

COMPUTER AIDED DESIGN AND SIMULATION OF YEAR AROUND
AIR CONDITIONING-COMFORT APPLICATION

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AIR CONDITIONING-COMFORT APPLICATION**

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ABSTRACT

COMPUTER AIDED DESIGN AND SIMULATION OF YEAR AROUND AIR CONDITIONING-COMFORT APPLICATION

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The aim of this thesis is to develop a computer program to design and simulate air conditioning-comfort application of a selected building, for a year period, on an hourly basis. In order to carry out this study, a computer program named “AHUSIM.m”, is prepared with Matlab computing language.

The design and simulation procedure starts with preparing the inputs like indoor, outdoor design states, zone cooling and heating loads, along with the general data for conditioning-comfort equipment. The program, in light of these input data, performs the plotting of the psychrometric processes -including the design and off design processes- on psychrometric charts, air conditioning-comfort system selection and calculating the response of this selected system at varying load conditions for a year. The program also calculates the energy requirements of parts of the selected system throughout the year. Furthermore, it lists dimensions of the parts of the air conditioning-comfort unit, the outdoor supply air and total air flow rates, air and water inlet and exit states.

Using numerical tools for heating, ventilating and air conditioning (HVAC) process design and simulation, can improve energy economy and comfort which are the main criteria of HVAC engineering. In such an attempt, major concern is the interaction between the comfort and energy consumption. The program, by designing the system and deciding its behavior throughout a year; provides a means of automatic control considering comfort and energy economy. This program also provides a tool for comparison of different techniques for putting limits to the relation between comfort and energy consumption.

Keywords: HVAC processes, psychrometrics, comfort conditions, energy economy, coil design, coil rating.

ÖZ

İKLİMLENDİRME HAVALANDIRMA-KONFOR UYGULAMASININ YILLIK BİLGİSAYAR DESTEKLİ TASARIMI VE BENZEŞİMİ

Ertuğ, Müzeyyen Oya

Yüksek Lisans, Makina Mühendisliği Bölümü

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Bu tez çalışmasının amacı, seçilmiş bir binanın bir yıllık periyot için, saatlik bir tabanda, iklimlendirme havalandırma-konfor uygulamasının tasarımı ve benzeşimini gerçekleştirmesi için bir bilgisayar programı geliştirmektir. Bu çalışmayı yürütmek için, Matlab hesaplama dili ile “AHUSIM.m” isimli bir bilgisayar programı hazırlanmıştır.

Tasarım ve benzeşme işlemi, iklimlendirme havalandırma-konfor ünitesinin genel özellikleriyle birlikte; iç, dış dizayn şartları, zon ısıtma ve soğutma yükleri gibi girdilerin hazırlanmasıyla başlar. Program, bu girdilerin ışığında -tam ve kısmi yük süreçlerini içeren- psikrometrik süreçleri psikrometrik diyagramlara çizdirme, iklimlendirme havalandırma-konfor sistemlerinin seçimi ve bu seçili sistemlerin bir yıl içinde değişen şartlar altında tepkilerini hesaplama işlerini yapar. Program ayrıca, yıl boyunca seçilmiş sistemin parçalarının enerji gereksinimlerini hesaplar. Buna ilaveten, iklimlendirme havalandırma-konfor ünitesinin parçalarının ölçülerini, taze hava ve toplam hava akış hızlarını, hava ve su giriş ve çıkış şartlarını listeler.

İklimlendirme süreç tasarım ve benzeşiminde numerik araçların kullanımı, iklimlendirme mühendisliğinin ana kriterleri olan enerji ekonomisi ve insan konforunu iyileştirebilir. Böyle bir girişimde, ana kaygı konfor ve enerji tüketimi arasındaki etkileşimdir. Program, sistem tasarlayıp, sistemin bir yıl boyunca tepkilerine karar vererek; bir otomatik kontrol aracı sağlar. Bu program, ayrıca konfor ve enerji tüketimi arasındaki ilişkiye sınırlar koyan farklı tekniklerin kıyaslanması için bir araç sağlar.

Anahtar Kelimeler: İklimlendirme süreçleri, psikrometri, konfor şartları, enerji ekonomisi, serpantin tasarımı, serpantin değerlendirilmesi.

To My Parents

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NOMENCLATURE

- C_n : Constants of equations (where n denotes any number)
- A : Area of the structural component, [m²]
- a : Transverse tube spacing of coil, [m]
- A_F : Finned area of the coil, [m²]
- A_{FACE} : Face (frontal) area of the coil, [m²]
- A_o : Heat transfer area of the coil, [m²]
- A_{pi} : Tube inside area of the coil, [m²]
- A_{pm} : Tube mean surface area of the coil, [m²]
- A_{po} : Tube outside area of the coil, [m²]
- A_{tot} : Total area of the enclosing surfaces, [m²]
- ADP : Apparatus dew point temperature, [°C]
- b : Leakage rate per m of crack length in m³/h for a pressure difference of 9.8 bar
- b_w : Slope of the saturated moist air enthalpy vs temperature curve, [kJ/kg · K]
- b_{cond} : Slope of the saturated moist air enthalpy vs temperature curve, at condensate temperature, [kJ/kg · K]
- BF : Bypass factor
- c : Longitudinal tube spacing of coil, [m]

- C_p : Specific heat at constant pressure of moist air, [kJ/kg · K]
- $C_{p_s,cond}$: Specific heat at constant pressure of saturated moist air at condensate layer temperature, [kJ/kg · K]
- C_{p_w} : Specific heat at constant pressure of saturated liquid water, [kJ/kg · K]
- D : Tube diameter, [m]
- D_R : Mean heat transfer coefficient of room
- D_h : Hydraulic diameter for air side [m]
- Δi_m : Mean enthalpy difference for wet coil, [kJ/kg]
- ΔP : Pressure difference, [kPa]
- ΔT_{zone} : Zone allowable temperature difference, [°C]
- ΔT_D : Daily temperature range, [K]
- ΔT_{FH} : Temperature rise due to fan motor heat, [°C]
- ΔT_{lm} : Log-mean temperature difference, [°C]
- ΔT_{SFH} : Temperature rise due to supply fan motor heat, [°C]
- ELH : Effective latent heat, [W]
- ESH : Effective sensible heat, [W]
- ESHF : Effective sensible heat factor
- ETH : Effective total heat, [W]
- η_{FAN} : Fan efficiency

- η_{MOT} : Fan motor efficiency
- F_h : Hourly temperature factor
- F_m : Monthly design temperature factor
- f_i : Friction factor for water flow inside tubes
- f_s : Correction (Enhancement) factor
- ϕ : Relative humidity of moist air, [%]
- ϕ_f : Fin efficiency
- $\phi_{f,w}$: Fin efficiency for wet coil
- G_{max} : Maximum mass velocity of moist air [$\text{kg}/\text{m}^2\text{s}$]
- GSHF : Grand sensible heat factor
- GTH : Grand total heat, [W]
- H_b : Building coefficient
- H_c : Height of coil, [m]
- h_i : Convective heat transfer coefficient for water flow inside tubes, [$\text{W}/\text{m}^2\text{K}$]
- $h_{\text{oeq},w}$: Equivalent outside film and transfer coefficient, [$\text{W}/\text{m}^2\text{K}$]
- $h_{o,d}$: Convective heat transfer for air side for dry coil, [$\text{W}/\text{m}^2\text{K}$]
- $h_{o,w}$: Outside air convection coefficient for wet coil, [$\text{W}/\text{m}^2\text{K}$]
- i : Specific enthalpy of moist air, [kJ/kg]
- i_{ADP} : Apparatus dew point enthalpy of moist air, [kJ/kg]

- i_g : Specific enthalpy of water vapor, [kJ/kg]
- i_L : Coil leaving specific enthalpy of moist air, [kJ/kg]
- i_M : Mixing state specific enthalpy of moist air, [kJ/kg]
- $i_{s,cond}$: Enthalpy of saturated moist air at condensate layer temperature, [kJ/kg]
- i_{sp} : Enthalpy of saturated moist air at tube temperature, [kJ/kg]
- i_{sw} : Enthalpy of saturated moist air at water temperature, [kJ/kg]
- i_w : Specific enthalpy of liquid water, [kJ/kg]
- j_H : Colburn factor for air side
- k_F : Thermal conductivity of fin material, [W / m · K]
- k_p : Thermal conductivity of tube material, [W / m · K]
- k_w : Thermal conductivity of saturated liquid water, [W / m · K]
- k_{cond} : Thermal conductivity of condensate layer, [W / m · K]
- l : Crack length of the windward facing windows and doors, [m]
- ℓ : An arbitrary constant length of tube, [m]
- L_c : Length of coil, [m]
- LH : Latent heat, [W]
- \dot{m} : Mass flow rate of moist air, [kg/s]
- \dot{m}_g : Mass flow rate of water vapor, [kg/s]
- \dot{m}_w : Mass flow rate of liquid water, [kg/s]

Nu_i : Nusselt number for water flow inside tubes
 μ : Viscosity of moist air [kg / m · s]
 n : Number of tubes per row in coil
 N_d : Number of the rows of the dry coil
 N_w : Number of the rows of the wet coil
 ν_w : Kinematic viscosity of saturated liquid water, [m²/s]
 OLH : Outdoor latent heat, [W]
 OSH : Outdoor sensible heat, [W]
 P : Pressure, [kPa]
 P_F : Fin pitch, [1/m]
 P_{ws} : Saturation pressure of water vapor in moist air, [kPa]
 P'_{ws} : Saturation pressure of pure water, [kPa]
 P_{ws}^* : Saturation water vapor pressure of moist air at wet bulb temperature, [kPa]
 Pr : Prandtl number of moist air
 Pr_w : Prandtl number of saturated liquid water
 \dot{Q} : Rate of heat, [W]
 \dot{Q}_H : Total heat requirement, [W]
 \dot{Q}_L : Air infiltration heat requirement, [W]
 \dot{Q}_o : Transmission heat loss, [W]

- \dot{Q}_T : Transmission heat requirement, [W]
- \dot{q}_o : Transmission heat loss of a single structural component, [W]
- R : Specific gas constant for air, [J/kg · K]
- R_c : Room coefficient
- Re_i : Reynolds number for water flow inside tubes
- $Re_{o,d}$: Reynolds number for air side
- RLH : Room latent heat, [W]
- RSH : Room sensible heat, [W]
- RSHF : Room sensible heat factor
- RTH : Room total heat, [W]
- ρ : Density of moist air, [kg/m³]
- SH : Sensible heat, [W]
- SHF : Sensible heat factor
- St : Stanton number for air side
- σ : Ratio of the free-flow area of the finned surface to the frontal area of the coil
- T : Temperature of moist air, [°C]
- T^* : Wet bulb temperature of moist air, [°C]
- $T_{a,h}$: Dry-bulb temperature for the hour h, [°C]
- $T_{db,m}$: Cooling design dry bulb for the month, [°C]

- T_{dp} : Dew point temperature of moist air, [°C]
- T_{es} : Effective surface temperature, [°C]
- T_i : Inside design temperature, [°C]
- T_L : Coil leaving temperature of moist air, [°C]
- T_M : Mixing state temperature of moist air, [°C]
- \bar{T}_m : Mean temperature, [°C]
- T_o : Outside design temperature, [°C]
- T_p : Tube temperature, [°C]
- T_S : Supply air temperature of moist air, [°C]
- T_{sdb} : Summer design dry bulb, [°C]
- T_w : Water temperature, [°C]
- T_{cond} : Temperature of condensate layer at tube wall at wet coil, [°C]
- T_Z : Zone design temperature of moist air, [°C]
- t_F : Fin thickness, [m]
- TH : Total heat, [W]
- TLH : Total latent heat, [W]
- TSH : Total sensible heat, [W]
- U : Overall heat transfer coefficient of the structural component, [W/m²K]
- $U_{o,d}$: Overall heat transfer coefficient for dry coil, [W/m²K]

- $U_{o,w}$: Overall heat transfer coefficient for wet coil, [W/m²K]
- v : Specific volume of moist air, [m³/kg]
- v_w : Specific volume of saturated liquid water, [m³/kg]
- V_c : Volume of the coil, [m³]
- V_{FACE} : Face velocity of coil, [m/s]
- V_{sf} : Standart face velocity of coil, [m/s]
- \dot{V}_{TA} : Volumetric flow rate of total air, [m³/s]
- \dot{V}_{VA} : Volumetric flow rate of outdoor ventilation air, [m³/s]
- V_w : Velocity of water, [m/s]
- W : Approximate crack length per unit area of window or door [m⁻¹]
- \dot{W} : Rate of work, [W]
- W_c : Width of coil, [m]
- \dot{W}_{FAN} : Fan power, [W]
- \dot{W}_{MOT} : Fan motor power, [W]
- w : Humidity ratio of moist air, [kg_{water} / kg_{air}]
- w_s : Supply state humidity ratio of moist air, [kg_{water} / kg_{air}]
- w_{hunl} : Humidifier leaving state humidity ratio of moist air, [kg_{water} / kg_{air}]
- w_s^* : Saturation humidity ratio of moist air at wet bulb temperature, [kg_{water} / kg_{air}]
- x_p : Tube thickness, [m]

- y_F : Half of the fin thickness, [m]
- y_{cond} : Condensate layer thickness, [m]
- Z : Altitude, [m]
- Z_A : Allowance to compensate for cold outside surfaces
- Z_D : Combined allowance
- Z_e : Corner window allowance factor
- Z_H : Allowance for aspect
- Z_U : Allowance for interruption heating

CHAPTER 1

INTRODUCTION

1.1. AIR CONDITIONING SYSTEM DESIGN AND ENERGY USE

The primary concerns of comfort air conditioning (AC) design and simulation are energy efficiency and comfort. By the drastically increasing air-pollution rates since 1950's [1] and with the energy crisis in 1970's [2] the energy saving measures and utilizing the natural sources effectively become very important. 84% of the used energy sources of the world are fossil fuels which are consumed 100000 times faster than they are replenished. Moreover the projected supply of petroleum is about 40 years. [1] As a consequence of these, energy utilization has become an important issue not only for the highly industrialized countries but also the whole world as well. Especially countries like Turkey must give more importance to efficient usage of energy for pollution and economic considerations.

In 2006 the energy consumption of Turkey is 99825000 TEP (Tons Equivalent Petroleum) [3] whereas the total energy production of Turkey in 2006 is 26763000 TEP. [3] According to this consumption and production, Turkey must import 73.2% of the energy consumed. Furthermore, the energy consumption of Turkey depends mainly fossil fuels which are not renewable and cause environmental pollution. A sectorial distribution of this energy for 2001 is [4]:

- 37.0% Industry
- 36.1% Housing and Services
- 21.6% Transportation
- 5.3% Agriculture

The energy consumption of housing, services and industry has a very important role on total energy consumption of Turkey. Considering that a significant amount of this

portion is consumed in HVAC applications, the energy efficiency in HVAC applications plays an important role in economy, preventing pollution and less consumption of depleting energy sources. The consumption of energy can be reduced and usage of renewable energy sources can be considered. The latter is beyond the scope of this thesis. In order to reduce the energy consumption, proper design and simulation rather than making designs just considering the peak loads and outdoor design conditions of the building plays an important role. In literature, it is shown that even 1°C lower thermostat setting in Utah for winter, the energy saved is 6.44% of the total energy consumed and leads to 1/3 tons of less CO₂ emission to the atmosphere. [1]

Energy consumption is not the only criterion in HVAC system design. On the contrary, an AC system has to be designed to satisfy the environmental requirements of comfort or a process in a specific building. Unfortunately, still most people understand the term “air conditioning” as “cooling” but it has a broader meaning in design which may be summarized as comfort. Therefore, the simultaneous encounter of temperature, humidity, air motion, indoor air quality, noise level and pressure control within a space should take place in an ideal HVAC design. [5] In literature, studies about the indoor air quality show that lower requirements for ventilation increases occupant complains about poor health owing to conditions of unsatisfactory indoor air quality. Complaints due to thermal and humidity conditions can be minimized by maintaining thermal environmental conditions in the appropriate ranges, which are recommended by ASHRAE. [6]

1.2. OUTLINE AND AIM OF THIS STUDY

In this thesis design and simulation of an AC application for a selected building is to be done. Hourly cooling and heating loads are calculated by Carrier Hourly Analysis Program version 4.22a (HAP 4.22a) and Microsoft Excel Worksheets prepared according to modified Turkish Standard (TS) “TS 2164 Principles For the Preparation of the Projects of the Central Heating Systems” with solar and internal loads. Simulation of the processes on psychrometric charts, system design and rating

are done by the computer program named “AHUSIM.m” which is written in Matlab computing language.

This study will give a general view of AC system design and its energy consumption. With this thesis, it will be possible to evaluate the response of a designed system to minimize its energy consumption with considering comfort as temperature, humidity, air motion, indoor air quality, noise level and pressure control within a space.

In the first chapter the main reasons lying under performing AC design and simulation is evaluated. Furthermore, a general outline is provided in this section.

In the following chapter, fundamentals in HVAC system design, system off-design response, equipment selection and equipment rating are provided. This chapter includes the literature survey done in the subjects that will be necessary in preparation of a computer program for the design and simulation of an AC unit and its inputs. These are hourly cooling and heating load evaluation, psychrometrics, water properties, basic HVAC calculations, types of AC systems that can be applied, coil design and rating.

In the third chapter the inputs, calculations and outputs of this study are clarified. As for inputs the weather data of Ankara, the general properties of the building to be simulated, the cooling and heating load calculation methods with the used tools with explanations and approximations is mentioned in detail. For the calculations part, psychrometric calculations -including plotting of psychrometric charts, psychrometric design of the zones and selection of off-design processes- and coil design and rating is explained. In the outputs part, the outputs of the program is studied in detail.

Finally in the forth chapter, the conclusions derived from this study are given. The energy savings from comfort sacrifices or decision techniques is represented. Some general conclusions with regard to the studies mentioned throughout the whole thesis are submitted and based on these results suggestions are provided for further accomplishments.

CHAPTER 2

THEORY

2.1. COOLING AND HEATING LOAD CALCULATIONS

Cooling load is the rate at which heat is removed from the space to keep the space at the desired temperature and humidity. [7] It differs from the heat gain -the rate at which the heat enters a space or generated within the space during a time interval. The main difference between the two is the storage of some portion of the radiant heat entering the space and the convective part of this stored heat contribute to the cooling load. [8]

Heating load is the rate at which heat is given to the space to keep the space at the desired temperature. Unlike the cooling loads the thermal storage effect of the building, solar and indoor heat gains are neglected. [6]

The proper estimation of the heating and cooling loads is essential because it is the physical constrained part of the main problem of design and simulation of the AC system.

2.1.1. Cooling Load Calculations

Determination of cooling load of the system is a complex problem; therefore there are different methods used for it. The heat balance (HB) approach is a fundamental concept in calculating the cooling loads. The transfer function method (TFM), cooling load temperature differences / solar cooling loads / cooling load factors (CLTD/SCL/CLF), total equivalent temperature differential / time averaging (TETD/TA) and radiant time series (RTS) method are all simplified versions of heat balance method. [9] In this thesis Carrier HAP 4.22a -a computer package that utilizes the transfer function method is used. The further explanation of the HB and

TFM methods are given in Appendix A. There are three other methods which are derived from the HB method which will be mentioned briefly in this section.

CLTD/SCL/CLF method is a manual load calculation principle derived from the TFM. This method makes use of CLTD's in case of walls and roofs, SCL's in case of solar gain through windows and CLF's for internal heat sources. It can be used to calculate cooling loads on an hourly basis if desired. The tabulated values of CLTD's, SCL's and CLF's can be used. [7]

In TETD/TA method, the response factors are used with a number of representative wall and roof assemblies from which data are derived to calculate TETD values as functions of sol-air temperature and the design room temperature. The instantaneous total rate of space heat gain is achieved by adding these values to internal heat gain elements. Heat gain is converted to cooling load by a time-averaging technique. Although it is a complicated process the simple averaging makes it a poor approximation of the actual physics of the systems. [9]

RTS method is the newest of all these methods derived directly from the heat balance method. It uses the radiant time series coefficients which are calculated from the HB method. In this method conduction, solar and internal gains are divided into radiative and convective parts. The convective parts and the radiative parts operated on by the radiant time series are added to obtain the total hourly cooling load. [10] Although this method seems very efficient, it still lacks the literature or computer software for complex systems.

2.1.2. Heating Load Calculations

The heating load calculations in the literature are for estimating the capacity of the heating system for the coldest time of winter, in other words winter design load. In Turkey; there is a standard for the calculation of heat requirement for the buildings TS 2164 which was adapted from German Standard DIN 4701. [11, 12]

When it is colder outside, sufficient heat should be applied to the space, in order to maintain a constant desired temperature. This supplied heat is lost to the outside in two different ways, which are:

1. by transmission through parts of the building which separate heated spaces from the outside air or from spaces which are at lower temperatures
2. by air leakage or infiltration of cold outside air and the simultaneous exfiltration of warm air through cracks, open doors and windows

The amount of heat, which should be supplied to the space, determines the total heat requirement, \dot{Q}_H and can be calculated with the following equation:

$$\dot{Q}_H = \dot{Q}_T + \dot{Q}_L \quad (2.1)$$

The transmission heat requirement of a room is found from the transmission heat loss (\dot{Q}_o) of the space multiplied by a factor Z comprising of some individual allowances.

The air infiltration heat requirement (\dot{Q}_L) takes care of the heating up, from outside temperature to room temperature, of the cold air infiltrating through cracks associated with the windows and external doors.

2.1.2.1. Transmission Heat Requirement

2.1.2.1.1. Transmission Heat Loss

The transmission heat loss, \dot{Q}_o of a room is composed of the heat losses \dot{q}_o of windows and doors, exterior walls, interior walls, floor and ceiling. The following equation applies to each building component:

$$\dot{q}_o = U \cdot A \cdot (T_i - T_o) \quad (2.2)$$

For the heat loss calculations, indoor and outdoor design temperatures should be known. These temperature values are determined by considering several factors. There exist many references in the literature for these values such as ASHRAE, DIN etc. As mentioned before, Turkey also has a standard called TS 2164, which includes internal design temperatures.

Outside design temperature values are determined based on the results of long-term meteorological observations for each city in Turkey. TS 2164 also includes the wind data for cities which are also effective in calculations. According to TS 2164, the outside design temperature for Ankara is -12°C and the wind condition is stated as windy.

Table 2.1 Indoor Design Temperatures for This Study

Space	Temperature, $^{\circ}\text{C}$
Ceremony Halls	20
Offices	20
Foyers	18
Corridors, Halls	18

Table 2.2 Unconditioned Space Temperatures

Outdoor Temperatures	$^{\circ}\text{C}$	3	0	-3	-6	-9	-12	-15
Attic Spaces	$K < 2$	9	7	4	2	-1	-3	-6
	$2 < K < 5$	6	4	1	-1	-4	-6	-9
	$K > 5$	3	1	-2	-4	-6	-9	-12
Unconditioned Spaces	Have doors or windows to inside or basement, surrounded by conditioned spaces mostly	15	14	12	10	9	7	5
	Have doors or windows to outside, surrounded by conditioned spaces partly	12	8	6	5	3	1	0
Ground Temperature	Below Grade	11	10	9	8	7	6	5
	Adjacent to Wall	5	4	3	2	1	0	-1

For the determination of temperature of spaces, comfort is the most important factor. According to the type and rate of activity such as working, sleeping, sitting, standing etc., the temperature of the spaces differ from each other. These temperature values are specified in TS 2164. The temperatures of the spaces taken according to TS 2164 are given in Table 2.1. Spaces, which are never or rarely used, are not heated but temperature of these spaces should be known to perform the heat loss calculations of the adjacent rooms. These temperatures are given in Table 2.2. Some temperature values for these kinds of spaces are also given in the same standard. However for more reliable results, it will be useful to calculate temperature values by applying the energy balance equation to these spaces.

2.1.2.1.2. Allowances for Transmission Heat Loss

In heat loss calculations, there exists some features, which can vary from one building to another or between two rooms of the same building. These features should be considered during the calculations and transmission heat losses should be multiplied by correction factors or in other words “allowances”. As indicated above, transmission heat losses are corrected for interrupted operation of heating system, aspect and cold interior surfaces. The correction factors are called “allowances” and they are as follows:

a) Allowance for interruption of heating, Z_U : After periods of restricted operation or interruptions in operation, the renewed heating of a building is only possible by the temporary supply of extra heat to warm up the building structure. Allowance for interruption of heating is used to compensate this thermal inertia of a building after a cooling period. The value of this allowance should increase as the number of interruptions for the heating period and the heating load of the building increase. The following three modes of operation are to be distinguished:

Mode I : Uninterrupted operation

Mode II : Daily upto 10 hours of interruption of heat supply

Mode III : Daily upto 14 hours of interruption of heat supply

b) Allowance to compensate for cold outside surfaces, Z_A : The degree of comfort experienced in a room depends not only on the air temperature, but also on the mean temperature of the room boundary surface area. Rooms with outside walls of large area, low thermal insulating performance or penetrated by large windows have disadvantages compared with rooms, which are well insulated or having small window area. The mean temperature of the room boundary surface area is reflected with mean heat transfer coefficient of room, D_R that can be calculated with the following equation:

$$D_R = \frac{Q_o}{A_{tot} \cdot (T_i - T_o)} \quad (2.3)$$

The two allowances Z_A and Z_U depend mainly on the D_R value and mode of operation and despite their completely different physical significance; they can be combined mathematically to give a single allowance Z_D . The values for this combined allowance, Z_D are given in Table 2.3

Table 2.3 Combined Allowance (Z_D)

Operation Mode	Mean Heat Transfer Coefficient, D_R (kcal/hm ² °C)			
	0.10-0.29	0.30-0.69	0.70-1.49	1.50
Mode 1	7	7	7	7
Mode 2	20	15	15	15
Mode 3	30	25	20	15

c) Allowance for aspect, Z_H : This allowance is used to take into account the gain of space from incident solar radiation. The criterion for the aspect of a room is the position of the outside wall in the case of rooms incorporated in the structure on three sides, and the direction in which the corner of the building faces in the case of corner rooms. The allowance values for aspect are presented in Table 2.4.

Table 2.4 Aspect Allowance (Z_H)

Aspect	Z _H (%)
South, Southwest, Southeast	-5
North, Northwest, Northeast	+5
West, East	0

Therefore, transmission heat requirement of the space can be calculated as:

$$Q_T = Q_o \cdot (1 + Z_D + Z_H) \quad (2.4)$$

2.1.2.2. Air Infiltration Heat Requirement

Even when the doors and windows of the spaces are closed; there always exist some gaps and cracks between the frames and the cases. Because of the pressure gradient between outside and space, cold air leaks through these gaps and cracks. This causes the inside warm air to exfiltrate with the entering cold air. This cold air should be heated to the room temperature. The amount of heat required to raise the temperature of this outdoor air to the inside air temperature is called air infiltration heat requirement and can be calculated by the following equation:

$$Q_L = \sum b \cdot l \cdot R_c \cdot H_b \cdot (T_i - T_o) \cdot Z_e \quad (2.5)$$

Table 2.5 Leakage Rate per meter of Crack Length (b)

Material	Window Type	b (m ³ /mh)
Wood or Plastic	Single window	3.0
	Composite window	2.5
	Double window and single window with guaranteed sealing	2.0
Metal	Single window	1.5
	Composite window	1.5
	Double window and single window with guaranteed sealing	1.2
Internal Doors	Unsealed (without threshold)	40
	Sealed (with threshold)	15

Leakage rate per m of crack length which is denoted by “b”, depends on the frame material and glass type of the windows and doors. Values for leakage rate per meter of crack length are given in Table 2.5

Crack length (l) is the periphery of the open able casements. Approximate crack length per unit area of windows and doors can be obtained from Table 2.6 according to type and dimension of windows and doors.

Room coefficient (R_c) represents the flow ability of the infiltrating cold air from outside to the inside of the room. It represents the resistance of the room to the flow of entering outside air. This resistance directly depends on material and type of construction of interior doors and windows. Values that can be used for room coefficient are introduced in Table 2.7. In this table FA/FT stands for the ratio of exterior window area to interior door area.

Table 2.6 Approximate Crack Lengths per unit Area of Windows and Doors (W)

Type	Window or Door Height	W
Windows with any number of cases	0.50	7.2
	0.63	6.2
	0.75	5.3
	0.88	4.9
	1.00	4.5
	1.25	4.1
	1.50	3.7
	2.00	3.3
	2.50	3.0
Doors with single casement	2.10	2.6
Doors with double casement	2.50	3.3

Building coefficient H_b contemplates the effects of construction type, building sitting and the wind condition of the region. Regions, where the average wind velocity is higher than 4.5 m/s, are called “windy regions”. Wind exposition of a building can be

classified in three groups as shielded, exposed and extremely exposed. The values for building coefficient are given in Table 2.8.

Table 2.7 Room Coefficients (R_c)

Material	Interior Door	FA/FT	R_c
Wood or Plastic	Unsealed	<3	0.9
	Sealed	<1.5	
Metal	Unsealed	<6	
	Sealed	<2.5	
Wood or Plastic	Unsealed	3-9	0.7
	Sealed	1.5-3	
Metal	Unsealed	6-20	
	Sealed	2.5-6	

Corner window allowance factor, Z_c is to be used only for windows or doors situated directly at the corner formed by two exterior walls, which meet each other and has a value of 1.2. It is not applied to any of the other window or door configurations of a room.

Table 2.8 House Coefficients (H_b)

Wind Condition	Wind Exposition of The Building	Building Type	
		Terrace	Detached
Normal	Shielded	0.24	0.34
	Exposed	0.41	0.58
	Extremely Exposed	0.60	0.84
Windy	Shielded	0.41	0.58
	Exposed	0.60	0.84
	Extremely Exposed	0.82	1.13

2.2. PSYCHROMETRICS

Psychrometrics is the study of thermodynamic properties of moist air and psychrometrics uses these properties to analyze the conditions and processes involving the moist air. [6] Since the air is a mixture of air and water vapor in the air,

ASHRAE PSYCHROMETRIC CHART NO. 1
 NORMAL TEMPERATURE SEA LEVEL
 BAROMETRIC PRESSURE 101.325 kPa.



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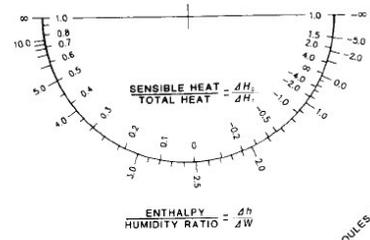
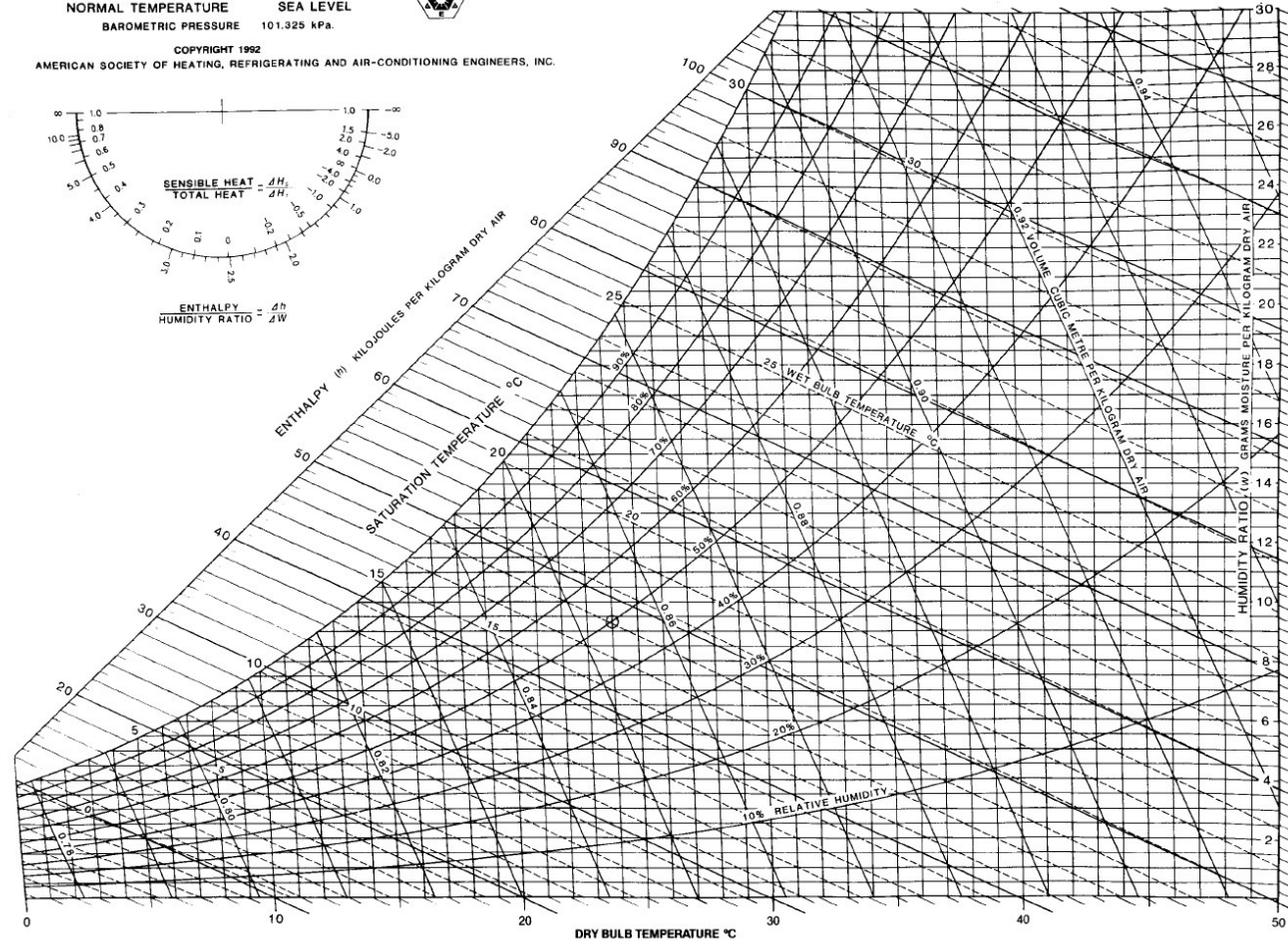


Figure 2.1 ASHRAE Psychrometric Chart at Sea Level

psychrometrics is important for AC applications. Therefore, the accuracy of a psychrometric chart is essential in this thesis.

2.2.1. Psychrometric Charts

Hyland-Wexler formulation are widely used for moist air properties, nowadays. [13, 14] The formulation uses the virial equations of state with the ideal gas heat capacity and the appropriate thermodynamic properties for the thermodynamic properties of moist air. The saturated moist air state requires an iterative calculation the enhancement factor and mole fractions of air and water vapor. [15] The whole procedure for moist air properties is given by literature. [16]

Although the Hyland and Wexler formulations are essential in cases where precision is crucial, ideal gas formulations can be used in almost every AC application. Literature states that ideal gas formulations can calculate moist air properties with errors less than 0.7%. [17] Furthermore, these errors decrease with decreasing pressure. [6]

2.2.2. Psychometric Relationships, Ideal Gas Approximations

The following sections give the psychrometric relationships used to calculate the psychrometric properties of moist air and plotting of psychrometric charts.

2.2.2.1. Saturated Water Vapor Pressure

To determine moist air properties saturation pressure must be determined. The well-known Clapeyron equation is a starting point in the data fitting and integration process.

$$\frac{dP}{dT} = \frac{\Delta i}{T \cdot \Delta v} \quad (2.6)$$

The saturation pressure over ice for the temperature range of -100°C to 0°C according to Hyland-Wexler formulation is [13]

$$\ln(P'_{ws}) = C_1 / T + C_2 + C_3 T + C_4 T^2 + C_5 T^3 + C_6 T^4 + C_7 \ln(T) \quad (2.7)$$

where curve fitting constants are

$$C_1 = - 5.6745359 \times 10^3$$

$$C_2 = 6.3925247$$

$$C_3 = - 9.677843 \times 10^{-3}$$

$$C_4 = 6.22115701 \times 10^{-7}$$

$$C_5 = 0.20747825 \times 10^{-8}$$

$$C_6 = - 9.484024 \times 10^{-13}$$

$$C_7 = 4.1635019$$

The saturation pressure over liquid water for the temperature range of 0 to 200°C according to Hyland and Wexler formulation is [13]

$$\ln(P'_{ws}) = C_8 / T + C_9 + C_{10} T + C_{11} T^2 + C_{12} T^3 + C_{13} \ln(T) \quad (2.8)$$

where

$$C_8 = - 5.8002206 \times 10^3$$

$$C_9 = 1.3914993$$

$$C_{10} = - 4.8640239 \times 10^{-2}$$

$$C_{11} = 4.1764768 \times 10^{-5}$$

$$C_{12} = - 1.4452093 \times 10^{-8}$$

$$C_{13} = 6.5459673$$

Note that the saturation vapor pressure in moist air differs from that for pure water obtained from Eqn.'s (2.7) and (2.8) for the same temperature. A correction (enhancement) factor, f_s can be defined so that

$$P_{ws} = f_s \cdot P'_{ws} \quad (2.9)$$

where, P'_{ws} is the saturation pressure of pure water and P_{ws} is the saturation pressure of vapor in the mixture. The factor f_s is a function of temperature and pressure. In order to simplify the correction factor, f_s , can be correlated with respect to pressure based on average data for the temperature at each fixed pressure. Asian [18] showed that the following polynomial equation correlates the correction factor within less than $\pm 0.5\%$ deviation;

$$f_s = C_1 + C_2 P + C_3 P^2 + C_4 P^3 \quad (2.10)$$

where

$$C_1 = 1.0$$

$$C_2 = 0.04420722$$

$$C_3 = -0.016326037$$

$$C_4 = 0.00237901$$

and P is the atmospheric pressure in MPa.[15]

Table 2.9 Standard Atmospheric Data for Altitudes to 5000 m

Altitude, m	Temperature, °C	Pressure, kPa
-500	18.2	107.478
0	15.0	101.325
500	11.8	95.461
1000	8.5	89.874
2000	2.0	79.495
3000	-4.5	70.108
4000	-11.0	61.640
5000	-17.5	54.020

As coming to the pressure, atmospheric pressure decreases as the elevation above sea level increases as given in Table 2.9. Aforementioned correction factor varies with

pressure according to formula (2.10). Literature correlates the barometric pressure with different altitudes as given below; [6]

$$P = 101.325 \cdot (1 - 2.255802 \cdot 10^{-5} \cdot Z)^{5.2561} \quad (2.11)$$

where Z is the altitude in m.

The altitude change also effects the shape of psychrometric charts. For a uniform grid of enthalpy and humidity ratio, as altitude increases (and pressure decreases), the lines defining the other properties change as follows; [15]

- 1- Dry bulb temperature unchanged.
- 2- Relative humidity lines expand up and to the left.
- 3- Wet bulb temperature lines expands up and to the right.
- 4- Specific volume lines expand up and to the right.
- 5- Enthalpy lines are unchanged.

2.2.3. Plotting The Psychrometric Chart

2.2.3.1. The Shape Of The Charts

In this thesis, the coordinates of the psychrometric charts were chosen as humidity ratio (kg_w/kg_a) and dry bulb temperature ($^{\circ}\text{C}$), whereas ASHRAE psychrometric charts are based on humidity ratio and enthalpy (w, i) coordinates. In other words, in ASHRAE charts humidity ratio lines and enthalpy lines are strictly parallel which leads to slightly skewed dry-bulb lines. Since, dry-bulb, humidity ratio (T, w) coordinates, simplifies the plotting procedure in computer graphics system and changes the representation of psychrometric charts slightly, is utilized in this study.

2.2.3.2. Relative Humidity Curves

Relative humidity curves shape the psychrometric charts as it is bounded by the saturation line (i.e., 100% relative humidity). The constructed relative humidity line intervals are 10%, starting with 10% upto 100%. In order to plot any property or property line on the psychrometric chart, it must be formulized as a function of T and

w. And by using psychrometric relations which can be taken from ASHRAE Fundamentals relative humidity can be plotted utilizing the formula; [6]

$$w = 0.62198 \frac{\phi \cdot f_s \cdot P_{ws}}{P - \phi \cdot f_s \cdot P_{ws}} \quad (2.12)$$

The pressure of saturated water vapor (P_{ws}) and correction factor f_s can be found for the appropriate temperature range by using the Eqn.'s (2.7), (2.8), (2.9) and (2.10).

2.2.3.3. Wet Bulb Lines

In literature, the humidity ratio can be written as; [6]

$$w = \frac{(2501 - 2.381 \cdot T^*) w_s^* - (T - T^*)}{2501 + 1.805 \cdot T - 4.186 \cdot T^*} \quad (2.13)$$

$$w_s^* = 0.62198 \frac{P_{ws}^*}{P - P_{ws}^*} \quad (2.14)$$

The pressure of saturated water vapor at temperatures can be converted to dry bulb temperature (T) in a similar way explained in Section 2.2.3.2. By using the same plotting logic, the constant wet bulb temperature (T^*) lines are drawn with an increment of 1°C on the chart. [15]

2.2.3.4. Enthalpy Lines

The enthalpy as a function of dry bulb temperature (T) and humidity ratio (w) can be defined as;

$$w = \frac{i - T}{2501 - 1.805 \cdot T} \quad (2.15)$$

With an increment of 10 kJ/kg, enthalpy lines can be plotted according to Eqn. (2.15) on the chart.

2.2.3.5. Specific Volume Lines

The specific volume as a function of humidity ratio (w) and absolute temperature (T) can be formulated as

$$v = \frac{R \cdot T}{P} (1 + 1.6078 \cdot w) \quad (2.16)$$

or

$$w = \frac{1}{1.6078} \left(\frac{Pv}{R \cdot (T + 273.15)} - 1 \right) \quad (2.17)$$

With an increment of $0.02 \text{ m}^3/\text{kg}$ and according to Eqn. (2.17) the specific volume lines can be constructed on the chart.

2.2.3.6. Dew Point Temperature

The dew point temperature, T_{dp} of moist air can be calculated directly by following Peppers equations. [6]

For the dew point temperature range of 0 to $93 \text{ }^\circ\text{C}$;

$$T_{dp} = C_1 + C_2 \alpha + C_3 \alpha^2 + C_4 \alpha^3 + C_5 (P_w)^{0.1984} \quad (2.18)$$

and for temperatures below $0 \text{ }^\circ\text{C}$;

$$T_{dp} = 6.09 + 12.608 \cdot \alpha + 0.4959 \cdot \alpha^2 \quad (2.19)$$

where

$$\alpha = \ln(P_w)$$

$$C_1 = 6.54$$

$$C_2 = 14.526$$

$$C_3 = 0.7389$$

$$C_4 = 0.09486$$

$$C_5 = 0.4569$$

2.3. WATER PROPERTIES

In this study, in the design and rating of the system water properties must be calculated since water is used as the cooling and heating medium in AC apparatuses. The water properties required in calculations are tabulated in literature. [6] The water properties are calculated from curve fitting techniques for the range of 0°C to 100°C for most AC applications in previous studies, however some of the properties are changed with the help of Matlab 7.0 curve fitting tools for a better representation of the tabulated properties in literature. [5, 6] The equations used for water are given below.

2.3.1. Saturated Liquid Water Specific Volume

$$v_w(T) = \sum_{i=0}^3 C_i \cdot T^i \quad (2.20)$$

where, v_w is in m^3/kg , T is in $^{\circ}C$ and C values are data fitting constants. [5]

$$C_0 = 1000.1028$$

$$C_1 = - 0. 01008764$$

$$C_2 = - 0. 0050646761$$

$$C_3 = 9.7803869 \times 10^{-7}$$

2.3.2. Saturated Liquid Water Specific Heat

$$C_{p_w}(T) = \sum_{i=0}^4 C_i \cdot T^i \quad (2.21)$$

where, C_{p_w} is in $kJ/kg \cdot K$, T is in $^{\circ}C$ and C values are data fitting constants. [5]

$$C_0 = 4.2175207$$

$$C_1 = - 0.0026916064$$

$$C_2 = 5.862064 \times 10^{-5}$$

$$C_3 = -4.8935164 \times 10^{-7}$$

$$C_4 = 1.6930784 \times 10^{-9}$$

2.3.3. Saturated Liquid Water Kinematic Viscosity

$$v_w(T) = \frac{1 \times 10^{-6}}{C_0 + C_1 \cdot T^{C_2}} \quad (2.22)$$

where, v_w is in $\text{kg/m} \cdot \text{s}$, T is in $^\circ\text{C}$ and C values are data fitting constants for the exponential fit of Matlab 7.0.

$$C_0 = 0.55805476$$

$$C_1 = 0.014459495$$

$$C_2 = 1.14163$$

2.3.4. Saturated Liquid Water Thermal Conductivity

$$k_w(T) = \sum_{i=0}^6 C_i \cdot T^i \quad (2.23)$$

where, k_w is in W/mK , T is in $^\circ\text{C}$ and C values are data fitting constants for the sixth order polynomial fit of Matlab 7.0 linear least squares method.

$$C_0 = 0.55224$$

$$C_1 = 0.0054624$$

$$C_2 = -0.00029294$$

$$C_3 = 9.7014 \times 10^{-6}$$

$$C_4 = -1.599 \times 10^{-7}$$

$$C_5 = 1.265 \times 10^{-9}$$

$$C_6 = -3.848 \times 10^{-12}$$

2.3.5. Saturated Liquid Water Prandtl Number

$$\text{Pr}_w(T) = \frac{1}{C_0 + C_1 \cdot T^{C_2}}$$

(2.24)

where, Pr_w is unitless, T is in °C and C values are data fitting constants for the exponential fit of Matlab 7.0.

$$C_0 = 0.07336156$$

$$C_1 = 0.0019817873$$

$$C_2 = 1.1914532$$

2.4. BASIC HVAC SYSTEM CALCULATIONS

2.4.1. Thermodynamics of HVAC Processes

In most of the AC applications flow can be assumed steady, so the classical mathematical expression for the energy balance can be reduced to [19]:

$$\dot{m} \left(i_i + \frac{V_i^2}{2} + gZ_i \right) + \dot{Q} = \dot{m} \left(i_o + \frac{V_o^2}{2} + gZ_o \right) + \dot{W} \quad (2.25)$$

where indices i and o denote inlet and outlet states respectively.

2.4.1.1. Air Conditioning Processes

Most commonly used AC processes are sensible cooling or heating of air. In sensible cooling or heating air is cooled or heated without moisture loss or gain. These processes can be represented on psychrometric chart by a horizontal straight line. Therefore, line from 1 to 2 on Figure 2.2 represents sensible cooling process whereas line from 1 to 4 on Figure 2.2 represents sensible heating process. The Eqn. (2.25) for this process reduces to:

$$\dot{m} \cdot i_i - \dot{m} \cdot i_o + \dot{Q} = 0 \quad (2.26)$$

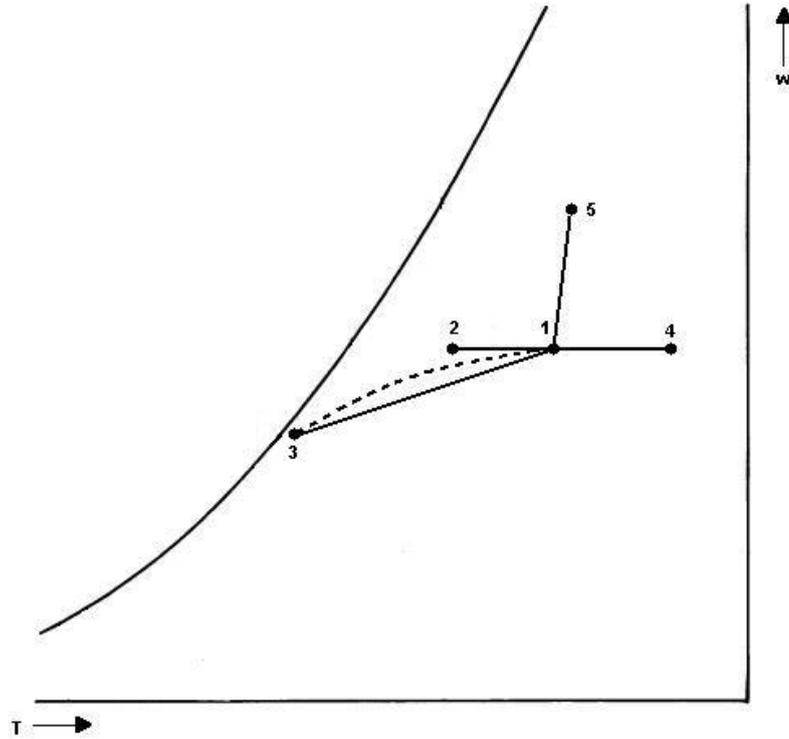


Figure 2.2 Psychrometric Processes on Psychrometric Chart

Another common process is cooling with dehumidification where air is cooled to a temperature below its dew point and some of the water vapor condenses which leads to dehumidification as well as cooling. The mass balance equation for this case is,

$$\dot{m} \cdot w_i = \dot{m} \cdot w_o + \dot{m}_w \quad (2.27)$$

or

$$\dot{m}_w = \dot{m} \cdot (w_i - w_o) \quad (2.28)$$

Humidification is another common process which can be done by injecting water or steam to the system. Nowadays, due to hygienic and cost considerations steam injecting humidifiers are more common. Therefore in this study, steam injecting humidifier is used, the psychrometric representation of this process is like the line from 1 to 5 on Figure 2.2, whose slope is fixed with the specific enthalpy of the

steam. The humidity requirement of the space is met, without a significant change in temperature. The mass balance equation and the energy balance equation for this process are;

$$\dot{m} \cdot w_i + \dot{m}_g = \dot{m} \cdot w_o \quad (2.30)$$

$$\dot{m} \cdot i_i + \dot{m}_g i_g = \dot{m} \cdot i_o \quad (2.31)$$

(2.30) and (2.31) can be reduced to:

$$\frac{i_o - i_i}{w_o - w_i} = i_g \quad (2.32)$$

Another widely used process is adiabatic mixing of two states; its representation is shown on Figure 2.3. Where mixing states are indicated by 1 and 2 and resulting states is indicated by 3. For water side mass balance equations can be reduced to:

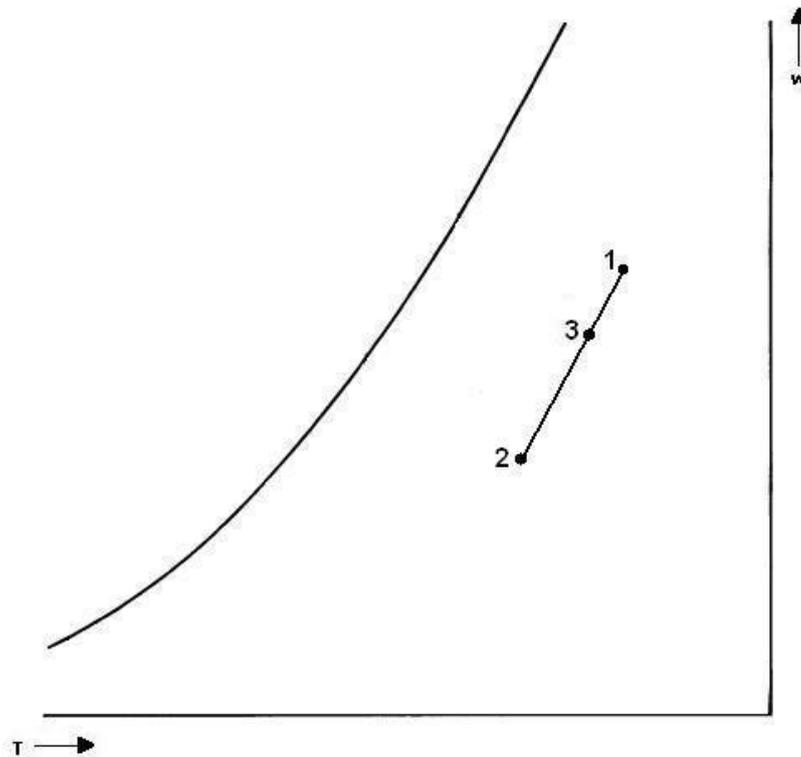


Figure 2.3 Adiabatic Mixing Process on Psychrometric Chart

$$\dot{m}_1 w_1 + \dot{m}_2 w_2 = \dot{m}_3 w_3 \quad (2.33)$$

For air side mass balance equation becomes,

$$\dot{m}_1 + \dot{m}_2 = \dot{m}_3 \quad (2.34)$$

Energy balance equation becomes,

$$\dot{m}_1 i_1 + \dot{m}_2 i_2 = \dot{m}_3 i_3 \quad (2.35)$$

From (2.33), (2.34) and (2.35),

$$\frac{i_2 - i_3}{i_3 - i_1} = \frac{w_2 - w_3}{w_3 - w_1} = \frac{\dot{m}_1}{\dot{m}_2} \quad (2.36)$$

2.4.2. Description of Terms and Factors of HVAC Processes

The selection of proper equipment to accomplish the desired conditioning in a space depends upon lots of factors. The ones affecting the psychrometrics of the processes will be discussed under this topic. They are room sensible heat factor (RSHF), grand sensible heat factor (GSHF), effective surface temperature (T_{es}), bypass factor (BF) and effective sensible heat factor (ESHF).

