Department of Environmental Engineering
(U 12116)

ČESKÉ VYSOKÉ UČENÍ TECHNICKÉ V PRAZE
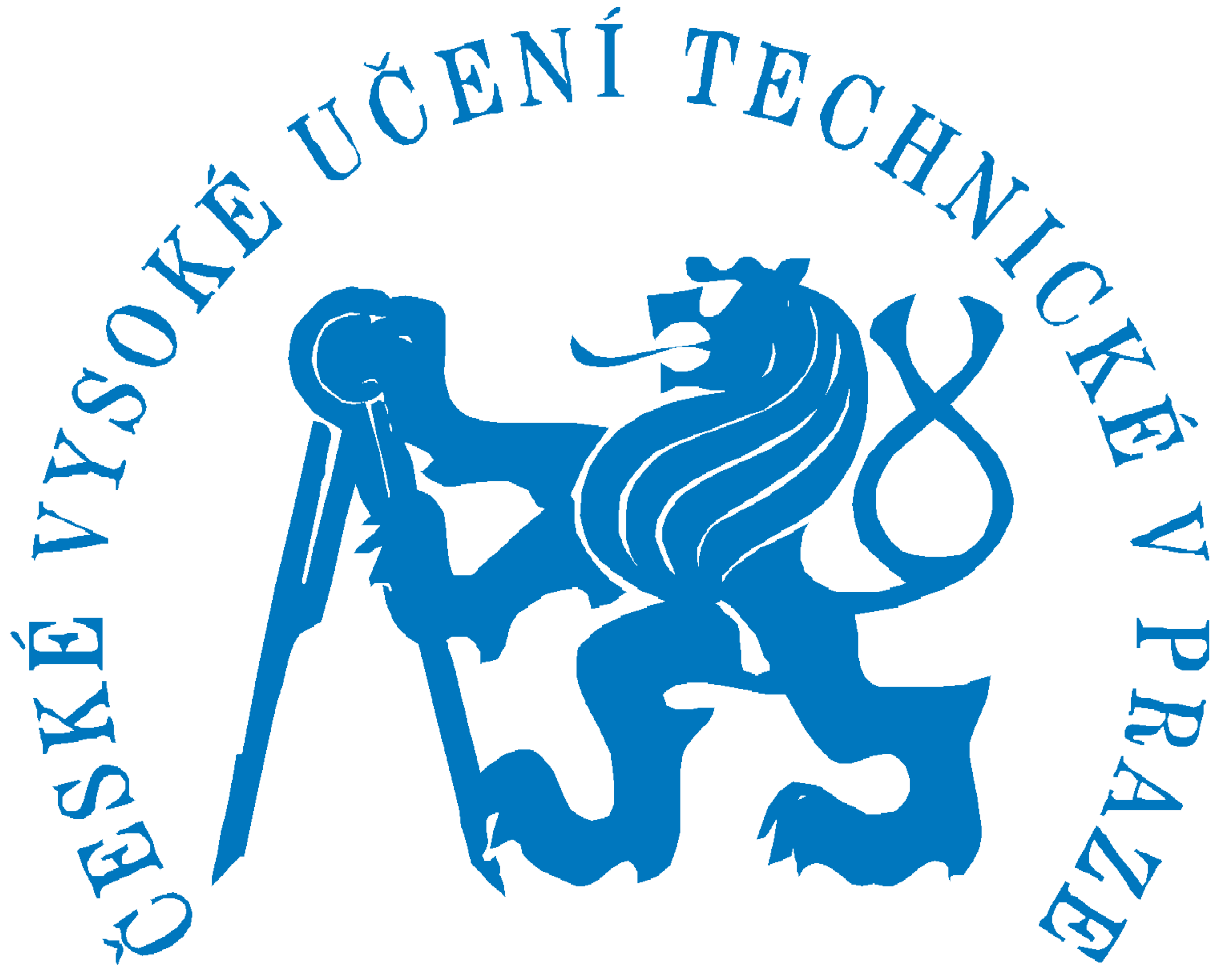
FAKULTA STROJNÍ

Design of an AC system for a building

(Bachelor Thesis)

2020

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Abstract

The design of an AHU and air conditioning unit for two different regions, namely Czechia and Kuwait, are considered for this thesis.

For the same given space, we use peak temperature conditions for both regions during the summer and winter periods to calculate the maximum total heat gain produced then estimate ventilation requirements from which a suitable AHU and air conditioning unit can be selected to meet the required heating and cooling demand.

Once the task of selection of appropriate AHU unit has been fulfilled, then preliminary piping connections and fittings are made to make sure of the proper supply of heating/cooling and ventilation.

Since calculations are done for the same building space but only in different regions with different weather conditions, we can then draw similarities and differences between the two.

Annotation sheet

Annotation - English: The design of an AHU and air conditioning unit for two different regions, namely Czechia and Kuwait, are considered for this thesis.

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Keywords: AC, AHU, design, Environmental, Floor design

Declaration

I hereby declare that I have completed this thesis entitled "Design of AC system." independently with consultations with my supervisor and I have attached a full list of used references and citations.

I do not have a compelling reason against the use of the thesis within the meaning of Section 60 of the Act No.121/2000 Coll., on copyright, rights related to copyright and amending some laws (Copyright Act).

In Prague, Date: ....31/07/2020..... ....
Name and Surname: Joshua Jonathan Donald

Acknowledgment

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Introduction:

Why do we need Air conditioning systems? The answer is quite simple - for thermal comfort! Thermal comfort is achieved in multiple ways such as heating or cooling a space to the desired temperature, and proper ventilation by continuous rejection of stale air, and the addition of clean filtered air. These processes are accomplished with the help of HVAC systems.

Thermal comfort is necessary, whether resting or working for good health and better productivity. Bad indoor air quality not only decreases productivity and causes stress but can also pose a severe risk to health. Hence, the installation of an HVAC system is of utmost importance.

Design and installation of an HVAC system is a factor to consider when designing a building along with other piping and wiring setups in plumbing, electrical, and lighting systems that are integrated into the building design.

In this thesis, the peak thermal weather conditions for two different countries, namely Czechia and Kuwait, are considered. Calculation of the total heat gain produced and then selection of a suitable type of air conditioning system and air handling unit considering all the possible factors of heat gains is done.

Before getting into the process of selecting an air conditioning and AHU unit, knowledge about heat gains is necessary. What are heat gains, and what are the types? The following section answers all these. Following that, information about air conditioners and AHU units and their types and components are discussed.
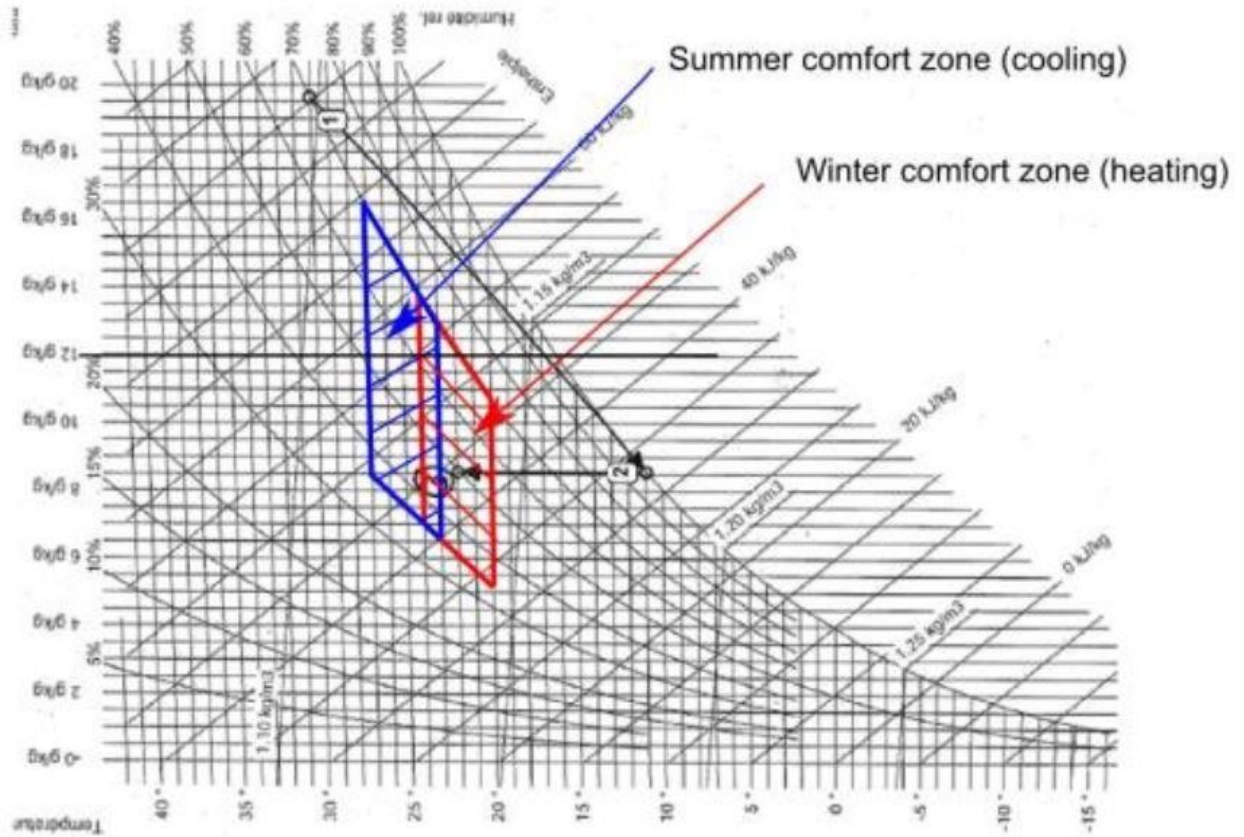
Figure 10 Comfort zone on mollier diagram[28]

The above figure shows us the region of thermal comfort during winter and summer given by temperature and relative humidity on the psychometric chart.

