HIVE

High efficiency honey processing facility

DESIGN OBJECTIVE

To develop a temperature and humidity controlled honey processing environment emphasizing food safety and a linearized workflow

CLIENT: Alberta Beekeepers Commission

ADVISOR: Dr. John Doucette

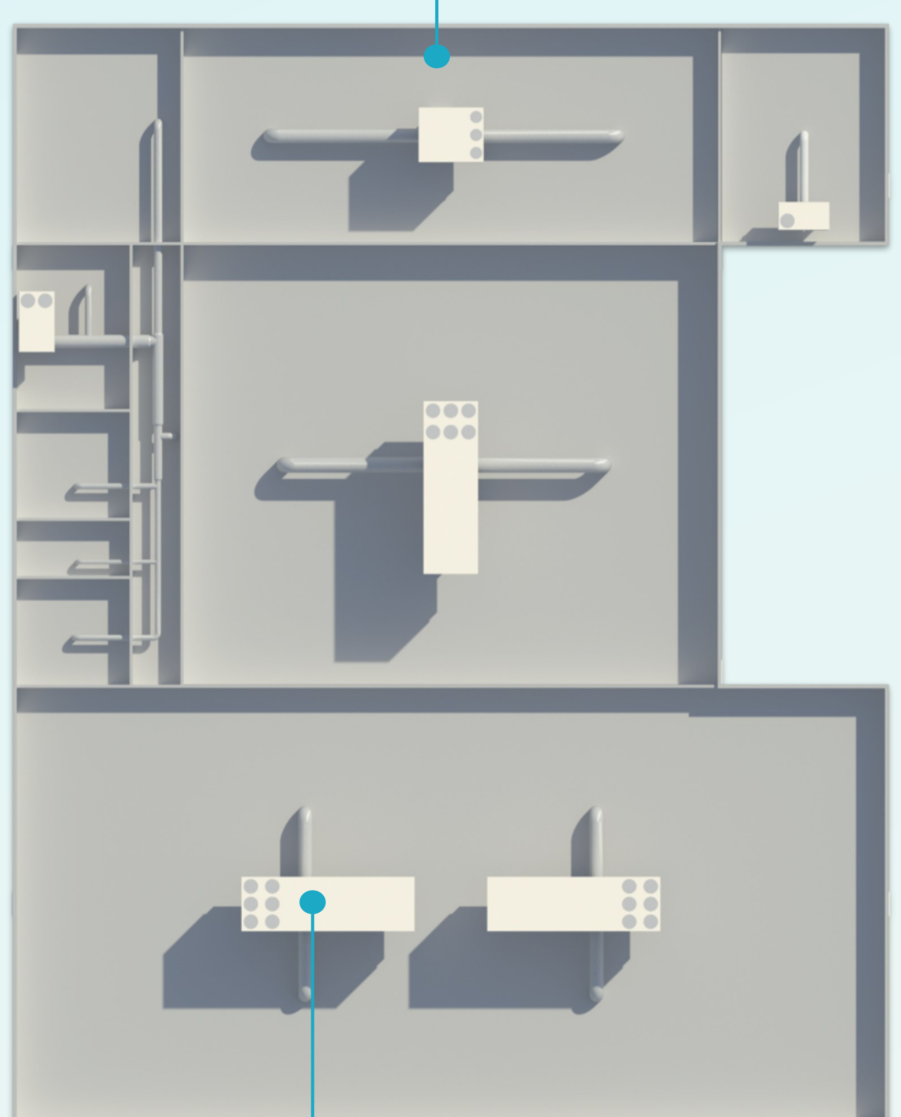
COURSE COORDINATOR: Dr. Kajsa Duke

Challenge

Create a regulated work environment to address the temperature and humidity challenges associated with producing high quality honey. Undesirable conditions can cause darkening, fermentation, and loss of nutritional benefits.

Air Circulation

12 air changes per hour in food processing zones and 6 air changes per hour in remaining zones to introduce clean air

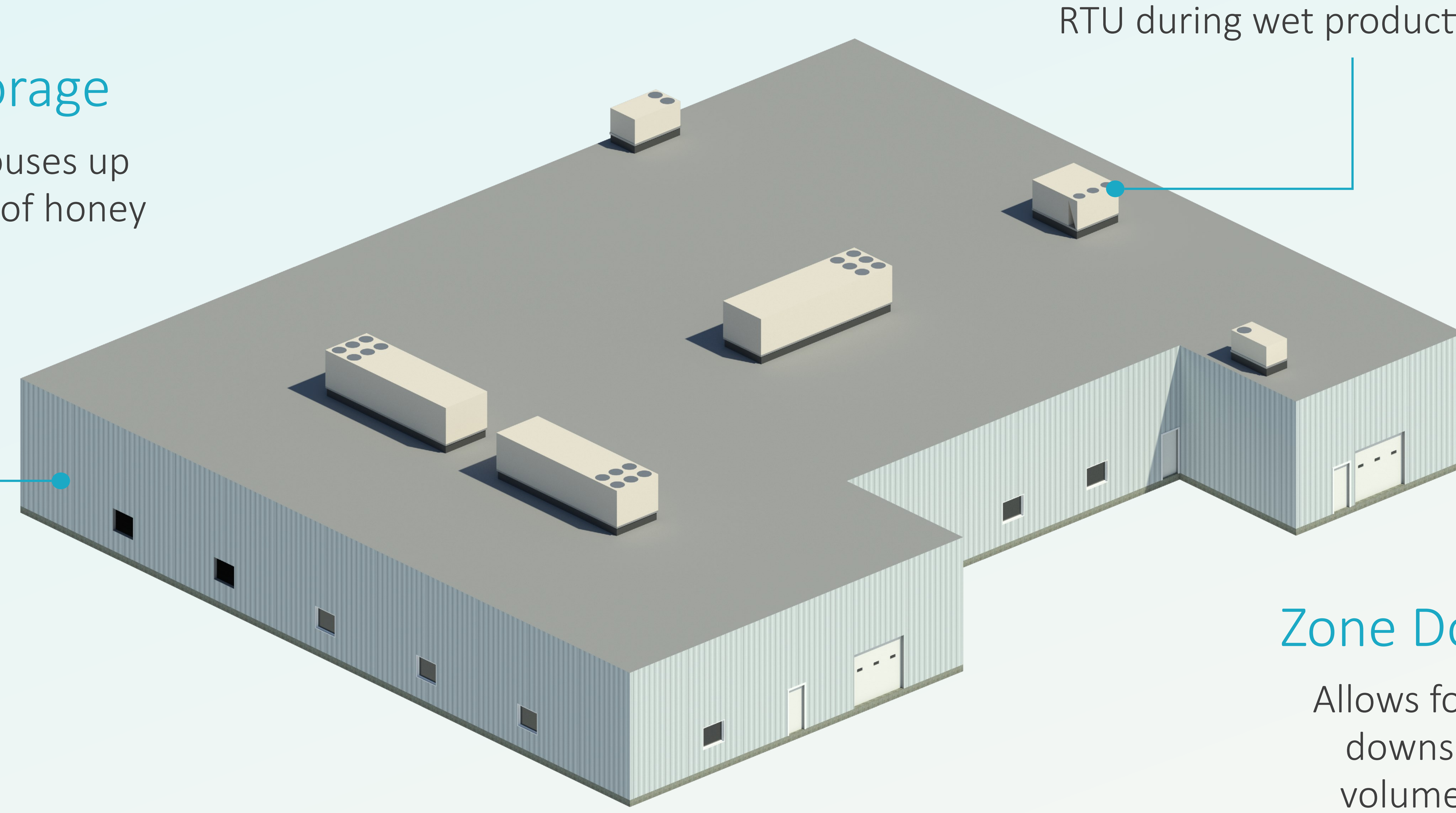


Rooftop Units (RTU)

Lennox units with built in pest control, dehumidification, and temperature regulation

Honey Storage

Cold storage houses up to 3,800 barrels of honey

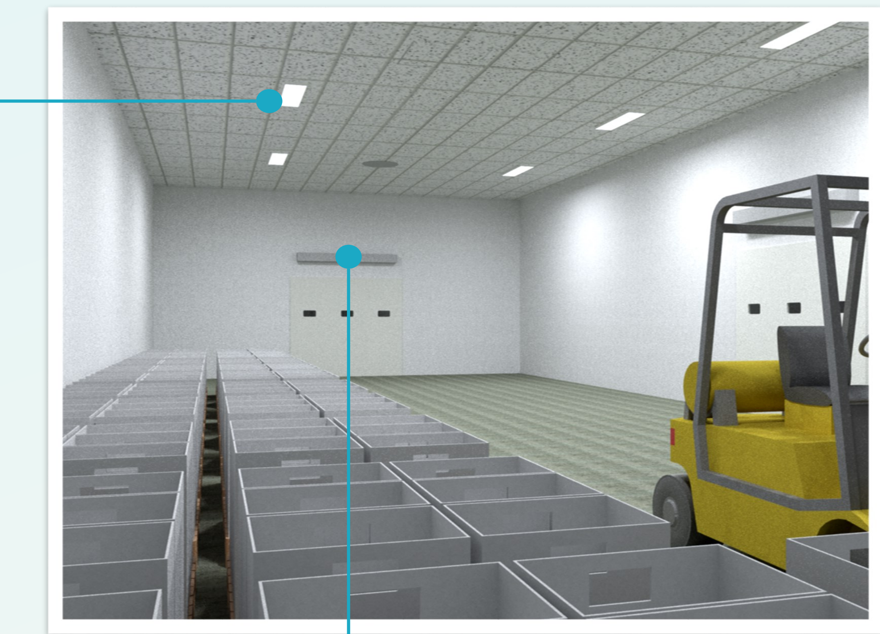


Humidity Control

Standalone dehumidifiers assist the RTU during wet production seasons

LED Lighting

In-ceiling LED lights prevent dust buildup and reduces energy costs



Air Curtain

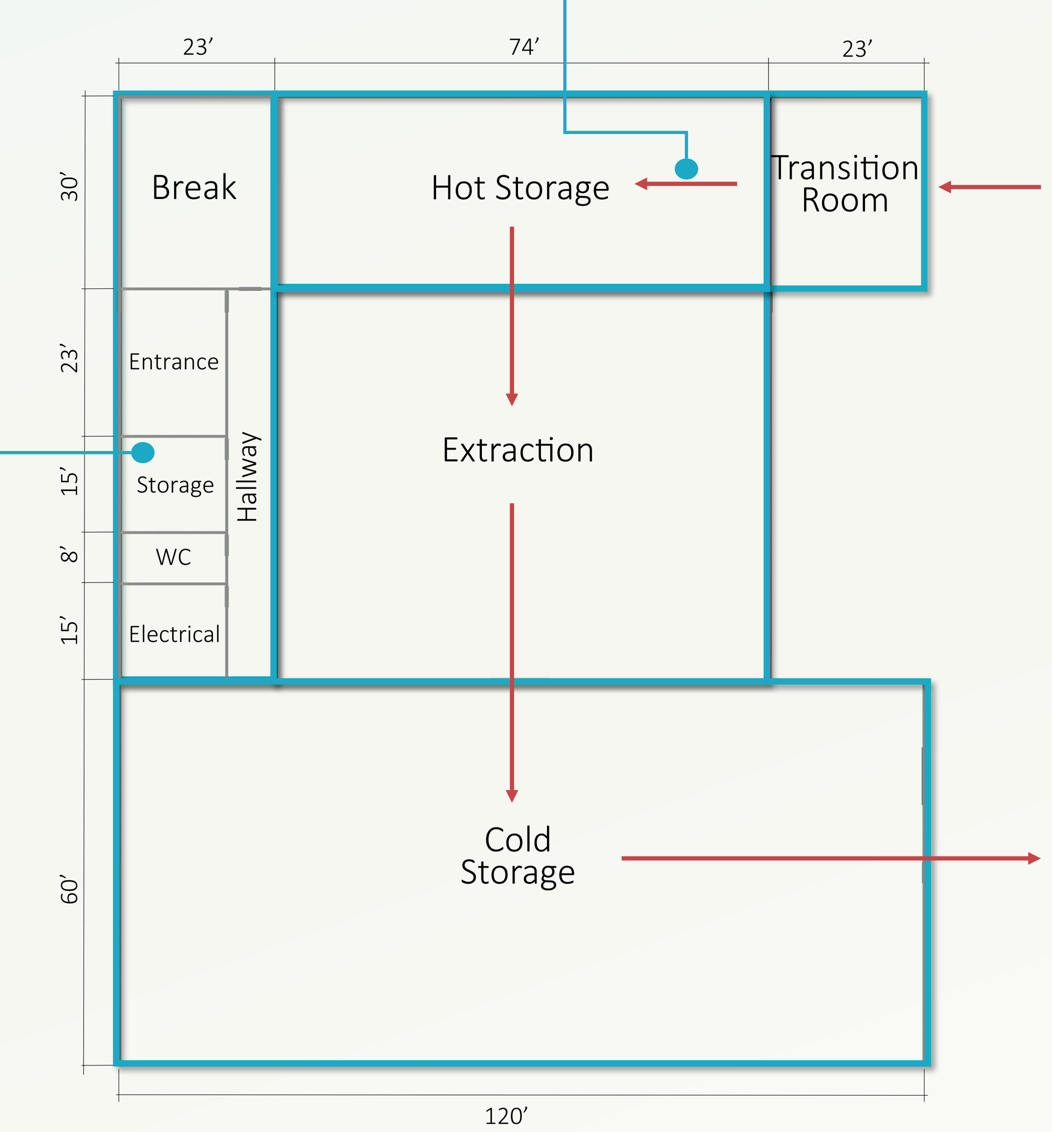
Activates when overhead door is open to prevent infiltration of contaminants

Linear Workflow

Allows operator to move from most to least sterile environment, while reducing travel distance to increase efficiency

Zone Dominated Design

Allows for potential upscale or downscale proportional to volume of honey produced



Key Features

Hot room is maintained at 30°C and 30% relative humidity to ensure high honey quality

Transition room ensures sterility and reduces heat loss

Durable, food safe materials for longevity, ease of cleaning, and a sterile processing environment

UNIVERSITY OF ALBERTA

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B.E.E. Consulting Services

Honey Packing House Design

Phase III: Final Report

December 2, 2019

B.E.E. Consulting Services

Executive Summary

B.E.E Consulting Services (BCS) was contracted by the Alberta Beekeepers Commission to design a honey packing house optimized for excellent honey production. To optimize honey production, a temperature set point of 30℃ and humidity set point of 30% must be maintained in areas where honey supers are stored, followed by ambient temperature and humidity set points in the remainder of the house. In response to client specifications, the HIVE honey house has been produced.

The HIVE honey house provides a high-performance design which utilizes equipment and materials to minimize heat loss and overall operating costs. The layout promotes an efficient workflow to maximize employee productivity. All elements of the design were chosen to meet food safety standards. Detailed analysis was performed to optimize the HVAC system, provide adequate humidification, and to determine the energy consumption of the facility. The total cost of the HIVE Honey House is estimated to be $649,550, with $63,000 of the total cost allocated to the BCS engineering team. A total of 700 hours was spent throughout all three phases of the project.

BCS has recommended future improvements to further refine the concept for the client and to ensure complete design viability.

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1 Introduction

Fluctuations in temperature and humidity during the honey packing process adversely affects honey quality and is the biggest challenge a producer must overcome. A good processing facility can make a significant difference for beekeepers by both ensuring the conditions are optimal for honey extraction and providing a comfortable work environment for the long days.

B.E.E Consulting Services (BCS) has been contracted by the Alberta Beekeepers Commission (ABC) to provide a design for a honey packing house that will maintain the temperature and humidity setpoints required for producing the highest quality honey, while remaining competitively priced and compliant with the Safe Food for Canadians Act [1]. BCS has developed the HIVE honey house design to satisfy the clients requirements.

2 HIVE

Figure 1. HIVE Honey House Rendering.

2.1 Concept Refinement

Following Phase 2, adjustments were made to the design to improve its overall functionality. These refinements are summarized in Sections 2.1.1 to 2.1.6.

2.1.1 HVAC System

In order to improve the final concept, the HVAC system was redesigned to include roof top air handling units (RTUs) that serve different areas of the building. The different temperature control zones in Figure 2 have been outlined in Table 1.

Table 1. Honey House Zones for Temperature Control.

Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
Entrance, Break Room, Storage Room, Washroom, Electrical Room and Hallway	Hot Storage Room	Transition Room	Extraction Room	Cold Storage Room

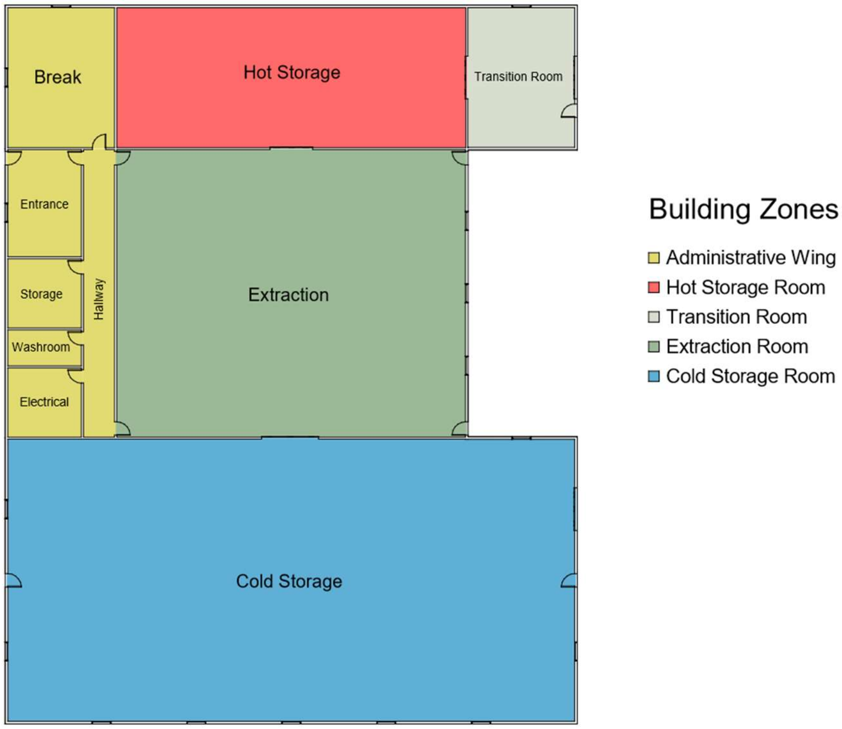


Figure 2. Building Zones

2.1.2 Air Exchange Rate

Minimum air exchange rates were calculated in Phase 2 based on current code requirements [4]. These rates were increased based on consultation from industry professionals to reduce build up of pollutants in a food processing operation. The air exchange rates in the building have been improved to 6 changes per hour in zones 1 and 3, and 12 changes per hour in zones 2, 4, and 5.

2.1.3 Dehumidifiers

Four stand-alone units will be required in the hot storage room to achieve 30% relative humidity.

2.1.4 Overhead Doors and Air Curtains

Overhead doors have been included between the areas of food processing and the loading docks to promote food safety and efficient workflow movement through the facility.

Air curtains have been included with the overhead doors at the entrance and exit of the hot room. The air curtains add an extra level of food safety protection for the supers being stored in the hot room and for their movement into the extraction room.

2.1.5 Ceiling Height Required for Ductwork

To accommodate the necessary ductwork in each zone, the ceiling height in each room was modified from the client’s initial recommendation of 16 ft. These modifications allow adequate spacing for forklift operations and honey processing equipment. The final height in each room is summarized in Table 2.

Table 2. Honey House Final Ceiling Heights by Room.

Zone	Room	Final Ceiling Height
1	Entrance	14’ 11 1/2”
	Break Room	15’ 3 1/2”
	Storage Room	15’ 6”
	Washroom	15’ 10”
	Electrical Room	15’ 6”
	Hallway	15’ 5”
2	Hot Storage Room	15’
3	Transition Room	15’ 5 1/2”
4	Extraction Room	13’ 6”
5	Cold Storage Room	15’

2.1.6 Addition of Emergency Exits

Emergency exits have been added to comply with the current code requirements [3].

2.2 Design Usability

Many design elements were considered during the development of the HIVE honey house including industrial requirements, human factors, and ergonomics, along with social, environmental, and sustainability factors.

The HIVE honey house was designed to be an industrial food processing facility with a minimum of 12 ft ceilings to accommodate the use of a forklift, a loading dock to move honey supers and processed honey, and overhead doors to separate work areas.

One of the most important considerations made in the design was food safety and compliance with the Safe Food for Canadians Act [1]. Therefore, all materials in the honey processing rooms were chosen to be food safe, air curtains were installed to isolate rooms, and employee workflow was designed in one direction to prevent contamination between rooms.

Another important consideration made in the design was worker efficiency, as the workers must be able to move through the facility quickly to maximize their work. In addition, the temperature set points in each room of the building is important, not only for the honey processing, but also to ensure worker comfort. Aside from the honey processing areas, the HIVE honey house includes amenities such as an employee entrance, break room, storage room, and washroom.

Environmental and sustainability considerations were made by the BCS team to choose a design and equipment that promote efficiency and energy conservation. The building was divided into temperature zones to allow for efficient heating and cooling in all seasons. In addition, insulation and windows were chosen to reduce heat losses. Finally, BCS has included a study of the impact that solar panels could have on the energy needs of the HIVE honey house and can be an add on if chosen by the client.

2.3 Design Features

HVAC Design

The HIVE design includes roof top air handling units to provide temperature control in the different zones as indicated in Figure 2.

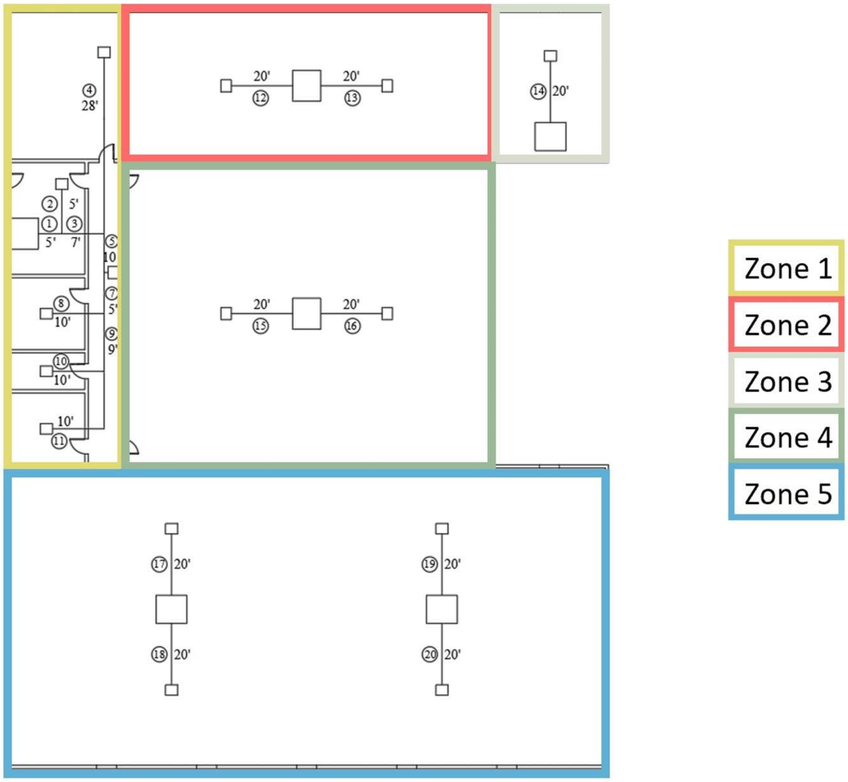


Figure 3. Features of the HVAC Design.

During the honey extraction periods from July to September, a temperature setpoint of 30℃ and a humidity setpoint of 30% is required in Zones 2 and 3. These conditions promote excellent honey quality when the supers enter the facility for extraction. Honey is a hygroscopic fluid and higher humidity promotes browning and unwanted yeast formation, decreasing quality. A temperature setpoint of 20℃ and a humidity setpoint of 45% is preferred in the remainder of the honey house. Stand-alone dehumidifiers have been included in the hot storage room to assist the RTU in maintaining the desired humidity.

During the winter months when honey is not being produced, Zone 1 is kept at a comfortable 20℃ and 45% humidity, whereas the remainder of the honey house is kept at a cooler 16℃ temperature. During the winter months beekeepers can use their honey houses for other purposes, such as building machinery. The reduced temperature lowers operating costs and prevents damage to the building, such as frozen pipes, due to winter conditions.

Workflow

The floorplan of the honey house has been refined to optimize the flow of honey through the house and promote worker efficiency. Overhead doors have been placed such that the workers take the most effective route and move in one direction through the hot storage, extraction, and cold storage rooms. The one directional flow promotes food safety as the workers move from the most to least sterile environments. A summary of the workflow through the honey house is shown in Figures 4 and 5.

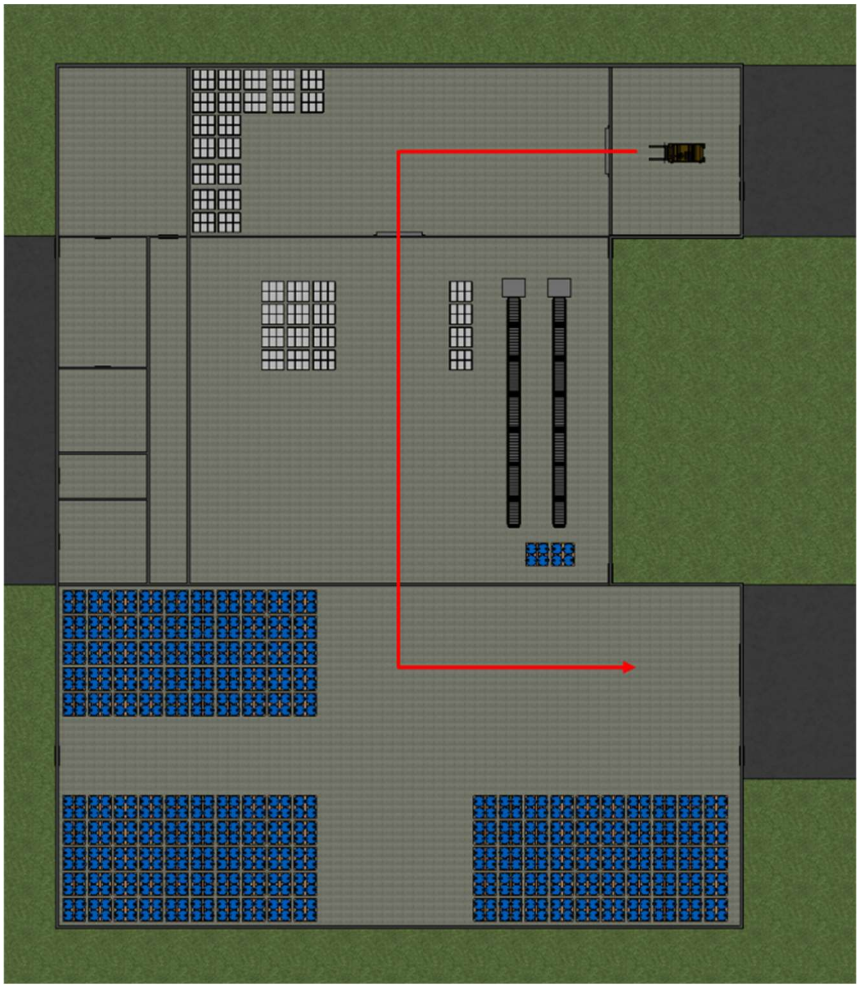
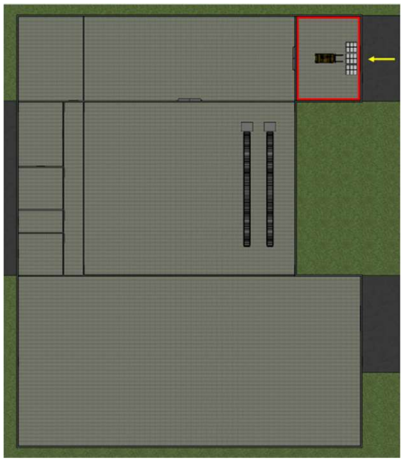
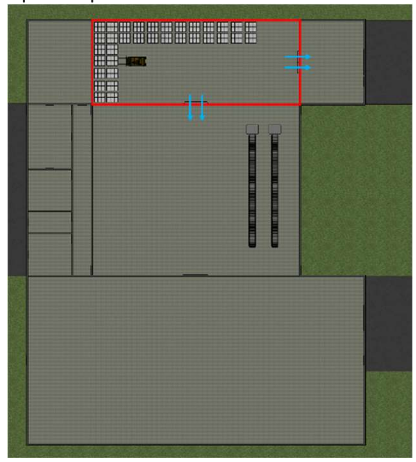


Figure 4. Complete Honey House Workflow.

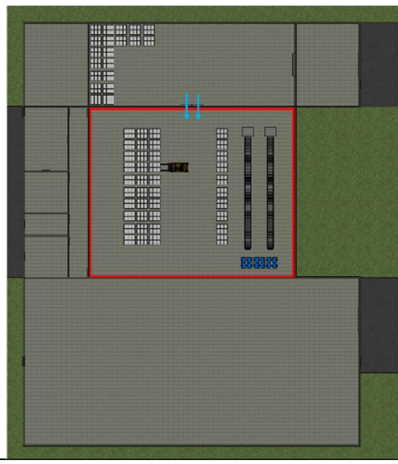
Step 1. Forklift to receive honey supers from delivery truck in the transition room.



Step 2. Forklift to transport honey supers from transition room and create a stockpile in the hot storage room. Air curtains to remain active while all doors leading to the hot room are open to prevent contaminants.



Step 3. Forklift to transport honey supers from the hot storage room to the extraction room for treatment. 55-gallon drums to be filled after honey has been treated. Air curtain between hot room and extraction room to be activated while door is open.



Step 4. Forklift to transport 55-gallon drums from the extraction room to the cold storage room. Seasons production to remain in storage as required. Honey to be transported out of the building through exit overhead door.

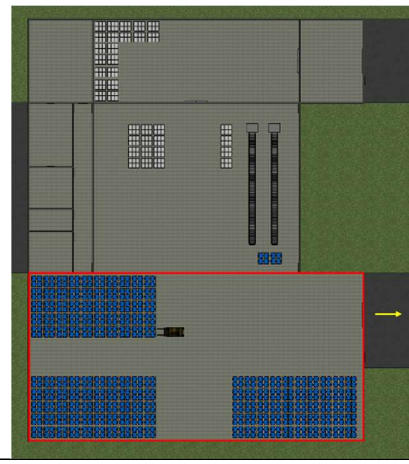


Figure 5. Overview of the Honey House Workflow.

Overhead Doors and Air Curtains

Overhead doors have been placed between the honey processing rooms and at each of the loading docks to promote food safety. The overhead doors have the added benefit of reducing heat transfer between the rooms in the house when compared to conventional methods, such as strip door curtains. As the overhead doors open and close relatively quickly, the efficiency of the workers is not hindered by the presence of the doors.

At the entrance and exit of the hot storage room an air curtain has been coupled with the overhead door. Since the hot storage is the first room that the supers are transported to, the air curtains provide an extra layer of protection to keep this area food safe. The air curtains do not have any notable effect on heat transfer.

Food Safe and Durable Materials

The materials chosen in the areas of honey processing have been selected due to their food safe quality. An epoxy coating on the concrete has been chosen as a food safe flooring option, whereas food safe panelling and tiles have been used for the walls and ceiling, respectively. In addition to the food safe materials, durability and cleanability are important qualities the chosen materials must have. This allows them to be sprayed down and sanitized often, while maintaining a long lifespan.

Scalable Design

The HIVE honey house can be scaled to accommodate different levels of honey production because of the zone dominated design. Therefore, with some calculation refinement, the floorplan and mechanical design can be manipulated to suit the needs of many beekeepers.

3 Design Analysis Performed

The viability of the final design was developed by performing the following calculations including: Air Exchange Rate, Heat Transfer, HVAC, Humidity, FEA Analysis, Energy Analysis, and Cost Analysis calculations. These calculations are summarized in sections 3.1 to 3.7.

3.1 Air Exchange Rate

To ensure the final design conforms to the air exchange rate recommended by BCS, air exchange rate calculations were completed. The project team recommends 6 changes per hour in zones 1 and 3, and 12 changes per hour in zones 2, 4, and 5. These calculations were performed assuming a maximum zone occupancy of 8 people.

Complete air exchange rate calculations for the final design can be found in Appendix B1. A summary of these calculations is shown in Table 3.

Table 3. Number of Air Exchanges Designed per Zone

Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
6 changes/hour	12 changes/hour	6 changes/hour	12 changes/hour	12 changes/hour

The objective of the air exchange rate calculations was to determine the required airflow rate in each zone.

3.2 Heat Transfer

To ensure that heat losses are accounted for in the HIVE design, heat transfer calculations were completed.

The goal of these calculations was to determine the total heating and cooling load in each zone to ensure that each zone could be maintained at the required temperature. A 10% safety factor was considered in the calculations to account for any additional heat loads, such as piping losses.

Heat transfer resulting from structural beams have not been considered as there are many variations in beam configurations. Additional civil engineering consultation is required as heat loss through structural beams would cause a decrease in heating load.

The air curtain was included in the design for the sole purpose of food safety. It is assumed to have a negligible affect on heat transfer for a conservative heat load estimate.

Complete heat transfer calculations can be found in Appendix B2. A summary of these calculations is shown in Table 4.

Table 4. Total Heating and Cooling Load for Each Zone.

Zone	Total Heat Load, including 10% safety factor, [W]	Total Cooling Load, including 10% safety factor, [W]
1	41,030	14,001
2	27,237	8,580
3	16,039	5,510
4	42,149	18,095
5	85,699	29,933
Building Total	**212,155**	**76,119**

The heating and cooling loads were used to determine the total heat loss of the building, and to determine the annual energy consumption of the facility.

3.3 Temperature Control

Temperature control in the honey house was a crucial specification indicated by the client as temperature during the extraction process can have a significant effect on honey quality. In order to ensure the final design conforms to client standards and code requirements, calculations were performed using the equal friction method to refine an appropriate HVAC system and account for calculated heat losses.

The goal of these calculations was to design a round duct system and to select RTUs. In the final design, economizers were added to the RTUs to create outdoor air circulation based on code requirements [4].

Each RTU is to be ordered with a 14-inch roof curb to allow for sufficient spacing for ducts between the ceiling and roof. Due to its large size, zone 5 will require two identical RTU units in order to meet its airflow requirements.

Complete HVAC calculations for the final design can be found in Appendix B3. A summary of the selected RTUs is shown in Table 5.

Table 5. RTU Chosen for Each Zone.

Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
Lennox Commercial Model: KGA120S4B Air Volume: 3500 cfm Motor: 786 rpm, 1.22 bhp	Lennox Commercial Model: KGA240S4B Air Volume: 7250 cfm Motor: 765 rpm, 3.10 bhp	Lennox Commercial Model: LGH060U4E Air Volume: 1431 cfm Motor: 716 rpm, 0.36 bhp	Lennox Commercial Model: LCH600H4B Air Volume: 15,000 cfm Motor: 735 rpm, 9.70 bhp	Lennox Commercial Model: LCH600H4B Air Volume: 12,000 cfm Motor: 610 rpm, 5.15 bhp

3.4 Humidity Control

Like temperature, humidity is a crucial specification for the client, as the hygroscopic nature of honey means high humidity can adversely affect honey quality. To ensure humidity conditions can be controlled, humidity calculations were performed to determine the moisture load of the building.

The goal of these calculations was to size stand-alone dehumidifiers to accommodate the calculated moisture load for the final design. Each RTU contains its own dehumidifier, which will be used to regulate the zone's humidity. Due to the humidity requirement of 30% in zone 2, four standalone dehumidification units will be used with the RTU to attain the zone's humidity requirements.

Complete humidity calculations for the final design can be found in Appendix B4. A summary of the selected dehumidifiers is shown in Table 6.

Table 6. Stand-Alone Humidifier Chosen for Each Zone.

Zone 1	Zone 2	Zone 3	Zone 4	Zone 5
Not Required	Dehumidifier Corporation of America (DCA) Model: DCA1500T	Not Required	Not Required	Not Required

3.5 FEA Analysis

To ensure the final design achieves appropriate heat transfer, FEA analysis was completed on the final design floor slab when exposed to different exterior conditions.

A simple ANSYS model was created to perform FEA on the concrete floor slab of the building in order to determine the heat losses from the slab to the soil. The temperature distribution from the slab to the soil was developed to illustrate heat losses to the ground. As shown in Appendix B5, the heat loss to the soil is not significant, thus confirming the assumption that heat loss occurs primarily at the perimeter of the slab. BCS recommends the addition of a 2-inch thick polystyrene insulation layer beneath the concrete slab to decrease heat losses. Complete FEA analysis for the final design can be found in Appendix B5.

3.6 Energy Analysis

The annual energy consumption was estimated using an average 10-hour work day during the honey production period from July to September, with the non-operational period of the building from October to June. The heating and cooling loads from Section 3.2 were used for this energy analysis.

The HIVE house was estimated to have an annual energy consumption of 74.3 MWh/year, resulting in an annual energy cost of approximately $5,313. Similarly, annual gas consumption was estimated to be 430 GJ/year, resulting in an annual cost in natural gas of approximately $1,336.

Table 7. HIVE Energy Assessment.

HIVE Energy Assessment		
Annual Estimated Energy Consumption:	74	MWh/Year
Current Energy Rate:	$71.5	/MWh
Annual Estimated Energy Cost:	$5,313	/Year
Annual Estimated Natural Gas Consumption:	432	GJ/Year
Current Natural Gas Rate:	$3.09	/GJ
Annual Estimated Energy Cost:	$1,336	/Year

Installing a 41.5 kW roof-top solar power array would be a valuable consideration to offset power costs of the building. This would require an initial investment of $57,990 that would have a 11.9% IRR over a 30-year economic life, with 9 years payback. The Solar PV System is estimated to generate 91.0 MWh/year, resulting in a surplus of 16.7 MWh/year. This would yield an annual credit of $6,506. Table 8 below provides a summary of the solar economic analysis.

Table 8. Solar PV System Economics.

Solar Assessment		
Solar PV System Rating:	41.5	kW
Cost to Install (minus 30% rebate):	$57,990	
Annual PV Power Generation:	91.0	MWh/Year
Annual Energy Surplus:	+16.7	MWh/Year
Annual Credit from Micro-Generation:	$6,505	/Year
Payback Period	9	Years

A detailed energy analysis is provided in Appendix B6.

3.7 Cost Analysis

For the final design, a detailed cost analysis was completed to determine the total estimated cost of construction and materials. The materials in the final design were chosen to optimize the heat transfer, HVAC, humidity, and air exchange rate values for the building.

The cost of the building was broken down into four sections: substructure, shell, interiors, and services/utilities. The substructure includes the standard foundation and the insulated concrete slab. The slab was specified to be 6”-thick reinforced concrete on grade with 2”-thick expanded polystyrene insulated sheets placed below the slab. The shell consists of all exterior features of the building including: the main steel framing and structure, the exterior walls, windows, doors, and roof finishes. A pre-fabricated steel I-beam kit was chosen to reduce the cost of the main building structure, compared to a wooden structure. The interior includes costs of the drywall, hygienic wall panels, doors, and all wall, floor and ceiling finishes. The services portion includes all plumbing fixtures, HVAC equipment, and electrical components.

The estimates that were obtained for chosen features of the building are included in Appendix D1. Costs of services were determined by researching local industry averages. For materials where costs were not readily available, estimates were referenced from RSMeans data. A 25% contingency charge was added to the cost of the project to account for additional costs from contractor overhead and profit.

The complete cost analysis for the final design can be found in Appendix D2

4 Design Compliance Matrix

The design compliance matrix shows the design improvements that BCS made from Phase 2. The design was assigned a score of 6 if it was found to adequately meet the scope and was given an appropriate upgrade if it surpassed expectations. Similarly, the design’s score was reduced if it did not meet expectations. Levels of importance were assigned values between 1 and 10 and descriptions of each level are shown in Table 9. Design specification matrix changes have been outlined in Appendix A1.

Table 9. Design Compliance Matrix Rating Descriptions.

Rating	Description	Definition
9-10	Crucial	Aspect is an essential element to a successful final design
7-8	Important	Feature adds significant value to the design
5-6	Desired	Required for an effective design but not essential
3-4	Discretionary	Not crucial, but desirable for optimizing operations
1-2	Optional	Not a compulsory feature, but has the possibility of adding value

Table 10. HIVE Design Compliance Matrix.

Item	Description	Design Authority	Importance (1-10)	HIVE: Phase 2	HIVE: Phase 3	Reasoning
1.0	**Building Layout and Dimensions**					
1.1	Building to include an extraction room, hot room, supply storage room, electrical room, an employee washroom, a break room, entrance, and a cold storage room. [A1]	BCS	7	7	7	Final design is spacious but requires the stacking of honey for storage.
1.2	Dimensions to accommodate an extraction line that produces at 3000 lb/hr for a standard workday of 10 hours	ABC	8	6	6	Dimensions achieve the specification, but do not provide room for production growth.
1.3	Dimensions to accommodate the storage and easy transport of 600 honey supers	BCS	7	6	6	Dimensions achieve the specification but require stacking of honey for storage and dimensions do not provide room for growth.
1.5	Shall be dimensioned to provide adequate room for maintenance work while following the national fire code	BCS Code [A2]	3	7	7	Adequate room provided for maintenance, but no extra space is provided in the room.
1.6	At least two doors will be placed in the hot room to allow for easy flow of traffic through the room [A1]	BCS	7	6	6	Two doors have been placed to promote efficient movement.
1.7	Ceiling height to be 16ft to accommodate a standard forklift provide space between bees and personnel on the floor [A1]	BCS	5	6	5	Some ceiling heights have been lowered to

						accommodate required mechanical ductwork.
1.8	Wall height to be 19ft to provide adequate spacing for an in-ceiling air duct system	BCS	5	6	6	Wall height has remained, however some ceilings had to be lowered to accommodate the ductwork.
1.10	Emergency exits will be placed at required locations in agreement with the 2019 national fire code	BCS Code [A2]	10	3	6	Doors have been placed to accommodate the fire code, but verification will be required later by the client.
1.11	Building workflow designed to promote easy transport of honey through the different stages of production	ABC	10	7	7	Design has been optimized to promote efficient workflow through the building.
2.0	**Building Functionality**					
2.1	The relative humidity of the hot room will be set to 30% with a tolerance of ±2%	ABC	9	6	8	Design has been refined to include a more reasonable and achievable relative humidity set point.
2.2	The temperature of the hot room and transition room will be set to 30°C ± 2°C	ABC	9	7	8	HVAC system has been refined to be more viable to achieve this temperature set point.
2.3	The temperature of the equipment room, washroom, entrance, and break room will be 20°C (adjustable to employee comfort)	BCS	6	7	8	HVAC system has been refined to be more viable to achieve this temperature set point.
2.4	The chosen ventilation system will provide a full air exchange at a minimum of twelve times per hour in areas of food processing and six times per hour elsewhere [A3]	ABC Code [A3]	8	3	6	HVAC system has been refined to achieve these air exchange rates more effectively.
2.5	One thermostat to be included in each of the extraction and hot rooms	BCS	3	5	5	One thermostat has been provided for each of these rooms.
2.6	One SUMP to be installed that will function as a honey receptacle and collect wash water [A1]	BCS	5	4	4	Sump addition has been considered but is listed as a future work item for the client.
2.7	Raised outside loading dock to connect to the overhead door to increase super transport efficiency	BCS	5	4	4	Loading dock has been provided in the final design, but it is at ground level.
2.8	Extraction, manoeuvring, and hot rooms to each contain a minimum of one floor drain	BCS	6	4	4	Floor drains have been considered but these are

		Code [A4] [A7]				listed as a future work item for the client.
2.9	Extraction, manoeuvring, and hot rooms floors to have slopes of 1% to the drainage location	BCS Code [A4] [A7]	6	4	4	Floor slope has been considered but is listed as a future work item for the client.
2.10	Building to be supplied with electrical power, natural gas, and water sources	BCS Code [A5]	6	3	3	Energy sources are important, but this is a future consideration for the client.
2.11	Lighting to be installed to provide adequate visibility in all rooms and all periods of the day	BCS Code [A4]	8	6	6	Lighting has been designed by BCS, but future work will be required by the client to ensure code requirements are met.
2.12	Extraction, cold storage, and hot rooms to each include at least one industrial sink with both hot and cold water [A7]	BCS	4	8	8	One sink has been provided in each of these rooms.
3.0	**Building Efficiency and Environmental Considerations**					
3.1	Window frames, and glass, will be chosen to minimize the buildings U factor and heating costs [A6]	BCS	5	7	8	Windows have been chosen to have an effective U factor.
3.2	Insulation to be installed to minimize heat loss while remaining in accordance with building and fire regulations	BCS Code [A2] [A4]	6	8	9	Insulation has been chosen to effectively prevent heat loss and meet minimum U value code requirements.
3.3	Lighting to consist of LED tubes where possible to increase energy efficiency	BCS	3	5	5	LED bulbs chosen to promote efficiency but options, like a skylight, could have been considered to reduce energy more.
3.4	High efficiency mechanical equipment to be selected where possible	BCS	3	5	5	Equipment chosen to meet the heating and cooling requirements of the building. Energy efficiency was a small consideration.
3.5	Environmentally friendly materials to be used where possible	BCS	4	5	7	Environmentally friendly materials were chosen and a Solar PV system was proposed.
4.0	**Safety and Health Considerations**					
4.1	Provide method of removing bees from the building	ABC	5	3	3	A bee escape has been considered but is listed as future work for the client.

4.2	Ceiling and walls will be chosen with smooth, non-absorbent, and easy to clean food-safe materials [A7]	BCS ABC Code [A7]	9	9	9	Wall and ceiling materials have been chosen to be food safe and durable for cleaning.
4.3	All wall to floor joints to be rounded to improve the sealing, leading to easier cleaning [A8]	BCS	9	7	7	Wall to floor joints have been sealed for easy cleaning.
4.4	Floors, windows, walls, ceilings, lighting, and ventilation will be designed to prevent entry of pests into the building [A7]	BCS Code [A7]	9	5	7	Pest entry has been considered and materials put in place to prevent their entry to the building.
4.5	One sink and one toilet will be provided for every ten people working in the honey-house [A1]	BCS	7	8	8	Specification has been met for the workforce indicated by the client.
4.6	Minimum of two doors between the extraction room and bathroom to minimize the risk of cross contamination [A1]	BCS	8	8	8	Requirement has been met with the final design.
5.0	**Material Specifications**					
5.1	Floor to be made of concrete with a durable impervious surface for water resistance and sanitation purposes [A1]	BCS Code [A7]	8	8	8	Chosen flooring is durable and food safe.
5.2	Concrete floor to have a minimum strength of 30 MPa in accordance with CSA A23.1-14 standards [A9]	BCS Code [A9]	8	8	8	Specification has been met by the final design.
5.4	Electrical room to be constructed of fire-resistant material in accordance with the national fire code	BCS Code [A2]	9	8	8	Specification met by design, but future work to be done by the client to ensure code compliance.
6.0	**Construction Considerations**					
6.1	Building will be designed to meet heating specifications based on an assumed minimum temperature of -31.4°C	ABC	8	6	9	Building design based on this minimum outdoor temperature.
6.2	Building will be designed to conform with standards for a F3 building classification [A4]	BCS	7	6	6	Future work by the client required to ensure code compliance.
6.3	B.E.E. Consulting Services to provide client with an engineering drawing package for construction purposes	BCS Other	5	3	5	Drawing package provided for the client but will require future work to meet construction drawing standards.
7.0	**Cost**					
7.1	Designed HVAC system and building will reduce the operational costs of maintaining the required humidity and temperature	BCS	9	8	9	System has been designed to be efficient and consider operating costs.

7.2	Building materials and overall design will result in a cost of approximately $570,000.	BCS	10	6	8	Building cost has been optimized to conform to the estimated value indicated by the client.
				1610	**1815**	**Overall Score**

The design compliance matrix has been discussed following Phase 2 and approved by the client.

5 Design Rendering and Drawing Package

Design renderings and a drawing package are included in Appendix C.

6 Future Considerations

Due to constraints limiting the project team, such as time and expertise, BCS recommends that the following future considerations are investigated by the client.

Dehumidification Requirements

BCS has designed HIVE to control humidity set points during the typical conditions seen in a honey production season. However, as weather conditions fluctuate and wet seasons may occur, dehumidification requirements for the honey may change and the client may decide that more dehumidification may be required to dry out the honey.

Food Safety Requirements

Outside of the building materials and construction, the client may want to consider other methods of promoting food safety such as clean room mats, employee uniforms, cleaning schedules, extraction equipment and processed honey storage racks.

Code and Building Standard Requirements

When applying for permits and performing construction the client should reference the relevant codes and building standards to ensure design compliance.

Structural, Civil and Electrical Requirements

When constructing the design, the client should have industry professionals provide consultation on the electrical, structural, and civil aspects of the building to ensure the viability of the design. BCS is not qualified to provide consultation in this field and cannot ensure the viability of these items, as indicated at the start of the project.

Floor Slope and Sumps

Due to time constraints on the BCS team, floor sloping and sumps will need to be considered by the client.

Lighting Requirements

BCS has designed the lighting in the building to the best of their ability, to ensure appropriate light coverage according to code. However, the client will have to ensure code lighting requirements are met when the building is completed, and all equipment is in place.

Bee escapes

Measures have been taken in the HIVE design to prevent bee entry into the building, such as screens on windows and specific diffusers to prevent pest infiltration, therefore bee escapes have not been included in the final design. BCS recommends that pressurized air be used to remove bees from the supers into a secondary container and manually removed from the building, rather than incorporating bee escapes into the building's construction.

Finite Element Analysis

A simplistic FEA model was developed by the BCS team to explore the heat losses through the floor slab under various environmental conditions. The client should consider more detailed analysis in future work.

7 Project Management

In Phase 3 a total of 224 engineering hours were required to complete the final design. These hours have been outlined by team member contribution in Table 11. Complete project team timesheets are shown in Appendix F2.

Table 11. Total Engineering Hours for Phase 3.

Team Member	Meeting Hours	Research Hours	Report Writing Hours	Calculation Hours	Design Hours	Total Hours
Elliott	7.5	3.75	8.5	10	0	29.75
Sai	8	0	4	14	8	34
Jake	7	8	0	3	20	38
Zoey	6.5	1	3	10.5	18	39
Jakub	4.25	3	0	16	15	38.25
Laura	7.5	1.5	36	0	0	45
Phase 3 Total	40.75	17.25	51.5	53.5	61	224

The total number of hours spent on the project in Phase 3 was higher than the estimated value of 218 hours in the project schedule revised during Phase 2. The discrepancy in these hours was largely caused by the number of calculations the project team was required to complete to refine the final design and the time required to complete CAD renderings and drawing package. In addition, the time spent compiling a report to summarize the final design was underestimated in Phases 2 and 3.

To date, the BCS team has completed a total of 700 engineering hours, costing $63,000 in consulting fees. Comparisons between the Phase 1 and 2 estimates, and actual engineering hours for the project is shown in Figure 6 below.

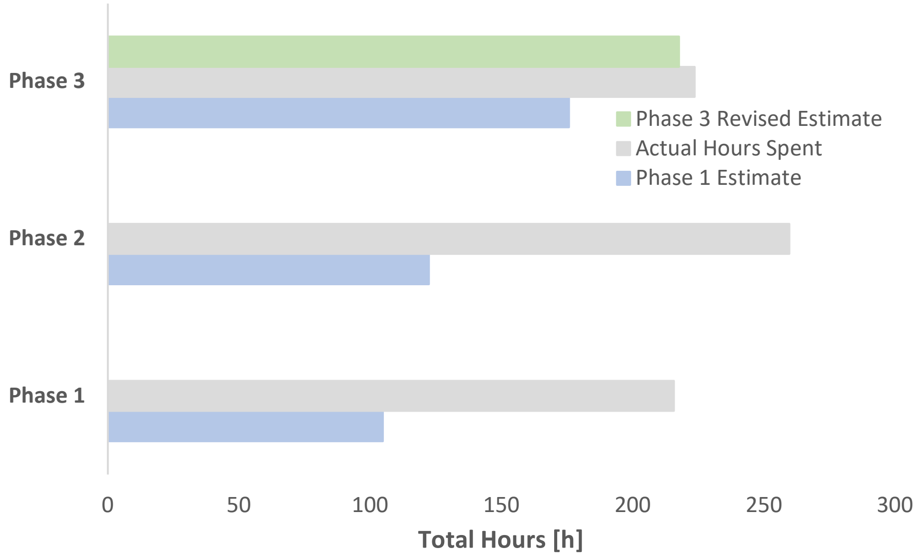


Figure 6. Estimated, Actual, and Project Engineering Hours

The final project schedule can be found in Appendix F1.

8 Conclusion

BCS has designed the HIVE honey house to optimize production conditions and produce high-quality honey. Through detailed air exchange, heat transfer, HVAC, and humidity calculations, HIVE provides a high-performance design which utilizes equipment and materials to minimize heat losses and to reduce overall operating costs. The resulting concept complies with all necessary building codes and standards. BCS has recommended several future improvements to further refine the concept for the client and to ensure a complete design.

References

[1] Minister of Justice, Safe Food for Canadians Act, Ottawa, ON: Government of Canada, 2019.

[2] J. Kienholz, Honey House and Equipment Layouts, Alberta Agriculture, 1983.

[3] National Resource Council Canada, National Fire Code – 2019 Alberta Edition, Edmonton, AB: Alberta Municipal Affairs, 2019.

[4] ASHRAE Standing Standard Project Committee 62.1, "Ventilation for Acceptable Air Quality", ASHRAE Standard 62.1, 2016.

[5] National Resource Council Canada, National Building Code – 2019 Alberta Edition, Edmonton, AB: Alberta Municipal Affairs, 2019.

[6] National Resource Council Canada, National Energy Code of Canada for Buildings 2017, Ottawa, ON: Canadian Commission on Building and Fire Codes, 2017.

[7] Office of Energy Efficiency and Renewable Energy, "Energy Saver: Window Types and Technologies", U.S. Department of Energy, Energy.gov. [Online]. Available: https://www.energy.gov/energysaver/window-types-and-technologies#277911-tab-1 [Accessed: September 22, 2019].

[8] Canadian Food Inspection Agency, Safe Food for Canadians Regulations 2019, Ottawa, ON: Government of Canada, 2019.

[9] B. F. Detroy, "Honey Removal, Processing and Packing," Beekeeping in the United States: Agricultural Handbook Number 335, pages 92-102, October 1980. [Online Serial]. Available: https://beesource.com/resources/usda/honey-removal-processing-and-packing/. [Accessed: September 22, 2019].

[10] Occupational Health and Safety, Occupational Health and Safety Regulation 2018, Edmonton, AB: Government of Alberta, 2018.

Appendices

Appendix A: Design Specification Matrix

A1 Phase 3 Updated Design Specifications Matrix

Appendix B: Design Calculations

B1 Air Exchange Rate Calculations

B2 Heat Transfer Calculations

B3 HVAC Calculations

B4 Humidity Calculations

B5 FEA Analysis

B6 Energy Analysis

Appendix C: CAD and Drawing Package

C1 CAD Renderings and Drawing Package

Appendix D: Cost Analysis

D1 Cost Analysis Estimates

D2 Complete Building Cost Analysis

Appendix E: Material Data Sheets

E1 Project Material Data Sheets

Appendix F: Project Management

F1 Final Project Schedule

F2 Project Team Timesheets

Appendix A: Design Specification Matrix

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Appendix A1: Phase 3 Updated Design Specification Matrix

Through further research and consultations with the client, the project design specifications matrix was updated to guide the team.

The following changes were made:

Section 1.0 - Building Layout and Dimension

The furnace room was eliminated and converted to an electrical room in the final design, as the team changed the building HVAC system to be comprised of several roof top air handling units instead of a single furnace.

Section 2.0 - Building Functionality

The client acknowledged that the previously discussed humidity set point for the hot room was too low, which resulted in a change in the relative humidity setpoint to 30% $\pm$ 2%.

Section 6.0 - Construction Considerations

In Phase 2, the client specified that the functional months for the building would be from July to September.

The client indicated the honey house could be used during the non-functional months (October to June), additional building calculations were performed using a minimum outdoor temperature of -31.4℃ and an internal set point of 16°C.

Section 7.0 - Cost

Through discussions with the client and comparing Phase 2 cost estimates to those gathered from existing honey houses in industry, a final construction cost of approximately $570,000 is to be achieved by the project team.

The above matrix changes have been summarized in Table 12. In the revised table all items that were deleted have been crossed out and all items that were added have been underlined.

Table 12. Revised Sections of the Design Specification Matrix.

Item	Description	Specification	Design Authority	Importance
1.0	**Building Layout and Dimensions**			
1.1	Building Areas	Building to include an extraction room, hot room, supply storage room, ~~furnace~~ <u>electrical room</u>, an employee washroom, a break room, entrance, and a cold storage room. [A1]	BCS	4

1.5	~~Furnace~~ Electrical Room Dimensions	Shall be dimensioned to provide adequate room for maintenance work while following the national fire code	BCS Code [A2]	5
2.0	**Building Functionality**			
2.1	Relative Humidity of Operational Rooms	The relative humidity of the hot room will be set to ~~18%~~ 30% with a tolerance of ±2%	ABC	5
2.4	Air Exchange Rate	The chosen ventilation system will provide a full air exchange at a minimum of ~~every twelve hours~~ twelve times per hour in areas of food processing and six times per hour elsewhere [A3]	ABC Code [A3]	5
5.0	**Material Specifications**			
5.4	~~Furnace~~ Electrical Room Material	~~Furnace~~ Electrical room to be constructed of fire-resistant material in accordance with the national fire code	BCS Code [A2]	5
6.0	**Construction Considerations**			
6.1	Temperature Considerations	Building will be designed to meet heating specifications based on an assumed minimum temperature of ~~-2.08°C~~ -31.4°C	ABC	4
7.0	**Cost**			
7.2	Construction Cost	Building materials and overall design will ~~lower the building's construction cost~~ result in a cost of approximately $570,000.	BCS	5

The Phase 3 Design Specification Matrix used the same importance scale as the Phase 1 (shown in Table 13). After adding the revisions shown above in Table 12, the complete Design Specification Matrix for Phase 3 is shown in Table 14.

Table 13. Design Specification Weighting Criteria.

Rating	Description	Definition
5	Mandatory	Essential to the proper function of the design, bound by appropriate codes and standards
4	Important	Needed by client but not critical for overall functionality
3	Necessary	Not requested by the client but needed the proper performance of the design
2	Discretionary	Not essential to the design, but desirable for improving operations
1	Optional	Not a required feature, but has the potential to add value

*For brevity, the design authorities in the design matrix will be given the following abbreviations:

- B.E.E Consulting Services = BCS
- Alberta Beekeepers Commission = ABC
- All codes in the design authority column will be labeled as "Code" and referenced.

Table 14. Phase 3 Design Specification Matrix.

Item	Description	Specification	Design Authority	Importance
1.0	**Building Layout and Dimensions**			
1.1	Building Areas	Building to include an extraction room, hot room, supply storage room, electrical room, an employee washroom, a break room, entrance, and a cold storage room. [A1]	BCS	4
1.2	Extraction Room Dimensions	Dimensions to accommodate an extraction line that produces at 3000 lb/hr for a standard workday of 10 hours	ABC	5
1.3	Hot Room Dimensions	Dimensions to accommodate the storage and easy transport of 600 honey supers	BCS	3
1.5	Electrical Room Dimensions	Shall be dimensioned to provide adequate room for maintenance work while following the national fire code	BCS Code [A2]	5
1.6	Hot Room Accessibility	At least two doors will be placed in the hot room to allow for easy flow of traffic through the room [A1]	BCS	2
1.7	Ceiling Height	16ft to accommodate a standard forklift provide space between bees and personnel on the floor [A1]	BCS	3
1.8	Wall Heights	19ft to provide adequate spacing for an in-ceiling air duct system	BCS	2
1.10	Emergency Exits	Emergency exits will be placed at required locations in agreement with the 2019 national fire code	BCS Code [A2]	5
1.11	Manoeuvrability	Building workflow designed to promote easy transport of honey through the different stages of production	ABC	5
2.0	**Building Functionality**			
2.1	Relative Humidity of Operational Rooms	The relative humidity of the hot room will be set to 30% with a tolerance of ±2%	ABC	5
2.2	Temperature of Operational Rooms	The temperature of the hot room and transition room will be set to 30°C ± 2°C	ABC	5
2.3	Temperature of Employee Rooms	The temperature of the equipment room, washroom, entrance, and break room will be 20°C (adjustable to employee comfort)	BCS	4
2.4	Air Exchange Rate	The chosen ventilation system will provide a full air exchange at a minimum of twelve times per hour in areas of food processing and six times per hour elsewhere [A3]	ABC Code [A3]	5
2.5	Temperature Control	One thermostat to be included in each of the extraction and hot rooms	BCS	5

2.6	Extraction Room SUMP Functionality	One SUMP to be installed that will function as a honey receptacle and collect wash water [A1]	BCS	2
2.7	Loading Dock	Raised outside loading dock to connect to the overhead door to increase super transport efficiency	BCS	1
2.8	Drainage	Extraction, manoeuvring, and hot rooms to each contain a minimum of one floor drain	BCS Code [A4, A7]	5
2.9	Floor Slope	Extraction, manoeuvring, and hot rooms floors to have slopes of 1% to the drainage location	BCS Code [A4, A7]	5
2.10	Utilities	Building to be supplied with electrical power, natural gas, and water sources	BCS Code [A5]	5
2.11	Lighting	Lighting to be installed to provide adequate visibility in all rooms and all periods of the day	BCS Code [A4]	5
2.12	Cleaning Water for Operational Rooms	Extraction, cold storage, and hot rooms to each include at least one industrial sink with both hot and cold water [A7]	BCS	3
3.0	**Building Efficiency and Environmental Considerations**			
3.1	Window Design	Window frames, and glass, will be chosen to minimize the buildings U factor and heating costs [A6]	BCS	3
3.2	Insulation	To be installed to minimize heat loss while remaining in accordance with building and fire regulations	BCS Code [A2, A4]	3
3.3	Lighting Efficiency	Lighting to consist of LED tubes where possible to increase energy efficiency	BCS	1
3.4	Equipment Selection	High efficiency mechanical equipment to be selected where possible	BCS	1
3.5	Material Selection	Environmentally friendly materials to be used where possible	BCS	1
4.0	**Safety and Health Considerations**			
4.1	Bee Escapes	Provide method of removing bees from the building	ABC	4
4.2	Wall and Ceiling Materials	Ceiling and walls will be chosen with smooth, non-absorbent, and easy to clean food-safe materials [A7]	BCS ABC Code [A7]	5
4.3	Wall Joints	All wall to floor joints to be rounded to improve the sealing, leading to easier cleaning [A8]	BCS	5
4.4	Pest Control	Floors, windows, walls, ceilings, lighting, and ventilation will be designed to prevent entry of pests into the building [A7]	BCS Code [A7]	5
4.5	Washroom Facility Requirements	One sink and one toilet will be provided for every ten people working in the honey-house [A1]	BCS	5

4.6	Washroom Facility Isolation	Minimum of two doors between the extraction room and bathroom to minimize the risk of cross contamination [A1]	BCS	4
5.0	**Material Specifications**			
5.1	Floor Materials	Floor to be made of concrete with a durable impervious surface for water resistance and sanitation purposes [A1]	BCS Code [A7]	5
5.2	Floor Strength	Concrete floor to have a minimum strength of 30 MPa in accordance with CSA A23.1-14 standards [A9]	BCS Code [A9]	5
5.4	Electrical Room Material	Electrical room to be constructed of fire-resistant material in accordance with the national fire code	BCS Code [A2]	5
6.0	**Construction Considerations**			
6.1	Temperature Considerations	Building will be designed to meet heating specifications based on an assumed minimum temperature of -31.4°C	ABC	4
6.2	Building Classification	Building will be designed to conform with standards for a F3 building classification [A4]	BCS	3
6.3	Building Instructions	B.E.E. Consulting Services to provide client with an engineering drawing package for construction purposes	BCS Other Contractors	4
7.0	**Cost**			
7.1	Operations Cost	Designed HVAC system and building will reduce the operational costs of maintaining the required humidity and temperature	BCS	4
7.2	Construction Cost	Building materials and overall design will result in a cost of approximately $570,000.	BCS	5

Appendix A References:

[A1] J. Kienholz, Honey House and Equipment Layouts, Alberta Agriculture, 1983.

[A2] National Resource Council Canada, National Fire Code – 2019 Alberta Edition, Edmonton, AB: Alberta Municipal Affairs, 2019.

[A3] ASHRAE Standing Standard Project Committee 62.1, “Ventilation for Acceptable Air Quality”, ASHRAE Standard 62.1, 2016.

[A4] ASHRAE Standing Standard Project Committee 62.1, “Ventilation for Acceptable Air Quality”, ASHRAE Standard 90.1, 2016.

[A5] National Resource Council Canada, National Energy Code of Canada for Buildings 2017, Ottawa, ON: Canadian Commission on Building and Fire Codes, 2017.

[A6] Office of Energy Efficiency and Renewable Energy, “Energy Saver: Window Types and Technologies”, U.S. Department of Energy, Energy.gov. [Online]. Available: https://www.energy.gov/energysaver/window-types-and-technologies#277911-tab-1 [Accessed: September 22, 2019].

[A7] Canadian Food Inspection Agency, Safe Food for Canadians Regulations 2019, Ottawa, ON: Government of Canada, 2019.

[A8] B. F. Detroy, “Honey Removal, Processing and Packing,” Beekeeping in the United States: Agricultural Handbook Number 335, pages 92-102, October 1980. [Online Serial]. Available: https://beesource.com/resources/usda/honey-removal-processing-and-packing/. [Accessed: September 22, 2019].

[A9] Occupational Health and Safety, Occupational Health and Safety Regulation 2018, Edmonton, AB: Government of Alberta, 2018.

Appendix B: Design Calculations

Appendix B1: Air Exchange Rate Calculations

Air Exchange Rate

By: Zoey Zhang

Date:November 25, 2019

Objective: The purpose of air exchange rate calculations is to quantify the amount of air that needs to be circulated throughout the house

Assumptions:
1. Air is an incompressible, ideal gas at standard conditions
2. There will be a maximum of 8 workers in one zone at once

As a rough guideline, the minimum infiltration outdoor air allowance may be taken as 0.5 air changes per hour (actually to produce a slight positive pressure within the structure producing exfiltration from the conditioned spaces). The minimum ventilation air allowance based on ASHRAE Standard 62.1 is 7.5 cfm per person plus 0.18 cfm/sqft

Minimum air exchange rates per hour:

$$ACH := \frac{Q \cdot 60\ \frac{\text{min}}{\text{hr}}}{VOL}$$

where:

ACH: air exchange rate (changes/hour)

Q: ventilation rate $\left(\frac{\text{ft}^3}{\text{min}}\right)$

VOL: gross space volume $\left(\text{ft}^3\right)$

Zone 1

$$ACH := \frac{\left(\frac{0.18\ \frac{\text{ft}^3}{\text{min}}}{\text{ft}^2} \cdot (23\ \text{ft} \cdot 91\ \text{ft}) + 7.5\ \frac{\text{ft}^3}{\text{min}} \cdot 8\right) \cdot 60\ \frac{\text{min}}{\text{hr}}}{23\ \text{ft} \cdot 91\ \text{ft} \cdot 16\ \text{ft}}$$

$ACH := 0.78$ changes/hour

Zone 2

$$ACH := \frac{\left(\frac{0.18\ \frac{\text{ft}^3}{\text{min}}}{\text{ft}^2} \cdot (74\ \text{ft} \cdot 30\ \text{ft}) + 7.5\ \frac{\text{ft}^3}{\text{min}} \cdot 8\right) \cdot 60\ \frac{\text{min}}{\text{hr}}}{30\ \text{ft} \cdot 74\ \text{ft} \cdot 16\ \text{ft}}$$

$ACH := 0.77$ changes/hour

Zone 3

$$ACH := \frac{\left(\frac{0.18\ \frac{ft^3}{min}}{ft^2}\cdot(23\ ft\cdot 30\ ft)+7.5\ \frac{ft^3}{min}\cdot 8\right)\cdot 60\ \frac{min}{hr}}{23\ ft\cdot 30\ ft\cdot 16\ ft}$$

$ACH := 1.00$ changes/hour

Zone 4

$$ACH := \frac{\left(\frac{0.18\ \frac{ft^3}{min}}{ft^2}\cdot(74\ ft\cdot 61\ ft)+7.5\ \frac{ft^3}{min}\cdot 8\right)\cdot 60\ \frac{min}{hr}}{74\ ft\cdot 61\ ft\cdot 16\ ft}$$

$ACH := 0.72$ changes/hour

Zone 5

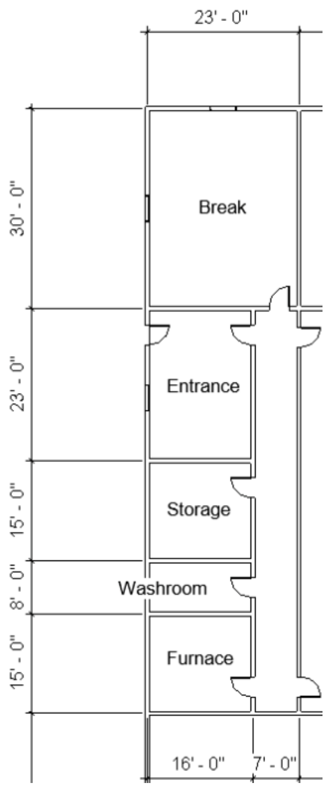
$$ACH := \frac{\left(\frac{0.18\ \frac{ft^3}{min}}{ft^2}\cdot(120\ ft\cdot 60\ ft)+7.5\ \frac{ft^3}{min}\cdot 8\right)\cdot 60\ \frac{min}{hr}}{120\ ft\cdot 60\ ft\cdot 16\ ft}$$

$ACH := 0.71$ changes/hour

Actual Changes per Hour

In practical applications, food processing buildings will have around 10-12 air changes per hour. As such zones 2,4 and 5 will have 12 changes per hour. Zones 1 and 3 are not critical in the honey processing/packing procedure, and will have 6 changes per hour. This meets the minimum air exchange rates calculated previously.

