

Design Project #2

MAE 3524 – Thermal Fluid Design

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Introduction:

This Project was assigned to teach and confirm students' knowledge about psychometrics. The goal of the project was to find the specifications for an evaporative air cooler and choose an appropriate model given a geographic location and room sizes, along with ideal room temperature and humidity.

Part 1- Load Calculation:

Part A – Infiltration:

Infiltration is the introduction of new fresh air into the room. By introducing new “unconditioned” air it adds heat to room. In this report the infiltration rate is 0.5 ACH, which mean half of the air in the room is replaced each hour. The sensible heat can be calculated using the mass flow rate and enthalpy values from the “conditioned” and “unconditioned” air. The mass flow rate can be calculated by multiplying the volume of the room by the infiltration rate and dividing by the specific volume of the “unconditioned” air. The enthalpy values can be found using given/table and psychometrics. The latent heat is found by multiplying the mass flow rate by the difference in absolute humidity and vaporization enthalpy. Below in Table 1 these values are summarized.

Quantity	Value (Units)
Volume of Conditioned Space	11,025 (ft ³)
Infiltration rate	0.5 ACH
Outdoor Air Dry Bulb/Wet Bulb Temperatures – 1% Cooling Design Conditions	98.2 (F) / 67.4 (F)
Indoor Air Dry Bulb Temperature/Relative Humidity Design Conditions	72 (F) / 50%
Outdoor Air enthalpy at Design Conditions	31.66 (BTU/hr)
Indoor Air enthalpy at Design Conditions	26.41 (BTU/hr)
$\dot{Q}_{sensible,infiltration}$	2,461 (BTU/hr)
$\dot{Q}_{latent,infiltration}$	416.2 (BTU/hr)
$\dot{Q}_{total,infiltration}$	2,877 (BTU/hr)

Table 1 - Infiltration Heat Load

Part B – Occupants:

Another source of heat that has to be accounted for is the heat that people create. In order to calculate the heat created by people the occupancy of the room and the representative rate at which heat and moisture are given off by human beings must be known. Using provided literature for this report it is known that 30 people can occupy 1000 square feet in a restaurant. Because this room in this report is 1050 square feet it is safe to say 30 people will fit into the room. The representative rate at which heat and moisture are given off by human beings doing sedentary work, like that of a restaurant is adjusted to 550 BTU/hr for a Male/Female mix. 275 BTU/hr is sensible and 275 BTU/hr is latent. The head rates are found by multiplying the rate of heat given off by the number of occupants. Table 2 summarizes the values discussed above for easy reference.

Quantity	Value (Units)
Area of Room	1050 (ft ²)
Occupant density	30 (People / 1000 ft ²)
Maximum Occupant Density	30 (People)
Total Heat/person	550 (BTU/hr)
Sensible Heat/person	275 (BTU/hr)
Latent Heat/person	275 (BTU/hr)
$\dot{Q}_{sensible,occupancy}$	8,250 (BTU/hr)
$\dot{Q}_{latent,occupancy}$	8,250 (BTU/hr)
$\dot{Q}_{total,occupancy}$	16,500 (BTU/hr)

Table 2 - Occupancy Heat Load

Part C – Lighting:

Lights are a source of heat in any space and must be accounted for. Using the provided literature for this report, the lighting density of a restaurant is 0.65 W/ft². Given the that restaurant is 1050 square feet, we can calculate the cooling load by multiplying the lighting density by floor space than converting Watts to BTU/hr. Table 3 summarizes these values.

Room	Function	Floor Area	Lighting Density	Cooling Load
102	Restaurant	1,050 (ft ²)	0.65 (W/ft ²)	2,329 (BTU/hr)

Table 3 - Lighting Heat Load

Part D – Equipment:

Restaurants have a lot of equipment that produce heat, such as stoves, ovens, dishwashers, etc. Using the literature provided for this report it was found that the sensible heat released from equipment was 1050 Watts per 1000 square feet, and the latent heat released is 3000 Watts per 1000 square feet. To find the total heat these values a multiplied by the floor space of the room, 1050 square feet, and converted to BTU/hr. The values after calculation can be found below in Table 4.