Part 1: Theory

1 Heat Gains:

Heat gain is the increase in temperature of a space caused by solar radiation, appliances, people, conduction, etc.(Heat is transmitted into the building) [1]
One main distinction between the types of heat gains is Internal heat gains and External heat gains. We shall look deeper into these topics in the following section.

Another significant distinction to note is between the types of heat - Sensible and Latent heat.

Sensible Heat: It is the amount of energy required to increase/decrease the temperature without any phase change.
Sensible capacity is the capacity needed to lower the temperature. [2]

Latent Heat: The energy released/absorbed from space during phase change; in other words, the heat that causes a change of state with no change in temperature.
Latent capacity is the capacity needed to remove the moisture present in the air[2],[3]

We use only sensible heat while calculating heat gains since latent heat is negligible in comparison to sensible heat emitted.

1.1Internal heat gain:

Internal heat gain: It is the increase in temperature of interior space due to the emission of sensible and latent heat by indoor equipment and occupants. Internal heat gains are relatively easier to estimate.[4]

Some of the major contributing factors to internal heat gains are:

1. Appliances/Equipment: The heat gain produced by the equipment is equal to the total power input supplied to it.

Equipment	Description	Max. Printing Speed, Pages per Minute	Name-plate Power, W	Peak Heat Gain,[a] W
Multifunction printer (copy, print, scan)	Large, multiuser, office type	40	1010	540 (Idle 29 W)
		30	1300	303 (Idle 116 W)
		28	1500	433 (Idle 28 W)
Average 15-min peak power consumption (range)			425 (303-540)	
	Multiuser, medium-office type	35	900	732 (Idle 18 W)
	Desktop, small-office type	25	470	56 (Idle 3 W)
Monochrome printer	Desktop, medium-office type	55	1000	222
		45	680	61
Average 15-min peak power consumption (range)			142 (61-222)	
Color printer	Desktop, medium-office type	40	620	120
Laser printer	Desktop, small-office type	14	310	89
		24	495	67
		26	1090	65

Figure 1 Recommended Heat Gain produced by different office equipment.[8]

From the above table, the heat gain emitted from different types of monitors and printers generally used is shown.
For calculations, Name-plate power is used.

2. Occupants: The amount of heat emitted by a person depends on the activity level of the person.

Degree of activity	Typical building	Total rate of heat emission for adult male / W	Rate of heat emission for mixture of males and females / W			Percentage of sensible heat that is radiant heat for stated air movement / %	
			Total	Sensible	Latent	High	Low
Seated at theatre	Theatre, cinema (matinee)	115	95	65	30	—	—
Seated at theatre, night	Theatre, cinema (night)	115	105	70	35	60	27
Seated, very light work	Offices, hotels, apartments	130	115	70	45	—	—
Moderate office work	Offices, hotels, apartments	140	130	75	55	—	—
Standing, light work; walking	Department store, retail store	160	130	75	55	58	38
Walking; standing	Bank	160	145	75	70	—	—
Sedentary work	Restaurant	145	160	80	80	—	—
Light bench work	Factory	235	220	80	140	—	—
Moderate dancing	Dance hall	265	250	90	160	49	35
Walking; light machine work	Factory	295	295	110	185	—	—
Bowling	Bowling alley	440	425	170	255	—	—
Heavy work	Factory	440	425	170	255	54	19
Heavy machine work; lifting	Factory	470	470	185	285	—	—
Athletics	Gymnasium	585	525	210	315	—	—

Source: ASHRAE Handbook: *Fundamentals* (2001)[6]

Figure 2 Recommended Heat Gain per person[9]

From the above table, the rate of heat emission per person depending on the degree of activity is shown.

3. Lighting: Lighting makes a significant impact on heat load since it makes up roughly 25% of total energy use in commercial buildings. Office space more than 5m away from the window uses lighting the area closer to the window uses sunlight, which significantly reduces heat gain by lighting.[5]

1.2 External heat gain:

The main exterior factor affecting the temperature in a given space is solar heat gains. Calculating solar heat gain can be more complicated compared to internal heat gain calculations. Many factors, such as insulation, shading, orientation, solar gain transmittance, and insulating

values, are some of the many factors taken into consideration while estimating total solar heat gain for a given space.

1.2.1 Solar heat gain

Solar heat gain is primarily caused by incident solar radiation. Solar heat is transmitted and absorbed by the surfaces, windows, roofs, floors, and walls of the space through conduction, convection, and radiation, which results in an increase of thermal energy in the area. Through the greenhouse effect phenomenon, the thermal energy accumulated causes heat gain.
During summer, solar heat gain, if unchecked, can cause overheating and undesirable living conditions. Whereas during winter, solar heat gain is beneficial since it can be used as passive heating to heat the building, saving heating energy.

Factors contributing to Solar Heat gain:

1. Solar angular position: It is fundamental knowledge that earth revolves around the sun while simultaneously rotating around its tilted axis. This rotation and revolution directly affect solar gain on a building. The following angles give the sun-earth position:
    ➔ Solar Altitude angle(β)
    ➔ Solar Azimuth angle(Φ_s or γ)
    ➔ Wall /Surface Azimuth angle(Φ_p or ξ)
    ➔ Wall Solar Azimuth angle($\Delta\Phi$ or α)
    ➔ Slope/Tilt angle(Φ_p)
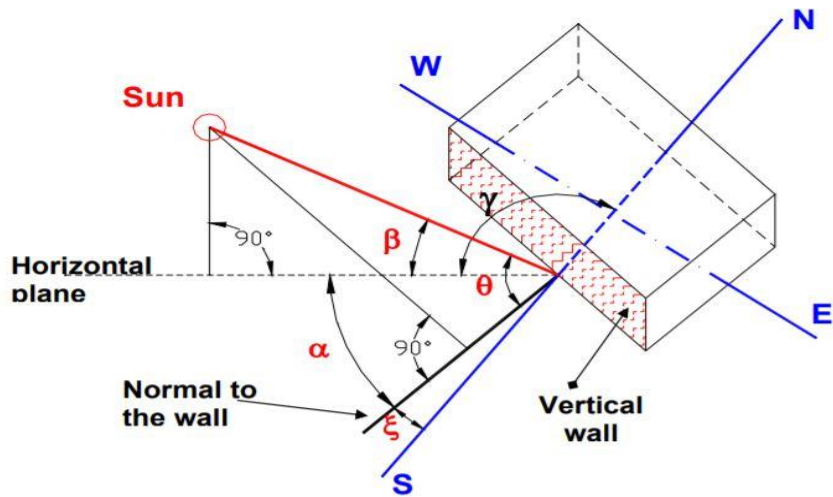   ➔ Solar Incidence angle(Φ_i or $\boldsymbol{\theta}$)
    [6][10][11]

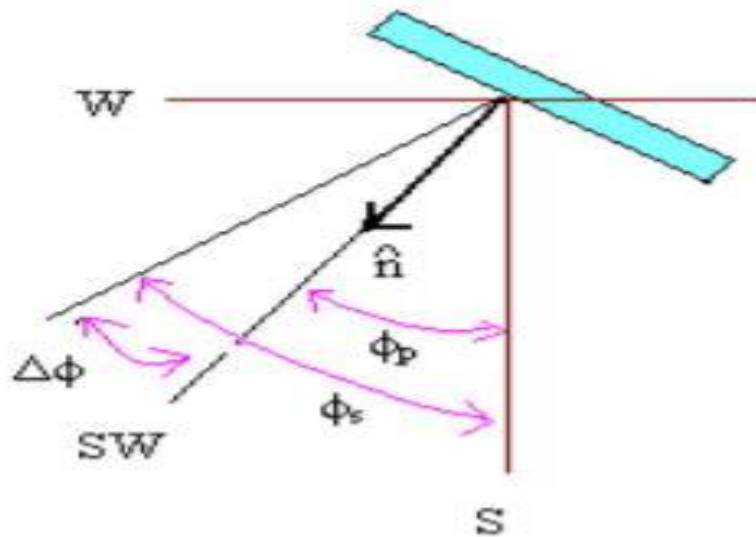Figure 3. Incident solar angle for vertical surface [11]

Figure 4.Wall Solar, Surface Azimuth, Slope, Incidence Angles [10]