The term Sensible Heat Factor (SHF) stands for the ratio of sensible heat to Total Heat (TH) where total heat is the sum of the Sensible Heat (SH) and Latent Heat (LH). It can be expressed as;

$$SHF = \frac{SH}{SH+LH} = \frac{SH}{TH} \quad (2.37)$$

2.4.2.1. Room Sensible Heat Factor

The ratio of sensible and total (sensible and latent) heat of the space calculated by cooling load calculation methods is called Room Sensible Heat factor. The expressions for this kind of heat factor is modified version of Eqn. (2.37) with addition of R in front of each symbol.

$$RSHF = \frac{RSH}{RSH+RLH} = \frac{RSH}{RTH} \quad (2.38)$$

The line, which connects room and supply air states and represents room sensible heat factor, is denoted by the line from S to Z on Figure 2.4. Assuming that supply air state falls on this line, if adequate air flow rate is provided, room requirements will be satisfied. [15, 20]

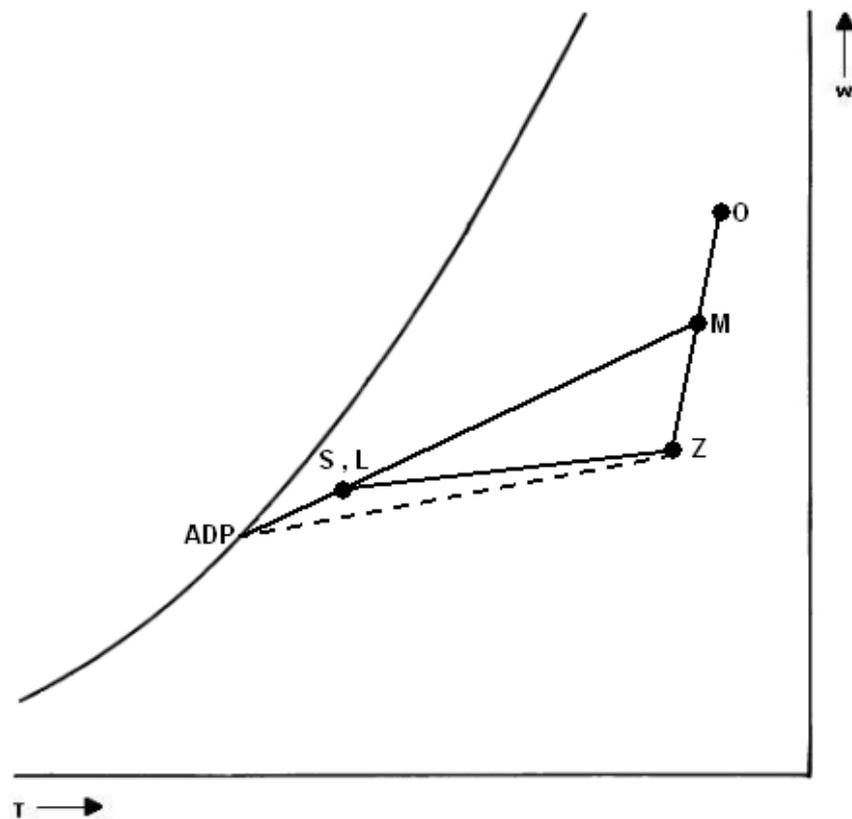


Figure 2.4 Heat Factors on Psychrometric Chart

2.4.2.2. Grand Sensible Heat Factor

Adding the sensible and latent part outdoor air heat loads to room air loads (OSH, OLH) we get total sensible and latent heat loads (TSH, TLH);

$$\text{TSH} = \text{RSH} + \text{OSH} \quad (2.39)$$

$$\text{TLH} = \text{RLH} + \text{OLH} \quad (2.40)$$

Summation of total sensible and latent heat loads give grand total heat load (GTH) and the ratio of total sensible load to grand total load gives Grand Sensible Heat Factor; (GSHF)

$$\text{GTH} = \text{TSH} + \text{TLH} \quad (2.41)$$

$$\text{GSHF} = \frac{\text{GSH}}{\text{GTH}} \quad (2.42)$$

The grand sensible heat factor is the slope of the line from the state of air entering the AC apparatus to the state of air leaving the apparatus. It can be represented by a line from M to L on Figure 2.4. With the known inlet state of air it is sure that the leaving state falls on this line.

The exact states and air flow rates needed to overcome the heat loads can be set according to RSHF, GSHF, coil inlet state and room design state. Intersection of lines drawn according to these gives the coil leaving state which is also the supply air state. Moreover, to calculate volumetric flow rate of total air (\dot{V}_{TA}) needed, these fixed states can be used as; [15, 20]

$$\dot{V}_{\text{TA}} = \frac{\text{RSH}}{\rho \cdot C_p \cdot (T_z - T_s)} \quad (2.43)$$

or

$$\dot{V}_{\text{TA}} = \frac{\text{TSH}}{\rho \cdot C_p \cdot (T_M - T_L)} \quad (2.44)$$

2.4.2.3. Effective Surface Temperature

Effective Surface Temperature (T_{es}) is an assumed uniform surface temperature of AC apparatus which maintains the same leaving condition of air, which in reality is

subjected to variable surface temperature. The effective surface temperature acts as a numerical criterion of selection of AC apparatus.

In cooling with humidification process the effective surface temperature is the intersection of grand sensible heat factor line with saturation line which is called as Apparatus Dewpoint Temperature (ADP). It is denoted by point ADP in the Figure 2.4. [20]

2.4.2.4. Bypass Factor

Bypass Factor (BF) represents the portion of air which is considered to pass through the AC apparatus completely unaltered. The bypass factor is an indication of operation conditions of the apparatus as well as its physical properties.

The entering and leaving conditions of the air handling unit and apparatus dewpoint temperature are related psychrometrically to the bypass factor. In spite of the fact that the relationship on the psychrometric chart is not exactly linear, this relationship can be represented as;

$$BF = \frac{T_L - ADP}{T_M - ADP} = \frac{i_L - i_{ADP}}{i_M - i_{ADP}} = \frac{W_L - W_{ADP}}{W_M - W_{ADP}} \quad (2.45)$$

2.4.2.5. Effective Sensible Heat Factor

To simplify the coil selection and rating Effective Sensible Heat Factor (ESHF), which relates the bypass factor and apparatus dewpoint temperature to the cooling, is used.

The effective sensible heat factor is the ratio of the effective sensible heat (ESH) to the effective total heat (ETH) which is the summation of the effective sensible heat and effective latent heat (ELH). Effective sensible and latent heats are comprised of room sensible and latent heats and the portions of outdoor sensible and latent heating loads which is assumed to be bypassed from the AC apparatus.

$$\begin{aligned}
\text{ESHF} &= \frac{\text{RSH} + \text{BF} \cdot \text{OSH}}{(\text{RSH} + \text{BF} \cdot \text{OSH}) + (\text{RLH} + \text{BF} \cdot \text{OLH})} \\
&= \frac{\text{ESH}}{\text{ESH} + \text{ELH}} = \frac{\text{ESH}}{\text{ETH}} \quad (2.46)
\end{aligned}$$

The effective sensible heat factor line on the psychrometric chart is the line from point Z to ADP on Figure 2.4.

As previously stated ESHF simplifies the calculation process greatly not only considering the room loads but also the outdoor air loads which are induced to the system by the air handling unit. To calculate the volumetric flow rate of air must be used to overcome the space load with considering the bypass factor and apparatus dewpoint temperature, ESHF can be used as; [20, 15]

$$\dot{V}_{\text{TA}} = \frac{\text{ESH}}{\rho \cdot C_p \cdot (T_z - \text{ADP})(1 - \text{BF})} \quad (2.47)$$

2.5. ALL-AIR SYSTEMS

In selecting an AC unit temperature, humidity, capacity, spatial requirements, cost, reliability and flexibility are main concern. Commonly used alternatives for this selection are all-air systems, in-room terminal systems, and decentralized heating and cooling systems. All-air systems controls the temperature, indoor air quality and humidity by the air supplied to the system. These kinds of systems will be studied in detail since they are used in this study. In-room terminal systems, terminal units installed in habitable spaces throughout a building conditions the spaces by distributing air and water which are cooled or heated by central equipment. The air supplied is called primary or ventilation air. Decentralized heating or cooling is by the name implied a system conditions the spaces with small kinds of equipment with no central air and water requirement. They are applicable in almost all cases, however they are more suitable for smaller projects with no central plant where low initial cost and simplified installation are important. [21]

All-air systems can be divided into two main parts single duct systems and dual duct systems. In single duct systems, a common duct system at a common air state feeds all terminal units, whereas in dual duct systems cold and warm air flows in separate duct systems. Single duct systems can also be divided into two main parts as constant air volume systems and variable air volume systems. [21]

A single duct constant air volume (CAV) is the simplest form of "all-air" HVAC systems. It controls the space load by changing supply air temperature, so it is limited to situations for single zone systems where space loads does not vary within system. For multiple zone systems, reheat or air bypass to return duct systems must be utilized.

2.5.1. Single Duct Variable Air Volume (VAV) Systems

The single duct Variable Air Volume (VAV) controls temperature in a space by varying the flow rate of outdoor ventilation air rather than varying supply air temperature. A VAV terminal unit at zone varies the flow rate of air to the space. These kinds of systems are well suited for almost all applications, since they can respond to varying space loads. In this study a single duct VAV system is selected as AC system.

The humidity and indoor air quality control can be a potential problem in this kind of system. The need for fresh air and humidity of the zone must be carefully decided and control system must respond to space needs with rising the supply air temperature, by injecting water or steam to the system and/or changing the system to all outdoor (primary) air systems or all return air with a careful consideration of energy consumption. [21]

This system offers many features that are favorable for its applications. Since the volume of air is reduced with a reduction in load, the refrigeration and fan power follows closely the actual air conditioning load of the building. Since the air flow rate is modulated to match the required space load, the fan motors (supply and return) have to be taken as frequency controlled motor in order to adjust the required air flow to match the required space load. [5]

2.5.2. Types of Air Handling Units

2.5.2.1. Types of Air Systems

Air handling units can be divided into three according to types of air systems; mixed air, all outdoor air and full return handling units. The room loads, ventilation needs, codes and standards are the criteria to determine type of air handling unit. When the ventilation needs, codes or standards require more fresh air flow rate than the flow rate of air required to overcome the room load all outdoor air handling units are chosen. However when the outdoor ventilation air flow rate is smaller than total air flow rate needed, the return air is mixed with outdoor air in a mixed air handling unit. If there is no need for outdoor ventilation air then full return air type of handling units are used.

2.5.2.2. Types of Fan Systems

There are two kinds of fan systems, draw through and blow through. In a draw through arrangement the supply fan is located at the downstream of the AC apparatus, whereas in draw through systems, the supply fan is located at the upstream of the AC apparatus.

2.5.3. Duct and Fan Heat Gains

Apart from the basic HVAC processes which represents ideal systems that does not include heat gains from system components, duct and fan heat gains are taken into account in this study.

Literature states that unless the return air ducts are extensive or exposed to extreme conditions, supply ducts can be counted as the main sources of heat gain from ducts. [6] Therefore, in practice supply ducts are insulated. In this study, only return duct heat gains are taken into account, since the supply duct system was considered to be insulated.

In an actual system, fans are required to move the air and some energy may be gained from fans. Fan and motor powers in Watts are computed as follows; [5]

$$\dot{W}_{FAN} = \frac{QTA \cdot \Delta P}{\eta_{FAN} \cdot 1000} \quad (2.48)$$

$$\dot{W}_{MOT} = \frac{\dot{W}_{FAN}}{\eta_{MOT}} \quad (2.49)$$

If fan and motor are both in air stream, the temperature rise due to supply and/or return fan motor heat, ΔT_{FH} is;

$$\Delta T_{FH} = \frac{\Delta P}{1000 \cdot \eta_{MOT} \cdot \eta_{FAN} \cdot C_p \cdot \rho} \quad (2.50)$$

and if fan only is in the air-stream, it becomes;

$$\Delta T_{FH} = \frac{\Delta P}{1000 \cdot \eta_{FAN} \cdot C_p \cdot \rho} \quad (2.51)$$

2.6. HEATING, COOLING AND DEHUMIDIFICATION OF MOIST AIR AROUND EXTENDED SURFACE COILS

2.6.1. Design and Rating of Sensible Heating and Cooling Coils (Dry Coil)

As a typical example of liquid to gas heat exchangers air handling units cooling and heating coils are usually tube-fin type compact heat exchangers. A heat exchanger having a surface area to volume ratio approximately greater than $250 \text{ m}^2/\text{m}^3$ is called a compact heat exchanger. This compactness achieved by the arrangement of tubes enhanced with fins. [22]

The compact heat exchangers can be divided into two types tube-fin types and plate-fin types. [22] In most of the air handling unit coils tube-fin types of compact heat exchanger are used as cooling and heating coils. Although in special applications and mediums, steel and aluminum can be used as tube and fin material, in low-pressure water-air systems aluminum fins on copper tubes are the most common ones. [21] Therefore, in this thesis aluminum flat plate fins on copper tube kind of coil arrangement is utilized.

2.6.1.1. Flow Arrangement

For optimum performance generally coils are multi row and counter flow type. This kind of arrangement can provide maximum heat exchange within the smallest depth since it has the closest temperature relationship between the water inside the tubes and air. Hence in this kind of arrangement, log mean temperature is maximized which is an indicator of performance of the coil. Therefore, counter-cross flow arrangement is selected as shown in Figure 2.5. [21]

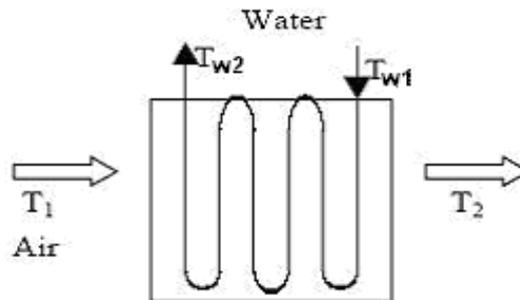


Figure 2.5 Counter-Cross Flow Arrangement

The required capacity \dot{Q} and the required mass flow rate of heating medium (air) \dot{m} from conservation of energy is,

$$\dot{Q} = \dot{m} \cdot C_p \cdot (T_2 - T_1) \quad (2.52)$$

$$\dot{Q} = \frac{\dot{V}_{TA}}{v_1} C_p \cdot (T_2 - T_1) \quad (2.53)$$

where,

$$C_p = 1.003 + 1.805 \cdot w_{1,2} \quad (2.54)$$

$$\dot{m}_w = \frac{\dot{Q}}{C_{P_w} (T_{w1} - T_{w2})} \quad (2.55)$$

where C_{p_w} is the specific heat of water.

2.6.1.2. Limitations to Coil Design and Rating

When selecting and rating a coil, the following factors should be considered [5]:

- Required capacity
- States of entering and leaving air
- Space and dimensional limitations or selected system geometry
- Air flow rate and coil face velocity

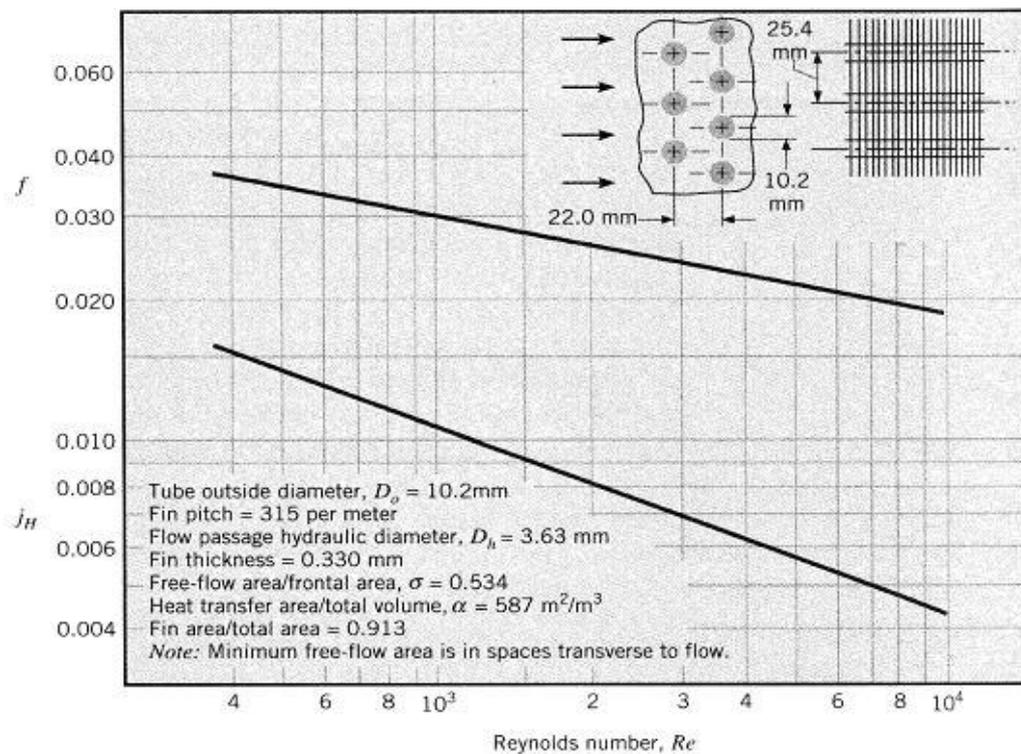


Figure 2.6 Heat Exchanger 8.0-3/8T

2.6.1.2.1. Air Side Parameters

There are various criteria to determine the air face velocity of a coil, but in common practice and according to ARI Standard 410 Forced-Circulation Air-Cooling and Air-Heating Coils, the coils rated with face velocities (V_{FACE}) between 1.5 and 4.0 m/s. [21]

There are many kinds of compact heat exchangers in literature. [23] However, in this study only flat plate fins-circular tube arrangement with surface 8.0-3/8T [24, 22] is used both for heating and cooling coils. In Figure 2.6 the graphical representation of air side parameters are shown for this kind of coil. In this figure, heat transfer results are correlated in terms of Colburn j_H factor,

$$j_H = St \cdot Pr^{2/3} \quad (2.56)$$

where, Stanton (St) number and Reynolds (Re) number are,

$$St = \frac{h_{o,d}}{G_{max} \cdot C_p} \quad (2.57)$$

$$Re_{o,d} = \frac{G_{max} \cdot D_h}{\mu} \quad (2.58)$$

where G_{max} is the maximum mass velocity of air in $kg/m^2 \cdot s$,

$$G_{max} = \frac{\dot{m} \cdot (1 + w)}{\sigma \cdot A_{FACE}} \quad (2.59)$$

where σ is the ratio of the minimum free-flow area to frontal area A_{FACE} and D_h is the hydraulic diameter of the flow in meters.

By combining Eqs. 2.57, 2.58 and 2.59, the airside (outside) convection heat transfer coefficient $h_{o,d}$ is,

$$h_{o,d} = j_H \cdot Pr^{-2/3} \cdot C_p \cdot G_{max} \quad (2.60)$$

where μ and Pr are calculated at \bar{T}_m

$$\bar{T}_m = T_w \mp \Delta T_{lm} \quad (+ \text{ for cooling, } - \text{ for heating}) \quad (2.61)$$

where, T_w is the average water temperature,

$$T_w = \frac{T_{w1} + T_{w2}}{2} \quad (2.62)$$

and ΔT_{lm} is the log-mean temperature difference,

$$\Delta T_{lm} = \frac{(T_{w1} - T_2) - (T_{w2} - T_1)}{\ln \frac{(T_{w1} - T_2)}{(T_{w2} - T_1)}} \quad (2.63)$$

In calculating Colburn j_H factor, least square approximation method may be used.

Then, Colburn j_H factor is of the form, [5]

$$j_H(Re) = C_1 + C_2 Re + C_3 Re^2 + C_4 Re^3 + C_5 Re^4 + C_6 Re^5 \quad (2.64)$$

where,

$$C_1 = 0.019024118$$

$$C_2 = - 0.012470709$$

$$C_3 = 0.0054888359$$

$$C_4 = - 1.2754088 \times 10^{-3}$$

$$C_5 = 1.4565692 \times 10^{-4}$$

$$C_6 = - 6.4227240 \times 10^{-6}$$

2.6.1.2.2. Water Side Parameters

To ensure efficiency of the coil proper movement of water must be ensured. Therefore, coils are usually constructed with top-outlet bottom-feed water connection [5, 21]

In practice water mean velocities are usually rated between 0.3 and 2.4 m/s. In the program in order to have a turbulent flow the water velocities are likely designed to be greater than 0.5 m/s. [21]

The waterside (inside) Reynolds number is calculated as, [22, 24]

$$\text{Re}_i = \frac{V_w \cdot D}{\nu_w} \quad (2.65)$$

Eqn. 2.64 is valid for fully developed turbulent flow which means $(X/D) > 10$. X is the length of the pipe, and D is the tube diameter. [24, 22] Since in this study and most of the HVAC applications, tube length is far more than tube diameter Eqn 2.65 can be used.

For fully developed turbulent flow and smooth surfaces the friction factor f_i developed from Petukhov [22, 24] is of the form,

$$f_i = (0.790 \cdot \ln \text{Re}_i - 1.64)^{-2} \quad (2.66)$$

which is valid for $3000 \leq \text{Re}_i \leq 5 \cdot 10^6$

And the Nusselt number for fully developed turbulent flow in a smooth circular tube is due to Gnielinski [22, 24] is of the form,

$$\text{Nu}_i = \frac{(f_i / 8)(\text{Re}_i - 1000) \text{Pr}_w}{1 + 12.7(f_i / 8)^{1/2} (\text{Pr}_w^{2/3} - 1)} \quad (2.67)$$

the correlation is valid for $0.5 < \text{Pr}_w < 2000$ and $3000 < \text{Re}_i < 5 \cdot 10^6$

The water-side (inside) convection heat transfer coefficient h_i is, [22, 24]

$$h_i = \frac{k_w}{D} \text{Nu}_i \quad (2.68)$$

2.6.1.2.3. The Fin Efficiency

The critical part of the heat transfer is occurs on the air side, so an enhancement should be done on this side. In most commercial applications this enhancement is provided with the use of extended surfaces outside the water tubes generally named as fins. [21] In this study a certain type of heat exchanger is used with a constant r_2/r_1 ratio of 2.61; Figure 2.7 for straight fin of uniform cross section can be used. [22, 24]

The curve was approximated in previous studies, by using least square approximation method, as such [5]

$$\Phi_f(\alpha) = C_1 + C_2 \alpha + C_3 \alpha^2 + C_4 \alpha^3 + C_5 \alpha^4 + C_6 \alpha^5 \quad (2.69)$$

where,

$$C_1 = 0.019024118$$

$$C_2 = - 0.012470709$$

$$C_3 = 0.0054888359$$

$$C_4 = - 1.2754088 \cdot 10^{-3}$$

$$C_5 = 1.4565692 \cdot 10^{-4}$$

$$C_6 = - 6.4227240 \cdot 10^{-6}$$

$$\alpha = L \sqrt{\frac{h_{o,d}}{k_F t_F}} \quad (2.70)$$

where r_2 and L may be calculated as,

$$r_2 = \sqrt{\frac{a \cdot c}{\pi}} \quad (2.71)$$

$$L = r_2 - r_1 \quad (2.72)$$

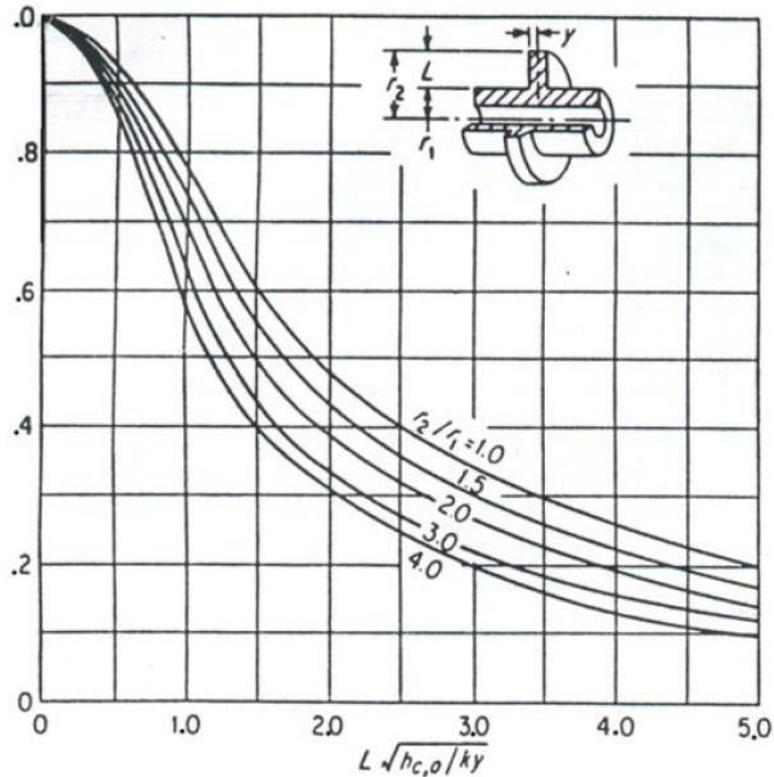


Figure 2.7 Fin Efficiencies

a and c values are horizontal and vertical tube spacing respectively and should be determined from Figure 2.6.

2.6.1.2.4. Heat Transfer in Dry Coil

The performance of sensible heating or cooling coils depends on three factors; the overall heat transfer coefficient $U_{o,d}$, the mean temperature difference ΔT_{lm} and the physical dimensions of the coil. [21]

Then, the overall heat transfer coefficient, $U_{o,d}$ may be defined as;

$$U_{o,d} = \left[\frac{A_o}{A_{pi}} \frac{1}{h_i} + \frac{A_o}{A_{pm}} \frac{x_p}{k_p} + \left(1 + \frac{1 - \phi_f}{\frac{A_{po}}{A_F} + \phi_f} \right) \cdot \frac{1}{h_{o,d}} \right]^{-1} \quad (2.73)$$

and since copper tubes are used the thermal conductivity of tube material (k_p) is very high whereas than tube is quite thin (x_p), therefore Eq. 2.73 can be rewritten as;

$$U_{o,d} = \left(\frac{A_o}{A_{pi}} \frac{1}{h_i} + \left(1 + \frac{1 - \phi_f}{\frac{A_{po}}{A_F} + \phi_f} \right) \cdot \frac{1}{h_{o,d}} \right)^{-1} \quad (2.74)$$

where,

$$A_{pi} = 2\pi r_i \ell \quad (2.75)$$

$$A_{po} = 2\pi r_1 (1 - 2y_F P_F) \ell \quad (2.76)$$

$$A_F = 2\pi P_F (r_2^2 - r_1^2) \ell \quad (2.77)$$

$$A_o = A_{po} + A_F \quad (2.78)$$

The overall heat transfer equation correlating all three factors is;

$$\dot{Q} = \dot{m} \cdot C_p \cdot (T_2 - T_1) \quad (2.79)$$

$$\dot{Q} = U_{o,d} (A_{FACE} \cdot a \cdot N_d \cdot \left(\frac{A_o}{V_c}\right)) \Delta T_{lm} \quad (2.80)$$

where, A_o/V_c is the ratio of heat transfer area to total volume, in m^2/m^3 and a is the horizontal tube spacing in meters, N_d is the number of rows. Number of rows and face area is fixed for a certain selection of coil size. [5]

2.6.2. Design of Cooling and Dehumidifying Coils (Wet Coil)

In most AC processes, the air to be cooled is a mixture of water vapor and dry air gases. When the surface temperatures of some rows of coil are below the dew point temperature of moist air passing through it, dehumidification – removal of latent

heat- occurs as well as sensible cooling. These kinds of coils are widely known as wet coils. [21]

Although simultaneous mass transfer changes the governing equations for heat transfer; flow arrangement, selection criteria, water and air side parameters are same for this kind of application.

2.6.2.1. Heat Transfer in Wet Coil

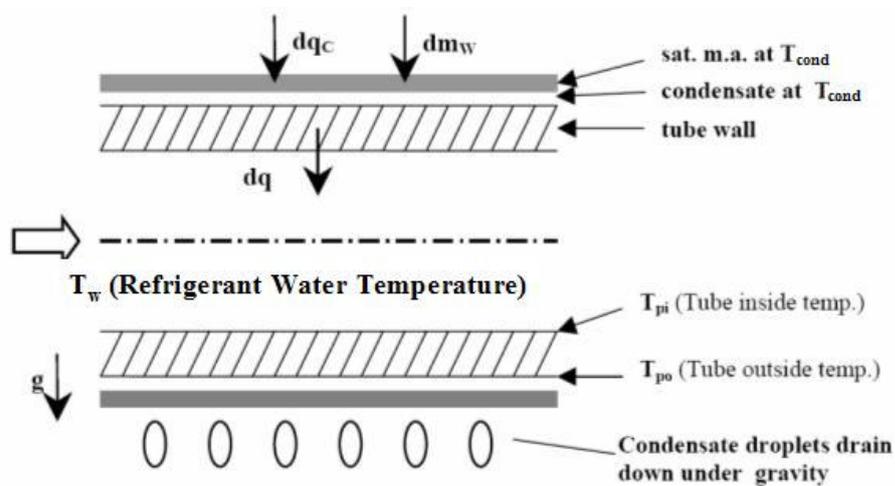


Figure 2.8 Cooling and Dehumidifying Coil (Wet-Coil)

Wet coils involve latent heat transfer as well as sensible heat transfer. Along with dehumidification, condensation on heat transfer surface results in a condensate layer and an air film layer at condensate temperature. In Figure 2.8, a schematic representation of wet coil is given. Due to condensation, the thermal resistances to heat transfer consist of those due to the air film, condensate water layer, metal wall and refrigerant film. Also, there is a mass-transfer resistance between the air and the finned surface. [5]

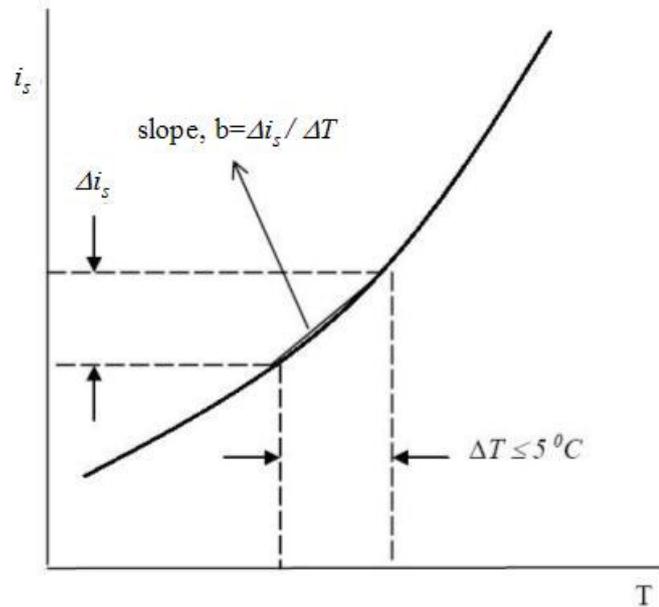


Figure 2.9 Physical Meaning of “b”

Since heat transfer at air side occurs by means of mass transfer as well as direct heat transfer, the heat transfer is directly proportional to both ΔT and Δw in case of wet coil, while heat is directly proportional to only ΔT in dry coils. In order to simplify the calculations ΔT and Δw values are eliminated by combining them into Δi_s values.

The heat transfer through the tube wall by conduction is very small, because the tube material is chosen with a high conduction heat transfer coefficient and its thickness is very low. Therefore, the conduction heat transfer is neglected and the tube inside and outside temperature is taken to be constant as T_p . The temperature difference between the condensate layer at tube wall T_{cond} and the tube temperature T_p and the temperature difference between the temperature of water flowing inside the tubes T_w and the tube temperature are less than $5^\circ C$. Therefore, the change of enthalpy with respect to temperature can be taken as linear and the slope b can be defined to convert ΔT 's to Δi_s values.

For sea level, by the use of curve fitting tools “ b ” value may be calculated from an exponential function,

$$b(T_s) = C_1 \cdot \exp(C_2 \cdot T) \quad (2.81)$$

where for $T_s \leq 0$,

$$C_1 = 1.6887$$

$$C_2 = 0.0174$$

for $T_s > 0$,

$$C_1 = 1.5491$$

$$C_2 = 0.0417$$

where, b_{cond} may be determined from Eq. 2.81 at T_{cond} , and b_w can be calculated from,

$$b_w = \frac{(i_{\text{sp}} - i_{\text{sw}})}{T_p - T_w} \quad (2.82)$$

where, $h_{\text{oeq,w}}$ may be defined as the equivalent outside film or transfer coefficient for outside convective and mass transfer, and conduction through the condensate on frost layer, is determined by the following equation,

$$h_{\text{oeq,w}} = \left(\frac{C_{\text{Ps,cond}}}{h_{\text{o,w}} \cdot b_{\text{cond}}} + \frac{y_{\text{cond}}}{k_{\text{cond}}} \right)^{-1} \quad (2.83)$$

where $h_{\text{o,w}}$ is the outside air convection coefficient for wet coil, which can be approximated by,

$$h_{\text{o,w}} = h_{\text{o,d}} (1.07 \cdot V_{\text{sf}}^{0.1}) \quad (2.84)$$

where $h_{\text{o,d}}$ is the outside convection coefficient for a dry-coil which is operating under the same conditions and V_{sf} is,

$$V_{\text{sf}} = \frac{\dot{m}(1+w)}{\rho \cdot A_{\text{FACE}}} \quad (2.85)$$

Then, the overall transfer coefficient U_{ow} for the coil fins may be expressed by;

$$U_{o,w} = \left[\frac{b_w}{h_i} \frac{A_o}{A_{pi}} + \frac{b_{cond}}{h_{oeq,w}} \left(1 + \frac{1 - \phi_{f,w}}{\frac{A_{po}}{A_F} + \phi_{f,w}} \right) \right]^{-1} \quad (2.86)$$

where the fin efficiency $\phi_{f,w}$, is calculated with outside convection coefficient for the wet coil $h_{o,w}$.

The heat transfer for cooling and dehumidifying coils may be written by combining conservation of energy and heat transfer equations as;

$$\dot{Q} = \dot{m}[(i_1 - i_2) - (w_1 - w_2)i_{fw}] \quad (2.87)$$

$$\dot{Q} = U_{o,w} (A_{FACE} \cdot a \cdot N_w \cdot \left(\frac{A_o}{V_c}\right))(\Delta i)_m \quad (2.88)$$

where, $(\Delta i)_m$ is the mean enthalpy difference which is defined as;

$$(\Delta i)_m = \frac{(i_1 - i_{sw2}) - (i_2 - i_{sw1})}{\ln \frac{(i_1 - i_{sw2})}{(i_2 - i_{sw1})}} \quad (2.89)$$

CHAPTER 3

DEVELOPMENT OF THE COMPUTER PROGRAM

3.1. INPUT DATA

In this thesis, computer aided design and simulation of a wedding ceremony hall at Ankara is done. The building has 18500m^3 volume based on 1700m^2 area. It will also be used as a concert hall and administrative office building for the recreation area where it is situated. It has a 700-m^2 -area wedding ceremony hall and its 400-m^2 -area foyer in the ground floor. In the building's ground floor there are also entrance, bride and wedding officer rooms, security office and a small wedding room. At first floor there are offices and technical spaces for the wedding hall. At basement, there are service rooms, artist rooms, and administrative offices. The building plans are at Appendix B.

The building is divided into three zones which use single duct VAV conditioning apparatuses. Each zone has similar operation times, usage types and load types, so one AC apparatus can meet its requirements. "Zone 1" which includes office rooms that is occupied during regular working hours, with low human and equipment density. "Zone 2" has auxiliary spaces for the wedding hall which has low people density but high equipment loads with operation times starting from afternoon to night, since they are technical spaces for the wedding hall. "Zone 3" has spaces like wedding ceremony hall, foyer and entrance which have big areas, high people density and high solar loads owing to large glass and roof areas.

The input data needed for the design and simulation of AC units for the three zones of the selected building is read by the program part "reader.m" from an excel file named "input.xls". This file is composed of five sheets named "General Data", "Coil

Data”, “Temperature”, “Sensible Loads” and “Latent Loads & Occupancy”. The printouts of “input.xls” are given in Appendix C.

The first sheet “General Data” is comprised of design data including altitude, indoor and outdoor design temperatures, allowable supply air temperature difference for a VAV system, characteristics of parts of air handling units like coils, fans and humidifiers, design sensible and latent cooling loads and fresh air flow rate requirements of zones for maximum occupancy.

“Coil Data” sheet consists of dimensions and material data of the heat exchanger of surface type “8.0-3/8T”. [22, 23] It also includes water inlet and outlet temperatures for winter and summer design.

“Temperature” sheet is comprised of averaged outdoor drybulb and wetbulb temperatures of Ankara for every hour of each month. In literature, there are different temperature data or methods of evaluating the temperature data. In Section “3.1.1. Temperature Data”, the method used by program HAP 4.22a and the temperature data taken from literature [25] is explained and compared.

“Sensible Loads” includes sensible cooling and heating loads for the zones for a 24-hour and 12-month basis like temperature data. The last sheet “Latent Loads & Occupancy” includes the latent loads and occupancy rates for a 24-hour basis. Since the variations of these are not strongly dependent on season or month, they are assumed to be constant with respect to months. The signs of sensible and latent loads are based on heating loads, so the cooling loads have negative values. In Section “3.1.2. Cooling and Heating Load Calculations”, the cooling and heating load calculation method is discussed.

3.1.1. Temperature Data

Temperature data is essential not only in simulation of AC apparatuses, but in calculations of cooling and heating loads. In this study, temperature data from two sources compared and studied. One of them is the program HAP 4.22a; the other is the website which is originally taken from the “World Climate Design Data 2001

Table 3.1 HAP 4.22a Hourly Temperature Profiles for Ankara

Hr	January		February		March		April		May		June		July		August		September		October		November		December	
	DB	WB	DB	WB	DB	WB	DB	WB	DB	WB	DB	WB	DB	WB	DB	WB	DB	WB	DB	WB	DB	WB	DB	WB
0000	-4,9	-6,1	-2,9	-3,9	3,2	2,0	19,3	12,7	19,3	12,7	16,2	10,8	10,4	7,4	5,1	3,4	-1,8	-3,1	8,7	6,1	14,0	9,5	17,6	11,4
0100	-5,7	-6,6	-3,7	-4,5	2,4	1,4	18,5	12,4	18,5	12,4	15,4	10,5	9,6	7,1	4,3	3,0	-2,6	-3,6	7,9	5,7	13,2	9,1	16,8	11,1
0200	-6,5	-7,2	-4,5	-5,1	1,6	0,9	17,7	12,1	17,7	12,1	14,6	10,1	8,8	6,7	3,5	2,6	-3,4	-4,1	7,2	5,4	12,4	8,8	16,0	10,8
0300	-7,1	-7,6	-5,1	-5,6	1,0	0,5	17,1	11,9	17,1	11,9	14,0	9,9	8,2	6,4	2,9	2,3	-4,0	-4,5	6,5	5,0	11,7	8,5	15,4	10,6
0400	-7,6	-7,9	-5,6	-5,9	0,5	0,2	16,6	11,7	16,6	11,7	13,5	9,7	7,7	6,2	2,4	2,0	-4,5	-4,8	6,0	4,8	11,3	8,3	14,9	10,4
0500	-7,8	-8,1	-5,8	-6,1	0,3	0,1	16,4	11,7	16,4	11,7	13,3	9,6	7,6	6,1	2,2	1,9	-4,7	-4,9	5,9	4,7	11,1	8,2	14,8	10,3
0600	-7,5	-7,8	-5,5	-5,8	0,6	0,3	16,8	11,8	16,8	11,8	13,6	9,7	7,9	6,3	2,5	2,1	-4,4	-4,7	6,2	4,9	11,4	8,4	15,1	10,4
0700	-6,7	-7,3	-4,7	-5,2	1,4	0,8	17,5	12,1	17,5	12,1	14,4	10,1	8,7	6,7	3,3	2,5	-3,6	-4,2	7,0	5,3	12,2	8,7	15,9	10,7
0800	-5,3	-6,3	-3,3	-4,2	2,9	1,8	19,0	12,6	19,0	12,6	15,9	10,6	10,1	7,3	4,7	3,3	-2,1	-3,3	8,4	6,0	13,6	9,3	17,3	11,3
0900	-3,2	-5,0	-1,2	-2,7	4,9	3,1	21,0	13,4	21,0	13,4	17,9	11,5	12,1	8,2	6,8	4,3	-0,1	-2,0	10,5	6,9	15,7	10,2	19,4	12,1
1000	-0,8	-3,5	1,2	-1,1	7,3	4,5	23,4	14,3	23,4	14,3	20,3	12,4	14,5	9,2	9,2	5,5	2,3	-0,6	12,8	8,0	18,1	11,1	21,7	13,0
1100	1,8	-1,8	3,8	0,6	10,0	6,1	26,1	15,2	26,1	15,2	23,0	13,4	17,2	10,4	11,8	6,7	5,0	1,0	15,5	9,2	20,7	12,2	24,4	14,0
1200	4,4	-0,4	6,4	2,2	12,5	7,5	28,6	16,0	28,6	16,0	25,5	14,3	19,7	11,4	14,4	7,9	7,5	2,5	18,0	10,2	23,3	13,1	26,9	14,9
1300	6,3	0,7	8,3	3,4	14,4	8,5	30,5	16,7	30,5	16,7	27,4	15,0	21,6	12,1	16,3	8,7	9,4	3,5	19,9	11,0	25,2	13,8	28,8	15,5
1400	7,5	1,4	9,5	4,2	15,6	9,2	31,7	17,1	31,7	17,1	28,6	15,4	22,9	12,6	17,5	9,2	10,6	4,2	21,2	11,5	26,4	14,3	30,1	16,0
1500	8,0	1,7	10,0	4,4	16,1	9,4	32,2	17,2	32,2	17,2	29,1	15,6	23,3	12,8	18,0	9,4	11,1	4,4	21,7	11,7	26,9	14,4	30,6	16,1
1600	7,5	1,4	9,5	4,2	15,6	9,2	31,7	17,1	31,7	17,1	28,6	15,4	22,9	12,6	17,5	9,2	10,6	4,2	21,2	11,5	26,4	14,3	30,1	16,0
1700	6,4	0,8	8,4	3,5	14,5	8,6	30,6	16,7	30,6	16,7	27,5	15,0	21,8	12,2	16,4	8,8	9,5	3,6	20,1	11,0	25,3	13,9	29,0	15,6
1800	4,7	-0,2	6,7	2,4	12,8	7,7	28,9	16,1	28,9	16,1	25,8	14,4	20,0	11,5	14,7	8,0	7,8	2,6	18,4	10,3	23,6	13,3	27,2	15,0
1900	2,6	-1,4	4,6	1,1	10,7	6,6	26,9	15,5	26,9	15,5	23,7	13,7	18,0	10,7	12,6	7,1	5,7	1,5	16,3	9,5	21,5	12,5	25,2	14,3
2000	0,6	-2,6	2,6	-0,2	8,7	5,4	24,8	14,8	24,8	14,8	21,7	12,9	15,9	9,8	10,6	6,1	3,7	0,2	14,3	8,6	19,5	11,7	23,1	13,5
2100	-1,2	-3,7	0,8	-1,3	7,0	4,3	23,1	14,1	23,1	14,1	20,0	12,3	14,2	9,1	8,8	5,3	2,0	-0,8	12,5	7,9	17,7	11,0	21,4	12,9
2200	-2,7	-4,7	-0,7	-2,4	5,4	3,4	21,5	13,6	21,5	13,6	18,4	11,7	12,6	8,4	7,3	4,5	0,4	-1,7	10,9	7,1	16,2	10,4	19,8	12,3
2300	-4,0	-5,5	-2,0	-3,3	4,1	2,6	20,2	13,1	20,2	13,1	17,1	11,2	11,3	7,9	6,0	3,9	-0,9	-2,5	9,7	6,6	14,9	9,8	18,6	11,8

ASHRAE Handbook”. [25, 26] The latter seems to represent Ankara’s drybulb and wetbulb temperatures better. HAP 4.22a calculates the hourly dry-bulb temperature profiles according to the ASHRAE cooling design temperatures, daily ranges. For the calculation of hourly dry-bulb temperatures the cooling design dry-bulb is calculated according to the formula given:

$$T_{db,m} = T_{sdb} - F_m \quad (3.1)$$

The monthly design temperature factors are tabulated in literature. [20] After cooling design dry-bulb is calculated the hourly dry-bulb temperatures can be calculated according to the formula:

$$T_{a,h} = T_{db,m} - \Delta T_D \cdot F_h \quad (3.2)$$

The hourly temperature factors are tabulated in literature. [9]

HAP 4.22a calculates the wet bulb temperatures by calculating the humidity of design wet-bulb temperatures coincident with the design dry-bulb temperature and calculates the wet-bulb temperatures according to this humidity. The default temperatures used by the program are given in Table 3.1.

In this thesis, temperature data for Ankara are taken from literature, which is provided in Appendix D. [25] The data includes the hourly summer dry bulb temperatures and relative humidity for 4 AM, 10 AM, 3 PM and 10 PM. The humidity ratios calculated by Microsoft Excel are given in Figure 3.1. As it can be seen from the graph the humidity ratios for 10 AM is a greater than the other hours during winter which physically means that humidity ratio within a day increases. Since increase of humidity within a day is meaningless, the humidity data averaged excluding the 10 AM values. With this calculated humidity ratio wet bulb temperatures for each hour is calculated with the incident dry-bulb temperatures and humidity ratios. The values of dry-bulb temperatures and wet-bulb temperatures are given in Table 3.2.

