000	0.000	0.716	0.000	0.716	1.432	0.716	0.716	1.432	0.000
07/01 11:	19.750	3.000	16.0	20.5	20.9	20.8	1.431	0.000	0.000	0.715	0.000	0.715	1.431	0.715	0.715	1.431	0.000
07/01 12:	20.000	3.000	16.0	20.7	21.0	21.0	1.429	0.000	0.000	0.715	0.000	0.715	1.429	0.715	0.715	1.429	0.000
07/01 12:	20.267	3.000	16.0	20.9	21.1	21.1	1.428	0.000	0.000	0.714	0.000	0.714	1.428	0.714	0.714	1.428	0.000
07/01 12:	20.533	3.000	16.0	21.1	21.3	21.2	1.426	0.000	0.000	0.713	0.000	0.713	1.426	0.713	0.713	1.426	0.000
07/01 12:	20.800	3.000	16.0	21.3	21.4	21.4	1.424	0.000	0.000	0.712	0.000	0.712	1.424	0.712	0.712	1.424	0.000
07/01 12:	21.067	3.000	16.0	21.5	21.5	21.5	1.423	0.000	0.000	0.711	0.000	0.711	1.423	0.711	0.711	1.423	0.000
07/01 12:	21.333	3.000	16.0	21.7	21.7	21.7	1.421	0.000	0.000	0.711	0.000	0.711	1.421	0.711	0.711	1.421	0.000
07/01 13:	21.600	3.000	16.0	21.9	21.8	21.9	1.420	0.000	0.000	0.710	0.000	0.710	1.420	0.710	0.710	1.420	0.000
07/01 13:	21.817	3.000	18.7	22.1	22.0	22.0	1.409	0.000	0.000	0.704	0.000	0.704	1.409	0.704	0.704	1.409	0.000
07/01 13:	22.033	3.000	21.3	22.3	22.1	22.2	1.398	0.000	0.000	0.699	0.000	0.699	1.398	0.699	0.699	1.398	0.000
07/01 13:	22.250	3.000	24.0	22.5	22.3	22.4	1.387	0.000	0.000	0.693	0.000	0.693	1.387	0.693	0.693	1.387	0.000

Date/Time	Environment:Outdoor Dry Bulb [C](TimeStep)	Environment:Wind Speed [m/s](TimeStep)	Environment:Wind Direction [deg](TimeStep)	WEST_ZONE:Zone Mean Air Temperature [C](TimeStep)	BALCONY_ZONE:Zone Mean Air Temperature [C](TimeStep)	LIVING_ZONE:Zone Mean Air Temperature [C](TimeStep)	WIN_BALC:AirflowNetwork Mass Flow Rate from Node 1 to 2 [kg/s](TimeStep)	WIN_BALC:AirflowNetwork Mass Flow Rate from Node 2 to 1 [kg/s](TimeStep)	WIN_EAST:AirflowNetwork Mass Flow Rate from Node 1 to 2 [kg/s](TimeStep)	WIN_EAST:AirflowNetwork Mass Flow Rate from Node 2 to 1 [kg/s](TimeStep)	WIN_WEST:Airflow Network Mass Flow Rate from Node 1 to 2 [kg/s](TimeStep)	WIN_WEST:Airflow Network Mass Flow Rate from Node 2 to 1 [kg/s](TimeStep)	Balcony: Net Mass Flow Rate from Node 1 to 2	Win_East Net Mass Flow Rate from Node 2 to 1	Win_West Net Mass Flow Rate from Node 2 to 1	Net Mass Flow Rates (through both windows) from Node 2 to 1	Difference between Net flow from Node 1 to 2 and Net flow from Node 2 to 1
07/01 13:	22.467	3.000	26.7	22.7	22.4	22.5	1.376	0.000	0.000	0.688	0.000	0.688	1.376	0.688	0.688	1.376	0.000
07/01 13:	22.683	3.000	29.3	22.8	22.6	22.7	1.365	0.000	0.000	0.682	0.000	0.682	1.365	0.682	0.682	1.365	0.000
07/01 14:	22.900	3.000	32.0	23.0	22.7	22.8	1.342	0.000	0.000	0.671	0.000	0.671	1.342	0.671	0.671	1.342	0.000