2. The intensity of solar radiation on the area exposed to the sun: The intensity of solar irradiation on a building surface varies at different hours of the day and different seasons. The intensity also varies depending on which cardinal direction the surface area of the building is facing. The west-facing side of the building receives maximum solar exposure between the hours of 10 am to 3 pm. The image below shows the solar irradiance or different hours of the day and peak sun hours.[6][12]
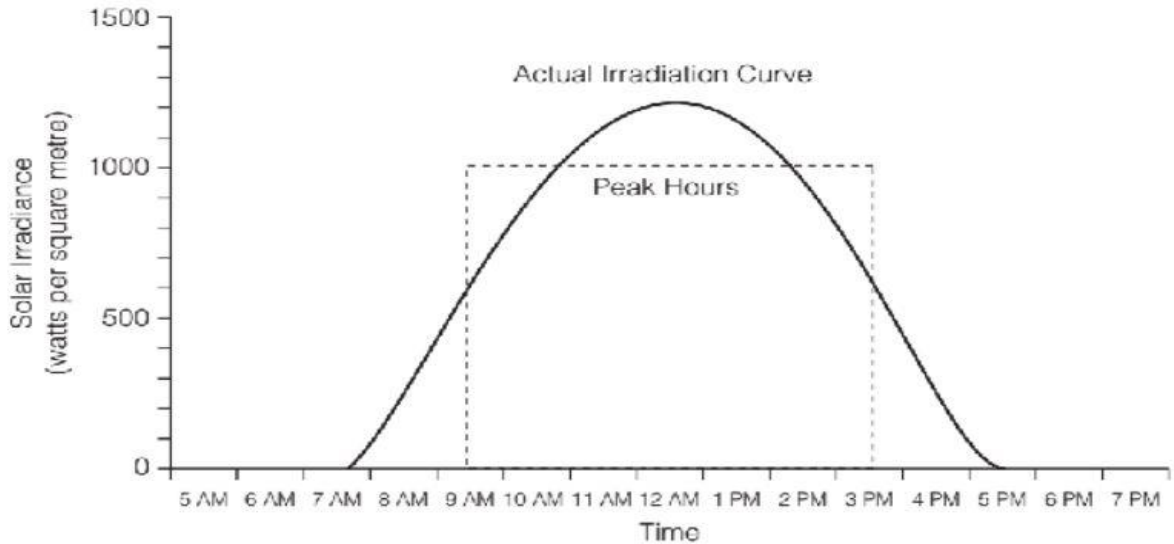
Figure 5. Irradiation curve [12]

3. Type of fenestration and glazing on fenestration: Fenestration refers to the installation, design, and arrangement of doors, windows, curtain walls, and skylights in an opening in a building envelope. Glazing refers to the transparent material used mostly in glass windows. It can be made up of 2 or more glazing layers. And it is usually separated by an edge seal and space in between each glass can be filled with gas- commonly, argon is used since it's a poor conductor of heat which lowers the overall heat transfer from the exterior and interior of the building. [6][13]
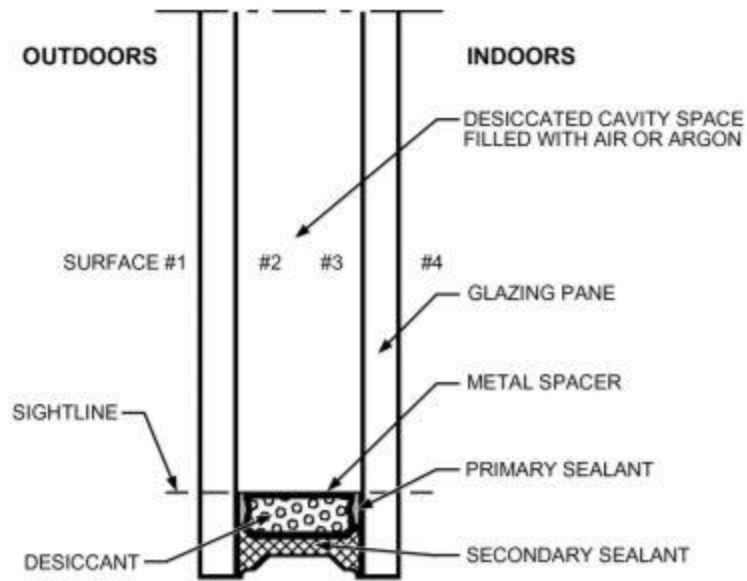
Figure 6 Construction Details of Typical Double-Glazing Unit [13].
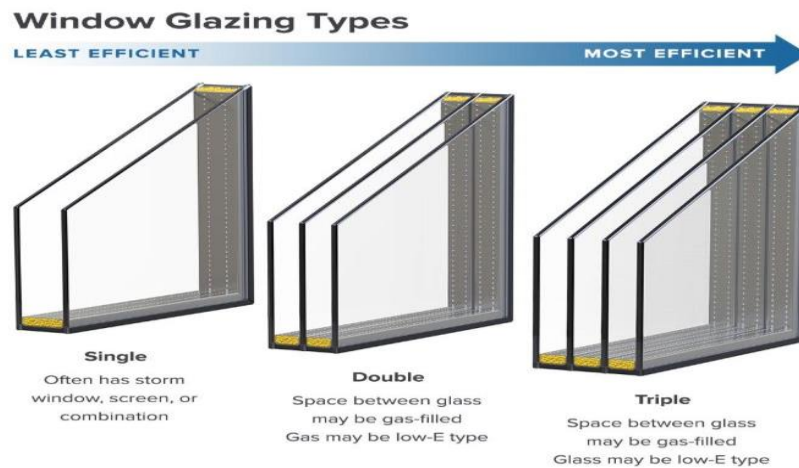
Figure 7 Types of window glazing [7]

4. Shading: Shading helps reduce cooling loads in a space. Shades can be placed in 3 different ways: Internal, External, and in between glazing units. The placement of shades affects shading ability from solar heat gains.
    Internal shades include blinds and curtains while they're easier to install and maintain they do not provide the best shading ability.
    Outdoor shades include overhangs, fins, shutters, blinds, and even trees in the summer.

While it is considerably harder to install and maintain outdoor shading units, it effectively reduces solar heat gains. Fenestration units fully shaded from the outdoors can reduce solar heat gain by 80%.

Another difference between shading units is Fenestration attachments and Integral. The former is when the shading device is placed after the fenestration unit was already installed. And the latter is when the shading device and fenestration unit is fitted as one whole unit. [6][15][16]

Figure 8 Types of shading devices[14]
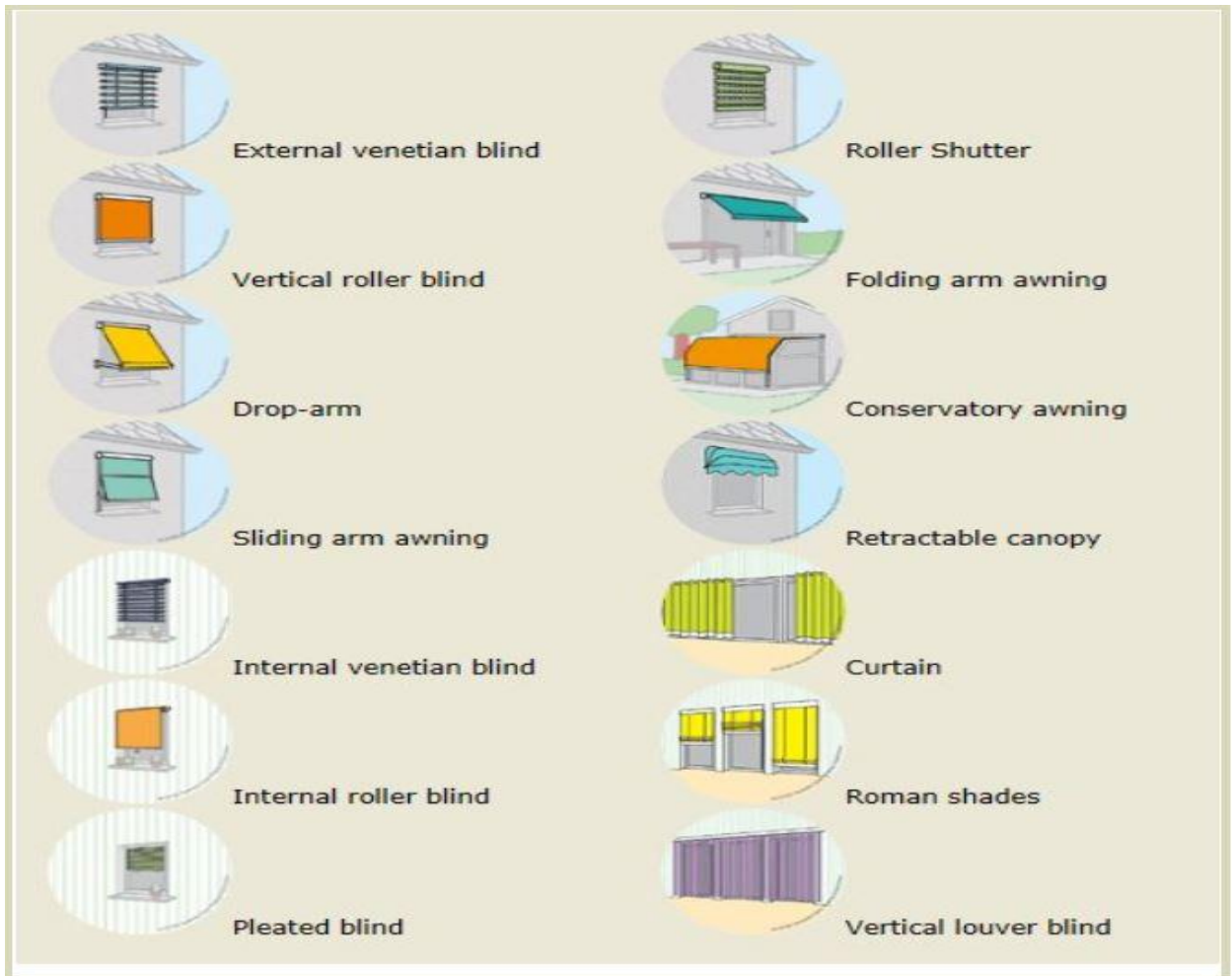
5. Transmittance and admittance of surfaces exposed to the sun: Different fractions of the irradiation are reflected, absorbed, and transmitted by a surface depending on the material properties: ρ reflectivity, α absorptivity, τ transmittance. Thermal transmittance must be minimal, and admittance should be maximum for superior insulation against solar heat gain.[6][10][17]