Table 3.2 User-Defined Temperature Profiles for Ankara

Hr	January		February		March		April		May		June		July		August		September		October		November		December	
	DB	WB	DB	WB	DB	WB	DB	WB	DB	WB	DB	WB	DB	WB	DB	WB	DB	WB	DB	WB	DB	WB	DB	WB
0000	-4,1	-4,5	-1,6	-2,8	-0,4	-1,5	17,9	12,9	16,9	12,0	13,0	9,7	7,5	5,4	1,9	0,7	-0,9	-1,4	5,8	4,2	9,6	8,0	12,4	9,7
0100	-4,5	-4,8	-1,6	-2,8	-0,9	-1,8	16,9	12,5	15,8	11,6	12,3	9,4	6,9	5,1	1,6	0,6	-0,9	-1,4	5,0	3,8	8,7	7,6	11,2	9,2
0200	-4,6	-4,9	-1,9	-2,9	-1,0	-1,8	16,2	12,3	15,0	11,2	11,2	9,0	6,4	4,9	1,3	0,4	-1,1	-1,5	4,7	3,7	8,3	7,4	10,5	8,9
0300	-4,9	-5,1	-2,3	-3,2	-1,3	-2,0	15,3	11,9	14,3	11,0	10,4	8,6	5,9	4,6	1,0	0,2	-1,1	-1,5	4,5	3,5	7,5	7,0	9,8	8,6
0400	-5,0	-5,1	-2,5	-3,3	-1,3	-2,0	14,4	11,6	13,5	10,6	9,7	8,3	5,6	4,5	0,7	0,1	-1,1	-1,5	4,0	3,3	7,1	6,8	9,0	8,2
0500	-5,1	-5,2	-2,5	-3,3	-1,6	-2,2	14,9	11,8	15,0	11,2	9,3	8,2	5,5	4,4	0,9	0,2	-1,0	-1,4	4,2	3,4	7,5	7,0	10,5	8,9
0600	-5,1	-5,2	-2,7	-3,4	-1,5	-2,1	16,3	12,3	16,7	11,9	10,3	8,6	5,5	4,4	1,1	0,3	-1,1	-1,5	4,9	3,8	9,0	7,7	12,3	9,6
0700	-5,3	-5,3	-2,8	-3,5	-0,6	-1,6	19,4	13,5	18,3	12,5	13,0	9,7	6,4	4,9	1,3	0,4	-1,2	-1,5	6,3	4,5	11,0	8,6	15,2	10,8
0800	-4,4	-4,8	-1,3	-2,6	1,4	-0,5	21,0	14,1	20,4	13,3	16,6	11,2	8,8	6,0	2,8	1,2	-0,2	-1,0	8,4	5,5	13,4	9,6	17,7	11,8
0900	-3,0	-3,9	0,1	-1,8	3,4	0,6	22,8	14,7	22,5	14,1	19,4	12,3	11,3	7,2	4,4	2,1	1,0	-0,3	10,1	6,3	15,5	10,5	19,7	12,6
1000	-1,7	-3,1	1,9	-0,8	4,7	1,3	24,3	15,2	24,6	14,8	21,1	12,9	13,6	8,2	6,0	2,9	2,1	0,3	11,7	7,0	17,4	11,2	21,2	13,2
1100	-0,2	-2,2	2,9	-0,2	5,5	1,7	25,1	15,5	25,6	15,2	22,6	13,5	14,9	8,8	6,8	3,3	3,0	0,8	12,2	7,3	18,3	11,6	22,3	13,6
1200	1,0	-1,6	3,6	-0,2	6,4	2,2	26,2	15,9	26,6	15,5	23,5	13,8	15,7	9,1	7,5	3,7	3,8	1,2	13,0	7,6	19,1	11,9	23,0	13,8
1300	1,8	-1,1	4,4	0,6	7,4	2,8	27,1	16,2	27,9	16,0	24,3	14,1	16,2	9,3	8,2	4,1	4,5	1,6	13,4	7,8	19,5	12,1	23,5	14,0
1400	2,1	-0,9	4,4	0,6	7,5	2,8	27,4	16,3	27,7	15,9	24,2	14,1	16,1	9,3	7,7	3,8	4,1	1,4	13,6	7,9	19,6	12,1	23,6	14,0
1500	1,9	-1,0	4,4	0,6	7,5	2,8	27,6	16,3	27,6	15,9	24,2	14,1	15,5	9,0	7,2	3,5	3,6	1,1	13,7	7,9	19,5	12,1	23,5	14,0
1600	1,1	-1,5	4,0	0,4	7,4	2,8	27,5	16,3	27,7	15,9	23,6	13,9	14,7	8,7	6,7	3,3	3,0	0,8	13,6	7,9	19,2	11,9	23,0	13,8
1700	-0,4	-2,4	3,0	-0,2	6,3	2,2	26,5	16,0	25,9	15,3	22,0	13,3	13,4	8,1	5,7	2,8	2,2	0,3	12,5	7,4	18,1	11,5	21,9	13,4
1800	-1,6	-3,1	2,1	-0,7	4,9	1,4	25,1	15,5	24,2	14,7	20,0	12,5	11,9	7,5	4,7	2,2	1,5	0,0	11,4	6,9	16,7	11,0	20,5	12,9
1900	-2,2	-3,4	1,4	-1,1	3,6	0,7	23,3	14,9	22,4	14,0	18,3	11,9	10,8	7,0	3,7	1,7	0,8	-0,4	9,9	6,2	15,0	10,3	18,5	12,1
2000	-2,6	-3,7	0,8	-1,4	2,3	0,0	22,1	14,4	21,2	13,6	16,6	11,2	9,8	6,5	3,2	1,4	0,3	-0,7	9,1	5,8	13,6	9,7	16,6	11,4
2100	-3,1	-4,0	0,3	-1,7	1,5	-0,5	20,8	14,0	20,1	13,2	15,6	10,8	8,9	6,1	2,6	1,1	-0,2	-1,0	8,1	5,3	12,5	9,2	15,1	10,8
2200	-3,6	-4,3	-0,2	-2,0	0,8	-0,8	19,6	13,5	18,9	12,7	14,6	10,4	8,3	5,8	2,2	0,9	-0,6	-1,2	7,3	4,9	11,4	8,7	13,9	10,3
2300	-3,9	-4,4	-0,7	-2,2	0,2	-1,2	18,9	13,3	17,9	12,4	13,8	10,1	7,6	5,5	2,0	0,8	-0,9	-1,4	6,7	4,7	10,6	8,4	13,1	10,0

Table 3.3 HAP 4.22a Hourly Solar Fluxes for July (W/m²)

Hour	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	HOR
0000	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
0100	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
0200	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
0300	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
0400	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
0500	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
0600	114,7	205,6	270,2	296,9	200,0	225,0	139,5	30,0	22,4	22,4	22,4	22,4	22,4	22,4	22,4	25,1	71,7
0700	163,7	360,1	514,8	600,9	603,0	520,6	368,6	173,5	59,9	57,6	57,6	57,6	57,6	57,6	57,6	59,5	251,4
0800	108,5	337,6	533,8	664,1	705,4	650,5	509,1	306,0	90,9	82,9	82,9	82,9	82,9	82,9	82,9	82,9	428,0
0900	108,0	247,9	450,9	604,7	683,1	672,4	574,6	406,5	196,6	105,7	102,5	102,5	102,5	102,5	102,5	102,5	584,9
1000	117,4	134,6	317,2	473,5	577,9	612,8	572,3	463,3	304,1	127,3	117,4	117,4	117,4	117,4	117,4	117,4	711,4
1100	127,3	132,0	162,3	301,5	417,2	490,7	509,8	471,4	381,9	255,9	136,5	130,1	127,3	127,3	127,3	127,3	799,0
1200	132,1	132,1	136,0	141,2	224,5	324,6	397,4	431,3	420,7	367,4	280,1	172,6	138,5	132,1	132,1	132,1	841,9
1300	131,6	131,6	131,6	131,6	136,2	141,8	248,4	347,9	416,4	442,9	423,0	360,0	264,1	150,6	136,9	131,6	837,2
1400	125,8	125,8	125,8	125,8	125,8	125,8	133,2	230,5	369,3	473,7	526,5	518,9	452,3	337,6	193,5	131,4	785,1
1500	117,4	114,8	114,8	114,8	114,8	114,8	114,8	123,2	284,8	455,8	577,8	630,1	603,9	503,5	346,1	157,6	689,2
1600	105,3	99,0	99,0	99,0	99,0	99,0	99,0	99,0	173,1	389,9	567,2	675,2	695,1	623,3	472,5	268,5	556,0
1700	122,8	78,4	78,4	78,4	78,4	78,4	78,4	78,4	85,1	281,8	487,6	634,5	696,9	663,6	540,5	349,4	394,2
1800	166,5	54,0	51,6	51,6	51,6	51,6	51,6	51,6	51,6	145,4	330,9	478,1	561,4	565,9	490,6	349,3	215,2
1900	78,9	15,9	13,9	13,9	13,9	13,9	13,9	13,9	13,9	19,2	84,9	141,6	179,6	192,3	177,1	136,9	40,4
2000	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
2100	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
2200	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0
2300	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

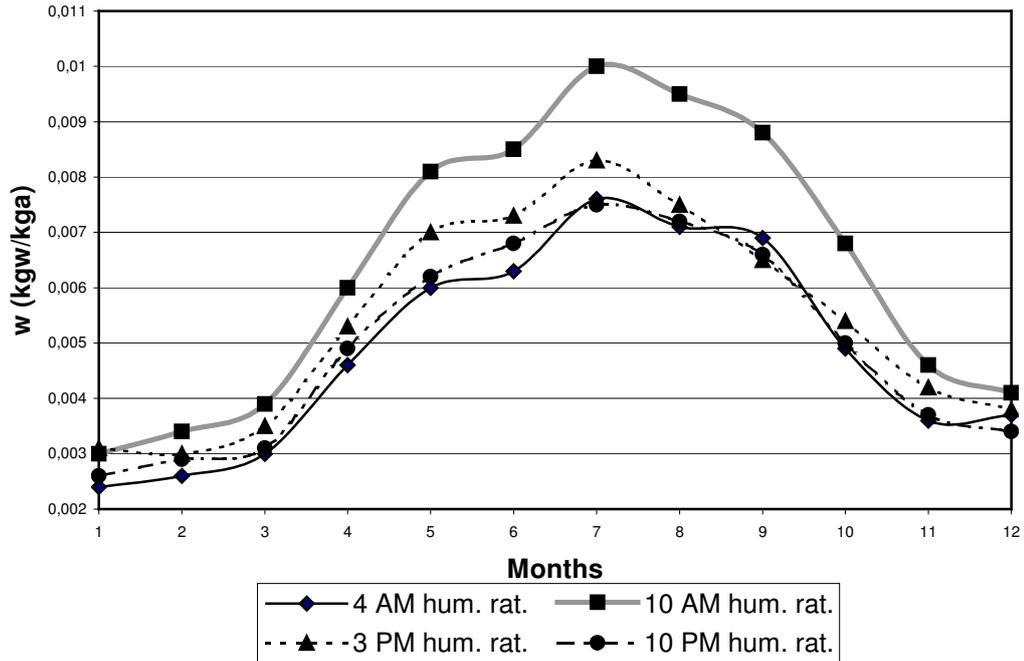


Figure 3.1 Humidity Ratio Curves for Different Hours [25]

3.1.2. Cooling and Heating Load Calculations

Cooling load calculations and some parts of heating load calculations of this thesis is done with the Carrier Hourly Analysis Program Version 4.22a (HAP 4.22a). Cooling load calculations are done directly with HAP 4.22a, whereas the heating loads are done with TS 2164 and only internal and solar parts of heating loads are done with HAP 4.22a. The program utilizes the transfer function method. For a better analysis the inputs of the program such as the weather data, constructional elements, internal loads and space parameters must be carefully considered.

3.1.2.1. Solar Data

HAP 4.22a calculates the diffuse and beam solar fluxes for the given latitude, hours and clearness numbers according to the principles described in ASHRAE. [9] If available empirical data for fluxes and clearness numbers is available, using them will be more accurate. However reliable solar data for Ankara cannot be found.

Therefore, the solar fluxes calculated by HAP 4.22a are utilized in this study. As an example, the hourly solar data used for July is provided in Table 3.3.

3.1.2.2. Constructional Elements

The overall heat transfer coefficients and areas of the structural elements surrounding the building are checked for the building's total heating energy requirements according to calculation method described in TS 825, "Turkish Standart for Thermal Insulation in Building". [26] These heat transfer coefficients and areas are tabulated in Table 3.4 and sample roof, exterior wall, ground touching slab and ground touching wall heat transfer coefficient calculations are given in Appendix E.

Table 3.4 Areas and Overall Heat Transfer Coefficients of Structural Elements Surrounding the Building

Name	Overall Heat Transfer Coefficient (W/m ² h°C)	Area (m ²)
Rf1-Terrace Roof 1	0,43	338,9
Rf2-Terrace Roof 2	0,42	100,8
Rf3-Terrace Roof 3	0,35	207,7
Rf4-Terrace Roof 4	0,35	20,4
Ew1- Exterior Wall 1	0,44	201,3
Ew2- Exterior Wall 2	0,40	98,2
Ew3- Exterior Wall 3	0,37	29,8
Ew4- Exterior Wall 4	0,46	20,0
Ew5- Exterior Wall 5	0,45	145,4
Ew6- Exterior Wall 6	0,44	41,4
Gs1-Ground Touching Slab 1	0,40	326,4
Gs2-Ground Touching Slab 2	0,41	116,5
Gs3-Ground Touching Slab 3	0,40	107,2
Gw1-Ground Touching Wall 1	0,46	229,7
Windows	2,6	238,9
Doors	2,6	1080,1

3.1.2.2.1. Walls and Roofs

In HAP 4.22a walls and roofs are defined as a sequence of material layers used in construction. These materials are identified with their properties like thermal

resistances, thicknesses, specific heats, outside surface colors and densities. With these properties the program calculates the transfer function coefficients and U values for the construction elements. A sample wall construction is provided in Table 3.5.

Table 3.5 HAP 4.22a "Ew1 Exterior Wall" Constructional Element Data

Wall Details					
Outside Surface Color	Medium				
Absorptivity	0,675				
Overall U-Value	0,445 W/(m ² -°K)				
Wall Layers Details (Inside to Outside)					
Layers	Thickness mm	Density kg/m³	Specific Ht. kJ / (kg - °K)	R-Value (m²-°K)/W	Weight kg/m²
Inside surface resistance	0,000	0,0	0,00	0,12064	0,0
Coat	30,000	1858,0	0,84	0,08598	55,7
Gas Concrete	200,000	609,0	0,84	0,90510	121,8
XPS	30,000	91,7	0,84	1,07481	2,8
Outside surface resistance	0,000	0,0	0,00	0,05864	0,0
Totals	260,000	-		2,24517	180,3

Table 3.6 HAP 4.22a "101-Window" Constructional Element Data

Window Details:				
Detailed Input	Evet			
Height	2,30 m			
Width 2,15	m			
Frame Type	Vinyl			
Internal Shade Type .	Roller Shades - Dark - Opaque			
Overall U-Value	2,600 W/(m ² -°K)			
Overall Shade Coefficient	0,630			
Glass Details:				
Gap Type	6mm Air Space			
Glazing	Glass Type	Transmissivity	Reflectivity	Absorptivity
Outer Glazing	3mm clear	0,841	0,078	0,081
Glazing #2	3mm clear	0,841	0,078	0,081
Glazing #3	not used	1,000	0,000	0,000

3.1.2.2.2. Windows and Doors

In HAP 4.22a windows and doors are defined by its physical characteristics such as number of glazings, types and optical properties of glass used, frame type, internal shading properties and window dimensions. Together these properties are used to

calculate the overall U-value and shade coefficient for the window. With these properties the program calculates the transfer function coefficients. A sample window is provided in Table 3.6.

3.1.2.2.3. External Shades

In HAP 4.22a windows and doors are defined by the dimensions of the reveal, overhang and fins which externally shade a window. Figure 3.2 shows what is meant by reveal, overhang and fin dimensions.

The external shade of the window in Figure 3.2 is provided in Table 3.7.

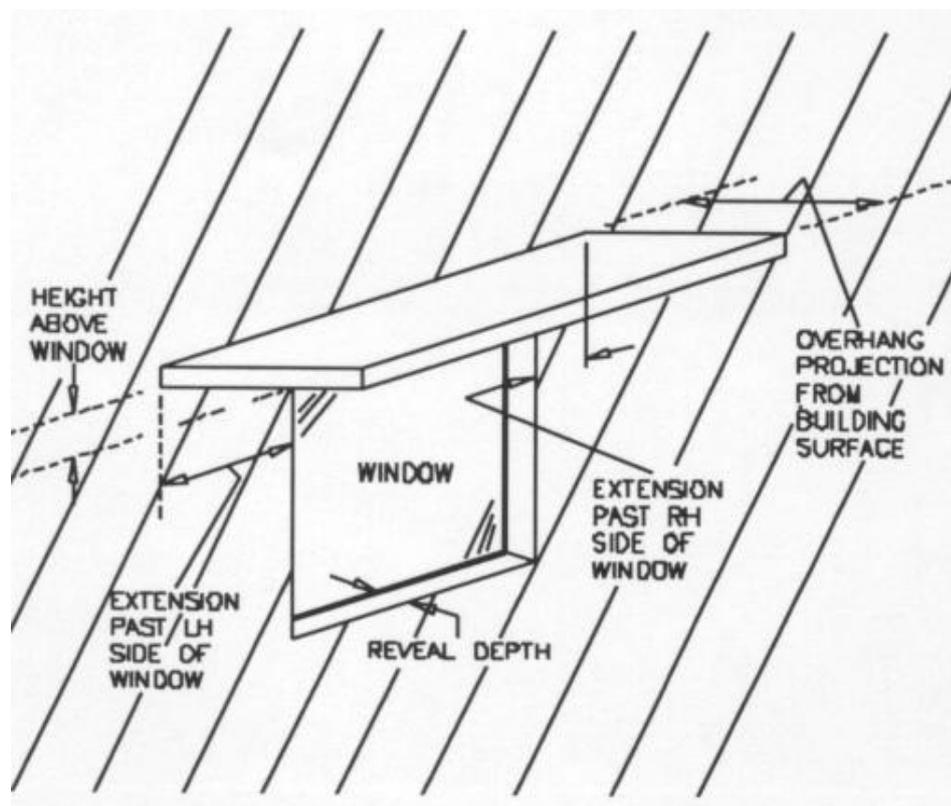


Figure 3.2 Representatiton of External Shade Dimensions

3.1.2.3. Internal Loads

In HAP 4.22a internal loads are composed of lighting loads, electrical equipment loads, people loads and miscellaneous loads. Any one of these loads can be divided

into sensible and latent components. Moreover, the operational schedule must be provided with them to define the hourly operation of an internal load. As a sample the occupancy schedule for an office type of room is given in Figure 3.3.

Table 3.7 HAP 4.22A “101-Window” External Shade Data

		Overhang:	
Reveal Depth.....	4,0 mm	Projection from surface	0,0 mm
		Height above window.....	0,0 mm
		Ext. past RH side of window	0,0 mm
Left Fin:		Right Fin:	
Projection from surface	2850,0 mm	Projection from surface	4150,0 mm
Height above window	1450,0 mm	Height above window	1450,0 mm
Dist. from edge of window	0,0 mm	Dist. from edge of window	0,0 mm

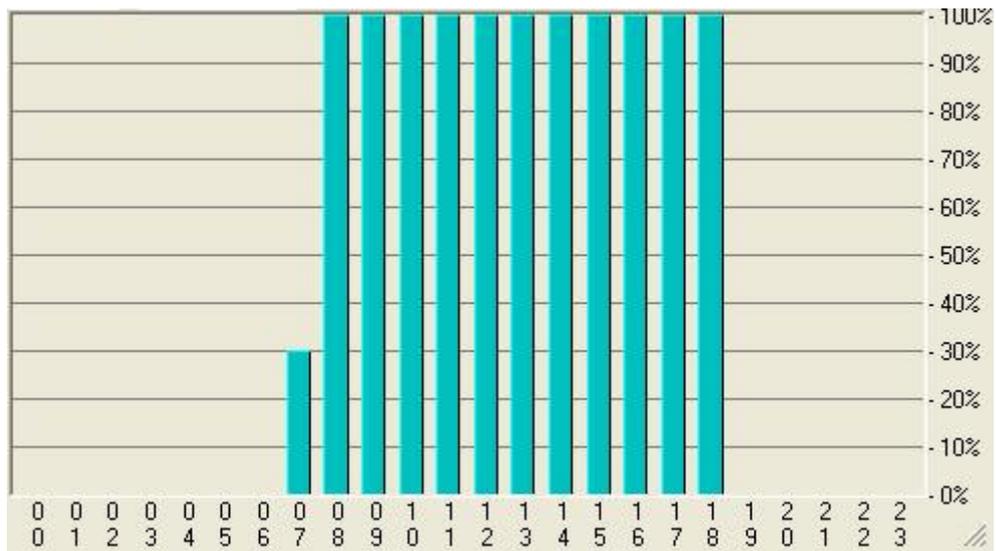


Figure 3.3 HAP 4.22a Occupancy Schedule for an Office Type of Room

3.1.2.4. Space Parameters

In HAP 4.22a space design is categorized as different parts such as “general”, “internals”, “walls, windows and doors”, “roofs and skylights”, “infiltration”, “floors” and “partitions”.

“General” contains the space name, total floor area, average floor to ceiling height and the building weight.

“Internals” contains information about internal heat gains from overhead lighting, task lighting, electrical equipment, occupants, and miscellaneous sources.

“Walls, Windows, Doors” contains data for wall exposures and the windows, external shading devices and doors which are part of these exposures.

“Roofs, Skylights” contains information about horizontal or sloped roofs any skylights which are part of these roof exposures.

“Infiltration” contains infiltration specifications.

“Floors” contains information about heat transfer through slab floors, basement floors or floors above an unconditioned region.

“Partitions” contains data about heat flow through walls or ceilings adjacent to unconditioned regions. [27]

A sample of space calculation inputs is provided for “101- Corridor” in Appendix F.

3.1.2.5. Heating Load Calculations

In Section “2.1.2 Heating Load Calculations” TS 2164, which is the standard for calculation of heating design load, is explained. Since in this thesis hourly heating and cooling loads must be found this standard cannot be used directly. Moreover, since TFM is mainly used for cooling loads, it has some problems in estimating the winter loads such as taking high solar loads or not evaluating the partitions loads and basements. Therefore, HAP 4.22a is not good at estimating the heating loads. Thus, it is more convenient to apply TS 2164 with some changes.

TS 2164 uses winter design conditions as the outdoor temperature. However, in this thesis the Microsoft Excel is used to construct the heating load calculation sheets with the dry-bulb temperatures given in Table 3.2. The heat loss calculation procedure is performed for every hour of the month in different sheets. Due to the

changing outdoor conditions, ground temperatures or unconditioned space temperatures are taken according to Table 3.2 with the coincident drybulb temperature of that specific time. Heating load calculation for space “101- Corridor” for January at 8 is given in Table 3.8.

Table 3.8 Heat Loss Calculation for “101-Corridor” at January Hour 8

Mogan Ceremony Hall									
Outside Temp.		-4,4 °C		Month: Jan.		Hour: 8			
Sign	Direction	Heat Transfer Coefficients	Temperature Difference	Area	Number	Temperature Diff. X Heat Tr. Coefficient	Heat Transfer without Allowances	Allowances	Heat Transfer with Allowances
		W / m ² .°C	°C	m ²		W / m ²	W	1+Z	W
101 Corridor					18 °C				
W1	W	2,60	22,4	4,95	1	58,2	288,0		
W2	W	2,60	22,4	5,64	1	58,2	327,9		
Ew4	W	0,46	22,4	5,42	1	10,3	55,8		
Rf4	-	0,35	22,4	57,00	1	7,9	450,7		
							1122,5	1,07	1201
									199
a	l	R_c	H_b	ΔT	Z_e				1400
2,5	3,0	0,9	1,13	22,4	1,0				

TS 2164 lack the internal loads and solar loads. The solar loads in winter months can be neglected but the internal loads must be taken into account. The internal loads calculated by HAP 4.22a are added to the heating loads for winter months. The tabulated forms of heating loads calculated according to TS 2164, hourly internal sensible heat gains, and hourly internal latent heat gains for a sample winter month (January) are given in Table 3.9, Table 3.10 and Table 3.11, respectively.

When the heating and cooling loads of transition months are considered the solar loads must be taken into account. Since HAP 4.22a is weak at heating load calculations for transition months, it is better to add solar loads to the calculated heating loads as well as the internal parts. Therefore, solar loads and internal loads

Table 3.9 Hourly Heat Loss Calculations at January

Room Name	Month: January																							
	Hour																							
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Temperature	-4.1	-4.5	-4.6	-4.9	-5.0	-5.1	-5.1	-5.3	-4.4	-3.0	-1.7	-0.2	1.0	1.8	2.1	1.9	1.1	-0.4	-1.6	-2.2	-2.6	-3.1	-3.6	-3.9
101 Corridor	1194	1219	1225	1244	1250	1256	1256	1269	1400	1312	1231	1137	1062	1012	994	1006	1056	1150	1225	1075	1100	1131	1162	1181
102+103 Hall + Elevator	626	639	642	652	656	659	659	665	734	688	646	597	557	531	521	528	554	603	642	564	577	593	610	620
104 Office	1213	1239	1245	1264	1270	1277	1277	1289	1550	1461	1378	1283	1207	1156	1137	1150	1200	1296	1372	1092	1118	1150	1181	1200
105-106 Office	966	986	991	1006	1011	1016	1016	1026	1234	1163	1097	1021	961	920	905	915	956	1031	1092	870	890	915	940	956
107 Office	1213	1239	1245	1264	1270	1277	1277	1289	1550	1461	1378	1283	1207	1156	1137	1150	1200	1296	1372	1092	1118	1150	1181	1200
108 Office	2715	2772	2787	2829	2843	2858	2858	2886	3469	3270	3085	2872	2701	2588	2545	2573	2687	2900	3071	2445	2502	2573	2644	2687
109-110-111 Hall	818	836	840	853	857	861	861	870	960	900	844	780	728	694	681	690	724	788	840	866	883	904	926	938
112 Hall	502	513	516	524	526	529	529	534	589	552	518	479	447	426	418	424	445	484	516	531	542	555	568	576
113 Projection Room	82	83	84	85	85	86	86	87	104	98	93	86	81	78	76	77	81	87	92	95	96	99	101	102
114 Light Room	66	67	67	69	69	69	69	70	84	79	75	70	65	63	62	62	65	70	74	76	78	80	81	82
115 Sound Room	66	67	67	69	69	69	69	70	84	79	75	70	65	63	62	62	65	70	74	76	78	80	81	82
116 Translation Room	161	164	165	167	168	169	169	171	205	193	182	170	160	153	151	152	159	172	182	187	190	194	198	201
Z01-201a Entrance	8903	9089	9136	9276	9322	9369	9369	9462	11122	10469	9863	9164	8605	8232	8092	8185	8558	9257	9817	10096	10283	10516	10749	10889
Z02 Foyer	15401	15690	15763	15979	16052	16124	16124	16268	18320	16774	15835	14751	13884	13306	13090	13234	13812	14896	15763	16196	16485	16846	17207	17424
Z03 Wedding Lounge	13708	13995	14067	14282	14354	14426	14426	14569	18416	17411	16478	15402	14541	13966	13751	13895	14469	15545	16407	16837	17124	17483	17842	18057
Z04 Backstage	326	333	335	340	342	343	343	347	417	393	371	345	324	311	306	309	323	348	369	379	386	395	403	408
Z05 Bride Room	533	544	547	555	558	561	561	566	681	642	606	564	530	508	499	505	527	569	603	619	631	645	659	667
Z06 Bnde Room	883	902	906	920	925	929	929	939	1128	1063	1003	934	879	842	828	837	874	943	999	1026	1045	1068	1091	1105
Z07 Wedding Officer	533	544	547	555	558	561	561	566	681	642	606	564	530	508	499	505	527	569	603	619	631	645	659	667
Z08 Wedding Officer	569	581	584	592	595	598	598	604	726	685	646	601	566	542	533	539	563	607	643	661	673	688	703	712
Z09 Wedding Room	777	793	797	810	814	818	818	826	993	936	883	822	773	740	728	736	769	830	879	903	919	940	960	972
Z10 Hall	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Z11 Service	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Z12 Security	1197	1222	1229	1247	1254	1260	1260	1272	1529	1442	1360	1266	1191	1141	1122	1135	1185	1279	1354	1392	1417	1448	1479	1498
Z13 Corridor	2995	3058	3073	3121	3136	3152	3152	3183	3513	3293	3089	2854	2666	2540	2493	2525	2650	2885	3073	3168	3230	3309	3387	3434
B01 Hall	522	522	522	522	522	522	522	522	688	522	522	522	522	522	522	522	522	522	522	357	357	357	357	357
B07 Artist Room	379	379	379	379	379	379	379	379	780	683	683	683	683	683	683	683	683	683	683	683	683	683	683	683
B09 Artist Room	146	146	146	146	146	146	146	146	439	390	390	390	390	390	390	390	390	390	390	390	390	390	390	390
B11 Hall	613	613	613	613	613	613	613	613	765	613	613	613	613	613	613	613	613	613	613	461	461	461	461	461
B12 Office	615	625	627	635	638	640	640	646	819	742	709	670	639	618	611	616	636	675	706	525	535	548	561	569
B13 Assistant Manager	405	412	414	419	421	423	423	426	538	489	467	440	420	406	400	404	418	444	465	475	355	364	372	378
B14 Secretary	340	346	348	352	354	355	355	359	448	410	390	367	349	337	332	335	348	371	389	398	301	309	317	321
B15 Manager	662	673	676	684	686	689	689	694	887	800	765	725	693	671	663	668	690	730	762	779	572	586	599	607

Table 3.10 Hourly Internal Sensible Heat Gains for January

Room Name	Month: January																							
	Hour																							
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Temperature	-4.1	-4.5	-4.6	-4.9	-5.0	-5.1	-5.1	-5.3	-4.4	-3.0	-1.7	-0.2	1.0	1.8	2.1	1.9	1.1	-0.4	-1.6	-2.2	-2.6	-3.1	-3.6	-3.9
101 Corridor	1194	1219	1225	1244	1250	1256	1256	1269	1400	1312	1231	1137	1062	1012	994	1006	1056	1150	1225	1075	1100	1131	1162	1181
102+103 Hall + Elevator	626	639	642	652	656	659	659	665	734	688	646	597	557	531	521	528	554	603	642	564	577	593	610	620
104 Office	1213	1239	1245	1264	1270	1277	1277	1289	1550	1461	1378	1283	1207	1156	1137	1150	1200	1296	1372	1092	1118	1150	1181	1200
105-106 Office	966	986	991	1006	1011	1016	1016	1026	1234	1163	1097	1021	961	920	905	915	956	1031	1092	870	890	915	940	956
107 Office	1213	1239	1245	1264	1270	1277	1277	1289	1550	1461	1378	1283	1207	1156	1137	1150	1200	1296	1372	1092	1118	1150	1181	1200
108 Office	2715	2772	2787	2829	2843	2858	2858	2886	3469	3270	3085	2872	2701	2588	2545	2573	2687	2900	3071	2445	2502	2573	2644	2687
109-110-111 Hall	818	836	840	853	857	861	861	870	960	900	844	780	728	694	681	690	724	788	840	866	883	904	926	938
112 Hall	502	513	516	524	526	529	529	534	589	552	518	479	447	426	418	424	445	484	516	531	542	555	568	576
113 Projection Room	82	83	84	85	85	86	86	87	104	98	93	86	81	78	76	77	81	87	92	95	96	99	101	102
114 Light Room	66	67	67	69	69	69	69	70	84	79	75	70	65	63	62	62	65	70	74	76	78	80	81	82
115 Sound Room	66	67	67	69	69	69	69	70	84	79	75	70	65	63	62	62	65	70	74	76	78	80	81	82
116 Translation Room	161	164	165	167	168	169	169	171	205	193	182	170	160	153	151	152	159	172	182	187	190	194	198	201
Z01-201a Entrance	8903	9089	9136	9276	9322	9369	9369	9462	11122	10469	9863	9164	8605	8232	8092	8185	8558	9257	9817	10096	10283	10516	10749	10889
Z02 Foyer	15401	15690	15763	15979	16052	16124	16124	16268	18320	16774	15835	14751	13884	13306	13090	13234	13812	14896	15763	16196	16485	16846	17207	17424
Z03 Wedding Lounge	13708	13995	14067	14282	14354	14426	14426	14569	18416	17411	16478	15402	14541	13966	13751	13895	14469	15545	16407	16837	17124	17483	17842	18057
Z04 Backstage	326	333	335	340	342	343	343	347	417	393	371	345	324	311	306	309	323	348	369	379	386	395	403	408
Z05 Bride Room	533	544	547	555	558	561	561	566	681	642	606	564	530	508	499	505	527	569	603	619	631	645	659	667
Z06 Bnde Room	883	902	906	920	925	929	929	939	1128	1063	1003	934	879	842	828	837	874	943	999	1026	1045	1068	1091	1105
Z07 Wedding Officer	533	544	547	555	558	561	561	566	681	642	606	564	530	508	499	505	527	569	603	619	631	645	659	667
Z08 Wedding Officer	569	581	584	592	595	598	598	604	726	685	646	601	566	542	533	539	563	607	643	661	673	688	703	712
Z09 Wedding Room	777	793	797	810	814	818	818	826	993	936	883	822	773	740	728	736	769	830	879	903	919	940	960	972
Z10 Hall	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Z11 Service	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Z12 Security	1197	1222	1229	1247	1254	1260	1260	1272	1529	1442	1360	1266	1191	1141	1122	1135	1185	1279	1354	1392	1417	1448	1479	1498
Z13 Corridor	2995	3058	3073	3121	3136	3152	3152	3183	3513	3293	3089	2854	2666	2540	2493	2525	2650	2885	3073	3168	3230	3309	3387	3434
B01 Hall	522	522	522	522	522	522	522	522	688	522	522	522	522	522	522	522	522	522	522	357	357	357	357	357
B07 Artist Room	379	379	379	379	379	379	379	379	780	683	683	683	683	683	683	683	683	683	683	683	683	683	683	683
B09 Artist Room	146	146	146	146	146	146	146	146	439	390	390	390	390	390	390	390	390	390	390	390	390	390	390	390
B11 Hall	613	613	613	613	613	613	613	613	765	613	613	613	613	613	613	613	613	613	613	461	461	461	461	461
B12 Office	615	625	627	635	638	640	640	646	819	742	709	670	639	618	611	616	636	675	706	525	535	548	561	569
B13 Assistant Manager	405	412	414	419	421	423	423	426	538	489	467	440	420	406	400	404	418	444	465	475	355	364	372	378
B14 Secretary	340	346	348	352	354	355	355	359	448	410	390	367	349	337	332	335	348	371	389	398	301	309	317	321
B15 Manager	662	673	676	684	686	689	689	694	887	800	765	725	693	671	663	668	690	730	762	779	572	586	599	607

Table 3.11 Hourly Internal Latent Heat Gains for January

Room Name	Month: January																							
	Hour																							
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
101 Corridor	0	0	0	0	0	0	0	24	79	79	79	79	79	79	79	79	79	79	79	0	0	0	0	0
102+103 Hall + Elevator	0	0	0	0	0	0	0	59	79	79	79	79	79	79	79	79	79	79	79	0	0	0	0	0
104 Office	0	0	0	0	0	0	0	36	120	120	120	120	120	120	120	120	120	120	120	0	0	0	0	0
105-106 Office	0	0	0	0	0	0	0	54	180	180	180	180	180	180	180	180	180	180	180	0	0	0	0	0
107 Office	0	0	0	0	0	0	0	36	120	120	120	120	120	120	120	120	120	120	120	0	0	0	0	0
108 Office	0	0	0	0	0	0	0	90	300	300	300	300	300	300	300	300	300	300	300	0	0	0	0	0
109-110-111 Hall	120	120	120	0	0	0	0	0	60	60	60	60	120	120	120	120	120	120	120	120	120	120	120	120
112 Hall	120	120	120	0	0	0	0	0	60	60	60	60	120	120	120	120	120	120	120	120	120	120	120	120
113 Projection Room	60	60	60	0	0	0	0	0	30	30	30	30	60	60	60	60	60	60	60	60	60	60	60	60
114 Light Room	60	60	60	0	0	0	0	0	30	30	30	30	60	60	60	60	60	60	60	60	60	60	60	60
115 Sound Room	60	60	60	0	0	0	0	0	30	30	30	30	60	60	60	60	60	60	60	60	60	60	60	60
116 Translation Room	120	120	120	0	0	0	0	0	60	60	60	60	120	120	120	120	120	120	120	120	120	120	120	120
Z01-Z01a Entrance	1890	1890	1890	0	0	0	0	0	945	945	945	945	1890	1890	1890	1890	1890	1890	1890	1890	1890	1890	1890	1890
Z02 Foyer	19775	19775	19775	0	0	0	0	0	9888	9888	9888	9888	19775	19775	19775	19775	19775	19775	19775	19775	19775	19775	19775	1975
Z03 Wedding Lounge	8800	8800	8800	0	0	0	0	0	4400	4400	4400	4400	8800	8800	8800	8800	8800	8800	8800	8800	8800	8800	8800	8800
Z04 Backstage	70	70	70	0	0	0	0	0	35	35	35	35	70	70	70	70	70	70	70	70	70	70	70	70
Z05 Bride Room	70	70	70	0	0	0	0	0	35	35	35	35	70	70	70	70	70	70	70	70	70	70	70	70
Z06 Bride Room	70	70	70	0	0	0	0	0	35	35	35	35	70	70	70	70	70	70	70	70	70	70	70	70
Z07 Wedding Officer	70	70	70	0	0	0	0	0	35	35	35	35	70	70	70	70	70	70	70	70	70	70	70	70
Z08 Wedding Officer	120	120	120	0	0	0	0	0	60	60	60	60	120	120	120	120	120	120	120	120	120	120	120	120
Z09 Wedding Room	880	880	880	0	0	0	0	0	440	440	440	440	880	880	880	880	880	880	880	880	880	880	880	880
Z10 Hall	79	79	79	0	0	0	0	0	40	40	40	40	79	79	79	79	79	79	79	79	79	79	79	79
Z11 Service	79	79	79	0	0	0	0	0	40	40	40	40	79	79	79	79	79	79	79	79	79	79	79	79
Z12 Security	120	120	120	0	0	0	0	0	60	60	60	60	120	120	120	120	120	120	120	120	120	120	120	120
Z13 Corridor	396	396	396	0	0	0	0	0	198	198	198	198	396	396	396	396	396	396	396	396	396	396	396	396
B01 Hall	396	396	396	0	0	0	0	0	198	198	198	198	396	396	396	396	396	396	396	396	396	396	396	396
B07 Artist Room	120	120	120	0	0	0	0	0	60	60	60	60	120	120	120	120	120	120	120	120	120	120	120	120
B09 Artist Room	120	120	120	0	0	0	0	0	60	60	60	60	120	120	120	120	120	120	120	120	120	120	120	120
B11 Hall	158	158	158	0	0	0	0	0	79	79	79	79	158	158	158	158	158	158	158	158	158	158	158	158
B12 Office	180	180	180	0	0	0	0	0	90	90	90	90	180	180	180	180	180	180	180	180	180	180	180	180
B13 Assistant Manager	120	120	120	0	0	0	0	0	60	60	60	60	120	120	120	120	120	120	120	120	120	120	120	120
B14 Secretary	78	78	78	0	0	0	0	0	39	39	39	39	78	78	78	78	78	78	78	78	78	78	78	78
B15 Manager	246	246	246	0	0	0	0	0	123	123	123	123	246	246	246	246	246	246	246	246	246	246	246	246

Table 3.12 Hourly Solar Heat Gains for April

Room Name	Month: April																							
	Hour																							
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Temperature	5.8	5.0	4.7	4.5	4.0	4.2	4.9	6.3	8.4	10.1	11.7	12.2	13.0	13.4	13.6	13.7	13.6	12.5	11.4	9.9	9.1	8.1	7.3	6.7
101 Corridor	0	0	0	0	0	0	181	307	397	469	525	564	604	696	901	1503	2204	2763	1890	0	0	0	0	0
102+103 Hall + Elevator	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
104 Office	0	0	0	0	0	0	466	505	561	671	788	879	935	997	1097	1182	1385	1533	1377	0	0	0	0	0
105-106 Office	0	0	0	0	0	0	642	659	677	697	718	737	760	853	1129	1488	1847	2098	1909	0	0	0	0	0
107 Office	0	0	0	0	0	0	433	474	504	531	558	580	601	652	806	1036	1246	1447	1301	0	0	0	0	0
108 Office	0	0	0	0	0	0	1127	1184	1259	1390	1529	1640	1721	1868	2211	2709	3288	3698	3346	0	0	0	0	0
109-110-111 Hall	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
112 Hall	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
113 Projection Room	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
114 Light Room	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
115 Sound Room	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
116 Translation Room	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Z01-Z01a Entrance	0	0	0	0	0	0	1168	1717	2099	2261	2414	2645	2838	2980	3059	3066	2990	2864	2639	0	0	0	0	0
Z02 Foyer	0	0	0	0	0	0	7967	16117	21029	23775	24642	24015	22183	20362	18877	18028	17112	16050	14771	0	0	0	0	0
Z03 Wedding Lounge	0	0	0	0	0	0	2019	2237	2606	3497	4495	5070	5559	6247	6485	6313	5756	5115	4640	0	0	0	0	0
Z04 Backstage	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Z05 Bride Room	0	0	0	0	0	0	49	98	178	351	536	675	749	734	291	251	219	180	131	0	0	0	0	
Z06 Bride Room	0	0	0	0	0	0	26	76	106	129	150	165	173	175	169	155	135	114	78	0	0	0	0	
Z07 Wedding Officer	0	0	0	0	0	0	49	98	178	351	536	675	749	734	291	251	219	180	131	0	0	0	0	
Z08 Wedding Officer	0	0	0	0	0	0	26	76	106	129	150	165	173	175	169	155	135	114	78	0	0	0	0	
Z09 Wedding Room	0	0	0	0	0	0	49	98	178	351	536	675	749	734	291	251	219	180	131	0	0	0	0	
Z10 Hall	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Z11 Service	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Z12 Security	0	0	0	0	0	0	179	202	222	243	266	287	306	336	391	443	480	492	459	0	0	0	0	
Z13 Corridor	0	0	0	0	0	0	1235	1286	1337	1393	1451	1503	1563	1627	1708	2400	3450	4202	3811	0	0	0	0	
B01 Hall	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
B07 Artist Room	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
B09 Artist Room	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
B11 Hall	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
B12 Office	0	0	0	0	0	0	128	203	341	391	410	396	359	329	305	291	276	259	238	0	0	0	0	
B13 Assistant Manager	0	0	0	0	0	0	90	95	110	147	193	237	273	295	301	287	258	226	207	0	0	0	0	
B14 Secretary	0	0	0	0	0	0	71	75	87	116	152	187	216	233	237	226	203	179	163	0	0	0	0	
B15 Manager	0	0	0	0	0	0	143	150	173	231	304	374	431	466	475	453	407	358	326	0	0	0	0	

for the months April, May, September and October calculated by HAP 4.22a are added to the heating loads calculated by modified TS 2164. The tabulated form of solar loads for April is given in Table 3.12.

3.1.2.5.1. Comparison of Modified TS 2164 and HAP 4.22a Calculations in Heating Load Calculations

As mentioned, HAP 4.22a is not appropriate for hourly heating load conditions because it is originally designed for cooling loads. It is weak at heating load calculations, mainly because of three reasons. The first one is that it does not evaluate the infiltration loads due to the cracks on doors and windows. Since in summer time the pressure gradient between the outside and inside is small therefore in summer calculations air leakage from the small cracks on the windows and doors are neglected. The second reason is that since the solar loads of the program are calculated theoretically it does not evaluate the cloudiness effect. Therefore it adds very high loads of sensible heat gain from windows and roofs, even in winter time. The third reason is that the program does not evaluate the unconditioned space loads and ground touching wall loads since they are not important in cooling load calculations.

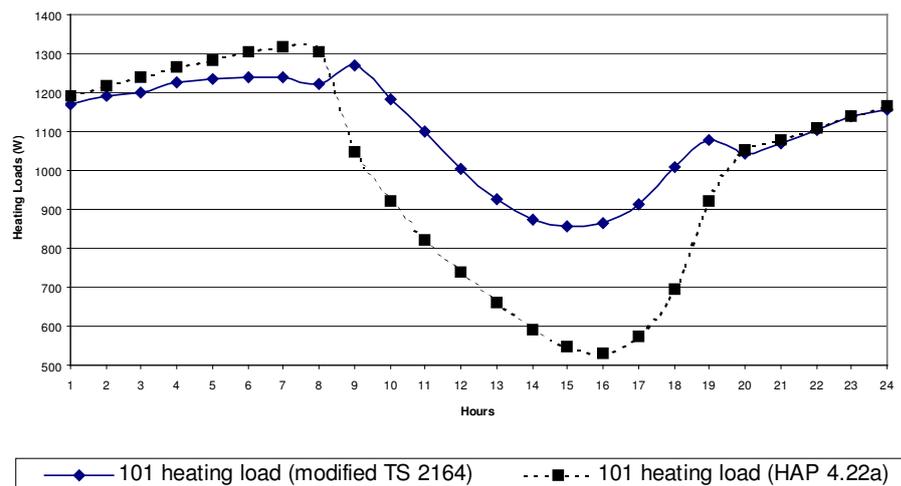


Figure 3.4 Hourly Heating Loads of “101-Corridor” at January

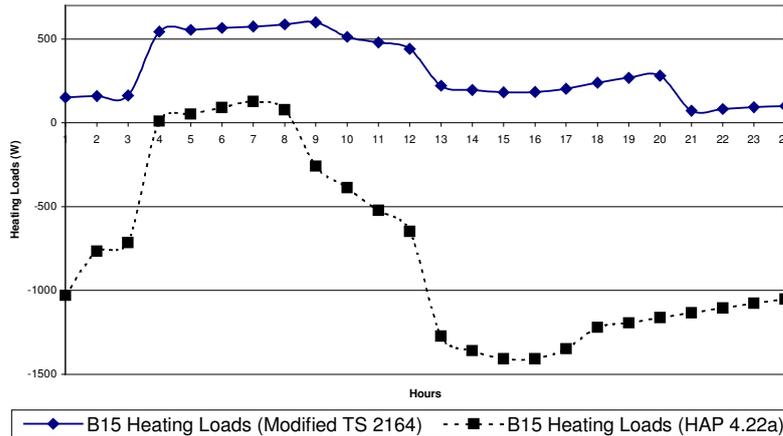


Figure 3.5 Hourly Heating Loads of “B15-Manager Room” at January

In transition cooling months the difference between the HAP 4.22a calculated values and the TS 2164 based calculations are smaller but they are still high for ground based spaces and spaces adjacent to unconditioned ones. Therefore the values calculated with TS 2164 including solar and internal gains seem more appropriate for simulation purposes.

To show the difference better, two spaces one with no ground touching wall “101-Corridor” and one with ground touching walls “B15- Manager Room” are selected. The heating loads of these spaces for January and April are given in Figure 3.4, Figure 3.5, Figure 3.6 and Figure 3.7.

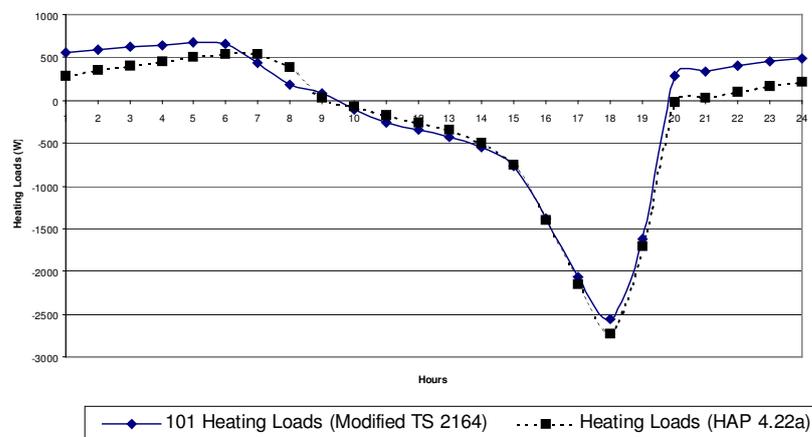


Figure 3.6 Hourly Heating Loads of “101-Corridor” at April

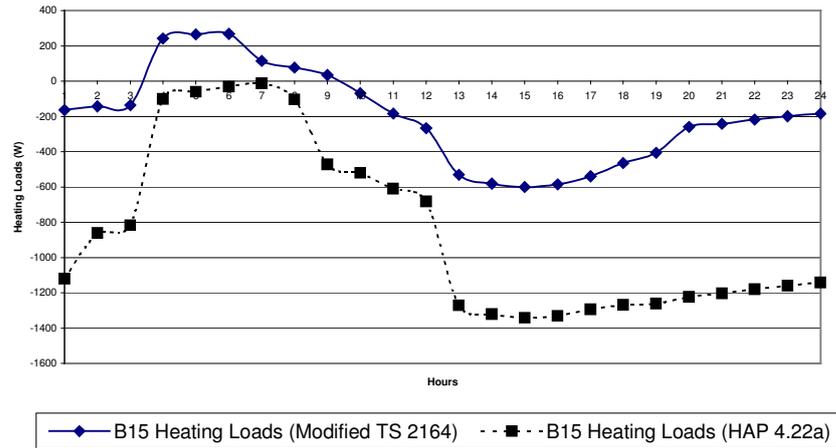


Figure 3.7 Hourly Heating Loads of “B15-Manager Room” at April

3.2. CALCULATIONS

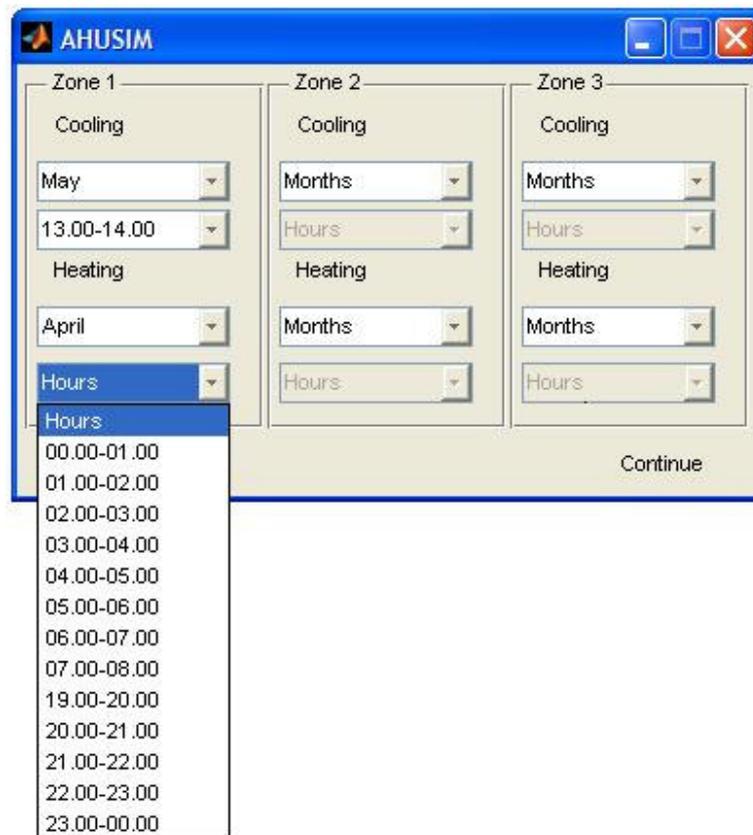


Figure 3.8 The Screen Output of “AHUSIM.fig”

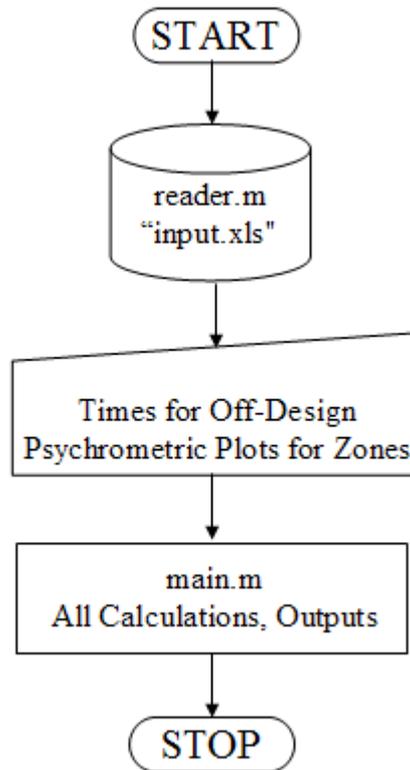


Figure 3.9 Flowchart of “AHUSIM.m”

Calculations of this study are done with Matlab computing language. The basic part of the Matlab computing language is the “.m” extension files which are named M-Files by the Matlab program. These M-Files are a set of command which can be executed by writing their names in another M-Files or Command Window. The interactive graphical part is done by built in Graphical User Interface Development Environment (GUIDE), which provides tools for creating Graphical User Interfaces (GUIs). A GUI is simply composed of a visual part –“.fig” extension Figure file- and a M-File which performs the operations carried out by the interface. [28]

In this study, the interactive visual part “AHUSIM.fig” is given in Figure 3.8. This part supplies a means of selection of times of the year for plotting the off-design psychrometric charts. After selection of the months from the dropdown menu, this part also filters the hours for cooling and heating to assure that each zone has a psychrometric chart representations of both cooling and heating modes of operation.