Zone 1



Break room

$$VOL := 23\ ft \cdot 30\ ft \cdot 16\ ft = 312.618\ m^3$$

$$ACH := \frac{6}{hr}$$

$$Q := \frac{ACH \cdot VOL}{3600\ \frac{s}{hr}}$$

$$Q = 0.521\ \frac{m^3}{s}$$

Entrance

$$VOL := 23\ ft \cdot 16\ ft \cdot 16\ ft = 166.7296\ m^3$$

$$ACH := \frac{6}{hr}$$

$$Q := \frac{ACH \cdot VOL}{3600\ \frac{s}{hr}}$$

$$Q = 0.2779\ \frac{m^3}{s}$$

Storage

$$VOL := 15\ ft \cdot 16\ ft \cdot 16\ ft = 108.7367\ m^3$$

$$ACH := \frac{6}{hr}$$

$$Q := \frac{ACH \cdot VOL}{3600\ \frac{s}{hr}}$$

$$Q = 0.1812\ \frac{m^3}{s}$$

Washroom

$$VOL := 8\ ft \cdot 16\ ft \cdot 16\ ft = 57.9929\ m^3$$

$$ACH := \frac{6}{hr}$$

$$Q := \frac{ACH \cdot VOL}{3600\ \frac{s}{hr}}$$

$Q = 0.0967\ \frac{m^3}{s}$

Electrical

$VOL := 15\ ft \cdot 16\ ft \cdot 16\ ft = 108.7367\ m^3$

$ACH := \frac{6}{hr}$

$Q := \frac{ACH \cdot VOL}{3600\ \frac{s}{hr}}$

$Q = 0.1812\ \frac{m^3}{s}$

Hallway

$VOL := 7\ ft \cdot 61\ ft \cdot 16\ ft = 193.4607\ m^3$

$ACH := \frac{6}{hr}$

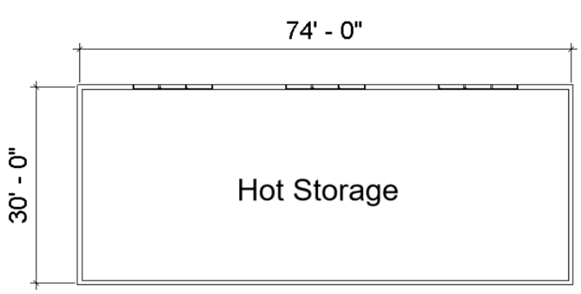
$Q := \frac{ACH \cdot VOL}{3600\ \frac{s}{hr}}$

$Q = 0.3224\ \frac{m^3}{s}$

Zone 1 Total:

$Q_{total} := 1.5805\ \frac{m^3}{s}$

Zone 2



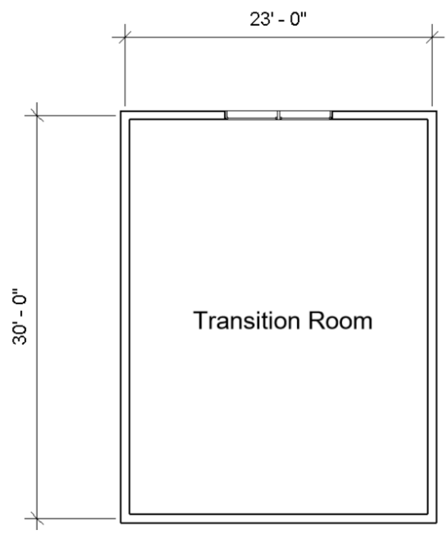
$VOL := 74\ ft \cdot 30\ ft \cdot 16\ ft = 1005.8144\ m^3$

$ACH := \frac{12}{hr}$

$Q := \frac{ACH \cdot VOL}{3600\ \frac{s}{hr}}$

$Q = 3.3527\ \frac{m^3}{s}$

Zone 3



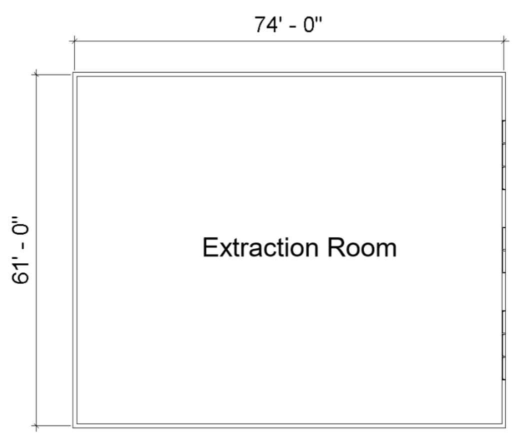
$$VOL := 23\ ft \cdot 30\ ft \cdot 16\ ft = 312.618\ m^3$$

$$ACH := \frac{6}{hr}$$

$$Q := \frac{ACH \cdot VOL}{3600\ \frac{s}{hr}}$$

$$Q = 0.521\ \frac{m^3}{s}$$

Zone 4



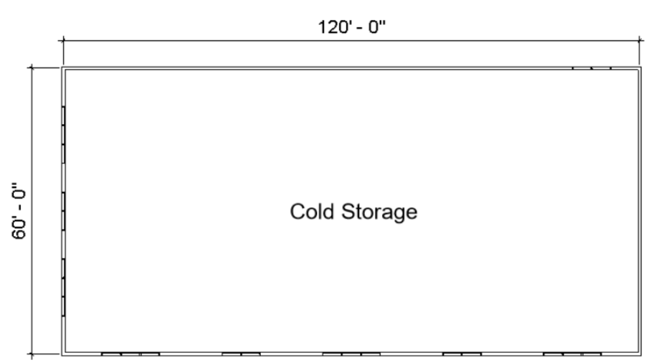
$$VOL := 61\ ft \cdot 74\ ft \cdot 16\ ft = 2045.1559\ m^3$$

$$ACH := \frac{12}{hr}$$

$$Q := \frac{ACH \cdot VOL}{3600\ \frac{s}{hr}}$$

$$Q = 6.8172\ \frac{m^3}{s}$$

Zone 5



$$VOL := 120\ ft \cdot 60\ ft \cdot 16\ ft = 3262.1007\ m^3$$

$$ACH := \frac{12}{hr}$$

$$Q := \frac{ACH \cdot VOL}{3600\ \frac{s}{hr}}$$

$$Q = 10.8737\ \frac{m^3}{s}$$

Appendix B2: Heat Transfer Calculations

Heating Load Calculations

By: Zoey Zhang

Date:November 23, 2019

Objective: The purpose of heating and cooling load calculations is to quantify the heating and cooling loads in areas of the honey packing house. These calculations form the basis for equipment selection and duct and piping design.

Assumptions:

1. Heat transfer throughout the building and all walls will be steady. Air temperatures in and outside the building will not likely fluctuate a lot in time. The design will aim to keep indoor temperatures constant.

2. Heat transfer is one dimensional, and occurs in the normal direction to the wall surface. No significant heat transfer will take place in the wall in other directions. This assumption is valid because heat transfer is only driven by the temperature gradient in a particular direction. Temperature measurements at several locations along one wall surface will likely be the same, i.e. the surface is isothermal.

3. All material properties will be assumed to have the same thermal conductivity properties throughout it's entire mass (isothermal)

4. Air is assumed to be an ideal gas

5. The local atmospheric pressure is at 1 atm

6. For walls that have the same temperatures on both sides, it will be assumed that no heat transfer occurs (i.e. both sides of the wall are at equilibrium)

7. Solar effects are not considered for a worst case load calculation

8. Internal gains of people, lighting, equipment are not considered for a worst case load calculation

9. All walls, windows, doors, ceilings are above grade. The ground is at grade.

10. Heat loss from a concrete slab floor is mostly through the perimeter rather than the rather than through the floor to the ground.

11. The total heating load will be a summation of the transmission and infiltration loads

Outdoor and Indoor Conditions

Outdoor

From ASHRAE 2017 Handbook- Fundamentals, the weather information at Grande Prairie for 99% design conditions were used.

Latitude: 55.180 N

Longitude: 118.880 W

Elevation: 669 m

Heating Dry Bulb Temperature: $T_{out} := -31.4\ °C$

$T_{out} := 241.75\ K$

Humidity Ratio: 0.1

$$W_{out} := 0.1 \frac{g}{kg} \frac{1\ kg}{1000\ g} = 0.0001$$

Indoor

The honey house will not be used for processing/packing in the winter. Instead, it will be used as an equipment storage/building space. Zone 1 will be kept at a comfortable temperature level(20°C) while the rest of the zones will be kept cooler to minimalize heating costs (16°C). Indoor humidity for all zones will be at 45% rh

$T_{zone1} := 20\ °C = 293.15\ K$

$T_{other\_zone} := 16\ °C = 289.15\ K$

$RH_{in} := 45\ \%$

From psychometric charts, humidity ratio is:

$$W_{zone1} := 7 \frac{g}{kg} \frac{1\ kg}{1000\ g} = 0.007$$

$$W_{other.zone} := 5 \frac{g}{kg} \frac{1\ kg}{1000\ g} = 0.005$$

Transmission Coefficients

Newton's Law of Cooling:

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

where:

q = total heat transfer (W)

U = U factor $\left(\frac{W}{m^2\ K}\right)$

A = area of surface perpendicular to heat transfer $\left(m^2\right)$

ΔT = temperature gradient (K)

and

$U := \frac{1}{R_T}$

where

R_T = total thermal resistances $\left(\frac{m^2\ K}{W}\right)$

For conduction, the following U values are used:
All construction U values are taken from manufacturer's specifications.Spec sheets can be found in Appendix D

Construction element	U Value
Window	0.30
Inner Wall	0.127
Outer Wall	0.128
Roofing	0.127
Gypsum Board (13mm)	12.5
Concrete Slab (1ft)	0.13
Door	2.73
Overhead Door	0.77

And their R values are calculated as:

$R_{window} := 3.33\ \frac{m^2\ K}{W}$

$R_{gypsum} := 0.08\ \frac{m^2\ K}{W}$

$R_{inner.wall} := 7.874\ \frac{m^2\ K}{W}$

$R_{door} := 0.366\ \frac{m^2\ K}{W}$

$R_{outer.wall} := 7.8125\ \frac{m^2\ K}{W}$

$R_{overhead} := 1.29\ \frac{m^2\ K}{W}$

$R_{roof} := 7.874\ \frac{m^2\ K}{W}$

For convection, the following R values are used. Values are taken from Table 10, Chapter 26, ASHRAE Handbook-Fundamentals 2017:

$R_{air.out} := 0.03 \frac{m^2 K}{W}$ moving air in winter

$R_{air.wall} := 0.12 \frac{m^2 K}{W}$ still air against vertical surface

$R_{air.roof} := 0.16 \frac{m^2 K}{W}$ still air against horizontal surface, with heat flow moving upwards

Ground (at grade)

$q := P \cdot F_p \cdot \Delta T$

where:

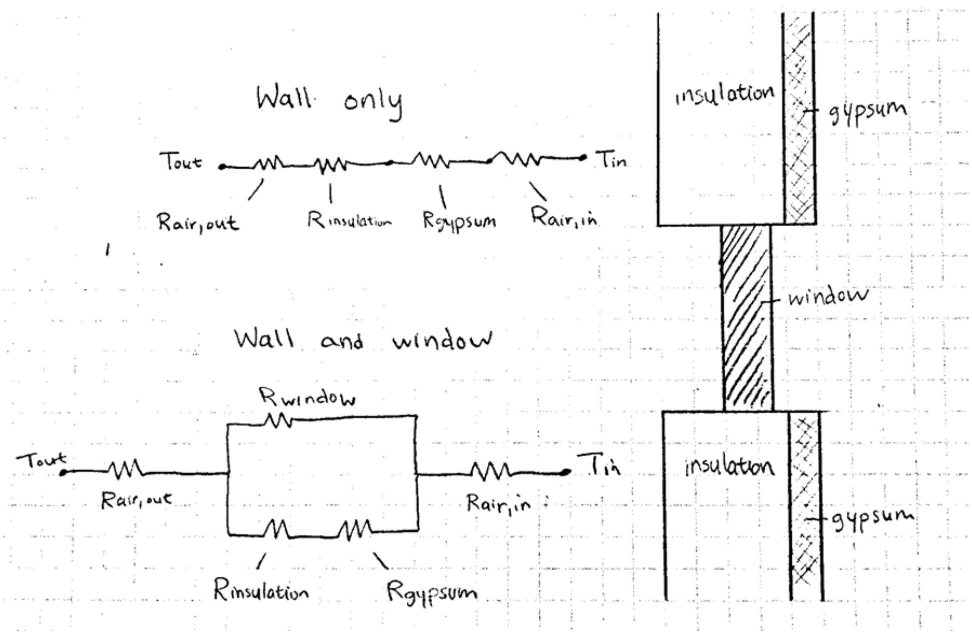
P = perimeter of exposed edge floor $\left(m^2\right)$

F_p = heat loss coefficient of perimeter $\left(\frac{W}{m\ K}\right)$

For poured concrete with an uninsulated perimeter, the heat loss coeficient from Table 24, Chapter 26, ASHRAE Handbook-Fundamentals 2017:

$F_p := 1.24 \frac{W}{m\ K}$

Resistance Diagram



For heat transfer through the wall only, all the resistances from conduction and convection are in series, and the individual R values are added to the total R value.

For heat transfer through the sides where there are windows/doors ,the resistances of the window and/or door and wall are also approximated as as series-path flow method. A parallel path flow method can also be used, but the series method is a good approximate.

According to NECB 2017, Table 3.2.2.2, the maximum U values of buildings in Alberta are:

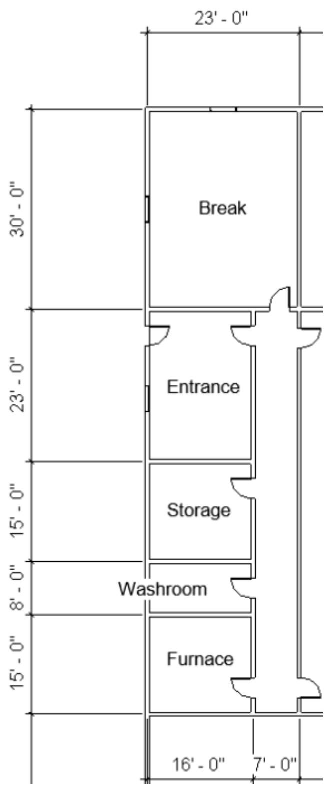
Table 3.2.2.2.
Overall Thermal Transmittance of Above-ground Opaque Building Assemblies
Forming Part of Sentences 3.2.2.2.(1) and (2)

Above-ground *Opaque Building Assembly*	Heating Degree-Days of *Building* Location,(1) in Celsius Degree-Days					
	Zone 4:(2) < 3000	Zone 5:(2) 3000 to 3999	Zone 6:(2) 4000 to 4999	Zone 7A:(2) 5000 to 5999	Zone 7B:(2) 6000 to 6999	Zone 8:(2) ≥ 7000
	Maximum *Overall Thermal Transmittance*, W/(m^2·K)					
Walls	0.315	0.278	0.247	0.210	0.210	0.183
Roofs	0.193	0.156	0.156	0.138	0.138	0.121
Floors	0.227	0.183	0.183	0.162	0.162	0.142

All U values of wall, roof and floor materials meet the requirement of maximum U values for Zone 7B. Metal frames that provide structural support were not included in the heat load calculations. Extra structural consulting is required to determine the size and placement of the metal frame, and were thus excluded from the calculations. However, the metal frames should decrease the heat load as they are another layer of material added to the overall thickness, and should not increase the heat load.

Transmission Calculations

Zone 1



Break room

North

$$R_{convection} := R_{air.out} + R_{air.wall}$$

$$R_{convection} := 0.85 \frac{m^2 K}{W}$$

$$U_{air} := \frac{1}{R_{convection}}$$

$$U_{air} := 1.1765 \frac{W}{m^2 K}$$

$$U_{wall} := \frac{1}{R_{outer.wall} + R_{gypsum}}$$

$$U_{wall} := 0.1267 \frac{W}{m^2 K}$$

$$U_{window} := \frac{1}{R_{window}}$$

$$U_{window} := 0.3003 \frac{W}{m^2 K}$$

$$q_{air} := U_{air} \cdot (23\ \mathrm{ft} \cdot 19\ \mathrm{ft}) \cdot \left(T_{zone1} - T_{out}\right) = 2455.0843\ \mathrm{W}$$

$$q_{wall} := U_{wall} \cdot \left(423.7\ \mathrm{ft}^2\right) \cdot \left(T_{zone1} - T_{out}\right) = 256.3469\ \mathrm{W}$$

$$q_{window} := U_{window} \cdot \left(13.3\ \mathrm{ft}^2\right) \cdot \left(T_{zone1} - T_{out}\right) = 19.0722\ \mathrm{W}$$

$$q_{north} := q_{air} + q_{wall} + q_{window} = 2730.5034\ \mathrm{W}$$

West

$$q_{air} := U_{air} \cdot (30\ \mathrm{ft} \cdot 19\ \mathrm{ft}) \cdot \left(T_{zone1} - T_{out}\right) = 3202.2839\ \mathrm{W}$$

$$q_{wall} := U_{wall} \cdot \left(556.7\ \mathrm{ft}^2\right) \cdot \left(T_{zone1} - T_{out}\right) = 336.8146\ \mathrm{W}$$

$$q_{window} := U_{window} \cdot \left(13.3\ \mathrm{ft}^2\right) \cdot \left(T_{zone1} - T_{out}\right) = 19.0722\ \mathrm{W}$$

$$q_{west} := q_{air} + q_{wall} + q_{window} = 3558.171\ \mathrm{W}$$

East

$$U_{door} := 2.7322\ \frac{\mathrm{W}}{\mathrm{m}^2\ \mathrm{K}}$$

$$q_{air} := U_{air} \cdot (30\ \mathrm{ft} \cdot 19\ \mathrm{ft}) \cdot \left(T_{zone1} - T_{other\_zone}\right) = 249.205\ \mathrm{W}$$

$$q_{wall} := U_{wall} \cdot (30\ \mathrm{ft} \cdot 19\ \mathrm{ft}) \cdot \left(T_{zone1} - T_{other\_zone}\right) = 26.8375\ \mathrm{W}$$

$$q_{east} := q_{air} + q_{wall} = 276.042\ \mathrm{W}$$

Ground

$$q_{ground} := F_p \cdot P \cdot \left(T_{in} - T_{out}\right)$$

$$q_{ground} := 1.24\ \frac{\mathrm{W}}{\mathrm{m\ K}} \cdot (2 \cdot 23\ \mathrm{ft} + 2 \cdot 30\ \mathrm{ft}) \cdot \left(T_{zone1} - T_{out}\right) = 2059.2337\ \mathrm{W}$$

Roof

$$U_{air} := 1.1765\ \frac{\mathrm{W}}{\mathrm{m}^2\ \mathrm{K}}$$

$$U_{wall} := 0.1267\ \frac{\mathrm{W}}{\mathrm{m}^2\ \mathrm{K}}$$

$$q_{air} := U_{air} \cdot (30\ \mathrm{ft} \cdot 23\ \mathrm{ft}) \cdot \left(T_{zone1} - T_{out}\right) = 3876.4489\ \mathrm{W}$$

$$q_{wall} := U_{wall} \cdot (30\ \mathrm{ft} \cdot 23\ \mathrm{ft}) \cdot \left(T_{zone1} - T_{out}\right) = 417.4637\ \mathrm{W}$$

$q_{roof} := q_{air} + q_{wall} = 4293.913 \text{ W}$

Break Room Total

$q_{breakroom} := q_{north} + q_{east} + q_{west} + q_{roof} + q_{ground} = 12917.8628 \text{ W}$

Entrance
West

$$U_{door} := 2.7322\ \frac{W}{m^2\ K}$$

$$q_{air} := U_{air} \cdot (23\ ft \cdot 19\ ft) \cdot \left(T_{zone1} - T_{out}\right) = 2455.0843\ W$$

$$q_{wall} := U_{wall} \cdot \left(404.7\ ft^2\right) \cdot \left(T_{zone1} - T_{out}\right) = 244.8516\ W$$

$$q_{window} := U_{window} \cdot \left(13.3\ ft^2\right) \cdot \left(T_{zone1} - T_{out}\right) = 19.0722\ W$$

$$q_{door} := U_{door} \cdot (6.7\ ft \cdot 2.83\ ft) \cdot \left(T_{zone1} - T_{out}\right) = 247.3812\ W$$

$$q_{west} := q_{air} + q_{wall} + q_{window} + q_{door} = 2966.389\ W$$

Ground

$$q_{ground} := F_p \cdot P \cdot \left(T_{in} - T_{out}\right)$$

$$q_{ground} := 1.24\ \frac{W}{m\ K} \cdot (2 \cdot 23\ ft + 2 \cdot 16\ ft) \cdot \left(T_{zone1} - T_{out}\right) = 1515.2852\ W$$

Roof

$$U_{air} := 1.1765\ \frac{W}{m^2\ K}$$

$$U_{wall} := 0.1267\ \frac{W}{m^2\ K}$$

$$q_{air} := U_{air} \cdot (16\ ft \cdot 23\ ft) \cdot \left(T_{zone1} - T_{out}\right) = 2067.4394\ W$$

$$q_{wall} := U_{wall} \cdot (16\ ft \cdot 23\ ft) \cdot \left(T_{zone1} - T_{out}\right) = 222.6473\ W$$

$$q_{roof} := q_{air} + q_{wall} = 2290.087\ W$$

Entrance Total

$$q_{entrance} := q_{west} + q_{roof} + q_{ground} = 6771.7612\ W$$

Storage

West

$$U_{door} := 2.7322\ \frac{W}{m^2\ K}$$

$$q_{air} := U_{air} \cdot (15\ ft \cdot 19\ ft) \cdot \left(T_{zone1} - T_{out}\right) = 1601.1419\ W$$

$$q_{wall} := U_{wall} \cdot (15\ ft \cdot 19\ ft) \cdot \left(T_{zone1} - T_{out}\right) = 172.4307\ W$$

$$q_{west} := q_{air} + q_{wall} = 1773.573\ W$$

Ground

$$q_{ground} := F_p \cdot P \cdot \left(T_{in} - T_{out}\right)$$

$$q_{ground} := 1.24\ \frac{W}{m\ K} \cdot (2 \cdot 15\ ft + 2 \cdot 16\ ft) \cdot \left(T_{zone1} - T_{out}\right) = 1204.4574\ W$$

Roof

$$U_{air} := 1.1765\ \frac{W}{m^2\ K}$$

$$U_{wall} := 0.1267\ \frac{W}{m^2\ K}$$

$$q_{air} := U_{air} \cdot (16\ ft \cdot 15\ ft) \cdot \left(T_{zone1} - T_{out}\right) = 1348.3301\ W$$

$$q_{wall} := U_{wall} \cdot (16\ ft \cdot 15\ ft) \cdot \left(T_{zone1} - T_{out}\right) = 145.2048\ W$$

$$q_{roof} := q_{air} + q_{wall} = 1493.535\ W$$

Storage Room Total

$$q_{storage} := q_{west} + q_{roof} + q_{ground} = 4471.5649\ W$$

Washroom

West

$$q_{air} := U_{air} \cdot (8\ \text{ft} \cdot 19\ \text{ft}) \cdot (T_{zone1} - T_{out}) = 853.9424\ \text{W}$$

$$q_{wall} := U_{wall} \cdot (8\ \text{ft} \cdot 19\ \text{ft}) \cdot (T_{zone1} - T_{out}) = 91.963\ \text{W}$$

$$q_{west} := q_{air} + q_{wall} = 945.905\ \text{W}$$

Ground

$$q_{ground} := F_p \cdot P \cdot (T_{in} - T_{out})$$

$$q_{ground} := 1.24\ \frac{\text{W}}{\text{m K}} \cdot (2 \cdot 8\ \text{ft} + 2 \cdot 16\ \text{ft}) \cdot (T_{zone1} - T_{out}) = 932.4832\ \text{W}$$

Roof

$$U_{air} := 1.1765\ \frac{\text{W}}{\text{m}^2\ \text{K}}$$

$$U_{wall} := 0.1267\ \frac{\text{W}}{\text{m}^2\ \text{K}}$$

$$q_{air} := U_{air} \cdot (16\ \text{ft} \cdot 8\ \text{ft}) \cdot (T_{zone1} - T_{out}) = 719.1094\ \text{W}$$

$$q_{wall} := U_{wall} \cdot (16\ \text{ft} \cdot 8\ \text{ft}) \cdot (T_{zone1} - T_{out}) = 77.4425\ \text{W}$$

$$q_{roof} := q_{air} + q_{wall} = 796.552\ \text{W}$$

Washroom Total

$$q_{washroom} := q_{west} + q_{roof} + q_{ground} = 2674.9405\ \text{W}$$

Electrical Room

West

$q_{air} := U_{air} \cdot (15 \text{ ft} \cdot 19 \text{ ft}) \cdot (T_{zone1} - T_{out}) = 1601.1419 \text{ W}$

$q_{wall} := U_{wall} \cdot (15 \text{ ft} \cdot 19 \text{ ft}) \cdot (T_{zone1} - T_{out}) = 172.4307 \text{ W}$

$q_{west} := q_{air} + q_{wall} = 1773.573 \text{ W}$

Ground

$q_{ground} := F_p \cdot P \cdot (T_{in} - T_{out})$

$q_{ground} := 1.24 \dfrac{\text{W}}{\text{m K}} \cdot (2 \cdot 15 \text{ ft} + 2 \cdot 16 \text{ ft}) \cdot (T_{zone1} - T_{out}) = 1204.4574 \text{ W}$

Roof

$U_{air} := 1.1765 \dfrac{\text{W}}{\text{m}^2 \text{ K}}$

$U_{wall} := 0.1267 \dfrac{\text{W}}{\text{m}^2 \text{ K}}$

$q_{air} := U_{air} \cdot (16 \text{ ft} \cdot 15 \text{ ft}) \cdot (T_{zone1} - T_{out}) = 1348.3301 \text{ W}$

$q_{wall} := U_{wall} \cdot (16 \text{ ft} \cdot 15 \text{ ft}) \cdot (T_{zone1} - T_{out}) = 145.2048 \text{ W}$

$q_{roof} := q_{air} + q_{wall} = 1493.535 \text{ W}$

Electrical Room Total

$q_{electrical} := q_{west} + q_{roof} + q_{ground} = 4471.5649 \text{ W}$

Hallway

East

$$q_{air} := U_{air} \cdot \left(1140\ \mathrm{ft}^2\right) \cdot \left(T_{zone1} - T_{other\_zone}\right) = 498.4099\ \mathrm{W}$$

$$q_{wall} := U_{wall} \cdot \left(1140\ \mathrm{ft}^2\right) \cdot \left(T_{zone1} - T_{other\_zone}\right) = 53.6749\ \mathrm{W}$$

$$q_{door} := U_{door} \cdot \left(6.7\ \mathrm{ft} \cdot 2.83\ \mathrm{ft}\right) \cdot \left(T_{zone1} - T_{other\_zone}\right) = 19.2515\ \mathrm{W}$$

$$q_{east} := q_{air} + q_{wall} + q_{door} = 571.336\ \mathrm{W}$$

Ground

$$q_{ground} := F_p \cdot P \cdot \left(T_{in} - T_{out}\right)$$

$$q_{ground} := 1.24\ \frac{\mathrm{W}}{\mathrm{m\ K}} \cdot \left(2 \cdot 7\ \mathrm{ft} + 2 \cdot 61\ \mathrm{ft}\right) \cdot \left(T_{zone1} - T_{out}\right) = 2642.0357\ \mathrm{W}$$

Roof

$$U_{air} := 1.1765\ \frac{\mathrm{W}}{\mathrm{m}^2\ \mathrm{K}}$$

$$U_{wall} := 0.1267\ \frac{\mathrm{W}}{\mathrm{m}^2\ \mathrm{K}}$$

$$q_{air} := U_{air} \cdot \left(7\ \mathrm{ft} \cdot 61\ \mathrm{ft}\right) \cdot \left(T_{zone1} - T_{out}\right) = 2398.9039\ \mathrm{W}$$

$$q_{wall} := U_{wall} \cdot \left(7\ \mathrm{ft} \cdot 61\ \mathrm{ft}\right) \cdot \left(T_{zone1} - T_{out}\right) = 258.3435\ \mathrm{W}$$

$$q_{roof} := q_{air} + q_{wall} = 2657.247\ \mathrm{W}$$

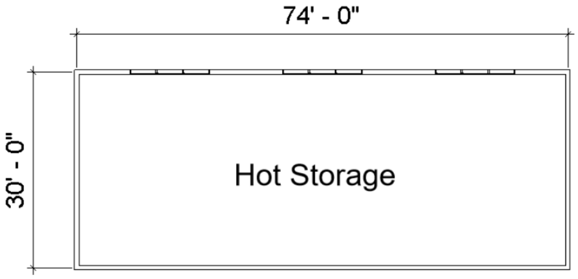
Hallway Total

$$q_{hallway} := q_{east} + q_{roof} + q_{ground} = 5870.6194\ \mathrm{W}$$

Zone 1 Total

$$q_{total} := q_{breakroom} + q_{entrance} + q_{storage} + q_{washroom} + q_{electrical} + q_{hallway} = 37178.3137\ \mathrm{W}$$

Zone 2



North

$U_{air} := 1.1765 \frac{W}{m^2 K}$

$U_{wall} := 0.1267 \frac{W}{m^2 K}$

$q_{air} := U_{air} \cdot (74\ ft \cdot 19\ ft) \cdot (T_{other\_zone} - T_{out}) = 7284.2613\ W$

$q_{wall} := U_{wall} \cdot (74\ ft \cdot 19\ ft) \cdot (T_{other\_zone} - T_{out}) = 784.4589\ W$

$q_{north} := q_{air} + q_{wall} = 8068.72\ W$

Ground

$q_{ground} := F_p \cdot P \cdot (T_{in} - T_{out})$

$q_{ground} := 1.24 \frac{W}{m\ K} \cdot (2 \cdot 30\ ft + 2 \cdot 74\ ft) \cdot (T_{other\_zone} - T_{out}) = 3726.3044\ W$

Roof

$U_{air} := 1.1765 \frac{W}{m^2 K}$

$U_{wall} := 0.1267 \frac{W}{m^2 K}$

$q_{air} := U_{air} \cdot (74\ ft \cdot 30\ ft) \cdot (T_{other\_zone} - T_{out}) = 11501.4653\ W$

$q_{wall} := U_{wall} \cdot (74\ ft \cdot 30\ ft) \cdot (T_{other\_zone} - T_{out}) = 1238.6193\ W$

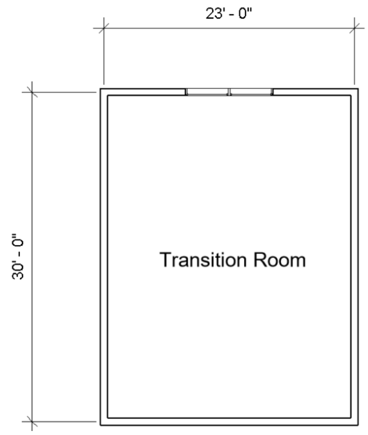
$q_{roof} := q_{air} + q_{wall} = 12740.085\ W$

Total

$q_{total} := q_{north} + q_{ground} + q_{roof} = 24535.1092\ W$

$q_{total} := 24.5\ kW$

Zone 3



North

$$U_{air} := 1.1765 \frac{W}{m^2 K}$$

$$U_{wall} := 0.1267 \frac{W}{m^2 K}$$

$$U_{window} := 0.3003 \frac{W}{m^2 K}$$

$$q_{air} := U_{air} \cdot (23\ ft \cdot 19\ ft) \cdot (T_{other\_zone} - T_{out}) = 2264.0272\ W$$

$$q_{wall} := U_{wall} \cdot \left(423.7\ ft^2\right) \cdot (T_{other\_zone} - T_{out}) = 236.3978\ W$$

$$q_{window} := U_{window} \cdot \left(13.3\ ft^2\right) \cdot (T_{other\_zone} - T_{out}) = 17.588\ W$$

$$q_{north} := q_{air} + q_{wall} + q_{window} = 2518.013\ W$$

East

$$U_{air} := 1.1765 \frac{W}{m^2 K}$$

$$U_{wall} := 0.1267 \frac{W}{m^2 K}$$

$$U_{overhead} := \frac{1}{R_{overhead}}$$

$$U_{overhead} := 0.77 \frac{W}{m^2 K}$$

$$U_{door} := 2.7322 \frac{W}{m^2 K}$$

$$q_{air} := U_{air} \cdot (30\ ft \cdot 19\ ft) \cdot (T_{other\_zone} - T_{out}) = 2953.0789\ W$$

$$q_{wall} := U_{wall} \cdot \left(423.7\ ft^2\right) \cdot (T_{other\_zone} - T_{out}) = 236.3978\ W$$

$$q_{overhead} := U_{overhead} \cdot (8\ ft \cdot 9\ ft) \cdot (T_{other\_zone} - T_{out}) = 244.1358\ W$$

$$q_{door} := U_{door} \cdot (6.7\ ft \cdot 2.83\ ft) \cdot (T_{other\_zone} - T_{out}) = 228.1298\ W$$

$$q_{east} := q_{air} + q_{wall} + q_{overhead} + q_{door} = 3661.742\ W$$

South

$$U_{air} := 1.1765\ \frac{W}{m^2\ K}$$

$$U_{wall} := 0.1267\ \frac{W}{m^2\ K}$$

$$q_{air} := U_{air} \cdot (23\ ft \cdot 19\ ft) \cdot \left(T_{other\_zone} - T_{out}\right) = 2264.0272\ W$$

$$q_{wall} := U_{wall} \cdot (23\ ft \cdot 19\ ft) \cdot \left(T_{other\_zone} - T_{out}\right) = 243.8183\ W$$

$$q_{south} := q_{air} + q_{wall} = 2507.845\ W$$

Ground

$$q_{ground} := F_p \cdot P \cdot \left(T_{in} - T_{out}\right)$$

$$q_{ground} := 1.24\ \frac{W}{m\ K} \cdot (2 \cdot 30\ ft + 2 \cdot 23\ ft) \cdot \left(T_{other\_zone} - T_{out}\right) = 1898.982\ W$$

Roof

$$U_{air} := 1.1765\ \frac{W}{m^2\ K}$$

$$U_{wall} := 0.1267\ \frac{W}{m^2\ K}$$

$$q_{air} := U_{air} \cdot (23\ ft \cdot 30\ ft) \cdot \left(T_{other\_zone} - T_{out}\right) = 3574.7798\ W$$

$$q_{wall} := U_{wall} \cdot (23\ ft \cdot 30\ ft) \cdot \left(T_{other\_zone} - T_{out}\right) = 384.9763\ W$$

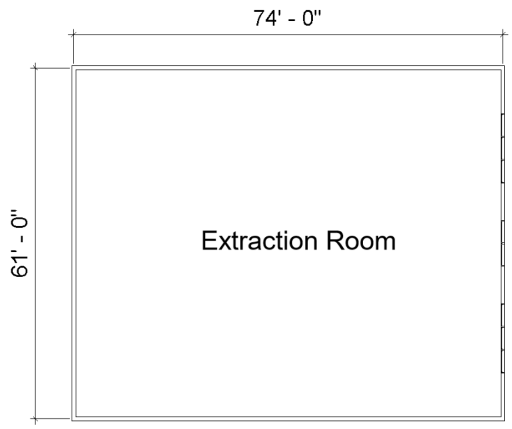
$$q_{roof} := q_{air} + q_{wall} = 3959.756\ W$$

Total

$$q_{total} := q_{north} + q_{east} + q_{south} + q_{ground} + q_{roof} = 14546.3387\ W$$

$$q_{total} := 14.6\ kW$$

Zone 4



East

$$U_{air} := 1.1765 \frac{W}{m^2 K}$$

$$U_{wall} := 0.1267 \frac{W}{m^2 K}$$

$$U_{window} := 0.3003 \frac{W}{m^2 K}$$

$$U_{door} := 2.7322 \frac{W}{m^2 K}$$

$$q_{air} := U_{air} \cdot (61\ ft \cdot 19\ ft) \cdot (T_{other\_zone} - T_{out}) = 6004.5938\ W$$

$$q_{wall} := U_{wall} \cdot (1081.2\ ft^2) \cdot (T_{other\_zone} - T_{out}) = 603.2411\ W$$

$$q_{window} := U_{window} \cdot (39.9\ ft^2) \cdot (T_{other\_zone} - T_{out}) = 52.7639\ W$$

$$q_{door} := U_{door} \cdot (6.7\ ft \cdot 2.83\ ft \cdot 2) \cdot (T_{other\_zone} - T_{out}) = 456.2596\ W$$

$$q_{east} := q_{air} + q_{wall} + q_{window} + q_{door} = 7116.858\ W$$

Ground

$$q_{ground} := F_p \cdot P \cdot (T_{in} - T_{out})$$

$$q_{ground} := 1.24 \frac{W}{m\ K} \cdot (2 \cdot 74\ ft + 2 \cdot 61\ ft) \cdot (T_{other\_zone} - T_{out}) = 4837.0297\ W$$

Roof

$$U_{air} := 1.1765\ \frac{\mathrm{W}}{\mathrm{m}^2\ \mathrm{K}}$$

$$U_{wall} := 0.1267\ \frac{\mathrm{W}}{\mathrm{m}^2\ \mathrm{K}}$$

$$q_{air} := U_{air} \cdot (74\ \mathrm{ft} \cdot 61\ \mathrm{ft}) \cdot \left(T_{other\_zone} - T_{out}\right) = 23386.3127\ \mathrm{W}$$

$$q_{wall} := U_{wall} \cdot (74\ \mathrm{ft} \cdot 61\ \mathrm{ft}) \cdot \left(T_{other\_zone} - T_{out}\right) = 2518.526\ \mathrm{W}$$

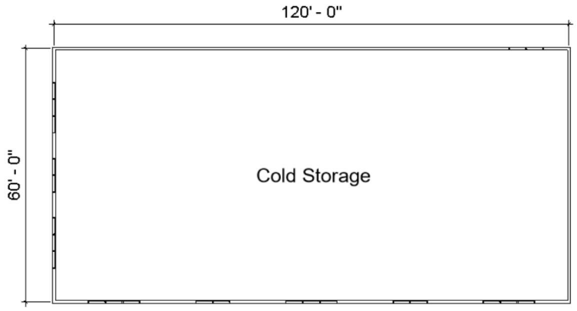
$$q_{roof} := q_{air} + q_{wall} = 25904.839\ \mathrm{W}$$

Total

$$q_{total} := q_{east} + q_{ground} + q_{roof} = 37858.7268\ \mathrm{W}$$

$$q_{total} := 37.9\ \mathrm{kW}$$

Zone 5



North

$$U_{air} := 1.1765 \frac{W}{m^2 K}$$

$$U_{wall} := 0.1267 \frac{W}{m^2 K}$$

$$U_{window} := 0.3003 \frac{W}{m^2 K}$$

$$q_{air} := U_{air} \cdot (23\ ft \cdot 19\ ft) \cdot (T_{other\_zone} - T_{out}) = 2264.0272\ W$$

$$q_{wall} := U_{wall} \cdot \left(423.7\ ft^2\right) \cdot (T_{other\_zone} - T_{out}) = 236.3978\ W$$

$$q_{window} := U_{window} \cdot \left(13.3\ ft^2\right) \cdot (T_{other\_zone} - T_{out}) = 17.588\ W$$

$$q_{north} := q_{air} + q_{wall} + q_{window} = 2518.013\ W$$

East

$$U_{air} := 1.1765 \frac{W}{m^2 K}$$

$$U_{wall} := 0.1267 \frac{W}{m^2 K}$$

$$U_{window} := 0.3003 \frac{W}{m^2 K}$$

$$U_{door} := 2.7322 \frac{W}{m^2 K}$$

$$U_{overhead} := 0.77 \frac{W}{m^2 K}$$

$$q_{air} := U_{air} \cdot (60\ ft \cdot 19\ ft) \cdot (T_{other\_zone} - T_{out}) = 5906.1578\ W$$

$$q_{wall} := U_{wall} \cdot \left(1035.7\ ft^2\right) \cdot \left(T_{other\_zone} - T_{out}\right) = 577.855\ W$$

$$q_{window} := U_{window} \cdot \left(13.3\ ft^2\right) \cdot \left(T_{other\_zone} - T_{out}\right) = 17.588\ W$$

$$q_{door} := U_{door} \cdot (6.7\ ft \cdot 2.83\ ft) \cdot \left(T_{other\_zone} - T_{out}\right) = 228.1298\ W$$

$$q_{overhead} := U_{overhead} \cdot (8\ ft \cdot 9\ ft) \cdot \left(T_{other\_zone} - T_{out}\right) = 244.1358\ W$$

$$q_{east} := q_{air} + q_{wall} + q_{window} + q_{door} + q_{overhead} = 6973.866\ W$$

South

$$U_{air} := 1.1765\ \frac{W}{m^2\ K}$$

$$U_{wall} := 0.1267\ \frac{W}{m^2\ K}$$

$$U_{window} := 0.3003\ \frac{W}{m^2\ K}$$

$$q_{air} := U_{air} \cdot (120\ ft \cdot 19\ ft) \cdot \left(T_{other\_zone} - T_{out}\right) = 11812.3157\ W$$

$$q_{wall} := U_{wall} \cdot \left(2213.5\ ft^2\right) \cdot \left(T_{other\_zone} - T_{out}\right) = 1234.9928\ W$$

$$q_{window} := U_{window} \cdot \left(66.5\ ft^2\right) \cdot \left(T_{other\_zone} - T_{out}\right) = 87.9398\ W$$

$$q_{south} := q_{air} + q_{wall} + q_{window} = 13135.248\ W$$

West

$$U_{air} := 1.1765\ \frac{W}{m^2\ K}$$

$$U_{wall} := 0.1267\ \frac{W}{m^2\ K}$$

$$U_{window} := 0.3003\ \frac{W}{m^2\ K}$$

$$U_{door} := 2.7322\ \frac{W}{m^2\ K}$$

$$q_{air} := U_{air} \cdot (60\ ft \cdot 19\ ft) \cdot \left(T_{other\_zone} - T_{out}\right) = 5906.1578\ W$$

$$q_{wall} := U_{wall} \cdot \left(1094.5\ ft^2\right) \cdot \left(T_{other\_zone} - T_{out}\right) = 610.6617\ W$$

$$q_{window} := U_{window} \cdot \left(26.6\ ft^2\right) \cdot \left(T_{other\_zone} - T_{out}\right) = 35.1759\ W$$

$q_{door} := U_{door} \cdot (6.7\ \text{ft} \cdot 2.83\ \text{ft}) \cdot (T_{other\_zone} - T_{out}) = 228.1298\ \text{W}$

$q_{west} := q_{air} + q_{wall} + q_{window} + q_{door} = 6780.125\ \text{W}$

Ground

$q_{ground} := F_p \cdot P \cdot (T_{in} - T_{out})$

$q_{ground} := 1.24\ \frac{\text{W}}{\text{m K}} \cdot (2 \cdot 120\ \text{ft} + 2 \cdot 60\ \text{ft}) \cdot (T_{other\_zone} - T_{out}) = 6449.3729\ \text{W}$

Roof

$U_{air} := 1.1765\ \frac{\text{W}}{\text{m}^2\ \text{K}}$

$U_{wall} := 0.1267\ \frac{\text{W}}{\text{m}^2\ \text{K}}$

$q_{air} := U_{air} \cdot (60\ \text{ft} \cdot 120\ \text{ft}) \cdot (T_{other\_zone} - T_{out}) = 37302.0496\ \text{W}$

$q_{wall} := U_{wall} \cdot (60\ \text{ft} \cdot 120\ \text{ft}) \cdot (T_{other\_zone} - T_{out}) = 4017.1438\ \text{W}$

$q_{roof} := q_{air} + q_{wall} = 41319.193\ \text{W}$

Total

$q_{total} := q_{north} + q_{east} + q_{south} + q_{west} + q_{ground} + q_{roof} = 77175.819\ \text{W}$

$q_{total} := 77.2\ \text{kW}$

Infiltration Heat Loss

$q_t := q_s + q_l$

q_t is the total infiltration heat loss (W)

Sensible:

$q_s := C_s \cdot Q \cdot \left(T_{in} - T_{out}\right)$

where:

q_s is the sensible heat gain due to infiltration (W)

Q is the infiltration rate $\left(\dfrac{\mathrm{m}^3}{\mathrm{s}}\right)$

T_{in} is the indoor temperature (K)

T_{out} is the outdoor temperature (K)

C_s is the air sensible heat factor $\left(\dfrac{\mathrm{W}}{\mathrm{m}^3\ \mathrm{s}\ \mathrm{K}}\right)$

Latent:

$q_l := C_l \cdot Q \cdot \left(W_{in} - W_{out}\right)$

where:

q_l is the latent heat gain due to infiltration (W)

Q is the infiltration rate $\left(\dfrac{\mathrm{m}^3}{\mathrm{s}}\right)$

W_{in} is the indoor humidity ratio $\left(\dfrac{\mathrm{kg}}{\mathrm{kg}}\right)$

W_{out} is the outdoor humidity ratio $\left(\dfrac{\mathrm{kg}}{\mathrm{kg}}\right)$

C_l is the air latent heat factor $\left(\dfrac{\mathrm{W}}{\mathrm{m}^3\ \mathrm{s}}\right)$

Elevation Correction

$$C_s := 1.23 \cdot \left(1 - \left(669 \cdot 2.25577 \cdot 10^{-5}\right)\right)^{5.2559} = 1.1355\ \frac{\mathrm{W}}{\mathrm{m}^3\ \mathrm{s}\ \mathrm{K}}$$

$$C_s := 1.1355\ \frac{\mathrm{W}}{\mathrm{m}^3\ \mathrm{s}\ \mathrm{K}}$$

$$C_l := 3010 \cdot \left(1 - \left(669 \cdot 2.25577 \cdot 10^{-5}\right)\right)^{5.2559} = 2778.7972\ \frac{\mathrm{W}}{\mathrm{m}^3\ \mathrm{s}}$$

$$C_l := 2778.7972\ \frac{\mathrm{W}}{\mathrm{m}^3\ \mathrm{s}}$$

Infiltration Calculation

Using the ventilation values calculated previously:

Zone 1
Break room

$$q_s := 1.1355 \frac{W}{m^3\ s\ K}\ 0.521 \frac{m^3}{s} \cdot \left(T_{zone1} - T_{out} \right)$$

$$q_s := 30.4\ W$$

$$q_l := 2778.7972 \frac{W}{m^3\ s}\ 0.521 \frac{m^3}{s} \cdot \left(W_{zone1} - W_{out} \right)$$

$$q_l := 9.99\ W$$

$$q_t = 40.39\ W$$

Entrance

$$q_s := 1.1355 \frac{W}{m^3\ s\ K}\ 0.2779 \frac{m^3}{s} \cdot \left(T_{zone1} - T_{out} \right)$$

$$q_s := 16.2\ W$$

$$q_l := 2778.7972 \frac{W}{m^3\ s}\ 0.2779 \frac{m^3}{s} \cdot \left(W_{zone1} - W_{out} \right)$$

$$q_l := 5.33\ W$$

$$q_t = 21.53\ W$$

Storage

$$q_s := 1.1355 \frac{W}{m^3\ s\ K}\ 0.1812 \frac{m^3}{s} \cdot \left(T_{zone1} - T_{out} \right)$$

$$q_s := 10.57\ W$$

$$q_l := 2778.7972 \frac{W}{m^3\ s}\ 0.1812 \frac{m^3}{s} \cdot \left(W_{zone1} - W_{out} \right)$$

$$q_l := 3.47\ W$$

$$q_t = 14.04\ W$$

Washroom

$$q_s := 1.1355 \frac{W}{m^3 \ s \ K} \ 0.0967 \frac{m^3}{s} \cdot \left(T_{zone1} - T_{out} \right)$$

$$q_s := 5.64 \ W$$

$$q_l := 2778.7972 \frac{W}{m^3 \ s} \ 0.0967 \frac{m^3}{s} \cdot \left(W_{zone1} - W_{out} \right)$$

$$q_l := 1.85 \ W$$

$$q_t = 7.49 \ W$$

Electrical Room

$$q_s := 1.1355 \frac{W}{m^3 \ s \ K} \ 0.1812 \frac{m^3}{s} \cdot \left(T_{zone1} - T_{out} \right)$$

$$q_s := 10.57 \ W$$

$$q_l := 2778.7972 \frac{W}{m^3 \ s} \ 0.1812 \frac{m^3}{s} \cdot \left(W_{zone1} - W_{out} \right)$$

$$q_l := 3.47 \ W$$

$$q_t = 14.04 \ W$$

Hallway

$$q_s := 1.1355 \frac{W}{m^3 \ s \ K} \ 0.3224 \frac{m^3}{s} \cdot \left(T_{zone1} - T_{out} \right)$$

$$q_s := 18.82 \ W$$

$$q_l := 2778.7972 \frac{W}{m^3 \ s} \ 0.3224 \frac{m^3}{s} \cdot \left(W_{zone1} - W_{out} \right)$$

$$q_l := 6.18 \ W$$

$$q_t = 25 \ W$$

Total Zone 1:

$$q_{zone1} := 122 \ W$$

Zone 2

$$q_s := 1.1355 \frac{\mathrm{W}}{\mathrm{m}^3\ \mathrm{s}\ \mathrm{K}}\ 3.3527 \frac{\mathrm{m}^3}{\mathrm{s}} \cdot \left(T_{other\_zone} - T_{out}\right)$$

$$q_s := 180.451\ \mathrm{W}$$

$$q_l := 2778.7972 \frac{\mathrm{W}}{\mathrm{m}^3\ \mathrm{s}}\ 3.3527 \frac{\mathrm{m}^3}{\mathrm{s}} \cdot \left(W_{other.zone} - W_{out}\right)$$

$$q_l := 45.65\ \mathrm{W}$$

$$q_t = 226.101\ \mathrm{W}$$

Zone 3

$$q_s := 1.1355 \frac{\mathrm{W}}{\mathrm{m}^3\ \mathrm{s}\ \mathrm{K}}\ 0.521 \frac{\mathrm{m}^3}{\mathrm{s}} \cdot \left(T_{other\_zone} - T_{out}\right)$$

$$q_s := 28.0416\ \mathrm{W}$$

$$q_l := 2778.7972 \frac{\mathrm{W}}{\mathrm{m}^3\ \mathrm{s}}\ 0.521 \frac{\mathrm{m}^3}{\mathrm{s}} \cdot \left(W_{other.zone} - W_{out}\right)$$

$$q_l := 7.09\ \mathrm{W}$$

$$q_t = 35.1316\ \mathrm{W}$$

Zone 4

$$q_s := 1.1355 \frac{\mathrm{W}}{\mathrm{m}^3\ \mathrm{s}\ \mathrm{K}}\ 6.8172 \frac{\mathrm{m}^3}{\mathrm{s}} \cdot \left(T_{other\_zone} - T_{out}\right)$$

$$q_s := 366.9201\ \mathrm{W}$$

$$q_l := 2778.7972 \frac{\mathrm{W}}{\mathrm{m}^3\ \mathrm{s}}\ 6.8172 \frac{\mathrm{m}^3}{\mathrm{s}} \cdot \left(W_{other.zone} - W_{out}\right)$$

$$q_l := 92.82\ \mathrm{W}$$

$$q_t = 459.7401\ \mathrm{W}$$

Zone 5

$$q_s := 1.1355\ \frac{\mathrm{W}}{\mathrm{m}^3\ \mathrm{s}\ \mathrm{K}}\ 10.8737\ \frac{\mathrm{m}^3}{\mathrm{s}} \cdot \left(T_{other\_zone} - T_{out}\right)$$

$$q_s := 585.2519\ \mathrm{W}$$

$$q_l := 2778.7972\ \frac{\mathrm{W}}{\mathrm{m}^3\ \mathrm{s}}\ 10.8737\ \frac{\mathrm{m}^3}{\mathrm{s}} \cdot \left(W_{other.zone} - W_{out}\right)$$

$$q_l := 148.1\ \mathrm{W}$$

$$q_t = 733.3519\ \mathrm{W}$$

Total Heat Loss

A safety factor of 10% was applied to the overall building heat load for allowances in piping, duct and other losses.

Zone	Transmission (W)	Infiltration (W)	Total Heat Load per Zone (W)	Total Heat Load per Zone with 10% Safety Factor (W)
1	37,178	122	37,300	41,030
2	24,535	226	24,761	27,237
3	14,546	35	14,581	16,039
4	37,858	460	38,318	42,149
5	77,176	733	77,909	85,699
TOTAL Heat Load of Entire Building			**192,869**	**212,155**

Safety Factor Discussion

From Principles of HVAC Design , 8th edition by Ronald H. Howell, a combined warm-up/safety allowance of 20% to 25% is fairly common but varies depending on the particular climate, building use, and type of construction. Engineering judgment must be applied for the particular project.Since the 99% design conditions were used in calculations, and since this building is new (air leakage is significantly less compared to that of older houses), a smaller safety factor of 10% can be applied. A 20% capacity shortfall typically results in a temperature excursion of at most about one or two degrees. With a safety factor of 10%, it would roughly translate to a maximum drop of 4°C. In a worst case scenario, a 4 degree drop would result in the indoor temperatures of 16 and 12 degrees for Zone 1 and Zones 2,3,4,5 respectively. This drop would not result in dire consequences such as hypothermia or pipe/duct freezing, and is still a relatively safe temperature for occupants (although not at optimal human comfort level). A safey factor of 10% also decreases the amount of energy that the building has to supply throughout the year, effectively decreasing costs.

Cooling Load Calculations

By: Zoey Zhang

Date:November 24, 2019

Objective: The purpose of heating and cooling load calculations is to quantify the heating and cooling loads in areas of the honey packing house. These calculations form the basis for equipment selection and duct and piping design.

Assumptions:

1. Heat transfer throughout the building and all walls will be steady. Air temperatures in and outside the building will not likely fluctuate a lot in time. The design will aim to keep indoor temperatures constant.

2. Heat transfer is one dimensional, and occurs in the normal direction to the wall surface. No significant heat transfer will take place in the wall in other directions. This assumption is valid because heat transfer is only driven by the temperature gradient in a particular direction. Temperature measurements at several locations along one wall surface will likely be the same, i.e. the surface is isothermal.

3. All material properties will be assumed to have the same thermal conductivity properties throughout it's entire mass (isothermal)

4. Air is assumed to be an ideal gas

5. The local atmospheric pressure is at 1 atm

6. For walls that have the same temperatures on both sides, it will be assumed that no heat transfer occurs (i.e. both sides of the wall are at equilibrium)

7. All walls, windows, doors, ceilings are above grade. The ground is at grade.

9. Internal gains due to equipment are not considered. The heating load is much greater than the cooling load, so the internal gains from equipment is negligible.

Outdoor and Indoor Conditions

Outdoor

From ASHRAE 2017 Handbook- Fundamentals, the weather information at Grande Prairie at 2% conditions

Latitude: 55.180 N

Longitude: 118.880 W

Elevation: 669 m

Cooling Dry Bulb Temperature: $T_{out} := 24\ °C = 297.15\ K$

Humidity Ratio:10.3

$$W_{out} := 10.3\ \frac{g}{kg}\ \frac{1\ kg}{1000\ g} = 0.0103$$

Extreme Annual Wind Speed: $11.3\ \frac{m}{s}$

Indoor

To keep the honey from crystallizing and absorbing moisture, Zones 2 and 3 will be kept at 30°C and 30% relative humidity, while Zones 1,4 and 5 will be kept at 20°C and 45% relative humidity for human comfort.

$T_{zone2.3} := 30\ °C = 303.15\ K$

$T_{zone1.4.5} := 20\ °C = 293.15\ K$

$RH_{zone2.3} := 30\ \%$

$RH_{zone1.4.5} := 45\ \%$

From psychometric charts, humidity ratio is:

$$W_{zone2.3} := 8\ \frac{g}{kg}\ \frac{1\ kg}{1000\ g} = 0.008$$

$$W_{zone1.4.5} := 7\ \frac{g}{kg}\ \frac{1\ kg}{1000\ g} = 0.007$$

External Heat Gain

Wall and roof transmission:

$$q := U \cdot A \cdot \left(T_{out} - T_{in}\right)$$

where:

q is the heat transfer rate (W)

U is the overall U factor $\left(\frac{\mathrm{W}}{\mathrm{m}^2\,\mathrm{K}}\right)$

A is the floor area $\left(\mathrm{m}^2\right)$

T_{in} is the conditioned space temperature (K)

T_{out} is the adjacent space temperature (K)

Ground (at grade)

$$q := P \cdot F_p \cdot \Delta T$$

where:

P = perimeter of exposed edge floor $\left(\mathrm{m}^2\right)$

F_p = heat loss coefficient of perimeter $\left(\frac{\mathrm{W}}{\mathrm{m}\,\mathrm{K}}\right)$

Fenestration:

$$q_c := U \cdot A \cdot \left(T_{out} - T_{in}\right)$$

where:

q_c is the fenestration transmission heat gain (W)

U is the overall U factor $\left(\frac{\mathrm{W}}{\mathrm{m}^2\,\mathrm{K}}\right)$

A is the window area $\left(\mathrm{m}^2\right)$

T_{in} is the indoor temperature (K)

T_{out} is the outdoor temperature (K)

$$q_b := A \cdot E_{tb} \cdot SHGC\theta \cdot IAC\theta\Omega$$

$$q_d := A \cdot \left(E_{td} + E_{tr}\right) \cdot SHGC_D \cdot IAC_D$$

where:

q_b is the direct beam solar heat gain (W)

q_b is the diffuse solar heat gain (W)

A is the window area $\left(\mathrm{m}^2\right)$

E_{tb}, E_{td}, E_{tr} are beam, sky diffuse, and ground-reflected diffuse irradiance

$SHGC\theta$ is the beam solar heat gain coefficient as a function of incident angle

$SHGC_D$ is the diffuse solar heat gain coefficient

$IAC\theta\Omega$ is the indoor solar attenuation coefficient for beam solar heat gain coefficient

IAC_D is the indoor solar attenuation coefficient for diffuse solar heat gain coefficient

total fenestration:

$$q_t := q_c + q_b + q_d$$

Fenestration Constants:

IAC_D and IACθΩ are equal to 1.0 because none of the windows are shaded

$SGHC\theta := 0.34$
$SGHC_D := 0.34$ from manufacturer's specifications

$$E_{tb} := E_b \cdot cos\theta$$

where :

E_b is the clear sky beam normal irradiance $\left(\frac{W}{m^2}\right)$

θ is the incident angle (°)

from Environment Canada, the maximum solar incident angle during summer is:

$$\theta := 62\ °$$

$$E_{td} := E_d \cdot Y$$

where:

E_d is the diffuse horizontal irradiance $\left(\frac{W}{m^2}\right)$

Y is the ratio of clear-sky diffuse irradiance on a vertical surface to the clear-sky diffuse irradiance on a horizontal surface

$$Y := max\left(0.45, 0.55 + 0.437 \cdot \cos(\theta) + 0.313 \cdot \cos(\theta)^2\right)$$

$$E_{tr} := \left(E_b \cdot \sin(\theta) + E_d\right) \cdot 0.2 \cdot \frac{1 - \cos(\theta)}{2}$$

From ASHRAE weather data 2017:a conservative estimate of the max solar irradiance (in June) was used

$$E_b := 899 \frac{W}{m^2}$$

$$E_d := 110 \frac{W}{m^2}$$

$$E_{tb} := 899 \frac{W}{m^2} \cdot \cos(62)$$

$$E_{tb} := 605.5 \frac{W}{m^2}$$

$$Y := max\left(0.45, 0.55 + 0.437 \cdot \cos(\theta) + 0.313 \cdot \cos(\theta)^2\right)$$

$$Y := 0.82$$

$$E_{td} := 110 \frac{W}{m^2} \cdot 0.824$$

$$E_{td} := 90.64 \frac{W}{m^2}$$

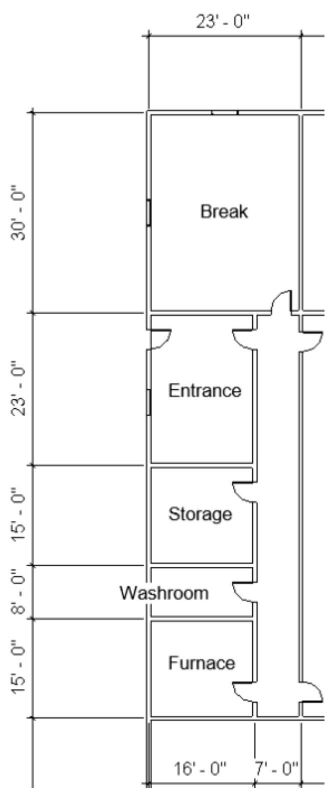
$$E_{tr} := \left(E_b \cdot \sin(\theta) + E_d\right) \cdot 0.2 \cdot \frac{1 - \cos(\theta)}{2}$$

$$E_{tr} := 47.95 \frac{W}{m^2}$$

External Heat Gain

Zone 1

For this zone, a total zone cooling load was calculated instead of the load per room, as was done in the heating load calculations. Since the heating load is assumed to be far greater than the cooling load, the ducts will be sized according to the heating load. This assumption will be checked later.



North

$$R_{convection} := R_{air.out} + R_{air.wall}$$

$$R_{convection} := 0.85 \frac{m^2 K}{W}$$

$$U_{air} := \frac{1}{R_{convection}}$$

$$U_{air} := 1.1765 \frac{W}{m^2 K}$$

$$U_{wall} := \frac{1}{R_{outer.wall} + R_{gypsum}}$$

$$U_{wall} := 0.1267 \frac{W}{m^2 K}$$

$$U_{window} := \frac{1}{R_{window}}$$

$$U_{window} := 0.3003 \frac{W}{m^2 K}$$

$$q_{air} := U_{air} \cdot (23\ ft \cdot 19\ ft) \cdot \left(T_{out} - T_{zone1.4.5}\right) = 191.0571\ W$$

$$q_{wall} := U_{wall} \cdot \left(423.7\ ft^2\right) \cdot \left(T_{out} - T_{zone1.4.5}\right) = 19.9492\ W$$

$$q_c := U \cdot A \cdot \left(T_{out} - T_{in}\right)$$
$$q_b := A \cdot E_{tb} \cdot SHGC\theta \cdot IAC\theta\Omega$$
$$q_d := A \cdot \left(E_{td} + E_{tr}\right) \cdot SHGC_D \cdot IAC_D$$

$$q_{window} := U_{window} \cdot 13.3\ ft^2 \cdot \left(T_{out} - T_{zone1.4.5}\right) + 13.3\ ft^2 \cdot 605.5 \frac{W}{m^2} \cdot 0.34 + = 427.1026\ W$$
$$+ 13.3\ ft^2 \cdot \left(90.64 \frac{W}{m^2} + 47.95 \frac{W}{m^2}\right)$$

$$q_{north} := q_{air} + q_{wall} + q_{window} = 638.109\ W$$

East

$$R_{convection} := R_{air.wall} + R_{air.wall}$$

$$R_{convection} := 1.36 \ \frac{m^2 \ K}{W}$$

$$U_{air} := \frac{1}{R_{convection}}$$

$$U_{air} := 0.7353 \ \frac{W}{m^2 \ K}$$

$$U_{wall} := \frac{1}{R_{inner.wall} + R_{gypsum}}$$

$$U_{wall} := 0.1257 \ \frac{W}{m^2 \ K}$$

$$U_{door} := 2.7322 \ \frac{W}{m^2 \ K}$$

$$q_{air} := U_{air} \cdot (91 \ ft \cdot 19 \ ft) \cdot \left(T_{zone2.3} - T_{zone1.4.5}\right) = 1181.1077 \ W$$

$$q_{wall} := U_{wall} \cdot \left(1691 \ ft^2\right) \cdot \left(T_{zone2.3} - T_{zone1.4.5}\right) = 197.4735 \ W$$

$$q_{door} := U_{door} \cdot (6.7 \ ft \cdot 2.83 \ ft \cdot 2) \cdot \left(T_{zone2.3} - T_{zone1.4.5}\right) = 96.2573 \ W$$

$$q_{east} := q_{air} + q_{wall} + q_{door} = 1474.838 \ W$$

West

$$U_{air} := 1.1765 \ \frac{W}{m^2 \ K} \qquad U_{door} := \frac{1}{R_{door}}$$

$$U_{wall} := 0.1267 \ \frac{W}{m^2 \ K} \qquad U_{door} := 2.7322 \ \frac{W}{m^2 \ K}$$

$$q_{air} := U_{air} \cdot (91 \ ft \cdot 19 \ ft) \cdot \left(T_{out} - T_{zone1.4.5}\right) = 755.9218 \ W$$

$$q_{wall} := U_{wall} \cdot \left(1683 \ ft^2\right) \cdot \left(T_{out} - T_{zone1.4.5}\right) = 79.2411 \ W$$

$$q_{window} := U_{window} \cdot 13.3 \ ft^2 \cdot 2 \cdot \left(T_{out} - T_{zone1.4.5}\right) + 13.3 \ ft^2 \cdot 2 \cdot 605.5 \ \frac{W}{m^2} \cdot 0.34 + = 854.2052 \ W$$
$$+ 13.3 \ ft^2 \cdot 2 \cdot \left(90.64 \ \frac{W}{m^2} + 47.95 \ \frac{W}{m^2}\right)$$

$$q_{door} := U_{door} \cdot (6.7 \ ft \cdot 2.83 \ ft) \cdot \left(T_{out} - T_{zone1.4.5}\right) = 19.2515 \ W$$

$$q_{west} := q_{air} + q_{wall} + q_{window} + q_{door} = 1708.62 \text{ W}$$

Ground

$$q_{ground} := F_p \cdot P \cdot \left(T_{out} - T_{in} \right)$$

$$q_{ground} := 1.24 \frac{\text{W}}{\text{m K}} \cdot (2 \cdot 23 \text{ ft} + 2 \cdot 91 \text{ ft}) \cdot \left(T_{out} - T_{zone1.4.5} \right) = 344.6922 \text{ W}$$

Roof

$$U_{air} := 1.1765 \frac{\text{W}}{\text{m}^2 \text{ K}}$$

$$U_{wall} := 0.1267 \frac{\text{W}}{\text{m}^2 \text{ K}}$$

$$q_{air} := U_{air} \cdot (91 \text{ ft} \cdot 23 \text{ ft}) \cdot \left(T_{out} - T_{zone1.4.5} \right) = 915.0632 \text{ W}$$

$$q_{wall} := U_{wall} \cdot (91 \text{ ft} \cdot 23 \text{ ft}) \cdot \left(T_{out} - T_{zone1.4.5} \right) = 98.5453 \text{ W}$$

$$q_{roof} := q_{air} + q_{wall} = 1013.608 \text{ W}$$

Total

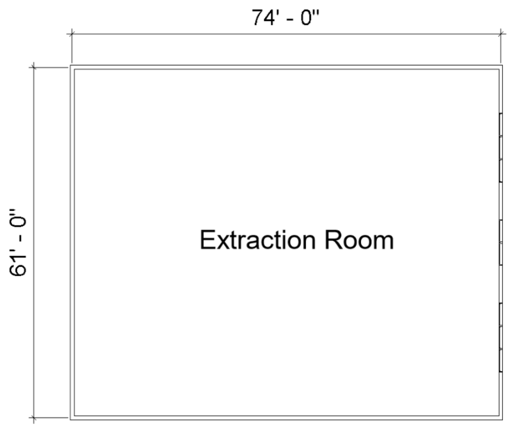
$$q_{total} := q_{north} + q_{east} + q_{west} + q_{ground} + q_{roof} = 5179.8675 \text{ W}$$

$$q_{total} := 5.179 \text{ kW}$$

Zones 2+ 3

These two zones must be maintained at a constant 30°C, which is greater than the cooling dry bulb temperature of 24°. Thus, a cooling load calculation is not required for these two zones, as the heating load is significantly higher. We will select the furnace and ducts for these two zones based on the heating load.