6. U- Factor and SHGC: U-factor measures the rate of heat transfer or transmittance by conduction, convection, and radiation, which indicates how well-insulated surface is. It is also known as the overall heat transfer coefficient. The lower the U-value, the better the insulation.[18][19]

   SHGC: SHGC stands for Solar Heat Gain Coefficient. .It is a number that indicates how much solar energy is admitted through a fenestration unit, either through transmission or absorption. The lower the number, the better the shading. [20][21]
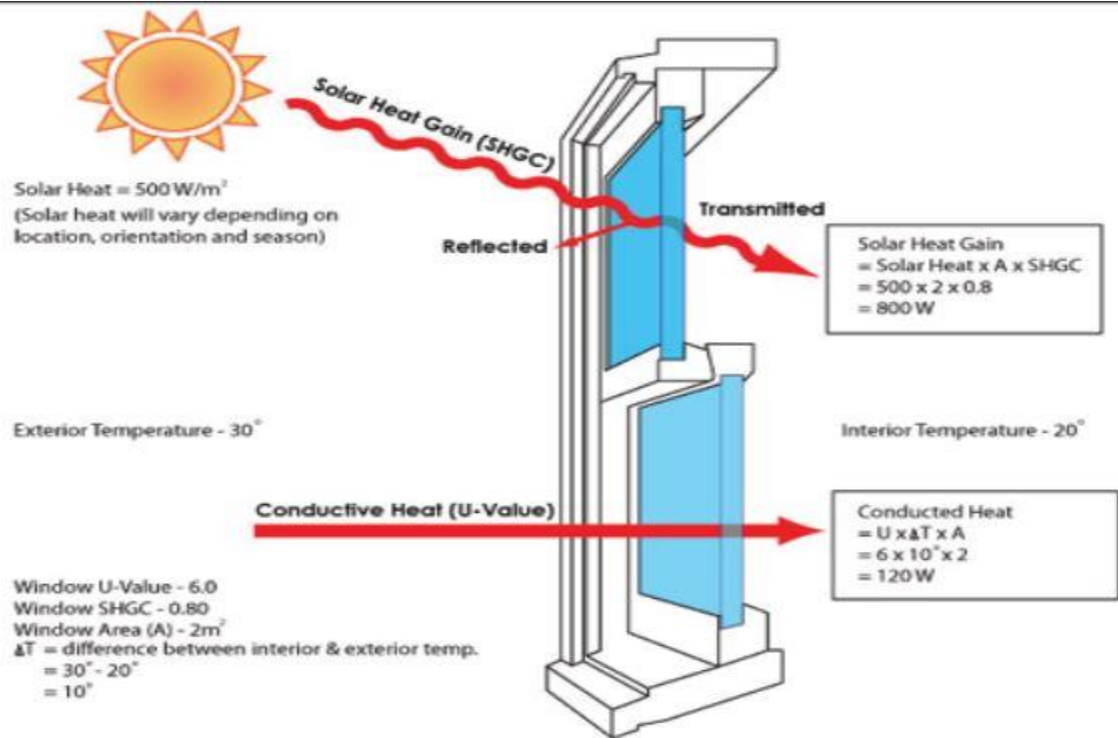
Figure 9. SHGC and U-value calculation.[22]

The ASHRAE handbook contains lists and tables of U-value and SHGC for windows, doors, and other fenestration units. It is helpful to refer to these while estimating heat gains.

There are few other contributing factors as well, such as storage of solar heat gains by the structure, absorption of solar radiation by the opaque body, and others that are not mentioned because it not needed for calculation in this thesis.

Part 2: HVAC

2.1 HVAC

HVAC stands for Heating, Ventilation, and Air conditioning. Just as the name suggests, it helps to heat or cool and ventilate indoor air. HVAC systems help maintain and control indoor air quality for thermal comfort.

HVAC systems are found in nearly every single building today, from residential houses to large scale industries. The demand for cost-effective and efficient HVAC systems are ever on the rise.

AHU and air conditioners are both an integral part of the HVAC system.

Air Handling Units: It is the central control for HVAC needs in a building. It is used to regulate and re-circulate the air in a building as part of HVAC.

Components in a typical AHU:
- Heating coils
- Cooling coils
- Supply fan
- Humidifier
- Pressure sensors
- Dampers
- Heat exchangers for heat recovery
- Sound attenuators

Components can be added or removed depending on the type of air treatment needed for the building.
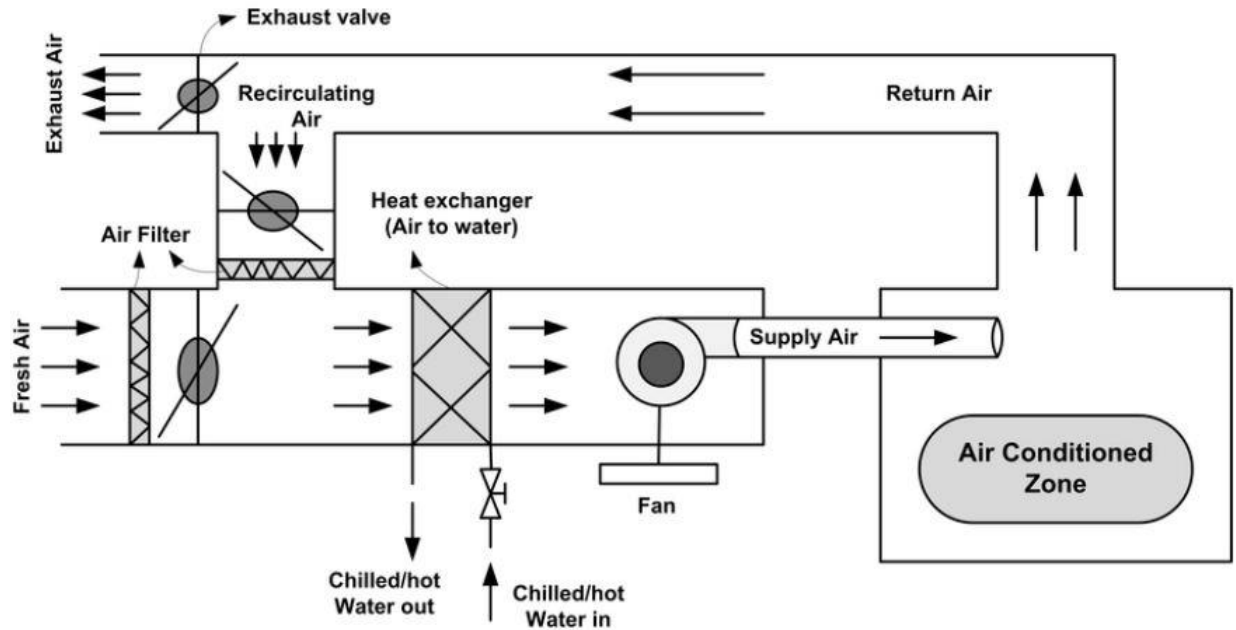
Figure 10 - AHU schematic[31]

For this thesis, an evaporative AHU is used since it is more suitable for the regions that are dealt with, and a DX coil is added to the AHU. A diffuser grill is added as well to remove and help re-circulate the air.

Air conditioners:

Air conditioners: Air conditioning uses energy to lower indoor air temperature and dehumidify the air compared to its surroundings; this is done by removing heat and moisture from the indoor space and rejecting it outside. The air conditioner works on the principles of the thermodynamic refrigeration cycle. There exist air, refrigerant, and water/steam systems.[23][24]

Main components in air conditioning units include:

1. Compressor
2. Condenser
3. Expansion valve
4. Evaporator

Installation types: There are many ways to install AC and heat pump units. It depends on area/areas that need to be cooled or heated, size of the area, cooling/heating load capacities, space availability, and other factors. Some installation types include

- Split System
- Mini Split System/Ductless System
- Portable System
- Packaged Units
- Evaporative Systems
- Window Units
- Hybrid Units

For this thesis, a VRV AC unit used. It is a fully automatic multi-split air conditioner. It consists of an indoor and an outdoor unit and uses a variable refrigerant flow control. Also, it enables individual climate control for each zone. Additionally, they come with a heat pump or heat recovery systems.

2.2 Piping calculation

Pipe calculation is needed for proper connections and supply of fresh air from the AHU unit to indoor units.

Preliminary piping calculations are done once the AHU unit has been selected.

The calculation is done first by calculating the flow rate through each pipe; this is usually done by taking the longest pipeline and dividing it into multiple sections.