07/01 14:	23.000	3.000	32.0	23.1	22.9	23.0	1.342	0.000	0.000	0.671	0.000	0.671	1.342	0.671	0.671	1.342	0.000
07/01 14:	23.100	3.000	32.0	23.2	23.0	23.1	1.342	0.000	0.000	0.671	0.000	0.671	1.342	0.671	0.671	1.342	0.000
07/01 14:	23.200	3.000	32.0	23.3	23.1	23.2	1.342	0.000	0.000	0.671	0.000	0.671	1.342	0.671	0.671	1.342	0.000
07/01 14:	23.300	3.000	32.0	23.4	23.2	23.3	1.342	0.000	0.000	0.671	0.000	0.671	1.342	0.671	0.671	1.342	0.000
07/01 14:	23.400	3.000	32.0	23.5	23.3	23.4	1.341	0.000	0.000	0.671	0.000	0.671	1.341	0.671	0.671	1.341	0.000
07/01 15:	23.500	3.000	32.0	23.6	23.4	23.5	1.341	0.000	0.000	0.671	0.000	0.671	1.341	0.671	0.671	1.341	0.000
07/01 15:	23.483	3.000	32.0	23.7	23.5	23.6	1.342	0.000	0.000	0.671	0.000	0.671	1.342	0.671	0.671	1.342	0.000
07/01 15:	23.467	3.000	32.0	23.7	23.6	23.6	1.342	0.000	0.000	0.671	0.000	0.671	1.342	0.671	0.671	1.342	0.000
07/01 15:	23.450	3.000	32.0	23.7	23.7	23.7	1.342	0.000	0.000	0.671	0.000	0.671	1.342	0.671	0.671	1.342	0.000
07/01 15:	23.433	3.000	32.0	23.7	23.7	23.7	1.343	0.000	0.000	0.671	0.000	0.671	1.343	0.671	0.671	1.343	0.000
07/01 15:	23.417	3.000	32.0	23.7	23.7	23.7	1.343	0.000	0.000	0.672	0.000	0.672	1.343	0.672	0.672	1.343	0.000
07/01 16:	23.400	3.000	32.0	23.7	23.8	23.7	1.344	0.000	0.000	0.672	0.000	0.672	1.344	0.672	0.672	1.344	0.000
07/01 16:	23.350	3.000	66.7	23.8	23.8	23.8	0.934	0.000	0.000	0.467	0.000	0.467	0.934	0.467	0.467	0.934	0.000
07/01 16:	23.300	3.000	101.3	24.1	23.7	23.8	0.000	0.613	0.307	0.000	0.307	0.000	-0.613	-0.307	-0.307	-0.613	0.000
07/01 16:	23.250	3.000	136.0	24.2	23.5	23.8	0.000	1.077	0.538	0.000	0.538	0.000	-1.077	-0.538	-0.538	-1.077	0.000
07/01 16:	23.200	3.000	170.7	24.1	23.4	23.6	0.000	1.147	0.573	0.000	0.573	0.000	-1.147	-0.573	-0.573	-1.147	0.000
07/01 16:	23.150	3.000	205.3	24.0	23.4	23.5	0.000	1.150	0.575	0.000	0.575	0.000	-1.150	-0.575	-0.575	-1.150	0.000
07/01 17:	23.100	3.000	240.0	24.0	23.4	23.6	0.000	0.979	0.489	0.000	0.489	0.000	-0.979	-0.489	-0.489	-0.979	0.000
07/01 17:	23.033	2.900	240.0	24.1	23.3	23.6	0.000	0.946	0.473	0.000	0.473	0.000	-0.946	-0.473	-0.473	-0.946	0.000
07/01 17:	22.967	2.800	240.0	24.1	23.3	23.6	0.000	0.913	0.457	0.000	0.457	0.000	-0.913	-0.457	-0.457	-0.913	0.000
07/01 17:	22.900	2.700	240.0	24.1	23.3	23.5	0.000	0.880	0.440	0.000	0.440	0.000	-0.880	-0.440	-0.440	-0.880	0.000
07/01 17:	22.833	2.600	240.0	24.1	23.2	23.5	0.000	0.848	0.424	0.000	0.424	0.000	-0.848	-0.424	-0.424	-0.848	0.000
07/01 17:	22.767	2.500	240.0	24.2	23.2	23.5	0.000	0.815	0.407	0.000	0.407	0.000	-0.815	-0.407	-0.407	-0.815	0.000