Quantity	Value (Units)
Building Use	Restaurant
$\dot{Q}_{sensible,equipment}$	3,762 (BTU/hr)
$\dot{Q}_{latent,equipment}$	10,748 (BTU/hr)
$\dot{Q}_{total,equipment}$	14,510 (BTU/hr)

Table 4 - Equipment Heat Load

Part E – Building Envelope:

The environment is a major cause for unwanted heat in a climatized space and should be account for when calculating the heat load. To find the heat load of the building envelope the heat transfer race is multiplied by the surface area in contact with the environment and the difference between the “conditioned” and “unconditioned” air. For this report the heat transfer coefficient is 0.50 and the area that in contact with the environment is 682.5 square feet. These intermediate and final values are displayed in Table 5.

Quantity	Value (Units)
Building Surface Area	682.5 (ft ²)
Average Heat Transfer Coefficient	0.5 (Btu/hr-ft ² -F)
T _{db,outdoor design condition}	98.2 (F)
T _{db,indoor design condition}	72 (F)
$\dot{Q}_{sensible,building\ envelope}$	8,941 (BTU/hr)

Table 5 - Building Envelope Heat Load

Part F – Combined Loads:

The pervious section has discussed how to find the heat load produced from a variety of sources. The combined loads are simply the sum of the previous sections. Table 6 displays the total heat load of all the previous section and the total heat load.

Quantity	$\dot{Q}_{sensible}$ (Units)	\dot{Q}_{latent} (Units)	\dot{Q}_{total} (Units)
Infiltration	2,461 (BTU/hr)	416.2 (BTU/hr)	2877 (BTU/hr)
Occupants	8,250 (BTU/hr)	8,250 (BTU/hr)	16,500 (BTU/hr)
Lighting	2,329 (BTU/hr)		2,329 (BTU/hr)
Equipment	3,762 (BTU/hr)	10,748 (BTU/hr)	14,510 (BTU/hr)
Building Envelope	8,941 (BTU/hr)		8,941 (BTU/hr)
Combined	25,742 (BTU/hr)	19,414 (BTU/hr)	45,156 (BTU/hr)

Table 6 - Combined and Total Heat Load

Part 2 – Evaporator Cooler Design:

The final required design of the cooler need a minimum volumetric flow rate of 2046 cubic feet per minute and a water flowrate of 5.199 gallon per hour. After selecting the cooler and finding the fan has a 16 inch diameter it is possible to find the Air velocity by dividing the mass flow rate by the area of the blade. The mass flow rate used is found by dividing the total heat load in Table 7 by the difference in enthalpy of the “conditioned” and “unconditioned” air. The selected cooler has two pads that are 10.5 inches x23 inches and one pad that is 21 inches x 23 inches. Lastly. The cooler effectiveness is 68.71%. This was found by dividing the difference of the “unconditioned” dry air and “conditioned” dry air by the difference of the “unconditioned” dry air and “conditioned wet air.

Specifications	Value (Units)
Air flowrate	2046 (CFM)
Water flowrate	5.199 (gal/hr)
Air velocity	1465 (FPM)
Pad size (Width, Height)	2x 10.5"x 23", 1x 21" x 23"
Evaporative cooler effectiveness (%)	68.71%

