

Let’s Get Mechanical: Outside Air Requirements and Heating Load - Student Activity Sheet

Name:\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ Date:\_\_\_\_\_\_\_\_\_\_\_\_

# Task 1

Clean, fresh air plays a vital factor in the role of today’s building designers.

How do technicians determine the amount of air that must flow into a certain space?

You are working to calculate the outside air requirements for the first floor of the provided floor plan. Using the provided information, determine the outside air requirements for each space.

**Minimum Ventilation Rates Per NC Mechanical Code**

|  |  |  |  |
| --- | --- | --- | --- |
|  | Occupant Density(Person/$1000 ft^{2}$) | People Outdoor Airflow Rate, $R\_{p}$(CFM/Person) | Area Outdoor Airflow Rate, $R\_{a}$(CFM/$ft^{2}$) |
| Office | 6 | 5 | 0.06 |
| Library | 25 | 10 | 0.12 |
| Conference room  | 50 | 5 | 0.06 |
| Corridor | 0 | 0 | 0.06 |
| Lobby/Reception | 30 | 5 | 0.06 |
| Multi-function | 100 | 7.5 | 0.06 |

Note: CFM = $ft^{3}/min$

Formula for required ventilation rate (airflow rate):

$V =R\_{p}P\_{z}+R\_{a}A\_{z}$,

where the variables/components of the formula are:

 $V=$Ventilation rate in CFM

$R\_{p}=$People outdoor airflow rate in CFM/person

 $P\_{z}=$Space occupancy, the whole # of people that the ventilation rate needs to account for

$R\_{a}=$Area outdoor airflow rate in CFM/$ft^{2}$

 $A\_{z}=$Space floor area in $ft^{2}$

## Exploration

1. Which two of the four components (variables) of the formula are provided in the table?

1. Which two components will you need to determine?
2. Which one of the two components which you must determine depends on the other?
3. What are the units of the product $R\_{a}A\_{z}$?
4. What are the units of the product $R\_{p}P\_{z}$?
5. The occupant density for Lobby is listed as 30 people per 1000 sq. ft. Suppose the area of a lobby is 710 sq. ft.
	1. A spreadsheet set up by a coworker is calculating the space occupancy as 21300 people. What is wrong with the spreadsheet?
	2. The space occupancy is the number of people which the ventilation system will have to account for when used in other calculations. Keeping this in mind, how should the correct space occupancy be rounded?

**Outside Air Requirements**

|  |  |  |  |
| --- | --- | --- | --- |
|  | Space Floor Area$$A\_{z}$$ | Space Occupancy$P\_{z}$  | Ventilation Rate$V$  |
| Offices (3 total) |  |  |  |
| Library |  |  |  |
| Conference room  |  |  |  |
| Corridor |  |  |  |
| Lobby/Reception\* |  |  |  |
| Multi-function |  |  |  |

\*Include hallway between toilets and elevators and stairway in Lobby/Reception

## Example: Office space

**Step 1**: Find the \_\_\_\_\_\_\_ of the space.

**Step 2**: Determine the amount of people (the space occupancy $P\_{z}$), using the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ and the \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ . (Round up)

**Step 3**: Use the table and the formula to find the Ventilation Rate.

1. Area of each office: $12 x 10 = 120 ft^{2}$
2. Amount of people $(P\_{z})$: $\frac{6 people}{1000 ft^{2}}=\frac{x}{120 ft^{2}}$; $x=0.72 people$; rounds up to $P\_{z}=1$ person
3. Ventilation Rate, $V$: $V=R\_{p}P\_{z}+R\_{a}A\_{z}=(5 CFM/person)× (1 person) + (0.06 CFM/ft^{2})×( 120 ft^{2}) $

$$V=5 CFM + 7.2 CFM = 12.2 CFM$$

So, each office requires 12.2 CFM of ventilation. This is approximately equivalent to a 2ft x 2ft x 3ft box of air being forced into the room each minute.



## Exercise

*Complete the Outside Air Requirements Table for the remaining spaces: library, conference, corridor, multi-function, lobby/reception. Compare the outside air requirements for each space and discuss the results with your group.*

# Task 2

Keeping a building warm in the winter and cool in the summer is a main concern for architectural design companies.

For our scenario, you are working to keep the building occupants warm in the winter by calculating the heating load for the exterior walls and windows of the rooms on the first floor. Which component contributes more to the heating load?

