AUTOMATED FILLING MACHINE

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MEC E 460 | FALL 2019 | DEPARTMENT OF MECHANICAL ENGINEERING

BEE Mechanical
UNIVERSITY OF ALBERTA
FACULTY OF ENGINEERING

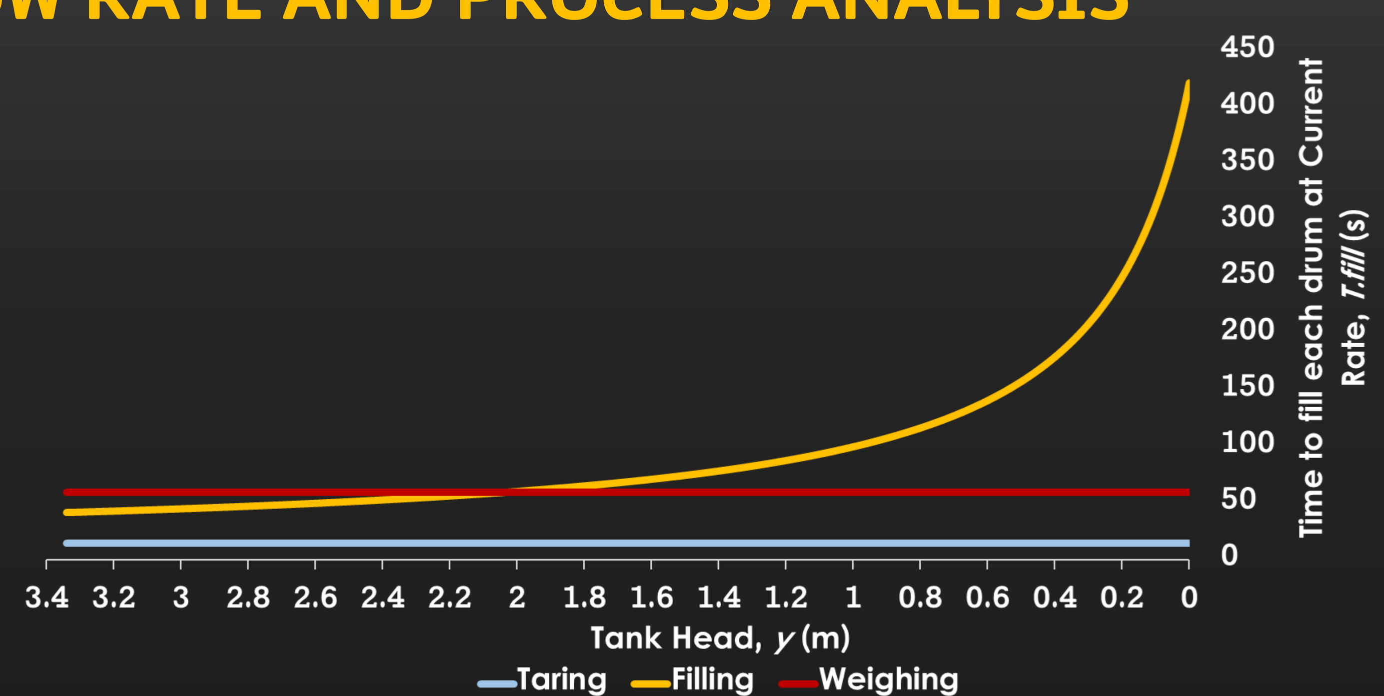
WHAT ARE THE CURRENT PROBLEMS?

- Current honey process lacks accuracy and control
- Manual filling of drums by opening and closing the valve
- Two operators are required for filling operation
- Fill up average of **20 drums/hr**
- High labour cost with low production efficiency

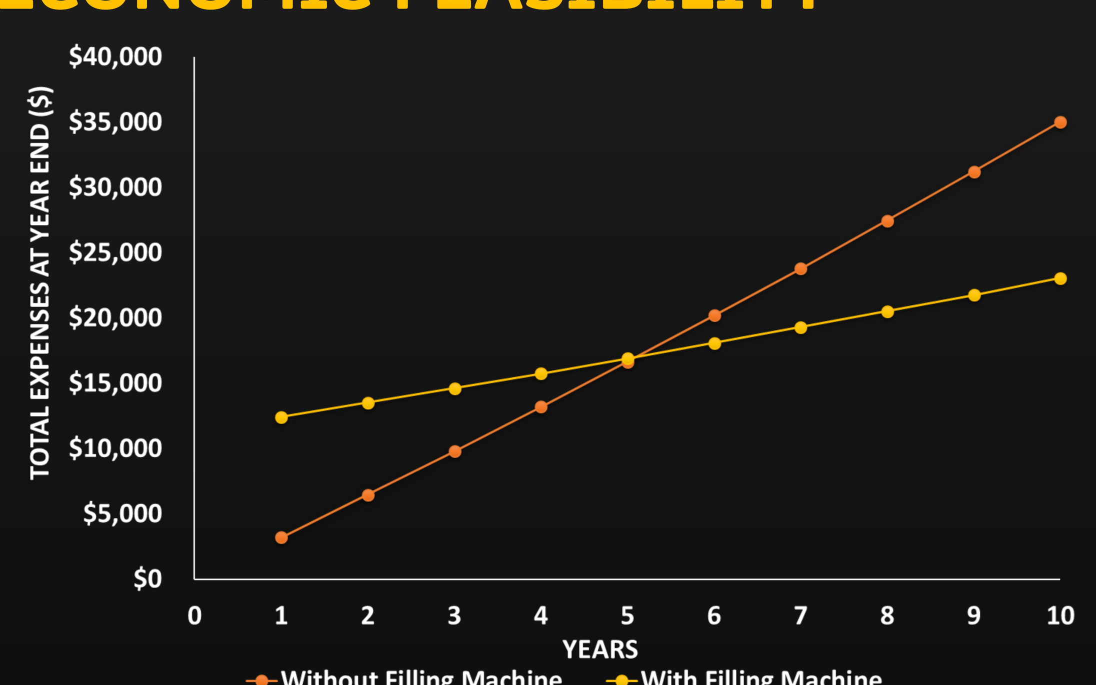
HOW WERE THE PROBLEMS RESOLVED?

- The equipment enables the filling process with only one operator working at the filling station
- Filling rate increases to **40 drums/hr** by automating the process
- Tare and gross weights are automatically measured by two weighing scales

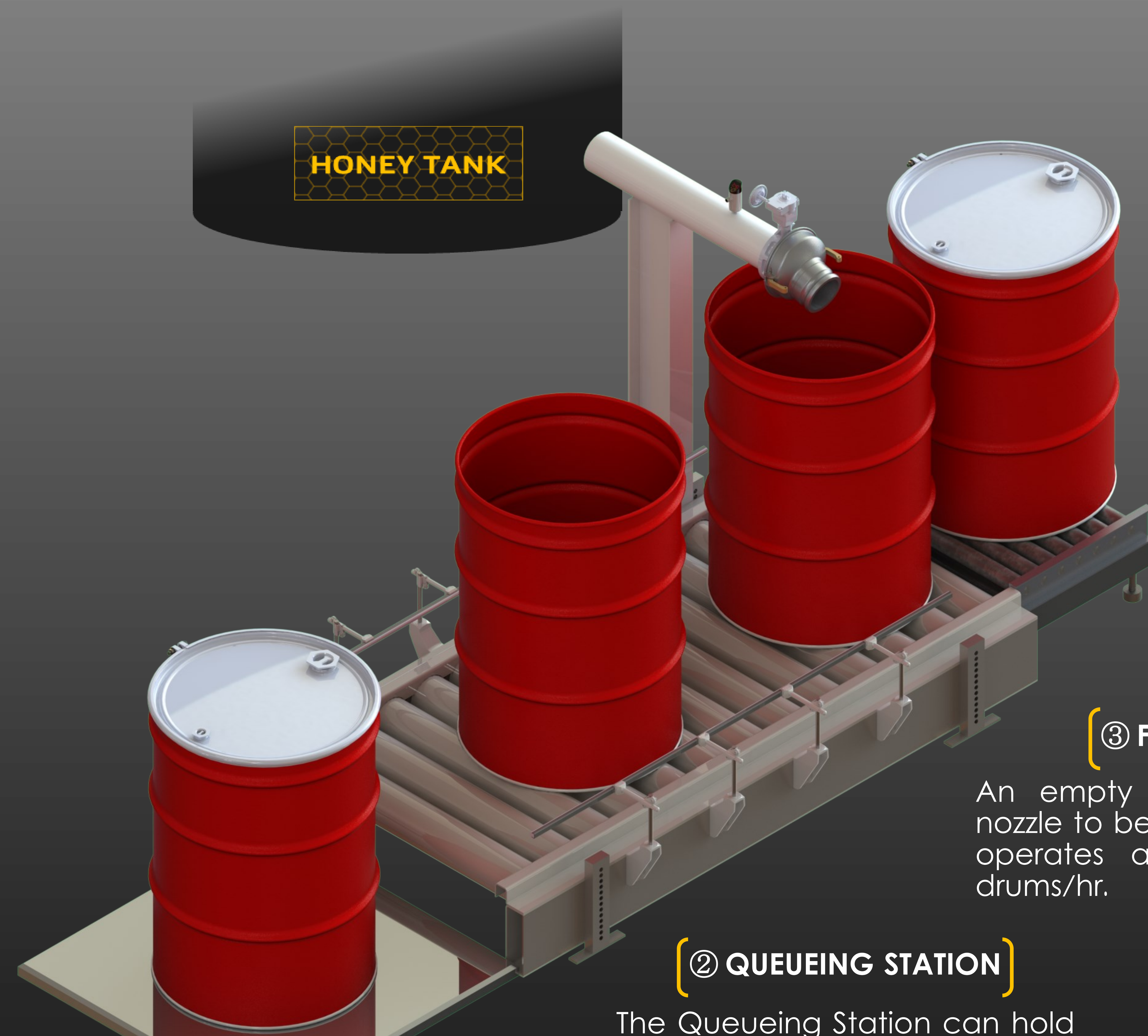
FLOW RATE AND PROCESS ANALYSIS



ECONOMIC FEASIBILITY



Year	Accumulated Expenses/ Savings at Year End
1	-$ 9,220
2	-$ 7,040
3	-$ 4,830
4	-$ 2,560
5	-$ 260
6	$ 2,100
7	$ 4,500
8	$ 6,950
9	$ 9,450
10	$ 11,990