07/01 18:	22.700	2.400	240.0	24.2	23.1	23.5	0.000	0.782	0.391	0.000	0.391	0.000	-0.782	-0.391	-0.391	-0.782	0.000
07/01 18:	22.633	2.300	240.0	24.2	23.1	23.4	0.000	0.749	0.374	0.000	0.374	0.000	-0.749	-0.374	-0.374	-0.749	0.000
07/01 18:	22.567	2.200	240.0	24.2	23.1	23.4	0.000	0.716	0.358	0.000	0.358	0.000	-0.716	-0.358	-0.358	-0.716	0.000
07/01 18:	22.500	2.100	240.0	24.2	23.0	23.4	0.000	0.682	0.341	0.000	0.341	0.000	-0.682	-0.341	-0.341	-0.682	0.000
07/01 18:	22.433	2.000	240.0	24.2	23.0	23.4	0.000	0.649	0.325	0.000	0.325	0.000	-0.649	-0.325	-0.325	-0.649	0.000
07/01 18:	22.367	1.900	240.0	24.2	23.0	23.4	0.000	0.616	0.308	0.000	0.308	0.000	-0.616	-0.308	-0.308	-0.616	0.000
07/01 19:	22.300	1.800	240.0	24.3	23.0	23.4	0.000	0.582	0.291	0.000	0.291	0.000	-0.582	-0.291	-0.291	-0.582	0.000
07/01 19:	22.183	1.667	208.0	24.3	22.9	23.4	0.000	0.634	0.317	0.000	0.317	0.000	-0.634	-0.317	-0.317	-0.634	0.000
07/01 19:	22.067	1.533	176.0	24.3	22.8	23.3	0.000	0.579	0.290	0.000	0.290	0.000	-0.579	-0.290	-0.290	-0.579	0.000
07/01 19:	21.950	1.400	144.0	24.3	22.8	23.3	0.007	0.520	0.257	0.000	0.257	0.000	-0.513	-0.257	-0.257	-0.513	0.000
07/01 19:	21.833	1.267	112.0	24.4	22.8	23.4	0.063	0.399	0.168	0.000	0.168	0.000	-0.336	-0.168	-0.168	-0.336	0.000
07/01 19:	21.717	1.133	80.0	24.3	23.2	23.7	0.369	0.140	0.000	0.114	0.000	0.114	0.228	0.114	0.114	0.228	0.000
07/01 20:	21.600	1.000	48.0	23.9	23.5	24.0	0.518	0.112	0.000	0.203	0.000	0.203	0.407	0.203	0.203	0.407	0.000
07/01 20:	21.417	0.967	48.0	23.6	23.6	23.9	0.540	0.143	0.000	0.198	0.000	0.198	0.397	0.198	0.198	0.397	0.000
07/01 20:	21.233	0.933	48.0	23.5	23.5	23.9	0.541	0.156	0.000	0.192	0.000	0.192	0.385	0.192	0.192	0.385	0.000

Date/Time	Environm ent:Outdo or Dry Bulb [C](TimeS tep)	Environm ent:Wind Speed [m/s](Tim eStep)	Environm ent:Wind Direction [deg](Tim eStep)	WEST_Z ONE:Zone Mean Air Temperat ure [C](TimeS tep)	BALCONY _ZONE:Z one Mean Air Temperat ure [C](TimeS tep)	LIVING_Z ONE:Zone Mean Air Temperat ure [C](TimeS tep)	WIN_BAL C:AirflowN etwork Mass Flow Rate from Node 1 to 2 [kg/s](Tim eStep)	WIN_BAL C:AirflowN etwork Mass Flow Rate from Node 2 to 1 [kg/s](Tim eStep)	WIN_EAS T:AirflowN etwork Mass Flow Rate from Node 1 to 2 [kg/s](Tim eStep)	WIN_EAS T:AirflowN etwork Mass Flow Rate from Node 2 to 1 [kg/s](Tim eStep)	WIN_WE ST:Airflow Network Mass Flow Rate from Node 1 to 2 [kg/s](Tim eStep)	WIN_WE ST:Airflow Network Mass Flow Rate from Node 2 to 1 [kg/s](Tim eStep)	Balcony: Net Mass Flow Rate from Node 1 to 2	Win_East Net Mass Flow Rate from Node 2 to 1	Win_Wes t Net Mass Flow Rate from Node 2 to 1	Net Mass Flow Rates (through both windows) from Node 2 to 1	Differenc e between Net flow from Node 1 to 2 and Net flow from Node 2 to 1