Zone 4



East

$$U_{air} := 1.1765 \frac{\mathrm{W}}{\mathrm{m}^2 \mathrm{K}}$$

$$U_{wall} := 0.1267 \frac{\mathrm{W}}{\mathrm{m}^2 \mathrm{K}}$$

$$U_{window} := 0.3003 \frac{\mathrm{W}}{\mathrm{m}^2 \mathrm{K}}$$

$$U_{door} := 2.7322 \frac{\mathrm{W}}{\mathrm{m}^2 \mathrm{K}}$$

$$q_{air} := U_{air} \cdot (61\ \mathrm{ft} \cdot 19\ \mathrm{ft}) \cdot \left(T_{out} - T_{zone1.4.5}\right) = 506.7168\ \mathrm{W}$$

$$q_{wall} := U_{wall} \cdot \left(1081.2\ \mathrm{ft}^2\right) \cdot \left(T_{out} - T_{zone1.4.5}\right) = 50.9064\ \mathrm{W}$$

$$q_{window} := U_{window} \cdot 13.3\ \mathrm{ft}^2 \cdot 3 \cdot \left(T_{out} - T_{zone1.4.5}\right) + 13.3\ \mathrm{ft}^2 \cdot 3 \cdot 605.5 \frac{\mathrm{W}}{\mathrm{m}^2} \cdot 0.34 + = 1281.3078\ \mathrm{W}$$
$$+ 13.3\ \mathrm{ft}^2 \cdot 3 \cdot \left(90.64 \frac{\mathrm{W}}{\mathrm{m}^2} + 47.95 \frac{\mathrm{W}}{\mathrm{m}^2}\right)$$

$$q_{door} := U_{door} \cdot (6.7\ \mathrm{ft} \cdot 2.83\ \mathrm{ft} \cdot 2) \cdot \left(T_{out} - T_{zone1.4.5}\right) = 38.5029\ \mathrm{W}$$

$$q_{east} := q_{air} + q_{wall} + q_{window} + q_{door} = 1877.434\ \mathrm{W}$$

Ground

$$q_{ground} := F_p \cdot P \cdot \left(T_{out} - T_{in}\right)$$

$$q_{ground} := 1.24 \ \frac{\text{W}}{\text{m K}} \cdot \left(2 \cdot 74 \ \text{ft} + 2 \cdot 61 \ \text{ft}\right) \cdot \left(T_{out} - T_{zone1.4.5}\right) = 408.1882 \ \text{W}$$

Roof

$$U_{air} := 1.1765 \ \frac{\text{W}}{\text{m}^2 \ \text{K}}$$

$$U_{wall} := 0.1267 \ \frac{\text{W}}{\text{m}^2 \ \text{K}}$$

$$q_{air} := U_{air} \cdot \left(74 \ \text{ft} \cdot 61 \ \text{ft}\right) \cdot \left(T_{out} - T_{zone1.4.5}\right) = 1973.5285 \ \text{W}$$

$$q_{wall} := U_{wall} \cdot \left(74 \ \text{ft} \cdot 61 \ \text{ft}\right) \cdot \left(T_{out} - T_{zone1.4.5}\right) = 212.5338 \ \text{W}$$

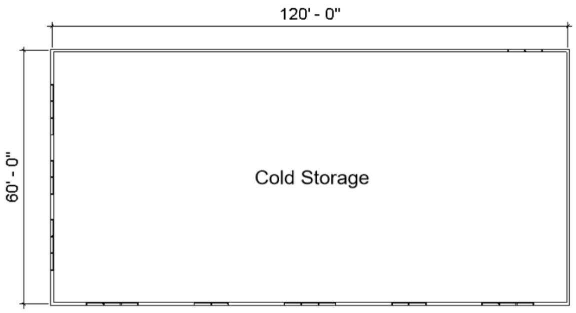
$$q_{roof} := q_{air} + q_{wall} = 2186.062 \ \text{W}$$

Total

$$q_{total} := q_{east} + q_{ground} + q_{roof} = 4471.6844 \ \text{W}$$

$$q_{total} := 4.5 \ \text{kW}$$

Zone 5



North

$$U_{air} := 1.1765 \frac{W}{m^2 K}$$

$$U_{wall} := 0.1267 \frac{W}{m^2 K}$$

$$U_{window} := 0.3003 \frac{W}{m^2 K}$$

$$q_{air} := U_{air} \cdot (23\ ft \cdot 19\ ft) \cdot \left(T_{out} - T_{zone1.4.5}\right) = 191.0571\ W$$

$$q_{wall} := U_{wall} \cdot \left(423.7\ ft^2\right) \cdot \left(T_{out} - T_{zone1.4.5}\right) = 19.9492\ W$$

$$q_{window} := U_{window} \cdot 13.3\ ft^2 \cdot \left(T_{out} - T_{zone1.4.5}\right) + 13.3\ ft^2 \cdot 605.5 \frac{W}{m^2} \cdot 0.34 + = 427.1026\ W$$
$$+ 13.3\ ft^2 \cdot \left(90.64 \frac{W}{m^2} + 47.95 \frac{W}{m^2}\right)$$

$$q_{north} := q_{air} + q_{wall} + q_{window} = 638.109\ W$$

East

$$U_{air} := 1.1765 \frac{W}{m^2 K}$$

$$U_{wall} := 0.1267 \frac{W}{m^2 K}$$

$$U_{window} := 0.3003 \frac{W}{m^2 K}$$

$$U_{door} := 2.7322 \frac{W}{m^2 K}$$

$$U_{overhead} := 0.77 \frac{W}{m^2 K}$$

$$q_{air} := U_{air} \cdot (60\ ft \cdot 19\ ft) \cdot (T_{out} - T_{zone1.4.5}) = 498.4099\ W$$

$$q_{wall} := U_{wall} \cdot (1035.7\ ft^2) \cdot (T_{out} - T_{zone1.4.5}) = 48.7641\ W$$

$$q_{window} := U_{window} \cdot 13.3\ ft^2 \cdot (T_{out} - T_{zone1.4.5}) + 13.3\ ft^2 \cdot 605.5 \frac{W}{m^2} \cdot 0.34 + = 427.1026\ W$$
$$+ 13.3\ ft^2 \cdot \left(90.64 \frac{W}{m^2} + 47.95 \frac{W}{m^2}\right)$$

$$q_{door} := U_{door} \cdot (6.7\ ft \cdot 2.83\ ft) \cdot (T_{out} - T_{zone1.4.5}) = 19.2515\ W$$

$$q_{overhead} := U_{overhead} \cdot (8\ ft \cdot 9\ ft) \cdot (T_{out} - T_{zone1.4.5}) = 20.6022\ W$$

$$q_{east} := q_{air} + q_{wall} + q_{window} + q_{door} + q_{overhead} = 1014.13\ W$$

South

$$U_{air} := 1.1765 \frac{W}{m^2 K}$$

$$U_{wall} := 0.1267 \frac{W}{m^2 K}$$

$$U_{window} := 0.3003 \frac{W}{m^2 K}$$

$$q_{air} := U_{air} \cdot (120\ ft \cdot 19\ ft) \cdot (T_{out} - T_{zone1.4.5}) = 996.8199\ W$$

$$q_{wall} := U_{wall} \cdot (2213.5\ ft^2) \cdot (T_{out} - T_{zone1.4.5}) = 104.2188\ W$$

$$q_{window} := U_{window} \cdot 13.3\ ft^2 \cdot 5 \cdot (T_{out} - T_{zone1.4.5}) + 13.3\ ft^2 \cdot 5 \cdot 605.5 \frac{W}{m^2} \cdot 0.34 + = 2135.5129\ W$$
$$+ 13.3\ ft^2 \cdot 5 \cdot \left(90.64 \frac{W}{m^2} + 47.95 \frac{W}{m^2}\right)$$

$$q_{south} := q_{air} + q_{wall} + q_{window} = 3236.552\ W$$

West

$U_{air} := 1.1765 \frac{W}{m^2 K}$

$U_{wall} := 0.1267 \frac{W}{m^2 K}$

$U_{window} := 0.3003 \frac{W}{m^2 K}$

$U_{door} := 2.7322 \frac{W}{m^2 K}$

$q_{air} := U_{air} \cdot (60\ ft \cdot 19\ ft) \cdot (T_{out} - T_{zone1.4.5}) = 498.4099\ W$

$q_{wall} := U_{wall} \cdot (1094.5\ ft^2) \cdot (T_{out} - T_{zone1.4.5}) = 51.5326\ W$

$$q_{window} := U_{window} \cdot 13.3\ ft^2 \cdot 2 \cdot (T_{out} - T_{zone1.4.5}) + 13.3\ ft^2 \cdot 2 \cdot 605.5 \frac{W}{m^2} \cdot 0.34 + = 854.2052\ W$$
$$+ 13.3\ ft^2 \cdot 2 \cdot \left(90.64 \frac{W}{m^2} + 47.95 \frac{W}{m^2}\right)$$

$q_{door} := U_{door} \cdot (6.7\ ft \cdot 2.83\ ft) \cdot (T_{out} - T_{zone1.4.5}) = 19.2515\ W$

$q_{west} := q_{air} + q_{wall} + q_{window} + q_{door} = 1423.399\ W$

Ground

$q_{ground} := F_p \cdot P \cdot (T_{in} - T_{out})$

$q_{ground} := 1.24 \frac{W}{m\ K} \cdot (2 \cdot 120\ ft + 2 \cdot 60\ ft) \cdot (T_{out} - T_{zone1.4.5}) = 544.2509\ W$

Roof

$U_{air} := 1.1765 \frac{W}{m^2 K}$

$U_{wall} := 0.1267 \frac{W}{m^2 K}$

$q_{air} := U_{air} \cdot (60\ ft \cdot 120\ ft) \cdot (T_{out} - T_{zone1.4.5}) = 3147.8523\ W$

$q_{wall} := U_{wall} \cdot (60\ ft \cdot 120\ ft) \cdot (T_{out} - T_{zone1.4.5}) = 338.9995\ W$

$q_{roof} := q_{air} + q_{wall} = 3486.852\ W$

Total

$q_{total} := q_{north} + q_{east} + q_{south} + q_{west} + q_{ground} + q_{roof} = 10343.2927\ W$

$q_{total} := 10.34\ kW$

Internal Heat Gain

Occupants:

$q_s := q_{s.per} \cdot N$

$q_l := q_{l.per} \cdot N$

where:

q_s is the occupant sensible heat gain (W)

q_l is the occupant latent heat gain (W)

$q_{s.per}$ is the sensible heat gain per person $\frac{(W)}{person}$

$q_{l.per}$ is the latent heat gain per person $\frac{(W)}{person}$

N is the number of occupants

Lighting:

$q_{el} := W \cdot F_{ul} \cdot F_{sa}$

where:

q_{el} is the heat gain from lights (W)

W is the total light wattage (W)

F_{ul} is the lighting use factor

F_{sa} is the lighting special allowance factor

Ventilation and Infiltration Air Heat Gain

(Variables were defined previously in the heating load calculations)

$q_t := q_s + q_l$

Internal Heat Gain

Occupants

For conservative approach, assume that there is a maximum of 8 people in one zone at one time. Sensible and latent heat per person is from Table 1, Chapter 18 of ASHRAE Handbook- Fundamentals. Degree of activity used was heavy lifting. This remains the same throughout all zones.

$N := 8$

$q_{s.per} := 185\ \mathrm{W}$

$q_{l.per} := 285\ \mathrm{W}$

$q_s := q_{s.per} \cdot N = 1480\ \mathrm{W}$

$q_l := q_{l.per} \cdot N = 2280\ \mathrm{W}$

Lighting

For commercial applications such as stores,offices and warehouses, the use factor is generally 1.0. For LED lights, the special allowance factor is 1.0. According to ASHRAE Standard 90.1 states that there needs to be a minimum of 1.7 watts/sqft for a manufacturing facility. To make sure we have adequate lighting, we will use 1.8watt/sqft

$F_{ul} := 1$

$F_{sa} := 1$

Zone 1

$$q_{el} := 1.8\ \frac{\mathrm{W}}{\mathrm{ft}^2} \cdot (23\ \mathrm{ft} \cdot 91\ \mathrm{ft}) \cdot F_{ul} \cdot F_{sa} = 3767.4\ \mathrm{W}$$

Zone 2

$$q_{el} := 1.8\ \frac{\mathrm{W}}{\mathrm{ft}^2} \cdot (74\ \mathrm{ft} \cdot 30\ \mathrm{ft}) \cdot F_{ul} \cdot F_{sa} = 3996\ \mathrm{W}$$

Zone 3

$$q_{el} := 1.8\ \frac{\mathrm{W}}{\mathrm{ft}^2} \cdot (23\ \mathrm{ft} \cdot 30\ \mathrm{ft}) \cdot F_{ul} \cdot F_{sa} = 1242\ \mathrm{W}$$

Zone 4

$$q_{el} := 1.8\ \frac{\mathrm{W}}{\mathrm{ft}^2} \cdot (74\ \mathrm{ft} \cdot 61\ \mathrm{ft}) = 8125.2\ \mathrm{W}$$

Zone 5

$$q_{el} := 1.8\ \frac{\mathrm{W}}{\mathrm{ft}^2} \cdot (120\ \mathrm{ft} \cdot 60\ \mathrm{ft}) \cdot F_{ul} \cdot F_{sa} = 12960\ \mathrm{W}$$

Ventilation and Infiltration Air Heat Gain

Using the ventilation values and heat factors calculated in the air exchange rate and heating load calculations:

Zone 1

$$q_s := 1.1355 \, \frac{\mathrm{W}}{\mathrm{m}^3 \, \mathrm{s} \, \mathrm{K}} \, 1.5805 \, \frac{\mathrm{m}^3}{\mathrm{s}} \cdot \left(T_{out} - T_{zone1.4.5} \right)$$

$$q_s := 7.12 \, \mathrm{W}$$

$$q_l := 2778.7972 \, \frac{\mathrm{W}}{\mathrm{m}^3 \, \mathrm{s}} \, 1.5805 \, \frac{\mathrm{m}^3}{\mathrm{s}} \cdot \left(W_{out} - W_{zone1.4.5} \right)$$

$$q_l := 14.49 \, \mathrm{W}$$

$$q_t := q_s + q_l = 21.61 \, \mathrm{W}$$

Zone 2

$$q_s := 1.1355 \, \frac{\mathrm{W}}{\mathrm{m}^3 \, \mathrm{s} \, \mathrm{K}} \, 3.3527 \, \frac{\mathrm{m}^3}{\mathrm{s}} \cdot \left(T_{zone2.3} - T_{out} \right)$$

$$q_s := 22.84 \, \mathrm{W}$$

$$q_l := 2778.7972 \, \frac{\mathrm{W}}{\mathrm{m}^3 \, \mathrm{s}} \, 3.3527 \, \frac{\mathrm{m}^3}{\mathrm{s}} \cdot \left(W_{out} - W_{zone2.3} \right)$$

$$q_l := 21.43 \, \mathrm{W}$$

$$q_t := q_s + q_l = 44.27 \, \mathrm{W}$$

Zone 3

$$q_s := 1.1355 \, \frac{\mathrm{W}}{\mathrm{m}^3 \, \mathrm{s} \, \mathrm{K}} \, 0.521 \, \frac{\mathrm{m}^3}{\mathrm{s}} \cdot \left(T_{zone2.3} - T_{out} \right)$$

$$q_s := 3.55 \, \mathrm{W}$$

$$q_l := 2778.7972 \, \frac{\mathrm{W}}{\mathrm{m}^3 \, \mathrm{s}} \, 0.521 \, \frac{\mathrm{m}^3}{\mathrm{s}} \cdot \left(W_{out} - W_{zone2.3} \right)$$

$$q_l := 3.33 \, \mathrm{W}$$

$$q_t := q_s + q_l = 6.88 \, \mathrm{W}$$

Zone 4

$$q_s := 1.1355 \, \frac{\mathrm{W}}{\mathrm{m}^3 \, \mathrm{s} \, \mathrm{K}} \, 6.8172 \, \frac{\mathrm{m}^3}{\mathrm{s}} \cdot \left(T_{out} - T_{zone1.4.5} \right)$$

$q_s := 30.96\ \mathrm{W}$

$q_l := 2778.7972\ \frac{\mathrm{W}}{\mathrm{m}^3\ \mathrm{s}}\ 6.8172\ \frac{\mathrm{m}^3}{\mathrm{s}} \cdot \left(W_{out} - W_{zone1.4.5} \right)$

$q_l := 62.51\ \mathrm{W}$

$q_t := q_s + q_l = 93.47\ \mathrm{W}$

Zone 5

$q_s := 1.1355\ \frac{\mathrm{W}}{\mathrm{m}^3\ \mathrm{s}\ \mathrm{K}}\ 10.8737\ \frac{\mathrm{m}^3}{\mathrm{s}} \cdot \left(T_{out} - T_{zone1.4.5} \right)$

$q_s := 49.39\ \mathrm{W}$

$q_l := 2778.7972\ \frac{\mathrm{W}}{\mathrm{m}^3\ \mathrm{s}}\ 10.8737\ \frac{\mathrm{m}^3}{\mathrm{s}} \cdot \left(W_{out} - W_{zone1.4.5} \right)$

$q_l := 99.71\ \mathrm{W}$

$q_t := q_s + q_l = 149.1\ \mathrm{W}$

Total Cooling Load

Zone	External Cooling Load (W)	Occupant Cooling Load (W)	Lighting Cooling Load (W)	Infiltration Cooling Load (W)	Total Cooling Load per Zone (W)	Total Heat Load per Zone with 10% Safety Factor (W)
1	5,180	3,760	3,767	21	12,728	14,001
2	-	3,760	3,996	44	7,800	8,580
3	-	3,760	1,242	7	5,009	5,510
4	4,472	3,760	8,125	93	16,450	18,095
5	10,343	3,760	12,960	149	27,212	29,933
TOTAL Cooling Load of Entire Building					**69,199**	**76,119**

The total cooling load is significantly less than the heating load (approximately 1/3 of the total heating load). The assumption while calculating zone 1 gains were valid.

Appendix B3: HVAC Calculations

HVAC Design Calculations

By: Sai Avuthu

Date: November 21, 2019

Objective:

Size a round duct system using the equal friction method, choose material, duct lengths, and add dampers to balance system. Rooftop units (RTU) will be selected for each of the five zones as indicated in the analysis.

Solution Method: The required airflow rate was determined using three different methods. These methods are explained in further detail below. Typically, the higher value was chosen as the limiting rate and the ducts were designed for that rate. Some cases such as in Zone 1, the lower value was chosen due to ease of design and cost considerations. The heat transfer values taken from the Heat Transfer Calculations were analyzed for the coldest estimated temperature and therefore, it was more practical to choose a less conservative airflow rate. In choosing the sizing, advice was taken from industry professionals.

Assumptions/Limitations/Constraints

1. Galvanized steel to be used as duct material. Typical material used for HVAC applications.

2. Maximum duct velocity to be 1200fpm in Zone 1 which contains the break room, entrance, storage room, washroom, electrical room, and the hallway. This limit is set to reduce noise from the ductwork and provide a quiet, relaxing place for the employees.

3. Maximum duct velocity to be 2200fpm elsewhere (Zones 2-5). To achieve a large amount of volumetric airflow required for these spacious rooms, a higher upper limit is placed.

4. Rooftop units have Bellmouth entrances to reduce pressure loss.

5. Target pressure drop on the order of 0.1 in.wg/100ft. (Standard)

6. Elbows are pleated to reduce pressure losses and for ease of installation.

7. All diffusers are assumed to have a pressure loss of 0.05 in. wg. (Standard)

8. High efficiency particulate air (HEPA) filter used. While this has a large pressure loss, it is vital to have from a food safety perspective.

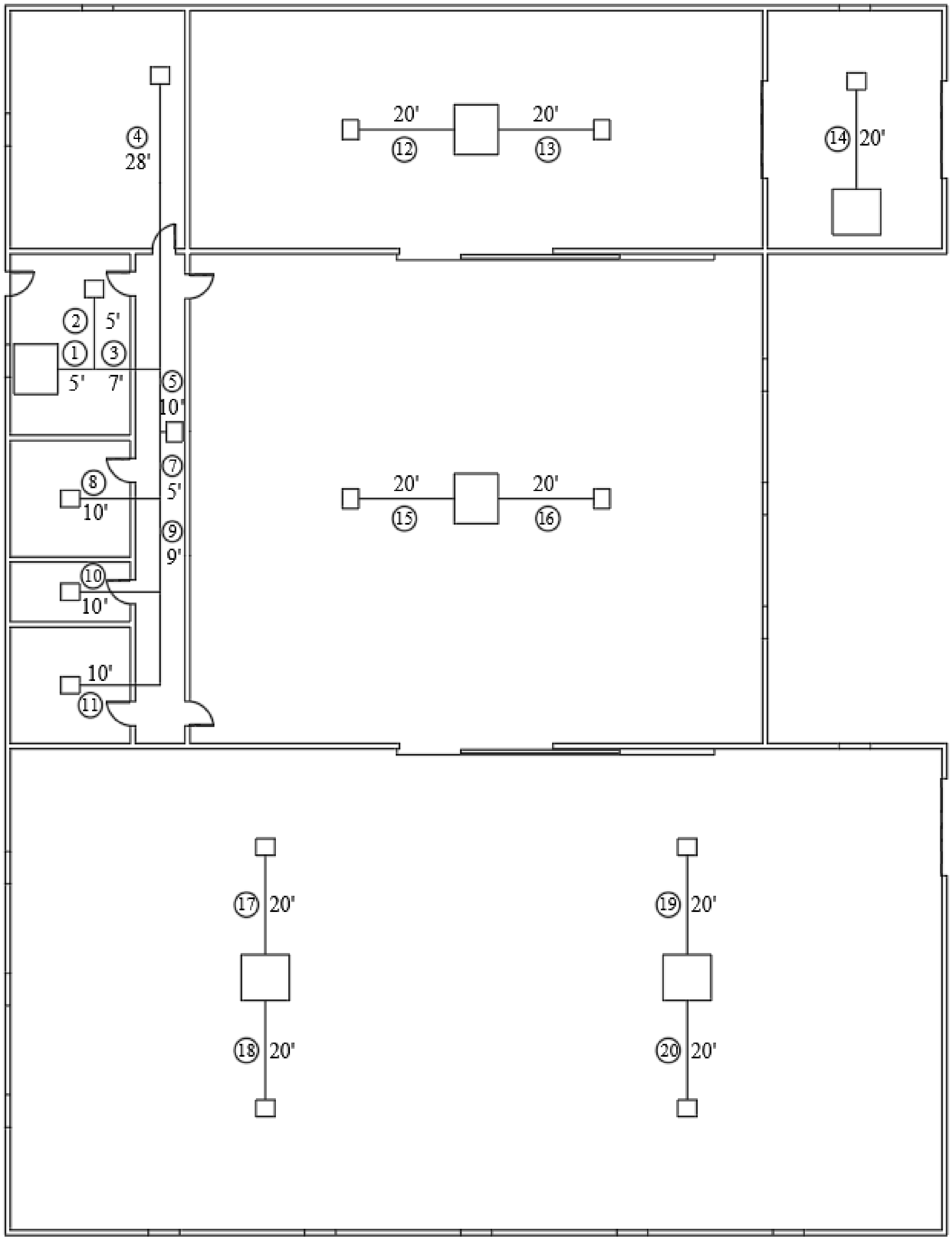
9. Heating and cooling coils assumed to have an air pressure loss of 0.35 in. wg. (Standard)

10. All heat transfer values taken from corresponding heat transfer calculations.

11. Temperature between design supply and design return air temperature assumed to be 8K.

12. For the food safe rooms (hot storage, extraction, and cold storage), an air exchange rate of 12 exchanges per hour was assumed to comply with food safety restrictions. For all other rooms, an air exchange rate of 6 exchanges per hour was assumed.

Sketch


4
28'
20'
12
20'
13
14
20'
2
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18
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20
20'

Analysis

$in\_wg := \mathrm{in\_wg}$

All zone air formulas, R_a, and R_p values taken from ANSI/ASHRAE Standard 62.1-2016

Duct sizing, pressure losses, and air velocities taken from Figure A.1 of Introduction to Thermo-Fluids Systems Design, First Edition. Andre G. McDonald and Hugh L. Magande

R_a -Outdoor airflow rate required per unit area

R_p -Outdoor airflow rate required per person

$P_z := 5$ -Maximum number of people in a room at any given time

$E_z := 0.8$ -Zone air distribution effectiveness

A_i -Zone floor area (square footage of rooms)

V_{bz} -Outdoor airflow required in the breathing zone of the occupiable spaces.

V_{oz} -Zone outdoor airflow provided to ventilation zone by supply air distribution system

$c_p := 1.026 \frac{\mathrm{kJ}}{\mathrm{kg\ K}}$ -Specific heat capacity of air

$\Delta T := 8\ \mathrm{K}$ -Temperature difference between design supply and design return air temperature

$p := 101.4\ \mathrm{kPa}$

$R := 287.1 \frac{\mathrm{J}}{\mathrm{kg\ K}}$

$T_{20} := 293\ \mathrm{K}$

$T_{30} := 303\ \mathrm{K}$

$\rho_{20} := \frac{p}{R \cdot T_{20}} = 1.2054 \frac{\mathrm{kg}}{\mathrm{m}^3}$ -Density of air at 20degC and 1 atm in Northern Alberta

$\rho_{30} := \frac{p}{R \cdot T_{30}} = 1.1656 \frac{\mathrm{kg}}{\mathrm{m}^3}$ -Density of air at 30degC and 1 atm in Northern Alberta

Q -Volume airflow rate

m -Mass airflow rate

Z -Heat loss of room

The required airflow rate based on ASHRAE Standard 62.1-2016 was calculated for each room using the equations below.

$$V_{bz} := R_p \cdot P_z + R_a \cdot A_i$$

$$V_{oz} := \frac{V_{bz}}{E_z}$$

From the heat transfer calculations, the rate of heat loss through each room was taken and using the equation below, the required airflow rate needed to sufficiently heat the room was calculated.

$$Z := mc\Delta T$$

$$Q := \frac{m}{p}$$

The required airflow rate for each room was also calculated based on the required air exchanges per hour.

Q.room = (Volume of the room)*(Number of required air exchanges per hour)

Of these three methods, the highest airflow rate was taken as the required airflow rate for each zone/room.

Ceiling Height - 16 ft

$h := 16\ \text{ft}$

RTU 1 - Administrative Wing

Break Room

$A_{br} := 23\ \text{ft} \cdot 30\ \text{ft} = 690\ \text{ft}^2$

ASHRAE Standard 62.1

$$R_{abr} := 0.06 \frac{\frac{ft^3}{min}}{ft^2} \qquad R_{pbr} := 5 \frac{ft^3}{min}$$

$$V_{bzbr} := R_{pbr} \cdot P_z + R_{abr} \cdot A_{br} = 66.4 \frac{ft^3}{min}$$

$$V_{ozbr} := \frac{V_{bzbr}}{E_z} = 83 \frac{ft^3}{min}$$

Air Exchange per Hour

$$V_{br} := A_{br} \cdot h = 11040 \ ft^3$$

$$Q_{br} := V_{br} \cdot \frac{6}{hr} \cdot \frac{(1 \ hr)}{60 \ min} = 1104 \frac{ft^3}{min}$$

Airflow rate based on 6 air exchanges per hour

Heat Loss

$$Z_{br} := 14254.08 \ W$$

$$m_{br} := \frac{Z_{br}}{c_p \cdot \Delta T} = 1.7366 \frac{kg}{s}$$

$$Q_{brx} := \frac{m_{br}}{p_{20}} = 3052.6082 \frac{ft^3}{min}$$

Entrance

$$A_{ent} := 23 \ ft \cdot 16 \ ft = 368 \ ft^2$$

ASHRAE Standard 62.1

$$R_{aent} := 0.06 \frac{\frac{ft^3}{min}}{ft^2} \qquad R_{pent} := 5 \frac{ft^3}{min}$$

$$V_{bzent} := R_{pent} \cdot P_z + R_{aent} \cdot A_{ent} = 47.08 \frac{ft^3}{min}$$

$$V_{ozent} := \frac{V_{bzent}}{E_z} = 58.85\ \frac{ft^3}{min}$$

Air Exchange per Hour

$$V_{ent} := A_{ent} \cdot h = 5888\ ft^3$$

$$Q_{ent} := V_{ent} \cdot \frac{6}{hr} \cdot \frac{(1\ hr)}{60\ min} = 588.8\ \frac{ft^3}{min}$$

Heat Loss

$$Z_{ent} := 7427.62\ W$$

$$m_{ent} := \frac{Z_{ent}}{c_p \cdot \Delta T} = 0.9049\ \frac{kg}{s}$$

$$Q_{entx} := \frac{m_{ent}}{\rho_{20}} = 1590.6753\ \frac{ft^3}{min}$$

Storage

$$A_{st} := 15\ ft \cdot 16\ ft = 240\ ft^2$$

ASHRAE Standard 62.1

$$R_{ast} := 0.06\ \frac{\frac{ft^3}{min}}{ft^2} \qquad R_{pst} := 5\ \frac{ft^3}{min}$$

$$V_{bzst} := R_{pst} \cdot P_z + R_{ast} \cdot A_{st} = 39.4\ \frac{ft^3}{min}$$

$$V_{ozst} := \frac{V_{bzst}}{E_z} = 49.25\ \frac{ft^3}{min}$$

Air Exchange per Hour

$$V_{st} := A_{st} \cdot h = 3840\ ft^3$$

$$Q_{st} := V_{st} \cdot \frac{6}{hr} \cdot \frac{(1\ hr)}{60\ min} = 384\ \frac{ft^3}{min}$$

Heat Loss

$$Z_{st} := 4934.165 \text{ W}$$

$$m_{st} := \frac{Z_{st}}{c_p \cdot \Delta T} = 0.6011 \frac{\text{kg}}{\text{s}}$$

$$Q_{stx} := \frac{m_{st}}{\rho_{20}} = 1056.685 \frac{\text{ft}^3}{\text{min}}$$

Washroom

$$A_{wr} := 8 \text{ ft} \cdot 16 \text{ ft} = 128 \text{ ft}^2$$

ASHRAE Standard 62.1

$$R_{awr} := 0.06 \frac{\frac{\text{ft}^3}{\text{min}}}{\text{ft}^2} \qquad R_{pwr} := 5 \frac{\text{ft}^3}{\text{min}}$$

$$V_{bzwr} := R_{pwr} \cdot P_z + R_{awr} \cdot A_{wr} = 32.68 \frac{\text{ft}^3}{\text{min}}$$

$$V_{ozwr} := \frac{V_{bzwr}}{E_z} = 40.85 \frac{\text{ft}^3}{\text{min}}$$

Air Exchange per Hour

$$V_{wr} := A_{wr} \cdot h = 2048 \text{ ft}^3$$

$$Q_{wr} := V_{wr} \cdot \frac{6}{\text{hr}} \cdot \frac{(1 \text{ hr})}{60 \text{ min}} = 204.8 \frac{\text{ft}^3}{\text{min}}$$

Heat Loss

$$Z_{wr} := 2950.674 \text{ W}$$

$$m_{wr} := \frac{Z_{wr}}{c_p \cdot \Delta T} = 0.3595 \frac{\text{kg}}{\text{s}}$$

$$Q_{wrx} := \frac{m_{wr}}{\rho_{20}} = 631.9069 \ \frac{ft^3}{min}$$

Electrical

$$A_{elec} := 15 \ ft \cdot 16 \ ft = 240 \ ft^2$$

ASHRAE Standard 62.1

$$R_{aelec} := 0.05 \ \frac{\frac{ft^3}{min}}{ft^2} \qquad R_{pelec} := 5 \ \frac{ft^3}{min}$$

$$V_{bzelec} := R_{pelec} \cdot P_z + R_{aelec} \cdot A_{elec} = 37 \ \frac{ft^3}{min}$$

$$V_{ozelec} := \frac{V_{bzelec}}{E_z} = 46.25 \ \frac{ft^3}{min}$$

Air Exchange per Hour

$$V_{elec} := A_{elec} \cdot h = 3840 \ ft^3$$

$$Q_{elec} := V_{elec} \cdot \frac{6}{hr} \cdot \frac{(1 \ hr)}{60 \ min} = 384 \ \frac{ft^3}{min}$$

Heat Loss

$$Z_{elec} := 4934.165 \ W$$

$$m_{elec} := \frac{Z_{elec}}{c_p \cdot \Delta T} = 0.6011 \ \frac{kg}{s}$$

$$Q_{elecx} := \frac{m_{elec}}{\rho_{20}} = 1056.685 \ \frac{ft^3}{min}$$

Hallway

$$A_{hall} := 7 \ ft \cdot (15 + 8 + 15 + 23) \ ft = 427 \ ft^2$$

ASHRAE Standard 62.1

$$R_{ahall} := 0.06 \ \frac{\frac{ft^3}{min}}{ft^2}$$

$$V_{bzhall} := R_{ahall} \cdot A_{hall} = 25.62\ \frac{ft^3}{min}$$

$$V_{ozhall} := \frac{V_{bzhall}}{E_z} = 32.025\ \frac{ft^3}{min}$$

Air Exchange per Hour

$$V_{hall} := A_{hall} \cdot h = 6832\ ft^3$$

$$Q_{hall} := V_{hall} \cdot \frac{6}{hr} \cdot \frac{(1\ hr)}{60\ min} = 683.2\ \frac{ft^3}{min}$$

Heat Loss

$$Z_{hall} := 4934.165\ W$$

$$m_{hall} := \frac{Z_{hall}}{c_p \cdot \Delta T} = 0.6011\ \frac{kg}{s}$$

$$Q_{hallx} := \frac{m_{hall}}{p_{20}} = 1056.685\ \frac{ft^3}{min}$$

RTU 1 Total

$$Q_{RTU1} := Q_{br} + Q_{ent} + Q_{st} + Q_{wr} + Q_{elec} + Q_{hall} = 3348.8\ \frac{ft^3}{min}$$

$\boxed{\text{RTU 2 - Hot Storage}}$

$$A_{hs} := 30\ ft \cdot 74\ ft = 2220\ ft^2$$

ASHRAE Standard 62.1

$$R_{ahs} := 0.06\ \frac{\frac{ft^3}{min}}{ft^2} \qquad R_{phs} := 10\ \frac{ft^3}{min}$$

$$V_{bzhs} := R_{phs} \cdot P_z + R_{ahs} \cdot A_{hs} = 183.2\ \frac{ft^3}{min}$$

$$V_{ozhs} := \frac{V_{bzhs}}{E_z} = 229\ \frac{ft^3}{min}$$

Air Exchange per Hour

$V_{hs} := A_{hs} \cdot 16\ ft = 35520\ ft^3$

$Q_{hs} := V_{hs} \cdot \frac{12}{hr} \cdot \frac{(1\ hr)}{60\ min} = 7104\ \frac{ft^3}{min}$ Airflow rate based on 12 exchanges per hour.

Heat Loss

$Z_{hs} := 27237.1\ W$

$m_{hs} := \frac{Z_{hs}}{c_p \cdot \Delta T} = 3.3184\ \frac{kg}{s}$

$Q_{hsx} := \frac{m_{hs}}{p_{30}} = 6032.0891\ \frac{ft^3}{min}$

$Q_{RTU2} := Q_{hs} = 7104\ \frac{ft^3}{min}$

RTU 3 - Transition Room

$A_{tr} := 23\ ft \cdot 30\ ft = 690\ ft^2$

ASHRAE Standard 62.1

$R_{atr} := 0.06\ \frac{\frac{ft^3}{min}}{ft^2}$ $R_{ptr} := 5\ \frac{ft^3}{min}$

$V_{bztr} := R_{ptr} \cdot P_z + R_{atr} \cdot A_{tr} = 66.4\ \frac{ft^3}{min}$

$V_{oztr} := \frac{V_{bztr}}{E_z} = 83\ \frac{ft^3}{min}$

Air Exchange per Hour

$V_{tr} := A_{tr} \cdot h = 11040\ ft^3$

$$Q_{tr} := V_{tr} \cdot \frac{6}{hr} \cdot \frac{(1\ hr)}{60\ min} = 1104\ \frac{ft^3}{min}$$

Heat Loss

$$Z_{tr} := 16039.1\ W$$

$$m_{tr} := \frac{Z_{tr}}{c_p \cdot \Delta T} = 1.9541\ \frac{kg}{s}$$

$$Q_{trx} := \frac{m_{tr}}{p_{30}} = 3552.1138\ \frac{ft^3}{min}$$

$$Q_{RTU3} := Q_{tr} = 1104\ \frac{ft^3}{min}$$

RTU 4 - Extraction

$$A_{ext} := 61\ ft \cdot 74\ ft = 4514\ ft^2$$

ASHRAE Standard 62.1

$$R_{aext} := 0.12\ \frac{\frac{ft^3}{min}}{ft^2} \qquad R_{pext} := 7.5\ \frac{ft^3}{min}$$

$$V_{bzext} := R_{pext} \cdot P_z + R_{aext} \cdot A_{ext} = 579.18\ \frac{ft^3}{min}$$

$$V_{ozext} := \frac{V_{bzext}}{E_z} = 723.975\ \frac{ft^3}{min}$$

Air Exchange per Hour

$$V_{ext} := A_{ext} \cdot h = 72224\ ft^3$$

$$Q_{ext} := V_{ext} \cdot \frac{12}{hr} \cdot \frac{(1\ hr)}{60\ min} = 14444.8\ \frac{ft^3}{min}$$

Heat Loss

$Z_{ext} := 42149.8\ \mathrm{W}$

$$m_{ext} := \frac{Z_{ext}}{c_p \cdot \Delta T} = 5.1352\ \frac{\mathrm{kg}}{\mathrm{s}}$$

$$Q_{extx} := \frac{m_{ext}}{p_{20}} = 9026.6664\ \frac{\mathrm{ft}^3}{\mathrm{min}}$$

$$Q_{RTU4} := Q_{ext} = 14444.8\ \frac{\mathrm{ft}^3}{\mathrm{min}}$$

RTU 5 & 6 - Cold Storage

$A_{cs} := 60\ \mathrm{ft} \cdot 120\ \mathrm{ft} = 7200\ \mathrm{ft}^2$

ASHRAE Standard 62.1

$$R_{acs} := 0.06\ \frac{\frac{\mathrm{ft}^3}{\mathrm{min}}}{\mathrm{ft}^2} \qquad R_{pcs} := 10\ \frac{\mathrm{ft}^3}{\mathrm{min}}$$

$$V_{bzcs} := R_{pcs} \cdot P_z + R_{acs} \cdot A_{cs} = 482\ \frac{\mathrm{ft}^3}{\mathrm{min}}$$

$$V_{ozcs} := \frac{V_{bzcs}}{E_z} = 602.5\ \frac{\mathrm{ft}^3}{\mathrm{min}}$$

Air Exchange per Hour

$V_{cs} := A_{cs} \cdot h = 1.152 \cdot 10^5\ \mathrm{ft}^3$

$$Q_{cs} := V_{cs} \cdot \frac{12}{\mathrm{hr}} \cdot \frac{(1\ \mathrm{hr})}{60\ \mathrm{min}} = 23040\ \frac{\mathrm{ft}^3}{\mathrm{min}}$$

Heat Loss

$Z_{cs} := 85699.9\ \mathrm{W}$

$$m_{cs} := \frac{Z_{cs}}{c_p \cdot \Delta T} = 10.441\ \frac{\mathrm{kg}}{\mathrm{s}}$$

$$Q_{csx} := \frac{m_{cs}}{p_{20}} = 18353.2165\ \frac{\mathrm{ft}^3}{\mathrm{min}}$$

$Q_{RTU5} := \dfrac{Q_{cs}}{2} = 11520\ \dfrac{ft^3}{min}$ $\qquad Q_{RTU6} := Q_{RTU5} = 11520\ \dfrac{ft^3}{min}$

Equivalent lengths of all fittings used in analysis:

All lengths taken from Figure A.1 of Introduction to Thermo-Fluids Systems Design, First Edition. Andre G. McDonald and Hugh L. Magande

Entrances Loss Equivalent Lengths

$L_{entrance10} := \left(\dfrac{10\ in}{12\ \dfrac{in}{ft}}\right) \cdot 30 = 25\ ft$ $\qquad L_{entrance14} := \left(\dfrac{14\ in}{12\ \dfrac{in}{ft}}\right) \cdot 30 = 35\ ft$

$L_{entrance22} := \left(\dfrac{22\ in}{12\ \dfrac{in}{ft}}\right) \cdot 30 = 55\ ft$ $\qquad L_{entrance24} := \left(\dfrac{24\ in}{12\ \dfrac{in}{ft}}\right) \cdot 30 = 60\ ft$

$L_{entrance26} := \left(\dfrac{26\ in}{12\ \dfrac{in}{ft}}\right) \cdot 30 = 65\ ft$ $\qquad L_{entrance27} := \left(\dfrac{27\ in}{12\ \dfrac{in}{ft}}\right) \cdot 30 = 67.5\ ft$

$L_{entrance28} := \left(\dfrac{28\ in}{12\ \dfrac{in}{ft}}\right) \cdot 30 = 70\ ft$ $\qquad L_{entrance30} := \left(\dfrac{30\ in}{12\ \dfrac{in}{ft}}\right) \cdot 30 = 75\ ft$

$L_{entrance34} := \left(\dfrac{34\ in}{12\ \dfrac{in}{ft}}\right) \cdot 30 = 85\ ft$ $\qquad L_{entrance40} := \left(\dfrac{40\ in}{12\ \dfrac{in}{ft}}\right) \cdot 30 = 100\ ft$

Tee Fittings

$L_{teebranch4} := \left(\dfrac{4\ in}{12\ \dfrac{in}{ft}}\right) \cdot 40 = 13.3333\ ft$ $\qquad L_{teethru5} := \left(\dfrac{5\ in}{12\ \dfrac{in}{ft}}\right) \cdot 8 = 3.3333\ ft$

$L_{teebranch5} := \left(\dfrac{5\ in}{12\ \dfrac{in}{ft}}\right) \cdot 40 = 16.6667\ ft$ $\qquad L_{teethru6} := 4\ ft$

$L_{teethru8} := 5\ ft$

$L_{teebranch6} := 20\ ft$

$L_{teebranch8} := 27\ ft$ $\qquad L_{teethru9} := 6\ ft$

$L_{teebranch10} := 33\ ft$ $\qquad L_{teethru10} := 7\ ft$

$L_{teebranch12} := 40\ ft$ $\qquad L_{teethru12} := 8\ ft$

$$L_{teebranch14} := \left(\frac{14\ \text{in}}{12\ \frac{\text{in}}{\text{ft}}}\right) \cdot 40 = 46.6667\ \text{ft}$$

$$L_{teethru14} := \left(\frac{14\ \text{in}}{12\ \frac{\text{in}}{\text{ft}}}\right) \cdot 8 = 9.3333\ \text{ft}$$

$$L_{teebranch16} := \left(\frac{16\ \text{in}}{12\ \frac{\text{in}}{\text{ft}}}\right) \cdot 40 = 53.3333\ \text{ft}$$

$$L_{teethru16} := \left(\frac{16\ \text{in}}{12\ \frac{\text{in}}{\text{ft}}}\right) \cdot 8 = 10.6667\ \text{ft}$$

$$L_{teebranch18} := \left(\frac{18\ \text{in}}{12\ \frac{\text{in}}{\text{ft}}}\right) \cdot 40 = 60\ \text{ft}$$

$$L_{teethru18} := \left(\frac{18\ \text{in}}{12\ \frac{\text{in}}{\text{ft}}}\right) \cdot 8 = 12\ \text{ft}$$

$$L_{teebranch24} := \left(\frac{24\ \text{in}}{12\ \frac{\text{in}}{\text{ft}}}\right) \cdot 40 = 80\ \text{ft}$$

$$L_{teethru20} := \left(\frac{20\ \text{in}}{12\ \frac{\text{in}}{\text{ft}}}\right) \cdot 8 = 13.3333\ \text{ft}$$

$$L_{teebranch26} := \left(\frac{26\ \text{in}}{12\ \frac{\text{in}}{\text{ft}}}\right) \cdot 40 = 86.6667\ \text{ft}$$

$$L_{teethru22} := \left(\frac{22\ \text{in}}{12\ \frac{\text{in}}{\text{ft}}}\right) \cdot 8 = 14.6667\ \text{ft}$$

$$L_{teebranch28} := \left(\frac{28\ \text{in}}{12\ \frac{\text{in}}{\text{ft}}}\right) \cdot 40 = 93.3333\ \text{ft}$$

$$L_{teebranch30} := \left(\frac{30\ \text{in}}{12\ \frac{\text{in}}{\text{ft}}}\right) \cdot 40 = 100\ \text{ft}$$

Pleated Elbows

$$L_{90\_elbow\_6} := 8\ \text{ft}$$

$$L_{90\_elbow\_8} := 10\ \text{ft}$$

$$L_{90\_elbow\_10} := 13\ \text{ft}$$

$$L_{90\_elbow\_12} := 15\ \text{ft}$$

$$L_{90\_elbow\_14} := \left(\frac{14\ \text{in}}{12\ \frac{\text{in}}{\text{ft}}}\right) \cdot 15 = 17.5\ \text{ft}$$

$$L_{90\_elbow\_22} := \left(\frac{22\ \text{in}}{12\ \frac{\text{in}}{\text{ft}}}\right) \cdot 15 = 27.5\ \text{ft}$$

$$L_{90\_elbow\_24} := \left(\frac{24\ \text{in}}{12\ \frac{\text{in}}{\text{ft}}}\right) \cdot 15 = 30\ \text{ft}$$

$$L_{90\_elbow\_26} := \left(\frac{26\ \text{in}}{12\ \frac{\text{in}}{\text{ft}}}\right) \cdot 15 = 32.5\ \text{ft}$$

$$L_{90\_elbow\_28} := \left(\frac{28\ \text{in}}{12\ \frac{\text{in}}{\text{ft}}}\right) \cdot 15 = 35\ \text{ft}$$

Reducers

$$L_{reducer10} := \left(\frac{10\ \text{in}}{12\ \frac{\text{in}}{\text{ft}}}\right) \cdot 4 = 3.3333\ \text{ft}$$

$$L_{reducer14} := \left(\frac{14\ \text{in}}{12\ \frac{\text{in}}{\text{ft}}}\right) \cdot 4 = 4.6667\ \text{ft}$$

$$L_{reducer18} := \left(\frac{18\ \text{in}}{12\ \frac{\text{in}}{\text{ft}}}\right) \cdot 4 = 6\ \text{ft}$$

$$L_{90\_elbow\_30} := \left(\frac{30\ in}{12\ \frac{in}{ft}} \right) \cdot 15 = 37.5\ ft$$

Pressure Losses for each Duct Section

The pressure losses for each duct section was determined based on the total airflow rate required and the length of the ducts. A targeted pressure loss of 0.1 in.wg/100ft was used to determined duct sizing, actual pressure loss per duct length, and duct air velocity as shown on the right hand side of the page.

$P_{diff} := 0.05\ in\_wg$ — Diffuser pressure loss (standard)

$P_{RTU1\_MERV13} := 0.07\ in\_wg$ — Pressure loss for MERV 13 filter for RTU 1

$P_{RTU1\_ccoil} := 0.11\ in\_wg$ — Pressure loss for cooling coil for RTU 1

$P_{RTU1\_heat} := 0.17\ in\_wg$ — Pressure loss for heat exchanger for RTU 1

$P_{RTU1\_econ} := 0.15\ in\_wg$ — Pressure loss for economizer for RTU 1

Similarly, the pressure loss for the filter, cooling coil, heat exchanger, and economizer is given for each RTU.

$P_{RTU2\_MERV13} := 0.09\ in\_wg$

$P_{RTU2\_ccoil} := 0.06\ in\_wg$

$P_{RTU2\_heat} := 0.21\ in\_wg$

$P_{RTU2\_econ} := 0.06\ in\_wg$

$P_{RTU3\_MERV13} := 0.07\ in\_wg$

$P_{RTU3\_ccoil} := 0.04\ in\_wg$

$P_{RTU3\_heat} := 0.02\ in\_wg$

$P_{RTU3\_econ} := 0.04\ in\_wg$

$P_{RTU4} := 0.48\ in\_wg$ — This value includes the pressure loss of the filter, heating, and economizer.

$P_{RTU4\_ccoil} := 0.27\ in\_wg$

$P_{RTU5\_6} := 0.33\ in\_wg$

This value includes the pressure loss of the filter, heating, and economizer.

$P_{RTU5\_6\_ccoil} := 0.20\ in\_wg$

RTU 1 - Administrative Wing

Duct size, pressure loss, air velocity

Section 1

$L_1 := 5\ ft$

22", 0.094" wg/100ft, 1270fpm

$$Q_1 := Q_{br} + Q_{ent} + Q_{hall} + Q_{st} + Q_{wr} + Q_{elec} = 3348.8\ \frac{ft^3}{min}$$

$$P_1 := \frac{0.094 \cdot in\_wg}{100\ ft} \cdot \left(L_1 + L_{entrance22} + L_{90\_elbow\_22}\right) + P_{RTU1\_MERV13} + = 0.5822\ in\_wg$$
$$+ P_{RTU1\_ccoil} + P_{RTU1\_heat} + P_{RTU1\_econ}$$

Section 2

$L_2 := 6\ ft$

$Q_2 := Q_{ent} = 588.8\ \frac{ft^3}{min}$

12", 0.076" wg/100ft, 750fpm

$$P_2 := \frac{0.076 \cdot in\_wg}{100\ ft} \cdot \left(L_{teebranch12} + L_2 + L_{90\_elbow\_12}\right) + P_{diff} = 0.0964\ in\_wg$$

Section 3

$L_3 := 7\ ft$

$Q_3 := Q_1 - Q_2 = 2760\ \frac{ft^3}{min}$

22", 0.079" wg/100ft, 1050fpm

$$P_3 := \frac{0.079 \cdot in\_wg}{100\ ft} \cdot \left(L_{teethru22} + L_3 + L_{reducer18}\right) = 0.0219\ in\_wg$$

Section 4

$L_4 := 29\ ft$

$Q_4 := Q_{br} = 1104\ \frac{ft^3}{min}$

14", 0.12" wg/100ft, 1050fpm

$$P_4 := \frac{0.12 \cdot in\_wg}{100\ ft} \cdot \left(L_{teebranch14} + L_{reducer14} + L_2 + L_{90\_elbow\_14}\right) + P_{diff} = 0.1398\ in\_wg$$

Section 5

$L_5 := 10\ \text{ft}$ $\qquad Q_5 := Q_3 - Q_4 = 1656\ \frac{\text{ft}^3}{\text{min}}$ $\qquad$ 18", 0.069" wg/100ft, 950fpm

$$P_5 := \frac{0.069 \cdot in\_wg}{100\ \text{ft}} \cdot \left(L_{teebranch18} + L_5\right) = 0.0483\ \text{in\_wg}$$

Section 6

$L_6 := 1\ \text{ft}$ $\qquad Q_6 := Q_{hall} = 683.2\ \frac{\text{ft}^3}{\text{min}}$ $\qquad$ 12", 0.1" wg/100ft, 860fpm

$$P_6 := \frac{0.1 \cdot in\_wg}{100\ \text{ft}} \cdot \left(L_{teebranch12} + L_{90\_elbow\_12} + L_6\right) + P_{diff} = 0.106\ \text{in\_wg}$$

Section 7

$L_7 := 5\ \text{ft}$ $\qquad Q_7 := Q_5 - Q_6 = 972.8\ \frac{\text{ft}^3}{\text{min}}$ $\qquad$ 14", 0.087" wg/100ft, 900fpm

$$P_7 := \frac{0.087 \cdot in\_wg}{100\ \text{ft}} \cdot \left(L_{teethru14} + L_{reducer10} + L_7\right) = 0.0154\ \text{in\_wg}$$

Section 8

$L_8 := 11\ \text{ft}$ $\qquad Q_8 := Q_{st} = 384\ \frac{\text{ft}^3}{\text{min}}$ $\qquad$ 10", 0.082" wg/100ft, 700fpm

$$P_8 := \frac{0.082 \cdot in\_wg}{100\ \text{ft}} \cdot \left(L_{teebranch10} + L_{90\_elbow\_10} + L_8\right) + P_{diff} = 0.0967\ \text{in\_wg}$$

Section 9

$L_9 := 9\ \text{ft}$ $\qquad Q_9 := Q_7 - Q_8 = 588.8\ \frac{\text{ft}^3}{\text{min}}$ $\qquad$ 10", 0.17" wg/100ft, 1030fpm

$$P_9 := \frac{0.17 \cdot in\_wg}{100\ \text{ft}} \cdot \left(L_{teethru10} + L_9\right) = 0.0272\ \text{in\_wg}$$

Section 10

$L_{10} := 11\ \mathrm{ft}$ $\quad Q_{10} := Q_{wr} = 204.8\ \frac{\mathrm{ft}^3}{\mathrm{min}}$ $\quad$ 8", 0.08" wg/100ft, 580fpm

$$P_{10} := \frac{0.08 \cdot in\_wg}{100\ \mathrm{ft}} \cdot \left(L_{teebranch8} + L_{10} + L_{90\_elbow\_8}\right) + P_{diff} = 0.0884\ \mathrm{in\_wg}$$

Section 11

$L_{11} := 20\ \mathrm{ft}$ $\quad Q_{11} := Q_{elec} = 384\ \frac{\mathrm{ft}^3}{\mathrm{min}}$ $\quad$ 10", 0.082" wg/100ft, 700fpm

$$P_{11} := \frac{0.082 \cdot in\_wg}{100\ \mathrm{ft}} \cdot \left(L_{teethru10} + L_{11} + 2 \cdot L_{90\_elbow\_10}\right) + P_{diff} = 0.0935\ \mathrm{in\_wg}$$

Zone 1 Return Air Duct

$L_{r1} := 4\ \mathrm{ft}$ $\quad Q_{r1} := Q_{RTU1} = 3348.8\ \frac{\mathrm{ft}^3}{\mathrm{min}}$ $\quad$ 24", 0.06" wg/100ft, 1080fpm

$$P_{r1} := \frac{0.06 \cdot in\_wg}{100\ \mathrm{ft}} \cdot \left(L_{r1} + L_{entrance24}\right) = 0.0384\ \mathrm{in\_wg}$$

The pressure losses through each branch of the administrative wing is given.

$$P_{1\_2} := P_1 + P_2 = 0.6786\ \mathrm{in\_wg}$$
$$P_{1\_3\_4} := P_1 + P_3 + P_4 = 0.7439\ \mathrm{in\_wg}$$
$$P_{1\_3\_5\_6} := P_1 + P_3 + P_5 + P_6 = 0.7584\ \mathrm{in\_wg}$$
$$P_{1\_3\_5\_7\_8} := P_1 + P_3 + P_5 + P_7 + P_8 = 0.7645\ \mathrm{in\_wg}$$
$$P_{1\_3\_5\_7\_9\_10} := P_1 + P_3 + P_5 + P_7 + P_9 + P_{10} = 0.7834\ \mathrm{in\_wg}$$
$$P_{1\_3\_5\_7\_9\_11} := P_1 + P_3 + P_5 + P_7 + P_9 + P_{11} = 0.7884\ \mathrm{in\_wg}$$

Based on these values, dampers were then added to the sections below to balance the HVAC system.

Section 2

$$P_{1\_3\_5\_7\_9\_11} - P_{1\_2} = 0.1098\ \mathrm{in\_wg}$$

Section 3

$$P_{1\_3\_5\_7\_9\_11} - P_{1\_3\_4} = 0.0445\ \mathrm{in\_wg}$$

Section 5

$$P_{1\_3\_5\_7\_9\_11} - P_{1\_3\_5\_6} = 0.03\ \text{in\_wg}$$

Section 9

$$P_{1\_3\_5\_7\_9\_11} - P_{1\_3\_5\_7\_8} = 0.0239\ \text{in\_wg}$$

Section 10

$$P_{1\_3\_5\_7\_9\_11} - P_{1\_3\_5\_7\_9\_10} = 0.0051\ \text{in\_wg}$$

RTU 2 - Hot Storage

Section 12

$L_{12} := 21\ \text{ft}$ $Q_{12} := \frac{Q_{hs}}{2} = 3552\ \frac{\text{ft}^3}{\text{min}}$ 24", 0.069" wg/100ft, 1130fpm

$$P_{12} := \frac{0.069 \cdot in\_wg}{100\ \text{ft}} \cdot \left(L_{entrance27} + L_{12} + 2 \cdot L_{90\_elbow\_24}\right) + P_{diff} + P_{RTU2\_ccoil} + P_{RTU2\_MERV13} + P_{RTU2\_heat} + P_{RTU2\_econ} = 0.5725\ \text{in\_wg}$$

Section 13

$L_{13} := 21\ \text{ft}$ $Q_{13} := Q_{12} = 3552\ \frac{\text{ft}^3}{\text{min}}$ 24", 0.069" wg/100ft, 1130fpm

$$P_{13} := \frac{0.069 \cdot in\_wg}{100\ \text{ft}} \cdot \left(L_{entrance27} + L_{13} + 2 \cdot L_{90\_elbow\_24}\right) + P_{diff} + P_{RTU2\_ccoil} + P_{RTU2\_MERV13} + P_{RTU2\_heat} + P_{RTU2\_econ} = 0.5725\ \text{in\_wg}$$

Zone 2 Return Air Duct

$L_{r2} := 4\ \text{ft}$ $Q_{r2} := Q_{RTU2} = 7104\ \frac{\text{ft}^3}{\text{min}}$ 18x36", 0.13" wg/100ft, 1650fpm

27" round duct equivalent

$$P_{r2} := \frac{0.13 \cdot in\_wg}{100\ \text{ft}} \cdot \left(L_{r2} + L_{entrance27}\right) = 0.093\ \text{in\_wg}$$

RTU 3 - Transition Room

Section 14

$L_{14} := 20\ \text{ft}$ $Q_{14} := Q_{tr} = 1104\ \frac{\text{ft}^3}{\text{min}}$ 14", 0.099" wg/100ft, 950fpm

$$P_{14} := \frac{0.099 \cdot in\_wg}{100\ ft} \cdot \left(L_{entrance14} + L_{14} + 2 \cdot L_{90\_elbow\_14}\right) + P_{diff} + = 0.3091\ in\_wg$$
$$+ P_{RTU3\_ccoil} + P_{RTU3\_MERV13} + P_{RTU3\_heat} + P_{RTU3\_econ}$$

Zone 3 Return Air Duct

$L_{r3} := 4\ ft$ $Q_{r3} := Q_{RTU3} = 1104\ \frac{ft^3}{min}$ 10", 0.5" wg/100ft, 1860fpm

$$P_{r3} := \frac{0.5 \cdot in\_wg}{100\ ft} \cdot \left(L_{r3} + L_{entrance10}\right) = 0.145\ in\_wg$$

RTU 4 - Extraction

Section 15

$L_{15} := 21\ ft$ $Q_{15} := \frac{Q_{ext}}{2} = 7222.4\ \frac{ft^3}{min}$ 26", 0.17" wg/100ft, 1940fpm

$$P_{15} := \frac{0.17 \cdot in\_wg}{100\ ft} \cdot \left(L_{entrance26} + L_{15} + L_{90\_elbow\_26} + L_{teebranch26}\right) + P_{diff} + = 1.1488\ in\_wg$$
$$+ P_{RTU4} + P_{RTU4\_ccoil}$$

Section 16

$L_{16} := 21\ ft$ $Q_{16} := Q_{14} = 1104\ \frac{ft^3}{min}$ 26", 0.17" wg/100ft, 1940fpm

$$P_{16} := \frac{0.17 \cdot in\_wg}{100\ ft} \cdot \left(L_{entrance26} + L_{16} + L_{90\_elbow\_26} + L_{teebranch26}\right) + P_{diff} + = 1.1488\ in\_wg$$
$$+ P_{RTU4} + P_{RTU4\_ccoil}$$

Zone 4 Return Air Duct

$L_{r4} := 4\ ft$ $Q_{r4} := Q_{RTU4} = 14444.8\ \frac{ft^3}{min}$ 24x48", 0.073" wg/100ft, 1650fpm

40" round duct equivalent

$$P_{r4} := \frac{0.1 \cdot in\_wg}{100\ ft} \cdot \left(L_{r4} + L_{entrance40}\right) = 0.104\ in\_wg$$

RTU 5 & 6 - Cold Storage

Section 17

$L_{17} := 21\ ft$ $Q_{17} := \frac{Q_{cs}}{4} = 5760\ \frac{ft^3}{min}$ 24", 0.16" wg/100ft, 1840fpm

$$P_{17} := \frac{0.16 \cdot in\_wg}{100\ ft} \cdot \left(L_{entrance24} + L_{17} + L_{90\_elbow\_24} + L_{teebranch24}\right) + P_{diff} + P_{RTU5\_6} + P_{RTU5\_6\_ccoil} = 0.8856\ in\_wg$$

Section 18

$L_{18} := 21\ ft$ $\quad Q_{18} := Q_{17} = 5760\ \frac{ft^3}{min}$ $\quad$ 24", 0.16" wg/100ft, 1840fpm

$$P_{18} := \frac{0.16 \cdot in\_wg}{100\ ft} \cdot \left(L_{entrance24} + L_{18} + L_{90\_elbow\_24} + L_{teebranch24}\right) + P_{diff} + P_{RTU5\_6} + P_{RTU5\_6\_ccoil} = 0.8856\ in\_wg$$

Section 19

$L_{19} := 21\ ft$ $\quad Q_{19} := \frac{Q_{cs}}{4} = 5760\ \frac{ft^3}{min}$ $\quad$ 24", 0.16" wg/100ft, 1840fpm

$$P_{19} := \frac{0.16 \cdot in\_wg}{100\ ft} \cdot \left(L_{entrance24} + L_{19} + L_{90\_elbow\_24} + L_{teebranch24}\right) + P_{diff} + P_{RTU5\_6} + P_{RTU5\_6\_ccoil} = 0.8856\ in\_wg$$

Section 20

$L_{20} := 21\ ft$ $\quad Q_{20} := Q_{19} = 5760\ \frac{ft^3}{min}$ $\quad$ 24", 0.16" wg/100ft, 1840fpm

$$P_{20} := \frac{0.16 \cdot in\_wg}{100\ ft} \cdot \left(L_{entrance24} + L_{20} + L_{90\_elbow\_24} + L_{teebranch24}\right) + P_{diff} + P_{RTU5\_6} + P_{RTU5\_6\_ccoil} = 0.8856\ in\_wg$$

Zone 5 (RTU 5&6) Return Air Ducts

$L_{r5} := 4\ ft$ $\quad Q_{r5} := Q_{RTU5} = 11520\ \frac{ft^3}{min}$ $\quad$ 24x48", 0.045" wg/100ft, 1210fpm

40" round duct equivalent

$L_{r6} := 4\ ft$ $\quad Q_{r6} := Q_{RTU5} = 11520\ \frac{ft^3}{min}$

$$P_{r5} := \frac{0.045 \cdot in\_wg}{100\ ft} \cdot \left(L_{r5} + L_{entrance40}\right) = 0.0468\ in\_wg$$

$$P_{r6} := P_{r5} = 0.0468\ in\_wg$$

RTU Selection

From the pressure losses in each section and the required airflow rates for each zone, the following rooftop units were selected:

RTU 1 - Administrative Wing

Rooftop Unit Model: KGA120S4B

Total air volume: 3500 cfm

Motor Specifications: 786 rpm, 1.22 bhp

RTU 2 - Hot Storage

Rooftop Unit Model: KGA240S4B

Total air volume: 7250 cfm

Motor Specifications: 765 rpm, 3.10 bhp

RTU 3 - Transition Room

Rooftop Unit Model: LGH060U4E

Total air volume: 1431 cfm

Motor Specifications: 716 rpm, 0.36 bhp

RTU 4 - Extraction

Rooftop Unit Model: LCH600H4B

Total air volume: 15000 cfm

Motor Specifications: 735 rpm, 9.70 bhp

RTU 5 & 6 - Cold Storage

Rooftop Unit Model: LCH600H4B

Total air volume: 12000 cfm

Motor Specifications: 610 rpm, 5.15 bhp

All RTUs can be provided by Lennox Commercial.

Conclusion

The ductwork system has been designed with round ducts as this provides the least pressure loss. Rectangular ducts were only used for a few return ducts as they cost less to install for some rooftop units. The material used is galvanized steel. All pressure losses were on the order of 0.1 in_wg. The air velocity for the administrative wing was limited to be less than 1200 fpm as this is an employee dwelling area and reduced noise levels are desired. The transition room, hot storage, extraction room, and cold storage were all limited to be less than 2200 fpm as this is the industrial standard. Dampers were added in the branches at the diffusers to balance the system.

Appendix B4: Humidity Calculations

Moisture Loading For Final Concept

November 26, 2019 Jakub McNally

Hot Room Moisture Loading

Moisture Loading is the measurement of how much water must be removed from the air in order to maintain a specified humidity level in a Zone. As the Hot Room is the only Zone in which humidity control is critical, it is the only zone analyzed. We will assume that the other unit's AC systems will be enough to keep the relative humidities less than 65%, which is only important for worker comfort and not for product quality. In these calculations, two target humidity loadings in the hot room will be explored:
The first case is a target relative humidity level of 45% (adequate to maintain honey's moisture content at 18% or less), and a lower, harder-to-reach target of 30% for rapid moisture extraction from the honey. A relative humidity lower than the target humidity does not harm the product quality of the honey, and thus the humidity targets serve as an upper bounds to the humidity level of the hot room.

Methodology

The worst-case scenario will be examined for this design. This worst-case would assume that the outdoor weather would be rain (100% relative outdoor humidity), at the greatest possible outdoor temperature to ensure the maximum mass of moisture in the air. This approach would require the maximum cooling and reheat loading from the selected RTU in the design to maintain the hot room temperature at the target 30 degrees Celsius.

This methodology will rely on 6 main methods of moisture loading operating in parallel:
1: Air infiltration into the hot room from both outdoors and surrounding portions of the building. A hybrid crack-length and fixture area method will be used to determine the air infiltration, as per the 1997 ASHRAE Fundamentals Handbook.
2: Outdoor air ingestion from cycling the air through the RTU (a portion of the CFM flowing through the RTU).
3: Air infiltration from opening doors to both other areas of the building and to the outside.
4: Evapouration of water from the honey in the hot room.
5: Moisture loading from combustion heating of the room and from workers.
6: Water infiltration into the hot room from the outdoors.

Preferred Solution

The most easy to operate a solution would be to use a humidity controller directly on the RTU, and to set a target humidity and have the unit control the room's humidity. If this is not possible, the next best solution would be to use an RTU humidity controller in conjunction with multiple stand-alone dehumidifers that could be switched on by the RTU controller. A best case scenario with this method would be to use only the RTU to accomplish dehumidification during low loading (ie. not raining) and the secondary dehumidifiers during periods of high loading. If the RTU cannot support low loading or becomes a hinderance at high loading, stand-alone dehumidifiers will be the only devices used to control room humidity.

Background Information

The maximum estimated external air temp in the region is 310K. This is 5K higher than the recorded max in the last 5 years according to historical data in the Government of AB.

$T_{ext} := 310\ K$ http://agriculture.alberta.ca/acis/alberta-weather-data-viewer.jsp

The average wind speed in the area, taken from historical data from the Government of AB, is:

$$V_w := 20\ \frac{km}{hr}$$

The water content of the air (absolute humidity) at various temperatures and relative humidities is as follows:

$$AH_{37100} := 43.1341\ \frac{g}{m^3} \qquad AH_{3045} := 13.5487\ \frac{g}{m^3} \qquad AH_{3030} := 9.0325\ \frac{g}{m^3}$$

The air damper on the RTU for the hot room is assumed to be set at 1% fresh air intake.

$$Damper := 0.01$$

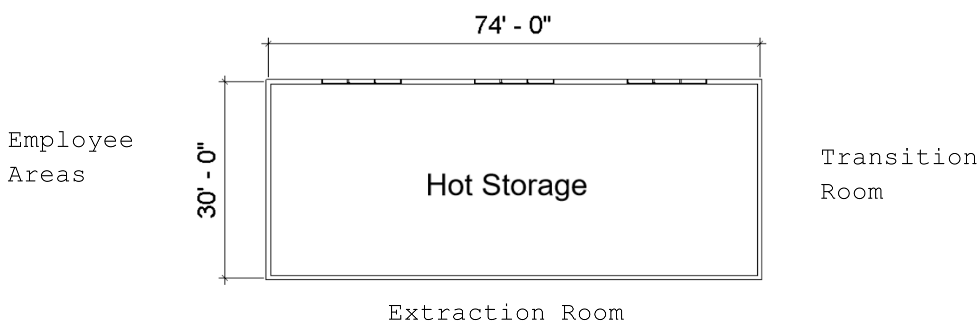
From calculations outlined in the heating, cooling, and ducting calculations, the air flow through the hot room RTU is known to be:

$$AF_{RTU} := 7104\ \frac{ft^3}{min}$$

From this, we know that the fresh air intake on the RTU is:

$$AF_{fresh} := AF_{RTU} \cdot Damper = 71.04\ \frac{ft^3}{min}$$

The design of the Hot Room and the surrounding rooms is as follows:



Note that the temperature of the Transition Room is held at 30 degrees Celsius, the Break Room is at 20 degrees Celsius, and the Processing Room is at 20 degrees Celsius. All of these areas will be air conditioned, but not humidity controlled. To determine the relative humidity of these areas during periods of high external humidity, their RTUs will be analyzed to determine the humidity drop in the inflow. The internal walls will be assumed to be 12 inch thick fiberglass insulation (double drywalled) between structural I-beams. An additional vapor barrier (Tyvek) will also be placed in this wall on the dry side below the drywall layer.

$$T_{HR} := 303\ K \qquad T_{TR} := 303\ K \qquad T_{Other} := 293\ K$$

Calculation: Air Infiltration

The known data on the air infiltration constants is given below.

Area-based:

Tyvek CommercialWrap: $ManuAI_{tyvek} := 0.01 \frac{ft^3}{min\ ft^2}$

https://www.dupont.com/content/dam/dupont/products-and-services/construction-materials/building-envelope-systems/documents/K-26060_ABAA_Commercial_Air_Barrier_Systems.pdf

Note that this value is based on various wind loadings, which cause various pressures on the Tyvek surface which drives this leakage. As Tyvek is on the interior surface, this pressure differential driving air exchange will be minimal. As such, the average pressure of the ASTM E283 test was determined to be 116 Pascals. A linear relationship of the air infiltration rate assumed, and with an assumed pressure difference of 0.03 inwg (7.5 Pa) between the rooms, the Manufacturer's rating for air infiltration was adjusted as follows:

$$AI_{tyvek} := \frac{7.47\ Pa}{116.75\ Pa} \cdot ManuAI_{tyvek} = 0.0006 \frac{ft^3}{min\ ft^2}$$

CF Flute Wall Panel (6"): $AI_{CF} := 0.0100 \frac{ft^3}{min\ ft^2}$

http://www.mbci.com/documents/astm-e-1646---1680---air-leakage---water-penetration-testing--insulated-metal-wall-panels/

$$WI_{BUR} := 0.02 \cdot \frac{g \cdot 10^{-9}}{s\ m^2\ Pa} = 2 \cdot 10^{-14} \frac{s}{m}$$

The roof is assumed to be asphalt BUR (built-up-roof), with an integral vapor barrier. This barrier's water vapor permeance is used in place of air infiltration.

The concrete floor is assumed impermeable.

Effective Area Air Leakage Area per unit or Linear Crack Length based:

Door Frame (Each): $EA_{DoorF} := 12\ cm^2$ Air leakage data taken from 1997 ASHRAE FUNDAMENTALS HANDBOOK Chapter 25, Table 3

Door Trim (per metre crack): $EA_{DT} := 1 \frac{cm^2}{m}$

Door Threshold (per metre crack): $EA_{DThre} := 2 \frac{cm^2}{m}$

Door Jamb (per metre crack): $EA_{DJ} := 8 \frac{cm^2}{m}$

Single Door, Weather Stripped (Each): $EA_{SDWS} := 12\ cm^2$ 2 to other Interal Rooms, 3 to external environment

Wiring/Pipe Penetrations, Sealed (Each): $EA_{WPS} := 6\ cm^2$ 4 Total for RTU.

External Gasketed Electrical Outlets (Each): $EA_{EOG} := 0.15\ cm^2$ Assume 1 by each external door, 1 every 20 feet in interior.

Overhead Door (8' x 9'), Model 418 w/Full weatherseals and insultion:

For the overhead doors, the length of the door components was summed to determine the air infiltration rate. For the selected size, the door will have 2 panels and 6 sections. Note that this is for the closed door.

https://www.overheaddoor.com/Documents/sectional-steel-door-systems-brochure.pdf

$$AI_{OD} := 7 \cdot EA_{DThre} \cdot 8\ \mathrm{ft} + 2 \cdot EA_{DJ} \cdot 9\ \mathrm{ft} = 78.0288\ \mathrm{cm}^2$$

Air/Moisture Infiltration Calculation:

For air infiltration through the North wall, without fixtures added in:

$$AI_{NW} := 74\ \mathrm{ft} \cdot 19\ \mathrm{ft} \cdot AI_{CF} = 14.06\ \frac{\mathrm{ft}^3}{\mathrm{min}}$$

For the South and West Walls, without Fixtures:

$$AI_{SWW} := \left(\left(74\ \mathrm{ft} + 30\ \mathrm{ft}\right) \cdot 19\ \mathrm{ft} - 8\ \mathrm{ft} \cdot 9\ \mathrm{ft}\right) \cdot AI_{tyvek} = 1.2182\ \frac{\mathrm{ft}^3}{\mathrm{min}}$$

For the East Wall:

$$AI_{EW} := \left(30\ \mathrm{ft} \cdot 19\ \mathrm{ft} - 8\ \mathrm{ft} \cdot 9\ \mathrm{ft}\right) \cdot AI_{tyvek} = 0.3186\ \frac{\mathrm{ft}^3}{\mathrm{min}}$$

For the fixtures on the external walls of the building:

The method chosen was the same method as presented in the ASHRAE FUNDAMENTALS HANDBOOK (1997), Chapter 25.

The stack coefficient of the building is as follows:

$$C_s := 0.000290 \cdot \frac{\left(\frac{\mathrm{L}}{\mathrm{s}}\right)^2}{\mathrm{cm}^4\ \mathrm{K}}$$

The Wind Coefficient is as follows (shielding class 1):

$$C_w := 0.00420 \cdot \frac{\left(\frac{\mathrm{L}}{\mathrm{s}}\right)^2}{\mathrm{cm}^4 \cdot \left(\frac{\mathrm{m}}{\mathrm{s}}\right)^2}$$

$$AI_{extfixtures} := \frac{\left(4 \cdot EA_{WPS} + 0 \cdot EA_{DoorF} + 0 \cdot EA_{SDWS} + 3 \cdot EA_{EOG}\right)}{1000} \cdot \sqrt{C_s \cdot \left(T_{ext} - T_{HR}\right) + C_w \cdot V_w^{\ 2}} = 0.0188\ \frac{\mathrm{ft}^3}{\mathrm{min}}$$

For the internal fixtures (between HR and other areas):

$$AI_{intfixtures} := \frac{\left(5 \cdot EA_{EOG} + 3 \cdot EA_{WPS} + EA_{DoorF} + EA_{SDWS} + AI_{OD}\right)}{1000} \cdot \sqrt{C_s \cdot \left(T_{HR} - T_{Other}\right)} = 0.0138\ \frac{\mathrm{ft}^3}{\mathrm{min}}$$

For the internal fixtures between the HR and the transition room:

$$AI_{TRintfixtures} := \frac{\left(2 \cdot EA_{EOG} + 2 \cdot EA_{WPS} + EA_{DoorF} + EA_{SDWS} + AI_{OD}\right)}{1000} \cdot \sqrt{C_s \cdot 1\ \mathrm{K}} = 0.0041\ \frac{\mathrm{ft}^3}{\mathrm{min}}$$

Note that the temperature delta between the rooms was assumed to be 1 degree Kelvin.

The interior humidity of the building must be determined to calculate the moisture transfer through interior walls. This can be done by determining the absolute humidity of the other rooms. We will assume that the RTU's are running in the most efficient manner in the other rooms, and this results in a discharge temperature 5 degrees lower than the room's target temperature, at 100% relative humidity. This is not an accurate estimation, but it provides a significant safety margin for further calculations.