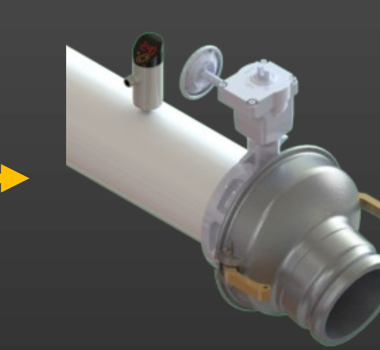


④ FINAL WEIGHING STATION

When the final weighing station is vacant, the conveyor restarts, moving the filled drum into position. Operator puts a lid on the drum, and the second scale measures the gross and net weight to the .CSV file. A CFIA compliant label with all required information is printed and manually applied to drum. Drum is removed by forklift.

③ FILLING STATION

An empty drum aligns with the nozzle to be filled. The Filling Station operates at an average of 40 drums/hr.



BUTTERFLY VALVE & FLOW SENSOR

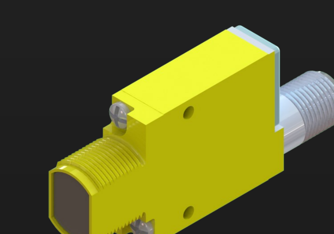
A butterfly valve opens allowing gravity-driven honey to fill the drum. The flow sensor detects temperature and flow rate and it closes the valve when the drum reaches 45 gallons.

② QUEUEING STATION

The Queueing Station can hold up to two empty drums while waiting to be filled. Conveyor moves empty drum to Filling Station.

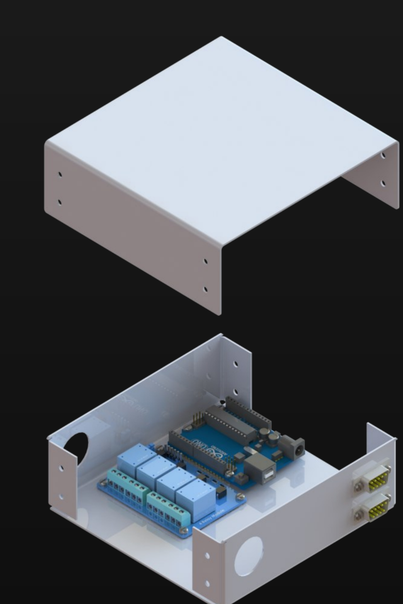
① TARE WEIGHING STATION

Operator loads an empty drum on the first scale. Tare weight is saved to .csv file. Operator removes lid, then loads drum onto electrically driven conveyor.



PHOTOELECTRIC SENSOR

A photoelectric senor will stop the conveyor once an empty drum aligns with the Filling Station.



ELECTRONIC BOX

Cold-rolled steel casing for the electrical components. It has two RS232 ports for connecting the scale to transmit information to a CSV. file. It also sends the information from the flow sensor to regulate the flow rate.

BEE
Mechanical

MEC E 460 Design Project
Group 6, Automated Filling Machine
Monday, December 2, 2019
Phase III Report

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Executive Summary

Bee Mechanical has developed an automated filling machine based on requirements set out by Worker Bee Honey and the Alberta Beekeepers Commission. The system can fill 45 gallons of honey in 55-gallon drums, can be operated by one person, and requires the operator to manually place empty drums on the system. The system automatically tares, fills, and weighs drums during operation and allows the operator to manually seal the drums with a lid and remove it for transport. The system can be integrated into Worker Bee Honey's existing facility and prints CFIA standard labels.

The final design has been prepared, analyzed, and modeled to meet design specifications. The system can fill an average of 40 drums per hour. There are four main sections to the design including taring, queuing, filling and weighing. Two electronic scales are used for taring and weighing. A chain-driven roller conveyor is used to move the drums across the system from the queuing section. A photoelectric sensor is used to determine the position of the drum on the conveyor and will trigger the filling process to begin when the drum has reached the nozzle. A gravity-fed nozzle attached to the honey storage tank is controlled using a butterfly valve and flow sensor. The valve closes once the flow sensor determines 45 gallons has been reached. A free-rolling conveyor is placed on top of the second scale for transporting drums away from the system. This design is innovative because multiple drums can be queued during the filling process, thus shortening the overall process time. The operator can move filled drums into storage while other empty drums are being filled.

Detailed analysis was performed to validate the design, including finite element analysis, flow calculations, cost feasibility, and life-cycle calculations. A preliminary electrical circuit for the filling process was also created, and design sustainability was analyzed. A design compliance matrix was used to determine if the design met the necessary specifications.

Bee Mechanical logged 648 hours for all three phases of the project with 257 hours in Phase III. The total engineering cost of this project is $58,680. The estimated cost of the Roller Conveyor system is $11,350, including parts and assembly labour.

Bee Mechanical recommends further analysis and optimization of electrical components as it was beyond the scope of the current project. It is recommended that each tank is analyzed before implementation, because a pump may be needed if the flow rate does not meet the minimum specification.

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Introduction/Background

The beekeeping industry in Canada has steadily increased over recent years. Alberta is at the forefront of the beekeeping industry in Canada, representing over 40% of Canada's honeybees with over 315,000 bee colonies [1]. Beekeepers in Alberta regularly harvest 160-200 lbs of honey per colony according to the Alberta Beekeepers Commission. As the bee industry continues to increase and new harvesting techniques are developed, the process of packing honey should also advance. Bee Mechanical's objective is to design an automated filling machine to improve Worker Bee Honey's current drum filling process. Their current process is limited in control and accuracy, which leads to a high risk of spills and product waste. Two workers are required for the operation and can only fill up to 20 drums per hour. This leads to high labor costs, low production efficiencies, and an inconsistent product output. Implementing an automated filling machine will mitigate product waste, reduce labour costs, and increase production efficiency.

Bee Mechanical has developed an automated filling machine based on requirements set out by Worker Bee Honey and the Alberta Beekeepers Commission. The system is operated by one person and requires the operator to manually place empty drums on the system. The system automatically tares, fills, and weighs the drums and allows the operator to manually seal the drums with a lid and remove it for transport. The system can be integrated into Worker Bee Honey's existing facility and prints CFIA compliant labels.

Design Updates

Several improvements were made to the design from Phase 2.

Increased the nozzle diameter

After performing calculations for the flow and filling time, the design was found to be unable to meet the 30 drum per hour specification. To increase flow rate, the nozzle diameter was increased from 2 inches to 4 inches. The flow sensor and valve were updated to accommodate for the increase in nozzle diameter.

Preliminary Electrical System

A preliminary electrical system was designed to control the flow sensor and valve.

Added Safety Feature

Emergency buttons for the roller conveyor and all other critical electrical components were added.

Changed the elbow from 90° to 45°

The facility has an existing 45° elbow. This provides better clearance for the drum during the filling process.

Final Design Description

Design Overview

The final design (Figure 1) consists of four main sections including taring, queuing, filling, and weighing (Figure 2). The taring section consists of an electronic scale to weigh the empty drums with lids. The queuing and filling sections use a chain-driven conveyor that uses side rails to prevent the drums from falling off the conveyor. The weighing section consists of a free-rolling conveyor atop another scale, allowing the gross and net weight to be determined. The drums will be filled using an existing gravity-fed nozzle at the facility, which will be fitted with a butterfly valve and flow sensor for flow regulation. The design is innovative because multiple drums can be queued during the filling process. This shortens the overall process time because the operator can move filled drums into storage while the other empty drums are being filled. The design of the conveyor meets the hygienic design criteria as specified by ISO [2].