Table 7 - Minimum and Selection Specifications

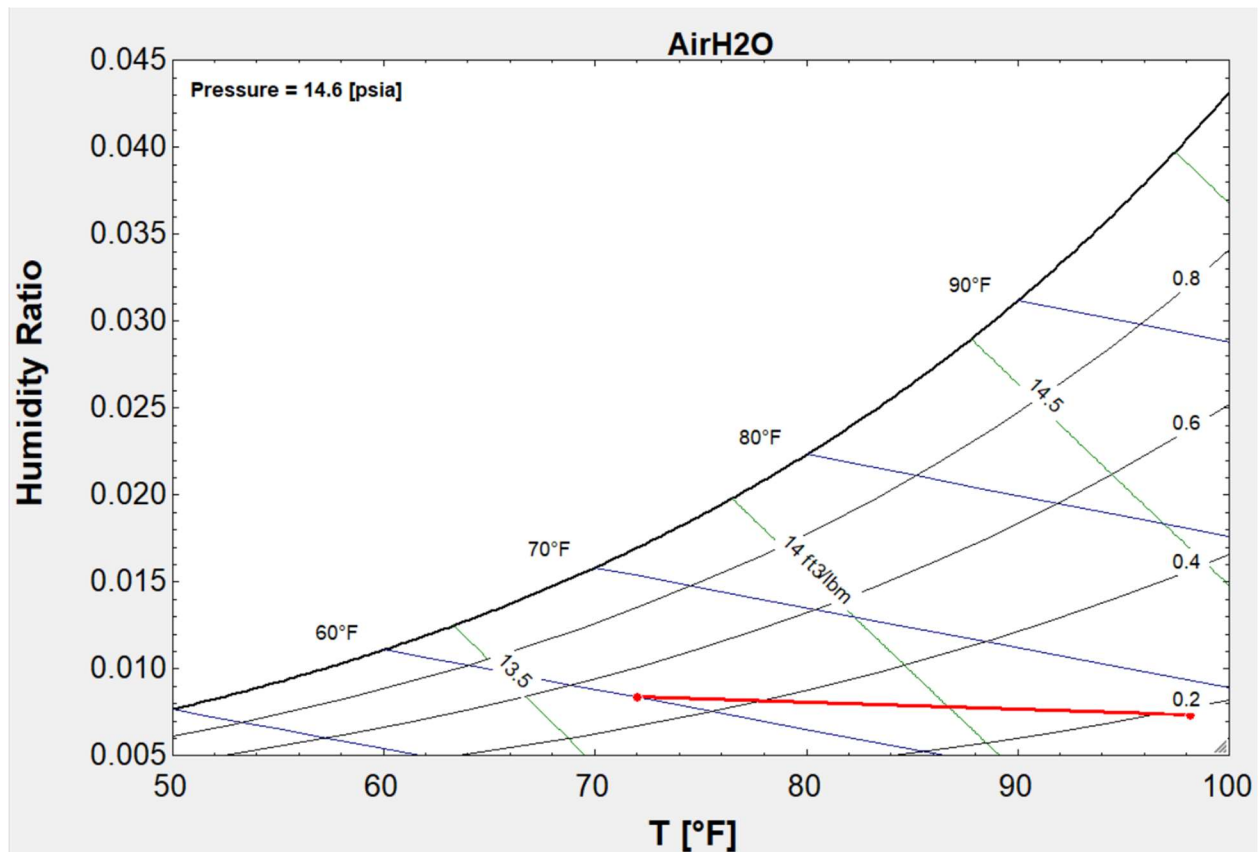


Figure 1 - Psychrometric Chart For Cooling Process

Part 3 – Evaporator Cooler Selection:

The cooler that was selected was the Honeywell CO610PM. This cooler met the needs that the space required. Because evaporative coolers are selected based on the volumetric flow rate this was a perfect solution. Table 7 shows that the volumetric flow rate needs to be a minimum of 2046 cubic feet per minute. The Honeywell CO610PM meets that with a volumetric flow rate of 2100 cubic feet per minute. In this situation the most important value in Table 8 is the Air Flowrate, because evaporator coolers are selected using flowrate and not cooling capacity.

Quantity	Info
Style (random-media or rigid-media)	Rigid-Media
Manufacturer	Honeywell
Product Name and/or Model Number	CO610PM
Air flowrate	2100 (CFM)
Water Capacity	14 (gal)
Size (Width x Depth x Height)	27.7" x 18" x 41.2"
Quantity Required	1
Link to product	https://www.honeywellstore.com/store/products/outdoor-portable-evaporative-air-cooler-2100-cfm-black-co610pm.htm

Table 8 - Final Selection Specifications