For the transition room:

$T_{room} := 303\ \mathrm{K}$

$T_{discharge} := 298\ \mathrm{K}$

$AH_{TR} := 22.88\ \dfrac{\mathrm{g}}{\mathrm{m}^3}$

For the extraction room:

$T_{room} := 293\ \mathrm{K}$

$T_{discharge} := 288\ \mathrm{K}$

$AH_{ER} := 12.77\ \dfrac{\mathrm{g}}{\mathrm{m}^3}$

For the employee areas:

$T_{room} := 293\ \mathrm{K}$

$T_{discharge} := 288\ \mathrm{K}$

$AH_{EA} := 12.77\ \dfrac{\mathrm{g}}{\mathrm{m}^3}$

Then, by multipling the air intrusion rate by the absolute humidity change, the moisture ingress can be determined.

$$MI_{NorthWall} := \left(AI_{NW} + AI_{extfixtures}\right) \cdot \left(AH_{37100} - AH_{3045}\right) = 0.7077\ \frac{\mathrm{kg}}{\mathrm{hr}}$$

$$MI_{EastWall} := \left(AI_{EW} + AI_{TRintfixtures}\right) \cdot \left(AH_{TR} - AH_{3045}\right) = 0.0051\ \frac{\mathrm{kg}}{\mathrm{hr}}$$

$$MI_{SouthWestWalls} := \left(AI_{SWW} + AI_{intfixtures}\right) \cdot \left(AH_{ER} - AH_{3045}\right) = -0.0016\ \frac{\mathrm{kg}}{\mathrm{hr}}$$

For the roof, we multiply the permeance by the area and building gauge pressure . (0.25 inwg).

$$MI_{Roof} := WI_{BUR} \cdot (74\ \mathrm{ft} \cdot 30\ \mathrm{ft}) \cdot 62.21\ \mathrm{Pa} = 9.2379 \cdot 10^{-7}\ \frac{\mathrm{kg}}{\mathrm{hr}}$$

We then sum these moisture infiltration values to determine the total moisture infiltration in the closed building.

$$MoistureInfiltration_{45} := MI_{NorthWall} + MI_{EastWall} + MI_{SouthWestWalls} + MI_{Roof} = 0.7112\ \frac{\mathrm{kg}}{\mathrm{hr}}$$

For the lower humidity environment (30% RH), we repeat:

$$MI_{NorthWall} := \left(AI_{NW} + AI_{extfixtures}\right) \cdot \left(AH_{37100} - AH_{3030}\right) = 0.8157\ \frac{\mathrm{kg}}{\mathrm{hr}}$$

$$MI_{EastWall} := \left(AI_{EW} + AI_{TRintfixtures}\right) \cdot \left(AH_{TR} - AH_{3030}\right) = 0.0076\ \frac{\mathrm{kg}}{\mathrm{hr}}$$

$$MI_{SouthWestWalls} := \left(AI_{SWW} + AI_{intfixtures}\right) \cdot \left(AH_{ER} - AH_{3030}\right) = 0.0078\ \frac{\mathrm{kg}}{\mathrm{hr}}$$

$$MoistureInfiltration_{30} := MI_{NorthWall} + MI_{EastWall} + MI_{SouthWestWalls} + MI_{Roof} = 0.8311\ \frac{\mathrm{kg}}{\mathrm{hr}}$$

Calculation: Outdoor Air Ingestion

To calculate outdoor air ingestion, the difference in the moisture content between the outdoor air and indoor air must be compared, and multiplied by the intake rate.

$$MoistureIngestion_{45} := AF_{fresh} \cdot \left(AH_{37100} - AH_{3045}\right) = 3.5709\ \frac{kg}{hr}$$

$$MoistureIngestion_{30} := AF_{fresh} \cdot \left(AH_{37100} - AH_{3030}\right) = 4.116\ \frac{kg}{hr}$$

Calculation: Door Opening Air Infiltration

Due to the doors of the building being opened, air will flow through. For the man-doors in the hot room, the following calculations were used.

Exterior Doors:

As all exterior doors on the hot room are fire escape doors, it is assumed that they are never used in operation. As such, they are disregarded. For interior doors, the air flow is as follows (we neglect the no use infiltration rate as it was already covered in Part 1):

$$AI_{InteriorDoor} := (6.5)\ \frac{ft^3}{min}$$

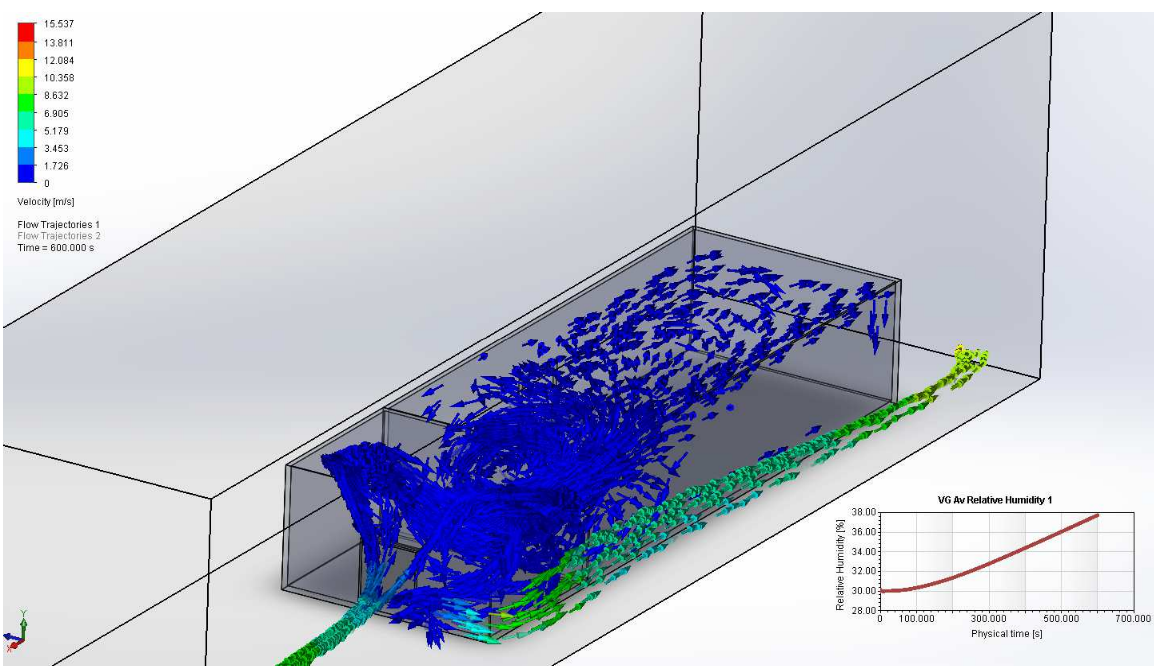
From Carrier Handbook of Air Conditioning System Design (1966), Chapter 6, Table 41

For the overhead doors, we use CFD to model the air flow through the doors.

For the trials when the room has a target humidity of 30% RH, the absolute humidity rise after 10 minutes of open door time is as follows (with a wind speed of 10 m/s):

$$AH_{10min} := 0.0119056\ \frac{kg}{m^3} = 11.9056\ \frac{g}{m^3} \qquad T_{10min} := 303.5\ K$$

$$AH_{delta} := AH_{10min} - AH_{3030} = 2.8731\ \frac{g}{m^3} \qquad RH_{10min} := 0.3770$$



We apply a safety factor of 25% to this model, and then calculate the moisture added to the room by multiplying this value by the room volume.

$$MI_{OpenDoor} := AH_{delta} \cdot 1.25 \cdot 30\ \mathrm{ft} \cdot 73\ \mathrm{ft} \cdot 19\ \mathrm{ft} = 4.2316\ \mathrm{kg}$$

To get a rate of moisture ingestion, we must assume a required time to dissipate this added moisture. Here we will assume that this time must be 20 minutes.

$$MI_{OpenDoorRate} := \frac{MI_{OpenDoor}}{0.3333\ \mathrm{hr}} = 12.696\ \frac{\mathrm{kg}}{\mathrm{hr}}$$

If an air curtain were to be used in this situation (with an assumed efficiency of 60%), the moisture transfer rate would fall by 60%, as seen below.

$$MI_{AirCurtain} := MI_{OpenDoorRate} \cdot (1 - .6) = 5.0784\ \frac{\mathrm{kg}}{\mathrm{hr}}$$

For the internal door, CFD analysis revealed a change in the absolute humidity of the hot room by the following (for an initial humidity of 30%, and 20 minutes of opening time, with a pressure differential of 0.005 inwg):

$$AH_{20min} := 9.0311\ \frac{\mathrm{g}}{\mathrm{m}^3} \qquad T_{20min} := 301\ \mathrm{K}$$

$$AH_{delta} := AH_{20min} - AH_{3030} = -0.0014\ \frac{\mathrm{g}}{\mathrm{m}^3}$$

We see a decrease in humidity in the room due to the loss of room pressure to the extraction room. Because of its low magnitude, the internal door humidity transfer will be disregarded. An air curtain would bring this value even closer to zero.

Calculation: Honey Evapouration Water

The evaporation of water from the honey is dependent on the amount of honey in the Hot room. As this can vary, it will be assumed that a maximum loading of 10000 lb will be in the room. From a study on the hygroscopic properties of honey, honey can lose up to 1% of its mass with a 50% humidity delta (55% RH is stable for honey at 18% RH). This setup can only accomplish a 25% humidity delta, and thus the evaporation rate is 0.5% per day. We will apply a safety factor of 2x in case this relationship is not linear. E. C. Martin, "The Hygroscopic Properties of Honey." Oct 1939.

$$Honey_{evap} := \frac{0.01}{\mathrm{day}} \cdot 10000\ \mathrm{lb} = 1.89\ \frac{\mathrm{kg}}{\mathrm{hr}}$$ Evaporation rate of water from honey.

Calculation: Moisture Loading from Combustion/Men

The selected RTU line, the Lennox KGA/B, has the burner circuit separated from the air circuit. Thus, no combustion products are left in the air circulated in the building and no humidity is added by combustion. Due to the low amount of time that will be spent in the Hot Room and the low amount of people - 8 at maximum - the man loading is disregarded.

Calculation: Water Infiltration

The wall insulation used (CF Flute Panels) has a water infiltration rate of zero. The BUR roof's water infiltration rate has already been accounted for in Part 1 of the calculations. Water infiltration via doors is minimized due to the vestibule (transition room), and thus disregarded.

Calculation: Overall Cooling and Heating Load for Humidity Control

To calculate the humidity loading, we must determine the humidity change when the ingested air travels over the indoor coil. For the Hot Room, we know that the unit used will be a Lennox KGA/B RTU, 13-25 tons, with humiditrol add-on. The minimum air flow in the room is 7100 CFM, as determined by the ducting calculations.

https://www.lennoxpros.com/docs/Technical/210824.pdf

A 17.5 ton unit is the minimum unit size that will meet this CFM specification, and the following calculations will be done based on it. We know the target temperature for the room and the outdoor temperature and humidity. To achieve the target room humidity, we must cool the intake air, and liquify the water in the air. The following calculations are for 45% RH.

$h_{airinlet} := 151.9\ \frac{kJ}{kg}$ $h_{airroom45} := 63.24\ \frac{kJ}{kg}$ (At 650m ASL, the height of GP)

$h_{airinletdry} := 37.18\ \frac{kJ}{kg}$ $h_{airroomdry45} := 30.14\ \frac{kJ}{kg}$

To achieve the targeted humidity, the coil must cool the air to its dew point at a low enough humidity to have the same absolute humidity as the room. We determine this temperature is 16 degrees Celsius, with an absolute humidity of:

$AH_{16100} := 13.567\ \frac{g}{m^3}$ $h_{intermediate45} := 47.22\ \frac{kJ}{kg}$ $h_{indermediatedry45} := 16.06\ \frac{kJ}{kg}$

This is the minimum air temperature of our cycle. The air will have to be reheated after to achieve the 30 degree target. Due to the high outdoor intake temperature, the unit will be able to saturate is cooling capacity of 200000 BTU/hr. Therefore, we can take the change enthalpies of the air to determine how much energy is going to have to be extracted to fulfill this, provided the unit would operate by only cooling the outdoor air (this is not how the unit works in practice).

$$MassFlow_{freshair} := AF_{fresh} \cdot 1.0528\ \frac{kg}{m^3} = 127.0706\ \frac{kg}{hr}$$

$$CoolingLoad_{Fresh} := MassFlow_{freshair} \cdot \left(h_{airinlet} - h_{intermediate45}\right) = 12607.6235\ \frac{BTU}{hr}$$

$$ReheatLoad_{Fresh} := MassFlow_{freshair} \cdot \left(h_{airroom45} - h_{intermediate45}\right) = 1929.4433\ \frac{BTU}{hr}$$

Given that there are no glaring issues with this cooling and heating load compared to the unit capacity, we continue. We then sum the other methods of air escape from the hot room.

$$VolumeFlow_{escape} := AI_{EW} + AI_{SWW} + AI_{NW} + AI_{extfixtures} + AI_{intfixtures} + AI_{TRintfixtures} = 15.6336\ \frac{ft^3}{min}$$

We can then compare this to the added air per cycle by the RTU.

$AF_{fresh} = 71.04\ \frac{ft^3}{min}$ $IntakeEscape_{ratio} := \frac{AF_{fresh}}{VolumeFlow_{escape}} = 4.5441$

We see that the RTU adds in more than 4 times more air than lost. Even with a 2x safety factor for the air lost due to infiltration, we see that the RTU will still replace it as part of its general cycle. We know that only RTU air will replace this, as the hotroom is pressurized to +0.25inwg versus atmosphere. Therefore, we disregard the infiltration air flow, and only use the fresh air flow for moisture loss calculations.

For the opening of external doors, we assume that outdoor dynamic pressure will overcome the building's internal pressure and force air in. Therefore, we directly use the overhead door's CFD result in calculations. We will continue with the air curtain rate.

$$MI_{AirCurtain} = 5.0784 \ \frac{kg}{hr}$$

Which, when multiplying by the absolute humidity of external air, gives the following infiltration rate:

$$AI_{AirCurtain} := \left(\frac{MI_{AirCurtain}}{AH_{37100}} \right) = 69.2965 \ \frac{ft^3}{min} \qquad IntakeDoor_{Ratio} := \frac{AF_{fresh}}{AI_{AirCurtain}} = 1.0252$$

Once again, we see that this air infiltration rate is approximately equal versus the RTU's intake rate. Knowing this, we can assume that the system will be able to quickly stabilize after the door opens due to the ratio between the door flow and fresh air intake. This leaves the only significant factors to humidity loading being the RTU intake, door intake, and honey evaporation.

Calculation: Moisture Addition within Room

While the air is in the room, moisture is added directly from the honey, and indirectly from the air infiltration from the overhead door. However, this infiltration air does not change the volume of the room, and cycles out some of the air in the building to replace it through the open door again (see CFD analysis). Thus, we can simply add the additional moisture caused by these two factors to determine how the room's moisture will change before being handled by the RTU.

$$MoistureAddition_{rate} := Honey_{evap} + MI_{AirCurtain} = 6.9684 \ \frac{kg}{hr}$$

Now, we can determine the rate of change in the rooms absolute humidity.

$$AH_{delta} := \frac{MoistureAddition_{rate}}{74 \ ft \cdot 30 \ ft \cdot 19 \ ft} = 0.0058 \ \frac{kg}{hr \ m^3}$$

This addition of water changes the enthalpy of the hot room air by the following rate:

$$h_{delta} := 2556.3 \ \frac{kJ}{kg} \cdot MoistureAddition_{rate} = 16883.7256 \ \frac{BTU}{hr}$$

However, this calculation is a simplification and assumes that the water can be extracted in a manner that is 100% efficient. This is not the case.

To calculate the true cooling load, we must determine the properties of the mix of air going into the coil. First, we start with the internal air's water content:

$$WaterFlowInternal_{30} := \left(AF_{RTU} - AF_{fresh} \right) \cdot AH_{3030} + MoistureAddition_{rate} = 114.8984 \ \frac{kg}{hr}$$

$$WaterFlowInternal_{45} := \left(AF_{RTU} - AF_{fresh}\right) \cdot AH_{3045} + MoistureAddition_{rate} = 168.8628\ \frac{kg}{hr}$$

$$AH_{IntakeInternal30} := \frac{WaterFlowInternal_{30}}{AF_{RTU} - AF_{fresh}} = 9.6157\ \frac{g}{m^3}$$

$$AH_{IntakeInternal45} := \frac{WaterFlowInternal_{45}}{AF_{RTU} - AF_{fresh}} = 14.1319\ \frac{g}{m^3}$$

Now, we mix this flow with the external air, with the 1% damper ratio.

$$AH_{PreCoil30} := AH_{IntakeInternal30} \cdot 0.99 + AH_{37100} \cdot 0.01 = 9.9509\ \frac{g}{m^3} \qquad h_{3030} := 52.07\ \frac{kJ}{kg}$$

$$AH_{PreCoil45} := AH_{IntakeInternal45} \cdot 0.99 + AH_{37100} \cdot 0.01 = 14.4219\ \frac{g}{m^3} \qquad h_{3045} := 63.24\ \frac{kJ}{kg}$$

$$h_{PreCoil30} := h_{airinlet} \cdot 0.01 + \left(h_{3030} + \left(AH_{IntakeInternal30} - AH_{3030}\right) \cdot 0.93\ \frac{m^3}{kg} \cdot 2556.3\ \frac{kJ}{kg}\right) \cdot .99 = 54.4408\ \frac{kJ}{kg}$$

$$h_{PreCoil45} := h_{airinlet} \cdot 0.01 + \left(h_{3045} + \left(AH_{IntakeInternal45} - AH_{3045}\right) \cdot 0.94\ \frac{m^3}{kg} \cdot 2556.3\ \frac{kJ}{kg}\right) \cdot .99 = 65.5139\ \frac{kJ}{kg}$$

$$T_{PreCoil30} := 304.05\ K \qquad Density_{30} := 1.07\ \frac{kg}{m^3}$$

$$T_{PreCoil45} := 303.97\ K \qquad Density_{45} := 1.06\ \frac{kg}{m^3}$$

Then, we determine how much this charge must be cooled. To reach our absolute humidity targets, the air must be cooled to a point where it has 100% RH and the target absolute humidity.

$$h_{intermediate30} := 29.46\ \frac{kJ}{kg}$$

$$Cooling_{Load30} := AF_{RTU} \cdot Density_{30} \cdot \left(h_{PreCoil30} - h_{intermediate30}\right) = 3.0578 \cdot 10^{5}\ \frac{BTU}{hr}$$

$$Cooling_{Load45} := AF_{RTU} \cdot Density_{45} \cdot \left(h_{PreCoil45} - h_{intermediate45}\right) = 2.2184 \cdot 10^{5}\ \frac{BTU}{hr}$$

$$Heating_{Load30} := AF_{RTU} \cdot 1.15\ \frac{kg}{m^3} \cdot \left(h_{3030} - h_{intermediate30}\right) = 2.9746 \cdot 10^{5}\ \frac{BTU}{hr}$$

$$Heating_{Load45} := AF_{RTU} \cdot 1.12\ \frac{kg}{m^3} \cdot \left(h_{3045} - h_{intermediate45}\right) = 2.0526 \cdot 10^{5}\ \frac{BTU}{hr}$$

We note that for both cooling situations, we exceed the units net cooling rating of 200000 BTU/hr. However, we note that we do not exceed the units Gas Heating Output Rating of 384000 BTU/hr for any case. As such, we will need dehumidifiers to aid the unit in dehumidifying the room. However, basic units will not offer enough tonnage to complete this. We also cannot decrease the coil flow rate without running the risk of freezing the coil.

Assumption: Coil Freezes at less than 360 CFM per Ton of Cooling.

Therefore we change the dehumidification unit to an industrial dehumidifier. We remove the humidtrol unit from the RTU, and only use it for heating and cooling load. Because we are using a stand-alone dehumidifier, we set our target to 30% RH for unit selection.

We know the amount of moisture ingestion that we expect for the entire hot room is as follows:

$$MoistureIntake_{30} := AF_{fresh} \cdot \left(AH_{37100} - AH_{3030}\right) + MoistureAddition_{rate} = 11.0844 \ \frac{kg}{hr}$$

$$MoistureIntake_{30} = 24.4368 \ \frac{lb}{hr}$$

And we select 4x DCA 1500T Dehumidifier, which will be able to extract 4x 7 lb/hr of moisture from the air at 30% RH at 30 degrees.

https://dehumidifiers.dehumidifiercorp.com/Asset/1500T-Product-Specification.pdf

We know that the net reheat of the unit is 4x 21500 BTU/hr, but we already calculated that the RTU will be able to handle the full reheat load.

Therefore our final choice for the dehumidifier is 4x DCA 1500T, with a reccomendation that any RTU chosen must be able to provide 214000 BTU/hr of heating without a humidity controller. System efficiency could be increased by setting the economizer damper to lower than 1%, with the additional note that a forced venting system with CO2 sensor would be required to maintain code. These dehumidifiers will be hung below the ceiling from the roof, with one in each corner of the hot room. The configuration used will be the horizontal inlet and bottom discharge opening on each dehumidifier.

No additional safety factor is provided due to the safety factors incorporated into the calculation of the individual moisture loadings in earlier parts. An additional, non-apparent factor of safety is the 100% RH at 37 degree outside air that is assumed, as humidity will likely be closer to 95% RH at a much lower temperature due to the evaporative cooling of rain.

Appendix B5: FEA Analysis

ANSYS Heat Transfer Analysis

To ensure the final design achieves appropriate heat transfer, ANSYS heat transfer analysis was completed on the final design floor slab when exposed to different exterior conditions.

A simple ANSYS model was created to perform FEA on the concrete floor slab of the building in order to determine the heat losses from the slab to the soil. The temperature distribution from the slab to the soil was developed, and a mesh dependency test was performed to validate the results. To simplify analysis, only the hot room and the cold room were evaluated. The hot room contains the highest temperature set point in the building, and the cold room has the largest floor area. Each of the rooms were analyzed considering winter conditions during the vacant period of the building and summer conditions during the honey production period of the building. The addition of a 2-inch insulation layer beneath the concrete slab was also considered to evaluate the effect on temperature distribution for both rooms. The Table B1 below provides a summary of the material properties and resulting elements and nodes produced for the uninsulated slab in the hot room.

Table B1: Material Properties for Hot Room Analysis of Uninsulated Slab

	Soil	Concrete	Polyurethane Foam
Density (kg/m^3)	2650	2300	192
Thermal Conductivity (W/m·K)	1.9	0.72	0.0045
Nodes	1213248	315385	127987
Elements	733603	62376	75105

In each of the operating periods, the exterior walls of the building and the boundaries of the soil edges were considered to be adiabatic. The bottom surface of the soil was set to 4°C as this is the average temperature of the soil at the frost depth of 10 feet.

Hot Room

During winter conditions, the hot room is maintained at a temperature of 16°C. The external ambient temperature was defined at -30°C. The temperature distribution through the floor slab without insulation and with insulation is illustrated in Figure B1 and B2 below, respectively.

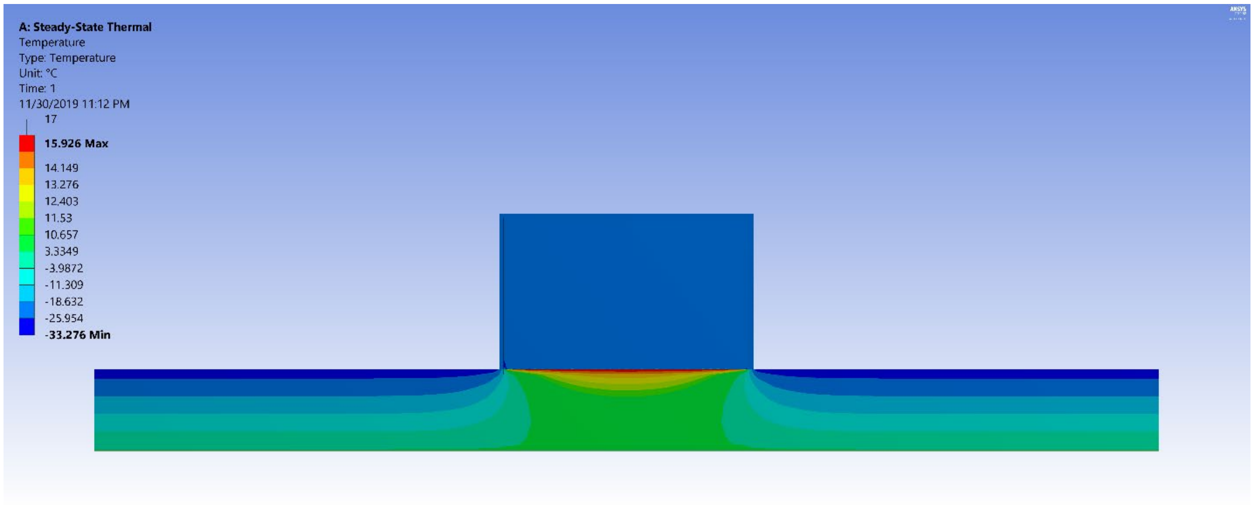


Figure B1: Hot Room Heat Loss in Winter (Uninsulated Slab)

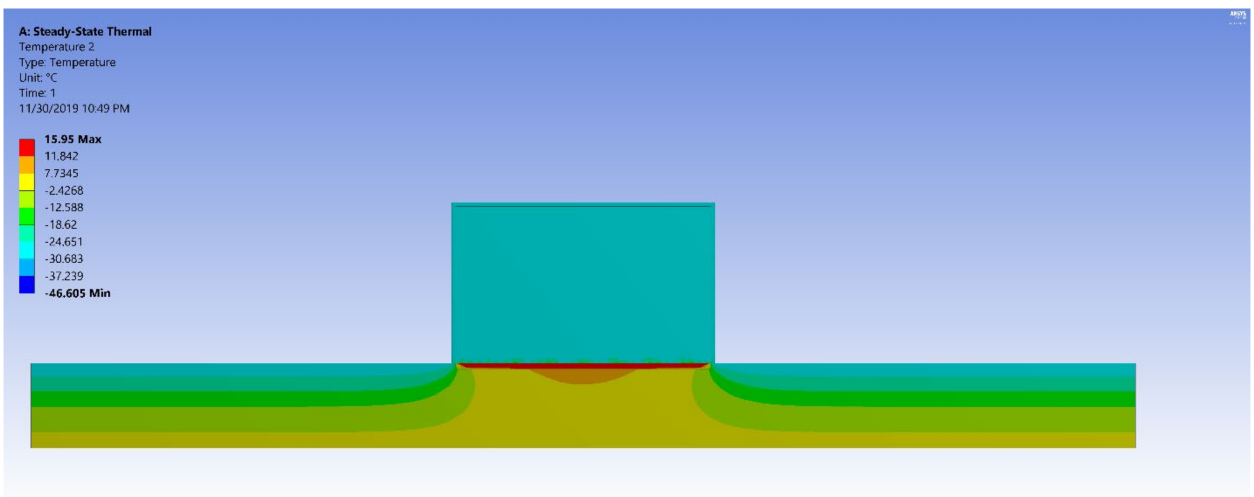


Figure B2: Hot Room Heat Loss in Winter (Insulated Slab)

In summer operating conditions the hot room is maintained at a temperature of 30°C. The external ambient temperature was considered to be 13°C, which is the average ambient temperature in the summer months in Watino, Alberta. The temperature distribution through the floor slab without insulation and with insulation is illustrated in Figure B3 and B4 below, respectively.

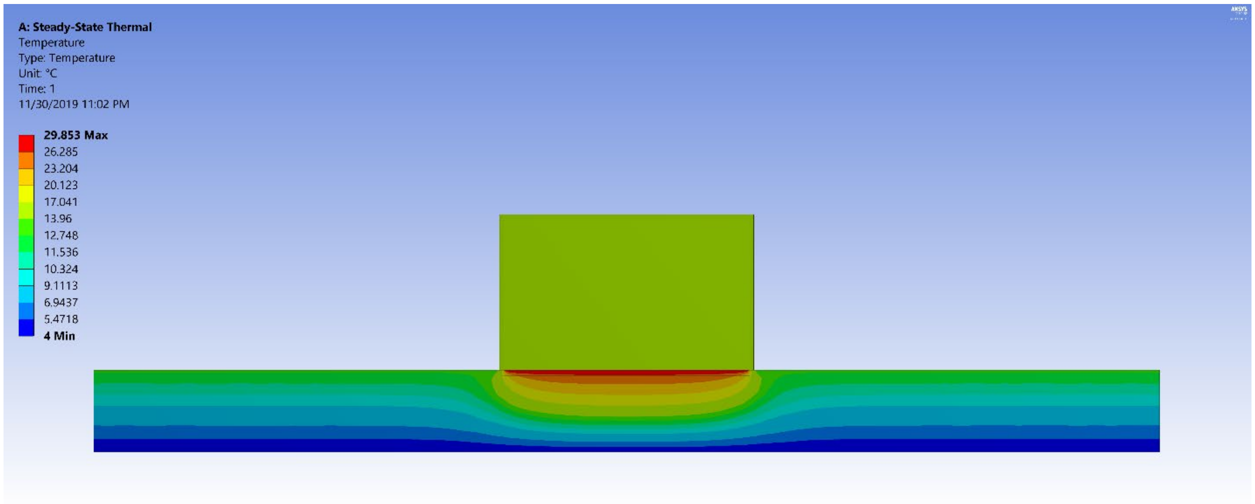


Figure B3: Hot Room Heat Loss in Summer (Uninsulated slab)

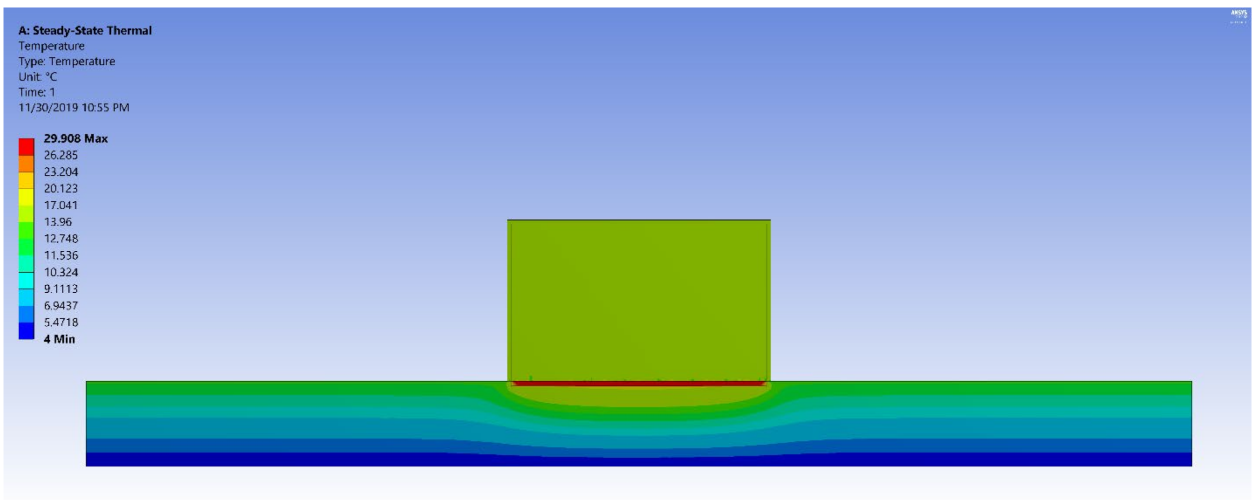


Figure B4: Hot Room Heat Loss in Summer (Insulated Slab)

Cold Room

During winter conditions, the cold room is maintained at a temperature of 20°C. The external ambient temperature was defined at -30°C. The temperature distribution through the floor slab without insulation and with insulation is illustrated in Figure B5 and B6 below, respectively.

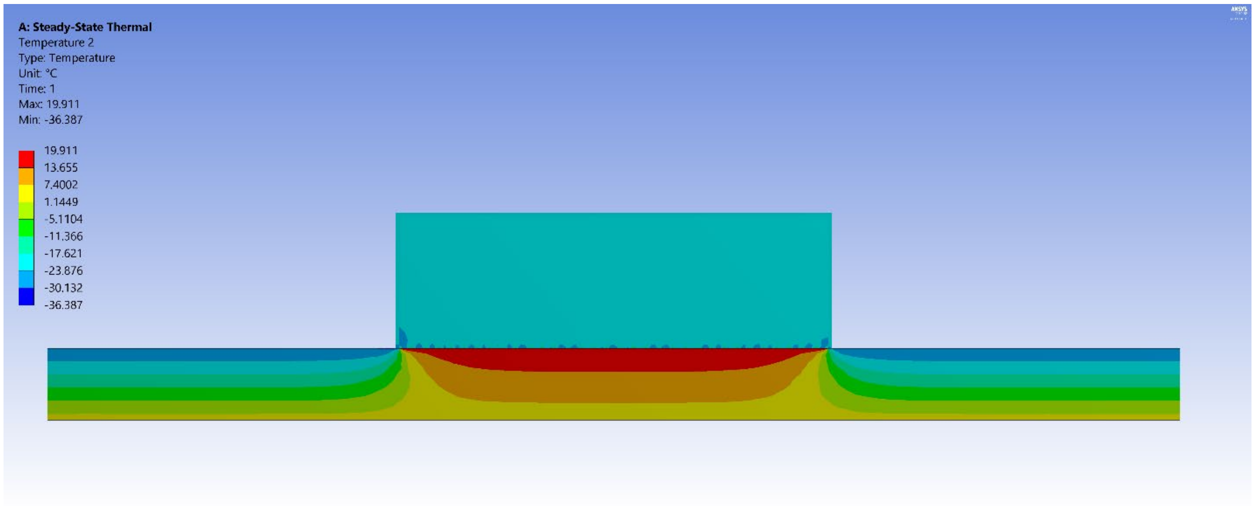


Figure B5: Cold Room Heat Loss in Winter (Uninsulated Slab)

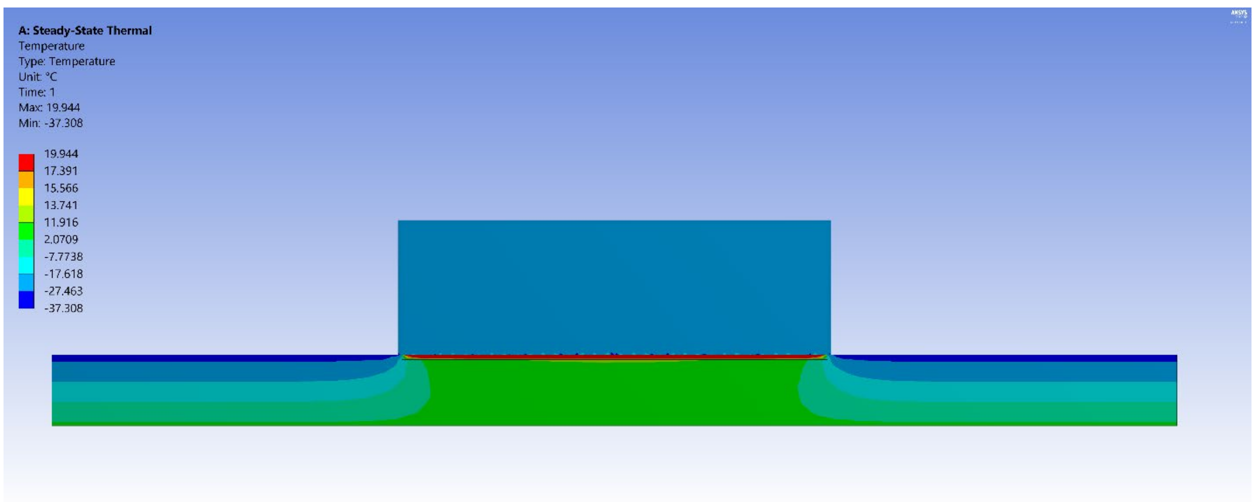


Figure B6: Cold Room Heat Loss in Winter (Insulated Slab)

In summer operating conditions the cold room is maintained at a temperature of 20°C. The external ambient temperature was considered to be 13°C, which is the average ambient temperature in the summer months in Watino, Alberta. The temperature distribution through the floor slab without insulation and with insulation is illustrated in Figure B7 and B8 below, respectively.

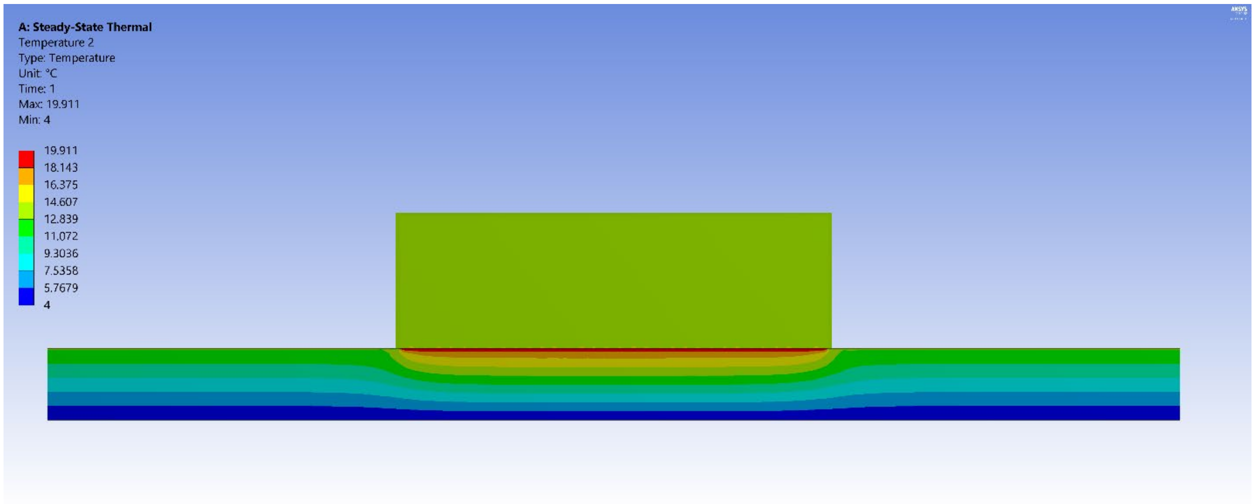


Figure B7: Cold Room Heat Loss in Summer (Uninsulated Slab)

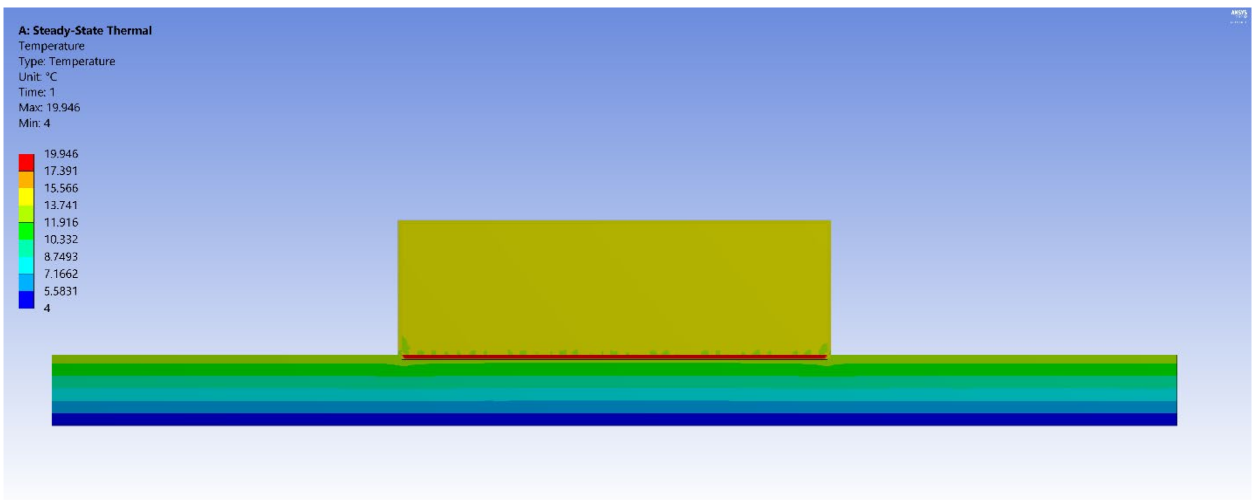


Figure B8: Cold Room Heat Loss in Summer (Insulated Slab)

As shown in each of the above figures, the addition of a 2”-thick polystyrene insulation layer benath the concrete slab significantly reduces heat losses to the soil.

Appendix B6: Energy Analysis

Energy Analysis

The annual energy consumption was estimated in a simple spreadsheet model using an average 10-hour work day during the honey production period from July to September, with the non-operational period of the building from October to June. The heating and cooling loads that were determined from the heat transfer analysis presented in Section 3.2 were used for this energy analysis.

The HIVE house was estimated to have an annual energy consumption of 74.3 MWh/year, or 9.29 kWh/hive. At the current regulated energy rate of $71.5/MWh [1], this results in an annual energy cost of approximately $5,313. The annual gas consumption was estimated to be 430 GJ/year, or 54.1 GJ/1000-hives. At the current regulated natural gas price of $3.09/GJ [2], this results in an annual cost in natural gas of approximately $1,336.

Installing a solar power array would be a valuable consideration to offset power costs of the building. A 41.5 kW roof-top solar system would require an initial investment of $57,990 that would have a 11.9% IRR over a 30-year economic life, with 9 years payback. Based on the average monthly sunlight hours in Watino, Alberta [3], the solar system is estimated to generate 91.0 MWh/year, with peak generation between the production months from May to September. This yields a surplus of 16.7 MWh/year; under micro-generation regulations, this electricity can be sent back to the grid and credited for at the current monthly retailer rates. At the 2019 average energy rate of $71.5/MWh, this would yield an annual credit of $6,506.

Figure B9 below provides an illustration of the average monthly sunlight hours in Watino, Alberta, and the corresponding solar PV system power generation.

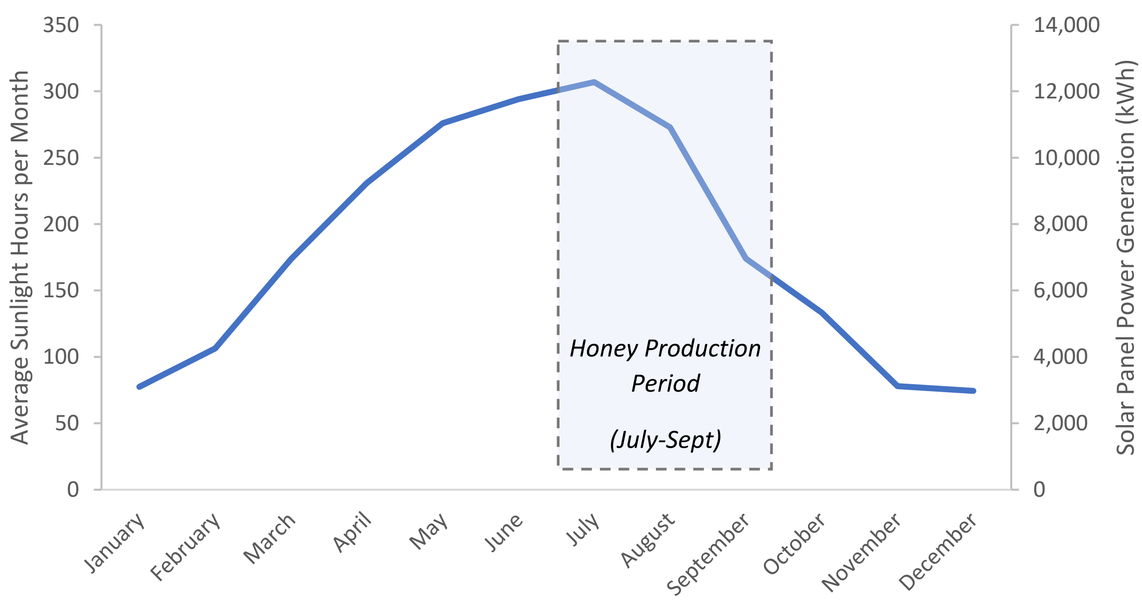


Figure B9: Solar PV System Monthly Power Generation

Appendix References

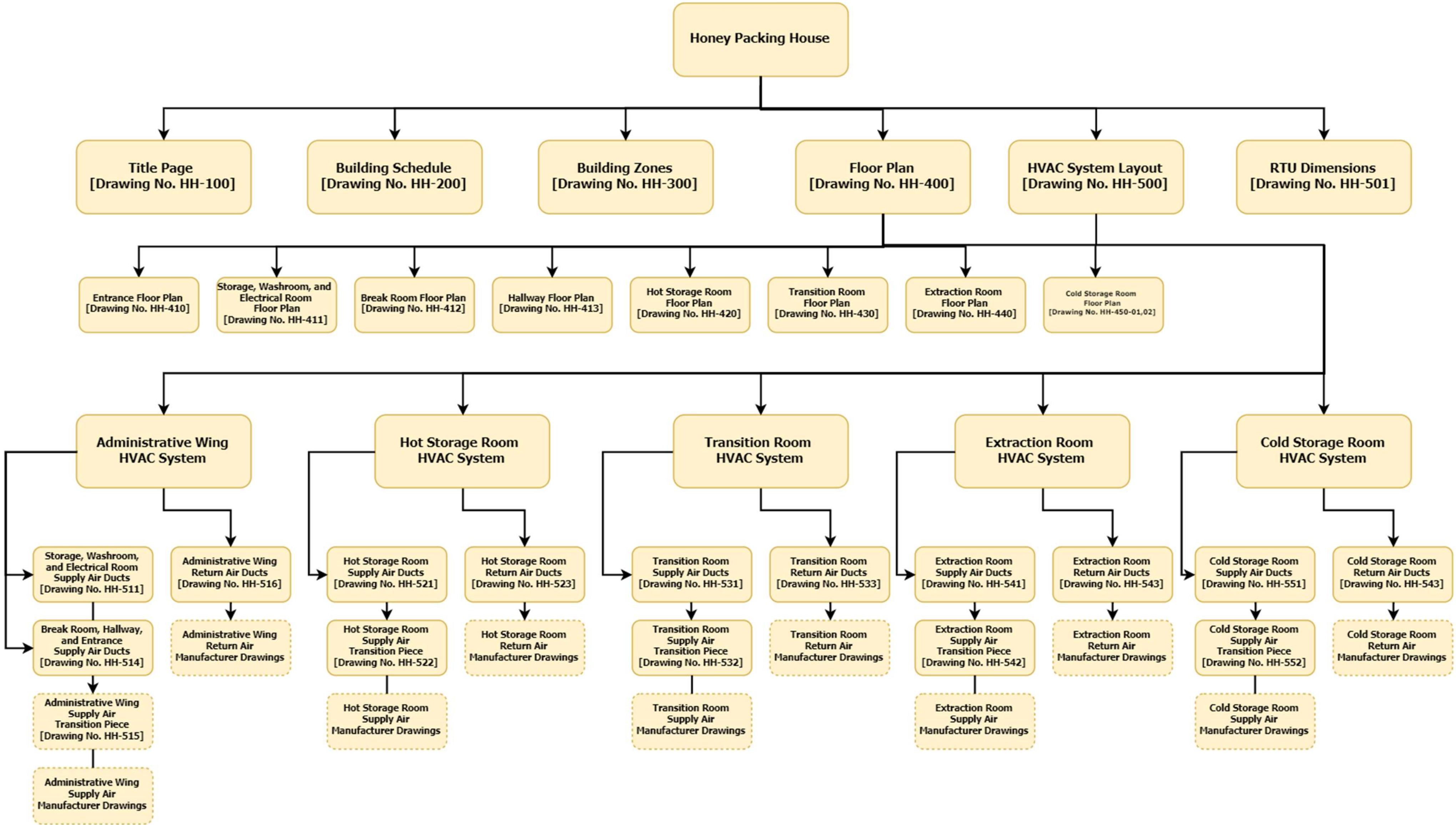
[1] “AUC,” [Online] Available: http://www.auc.ab.ca/Pages/current-rates-electric.aspx [Accessed on: December 1, 2019].

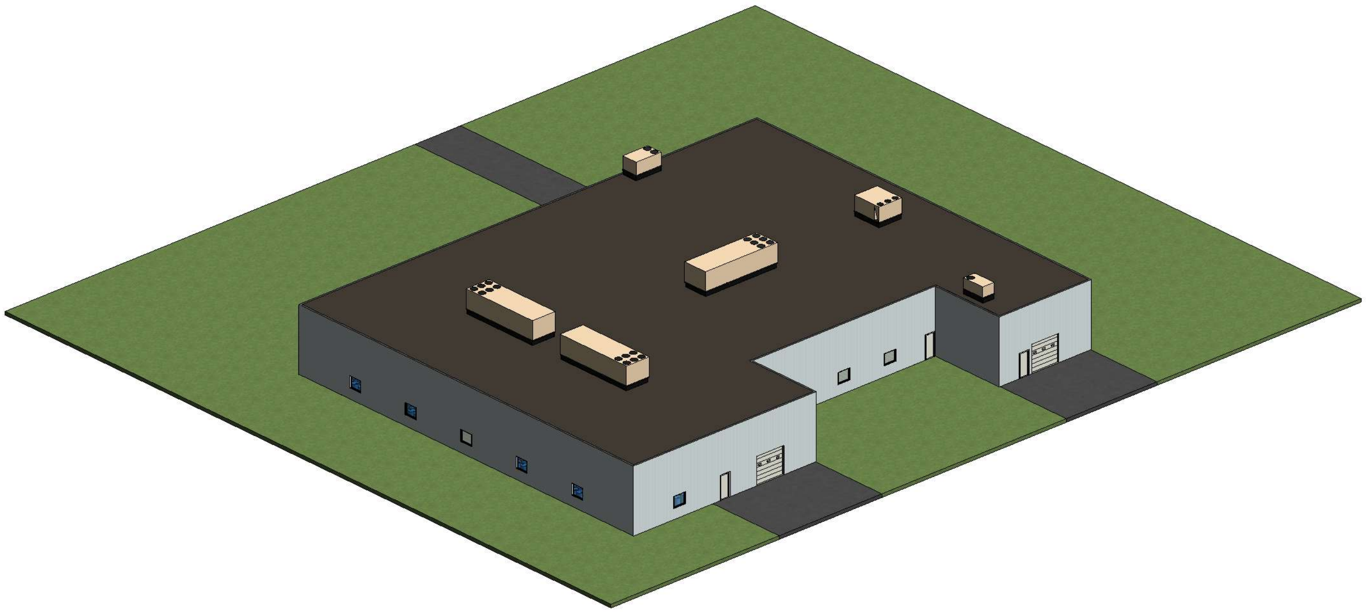
[2] “AUC,” [Online] Available: http://www.auc.ab.ca/Pages/current-rates-gas.aspx [Accessed on: December 1, 2019].

[3] “Climate Date,” [Online] Available: https://en.climate-data.org/north-america/canada/alberta/watino-11379/#temperature-graph [Accessed on: December 1, 2019].

Appendix C: CAD and Drawing Package

Appendix C1: CAD Renderings and Drawing Package


Honey Packing House
Title Page [Drawing No. HH-100]
Building Schedule [Drawing No. HH-200]
Building Zones [Drawing No. HH-300]
Floor Plan [Drawing No. HH-400]
HVAC System Layout [Drawing No. HH-500]
RTU Dimensions [Drawing No. HH-501]
Entrance Floor Plan [Drawing No. HH-410]
Storage, Washroom, and Electrical Room Floor Plan [Drawing No. HH-411]
Break Room Floor Plan [Drawing No. HH-412]
Hallway Floor Plan [Drawing No. HH-413]
Hot Storage Room Floor Plan [Drawing No. HH-420]
Transition Room Floor Plan [Drawing No. HH-430]
Extraction Room Floor Plan [Drawing No. HH-440]
Cold Storage Room Floor Plan [Drawing No. HH-450-01,02]
Administrative Wing HVAC System
Hot Storage Room HVAC System
Transition Room HVAC System
Extraction Room HVAC System
Cold Storage Room HVAC System
Storage, Washroom, and Electrical Room Supply Air Ducts [Drawing No. HH-511]
Break Room, Hallway, and Entrance Supply Air Ducts [Drawing No. HH-514]
Administrative Wing Supply Air Transition Piece [Drawing No. HH-515]
Administrative Wing Supply Air Manufacturer Drawings
Administrative Wing Return Air Ducts [Drawing No. HH-516]
Administrative Wing Return Air Manufacturer Drawings
Hot Storage Room Supply Air Ducts [Drawing No. HH-521]
Hot Storage Room Supply Air Transition Piece [Drawing No. HH-522]
Hot Storage Room Supply Air Manufacturer Drawings
Hot Storage Room Return Air Ducts [Drawing No. HH-523]
Hot Storage Room Return Air Manufacturer Drawings
Transition Room Supply Air Ducts [Drawing No. HH-531]
Transition Room Supply Air Transition Piece [Drawing No. HH-532]
Transition Room Supply Air Manufacturer Drawings
Transition Room Return Air Ducts [Drawing No. HH-533]
Transition Room Return Air Manufacturer Drawings
Extraction Room Supply Air Ducts [Drawing No. HH-541]
Extraction Room Supply Air Transition Piece [Drawing No. HH-542]
Extraction Room Supply Air Manufacturer Drawings
Extraction Room Return Air Ducts [Drawing No. HH-543]
Extraction Room Return Air Manufacturer Drawings
Cold Storage Room Supply Air Ducts [Drawing No. HH-551]
Cold Storage Room Supply Air Transition Piece [Drawing No. HH-552]
Cold Storage Room Supply Air Manufacturer Drawings
Cold Storage Room Return Air Ducts [Drawing No. HH-543]
Cold Storage Room Return Air Manufacturer Drawings



B.E.E. Consulting Services

B.E.E Consulting Services

Notes:

MecE 460

Instructor: Dr. Duke

Title Page

Project Name:	Honey House
Date	November 30, 2019
Drawn by	Jake Bellerose
Checked by	Sai Avuthu

HH-100

Scale

01/12/2019 09:47:26

Part Number	Description	Vendor	Quantity	Comments
HH-01	19ft long, 42in wide, 6in thick CF Flute insulated wall panels	MBCI Manufacturing	166	Refer to supplier data sheet for installation details
HH-02-40	40ft long, 42 in wide, 6in thick LS-36 insulated roof panels	MBCI Manufacturing	85	Refer to supplier data sheet for installation details
HH-02-47	47ft long, 42 in wide, 6in thick LS-36 insulated roof panels	MBCI Manufacturing	21	Refer to supplier data sheet for installation details
HH-02-50	50ft long, 42 in wide, 6in thick LS-36 insulated roof panels	MBCI Manufacturing	21	Refer to supplier data sheet for installation details
HH-03	18.5ft long, 42in wide, 4in thick CF 45 insulated wall panels	MBCI Manufacturing	134	Refer to supplier data sheet for installation details
HH-04	2ft by 4ft by 5/8in thick food safe ceiling tiles	To be determined	2010	Vendor to be determined as future considerations
HH-05	34" by 80" Standard Door - item number THDJW184900102	The Home Depot	13	N/A
HH-06	48" by 40" window - part number 416782	Lowe's Canada	16	N/A
HH-07	8" Diameter Diffuser – part number 1988K42	McMaster Carr	1	N/A
HH-08	10" Diameter Diffuser – part number 1988K43	McMaster Carr	3	N/A
HH-09	12" Diameter Diffuser – part number 800R14	Ecco Supply	2	N/A
HH-10	14" Diameter Diffuser – part number 1988K46	McMaster Carr	2	N/A
HH-11	24" Diameter Diffuser – part number 800R24	Ecco Supply	7	N/A
HH-12	26" Diameter Diffuser	Ecco Supply	2	Piece to be custom made by Ecco Supply
HH-13	18" by 36" Ceiling Diffuser	HVAC Premium	1	N/A
HH-14	24" by 48" Ceiling Diffuser	HVAC Premium	3	N/A
RTU 1	Unit Model: KGA120S4B	Lennox Commercial	1	Refer to supplier data sheet for installation details
AW-01	Administration Wing Supply Air System	-	1	Refer to drawing HH-511 for construction details
AW-03	Administration Wing Return Air System	-	1	Refer to drawing HH-516 for construction details
RTU 2	Unit Model: KGA240S4B	Lennox Commercial	1	Refer to supplier data sheet for installation details
HS-01	Hot Storage Supply Air System	-	2	Refer to drawing HH-521 for construction details
HS-03	Hot Storage Return Air System	-	1	Refer to drawing HH-523 for construction details
RTU 3	Unit Model: LGH060U4E	Lennox Commercial	1	Refer to supplier data sheet for installation details
TR-01	Transition Room Supply Air System	-	1	Refer to drawing HH-531 for construction details
TR-03	Transition Room Return Air System	-	1	Refer to drawing HH-533 for construction details
RTU 4	Unit Model: LCH600H4B	Lennox Commercial	1	Refer to supplier data sheet for installation details
EX-01	Extraction Room Supply Air System	-	1	Refer to drawing HH-541 for construction details
EX-03	Extraction Room Return Air System	-	1	Refer to drawing HH-543 for construction details
RTU 5	Unit Model: LCH600H4B	Lennox Commercial	1	Refer to supplier data sheet for installation details
RTU 6	Unit Model: LCH600H4B	Lennox Commercial	1	Refer to supplier data sheet for installation details
CS-01	Cold Storage Supply Air System	-	1	Refer to drawing HH-551 for construction details
CS-03	Cold Storage Return Air System	-	1	Refer to drawing HH-553 for construction details
WG-01	Unit model: SG-3014 RAG (In wall air exchange grille)	The Home Depot	5	N/A

B.E.E. Consulting Services

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Notes:

1.) Supplementary details for lighting, dehumidifiers, floor slopes, a honey SUMP, toilet, sinks, thermostats, structural components, floor drains, electrical connections, natural gas connections, water sources, and bee escapes will be included in future work considerations

MecE 460

Instructor: Dr. Duke

Building Schedule

Project Name:	Honey House
Date	November 30, 2019
Drawn by	Jake Bellerose
Checked by	Zoey Zhang

HH-200

Scale

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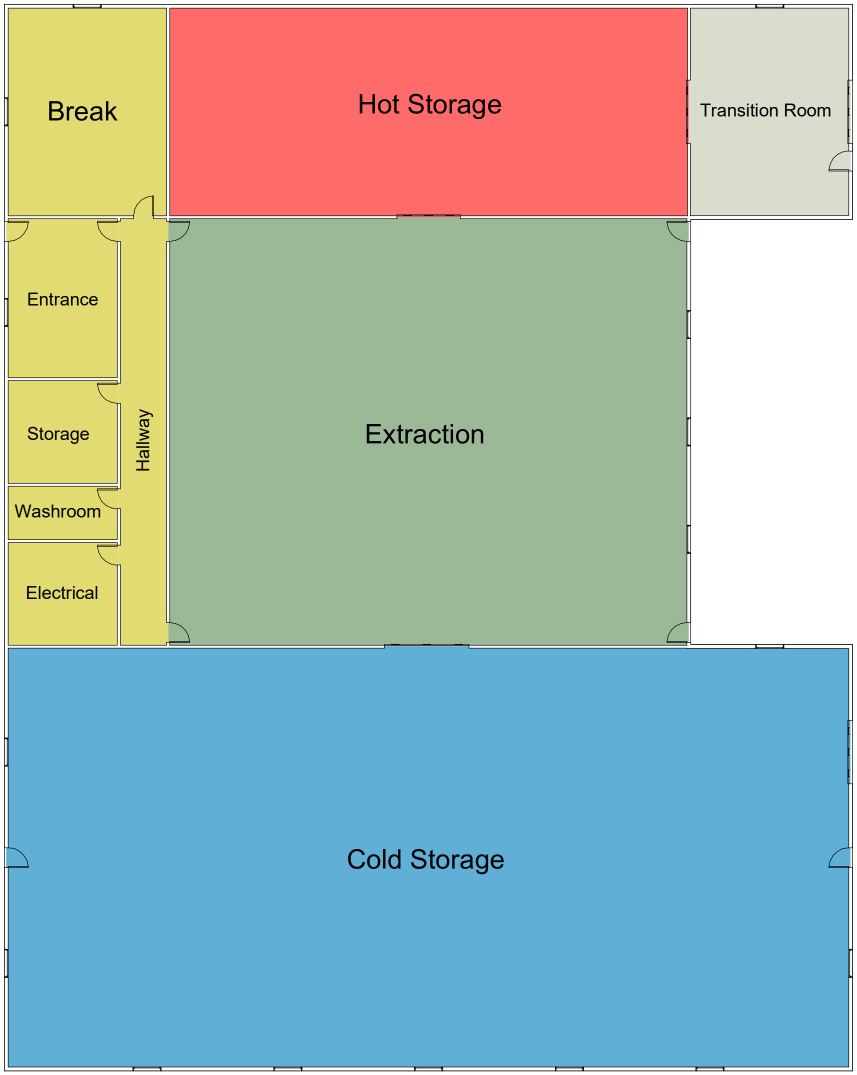

Building Zones

- Administrative Wing
- Hot Storage Room
- Transition Room
- Extraction Room
- Cold Storage Room

B.E.E Consulting Services

Notes:

MecE 460

Instructor: Dr. Duke

Building Zones

Project Name:	Honey House
Date	November 30, 2019
Drawn by	Jake Bellerose
Checked by	Zoey Zhang

HH-300

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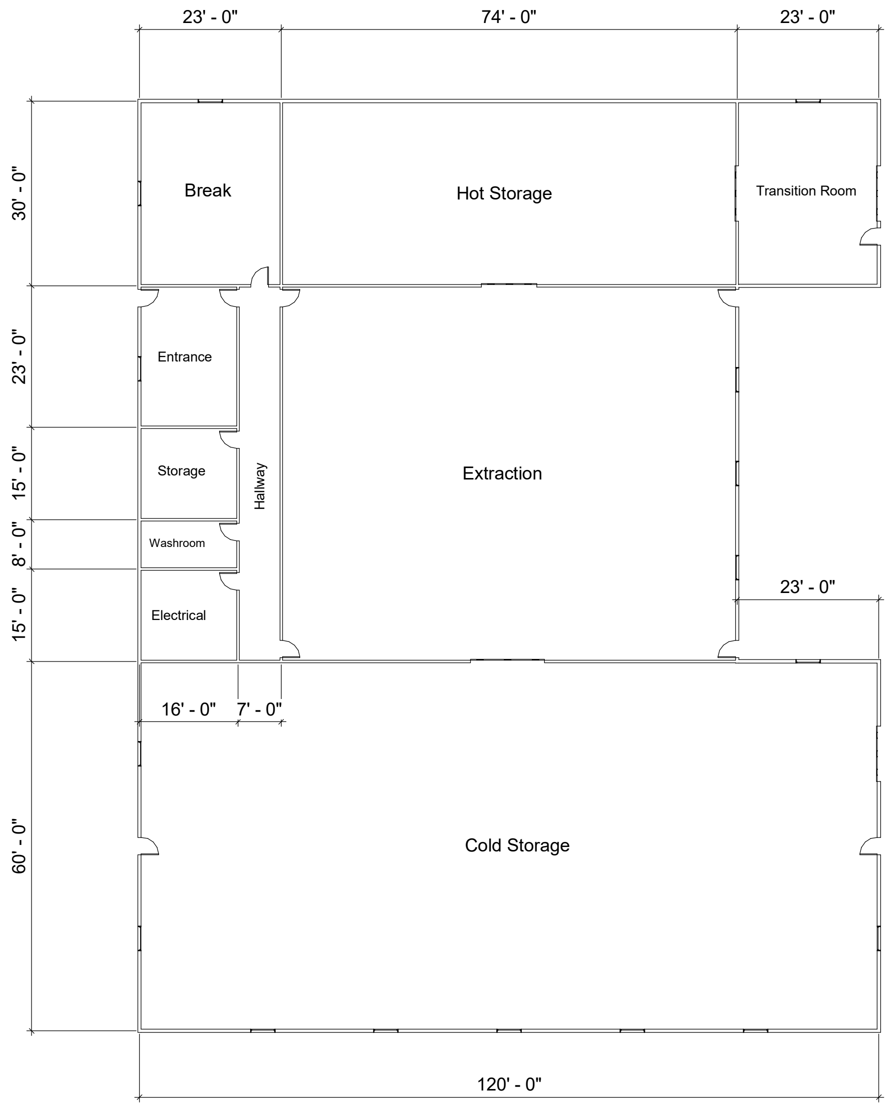

B.E.E. Consulting Services

B.E.E Consulting Services

Notes:

1.) Refer to drawings HH-410 to HH-450 for detailed drawings of each room

MecE 460

Instructor: Dr. Duke

Floor Plan

Project Name:	Honey House
Date	November 30, 2019
Drawn by	Jake Bellerose
Checked by	Sai Avuthu

HH-400

Scale	1 : 80

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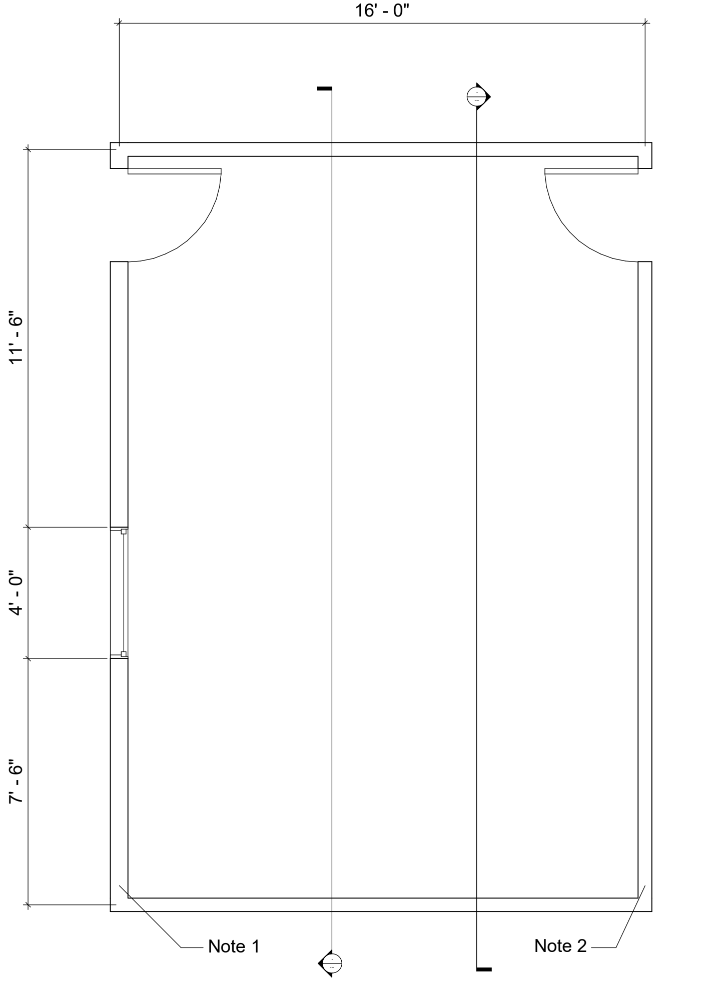
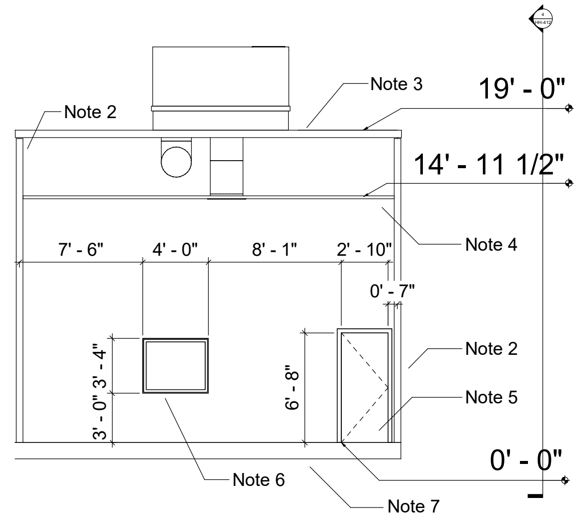
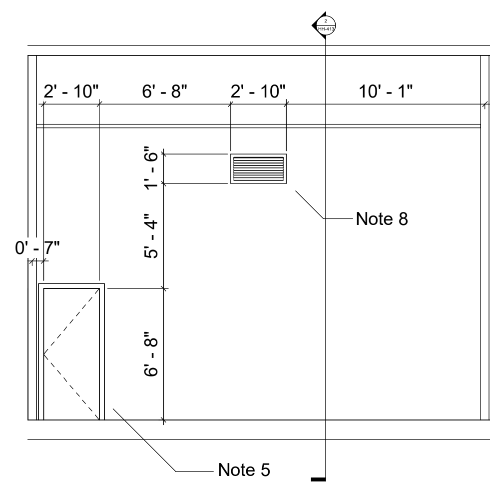


1 Plan View
1 : 15



2 West Section View
1 : 30



3 East Section View
1 : 25

B.E.E. Consulting Services

B.E.E Consulting Services

Notes:

1.) Exterior Wall - 6" CF Flute Wall Panels with 1/2" gypsum wall boards on each interior surface

2.) Interior Wall - 4" CF 45 Flute Wall Panels with 1/2" gypsum wall boards on each surface

3.) Roof - 6" LS-36 Roof Panels

4.) Ceiling - food safe 2' x 4' x 5/8" tile ceiling grid

5.) 34" by 80" Standard Door - item number THDJW184900102 from The Home Depot

6.) 48" by 40" window - part number 416782 from lowes Canada

7.) Concrete Slab - 300mm thickness with 30MPa strength

8.) 30" by 14" wall grille - item number SG-3014 RAG from The Home Depot

MecE 460

Instructor: Dr. Duke

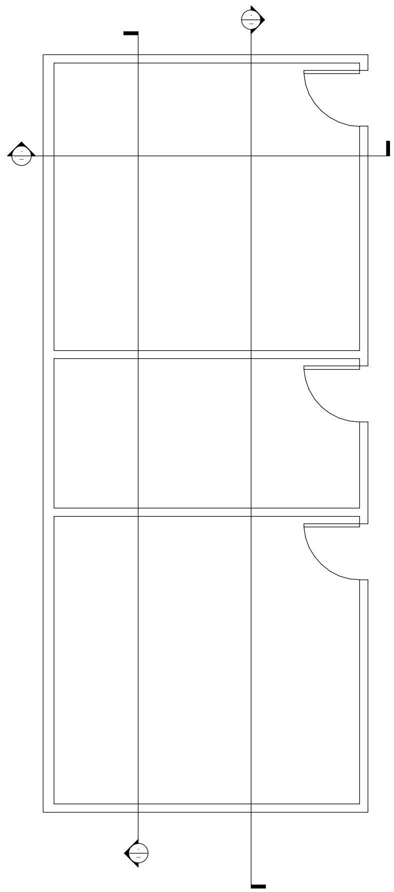
Entrance

Project Name:	Honey House
Date	November 30, 2019
Drawn by	Jake Bellerose
Checked by	Zoey Zhang