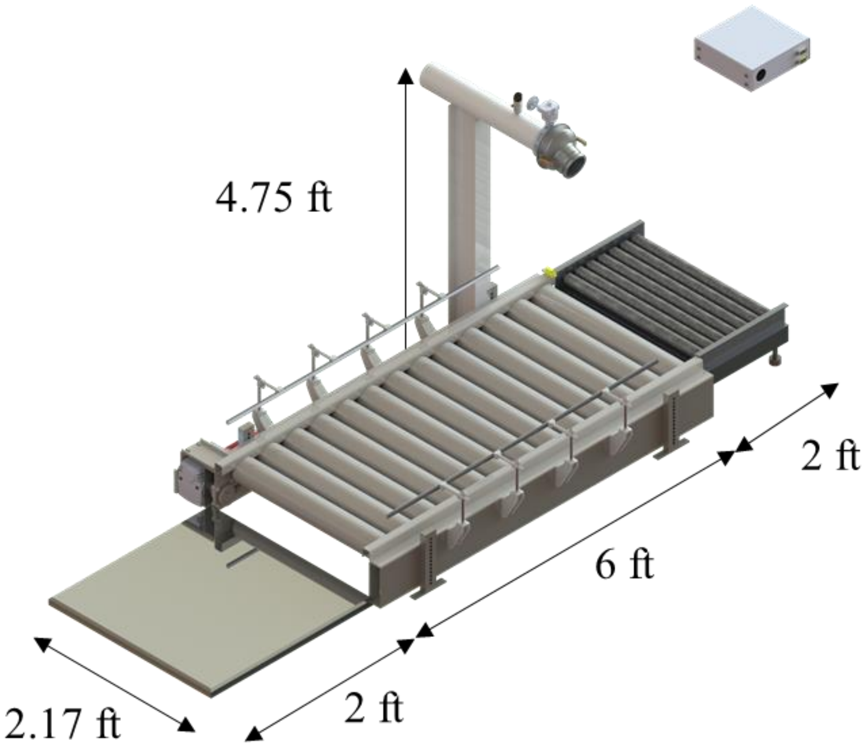


Figure 1: Isometric view of the final design with dimensions

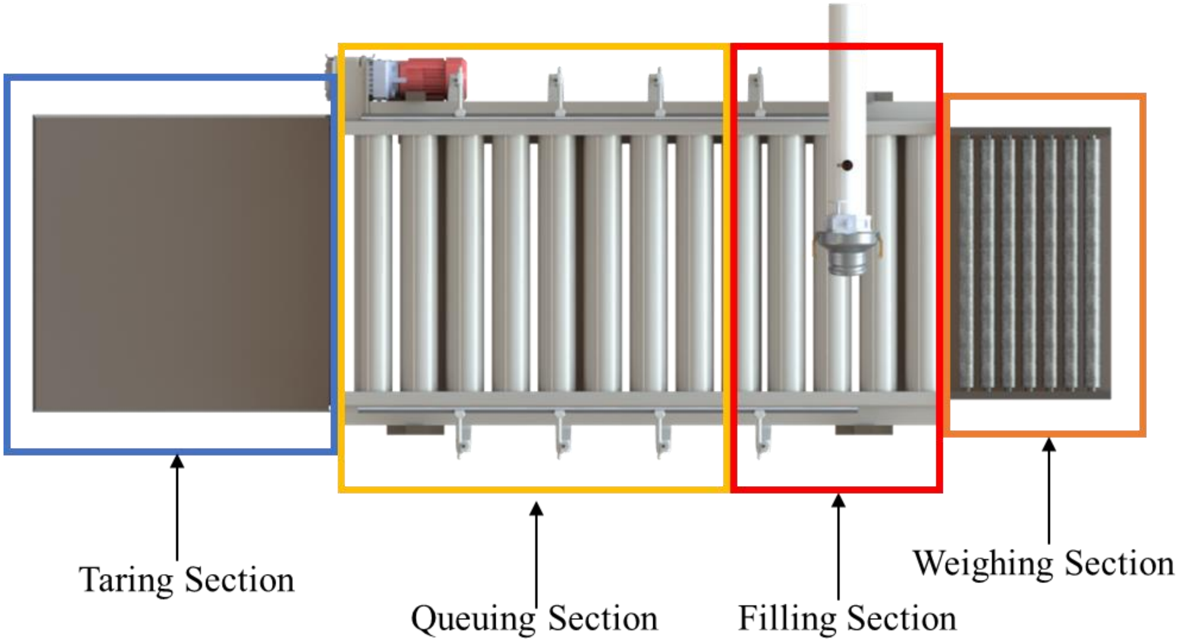


Figure 2: Top view of the final design with the labeled sections

Process

The process begins at the taring section where the empty drum with its lid will be weighed. The tare weight will be recorded and saved in a .CSV file. The lid will be removed, and the drum will be placed on the roller conveyor in the queuing section. This section can hold up to two empty drums at a time. The drums will then be transported by the chain-driven rollers to the filling section. A photoelectric sensor determines the position of the drums on the conveyor and will signal the roller conveyor to stop when the drum reaches the filling section. The filling process uses a gravity-fed nozzle with a butterfly valve and flow sensor. The butterfly valve opens, and closes based on information relayed from the flow sensor. The sensor measures flow rate and temperature to calculate volume based on the density of honey. When 45 gallons is reached, the system will cut power to the valve, automatically closing it. After filling, the roller conveyor will push the filled drum to the weighing section, and the lid will be placed back on the drum. The gross weight will be recorded in the same .CSV file, and the net weight will be determined by subtracting the tare weight. The data needed on the label will be automatically generated using the information from the .CSV file. After the label is manually placed, the drum will be removed by a forklift with a drum attachment. This process is repeated to fill 40 drums per hour. The process flow chart can be seen in Figure 3.

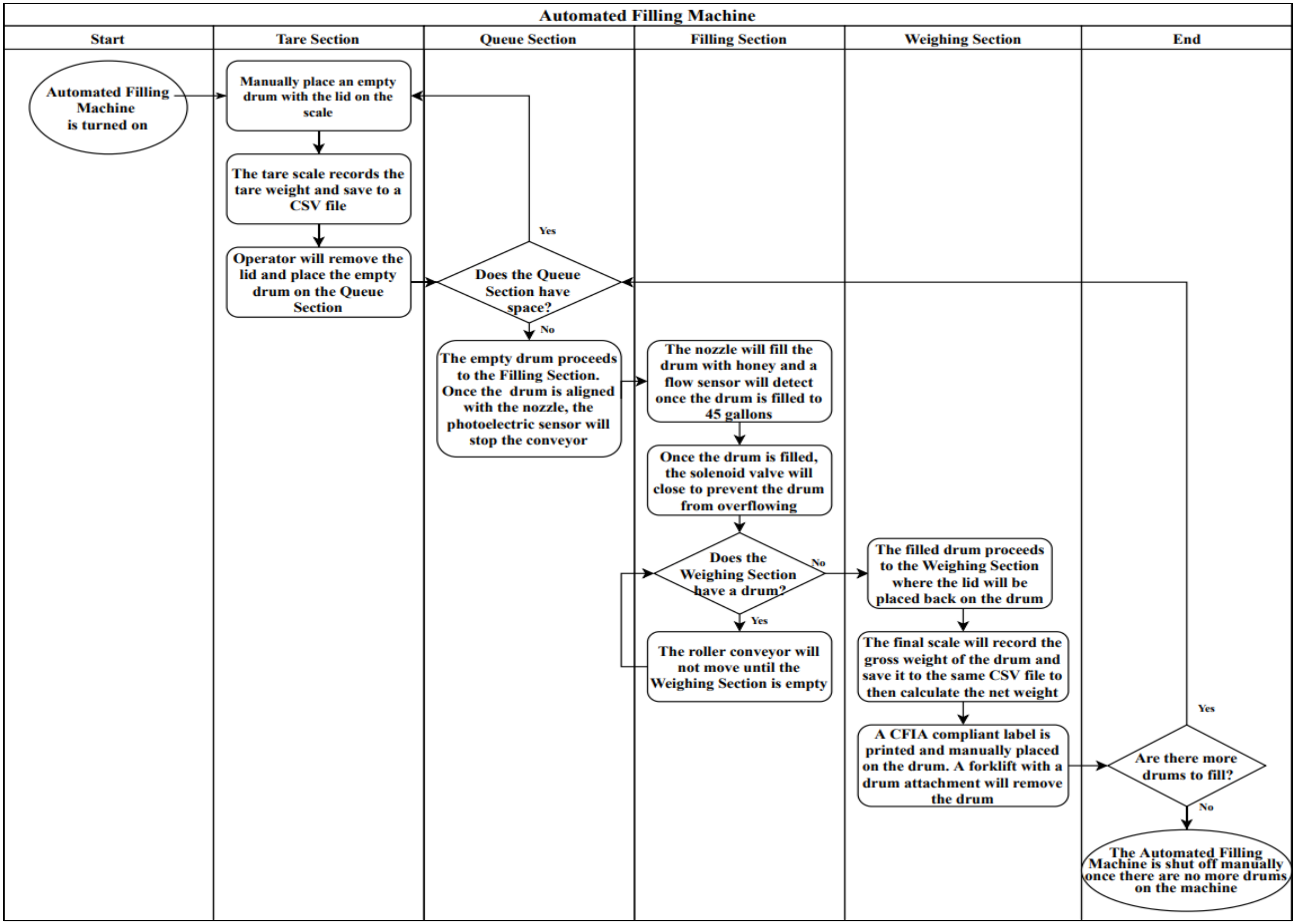


Figure 3: Process flow chart for the final design

Design Details

An exploded view of the subassemblies and individual components can be seen in Figure 4 and 5, respectively. Table 1 outlines the part breakdown of the system. Part data sheets and CAD drawings are available in Appendix C and G, respectively.