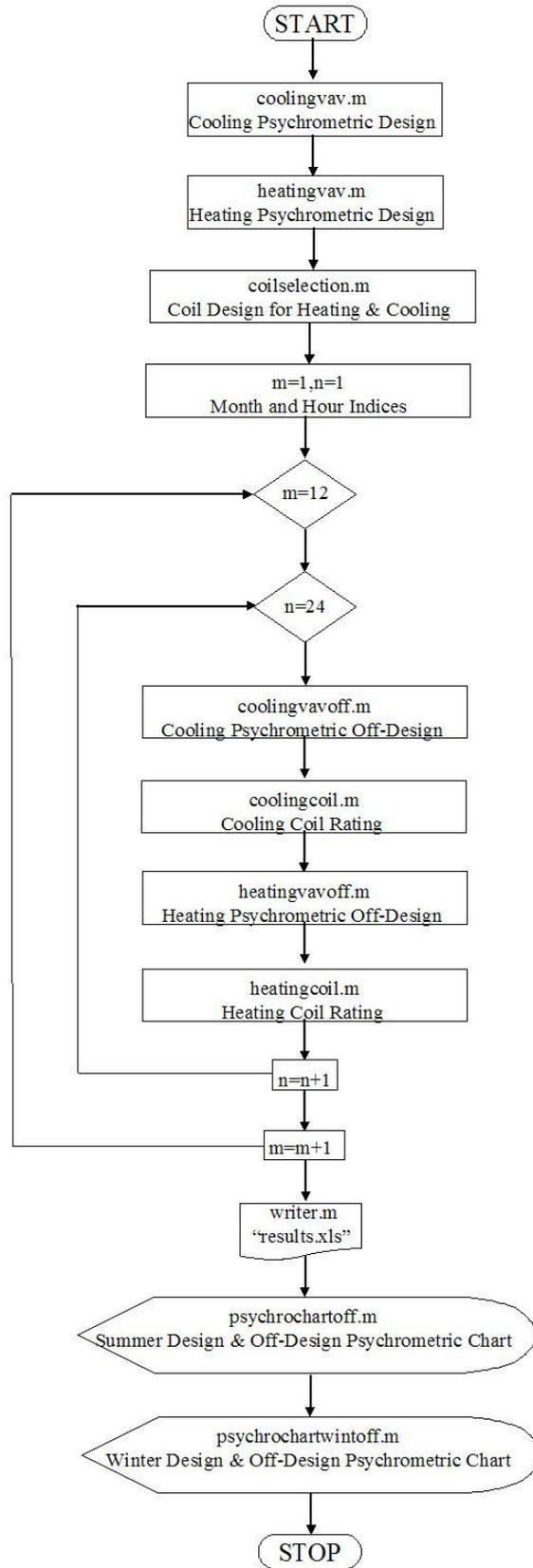


Figure 3.10 Flowchart of “main.m”

The M-File part of the program “AHUSIM.m” performs a set of operations provided in flowchart in Figure 3.9. It uses the “reader.m” file to read data from the “input.xls” and to guide the user to input the times of off-design psychrometric charts.

As it can be seen from Figure 3.9, “AHUSIM.m” calls another M-File “main.m” to carry out all the calculations carried out and to present outputs. The flowchart for the “main.m” is provided in Figure 3.10. As it can be seen from the flowchart, at first this program performs the cooling and heating design, cooling and heating coil design, and after these it performs the off-design psychrometric cooling and heating calculations and coil ratings in an iterative procedure for every hour of every month. In off-design psychrometric cooling and heating parts the zone design temperatures are also decided. Since the zone design temperatures are mainly affected by seasonal clothing, the zone design temperatures are taken constant within a month regardless of the hour or space load being cooling or heating. For the months from October to April the zone design temperature is taken as the winter design temperature, whereas for the months from May to September the zone design temperature is taken as summer design temperature. The last procedure is the preparing the outputs which are comprised of a Microsoft Excel file called “results.xls” and two psychrometric charts for each zone which includes the design and off-design representations of psychrometric charts for cooling and heating.

3.2.1. Psychrometric Calculations

3.2.1.1. Plotting of Psychrometric Chart in Computer Graphics Environment

Determination of the thermodynamic properties of the states of moist air is essential in almost of all programming required in this study. In this process the formulae described in part “2.2.3 Plotting The Psychrometric Chart” are used. There are four small subprograms named “dbrh.m”, “dbtd.m”, “dbw.m” and “dbwb.m” as their name implies they calculate properties of points which are defined by drybulb temperature-relative humidity, drybulb temperature-dewpoint temperature, drybulb temperature-humidity ratio and drybulb temperature-wetbulb temperature couples along with ambient pressure respectively.

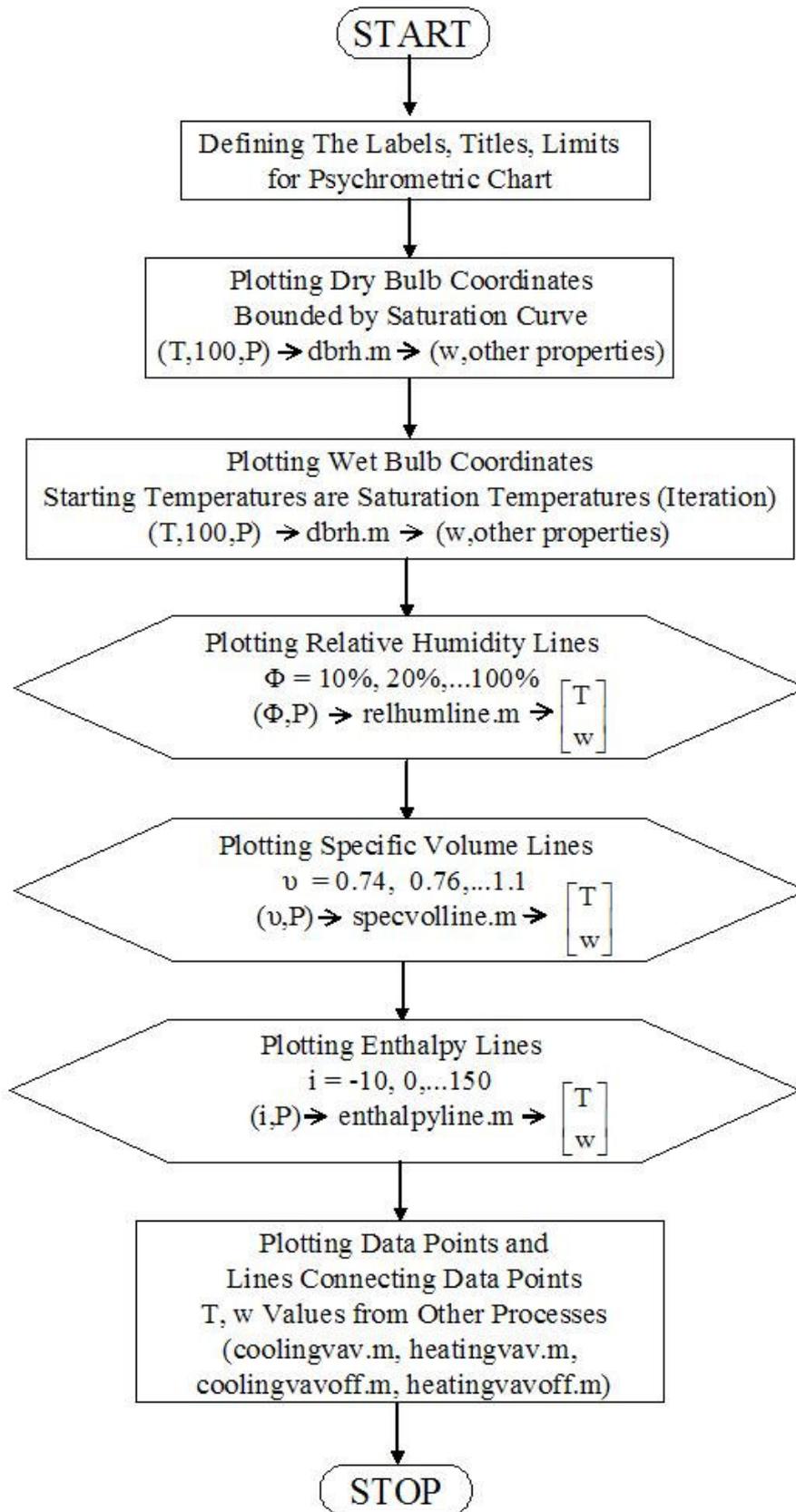


Figure 3.11 Flowchart of Plotting Psychrometric Chart

Plotting of psychrometric charts is the main step in “psychochartoff.m” and “psychrochatwintoff.m”, since the states in them is a simple point plotting with known coordinates. The flowchart for plotting the psychrometric chart is given in Figure 3.11. This procedure starts with drawing drybulb temperature gridlines with 1°C increments. For cutting the gridlines at saturation, the humidity ratio at saturation is found from “dbrh.m” with inputs (T, 100%, P). After this step, the humidity ratio gridlines are drawn. In cutting the relative humidity gridlines, the saturation state temperatures of the humidity ratios are again found from “dbrh.m” with an iteration process with increasing temperatures until it catches the desired humidity ratios.

After drawing the gridlines, relative humidity lines are drawn with 10% increments by “relhumline.m” with inputs (Φ, P). After that the specific volume lines are drawn with 0.02 m³/kg increments by “specvolline.m”. The specific volume lines are cut at saturation with an iterative procedure like humidity ratio gridlines. To complete the psychrometric chart, the enthalpy lines are drawn with 10 kJ/kg increments by “enthalpyline.m”. At last, the state points and lines are drawn with the input data coming from “coolingvav.m” and “coolinvavoff.m” for summer design and off-design psychrometric chart, “heatingvav.m” and “heatingvavoff.m” for winter design and off-design psychrometric chart.

3.2.1.2. Cooling Design Process

In determination of states of air in the cooling design “coolingvav.m” which uses an iterative method which utilizes the basic terms and factors of HVAC systems described in section “2.4.2. Description of Terms and Factors of HVAC Processes” is used. The flowchart of this part is provided in Figure 3.12.

This program calculates ESHF and TLH from known states and loads. After that, program calculates the volumetric flow rate of total air needed from the Eqn. 2.43. Then, whether the conditions require cooling with humidification or cooling with dehumidification is checked by looking at TLH. If it requires cooling with moist addition the actual process involves sensible cooling and steam humidification. The steam humidifier is placed after the cooling coil. Therefore, the humidity ratio of the

supply air state which is also the humidifier leaving state is calculated from RLH. Then, the humidifier entering temperature which is also the coil leaving temperature is calculated with Eqn (2.32). Moreover, since in sensible cooling process, there is no ADP concept and only one subprogram used to evaluate both cooling with dehumidification and sensible cooling processes; assignment of ADP is an obligation coming from coding nature. Therefore, a physically meaningless ADP value is assigned in sensible cooling process, which is also used to separate one kind of process from another in coil design and rating programs.

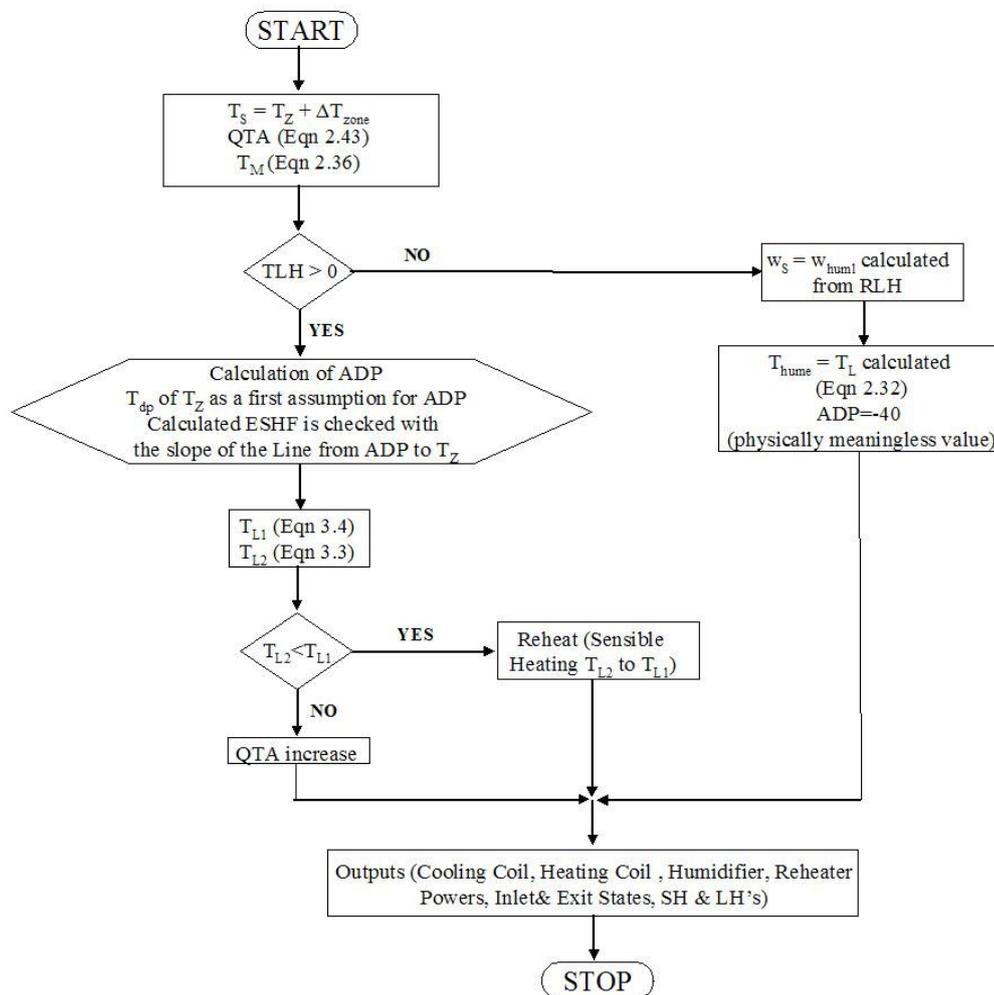


Figure 3.12 Flowchart of “coolingvav.m”

If the states require cooling with dehumidification, as a first assumption apparatus dewpoint temperature is taken as the dewpoint of the room design state and the apparatus dewpoint temperature is decreased by 0.01 °C increments until the effective sensible heat factor calculated by the temperatures catches the one found from loads. After that the coil leaving temperature is calculated from the found apparatus dewpoint temperature and zone design temperature according to formulae;

$$T_L = T_{ADP} + BF \cdot (T_{MA} - T_{ADP}) \quad (3.3)$$

$$T_L = T_Z - \Delta T_{zone} - \Delta T_{SFH} \quad (3.4)$$

If the value found from Eqn. (3.3) is lower than the one found from Eqn. (3.4) then it is reheated to latter one. If it is vice versa the volumetric flow rate of total air recalculated according to Eqn. (2.43).

3.2.1.3. Cooling Off-Design Process

The Matlab subprogram “coolingvavoff.m” is used in the determination of air states. The formulae and concepts used are same as section “3.2.1.2. Cooling Design Process”. However, two methods of calculating the volumetric flow rate of outdoor ventilation air compared and one of them is preferred considering the total power required for the processes cooling, humidification and reheating. In the first method the volumetric flow rate of outdoor ventilation air is calculated according to the instantaneous fresh air need of the space which comes directly from input data, whereas in the second one fresh air need is calculated according to room latent heat. Then, both are compared with respect to total energy consumption of AC unit parts and the one with less energy consumption is preferred. This method lead to less energy consumption especially in transition times like spring and fall, where the volumetric flow rate of outdoor ventilation air calculated from second method is preferred by the program. The program limits the volumetric flow rate of outdoor ventilation air from 0% to 100% of volumetric flow rate of total air of the design conditions, it limits the volumetric flow rate of total air to a minimum of 10% of the design conditions. The design parameters mentioned here is the summer design parameters, since they are greater in value than the winter design parameters.

3.2.1.4. Heating Design and Off-Design Process

Heating design states are fixed by the Matlab subprogram “heatingvav.m”. This part, performs a calculation procedure quite similar to sensible cooling and cooling with humidification part in “coolingvav.m”. The only difference in the procedure is one involves sensible heating whereas one involves sensible cooling.

The “heatingvavoff.m” is used in the determination of states of air, in the heating off-design process. The formulae and concepts used are same as “heatingvav.m”.

3.2.2. Air Handling Unit Selection and Rating

In air handling unit selection and rating, the information discussed in section “2.6. Heating, Cooling and Dehumidification of Moist Air Around Extended Surface Coils” is used. The schematic lay-outs of AC units selected are given in Appendix G. In both selection and rating process of cooling coils whether the coil is cooling with dehumidification coil or not must be carefully evaluated, since the calculation procedure changes considerably. In the psychrometric design part sensible cooling coils are splitted by assigning imaginary specific apparatus dewpoint temperatures.

3.2.2.1. Air Handling Unit Selection

The selection of air handling units of cooling and heating design processes are done with subprogram “coilselection.m”. The flowchart for air-handling unit coil design is given in Figure 3.13. The design air and water mass flow rates and inlet and outlet states are known as well as the geometric data of the desired coil and the maximum allowed air face velocity. With this data properties, coil geometry parameters are calculated. After this step, whether the coil is wet or dry is fixed with the ADP coming from the psychrometric design part.

As for wet coils, the procedure starts with initial assumptions for T_{cond} , T_p . After this step, properties related to these temperatures are calculated. Then A_{FACE} , n (number

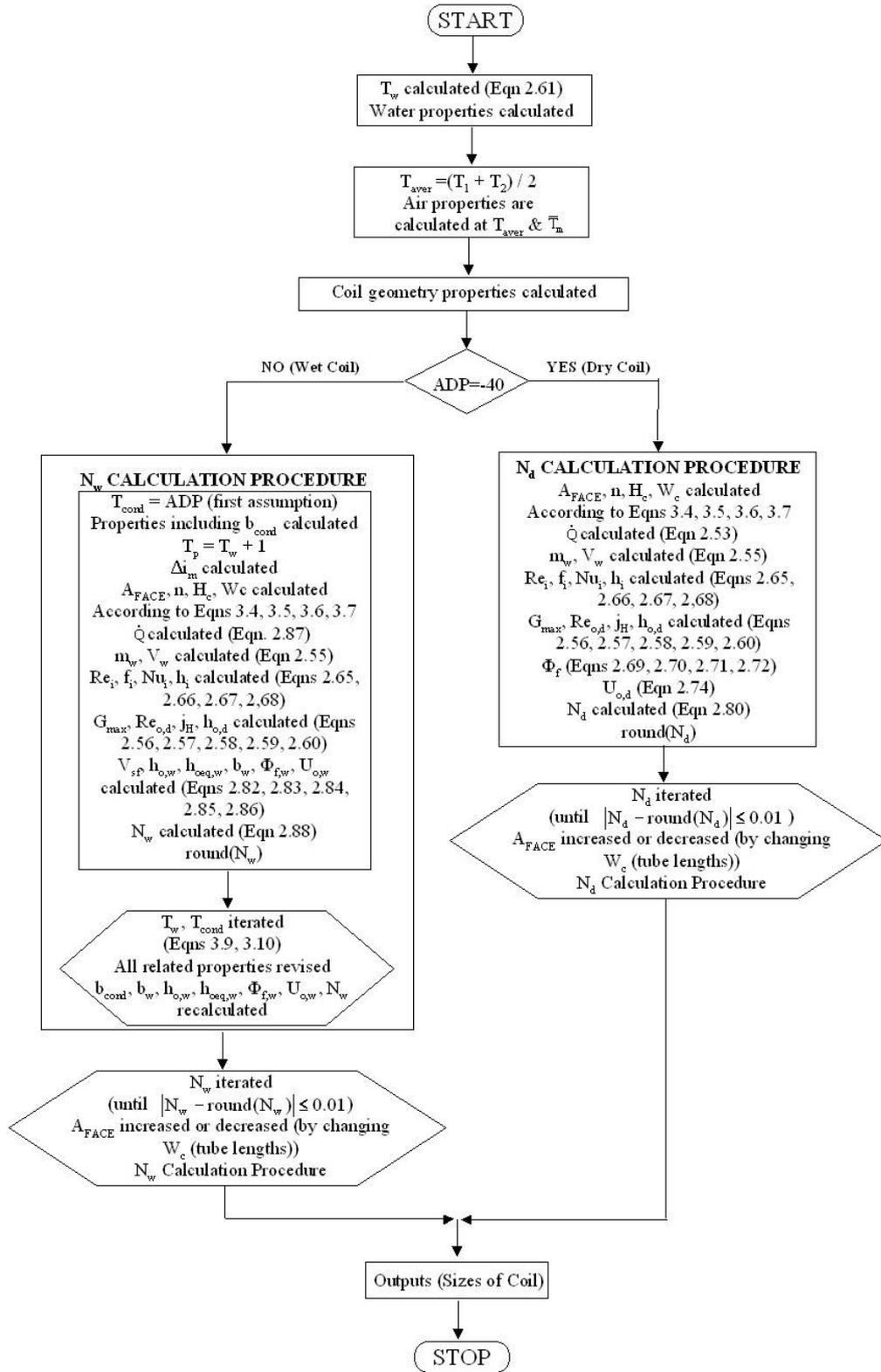


Figure 3.13 Flowchart of “coilsizing.m”

of tubes per row), H_c (height of the coil), W_c (width of the coil) are calculated according to formulae given;

$$A_{\text{FACE}} = \frac{\dot{V}_{\text{TA}}}{V_{\text{FACE}}} \quad (3.5)$$

$$n = \text{round} \left(\frac{\sqrt{A_{\text{FACE}}}}{c} \right) \quad (3.6)$$

$$H_c = n \cdot c \quad (3.7)$$

$$W_c = \frac{A_{\text{FACE}}}{H_c} \quad (3.8)$$

After that, the program calculates \dot{Q} from Eqn. 2.87, and from \dot{Q} water side mass flow rate and velocity of water flowing inside the tubes are calculated. With this flow rates water side parameters are calculated as described in section “2.6.1.2.2 Water Side Parameters”. As for the air side, firstly the dry coil parameters are calculated, the calculations are carried out as described in section “2.6.1.2.1 Air Side Parameters”.

The $U_{o,w}$, N_w (number of rows for wet coil) is calculated according to procedure described in sections “2.6.1.2.3 The Fin Efficiency” and “2.6.2.1 Heat Transfer in Wet Coil”. The calculated N_w value is rounded since number of rows must be an integer value. Then, the assumptions for T_p and T_{cond} is iterated until they converge to a specific value, the new temperatures are found from equations;

$$T_p = T_w + \frac{U_{o,w}}{h_i} \cdot \frac{A_o}{A_{pi}} (\Delta i)_m \quad (3.9)$$

$$i_{s,\text{cond}} = i_{sw} + \left[1 - \frac{C_{Ps,\text{cond}}}{b_{\text{cond}}} \frac{h_{\text{oeq},w}}{h_{o,w}} \phi_{\text{fw}} \left(1 - b_w \frac{U_{o,w}}{h_i} \left(\frac{A_o}{A_{pi}} \right) \right) \right] (\Delta i)_m \quad (3.10)$$

In this iteration process all the calculations for founding N_w value are revised according to this new temperatures. After the temperatures fixed, the rounding-off error from calculation of N_w is eliminated, by an iterative process. In this process A_{FACE} is increased or decreased by changing the W_c (also the length of the tubes). In this iteration process all calculation for the wet coil mentioned upto this point are revised until the round-off error is eliminated.

The design of dry coil requires a simpler process, which is almost done in the wet coil part. All the calculations upto $U_{o,w}$, N_w except for assumptions for T_{cond} and T_p are done. Then, $U_{o,d}$ and N_d are calculated according to procedure described in sections “2.6.1.2.3 The Fin Efficiency” and “2.6.1.2.4 Heat Transfer in Dry Coil”. The iterative part for N_d is carried out in a way identical with the one for N_w .

3.2.2.2. Air Handling Unit Rating

The rating of the cooling and heating coils are done by programs “coolingcoil.m” and “heatingcoil.m” respectively. The procedure described in section “3.2.2.1 Air Handling Unit Sizing” is used. However, this time the outputs for the program are water inlet and outlet temperatures, not size of the coil. This time water and air mass flow rates, air inlet and outlet states are fixed coupled with the dimensions and geometric properties of the coil are known. With these data, water inlet and outlet temperature difference is calculated from the formulae 2.52, 2.54 and 2.55. After that, an iterative process where design water inlet temperature is taken as the water inlet temperature as a first assumption, calculates water inlet and outlet temperatures with all known data. In this iterative process, the calculations up to calculation of $U_{o,d}$ or $U_{o,w}$ is repeated until the heat transfer rate is calculated with Eqn. 2.52 is checked with the one calculated by Eqn. 2.80 for dry coil, by Eqn. 2.88 for wet coil.

CHAPTER 4

RESULTS

The main program “simahumain.m” gives two kinds of outputs. First one is an excel file called “results.xls”. The second one is the psychrometric charts including design and off-design processes on them. The main input screen of the main program “simahumain.m” as seen on Figure 3.8, only contains data to select times for the three zones where the cooling and heating off-design psychrometric processes can be seen along with the design processes of these zones on the psychrometric chart. In other words, the program always simulate three-zones 12-month-24-hour basis but the inputs on the program window decides the psychrometric process times to be represented.

4.1. THE EXCEL FILE “results.xls”

First output of the program is excel file which contains nine sheets, three sheets for each zone. The printouts of this file are presented in Appendix H. The first sheet of each zone is cooling outputs, which include volumetric flow rate of total air, volumetric flow rate of outdoor ventilation air , air coil entering, coil leaving and zone supply temperatures and humidity ratios, coil water inlet and outlet temperature, cooling coil, humidifier and reheater power data on 12-month-24-hour basis. The second sheet of each zone mainly comprised of 12-month-24-hour basis heating data including the volumetric flow rate of total air, volumetric flow rate of outdoor ventilation air, air coil entering, coil leaving and zone supply temperatures and humidity ratios, coil water inlet and outlet temperature, heating coil, humidifier and preheater power. The third sheet of each zone includes apparatus data for cooling and heating. Dimensions of coil width, height and length, number of tubes in the width and length direction, face area, the maximum and design powers of apparatus parts

cooling coil, reheater and humidifier for cooling and preheater, heating coil and humidifier.

4.2. PSYCHROMETRIC CHARTS

The second output is the psychrometric charts are drawn on every execution of the program. Each execution draws 6 psychrometric charts; two for each zone one for cooling the other for heating. A sample screenshot of the psychrometric charts is given in Figure 4.1. The psychrometric charts include data like time of design (month and hour), quantities of total and supply air at design and off-design, sensible heating factors and names of states. The psychrometric chart outputs of the program enhances the understanding of the processes. Some descriptive psychrometric charts will be represented in this section and the corresponding cells are highlighted in grey color in the printout of the “results.xls” in Appendix H.

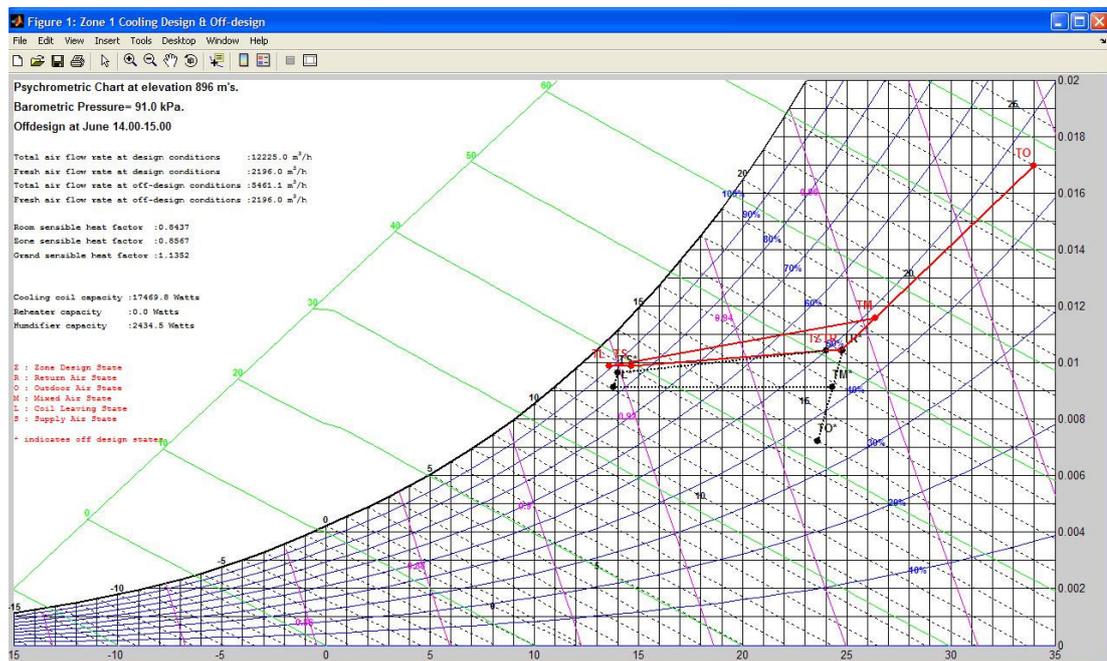


Figure 4.1 Sample Screenshot of Psychrometric Charts Drawn by AHUSIM.m

4.2.1. Psychrometric Charts for Cooling Mode

The first psychrometric chart is for “Zone 1” (office type of zone) at June 13.00-14.00 is given in Figure 4.2. “Zone 1” cooling design process, which is represented by the red-solid line, requires cooling with dehumidification of mixed outdoor and return air, this process overcools the air so humidity control is achieved by using the reheater coil. The off-design process at June 13.00-14.00 which is represented by black dotted line is a mixed air process with sensible cooling and steam humidification. Moreover, the volumetric flow rate of outdoor ventilation air of this incident comes directly from the input file. Another mixed air process is sensible cooling process with no humidification or reheat which is the off-design process for “Zone 3” (wedding lounge and foyer zone) at July 13.00-14.00 time interval provided in Figure 4.3. The design process is same as “Zone 1” except for the values. The volumetric flow rate of outdoor ventilation air in this case is calculated from the latent heat of the zone, which reduces the energy consumption considerably. The value of volumetric flow rate of outdoor ventilation air is limited by design volumetric flow rate of total air. The change of energy consumption along with the process types can be evaluated from Figure 4.4, where the volumetric flow rate of outdoor ventilation air is taken directly from the input data (instantaneous need for occupancy) for the same time interval and loads. In Figure 4.4, the process becomes cooling with dehumidification with humidity control by reheating. Even for a summer time process, energy consumption change is dramatic. It increases considerably during the spring and fall season where volumetric flow rate of outdoor ventilation air calculated surpasses the volumetric flow rate of total air (full outdoor air), even for some time intervals if volumetric flow rate of outdoor ventilation air is taken from the instantaneous occupancy need there is no way of cooling the zone. Another, interesting example for mixed air cooling type of process is for the times when the cooling loads require less volumetric flow rate of total air then the minimum allowable volumetric flow rate of total air (10% of design volumetric flow rate of total air) and the program raises volumetric flow rate of total air to the minimum value. This will result in air supply temperature higher then the other processes which have T_s values according to ΔT_{ZONE} which is taken as 10°C in this

Psychrometric Chart at elevation 896 m's.
 Barometric Pressure= 91.0 kPa.
 Offdesign at July 13.00-14.00

Total air flow rate at design conditions : 28760.7 m³/h
 Fresh air flow rate at design conditions : 10080.0 m³/h
 Total air flow rate at off-design conditions : 23292.3 m³/h
 Fresh air flow rate at off-design conditions : 20763.6 m³/h

Room sensible heat factor : 0.6978
 Zone sensible heat factor : 0.7373
 Grand sensible heat factor : 1.0000

Cooling coil capacity : 91920.1 Watts
 Reheater capacity : 0.0 Watts
 Humidifier capacity : -0.0 Watts

Z : Zone Design State
 R : Return Air State
 O : Outdoor Air State
 M : Mixed Air State
 L : Coil Leaving State
 S : Supply Air State

* indicates off design states

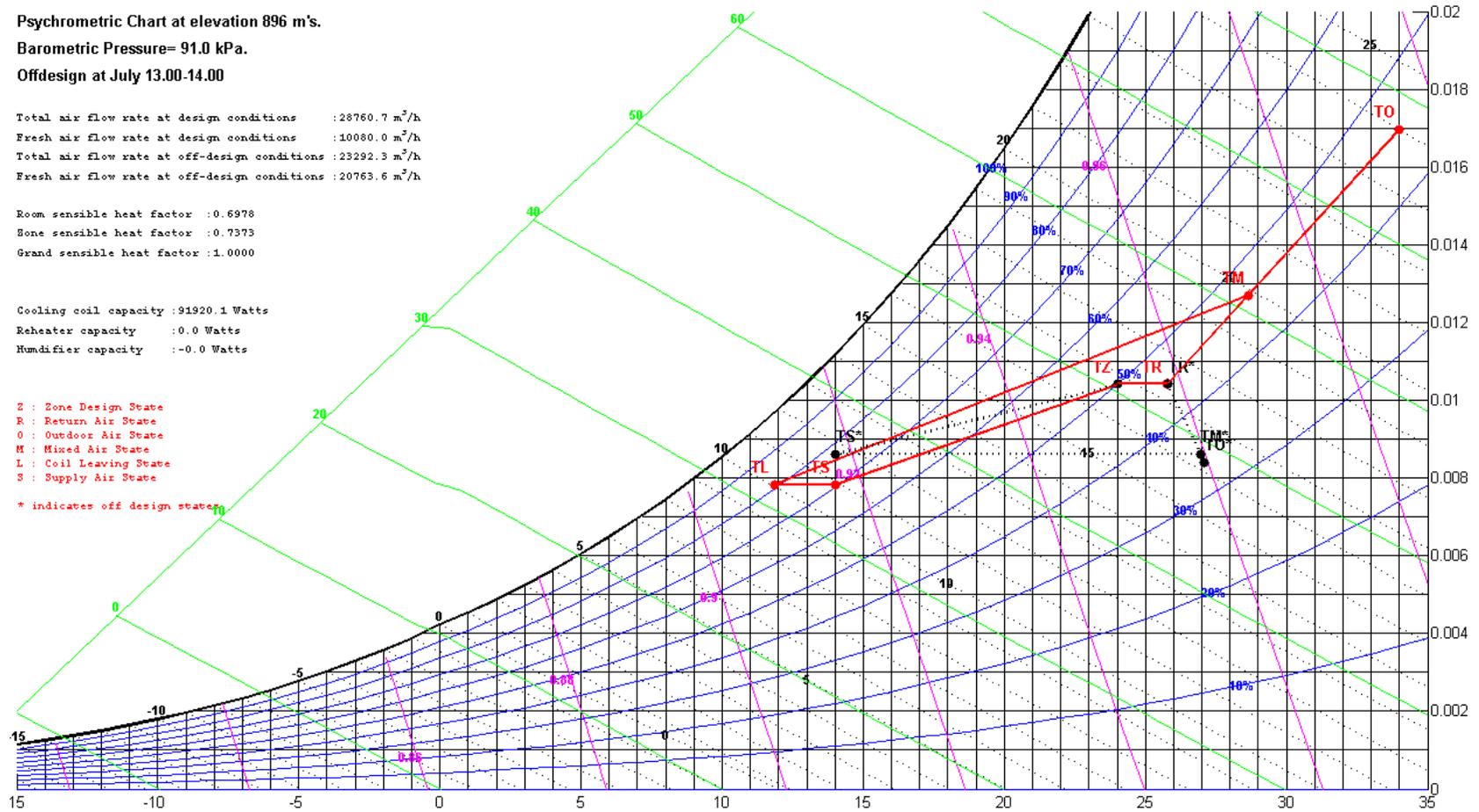


Figure 4.3 “Zone 3” Cooling Design and Off-Design at July 13.00-14.00

Psychrometric Chart at elevation 896 m's.
 Barometric Pressure= 91.0 kPa.
 Offdesign at July 13.00-14.00

Total air flow rate at design conditions : 28760.7 m³/h
 Fresh air flow rate at design conditions : 10080.0 m³/h
 Total air flow rate at off-design conditions : 23292.3 m³/h
 Fresh air flow rate at off-design conditions : 10080.0 m³/h

Room sensible heat factor : 0.6978
 Zone sensible heat factor : 0.7373
 Grand sensible heat factor : 0.8694
 Effective sensible heat factor: 0.7504

Cooling coil capacity : 121576.4 Watts
 Reheater capacity : 17569.4 Watts
 Humidifier capacity : 0.0 Watts

Z : Zone Design State
 R : Return Air State
 O : Outdoor Air State
 M : Mixed Air State
 L : Coil Leaving State
 S : Supply Air State

* indicates off design states

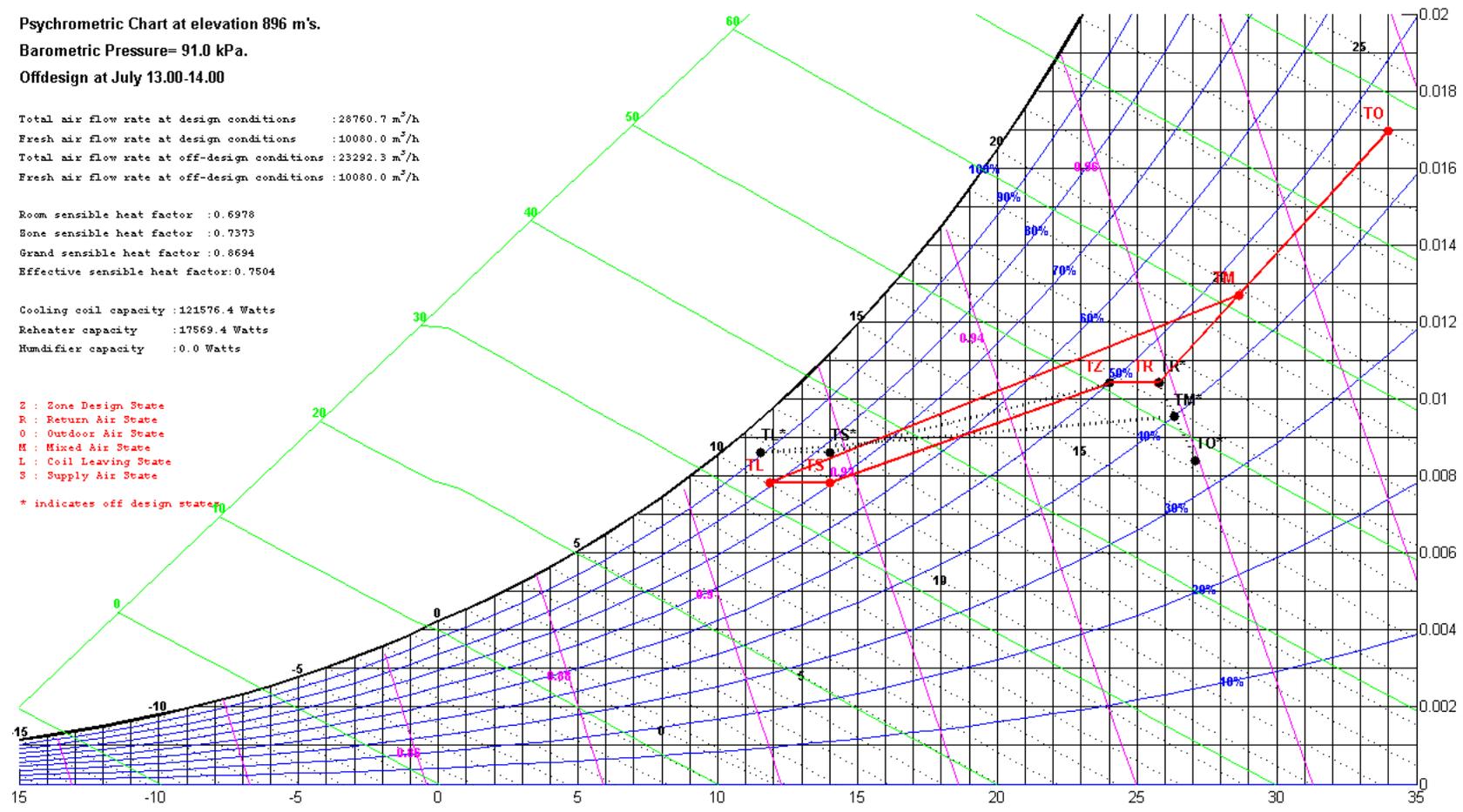


Figure 4.4 "Zone 3" Cooling Design and Off-Design at July 13.00-14.00 (with Volumetric Flow Rate of Ventilation Air from

Psychrometric Chart at elevation 896 m's.
 Barometric Pressure= 91.0 kPa.
 Offdesign at September 07.00-08.00

Total air flow rate at design conditions : 12225.0 m³/h
 Fresh air flow rate at design conditions : 2196.0 m³/h
 Total air flow rate at off-design conditions : 1222.5 m³/h
 Fresh air flow rate at off-design conditions : 658.8 m³/h

Room sensible heat factor : 0.5018
 Zone sensible heat factor : 0.5819
 Grand sensible heat factor : 0.5838

Cooling coil capacity : 0.0 Watts
 Reheater capacity : 847.8 Watts
 Humidifier capacity : 707.6 Watts

Z : Zone Design State
 R : Return Air State
 O : Outdoor Air State
 M : Mixed Air State
 L : Coil Leaving State
 S : Supply Air State

* indicates off design states

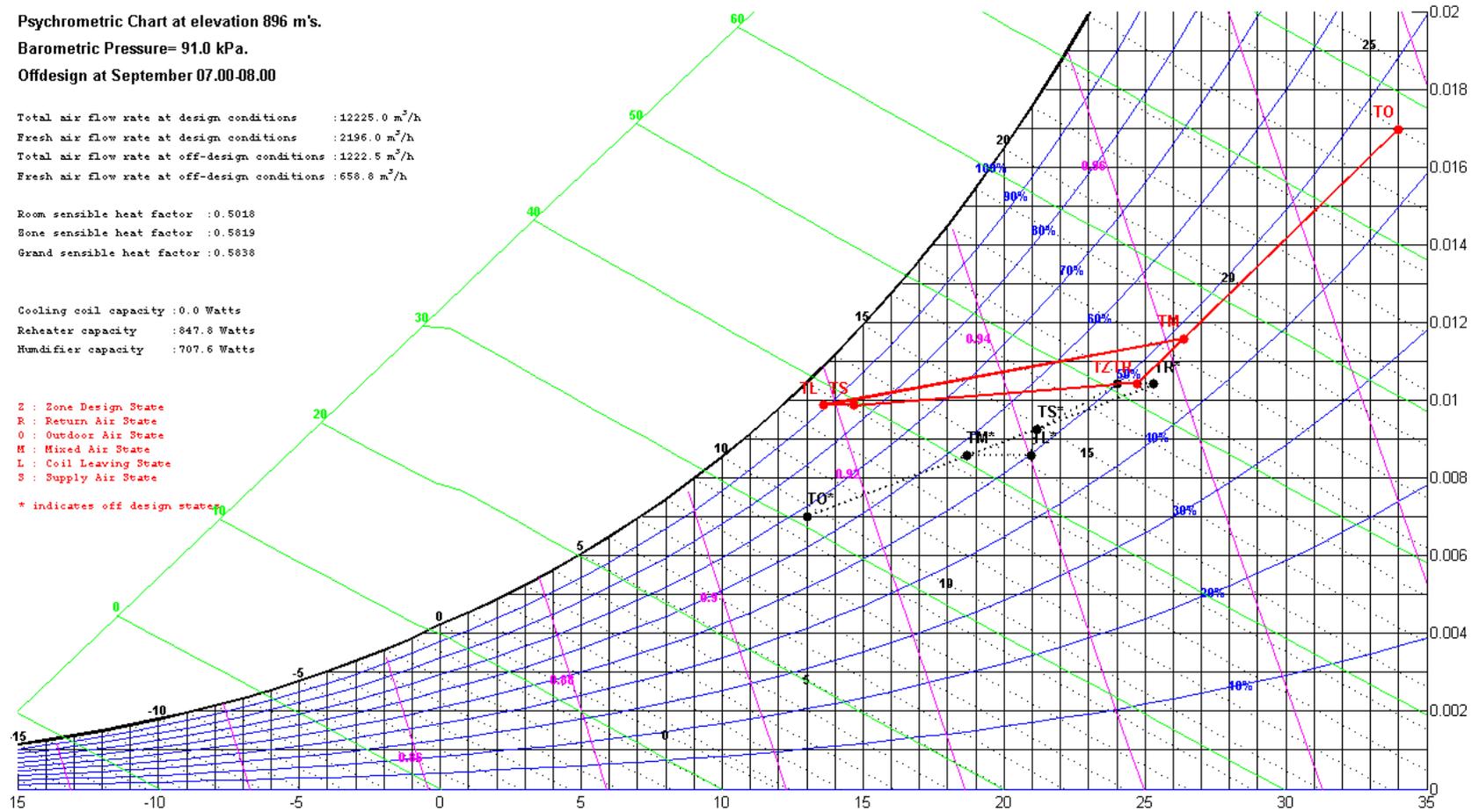


Figure 4.5 "Zone 1" Cooling Design and Off-Design at September 07.00-08.00

study. An example of this process occurs at September 07.00-08.00 time interval in “Zone 1” is given in Figure 4.5. In the process in Figure 4.5, mixed air reheated and humidified to an increased supply temperature.

Another kind of cooling process is cooling with full return air where there is no need for outdoor ventilation air (unoccupied hours). Moreover, in this hours there is no latent load, so no humidification or reheat is needed, only sensible cooling is used. In this process, full return air is cooled to supply temperature and given to the zone to take the zone cooling load. Normally, T_S is fixed by ΔT_{ZONE} but when volumetric flow rate of total air is smaller than 10% of design volumetric flow rate of total air T_S is raised due to recalculation from fixed volumetric flow rate of total air just like in mixed air type process in Figure 4.5. A sample process for full return air sensible cooling process with raised T_S (minimum volumetric flow rate of total air) is given in Figure 4.6. This process is for “Zone 1” at June 06.00-07.00 time interval.

Another cooling process type is full outdoor air cooling process. In this kind of processes, either the volumetric flow rate of total air calculated from the sensible cooling load of the zone is less than required instantaneous volumetric flow rate of outdoor ventilation air coming directly from the input data or the raised volumetric flow rate of outdoor ventilation air calculated from the latent cooling load of the zone. In this kind of processes, since the outside air is always drier than the zone temperature in Ankara conditions, sensible cooling or heating with or without humidification is used. If the sensible heating is lower than 10% cooling design load electrical reheater is used, otherwise the heating coil is used for cooling the zone. In Figure 4.7, the cooling process for “Zone 3” at April 21.00-22.00 time interval, the space is cooled by only sensible heating with increased volumetric flow rate of outdoor ventilation air. Furthermore, since heating load exceeds 10% of cooling design load, for sensible heating the heating coil is used, therefore the process is plotted on heating design and off-design psychrometric chart. Moreover, since months from October to April are considered to have winter design zone conditions the T_Z is 20°C whereas up to now all the cooling design zone temperatures are 24°C. To prevent misunderstanding it must be clearly stated that, the T_Z being 20°C has nothing to do with the zone being cooled or heated but it is just a parameter related to

Psychrometric Chart at elevation 896 m's.
 Barometric Pressure= 91.0 kPa.
 Offdesign at June 06.00-07.00

Total air flow rate at design conditions : 12225.0 m³/h
 Fresh air flow rate at design conditions : 2196.0 m³/h
 Total air flow rate at off-design conditions : 1222.5 m³/h
 Fresh air flow rate at off-design conditions : 0.0 m³/h

Room sensible heat factor : 1.0000
 Zone sensible heat factor : 1.0000
 Grand sensible heat factor : 1.0000

Cooling coil capacity : 2921.5 Watts
 Reheater capacity : 0.0 Watts
 Humidifier capacity : 0.0 Watts

Z : Zone Design State
 R : Return Air State
 O : Outdoor Air State
 M : Mixed Air State
 L : Coil Leaving State
 S : Supply Air State

* indicates off design states

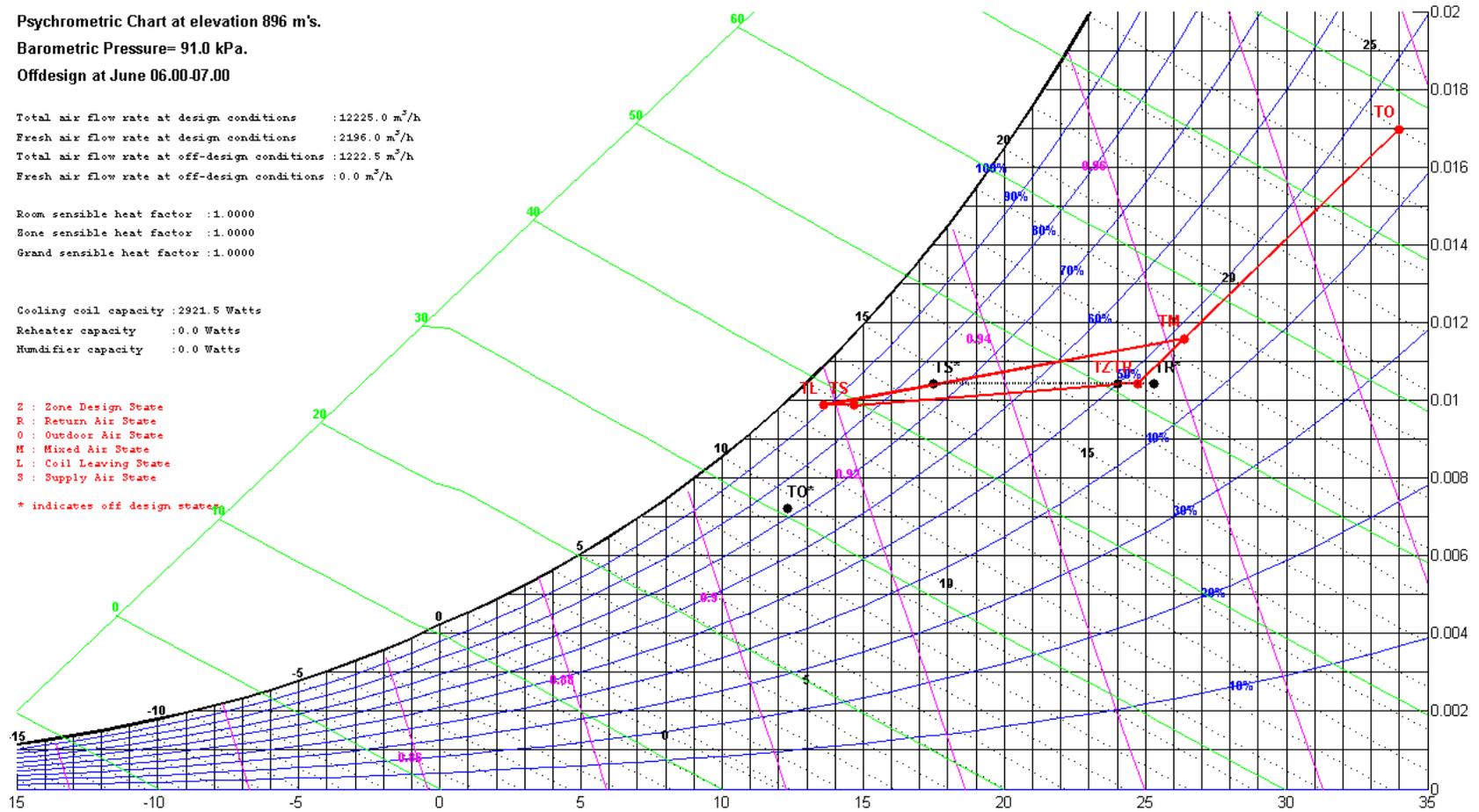


Figure 4.6 “Zone 1” Cooling Design and Off-Design at June 06.00-07.00

Psychrometric Chart at elevation 896 m's.
 Barometric Pressure= 91.0 kPa.
 Offdesign at April 21.00-22.00

Total air flow rate at design conditions :21616.3 m³/h
 Fresh air flow rate at design conditions :10080.0 m³/h
 Total air flow rate at off-design conditions :13455.0 m³/h
 Fresh air flow rate at off-design conditions :13455.0 m³/h

Room sensible heat factor :0.3423
 Zone sensible heat factor :0.4470
 Grand sensible heat factor :1.0000

Heating coil capacity :32609.1 Watts
 Humidifier capacity :0.0 Watts

Z : Zone Design State
 R : Return Air State
 O : Outdoor Air State
 M : Mixed Air State
 L : Coil Leaving State
 S : Supply Air State

* indicates off design states.