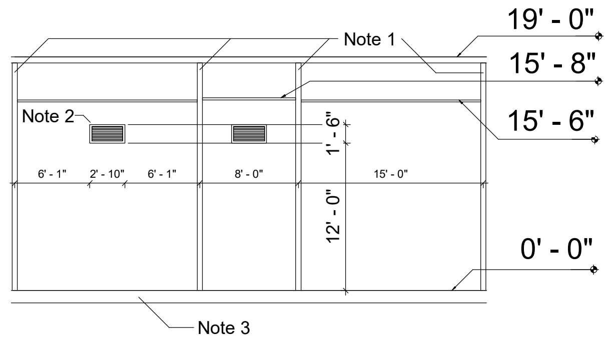
HH-410

Scale	As indicated

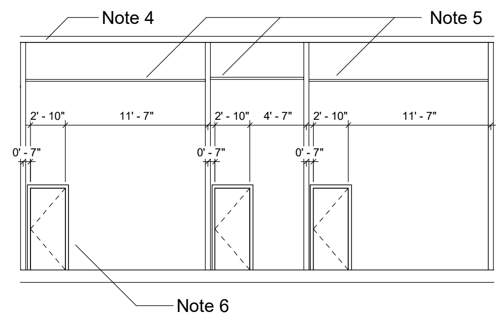
01/12/2019 14:24:12



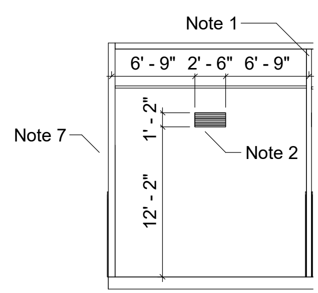
1 Plan View
1 : 25



2 West Section View
1 : 40



3 East Section View
1 : 40



4 North Section View
1 : 40

B.E.E. Consulting Services

B.E.E Consulting Services

Notes:

1.) Interior Wall - 4" CF 45 Flute Wall Panels with 1/2" gypsum wall boards on each surface

2.) 30" by 14" wall grille - item number SG-3014 RAG from The Home Depot

3.) Concrete Slab - 300mm thickness with 30MPa strength

4.) Roof - 6" LS-36 Roof Panels

5.) Ceiling - food safe 2' x 4' x 5/8" tile ceiling grid

6.) 34" by 80" Standard Door - item number THDJW184900102 from The Home Depot

7.) Exterior Wall - 6" CF Flute Wall Panels with 1/2" gypsum wall boards on each interior surface

MecE 460

Instructor: Dr. Duke

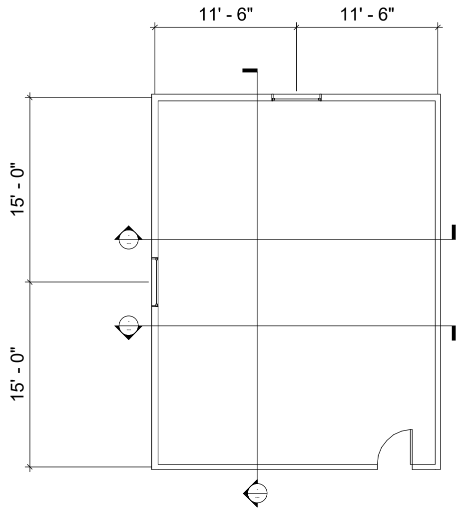
Storage Room, Washroom, and Electrical Room

Project Name:	Honey House
Date	November 30, 2019
Drawn by	Jake Bellerose
Checked by	Zoey Zhang

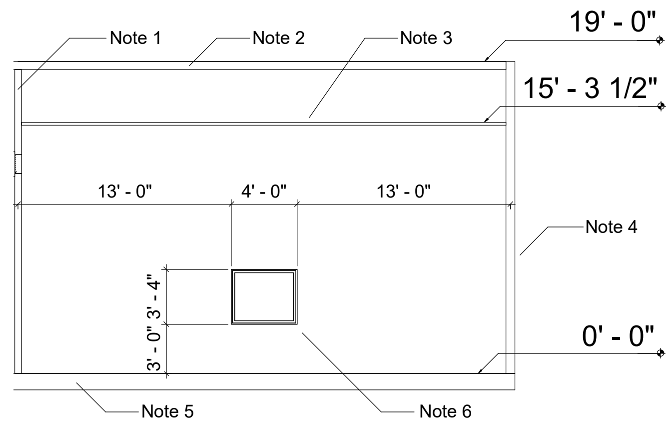
HH-411

Scale	As indicated

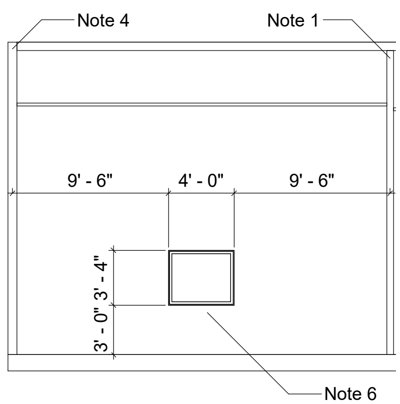
01/12/2019 16:52:13



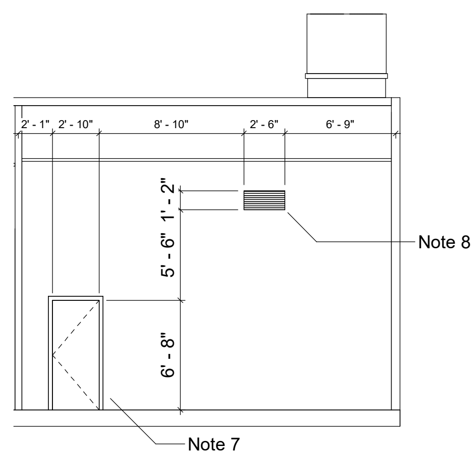
1 Plan View
1 : 40



2 West Section View
1 : 30



3 North Section View
1 : 30



4 South Section View
1 : 30

B.E.E Consulting Services

Notes:

1.) Interior Wall - 4" CF 45 Flute Wall Panels with 1/2" gypsum wall boards on each surface

2.) Roof - 6" LS-36 Roof Panels

3.) Ceiling - food safe 2' x 4' x 5/8" tile ceiling grid

4.) Exterior Wall - 6" CF Flute Wall Panels with 1/2" gypsum wall boards on each interior surface

5.) Concrete Slab - 300mm thickness with 30MPa strength

6.) 48" by 40" window - part number 416782 from lowes Canada

7.) 34" by 80" Standard Door - item number THDJW184900102 from The Home Depot

8.) 30" by 14" wall grille - item number SG-3014 RAG from The Home Depot

MecE 460

Instructor: Dr. Duke

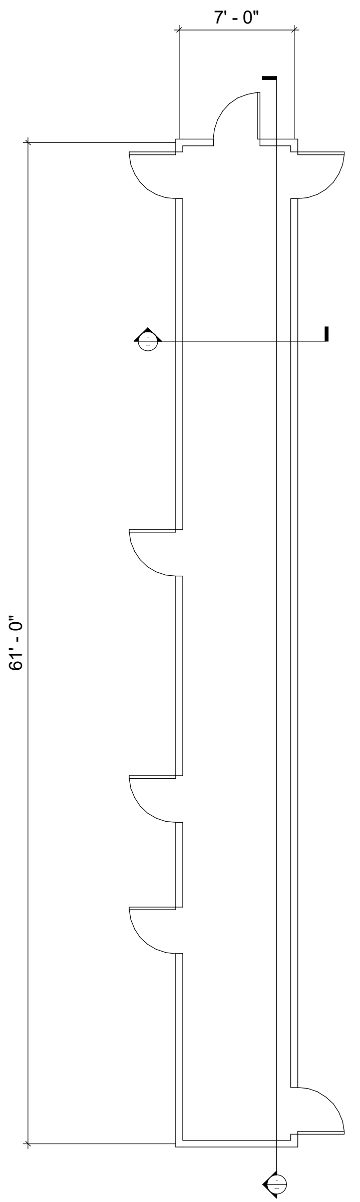
Break Room

Project Name:	Honey House
Date	November 30, 2019
Drawn by	Jake Bellerose
Checked by	Sai Avuthu

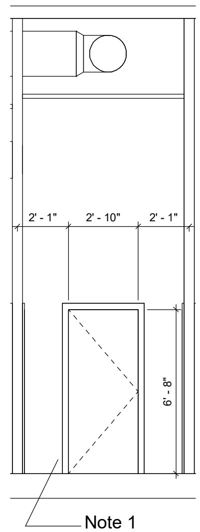
HH-412

Scale	As indicated

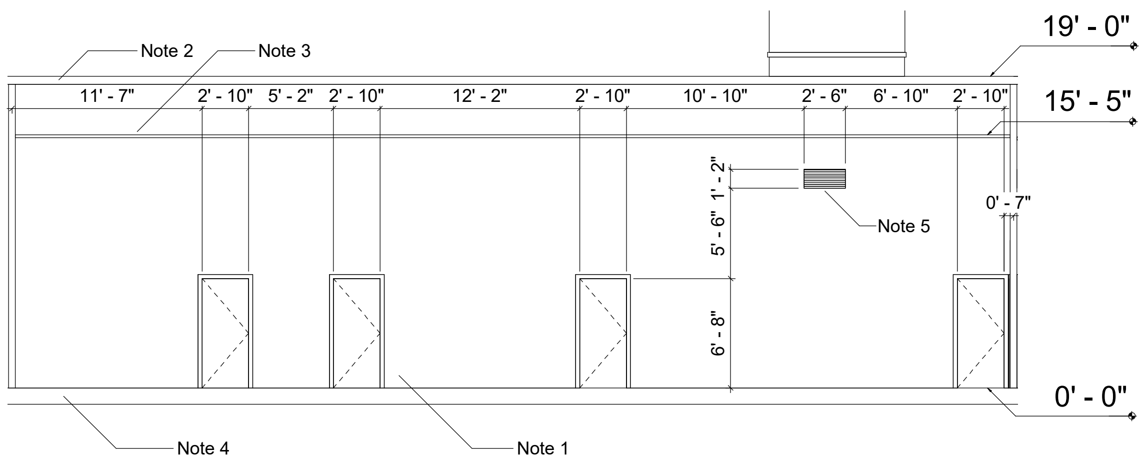
01/12/2019 14:26:24



1 Plan View
1 : 30



2 North Section View
1 : 20



3 West Section View
1 : 30

B.E.E. Consulting Services

B.E.E Consulting Services

Notes:

1.) 34" by 80" Standard Door - item number THDJW184900102 from The Home Depot

2.) Roof - 6" LS-36 Roof Panels

3.) Ceiling - food safe 2' x 4' x 5/8" tile ceiling grid

4.) Concrete Slab - 300mm thickness with 30MPa strength

5.) 30" by 14" wall grille - item number SG-3014 RAG from The Home Depot

6.) All hallway walls will be Interior Walls - 4" CF 45 Flute Wall Panels with 1/2" gypsum wall boards on each surface

MecE 460

Instructor: Dr. Duke

Hallway

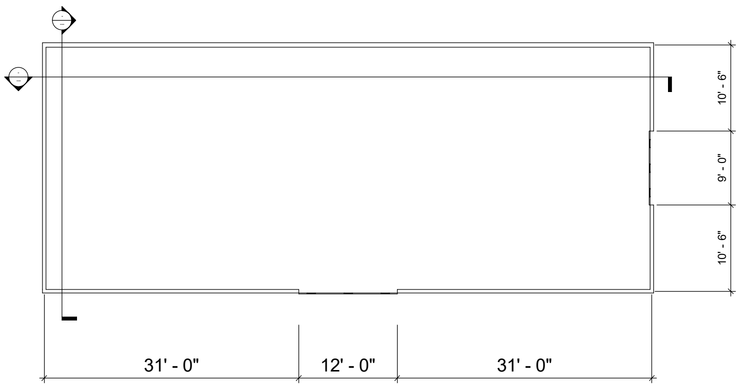
Project Name:	Honey House
Date	November 30, 2019
Drawn by	Jake Bellerose
Checked by	Sai Avuthu

HH-413

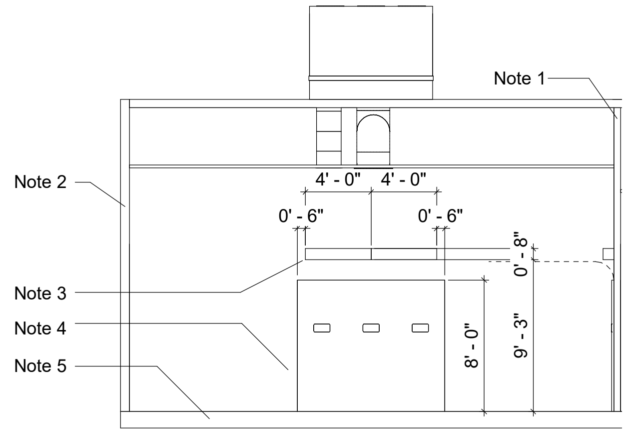
Scale	As indicated

01/12/2019 14:22:17

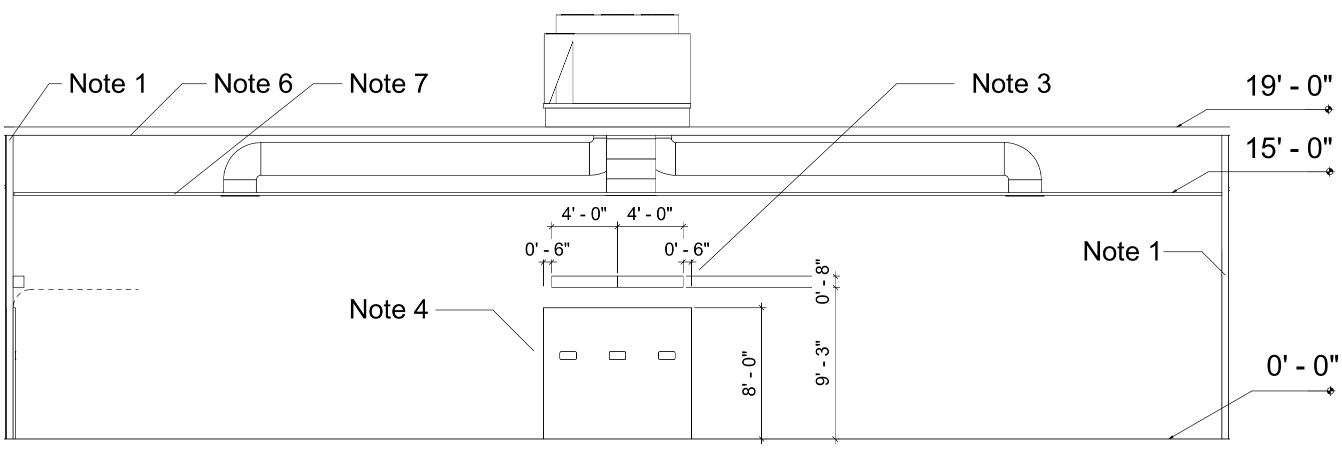
North



1 Plan View
1 : 60



2 East Section View
1 : 30



3 South Section View
1 : 30

B.E.E. Consulting Services

B.E.E Consulting Services

Notes:

1.) Interior Wall - 4" CF 45 Flute Wall Panels with 1/2" gypsum wall boards on each surface

2.) Exterior Wall - 6" CF Flute Wall Panels with 1/2" gypsum wall boards on each interior surface

3.) 48" Low Profile Air Curtain - item number WWG32V346 from acklands grainger

4.) 9' by 8' Overhead Door

5.) Concrete Slab - 300mm thickness with 30MPa strength

6.) Roof - 6" LS-36 Roof Panels

7.) Ceiling - food safe 2' x 4' x 5/8" tile ceiling grid

MecE 460

Instructor: Dr. Duke

Hot Storage Room

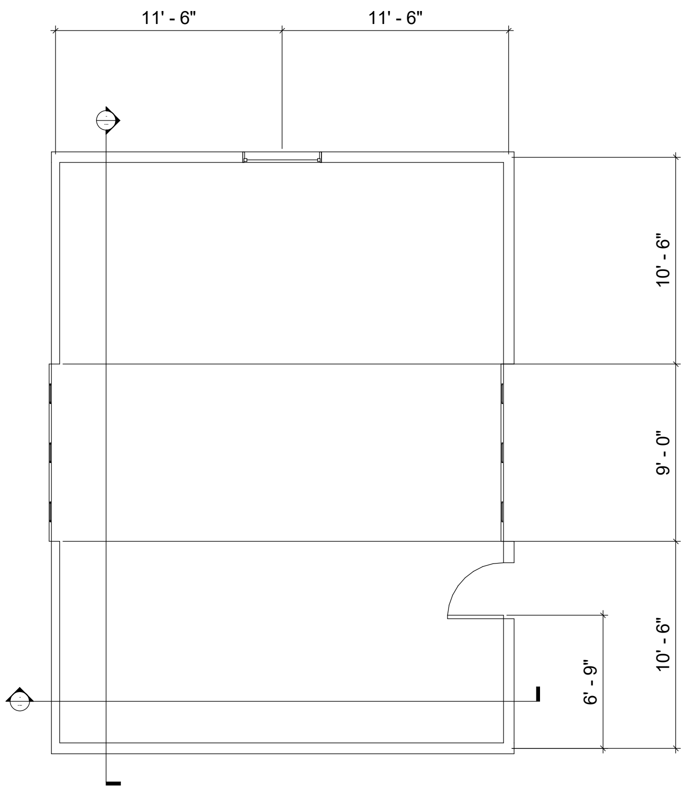
Project Name:	Honey House
Date	November 30, 2019
Drawn by	Jake Bellerose
Checked by	Zoey Zhang

HH-420

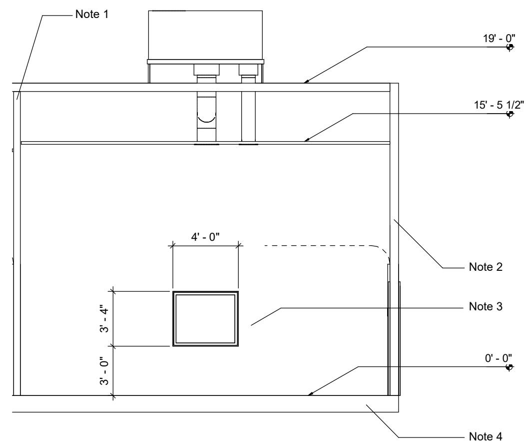
Scale	As indicated

01/12/2019 10:21:10

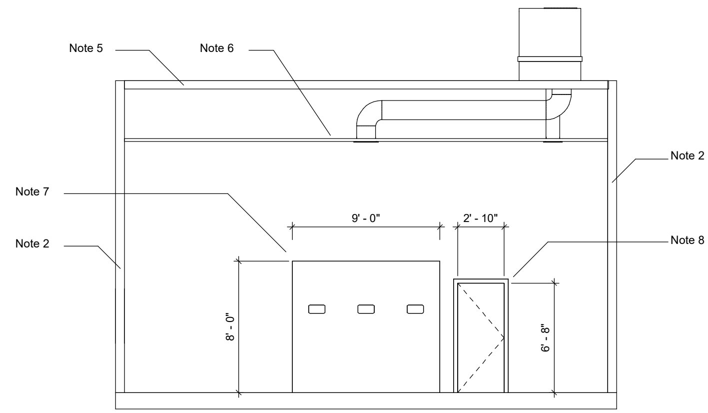
North



1 Transition Room - Plan View
1 : 25



2 North Section View
1 : 30



3 East Section View
1 : 30

B.E.E. Consulting Services

B.E.E Consulting Services

Notes:

1.) Interior Wall - 4" CF 45 Flute Wall Panels with 1/2" gypsum wall boards on each surface

2.) Exterior Wall - 6" CF Flute Wall Panels with 1/2" gypsum wall boards on each interior surface

3.) 48" by 40" window - part number 416782 from lowes Canada

4.) Concrete Slab - 300mm thickness with 30MPa strength

5.) Roof - 6" LS-36 Roof Panels

6.) Ceiling - food safe 2' x 4' x 5/8" tile ceiling grid

7.) 9' by 8' Overhead Door

8.) 34" by 80" Standard Door - item number THDJW184900102 from The Home Depot

MecE 460

Instructor: Dr. Duke

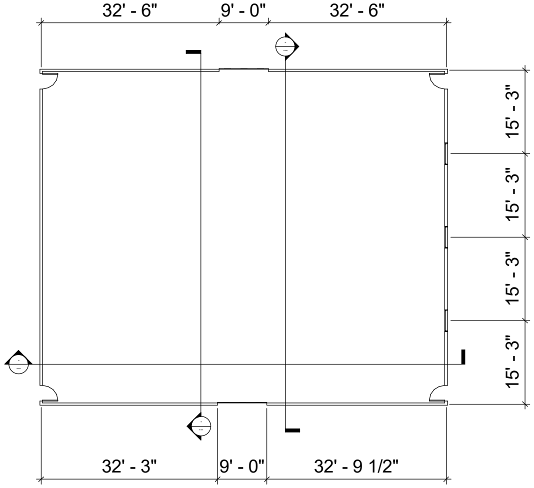
Transition Room

Project Name:	Honey House
Date	November 30, 2019
Drawn by	Sai Avuthu
Checked by	Zoey Zhang

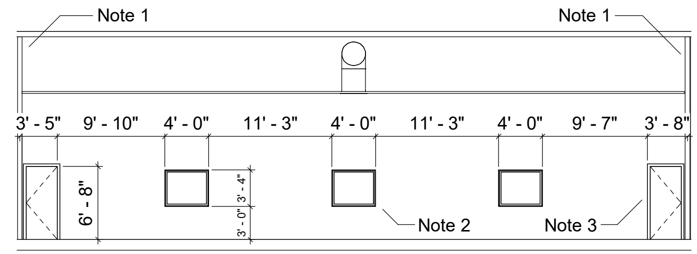
HH-430

Scale: As indicated

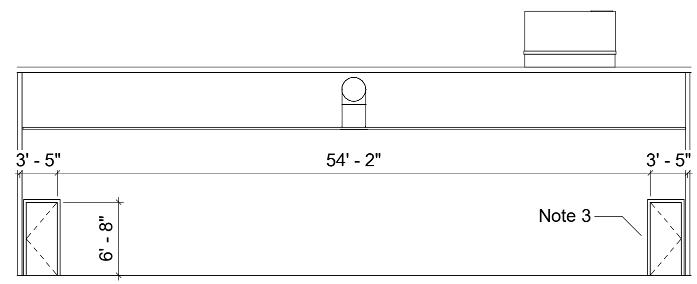
30/11/2019 14:48:14



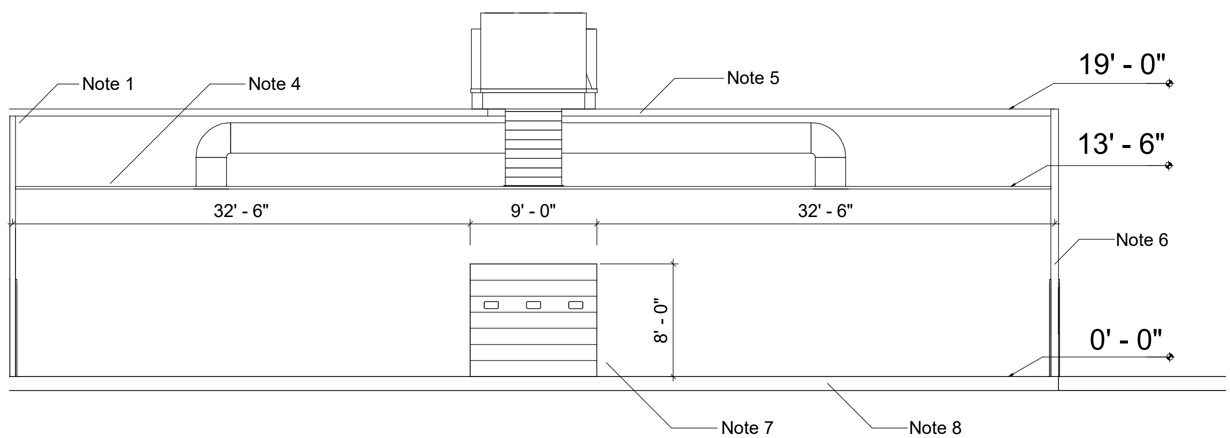
1 Plan View
1 : 90



2 East Section View
1 : 45



3 West Section View
1 : 45



4 North Section View
1 : 35

B.E.E. Consulting Services

B.E.E Consulting Services

Notes:

1.) Interior Wall - 4" CF 45 Flute Wall Panels with 1/2" gypsum wall boards on each surface

2.) 48" by 40" window - part number 416782 from lowes Canada. Three windows on the east wall

3.) 34" by 80" Standard Door - item number THDJW184900102 from The Home Depot. Two doors on the west wall and two walls on the east wall

4.) Ceiling - food safe 2' x 4' x 5/8" tile ceiling grid

5.) Roof - 6" LS-36 Roof Panels

6.) Exterior Wall - 6" CF Flute Wall Panels with 1/2" gypsum wall boards on each interior surface

7.) 9' by 8' Overhead Door. One overhead door on the south wall and one overhead door on the north wall

8.) Concrete Slab - 300mm thickness with 30MPa strength

MecE 460

Instructor: Dr. Duke

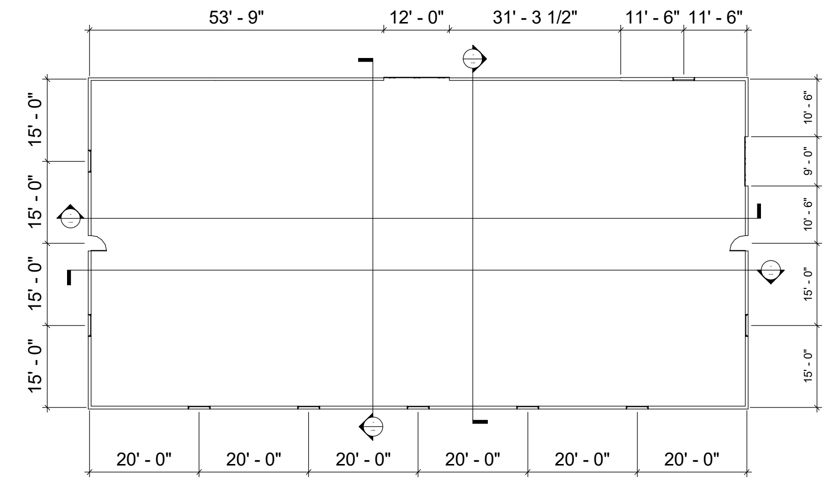
Extraction Room

Project Name:	Honey House
Date	November 30, 2019
Drawn by	Jake Bellerose
Checked by	Sai Avuthu

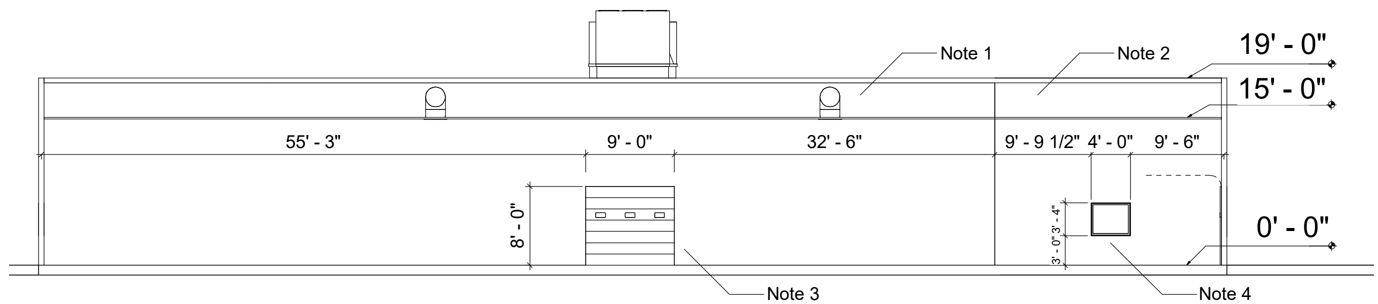
HH-440

Scale	As indicated

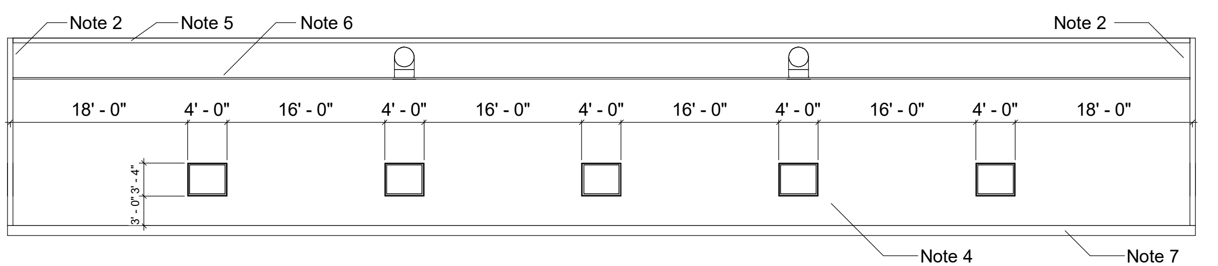
01/12/2019 11:11:55



1 Plan View
1 : 90



2 North Section View
1 : 50



3 South Section View
1 : 50

B.E.E. Consulting Services

B.E.E Consulting Services

Notes:

1.) Interior Wall - 4" CF 45 Flute Wall Panels with 1/2" gypsum wall boards on each surface

2.) Exterior Wall - 6" CF Flute Wall Panels with 1/2" gypsum wall boards on each interior surface

3.) 9' by 8' Overhead Door

4.) 48" by 40" window - part number 416782 from lowes Canada

5.) Roof - 6" LS-36 Roof Panels

6.) Ceiling - food safe 2' x 4' x 5/8" tile ceiling grid

7.) Concrete Slab - 300mm thickness with 30MPa strength

8.) Refer to drawing HH-450-02 for east and west section views

MecE 460

Instructor: Dr. Duke

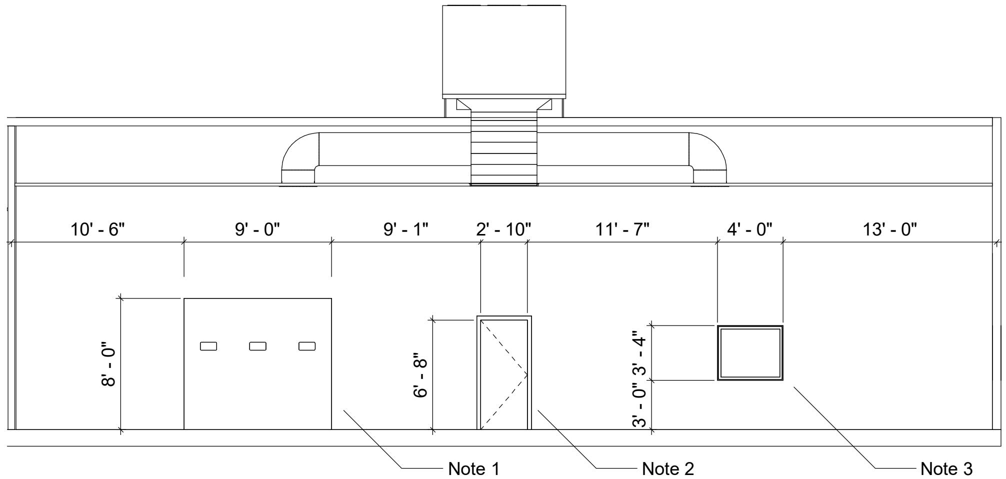
Cold Storage

Project Name:	Honey House
Date	November 30, 2019
Drawn by	Jake Bellerose
Checked by	Sai Avuthu

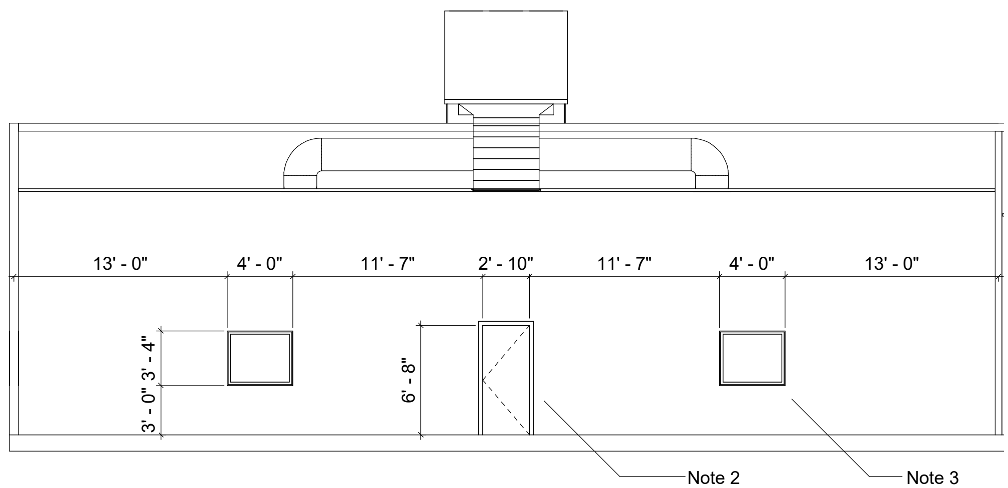
HH-450-01

Scale	As indicated

01/12/2019 12:21:00



1 East Section View
1 : 30



2 West Section View
1 : 30

B.E.E. Consulting Services

B.E.E Consulting Services

Notes:

1.) 9' by 8' Overhead Door

2.) 34" by 80" Standard Door - item number THDJW184900102 from The Home Depot

3.) 48" by 40" window - part number 416782 from lowes Canada

MecE 460

Instructor: Dr. Duke

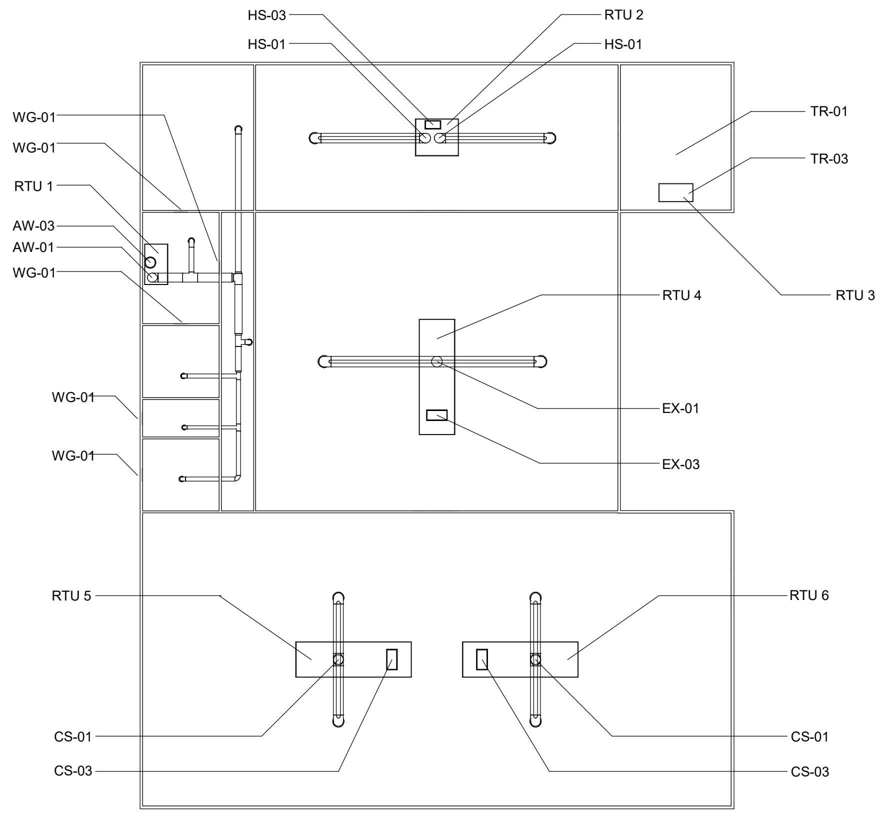
Cold Storage

Project Name:	Honey House
Date	November 30, 2019
Drawn by	Jake Bellerose
Checked by	Zoey Zhang

HH-450-02

Scale	1 : 30

North



Part Number	Description	Vendor	Quantity	Comments
RTU 1	Unit Model: KGA120S4B	Lennox Commercial	1	Refer to supplier data sheet for installation details
AW-01	Administration Wing Supply Air System	-	1	Refer to drawing HH-511 for construction details
AW-03	Administration Wing Return Air System	-	1	Refer to drawing HH-516 for construction details
RTU 2	Unit Model: KGA240S4B	Lennox Commercial	1	Refer to supplier data sheet for installation details
HS-01	Hot Storage Supply Air System	-	2	Refer to drawing HH-521 for construction details
HS-03	Hot Storage Return Air System	-	1	Refer to drawing HH-523 for construction details
RTU 3	Unit Model: LGH060U4E	Lennox Commercial	1	Refer to supplier data sheet for installation details
TR-01	Transition Room Supply Air System	-	1	Refer to drawing HH-531 for construction details
TR-03	Transition Room Return Air System	-	1	Refer to drawing HH-533 for construction details
RTU 4	Unit Model: LCH600H4B	Lennox Commercial	1	Refer to supplier data sheet for installation details
EX-01	Extraction Room Supply Air System	-	1	Refer to drawing HH-541 for construction details
EX-03	Extraction Room Return Air System	-	1	Refer to drawing HH-543 for construction details
RTU 5	Unit Model: LCH600H4B	Lennox Commercial	1	Refer to supplier data sheet for installation details
RTU 6	Unit Model: LCH600H4B	Lennox Commercial	1	Refer to supplier data sheet for installation details
CS-01	Cold Storage Supply Air System	-	1	Refer to drawing HH-551 for construction details
CS-03	Cold Storage Return Air System	-	1	Refer to drawing HH-553 for construction details
WG-01	Unit model: SG-3014 RAG (In wall air exchange grille)	The Home Depot	5	N/A

B.E.E. Consulting Services

B.E.E Consulting Services

Notes:

1.) Refer to drawing HH-501 for location dimensions of RTUs
2.) All RTU units to be ordered with 14" roof curbs

MecE 460

Instructor: Dr. Duke

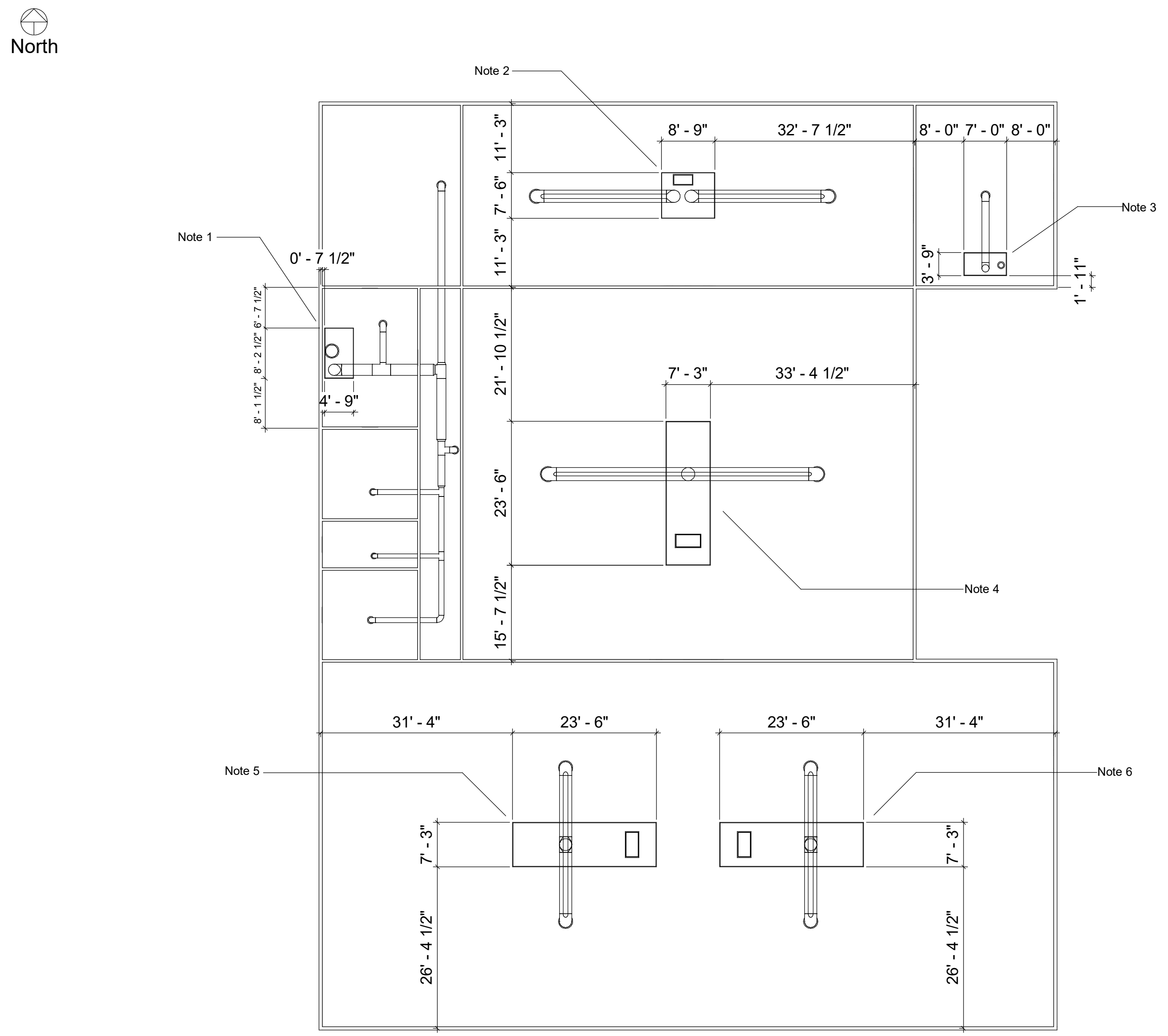
HVAC System Layout

Project Name:	Honey House
Date	November 30, 2019
Drawn by	Jake Bellerose
Checked by	Zoey Zhang

HH-500

Scale	1 : 100

02/12/2019 00:18:49



B.E.E Consulting Services

Notes:

1.) Install RTU 1 with return air opening facing to the north

2.) Install RTU 2 with return air opening facing to the north

3.) Install RTU 3 with return air opening facing to the east

4.) Install RTU 4 with return air opening facing to the south

5.) Install RTU 5 with return air opening facing to the east

6.) Install RTU 6 with return air opening facing to the west

MecE 460

Instructor: Dr. Duke

RTU Dimensions

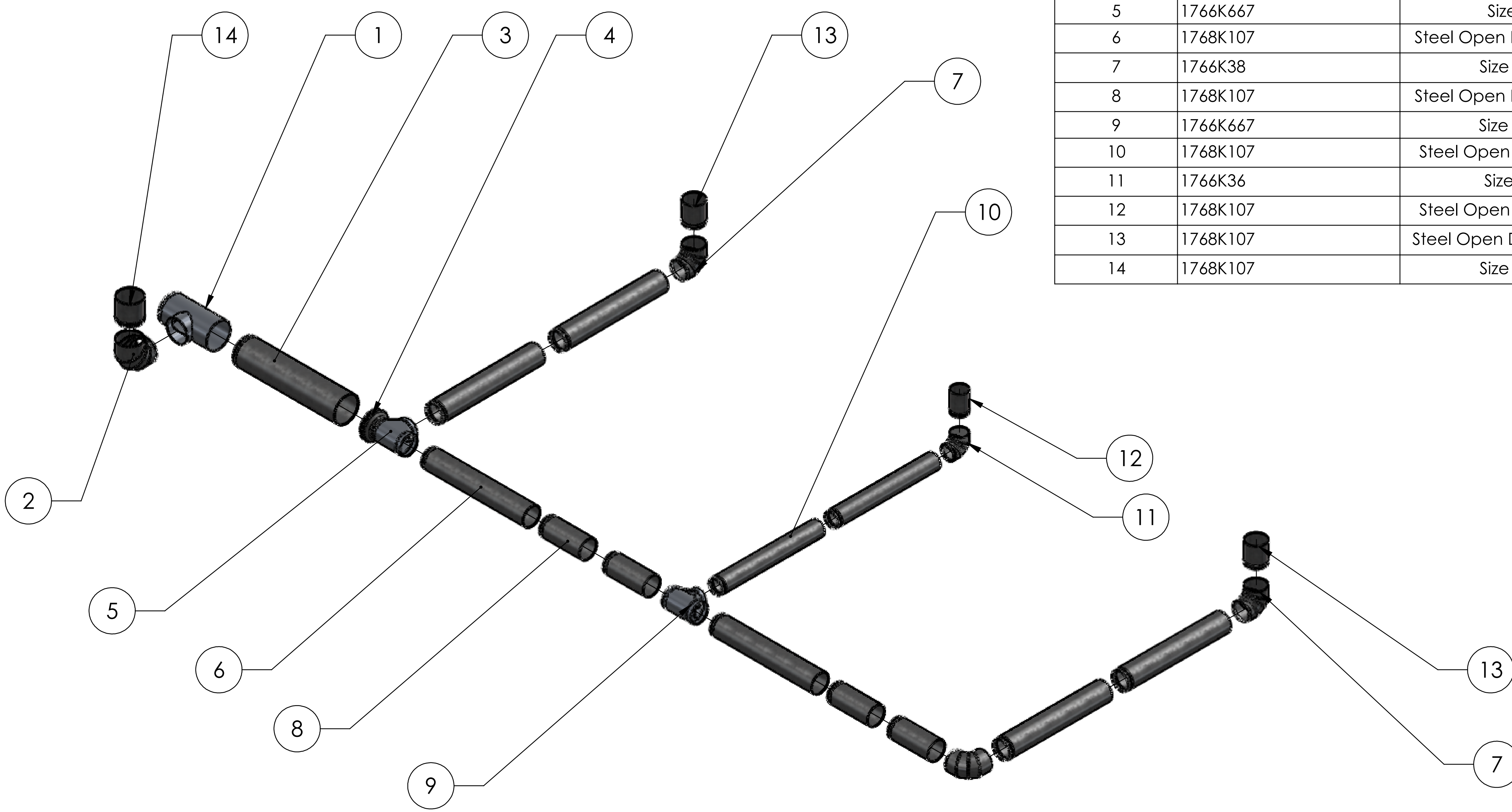
Project Name:	Honey House
Date	November 30, 2019
Drawn by	Jake Bellerose
Checked by	Zoey Zhang

HH-501

Scale	1 : 70

01/12/2019 09:55:55

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	1773K92	Size 14x12 Tee Connector	1
2	1766K39	Size 12 90 Degree Elbow	1
3	Assem1^Admin Wing		1
4	2013K64	Size 14x10 Reducer	1
5	1766K667	Size 10 Tee Connector	1
6	1768K107	Steel Open Duct Trade Size 10, Length 5'	6
7	1766K38	Size 10 90 Degree Elbow	3
8	1768K107	Steel Open Duct Trade Size 10, Length 2'	4
9	1766K667	Size 10x8 Tee Connector	1
10	1768K107	Steel Open Duct Trade Size 8, Length 5'	2
11	1766K36	Size 8 90 Degree Elbow	1
12	1768K107	Steel Open Duct Trade Size 8, Length 1'	1
13	1768K107	Steel Open Duct Trade Size 10, Length 2'	2
14	1768K107	Size 12 90 Degree Elbow	1



MecE 460
Instructor:
Dr. Duke
Fall 2019
Comments:
All parts available from McMaster-Carr

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X = ± 0.5
X.X = ± 0.1
X.XX = ± 0.025
SURFACE FINISH µm 0.6
DO NOT SCALE DRAWING

COMPANY NAME:
S.L.L. Consulting Services

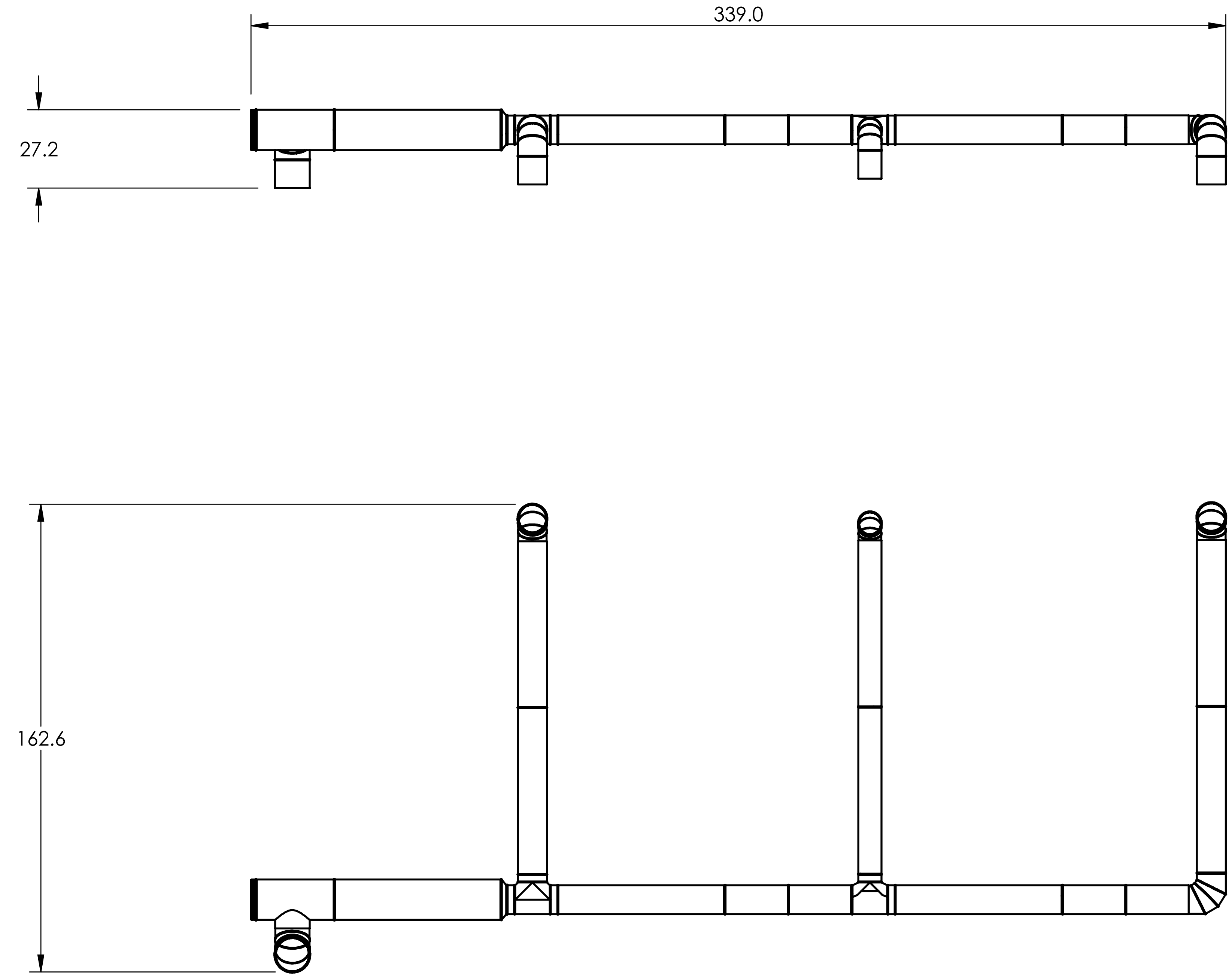
Modeled by: Jake Bellerose
Drawn by: Sai Avuthu
Checked by: Zoey Zhang
Date: November 29, 2019

The Department of Mechanical Engineering
UNIVERSITY OF ALBERTA

TITLE:
Storage, Washroom, Electrical Supply Air Duct System

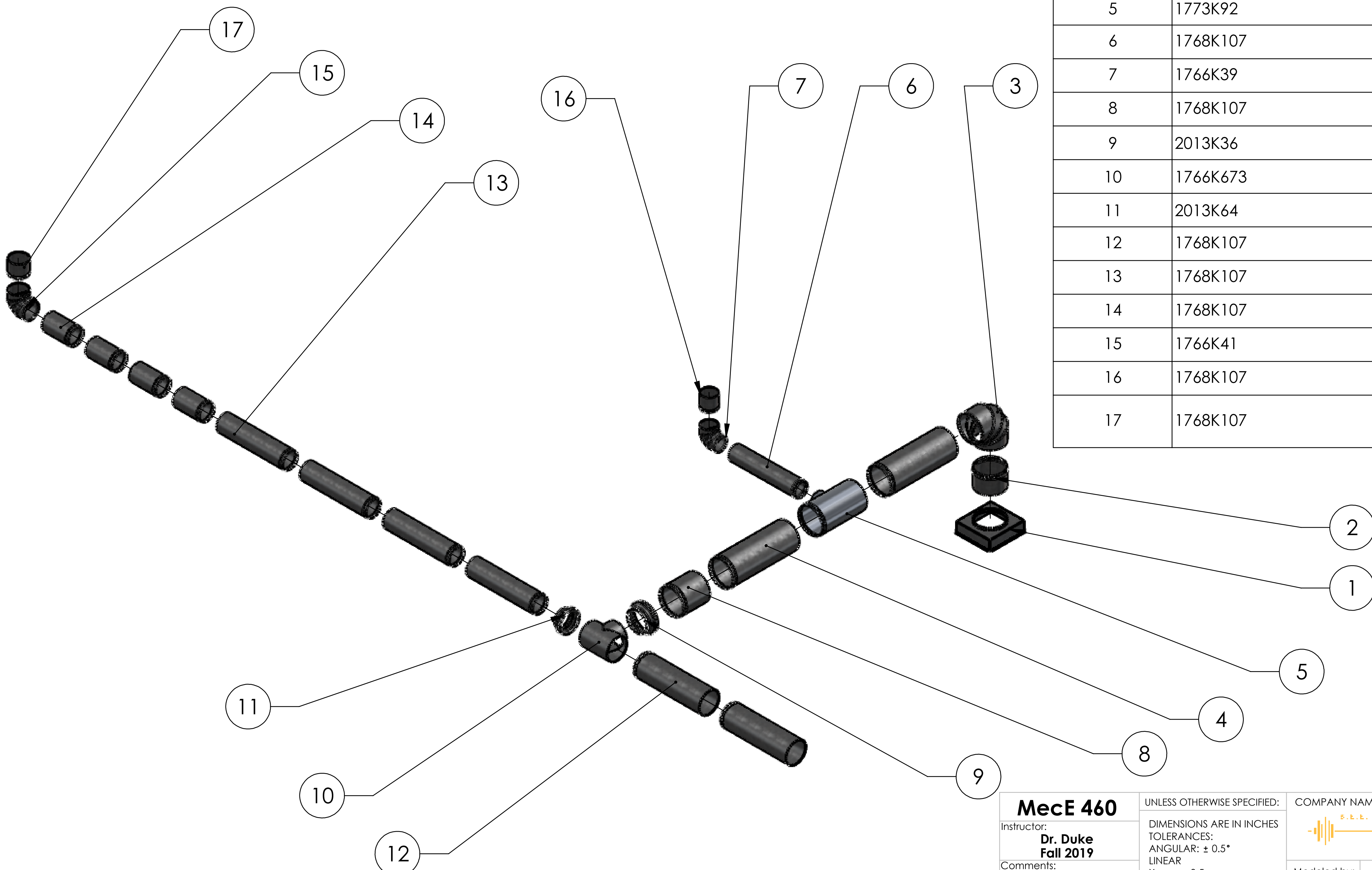
SIZE B | Part No: SWE-01 | REV 1

MATERIAL: Galvanized Steel
FILE NAME: HH-511
SCALE: 1:50 Mass: 201.59 SHEET 1 OF 2



MecE 460 Instructor: **Dr. Duke** **Fall 2019** Comments: All parts available from McMaster-Carr	UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES TOLERANCES: ANGULAR: ± 0.5° LINEAR X = ± 0.5 X.X = ± 0.1 X.XX = ± 0.025 SURFACE FINISH µm 0.6 DO NOT SCALE DRAWING	COMPANY NAME: Modeled by: Jake Bellerose Drawn by: Sai Avuthu Checked by: Zoey Zhang Date: November 29, 2019	The Department of Mechanical Engineering UNIVERSITY OF ALBERTA TITLE: Storage, Washroom, Electrical Supply Air Duct System SIZE **B** Part No: SWE-01 REV 1
MATERIAL: Galvanized Steel			
FILE NAME: HH-511			SCALE: 1:50 Mass: 201.59 SHEET 2 OF 2

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	AW-02	Administrative Wing Transition Piece	1
2	1768K107	Steel Open Duct Trade Size 22, Length 1.5'	1
3	1766K45	Size 22 90 Degree Elbow	1
4	1768K107	Steel Open Duct Trade Size 22, Length 5'	2
5	1773K92	Size 22x12 Tee Connector	1
6	1768K107	Steel Open Duct Trade Size 12, Length 5'	1
7	1766K39	Size 12 90 Degree Elbow	1
8	1768K107	Steel Open Duct Trade Size 12, Length 2'	1
9	2013K36	Size 22x18 Reducer	1
10	1766K673	Size 18x18 Tee Connector	1
11	2013K64	Size 18x14 Reducer	1
12	1768K107	Steel Open Duct Trade Size 18, Length 5'	2
13	1768K107	Steel Open Duct Trade Size 14, Length 5'	4
14	1768K107	Steel Open Duct Trade Size 14, Length 2'	4
15	1766K41	Size 14 90 Degree Elbow	1
16	1768K107	Size 12 90 Degree Elbow	1
17	1768K107	Steel Open Duct Trade Size 14, Length 1'	1



MecE 460
Instructor:
Dr. Duke
Fall 2019
Comments:
All parts available from McMaster-Carr

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X = ± 0.5
X.X = ± 0.1
X.XX = ± 0.025
SURFACE FINISH µm 0.6
DO NOT SCALE DRAWING

MATERIAL:
Galvanized Steel

FILE NAME:
HH-514

COMPANY NAME:
S.T.L. Consulting Services

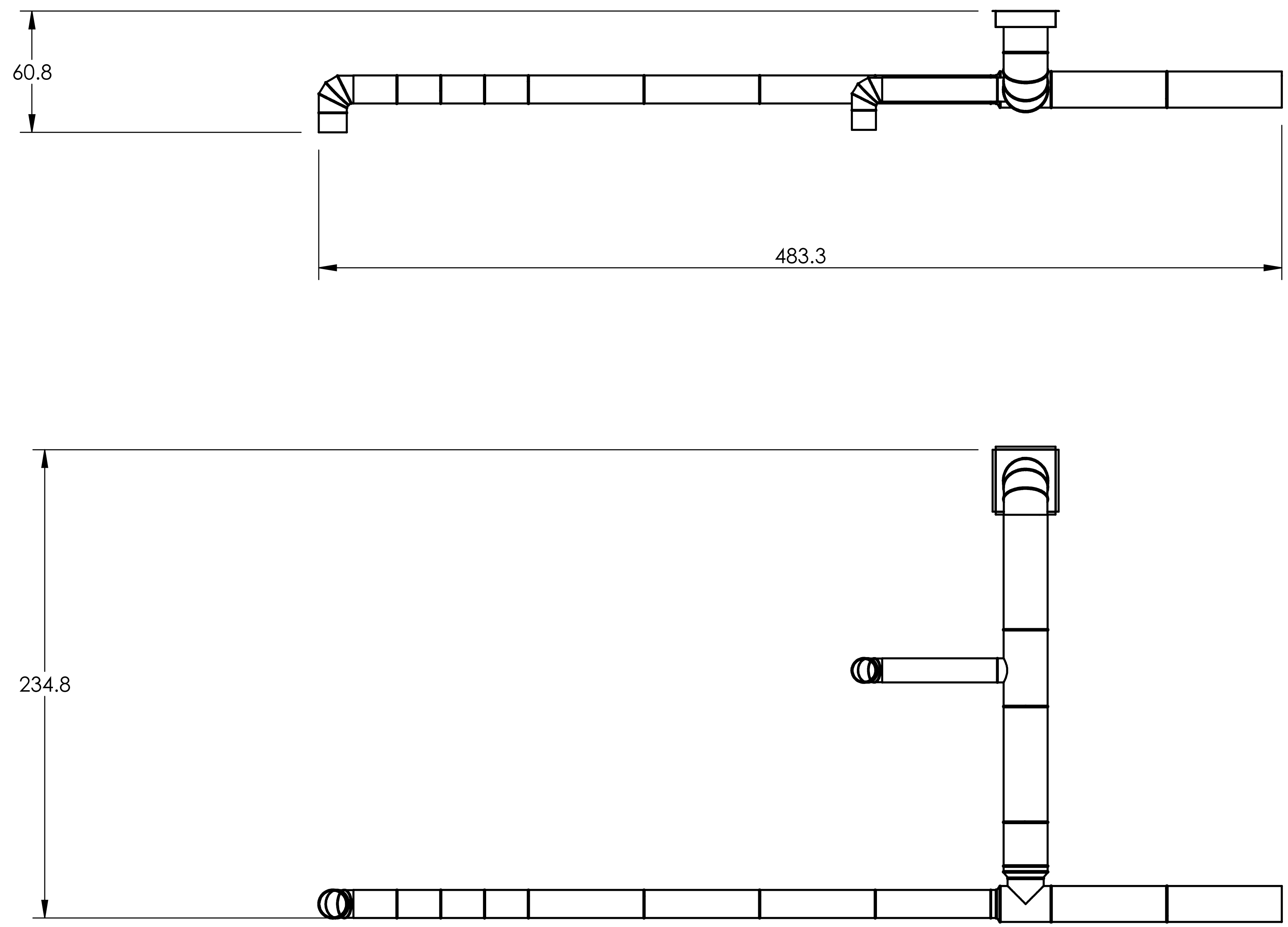
Modeled by: Jake Bellerose
Drawn by: Sai Avuthu
Checked by: Zoey Zhang
Date: November 30, 2019

The Department of Mechanical Engineering
UNIVERSITY OF ALBERTA

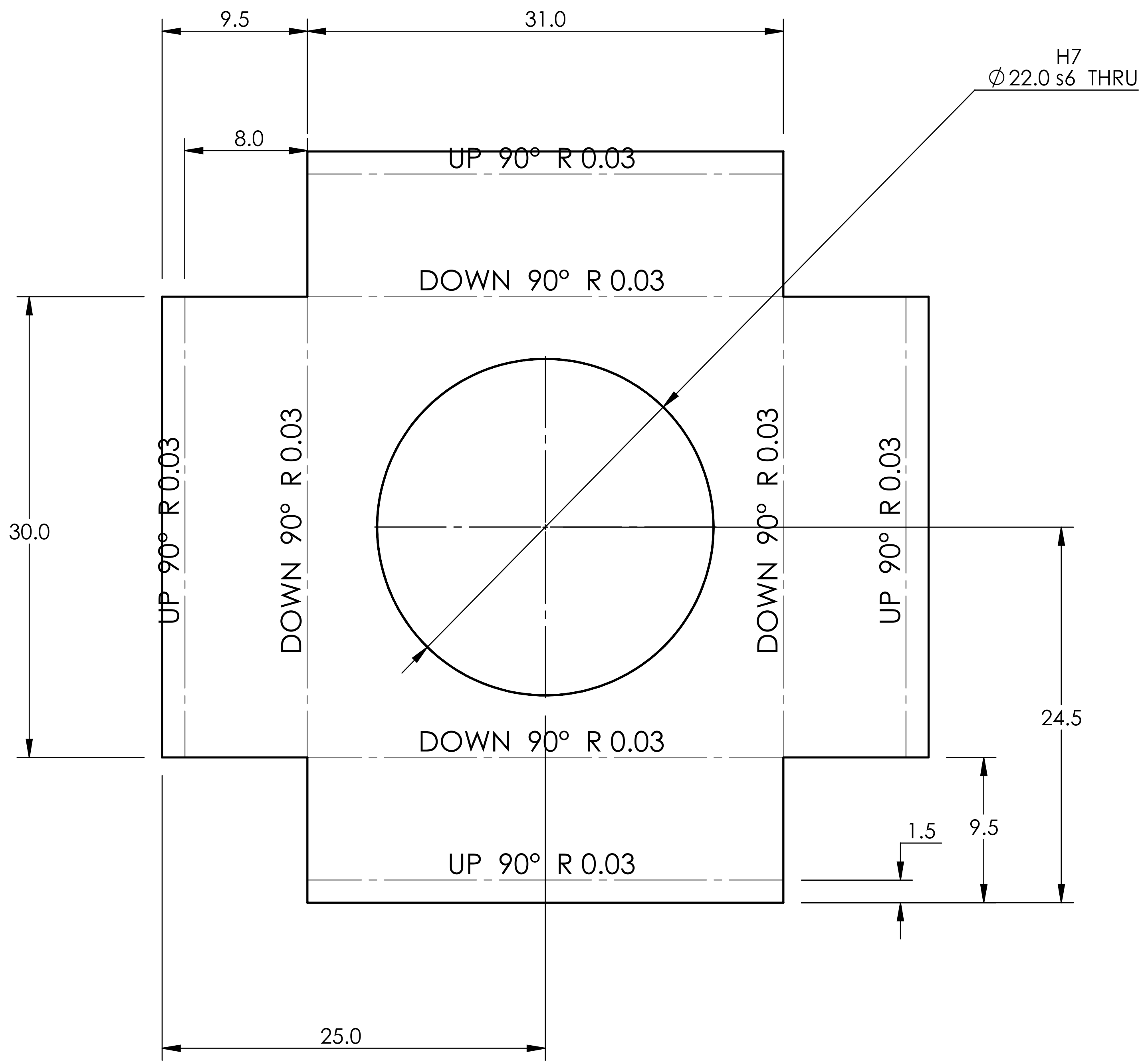
TITLE: Break, Hallway, Entrance Supply Air Duct System

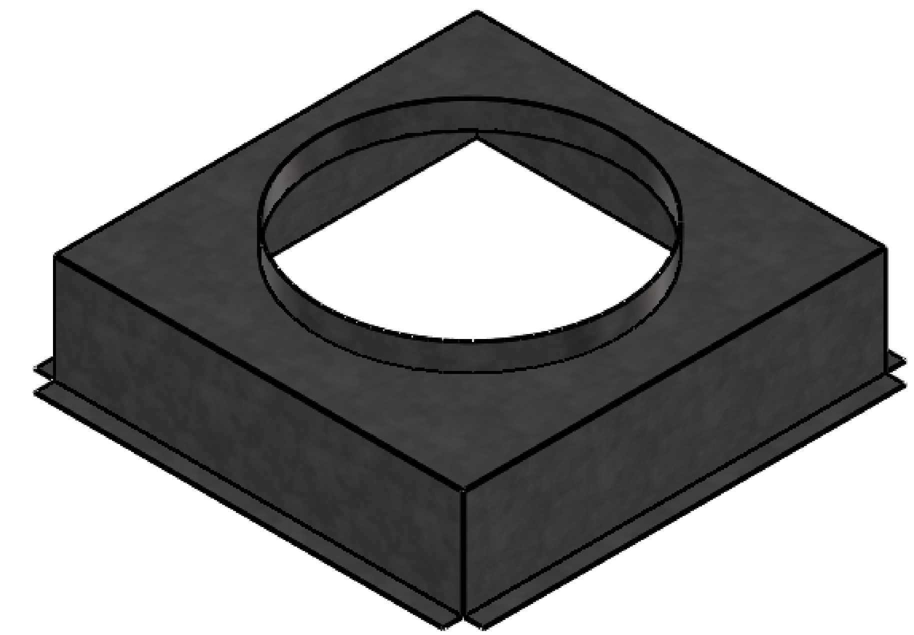
SIZE B | Part No: BHE-01 | REV 1

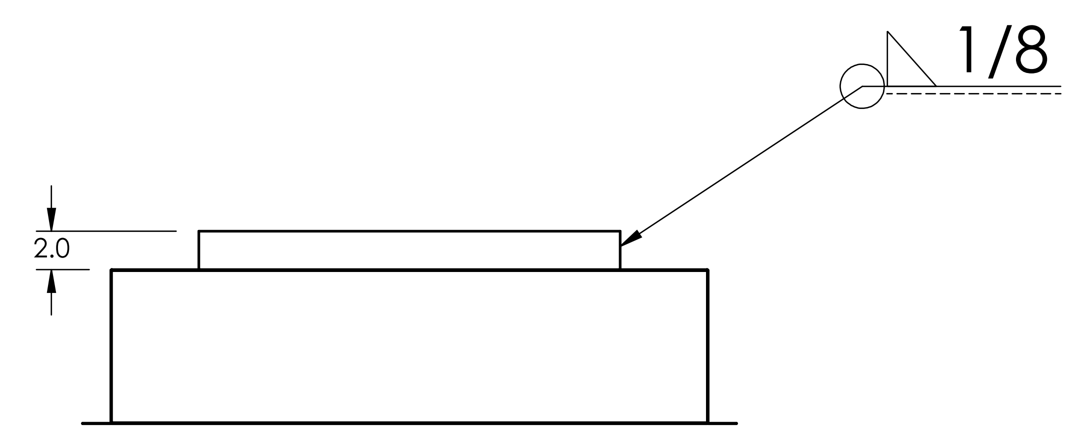
SCALE: 1:75 | Mass: 386.86 | SHEET 1 OF 2



MecE 460 Instructor: **Dr. Duke** **Fall 2019** Comments: All parts available from McMaster-Carr	UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES TOLERANCES: ANGULAR: ± 0.5° LINEAR X = ± 0.5 X.X = ± 0.1 X.XX = ± 0.025 SURFACE FINISH µm 0.6 DO NOT SCALE DRAWING	COMPANY NAME: Modeled by: Jake Bellerose Drawn by: Sai Avuthu Checked by: Zoey Zhang Date: November 30, 2019	The Department of Mechanical Engineering UNIVERSITY OF ALBERTA TITLE: Break, Hallway, Entrance Supply Air Duct System SIZE **B** Part No: BHE-01 REV 1
MATERIAL: Galvanized Steel			
FILE NAME: HH-514			SCALE: 1:75 Mass: 386.86 SHEET 2 OF 2







MecE 460
Instructor:
Dr. Duke
Fall 2019
Comments:

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X = ± 0.5
X.X = ± 0.1
X.XX = ± 0.025
SURFACE FINISH µm 0.6
DO NOT SCALE DRAWING

MATERIAL:
Galvanized Steel, 24 Gauge
FILE NAME:
HH-516

COMPANY NAME:

Modeled by:	Jake Bellerose
Drawn by:	Sai Avuthu
Checked by:	Zoey Zhang
Date:	November 30, 2019

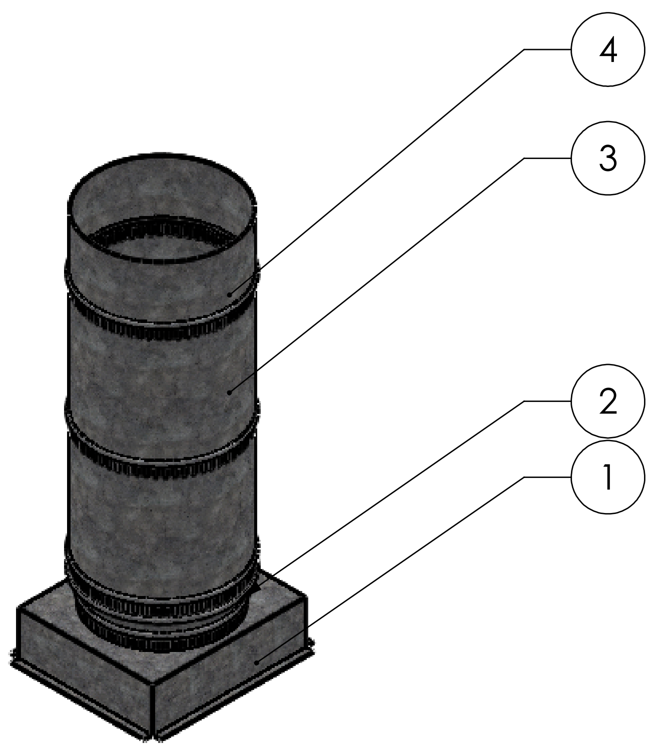
The Department of Mechanical Engineering
UNIVERSITY OF ALBERTA