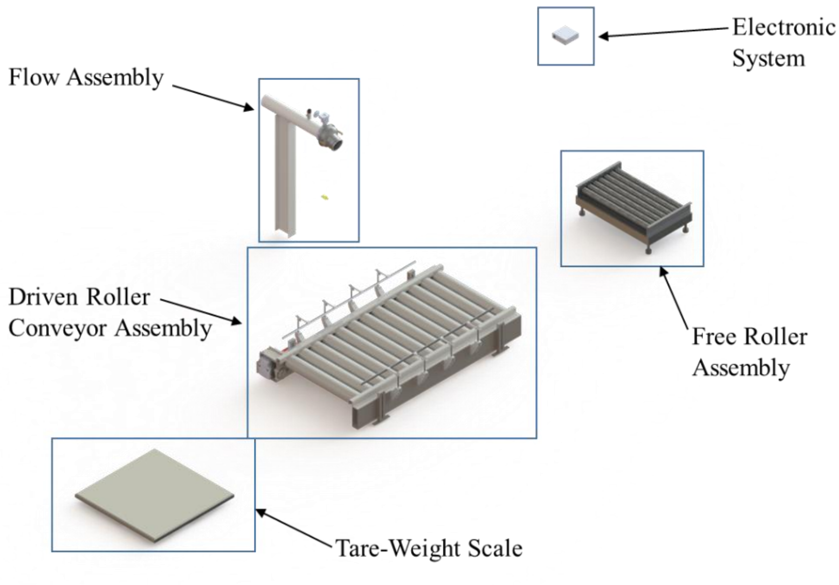


Figure 4: Exploded view of the final design with annotated subassemblies

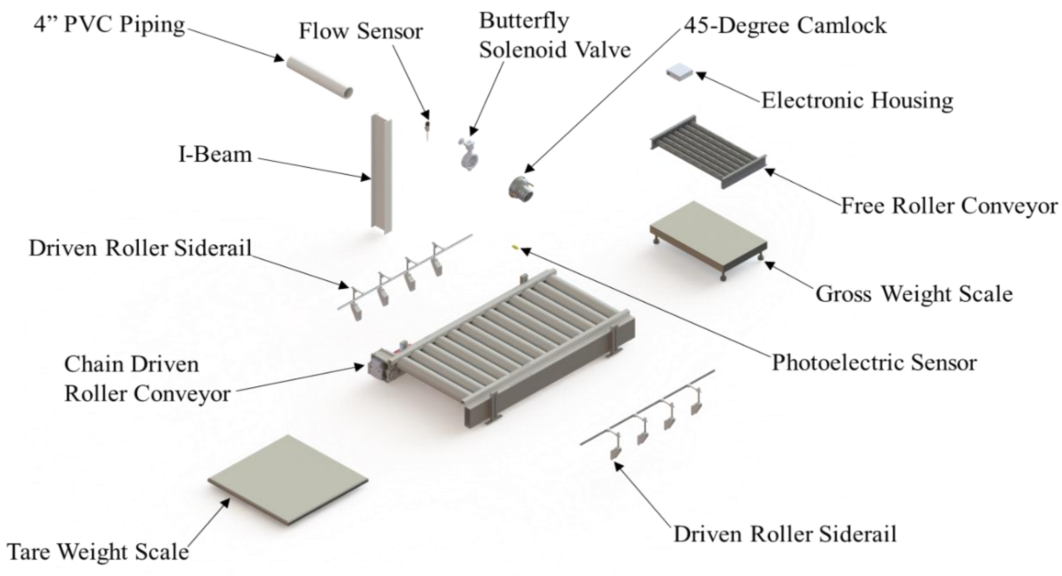


Figure 5: Exploded view of the final design with annotated parts

Table 1: Parts in the final design with quantity and description

Sub-assembly	Part Name	Qty.	Description
Roller Conveyor	Model 535 Chain Driven Live Roller Conveyor	1	Chain driven roller conveyor used to move drums across the system
Roller Conveyor	Side Rail	2	Prevents drums from falling off the conveyor
Roller Conveyor	Conveyor Emergency Stop	1	Cuts off power to conveyor system in an emergency
Weighing	Taring Scale	1	Determines the tare weight of the drums with lids
Weighing	Weighing Scale	1	Determines the gross weight of the drums in the weighing station
Weighing	Roller Conveyor YRO	1	Free-rolling conveyor that is placed on scale at the weighing station for easy transport of drums
Labelling	Thermal Label Printer	1	Prints label
Flow Control	Photoelectric Sensor	1	Determines the position of drums on the conveyor and signals conveyor to start and stop
Flow Control	4" Electrical Butterfly Valve D971X-10S	1	Valve that regulates flow
Flow Control	Flow Sensor FTS100-1002	1	Measures the flow rate and the volume that has been filled in each drum
Flow Control	Arduino UNO	1	Controls flow control system
Flow Control	AC to DC Transformer	1	Converts wall AC power to DC power to provide power to the flow sensor
Flow Control	Power Cord	1	Connects to wall outlet and provides power to solenoid valve
Flow Control	5V Relay Module	1	Switch that can be turned on to let current pass, and can be controlled with low voltages from Arduino
Flow Control	Emergency Shut-off Button	1	Cuts off power to the butterfly valve in an emergency
Flow Control	USB A to B	1	Connects computer to Arduino
Flow Control	Wires	1	Used to connect electronic parts
Flow Control	Standard Steel I-Beam	1	Supports flow assembly
Flow Control	PVC Pipe	1	Connects tank to flow assembly
Flow Control	45-Degree Camlock	1	45-degree elbow
Electronics Housing	DB9 Panel-Mount 9-pin Serial Coupler	2	Connector for both scales (RS232)
Electronics Housing	USB Port	1	Port for USB connection
Electronics Housing	Electronics Housing	1	Houses electronic components
Electronics Housing	Bolt RM3X8MM-2701	4	Connection for the electronic housing

Sub-assembly	Part Name	Qty.	Description
Electronics Housing	Bolt SM3X6MM-2701	4	Connection for the electronic housing
Electronics Housing	M3 Flat Head Countersunk Screw Kit, M3 4mm	4	Connection for the electronic housing
Electronics Housing	Metric hex nuts, Stainless steel 18-8 (A-2), 3mm x 0.5mm	12	Connection for the electronic housing
Electronics Housing	M4-0.7 x 5 mm. Phillips-Square Flat-Head Machine Screws	8	Connection for the electronic housing
Electronics Housing	HN-M4-79/RPC3083-ND Nut	8	Connection for the electronic housing

Critical Detailed Design Analysis

Roller Calculation

The roller calculation was performed to find the smallest acceptable roller diameter. As detailed in Appendix A1, it was calculated to be 1.5 inches with a factor of safety of 2.26. This value was used as the minimum roller size when selecting a roller conveyor. The chosen roller conveyor has a roller size of 2.5 inches.

Finite Element Analysis

The stress and minimum factor of safety values for normal operating conditions were determined to predict roller performance. From the detailed roller analysis found in Appendix A2.1, the maximum stress that each roller experienced was 98.96MPa with a minimum factor of safety of 2.86. This indicates that the roller will not fail under normal conditions.

Another analysis was performed for the worst-case scenario, which occurs when all the weight of a filled drum is on a single roller. To verify that the thickness of roller was optimized, a design study (Appendix A2.2) was completed to determine the maximum inner roller diameter. The maximum inner roller diameter was determined to be 60.5mm with a minimum factor of safety of 1.09. The chosen conveyor has an inner roller diameter of 60.325mm, which results in a minimum factor of safety of 1.104. This confirms that rollers in the chosen conveyor are optimized for the worst case. It should be noted that a protective outer coating may be needed if drums have a smaller than standard rim. Contact with the rollers may cause large stress concentration factors.

Flow and Time Calculation

To determine how many drums could be filled by the design, flow rate and total process time was analyzed (Appendix A3). Table 2 shows the estimated time a drum spends at a given section. Filling time is dependent on the height of honey in the tank. Therefore, flow rates were determined for different levels honey to analyze the system's ability to meet the client's specification. Figure 6 shows the rate of drums filled per hour for each section as a function of tank head. It can be observed that the limiting stage in the process will be the weighing section when the head within the tank is above 2.04m. After this point, the limiting step will be the filling stage. The filling rate will drop below the minimum rate of 30 drums per hour when the head falls below 0.77m. Bee Mechanical recommends keeping the head height above 0.77m to exceed this minimum operating speed. The time required to empty a full 10,000L tank of honey into 58 drums was determined to be 87.3 minutes, resulting in a filling rate of 40 drums per hour. When the tank is nearly empty, the time for one drum to pass through the entire process is 11.6 minutes.

Table 2: Time a single drum spends at the a given section

Section	Time (s)
Taring	15
Filling	Height Dependent
Weighing	60

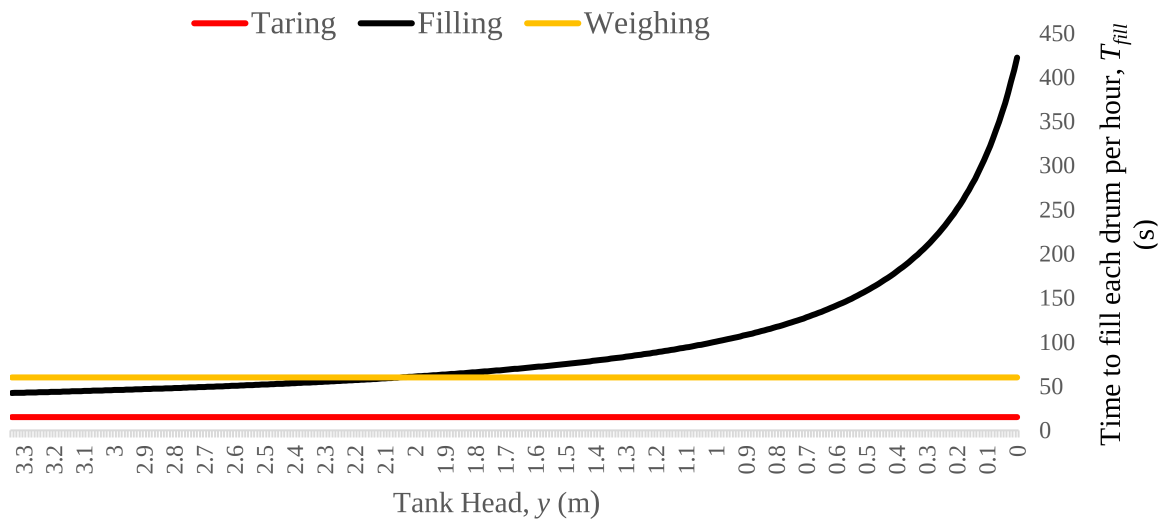


Figure 6: Rate of drums filled per hour as function of fluid height

Circuit Analysis

A preliminary electrical prototype was designed for the filling process. An Arduino UNO takes temperature and flow inputs from the flow sensor and sends voltage to open the valve until 45 gallons has been filled in the drum. The temperature input is used to determine the density of the honey. The system accounts for density changes and its effect on the flow rate and volume. The flow rate and volume are displayed on the serial monitor in Arduino software. Figure 7 shows the electronic set up of the system. The circuit code is provided in Appendix A4.