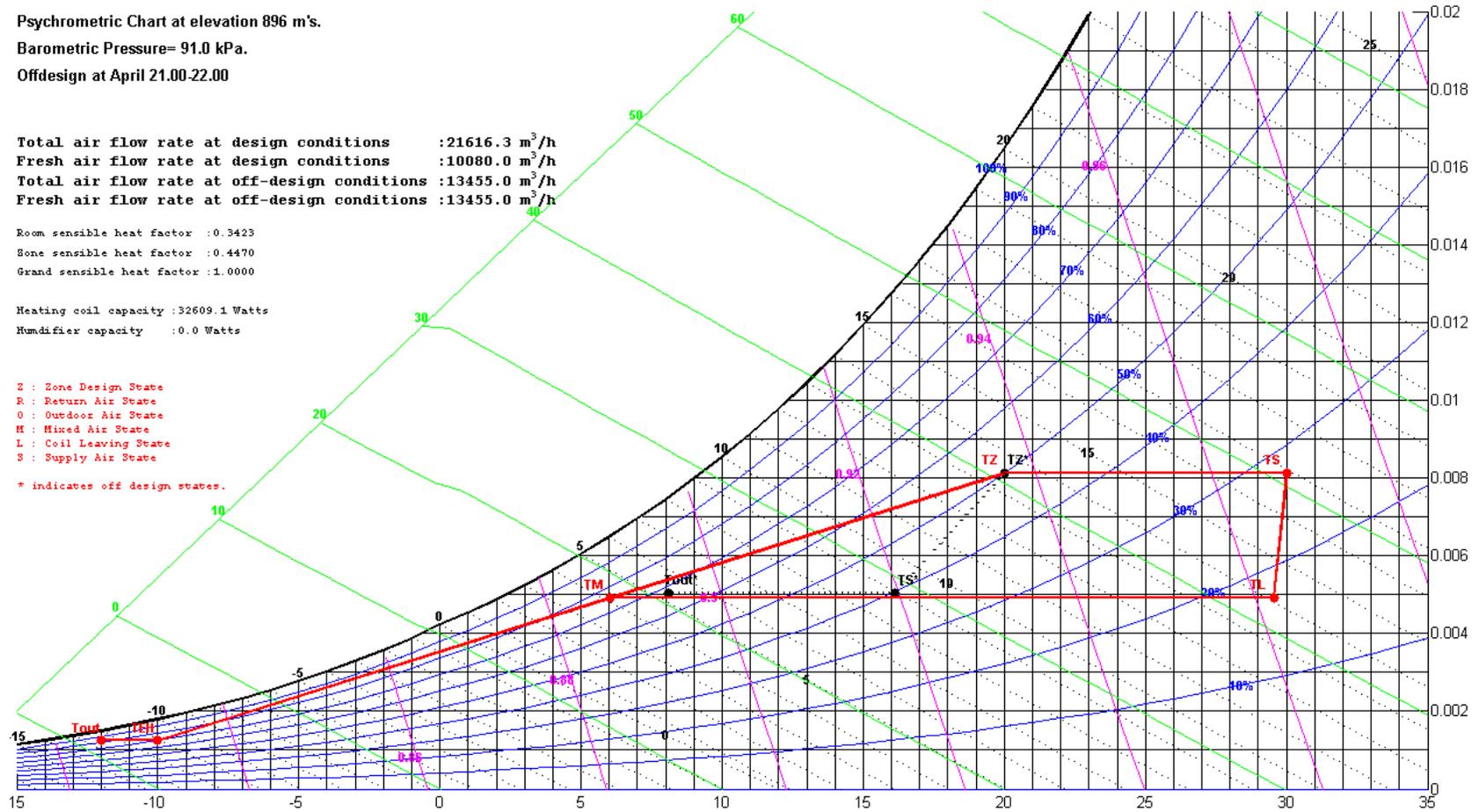


Figure 4.7 "Zone 3" Heating Design and Cooling Off-Design at April 21.00-22.00

the time interval. Moreover, in Figure 4.7 T_S temperature is again raised due to increased volumetric flow rate of outdoor ventilation air. Since, the time is a spring night with relatively low cooling load and T_o (outside design temperature) lower than T_Z , the effects of increased volumetric flow rate of outdoor ventilation air method is drastic. As it can be seen from Figure 4.8, the same zone same time interval with volumetric flow rate of outdoor ventilation air coming from occupancy, the nature of the process is changed so much that it does not give out a meaningful result. Another process where sensible cooling with humidification with full outdoor air occurs, is given in Figure 4.9. In this figure, cooling design and off-design processes for “Zone 2” (technical spaces for wedding lounge) at October 19.00-20.00 is given. Cooling design process is just like the cooling design processes of other zones, it only differ in values. T_Z in off-design process is again winter design temperature (20°C), since the month is October.

4.2.2. Psychrometric Charts for Heating Mode

As for heating processes, all the zone design processes are same except for values. In design processes the outdoor air is preheated to prevent condensation in the mixing part of the AC unit, since the outdoor design temperature is below -10°C . After return and outdoor airs are mixed, the air is heated and humidified by steam humidifier to T_S . In the off-design processes, all three air types (mixed air, full return air and full outdoor air) of cooling processes are utilized. Figure 4.10 shows the design and off-design heating processes for “Zone 1” at April 07.00-08.00. The off-design process is a mixed air type of process with sensible heating and humidification by volumetric flow rate of total air raised to minimum value of 10% of summer design volumetric flow rate of total air. The volumetric flow rate of total air rise leads to a decrease in T_S , because it is calculated from the volumetric flow rate of total air, T_Z and zone sensible heating load. Figure 4.11, the heating design and off-design processes for “Zone 3” at April 23.00-00.00, is quite similar to previous figure. The off-design process of this figure is also a mixed air process with only sensible heating. An example of full return air process is provided in Figure 4.12, the heating design and off-design processes for “Zone 2” at September 01.00-

Psychrometric Chart at elevation 896 m's.
 Barometric Pressure= 91.0 kPa.
 Offdesign at April 21.00-22.00

Total air flow rate at design conditions :21616.3 m³/h
 Fresh air flow rate at design conditions :10080.0 m³/h
 Total air flow rate at off-design conditions :10080.0 m³/h
 Fresh air flow rate at off-design conditions :10080.0 m³/h

Room sensible heat factor :0.3423
 Zone sensible heat factor :0.4240
 Grand sensible heat factor :0.9902

Heating coil capacity :772829.8 Watts
 Humidifier capacity :0.0 Watts

Z : Zone Design State
 R : Return Air State
 O : Outdoor Air State
 M : Mixed Air State
 L : Coil Leaving State
 S : Supply Air State

* indicates off design states.

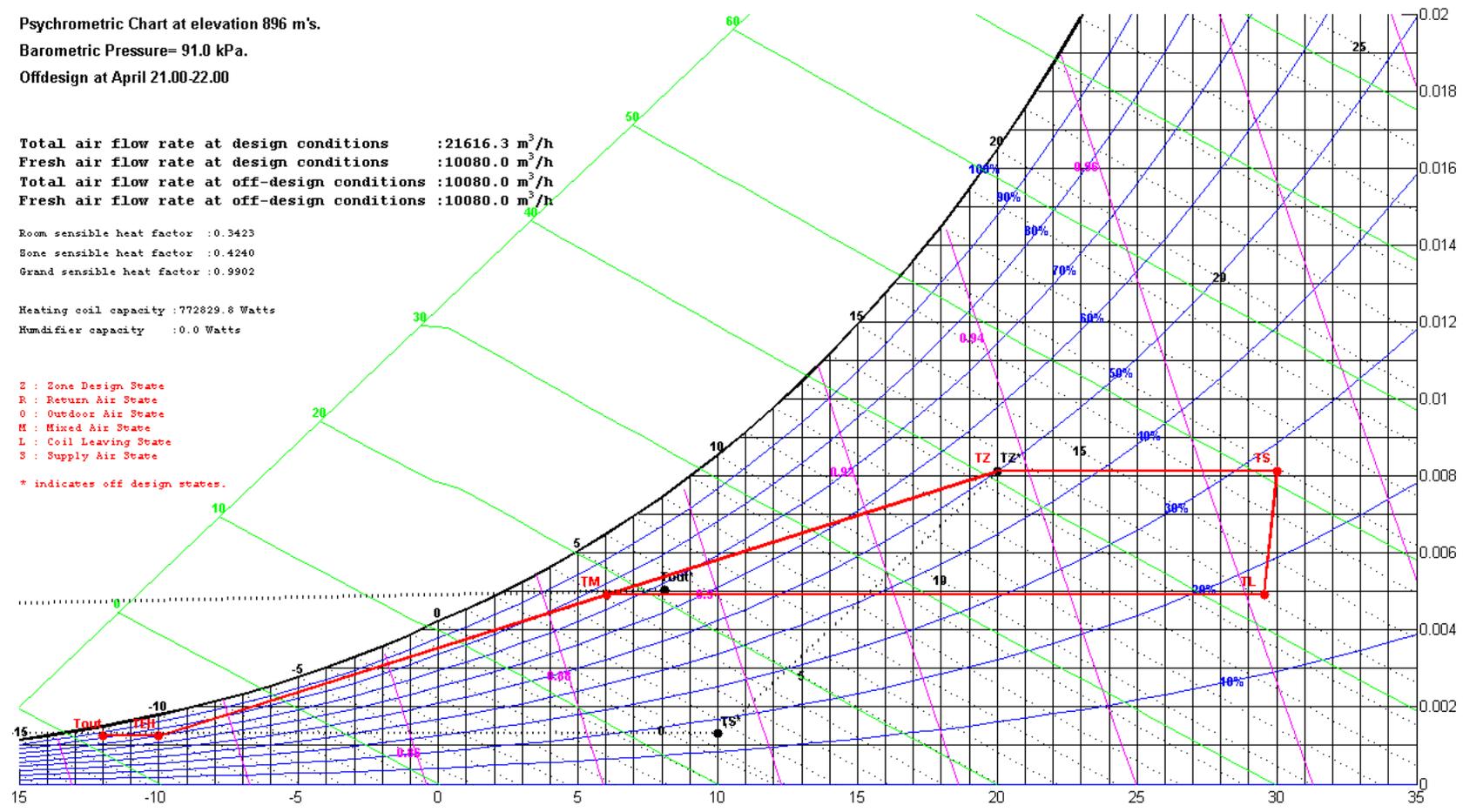


Figure 4.8 “Zone 3” Heating Design and Cooling Off-Design at April 21.00-22.00 (with Volumetric Flow Rate Of Outdoor Ventilation Air from input data)

Psychrometric Chart at elevation 896 m's.
 Barometric Pressure= 91.0 kPa.
 Offdesign at October 19.00-20.00

Total air flow rate at design conditions : 1698.0 m³/h
 Fresh air flow rate at design conditions : 648.0 m³/h
 Total air flow rate at off-design conditions : 648.0 m³/h
 Fresh air flow rate at off-design conditions : 648.0 m³/h

Room sensible heat factor : 0.5521
 Zone sensible heat factor : 0.5729
 Grand sensible heat factor : 3.5921

Cooling coil capacity : 175.6 Watts
 Reheater capacity : 0.0 Watts
 Humidifier capacity : 149.2 Watts

Z : Zone Design State
 R : Return Air State
 O : Outdoor Air State
 M : Mixed Air State
 L : Coil Leaving State
 S : Supply Air State

* indicates off design states

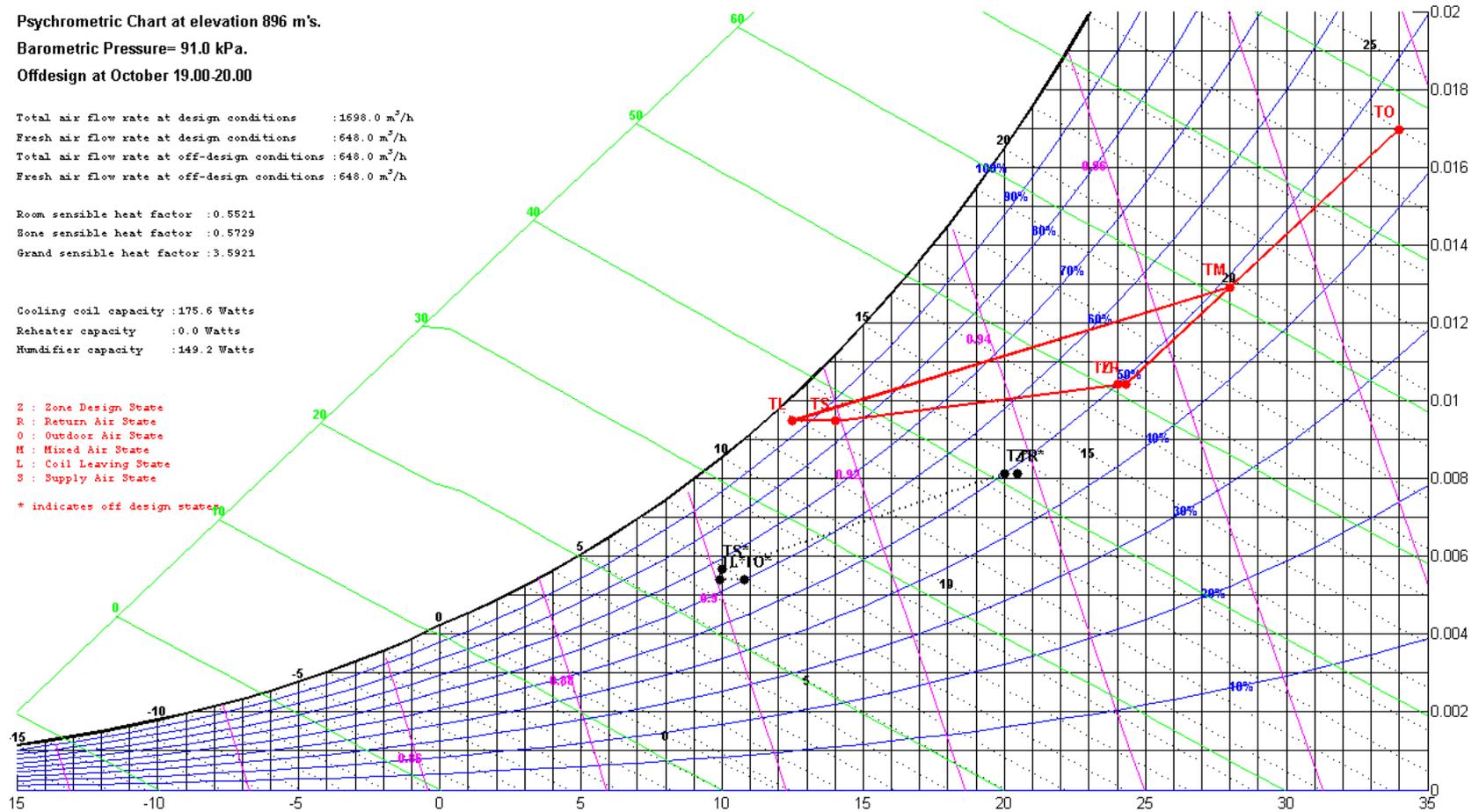


Figure 4.9 "Zone 2" Cooling Design and Off-Design at October 19.00-20.00

Psychrometric Chart at elevation 896 m's.
 Barometric Pressure= 91.0 kPa.
 Offdesign at April 07.00-08.00

Total air flow rate at design conditions : 9172.5 m³/h
 Fresh air flow rate at design conditions : 2196.0 m³/h
 Total air flow rate at off-design conditions : 1222.5 m³/h
 Fresh air flow rate at off-design conditions : 658.8 m³/h

Room sensible heat factor : 0.7598

Heating coil capacity : 6065.4 Watts
 Humidifier capacity : 522.8 Watts

Z : Zone Design State
 R : Return Air State
 O : Outdoor Air State
 M : Mixed Air State
 L : Coil Leaving State
 S : Supply Air State

* indicates off design states.

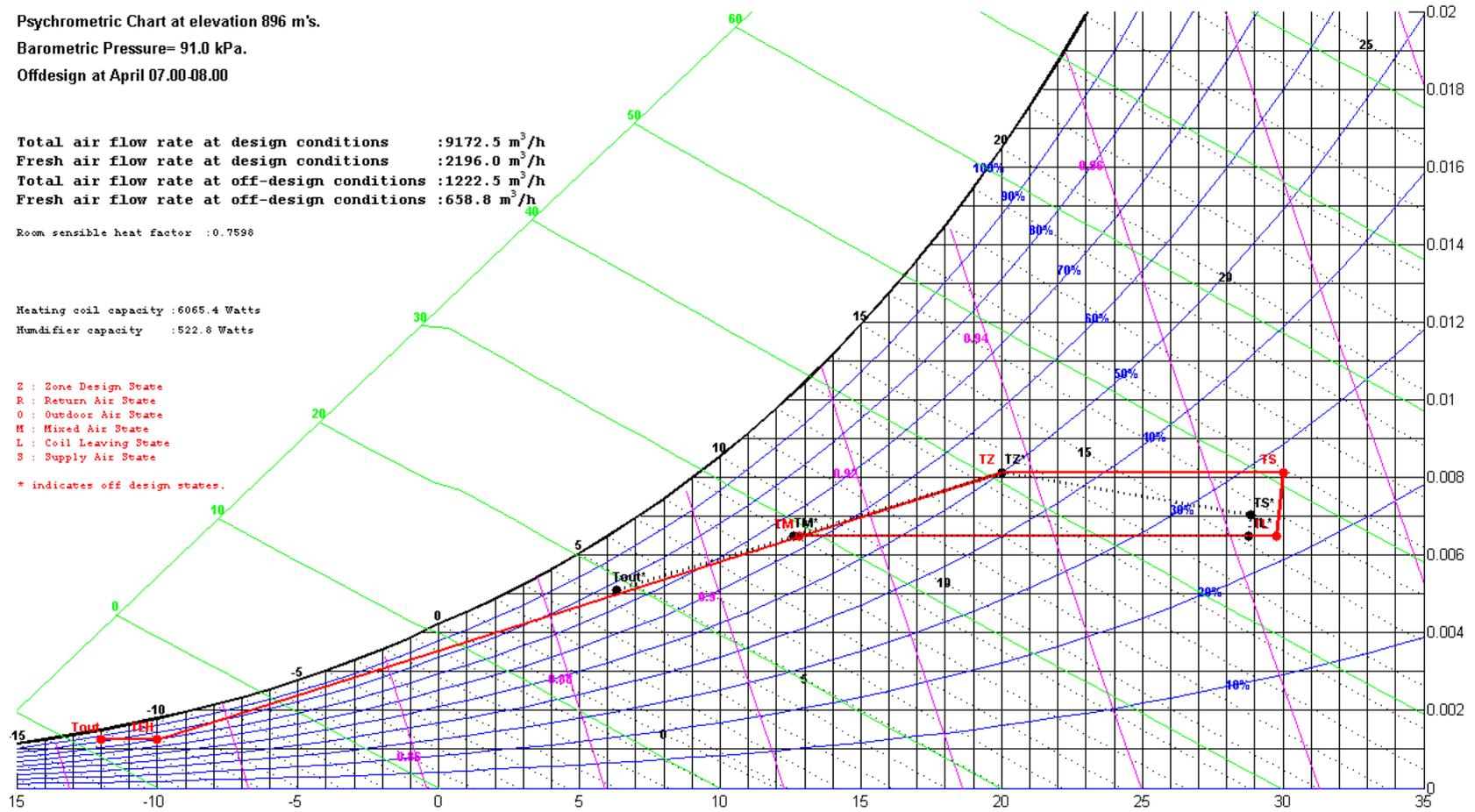


Figure 4.10 "Zone 1" Heating Design and Off-Design at April 07.00-08.00

Psychrometric Chart at elevation 896 m's.
 Barometric Pressure= 91.0 kPa.
 Offdesign at April 23.00-00.00

Total air flow rate at design conditions : 21616.3 m³/h
 Fresh air flow rate at design conditions : 10080.0 m³/h
 Total air flow rate at off-design conditions : 3225.9 m³/h
 Fresh air flow rate at off-design conditions : 1008.0 m³/h

Room sensible heat factor : 0.7622

Heating coil capacity : 15177.5 Watts
 Humidifier capacity : 0.0 Watts

Z : Zone Design State
 R : Return Air State
 O : Outdoor Air State
 M : Mixed Air State
 L : Coil Leaving State
 S : Supply Air State

* indicates off design states.

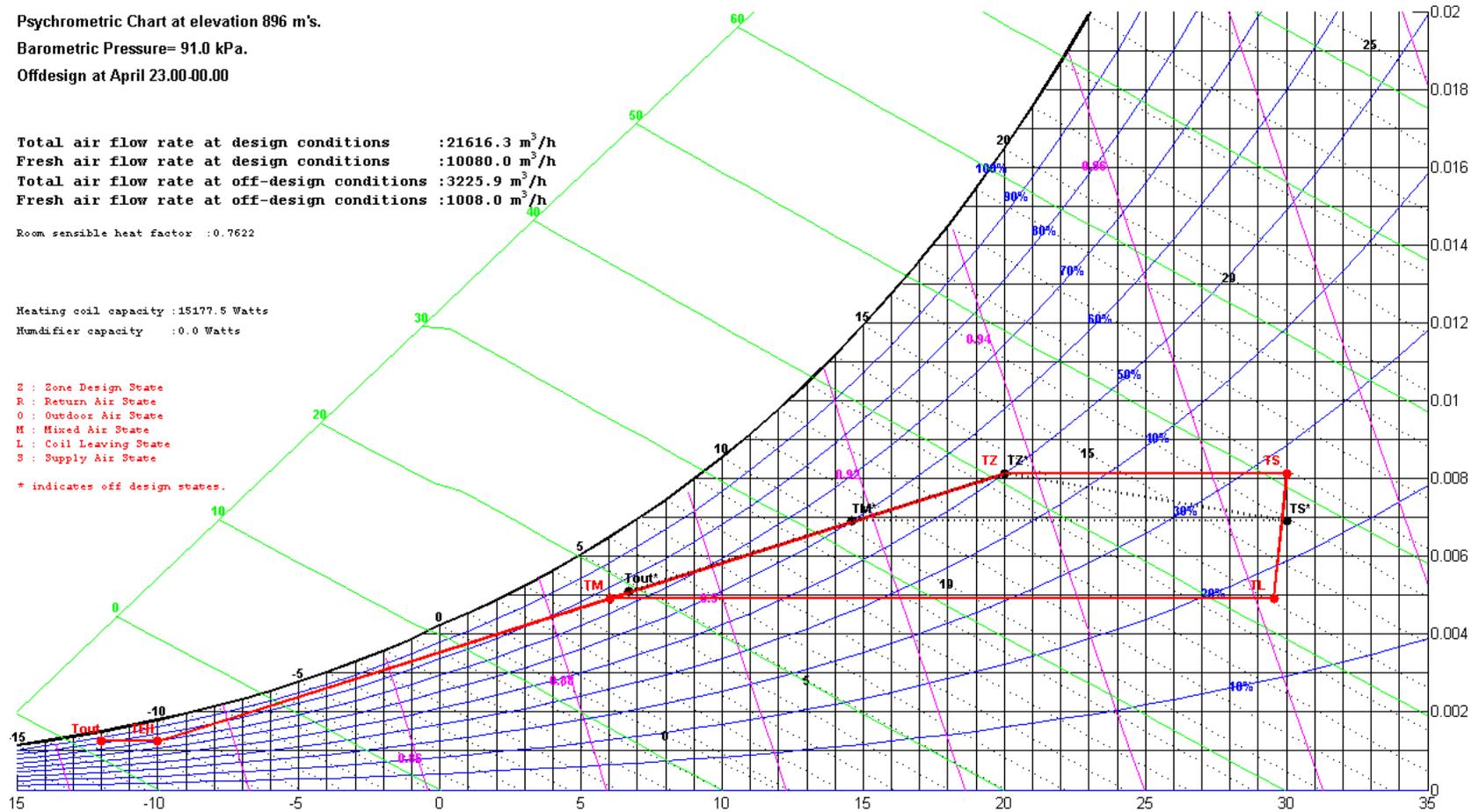


Figure 4.11 "Zone 3" Heating Design and Off-Design at April 23.00-00.00

Psychrometric Chart at elevation 896 m's.
 Barometric Pressure= 91.0 kPa.
 Offdesign at September 01.00-02.00

Total air flow rate at design conditions :21616.3 m³/h
 Fresh air flow rate at design conditions :10080.0 m³/h
 Total air flow rate at off-design conditions :2876.1 m³/h
 Fresh air flow rate at off-design conditions :0.0 m³/h

Room sensible heat factor :1.0000

Heating coil capacity :3065.0 Watts
 Humidifier capacity :0.0 Watts

- Z : Zone Design State
- R : Return Air State
- O : Outdoor Air State
- M : Mixed Air State
- L : Coil Leaving State
- S : Supply Air State

* indicates off design states.

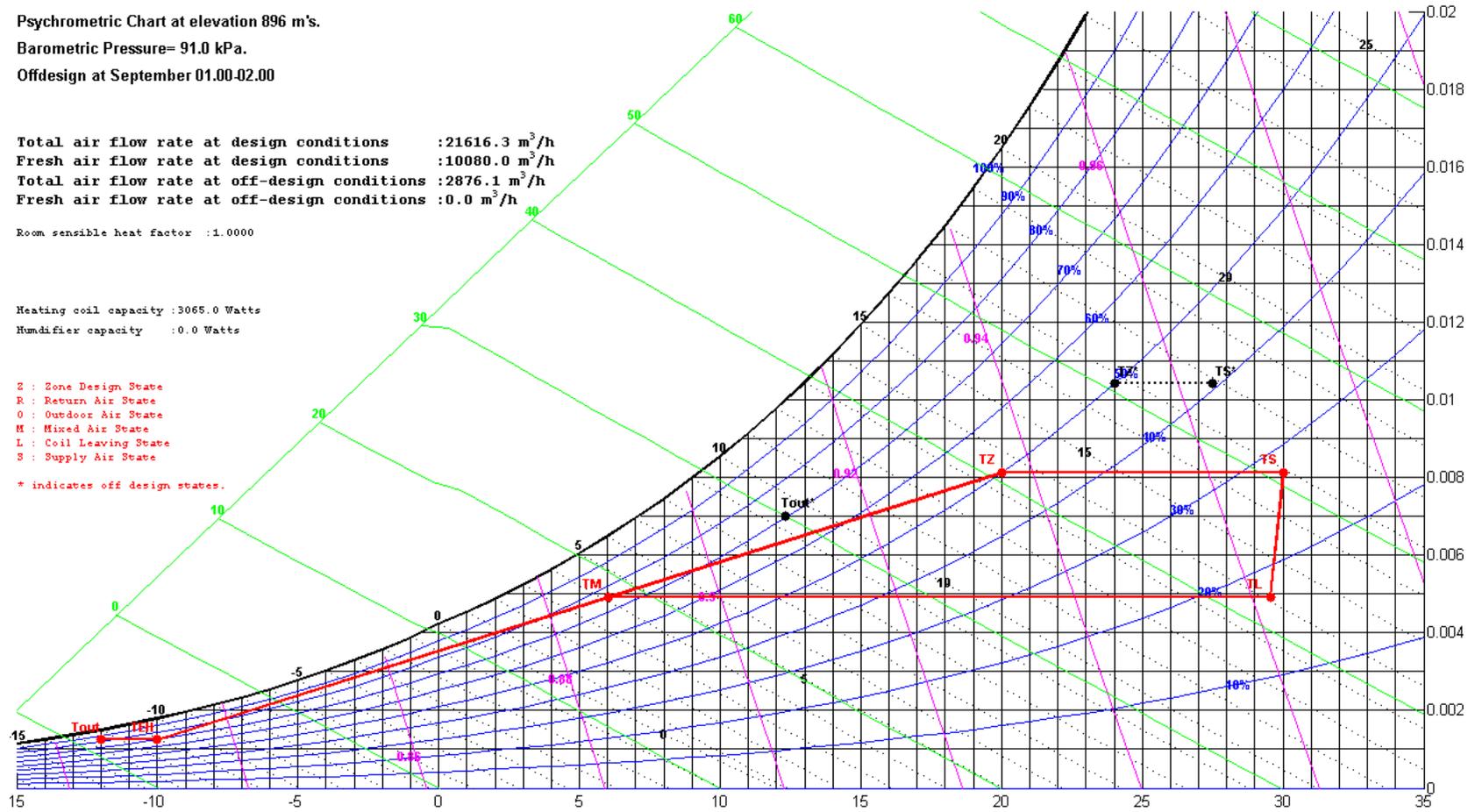


Figure 4.12 "Zone 3" Heating Design and Off-Design at September 01.00-02.00

Psychrometric Chart at elevation 896 m's.
 Barometric Pressure= 91.0 kPa.
 Offdesign at November 22.00-23.00

Total air flow rate at design conditions :1442.1 m³/h
 Fresh air flow rate at design conditions :648.0 m³/h
 Total air flow rate at off-design conditions :324.0 m³/h
 Fresh air flow rate at off-design conditions :324.0 m³/h

Room sensible heat factor :0.5819

Heating coil capacity :2580.4 Watts
 Humidifier capacity :474.6 Watts

Z : Zone Design State
 R : Return Air State
 O : Outdoor Air State
 M : Mixed Air State
 L : Coil Leaving State
 S : Supply Air State

* indicates off design states.

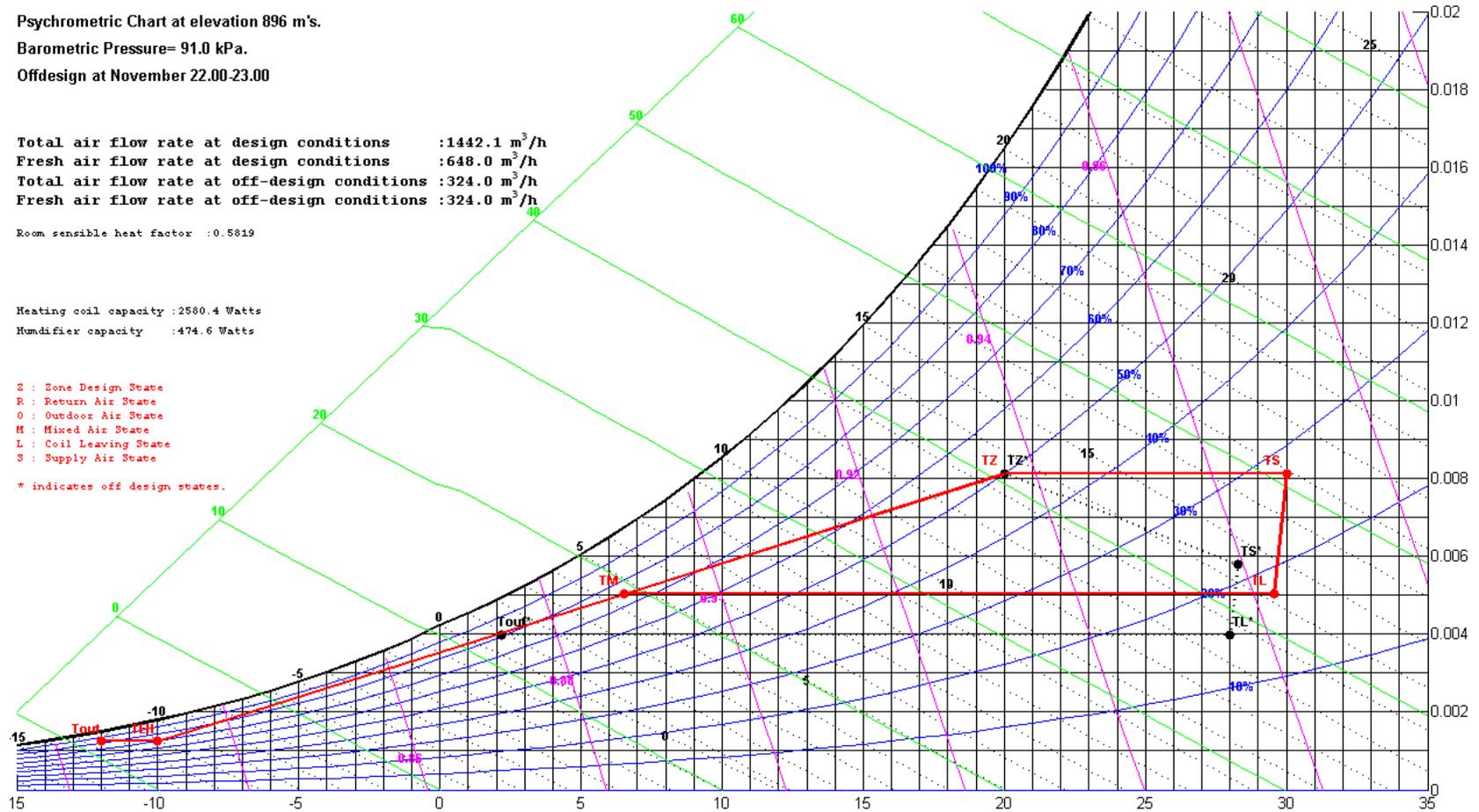


Figure 4.13 "Zone 2" Heating Design and Off-Design at November 22.00-23.00

Psychrometric Chart at elevation 896 m's.
 Barometric Pressure= 91.0 kPa.
 Offdesign at April 22.00-23.00

Total air flow rate at design conditions : 21616.3 m³/h
 Fresh air flow rate at design conditions : 10080.0 m³/h
 Total air flow rate at off-design conditions : 5040.0 m³/h
 Fresh air flow rate at off-design conditions : 5040.0 m³/h

Room sensible heat factor : 0.0398

Heating coil capacity : 20194.4 Watts
 Humidifier capacity : 0.0 Watts

Z : Zone Design State
 R : Return Air State
 O : Outdoor Air State
 M : Mixed Air State
 L : Coil Leaving State
 S : Supply Air State

* indicates off design states.

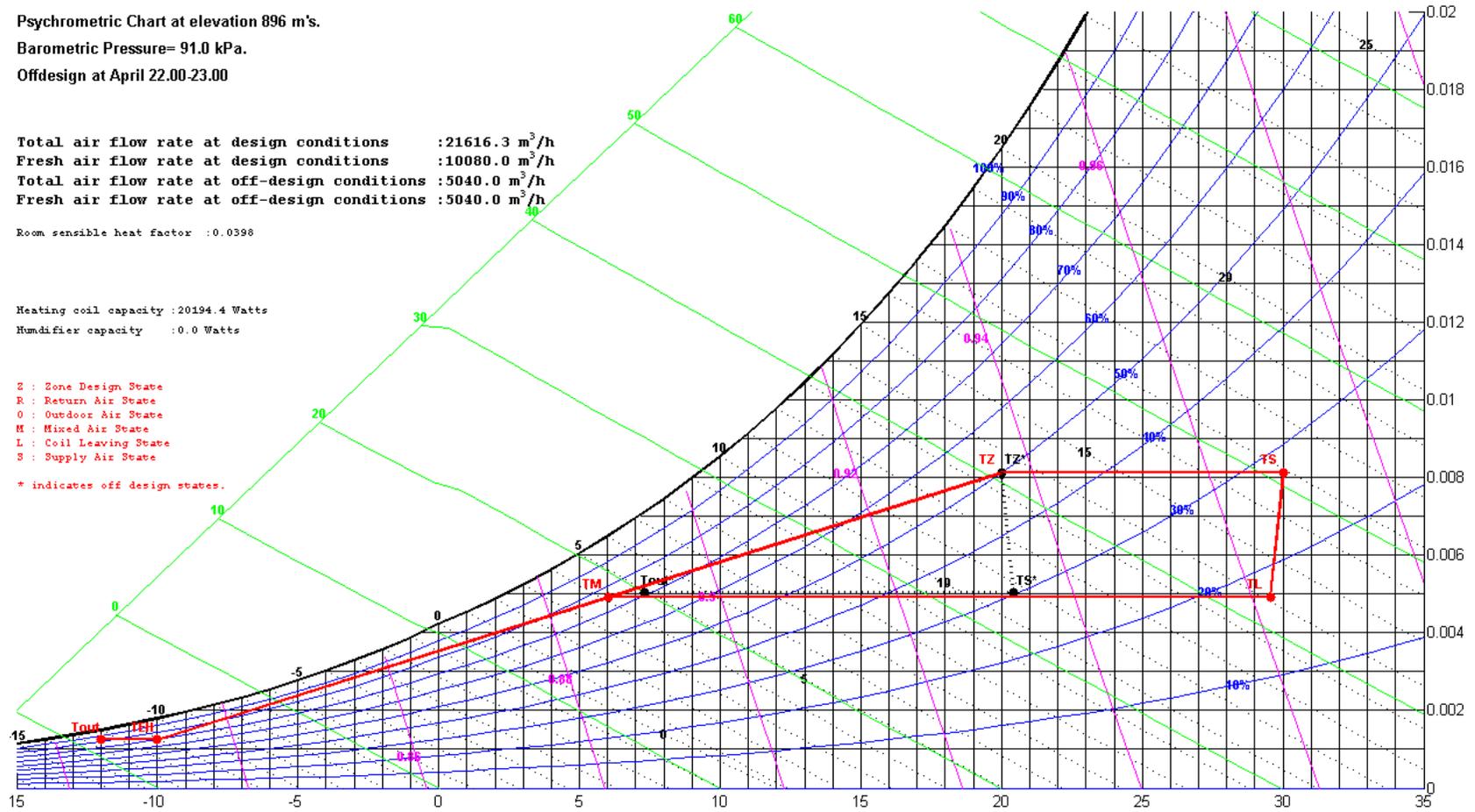


Figure 4.14 "Zone 3" Heating Design and Off-Design at April 22.00-23.00

02.00 time interval. As it can be seen from the figure, T_Z is summer design temperature (24°C) and T_S is decreased because the volumetric flow rate of total air is raised to the minimum volumetric flow rate of total air value. Full outdoor air, design and off-design processes for “Zone 2” at November 22.00-23.00 and “Zone 3” at April 22.00-23.00 are given in Figure 4.13 and Figure 4.14, respectively. In both cases, sensible heating occurs and T_S decreases, since the volumetric flow rate of outdoor ventilation air volumes come from the occupancy needs are greater than volumetric flow rates of total air required to heat the zones which is actually reasoning behind the selection of full outdoor air type process. Therefore, ΔT_{ZONE} is decreased to compensate for this air volume increase. The difference between two off-design processes is the need for steam humidification in Figure 4.14.

CHAPTER 5

DISCUSSION AND CONCLUSION

The aim of this study is to design, simulate and evaluate the behavior of an AC application for zones of a building with different characteristics, throughout a year on 12-month-24-hour basis. In other words, it is an implementation of performing different kinds of cooling and heating processes for zones which are submitted to different kinds of outdoor and indoor conditions and loads. In order to perform this study a computer program named “AHUSIM.m” is prepared with Matlab computing language. The programming procedure is comprised of three main parts, the preparation of the inputs of the program, the actual programming part and evaluation of results of the program.

5.1. COMMENTS ON INPUTS OF THE PROGRAM

The main input of the program is hourly heating and cooling loads and weather data. Since, for heating and cooling loads the weather data is also required, the accuracy of the programming is mostly dependent on accuracy of the weather data. Unfortunately, reliable weather data especially for solar loads is not available in Turkey. Therefore, in this study the temperature and humidity data taken from literature [25] and theoretical solar data calculated by the Carrier HAP 4.22a is used. This theoretical solar data is only a function of latitude and longitude, it misses some parts of the specific features of location, like cloudiness characteristics, ground absorbance and reflectance of the place. Therefore, usage of averaged experimental data collected for decades like the one used for temperature and humidity will be more accurate.

As for cooling and heating load parts, it is impossible to measure these loads exactly for a selected building because of two major reasons. The first one is, as mentioned

previously, the lack of reliable experimental weather data. The second reason is that, heating and cooling loads are hard to evaluate since they involve simultaneous solution of tedious equations for even very simple cases. Therefore, in order to apply them to buildings some simplifications must be done for ease of computing and reducing computing time, which means loss of accuracy. Also, the present methods that claim to be very accurate, very practical still lacks literature to be put into practice for such a comprehensive study. In this study for the load calculation a computer program that utilizes the transfer function method “Carrier Hourly Analysis Program Version 4.22a (HAP 4.22a) is used for cooling load calculations with corrections for the outdoor dry and wet bulb temperatures is used. [25] And as for the heating part the TS 2164 which is originally used for design load, is modified with the outdoor dry bulb temperatures, and the solar and internal loads taken from HAP 4.22a is used. [11, 25]

5.2. COMMENTS ON COMPUTATIONAL PART OF THE PROGRAM

In computation part of the program, main assumption behind the computation is that all processes occurring are assumed steady and constant throughout the same hours of a month. The computing of transient behavior of the zones and systems cannot be done even with today’s computers for such zones suspected to various parameters. Moreover, the results of such a study is not essential in standard HVAC applications. The response of the system being constant at same hours of a month, comes from the averaged weather data and cooling and heating loads calculated according to them. If a more detailed data can be found the program can easily be converted to respond such data and the relations between the energy consumption and human comfort will be vivider.

Simple ideal gas formulation with enhancement factor (f_s) was employed for property solutions and the construction of the psychrometric chart instead of Hyland-Wexler formulation, in this study. Although the Hyland-Wexler formulation gives more accurate solutions, the ideal gas formulation with enhancement factor was preferred to minimize the computational time and ease of programming. Still this formulation yields better results than reading a psychrometric chart, this loss of

accuracy is assumed to be acceptable. Furthermore, psychrometric charts drawn by the help of graphic tools of Matlab language, were constructed on the dry-bulb temperature and humidity ratio rectangular coordinates. In contrast with ASHRAE's oblique-angle coordinates for humidity ratio and enthalpy, the coordinates chosen significantly simplify the plotting procedure in computer graphics system. Although the selection of coordinates is arbitrary [6], the use of these coordinates leads slightly curved enthalpy lines when compared to the use of humidity ratio and enthalpy coordinates. For correct design, accurate equipment capacities and true control set points, the psychrometric charts should be corrected according to the altitude, which affects the atmospheric pressure and air density of the location. Since the atmospheric pressure decreases as the altitude increases, the performance of HVAC equipment changes. So, the program eliminates these affects for engineers by providing pressure corrected psychrometric charts.

5.3. COMMENTS ON OUTPUTS OF THE PROGRAM

The main aim of this study is to provide some inferences from the relation between energy economy and human comfort. Therefore, along with the main set of outputs provided in Appendix H, some outputs showing other kinds of cases where human comfort requirements and techniques used to maintain energy changes are prepared. In this outputs, yearly energy consumptions for apparatus parts integrated within an hour of a month and these integrated energies multiplied by the day number of months. (Year is assumed as a non-leap-year.)

The first case to be evaluated is increasing the volumetric flow rate of outdoor ventilation air by calculating from the latent heat of the room. This method is a powerful tool for energy economy. Even for some cases like in Figure 4.8 without using this tool there does not exist a physically meaningful solution. The effect of this tool is studied by putting a limit to volumetric flow rate of outdoor ventilation air. If this limit is too low the systems cannot respond to some cases as mentioned above. For example, if this limit is taken as one and a half times the original design volumetric flow rate of outdoor ventilation air, the program gives error for some cases. Therefore for representation of effect of this method, the volumetric flow rate

of outdoor ventilation air limited to two times the original design volumetric flow rate of outdoor ventilation air. Effect of this method can be seen from Table 5.1 where yearly energy consumptions and percent changes of the cases are tabulated. As it can be seen from the figure, there is no increase for heating processes, since this method is not utilized in heating mode. Moreover, there is no change in cooling energy consumptions of “Zone 1” and “Zone 2”, which should not lead to a deduction that the method is not required in this cases but the volumetric flow rate of outdoor ventilation air increased up to 2 times, is sufficient in them.

Table 5.1 Effect of Increasing Volumetric Flow Rate Of Outdoor Ventilation Air

	Yearly Energy Consumptions of Standard Outputs in MJ's	Limited \dot{V}_{VA} Outputs	
		Yearly Energy Consumptions in MJ's	% Increase in Energy Consumptions
Zone 1 Cooling Coil	158139	158139	0%
Zone 1 Humidifier (Cooling)	17313	17313	0%
Zone 1 Reheater	367	367	0%
<u>Zone 1 Cooling Total</u>	<u>175820</u>	<u>175820</u>	<u>0%</u>
Zone 1 Preheater	0	0	0%
Zone 1 Heating Coil	280126	280126	0%
Zone 1 Humidifier (Heating)	33529	33529	0%
<u>Zone 1 Heating Total</u>	<u>313705</u>	<u>313705</u>	<u>0%</u>
<u>Zone 1 Total</u>	<u>489525</u>	<u>489525</u>	<u>0%</u>
Zone 2 Cooling Coil	17392	17392	0%
Zone 2 Humidifier (Cooling)	4986	4986	0%
Zone 2 Reheater	1840	1840	0%
<u>Zone 2 Cooling Total</u>	<u>24758</u>	<u>24758</u>	<u>0%</u>
Zone 2 Preheater	0	0	0%
Zone 2 Heating Coil	37276	37276	0%
Zone 2 Humidifier (Heating)	4401	4401	0%
<u>Zone 2 Heating Total</u>	<u>41676</u>	<u>41676</u>	<u>0%</u>
<u>Zone 2 Total</u>	<u>66435</u>	<u>66435</u>	<u>0%</u>
Zone 3 Cooling Coil	558070	572847	2.6%
Zone 3 Humidifier (Cooling)	7352	7352	0%

Table 5.1 cont.'d

Zone 3 Reheater	35686	49971	40.0%
<u>Zone 3 Cooling Total</u>	<u>601108</u>	<u>630170</u>	<u>4.8%</u>
Zone 3 Preheater	0	0	0%
Zone 3 Heating Coil	507856	507856	0%
Zone 3 Humidifier (Heating)	27747	27747	0%
<u>Zone 3 Heating Total</u>	<u>535603</u>	<u>535603</u>	<u>0%</u>
<u>Zone 3 Total</u>	<u>1136711</u>	<u>1165744</u>	<u>2.6%</u>

The second effect to be studied is the transition months' zone design temperatures, in Table 5.2 zone design temperature of April is taken as summer zone design temperature, whereas in original program it is taken as winter zone design temperature. From table, it is obvious that when even a single month is changed the total energy consumptions increase by around 1-2% percent. Furthermore, in April people still tend to cloth heavier then summer, so careful decision of indoor zone design temperatures are important not only for energy consumption but also for human comfort.

Table 5.2 Effect of Zone Design Temperature Change in Transition Months

	Yearly Energy Consumptions of Standard Outputs in MJ's	Zone Design Temperature of Month April Taken As Summer Zone Design Temperature Outputs	
		Yearly Energy Consumptions in MJ's	% Increase in Energy Consumptions
Zone 1 Cooling Coil	158139	156030	-1.3%
Zone 1 Humidifier (Cooling)	17313	22455	29.7%
Zone 1 Reheater	367	791	115.4%
<u>Zone 1 Cooling Total</u>	<u>175820</u>	<u>179276</u>	<u>2.0%</u>
Zone 1 Preheater	0	0	0%
Zone 1 Heating Coil	280126	280242	0.04%
Zone 1 Humidifier (Heating)	33529	33574	0.5%
<u>Zone 1 Heating Total</u>	<u>313705</u>	<u>313996</u>	<u>0.1%</u>
<u>Zone 1 Total</u>	<u>489525</u>	<u>493272</u>	<u>0.8%</u>
Zone 2 Cooling Coil	17392	17979	0.3%

Table 5.2 cont.'d

Zone 2 Humidifier (Cooling)	4986	6227	24.9%
Zone 2 Reheater	1840	1958	6.4%
<u>Zone 2 Cooling Total</u>	<u>24758</u>	<u>26165</u>	<u>5.7%</u>
Zone 2 Preheater	0	0	0%
Zone 2 Heating Coil	37276	37353	0.2%
Zone 2 Humidifier (Heating)	4401	4517	2.6%
<u>Zone 2 Heating Total</u>	<u>41676</u>	<u>41870</u>	<u>0.5%</u>
<u>Zone 2 Total</u>	<u>66435</u>	<u>68035</u>	<u>2.4%</u>
Zone 3 Cooling Coil	558070	556993	-0.2%
Zone 3 Humidifier (Cooling)	7352	17854	142.8%
Zone 3 Reheater	35686	40172	12.6%
<u>Zone 3 Cooling Total</u>	<u>601108</u>	<u>615018</u>	<u>2.3%</u>
Zone 3 Preheater	0	0	0%
Zone 3 Heating Coil	507856	499396	-1.6%
Zone 3 Humidifier (Heating)	27747	28637	3.2%
<u>Zone 3 Heating Total</u>	<u>535603</u>	<u>528033</u>	<u>-1.4%</u>
<u>Zone 3 Total</u>	<u>1136711</u>	<u>1143051</u>	<u>0.6%</u>

The occupancy rates for zones must be carefully selected, since it affects the sensible and latent load of the zone and volumetric flow rate of outdoor ventilation air requirements. For understanding the system response better a densely occupied zone “Zone 3” of the building is studied in Table 5.3. With the loads and volumetric flow rate of outdoor ventilation air requirements of the zone, which is occupied by 30% percent of the people of standard case, the system response is studied in detail. As it can be seen from the table the effect of occupancy is very high, therefore in control systems the indoor air quality and temperature reading elements must be given enough importance to reduce energy consumption.