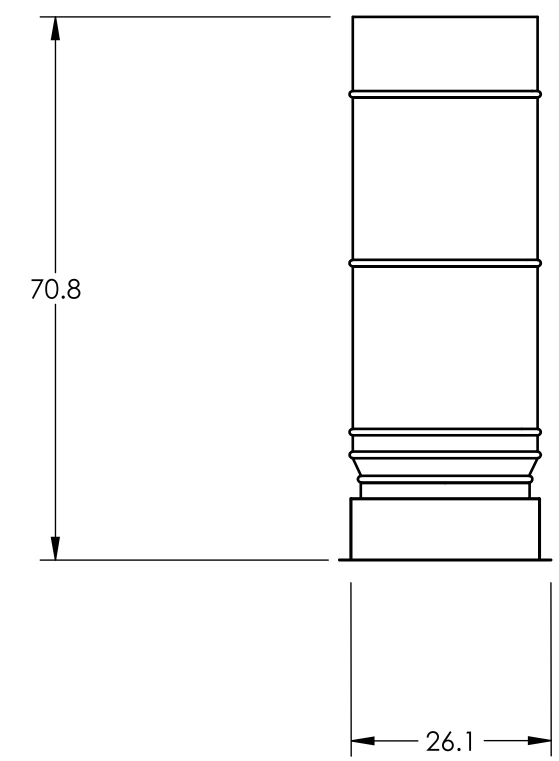
TITLE:
Administrative Wing Supply Air Transition

SIZE B | Part No: AW-03 | REV 1

SCALE: 1:10 Mass: 12.66 SHEET 1 OF 1

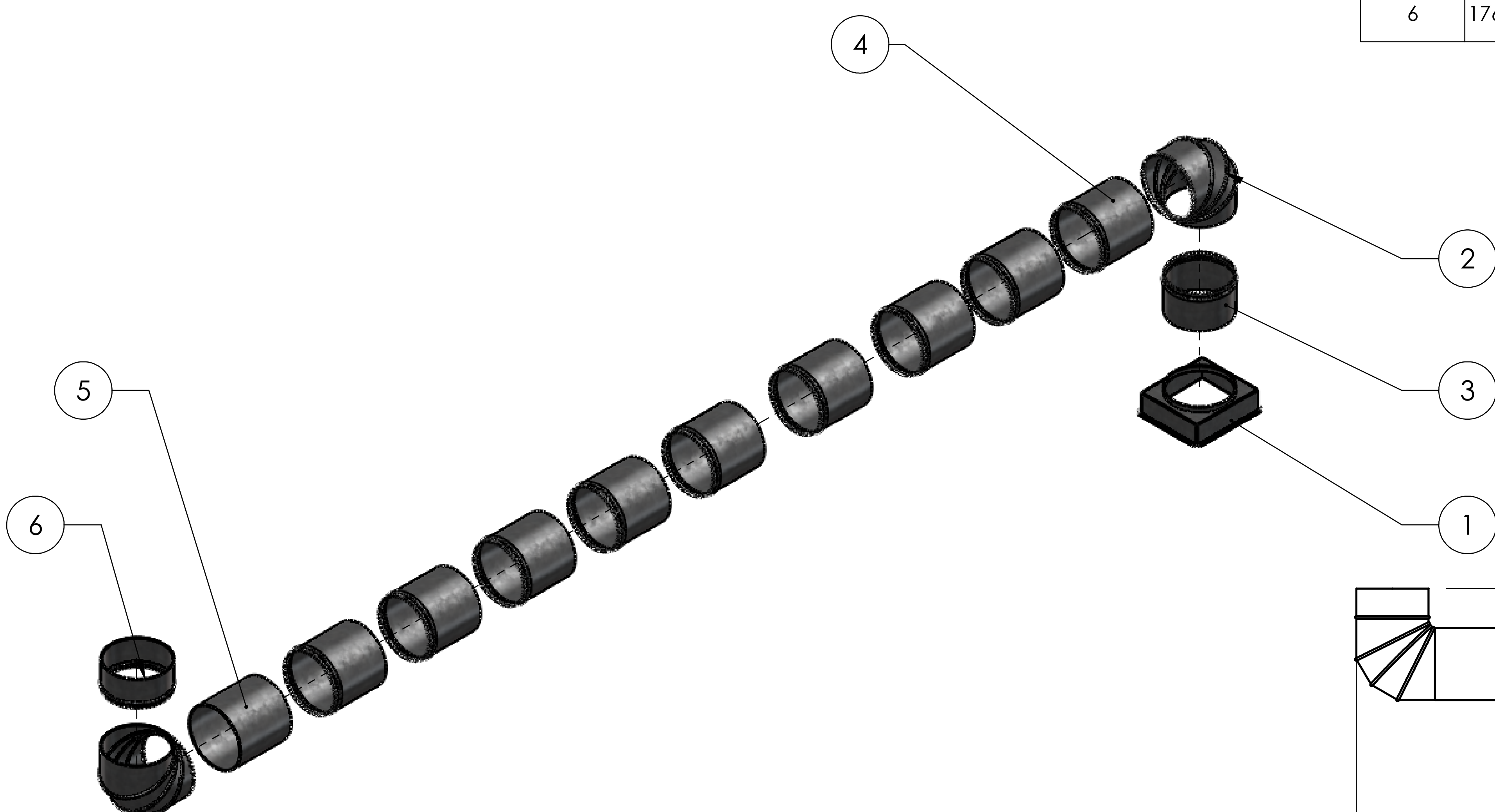
ITEM NO.	PART NUMBER	DESCRIPTION	VENDOR	QTY.
1	AW-03	Administrative Wing Transition Piece	McMaster-Carr	1
2	2013K36	Size 24x22 Reducer	McMaster-Carr	1
3	1768K107	Steel Open Duct Trade Size 24, Length 2'	McMaster-Carr	2
4	1768K107	Steel Open Duct Trade Size 24, Length 1'	McMaster-Carr	1

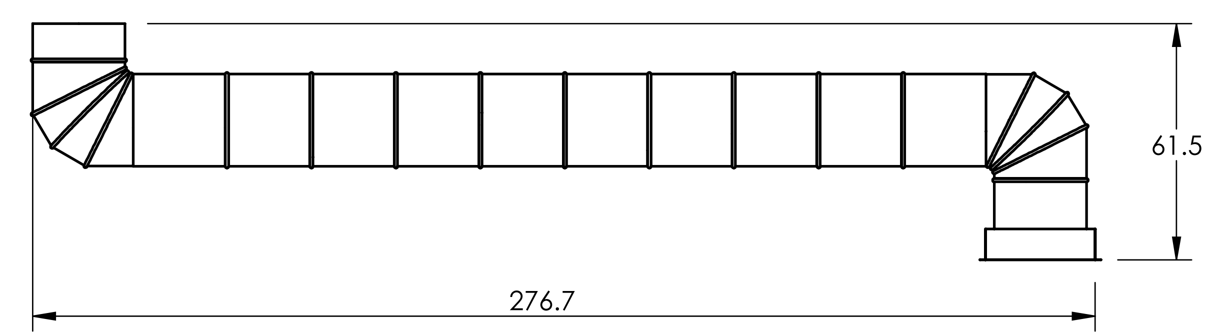




MecE 460 Instructor: **Dr. Duke Fall 2019** Comments:	UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES TOLERANCES: ANGULAR: ± 0.5° LINEAR X = ± 0.5 X.X = ± 0.1 X.XX = ± 0.025 SURFACE FINISH µm 0.6 DO NOT SCALE DRAWING	COMPANY NAME: S.L.L. Consulting Services	The Department of Mechanical Engineering UNIVERSITY OF ALBERTA
		Modeled by: Jake Bellerose	TITLE: Administrative Wing Return Air Duct System
		Drawn by: Sai Avuthu	
		Checked by: Zoey Zhang	
MATERIAL: Galvanized Steel		Date: November 30, 2019	SIZE B Part No: BHE-03 REV 1
FILE NAME: HH-516			SCALE: 1:25 Mass: 69.01 SHEET 1 OF 1

ITEM NO.	PART NUMBER	DESCRIPTION	VENDOR	QTY.
1	TR-03	Hot Storage Transition Piece		1
2	1766K46	Size 24 90 Degree Elbow	McMaster-Carr	2
3	1768K107-A1	Steel Open Duct Trade Size 24, Length 1'3"	McMaster-Carr	1
4	1768K107	Steel Open Duct Trade Size 24	McMaster-Carr	9
5	1768K107-A2	Steel Open Duct Trade Size 24, Length 1'11"	McMaster-Carr	1
6	1768K107-A3	Steel Open Duct Trade Size 24, Length 1'	McMaster-Carr	1





NOTE: Parts 1768K107-A1, 1768K107-A2 and 1768K107-A3 will be stock parts ordered from McMaster-Carr (ID 1768K107)to be cut to length specified in bill of materials

MecE 460
Instructor: **Dr. Duke**
Fall 2019
Comments:

MATERIAL: Galvanized Steel
Drawing Number: HH-521

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X = ± 0.5
X.X = ± 0.1
X.XX = ± 0.025
SURFACE FINISH µm 0.6
DO NOT SCALE DRAWING

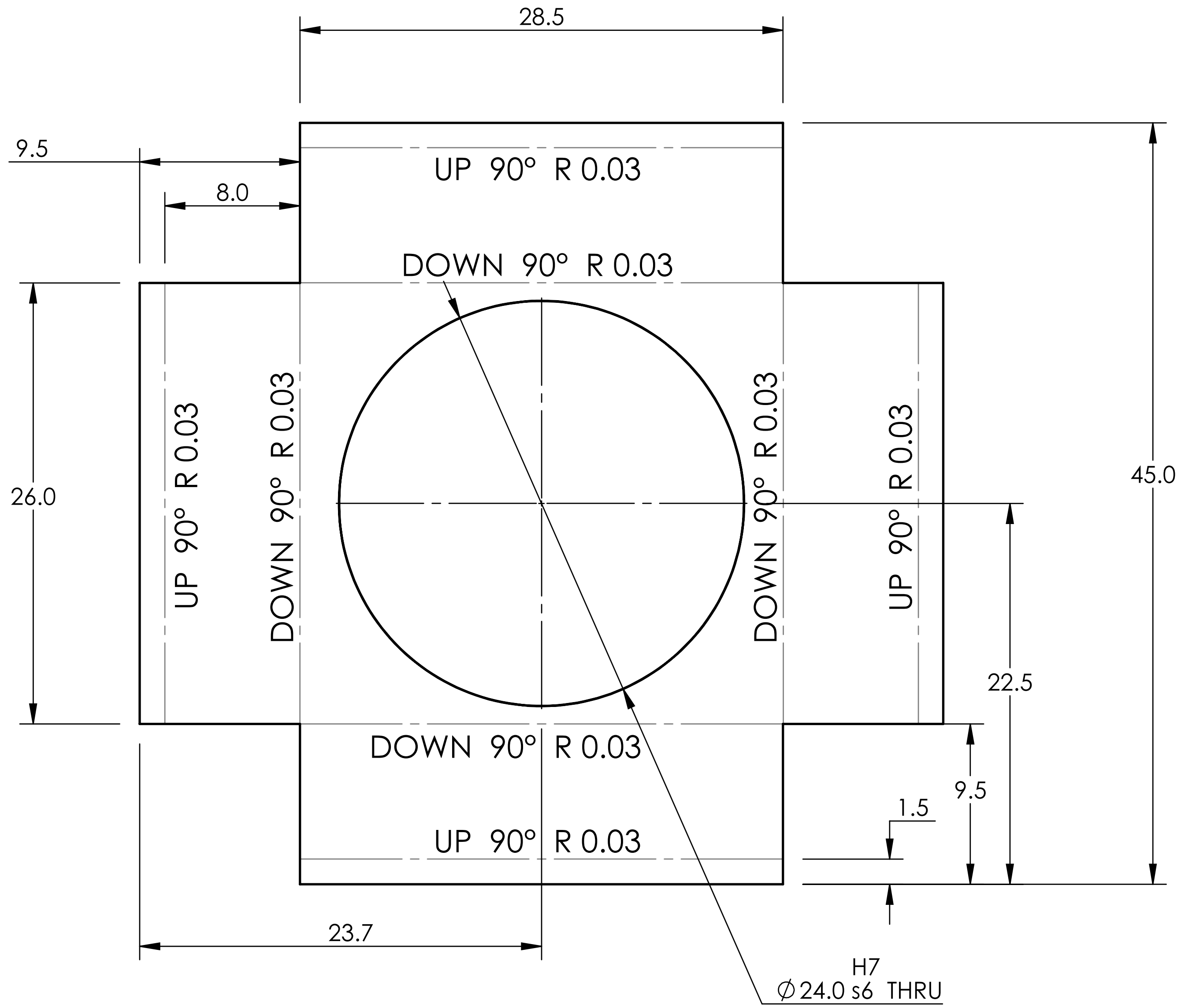
COMPANY NAME: S.E.L. Consulting Services
Modeled by: Jake Bellerose
Drawn by: Zoey Zhang
Checked by: Jake Bellerose
Date: November 29, 2019

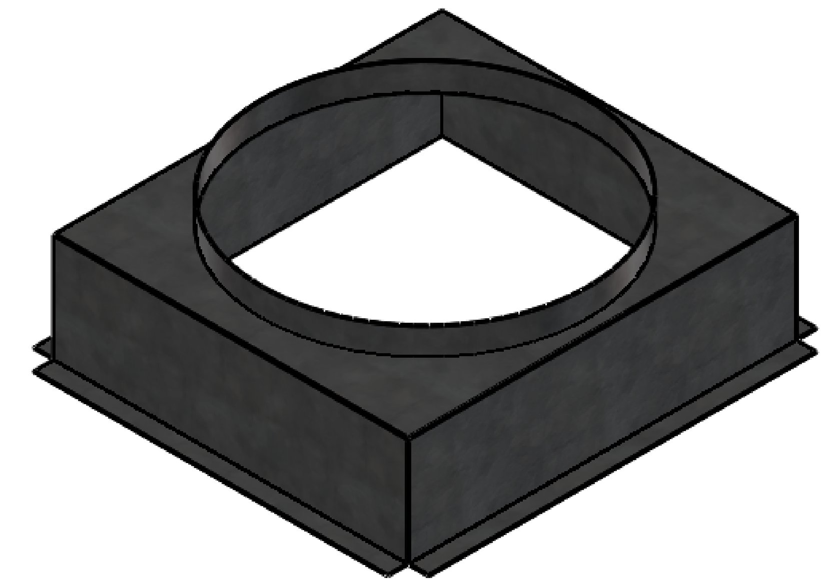
The Department of Mechanical Engineering
UNIVERSITY OF ALBERTA

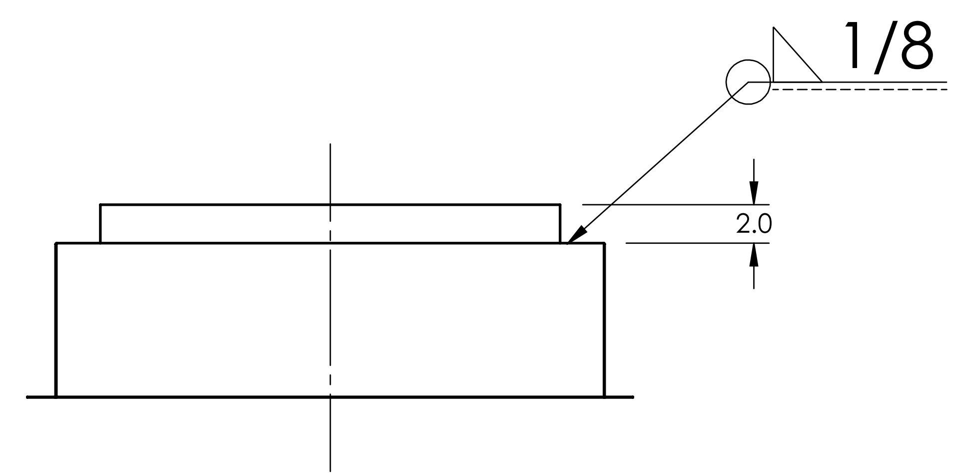
TITLE: Hot Storage Supply Air Duct

SIZE **B** | Part No: HS-01 | REV 1

SCALE: 1:50 | Mass: 272.05 | SHEET 1 OF 1







MecE 460
Instructor:
Dr.Duke
Fall 2019
Comments:

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DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X = ± 0.5
X.X = ± 0.1
X.XX = ± 0.025
SURFACE FINISH µm 0.6
DO NOT SCALE DRAWING

COMPANY NAME:
S.E.E. Consulting Services

Modeled by:	Jake Bellerose
Drawn by:	Zoey Zhang
Checked by:	Sai Avuthu
Date:	November 29, 2019

MATERIAL:
Galvanized Steel, 24 Gauge

Drawing Number:
HH-522

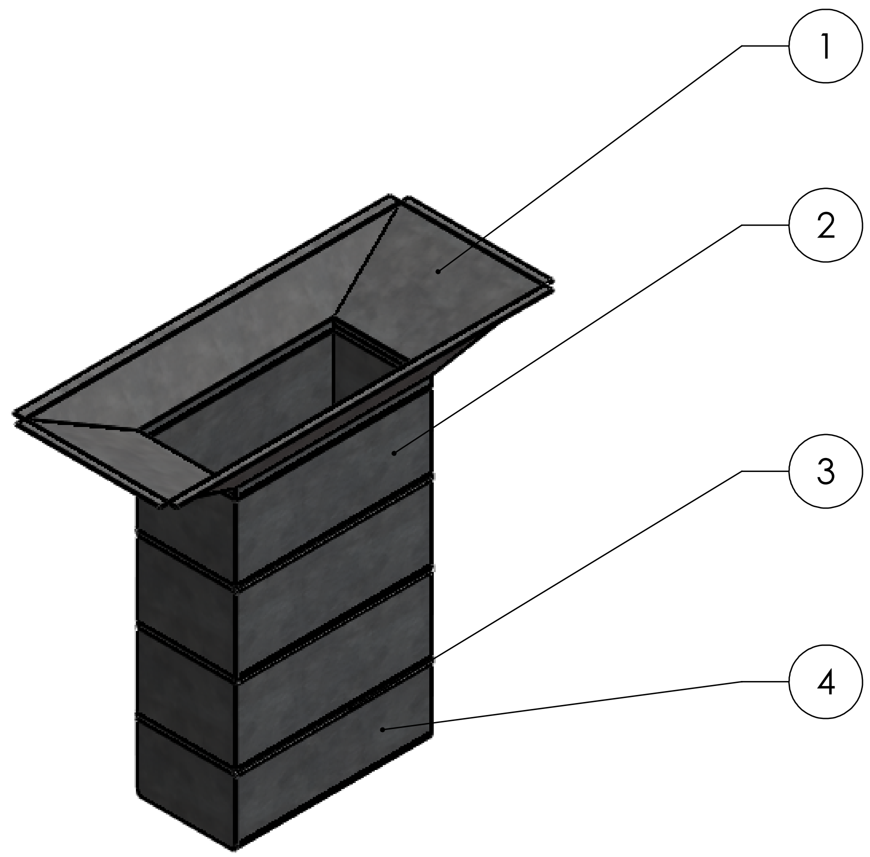
The Department of Mechanical Engineering
UNIVERSITY OF ALBERTA

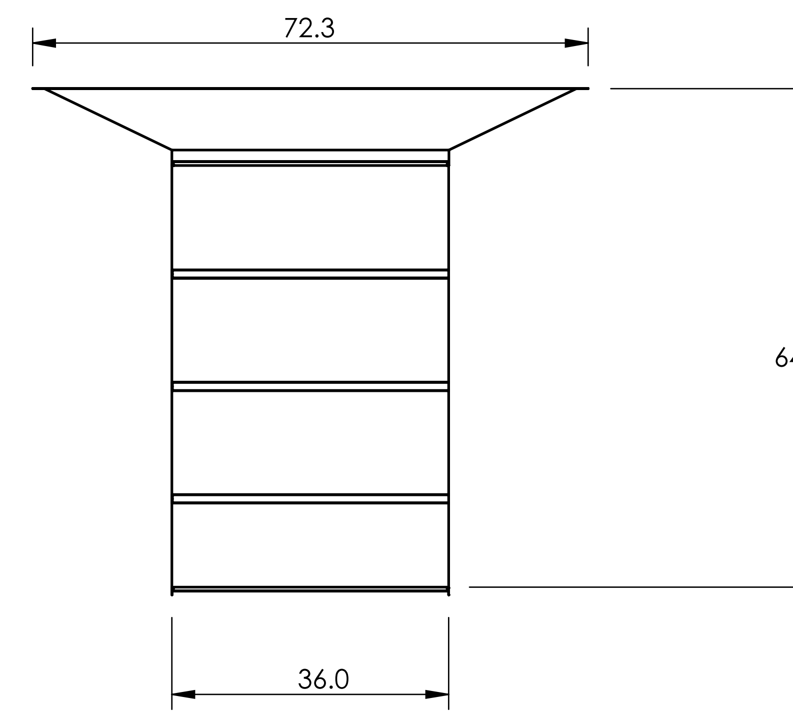
TITLE:
Hot Room Supply Air Transition

SIZE **B** Part No: HR-02 REV 1

SCALE: 1:10 Mass: 9.97 SHEET 1 OF 1

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	HS-04	Return Supply Air Piece 18"x36"	1
2	1964K87	Rectangular Duct 18"x36"x4'	3
3	1964K94	Drive Bracket	6
4	1964K86	Rectangular Duct 18"x36"x1'	1





MecE 460
Instructor: **Dr. Duke**
Fall 2019
Comments:

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DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X = ± 0.5
X.X = ± 0.1
X.XX = ± 0.025
SURFACE FINISH µm 0.6
DO NOT SCALE DRAWING

MATERIAL:

COMPANY NAME:
Modeled by: Jake Bellerose
Drawn by: Jake Bellerose
Checked by: Zoey Zhang
Date: November 29, 2019

The Department of Mechanical Engineering
UNIVERSITY OF ALBERTA

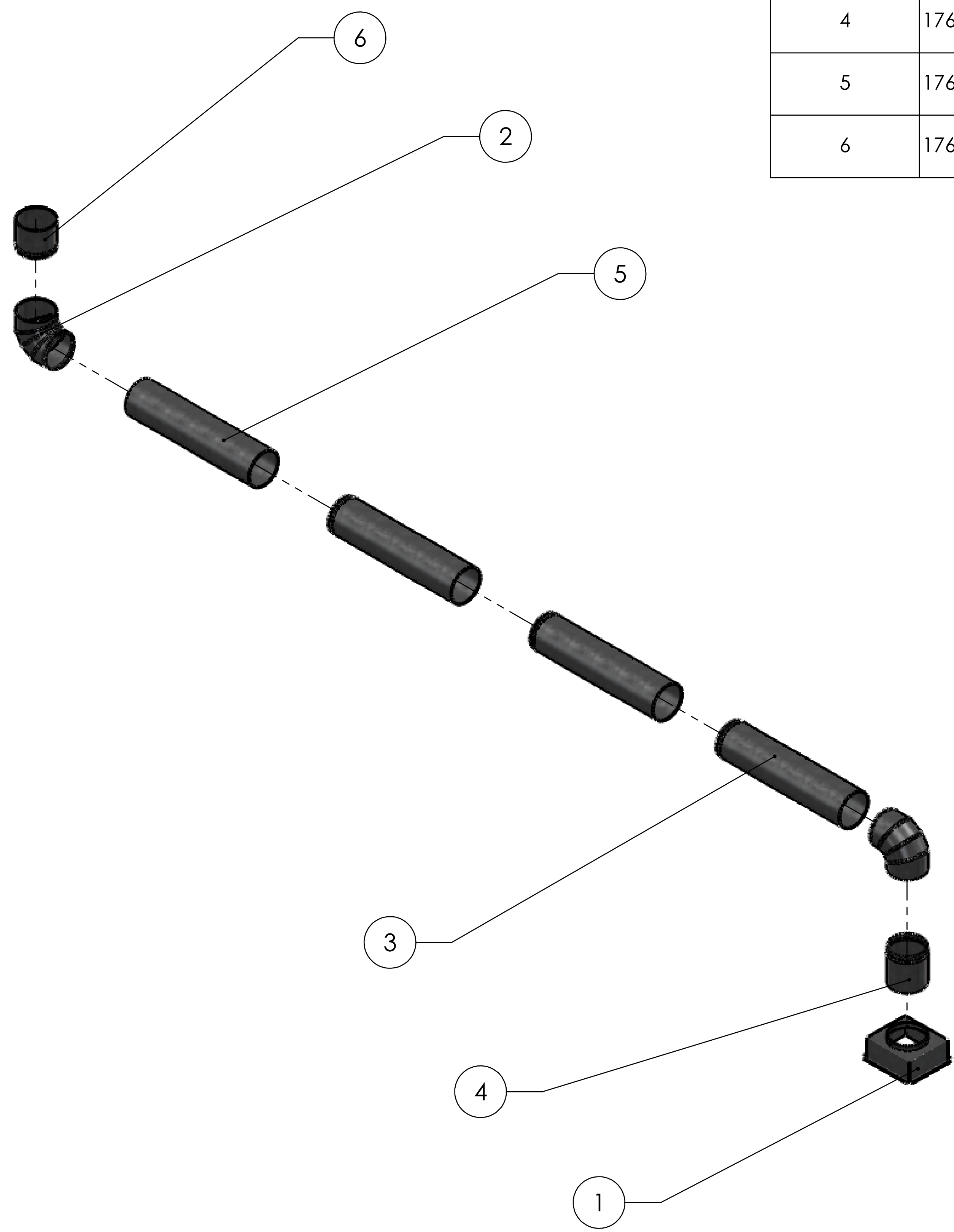
TITLE:
Hot Room Return Air Duct System

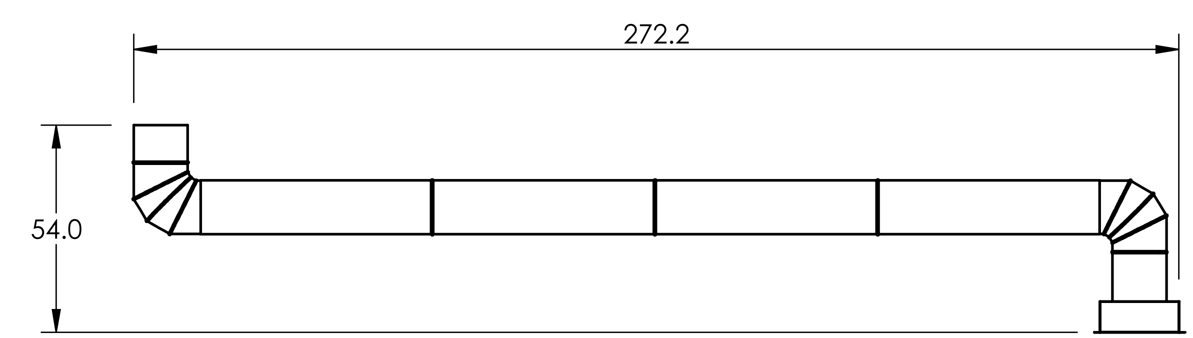
SIZE **B** | Part No: HR-03 | REV 1

Drawing Number: HH-523

SCALE: 1:25 Mass: SHEET 1 OF 1

ITEM NO.	PART NUMBER	DESCRIPTION	VENDOR	QTY.
1	TR-03	Transition Room Transition Piece	McMaster-Carr	1
2	1766K41	Size 14 90 Degree Elbow	McMaster-Carr	2
3	1768K107	Steel Open Duct Trade Size 14 MxF, Length 5'	McMaster-Carr	3
4	1768K107-D1	Steel Open Duct Trade Size 14 MxF, Length 1.5'	McMaster-Carr	1
5	1768K107-D2	Steel Open Duct Trade Size 14 FxF, Length 5'	McMaster-Carr	1
6	1768K107-D3	Steel Open Duct Trade Size 14 MxF, Length 1'	McMaster-Carr	1





MecE 460
Instructor:
Dr. Duke
Fall 2019
Comments:

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DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X = ± 0.5
X.X = ± 0.1
X.XX = ± 0.025
SURFACE FINISH µm 0.6
DO NOT SCALE DRAWING

COMPANY NAME:
S.E.L. Consulting Services

Modeled by: Jake Bellerose
Drawn by: Sai Avuthu
Checked by: Zoey Zhang
Date: November 30, 2019

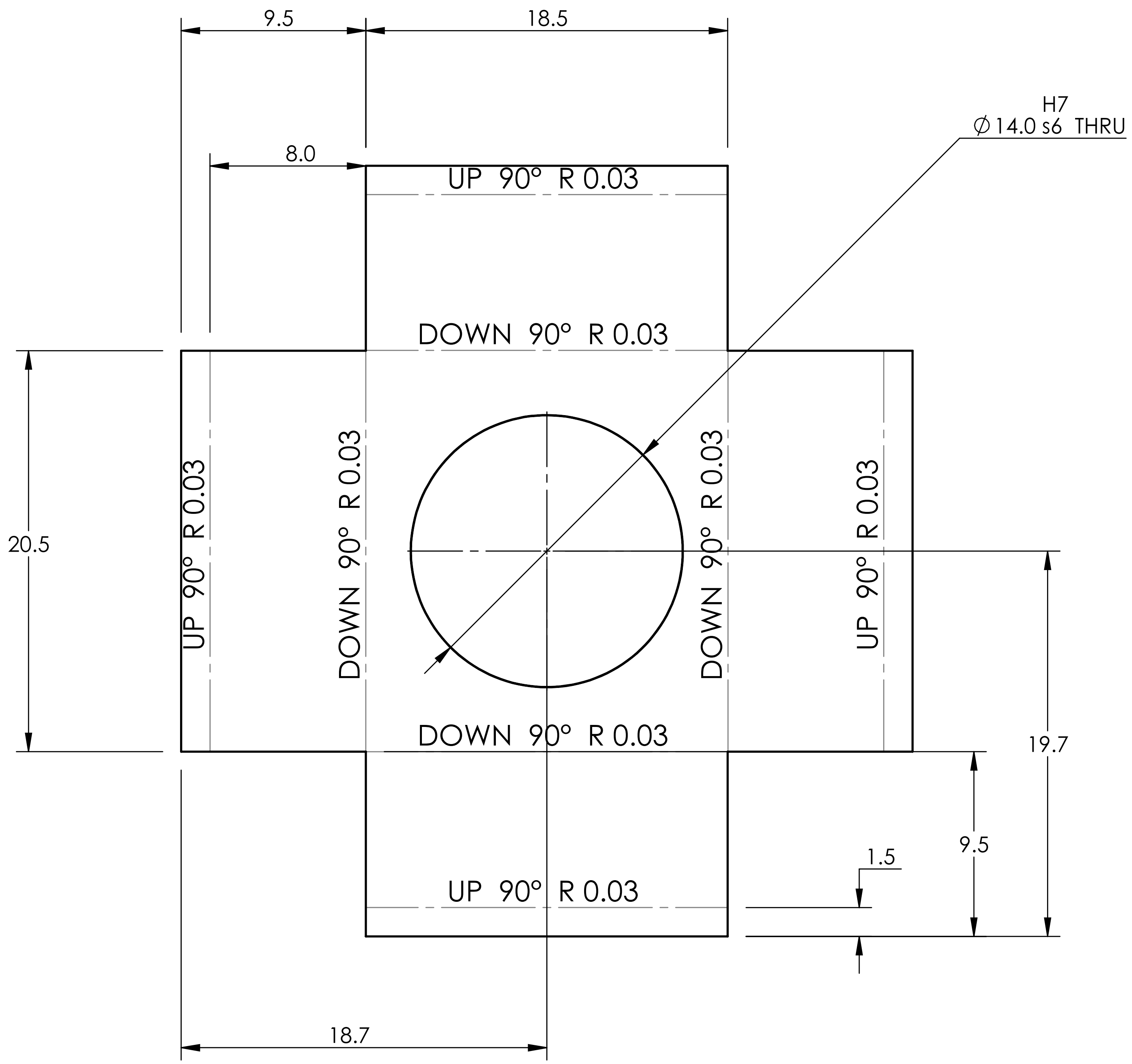
The Department of Mechanical Engineering
UNIVERSITY OF ALBERTA

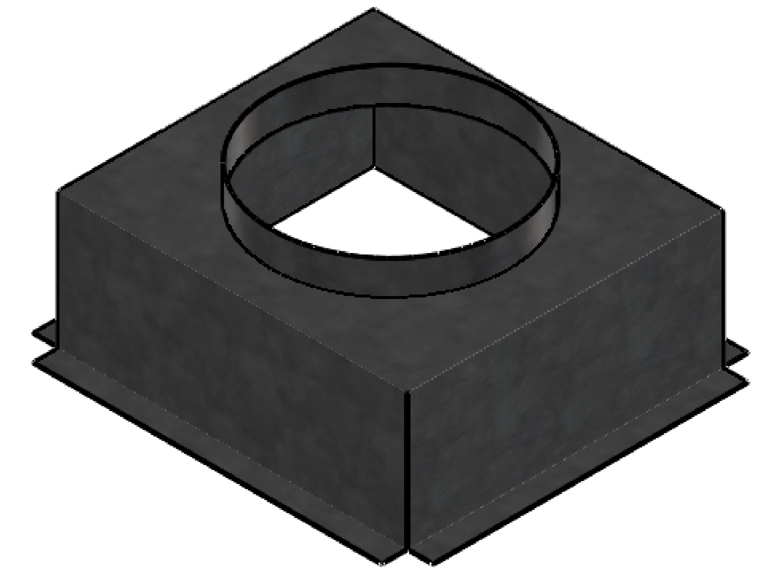
TITLE:
Transition Room Supply Air Duct System

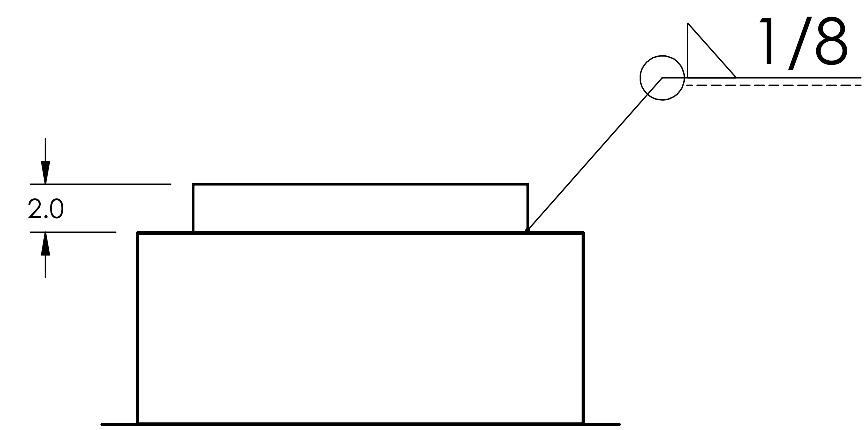
MATERIAL: Galvanized Steel
FILE NAME: HH-531

SIZE **B** | Part No: TR-01 | REV 1

SCALE: 1:50 | Mass: 121.18 | SHEET 1 OF 1







MecE 460
Instructor:
Dr. Duke
Fall 2019
Comments:

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TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X = ± 0.5
X.X = ± 0.1
X.XX = ± 0.025
SURFACE FINISH µm 0.6
DO NOT SCALE DRAWING

MATERIAL:
Galvanized Steel, 24 Gauge
FILE NAME:
HH-532

COMPANY NAME:

Modeled by:	Jake Bellerose
Drawn by:	Sai Avuthu
Checked by:	Zoey Zhang
Date:	November 30, 2019

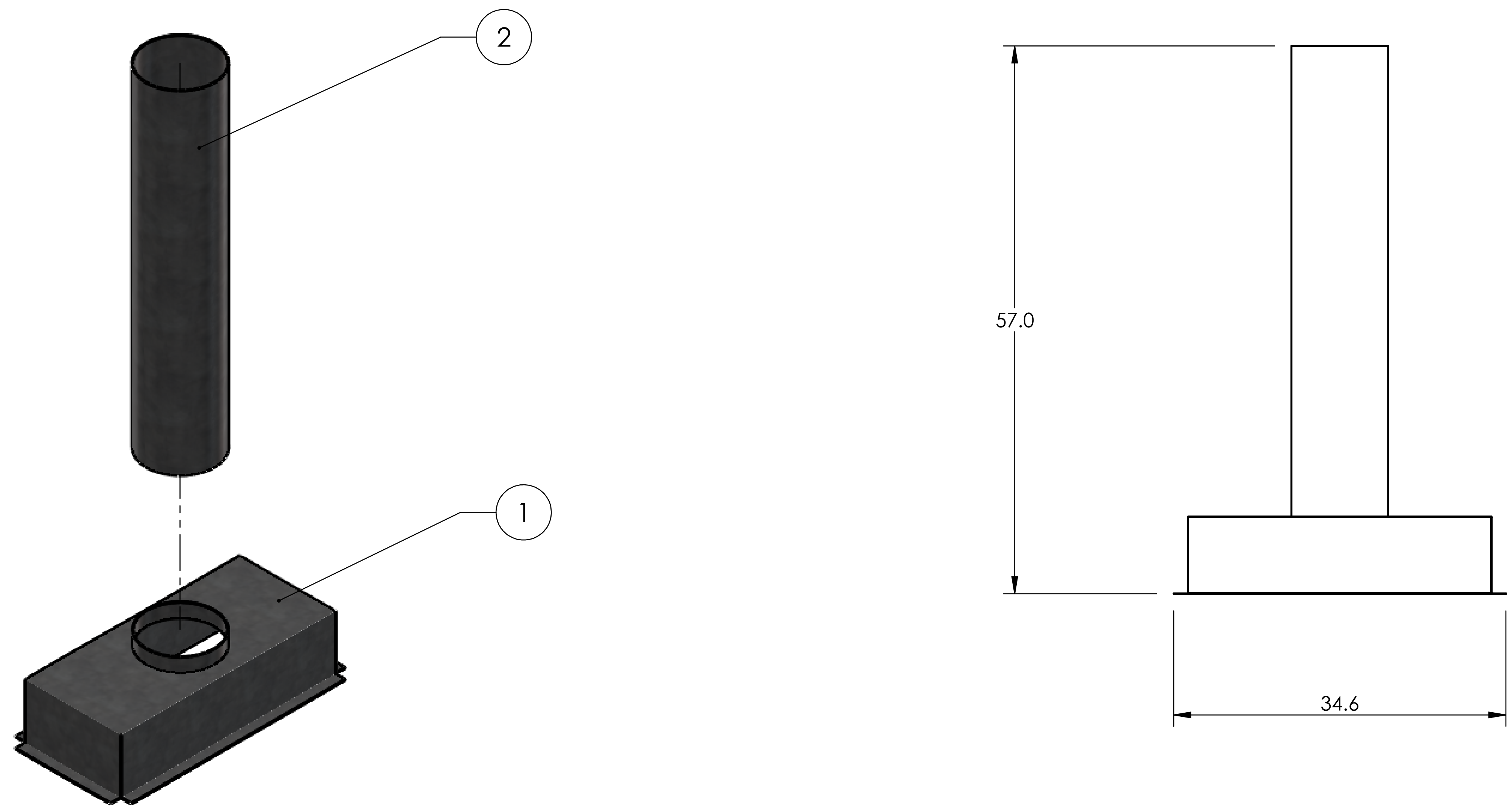
The Department of Mechanical Engineering
UNIVERSITY OF ALBERTA

TITLE:
Transition Room Supply Air Transition

SIZE **B**
Part No: TR-02
REV 1

SCALE: 1:8 Mass: 7.20 SHEET 1 OF 1

ITEM NO.	PART NUMBER	DESCRIPTION	VENDOR	QTY.
1	TR-03	Transition Room Transition Piece	McMaster-Carr	1
2	1768K107	Steel Open Duct Trade Size 10 FxF	McMaster-Carr	1



MecE 460
Instructor: **Dr. Duke**
Fall 2019
Comments:

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TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X = ± 0.5
X.X = ± 0.1
X.XX = ± 0.025
SURFACE FINISH µm 0.6
DO NOT SCALE DRAWING

COMPANY NAME: S.L.E. Consulting Services

Modeled by:	Jake Bellerose
Drawn by:	Sai Avuthu
Checked by:	Zoey Zhang
Date:	November 30, 2019

MATERIAL: Galvanized Steel
FILE NAME: HH-533

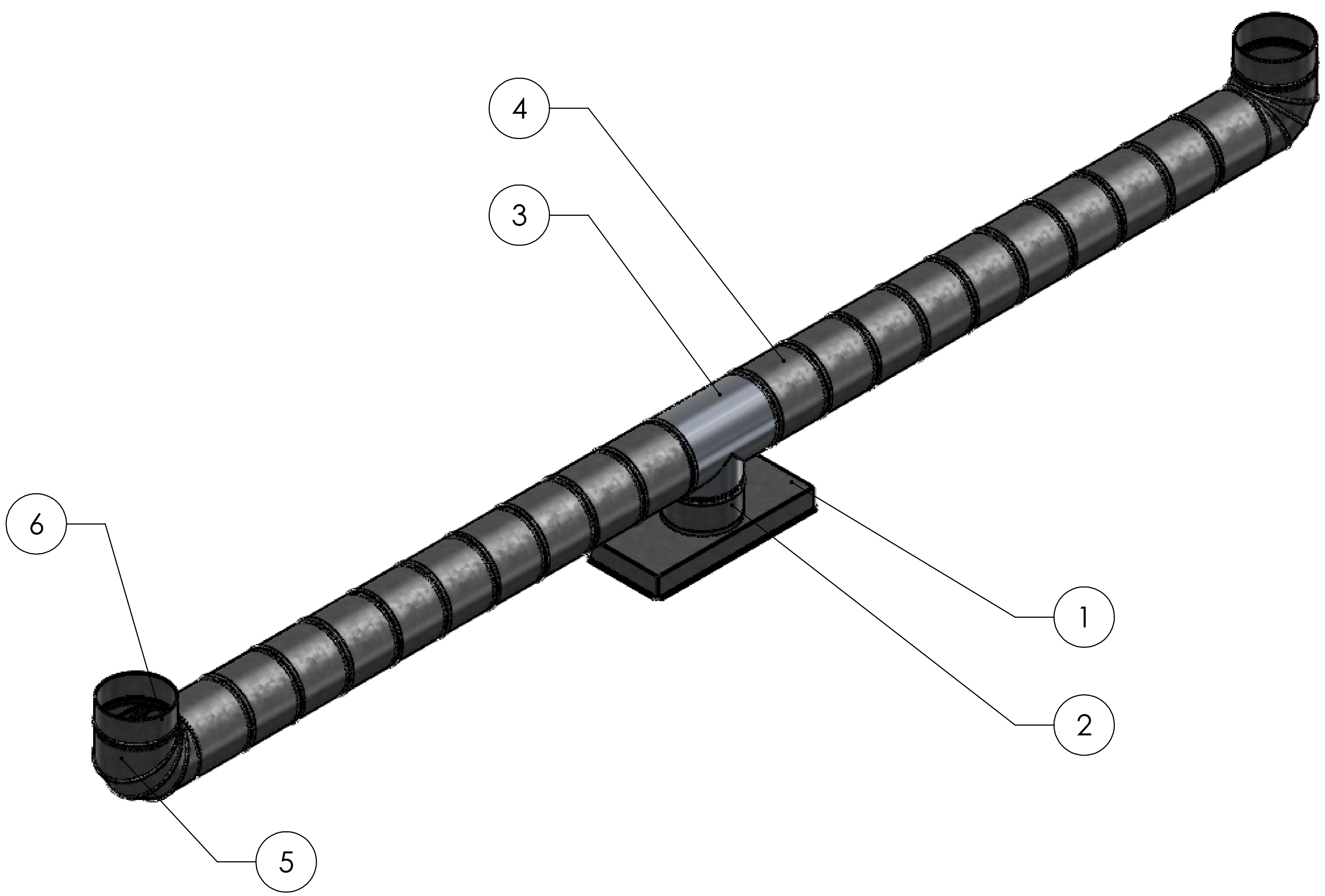
The Department of Mechanical Engineering
UNIVERSITY OF ALBERTA

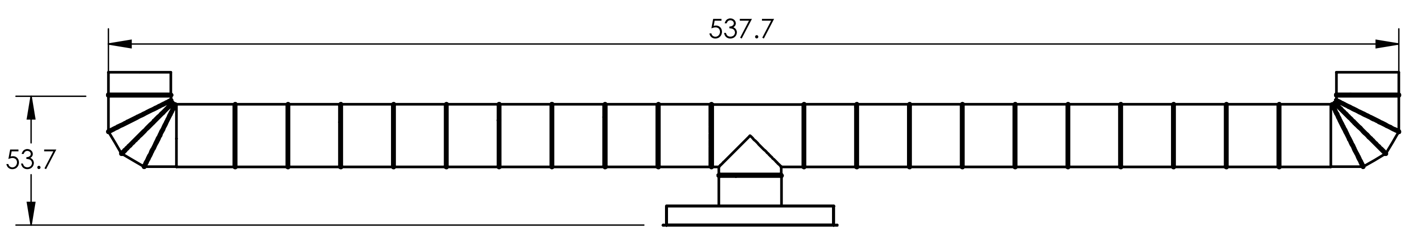
TITLE:
Transition Room Return Air Duct System

SIZE B | Part No: TR-03 | REV 1

SCALE: 1:15 | Mass: 21.07 | SHEET 1 OF 1

ITEM NO.	PART NUMBER	DESCRIPTION	VENDOR	QTY.
1	EX-02	Extraction room Supply Air Transition		1
2	1768K107-C1	Steel Open Duct Trade Size 24, Length 1'3"	McMaster-Carr	1
3	1773K92	Trade Size 20 Aluminum Tee Connector	McMaster-Carr	1
4	1768K107	Steel Open Duct Trade Size 24	McMaster-Carr	20
5	1766K46	Size 24 90 Degree Elbow	McMaster-Carr	2
6	1768K107-C2	Steel Open Duct Trade Size 24, Length 1'11"	McMaster-Carr	2





Scale 1:80

NOTE: Parts 1768K107-C1 and 1768K107-C2 will be stock parts ordered from McMaster-Carr (ID 1768K107)to be cut to length specified in bill of materials

MecE 460
Instructor: Dr.Duke
Fall 2019
Comments:

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TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X = ± 0.5
X.X = ± 0.1
X.XX = ± 0.025
SURFACE FINISH µm 0.6
DO NOT SCALE DRAWING

MATERIAL: Various
Drawing Number: HH-541

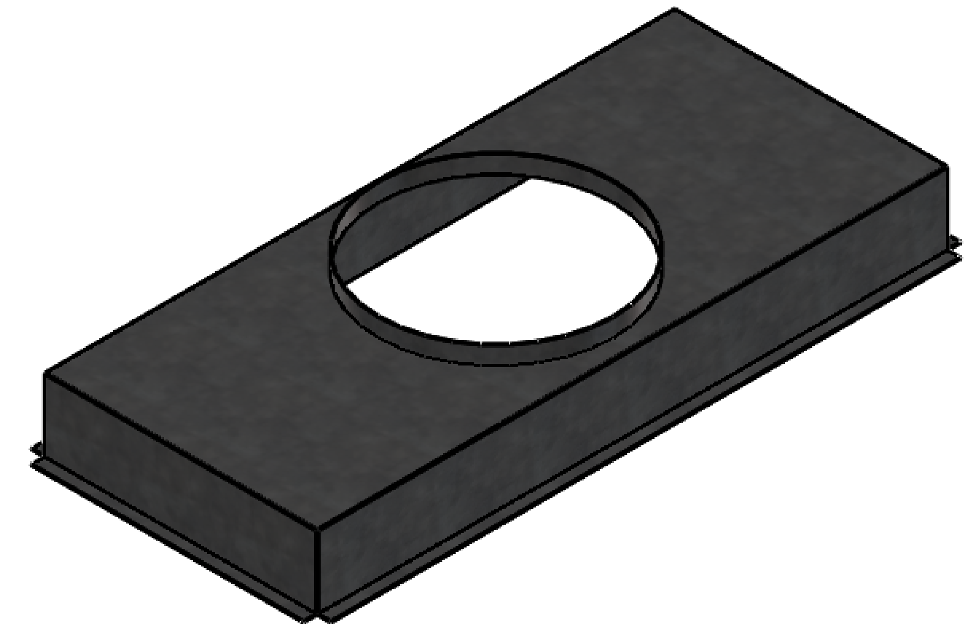
COMPANY NAME:
Modeled by: Jake Bellerose
Drawn by: Zoey Zhang
Checked by: Sai Avathu
Date: November 29, 2019

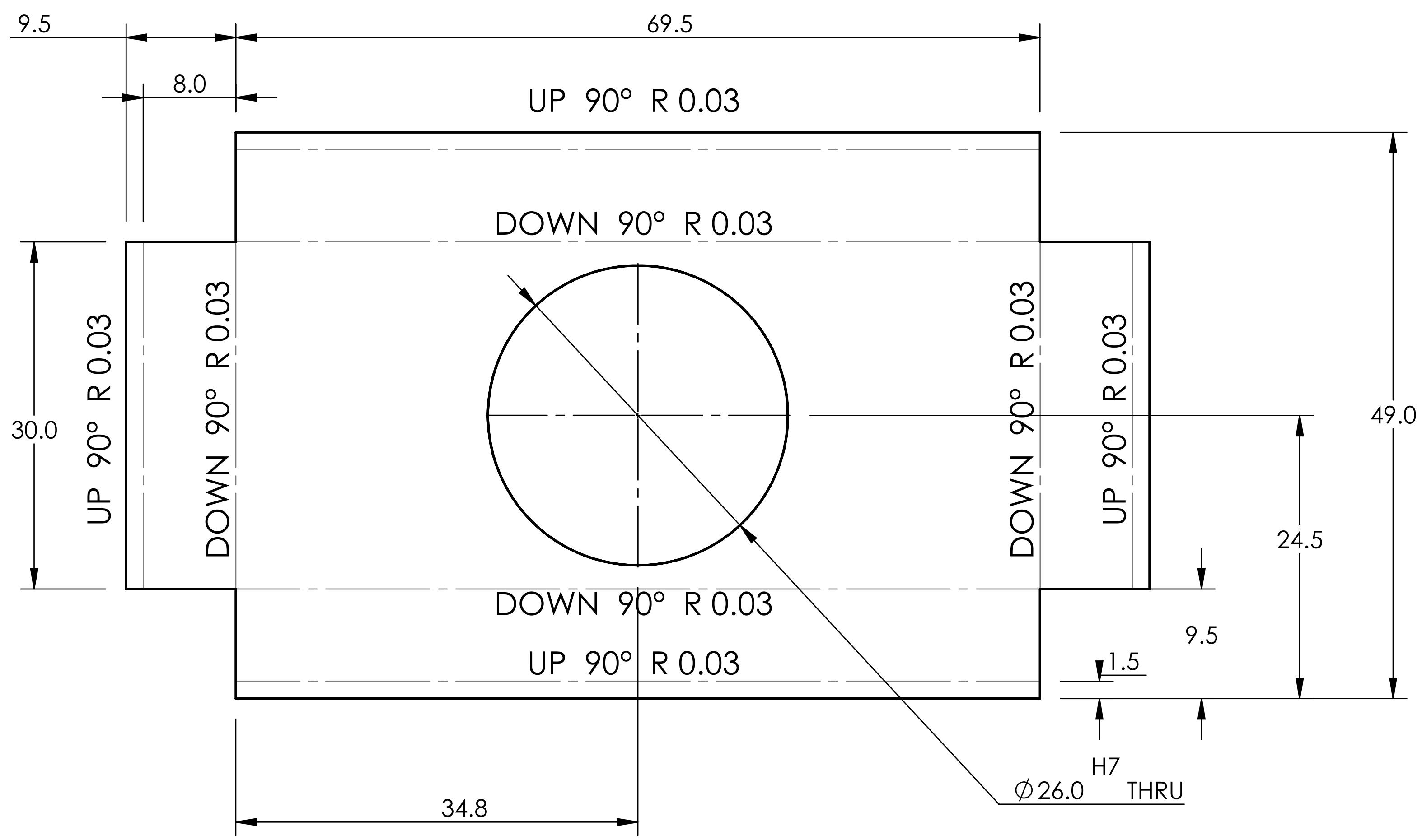
The Department of Mechanical Engineering
UNIVERSITY OF ALBERTA

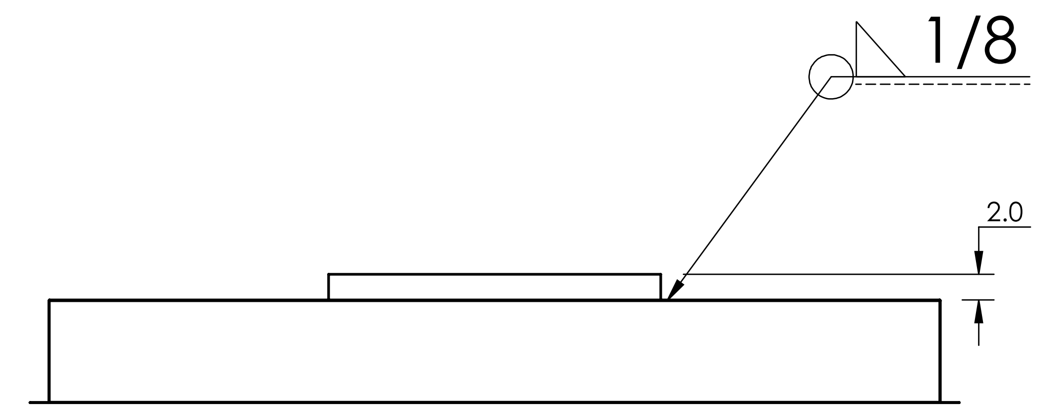
TITLE:
Extraction Room Supply Air Duct System

SIZE B | Part No: EX-01 | REV 1

SCALE: 1:50 Mass: 585.37 SHEET 1 OF 1







MecE 460
Instructor: Dr.Duke
Fall 2019
Comments:

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TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X = ± 0.5
X.X = ± 0.1
X.XX = ± 0.025
SURFACE FINISH µm 0.6
DO NOT SCALE DRAWING

COMPANY NAME:
Modeled by: Jake Bellerose
Drawn by: Zoey Zhang
Checked by: Sai Avuthu
Date: November 29, 2019

The Department of Mechanical Engineering
UNIVERSITY OF ALBERTA

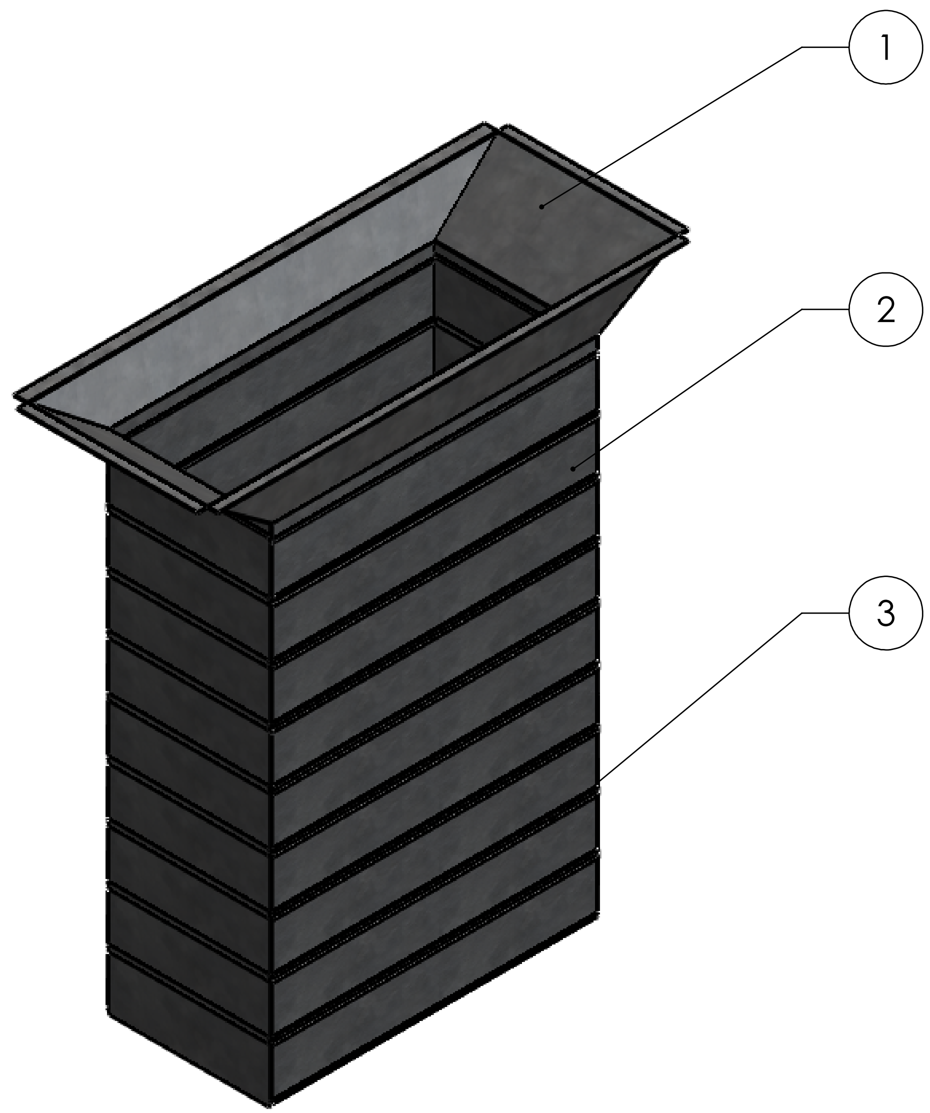
TITLE:
Extraction Room Supply Air Transition

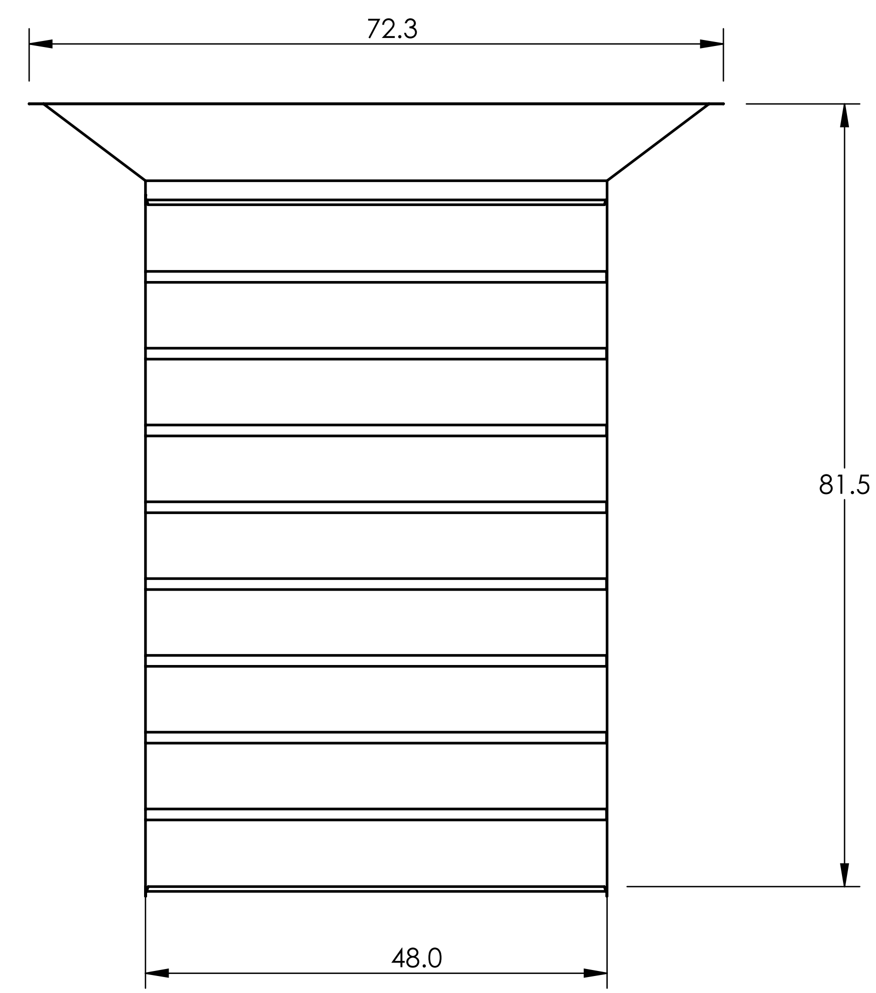
MATERIAL: Galvanized Steel, Gauge 24
Drawing Number: HH-542

SIZE B | Part No: EX-02 | REV 1

SCALE: 1:15 Mass: 25.09 SHEET 1 OF 1

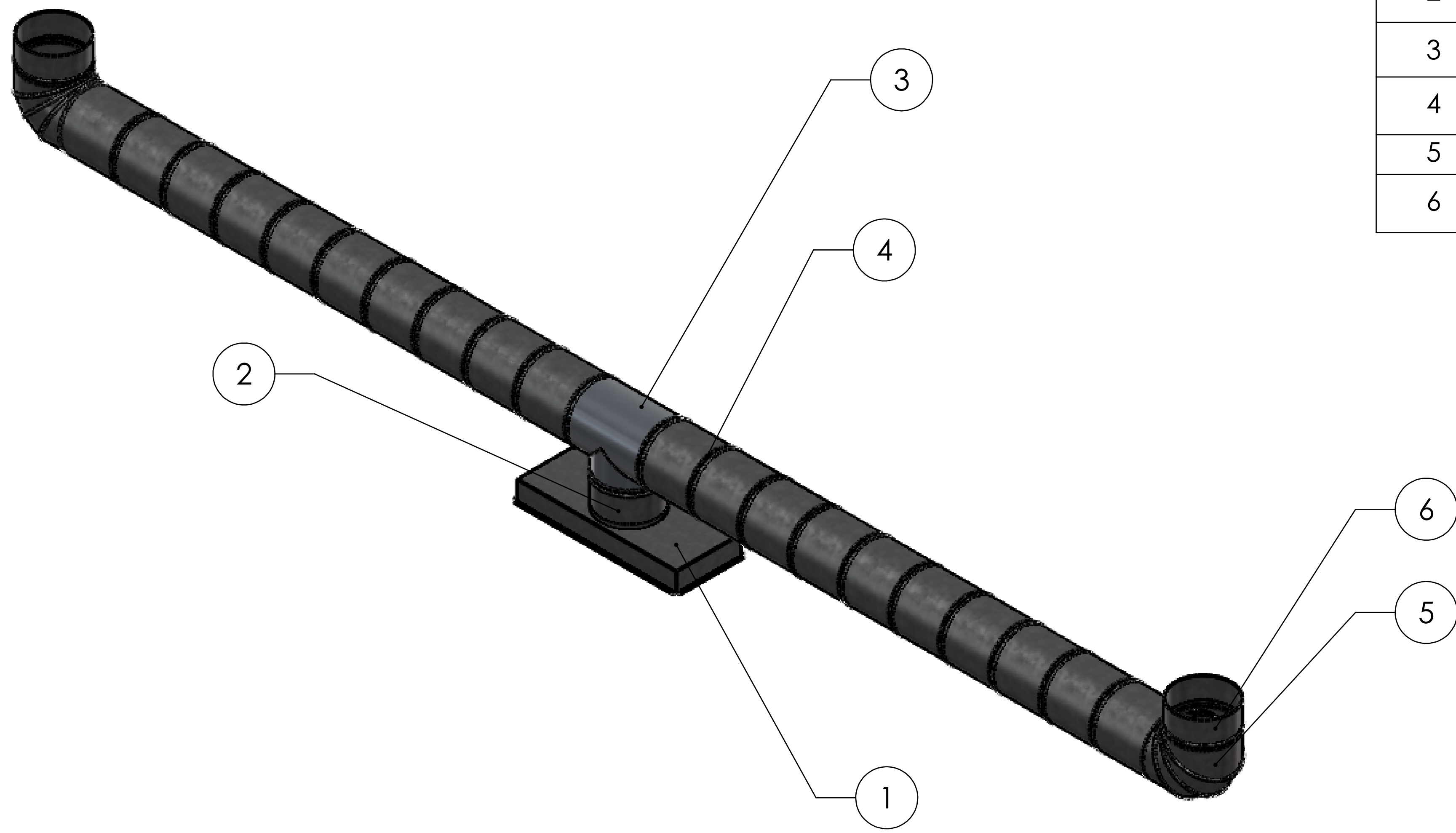
ITEM NO.	PART NUMBER	DESCRIPTION	VENDOR	QTY.
1	CS-04	Return Supply Air Piece 24"x48"	Lennox Commercial	1
2	1964K87	Rectangular Duct 24"x48"x4'	McMaster-Carr	9
3	1964K94	Drive Bracket	McMaster-Carr	9

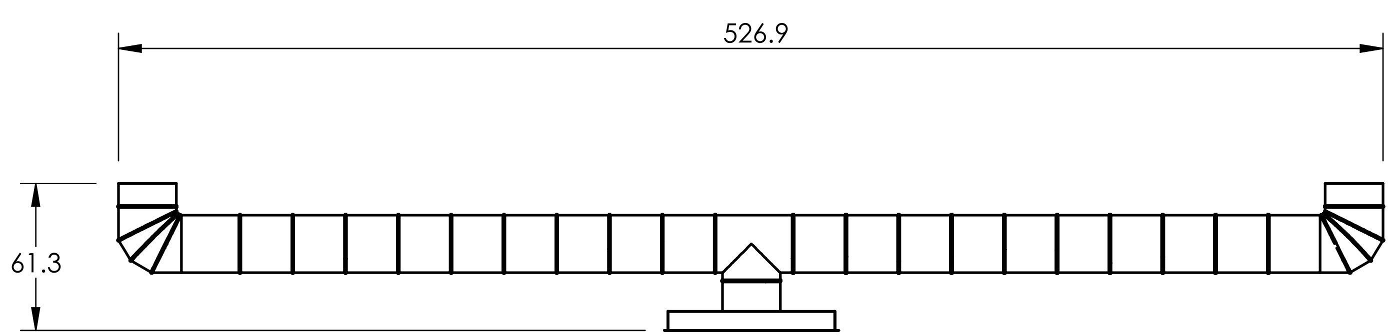




MecE 460 Instructor: Dr.Duke Fall 2019 Comments:	UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES TOLERANCES: ANGULAR: ± 0.5° LINEAR X = ± 0.5 X.X = ± 0.1 X.XX = ± 0.025 SURFACE FINISH µm 0.6 DO NOT SCALE DRAWING	COMPANY NAME: S.L.L. Consulting Services Modeled by: Jake Bellerose Drawn by: Jake Bellerose Checked by: Zoey Zhang Date: November 29, 2019	The Department of Mechanical Engineering UNIVERSITY OF ALBERTA TITLE: Extraction Room Return Air Duct System SIZE B Part No: EX-03 REV 1
MATERIAL:			SCALE: 1:20 Mass: SHEET 1 OF 1
Drawing Number: HH-543			

ITEM NO.	PART NUMBER	DESCRIPTION	VENDOR	QTY.
1	CS-02	Cold Storage Room Supply Air Transition		1
2	1768K107-B1	Steel Open Duct Trade Size 24, Length 1'3"	McMaster-Carr	1
3	1773K92	Trade Size 20 Aluminum Tee Connector	McMaster-Carr	1
4	1768K107	Steel Open Duct Trade Size 24	McMaster-Carr	20
5	1766K46	Size 24 90 Degree Elbow	McMaster-Carr	2
6	1768K107-B2	Steel Open Duct Trade Size 24, Length 1'11"	McMaster-Carr	2





Scale 1:80

NOTE: Parts 1768K107-B1 and 1768K107-B2 will be stock parts ordered from McMaster-Carr (ID 1768K107)to be cut to length specified in bill of materials

MecE 460
Instructor: Dr. Duke
Fall 2019
Comments:

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DIMENSIONS ARE IN INCHES
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X = ± 0.5
X.X = ± 0.1
X.XX = ± 0.025
SURFACE FINISH μm 0.6
DO NOT SCALE DRAWING

COMPANY NAME: S.E.L. Consulting Services

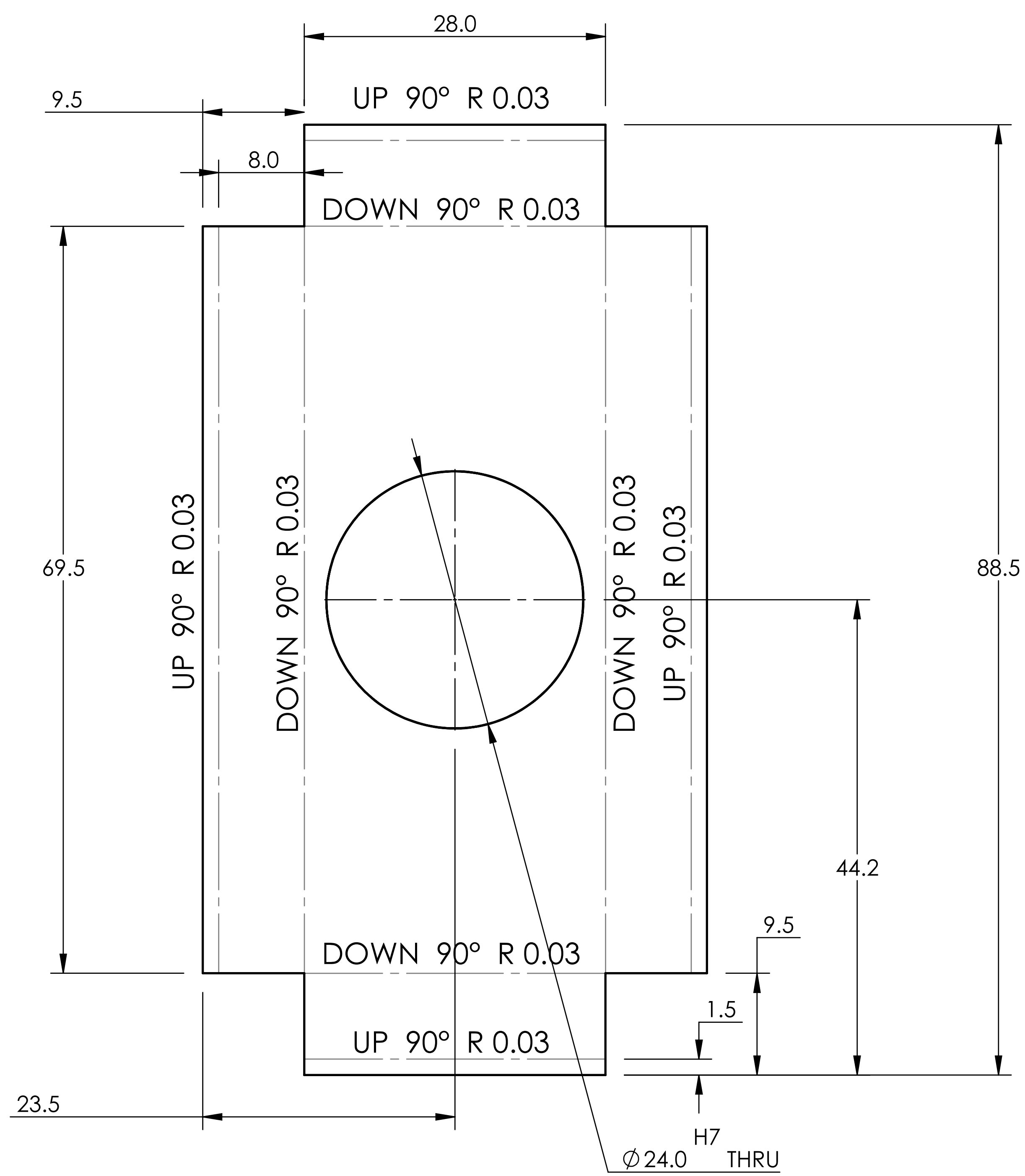
Modeled by: Jake Bellerose
Drawn by: Jake Bellerose
Checked by: Zoey Zhang
Date: November 29, 2019

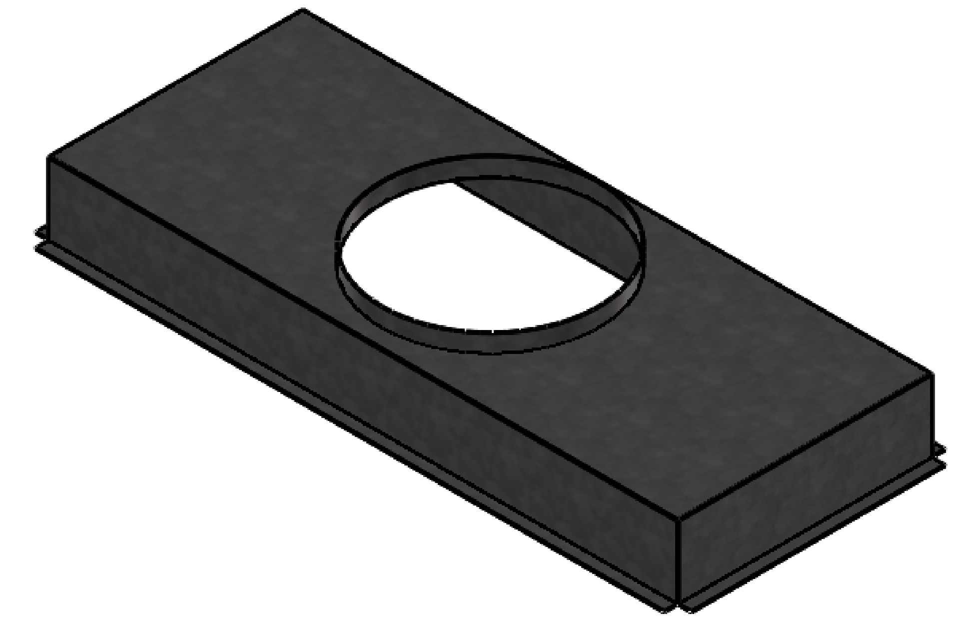
MATERIAL: Various
Drawing Number: HH-551

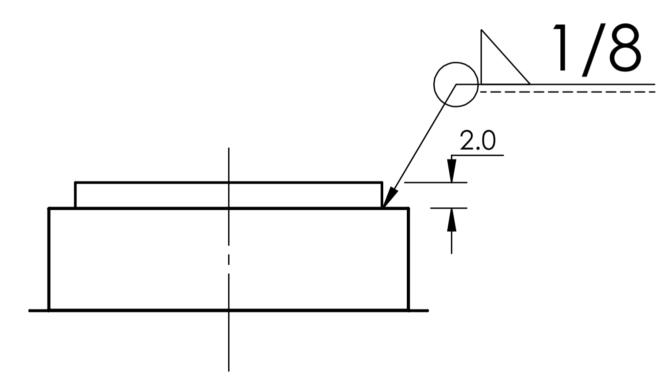
The Department of Mechanical Engineering
UNIVERSITY OF ALBERTA

TITLE: Cold Storage Supply Air Duct System

SIZE: B
Part No: CS-01
REV: 1
SCALE: 1:50 Mass: 511.44 SHEET 1 OF 1

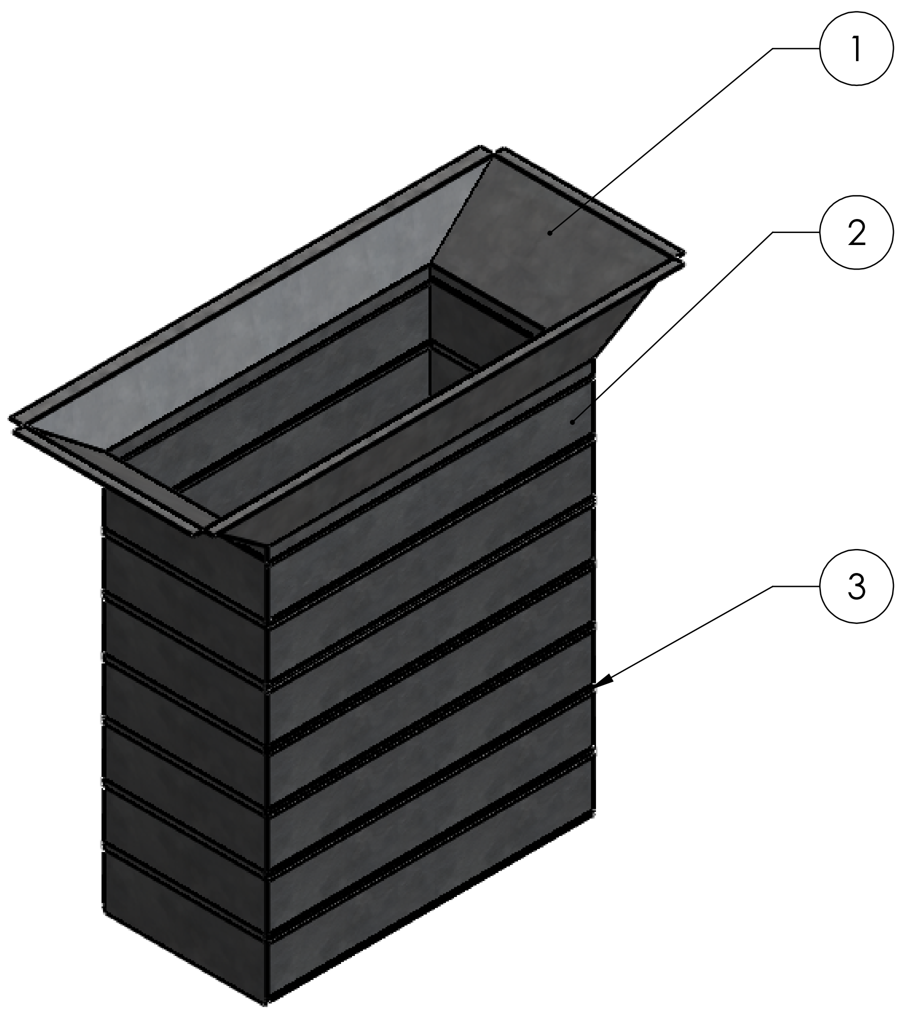


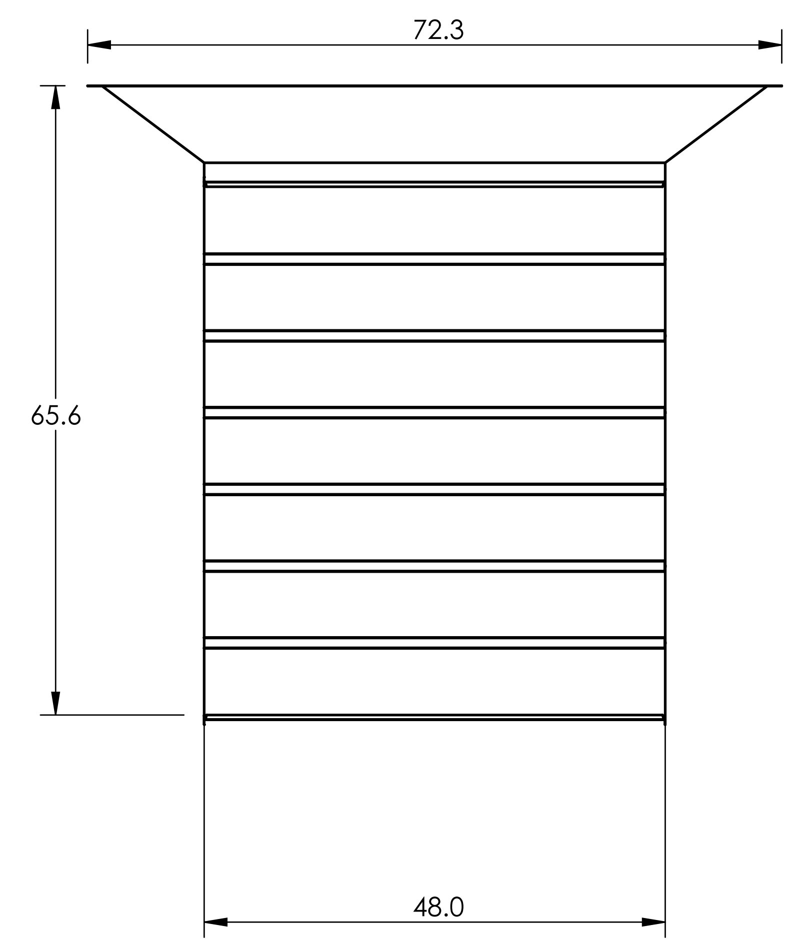




MecE 460 Instructor: **Dr. Duke** **Fall 2019** Comments:	UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN INCHES TOLERANCES: ANGULAR: ± 0.5° LINEAR X = ± 0.5 X.X = ± 0.1 X.XX = ± 0.025 SURFACE FINISH µm 0.6 DO NOT SCALE DRAWING	COMPANY NAME: Modeled by: Jake Bellerose Drawn by: Jake Bellerose Checked by: Zoey Zhang Date: November 29, 2019	The Department of Mechanical Engineering UNIVERSITY OF ALBERTA TITLE: Cold Storage Supply Air Transition SIZE B Part No: CS-02 REV 1
MATERIAL: Galvanized Steel, 24 Gauge Drawing Number: HH-552			SCALE: 1:15 Mass: 24.34 SHEET 1 OF 1

ITEM NO.	PART NUMBER	DESCRIPTION	VENDOR	QTY.
1	CS-04	Return Supply Air Piece 24"x48"	Lennox Commercial	1
2	1964K87	Rectangular Duct 24"x 48"x4'	McMaster-Carr	7
3	1964K94	Drive Bracket	McMaster-Carr	12





MecE 460
Instructor: Dr. Duke Fall2019
Comments:

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TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X = ± 0.5
X.X = ± 0.1
X.XX = ± 0.025
SURFACE FINISH μm 0.6
DO NOT SCALE DRAWING

MATERIAL:

COMPANY NAME:
Modeled by: Jake Bellerose
Drawn by: Jake Bellerose
Checked by: Zoey Zhang
Date: November 29, 2019

The Department of Mechanical Engineering
UNIVERSITY OF ALBERTA

TITLE:
Cold Storage Return Air Duct System

SIZE **B** | Part No: CS-03 | REV 1

Drawing Number: HH-553

SCALE: 1:20 Mass: SHEET 1 OF 1

Appendix D: Cost Analysis

Appendix D1: Cost Analysis Estimates

Cost Analysis

For the final design, a complete cost analysis was completed to determine the total estimated cost of construction and materials. The materials in the final design were chosen to optimize the heat transfer, HVAC, humidity and air exchange rate values for the design.