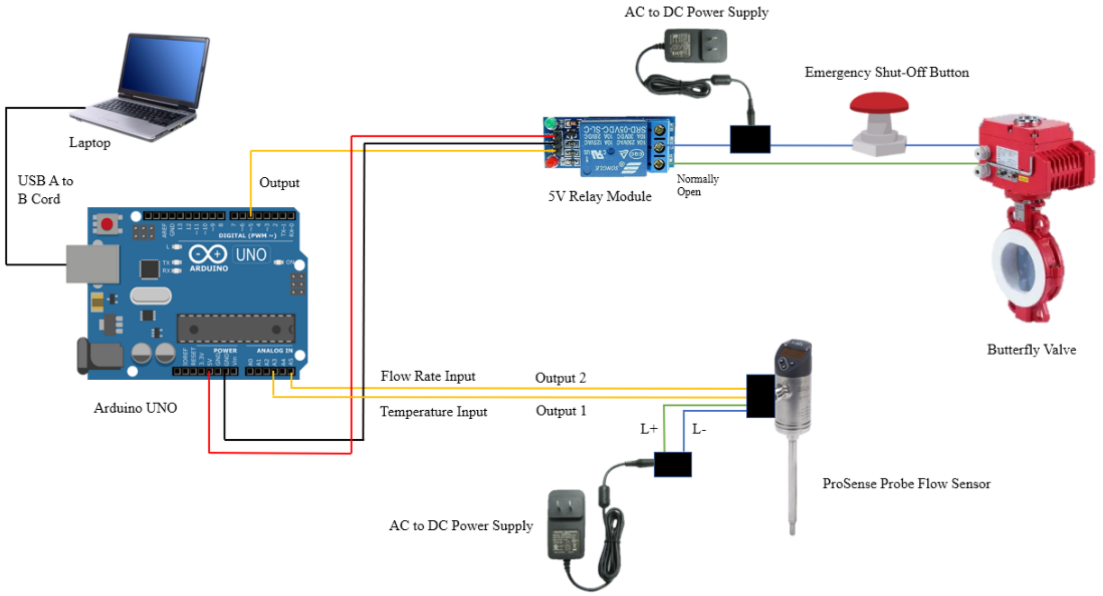
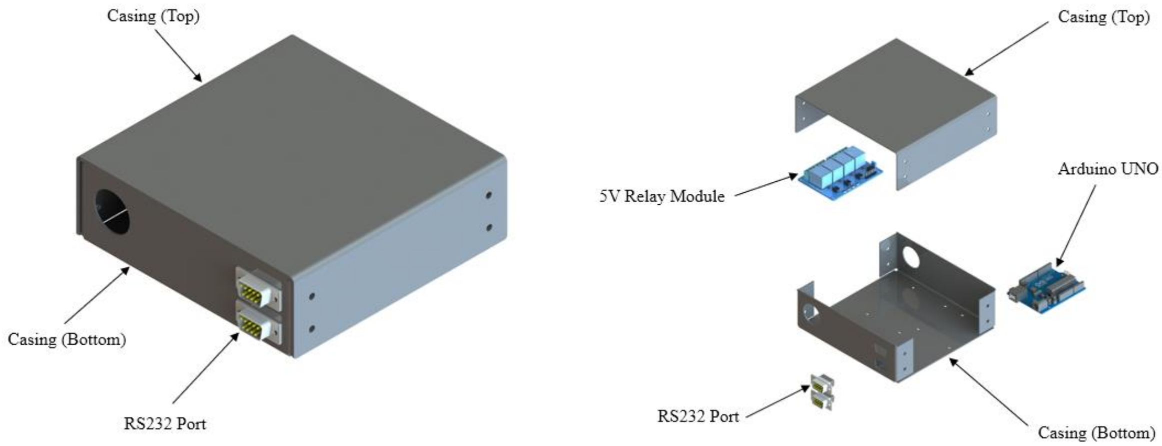


Figure 7: Electronic system set up

Electronics will be stored in an electronic housing made from cold-rolled steel. It features two RS232 ports to connect the scales and two holes to allow wires to connect to the sensors and an emergency stop button. Figure 8 shows an isometric view and an exploded view of the electronic housing.



(i) (ii)

Figure 8: Electronic housing: (i) isometric view, (ii) exploded view

A block diagram was created to enable coding implementation for the entire system (Figure 9). Three control loops are used to control both scales, the roller conveyor, and printer.

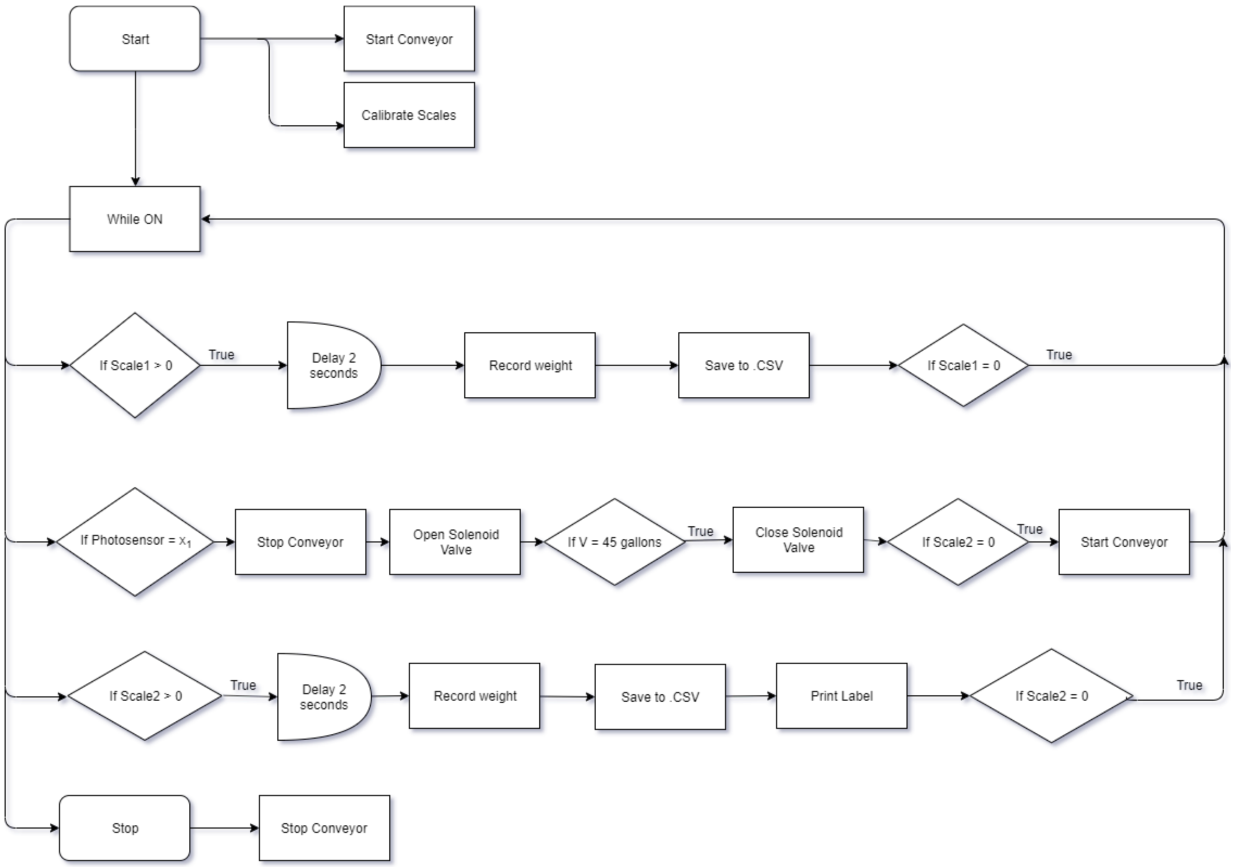


Figure 9: Flow diagram for coding implementation

Cost Analysis

The overall cost of the system is $11,350 CAD. Table 3 shows the parts cost and assembly cost of subsystems in the design. Assembly costs are based on the current working hours of two employees. It should be noted that the only custom part was the electronic housing and its part cost includes machining cost. The price breakdown of individual components is shown in Appendix B.

Table 3: Parts and assembly cost of each subsystem

Subsystem	Parts Cost (CAD)	Assembly Cost (CAD)	Total Cost (CAD)
Roller Conveyor	$6,659.40	$80	$6,739.40
Weighing	$2,765.31	$20	$2,785.31
Labelling	$283.80	$20	$303.80
Flow Control	$1,091.05	$80	$1,171.05
Electronic Housing	$310.16	$40	$350.16
Total	$11,109.72	$240	**$11,350**

Figure 10 compares the total annual expenses when operating with or without the filling machine. The estimated expenses of operating without the filling machine is based on two workers receiving $20/hr to fill 1500 drums in 8 weeks, working 5 days a week for 2 hours a day. Without the filling machine, annual operation takes 80 hours. However, the annual operating hours would decrease to 38 if the filling machine is used. This is because the machine requires one worker to operate so the company would save on wage expenses.