As mentioned, zone design temperatures are of great importance in energy saving procedures. To study, this effect zone loads are revised with 1°C higher summer zone design temperatures and 1°C lower winter zone design temperatures. The comparison of this case is given in Table 5.4. From the table, it can be observed that it can

provide 5 to 10% energy saving, so the priority of human comfort or energy saving should be decided properly, with awareness of the consequences.

Table 5.3 Effect of Decreasing Occupancy

	Yearly Energy Consumptions of Standard Outputs in MJ's	"Zone 3" Occupancy Decreased to 30%	
		Yearly Energy Consumptions in MJ's	% Decrease in Energy Consumptions
Zone 3 Cooling Coil	558070	462656	17.1%
Zone 3 Humidifier (Cooling)	7352	0	100%
Zone 3 Reheater	35686	2653	92.6%
<u>Zone 3 Cooling Total</u>	<u>601108</u>	<u>465308</u>	<u>22.6%</u>
Zone 3 Preheater	0	0	0%
Zone 3 Heating Coil	507856	565187	-11.9%
Zone 3 Humidifier (Heating)	27747	10249	63.1%
<u>Zone 3 Heating Total</u>	<u>535603</u>	<u>575437</u>	<u>-7.4%</u>
<u>Zone 3 Total</u>	<u>1136711</u>	<u>1040745</u>	<u>8.4%</u>

Table 5.4 Effect of Changing Zone Design Temperatures by 1°C

	Yearly Energy Consumptions of Standard Outputs in MJ's	Zone Design Temperatures Changed by 1°C Outputs	
		Yearly Energy Consumptions in MJ's	% Decrease in Energy Consumptions
Zone 1 Cooling Coil	158139	150541	14.8%
Zone 1 Humidifier (Cooling)	17313	22985	-32.8%
Zone 1 Reheater	367	70	80.0%
<u>Zone 1 Cooling Total</u>	<u>175820</u>	<u>173595</u>	<u>1.3%</u>
Zone 1 Preheater	0	0	0%
Zone 1 Heating Coil	280126	258299	7.8%
Zone 1 Humidifier (Heating)	33529	27855	17.0%
<u>Zone 1 Heating Total</u>	<u>313705</u>	<u>286154</u>	<u>8.8%</u>
<u>Zone 1 Total</u>	<u>489525</u>	<u>459749</u>	<u>6.1%</u>
Zone 2 Cooling Coil	17392	16839	6.1%
Zone 2 Humidifier (Cooling)	4986	5967	-19.7%
Zone 2 Reheater	1840	1815	1.4%

Table 5.4 cont.'d

<u>Zone 2 Cooling Total</u>	<u>24758</u>	<u>24620</u>	<u>0.6%</u>
Zone 2 Preheater	0	0	0%
Zone 2 Heating Coil	37276	32103	13.9%
Zone 2 Humidifier (Heating)	4401	3213	26.9%
<u>Zone 2 Heating Total</u>	<u>41676</u>	<u>35316</u>	<u>15.3%</u>
<u>Zone 2 Total</u>	<u>66435</u>	<u>59936</u>	<u>9.8%</u>
Zone 3 Cooling Coil	558070	532239	4.6%
Zone 3 Humidifier (Cooling)	7352	4997	32.3%
Zone 3 Reheater	35686	16397	54.1%
<u>Zone 3 Cooling Total</u>	<u>601108</u>	<u>553632</u>	<u>7.9%</u>
Zone 3 Preheater	0	0	0%
Zone 3 Heating Coil	507856	493375	2.9%
Zone 3 Total	27747	12642	54.4%
<u>Zone 3 Heating Total</u>	<u>535603</u>	<u>506017</u>	<u>5.5%</u>
<u>Zone 3 Total</u>	<u>1136711</u>	<u>1059649</u>	<u>6.8%</u>

5.4. FUTURE RECOMENDATIONS

In this thesis as stated before, for cooling and heating load calculations Carrier HAP 4.22a implementing transfer function method and prepared Microsoft Excel sheets prepared according to a slightly modified TS 2164 [11] is used respectively. However, with developing hardware and software the use of heat balance method will evidently improve the estimation of cooling and heating loads. Moreover, as the available literature about the radiant time series method [10] develops, the use of it in load estimation should be considered. Also, this limits the program's flexibility in design and simulation of different buildings. Therefore if a load calculation is done by the main program, it will also give flexibility to the program.

In this study, simple ideal gas formulation with enhancement factor (f_s) was used for state evaluations and the construction of the psychrometric chart instead of Hyland-Wexler formulation. In order to get better accuracy Hyland-Wexler formulation may be used.

Furthermore, the building studied here is a commercial building where the major concern is the human comfort limits, if a building with industrial usage is chosen the comfort criteria such as temperature, humidity, etc. will change. This criteria change may lead to different system selections, responses and techniques in reducing energy consumption.

As a last recommendation, in the design of heating and cooling-dehumidifying coils, different type of coil geometries may be selected for each type of coils, in order to satisfy the desired water temperature ranges initially given by the designers. This may provide a tool for comparing the responses of coil geometries.

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APPENDIX A

HEAT BALANCE METHOD AND TRANSFER FUNCTION METHOD

A.1. HEAT BALANCE METHOD

A surface-by-surface conductive, convective and radiative heat balance for each room surface and a convective heat balance for the room air is calculated for the estimation of a cooling load for the space. Using the HB Method to solve this heat transfer problem would require writing heat balance equations for each surface and mass element considering each process involved:

- Convection of heat from the light to room air
- Radiation from the light to each surface in the room
- Conduction, convection and radiation exchange for each surface in the room
- Conduction and heat storage for each mass element in contact with a surface
- Heat gains caused by people, light and other equipment

Considering a sample room with four walls, a ceiling and a floor with infiltration air, ventilation air and normal internal energy sources eases the demonstration of the method. The calculations that govern energy exchange at each inside surface for the sample room at given time are formulated [27] as:

$$q_{i,\theta} = \left[h_{ci}(T_{a,\theta} - T_{i,\theta}) + \sum_{j=1, j \neq i}^n g_{ij}(T_{j,\theta} - T_{i,\theta}) \right] \cdot A_i + RS_{i,\theta} + RL_{i,\theta} + RE_{i,\theta} \quad (1)$$

where;

n = number of surfaces in a room

$q_{i,\theta}$ = rate of heat conducted into the surface i at inside surface at time θ

A_i = area of surface i

h_{ci} = convective heat transfer coefficient at interior surface i

$T_{a,\theta}$ = inside air temperature at time θ

$T_{i,\theta}$ = average temperature of interior surface i at time θ

$T_{j,\theta}$ = average temperature of interior surface j at time θ

$RS_{i,\theta}$ = rate of solar energy coming through windows and absorbed by surface i at time θ

$RL_{i,\theta}$ = rate of heat radiated from lights and absorbed by surface i at time θ

$RE_{i,\theta}$ = rate of heat radiated from equipment and occupants and absorbed by surface i at time θ

The Eqn. (1) does not cover the conductive part, which must be simultaneously solved with it. The governing equations of conduction for all surfaces of a room called the conduction transfer functions (CTF) are formulated [6] as:

$$q_{in,\theta} = \sum_{m=1}^M Y_{k,m} T_{o,\theta-m+1} - \sum_{m=1}^M Z_{k,m} T_{in,\theta-m+1} + \sum_{m=1}^M F_m q_{in,\theta-m} \quad (2)$$

where;

q = rate of heat conducted into a specific surface at a specific hour

in = inside surface subscript

k = order of CTF

m = time index variable

M = number of nonzero CTF values

o = outside surface subscript

T = temperature

θ = time

X = exterior CTF values

Y = cross CTF values

Z = interior CTF values

F_m = flux (heat flow rate) history coefficients

With Eqn.'s (1) and (2), the energy balance on the space air must be solved simultaneously. This space air energy balance is formulated as:

$$Q_{L,\theta} = \left[\sum_{i=1}^n h_{ci} (T_{i,\theta} - T_{a,\theta}) \right] \cdot A_i + \rho C V_{L,\theta} (T_{o,\theta} - T_{a,\theta}) \quad (3)$$

$$+ \rho C V_{v,\theta} (T_{v,\theta} - T_{a,\theta}) + RS_{a,\theta} + RL_{a,\theta} + RE_{a,\theta}$$

where;

ρ = air density

C = specific air heat

$V_{L,\theta}$ = volume flow rate of outdoor air infiltrating into room at time θ

$t_{o,\theta}$ = outdoor air temperature at time θ

$V_{v,\theta}$ = volume flow rate ventilation air at time θ

$T_{v,\theta}$ = ventilation air temperature at time θ

$RS_{a,\theta}$ = rate of solar energy coming through windows and convected to room air at time θ

$RL_{i,\theta}$ = rate of heat radiated from lights and absorbed by surface i convected into room air at time θ

$RE_{i,\theta}$ = rate of heat radiated from equipment and occupants and convected into room air at time θ

Even for this sample case the heat balance needs simultaneous solution of this tedious equations. Even with today's desktop computers the heat balance method is limited to calculation of cooling loads of some simple spaces. However the understanding of heat balance method is essential, since the other methods are evolved from this method.

A.2. TRANSFER FUNCTION METHOD

Although the heat balance method is a comprehensive approach to modeling the actual heat transfer processes in a building, the transfer function method, which is evolved from HB method, is able to provide sophisticated, accurate building load estimates by using key assumptions that shortens the calculation times Carrier Tez. The transfer function method relies on two important concepts; conduction transfer functions and room transfer functions. Both of them are time series that relate a

current variable to past values of itself and other variables at discrete time intervals. [6]

Transfer functions are derived from response factors, which are infinite series that relate a current variable to past values of other variables. [6] The principles which the response factors are based on, are as follows: [27]

- The Principle of Superposition: The total room load is equal to the sum of loads calculated separately for each heat gain component.

-The Principle of Linearity: The magnitude of the thermal response to a heat gain varies linearly with the size of the heat gain.

-The Principle of Invariability: Two heat gains of equal size occurring at different times will produce the same thermal response in a room.

A.2.1. Room Transfer Functions

Room transfer functions relate the hourly cooling load due to individual types of heat gains to past values of that type of heat gain and previous values of the cooling load due to that type of heat gain. The mathematical relationship used for the room transfer functions by Carrier HAP 4.22a [27] is as follows:

$$Q_0 = v_0q_0 + v_1q_1 + v_2q_2 + w_1Q_1 + w_2Q_2 \quad (4)$$

A.2.2. Conduction Transfer Functions

where,

Q = Cooling loads

q = Heat gains

v, w = Room transfer function coefficients that are tabulated by ASHRAE [9]

for different heat gain components, room types and building weights.

0 = Subscript indicating the current hour

1, 2 = Subscripts indicating the previous and two previous hours respectively

Conduction transfer functions are used by the TFM to describe the heat flux at the inside of a wall, roof, partition, ceiling or floor as a function of previous values of the heat flux and previous values of inside and outside temperatures. TFM uses the sol-air temperature for the outside temperature and design temperature as the inside temperature. [6] The sol-air temperature is an effective measure of the heat gain at the exterior surface of a wall. [27] It can be formulated as:

$$T_{sa} = T_{oa} + \alpha \frac{G_t}{h_o} + \frac{\epsilon \Delta R}{h_o} \quad (5)$$

where,

T_{sa} = Sol-air temperature

T_{oa} = Outdoor dry-bulb temperature

α = Wall or roof exterior surface absorptivity for solar radiation, dimensionless

G_t = Total solar flux on wall or roof surface, W/m^2

h_o = Convective heat transfer coefficient on exterior wall or roof surface. A value of $17.0 W/m^2K$ is used.

ϵ = Hemispherical emittance of exterior surface. A value of 1.0 is used.

ΔR = Difference between longwave radiation incident on exterior surface and blackbody radiation at T_{oa} , W/m^2 . For vertical surfaces, $\Delta R = 0$. For horizontal surfaces, $\Delta R = 20$.

And the mathematical relationship used for conduction transfer functions is as follows:

$$\frac{q_0}{A} = b_0 T_{sa0} + b_1 T_{sa1} + b_2 T_{sa2} + b_3 T_{sa3} + b_4 T_{sa4} + b_5 T_{sa5} + b_6 T_{sa6} \quad (6)$$

$$- d_1 q_1 - d_2 q_2 - d_3 q_3 - d_4 q_4 - d_5 q_5 - d_6 q_6 - T_{rc} \sum c_n$$

where,

q = Heat gains

b, d, c_n = Conduction transfer function coefficients that are tabulated by ASHRAE [9] for different constructions of walls or ceilings

0 = Subscript indicating the current hour

1, 2, 3, 4, 5, 6 = Subscripts indicating the previous and two previous hours and so forth

T_{rc} = Indoor air temperature

A = Area

APPENDIX B

BUILDING PLANS

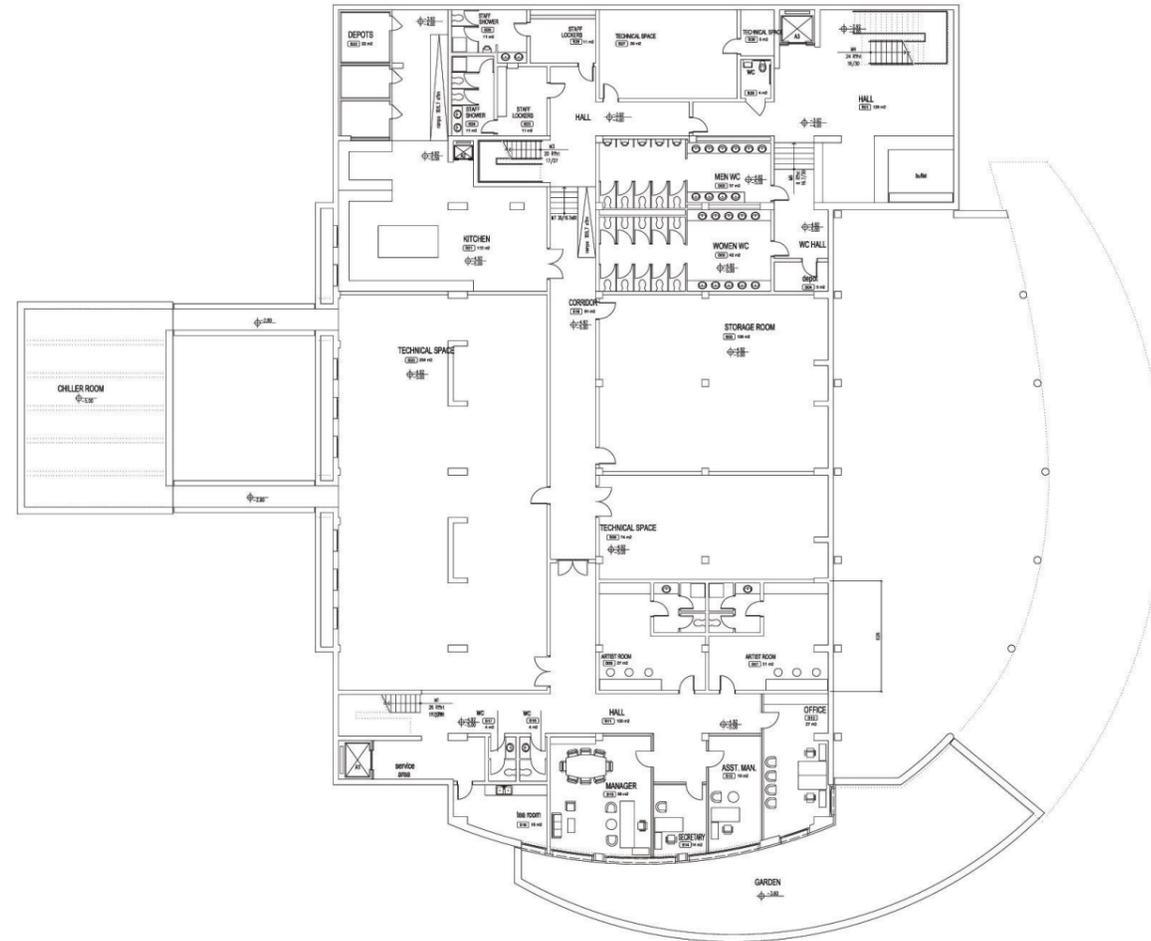


Figure B.1 Basement Plan (Scale 1/400)

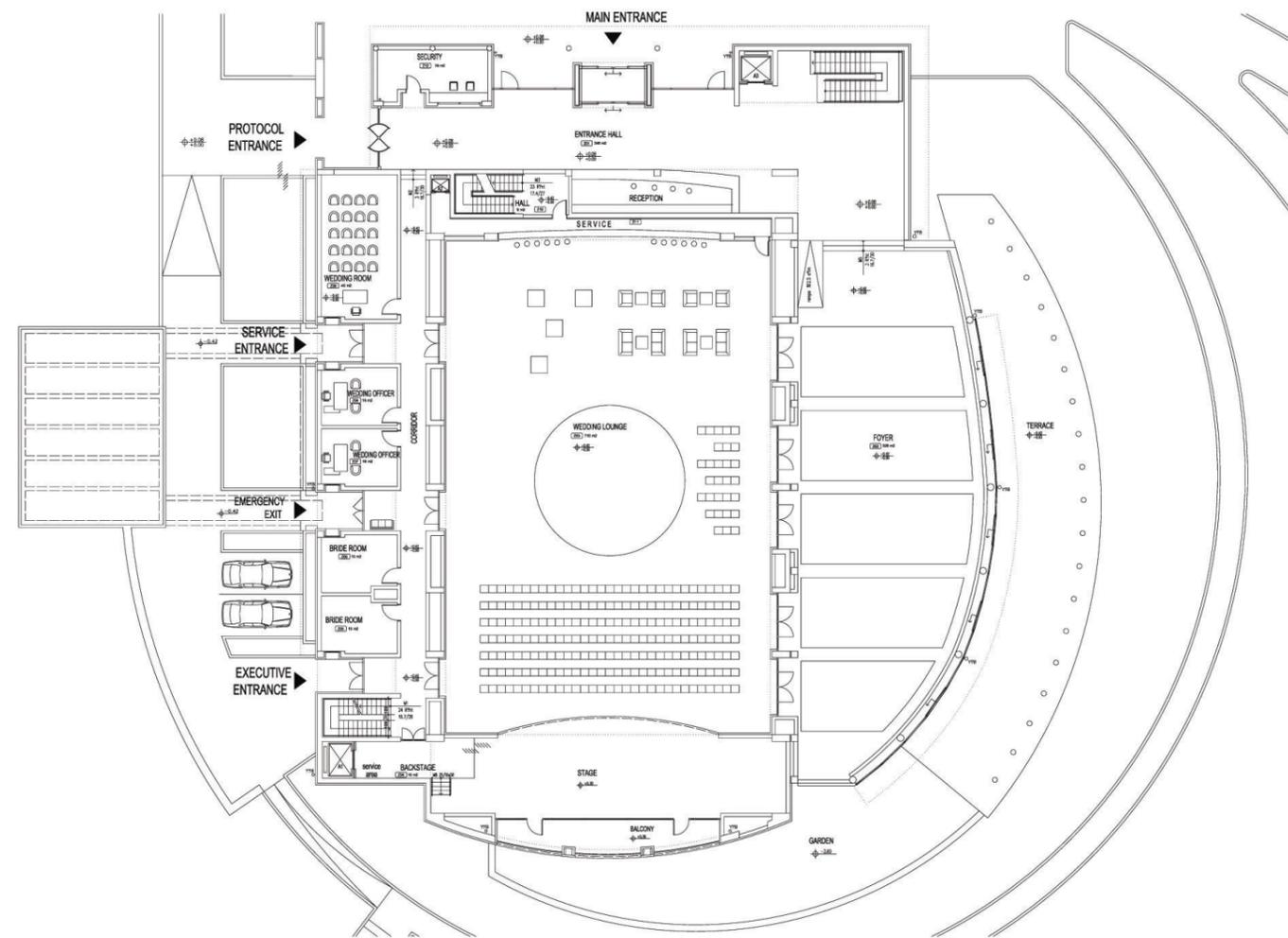


Figure B.2 Ground Floor Plan (Scale 1/400)

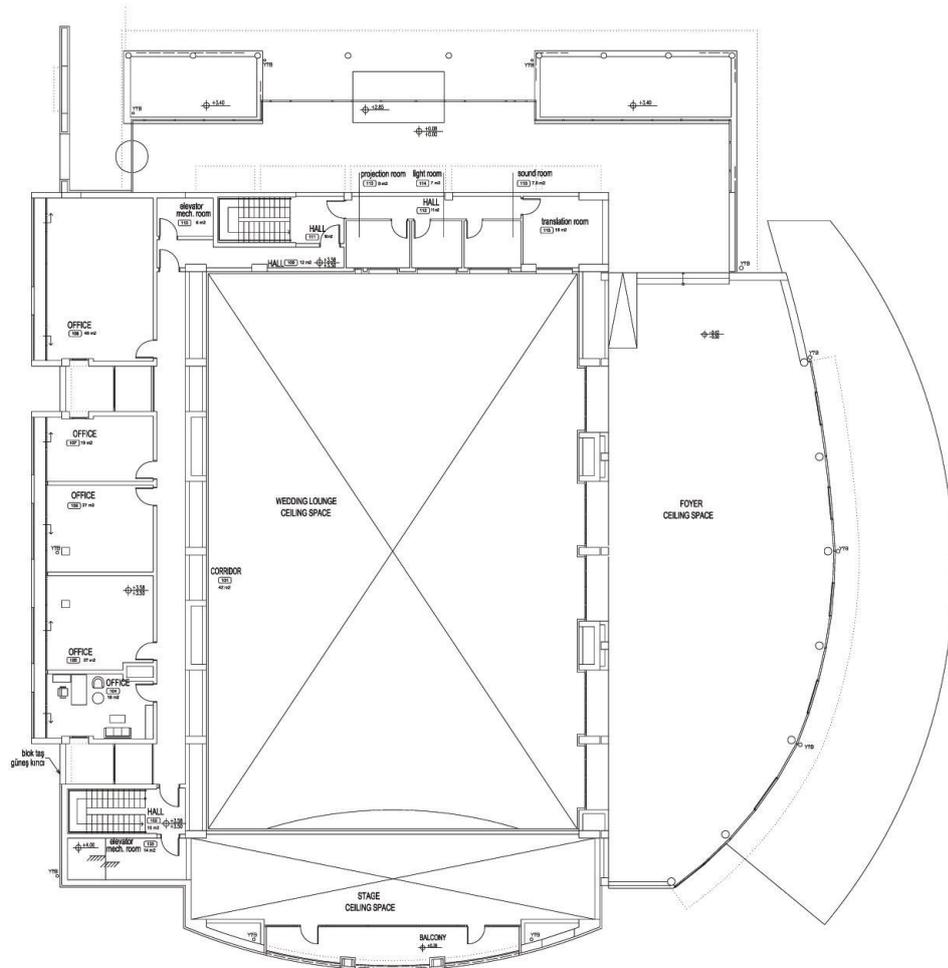


Figure B.3 First Floor Plan (Scale 1/400)

APPENDIX C

PRINTOUTS OF INPUT.XLS

Table C.1 Printout of “General Data” Sheet of “input.xls”

	Zone 1	Zone 2	Zone 3
Altitude (m)		896	
Summer Room Design Temperature (oC)		24	
Summer Room Design Relative Humidity (%)		50	
Summer Outdoor Design Drybulb Temperature (oC)		34	
Summer Outdoor Design Wetbulb Temperature (oC)		24	
Winter Room Design Temperature (oC)		20	
Winter Room Design Relative Humidity (%)		50	
Winter Outdoor Design Drybulb Temperature (oC)		-12	
Winter Outdoor Design Wetbulb Temperature (oC)		-12,5	
Maximum Allowable Supply Air Temperature Difference (oC)		10	
Supply Fan Efficiency		0,65	
Supply Fan Motor Efficiency		0,65	
Return Fan Efficiency		0,65	
Return Fan Motor Efficiency		0,65	
Bypass Factor		0,1	
Saturated Steam Temperature (Steam Humidifer) (oC)		110	
Summer Design Sensible Cooling Load (W)	35107	5188	87706
Summer Design Latent Cooling Load (W)	3266	1176	30813
Winter Design Sensible Heating Load (W)	28025	4406	66045
Winter Design Latent Cooling Load (W)	0	0	0
Fresh Air Requirement For Maximum Occupancy (m ³ /h)	2196	648	10080
Pressure of Supply Fan (kPa)	500	300	1000
Pressure of Return Fan (kPa)	300	90	800
Zone Return Heat Gain (W)	250	50	400

Table C.2 Printout of “Coil Data” Sheet of “input.xls”

Horizontal Tube Spacing (a) (mm)	22
Vertical Tube Spacing (c) (mm)	25,4
Tube Inner Diameter (D_i) (mm)	8,6
Tube Outer Diameter (D_o) (mm)	10,2
Fin Pitch (P) (per mm)	0,315
Fin Thickness (t_f) (mm)	0,33
Fin Area / Total Area (A_f/A)	0,913
Thermal Conductivity of Fin Material (W/mK)	200
Air Passage Equivalent Diameter (D_H) (mm)	3,63
Free Flow Area / Frontal Area (σ)	0,534
Heat Transfer Area / Total Volume (α) (m²/m³)	587,3
Air Face Velocity (V_{FACE}) (m/s)	3
Cooling Coil Water Inlet Design Temperature (oC)	6
Cooling Coil Water Outlet Design Temperature (oC)	10
Heating Coil Water Inlet Design Temperature (oC)	90
Heating Coil Water Outlet Design Temperature (oC)	70

Table C.3 Printout of “Temperature” Sheet of “input.xls”

Hours		00.00	01.00	02.00	03.00	04.00	05.00	06.00	07.00	08.00	09.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	23.00	00.00
Jan	DRYBULB TEMPERATURE (°C)	-4,1	-4,5	-4,6	-4,9	-5,0	-5,1	-5,1	-5,3	-4,4	-3,0	-1,7	-0,2	1,0	1,8	2,1	1,9	1,1	-0,4	-1,6	-2,2	-2,6	-3,1	-3,6	-3,9		
		-1,6	-1,6	-1,9	-2,3	-2,5	-2,5	-2,7	-2,8	-1,3	0,1	1,9	2,9	3,6	4,4	4,4	4,4	4,0	3,0	2,1	1,4	0,8	0,3	-0,2	-0,7		
		-0,4	-0,9	-1,0	-1,3	-1,3	-1,6	-1,5	-0,6	1,4	3,4	4,7	5,5	6,4	7,4	7,5	7,5	7,4	6,3	4,9	3,6	2,3	1,5	0,8	0,2		
		5,8	5,0	4,7	4,5	4,0	4,2	4,9	6,3	8,4	10,1	11,7	12,2	13,0	13,4	13,6	13,7	13,6	12,5	11,4	9,9	9,1	8,1	7,3	6,7		
		9,6	8,7	8,3	7,5	7,1	7,5	9,0	11,0	13,4	15,5	17,4	18,3	19,1	19,5	19,6	19,5	19,2	18,1	16,7	15,0	13,6	12,5	11,4	10,6		
		12,4	11,2	10,5	9,8	9,0	10,5	12,3	15,2	17,7	19,7	21,2	22,3	23,0	23,5	23,6	23,5	23,0	21,9	20,5	18,5	16,6	15,1	13,9	13,1		
		17,9	16,9	16,2	15,3	14,4	14,9	16,3	18,4	21,0	22,8	24,3	25,1	26,2	27,1	27,4	27,6	27,5	26,5	25,1	23,3	22,1	20,8	19,6	18,9		
		16,9	15,8	15,0	14,3	13,5	15,0	16,7	18,3	20,4	22,5	24,6	26,6	27,9	27,7	27,6	27,7	27,6	27,7	25,9	24,2	22,4	21,2	20,1	18,9	17,9	
		13,0	12,3	11,2	10,4	9,7	9,3	10,3	13,0	16,6	19,4	21,1	22,6	23,5	24,3	24,2	24,2	23,6	22,0	20,0	18,3	16,6	15,6	14,6	13,8		
		7,5	6,9	6,4	5,9	5,6	5,5	5,5	6,4	8,8	11,3	13,6	14,9	15,7	16,2	16,1	15,5	14,7	13,4	11,9	10,8	9,8	8,9	8,3	7,6		
		1,9	1,6	1,3	1,0	0,7	0,9	1,1	1,3	2,8	4,4	6,0	6,8	7,5	8,2	7,7	7,2	6,7	5,7	4,7	3,7	3,2	2,6	2,2	2,0		
		-0,9	-0,9	-1,1	-1,1	-1,1	-1,0	-1,1	-1,2	-0,2	1,0	2,1	3,0	3,8	4,5	4,1	3,6	3,0	2,2	1,5	0,8	0,3	-0,2	-0,6	-0,9		
Feb	DRYBULB TEMPERATURE (°C)	-4,5	-4,8	-4,9	-5,1	-5,1	-5,2	-5,2	-5,3	-4,8	-3,9	-3,1	-2,2	-1,6	-1,1	-0,9	-1,0	-1,5	-2,4	-3,1	-3,4	-3,7	-4,0	-4,3	-4,4		
		-2,8	-2,8	-2,9	-3,2	-3,3	-3,3	-3,4	-3,5	-2,6	-1,8	-0,8	-0,2	0,6	0,6	0,6	0,4	-0,2	-0,7	-1,1	-1,4	-1,7	-2,0	-2,2			
		-1,5	-1,8	-1,8	-2,0	-2,0	-2,2	-2,1	-1,6	-0,5	0,6	1,3	1,7	2,2	2,8	2,8	2,8	2,8	2,2	1,4	0,7	0,0	-0,5	-0,8	-1,2		
		4,2	3,8	3,7	3,5	3,3	3,4	3,8	4,5	5,5	6,3	7,0	7,3	7,6	7,8	7,9	7,9	7,9	7,4	6,9	6,2	5,8	5,3	4,9	4,7		
		8,0	7,6	7,4	7,0	6,8	7,0	7,7	8,6	9,6	10,5	11,2	11,6	11,9	12,1	12,1	12,1	11,9	11,5	11,0	10,3	9,7	9,2	8,7	8,4		
		9,7	9,2	8,9	8,6	8,2	8,9	9,6	10,8	11,8	12,6	13,2	13,6	13,8	14,0	14,0	14,0	13,8	13,4	12,9	12,1	11,4	10,8	10,3	10,0		
		12,9	12,5	12,3	11,9	11,6	11,8	12,3	13,5	14,1	14,7	15,2	15,5	15,9	16,2	16,3	16,3	16,3	16,0	15,5	14,9	14,4	14,0	13,5	13,3		
		12,0	11,6	11,2	11,0	10,6	11,2	11,9	12,5	13,3	14,1	14,8	15,2	15,5	16,0	15,9	15,9	15,9	15,3	14,7	14,0	13,6	13,2	12,7	12,4		
		9,7	9,4	9,0	8,6	8,3	8,2	8,6	9,7	11,2	12,3	12,9	13,5	13,8	14,1	14,1	14,1	13,9	13,3	12,5	11,9	11,2	10,8	10,4	10,1		
		5,4	5,1	4,9	4,6	4,5	4,4	4,4	4,9	6,0	7,2	8,2	8,8	9,1	9,3	9,3	9,0	8,7	8,1	7,5	7,0	6,5	6,1	5,8	5,5		
		0,7	0,6	0,4	0,2	0,1	0,2	0,3	0,4	1,2	2,1	2,9	3,3	3,7	4,1	3,8	3,5	3,3	2,8	2,2	1,7	1,4	1,1	0,9	0,8		
		-1,4	-1,4	-1,5	-1,5	-1,5	-1,4	-1,5	-1,5	-1,5	-1,0	-0,3	0,3	0,8	1,2	1,6	1,4	1,1	0,8	0,3	0,0	-0,4	-0,7	-1,0	-1,2	-1,4	
March	DRYBULB TEMPERATURE (°C)	-4,1	-4,5	-4,6	-4,9	-5,0	-5,1	-5,1	-5,3	-4,4	-3,0	-1,7	-0,2	1,0	1,8	2,1	1,9	1,1	-0,4	-1,6	-2,2	-2,6	-3,1	-3,6	-3,9		
		-1,6	-1,6	-1,9	-2,3	-2,5	-2,5	-2,7	-2,8	-1,3	0,1	1,9	2,9	3,6	4,4	4,4	4,4	4,0	3,0	2,1	1,4	0,8	0,3	-0,2	-0,7		
		-0,4	-0,9	-1,0	-1,3	-1,3	-1,6	-1,5	-0,6	1,4	3,4	4,7	5,5	6,4	7,4	7,5	7,5	7,4	6,3	4,9	3,6	2,3	1,5	0,8	0,2		
		5,8	5,0	4,7	4,5	4,0	4,2	4,9	6,3	8,4	10,1	11,7	12,2	13,0	13,4	13,6	13,7	13,6	12,5	11,4	9,9	9,1	8,1	7,3	6,7		
		9,6	8,7	8,3	7,5	7,1	7,5	9,0	11,0	13,4	15,5	17,4	18,3	19,1	19,5	19,6	19,5	19,2	18,1	16,7	15,0	13,6	12,5	11,4	10,6		
		12,4	11,2	10,5	9,8	9,0	10,5	12,3	15,2	17,7	19,7	21,2	22,3	23,0	23,5	23,6	23,5	23,0	21,9	20,5	18,5	16,6	15,1	13,9	13,1		
		17,9	16,9	16,2	15,3	14,4	14,9	16,3	18,4	21,0	22,8	24,3	25,1	26,2	27,1	27,4	27,6	27,5	26,5	25,1	23,3	22,1	20,8	19,6	18,9		
		16,9	15,8	15,0	14,3	13,5	15,0	16,7	18,3	20,4	22,5	24,6	26,6	27,9	27,7	27,6	27,7	27,6	27,7	25,9	24,2	22,4	21,2	20,1	18,9	17,9	
		13,0	12,3	11,2	10,4	9,7	9,3	10,3	13,0	16,6	19,4	21,1	22,6	23,5	24,3	24,2	24,2	23,6	22,0	20,0	18,3	16,6	15,6	14,6	13,8		
		7,5	6,9	6,4	5,9	5,6	5,5	5,5	6,4	8,8	11,3	13,6	14,9	15,7	16,2	16,1	15,5	14,7	13,4	11,9	10,8	9,8	8,9	8,3	7,6		
		1,9	1,6	1,3	1,0	0,7	0,9	1,1	1,3	2,8	4,4	6,0	6,8	7,5	8,2	7,7	7,2	6,7	5,7	4,7	3,7	3,2	2,6	2,2	2,0		
		-0,9	-0,9	-1,1	-1,1	-1,1	-1,0	-1,1	-1,2	-0,2	1,0	2,1	3,0	3,8	4,5	4,1	3,6	3,0	2,2	1,5	0,8	0,3	-0,2	-0,6	-0,9		
April	DRYBULB TEMPERATURE (°C)	-4,5	-4,8	-4,9	-5,1	-5,1	-5,2	-5,2	-5,3	-4,8	-3,9	-3,1	-2,2	-1,6	-1,1	-0,9	-1,0	-1,5	-2,4	-3,1	-3,4	-3,7	-4,0	-4,3	-4,4		
		-2,8	-2,8	-2,9	-3,2	-3,3	-3,3	-3,4	-3,5	-2,6	-1,8	-0,8	-0,2	0,6	0,6	0,6	0,4	-0,2	-0,7	-1,1	-1,4	-1,7	-2,0	-2,2			
		-1,5	-1,8	-1,8	-2,0	-2,0	-2,2	-2,1	-1,6	-0,5	0,6	1,3	1,7	2,2	2,8	2,8	2,8	2,8	2,2	1,4	0,7	0,0	-0,5	-0,8	-1,2		
		4,2	3,8	3,7	3,5	3,3	3,4	3,8	4,5	5,5	6,3	7,0	7,3	7,6	7,8	7,9	7,9	7,9	7,4	6,9	6,2	5,8	5,3	4,9	4,7		
		8,0	7,6	7,4	7,0	6,8	7,0	7,7	8,6	9,6	10,5	11,2	11,6	11,9	12,1	12,1	12,1	11,9	11,5	11,0	10,3	9,7	9,2	8,7	8,4		
		9,7	9,2	8,9	8,6	8,2	8,9	9,6	10,8	11,8	12,6	13,2	13,6	13,8	14,0	14,0	14,0	13,8	13,4	12,9	12,1	11,4	10,8	10,3	10,0		
		12,9	12,5	12,3	11,9	11,6	11,8	12,3	13,5	14,1	14,7	15,2	15,5	15,9	16,2	16,3	16,3	16,3	16,0	15,5	14,9	14,4	14,0	13,5	13,3		
		12,0	11,6	11,2	11,0	10,6	11,2	11,9	12,5	13,3	14,1	14,8	15,2	15,5	16,0	15,9	15,9	15,9	15,3	14,7	14,0	13,6	13,2	12,7	12,4		
		9,7	9,4	9,0	8,6	8,3	8,2	8,6	9,7	11,2	12,3	12,9	13,5	13,8	14,1	14,1	14,1	13,9	13,3	12,5	11,9	11,2	10,8	10,4	10,1		
		5,4	5,1	4,9	4,6	4,5	4,4	4,4	4,9	6,0	7,2	8,2	8,8	9,1	9,3	9,3	9,0	8,7	8,1	7,5	7,0	6,5	6,1	5,8	5,5		
		0,7	0,6	0,4	0,2	0,1	0,2	0,3	0,4	1,2	2,1	2,9	3,3	3,7	4,1	3,8	3,5	3,3	2,8	2,2	1,7	1,4	1,1	0,9	0,8		
		-1,4	-1,4	-1,5	-1,5	-1,5	-1,4	-1,5	-1,5	-1,5	-1,0	-0,3	0,3	0,8	1,2	1,6	1,4	1,1	0,8	0,3	0,0	-0,4	-0,7	-1,0	-1,2	-1,4	
May	DRYBULB TEMPERATURE (°C)	-4,1	-4,5	-4,6	-4,9	-5,0	-5,1	-5,1	-5,3	-4,4	-3,0	-1,7	-0,2	1,0	1,8	2,1	1,9	1,1	-0,4	-1,6	-2,2	-2,6	-3,1	-3,6	-3,9		
		-1,6	-1,6	-1,9	-2,3	-2,5	-2,5	-2,7	-2,8	-1,3	0,1	1,9	2,9	3,6	4,4	4,4	4,4	4,0	3,0	2,1	1,4	0,8	0,3	-0,2	-0,7		
		-0,4	-0,9	-1,0	-1,3	-1,3	-1,6	-1,5	-0,6	1,4	3,4	4,7	5,5	6,4	7,4	7,5	7,5	7,4	6,3	4,9	3,6	2,3	1,5	0,8	0,2		
		5,8	5,0	4,7	4,5	4,0	4,2	4,9	6,3	8,4	10,1	11,7	12,2	13,0	13,4	13,6	13,7	13,6	12,5	11,4	9,9	9,1	8,1	7,3	6,7		
		9,6	8,7	8,3	7,5	7,1	7,5	9,0	11,0	13,4	15,5	17,4	18,3	19,1	19,5	19,6	19,5	19,2	18,1	16,7	15,0	13,6	12,5	11,4	10,6		
		12,4	11,2	10,5	9,8	9,0	10,5	12,3	15,2	17,7	19,7	21,2	22,3	23,0	23,5	23,6	23,5	23,0	21,9	20,5	18,5	16,6	15,1	13,9	13,1		
		17,9	16,9	16,2	15,3	14,4	14,9	16,3	18,4	21,0	22,8	24,3	25,1	26,2	27,1	27,4	27,6	27,5	26,5	25,1	23,3	22,1	20,8	19,6	18,9		
		16,9	15,8	15,0	14,3	13,5	15,0	16,7	18,3	20,4	22,5	24,6	26,6	27,9	27,7	27,6	27,7	27,6	27,7	25,9	24,2	22,4	21,2	20,1	18,9	17,9	
		13,0	12,3	11,2	10,4	9,7	9,3	10,3	13,0	16,6																	

Table C.4 Printout of “Sensible Loads” Sheet of “input.xls”

		Hours																								
		00.00	01.00	02.00	03.00	04.00	05.00	06.00	07.00	08.00	09.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	00.00
Zone 1 (Watts)	Jan Sensible Heat Loss	19783	20221	20412	20757	20930	21093	21180	18599	15067	13445	12202	11471	10367	9595	9251	9330	9909	10416	11307	14972	17728	18288	18836	19213	
	Feb. Sensible Heat Loss	17427	17533	17690	18318	18574	18654	18907	16243	12213	10872	9215	8899	8209	7438	7342	7255	7502	7595	8237	11985	14907	15467	16014	16557	
	Mar. Sensible Heat Loss	18431	18952	17143	17488	17578	17907	17911	14417	9973	8134	6891	6742	5886	4949	4770	4683	4881	4857	5914	10159	13682	14471	15185	15811	
	April Sensible Heat Loss	11287	12057	12413	12875	13180	13094	7686	3908	-2028	-4772	-7453	-8270	-9647	-10598	-10873	-13100	-15955	-17819	-14597	-8332	6019	8934	9791	10417	
	May Sensible Heat Loss	8134	8986	9426	10186	10608	10356	3830	-1400	-6693	-9351	-12008	-13011	-14322	-15300	-16233	-18624	-21805	-22845	-19972	-14453	4285	5343	6389	7181	
	June Sensible Heat Loss	-5770	-4688	-3764	-2869	-1980	-1712	-2480	-6356	-10208	-11423	-12801	-13404	-14405	-15340	-16685	-19578	-22516	-24387	-23201	-15843	-10152	-8930	-7784	-6752	
	July Sensible Heat Loss	-8449	-7450	-6557	-5641	-4752	-4251	-4620	-8687	-12328	-13580	-15047	-15644	-16775	-17784	-18773	-21660	-24758	-26895	-25819	-17778	-12706	-11563	-10447	-9474	
	Aug. Sensible Heat Loss	-7390	-6401	-5514	-4677	-3842	-3625	-3617	-7421	-11385	-13163	-15070	-15855	-17023	-18233	-18434	-20852	-23924	-26312	-23924	-14863	-11520	-10464	-9387	-8378	
	Sept Sensible Heat Loss	5312	5999	7020	7780	8451	8862	8120	-1054	-8293	-12360	-15287	-17009	-18516	-19436	-18847	-20495	-22527	-22287	-14828	-9645	1798	2771	3734	4525	
	Oct Sensible Heat Loss	9876	10480	11003	11514	11853	12016	12103	5592	-1318	-5381	-8938	-10476	-11893	-11296	-11267	-11965	-12744	-9550	105	4185	7439	8330	8961	9870	
	Nov Sensible Heat Loss	14523	14878	15295	15580	15919	15833	15754	12841	8811	7304	5813	5663	4973	4285	4604	4932	5262	5355	6079	10076	12915	13588	14023	14317	
	Dec Sensible Heat Loss	16848	16952	17226	17322	17412	17409	17579	14915	11300	10126	9049	8816	8043	7355	7591	7919	8332	8259	8735	12483	15322	15881	16346	16723	
	Zone 2 (Watts)	Jan Sensible Heat Loss	2999	3383	3427	3503	3562	3614	3855	3712	3669	3269	3184	2799	2714	561	486	424	433	318	189	154	121	110	1783	2829
Feb. Sensible Heat Loss		2015	2343	2425	2511	2578	2621	2680	2728	2632	2544	2414	2073	2033	-120	-188	-248	-274	-436	-610	-616	-606	-842	1031	1895	
Mar. Sensible Heat Loss		1909	2281	2345	2422	2472	2541	2574	2533	2392	2251	2165	1843	1785	-986	-463	-523	-576	-728	-858	-811	-764	-749	943	1815	
April Sensible Heat Loss		1359	1758	1839	1907	2002	2027	2006	1921	1771	1656	1544	1248	1199	-918	-1004	-1073	-1126	-1279	-1435	-1370	-1367	-1334	366	1238	
May Sensible Heat Loss		1022	1430	1520	1641	1727	1734	1642	1504	1328	1177	1039	707	658	-1460	-1536	-1588	-1623	-1775	-1905	-2266	-1766	-1725	2	892	
June Sensible Heat Loss		-752	-382	-276	-176	-79	12	47	-53	-278	-543	-795	-1286	-1462	-3669	-3796	-3845	-3818	-3912	-3949	-3753	-3542	-3422	-1704	-836	
July Sensible Heat Loss		-1199	-827	-726	-630	-533	-440	-385	-438	-645	-896	-1142	-1634	-1809	-4024	-4163	-4220	-4201	-4302	-4342	-4144	-3940	-3846	-2141	-1279	
Aug. Sensible Heat Loss		-1069	-695	-592	-495	-402	-316	-270	-280	-439	-687	-948	-1458	-1644	-3862	-4002	-4046	-4010	-4096	-4109	-3896	-3733	-3692	-2010	-1152	
Sept Sensible Heat Loss		720	1110	1263	1384	1496	1574	1627	1326	1044	831	710	325	268	-1885	-1945	-2005	-2013	-2121	-2198	-2115	-2032	-2000	-282	608	
Oct Sensible Heat Loss		1208	1589	1689	1783	1860	1912	1953	1912	1736	1550	1376	1009	960	-1167	-1226	-1233	-1224	-1358	-1479	-1450	-1429	-1405	277	1158	
Nov Sensible Heat Loss		1705	2060	2141	2218	2294	2320	2343	2364	2268	2162	2050	1727	1687	-457	-481	-496	-514	-675	-841	-820	-843	-846	818	1655	
Dec Sensible Heat Loss		1953	2281	2354	2404	2454	2488	2538	2586	2534	2464	2396	2064	2015	-129	-161	-177	-186	-365	-557	-562	-568	-598	1067	1912	
Zone 3 (Watts)		Jan Sensible Heat Loss	34710	39003	40164	41604	42615	43573	44283	45345	44176	41441	39399	34291	32192	10596	8749	7976	8530	8701	8312	8432	8227	8282	24324	32947
	Feb. Sensible Heat Loss	27172	30670	32229	33867	35076	35836	36943	37806	35446	33246	30210	26095	24990	3393	2142	972	731	-91	-1075	-756	-565	-510	15532	24552	
	Mar. Sensible Heat Loss	24789	29280	30441	31881	32693	34049	34560	33437	30084	26692	24649	20931	19429	-2565	-4014	-5184	-6021	-6644	-6836	-5125	-3543	-2893	13546	22765	
	April Sensible Heat Loss	12476	17562	19121	20362	22167	22530	10517	-539	-9774	-16390	-21069	-24391	-24564	-44406	-44941	-45347	-44672	-43478	-42054	-17637	-17048	-16000	638	9856	
	May Sensible Heat Loss	4929	10214	11972	14405	16011	15977	-2004	-11895	-20550	-27014	-31602	-35169	-34900	-54608	-55608	-55756	-55051	-54366	-52853	-57939	-25985	-24738	-7505	2111	
	June Sensible Heat Loss	-24306	-18128	-14837	-11703	-8651	-7141	-13047	-20882	-27876	-33524	-37607	-42345	-42972	-64179	-67053	-68836	-69220	-69944	-69295	-64589	-59533	-56511	-38275	-27556	
	July Sensible Heat Loss	-32778	-26770	-23558	-20376	-17299	-15195	-18932	-27269	-33995	-39714	-44000	-48839	-49911	-71166	-73976	-75972	-76579	-77292	-76518	-71642	-67416	-64745	-46675	-36120	
	Aug. Sensible Heat Loss	-30792	-24736	-21471	-18411	-15430	-13988	-14237	-23159	-30825	-37509	-42820	-48408	-49952	-71597	-73881	-75441	-75717	-75268	-73290	-67870	-64869	-62687	-44798	-34129	
	Sept Sensible Heat Loss	-1823	3065	6213	8645	10847	12402	11126	-10390	-24775	-34627	-40275	-47599	-47527	-68621	-67727	-67744	-65743	-62789	-58777	-55007	-31943	-30895	-13860	-4244	
	Oct Sensible Heat Loss	9100	13789	15745	17582	18990	19948	20658	7964	-6894	-17578	-24863	-31723	-32660	-53595	-52511	-51072	-47998	-44785	-20538	-19424	-18438	-17589	-1348	8069	
	Nov Sensible Heat Loss	20221	24315	25874	27313	28721	29084	29397	29664	27304	24706	22068	18350	17245	-4154	-4412	-4589	-4631	-5453	-6239	-5324	-5331	-5077	10766	19190	
	Dec Sensible Heat Loss	25782	29280	30640	31484	32296	32857	33766	34628	33261	31458	29813	25896	24593	3194	2174	1498	116	435	428	483	16327	24950			
	Zone 3 %30 Occupancy (Watts)	Jan Sensible Heat Loss	44458	47087	47887	48657	49207	49732	50037	50721	49200	46133	43784	39592	37327	26424	25347	25291	26457	27315	27511	28177	28485	29018	39479	43188
Feb. Sensible Heat Loss		36920	38754	39752	40920	41668	41995	42697	43182	40470	37938	34595	31396	30125	19221	18740	18287	18658	18523	18124	18989	19693	20226	30687	34793	
March Sensible Heat Loss		34537	37364	37964	38934	39285	40208	40314	38813	35108	31384	29034	26232	24564	13263	12584	12131	11906	11970	12563	14020	16715	17843	28701	33006	
April Sensible Heat Loss		22224	25646	26644	27415	28759	28689	16271	4837	-4750	-11698	-16684	-19090	-19429	-28578	-28343	-28032	-26745	-24864	-22855	2168	3210	4736	15793	20097	
May Sensible Heat Loss		14677	18298	19495	21458	22603	22136	3750	-6519	-15526	-22322	-27217	-29688	-29765	-38780	-39010	-38441	-37124	-35752	-33654	-38194	-5727	-4002	7650	12352	
June Sensible Heat Loss		-14557	-10044	-7284	-4647	-2058	-982	-7293	-15505	-22853	-28831	-33222	-37043	-37837	-48351	-50456	-51521	-51233	-51330	-50095	-44842	-39275	-35775	-23120	-17315	
July Sensible Heat Loss		-23029	-18686	-16006	-13319	-10706	-9036	-13177	-21892	-28972	-35021	-39616	-43537	-44776	-55338	-57379	-58657	-58593	-58678	-57318	-51894	-47157	-44008	-31520	-25878	
Aug. Sensible Heat Loss		-21043	-16652	-13918	-11355	-8837	-7828	-8482	-17783	-25801	-32816	-38436	-43106	-44817	-55769	-57284	-58125	-57730	-56654	-54090	-48123	-44611	-41951	-29643	-23887	
Sept Sensible Heat Loss		7925	11149	13736	15698	17439	18561	16880	-5014	-19751	-29935	-35890	-42298	-42392	-52793	-51129	-50429	-47816	-44175	-39578	-35262	-11685	-10159	1295	5997	
Oct Sensible Heat Loss		18848	21873	23268	24635	25582	26107	26412	13340	-1870	-12886	-20478	-26422	-27525	-37767	-35913	-33757	-30071	-26171	-1339	321	1820	3147	13807	18310	
Nov Sensible Heat Loss		29969	32399	33397	34366	35313	35243	35151	35040	32328	29398	26453	23651	22380	11674	12186	12726	13296	13161	12960	14421	14927	15659	25921	29431	
Dec Sensible Heat Loss		35530	37384	38163	38537	38888	39016	39520	40004	38285	36150	34198	31197	29728	19022	19336	19876	20644	20112	19315	20180	20686	21219	31482	35191	

Table C.5 Printout of “Latent Loads & Occupancy Rate” Sheet of “input.xls”

		00.00	01.00	02.00	03.00	04.00	05.00	06.00	07.00	08.00	09.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00
Hours		01.00	02.00	03.00	04.00	05.00	06.00	07.00	08.00	09.00	10.00	11.00	12.00	13.00	14.00	15.00	16.00	17.00	18.00	19.00	20.00	21.00	22.00	23.00	00.00
Latent Heat Loss (Watts)	Zone 1	0	0	0	0	0	0	0	-1046	-3010	-3010	-3010	-3010	-3010	-3090	-3090	-3090	-3090	-3090	-3090	-239	0	0	0	0
	Zone 2	-118	0	0	0	0	0	0	0	0	0	0	-118	-118	-1176	-1176	-1176	-1176	-1176	-1176	-1176	-1176	-1176	-588	-118
	Zone 3	-3082	0	0	0	0	0	0	0	0	0	0	-3082	-3082	-30813	-30813	-30813	-30813	-30813	-30813	-30743	-30743	-30743	-15373	-3075
	Zone 3 %3	-949	0	0	0	0	0	0	0	0	0	0	-949	-949	-9494	-9494	-9494	-9494	-9494	-9494	-9424	-9424	-9424	-4712	-942
Occupancy Rate	Zone 1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.30	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.10	0.00	0.00	0.00
	Zone 2	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.10	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.10
	Zone 3	0.10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.10	0.10	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.50	0.10
	Zone 3 %3	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.03	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.15

APPENDIX D

WEATHER DATA FOR ANKARA[25]

Statistics for TUR_Ankara_IWEC

Location -- ANKARA TUR

{N 40° 7'} {E 32° 58'} {GMT +2.0 Hours}

Elevation -- 949m above sea level

Standard Pressure at Elevation -- 90432Pa

Data Source -- IWEC Data

WMO Station 171280

- Using Design Conditions from "World Climate Design Data 2001 ASHRAE Handbook"
- If the design condition source is ASHRAE, the design conditions are carefully generated
- from a period of record (typically 30 years) to be representative of that location and
- be suitable for use in heating/cooling load calculations. If the source is not ASHRAE,
- please consult the referenced source for the reasoning behind the data.