Once flow rates are known for each pipe use theoretical velocity (usually between 4-6m/s) to calculate the theoretical Diameter needed for each pipe in each section using the following formula:

$$d = \sqrt{\frac{4 \times V}{\Pi \times v}}$$

Where $\dot{V}$ = Volumetric Flow Rate(m^3/s)
v = theoretical velocity(m/s)
d = theoretical diameter(m)

Then from the theoretical diameter using a pipe manufacturer manual, select standard diameters close to the calculated theoretical diameters.

From this standard/real diameter, re-calculate velocity to get real velocity using the formula below finally:

$$\hat{v} = \sqrt{\frac{4V}{\Pi \hat{d}^2}}$$

Where $\dot{V}$ = Volumetric Flow Rate(m^3/s)

$\hat{v}$ = real velocity(m/s)

$\hat{d}^2$ = real diameter(m).

With these values, ΔP is estimated for each section. The sum of all the estimated ΔP in the whole piping connections should be less than allowable pressure loss given by the AHU.

In this thesis, all piping connections are chosen from the LindabSafe manual.

For circular pipes: SR fittings [25]
For elbow pipes: BU 90° fittings[26]
For T- pipes: TCPU fittings [27]

In joining two pipes of different diameters, a reducer such as RCLFA(Symmetric) or RLFU(Asymmetric) can be used.

Part 3: Calculations
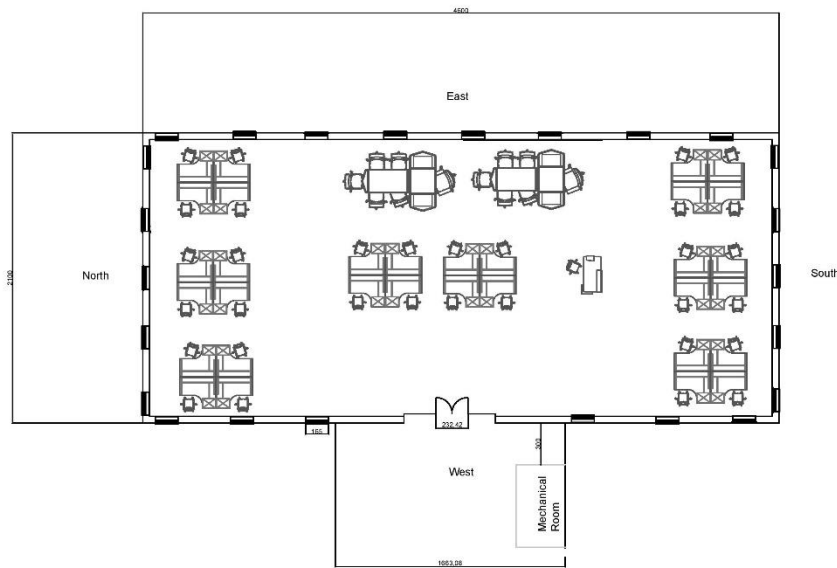
Drawing 1 Floor plan design

The design and installation of an AHU and air conditioner are done for the above open office building. The building is comprised of 4 floors; each of them has the same floor designs.

The same office building is considered for both regions(CZ and KWT) and uses each region's respective weather conditions, values, constants, and coefficients for calculations.
This way, a better comparison can be concluded.

The floor plan is $900m^2$, and it is big enough to fit in 50 occupants comfortably. The west side of the building has a corridor that leads up to the office. The corridor contains the kitchen, bathrooms, and most importantly, it includes the mechanical room. The mechanical room is about 3m away from the office to avoid noise from the AHU unit; a silencer is used to help reduce noise from the AHU.

	Length(m)	Width(m)	Height(m)
Walls	45	20	3
Windows		1.65	1.82
Doors		2.3	2
Corridor		16.63	3
Roof	45	20	

Table3.1

The table above shows the dimensions of the building, windows, walls, door, and the corridor. These dimensions are used to calculate the surface area for lighting and solar heat gain in the space.

	North(m^2)	South(m^2)	East(m^2)	West(m^2)
Window	15.015	15.015	24.024	18.018
Wall	44.985	44.985	110.976	67.092
Corridor				49.89
Roof	900			

Table3.2

The table above shows the surface area for the windows, walls, roofs, and corridors.
The surface area of the wall is calculated, taking into account the surface area of the windows.

Wall Surface Area = Total surface area of the wall - Surface area of window $\times$ Number of windows.

Wall surface area of the west side = Total surface area of the wall - Surface area of window $\times$ Number of windows - Surface area of the corridor.

Internal heat gains for all four floors remain the same since occupancy, lighting, and equipment and other miscellaneous sources are assumed to be the same.

Solar heat gain for floors 1,2 and 3 remain the same as well.

Calculation Procedure:

Estimation of internal heat gain:

Internal heat gain is determined by the sum of all heat gains caused by equipment, lighting, and occupants.

Estimation of solar heat gain:

Before calculating solar heat gains, some assumption is made to reduce the complexity in the calculation:

Assumptions made for more straightforward calculation:

- Shading device blocks all radiation and so all solar heat gain is caused due to conductive heat gain on walls, windows, and roof.
- The roof is made of light construction material, so there will be no delay in heat gain. This means the roof has a lower U-value.
- The building is well insulated, so infiltration is neglected.

From the above assumptions, heat gain caused by solar radiation on a surface is through conduction only.

The formula for conductive heat gain:

$$q \ = \ U \ A \ \Delta T$$

Where q = conductive heat gain
U = Heat transfer Coefficient (U-value)
A = Surface area of wall/window

Therefore to get the Total Heat Gain, we can add the sum of internal Heat Gain and sum of solar heat gain from all orientations.

Total Heat Gain = Internal Gains + Solar Heat Gains.

This above equation is suitable for floors 1,2, and 3. However, solar heat gain on the last level, i.e., the 4th floor will be higher since the addition of heat gain through the roof is added. So to estimate Solar heat gain for the 4th floor:

Total heat Gain for 4th floor = Internal Heat Gain + Solar Heat Gain + Solar Heat Gain through the roof.

The number of occupants $\times$ 35 gives the supply of fresh air $m^3/hr = 50 \times 35 = 1750 m^3/hr = 0.5 m^3/s$.

Part 3.1: Calculation Using CZ values and constants

	Windows	Walls	Roof
U-factor(W/(m^2.K))	1.20	0.20	0.16

Table 3.3

Surface	Orientation			
	North	South	East	West
Walls	35	50.3	42	54.9
Windows	167	167	167	167
Roof	37	37	37	37

Table 3.4

The above tables 3.3 and 3.4 show the U-value coefficients and ΔT for each surface and orientation. These values are chosen from the 1997 and 2005 ASHRAE Fundamental Handbook standards for Czechia.

Internal Heat Gain :

Source	Calculation	Heat Gain(W)
People	50×75W	3750
Lighting	350×13.3W	4655
Laptops	50×116W	5800
Printers	2×540W	1080
Other Miscellaneous Sources	1×1000W	1000
		Σ = 16285W

Table 3.5

Solar Heat Gain due to conduction:

From table 3.2,3.3 and 3.4, solar heat gain through conduction can be calculated using the formula:

$$q = U A \Delta T$$

Orientation	North(W)	South(W)	East(W)	West(W)
Walls	314.895	452.5491	932.1984	736.6702
Windows	3009.006	3009.006	4814.41	3610.807
Σ	3323.901	3461.555	5746.608	4347.477

Table3.6

Total Solar Heat Gain = 3323.901+3461.555+5746.608+4347.477 = 16879.542W.
This sum is the total solar heat gain for floors 1,2, and 3.

Total Heat Gain = Total Internal Heat Gain + Total Solar Heat Gain = 16285+16879.54 = 33,164.5 ≅ 33,165W = 33.1kW.

Therefore to cool the space for floors 1,2, and 3, an air-conditioning unit of at least 33.1kW is needed.

Roof Solar Heat Gain

Source	Calculation	Heat Gain
Roof	37*900*0.16	5328

Table 3.7

Total Solar Heat Gain for 4th floor = 16879.542 + 5328 = 22207.54W = 22.2kW
Total Heat Gain for 4th floor = 16285 + 22207.54 = 38492.5W = 38.49kW

Therefore to cool the space for the 4th floor, an air-conditioning unit of at least 38.9kW is needed.

Selection of Air conditioning unit:

Total heat gain in floor 1,2, and 3 = 33.1kW
Total heat gain 4th floor = 38.9

The selected air condition unit that meets the cooling load requirement is a VRV air condition unit. It consists of an indoor and outdoor unit with a heat pump. It is placed on each floor, with each level having its own indoor and outdoor unit.

Specifications:
Indoor unit specification :
Model: Round-Flow Cassette FXFA - 40A

Cooling Capacity(kW)	Heating Capacity(kW)	Refrigrant	Dimensions(mm)
4.50	5	R-32/675	204×840×840

Table 3.8

Therefore total cooling capacity = 4.5×9 = 40.5kW

Outdoor unit specification:
Model: RXYQ 16U

Cooling capacity(kW)	Heating Capacity(kW)	Max. number of connectable units	Dimensions(mm)
45	50	64	1,685×1,240×765

Table 3.9

Figure 11 Indoor Unit FXFA - 40A

Figure 12 Outdoor unit RXYQ 16U

The following psychrometric chart is obtained from using CZ weather conditions in Summer and Winter.