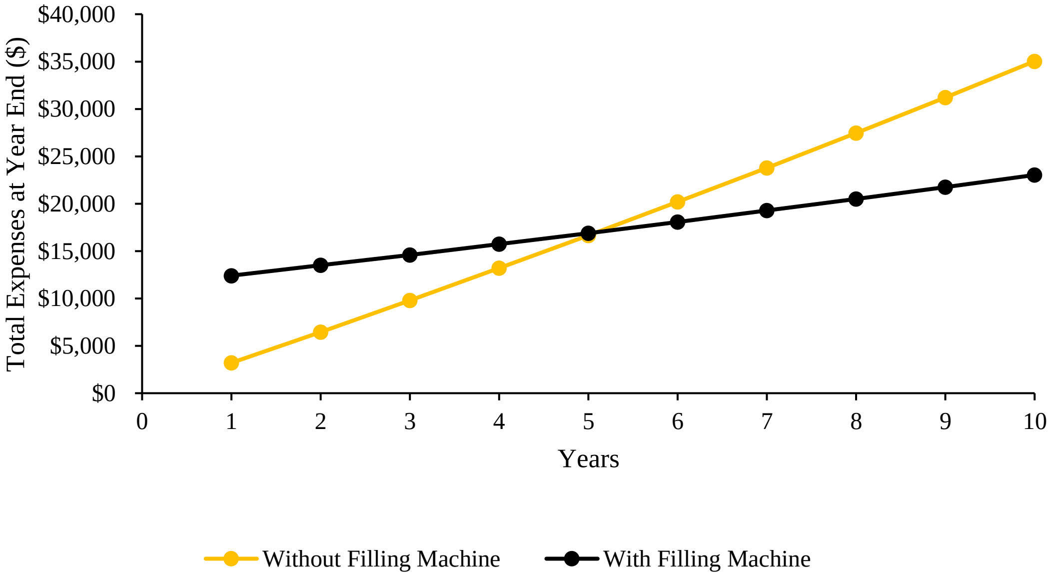


Figure 10: Accumulated expenses with and without filling machine

Figure 11 compares the annual accumulated expenses/savings for the filling machine to current operation in a 10-year period, and Table 4 shows the dollar value each year. The initial increase in expenses for the filling machine is due to the capital cost of the machine. The company would start saving money each year since the operating costs are significantly cheaper. The breakeven point occurs at the beginning of year 6, and they would save $11,993 by the end of year 10. The annual savings can increase if the company fills more drums per year because of reduced operation costs.

Table 4: Accumulated expenses/savings at year end

Year	Accumulated Expenses / Savings at Year End
1	($9,218)
2	($7,044)
3	($4,826)
4	($2,563)
5	($256)
6	$2,098
7	$4,499
8	$6,947
9	$9,445
10	$11,993

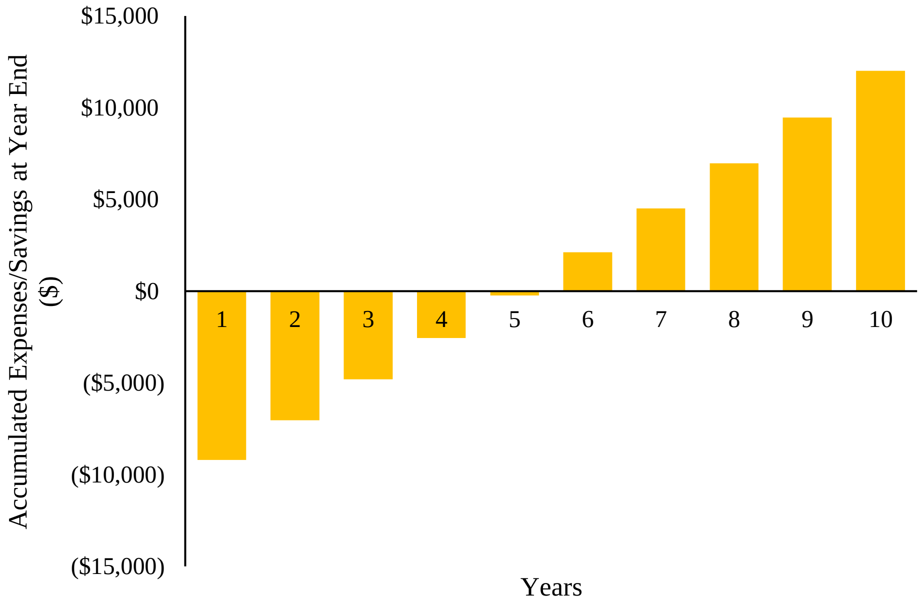


Figure 11: Accumulated expenses/savings at year end

Sustainability

Sustainability was considered during the developmental design phase. A sustainable design has a long service life and meets technical and functional requirements [3]. To maximize service life, stainless steel was chosen for all components that are in contact with food as the material has exceptional corrosion resistance and extends the overall lifetime of the design. Based on life cycle calculations (Appendix D), the design can be used for more than 10 years because components with sufficiently high safety factors were selected. Maintainability and repairability are also important aspects of sustainable design because it allows the design to reach its maximum life cycle. The overall system can be easily disassembled and reassembled to allow for the components to be thoroughly cleaned or repaired. A maintenance schedule is provided to the client in Appendix B3. Additionally, reducing energy intensity of the design was emphasized during Phase III. Components with low electricity consumption were applied, thus the design consumes minimal electricity at a rate of 19.82kWh. If energy consumption is extrapolated to a regular work schedule of 8 hours a day, 5 days a week for an entire year, the rate would increase to 1649kWh per year. This is still a minimal consumption of electricity, which can be attributed to the use of a gravity-fed nozzle instead of a pump. The only required power is supplied to the motor that turns the rollers on the conveyor, weighing scales, butterfly valve, and flow sensor. The benefit of a low energy consumption design is that it enables the client to expand their production levels without significant increase to their electricity costs while minimizing environmental impact.

Design Compliance Matrix

The design compliance matrix (Table 5) was evaluated at the end of the design process to ensure that the necessary specifications were achieved. No specifications were changed from Phase II. The design met all specifications. The signed copy of the design compliance is in Appendix E.

Table 5: Design Compliance Matrix

Item	Specification	Design Authority	Description	Relative Importance (1-5)	Compliance (Yes/No)	Design Compliance Comments
Project Management						
1.1	Budget	Bee Mechanical	The client has specified a $15,000 budget.	5	Yes	Design has an estimated cost of $11,350.
1.2	Schedule	Dr. Duke	All deliverables should be submitted as per course schedule.	5	Yes	All deliverables have been submitted as per course schedule.
1.3	Manufacturability	Bee Mechanical	The design should be easily sourced and easily manufactured.	3	Yes	All parts are stock parts that can be purchased.
1.4	Design	Bee Mechanical	Complexity of the design should be minimized.	3	Yes	The complexity of the design was minimized. There are only 4 sub-assemblies.
Functionality						
2.1	Size	Client	Entire system must fit within an area of 5ft x 15ft.	5	Yes	The overall dimensions of the design are 3.5ft x 10ft.
2.2	Life cycle	Bee Mechanical	System should have a minimum operating life of 10 years when operating 2 hours per day for 6-8 weeks every year.	4	Yes	The design can operate 6-8 weeks per year for 2 hours a day. The operating life exceeds 10 years.

Item	Specification	Design Authority	Description	Relative Importance (1-5)	Compliance (Yes/No)	Design Compliance Comments
2.4	Speed	Bee Mechanical	System must be able to fill more than thirty 55-gallon drums to 45 gallons per hour.	5	Yes	The system can fill 40 drums per hour.
2.5	Reliability	Bee Mechanical	Design must allow for 2 years of warranty without system failure due to a design error.	3	Yes	The design warranty is over 10 years. Safety factors are sufficiently high to prevent design failure.
2.7	User Friendly	Bee Mechanical / Client	Design must be easily operated by a single user. Minimal training time would be preferred (1-2 hours).	5	Yes	The design can be operated by one worker. The training required would be minimal since the process is simple.
2.8	Adaptiveness	Bee Mechanical	Design must be integrated into Worker Bee Honey's current facility.	5	Yes	The design was made specifically for Worker Bee Honey.
2.9	Noise	Bee Mechanical	Noise of the system should not exceed 100 dB.	2	Yes	The loudest part of the design is the motor, which would not exceed 100 dB.
2.1	Weighing	Client	Design must be able to determine the gross weight of the drum with lid, tare weight of the empty drum and lid and net weight of honey. The tolerance of the weight is to the 0.2 kg.	5	Yes	The design has different sections that can measure the tare and gross weight. The net weight of the honey is calculated from the CSV file. The scales have a tolerance of 0.1kg.
2.11	Labelling	Client	Labels must be generated and printed. Placing label on drum is a desirable extra but not mandatory. All labels must be CFIA compliant.	5	Yes	The design includes a printer that can generate a CFIA complaint label from the CSV file data.
2.12	Logging	Client	The design must be able to generate a log of drums filled that can be exported to a CSV file or similar.	5	Yes	The design has can track each drum and record the information on a CSV file.