Design Stat	HDB 99.6%	HDB 99%	X WS 1%	X WS 2.5%	X WS 5%	CM WS .4%	CM MDB .4%	CM WS 1%	CM MDB 1%	MWS 99.6%	PWD 99.6%	MWS .4%	PWD .4%
Units	{°C}	{°C}	{m/s}	{m/s}	{m/s}	{m/s}	{°C}	{m/s}	{°C}	{m/s}	{Degree}	{m/s}	{Degree}
HEATING	-16.9	-13.1	9.2	7.9	6.9	8.7	0.6	7.3	0.8	0.4	20	3.5	270
Design Stat	X MnDB Max		X MnDB Min		X StdDB Max		X StdDB Min						
Units	{°C}		{°C}		{°C}		{°C}						
HEATING	35		-19		2.7		5.3						
Design Stat	CDB .4%	C MWB .4%	CDB 1%	C MWB 1%	CDB 2%	C MWB 2%	E WB .4%	E MDB .4%	E WB 1%	E MDB 1%	E WB 2%	E MDB 2%	DP .4%
Units	{°C}	{°C}	{°C}	{°C}	{°C}	{°C}	{°C}	{°C}	{°C}	{°C}	{°C}	{°C}	{°C}
COOLING	32	17.3	30.2	17.1	28.8	16.4	18.6	29	17.8	28.1	17	27.4	14.8
Design Stat	HR .4%	MDB .4%	DP 1%	HR 1%	MDB 1%	DP 2%	HR 2%	MDB 2%	DB Range				
Units	{g/kg}	{°C}	{°C}	{g/kg}	{°C}	{°C}	{g/kg}	{°C}	{°C}				
COOLING	11.8	23	13.9	11.1	22	13	10.5	21.3	15.8				

- Monthly Statistics for Dry Bulb temperatures °C

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Maximum	9.0	13.4	18.2	22.0	28.6	32.6	33.6	33.8	30.0	28.6	19.2	10.8
Day:Hour	5:15	27:14	30:14	24:16	16:14	8:14	3:17	26:14	1:16	1:14	1:14	2:14
Minimum	-22.0	-8.1	-9.0	-4.0	-0.2	0.7	9.0	9.8	4.0	-3.0	-10.1	-9.0
Day:Hour	31:06	1:01	25:04	4:07	3:05	4:05	6:06	23:05	29:06	31:03	28:05	17:05
Daily Avg	-2.4	0.6	2.6	8.9	13.7	17.0	21.5	21.1	17.1	10.3	3.8	0.8

- Maximum Dry Bulb temperature of 33.8°C on Aug 26

- Minimum Dry Bulb temperature of -22.0°C on Jan 31

- Average Hourly Statistics for Dry Bulb temperatures °C

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0:01- 1:00	-4.1	-1.6	-0.4	5.8	9.6	12.4	17.9	16.9	13.0	7.5	1.9	-0.9
1:01- 2:00	-4.5	-1.6	-0.9	5.0	8.7	11.2	16.9	15.8	12.3	6.9	1.6	-0.9
2:01- 3:00	-4.6	-1.9	-1.0	4.7	8.3	10.5	16.2	15.0	11.2	6.4	1.3	-1.1
3:01- 4:00	-4.9	-2.3	-1.3	4.5	7.5	9.8	15.3	14.3	10.4	5.9	1.0	-1.1
4:01- 5:00	-5.0	-2.5	-1.3	4.0	7.1	9.0	14.4	13.5	9.7	5.6	0.7	-1.1
5:01- 6:00	-5.1	-2.5	-1.6	4.2	7.5	10.5	14.9	15.0	9.3	5.5	0.9	-1.0
6:01- 7:00	-5.1	-2.7	-1.5	4.9	9.0	12.3	16.3	16.7	10.3	5.5	1.1	-1.1
7:01- 8:00	-5.3	-2.8	-0.6	6.3	11.0	15.2	19.4	18.3	13.0	6.4	1.3	-1.2
8:01- 9:00	-4.4	-1.3	1.4	8.4	13.4	17.7	21.0	20.4	16.6	8.8	2.8	-0.2
9:01-10:00	-3.0	0.1	3.4	10.1	15.5	19.7	22.8	22.5	19.4	11.3	4.4	1.0
10:01-11:00	-1.7	1.9	4.7	11.7	17.4	21.2	24.3	24.6	21.1	13.6	6.0	2.1
11:01-12:00	-0.2	2.9	5.5	12.2	18.3	22.3	25.1	25.6	22.6	14.9	6.8	3.0
12:01-13:00	1.0	3.6	6.4	13.0	19.1	23.0	26.2	26.6	23.5	15.7	7.5	3.8
13:01-14:00	1.8	4.4	7.4	13.4	19.5	23.5	27.1	27.9	24.3	16.2	8.2	4.5
14:01-15:00	2.1	4.4	7.5	13.6	19.6	23.6	27.4	27.7	24.2	16.1	7.7	4.1
15:01-16:00	1.9	4.4	7.5	13.7	19.5	23.5	27.6	27.6	24.2	15.5	7.2	3.6
16:01-17:00	1.1	4.0	7.4	13.6	19.2	23.0	27.5	27.7	23.6	14.7	6.7	3.0
17:01-18:00	-0.4	3.0	6.3	12.5	18.1	21.9	26.5	25.9	22.0	13.4	5.7	2.2
18:01-19:00	-1.6	2.1	4.9	11.4	16.7	20.5	25.1	24.2	20.0	11.9	4.7	1.5
19:01-20:00	-2.2	1.4	3.6	9.9	15.0	18.5	23.3	22.4	18.3	10.8	3.7	0.8
20:01-21:00	-2.6	0.8	2.3	9.1	13.6	16.6	22.1	21.2	16.6	9.8	3.2	0.3
21:01-22:00	-3.1	0.3	1.5	8.1	12.5	15.1	20.8	20.1	15.6	8.9	2.6	-0.2
22:01-23:00	-3.6	-0.2	0.8	7.3	11.4	13.9	19.6	18.9	14.6	8.3	2.2	-0.6
23:01-24:00	-3.9	-0.7	0.2	6.7	10.6	13.1	18.9	17.9	13.8	7.6	2.0	-0.9
Max Hour	15	15	15	16	15	15	16	14	14	14	14	14
Min Hour	8	8	6	5	5	5	5	5	6	6	5	8

- Monthly Statistics for Dew Point temperatures °C

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Maximum	4.6	4.1	7.0	10.3	14.0	13.0	16.0	14.2	14.0	12.0	8.9	6.8
Day:Hour	8:14	28:19	31:15	26:08	15:19	1:09	4:14	11:13	1:09	1:09	11:14	1:06
Minimum	-24.4	-11.6	-16.0	-9.6	-7.0	-0.6	2.0	-1.2	-5.0	-7.0	-14.4	-11.0
Day:Hour	31:08	19:02	9:13	2:05	2:01	4:05	15:17	1:14	15:16	9:03	6:16	14:10
Daily Avg	-5.5	-4.7	-3.5	2.3	6.2	7.3	9.4	8.1	7.0	3.0	-0.9	-2.1

- Maximum Dew Point temperature of 16.0°C on Jul 4

- Minimum Dew Point temperature of -24.4°C on Jan 31

- Monthly Statistics for Wind Chill/Heat Index temperatures °C **

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Minimum WC	-21	-17	-17	-14	-9	4		9	2	-5	-16	-19
Day:Hour	20:07	22:04	24:22	1:24	2:02	2:24		23:05	6:05	30:02	6:20	14:20
Average WC	-7	-4	-3	2	0	7		9	7	3	-1	-2
Avg Del WC	5	5	5	4	5	2		1	2	3	4	4
# Hours WC	236	386	425	218	49	21		1	5	147	393	308
Maximum HI							28					
Day:Hour							14:12					
Average HI							27					
Avg Del HI							0					
# Hours HI							5					

- **WindChill/HeatIndex Temps -- statistics...only those different from Air Temps

- Monthly Statistics for Extreme temperatures °C

#Days	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max >= 32						1	4	5				
Max <= 0	12	1	2								2	4
Min <= 0	30	26	25	7	2					6	12	25
Min <=-18	1											

- Monthly Heating/Cooling Degree Days/Hours

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
HDD base 10C	384	265	234	58	9	1	0	0	0	50	186	285
HDD base 18C	632	489	478	272	138	58	0	1	40	241	426	533
CDD base 10C	0	0	4	25	123	211	357	345	212	60	0	0
CDD base 18C	0	0	0	0	4	28	109	98	12	3	0	0
CDH base 20C	0	0	0	13	312	1098	2182	2101	875	120	0	0
CDH base 23C	0	0	0	0	96	532	1071	1095	264	36	0	0
CDH base 27C	0	0	0	0	8	131	279	290	19	4	0	0

- 1338 annual cooling degree-days (10°C baseline)

- 1472 annual heating degree-days (10°C baseline)

- 253 annual cooling degree-days (18°C baseline)

- 3307 annual heating degree-days (18°C baseline)

- Monthly Average Daily Relative Humidity %

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
4am	85	77	78	81	86	79	66	66	80	77	80	87
10am	81	69	65	62	58	48	47	44	50	63	71	82
3pm	63	52	49	49	44	36	32	29	31	44	59	69
10pm	82	70	68	69	66	61	47	47	57	66	75	83
Maximum	100	92	97	97	100	93	88	91	100	100	95	100
Day:Hour	2:01	2:03	6:07	4:06	11:03	1:24	16:23	11:04	23:01	17:07	11:08	24:17
Minimum	35	32	15	16	19	20	14	11	13	24	27	45
Day:Hour	28:16	24:15	29:17	4:17	3:15	9:14	15:17	26:14	15:16	8:14	6:15	31:14

- Monthly Indicators for Precipitation/Moisture (kPa)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5	0.4	0.5	0.7	1.0	1.0	1.1	1.1	0.9	0.8	0.6	0.6

- Monthly Statistics for Solar Wh/m²

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Direct Avg	1216	2353	1817	2096	2961	4615	5828	5888	4983	2386	1422	564
Direct Max	5309	6632	7883	7246	8233	9224	8985	8510	7038	7015	5409	2750
Day	27	26	29	4	3	9	15	2	16	7	8	22
Diffuse Avg	1120	1465	2259	2959	3350	3167	2844	2276	1993	1806	1242	998

- Maximum Direct Solar of 9224 Wh/m² on Jun 9

- Monthly Average Daily Wind Direction ° {N=0 or 360,E=90,S=180,W=270}

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
46	99	139	136	109	120	93	93	68	86	89	83

- Monthly Statistics for Wind Speed m/s

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Maximum	9.3	12.4	11.0	14.4	10.3	11.3	11.8	12.9	11.8	10.3	12.9	10.3
Day:Hour	20:16	18:12	24:14	1:13	7:12	1:18	30:14	10:17	21:16	1:14	6:14	13:14
Minimum	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Day:Hour	1:01	1:01	1:01	1:05	3:03	1:04	1:05	1:02	1:02	1:01	1:02	2:23
Daily Avg	1.3	2.6	2.8	2.7	2.1	2.4	3.4	3.4	2.4	2.1	2.5	1.7

- Maximum Wind Speed of 14.4 m/s on Apr 1

- Minimum Wind Speed of 0.0 m/s on Jan 1

- Monthly Calculated "undisturbed" Ground Temperatures °C

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.5 m	-0.2	-1.2	0.5	3.2	10.2	15.6	19.3	20.4	18.5	14.3	8.7	3.5
2.0 m	3.3	1.6	1.9	3.4	8.1	12.3	15.7	17.5	17.1	14.8	10.9	6.8
4.0 m	6.3	4.5	4.1	4.6	7.3	10.2	12.8	14.6	15.0	14.0	11.7	9.0

- Climate type "Dfb" (Köppen classification)

- Moist continental (warm summer, cold winter, no dry season, lat. 30-60°N)

- Typical/Extreme Period Determination

- Summer is Jun:Aug

Extreme Summer Week (nearest maximum temperature for summer)

Extreme Hot Week Period selected: Jul 13:Jul 19, Maximum Temp= 33.80°C, Deviation=|10.998|°C

Typical Summer Week (nearest average temperature for summer)

Typical Week Period selected: Aug 17:Aug 23, Average Temp= 19.91°C, Deviation=|0.034|°C

- Winter is Dec:Feb

Extreme Winter Week (nearest minimum temperature for winter)

Extreme Cold Week Period selected: Jan 27:Feb 2, Minimum Temp= -22.00°C, Deviation=|17.256|°C

Typical Winter Week (nearest average temperature for winter)

Typical Week Period selected: Dec 22:Jan 5, Average Temp= -0.37°C, Deviation=|0.098|°C

- Autumn is Sep:Nov

Typical Autumn Week (nearest average temperature for autumn)

Typical Week Period selected: Oct 6:Oct 12, Average Temp= 10.39°C, Deviation=|0.624|°C

- Spring is Mar:May

Typical Spring Week (nearest average temperature for spring)

Typical Week Period selected: Apr 26:May 2, Average Temp= 8.39°C, Deviation=|0.523|°C

APPENDIX E

HEAT TRANSFER COEFFICIENT CALCULATIONS

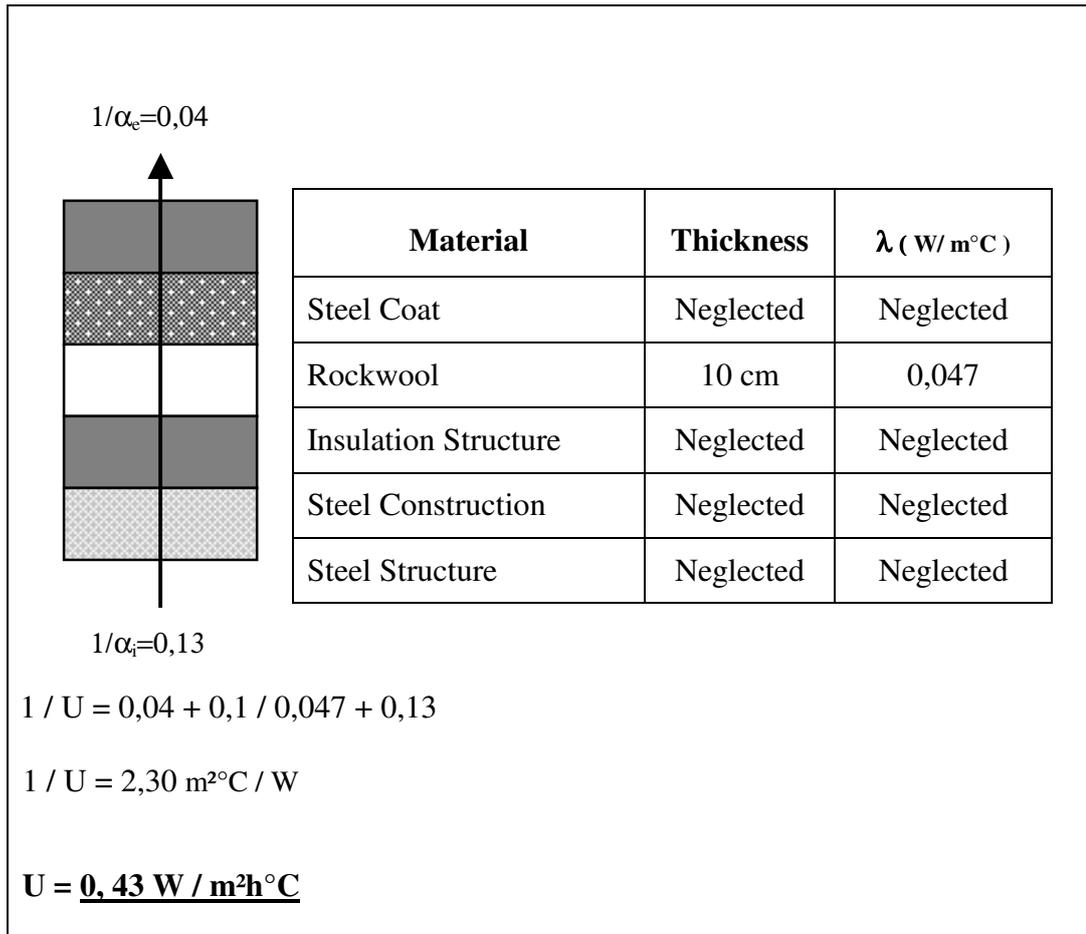


Figure E.1 “Rf-1 Terrace Roof 1” Overall Heat Transfer Coefficient Calculation

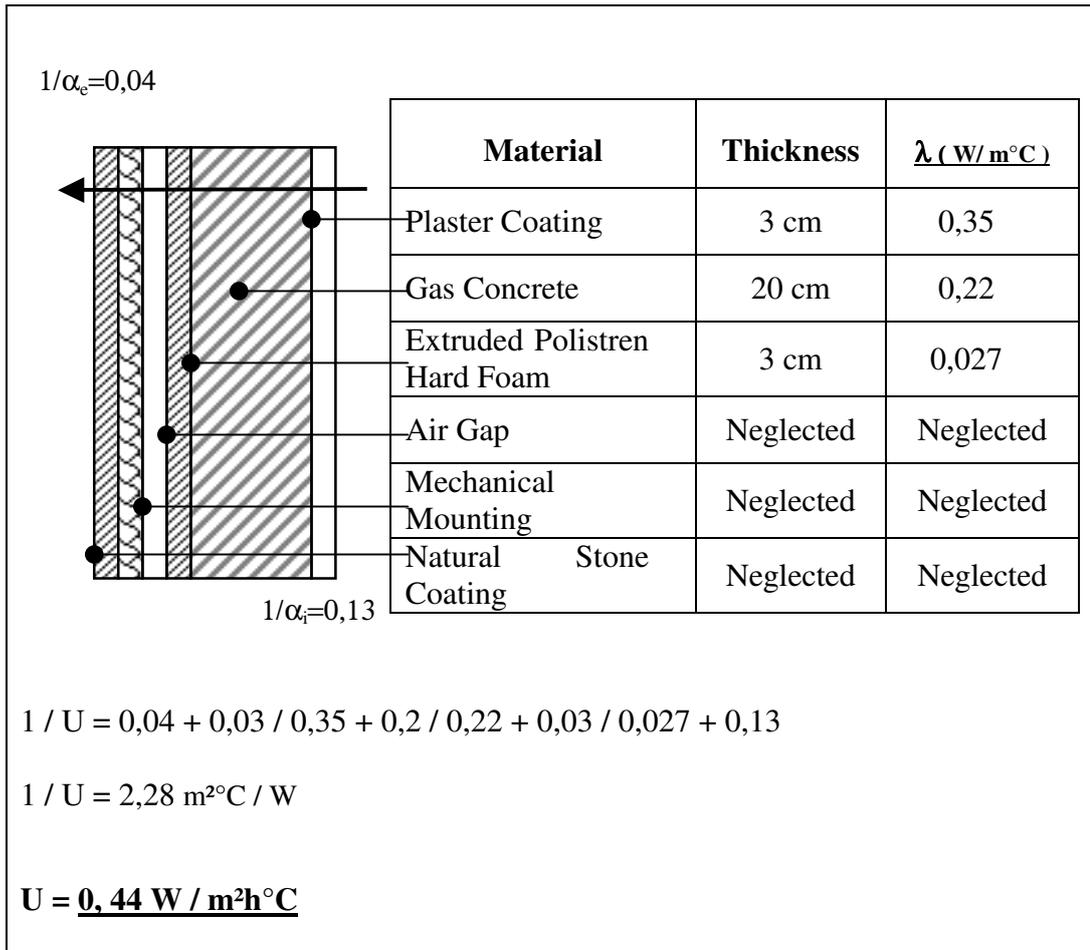


Figure E.2 “Ew-1 Exterior Wall 1” Overall Heat Transfer Coefficient Calculation

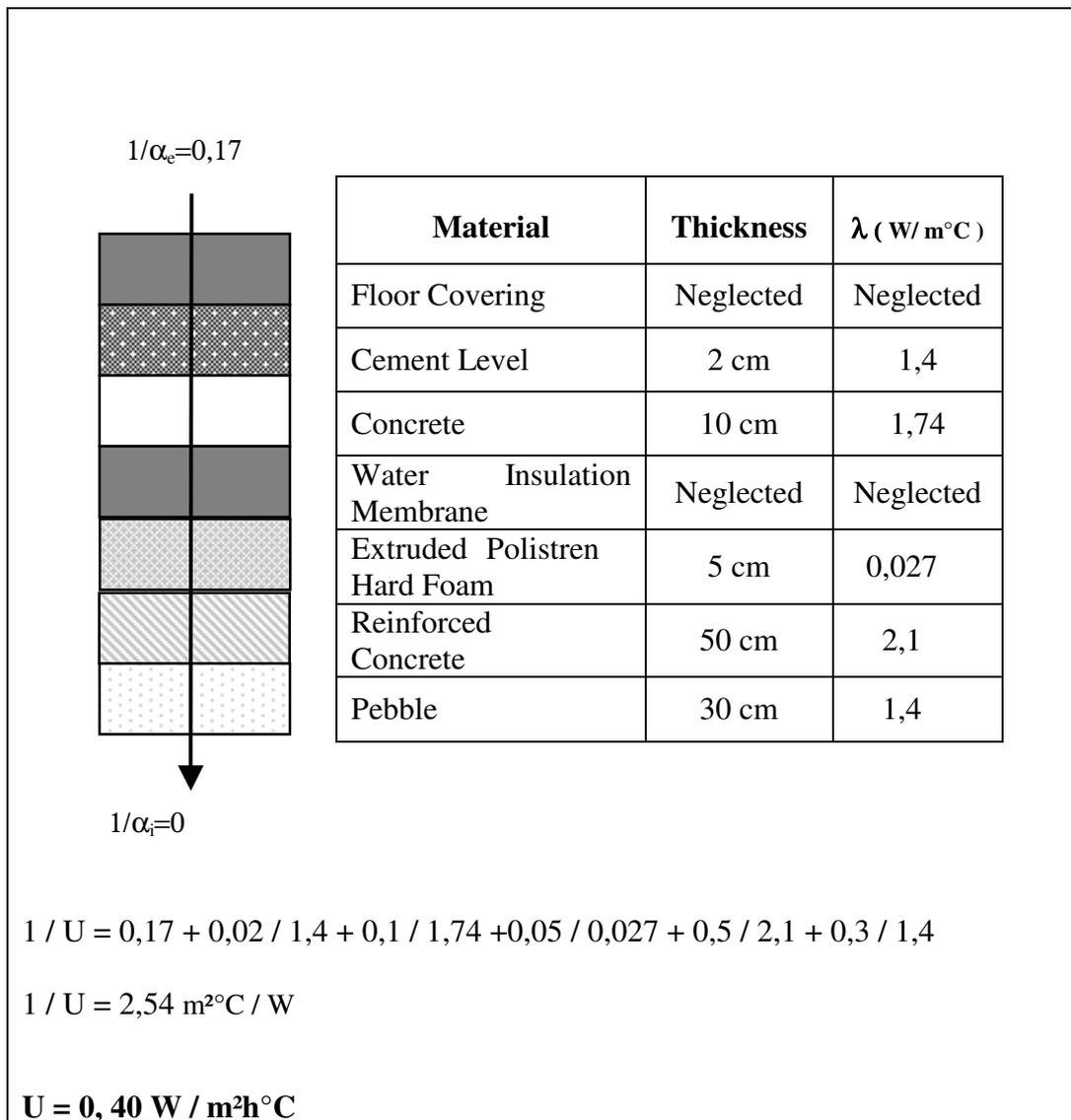


Figure E.3 “Gs-1 Ground Touching Slab 1” Overall Heat Transfer Coefficient Calculation

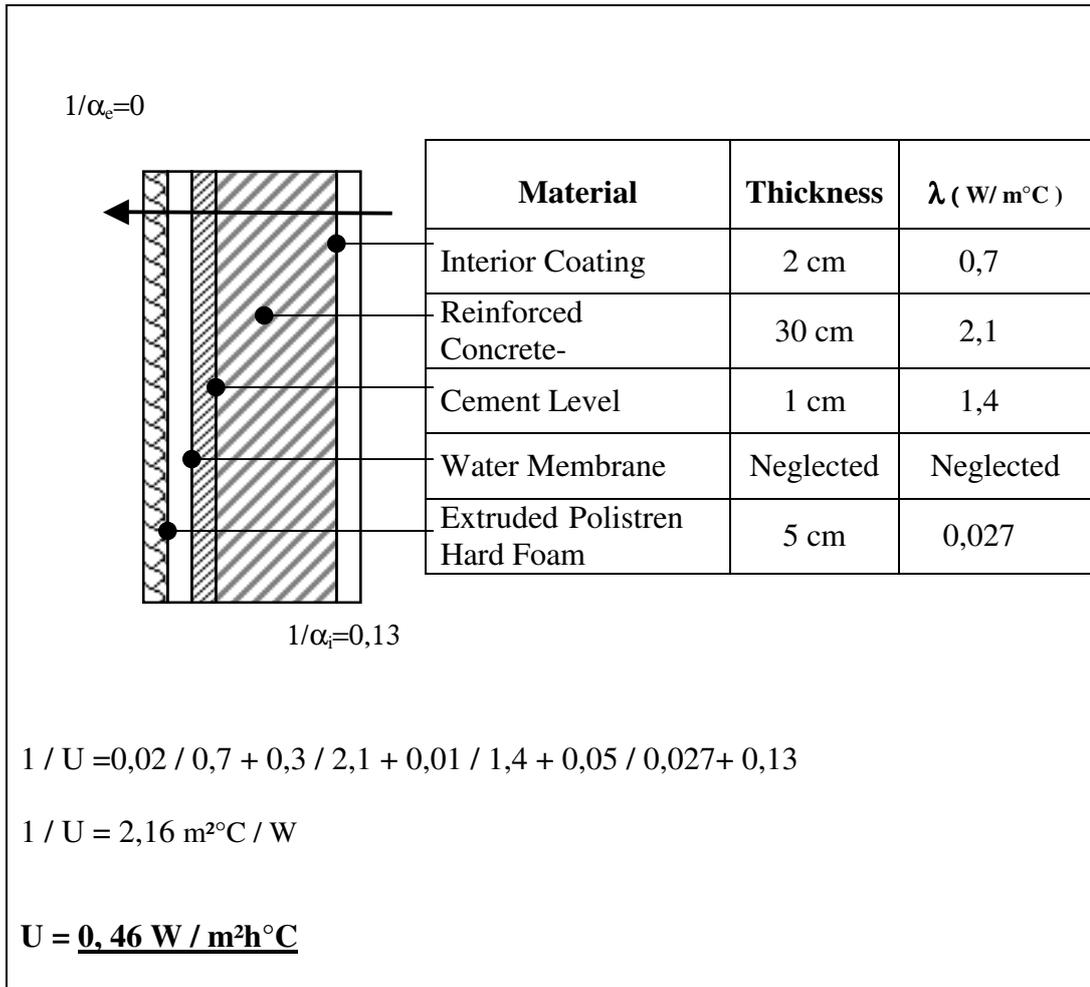


Figure E.4 “Gw-1 Ground Touching Wall 1” Overall Heat Transfer Coefficient Calculation

APPENDIX F

INPUT DATA FOR SPACE LOAD CALCULATION “101-CORRIDOR”

101-Corridor

1. General Details:

Floor Area 57,0 m²
Avg. Ceiling Height 3,2 m
Building Weight 341,8 kg/m²

1.1. OA Ventilation Requirements:

Space Usage **User-Defined**
OA Requirement 1 0,0 L/s/person
OA Requirement 2 0,00 L/(s·m²)

2. Internals:

2.1. Overhead Lighting:

Fixture Type **Recessed (Unvented)**
Wattage 5,00 W/m²
Ballast Multiplier 1,00
Schedule **Lighting-commercial**

2.2. Task Lighting:

Wattage 0,00 W/m²
Schedule **None**

2.3. Electrical Equipment:

Wattage 0,00 W/m²
Schedule **None**

2.4. People:

Occupancy 1 Person
Activity Level **Sedentary Work**

Sensible **82,1** W/person
 Latent **79,1** W/person
 Schedule **Human-Commercial**

2.5. Miscellaneous Loads:

Sensible **0** W
 Schedule **None**
 Latent **0** W
 Schedule **None**

3. Walls, Windows, Doors:

Exp.	Wall Gross Area (m²)	Window 1 Qty.	Window 2 Qty.	Door 1 Qty.
W	16,0	1	1	0

3.1. Construction Types for Exposure W

Wall Type **Ew4**
 1st Window Type **101 Window**
 1st Window Shade Type **101-Shade**
 2nd Window Type **101 Window(2)**
 2nd Window Shade Type **Z13-Shade**

4. Roofs, Skylights:

Exp.	Roof Gross Area (m²)	Roof Slope (deg.)	Skylight Qty.
H	57,0	0	0

4.1. Construction Types for Exposure H

Roof Type **Rf4**

5. Infiltration:

Design Cooling **0,00** L/s
 Design Heating **0,00** L/s
 Energy Analysis **0,00** L/s

Infiltration occurs only when the fan is off.

6. Floors:

Type **Floor Above Conditioned Space**.....

(No additional input required for this floor type).

7. Partitions:

(No partition data).

APPENDIX G

SCHEMATIC LAY-OUTS OF AC UNITS

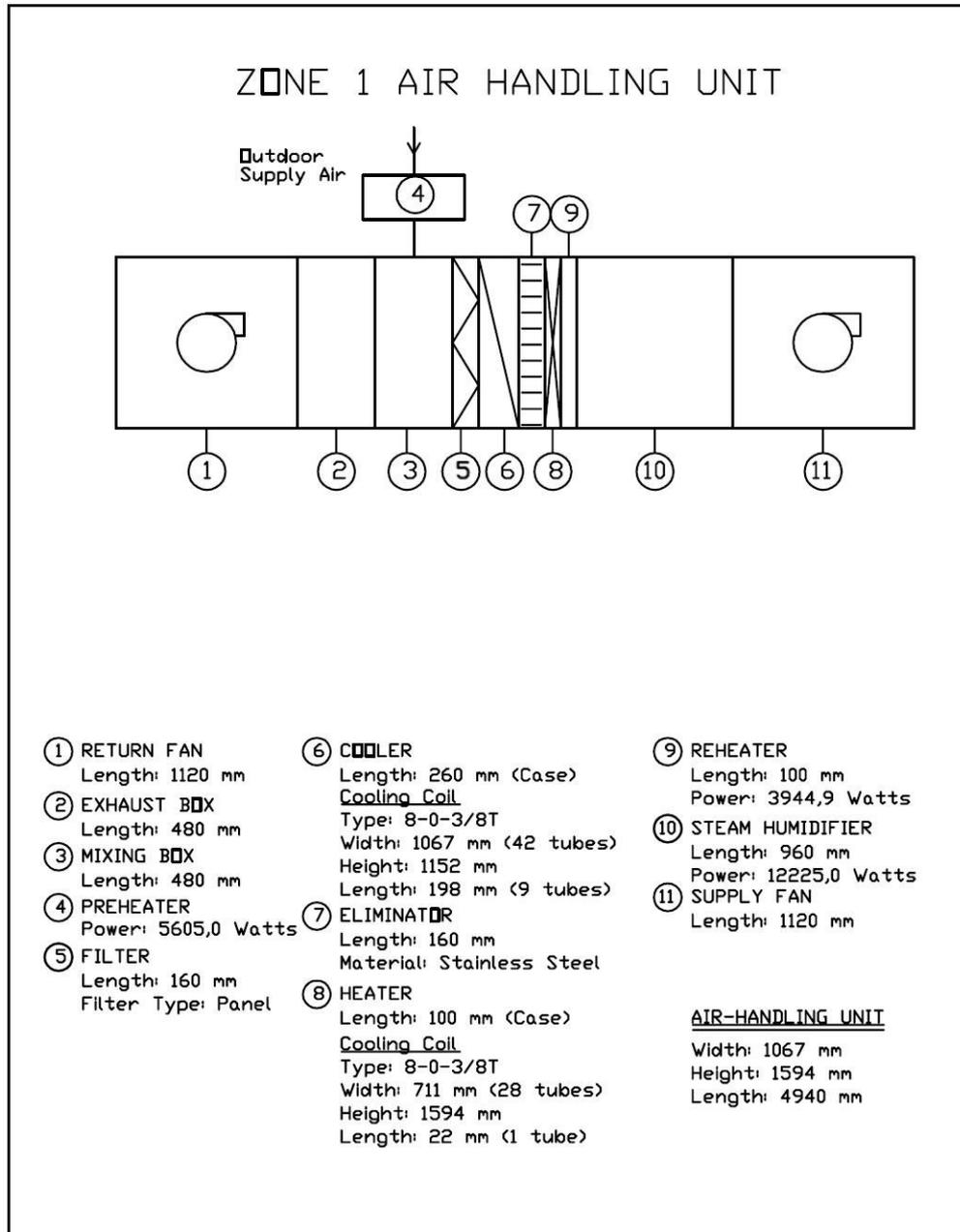


Figure G.1 Schematic Lay-out of Air Handling Unit of “Zone 1”

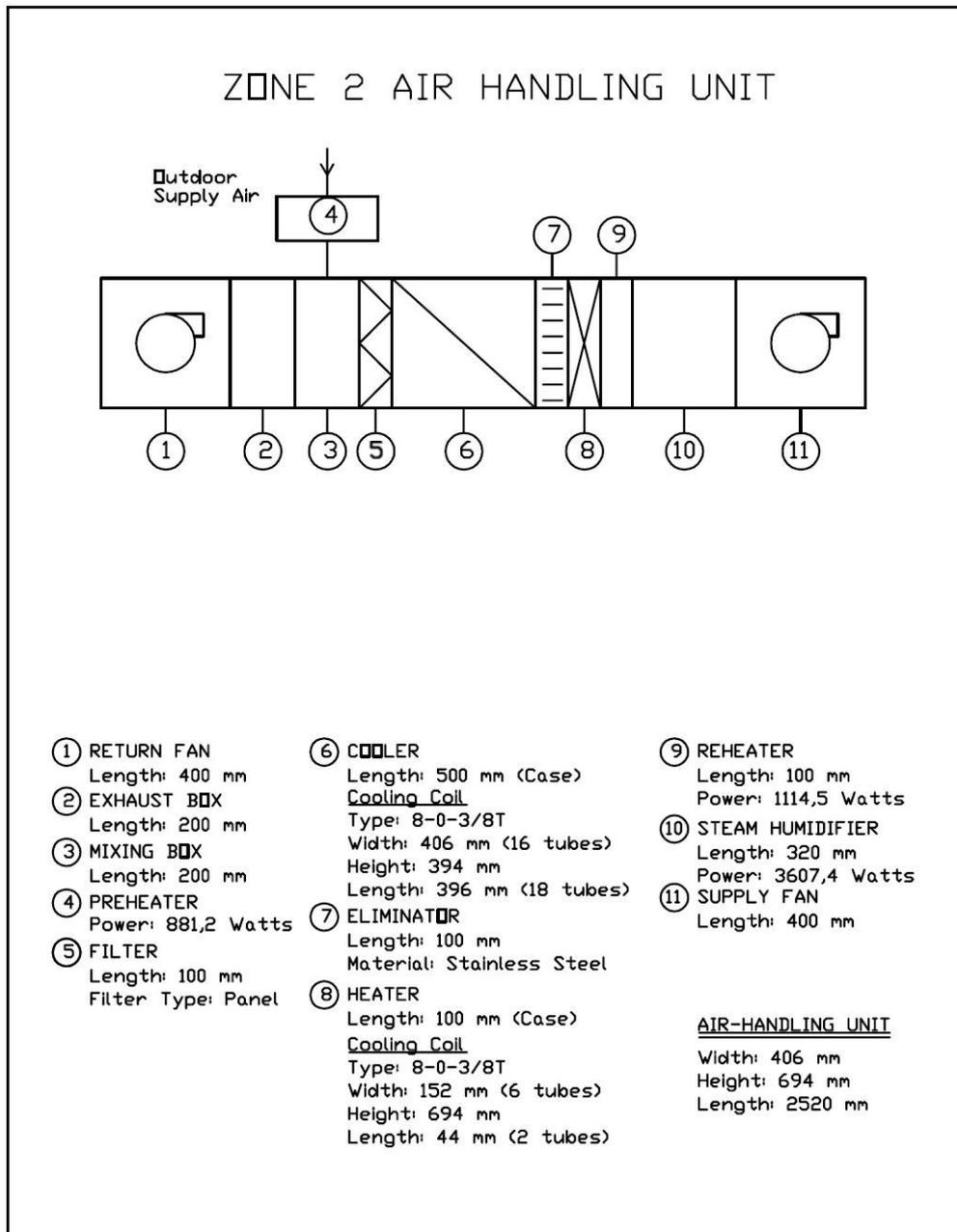
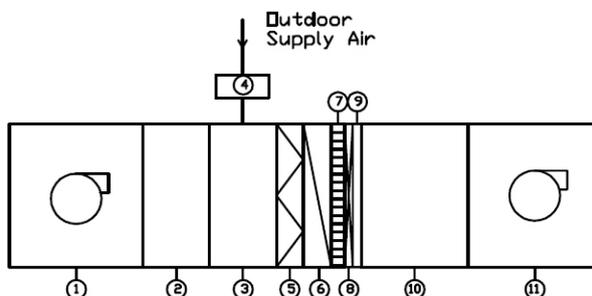


Figure G.2 Schematic Lay-out of Air Handling Unit of “Zone 2”

ZONE 3 AIR HANDLING UNIT



- | | | |
|--|---|--|
| <p>① RETURN FAN
Length: 1600 mm</p> <p>② EXHAUST BOX
Length: 800 mm</p> <p>③ MIXING BOX
Length: 800 mm</p> <p>④ PREHEATER
Power: 13209,0 Watts</p> <p>⑤ FILTER
Length: 320 mm
Filter Type: Panel</p> | <p>⑥ COOLER
Length: 320 mm (Case)
<u>Cooling Coil</u>
Type: 8-0-3/8T
Width: 1626 mm (64 tubes)
Height: 1696 mm
Length: 264 mm (12 tubes)</p> <p>⑦ ELIMINATOR
Length: 160 mm
Material: Stainless Steel</p> <p>⑧ HEATER
Length: 100 mm (Case)
<u>Heating Coil</u>
Type: 8-0-3/8T
Width: 1626 mm (64 tubes)
Height: 2410 mm
Length: 22 mm (1 tube)</p> | <p>⑨ REHEATER
Length: 100 mm
Power: 23317,5 Watts</p> <p>⑩ STEAM HUMIDIFIER
Length: 1280 mm
Power: 56114,7 Watts</p> <p>⑪ SUPPLY FAN
Length: 1600 mm</p> |
| <p><u>AIR-HANDLING UNIT</u>
Width: 1626 mm
Height: 2410 mm
Length: 7080 mm</p> | | |

Figure G.3 Schematic Lay-out of Air Handling Unit of “Zone 3”

Table H.1 Printout of “Zone1coil” Sheet of “result.xls”

Zone 1 Cooling Coil					
Cooling Coil Water Mass Flow Rate (kg/s)					
2,798					
Number of Tubes (Width)	Width (m)	Height (m)	Air Face Area (m ²)	Number of Tubes (Length)	Length (m)
42,0	1,067	1,152	1,229	9,0	0,198
Cooling Coil Power at Design (Watts)	Reheater Power at Design (Watts)	Humidifier Power at Design (Watts)	Maximum Cooling Coil Power (Watts)	Maximum Reheater Power (Watts)	Maximum Humidifier Power (Watts)
59767,1	3944,9	0,0	30062,4	887,2	3470,4
Zone 1 Heating Coil					
Heating Coil Water Mass Flow Rate (kg/s)					
0,645					
Number of Tubes (Width)	Width (m)	Height (m)	Air Face Area (m ²)	Number of Tubes (Length)	Length (m)
28,0	0,711	1,594	1,134	1,0	0,022
Preheater Power at Design (Watts)	Heating Coil Power at Design (Watts)	Humidifier Power at Design (Watts)	Maximum Preheater Power (Watts)	Maximum Heating Coil Power (Watts)	Maximum Humidifier Power (Watts)
5605,0	48153,6	12225,0	0,0	31438,3	6560,0

Table H.2 cont.'d

Zone1	Hours	00.00-01.00	01.00-02.00	02.00-03.00	03.00-04.00	04.00-05.00	05.00-06.00	06.00-07.00	07.00-08.00	08.00-09.00	09.00-10.00	10.00-11.00	11.00-12.00	12.00-13.00	13.00-14.00	14.00-15.00	15.00-16.00	16.00-17.00	17.00-18.00	18.00-19.00	19.00-20.00	20.00-21.00	21.00-22.00	22.00-23.00	23.00-00.00
	Jan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Feb	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	March	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	April	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.1	5.1	5.3	5.7	6.0	6.2	6.2	6.5	6.8	7.0	6.7	0.0	0.0	0.0	0.0	0.0
	May	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.5	6.8	7.8	8.4	8.5	8.7	8.8	8.9	9.1	9.3	9.3	9.2	10.2	0.0	0.0	0.0	0.0
	June	10.4	10.4	10.4	10.4	10.4	10.4	10.4	9.4	8.3	8.8	8.8	8.9	8.9	9.0	9.1	9.3	9.5	9.5	9.5	10.3	10.4	10.4	10.4	10.4
	July	10.4	10.4	10.4	10.4	10.4	10.4	10.4	9.9	9.3	9.4	9.5	9.5	9.6	9.7	9.7	9.8	9.9	9.9	9.9	10.3	10.4	10.4	10.4	10.4
	Aug	10.4	10.4	10.4	10.4	10.4	10.4	10.4	9.7	8.8	9.1	9.2	9.3	9.4	9.5	9.5	9.6	9.7	9.7	9.7	10.3	10.4	10.4	10.4	10.4
	Sept	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.6	7.7	8.6	8.9	9.1	9.2	9.3	9.2	9.3	9.4	9.4	8.9	10.2	0.0	0.0	0.0	0.0
	Oct	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.3	5.4	6.0	6.4	6.6	6.5	6.5	6.6	6.7	6.2	0.0	0.0	0.0	0.0	0.0	0.0
	Nov	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Dec	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Jan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Feb	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	March	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	April	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	0.0	0.0	0.0	0.0	0.0
	May	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.3	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0
	June	14.0	14.0	14.0	16.3	18.7	19.4	17.5	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0
	July	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.4	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0
	Aug	14.0	14.0	14.0	14.0	14.0	14.3	14.3	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0
	Sept	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.2	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	0.0	0.0	0.0	0.0	0.0
	Oct	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	12.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	0.0	0.0	0.0	0.0	0.0
	Nov	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Dec	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Jan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Feb	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	March	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	April	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.3	6.3	6.5	6.8	6.8	6.9	6.9	7.2	7.3	7.4	7.3	0.0	0.0	0.0	0.0	0.0
	May	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.3	8.8	9.1	9.4	9.5	9.5	9.6	9.6	9.7	9.8	9.8	9.8	10.3	0.0	0.0	0.0	0.0
	June	10.4	10.4	10.4	10.4	10.4	10.4	10.4	9.7	9.2	9.3	9.4	9.5	9.5	9.6	9.6	9.8	9.8	9.9	9.9	10.3	10.4	10.4	10.4	10.4
	July	10.4	10.4	10.4	10.4	10.4	10.4	10.4	9.9	9.4	9.5	9.6	9.6	9.7	9.7	9.7	9.8	9.9	9.9	9.9	10.4	10.4	10.4	10.4	10.4
	Aug	10.4	10.4	10.4	10.4	10.4	10.4	10.4	9.8	9.3	9.5	9.6	9.6	9.7	9.7	9.7	9.8	9.9	9.9	9.9	10.3	10.4	10.4	10.4	10.4
	Sept	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.3	8.9	9.4	9.6	9.7	9.7	9.8	9.7	9.8	9.8	9.8	9.8	10.3	0.0	0.0	0.0	0.0
	Oct	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.3	6.3	6.7	6.9	7.1	7.0	7.0	7.1	7.1	6.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Nov	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Dec	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Jan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Feb	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	March	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	April	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.6	9.6	9.6	9.6	9.6	9.6	9.5	9.4	9.3	9.5	0.0	0.0	0.0	0.0	0.0
	May	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.5	13.4	13.4	13.3	13.3	13.3	13.2	13.0	13.0	13.2	13.5	0.0	0.0	0.0	0.0
	June	13.9	13.9	13.9	16.2	18.6	19.4	17.4	13.8	13.5	13.5	13.4	13.4	13.3	13.3	13.2	13.1	13.0	12.9	13.0	13.4	13.7	13.8	13.8	13.8
	July	13.8	13.8	13.8	13.9	13.9	13.9	13.9	14.2	13.7	13.6	13.5	13.4	13.3	13.3	13.2	13.0	12.8	12.7	12.8	13.3	13.6	13.7	13.7	13.7
	Aug	13.8	13.8	13.9	13.9	13.9	14.2	13.8	13.8	13.6	13.5	13.4	13.3	13.2	13.1	13.1	13.0	12.8	12.7	12.9	13.5	13.7	13.7	13.8	13.8
	Sept	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.5	13.4	13.3	13.2	13.1	13.1	13.0	12.9	13.0	13.4	13.7	0.0	0.0	0.0	0.0
	Oct	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.6	9.6	9.5	9.5	9.6	9.5	9.5	9.6	0.0	0.0	0.0	0.0	0.0	0.0
	Nov	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Dec	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Jan	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Feb	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	March	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	April	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.7	9.8	9.9	10.0	10.2	10.2	10.3	10.5	10.5	10.3	0.0	0.0	0.0	0.0	0.0
	May	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.8	14.1	14.3	14.3	14.4	14.5	14.6	14.7	14.7	14.8	14.8	0.0	0.0	0.0	0.0
	June	14.4	14.3	14.3	16.5	18.8	19.5	17.6	14.2	14.1	14.3	14.4	14.5	14.5	14.6	14.7	14.8	15.0	15.1	15.2	15.1	14.9	14.8	14.8	14.8
	July	14.6	14.5	14.4	14.4	14.3	14.3	14.3																	