Supply of fresh air(Volumetric flow rate) = 1750 m^3/hr

During Summer:

Cooling Coil temperature = 3°C
Outside temperature = 32°C
Desired indoor temperature = 24°C
Enthalpy = 60kJ/kg

During Winter:
Outside temperature = -15°C
Desired indoor temperature = 22°C
Heat Recovery temperature = 11.64°C
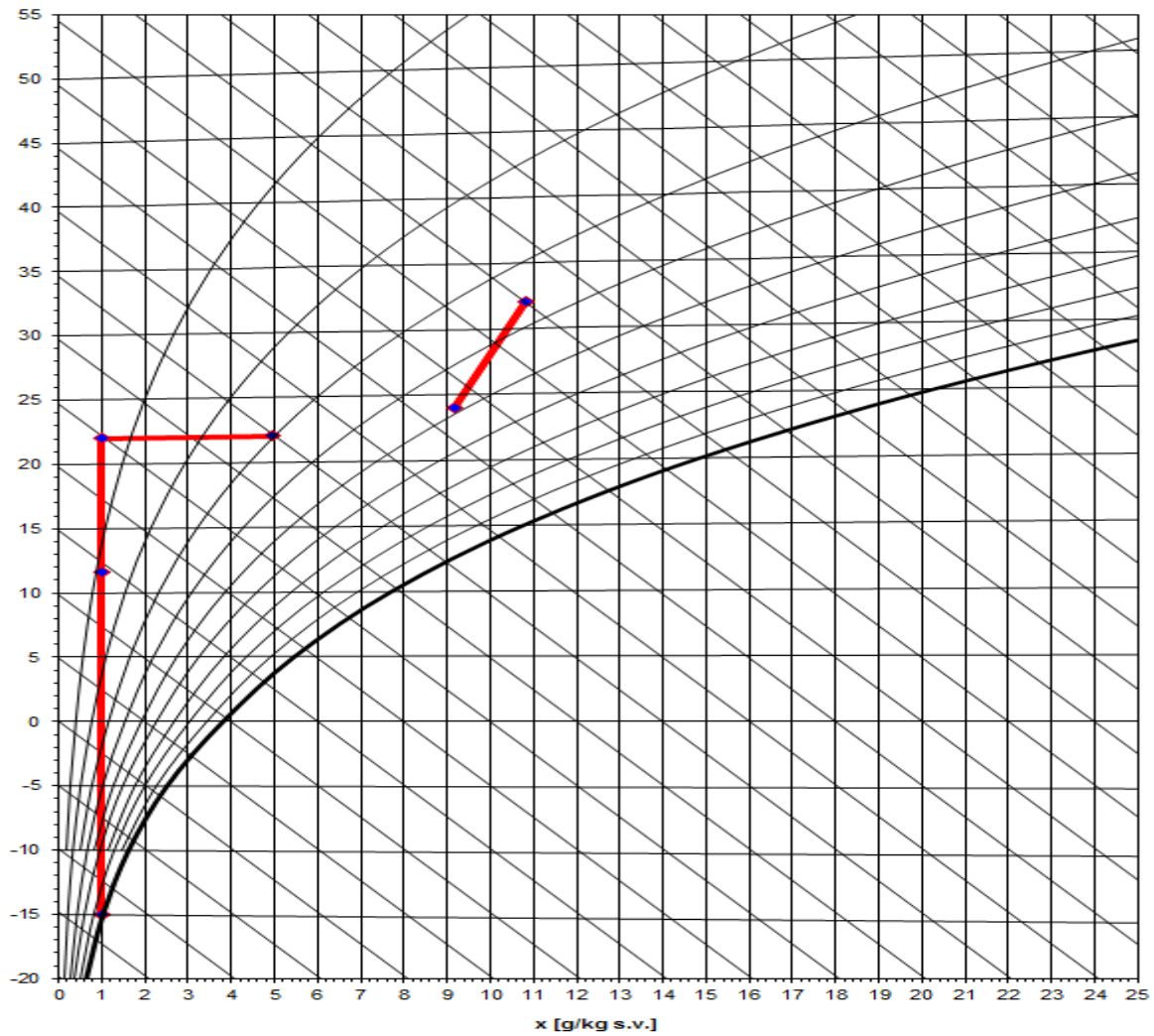X = 1 g/kg
Relative humidity/Humidification = 30%

Figure 13 Psychometric Heating/Cooling chart

The above psychrometric chart shows the cooling/heating capacity and humidification needed by the AHU for winter and summer conditions.

Required Cooling Coil Capacity = 7.3kW
Required Heating Coil Capacity = 6.1kW

Selection of AHU:

The selection of the AHU unit is based on the supply of fresh air needed in a space. Checking the AHU flow rate is the first step. After finding AHU with the desired flow rate check if AHU meets cooling coil and heating coil capacity.
For our desired conditions chosen AHU unit is: Duplex Multi 1500
It is mounted as an under ceiling unit and is placed on each floor of the building. A DX coil(CHF) is additionally added to the AHU for evaporative cooling.

Specification of Duplex Multi 1500

Supply air(m^3/hr)	Heat recovery efficiency(%)	Heating Coil Capacity(kW)	Cooling Coil capacity (kW)
2200	93	22	10

Table3.10
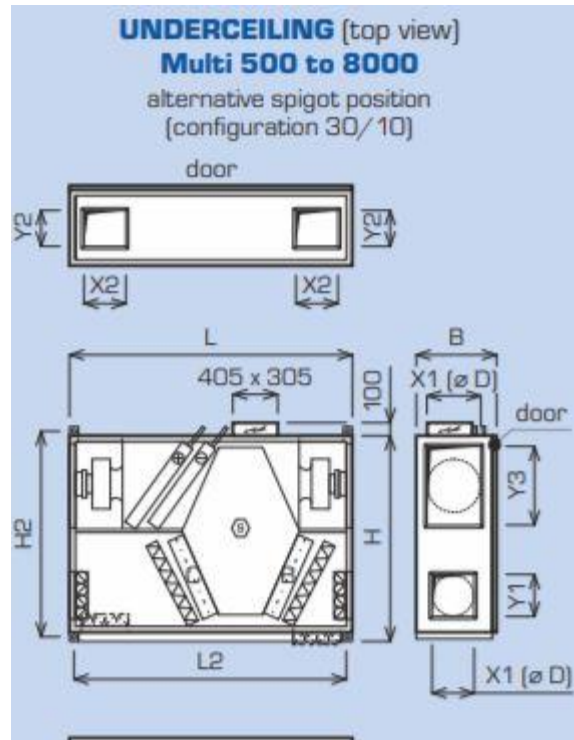
Figure 14 Duplex Multi 1500 mounted under the ceiling.

A compact diffuser grill is connected as return air to the AHU. Specification of the diffuser is in the user manual of SCHAKO:

Velocity = 3m/s

Noise produced = 36dB

ΔP = 6Pa

A silencer is attached as well to reduce noise from the AHU unit. A silencer such as PVA 150 taken from the Lindab manual can be used.

Installation of VRV AC unit and AHU:
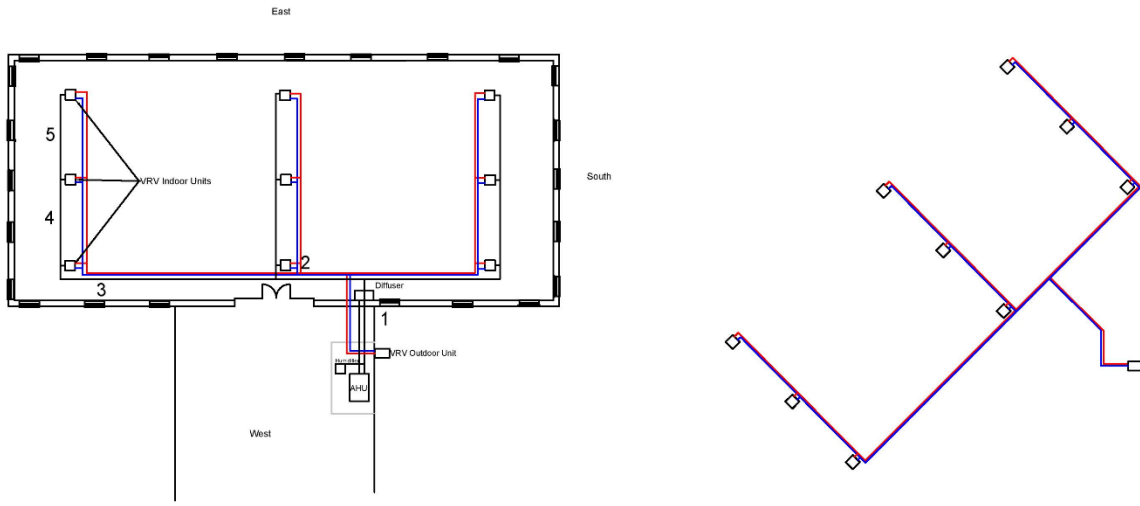
Drawing 2 Floor Design with VRV AC unit and AHU