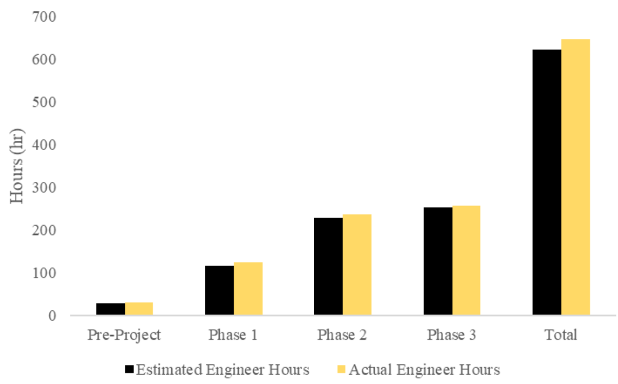
Item	Specification	Design Authority	Description	Relative Importance (1-5)	Compliance?	Design Compliance Comments
Safety						
3.1	Safety	Canadian Government / ISO	Material in direct contact with honey should be food grade material or lined with food grade material [2][4].	5	Yes	All components in contact with honey are stainless steel.
3.2	Safety	ISO	System shall meet the criteria of a hygienic design as specified by ISO TS 2200-4 4.5.2.[2]	5	Yes	The design meets the hygienic criteria specified by ISO TS 2200-5 4.5.2.
Maintenance						
4.1	Cleaning	Bee Mechanical	The components should be easy to clean and capable of withstanding repeated cleaning.	4	Yes	The conveyor can be easily disassembled.
4.2	Ease of Maintenance	Bee Mechanical/Canadian Government	System should be accessible and able to be easily disassembled for its cleaning, sanitizing, maintenance or inspection [5].	3	Yes	The conveyor can be easily disassembled.
4.3	Maintenance Procedure	Bee Mechanical/ISO	A system of planned maintenance shall be in place as specified by ISO 2200-4 Section 4.5.4[2].	3	Yes	A maintenance schedule is provided (Appendix B3).

Project Management

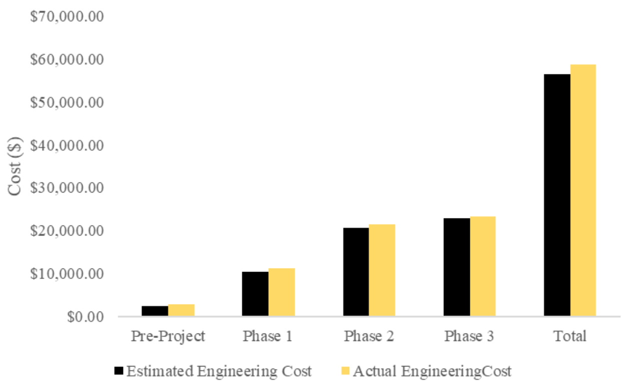
The project was estimated to take 623.5 hours to complete. However, an additional 24.5 hours were required to complete the project. Majority of additional hours were added in Phase II as there were discrepancies between the initial scope and scope revisions from the client. 9 hours were added for 3D modelling, calculations and material research in Phase II. In Phase III, 4 hours were added for calculations and final editing and formatting of the report. The project resulted in a total of 648 hours and a total cost of $58,680, exceeding the original estimate cost by $2,115. The breakdown of engineering cost between estimated and actual hours for each phase is summarized in Table 6 and displayed in Figure 12. Appendix F shows the detailed task tracker.

Table 6: Breakdown of the estimated and actual engineering hours spent on the design

	Junior Engineer Hours (hr)		Intermediate Engineer Hours (hr)		Total Engineer Hours (hr)		Total Cost ($)	
	Estimated	**Actual**	**Estimated**	**Actual**	**Estimated**	**Actual**	**Estimated**	**Actual**
Pre-Project	27.5	30.5	0	0	27.5	30.5	$2,475.00	$2,745.00
Phase 1	114	122.5	1	1	115	123.5	$10,410.00	$11,175.00
Phase 2	225	235	3	2	228	237	$20,700.00	$21,450.00
Phase 3	250	254	3	3	253	257	$22,950.00	$23,310.00
Total	616.5	642	7	6	623.5	648	$56,535.00	$58,680.00



(i)



(ii)

Figure 12: Breakdown of estimated and actual engineering hours (i) and engineering cost (ii)

Future Work

Future work is required to make the design fully operational. Bee Mechanical recommends further analysis and optimization of electrical components. Due to time constraints, it was beyond the scope of the current project and therefore, only preliminary electronic groundwork was created. Specific recommendations include:

- Packaging electronics by using a printed circuit board
- Implementation of an LED monitor to display flow rate and volume
- Computational fluid dynamics analysis to determine the thermal profile and cooling of the electronics housing to prevent failure from excess heat

In the analysis of flow and filling time, several assumptions were made about the size and height of the tank. Tank sizes may differ and can cause different flow rates than those presented in the report. Therefore, tank analysis is recommended before implementation, so that the design is tailored to the tank. A pump may be needed if the flow rate does not meet the minimum specification. Additional safety features can be added to the design if the client desires.

Conclusion

Bee Mechanical has developed an automated filling machine design to satisfy the requirements set by Worker Bee Honey and Alberta Beekeepers Commission. The innovation of this design is that multiple drums can be queued during the filling process, shortening the overall process time. The system can fill an average of 40 drums per hour. CAD models and drawings were prepared for the system. Critical calculations were performed to validate the design including roller analysis, flow and time calculations, cost feasibility, and life cycle calculations. Finite element analysis was also used to analyze the rollers for the normal and worst-case conditions of the conveyor. A preliminary electrical circuit for the filling process was also created, and design sustainability was analyzed. The design met all specifications when evaluated by the design compliance matrix. The estimated cost of the design is $11,350, including parts and labor. Bee Mechanical logged 648 hours for all three phases of the project with 257 hours in Phase III. This exceeded Bee Mechanical's estimated hours of 616.5. The total engineering cost of this project is $58,680. Due to time constraints, Bee Mechanical makes several recommendations to ensure the design is fully operational. The most crucial recommendation is further analysis and optimization of electrical components as it was beyond the scope of the current project. Tank dimensions can vary; hence, tank analysis is recommended before implementation. A pump may be needed if the flow rate does not meet the filling specification. Additional safety features can also be added to the design if the client desires.

References

[1] Government of Alberta, ‘Apiculture’, 2019 [Online]. Available: https://www.alberta.ca/apiculture.aspx. [Accessed: 22-Sep-2019].

[2] Government of Canada, Canadian Food Inspection Agency and Food Safety and Consumer Protection Directorate, “Labelling Requirements for Honey,” Food - Canadian Food Inspection Agency, 22-May-2019. [Online]. Available: https://www.inspection.gc.ca/food/requirements-andguidance/labelling/industry/honey/eng/1392907854578/1392907941975?chap=0. [Accessed: 30-Oct-2019]

[3] MEC E 460 Fall 2019 Lecture 20

[4] Organic Production Systems General Principles and Management Standards, CAN/CGSB-32.310, 2015

[5] Prerequisite programs on food safety — Part 4: Food packaging manufacturing, ISO TS 22002-4, 20

Appendix A: Calculations

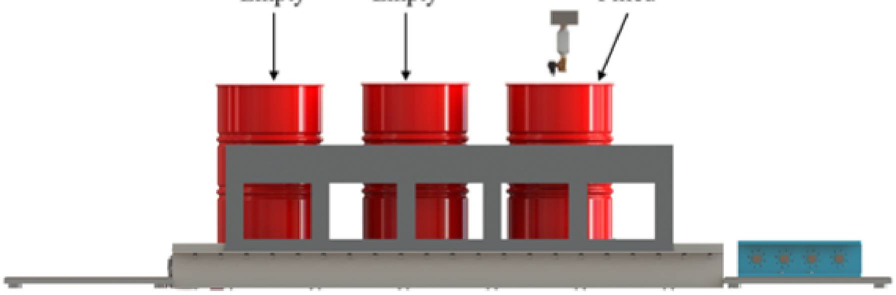
Appendix A1: Roller Calculation

Name: Adam Dumanowski
Reviewed by: Dustin Evangelista
Torque Calculations

Created Date: October 10, 2019
Modified Date: November 24, 2019

Objective:

Determine the torque that is required for each gear in the chain drive to move two empty drums and one filled drum.