The cost of the building was broken down into four sections: substructure, shell, interiors, and services/utilities. The substructure includes the standard foundation and the insulated concrete slab. The slab was specified to be 6”-thick reinforced concrete on grade with 2”-thick expanded polystyrene insulated sheets placed below the slab. The shell includes all of the exterior features of the building. This is composed of the main steel framing and structure, and the exterior walls, windows, doors, and roof finishes. A pre-fabricated steel I-beam kit was chosen to reduce the cost of the main building structure, compared to a wooden structure. The interiors includes costs of the drywall, hygienic wall panels, doors, and all wall, floor and ceiling finishes. The services portion includes all plumbing fixtures, HVAC equipment, and electrical components.

Costs of services were determined by researching local industry averages. For materials where costs were not readily available, estimates were referenced from RSMeans data. A 25% contingency charge was added to the cost of the project to account for additional costs from contractor overhead and profit. The references to price estimates used in this analysis are provided in the appendix references below.

Appendix References

[1] “Gen Steel,” [Online]. Available: https://gensteel.com/building-faqs/building-customizations/components [Accessed on: November 3, 2019].

[2] “Buildings Guide,” [Online]. Available: https://www.buildingsguide.com/estimates/building-cost-estimate/ [Accessed on: November 3, 2019]

[3] “Natural Resources Canada,” [Online]. Available: http://oee.nrcan.gc.ca/pml-lmp/index.cfm?action=app.formHandler&operation=details-details&ref=31276617&appliance=WINDOWS&nr=1 [Accessed on: November 3, 2019].

[4] “Home Depot,” [Online]. Available: https://www.homedepot.ca/product/jeld-wen-windows-doors-48-inch-x-36-inch-3500-series-sliding-vinyl-window-energy-star-/1000526620 [Accessed on: November 3, 2019].

[5] “Natural Resources Canada,” [Online]. Available: http://oee.nrcan.gc.ca/pml-lmp/index.cfm?action=app.formHandler&operation=details-details&ref=17699986&appliance=WINDOWS&nr=1 [Accessed on: November 3, 2019].

[6] “Natural Resources Canada,” [Online]. Available: http://oee.nrcan.gc.ca/pml-lmp/index.cfm?action=app.formHandler&operation=details-details&ref=33553380&appliance=WINDOWS&nr=1 [Accessed on: November 3, 2019].

[7] “Home Depot,” [Online]. Available: https://www.homedepot.com/p/L-I-F-Industries-36-in-x-80-in-Gray-Flush-Steel-Vision-Light-Commercial-Door-Unit-with-Hardware-UKHG3680L/202516062 [Accessed on: November 3, 2019].

[8] “ThermoStop,” [Online]. Available: http://www.thermostop.com/door-application-guide/general-warehouse [Accessed on: November 3, 2019].

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[10] “Restoration Master Finder,” [Online]. Available: https://restorationmasterfinder.com/restoration/commercial-fire-sprinkler-systems/ [Accessed on: November 3, 2019].

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Appendix D2: Complete Building Cost Analysis

B.E.E. Consulting Services

Project:	HIVE House
Location:	Watino, Alberta
Customer:	Paradis Valley Honey Ltd.
Date:	December 2, 2019

	Item Description	% of Total	Unit Price	Unit	Cost
A	Substructure	13.0%	$3.06	SQFT	$76,229.52
A1010	Standard Foundations				
	Strip footing, concrete, reinforced, load 2.6 KLF, soil bearing capacity 3 KSF, 8" deep x 16" wide		$0.56	SQFT	$9,361.52
	Spread footings, 3000 PSI concrete, load 150K, soil bearing capacity 6 KSF, 5' - 6" square x 18" deep		$0.69	SQFT	$11,534.73
A1030	Slab on Grade				
	Slab on grade, 6" thick, non industrial, reinforced		$1.81	SQFT	$30,257.77
	SilveRboard EPS Laminated Exterior Under-Slab Insulation Sheet (2-in x 4-ft x 8-ft)		$1.50	SQFT	$25,075.50
B	Shell	34.4%	$3,355.97	SQFT	$201,738.00
B2000	Framing and Structure				
	Pre-fabricated steel I-beam building, kit		$6.00	SQFT	$100,302.00
B2010	Exterior Walls				
	MBCI CF Flute Insulated Metal Panels		$2.97	SQFT	$31,185.00
B2020	Exterior Windows				
	AM Window & Door Solutions, Prima Series, Single Slider, vinyl frame,		$250.00	EA	$4,000.00
B2030	Exterior Doors				
	Door, steel 18 gauge, hollow metal, 1 door with frame, no label, 3'-0" x 7'-0" opening		$600.00	EA	$3,600.00
	Door, steel 24 gauge, overhead, sectional, manual operation, 8'-0" x 9'-0" opening		$2,500.00	EA	$12,500.00
B3010	Roof Coverings				
	Asphalt-based coating and sealant		$3.00	SQFT	$50,151.00
C	Interiors	13.9%	$453.50	SQFT	$81,519.19
C1010	Walls				
	Drywall, 1/2-inch thick, 4 ft x 8 ft panels, installed, finished		$1.60	SQFT	$13,571.20
	HYGI Polyester resin wall panel, 4 ft x 8 ft, food safe, hygienic		$50.00	EA	$22,029.69
C1020	Interior Doors				
	Door, single leaf, kd steel frame, hollow metal, commercial quality, flush, 3'-0" x 7'-0" x 1-3/8"		$350.00	EA	$2,450.00
C3010	Wall Finishes				
	Painting, interior on plaster and drywall, walls & ceilings, roller work, primer & 2 coats		$0.40	SQFT	$3,392.80
C3020	Floor Finishes				
	Fluid applied epoxy coating		$1.50	SQFT	$25,075.50
C3030	Ceiling Finishes				
	HYGI Polyester resin roof panel, 4 ft x 8 ft, food safe, hygienic		$50.00	EA	$15,000.00
D	Services	18.7%	$1,516.44	SQFT	$109,754.08
D2010	Plumbing Fixtures				
	Service sink w/trim for cleaning equipment, incl. faucet		$0.10	SQFT	$1,671.70
	Bathroom, lavatory & water closet, 2 wall plumbing, stand alone		$0.15	SQFT	$2,507.55
D2020	Domestic Water Distribution				
	Electric water heater, residential, 100< F rise, 50 gal tank		$1,500.00	EA	$1,500.00
D2040	Rain Water Drainage				
	Roof drain, galvanized steel gutters		$5.00	FT	$2,230.00
D3010	Heat Generating Systems				
	Lennox RTU, 10 ton, KGA120S4B		1	EA	$7,497.00
	Lennox RTU, 20 ton, KGA240S4B		1	EA	$8,397.00
	Lennox RTU, 5 ton, LGH060U4E		1	EA	$6,797.00
	Lennox RTU, 50 ton, LCH600H4B		1	EA	$8,597.00
	Lennox RTU, 50 ton, LCH600H4B		2	EA	$17,194.00

D4020	**Standpipes**				
	Wet standpipe risers, class III, steel, black, sch 40, 4" diam pipe, 1 floor		$0.45	SQFT	$7,522.65
D5010	**Electrical Service/Distribution**				
	Service installation, includes breakers, metering, 20' conduit & wire, 3 phase, 4 wire, 120/208 V, 600 A		$0.19	SQFT	$3,176.23
	Feeder installation 600 V, including RGS conduit and XHHW wire, 200 A		$0.12	SQFT	$2,006.04
	Switchgear installation, incl switchboard, panels & circuit breaker, 400 A		$0.26	SQFT	$4,346.42
D5020	**Lighting and Branch Wiring**				
	Receptacles incl plate, box, conduit, wire, 2.5 per 1000 SF, .3 watts per SF		$1.00	SQFT	$16,717.00
	Wall switches, 1.0 per 1000 SF		$0.14	SQFT	$2,340.38
	Miscellaneous power, to .5 watts		$0.14	SQFT	$2,340.38
	LED fixtures recess mounted in ceiling, 0.8 watt per SF, 2700 W total		$2.50	SQFT	$8,437.50
D5030	**Communications and Security**				
	Communication and alarm systems, fire detection, addressable, 25 detectors, includes outlets, boxes, conduit and wire		$0.18	SQFT	$3,000.00
	Internet wiring, 1 dedicated data/voice outlet		$0.02	SQFT	$300.00
D5090	**Other Electrical Systems**				
	Generator sets, w/battery, charger, muffler and transfer switch, gas/gasoline operated, 3 phase, 4 wire, 277/480 V, 7.5 kW		$0.19	SQFT	$3,176.23
E	**Equipment & Furnishings**	**0.00%**	**$0.00**	**SQFT**	**$0.00**
E1090	**Other Equipment**		**$0.00**	**SQFT**	**$0.00**
F	**Special Construction**	**0.00%**	**$0.00**	**SQFT**	**$0.00**
G	**Building Sitework**	**0.00%**	**$0.00**	**SQFT**	**$0.00**
SubTotal		**100%**	**$28.07**	**SQFT**	**$469,240.79**
Contractor Fees (General Conditions,Overhead,Profit)		**25%**	**$7.02**	**SQFT**	**$117,310.20**
Total Building Cost			**$35.09**	**SQFT**	**$586,550.98**

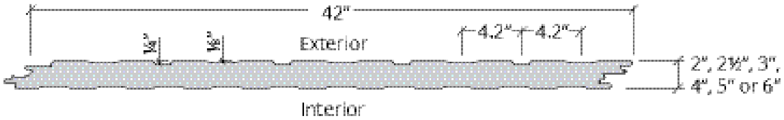
Appendix E: Material Data Sheets

Appendix E1: Project Material Data Sheets

INSULATED METAL PANELS

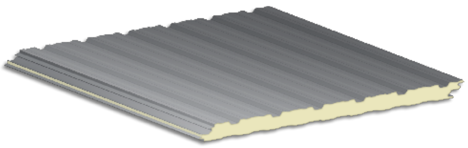
CF FLUTE

The traditional styling and distinct vertical lines of the CF Flute panel are ideal for custom-designed or conventional building construction, especially commercial and industrial applications. It can also be used in cold storage applications. The interior skin employs a Mesa profile. The CF Flute panel is available in a width of 42".



Features and Benefits:

- The CF Flute panel utilizes concealed clips and eliminates thermal short circuits.
- The standard exterior surface is 26, 24 or 22 gauge Galvalume® coated steel with silicone polyester or PVDF coatings.
- Insulated metal panels allow for fast assembly times and easy installation, resulting in reduced construction labor costs and earlier business starts.



Product Specifications

Applications: Wall (Vertical)

Coverage Widths: 42"

Thicknesses: 2", 2½", 2¾"*, 3", 4", 5", 6"

Lengths: 8'-0" to 32'-0" for horizontal
8'-0" to 52'-0" for vertical

Attachment: Concealed fastening system

Insulation Material: Non-CFC foamed-in-place polyurethane foam cured to achieve a minimum density of 2.2 pounds

Accessories: Fasteners, sealants, standard and custom trim

Exterior Gauge: 26 (standard); 24, 22 (optional)

Interior Gauge: 26 (standard); 24, 22 (optional)

Exterior Finishes: Stucco-embossed

Interior Finishes: Stucco-embossed, Mesa profile

Exterior Coatings: Signature® 200, Signature® 300, Signature® 300 Metallic

Interior Coating: Igloo White (standard)

U-Factors and R-Values**

U-Factor (BTU·/h·ft^{2}·° F)

PANEL WIDTH: 42"

	75°
2"	0.0721
2½"	0.0523
3"	0.0432
4"	0.0328
5"	0.0267
6"	0.0226

PANEL WIDTH: 42"

	40°
2"	0.0692
2½"	0.0498
3"	0.0410
4"	0.0311
5"	0.0252
6"	0.0214

R-Value (h·ft^{2}·° F/BTU)

PANEL WIDTH: 42"

	75°
2"	13.87
2½"	19.12
3"	23.15
4"	30.49
5"	37.45
6"	44.25

PANEL WIDTH: 42"

	40°
2"	14.45
2½"	20.08
3"	24.39
4"	32.15
5"	39.68
6"	46.73

*Available only from Metl-Span's Nevada plant
**Based on ASTM C518, ASTM C1363 and thermal modeling, 75°F and 40° F core mean temp.

INSULATED METAL PANELS

CF FLUTE

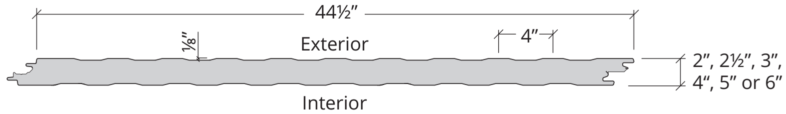
CATEGORY	CHARACTERISTIC	TEST METHOD	PURPOSE	RESULT
ENVIRONMENTAL	Thermal Transmission	ASTM C518	Measure the heat transmission coefficient per unit thickness (k-factor)	0.140 BTU·in/hr·ft^{2}·° F (7.14/inch) at 75° F mean temperature 0.126 BTU·in/hr·ft^{2}·° F (7.94/inch) at 40° F mean temperature 0.118 BTU·in/hr·ft^{2}·° F (8.47/inch) at 20° F mean temperature
		ASTM C1363	Measures the resistance to heat flow (or R-Value) of a construction assembly in a guarded hot box	Varies up to R-8.5/inch of panel thickness at 40° F mean temperature (See Appendix A)
	Air Leakage Through Wall Panel Joints	ASTM E283	Determines the air leakage characteristics of metal wall panels under specified air pressure differences at ambient conditions	0.01 cfm/ft^{2} at 20 psf static pressure
	Water Penetration Through Wall Panel Joints	ASTM E331	Determines the resistance to water penetration of metal wall panels under uniform static air pressure difference	No uncontrolled water penetration through the panel joints at a static pressure of 20 psf
FOAM PROPERTIES	Foam Density	ASTM D1622	Determines the apparent density of rigid cellular plastics	2.3 pcf
	Foam Compressive Strength	ASTM D1621	Determines the behavior of cellular materials under compressive load	15 psi through-thickness 22 psi other directions
	Foam Tensile Strength	ASTM D1623	Measures the tensile strength of the foam from a cored sample	30 psi through-thickness 33 psi lowest any other direction
	Foam Shear Strength	ASTM C273	Measures the shear strength of the foam from a cored sample	16 psi lowest in any direction
FIRE RESISTANCE	Surface Burning Characteristics	ASTM E84	Provides comparative measurements of surface flame spread and smoke density measurements relative to that of select grade red oak and fiber-cement board surfaces under specific fire exposure conditions	Flame Spread index of 20, Smoke Developed index of 350
	Room Fire Performance	FM 4880	Evaluates insulated roof and wall panels, interior finishes or coatings, and exterior wall systems for their performance in regard to fire	Class 1 Rating of wall and roof panels for use in unlimited height structures
		NFPA 286	Fire tests for the flammability characteristics of wall and ceiling interior finishes	The Panels meet the criteria of the IBC Section 803.1.2.1
		CAN/ULC S101	Standard method of fire endurance tests of building construction and materials	The Panels provide 15-minute remain-in-place fire resistance rating
		CAN/ULC S102	Standard method of test for surface burning characteristics of building material and assemblies	Flame Spread index of 0 Smoke Developed Index of 45 Fuel Contributing Value of 0
		CAN/ULC S134	Standard method of fire test of exterior wall assemblies	The Panels meet the criteria published in the standard
		CAN/ULC S138	Standard method of test for fire growth of insulated building panels in a full-scale room configuration	The Panels meet the criteria published in the standard
	Wall Fire Performance	NFPA 285	Evaluation of fire propagation characteristics of exterior non-load bearing wall assemblies in regard to fire	Panels meet the requirement of the standard
STRUCTURAL	Uplift Resistance	ASTM E72 ASTM E330	Provides a standard procedure to evaluate or confirm structural performance under uniform static air pressure difference	See Load Chart Section
	Positive Load Resistance	ASTM E72	Tests the behavior of segments of wall construction under conditions representative of those encountered in service	See Load Chart Section
WALL LISTINGS	Wall Performance – FM Global® (See Note 1 below)	FM 4881	Sets performance standards for panel walls including wind load resistance and hail resistance Requires a Class 1 rating by FM Global Standard 4880 as a prerequisite	See FM Global Approval Guide for Building Products complete listings

Notes:
1. Wall panels with textured coatings are not approved for the FM 4881 test method.

INSULATED METAL PANELS

CF45 INTERIOR WALL

The CF45 Interior Wall panel is the optimal choice for interior partitions. The interior and exterior panel faces are identical images with the same profile for each. The profiles have ⅛" ribs that are on 4" on center. The Interior Partition and Ceiling panel is available in a width of 44 ½".



Features and Benefits:

- The standard exterior surface is 26 gauge Igloo White coated steel with polyester.
- IMPs allow for fast assembly times and easy installation, resulting in reduced construction labor costs and earlier business starts. Fastening required at top; Bottom only with no additional framing. See load tables on reverse side.

Product Specifications

Applications: Wall

Coverage Widths: 44½"

Thicknesses: 2", 2½", 2¾"*, 3", 4", 5", 6"

Length:
8'-0" to 52'-0" for vertical embossed
8'-0" to 40'-0" for vertical unembossed

Attachment: Tongue-and-groove with exposed fasteners

Insulation Material: Non-CFC foamed-in-place polyurethane foam cured to achieve a minimum density of 2.2 pounds

Accessories: Fasteners, sealants, standard and custom trim

Exterior Gauge: 26, 24, 22

Interior Gauge: 26, 24, 22

Exterior Finishes: Stucco-embossed, Mesa profile

Interior Finishes: Stucco-embossed, Mesa profile

Exterior Coatings: Igloo White

Interior Coating: Igloo White

U-Factors and R-Values*

U-Factor (BTU/h·ft²·° F)		R-Value (h·ft²·° F/BTU)	
PANEL WIDTH: 44½"		PANEL WIDTH: 44½"	
	75°		75°
2"	0.0706	2"	14.16
2½"	0.0516	2½"	19.38
2¾"	0.0470	2¾"	21.28
3"	0.0424	3"	23.58
4"	0.0324	4"	30.86
5"	0.0264	5"	37.88
6"	0.0224	6"	44.64
PANEL WIDTH: 44½"		PANEL WIDTH: 44½"	
	40°		40°
2"	0.0669	2"	14.95
2½"	0.0491	2½"	20.37
2¾"	0.0446	2¾"	22.42
3"	0.0401	3"	24.94
4"	0.0305	4"	32.79
5"	0.0248	5"	40.32
6"	0.0210	6"	47.62

*Available only from Metl-Span's Nevada plant

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INSULATED METAL PANELS

INTERIOR PARTITION

CATEGORY	CHARACTERISTIC	TEST METHOD	PURPOSE	RESULT
ENVIRONMENTAL	Thermal Transmission	ASTM C518	Measure the heat transmission coefficient per unit thickness (k-factor)	0.140 BTU·in/hr·ft^{2}·° F (7.14/inch) at 75° F mean temperature 0.126 BTU·in/hr·ft^{2}·° F (7.94/inch) at 40° F mean temperature 0.118 BTU·in/hr·ft^{2}·° F (8.47/inch) at 20° F mean temperature
		ASTM C1363	Measures the resistance to heat flow (or R-Value) of a construction assembly in a guarded hot box	Varies up to R-8.5/inch of panel thickness at 40° F mean temperature (See Appendix A)
	Air Leakage Through Wall Panel Joints	ASTM E283	Determines the air leakage characteristics of metal wall panels under specified air pressure differences at ambient conditions	0.01 cfm/ft^{2} at 20 psf static pressure
	Water Penetration Through Wall Panel Joints	ASTM E331	Determines the resistance to water penetration of metal wall panels under uniform static air pressure difference	No uncontrolled water penetration through the panel joints at a static pressure of 20 psf
FIRE RESISTANCE	Surface Burning Characteristics	ASTM E84	Provides comparative measurements of surface flame spread and smoke density measurements relative to that of select grade red oak and fiber-cement board surfaces under specific fire exposure conditions	Flame Spread index of 20, Smoke Developed index of 350
	Room Fire Performance	FM 4880	Evaluates insulated roof and wall panels, interior finishes or coatings, and exterior wall systems for their performance in regard to fire	Class 1 Rating of wall and roof panels for use in unlimited height structures
	Wall Fire Performance	NFPA 285	Evaluation of fire propagation characteristics of exterior non-load bearing wall assemblies in regard to fire	Panels meet the requirement of the standard
WALL LISTINGS	Wall Performance – FM Global® (See Note 1 below)	FM 4881	Sets performance standards for panel walls including wind load resistance and hail resistance Requires a Class 1 rating by FM Global Standard 4880 as a prerequisite	See FM Global Approval Guide for Building Products complete listings

CF-42 & CF-45 PARTITION MESA WALL PANELS

PANEL TYPE	THICKNESS (in)	DESIGN CRITERIA Bending Stress	 Shear Stress	 Deflection Limit L/120	ALLOWABLE SPAN (ft)
Allowable Single Span for Inward and Outward Load of 5 psf					
CF-42 OR CF-45 MESA/MESA	2"	27.5	77.2	20.2	20.2'
	2.5"	29.6	87.7	23.7	23.7'
	3"	31.4	97.1	27.0	27.0'
	4"	37.6	101.6	33.1	33.1'
	5"	42.4	114.5	38.5	38.5'
	6"	45.7	126.0	43.5	43.5'
Allowable Single Span for Inward and Outward Load of 10 psf					
CF-42 OR CF-45 MESA/MESA	2"	18.1	38.5	15.8	15.8'
	2.5"	19.5	43.8	18.6	18.6'
	3"	20.6	48.5	21.2	20.6'
	4"	24.7	50.8	26.0	24.7'
	5"	27.9	57.2	30.3	27.9'
	6"	30.1	63.3	34.0	30.1'

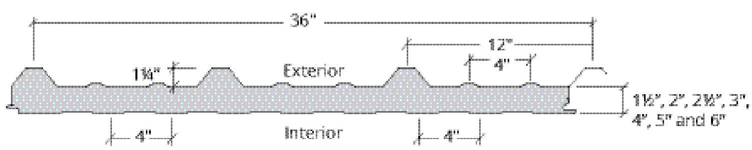
Notes:

1. Wall panels with textured coatings are not approved for the FM 4881 test method.
2. Based on panels with 26 gage exterior and 26 gage interior face (min Fy = 33 ksi) for single span condition.
3. Allowable span is the lowest value of panel bending strength, shear strength and deflection limit. The spans based on panel stress and deflection design criteria are derived from E-72 structural testing. The allowable loads are calculated with a factor of safety of 2.0 and 3.0 for bending and shear stresses, respectively and deflection limitation of L/120.
4. The structural capacity of support members and panel attachment to the support members are not considered and must be examined independently.

INSULATED METAL PANELS

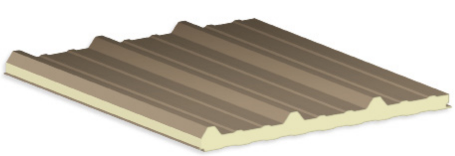
LS-36™

The versatility of the LS-36™ panel offers a multitude of design options and can be utilized for roof or wall applications. The standard exterior skin is smooth but can be embossed if requested. The interior skin is roll-formed with our standard interior Mesa profile.



Features and Benefits:

- The LS-36™ panel utilizes a through-fastened attachment.
- The exterior surface is available in 26, 24 or 22 gauge Galvalume® coated steel with silicone polyester or PVDF coatings
- Insulated metal panels allow for fast assembly times and easy installation, resulting in reduced construction labor costs and earlier business starts.



Product Specifications

Applications: Roof and Wall

Coverage Widths: 36"

Thicknesses: 1½", 2", 2½", 3", 4", 5", 6"

Lengths: 8'-0" to 50'-0"

Attachment: Exposed fastening system

Insulation Material: Non-CFC foamed-in-place polyurethane foam cured to achieve a minimum density of 2.2 pounds

Accessories: Fasteners, sealants, standard and custom trim

Exterior Gauge: 26, 24, 22

Interior Gauge: 26, 24, 22

Exterior Finishes: Smooth; Embossed

Interior Finishes: Stucco-embossed, Mesa profile

Exterior Coatings: Galvalume Plus® , Signature® 200, Signature® 300, Applied Finishes (wall application only)

Interior Coating: Igloo White (standard)

Roof U-Factors and R-Values*

U-Factor (BTU·/h·ft$^{2\cdot\circ}$ F) — PANEL WIDTH: 36"

	75°
1½"	0.0788
2"	0.0603
2½"	0.0492
3"	0.0416
4"	0.0327
5"	0.0267
6"	0.0223

R-Value (h·ft$^{2\cdot\circ}$ F/BTU) — PANEL WIDTH: 36"

	75°
1½"	12.69
2"	16.58
2½"	20.33
3"	24.04
4"	30.58
5"	37.45
6"	44.84

Wall U-Factors and R-Values*

U-Factor (BTU·/h·ft$^{2\cdot\circ}$ F) — PANEL WIDTH: 36"

	75°
1½"	0.0783
2"	0.0602
2½"	0.0491
3"	0.0414
4"	0.0326
5"	0.0268
6"	0.0227

R-Value (h·ft$^{2\cdot\circ}$ F/BTU) — PANEL WIDTH: 36"

	75°
1½"	12.77
2"	16.61
2½"	20.37
3"	24.15
4"	30.67
5"	37.31
6"	44.05

*Based on ASTM C518, ASTM C1363 and thermal modeling, 75° F core mean temp.

INSULATED METAL PANELS

LS-36™

CATEGORY	CHARACTERISTIC	TEST METHOD	PURPOSE	RESULT
ENVIRONMENTAL	Thermal Transmission	ASTM C518	Measure the heat transmission coefficient per unit thickness (k-factor)	0.140 BTU·in/hr·ft²·° F (7.14/inch) at 75° F mean temperature 0.126 BTU·in/hr·ft²·° F (7.94/inch) at 40° F mean temperature 0.118 BTU·in/hr·ft²·° F (8.47/inch) at 20° F mean temperature
		ASTM C1363	Measures the resistance to heat flow (or R-Value) of a construction assembly in a guarded hot box	Varies up to R-8.5/inch of panel thickness at 40° F mean temperature (See Appendix A)
	Air Leakage Through Roof Panel Joints	ASTM E1680	Determines the resistance of exterior metal roof panel systems to air infiltration resulting from either positive or negative air pressure differences	0.0037 cfm/ft² at 12 psf static pressure
	Water Penetration Through Roof Panel Joints	ASTM E1646	Determines the resistance to water penetration of metal roof panels under uniform positive static air pressure differences	No uncontrolled water penetration through the panel joints at a static pressure of 20 psf
FOAM PROPERTIES	Foam Density	ASTM D1622	Determines the apparent density of rigid cellular plastics	2.3 pcf
	Foam Compressive Strength	ASTM D1621	Determines the behavior of cellular materials under compressive load	15 psi through-thickness 22 psi other directions
	Foam Tensile Strength	ASTM D1623	Measures the tensile strength of the foam from a cored sample	30 psi through-thickness 33 psi lowest any other direction
	Foam Shear Strength	ASTM C273	Measures the shear strength of the foam from a cored sample	16 psi lowest in any direction
FIRE RESISTANCE	Surface Burning Characteristics	ASTM E84	Provides comparative measurements of surface flame spread and smoke density measurements relative to that of select grade red oak and fiber-cement board surfaces under specific fire exposure conditions	Flame Spread index of 20, Smoke Developed index of 350
	Room Fire Performance	FM 4880	Evaluates insulated roof and wall panels, interior finishes or coatings, and exterior wall systems for their performance in regard to fire	Class 1 Rating of wall and roof panels for use in unlimited height structures
		NFPA 286	Fire tests for the flammability characteristics of wall and ceiling interior finishes	The Panels meet the criteria of the IBC Section 803.1.2.1
		CAN/ULC S102	Standard method of test for surface burning characteristics of building material and assemblies	Flame Spread index of 10 Smoke Developed Index of 40 Fuel Contributing Value of
		CAN/ULC S138	Standard method of test for fire growth of insulated building panels in a full-scale room configuration	The Panels meet the criteria published in the standard
		CAN/ULC S126	Standard method of test for fire spread under roof-deck assemblies	The Panels meet the criteria published in the standard
STRUCTURAL	Uplift Resistance	ASTM E72 ASTM E330	Provides a standard procedure to evaluate or confirm structural performance under uniform static air pressure difference	See Load Chart Section
	Positive Load Resistance	ASTM E72	Tests the behavior of segments of wall construction under conditions representative of those encountered in service	See Load Chart Section
ROOF LISTINGS	Roof Performance – FM Global®	FM 4471	Sets performance requirements for panel roofs including uplift resistance. Requires a Class 1 Rating by FM Global Standard 4880 as a prerequisite.	Class 1-105 Rating at 5'-0" for min. 16 ga.

BLOWER DATA

092S AND 102S STANDARD EFFICIENCY BELT DRIVE BLOWER − BASE UNIT

BLOWER TABLE INCLUDES RESISTANCE FOR BASE UNIT ONLY (NO HEAT SECTION) WITH DRY INDOOR COIL AND AIR FILTERS IN PLACE. FOR ALL UNITS ADD:

1 − Wet indoor coil air resistance of selected unit.

2 − Any factory installed options air resistance (heat section, economizer, etc.)

3 − Any field installed accessories air resistance (duct resistance, diffuser, etc.)

Then determine from blower table blower motor output required.

See page 29 for blower motors and drives.

See page 29 for wet coil and option/accessory air resistance data.

MAXIMUM STATIC PRESSURE WITH GAS HEAT - 2.0 in. w.g.

Total Air Volume cfm	Total Static Pressure − in. w.g.																									
	0.2		0.4		0.6		0.8		1.0		1.2		1.4		1.6		1.8		2		2.2		2.4		2.6	
	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
1750	608	0.05	651	0.03	696	0.06	744	0.22	794	0.60	845	0.95	894	1.24	934	1.38	978	1.47	1047	1.66	1120	1.89	1179	2.15	1230	2.40
2000	615	0.07	657	0.05	702	0.10	748	0.36	797	0.72	846	1.05	892	1.30	933	1.45	977	1.55	1049	1.75	1124	2.00	1181	2.23	1234	2.47
2250	624	0.09	664	0.07	707	0.14	753	0.50	800	0.84	847	1.15	892	1.38	934	1.53	979	1.65	1051	1.86	1126	2.12	1183	2.36	1238	2.62
2500	632	0.11	672	0.09	714	0.29	758	0.64	803	0.97	849	1.26	893	1.48	936	1.63	983	1.75	1052	1.96	1124	2.22	1184	2.49	1241	2.77
2750	641	0.13	680	0.11	721	0.45	763	0.78	807	1.09	852	1.37	896	1.58	940	1.74	989	1.88	1053	2.08	1121	2.34	1185	2.63	1244	2.93
3000	651	0.15	689	0.29	728	0.61	770	0.93	812	1.23	856	1.49	901	1.70	947	1.87	996	2.02	1055	2.21	1120	2.47	1186	2.78	1248	3.10
3250	661	0.17	698	0.46	737	0.78	777	1.09	819	1.38	862	1.63	908	1.84	955	2.01	1004	2.17	1059	2.36	1122	2.62	1189	2.94	1252	3.28
3500	672	0.36	708	0.65	746	0.95	786	1.25	827	1.53	870	1.78	916	1.99	965	2.17	1013	2.33	1065	2.52	1126	2.79	1193	3.12	1257	3.47
3750	684	0.56	719	0.85	756	1.14	795	1.43	836	1.70	880	1.95	927	2.16	976	2.34	1023	2.51	1073	2.71	1133	2.98	1198	3.32	1263	3.67
4000	697	0.78	731	1.05	768	1.34	807	1.62	848	1.89	892	2.13	940	2.34	988	2.53	1034	2.71	1083	2.91	1141	3.19	1205	3.53	1270	3.89
4250	710	1.00	745	1.27	781	1.55	819	1.83	861	2.09	906	2.33	954	2.55	1001	2.74	1046	2.93	1094	3.14	1151	3.42	1214	3.76	1278	4.12

BLOWER DATA

092H AND 102H HIGH EFFICIENCY BELT DRIVE BLOWER − BASE UNIT

BLOWER TABLE INCLUDES RESISTANCE FOR BASE UNIT ONLY (NO HEAT SECTION) WITH DRY INDOOR COIL AND AIR FILTERS IN PLACE. FOR ALL UNITS ADD:

1 − Wet indoor coil air resistance of selected unit.

2 − Any factory installed options air resistance (heat section, economizer, etc.)

3 − Any field installed accessories air resistance (duct resistance, diffuser, etc.)

Then determine from blower table blower motor output required.

See page 29 for blower motors and drives.

See page 29 for wet coil and option/accessory air resistance data.

MAXIMUM STATIC PRESSURE WITH GAS HEAT - 2.0 in. w.g.

Total Air Volume cfm	Total Static Pressure − in. w.g.																									
	0.2		0.4		0.6		0.8		1.0		1.2		1.4		1.6		1.8		2.0		2.2		2.4		2.6	
	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
1750	481	0.21	549	0.4	618	0.57	688	0.7	758	0.82	824	0.93	885	1.08	941	1.23	991	1.39	1038	1.54	1082	1.68	1124	1.82	1166	1.95
2000	493	0.29	561	0.47	629	0.64	700	0.77	768	0.9	832	1.02	892	1.17	946	1.33	995	1.49	1041	1.66	1085	1.81	1126	1.97	1167	2.12
2250	507	0.37	574	0.56	643	0.72	712	0.86	779	0.99	842	1.13	900	1.28	953	1.44	1001	1.61	1045	1.78	1088	1.95	1128	2.12	1168	2.3
2500	521	0.46	588	0.64	657	0.81	727	0.95	792	1.09	853	1.24	909	1.4	960	1.57	1007	1.74	1050	1.93	1091	2.11	1130	2.29	1170	2.48
2750	537	0.56	604	0.74	674	0.91	743	1.06	806	1.21	865	1.36	920	1.53	969	1.71	1014	1.89	1055	2.08	1095	2.27	1133	2.47	1172	2.66
3000	554	0.67	622	0.86	692	1.02	760	1.18	822	1.34	878	1.5	931	1.68	979	1.86	1021	2.06	1061	2.26	1099	2.46	1136	2.65	1174	2.85
3250	572	0.78	641	0.98	712	1.15	778	1.32	838	1.49	892	1.66	943	1.84	989	2.03	1030	2.24	1068	2.45	1105	2.65	1141	2.85	1178	3.06
3500	592	0.9	663	1.12	733	1.3	798	1.47	855	1.65	907	1.83	956	2.02	1000	2.22	1039	2.44	1076	2.65	1111	2.86	1146	3.07	1183	3.27
3750	614	1.04	687	1.28	756	1.47	818	1.65	872	1.83	923	2.02	970	2.22	1011	2.43	1049	2.65	1084	2.87	1118	3.09	1152	3.29	1189	3.51
4000	639	1.22	713	1.48	780	1.66	838	1.83	890	2.02	939	2.22	984	2.44	1023	2.66	1059	2.89	1093	3.11	1126	3.33	1160	3.54	1197	3.77
4250	667	1.43	741	1.69	805	1.86	859	2.02	909	2.22	956	2.45	998	2.68	1036	2.92	1070	3.15	1103	3.37	1135	3.59	1169	3.81	1207	4.05

BLOWER DATA

120S STANDARD EFFICIENCY BELT DRIVE BLOWER − BASE UNIT

BLOWER TABLE INCLUDES RESISTANCE FOR BASE UNIT ONLY (NO HEAT SECTION) WITH DRY INDOOR COIL AND AIR FILTERS IN PLACE. FOR ALL UNITS ADD:

1 − Wet indoor coil air resistance of selected unit.

2 − Any factory installed options air resistance (heat section, economizer, etc.)

3 − Any field installed accessories air resistance (duct resistance, diffuser, etc.)

Then determine from blower table blower motor output required.

See page 29 for blower motors and drives.

See page 29 for wet coil and option/accessory air resistance data.

MAXIMUM STATIC PRESSURE WITH GAS HEAT - 2.0 in. w.g.

Total Air Volume cfm	Total Static Pressure − in. w.g.																									
	0.2		0.4		0.6		0.8		1.0		1.2		1.4		1.6		1.8		2		2.2		2.4		2.6	
	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
2000	593	0.11	636	0.07	682	0.10	731	0.22	784	0.60	840	0.96	898	1.26	948	1.38	996	1.47	1045	1.57	1092	1.71	1140	1.92	1188	2.32
2250	604	0.15	645	0.11	690	0.15	739	0.39	790	0.74	846	1.08	901	1.34	953	1.48	1002	1.57	1052	1.70	1100	1.86	1149	2.09	1197	2.42
2500	615	0.19	655	0.15	699	0.20	747	0.55	797	0.89	851	1.20	906	1.44	959	1.58	1009	1.68	1059	1.83	1108	2.01	1158	2.26	1206	2.52
2750	626	0.23	666	0.19	709	0.37	755	0.71	805	1.03	858	1.32	912	1.55	966	1.70	1017	1.81	1067	1.97	1117	2.17	1166	2.44	1215	2.71
3000	637	0.27	677	0.24	719	0.55	764	0.87	813	1.18	866	1.45	920	1.67	975	1.82	1026	1.96	1076	2.13	1126	2.35	1176	2.63	1225	2.92
3250	650	0.31	688	0.43	730	0.73	775	1.04	823	1.34	875	1.60	930	1.81	985	1.97	1036	2.12	1086	2.31	1136	2.54	1186	2.83	1235	3.13
3500	663	0.35	700	0.63	741	0.92	786	1.22	834	1.50	886	1.76	942	1.96	997	2.14	1048	2.31	1097	2.51	1147	2.75	1196	3.04	1245	3.35
3750	676	0.57	714	0.84	754	1.12	798	1.41	846	1.68	899	1.93	956	2.14	1010	2.32	1060	2.51	1109	2.72	1158	2.98	1207	3.27	1255	3.58
4000	691	0.79	728	1.05	768	1.33	812	1.61	860	1.88	914	2.12	971	2.34	1023	2.53	1072	2.73	1121	2.95	1169	3.22	1218	3.51	1266	3.83
4250	706	1.03	743	1.28	783	1.55	827	1.82	876	2.09	931	2.33	987	2.55	1037	2.76	1085	2.97	1133	3.20	1181	3.47	1229	3.76	1277	4.08
4500	722	1.27	759	1.52	799	1.78	844	2.05	894	2.31	949	2.56	1003	2.79	1052	3.00	1098	3.22	1145	3.46	1193	3.73	1241	4.03	1289	4.34
4750	739	1.53	776	1.77	817	2.03	862	2.30	913	2.56	968	2.81	1020	3.04	1066	3.27	1112	3.49	1158	3.74	1205	4.01	1253	4.30	1301	4.61
5000	757	1.79	794	2.04	835	2.30	882	2.56	934	2.83	988	3.08	1036	3.32	1081	3.55	1125	3.78	1171	4.02	1218	4.29	1265	4.59	1312	4.89

BLOWER DATA

120H HIGH EFFICIENCY AND 150S STANDARD EFFICIENCY BELT DRIVE BLOWER − BASE UNIT

BLOWER TABLE INCLUDES RESISTANCE FOR BASE UNIT ONLY (NO HEAT SECTION) WITH DRY INDOOR COIL AND AIR FILTERS IN PLACE. FOR ALL UNITS ADD:

1 − Wet indoor coil air resistance of selected unit.

2 − Any factory installed options air resistance (heat section, economizer, etc.)

3 − Any field installed accessories air resistance (duct resistance, diffuser, etc.)

Then determine from blower table blower motor output required.

See page 29 for blower motors and drives.

See page 29 for wet coil and option/accessory air resistance data.

MAXIMUM STATIC PRESSURE WITH GAS HEAT - 2.0 in. w.g.

Total Air Volume cfm	Total Static Pressure − in. w.g.																									
	0.2		0.4		0.6		0.8		1.0		1.2		1.4		1.6		1.8		2.0		2.2		2.4		2.6	
	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
2000	497	0.25	558	0.44	624	0.6	694	0.74	764	0.85	830	0.99	889	1.16	943	1.34	994	1.52	1045	1.71	1096	1.89	1146	2.08	1197	2.27
2250	511	0.34	573	0.52	638	0.68	708	0.82	776	0.94	839	1.09	896	1.26	948	1.45	998	1.64	1048	1.83	1098	2.01	1149	2.2	1200	2.4
2500	527	0.44	589	0.62	654	0.78	723	0.91	789	1.05	850	1.21	904	1.39	955	1.58	1003	1.77	1052	1.96	1101	2.14	1152	2.33	1203	2.53
2750	545	0.55	606	0.72	672	0.88	740	1.03	804	1.17	861	1.34	914	1.53	962	1.72	1010	1.92	1057	2.10	1105	2.29	1154	2.47	1206	2.68
3000	564	0.66	626	0.84	692	1.01	759	1.16	819	1.32	874	1.49	924	1.68	971	1.88	1017	2.08	1063	2.26	1110	2.44	1158	2.63	1208	2.83
3250	585	0.79	648	0.98	714	1.14	778	1.31	836	1.48	887	1.66	935	1.86	981	2.06	1026	2.26	1071	2.45	1117	2.63	1163	2.80	1213	3.00
3500	607	0.93	672	1.13	737	1.31	798	1.48	852	1.66	901	1.85	948	2.05	993	2.26	1037	2.46	1081	2.65	1125	2.83	1171	3.01	1221	3.21
3750	632	1.10	698	1.31	762	1.50	819	1.67	869	1.86	915	2.05	961	2.25	1005	2.47	1049	2.68	1092	2.88	1136	3.05	1181	3.24	1231	3.45
4000	660	1.30	726	1.52	787	1.70	838	1.87	885	2.06	930	2.26	974	2.48	1018	2.71	1062	2.93	1105	3.12	1149	3.30	1194	3.49	1245	3.72
4250	691	1.53	755	1.75	810	1.91	857	2.07	901	2.27	945	2.50	990	2.74	1034	2.98	1077	3.20	1120	3.39	1163	3.58	1210	3.79	1262	4.03
4500	724	1.78	783	1.98	831	2.12	874	2.28	917	2.50	962	2.75	1006	3.02	1051	3.27	1094	3.49	1137	3.70	1181	3.89	1228	4.11	1281	4.38
4750	757	2.05	809	2.20	851	2.33	891	2.51	935	2.76	980	3.05	1025	3.33	1070	3.59	1113	3.82	1156	4.03	1201	4.24	1249	4.47	1303	4.75
5000	787	2.31	831	2.43	870	2.57	910	2.78	954	3.06	1000	3.38	1046	3.68	1091	3.95	1135	4.19	1178	4.40	1224	4.62	1272	4.86	1325	5.13
5250	814	2.55	852	2.66	889	2.83	930	3.09	975	3.41	1023	3.76	1070	4.08	1115	4.35	1159	4.59	1203	4.81	1248	5.03	1297	5.27	1350	5.53
5500	835	2.78	871	2.91	909	3.13	952	3.44	999	3.81	1049	4.18	1096	4.51	1142	4.79	1186	5.03	1229	5.24	1275	5.46	1324	5.69	- - -	- - -
5750	854	3.01	890	3.19	930	3.48	977	3.86	1027	4.27	1078	4.66	1126	4.99	1171	5.26	1214	5.49	1258	5.70	- - -	- - -	- - -	- - -	- - -	- - -
6000	871	3.26	910	3.53	955	3.90	1006	4.34	1060	4.80	1111	5.19	1158	5.51	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
6250	890	3.57	934	3.94	985	4.41	1041	4.91	1096	5.38	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -

FACTORY INSTALLED BELT DRIVE KIT SPECIFICATIONS

Nominal hp	Maximum hp	Drive Kit Number	RPM Range
2	2.3	1	590 - 890
2	2.3	2	800 - 1105
2	2.3	3	795 - 1195
3	3.45	4	730 - 970
3	3.45	5	940 - 1200
3	3.45	6	1015 - 1300
5	5.75	10	900 - 1135
5	5.75	11	1040 - 1315
5	5.75	12	1125 - 1425

NOTE - Using total air volume and system static pressure requirements determine from blower performance tables rpm and motor output required. Maximum usable output of motors furnished are shown. In Canada, nominal motor output is also maximum usable motor output. If motors of comparable output are used, be sure to keep within the service factor limitations outlined on the motor nameplate.

NOTE – Units equipped with Single Zone VAV Supply Fan option are limited to a motor service factor of 1.0.

POWER EXHAUST FAN PERFORMANCE

Return Air System Static Pressure	Air Volume Exhausted
in. w.g.	cfm
0	3175
0.05	2955
0.10	2685
0.15	2410
0.20	2165
0.25	1920
0.30	1420
0.35	1200

FACTORY INSTALLED OPTIONS/FIELD INSTALLED ACCESSORY AIR RESISTANCE - in. w.g.

Air Volume cfm	Wet Indoor Coil		Gas Heat Exchanger			Economizer	Filters	
	092, 102	120, 150	Standard Heat	Medium Heat	High Heat		MERV 8	MERV 13
1750	0.04	0.04	0.06	0.02	0.02	0.05	0.01	0.03
2000	0.05	0.05	0.07	0.05	0.06	0.06	0.01	0.03
2250	0.06	0.06	0.07	0.07	0.08	0.08	0.01	0.04
2500	0.07	0.07	0.09	0.10	0.11	0.11	0.01	0.05
2750	0.08	0.08	0.09	0.11	0.12	0.12	0.02	0.05
3000	0.10	0.09	0.11	0.12	0.13	0.13	0.02	0.06
3250	0.11	0.10	0.12	0.15	0.16	0.15	0.02	0.06
3500	0.12	0.11	0.12	0.16	0.17	0.15	0.03	0.07
3750	0.14	0.13	0.14	0.19	0.20	0.15	0.03	0.08
4000	0.15	0.14	0.14	0.21	0.22	0.19	0.04	0.08
4250	0.17	0.15	0.14	0.24	0.28	0.19	0.04	0.09
4500	0.19	0.17	0.15	0.26	0.32	0.22	0.04	0.09
4750	0.20	0.18	0.16	0.29	0.37	0.25	0.05	0.10
5000	0.22	0.20	0.16	0.34	0.43	0.29	0.06	0.10
5250	0.24	0.22	0.16	0.37	0.47	0.32	0.06	0.11
5500	0.25	0.23	0.18	0.44	0.54	0.34	0.07	0.12
5750	0.27	0.25	0.19	0.49	0.59	0.45	0.07	0.12
6000	0.29	0.27	0.20	0.54	0.64	0.52	0.08	0.13

BLOWER DATA

BLOWER TABLE INCLUDES RESISTANCE FOR BASE UNIT ONLY WITH DRY INDOOR COIL & AIR FILTERS IN PLACE
FOR ALL UNITS ADD:

1 - Wet indoor coil air resistance of selected unit.
2 - Any factory installed options air resistance (heat section, economizer, etc.)
3 - Any field installed accessories air resistance (heat section, duct resistance, diffuser, etc.)

Then determine from blower table blower motor output and drive required.
See page 30 for wet coil and option/accessory air resistance data.
See page 30 for factory installed drive kit specifications.

MINIMUM AIR VOLUME REQUIRED FOR DIFFERENT GAS HEAT SIZES

Standard (S) and Medium Heat (M) - 4500 cfm minimum
High Heat (H) - 5125 cfm minimum

Air Volume cfm	TOTAL STATIC PRESSURE - Inches Water Gauge (Pa)																									
	0.20		0.40		0.60		0.80		1.00		1.20		1.40		1.60		1.80		2.00		2.20		2.40		2.60	
	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
2750	385	0.30	505	0.50	600	0.70	680	0.90	755	1.10	820	1.30	---	---	---	---	---	---	---	---	---	---	---	---	---	---
3000	395	0.35	515	0.55	610	0.75	685	1.00	760	1.20	825	1.45	885	1.70	---	---	---	---	---	---	---	---	---	---	---	---
3250	405	0.40	520	0.60	615	0.85	695	1.10	765	1.30	830	1.60	890	1.85	950	2.10	---	---	---	---	---	---	---	---	---	---
3500	415	0.45	530	0.70	620	0.95	700	1.20	775	1.45	840	1.70	900	2.00	955	2.25	1005	2.55	---	---	---	---	---	---	---	---
3750	425	0.50	540	0.75	630	1.05	710	1.30	780	1.60	845	1.85	905	2.15	960	2.45	1010	2.70	1060	3.00	1110	3.30	---	---	---	---
4000	435	0.55	545	0.85	635	1.10	715	1.40	785	1.70	850	2.00	910	2.30	965	2.60	1020	2.90	1070	3.25	1115	3.55	1160	3.85	1205	4.15
4250	445	0.60	555	0.90	645	1.25	725	1.55	795	1.85	855	2.15	915	2.45	970	2.80	1025	3.10	1075	3.45	1120	3.75	1165	4.10	1210	4.45
4500	455	0.70	565	1.00	655	1.35	730	1.65	800	2.00	865	2.35	925	2.65	980	3.00	1030	3.30	1080	3.65	1130	4.05	1175	4.35	1215	4.70
4750	470	0.75	575	1.10	660	1.45	740	1.80	810	2.15	870	2.50	930	2.85	985	3.20	1040	3.55	1085	3.90	1135	4.25	1180	4.65	1225	5.00
5000	480	0.85	585	1.25	670	1.60	750	1.95	815	2.30	880	2.70	940	3.05	995	3.40	1045	3.80	1095	4.15	1140	4.50	1185	4.90	1230	5.30
5250	495	0.95	595	1.35	680	1.70	755	2.10	825	2.50	890	2.90	945	3.25	1000	3.65	1050	4.00	1100	4.40	1150	4.80	1195	5.20	1235	5.60
5500	505	1.05	605	1.45	690	1.85	765	2.25	835	2.65	895	3.05	955	3.45	1010	3.85	1060	4.25	1110	4.70	1155	5.10	1200	5.50	1240	5.90
5750	520	1.15	615	1.60	700	2.00	775	2.45	840	2.85	905	3.25	960	3.65	1015	4.10	1065	4.50	1115	4.95	1160	5.35	1205	5.80	1250	6.25
6000	530	1.30	630	1.75	710	2.15	785	2.60	850	3.05	910	3.45	970	3.90	1025	4.35	1075	4.80	1120	5.20	1170	5.65	1215	6.10	1255	6.55
6250	545	1.40	640	1.90	720	2.35	795	2.80	860	3.25	920	3.70	975	4.15	1030	4.60	1080	5.05	1130	5.50	1175	5.95	1220	6.45	1265	6.90
6500	560	1.55	650	2.05	730	2.50	805	3.00	870	3.45	930	3.95	985	4.40	1040	4.85	1090	5.35	1140	5.85	1185	6.30	1225	6.75	1270	7.25
6750	570	1.70	665	2.20	745	2.70	815	3.20	880	3.70	940	4.20	995	4.65	1045	5.10	1095	5.60	1145	6.10	1190	6.60	1235	7.10	1275	7.60
7000	585	1.85	675	2.35	755	2.90	825	3.40	890	3.95	950	4.45	1005	4.95	1055	5.40	1105	5.95	1155	6.45	1200	6.95	1240	7.45	1285	8.00
7250	600	2.00	690	2.60	765	3.10	835	3.65	900	4.15	955	4.65	1015	5.25	1065	5.75	1115	6.25	1160	6.75	1205	7.30	1250	7.85	1290	8.35
7500	615	2.20	700	2.75	775	3.30	845	3.85	910	4.45	965	4.95	1020	5.50	1075	6.05	1125	6.60	1170	7.15	1215	7.65	1260	8.25	1300	8.75
7750	630	2.40	715	3.00	790	3.55	855	4.10	920	4.70	975	5.25	1030	5.80	1080	6.35	1130	6.90	1180	7.50	1225	8.05	1265	8.60	1305	9.15
8000	640	2.55	725	3.20	800	3.80	865	4.35	930	4.95	985	5.50	1040	6.10	1090	6.70	1140	7.25	1185	7.85	1230	8.40	1275	9.00	1315	9.60
8250	655	2.80	740	3.40	810	4.00	880	4.65	940	5.25	995	5.85	1050	6.45	1100	7.05	1150	7.65	1195	8.25	1240	8.85	1280	9.40	1325	10.05
8500	670	3.00	750	3.65	825	4.30	890	4.90	950	5.55	1005	6.15	1060	6.80	1110	7.40	1160	8.05	1205	8.65	1250	9.25	1290	9.85	1330	10.45
8750	685	3.25	765	3.90	835	4.55	900	5.20	960	5.85	1015	6.45	1070	7.15	1120	7.75	1165	8.35	1215	9.05	1255	9.65	1300	10.30	1340	10.90
9000	700	3.50	780	4.20	850	4.85	910	5.50	970	6.15	1025	6.80	1080	7.50	1130	8.15	1175	8.75	1220	9.40	1265	10.10	1310	10.80	1350	11.40
9250	715	3.75	790	4.45	860	5.15	925	5.85	985	6.55	1040	7.20	1090	7.85	1140	8.55	1185	9.20	1230	9.85	1275	10.55	1315	11.20	---	---
9500	730	4.00	805	4.75	875	5.45	935	6.15	995	6.90	1050	7.60	1100	8.25	1150	8.95	1195	9.60	1240	10.30	1285	11.05	---	---	---	---
9750	745	4.30	820	5.05	885	5.75	950	6.55	1005	7.20	1060	7.95	1110	8.65	1160	9.40	1205	10.05	1250	10.80	1295	11.50	---	---	---	---
10,000	760	4.60	835	5.40	900	6.15	960	6.85	1015	7.60	1070	8.35	1120	9.05	1170	9.80	1215	10.50	1260	11.25	---	---	---	---	---	---
10,250	775	4.90	845	5.65	910	6.45	970	7.20	1030	8.00	1080	8.75	1135	9.55	1180	10.25	1225	11.00	---	---	---	---	---	---	---	---
10,500	790	5.20	860	6.00	925	6.85	985	7.65	1040	8.40	1095	9.20	1145	10.00	1190	10.70	1235	11.45	---	---	---	---	---	---	---	---
10,750	805	5.55	875	6.40	940	7.25	1000	8.05	1055	8.85	1105	9.65	1155	10.45	1200	11.20	---	---	---	---	---	---	---	---	---	---
11,000	820	5.90	890	6.80	950	7.60	1010	8.45	1065	9.30	1115	10.05	1165	10.90	---	---	---	---	---	---	---	---	---	---	---	---

BLOWER DATA

FACTORY INSTALLED BELT DRIVE KIT SPECIFICATIONS

Motor Efficiency	Nominal hp	Maximum hp	Drive Kit Number	RPM Range
Standard or High	2	2.30	1	535 - 725
Standard or High	2	2.30	2	710 - 965
Standard	3	3.45	1	535 - 725
Standard	3	3.45	2	710 - 965
Standard	5	5.75	3	685 - 856
Standard	5	5.75	4	850 - 1045
Standard	5	5.75	5	945 - 1185
Standard	7.5	8.63	6	850 - 1045
Standard	7.5	8.63	7	945 - 1185
Standard	7.5	8.63	8	1045 - 1285
Standard	10	11.50	7	945 - 1185
Standard	10	11.50	10	1045 - 1285
Standard	10	11.50	11	1135 - 1365

NOTE - Using total air volume and system static pressure requirements determine from blower performance tables rpm and motor output required. Maximum usable output of motors furnished are shown. In Canada, nominal motor output is also maximum usable motor output. If motors of comparable output are used, be sure to keep within the service factor limitations outlined on the motor nameplate.

NOTE – Units equipped with MSAV® (Multi-Stage Air Volume) option are limited to a motor service factor of 1.0.

FACTORY INSTALLED OPTIONS/FIELD INSTALLED ACCESSORY AIR RESISTANCE - in. w.g.

Air Volume cfm	Wet Indoor Coil			Gas Heat Exchanger			Economizer	Filters		Horizontal Roof Curb	
	180S	156H 180H 210S	210H 240H 240S 300H 300S	Standard Heat	Medium Heat	High Heat		MERV 8	MERV 13	156H 180H 180S 210H 210S 240H 240S	300H 300S
2750	0.01	0.01	0.02	0.02	0.04	0.05	- - -	0.01	0.03	0.03	- - -
3000	0.01	0.01	0.02	0.03	0.04	0.05	- - -	0.01	0.03	0.04	- - -
3250	0.02	0.01	0.03	0.03	0.05	0.06	- - -	0.01	0.04	0.04	0.01
3500	0.02	0.01	0.03	0.03	0.05	0.06	- - -	0.01	0.04	0.05	0.01
3750	0.02	0.01	0.03	0.04	0.06	0.07	- - -	0.01	0.04	0.05	0.01
4000	0.02	0.02	0.04	0.04	0.06	0.07	- - -	0.01	0.04	0.06	0.02
4250	0.02	0.02	0.04	0.04	0.06	0.08	- - -	0.01	0.05	0.07	0.02
4500	0.02	0.02	0.05	0.05	0.07	0.09	- - -	0.01	0.05	0.07	0.02
4750	0.02	0.02	0.05	0.05	0.08	0.10	- - -	0.02	0.05	0.08	0.03
5000	0.03	0.02	0.05	0.05	0.09	0.11	- - -	0.02	0.06	0.08	0.03
5250	0.03	0.02	0.06	0.06	0.10	0.12	- - -	0.02	0.06	0.09	0.04
5500	0.03	0.02	0.07	0.06	0.10	0.13	- - -	0.02	0.06	0.10	0.04
5750	0.03	0.03	0.07	0.06	0.11	0.14	- - -	0.02	0.07	0.11	0.05
6000	0.04	0.03	0.08	0.07	0.12	0.15	- - -	0.03	0.07	0.11	0.06
6250	0.04	0.03	0.08	0.07	0.12	0.16	0.01	0.03	0.07	0.12	0.07
6500	0.04	0.03	0.09	0.08	0.13	0.17	0.02	0.03	0.08	0.13	0.08
6750	0.05	0.04	0.10	0.08	0.14	0.18	0.03	0.03	0.08	0.14	0.08
7000	0.05	0.04	0.10	0.09	0.15	0.19	0.04	0.04	0.08	0.15	0.09
7250	0.06	0.04	0.11	0.09	0.16	0.20	0.05	0.04	0.09	0.16	0.10
7500	0.06	0.05	0.12	0.10	0.17	0.21	0.06	0.04	0.09	0.17	0.11
8000	0.07	0.05	0.13	0.11	0.19	0.24	0.09	0.05	0.10	0.19	0.13
8500	0.08	0.06	0.15	0.12	0.20	0.26	0.11	0.05	0.10	0.21	0.15
9000	0.09	0.07	0.16	0.13	0.23	0.29	0.14	0.06	0.11	0.24	0.17
9500	0.10	0.08	0.18	0.14	0.25	0.32	0.16	0.07	0.12	0.26	0.19
10000	0.11	0.08	0.20	0.16	0.27	0.35	0.19	0.07	0.12	0.29	0.21
10500	0.12	0.09	0.22	0.17	0.30	0.38	0.22	0.08	0.13	0.31	0.24
11000	0.14	0.11	0.24	0.18	0.31	0.40	0.25	0.09	0.14	0.34	0.27

BLOWER DATA

CEILING DIFFUSER AIR RESISTANCE - in. w.g.

Air Volume cfm	Step-Down Diffuser						Flush Diffuser	
	RTD11-185S			RTD11-275			FD11-185S	FD11-275
	2 Ends Open	1 Side/2 Ends Open	All Ends & Sides Open	2 Ends Open	1 Side/2 Ends Open	All Ends & Sides Open		
5000	.51	.44	.39	- - -	- - -	- - -	.27	- - -
5200	.56	.48	.42	- - -	- - -	- - -	.30	- - -
5400	.61	.52	.45	- - -	- - -	- - -	.33	- - -
5600	.66	.56	.48	- - -	- - -	- - -	.36	- - -
5800	.71	.59	.51	- - -	- - -	- - -	.39	- - -
6000	.76	.63	.55	.36	.31	.27	.42	.29
6200	.80	.68	.59	- - -	- - -	- - -	.46	- - -
6400	.86	.72	.63	- - -	- - -	- - -	.50	- - -
6500	- - -	- - -	- - -	.42	.36	.31	- - -	.34
6600	.92	.77	.67	- - -	- - -	- - -	.54	- - -
6800	.99	.83	.72	- - -	- - -	- - -	.58	- - -
7000	1.03	.87	.76	.49	.41	.36	.62	.40
7200	1.09	.92	.80	- - -	- - -	- - -	.66	- - -
7400	1.15	.97	.84	- - -	- - -	- - -	.70	- - -
7500	- - -	- - -	- - -	.51	.46	.41	- - -	.45
7600	1.20	1.02	.88	- - -	- - -	- - -	.74	- - -
8000	- - -	- - -	- - -	.59	.49	.43	- - -	.50
8500	- - -	- - -	- - -	.69	.58	.50	- - -	.57
9000	- - -	- - -	- - -	.79	.67	.58	- - -	.66
9500	- - -	- - -	- - -	.89	.75	.65	- - -	.74
10,000	- - -	- - -	- - -	1.00	.84	.73	- - -	.81
10,500	- - -	- - -	- - -	1.10	.92	.80	- - -	.89
11,000	- - -	- - -	- - -	1.21	1.01	.88	- - -	.96

CEILING DIFFUSER AIR THROW DATA

Model No.	Air Volume cfm	[1] Effective Throw Range - ft.	
		RTD11-185S Step-Down	FD11-185S Flush
156 180	5600	39 - 49	28 - 37
	5800	42 - 51	29 - 38
	6000	44 - 54	40 - 50
	6200	45 - 55	42 - 51
	6400	46 - 55	43 - 52
	6600	47 - 56	45 - 56

[1] Throw is the horizontal or vertical distance an airstream travels on leaving the outletor diffuser before the maximum velocity is reduced to 50 ft. per minute. Four sides open.