Table H.2 cont.'d

Zone 1	Hours	00.00-01.00	01.00-02.00	02.00-03.00	03.00-04.00	04.00-05.00	05.00-06.00	06.00-07.00	07.00-08.00	08.00-09.00	09.00-10.00	10.00-11.00	11.00-12.00	12.00-13.00	13.00-14.00	14.00-15.00	15.00-16.00	16.00-17.00	17.00-18.00	18.00-19.00	19.00-20.00	20.00-21.00	21.00-22.00	22.00-23.00	23.00-00.00	
	Jan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Feb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	March	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	April	0	0	0	0	0	0	0	0	0	349	2231	3434	5484	6736	6948	9623	12595	13849	9681	0	0	0	0	0	
	May	0	0	0	0	0	0	0	0	0	4280	8427	10095	12040	13334	14409	16890	20108	20260	16456	15024	0	0	0	0	
	June	6392	5241	4257	3361	2471	2203	2922	5100	6578	9216	11692	13076	12632	15963	17470	20498	23297	24557	22349	16729	11058	9758	8537	7438	
	July	9245	8182	7230	6256	5309	4775	5169	8343	10806	13368	15951	17121	19061	20733	21991	25122	28461	30082	27771	19085	13777	12561	11373	10336	
	Aug	8117	7065	6120	5230	4340	4116	4108	6833	9537	12845	16308	17904	19736	21874	21963	24479	27930	29170	25485	15937	12515	11391	10244	9169	
	Sept	0	0	0	0	0	0	0	0	3810	10068	14355	17192	19414	20919	20213	21975	23740	22416	13113	10114	0	0	0	0	
	Oct	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Nov	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Dec	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Jan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Feb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	March	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	April	0	0	0	0	0	0	0	0	0	2255	2267	2335	2214	2317	2188	2169	2246	2169	2181	2179	0	0	0	0	0
	May	0	0	0	0	0	0	0	0	842	3408	3348	3470	3382	3404	3220	3297	3220	3388	3331	3224	408	0	0	0	0
	June	0	0	0	0	0	0	0	0	596	2522	2454	2371	2379	2494	2357	2435	2357	2400	2399	2361	326	0	0	0	0
	July	0	0	0	0	0	0	0	0	0	299	379	422	381	293	197	195	350	272	199	268	104	0	0	0	0
	Aug	0	0	0	0	0	0	0	0	308	1543	1461	1551	1429	1523	1284	1361	1284	1361	1342	1370	232	0	0	0	0
	Sept	0	0	0	0	0	0	0	0	708	2853	2833	2918	2822	2890	2759	2682	2682	2649	2687	2796	351	0	0	0	0
	Oct	0	0	0	0	0	0	0	0	0	1758	1692	1742	1683	1761	1690	1614	1693	1614	1669	0	0	0	0	0	0
	Nov	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Dec	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Jan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Feb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	March	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	April	0	0	0	0	0	0	0	0	0	782	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	May	0	0	0	0	0	0	0	0	887	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	June	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	July	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Aug	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sept	0	0	0	0	0	0	0	0	848	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Oct	0	0	0	0	0	0	0	0	0	579	243	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Nov	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Dec	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table H.3 cont.'d

Zone1	Hours	00.00-01.00	01.00-02.00	02.00-03.00	03.00-04.00	04.00-05.00	05.00-06.00	06.00-07.00	07.00-08.00	08.00-09.00	09.00-10.00	10.00-11.00	11.00-12.00	12.00-13.00	13.00-14.00	14.00-15.00	15.00-16.00	16.00-17.00	17.00-18.00	18.00-19.00	19.00-20.00	20.00-21.00	21.00-22.00	22.00-23.00	23.00-00.00	
Air Coil Leaving Humidity Ratio (gWater / kgAir)	Jan	8.1	8.1	8.1	8.1	8.1	8.1	8.1	7.5	5.7	5.4	5.2	5.0	4.7	4.4	4.3	4.3	4.5	4.7	4.9	7.9	8.1	8.1	8.1	8.1	
	Feb	8.1	8.1	8.1	8.1	8.1	8.1	8.1	7.5	5.3	4.9	4.4	4.3	3.9	3.4	3.3	3.3	3.5	3.6	3.9	7.8	8.1	8.1	8.1	8.1	
	March	8.1	8.1	8.1	8.1	8.1	8.1	8.1	7.5	4.9	4.1	3.4	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	7.8	8.1	8.1	8.1	8.1	
	April	8.1	8.1	8.1	8.1	8.1	8.1	8.1	6.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.7	8.1	8.1	8.1	8.1	
	May	10.4	10.4	10.4	10.4	10.4	10.4	10.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.4	10.4	10.4	10.4	10.4
	June	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	July	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Aug	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Sept	10.4	10.4	10.4	10.4	10.4	10.4	10.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.4	10.4	10.4	10.4	10.4
	Oct	8.1	8.1	8.1	8.1	8.1	8.1	8.1	7.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.4	7.7	8.1	8.1	8.1	8.1	
	Nov	8.1	8.1	8.1	8.1	8.1	8.1	8.1	7.5	5.0	4.3	4.0	3.9	4.0	4.0	4.0	4.0	3.9	4.0	4.0	3.9	7.9	8.1	8.1	8.1	8.1
	Dec	8.1	8.1	8.1	8.1	8.1	8.1	8.1	7.5	5.4	5.2	4.8	4.7	4.3	4.0	4.1	4.3	4.5	4.4	4.7	7.9	8.1	8.1	8.1	8.1	
Air Room Supply Temperature (°C)	Jan	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	
	Feb	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	
	March	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	28.8	27.4	27.1	27.0	27.0	27.2	28.8	30.0	30.0	30.0	30.0	30.0	
	April	30.0	30.0	30.0	30.0	30.0	30.0	30.0	28.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	30.0	30.0	30.0	30.0	30.0	
	May	34.0	34.0	34.0	34.0	34.0	34.0	33.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	34.0	34.0	34.0	34.0	
	June	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	July	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Aug	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Sept	34.0	34.0	34.0	34.0	34.0	34.0	34.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	28.8	31.4	34.0	34.0	
	Oct	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.2	30.0	30.0	30.0	30.0	30.0	
	Nov	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	28.7	28.4	27.4	26.4	26.9	27.4	27.8	28.0	29.1	30.0	30.0	30.0	30.0	30.0	
	Dec	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	
Air Room Supply Humidity Ratio (gWater / kgAir)	Jan	8.1	8.1	8.1	8.1	8.1	8.1	8.1	7.9	7.3	7.2	7.2	7.1	7.0	6.9	6.8	6.8	6.9	7.0	7.1	8.1	8.1	8.1	8.1	8.1	
	Feb	8.1	8.1	8.1	8.1	8.1	8.1	8.1	7.9	7.2	7.0	6.8	6.8	6.7	6.5	6.5	6.5	6.5	6.5	6.7	8.0	8.1	8.1	8.1	8.1	
	March	8.1	8.1	8.1	8.1	8.1	8.1	8.1	7.8	6.9	6.7	6.4	6.4	6.4	6.3	6.3	6.3	6.3	6.3	6.3	8.1	8.1	8.1	8.1	8.1	
	April	8.1	8.1	8.1	8.1	8.1	8.1	8.1	7.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.9	8.1	8.1	8.1	8.1		
	May	10.4	10.4	10.4	10.4	10.4	10.4	10.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.4	10.4	10.4	10.4	
	June	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	July	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Aug	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Sept	10.4	10.4	10.4	10.4	10.4	10.4	10.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.4	10.4	10.4	10.4	
	Oct	8.1	8.1	8.1	8.1	8.1	8.1	8.1	7.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.3	7.9	8.1	8.1	8.1	8.1	
	Nov	8.1	8.1	8.1	8.1	8.1	8.1	8.1	7.8	6.8	6.5	6.4	6.4	6.4	6.3	6.3	6.3	6.3	6.3	6.3	6.3	8.1	8.1	8.1	8.1	
	Dec	8.1	8.1	8.1	8.1	8.1	8.1	8.1	7.9	7.1	7.0	6.8	6.8	6.7	6.5	6.5	6.5	6.5	6.7	6.7	6.7	8.1	8.1	8.1	8.1	
Water Coil Entering Temperature (°C)	Jan	61.0	61.5	61.5	62.0	62.0	62.5	62.5	63.0	64.5	68.0	68.0	68.0	77.5	77.0	78.5	78.5	78.5	79.5	81.0	82.0	89.5	89.5	89.5	89.5	
	Feb	59.0	59.0	59.5	60.0	60.0	60.0	60.5	60.5	61.5	60.0	78.5	77.5	77.0	78.5	77.0	77.0	77.5	79.0	79.5	80.5	89.5	89.5	89.5	89.5	
	March	58.0	58.5	58.5	59.0	59.0	59.5	59.5	59.5	63.5	79.0	77.5	77.0	78.0	71.0	65.0	64.0	63.5	63.5	66.5	74.0	54.5	55.5	56.5	57.0	
	April	53.5	54.0	54.5	54.5	55.0	55.0	55.5	55.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	50.0	50.5	51.5	52.0	
	May	54.0	55.0	55.5	56.0	56.5	56.0	49.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	51.0	52.0	52.5	53.5	
	June	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	July	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Aug	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Sept	52.0	52.5	53.5	54.0	54.5	55.0	54.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.0	49.5	50.0	50.5	
	Oct	52.0	52.5	53.0	53.5	54.0	54.0	54.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	Nov	56.5	56.5	57.0	57.5	57.5	57.5	57.5	62.0	78.0	77.0	71.5	69.5	65.0	61.0	63.0	65.5	68.0	70.0	75.0	54.5	55.0	55.5	56.0	56.0	
	Dec	58.5	58.5	59.0	59.0	59.0	59.0	59.0	64.0	80.5	79.5	78.5	77.5	77.0	77.0	77.0	77.5	78.0	79.5	80.0	57.0	57.0	57.5	58.0	58.5	
Water Coil Leaving Temperature (°C)	Jan	53.9	54.3	54.2	54.8	54.5	55.0	54.9	59.5	73.2	72.6	72.4	71.0	70.7	70.7	70.9	70.8	71.4	72.3	72.7	53.6	53.2	53.5	53.8	53.6	
	Feb	52.8	52.7	53.1	53.5	53.4	53.3	53.7	58.1	72.0	71.3	70.8	70.2	70.1	70.1	70.6	70.6	70.9	72.2	72.2	51.8	51.2	51.5	51.8	52.1	
	March	52.1	52.4	52.4	52.8	52.7	53.1	53.1	56.9	70.9	70.6	70.8	70.1	65.6	60.2	59.3	58.8	58.8	61.5	68.2	50.5	50.6	51.3	51.6	51.9	
	April	49.5	49.7	50.1	50.0	50.3	50.3	47.7	53.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	48.0	47.6	48.3	48.5	48.8	
	May	51.1	51.8	52.2	52.4	52.8	52.4	48.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	49.5	50.1	50.2	51.0	51.0	
	June	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	July	0.0	0.0	0.0																						

Table H.3 cont.'d

Zone1	Hours	00.00-01.00	01.00-02.00	02.00-03.00	03.00-04.00	04.00-05.00	05.00-06.00	06.00-07.00	07.00-08.00	08.00-09.00	09.00-10.00	10.00-11.00	11.00-12.00	12.00-13.00	13.00-14.00	14.00-15.00	15.00-16.00	16.00-17.00	17.00-18.00	18.00-19.00	19.00-20.00	20.00-21.00	21.00-22.00	22.00-23.00	23.00-00.00
	Preheater Power (Watts)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jan	Preheater Power (Watts)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb	Preheater Power (Watts)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
March	Preheater Power (Watts)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
April	Preheater Power (Watts)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May	Preheater Power (Watts)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June	Preheater Power (Watts)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
July	Preheater Power (Watts)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug	Preheater Power (Watts)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sept	Preheater Power (Watts)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct	Preheater Power (Watts)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov	Preheater Power (Watts)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dec	Preheater Power (Watts)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jan	Heating Coil Power (Watts)	19783	20221	20412	20757	20930	21093	21180	23691	31438	28877	26762	25025	23115	21807	21281	21474	22590	24104	25800	16462	17728	18288	18836	19213
Feb	Heating Coil Power (Watts)	17427	17533	17890	18318	18574	18654	18907	20832	26504	24224	21359	20372	19213	17905	17809	17722	18238	19001	20247	13233	14907	15467	16014	16557
March	Heating Coil Power (Watts)	16431	16952	17143	17488	17578	17907	17911	18564	22452	19272	17157	16470	15011	13403	13157	13070	13135	14049	16045	11260	13662	14471	15185	15811
April	Heating Coil Power (Watts)	11287	12057	12413	12675	13180	13094	7886	6065	0	0	0	0	0	0	0	0	0	0	5609	8019	8994	9791	10417	
May	Heating Coil Power (Watts)	8134	8986	9426	10186	10608	10356	3630	0	0	0	0	0	0	0	0	0	0	0	0	4285	5343	6389	7181	
June	Heating Coil Power (Watts)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
July	Heating Coil Power (Watts)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Aug	Heating Coil Power (Watts)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
Sept	Heating Coil Power (Watts)	5312	5999	7020	7780	8451	8882	8120	0	0	0	0	0	0	0	0	0	0	0	0	0	1796	2771	3734	4525
Oct	Heating Coil Power (Watts)	9876	10480	11003	11514	11853	12016	12103	8329	0	0	0	0	0	0	0	0	0	0	5540	4802	7439	8330	8961	9670
Nov	Heating Coil Power (Watts)	14523	14878	15235	15580	15919	15833	15754	16605	20351	17771	15206	14519	13360	12202	12857	13520	14186	14949	16345	11170	12915	13558	14023	14317
Dec	Heating Coil Power (Watts)	16846	16952	17226	17322	17412	17409	17579	19182	24854	22874	21059	20222	18913	17755	18259	18923	19738	20202	21147	13771	15322	15881	16346	16723
Jan	Humidifier Power (Watts)	0	0	0	0	0	0	0	1807	6560	6475	6410	6331	6386	6212	6160	6154	6248	6352	6389	707	0	0	0	0
Feb	Humidifier Power (Watts)	0	0	0	0	0	0	0	1700	6097	6055	5996	5889	6129	6107	6107	6107	6077	5869	5917	669	0	0	0	0
March	Humidifier Power (Watts)	0	0	0	0	0	0	0	1485	5315	5477	5499	5544	5521	5339	5410	5410	5339	5366	5428	614	0	0	0	0
April	Humidifier Power (Watts)	0	0	0	0	0	0	0	523	0	0	0	0	0	0	0	0	0	0	0	294	0	0	0	0
May	Humidifier Power (Watts)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June	Humidifier Power (Watts)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
July	Humidifier Power (Watts)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug	Humidifier Power (Watts)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sept	Humidifier Power (Watts)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct	Humidifier Power (Watts)	0	0	0	0	0	0	0	369	0	0	0	0	0	0	0	0	0	0	0	1620	235	0	0	0
Nov	Humidifier Power (Watts)	0	0	0	0	0	0	0	1121	4271	4224	4283	4303	4245	4096	4164	4227	4148	4123	4221	490	0	0	0	0
Dec	Humidifier Power (Watts)	0	0	0	0	0	0	0	1316	4914	4816	4932	4934	4987	4879	4856	4891	4851	4920	4674	546	0	0	0	0

Table H.4 Printout of “Zone2coil” Sheet of “result.xls”

Zone 2 Cooling Coil					
Cooling Coil Water Mass Flow Rate (kg/s)					
0,471					
Number of Tubes (Width)	Width (m)	Height (m)	Air Face Area (m ²)	Number of Tubes (Length)	Length (m)
16,0	0,406	0,394	0,160	18,0	0,396
Cooling Coil Power at Design (Watts)	Reheater Power at Design (Watts)	Humidifier Power at Design (Watts)	Maximum Cooling Coil Power (Watts)	Maximum Reheater Power (Watts)	Maximum Humidifier Power (Watts)
11713,8	778,6	0,0	5107,2	1114,5	1560,6
Zone 2 Heating Coil					
Heating Coil Water Mass Flow Rate (kg/s)					
0,141					
Number of Tubes (Width)	Width (m)	Height (m)	Air Face Area (m ²)	Number of Tubes (Length)	Length (m)
6,0	0,152	0,694	0,106	2,0	0,044
Preheater Power at Design (Watts)	Heating Coil Power at Design (Watts)	Humidifier Power at Design (Watts)	Maximum Preheater Power (Watts)	Maximum Heating Coil Power (Watts)	Maximum Humidifier Power (Watts)
881,2	10345,6	3607,4	0,0	4683,3	1624,4

Table H.5 Printout of “Zone2cool” Sheet of “result.xls”

Zone 2	Hours	00.00-01.00	01.00-02.00	02.00-03.00	03.00-04.00	04.00-05.00	05.00-06.00	06.00-07.00	07.00-08.00	08.00-09.00	09.00-10.00	10.00-11.00	11.00-12.00	12.00-13.00	13.00-14.00	14.00-15.00	15.00-16.00	16.00-17.00	17.00-18.00	18.00-19.00	19.00-20.00	20.00-21.00	21.00-22.00	22.00-23.00	23.00-00.00		
Jan	Volumetric Flow Rate of Total Air (m³/h)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
Feb	Volumetric Flow Rate of Total Air (m³/h)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0		
March	Volumetric Flow Rate of Total Air (m³/h)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0		
April	Volumetric Flow Rate of Total Air (m³/h)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0		
May	Volumetric Flow Rate of Total Air (m³/h)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0		
June	Volumetric Flow Rate of Total Air (m³/h)	246.3	169.8	169.8	169.8	169.8	0.0	0.0	169.8	169.8	177.6	260.1	420.8	478.4	1200.9	1242.5	1258.5	1249.7	1280.3	1292.6	1228.2	1159.2	1120.1	557.5	273.6		
July	Volumetric Flow Rate of Total Air (m³/h)	396.0	270.8	237.7	206.1	174.4	169.8	169.8	169.8	169.8	211.1	293.3	373.9	553.8	615.9	1317.1	1362.4	1381.3	1375.0	1408.1	1421.2	1356.4	1289.4	1258.6	700.9	424.8	
Aug	Volumetric Flow Rate of Total Air (m³/h)	349.7	227.5	193.9	169.8	169.8	169.8	169.8	169.8	169.8	224.7	310.2	477.1	539.2	0.0	648.0	648.0	1309.7	1324.2	1312.4	1340.6	1344.7	1275.2	1221.9	1208.2	857.8	377.0
Sept	Volumetric Flow Rate of Total Air (m³/h)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	648.0	648.0	655.9	654.3	719.4	692.3	685.2	654.4	324.0	0.0	0.0		
Oct	Volumetric Flow Rate of Total Air (m³/h)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	
Nov	Volumetric Flow Rate of Total Air (m³/h)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	
Dec	Volumetric Flow Rate of Total Air (m³/h)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	
Jan	Volumetric Flow Rate of Outdoor Ventilation Air (m³/h)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Feb	Volumetric Flow Rate of Outdoor Ventilation Air (m³/h)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	
March	Volumetric Flow Rate of Outdoor Ventilation Air (m³/h)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	
April	Volumetric Flow Rate of Outdoor Ventilation Air (m³/h)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	
May	Volumetric Flow Rate of Outdoor Ventilation Air (m³/h)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	
June	Volumetric Flow Rate of Outdoor Ventilation Air (m³/h)	64.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	64.8	64.8	64.8	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	324.0	64.8	
July	Volumetric Flow Rate of Outdoor Ventilation Air (m³/h)	76.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	76.5	79.5	79.5	792.5	793.0	751.9	777.1	792.0	781.1	792.0	781.1	751.6	778.2	375.5	77.7	
Aug	Volumetric Flow Rate of Outdoor Ventilation Air (m³/h)	64.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	64.8	64.8	64.8	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	324.0	64.8	
Sept	Volumetric Flow Rate of Outdoor Ventilation Air (m³/h)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	
Oct	Volumetric Flow Rate of Outdoor Ventilation Air (m³/h)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	
Nov	Volumetric Flow Rate of Outdoor Ventilation Air (m³/h)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	
Dec	Volumetric Flow Rate of Outdoor Ventilation Air (m³/h)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	648.0	
Jan	Air Coil Entering Temperature (C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Feb	Air Coil Entering Temperature (C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.4	4.4	4.4	4.0	3.0	2.1	1.4	0.8	0.3	0.0	0.0	0.0	
March	Air Coil Entering Temperature (C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.4	7.5	7.5	7.4	6.3	4.9	3.6	2.3	1.5	0.0	0.0	0.0	
April	Air Coil Entering Temperature (C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.4	13.6	13.7	13.6	12.5	11.4	9.9	9.1	8.1	0.0	0.0	0.0	
May	Air Coil Entering Temperature (C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.5	19.6	19.5	19.2	18.1	16.7	16.2	13.8	12.5	0.0	0.0	0.0	
June	Air Coil Entering Temperature (C)	21.6	25.2	25.2	25.2	25.2	0.0	0.0	25.2	25.2	25.1	24.8	24.2	24.3	23.9	23.9	23.9	23.6	23.1	22.4	21.3	20.0	19.0	19.3	22.0	22.0	
July	Air Coil Entering Temperature (C)	23.3	24.8	24.9	25.0	25.1	25.2	25.2	25.2	25.2	25.0	24.6	24.6	24.7	25.0	25.1	25.1	25.1	25.1	25.5	24.7	23.7	23.0	22.1	21.8	23.5	
Aug	Air Coil Entering Temperature (C)	23.2	24.9	25.0	25.2	25.2	25.2	25.2	25.2	25.2	24.9	24.7	24.7	24.8	25.2	25.0	25.9	26.0	25.1	24.3	23.3	22.7	22.1	21.7	23.5	23.5	
Sept	Air Coil Entering Temperature (C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	24.3	24.2	24.2	23.6	22.2	20.4	18.7	16.8	15.7	14.6	0.0	
Oct	Air Coil Entering Temperature (C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	16.2	16.1	15.5	14.7	13.4	11.9	10.8	9.8	8.9	0.0	0.0	0.0	
Nov	Air Coil Entering Temperature (C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.2	7.7	7.2	6.7	5.7	4.7	3.7	3.2	2.8	0.0	0.0	0.0	
Dec	Air Coil Entering Temperature (C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	4.1	3.6	3.0	2.2	1.5	0.8	0.3	-0.2	0.0	0.0	0.0	
Jan	Air Coil Entering Humidity Ratio (gWater/kgAir)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Feb	Air Coil Entering Humidity Ratio (gWater/kgAir)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.9	2.9	2.9	2.9	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	
March	Air Coil Entering Humidity Ratio (gWater/kgAir)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.4	3.3	0.0	0.0	0.0	
April	Air Coil Entering Humidity Ratio (gWater/kgAir)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.1	5.1	5.0	5.1	5.1	5.1	5.1	5.1	5.0	0.0	0.0	0.0	
May	Air Coil Entering Humidity Ratio (gWater/kgAir)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.8	6.8	6.8	6.7	6.8	6.8	6.8	6.8	6.7	0.0	0.0	0.0	
June	Air Coil Entering Humidity Ratio (gWater/kgAir)	9.8	10.4	10.4	10.4	10.4	0.0	0.0	10.4	10.4	10.4	10.4	9.9	10.0	8.7	8.7	8.8	8.8	8.8	8.8	8.7	8.6	8.6	8.6	9.7	9.7	
July	Air Coil Entering Humidity Ratio (gWater/kgAir)	10.0	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.1	10.2	9.2	9.2	9.3	9.3	9.3	9.3	9.2	9.2	9.1	9.1	10.0	10.0	
Aug	Air Coil Entering Humidity Ratio (gWater/kgAir)	9.9	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.1	10.1	9.1	9.1	9.1	9.1	9.1	9.1	9.0	9.0	9.0	9.1	10.0	10.0	
Sept	Air Coil Entering Humidity Ratio (gWater/kgAir)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.1	7.1	7.1	7.2	7.3	7.4	7.3	7.1	7.1	7.1	7.1	7.1	
Oct	Air Coil Entering Humidity Ratio (gWater/kgAir)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.3	5.4	5.3	5.4	5.3	5.4	5.4	5.4	5.4	5.4	5.4	5.4	
Nov	Air Coil Entering Humidity Ratio (gWater/kgAir)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	4.0	3.9	4.0	4.0	3.9	4.0	3.9	4.0	4.0	4.0	4.0	
Dec	Air Coil Entering Humidity Ratio (gWater/kgAir)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.6	3.6	3.6	3.6	3.6	3.7	3.7	3.6	3.6	3.6	3.6	3.6	
Jan																											

Table H.5 cont.'d

Zone 2	Hours	00.00-01.00	01.00-02.00	02.00-03.00	03.00-04.00	04.00-05.00	05.00-06.00	06.00-07.00	07.00-08.00	08.00-09.00	09.00-10.00	10.00-11.00	11.00-12.00	12.00-13.00	13.00-14.00	14.00-15.00	15.00-16.00	16.00-17.00	17.00-18.00	18.00-19.00	19.00-20.00	20.00-21.00	21.00-22.00	22.00-23.00	23.00-00.00
Cooling Coil Power (Watts)	Jan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Feb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	March	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	April	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	22	0	0	0
	May	0	0	0	0	0	0	0	0	0	0	0	0	0	642	741	770	752	685	535	572	2	0	0	0
	June	574	442	336	236	139	0	0	113	338	603	860	1319	1513	3662	3815	3843	3718	3597	3358	2764	2170	1752	760	674
	July	1115	893	790	692	593	500	445	498	708	964	1215	1730	1937	4816	5031	5107	5079	4956	4655	4023	3548	3125	1676	1219
	Aug	986	759	654	555	462	376	330	340	499	750	1016	1557	1768	4693	4799	4822	4808	4540	4218	3649	3242	2982	1555	1091
	Sept	0	0	0	0	0	0	0	0	0	0	0	0	0	1995	2032	2092	1982	1761	1471	1046	628	397	90	0
	Oct	0	0	0	0	0	0	0	0	0	0	0	0	0	434	470	362	193	74	0	176	0	0	0	0
	Nov	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Dec	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Humidifier Power (Watts)	Jan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Feb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	March	0	0	0	0	0	0	0	0	0	0	0	0	0	1319	1341	1341	1319	1327	1347	1341	0	0	0	0
	April	0	0	0	0	0	0	0	0	0	0	0	0	0	337	332	354	332	335	335	336	346	356	0	0
	May	0	0	0	0	0	0	0	0	0	0	0	0	0	642	664	642	691	674	643	650	681	680	0	0
	June	38	0	0	0	0	0	0	0	0	0	0	36	40	387	410	387	400	400	388	414	391	392	199	38
	July	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Aug	10	0	0	0	0	0	0	0	0	0	0	8	11	70	93	70	93	98	96	136	115	113	72	9
	Sept	0	0	0	0	0	0	0	0	0	0	0	0	0	506	483	483	473	484	517	486	506	506	251	0
	Oct	0	0	0	0	0	0	0	0	0	0	0	0	0	190	188	191	168	184	149	149	168	157	0	0
	Nov	0	0	0	0	0	0	0	0	0	0	0	0	0	928	949	989	944	936	967	952	0	0	0	0
	Dec	0	0	0	0	0	0	0	0	0	0	0	0	0	1174	1167	1178	0	0	0	0	0	0	0	0
Reheater Power (Watts)	Jan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Feb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	March	0	0	0	0	0	0	0	0	0	0	0	0	0	344	322	322	344	558	829	1084	0	0	0	0
	April	0	0	0	0	0	0	0	0	0	0	0	0	0	344	220	130	99	163	224	0	133	328	0	0
	May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	June	0	0	0	0	0	12	47	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	July	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Aug	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sept	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Oct	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Nov	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	105	0	18	196	0	0
	Dec	0	0	0	0	0	0	0	0	0	0	0	0	0	237	332	427	528	725	917	1115	0	0	0	0

Table H.6 cont.'d

Zone 2	Hours	00.00-01.00	01.00-02.00	02.00-03.00	03.00-04.00	04.00-05.00	05.00-06.00	06.00-07.00	07.00-08.00	08.00-09.00	09.00-10.00	10.00-11.00	11.00-12.00	12.00-13.00	13.00-14.00	14.00-15.00	15.00-16.00	16.00-17.00	17.00-18.00	18.00-19.00	19.00-20.00	20.00-21.00	21.00-22.00	22.00-23.00	23.00-00.00
	Jan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Feb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	March	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	April	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	June	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	July	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Aug	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sept	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Oct	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Nov	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Dec	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Jan	3476	3383	3427	3503	3582	3614	3655	3712	3669	3269	3184	3198	3090	4164	4010	4008	4175	4355	4445	4549	4596	4683	4119	3102
	Feb	2443	2343	2425	2511	2578	2621	2680	2728	2632	2544	2414	2412	2358	0	0	0	0	1183	1357	1492	1610	1706	3031	2204
	March	2313	2281	2345	2422	2472	2541	2574	2533	2392	2251	2165	2130	2054	0	0	0	0	0	0	0	1348	1499	2843	2207
	April	1640	1758	1839	1907	2002	2027	2006	1921	1771	1656	1544	1403	1338	0	0	0	0	0	0	0	0	0	1823	1501
	May	1307	1430	1520	1641	1727	1734	1642	1504	1328	1177	1039	820	755	0	0	0	0	0	0	0	0	0	1249	1157
	June	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	July	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Aug	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sept	938	1110	1263	1384	1496	1574	1527	1326	1044	831	710	353	277	0	0	0	0	0	0	0	0	0	0	810
	Oct	1456	1589	1689	1783	1860	1912	1953	1912	1736	1550	1376	1110	1045	0	0	0	0	0	0	0	0	0	1435	1404
	Nov	2063	2060	2141	2218	2294	2320	2343	2364	2268	2162	2050	1989	1935	0	0	0	0	0	0	0	1211	1330	2580	2011
	Dec	2367	2281	2354	2404	2454	2488	2538	2586	2534	2464	2396	2401	2336	0	0	0	1224	1378	1525	1659	1755	1851	3106	2326
	Jan	159	0	0	0	0	0	0	0	0	0	158	158	1558	1542	1541	1588	1599	1610	1597	1621	1624	814	160	
	Feb	151	0	0	0	0	0	0	0	0	0	143	150	0	0	0	0	1486	1501	1514	1508	1521	750	147	
	March	129	0	0	0	0	0	0	0	0	0	133	133	0	0	0	0	0	0	0	1268	1305	633	129	
	April	38	0	0	0	0	0	0	0	0	0	36	39	0	0	0	0	0	0	0	0	0	201	36	
	May	67	0	0	0	0	0	0	0	0	0	68	69	0	0	0	0	0	0	0	0	0	358	69	
	June	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	July	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Aug	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	Sept	55	0	0	0	0	0	0	0	0	0	52	54	0	0	0	0	0	0	0	0	0	0	52	
	Oct	22	0	0	0	0	0	0	0	0	0	21	23	0	0	0	0	0	0	0	0	0	109	20	
	Nov	96	0	0	0	0	0	0	0	0	0	97	95	0	0	0	0	0	0	0	0	964	953	475	94
	Dec	116	0	0	0	0	0	0	0	0	0	115	117	0	0	0	1165	1187	1110	1127	1144	1159	573	116	

Table H.7 Printout of “Zone3coil” Sheet of “result.xls”

Zone 3 Cooling Coil					
Cooling Coil Water Mass Flow Rate (kg/s)					
8,628					
Number of Tubes (Width)	Width (m)	Height (m)	Air Face Area (m ²)	Number of Tubes (Length)	Length (m)
64,0	1,626	1,696	2,757	12,0	0,264
Cooling Coil Power at Design (Watts)	Reheater Power at Design (Watts)	Humidifier Power at Design (Watts)	Maximum Cooling Coil Power (Watts)	Maximum Reheater Power (Watts)	Maximum Humidifier Power (Watts)
235438,9	18561,6	0,0	100611,8	23317,5	8731,1
Zone 3 Heating Coil					
Heating Coil Water Mass Flow Rate (kg/s)					
2,155					
Number of Tubes (Width)	Width (m)	Height (m)	Air Face Area (m ²)	Number of Tubes (Length)	Length (m)
64,0	1,626	2,410	3,918	1,0	0,022
Preheater Power at Design (Watts)	Heating Coil Power at Design (Watts)	Humidifier Power at Design (Watts)	Maximum Preheater Power (Watts)	Maximum Heating Coil Power (Watts)	Maximum Humidifier Power (Watts)
13209,0	158438,4	56114,7	0,0	79424,8	12301,1

Table H.8 cont.'d

Zone 3	Hours	00.00-01.00	01.00-02.00	02.00-03.00	03.00-04.00	04.00-05.00	05.00-06.00	06.00-07.00	07.00-08.00	08.00-09.00	09.00-10.00	10.00-11.00	11.00-12.00	12.00-13.00	13.00-14.00	14.00-15.00	15.00-16.00	16.00-17.00	17.00-18.00	18.00-19.00	19.00-20.00	20.00-21.00	21.00-22.00	22.00-23.00	23.00-00.00
Jan	Air Coil Leaving Humidity Ratio (g/Water / kgAir)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feb	Air Coil Leaving Humidity Ratio (g/Water / kgAir)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
March	Air Coil Leaving Humidity Ratio (g/Water / kgAir)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.4	3.4	3.3	0.0
April	Air Coil Leaving Humidity Ratio (g/Water / kgAir)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.1	8.1	8.1	8.1	7.7	7.7	5.3	5.3	5.3	5.3	5.2	5.1	5.1	5.1	5.0	0.0	0.0
May	Air Coil Leaving Humidity Ratio (g/Water / kgAir)	0.0	0.0	0.0	0.0	0.0	0.0	10.4	10.4	10.4	10.4	10.4	10.1	10.1	8.1	8.1	8.1	8.1	8.1	8.0	8.2	8.8	8.7	8.7	0.0
June	Air Coil Leaving Humidity Ratio (g/Water / kgAir)	10.0	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.2	10.2	8.4	8.5	8.6	8.6	8.6	8.6	8.4	8.3	8.2	8.8	10.0
July	Air Coil Leaving Humidity Ratio (g/Water / kgAir)	10.1	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.2	10.2	8.6	8.7	8.7	8.7	8.8	8.7	8.6	8.5	8.4	9.1	10.1
Aug	Air Coil Leaving Humidity Ratio (g/Water / kgAir)	10.1	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.2	10.2	8.6	8.7	8.7	8.7	8.7	8.7	8.5	8.5	8.4	9.0	10.1
Sept	Air Coil Leaving Humidity Ratio (g/Water / kgAir)	9.0	0.0	0.0	0.0	0.0	0.0	0.0	10.4	10.4	10.4	10.4	10.2	10.2	8.6	8.5	8.5	8.5	8.4	8.2	8.1	7.1	7.1	7.1	9.0
Oct	Air Coil Leaving Humidity Ratio (g/Water / kgAir)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.1	8.1	8.1	7.8	7.8	5.8	5.7	5.6	5.5	5.3	5.4	5.4	5.4	5.4	5.4	0.0
Nov	Air Coil Leaving Humidity Ratio (g/Water / kgAir)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	4.0	3.9	4.0	3.9	4.0	3.9	4.0	3.9	4.0	0.0
Dec	Air Coil Leaving Humidity Ratio (g/Water / kgAir)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jan	Air Room Supply Temperature (C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feb	Air Room Supply Temperature (C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
March	Air Room Supply Temperature (C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	10.0	0.0	0.0
April	Air Room Supply Temperature (C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.4	10.0	10.0	10.0	10.0	11.5	11.5	10.0	10.0	10.0	10.0	10.0	10.0	15.8	15.9	16.1	0.0
May	Air Room Supply Temperature (C)	0.0	0.0	0.0	0.0	0.0	0.0	21.7	14.0	14.0	14.0	14.0	15.6	15.6	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	16.6	16.9	19.6
June	Air Room Supply Temperature (C)	15.3	14.0	14.0	14.0	14.2	15.9	14.0	14.0	14.0	14.0	14.0	15.7	15.7	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	15.4
July	Air Room Supply Temperature (C)	15.5	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	15.7	15.7	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.2
Aug	Air Room Supply Temperature (C)	15.5	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	15.7	15.7	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.1
Sept	Air Room Supply Temperature (C)	21.9	0.0	0.0	0.0	0.0	0.0	0.0	14.0	14.0	14.0	14.0	15.7	15.7	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	15.6	15.8	16.7
Oct	Air Room Supply Temperature (C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.2	10.0	10.0	11.7	11.7	11.7	10.0	10.0	10.0	10.0	10.0	10.2	15.6	15.8	16.0	16.2	19.4
Nov	Air Room Supply Temperature (C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	18.7	10.0	10.0	10.0	10.0	18.2	10.0	10.0	10.0	10.0	0.0
Dec	Air Room Supply Temperature (C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jan	Air Room Supply Humidity Ratio (g/Water / kgAir)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feb	Air Room Supply Humidity Ratio (g/Water / kgAir)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
March	Air Room Supply Humidity Ratio (g/Water / kgAir)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	0.0	0.0
April	Air Room Supply Humidity Ratio (g/Water / kgAir)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.1	8.1	8.1	8.1	7.7	7.7	5.3	5.3	5.3	5.3	5.2	5.1	5.1	5.1	5.0	0.0	0.0
May	Air Room Supply Humidity Ratio (g/Water / kgAir)	0.0	0.0	0.0	0.0	0.0	0.0	10.4	10.4	10.4	10.4	10.4	10.1	10.1	8.1	8.1	8.1	8.1	8.1	8.0	8.2	8.8	8.7	8.7	0.0
June	Air Room Supply Humidity Ratio (g/Water / kgAir)	10.0	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.2	10.2	8.4	8.5	8.6	8.6	8.6	8.6	8.4	8.3	8.2	8.8	10.0
July	Air Room Supply Humidity Ratio (g/Water / kgAir)	10.1	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.2	10.2	8.6	8.7	8.7	8.7	8.8	8.7	8.6	8.5	8.4	9.1	10.1
Aug	Air Room Supply Humidity Ratio (g/Water / kgAir)	10.1	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.4	10.2	10.2	8.6	8.7	8.7	8.7	8.7	8.7	8.5	8.5	8.4	9.0	10.1
Sept	Air Room Supply Humidity Ratio (g/Water / kgAir)	9.0	0.0	0.0	0.0	0.0	0.0	0.0	10.4	10.4	10.4	10.4	10.2	10.2	8.6	8.5	8.5	8.5	8.4	8.2	8.1	7.1	7.1	7.1	9.0
Oct	Air Room Supply Humidity Ratio (g/Water / kgAir)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.1	8.1	8.1	7.8	7.8	7.8	5.8	5.7	5.6	5.5	5.3	5.4	5.4	5.4	5.4	5.4	0.0
Nov	Air Room Supply Humidity Ratio (g/Water / kgAir)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	0.0
Dec	Air Room Supply Humidity Ratio (g/Water / kgAir)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jan	Water Coil Entering Temperature (C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feb	Water Coil Entering Temperature (C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
March	Water Coil Entering Temperature (C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
April	Water Coil Entering Temperature (C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.4	10.1	10.2	9.9	11.4	11.4	9.9	9.9	9.9	9.9	9.9	9.9	10.0	0.0	0.0	0.0	0.0
May	Water Coil Entering Temperature (C)	0.0	0.0	0.0	0.0	0.0	0.0	21.7	14.1	13.9	13.9	13.9	6.0	6.0	13.8	13.8	13.8	13.8	13.8	13.8	13.9	13.8	0.0	0.0	0.0
June	Water Coil Entering Temperature (C)	15.3	14.2	14.1	14.1	14.2	15.9	14.1	13.9	13.9	13.9	13.8	6.0	6.0	13.8	13.5	13.5	13.5	13.5	13.5	13.6	6.0	13.8	13.9	15.3
July	Water Coil Entering Temperature (C)	15.4	13.9	13.9	13.9	14.2	14.2	14.0	13.9	13.9	13.8	13.8	6.0	6.0	13.9	13.2	13.2	13.2	13.2	13.2	13.3	13.4	13.6	14.0	6.0
Aug	Water Coil Entering Temperature (C)	15.4	13.9	13.9	13.9	14.2	14.2	14.1	14.1	13.9	13.9	13.8	6.0	6.0	13.9	13.3	13.2	13.2	13.2	13.2	13.3	13.4	13.6	14.0	6.0
Sept	Water Coil Entering Temperature (C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.1	13.9	13.9	13.8	6.0	6.0	13.5	13.5	13.5	13.5	13.6	13.7	13.8	15.6	0.0	0.0	19.2
Oct	Water Coil Entering Temperature (C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.2	10.2	9.9	11.6	11.6	11.6	9.8	9.8	9.8	9.9	10.1	0.0	0.0	0.0	0.0	0.0	0.0
Nov	Water Coil Entering Temperature (C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dec	Water Coil Entering Temperature (C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Jan	Water Coil Leaving Temperature (C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Feb	Water Coil Leaving Temperature (C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
March	Water Coil Leaving Temperature (C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
April	Water Coil Leaving Temperature (C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.5	10.4	10.7	10.6	12.1	12.1	10.4										

Table H.8 cont.'d

Zone 3	Hours	00.00-01.00	01.00-02.00	02.00-03.00	03.00-04.00	04.00-05.00	05.00-06.00	06.00-07.00	07.00-08.00	08.00-09.00	09.00-10.00	10.00-11.00	11.00-12.00	12.00-13.00	13.00-14.00	14.00-15.00	15.00-16.00	16.00-17.00	17.00-18.00	18.00-19.00	19.00-20.00	20.00-21.00	21.00-22.00	22.00-23.00	23.00-00.00
	Jan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Feb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	March	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	April	0	0	0	0	0	0	0	2442	11809	19533	24997	25525	26144	17265	19607	19938	18292	12417	6186	0	0	0	0	0
	May	0	0	0	0	0	0	3917	14344	24489	32067	37445	40100	40067	41986	43756	43335	42010	37206	30089	30291	0	0	0	0
	June	24059	21650	17792	14119	10564	9054	15694	24878	33077	39698	44484	50033	51103	66158	70052	71832	70147	68590	60098	46981	33034	23498	21287	28297
	July	34981	31780	28016	24285	20678	18212	22592	32365	40250	46954	51978	58928	60929	91920	97133	100296	100612	95333	85646	68808	57139	45162	36564	39605
	Aug	33107	29396	25569	21982	18487	16797	17089	27548	36534	44369	50595	58747	61109	94505	96060	97550	98219	88975	79428	63828	54362	46522	36724	37635
	Sept	0	0	0	0	0	0	12580	29442	40991	47612	56629	56898	74982	73481	73501	68811	59275	47298	36090	3932	0	0	1424	0
	Oct	0	0	0	0	0	0	0	8772	20921	29425	35304	36862	37420	35318	31316	23614	14468	0	0	0	0	0	0	0
	Nov	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Dec	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Jan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Feb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8495	8731	0	0	0	0	0
	March	0	0	0	0	0	0	0	0	0	0	0	0	0	5904	6253	6253	5904	6036	6338	6324	5201	0	0	0
	April	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	June	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	July	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Aug	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sept	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Oct	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Nov	0	0	0	0	0	0	0	0	0	0	0	0	0	0	152	464	78	0	436	284	471	292	0	0
	Dec	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Jan	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Feb	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	20219	22924	0	0	0	0
	March	0	0	0	0	0	0	0	0	0	0	0	0	0	7172	6824	6824	7172	10500	14720	18675	22774	0	0	0
	April	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	May	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10282	14961	14051	0
	June	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	July	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Aug	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Sept	1209	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	868	3923	0
	Oct	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17212	23317	0	0	0	0
	Nov	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6984	8467	10039	0	16083	19147	20645	22496	0	0
	Dec	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table H.9 Printout of “Zone3heat” Sheet of “result.xls”

Zone 3	Hours	00.00-01.00	01.00-02.00	02.00-03.00	03.00-04.00	04.00-05.00	05.00-06.00	06.00-07.00	07.00-08.00	08.00-09.00	09.00-10.00	10.00-11.00	11.00-12.00	12.00-13.00	13.00-14.00	14.00-15.00	15.00-16.00	16.00-17.00	17.00-18.00	18.00-19.00	19.00-20.00	20.00-21.00	21.00-22.00	22.00-23.00	23.00-00.00		
Jan	Volumetric Flow Rate of Total Air (m ³ /h)	11360.6	12765.4	13145.6	13616.9	13947.6	14261.4	14493.8	14841.1	14455.7	13563.6	12695.0	11223.2	10536.4	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	
Feb	Volumetric Flow Rate of Total Air (m ³ /h)	8895.2	10038.1	10548.3	11084.5	11480.3	11729.0	12091.4	12373.7	11801.3	10881.2	9887.6	8540.8	8179.1	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0
March	Volumetric Flow Rate of Total Air (m ³ /h)	8115.2	9583.1	9883.3	10434.5	10700.3	11144.0	11311.4	10943.7	9846.3	8736.2	8067.6	6850.8	6359.1	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0
April	Volumetric Flow Rate of Total Air (m ³ /h)	4083.2	5748.1	6258.3	6664.5	7255.3	7374.1	3442.2	0.0	0.0	0.0	0.0	0.0	0.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0
May	Volumetric Flow Rate of Total Air (m ³ /h)	2876.1	3343.1	3918.3	4714.6	5240.3	5229.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0
June	Volumetric Flow Rate of Total Air (m ³ /h)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0
July	Volumetric Flow Rate of Total Air (m ³ /h)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0
Aug	Volumetric Flow Rate of Total Air (m ³ /h)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0
Sept	Volumetric Flow Rate of Total Air (m ³ /h)	0.0	2876.1	2876.1	2876.1	3550.3	4059.1	3841.5	0.0	0.0	0.0	0.0	0.0	0.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0
Oct	Volumetric Flow Rate of Total Air (m ³ /h)	2978.2	4513.1	5153.3	5754.5	6215.3	6529.1	6761.4	2876.1	0.0	0.0	0.0	0.0	0.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0
Nov	Volumetric Flow Rate of Total Air (m ³ /h)	6818.2	7958.1	8488.3	8939.5	9400.3	9519.0	9621.4	9708.7	8938.4	8098.2	7222.8	6005.8	5644.1	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0
Dec	Volumetric Flow Rate of Total Air (m ³ /h)	8438.2	9583.1	10028.3	10304.5	10570.3	10754.0	11051.4	11333.7	10888.3	10296.2	9757.6	8475.8	8049.1	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0
Jan	Volumetric Flow Rate of Outdoor Ventilation Air (m ³ /h)	10080.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0
Feb	Volumetric Flow Rate of Outdoor Ventilation Air (m ³ /h)	10080.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0
March	Volumetric Flow Rate of Outdoor Ventilation Air (m ³ /h)	10080.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0
April	Volumetric Flow Rate of Outdoor Ventilation Air (m ³ /h)	10080.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0
May	Volumetric Flow Rate of Outdoor Ventilation Air (m ³ /h)	10080.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0
June	Volumetric Flow Rate of Outdoor Ventilation Air (m ³ /h)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0
July	Volumetric Flow Rate of Outdoor Ventilation Air (m ³ /h)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0
Aug	Volumetric Flow Rate of Outdoor Ventilation Air (m ³ /h)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0
Sept	Volumetric Flow Rate of Outdoor Ventilation Air (m ³ /h)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0
Oct	Volumetric Flow Rate of Outdoor Ventilation Air (m ³ /h)	10080.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0
Nov	Volumetric Flow Rate of Outdoor Ventilation Air (m ³ /h)	10080.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0
Dec	Volumetric Flow Rate of Outdoor Ventilation Air (m ³ /h)	10080.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0	10080.0
Jan	Air Coil Entering Temperature (°C)	17.9	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	18.2	18.2	1.8	2.1	1.9	1.1	-0.4	-1.8	-2.2	-2.8	-3.1	-5.1	5.1	17.8	
Feb	Air Coil Entering Temperature (°C)	17.6	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	18.0	18.0	4.4	4.4	4.4	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	17.4	
March	Air Coil Entering Temperature (°C)	17.5	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	17.9	17.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	17.3	
April	Air Coil Entering Temperature (°C)	15.5	20.0	20.0	20.0	20.0	20.0	20.0	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.3	14.8	
May	Air Coil Entering Temperature (°C)	18.5	24.0	24.0	24.0	24.0	24.0	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	19.0	
June	Air Coil Entering Temperature (°C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
July	Air Coil Entering Temperature (°C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Aug	Air Coil Entering Temperature (°C)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Sept	Air Coil Entering Temperature (°C)	0.0	24.0	24.0	24.0	24.0	24.0	24.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
Oct	Air Coil Entering Temperature (°C)	14.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	13.7	
Nov	Air Coil Entering Temperature (°C)	17.2	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	17.8	17.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2	17.1
Dec	Air Coil Entering Temperature (°C)	17.5	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	18.0	18.0	4.5	4.1	3.6	3.0	2.2	1.5	0.8	0.3	-0.2	0.6	17.4	17.4	
Jan	Air Coil Entering Humidity Ratio (gWater / kgAir)	7.7	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	7.8	7.8	2.8	2.9	2.9	2.8	2.7	2.7	2.7	2.7	2.7	2.7	4.7	7.6	
Feb	Air Coil Entering Humidity Ratio (gWater / kgAir)	7.5	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	8.1	7.5	7.5	2.9	2.9	2.9	2.9	0.0	0.0	0.0	0.0	0.0	0.0	3.0	7.	

Table H.9 cont.'d

Zone 3	Hours	00.00-01.00	01.00-02.00	02.00-03.00	03.00-04.00	04.00-05.00	05.00-06.00	06.00-07.00	07.00-08.00	08.00-09.00	09.00-10.00	10.00-11.00	11.00-12.00	12.00-13.00	13.00-14.00	14.00-15.00	15.00-16.00	16.00-17.00	17.00-18.00	18.00-19.00	19.00-20.00	20.00-21.00	21.00-22.00	22.00-23.00	23.00-00.00
	Preheater Power (Watts)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Jan		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feb		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
March		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
April		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
July		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sept		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dec		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Heating Coil Power (Watts)	42133	39003	40184	41604	42615	43573	44283	45345	44176	41441	39399	40512	38044	66648	63877	63720	66738	71528	74835	76804	77830	79425	60665	40307
Jan		33824	30670	32229	33867	35076	35836	36943	37806	35446	33246	30210	31361	30041	51438	50187	49017	50008	0	0	25014	26850	28345	46638	30928
Feb		31071	29280	30441	31881	32693	34049	34560	33437	30084	26692	24649	25397	23618	0	0	0	0	0	0	0	25134	43112	28863	
March		18090	17582	19121	20362	22167	22530	10517	0	0	0	0	0	0	0	0	0	0	0	0	24134	27743	32609	20194	15177
April		9754	10214	11972	14405	16011	15977	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6545
May		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
July		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sept		0	3065	6213	8645	10847	12402	11126	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct		14579	13789	15745	17582	18990	19948	20658	7964	0	0	0	0	0	0	0	0	0	0	0	0	28346	33651	25458	13579
Nov		25795	24315	25874	27313	28721	29084	29397	29664	27304	24706	22068	22415	21094	32005	0	0	0	38211	0	0	0	0	38176	24734
Dec		32218	29280	30640	31484	32296	32857	33766	34628	33261	31458	29813	31132	29582	50931	51706	53069	55074	56318	57092	59567	61100	62695	48049	31386
	Humidifier Power (Watts)	1180	0	0	0	0	0	0	0	0	0	1135	1180	11193	10954	10930	11359	11836	12008	11880	12243	12301	6171	1196	
Jan		1045	0	0	0	0	0	0	0	0	0	932	1042	10714	10714	10714	10576	0	0	9024	8928	9122	5182	998	
Feb		701	0	0	0	0	0	0	0	0	0	774	763	0	0	0	0	0	0	0	0	0	5767	3354	718
March		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
April		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
May		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
June		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
July		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sept		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Oct		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nov		192	0	0	0	0	0	0	0	0	0	204	177	0	0	0	0	0	0	0	0	0	0	897	173
Dec		502	0	0	0	0	0	0	0	0	0	494	518	5073	4970	5129	4946	5262	4135	4464	4705	4929	2436	509	