Preliminary Pipe installation and calculation:
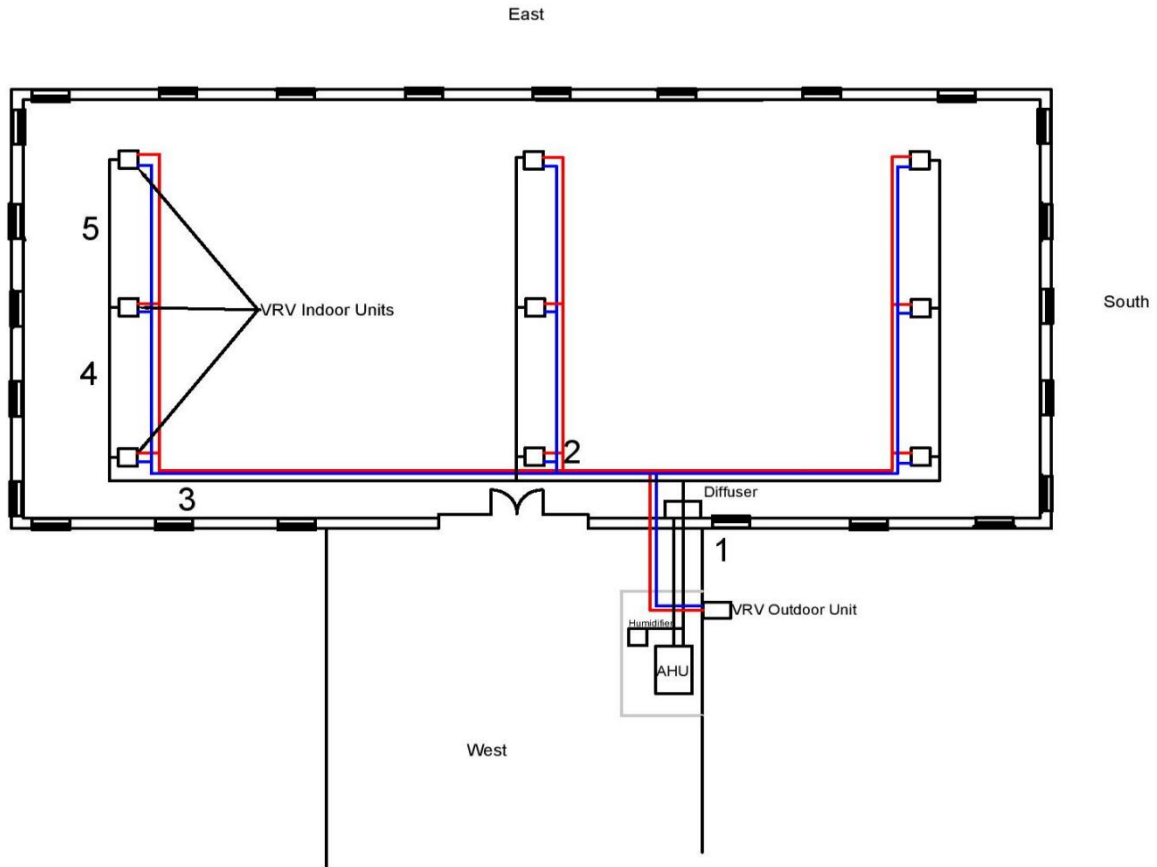
Drawing 3 Circular pipe marking

For circular pipes – SR(from lindab manual)

Pipe No.	$\dot{V}$ (m³/HR)	Theoretical velocity (m/s)	Theoretical Diameter(m)	Real Diameter(m)	Real velocity (m/s)	ΔP/m (Pa/m)	l(m)	ΔP×l (Pa)
1	1750	6	0.325	0.315	6.4	1	8	8
2	1167	6	0.260	0.250	6.5	1.5	7.5	11.25
3	583.5	5	0.201	0.200	5.09	1.2	18	21.6
4	389	4	0.187	0.180	4.32	1.1	7.2	7.92
5	194.5	4	0.126	0.125	4.07	1.4	7.1	9.94
Σ								58.71

Table3.11

Note that the lengths have been rounded up to account for bends in the pipe as well.
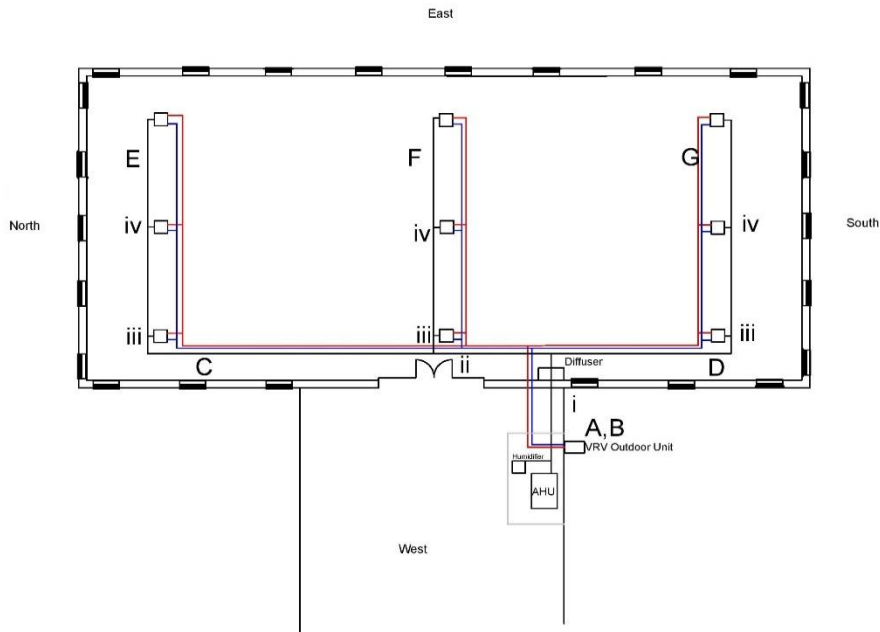
Drawing 4 Elbow bend drawing

For elbow bends and T-bend - BU 90° and TCPU((from lindab manual).

Pipe	$\dot{V}$ (m^3/hr)	Real velocity (m/s)	Real Diameter(m)
A, B	1750	6.4	0.315
C, D	583.5	5.09	0.200
E,F,G	194.5	4.07	0.125
i	1750	6.4	0.315
ii	1167	6.5	0.250
iii	583.5	5.09	0.200
iv	389	4.07	0.125

Table3.12

Note that real velocity and real Diameter are used since elbow bend, and T-bend pipes are connected to circular pipes also ΔP is negligible.

3.1.2 Discussion:

Internal and Solar Heat gains were estimated using the assumptions mentioned above and using standard values from CSN 73 0548 and ASHRAE Handbook - Fundamentals.
After calculating total heat gains from internal, solar and roof heat gains, an appropriate VRV with a heat pump air conditioning unit was chosen from the Daikin catalog. The selected indoor unit was FXFA - 40A, with a capacity of 4.5kW per unit. Nine indoor units are installed in the space to meet cooling demand. These units are then connected to the selected outdoor unit - RXYQ 16U, with a cooling capacity of 45kW. Next, the selection of the AHU unit was made according to the supply of fresh air needed. After finding AHU with the required flowrate, the next step was to check if Cooling and Heating coil capacity were enough for the office space. The chosen AHU unit was Duplex multi 1500. A diffuser grill was installed for the return of stale air into the AHU unit. A humidifier is also installed connecting to the supply air pipe of the AHU to humidify the air during winter heating. The AHU is also placed at least 2m away from

the office space due to noise concern; further, still, a silencer is installed to reduce noise. .The psychometric chart shows the cooling and heating of air needed for thermal comfort in CZ during summer and winter. As shown in the psychometric chart, heat recovery is required only for winter.

The preliminary pipe calculation was done based on the installation of pipe in the office space. The sum of the pressure loss in the whole pipework was less than the allowable pressure difference of the AHU unit, which is necessary for proper working.

3.2: Calculation Using KWT values and constants

	Windows	Walls	Roof
U-factor(W/(m^2.K))	1.2	0.36	0.15

Table 3.13

Surface	Orientation			
	North	South	East	West
Walls	39	54	45	58
Windows	167	167	167	167
Roofs	40	40	40	40

Table 3.14

The above tables 2.13 and 2.4 show the U-value coefficients and ΔT for each surface and orientation. These values are chosen from the 1997 and 2005 ASHRAE Fundamental Handbook standards for Kuwait.

Internal Heat Gain

Source	Calculation	Heat Gain(W)
People	50×75	3750
Lighting	350×13.3	4655
Laptops	50×116	5800
Printers	2×540	1080
Other Miscellaneous Sources	1000×1	1000
		$\Sigma = 16285$

Table 3.15

Solar Heat Gain:

From tables 3.2, 3.13, and 3.14 solar heat gain due to conduction can be calculated using the formula :

$$q = U A \Delta T$$

Orientation	North	South	East	West
Walls	631.589	874.5084	1797.811	1400.881
Windows	3009.006	3009.006	4814.41	3610.807
Σ	3640.595W	3883.514W	6612.221W	5011.688W

Table 3.16

Total Solar Heat Gain =3009.006+3009.006+4814.41+3610.807 = 19147.98W = 19.1kW.
This sum is the total solar heat gain for floors 1,2, and 3.

Total Heat Gain = Total Internal Heat Gain + Total Solar Heat Gain = 16285+19147.98 = 35,432.9≅35,433W =35.4 kW.