07/01 20:	21.050	0.900	48.0	23.4	23.3	23.8	0.538	0.165	0.000	0.186	0.000	0.186	0.373	0.186	0.186	0.373	0.000
07/01 20:	20.867	0.867	48.0	23.4	23.2	23.7	0.534	0.174	0.000	0.180	0.000	0.180	0.361	0.180	0.180	0.361	0.000
07/01 20:	20.683	0.833	48.0	23.3	23.1	23.7	0.534	0.186	0.000	0.174	0.000	0.174	0.348	0.174	0.174	0.348	0.000
07/01 21:	20.500	0.800	48.0	23.3	23.0	23.7	0.534	0.199	0.000	0.168	0.000	0.168	0.336	0.168	0.168	0.336	0.000
07/01 21:	20.350	0.733	48.0	23.2	22.9	23.7	0.523	0.213	0.000	0.155	0.000	0.155	0.310	0.155	0.155	0.310	0.000
07/01 21:	20.200	0.667	48.0	23.3	22.8	23.7	0.510	0.225	0.000	0.143	0.000	0.143	0.285	0.143	0.143	0.285	0.000
07/01 21:	20.050	0.600	48.0	23.3	22.7	23.6	0.497	0.238	0.000	0.130	0.000	0.130	0.260	0.130	0.130	0.260	0.000
07/01 21:	19.900	0.533	48.0	23.3	22.6	23.6	0.488	0.254	0.000	0.117	0.000	0.117	0.235	0.117	0.117	0.235	0.000
07/01 21:	19.750	0.467	48.0	23.4	22.5	23.6	0.477	0.267	0.000	0.105	0.000	0.105	0.210	0.105	0.105	0.210	0.000
07/01 22:	19.600	0.400	48.0	23.4	22.3	23.6	0.463	0.281	0.003	0.094	0.003	0.094	0.182	0.091	0.091	0.182	0.000
07/01 22:	19.533	0.333	40.0	23.3	22.3	23.5	0.446	0.284	0.006	0.087	0.006	0.087	0.162	0.081	0.081	0.162	0.000
07/01 22:	19.467	0.267	32.0	23.2	22.2	23.5	0.438	0.295	0.008	0.080	0.008	0.080	0.143	0.071	0.072	0.143	0.000
07/01 22:	19.400	0.200	24.0	23.2	22.1	23.4	0.427	0.305	0.012	0.072	0.012	0.073	0.122	0.061	0.061	0.122	0.000
07/01 22:	19.333	0.133	16.0	23.3	22.0	23.4	0.417	0.310	0.015	0.068	0.015	0.068	0.107	0.053	0.054	0.107	0.000
07/01 22:	19.267	0.067	8.0	23.3	21.9	23.3	0.410	0.313	0.017	0.066	0.017	0.066	0.097	0.048	0.048	0.097	0.000
07/01 23:	19.200	0.000	0.0	23.3	21.9	23.3	0.407	0.314	0.018	0.065	0.018	0.065	0.093	0.047	0.047	0.093	0.000
07/01 23:	19.133	0.000	0.0	23.2	21.8	23.3	0.410	0.317	0.018	0.065	0.019	0.065	0.094	0.047	0.047	0.094	0.000
07/01 23:	19.067	0.000	0.0	23.2	21.7	23.2	0.413	0.319	0.019	0.066	0.019	0.066	0.094	0.047	0.047	0.094	0.000
07/01 23:	19.000	0.000	0.0	23.1	21.7	23.2	0.415	0.320	0.019	0.066	0.019	0.066	0.094	0.047	0.047	0.094	0.000
07/01 23:	18.933	0.000	0.0	23.1	21.6	23.1	0.417	0.322	0.019	0.066	0.019	0.066	0.095	0.047	0.047	0.095	0.000
07/01 23:	18.867	0.000	0.0	23.1	21.6	23.1	0.419	0.324	0.019	0.067	0.019	0.067	0.095	0.048	0.048	0.095	0.000
07/01 24:	18.800	0.000	0.0	23.0	21.5	23.1	0.421	0.325	0.019	0.067	0.019	0.067	0.096	0.048	0.048	0.096	0.000