Model No.	Air Volume cfm	[1] Effective Throw Range - ft.	
		RTD11-275 Step-Down	FD11-275 Flush
210 240 300	7200	33 - 38	26 - 35
	7400	35 - 40	28 - 37
	7600	36 - 41	29 - 38
	7800	38 - 43	40 - 50
	8000	39 - 44	42 - 51
	8200	41 - 46	43 - 52
	8400	43 - 49	44 - 54
	8600	44 - 50	46 - 57
	8800	47 - 55	48 - 59

POWER EXHAUST FAN PERFORMANCE

Return Air System Static Pressure in. w.g.	Air Volume Exhausted cfm
0.00	8630
0.05	8210
0.10	7725
0.15	7110
0.20	6470
0.25	5790
0.30	5060
0.35	4300
0.40	3510
0.45	2690
0.50	1840

BLOWER DATA - DIRECT DRIVE - 3 TON

036 DIRECT DRIVE BLOWER - BASE UNIT

BLOWER TABLE INCLUDES RESISTANCE FOR BASE UNIT ONLY WITH DRY INDOOR COIL AND AIR FILTERS IN PLACE.

FOR ALL UNITS ADD:
1 - Any factory installed options air resistance (heat section, economizer, etc.).
2 - Any field installed accessories air resistance (duct resistance, diffuser, etc.).

See page 24 or blower motors and drives and wet coil and options/accessory air resistance data.

DOWNFLOW

External Static Press. in. w.g.	Percentage of Total Motor Torque																													
	10%			20%			30%			40%			50%			60%			70%			80%			90%			100%		
	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM
0.1	459	29	380	698	47	414	903	76	475	1069	110	539	1224	153	598	1374	195	632	1500	248	677	1617	312	723	1729	375	763	1821	447	803
0.2	357	32	464	596	55	520	828	86	563	1023	120	597	1180	165	634	1331	210	685	1461	264	727	1590	325	757	1704	387	796	1796	460	835
0.3	255	36	554	521	61	596	772	94	607	977	130	654	1137	177	706	1302	220	720	1435	274	776	1550	344	808	1666	406	843	1772	473	866
0.4	166	39	637	445	67	669	716	102	694	916	143	728	1108	185	740	1258	235	772	1397	289	808	1523	356	841	1641	417	874	1735	492	911
0.5	- - -	- - -	- - -	369	72	739	661	111	759	869	153	782	1050	200	807	1214	249	822	1358	304	855	1483	372	889	1603	434	919	1710	504	940
0.6	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	823	162	834	1006	212	856	1171	262	872	1319	318	900	1456	383	920	1565	450	962	1674	521	983
0.7	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	762	175	901	963	223	903	1127	275	920	1280	331	944	1416	398	966	1540	460	991	1637	536	1024
0.8	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	716	184	950	905	237	964	1083	287	968	1241	344	986	1376	412	1011	1502	474	1032	1612	546	1050
0.9	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	670	193	997	862	247	1007	1040	299	1014	1202	356	1027	1336	425	1054	1464	488	1072	1576	560	1088
1.0	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	623	202	1043	818	257	1049	981	314	1074	1151	371	1079	1296	437	1095	1426	501	1110	1539	573	1125
1.1	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	938	325	1118	1112	382	1117	1256	447	1135	1388	513	1147	1490	589	1171
1.2	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	1215	457	1174	1344	526	1188	1453	600	1204

HORIZONTAL

External Static Press. in. w.g.	Percentage of Total Motor Torque																													
	10%			20%			30%			40%			50%			60%			70%			80%			90%			100%		
	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM
0.1	432	29	395	674	49	443	882	79	511	1053	115	567	1211	156	617	1334	205	676	1463	260	725	1583	322	769	1692	391	813	1791	466	852
0.2	334	32	479	581	56	537	822	87	582	1021	122	609	1178	165	659	1308	215	712	1439	270	758	1560	333	801	1670	402	843	1771	477	877
0.3	217	36	578	517	61	603	763	96	651	953	137	696	1128	179	720	1265	230	768	1400	286	809	1522	350	850	1634	420	888	1737	494	920
0.4	149	39	636	436	68	684	703	105	719	918	145	738	1079	193	781	1237	239	805	1374	297	842	1498	361	881	1611	431	917	1714	505	947
0.5	- - -	- - -	- - -	372	73	749	644	114	786	867	155	799	1046	201	820	1194	254	858	1335	312	891	1460	377	927	1576	447	960	1680	521	987
0.6	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	816	166	858	997	214	879	1152	267	909	1296	326	938	1435	387	957	1552	457	987	1645	536	1026
0.7	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	765	176	915	948	227	936	1109	280	959	1257	339	983	1398	401	1000	1517	471	1026	1611	550	1063
0.8	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	714	185	970	915	235	974	1081	288	991	1231	348	1013	1360	415	1041	1482	484	1064	1588	558	1087
0.9	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	663	194	1022	866	247	1030	1024	304	1052	1179	364	1070	1322	427	1081	1434	500	1112	1542	575	1133
1.0	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	611	203	1073	816	259	1085	981	315	1096	1140	376	1112	1285	438	1118	1399	511	1146	1508	586	1165
1.1	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	939	325	1138	1101	387	1152	1235	452	1166	1364	521	1178	1474	596	1197
1.2	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	1198	461	1200	1323	532	1214	1439	606	1227

BLOWER DATA - DIRECT DRIVE - 4 TON

048 DIRECT DRIVE BLOWER - BASE UNIT

BLOWER TABLE INCLUDES RESISTANCE FOR BASE UNIT ONLY WITH DRY INDOOR COIL AND AIR FILTERS IN PLACE.

FOR ALL UNITS ADD:
1 - Any factory installed options air resistance (heat section, economizer, etc.).
2 - Any field installed accessories air resistance (duct resistance, diffuser, etc.).

See page 24 for blower motors and drives and wet coil and options/accessory air resistance data.

DOWNFLOW

External Static Press.	Percentage of Total Motor Torque																													
	10%			20%			30%			40%			50%			60%			70%			80%			90%			100%		
in. w.g.	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM
0.1	682	46	420	894	79	499	1148	131	579	1366	192	651	1551	268	726	1725	348	781	1885	445	840	2031	550	893	2165	669	950	2290	790	993
0.2	583	52	510	836	87	562	1105	142	635	1329	204	697	1530	279	756	1695	368	827	1856	466	883	2006	567	925	2149	683	972	2271	813	1023
0.3	484	59	601	778	96	629	1062	152	688	1292	217	744	1500	294	800	1675	380	856	1837	479	910	1981	585	958	2125	704	1005	2252	834	1051
0.4	410	64	666	720	105	697	1019	162	739	1255	231	792	1469	309	841	1645	397	898	1808	498	950	1956	603	992	2100	723	1036	2233	851	1076
0.5	---	---	---	662	114	764	961	176	805	1218	244	840	1428	327	895	1615	414	937	1780	515	987	1931	622	1025	2076	741	1066	2205	874	1111
0.6	---	---	---	---	---	---	---	---	---	1182	257	887	1398	341	934	1585	429	974	1751	532	1022	1906	641	1058	2052	758	1095	2186	886	1131
0.7	---	---	---	---	---	---	---	---	---	1145	270	933	1367	354	972	1555	443	1009	1722	548	1056	1874	663	1098	2028	774	1122	2148	903	1167
0.8	---	---	---	---	---	---	---	---	---	1096	287	992	1326	372	1021	1515	462	1056	1693	564	1090	1850	679	1129	1996	792	1157	2111	913	1196
0.9	---	---	---	---	---	---	---	---	---	1047	302	1047	1296	385	1058	1485	476	1090	1664	579	1123	1824	693	1157	1963	807	1188	2073	916	1219
1.0	---	---	---	---	---	---	---	---	---	1010	312	1085	1255	403	1107	1455	491	1125	1635	594	1155	1787	710	1195	1931	818	1216	2036	912	1236
1.1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1425	505	1160	1606	609	1188	1762	717	1216	1883	828	1250	1960	890	1260
1.2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1687	715	1254	1834	827	1275	1848	834	1274

HORIZONTAL

External Static Press.	Percentage of Total Motor Torque																													
	10%			20%			30%			40%			50%			60%			70%			80%			90%			100%		
in. w.g.	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM
0.1	641	46	443	875	82	522	1127	137	614	1334	202	691	1524	280	762	1694	367	827	1866	470	881	1997	581	955	2119	699	1010	2241	830	1058
0.2	568	50	505	831	90	582	1097	144	650	1310	211	723	1504	290	793	1671	379	859	1829	484	921	1977	600	986	2106	715	1032	2227	846	1080
0.3	483	56	584	778	98	647	1050	155	706	1269	225	777	1470	308	844	1642	396	900	1799	498	957	1953	621	1022	2079	743	1072	2199	873	1118
0.4	398	62	661	724	106	707	1004	167	764	1228	240	831	1436	325	891	1612	413	941	1777	511	985	1930	640	1055	2062	758	1096	2181	888	1140
0.5	---	---	---	671	113	763	957	179	822	1201	250	867	1413	335	921	1588	427	973	1748	530	1025	1906	657	1087	2036	777	1129	2153	904	1170
0.6	---	---	---	---	---	---	---	---	---	1161	265	919	1378	350	964	1552	447	1019	1718	549	1064	1874	676	1124	2000	796	1166	2115	917	1202
0.7	---	---	---	---	---	---	---	---	---	1120	279	970	1344	365	1006	1529	459	1049	1696	564	1093	1850	688	1150	1974	805	1189	2078	922	1228
0.8	---	---	---	---	---	---	---	---	---	1093	288	1003	1310	379	1047	1493	477	1091	1667	583	1131	1818	700	1180	1930	812	1220	2040	919	1246
0.9	---	---	---	---	---	---	---	---	---	1052	302	1051	1275	393	1087	1469	488	1118	1644	595	1158	1779	711	1213	1896	812	1239	1984	903	1265
1.0	---	---	---	---	---	---	---	---	---	1012	314	1096	1241	407	1128	1434	502	1155	1615	610	1191	1747	715	1235	1843	802	1259	1910	865	1276
1.1	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1386	516	1201	1571	625	1232	1684	713	1266	1738	760	1277	1760	775	1282
1.2	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	1620	697	1282	1633	707	1283	1667	736	1296

BLOWER DATA - DIRECT DRIVE - 5 AND 6 TON

060/074 DIRECT DRIVE BLOWER - BASE UNIT

BLOWER TABLE INCLUDES RESISTANCE FOR BASE UNIT ONLY WITH DRY INDOOR COIL AND AIR FILTERS IN PLACE.

FOR ALL UNITS ADD:
1 - Any factory installed options air resistance (heat section, economizer, etc.).
2 - Any field installed accessories air resistance (duct resistance, diffuser, etc.).

See page 24 for blower motors and drives and wet coil and options/accessory air resistance data.

DOWNFLOW

External Static Press.	Percentage of Total Motor Torque																													
	10%			20%			30%			40%			50%			60%			70%			80%			90%			100%		
in. w.g.	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM
0.1	743	58	428	992	100	492	1284	161	556	1526	231	607	1726	327	678	1890	427	737	2072	557	800	2220	686	848	2362	842	901	2478	996	938
0.2	661	65	497	928	110	556	1231	175	610	1479	251	662	1685	348	726	1872	440	761	2052	574	827	2198	705	876	2344	860	925	2468	1016	969
0.3	579	71	563	881	118	602	1179	188	663	1431	270	716	1658	362	757	1835	466	807	2024	597	863	2176	724	903	2322	881	952	2448	1035	993
0.4	518	76	611	818	128	662	1126	202	716	1400	283	751	1618	383	802	1811	483	837	1995	619	898	2153	743	930	2301	900	978	2428	1053	1016
0.5	- - -	- - -	- - -	754	138	719	1074	216	768	1352	301	801	1578	403	847	1775	507	881	1972	636	925	2120	769	968	2280	919	1002	2403	1074	1043
0.6	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	1305	319	850	1551	416	875	1738	529	922	1938	659	963	2098	785	992	2248	945	1037	2383	1090	1064
0.7	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	1273	330	882	1511	434	917	1714	544	948	1903	681	1000	2064	808	1026	2227	961	1059	2353	1113	1094
0.8	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	1226	347	928	1470	453	957	1678	564	986	1869	701	1033	2031	830	1058	2195	983	1090	2323	1133	1121
0.9	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	1178	363	972	1430	470	997	1641	583	1022	1835	720	1065	1998	849	1088	2163	1004	1119	2293	1151	1147
1.0	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	1147	374	1000	1390	487	1034	1605	601	1057	1800	737	1094	1953	873	1125	2131	1022	1146	2263	1167	1170
1.1	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	1556	623	1099	1755	756	1129	1920	888	1151	2089	1043	1177	2203	1193	1211
1.2	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	1875	906	1181	2036	1063	1211	2169	1213	1227

HORIZONTAL

External Static Press.	Percentage of Total Motor Torque																													
	10%			20%			30%			40%			50%			60%			70%			80%			90%			100%		
in. w.g.	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM	Cfm	Watts	RPM
0.1	695	49	431	1051	88	470	1280	157	562	1430	314	665	1615	420	753	1798	526	807	1957	656	873	2100	793	925	2228	947	979	2351	1107	1022
0.2	610	55	495	973	96	543	1233	166	607	1382	332	715	1589	433	782	1762	547	847	1927	677	905	2079	808	947	2207	965	1002	2332	1126	1043
0.3	525	61	560	914	104	612	1186	177	657	1347	345	752	1563	446	811	1738	561	873	1907	690	927	2047	830	979	2186	982	1024	2308	1148	1069
0.4	461	66	611	856	115	695	1138	190	714	1312	358	788	1525	464	853	1702	581	911	1877	709	958	2026	844	999	2165	998	1046	2289	1164	1088
0.5	- - -	- - -	- - -	822	122	749	1095	202	772	1277	370	823	1486	482	893	1678	593	936	1847	726	987	1995	864	1030	2144	1013	1067	2264	1182	1111
0.6	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	1242	382	857	1460	494	919	1642	612	972	1827	738	1007	1974	877	1050	2112	1035	1096	2239	1197	1133
0.7	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	1194	398	901	1421	510	957	1618	624	995	1787	760	1044	1943	896	1079	2091	1048	1115	2208	1213	1158
0.8	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	1148	413	943	1382	527	993	1582	641	1029	1757	775	1071	1912	914	1107	2059	1065	1142	2184	1223	1176
0.9	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	1112	424	974	1343	542	1028	1546	657	1061	1727	789	1096	1880	932	1135	2028	1081	1167	2147	1233	1200
1.0	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	1069	438	1011	1305	557	1062	1510	673	1092	1687	807	1129	1849	948	1162	1996	1095	1191	2110	1238	1221
1.1	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	1474	688	1122	1652	822	1156	1818	964	1188	1964	1107	1212	2060	1235	1243
1.2	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	1781	982	1217	1912	1123	1245	2010	1221	1258

BLOWER DATA

FACTORY INSTALLED OPTIONS/FIELD INSTALLED ACCESSORY AIR RESISTANCE - in. w.g.

Air Volume cfm	Wet Indoor Coil		Gas Heating		Economizer	Filters	
	036, 048	060, 074	Medium Heat	High Heat		MERV 8	MERV 13
800	0.01	- - -	0.02	0.02	0.04	0.04	0.05
1000	0.02	0.02	0.02	0.02	0.04	0.04	0.07
1200	0.03	0.04	0.02	0.02	0.04	0.04	0.07
1400	0.04	0.05	0.02	0.03	0.04	0.04	0.07
1600	0.05	0.07	0.03	0.04	0.04	0.04	0.07
1800	0.06	0.08	0.04	0.05	0.05	0.04	0.07
2000	0.08	0.10	0.04	0.06	0.05	0.05	0.08
2200	- - -	0.11	0.04	0.07	0.05	0.05	0.08
2400	- - -	0.13	0.05	0.08	0.05	0.05	0.08

POWER EXHAUST FAN PERFORMANCE

Return Air System Static Pressure in. w.g.	Air Volume Exhausted cfm
0.00	2000
0.05	1990
0.10	1924
0.15	1810
0.20	1664
0.25	1507
0.30	1350
0.35	1210

CEILING DIFFUSERS AIR RESISTANCE (in. w.g.)

Air Volume - cfm	RTD11-95S Step-Down Diffuser			FD11-95S Flush Diffuser
	2 Ends Open	1 Side & 2 Ends Open	All Ends & Sides Open	
1800	0.13	0.11	0.09	0.09
2000	0.15	0.13	0.11	0.10
2200	0.18	0.15	0.12	0.12
2400	0.21	0.18	0.15	0.14
2600	0.24	0.21	0.18	0.17
2800	0.27	0.24	0.21	0.20
3000	0.32	0.29	0.25	0.25

CEILING DIFFUSER AIR THROW DATA

Air Volume - cfm	[1] Effective Throw - ft.	
	RTD11-95S	FD11-95S
2600	24 - 29	19 - 24
2800	25 - 30	20 - 28
3000	27 - 33	21 - 29

[1] Effective throw based on terminal velocities of 75 ft. per minute.

BLOWER DATA

BLOWER TABLE INCLUDES RESISTANCE FOR BASE UNIT ONLY WITH DRY INDOOR COIL, ELECTRIC HEAT, ECONOMIZER, ONE ROW REHEAT COIL & AIR FILTERS IN PLACE

Add factory installed options air resistance, then determine from blower table blower motor output and drive kit required.
See page 53 for horizontal configured unit air resistance.
See page 54 for factory installed options air resistance data.
See page 55 for factory installed drive kit specifications.

TOTAL STATIC PRESSURE - 0.2 Thru 2.4 in. w.g.
For 2.6 thru 4.6 in. w.g., see next page

Air Volume cfm	0.20		0.40		0.60		0.80		1.0		1.2		1.4		1.6		1.8		2.0		2.2		2.4	
	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
10,500	460	3.25	500	3.25	535	3.45	575	3.90	620	4.50	670	5.40	715	6.25	755	7.05	790	7.75	820	8.40	850	9.05	- - -	- - -
11,000	490	3.70	520	3.75	550	3.90	585	4.25	630	4.85	675	5.65	720	6.55	760	7.40	795	8.20	830	9.00	860	9.70	890	10.40
11,500	520	4.25	540	4.25	565	4.35	600	4.70	635	5.20	680	5.95	725	6.85	765	7.75	805	8.70	840	9.60	870	10.35	900	11.10
12,000	540	4.80	555	4.80	580	4.90	610	5.15	650	5.70	690	6.40	730	7.20	770	8.15	810	9.10	845	10.05	880	10.95	910	11.80
12,500	560	5.45	575	5.45	600	5.50	625	5.70	660	6.15	695	6.75	735	7.55	780	8.60	815	9.55	850	10.50	885	11.50	915	12.35
13,000	580	6.10	600	6.10	620	6.20	645	6.35	675	6.75	705	7.25	745	8.05	785	9.00	820	9.95	860	11.10	895	12.15	925	13.05
13,500	600	6.85	615	6.85	635	6.85	660	7.05	685	7.30	720	7.90	750	8.50	790	9.45	830	10.50	865	11.55	900	12.65	930	13.60
14,000	620	7.60	635	7.60	655	7.65	675	7.75	700	8.05	730	8.50	760	9.05	795	9.85	835	10.95	870	12.00	905	13.15	940	14.30
14,500	640	8.45	660	8.45	675	8.50	690	8.55	720	8.85	745	9.20	775	9.80	805	10.50	840	11.45	875	12.50	910	13.65	945	14.85
15,000	665	9.35	680	9.35	690	9.40	715	9.50	735	9.70	755	9.95	785	10.50	815	11.15	850	12.10	880	13.00	915	14.15	950	15.40
15,500	685	10.35	695	10.35	715	10.35	730	10.40	750	10.55	775	10.90	800	11.35	825	11.90	855	12.65	890	13.70	920	14.70	955	16.00
16,000	705	11.40	720	11.40	735	11.40	750	11.45	770	11.60	790	11.85	810	12.15	840	12.80	865	13.40	895	14.30	930	15.45	960	16.55
16,500	730	12.45	740	12.45	750	12.45	770	12.50	785	12.60	805	12.85	825	13.15	850	13.65	875	14.25	905	15.10	935	16.10	965	17.20
17,000	745	13.65	760	13.65	775	13.65	790	13.65	805	13.75	820	13.90	845	14.30	865	14.65	890	15.25	915	16.00	945	16.95	975	18.05
17,500	770	14.90	780	14.90	795	14.90	805	14.90	820	14.95	840	15.15	860	15.40	880	15.80	905	16.35	925	16.90	955	17.85	980	18.75
18,000	790	16.20	800	16.20	810	16.20	825	16.20	845	16.30	860	16.40	875	16.60	895	16.95	915	17.40	940	18.05	965	18.85	990	19.70
18,500	810	17.60	820	17.60	835	17.60	850	17.60	860	17.60	875	17.75	895	17.95	910	18.20	930	18.65	950	19.15	975	19.90	1000	20.75
19,000	830	19.05	845	19.05	855	19.05	865	19.05	880	19.05	895	19.15	910	19.35	930	19.65	945	19.95	965	20.45	990	21.15	1010	21.85
19,500	855	20.60	865	20.60	875	20.60	885	20.60	900	20.60	915	20.70	930	20.85	945	21.05	960	21.35	980	21.80	1000	22.35	1025	23.20
20,000	875	22.20	885	22.20	895	22.20	910	22.20	920	22.20	935	22.30	945	22.40	965	22.65	980	22.95	995	23.30	1015	23.80	1035	24.45
20,500	895	23.90	905	23.90	915	23.90	930	23.90	940	23.90	950	23.95	965	24.05	980	24.25	995	24.50	1010	24.85	1030	25.35	1050	25.95
21,000	920	25.70	925	25.70	935	25.70	945	25.70	960	25.70	970	25.75	985	25.85	1000	26.00	1010	26.20	1030	26.60	1045	26.95	1065	27.55
21,500	940	27.60	945	27.60	960	27.60	970	27.60	980	27.60	990	27.60	1000	27.65	1015	27.80	1030	28.00	1045	28.30	1060	28.65	1080	29.20
22,000	960	29.55	970	29.55	980	29.55	990	29.55	1000	29.55	1010	29.55	1025	29.65	1035	29.75	1050	29.95	1060	30.15	1075	30.45	1095	31.00
22,500	980	31.65	990	31.65	1000	31.65	1010	31.65	1020	31.65	1030	31.65	1045	31.70	1055	31.80	1065	31.90	1080	32.15	1095	32.45	1110	32.85

NOTE − Minimum CFM requirements for units with electric heat:
LCH420 − 9800 cfm, LCH480 − 11,200 cfm, LCH540 − 12,600 cfm, LCH600 − 14,000 cfm.

BLOWER DATA

BLOWER TABLE INCLUDES RESISTANCE FOR BASE UNIT ONLY WITH DRY INDOOR COIL, ELECTRIC HEAT, ECONOMIZER, ONE ROW REHEAT COIL & AIR FILTERS IN PLACE

Add factory installed options air resistance, then determine from blower table blower motor output and drive kit required.
See page 53 for horizontal configured unit air resistance.
See page 54 for factory installed options air resistance data.
See page 55 for factory installed drive kit specifications.

TOTAL STATIC PRESSURE - 0.2 Thru 2.4 in. w.g.
For .2 thru 2.4 in. w.g., see previous page

Air Volume cfm	2.6		2.8		3.0		3.2		3.4		3.6		3.8		4.0		4.2		4.4		4.6	
	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
8000	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
8500	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
9000	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
9500	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
10,000	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
10,500	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
11,000	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
11,500	925	11.70	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
12,000	935	12.50	965	13.30	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
12,500	945	13.25	975	14.15	1000	14.90	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
13,000	955	14.00	980	14.80	1010	15.75	1035	16.60	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
13,500	960	14.60	990	15.65	1015	16.50	1045	17.55	1070	18.40	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
14,000	970	15.35	1000	16.45	1025	17.35	1050	18.30	1075	19.20	1100	20.15	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
14,500	975	15.95	1005	17.10	1035	18.25	1060	19.25	1085	20.20	1110	21.20	1135	22.25	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
15,000	980	16.55	1010	17.70	1040	18.95	1070	20.15	1095	21.20	1120	22.30	1140	23.15	1165	24.20	1185	25.10	- - -	- - -	- - -	- - -
15,500	985	17.15	1020	18.55	1045	19.60	1075	20.90	1100	22.00	1125	23.10	1150	24.25	1175	25.40	1195	26.30	1215	27.25	1235	28.15
16,000	995	17.95	1025	19.20	1055	20.50	1080	21.65	1110	23.00	1135	24.20	1160	25.35	1180	26.35	1205	27.55	1225	28.50	1245	29.50
16,500	1000	18.60	1030	19.85	1060	21.20	1085	22.35	1115	23.80	1140	25.00	1165	26.25	1190	27.50	1215	28.80	1235	29.80	1255	30.85
17,000	1005	19.25	1035	20.55	1065	21.90	1095	23.30	1120	24.55	1145	25.80	1170	27.10	1195	28.40	1220	29.75	1245	31.10	1265	32.20
17,500	1010	19.95	1040	21.25	1070	22.60	1100	24.05	1125	25.30	1155	26.90	1180	28.25	1205	29.60	1225	30.70	1250	32.15	1275	33.55
18,000	1020	20.90	1045	21.95	1075	23.35	1105	24.80	1130	26.10	1160	27.70	1185	29.10	1210	30.50	1235	31.95	1260	33.40	1280	34.60
18,500	1025	21.70	1055	23.00	1080	24.15	1110	25.60	1135	26.90	1165	28.55	1190	29.95	1215	31.40	1240	32.90	1265	34.40	- - -	- - -
19,000	1035	22.80	1060	23.85	1090	25.20	1115	26.45	1145	28.00	1170	29.40	1195	30.85	1220	32.30	1245	33.85	1270	35.40	- - -	- - -
19,500	1045	23.95	1070	24.95	1095	26.10	1125	27.55	1150	28.90	1175	30.25	1200	31.75	1225	33.25	1255	35.10	- - -	- - -	- - -	- - -
20,000	1060	25.35	1080	26.15	1105	27.30	1130	28.50	1155	29.80	1180	31.20	1205	32.65	1235	34.50	- - -	- - -	- - -	- - -	- - -	- - -
20,500	1070	26.65	1090	27.45	1115	28.55	1140	29.75	1165	31.05	1190	32.45	1215	33.90	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
21,000	1085	28.25	1105	29.00	1125	29.90	1150	31.05	1170	32.10	1195	33.45	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
21,500	1095	29.70	1115	30.45	1135	31.30	1160	32.45	1180	33.45	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
22,000	1110	31.45	1130	32.20	1150	33.00	1170	33.95	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
22,500	1125	33.30	1145	34.05	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -

NOTE − Minimum CFM requirements for units with electric heat:
LCH420 − 9800 cfm, LCH480 − 11,200 cfm, LCH540 − 12,600 cfm, LCH600 − 14,000 cfm.

POWER EXHAUST FANS

[1] 50% HIGH STATIC OPERATION, NO ERW

Air Volume cfm	Return Duct Negative Static Pressure - Inches Water Gauge (Pa)																					
	0		0.1		0.2		0.3		0.4		0.5		0.6		0.7		0.8		0.9		1.0	
	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
4000	410	0.75	465	1.00	520	1.25	575	1.50	630	1.80	685	2.15	740	2.50	795	2.85	845	3.25	900	3.70	955	4.15
4500	460	1.10	510	1.35	560	1.60	610	1.90	655	2.20	705	2.55	755	2.90	805	3.30	850	3.70	900	4.15	945	4.55
5000	510	1.50	555	1.75	600	2.05	645	2.40	690	2.70	735	3.10	775	3.40	820	3.85	865	4.25	910	4.70	950	5.15
5500	560	2.00	600	2.25	645	2.60	685	2.95	725	3.30	765	3.70	805	4.05	845	4.50	885	4.90	925	5.35	965	5.85
6000	610	2.55	650	2.90	685	3.25	725	3.60	760	3.95	800	4.40	835	4.80	870	5.20	910	5.65	945	6.10	980	6.55
6500	665	3.30	700	3.65	730	3.95	765	4.35	800	4.75	835	5.20	870	5.60	905	6.10	935	6.50	970	7.00	1005	7.50
7000	715	4.10	745	4.45	780	4.90	810	5.25	840	5.65	875	6.15	905	6.55	940	7.05	970	7.50	1000	8.00	1030	8.50
7500	765	5.05	795	5.45	825	5.85	855	6.30	885	6.75	915	7.20	945	7.65	975	8.15	- - -	- - -	- - -	- - -	- - -	- - -
8000	815	6.10	845	6.55	870	6.95	900	7.45	930	7.95	955	8.35	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
8500	865	7.30	895	7.80	920	8.25	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -

POWER EXHAUST FANS

[1] 100% HIGH STATIC OPERATION, NO ERW

Air Volume cfm	Return Duct Negative Static Pressure - Inches Water Gauge (Pa)																					
	0		0.1		0.2		0.3		0.4		0.5		0.6		0.7		0.8		0.9		1.0	
	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
8000	410	1.45	450	1.70	495	2.05	535	2.35	580	2.70	625	3.10	665	3.50	710	3.95	750	4.40	790	4.85	835	5.35
8500	435	1.70	475	2.00	515	2.35	555	2.70	595	3.05	635	3.45	675	3.85	715	4.30	755	4.75	795	5.25	835	5.75
9000	460	2.05	495	2.35	535	2.70	575	3.05	610	3.40	650	3.85	690	4.30	725	4.70	765	5.20	800	5.65	840	6.20
9500	485	2.40	520	2.70	555	3.05	595	3.45	630	3.85	665	4.25	700	4.70	740	5.20	775	5.65	810	6.15	845	6.65
10,000	510	2.80	545	3.15	580	3.50	615	3.90	650	4.35	680	4.70	715	5.15	750	5.65	785	6.15	820	6.65	855	7.20
10,500	535	3.20	570	3.60	600	3.95	635	4.40	665	4.80	700	5.25	730	5.70	765	6.20	795	6.65	830	7.20	860	7.70
11,000	560	3.70	590	4.05	625	4.50	655	4.90	685	5.35	720	5.85	750	6.30	780	6.75	810	7.25	840	7.75	875	8.40
11,500	585	4.20	615	4.60	645	5.05	675	5.45	705	5.90	735	6.40	765	6.90	795	7.40	825	7.90	855	8.45	885	9.00
12,000	610	4.80	640	5.20	670	5.70	700	6.15	725	6.55	755	7.05	785	7.60	815	8.10	840	8.60	870	9.15	900	9.75
12,500	635	5.40	665	5.90	690	6.30	720	6.80	750	7.30	775	7.75	805	8.30	830	8.80	860	9.40	885	9.90	915	10.55
13,000	660	6.10	690	6.60	715	7.00	740	7.45	770	8.05	795	8.50	820	9.00	850	9.65	875	10.15	900	10.70	930	11.35
13,500	690	6.90	715	7.35	740	7.80	765	8.30	790	8.80	815	9.30	840	9.85	865	10.40	895	11.05	920	11.65	945	12.20
14,000	715	7.65	740	8.15	765	8.65	785	9.10	810	9.60	835	10.15	860	10.70	885	11.30	910	11.90	935	12.50	960	13.10
14,500	740	8.50	765	9.05	785	9.45	810	10.00	835	10.60	860	11.20	880	11.65	905	12.25	930	12.90	955	13.55	975	14.05
15,000	765	9.40	785	9.85	810	10.45	835	11.05	855	11.50	880	12.15	905	12.75	925	13.30	950	13.95	970	14.50	995	15.20
15,500	790	10.35	810	10.85	835	11.45	855	11.95	880	12.60	900	13.15	925	13.80	945	14.35	970	15.05	990	15.65	1015	16.35
16,000	815	11.40	835	11.90	860	12.55	880	13.10	900	13.65	925	14.35	945	14.90	965	15.50	990	16.20	1010	16.85	- - -	- - -
16,500	840	12.50	860	13.05	885	13.70	905	14.30	925	14.85	945	15.45	965	16.05	990	16.80	- - -	- - -	- - -	- - -	- - -	- - -
17,000	865	13.65	885	14.20	905	14.80	925	15.40	950	16.15	970	16.80	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
17,500	890	14.85	910	15.50	930	16.10	950	16.75	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
18,000	915	16.15	935	16.80	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -

NOTE - See page 55 for factory installed drive kit specifications.

[1] Size power exhaust fans in economizer mode to minimize building static pressure during free" cooling.

BLOWER DATA

POWER EXHAUST FANS

[1] 50% HIGH STATIC OPERATION WITH ERW (BY-PASS DAMPERS CLOSED)

Air Volume cfm	Return Duct Negative Static Pressure - Inches Water Gauge (Pa)																					
	0		0.1		0.2		0.3		0.4		0.5		0.6		0.7		0.8		0.9		1.0	
	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
2500	390	0.35	460	0.50	530	0.70	600	0.90	670	1.15	735	1.40	805	1.70	870	2.00	935	2.35	1005	2.75	1070	3.10
3000	465	0.60	525	0.75	585	1.00	645	1.20	700	1.45	760	1.75	815	2.05	870	2.35	930	2.70	985	3.05	1040	3.45
3500	545	0.95	595	1.15	645	1.35	695	1.60	745	1.90	795	2.20	845	2.50	895	2.85	945	3.20	990	3.55	1040	3.95
4000	620	1.35	665	1.60	710	1.90	755	2.15	800	2.45	840	2.75	885	3.10	930	3.45	975	3.80	1015	4.15	1060	4.60
4500	700	1.95	740	2.25	780	2.55	820	2.85	855	3.10	895	3.45	935	3.80	975	4.20	1015	4.60	1050	4.95	- - -	- - -
5000	775	2.70	815	3.00	850	3.30	885	3.65	920	4.00	955	4.35	990	4.70	1025	5.10	1060	5.50	- - -	- - -	- - -	- - -
5500	855	3.60	885	3.90	920	4.25	950	4.60	985	5.00	1015	5.35	1050	5.75	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
6000	935	4.70	965	5.05	990	5.35	1020	5.75	1050	6.15	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -

POWER EXHAUST FANS

[1] 100% HIGH STATIC OPERATION WITH ERW (BY-PASS DAMPERS CLOSED)

Air Volume cfm	Return Duct Negative Static Pressure - Inches Water Gauge (Pa)																					
	0		0.1		0.2		0.3		0.4		0.5		0.6		0.7		0.8		0.9		1.0	
	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
5000	445	0.85	505	1.15	565	1.45	625	1.85	680	2.20	740	2.65	800	3.15	855	3.60	910	4.15	970	4.75	1025	5.30
5500	490	1.15	545	1.45	600	1.80	650	2.15	705	2.55	760	3.05	810	3.50	865	4.00	915	4.55	970	5.15	1020	5.70
6000	535	1.45	585	1.80	635	2.15	685	2.60	735	3.00	780	3.45	830	3.95	880	4.50	925	5.00	975	5.60	1020	6.15
6500	580	1.85	625	2.20	670	2.60	715	3.00	760	3.45	805	3.95	850	4.45	895	4.95	940	5.50	985	6.10	1030	6.75
7000	625	2.35	665	2.70	710	3.15	750	3.55	795	4.05	835	4.50	880	5.05	920	5.60	960	6.15	1005	6.80	1045	7.40
7500	670	2.90	710	3.30	750	3.75	790	4.20	825	4.65	865	5.15	905	5.70	945	6.25	985	6.85	1025	7.50	1060	8.05
8000	715	3.50	750	3.90	790	4.40	825	4.85	860	5.35	900	5.90	935	6.45	975	7.05	1010	7.65	1045	8.25	- - -	- - -
8500	760	4.20	795	4.65	830	5.15	865	5.65	900	6.20	935	6.75	970	7.30	1000	7.85	1035	8.45	1070	9.10	- - -	- - -
9000	800	4.90	835	5.45	870	5.95	900	6.45	935	7.05	970	7.65	1000	8.20	1035	8.85	1065	9.40	- - -	- - -	- - -	- - -
9500	845	5.80	880	6.35	910	6.85	940	7.40	975	8.05	1005	8.60	1035	9.20	1065	9.80	- - -	- - -	- - -	- - -	- - -	- - -
10,000	890	6.75	920	7.30	950	7.85	980	8.45	1010	9.05	1040	9.65	1070	10.30	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
10,500	935	7.85	965	8.45	995	9.05	1020	9.60	1050	10.25	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
11,000	980	9.00	1010	9.65	1035	10.25	1060	10.80	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
11,500	1025	10.30	1050	10.90	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
12,000	1070	11.75	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -

NOTE - See page 55 for factory installed drive kit specifications.

[1] Size power exhaust fans with ERW in economizer mode to minimize building static pressure during free" cooling.

BLOWER DATA

POWER EXHAUST FANS

[1] 50% HIGH STATIC OPERATION WITH ERW IN ECONOMIZER MODE (BY-PASS DAMPERS OPEN)

Air Volume cfm	Return Duct Negative Static Pressure - Inches Water Gauge (Pa)																					
	0		0.1		0.2		0.3		0.4		0.5		0.6		0.7		0.8		0.9		1.0	
	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
3500	380	0.55	435	0.70	495	0.90	555	1.10	615	1.35	675	1.60	730	1.85	790	2.15	845	2.45	900	2.80	960	3.15
4000	430	0.80	485	1.00	535	1.20	585	1.40	640	1.65	690	1.95	740	2.20	790	2.50	845	2.85	895	3.20	945	3.55
4500	485	1.10	530	1.30	575	1.55	625	1.80	670	2.05	715	2.35	760	2.65	805	2.95	855	3.30	900	3.65	945	4.00
5000	540	1.55	580	1.75	620	2.00	665	2.30	705	2.55	745	2.85	790	3.20	830	3.50	870	3.85	910	4.15	950	4.55
5500	590	2.05	630	2.30	670	2.60	705	2.85	745	3.15	780	3.45	820	3.80	855	4.10	895	4.50	930	4.80	970	5.25
6000	645	2.65	680	2.90	715	3.20	750	3.50	785	3.85	820	4.15	855	4.50	890	4.85	925	5.25	960	5.65	995	6.05
6500	700	3.35	730	3.65	765	4.00	795	4.30	830	4.65	860	5.00	890	5.30	925	5.70	955	6.10	990	6.50	1020	6.90
7000	755	4.20	785	4.55	815	4.90	845	5.20	875	5.60	905	5.95	935	6.35	960	6.65	990	7.05	1020	7.45	1050	7.90
7500	805	5.15	835	5.50	865	5.90	890	6.20	920	6.60	945	6.95	975	7.40	1000	7.75	1030	8.20	1060	8.65	- - -	- - -
8000	860	6.25	885	6.60	915	7.05	940	7.40	965	7.80	990	8.15	1020	8.65	1045	9.05	1070	9.45	- - -	- - -	- - -	- - -
8500	915	7.55	940	7.90	965	8.35	990	8.75	1015	9.15	1040	9.60	1060	9.95	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -

POWER EXHAUST FANS

[1] 100% HIGH STATIC OPERATION WITH ERW IN ECONOMIZER MODE (BY-PASS DAMPERS OPEN)

Air Volume cfm	Return Duct Negative Static Pressure - Inches Water Gauge (Pa)																					
	0		0.1		0.2		0.3		0.4		0.5		0.6		0.7		0.8		0.9		1.0	
	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP	RPM	BHP
7000	415	1.15	470	1.50	520	1.80	570	2.10	620	2.50	675	2.90	725	3.35	775	3.80	825	4.30	875	4.80	925	5.35
7500	445	1.45	495	1.75	540	2.05	590	2.45	640	2.85	685	3.25	735	3.70	780	4.15	825	4.65	875	5.20	920	5.70
8000	475	1.75	520	2.05	565	2.40	610	2.80	655	3.20	700	3.65	745	4.10	790	4.55	835	5.10	880	5.60	920	6.10
8500	505	2.10	545	2.40	590	2.80	635	3.25	675	3.60	715	4.05	760	4.55	800	5.00	845	5.55	885	6.05	925	6.60
9000	535	2.50	575	2.85	615	3.25	655	3.65	695	4.10	735	4.55	775	5.00	815	5.50	855	6.05	895	6.60	935	7.15
9500	565	2.95	600	3.30	640	3.70	680	4.15	715	4.55	755	5.05	790	5.50	830	6.05	870	6.60	905	7.15	945	7.75
10,000	595	3.45	630	3.80	665	4.20	700	4.65	740	5.15	775	5.65	810	6.10	845	6.65	880	7.15	920	7.80	955	8.35
10,500	625	4.00	660	4.40	690	4.80	725	5.25	760	5.75	795	6.25	830	6.75	865	7.30	900	7.90	935	8.50	965	9.00
11,000	655	4.60	685	4.95	720	5.45	750	5.90	785	6.40	820	6.95	850	7.45	885	8.05	915	8.55	950	9.20	980	9.75
11,500	680	5.15	715	5.65	745	6.10	775	6.60	810	7.15	840	7.65	870	8.20	905	8.80	935	9.40	965	9.95	995	10.55
12,000	710	5.85	740	6.35	775	6.90	805	7.40	835	7.95	865	8.50	895	9.05	925	9.65	955	10.25	985	10.85	1015	11.50
12,500	740	6.65	770	7.15	800	7.70	830	8.25	860	8.80	885	9.30	915	9.90	945	10.50	975	11.15	1005	11.80	1030	12.35
13,000	770	7.50	800	8.05	825	8.50	855	9.10	885	9.70	910	10.20	940	10.85	965	11.40	995	12.10	1020	12.65	1050	13.40
13,500	800	8.40	830	9.00	855	9.50	880	10.00	910	10.65	935	11.20	965	11.90	990	12.50	1015	13.10	1045	13.85	- - -	- - -
14,000	830	9.35	855	9.90	885	10.55	910	11.10	935	11.70	960	12.30	985	12.90	1010	13.50	1040	14.25	1065	14.90	- - -	- - -
14,500	860	10.40	885	11.00	910	11.55	935	12.15	960	12.75	985	13.40	1010	14.05	1035	14.70	1060	15.40	- - -	- - -	- - -	- - -
15,000	890	11.55	915	12.15	940	12.75	965	13.40	985	13.95	1010	14.60	1035	15.30	1060	16.00	- - -	- - -	- - -	- - -	- - -	- - -
15,500	920	12.75	945	13.40	965	13.90	990	14.60	1015	15.30	1035	15.85	1060	16.60	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
16,000	950	14.00	970	14.55	995	15.25	1020	16.00	1040	16.60	1065	17.35	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
16,500	980	15.35	1000	15.95	1025	16.70	1045	17.30	1065	17.95	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
17,000	1010	16.80	1030	17.45	1050	18.10	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -

NOTE - See page 55 for factory installed drive kit specifications.

[1] Size power exhaust fans in economizer mode to minimize building static pressure during free" cooling.

BLOWER DATA

POWER EXHAUST FANS

STANDARD STATIC ([1] TWO FAN OPERATION)

Return Duct Negative Static Pressure Inches Water Gauge	Air Volume cfm	Return Duct Negative Static Pressure Inches Water Gauge	Air Volume cfm
0	12,100	0.50	5700
0.05	11,600	0.55	5000
0.10	11,150	0.60	4300
0.15	10,600	0.65	3800
0.20	10,100	0.70	3400
0.25	9500	0.75	3000
0.30	8900	0.80	2500
0.35	8200	0.85	2300
0.40	7400	0.90	2000
0.45	6500		

[1] For one fan operation, use half of the air volume value.

OUTDOOR AIR PERCENTAGE VS. FRESH AIR DAMPER ANGLE - Less ERW

Fresh Air Damper Opening Angle	Percentage of Outdoor Air Available at Various Return Duct Static Pressures - in. w.g.			
	0.2	0.4	0.6	0.8
10°	5%	11%	16%	21%
20°	19%	25%	30%	36%
30°	34%	39%	44%	50%
40°	48%	53%	59%	64%
50°	62%	68%	73%	79%
60°	77%	82%	87%	93%
70°	91%	96%	100%	100%
80°	100%	100%	100%	100%

NOTE - Outdoor air percentage will vary when a variable frequency drive (VFD) drive is used on the supply air blower.

OUTDOOR AIR PERCENTAGE VS. FRESH AIR DAMPER ANGLE - With ERW

[1] ERW Static Pressure		Percentage of Outdoor Air Available at Various Return Duct Static Pressures																	
		0 Return Duct Static						0.2 Return Duct Static						0.4 Return Duct Static					
	in. w.g.	1.2	1.0	0.8	0.6	0.4	0.2	1.2	1.0	0.8	0.6	0.4	0.2	1.2	1.0	0.8	0.6	0.4	0.2
Fresh Air Damper Opening Angle	10°	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
	20°	9%	4%	- - -	- - -	- - -	- - -	14%	9%	4%	- - -	- - -	- - -	19%	14%	9%	4%	- - -	- - -
	30°	23%	18%	13%	8%	2%	- - -	28%	23%	18%	13%	8%	2%	34%	28%	23%	18%	13%	8%
	40°	38%	32%	27%	22%	17%	11%	43%	38%	32%	27%	22%	17%	48%	43%	38%	32%	27%	22%
	50°	52%	46%	41%	36%	31%	25%	57%	52%	46%	41%	36%	31%	62%	57%	52%	46%	41%	36%
	60°	66%	61%	55%	50%	45%	39%	71%	66%	61%	55%	50%	45%	77%	71%	66%	61%	55%	50%
	70°	81%	75%	70%	64%	59%	54%	86%	81%	75%	70%	64%	59%	91%	86%	81%	75%	70%	64%
	80°	95%	89%	84%	78%	73%	68%	100%	95%	89%	84%	78%	73%	100%	100%	95%	89%	84%	78%

[1] ERW Static Pressure		Percentage of Outdoor Air Available at Various Return Duct Static Pressures											
		0.6 Return Duct Static						0.8 Return Duct Static					
	in. w.g.	1.2	1.0	0.8	0.6	0.4	0.2	1.2	1.0	0.8	0.6	0.4	0.2
Fresh Air Damper Opening Angle	10°	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -
	20°	25%	19%	14%	9%	4%	- - -	30%	25%	19%	14%	9%	4%
	30°	39%	34%	28%	23%	18%	13%	44%	39%	34%	28%	23%	18%
	40°	54%	48%	43%	38%	32%	27%	59%	54%	48%	43%	38%	32%
	50°	68%	62%	57%	52%	46%	41%	73%	68%	62%	57%	52%	46%
	60°	84%	77%	71%	66%	61%	55%	87%	84%	77%	71%	66%	61%
	70°	97%	91%	86%	81%	75%	70%	100%	97%	91%	86%	81%	75%
	80°	100%	100%	100%	95%	89%	84%	100%	100%	100%	100%	95%	89%

NOTE - Outdoor air percentage will vary when a variable frequency drive (VFD) drive is used on the supply air blower.
[1] See page 56 for Energy Recovery Wheel Specifications.

BLOWER DATA

AIR RESISTANCE

HORIZONTAL AIRFLOW APPLICATIONS

Air Volume	Standard Static Power Exhaust fans or No Power Exhaust Fans	50% High Static Power Exhaust Fans	100% High Static Power Exhaust Fans
cfm	in. w.g.	in. w.g.	in. w.g.
10,000	.20	.23	.25
10,500	.20	.25	.30
11,000	.20	.25	.30
11,500	.20	.30	.40
12,000	.20	.33	.45
12,500	.20	.35	.50
13,000	.20	.38	.55
13,500	.25	.43	.60
14,000	.25	.45	.65
14,500	.25	.48	.70
15,000	.30	.55	.80
15,500	.30	.58	.85
16,000	.30	.63	.95
16,500	.30	.63	.95
17,000	.30	.68	1.05
17,500	.30	.70	1.10
18,000	.30	.75	1.20
18,500	.30	.78	1.25
19,000	.30	.83	1.35
19,500	.30	.83	1.40
20,000	.30	.90	1.50
20,500	.35	.94	1.60
21,000	.35	.98	1.70
21,500	.35	1.02	1.80
22,000	.35	1.04	1.90
22,500	.35	1.10	2.00

BLOWER DATA

FACTORY INSTALLED OPTIONS AIR RESISTANCE

ECONOMIZER RETURN AIR DAMPER WITH ERW

Outdoor Air Volume With ERW cfm	Return Duct Negative Static Pressure 0 in. w.g.				
	0.2	0.4	0.6	0.8	1.0
3250	0.32	0.12	- - -	- - -	- - -
3500	0.36	0.16	- - -	- - -	- - -
3750	0.40	0.20	- - -	- - -	- - -
4000	0.44	0.24	0.04	- - -	- - -
4250	0.48	0.28	0.08	- - -	- - -
4500	0.52	0.32	0.12	- - -	- - -
4750	0.57	0.37	0.17	- - -	- - -
5000	0.60	0.40	0.20	- - -	- - -
5250	0.65	0.45	0.25	0.05	- - -
5500	0.68	0.48	0.28	0.08	- - -
5750	0.73	0.53	0.33	0.13	- - -
6000	0.76	0.56	0.36	0.16	- - -
6250	0.81	0.61	0.41	0.21	0.01
6500	0.84	0.64	0.44	0.24	0.04
6750	0.89	0.69	0.49	0.29	0.09
7000	0.93	0.73	0.53	0.33	0.13
7250	0.97	0.77	0.57	0.37	0.17
7500	1.01	0.81	0.61	0.41	0.21
7750	1.05	0.85	0.65	0.45	0.25
8000	1.09	0.89	0.69	0.49	0.29
8250	1.13	0.93	0.73	0.53	0.33
8500	1.17	0.97	0.77	0.57	0.37
8750	1.21	1.01	0.81	0.61	0.41
9000	1.25	1.05	0.85	0.65	0.45

WET INDOOR COIL

Air Volume cfm	Wet Indoor Coil in.w.g.
12,000	0.20
13,000	0.22
14,000	0.24
15,000	0.27
16,000	0.30
17,000	0.33
18,000	0.36
19,000	0.39
20,000	0.42
21,000	0.45
22,000	0.48

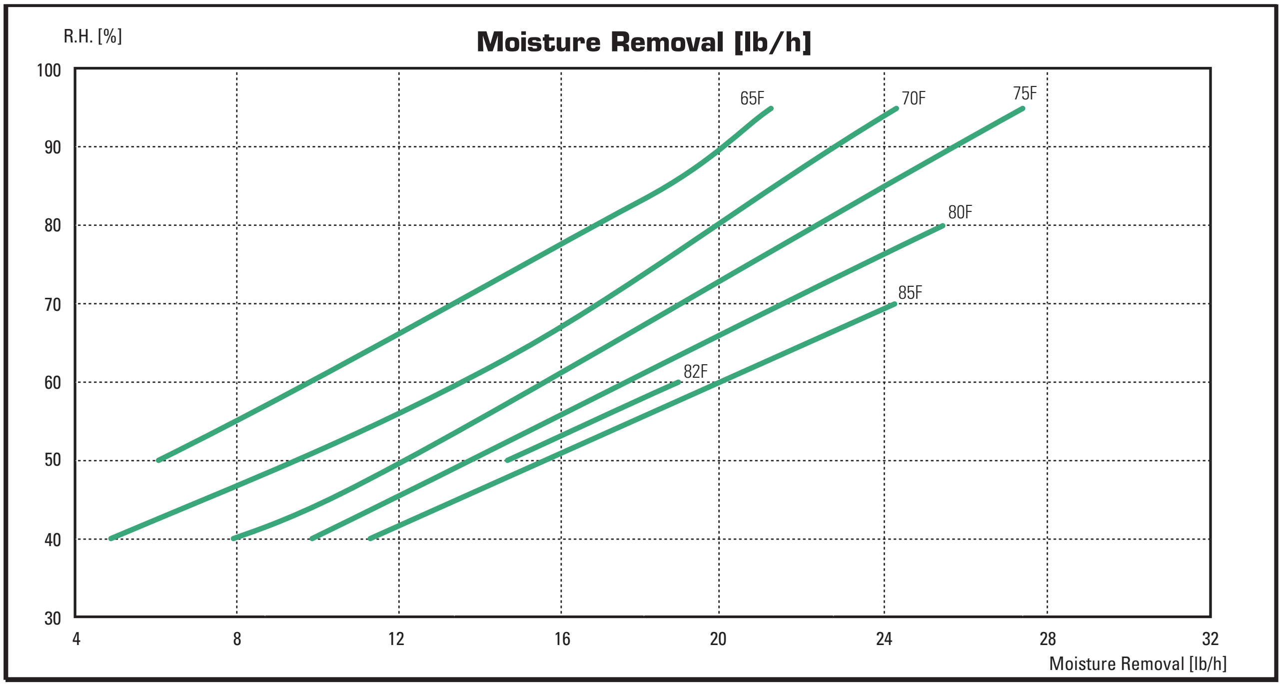
DCA DEHUMIDIFIER CORPORATION OF AMERICA

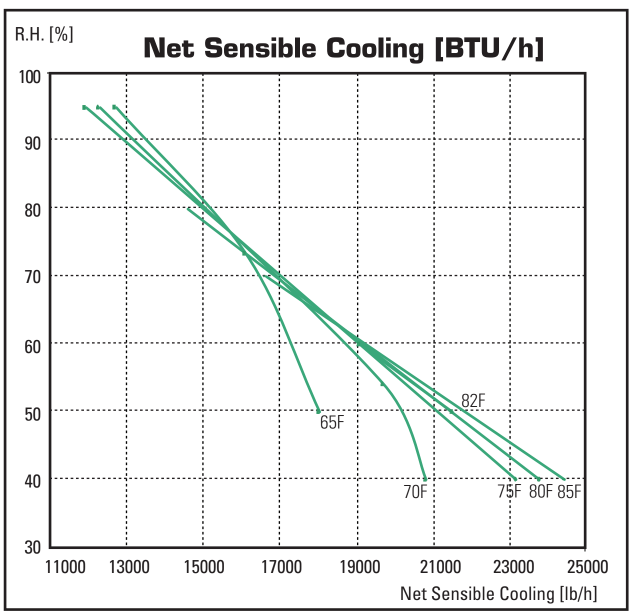
R-407C REFRIGERANT

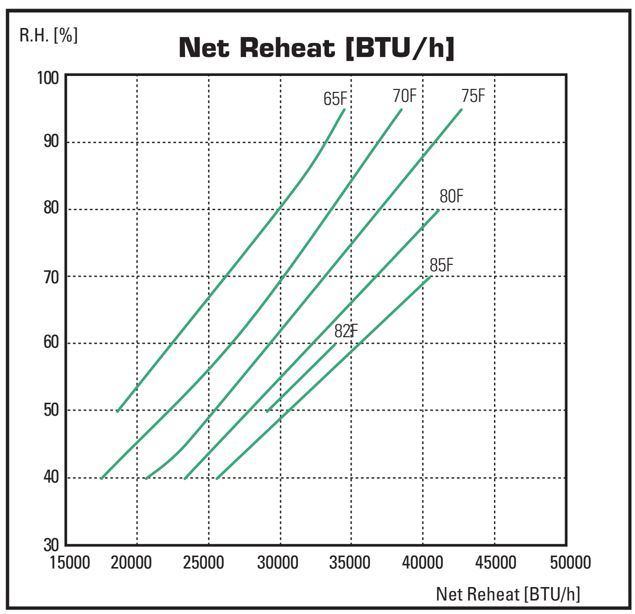
DCA 1500T AIR COOLED - NON WATER HEATING DEHUMIDIFIER

DCA 1500TWH WATER HEATING ASSIST DEHUMIDIFIER

PERFORMANCE







Performance	82DB / 50% R.H.	82DB / 60% R.H.	Notes
Moisture Removal, LB/HR	14.7	18.9	1
Net Sensible Cooling, MBH	21.6	19.2	2
Net Reheat, MBH	24.3	29.1	3
Water Heating, MBH (Water Heating Models Only)	46.2	48.4	4

Notes:

1. Reheat mode assuming 1050 BTU/lb.
2. Cooling mode with remote condenser at 95F.
3. Defined as sum of latent and compressor input. Use dehumidifier for supplemental heat only.
4. Assuming 85F entering water temperature.
5. For conditions and data not shown contact the factory.

CAUTIONS: The reheat capacity rating includes latent recovery and heat of compression. It is recommended that dehumidifiers be used for supplemental heat only. The cooling capacity is based on an ambient temperature of 95˚F. As outside conditions vary, so will the performance of the dehumidifier. Ratings are subject to change without notice.

DCA 1500T AIR COOLED - NON WATER HEATING DEHUMIDIFIER
DCA 1500TWH WATER HEATING ASSIST DEHUMIDIFIER

DESIGN SPECIFICATIONS

Electrical	208/230V	208/230V	460V	575V
Phase/Hz	1/60	3/60	3/60	3/60
Compressor B.T.U.	36,600	36,900	36,900	36,900
Compressor RLA	19.2	12.2	5.8	4.4
Compressor LRA	112	93	48	33
Blower Motor H.P.	1	1	1	1
Blower Motor FLA	6.4	3.8	1.9	1.5
Unit FLA	27.0	17.4	8.4	6.5
Maximum Fuse Size	40	25	12	10
Minimum Circuit Amp.	31.8	20.5	9.9	7.6
Operating kW	4.11	4.05	4.05	4.04

CFM 1500
External Static Pressure .... 0.50” H_2O
Refrigerant .... R-407C (Factory Charged 20 lbs.)
Compressor Type .... Scroll
Filter (Quantity: 1) .... 25” x 25” x 1” Fiberglass
Drain Connection .... 1” Bar Drain
DCA 1500T Weight .... 470 lbs.
DCA 1500TWH Weight .... 580 lbs.
Liquid Inlet [inches O.D.] (up to 50’)[1] 0.5
Hot Gas Outlet [inches O.D.] (up to 50’)[1] 0.75
Water Inlet [inches O.D] 0.875
Water Outlet [inches O.D.] 0.875
Water Flow G.P.M.[2] 6.0
Pressure Drop (Ft. WC)[2] 5.3

[1] Over 50ft contact factory
[2] Water Flow data based on 50% RH + Return Air 82˚F and Pool Water at 85˚F

STANDARD FEATURES

- MET Laboratory Safety Listed To UL 1995
- 3 Year Parts Warranty
- Single Refrigeration Circuit
- Single Scroll Compressor
- Powder Coated, Galvannealed Steel Cabinet
- Low Ambient Head Pressure Control
- Remote Condenser Ready
- Rifle Tube Refrigeration Coils
- TEFC Blower Motor
- Stainless Steel Condensate Drain Pan
- Standard Microprocessor Control System (WH Models Only)
- ElectroFin Coated Coils

OPTIONAL FEATURES

- Right Side Component Service Access
- Top or Bottom Discharge (Not Field Convertible)
- Extended Surface Filters 2” & 4”
- Outdoor Installation Package
- Outdoor Make Up Air Assembly with Damper & Filter
- External Static Upgrade
- Water Cooled Condenser For Water Heating Or A/C Available
- Motorized Evaporator Bypass Damper
- Remote Ready Delete
- Defrost Timer Package
- Control Options
- Space Heating Options Available
- Other Options Available

W53 N550 HIGHLAND DRIVE
P.O. BOX 0917
CEDARBURG, WI 53012
PHONE: 262-377-7501
FAX: 262-377-7502
E-MAIL: info@dehumidifiercorp.com

Appendix F: Project Management

Appendix F1: Final Project Schedule

A final updated project schedule can be found in Table 14.

Table 14. Final Project Schedule.

Project Folders	Owners	Total [E]	Finish [E]	09/06 09/09 09/16 09/23 09/30 10/07 10/14 10/21 10/28 11/04 11/11 11/18 11/25 12/02 12/07
INBOX	Laura	0h		
ACTIVE PROJECTS	Laura	118h	12/13/19	
Phase 1	[Laura]	0h		
Logo Creation	[Zoey]	0h		
Cover Letter	[Laura]	0h		
Introduction	[Elliott]	0h		
Design Specification Report	[Sai]	0h		
Design Specification Matrix	[Jake]	0h		
Effective Project Management	[Laura]	0h		
Conclusion	[Elliott]	0h		
Draft 1 Complete	[Laura, Elliott]	0h		
Report Complete	[Laura, Elliott]	0h		
Self Evaluation	[Laura, Elliott, Jake, Jakub, Sai, Zoey]	0h		
Phase 2	[Laura]	0h		
Concept Design 1	[Laura]	0h		
Concept Design 2	[Laura]	0h		
Concept Design 3	[Laura]	0h		
Cover Letter	[Laura]	0h		
Executive Summary	[Laura, Elliott, Jake, Jakub, Sai, Zoey]	0h		
Introduction	[Elliott]	0h		
Conceptual Design Report	[Laura]	0h		
Design Evaluation Matrix	[Laura]	0h		
Effective Project Management	[Laura]	0h		
Conceptual Design Diagrams, Sketches, and Solid Models	[Laura]	0h		
Conceptual Design Calculations	[Laura]	0h		
Conclusion	[Elliott]	0h		
Draft 1 Complete	[Laura, Elliott]	0h		
Report Complete	[Laura, Elliott]	0h		
Self Evaluation	[Laura, Sai, Zoey, Jakub, Jake, Elliott]	0h		
Phase 3	Laura	3.5h	12/13/19	
Cover Letter	[Laura]	0h		
Executive Summary	[Elliott, Jake, Jakub, Laura, Sai, Zoey]	0h		
Introduction	[Elliott]	0h		
Detailed Design Report	[Laura]	0h		
Design Compliance Matrix	[Laura]	0h		
Effective Project Management	[Laura]	0h		
Detailed Design Calculations	[Laura]	0h		
Set Of Detailed Design Drawings	[Laura]	0h		
Conclusion	[Laura]	0h		
Draft 1 Complete	[Laura, Elliott]	0h		
Report Complete	[Laura, Elliott]	0h		
USB/ Electronic Submission	Laura	0.5h	12/02/19	
Self Evaluation	Laura, Elliott, Jake, Jakub, Sai, Zoey	3h	12/13/19	
Design Poster	Laura	30.5h	12/03/19	
Poster Creation	Laura, Elliott, Jake, Jakub, Sai, Zoey	30h	12/03/19	
Poster Printing	Laura	0.5h	12/03/19	
Presentation	Laura	84h	12/06/19	
Presentation Creation	Laura, Elliott, Jake, Jakub, Sai, Zoey	42h	12/04/19	
Presentation Practice	Laura, Elliott, Jake, Jakub, Sai, Zoey	3h	12/05/19	
Design Conference	Laura, Elliott, Jake, Jakub, Sai, Zoey	39h	12/06/19	

Generated on 12/02/19 using
LiquidPlanner

Appendix F2: Project Team Timesheets

To determine the overall project cost for design work, timecards were collected from the project team. The timecard for each member can be found in Figures 7 through 12.

Name: Zoey Zhang

Time Entry Form									
			Time						
Week #	Date	Day of Week	Meetings	Research	Report Writing	Calculations	Design	Daily Total
	05-Nov	Tuesday	1					1.0
	06-Nov	Wednesday						0.0
10	07-Nov	Thursday						0.0
	08-Nov	Friday						0.0
	09-Nov	Saturday						0.0
	10-Nov	Sunday						0.0
	11-Nov	Monday						0.0
	12-Nov	Tuesday						0.0
11	13-Nov	Wednesday						0.0
	14-Nov	Thursday						0.0
	15-Nov	Friday						0.0
	16-Nov	Saturday					0.75	0.8
	17-Nov	Sunday					1.5	1.5
	18-Nov	Monday						0.0
	19-Nov	Tuesday	2	0.8				2.8
12	20-Nov	Wednesday				2.5		2.5
	21-Nov	Thursday	0.5			1		1.5
	22-Nov	Friday						0.0
	23-Nov	Saturday				5		5.0
	24-Nov	Sunday				4		4.0
	25-Nov	Monday				5		5.0
	26-Nov	Tuesday	2			3		5.0
13	27-Nov	Wednesday	1				3	4.0
	28-Nov	Thursday					5	5.0
	29-Nov	Friday					3	3.0
	30-Nov	Saturday					6	6.0
14	**01-Dec**	**Sunday**					**4**	**4.0**
	02-Dec	Monday			3			3.0

Figure 7. Timecard: Zoey Zhang.

Name: Sai Avuthu

Time Entry Form								
			Time					
Week #	Date	Day of Week	Meetings	Research	Report Writing	Calculations	Design	Daily Total
	05-Nov	Tuesday	2					2.0
	06-Nov	Wednesday	1					1.0
10	07-Nov	Thursday						0.0
	08-Nov	Friday						0.0
	09-Nov	Saturday						0.0
	10-Nov	Sunday						0.0
	11-Nov	Monday						0.0
	12-Nov	Tuesday						0.0
11	13-Nov	Wednesday						0.0
	14-Nov	Thursday						0.0
	15-Nov	Friday						0.0
	16-Nov	Saturday						0.0
	17-Nov	Sunday						0.0
	18-Nov	Monday						0.0
	19-Nov	Tuesday	2					2.0
12	20-Nov	Wednesday					1	1.0
	21-Nov	Thursday	1					1.0
	22-Nov	Friday						0.0
	23-Nov	Saturday						0.0
	24-Nov	Sunday						0.0
	25-Nov	Monday				3		3.0
	26-Nov	Tuesday	2			1		3.0
13	27-Nov	Wednesday				5		5.0
	28-Nov	Thursday						0.0
	29-Nov	Friday						0.0
	30-Nov	Saturday					7	7.0
14	01-Dec	Sunday				5		5.0
	02-Dec	**Monday**			**4**			**4.0**

Figure 8. Timecard: Sai Avuthu.

Name: Elliott van Ramshorst

Time Entry Form

Week #	Date	Day of Week	Time					Daily Total
			Meetings	Research	Report Writing	Calculations	Design	
	05-Nov	Tuesday	2					2.0
	06-Nov	Wednesday						0.0
10	07-Nov	Thursday						0.0
	08-Nov	Friday						0.0
	09-Nov	Saturday						0.0
	10-Nov	Sunday						0.0
	11-Nov	Monday						0.0
	12-Nov	Tuesday						0.0
11	13-Nov	Wednesday						0.0
	14-Nov	Thursday						0.0
	15-Nov	Friday						0.0
	16-Nov	Saturday						0.0
	17-Nov	Sunday						0.0
	18-Nov	Monday						0.0
	19-Nov	Tuesday	2					2.0
12	20-Nov	Wednesday		0.5				0.5
	21-Nov	Thursday	0.5					0.5
	22-Nov	Friday		0.25				0.3
	23-Nov	Saturday						0.0
	24-Nov	Sunday		1				1.0
	25-Nov	Monday						0.0
	26-Nov	Tuesday	2	1		1.5		4.5
13	27-Nov	Wednesday			0.5			0.5
	28-Nov	Thursday	1			2.5		3.5
	29-Nov	Friday			1			1.0
	30-Nov	Saturday		1		1		2.0
14	01-Dec	Sunday			4	4		8.0
	02-Dec	**Monday**			**3**	**1**		**4.0**

Figure 9. Timecard: Elliott van Ramshorst.

Name: Jacob Bellerose

Time Entry Form

Week #	Date	Day of Week	Time					Daily Total
			Meetings	Research	Report Writing	Calculations	Design	
	05-Nov	Tuesday	1					1.0
	06-Nov	Wednesday						0.0
10	07-Nov	Thursday						0.0
	08-Nov	Friday						0.0
	09-Nov	Saturday						0.0
	10-Nov	Sunday						0.0
	11-Nov	Monday						0.0
	12-Nov	Tuesday						0.0
11	13-Nov	Wednesday						0.0
	14-Nov	Thursday						0.0
	15-Nov	Friday						0.0
	16-Nov	Saturday						0.0
	17-Nov	Sunday						0.0
	18-Nov	Monday						0.0
	19-Nov	Tuesday	2	1				3.0
12	20-Nov	Wednesday				2		2.0
	21-Nov	Thursday	1					1.0
	22-Nov	Friday		1				1.0
	23-Nov	Saturday		1				1.0
	24-Nov	Sunday		3			1	4.0
	25-Nov	Monday		2		1	1	4.0
	26-Nov	Tuesday	2				3	5.0
13	27-Nov	Wednesday					3	3.0
	28-Nov	Thursday	1				3	4.0
	29-Nov	Friday					2	2.0
	30-Nov	Saturday					4	4.0
14	01-Dec	Sunday					3	3.0
	02-Dec	**Monday**						**0.0**

Figure 10. Timecard: Jacob Bellerose.

Name: Jakub McNally

Time Entry Form

Week #	Date	Day of Week	Meetings	Research	Report Writing	Calculations	Design	Daily Total
			Time					
	05-Nov	Tuesday						0.0
	06-Nov	Wednesday						0.0
10	07-Nov	Thursday						0.0
	08-Nov	Friday						0.0
	09-Nov	Saturday						0.0
	10-Nov	Sunday						0.0
	11-Nov	Monday						0.0
	12-Nov	Tuesday						0.0
11	13-Nov	Wednesday						0.0
	14-Nov	Thursday		3				3.0
	15-Nov	Friday						0.0
	16-Nov	Saturday						0.0
	17-Nov	Sunday						0.0
	18-Nov	Monday						0.0
	19-Nov	Tuesday	2					2.0
12	20-Nov	Wednesday						0.0
	21-Nov	Thursday	0.25			1	2	3.3
	22-Nov	Friday						0.0
	23-Nov	Saturday						0.0
	24-Nov	Sunday						0.0
	25-Nov	Monday						0.0
	26-Nov	Tuesday	2					2.0
13	27-Nov	Wednesday				1		1.0
	28-Nov	Thursday						0.0
	29-Nov	Friday				3	4	7.0
	30-Nov	Saturday				7	3	10.0
14	01-Dec	Sunday				4	6	10.0
	02-Dec	**Monday**						**0.0**

Figure 11. Timecard: Jakub McNally.

Name: Laura Mueller

Time Entry Form

Week #	Date	Day of Week	Meetings	Research	Report Writing	Calculations	Design	Daily Total
			Time					
	05-Nov	Tuesday	1					1.0
	06-Nov	Wednesday						0.0
10	07-Nov	Thursday	0.5	0.5	2			3.0
	08-Nov	Friday						0.0
	09-Nov	Saturday						0.0
	10-Nov	Sunday						0.0
	11-Nov	Monday						0.0
	12-Nov	Tuesday						0.0
11	13-Nov	Wednesday						0.0
	14-Nov	Thursday						0.0
	15-Nov	Friday						0.0
	16-Nov	Saturday						0.0
	17-Nov	Sunday						0.0
	18-Nov	Monday			3			3.0
	19-Nov	Tuesday	2		1			3.0
12	20-Nov	Wednesday						0.0
	21-Nov	Thursday	0.5		3			3.5
	22-Nov	Friday						0.0
	23-Nov	Saturday			2			2.0
	24-Nov	Sunday			2			2.0
	25-Nov	Monday			2			2.0
	26-Nov	Tuesday	2		3			5.0
13	27-Nov	Wednesday	1		3			4.0
	28-Nov	Thursday	0.5					0.5
	29-Nov	Friday		1	3			4.0
	30-Nov	Saturday			8			8.0
14	01-Dec	Sunday			4			4.0
	02-Dec	**Monday**						**0.0**

Figure 12. Timecard: Laura Mueller.