Formula for heating or cooling load:

$Q = UA (T\_{i}-T\_{o})$,

where the variables/components of the formula are:

 $Q=$Heating or cooling load in BTU/hr (amount of energy needed to keep space heated)

 $U=$Total U-value for assembly in $BTU/(hr×ft^{2}×℉$)

 $A=$Area in $ft^{2}$

 $T\_{i}$ = Indoor temperature in $℉$

 $T\_{o}$ = Outdoor temperature in$℉$

The temperatures for Raleigh, NC, are given below.

|  |  |  |
| --- | --- | --- |
|  | Winter | Summer |
| Peak Outdoor Design Conditions for Raleigh, NC, $T\_{o}$ | $$20.4^{∘}F$$ | $$95^{∘}F$$ |
| Indoor Design Conditions for Building, $T\_{i}$ | $$70^{∘}F$$ | $$75^{∘}F$$ |

The exterior components of the building are insulated to prevent heat exchange. Each component is assigned a U-Value, which has units $BTU/(hr×ft^{2}×℉)$. The unit $BTU$ is a measure of energy (1000 BTU is approximately 0.293071 kWh) called a British thermal unit.

|  |  |
| --- | --- |
|  | U-Value in $BTU/(hr×ft^{2}×^{∘}F)$ |
| Wall | 0.064 |
| Window | 0.4 |
| Roof | 0.048 |

For this floor plan, the exterior wall height is $13'$, and a typical window is $3'×4'$.

## Exploration

1. Why should we only include exterior walls in the calculation for heating load?
2. Which three of the four components (variables) of the formula are provided in the information above?
3. Which component will you need to determine?

## Example (Corner Office)

Determine the heating load caused by the corner office. Because the U-values are given by wall/window, we will need to do each separately.

Step 1: Find the area of the windows.

 $3'×4'=12 ft^{2}$; Total of $2×12 = 24 ft^{2}$

Step 2: Calculate the Heating Load caused by the windows, using the formula above.

 $Q = UA (T\_{i}-T\_{o})=(0.4\frac{BTU}{hr×ft^{2}×∘F})(24 ft^{2})(70^{∘}F-20.4^{∘}F)=476.16 BTU/hr$

Step 3: Find the area of the exterior walls of the corner office (without the windows).

 $12'+10'=22'$ length of exterior wall, at a height of $13'$ gives $22'×13'=286 ft^{2}$

 subtracting the windows gives $286-24=264 ft^{2}$

Step 4: Calculate the Heating Load using the formula above.

 $Q = UA (T\_{i}-T\_{o})=(0.064\frac{BTU}{hr×ft^{2}×∘F})(264 ft^{2})(70^{∘}F-20.4^{∘}F)=838.04 BTU/hr$

Step 5: Add the heating loads from the windows and the walls:

 Total $Q= 476.16 BTU/hr+838.04 BTU/hr=1314.2 BTU/hr $

|  |  |  |
| --- | --- | --- |
| Corner Office | Area $(ft^{2})$ | Heating Load $(BTU/hr)$ |
| Windows  | 24 | 476.16 |
| Walls | 264 | 834.04 |

So, the walls contribute more to the heating load.

## Exercises

1. Determine the heating load for the conference room. Only consider external walls/windows.

|  |  |  |
| --- | --- | --- |
| Conference Room | Area $(ft^{2})$ | Heating Load $(BTU/hr)$ |
| Windows  |  |  |
| Walls |  |  |

1. Determine the heating load for the library. Only consider external walls/windows; you may treat the double door onto the patio as a wall.

|  |  |  |
| --- | --- | --- |
| Library | Area $(ft^{2})$ | Heating Load $(BTU/hr)$ |
| Windows  |  |  |
| Walls |  |  |

# Discussion

1. For each room above (corner office, conference room, library) determine the component which contributes the most to the heating load.
2. Explain why all three rooms did not have the same component that contributed the most to the heating load.
3. Why is it not enough to just compare the area of windows to the area of walls?
4. Consider the formula for the heating load $Q = UA (T\_{i}-T\_{o})$.
	1. What will happen to the heating load if the height of the wall is decreased?
	2. Suppose another wall assembly is chosen with “better” insulation. Should this correspond to a greater or smaller U-value?
	3. Which month(s) of the year will the heating/cooling bills be most expensive? How does this relate to the formula?