Therefore to cool the space for floors 1,2, and 3, an air-conditioning unit of at least 35.4kW is needed.

Roof Solar Heat Gain

Source	Calculation	Heat Gain
Roof	40*900*0.15	5400W

Table 3.17

Total Solar Heat Gain for 4th floor = 19147.98 + 5400 = 24547.98W = 24.5 kW
Total Heat Gain for 4th floor = 16285 + 24547.98 = 40,800W = 40.8kW

Therefore to cool the space for the 4th floor, an air-conditioning unit of at least 40.8 kW is needed.

Selection of AC unit:

The same VRV AC unit installed for the CZ region can be installed for Kuwait since the cooling capacity of the VRV system is within range of the cooling load.
 The selected indoor unit is FXFA- 40A
The selected outdoor unit is RXYQ 16U

The following psychrometric chart is obtained from using KWT weather conditions in Summer and Winter.

Supply of fresh air(Volumetric flow rate) = 1750 m^3/hr
During Summer:
Cooling Coil temperature = 3°C
Outside temperature = 47.9°C
Desired indoor temperature = 24°C
Heat Recovery temperature = 30.69°C
Enthalpy =65 kJ/kg

During Winter:
Outside temperature = 4.1°C
Desired indoor temperature = 22°C
X = 1.5 g/kg
Relative humidity/Humidification = 30%
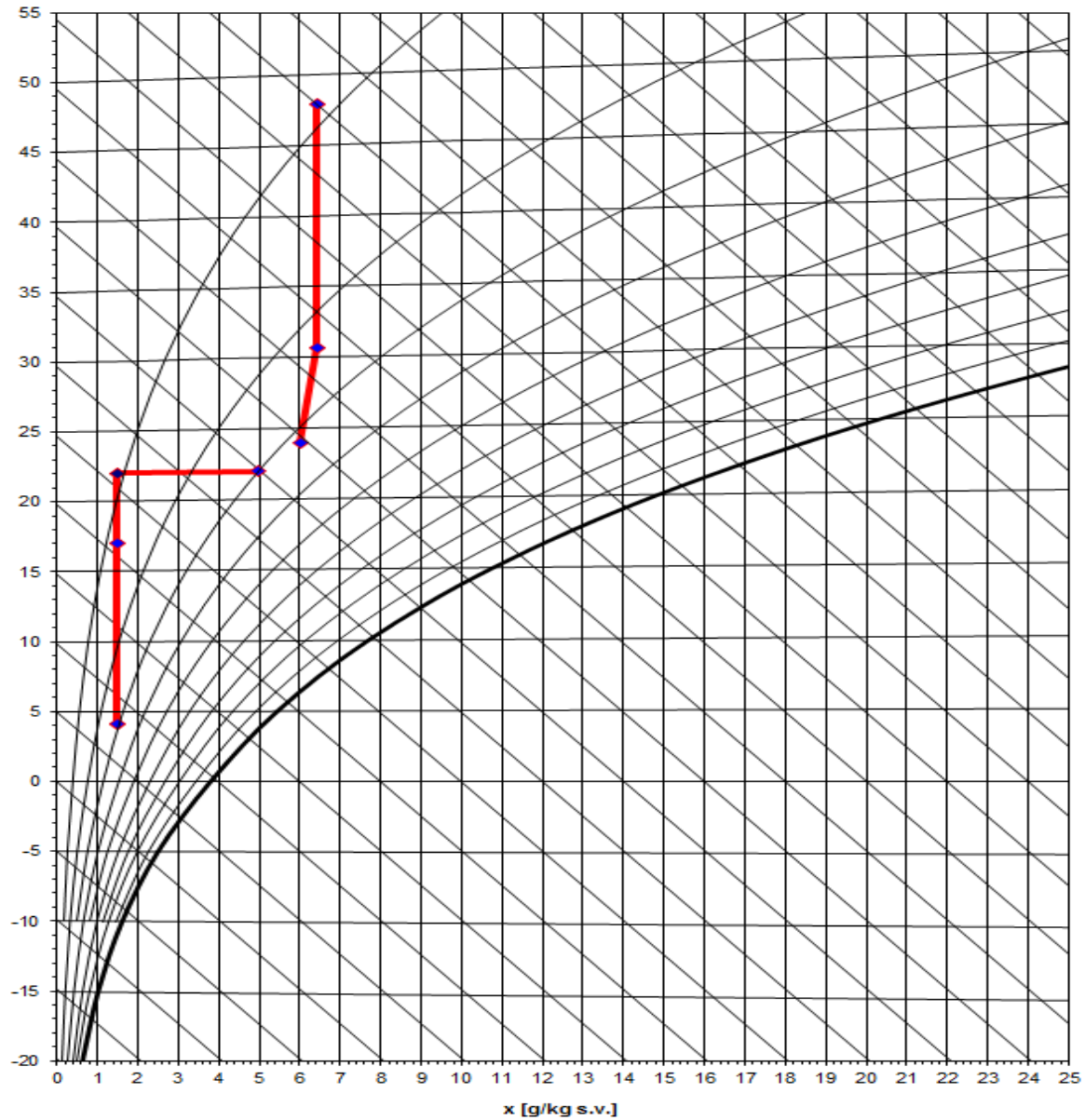
Figure 15 – Psychometric Heating/Cooling Chart

Required Cooling Coil Capacity = 4.6kW
Required Heating Coil Capacity = 3 kW

Selection of AHU unit:

Again the same unit installed in the CZ region can be used for Kuwait as well since the AHU meets the cooling coil and heating coil capacity in Kuwait.
AHU suplex Multi 500 is installed.
The humidifier and diffuser can be set up in the same as in CZ as well.

3.2.1 Discussion:

A similar discussion to Czechia can be made since here is only a couple of kW differences in heat gains. The same VRV AC units and AHU units are used with the same diffuser to return air and a humidifier installed to the supply pipe of the AHU. Since the units and the floor design are the same, the installation and preliminary calculation of the pipeline remains the same. Including the pressure loss!

Conclusion:

On the comparison between the design of an AC system for Czechia and Kuwait, there isn't much difference. Due to the assumption made the internal heat gain for both regions stayed the same, also because of complete and effective shading, there was no radiation just conduction heat transfer, and there was no infiltration air as well.

However, the solar heat gains in Kuwait were found to be slightly higher about 2kW for each level even then the same VRV AC system could be installed for both regions along with the same AHU, humidifier, and diffuser. Although in Czechia, heat recovery is needed only in winter, on the other hand, for Kuwait, heat recovery for both summer and winter is necessary for better and more efficient heating and cooling. A humidifier is installed for the humidification of the air in winter. It is connected to the supply pipeline coming from the AHU unit.

Annual Cooling, Dehumidification, and Enthalpy Design Conditions

Hottest month	Hottest month DB range	Cooling DB/MCWB						Evaporation WB/MCDB						MCWS/PCWD to 0.4% DB	
		0.4%		1%		2%		0.4%		1%		2%			
		DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB	MCWS	PCWD
7	8	9a	9b	9c	9d	9e	9f	10a	10b	10c	10d	10e	10f	11a	11b
7	10.5	29.0	18.6	26.9	18.0	25.1	17.2	19.8	26.2	18.8	25.0	18.0	23.5	3.5	110

Dehumidification DP/MCDB and HR									Enthalpy/MCDB					
0.4%			1%			2%			0.4%		1%		2%	
DP	HR	MCDB	DP	HR	MCDB	DP	HR	MCDB	Enth	MCDB	Enth	MCDB	Enth	MCDB
12a	12b	12c	12d	12e	12f	12g	12h	12i	13a	13b	13c	13d	13e	13f
17.6	13.2	22.4	16.7	12.5	21.0	15.9	11.8	20.4	58.1	26.4	54.9	25.2	52.1	23.5

Figure 16 Annual Cooling Dehumidification and Enthalpy Design Condition in Prague, CZ[29]

Annual Cooling, Dehumidification, and Enthalpy Design Conditions

Hottest Month	Hottest Month DB Range	Cooling DB/MCWB						Evaporation WB/MCDB						MCWS/PCWD to 0.4% DB	
		0.4%		1%		2%		0.4%		1%		2%			
		DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB	MCWS	PCWD
7	15.1	48.0	20.8	47.0	20.5	46.0	20.3	28.2	35.1	26.5	34.8	24.7	34.7	6.3	320

Dehumidification DP/MCDB and HR									Enthalpy/MCDB						Extreme Max WB
0.4%			1%			2%			0.4%		1%		2%		
DP	HR	MCDB	DP	HR	MCDB	DP	HR	MCDB	Enth	MCDB	Enth	MCDB	Enth	MCDB	
26.6	22.3	32.9	24.1	19.2	31.8	21.9	16.7	30.5	91.6	35.0	83.2	34.1	75.4	34.6	32.2

Figure 17 Annual Cooling Dehumidification and Enthalpy Design Condition in KWT, KWT [30]

Another difference to notice is the dry-bulb temperature for both regions. The above tables show dry-bulb temperature for both countries during the hottest month of the year and show how often it reaches that dry bulb temperature; this directly affects cooling loads.

Due to the higher dry bulb temperature in Kuwait, the cooling load is for longer hours compared to Czechia.

The preliminary pipe installation and calculations were done. Still, it is better to consult a Civil/Structural engineer for installation not to damage the strength and integrity of the building structure.

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