Assumptions:

1. Density of honey is between 1.38 kg/l and 1.45 kg/l
2. Drums are filled to 45 gallons
3. An empty drum weighs 40 lbs
4. The static coefficient of friction is 0.5 for steel on steel

Weight Calculation:

1. The average density of honey was determined first using the range of density values

$$\rho_{avg} := \frac{1.38\,\frac{kg}{L} + 1.45\,\frac{kg}{L}}{2} = 11.8087\,\frac{lb}{gal}$$

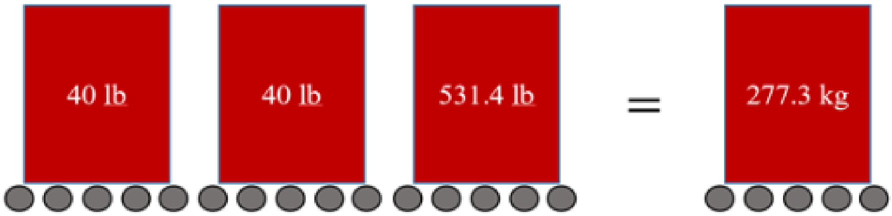
2. The weight of a drum filled with 45 gallons of honey was next calculated

$$W_{filled} := \rho_{avg} \cdot 45\,gal = 241.0361\,kg$$

3. The total weight on the conveyor was calculated

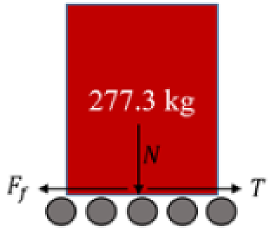
Maximum weight on conveyor = 2(Weight of empty drum)+(Weight of filled drum)

$$W_{total} := W_{filled} + 2 \cdot 40\,lb = 277.3235\,kg$$



Tension Calculation:

Free Body Diagram



Where:

Normal Force = Total Weight * Acceleration due to gravity

$N := W_{total} \cdot 9.81 \frac{m}{s^2} = 2720.5435\ N$

Frictional Force = Frictional Coefficient * Normal Force

F.f = μ*N

$F_f := 0.5 \cdot (N) = 1360.2718\ N$

Sum of Forces in the x-direction = 0

$T := F_f = 1360.2718\ N$

$F_x := T - F_f = 0$

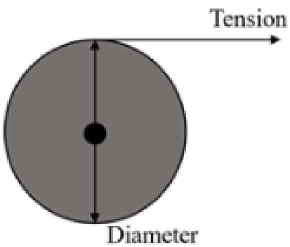
Torque Calculation:

Where:

Torque = Tension * Radius of Roller

Torque: τ

Radius: r



$r := \frac{63.5\ mm}{2} = 0.0318\ m$

$\tau := T \cdot r = 43.1886\ N\ m$

Conclusion:

In conlusion, the torque that was required to move a total weight of 277.3 kg was calculation to be 43.19 Nm. This torque value will be used in the shaft analysis calculations to determine the minimum diameter for the shaft.

Shaft Analysis

Created Date: October 10, 2019

By: Dustin Evangelista

Modified Date: November 24, 2019

Reviewed by Adam Dumanowski

Objective: To obtain the minimum roller diameter and to verify that the sourced roller conveyor works.

Number of Rollers

$N_r := \frac{72}{\left(4+\frac{3}{8}\right)} = 16.4571$ — Number of rollers in entire conveyor

$T := \frac{43.1886}{N_r}\ N\ m = 2.6243\ N\ m$ — Torque on each roller

$dsprock := 60\ mm$ — Diameter of each sprocket

Material Property — *AISI 1018 Cold Rolled Steel*

$E := 200\ GPa$ — Modulus of Elasticity

$G := 140\ GPa$ — Shear Modulus

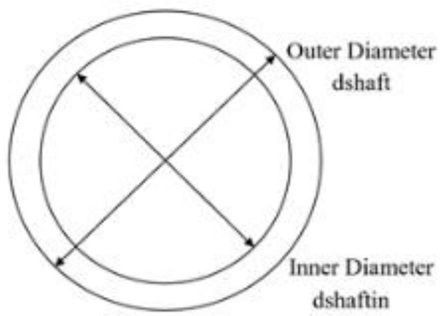
$Sy := 415\ MPa$ — Yield Strength

$Sut := 540\ MPa$ — Ultimate Strength

Shaft Geometry Properties

$dshaft := 2.5\ in = 63.5\ mm$ — Diameter of the Roller (Shaft)

$dshaftin := dshaft - \frac{1}{8}\ in = 60.325\ mm$ — Inner Diameter of the Roller (Hollow Shaft)



$I := \frac{\pi}{32}\cdot\left(dshaft^4 - dshaftin^4\right) = 2.9609\cdot10^{-7}\ m^4$ — Moment of Inertia

$J := 2\cdot I = 5.9218\cdot10^{-7}\ m^4$ — Geometry Factor

$Lt := 30\ in = 762\ mm$ — Total length of shaft

$Lld := 4\ in = 101.6\ mm$ — Distance of Fld from left end of the shaft

$Lrd := 26\ in = 660.4\ mm$ — Distance of Frd from left end of the shaft

$Lg := 27\ in = 685.8\ mm$ — Distance of gear from left end of shaft

Calculation of Endurance Strength

Surface Condtion Modification Factor *Assume Machined*

$a := 4.51$

$b := -0.265$

$$ka := a \cdot \left(\frac{Sut}{MPa}\right)^{b} = 0.8513$$

Table 4-2: Coefficient for the surface-factor equation 4.5 [Shigley]

	MPa		kpsi	
Surface finish	a	b	a	b
Ground (standard unless otherwise indicated)	*1.58*	*-0.085*	*1.34*	*-0.085*
Machined or Cold drawn	4.51	-0.265	2.7	-0.265
Hot-rolled	57.7	-0.718	14.4	-0.718
As-forged	272	-0.995	39.9	-0.995

Size Modification Factor

$$kb := \begin{aligned} &\text{if } (dshaft \le 254\,mm) \wedge (dshaft > 51\,mm) \\ &\quad 1.51 \cdot \left(\frac{dshaft}{mm}\right)^{-0.157} \\ &\text{else} \\ &\quad \text{if } (dshaft \le 51\,mm) \wedge (dshaft \ge 2.79\,mm) \\ &\quad\quad 1.24 \cdot \left(\frac{dshaft}{mm}\right)^{-0.107} \\ &\quad \text{else} \\ &\quad\quad 0.6 \end{aligned}$$

Valid for 51<d<254mm

Valid for 2.79<d<51mm

$$k_b = \begin{cases} 0.879d^{-0.107} & 0.11 \le d \le 2\text{ in} \\ 0.91d^{-0.157} & 2 < d \le 10\text{ in} \\ 1.24d^{-0.107} & 2.79 \le d \le 51\text{ mm} \\ 1.51d^{-0.157} & 51 < d \le 254\text{ mm} \end{cases}$$

$kb = 0.7869$

Load Modification Factor

Bending Dominant

$kc := 1$

$$k_c = \begin{cases} 1 & \text{Bending} \\ 0.85 & \text{Axial} \\ 0.59 & \text{Pure torsion, shear} \end{cases}$$

Temperature Modification Factor

Assume normal temperature

$kd := 1$

$$k_d = \begin{bmatrix} 0.975 + 0.32 \cdot 10^{-3} \cdot T_f - 0.115 \cdot 10^{-5} \cdot T_f^{\,2} + \ldots \\ 0.104 \cdot 10^{-8} \cdot T_f^{\,3} - 0.595 \cdot 10^{-12} \cdot T_f^{\,4} \end{bmatrix}$$

Reliability Modification Factor

Taking 95% reliability

$ke := 0.868$

Reliability	k_e
50	1
90	0.897
95	0.868
99	0.814
99.9	0.753
99.99	0.702
99.999	0.659
99.9999	0.62

Miscellaneous Modification Factor

Assuming no misc. factors

$kf := 1$

Rotary Beam Endurance Limit

$Se' := 0.504 \cdot Sut = 2.7216 \cdot 10^{8}\ Pa$ *Valid if ultimate strength is lower than 1463 MPa*

Endurance Strength

$Se := ka \cdot kb \cdot kc \cdot kd \cdot ke \cdot kf \cdot Se' = 1.5826 \cdot 10^{8}\ Pa$

Calculation of Safety Factor

$nm := 1.0$ *Material is well known*

$ns := 1.1$ *Stress analysis is assumed to be accurate*

$ng := 1.0$ *Manufacturing tolerances tight and held*

$nf := 1.1$ *Failure analysis is based on simple uniaxial static load*

$nr := 1.2$ *Reliability between 90% to 98%*

$n := nm \cdot ns \cdot ng \cdot nf \cdot nr = 1.452$

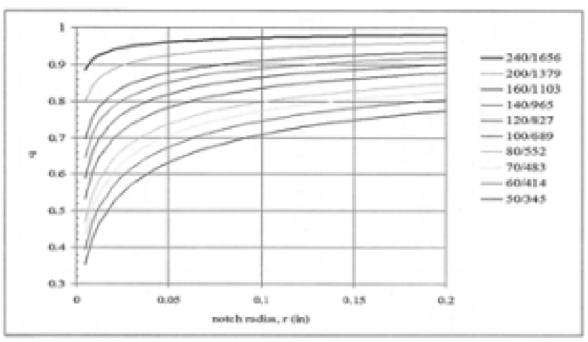
Stress Concentration Factor

Table 6-2: Using tapered key

$Kt := 2.2$
$Kts := 3.0$

Component	Advantage	Disadvantage	SCF	Picture
Keys				
Parallel	• Inexpensive	• Light loads • No axial restraint • SCF	K_t =2.2 K_{ts} =3	
Tapered	• Tight fit • Self locking	• Light loads • SCF		
Woodruff	• Self aligning • Tapered shaft	• Light loads • SCF		

$q := 0.70$
$qs := 0.75$



$Kf := 1 + q \cdot (Kt - 1) = 1.84$
$Kfs := 1 + qs \cdot (Kts - 1) = 2.5$

$$q = \frac{K_f - 1}{K_t - 1} \quad \text{and} \quad q_{shear} = \frac{K_{fs} - 1}{K_{ts} - 1}$$

Reaction Forces, Singularity Equations and Shear Flow, Shear Forces & Moment Equations

Reaction Forces on Bearing 1:

$$Fld := 9.81\ \mathrm{m\ s^{-2}} \cdot 130\ \mathrm{kg} = 1275.3\ \mathrm{N}$$

$$Frd := Fld = 1275.3\ \mathrm{N}$$

$$Fg := \frac{T}{\frac{dsprock}{2}} = 87.4769\ \mathrm{N}$$

$$Ry1 := \frac{(Fld \cdot (Lt - Lld) + Frd \cdot (Lt - Lrd))}{Lt} = 1275.3\ \mathrm{N}$$

$$Rz1 := \frac{(Fg \cdot (Lt - Lg))}{Lt} = 8.7477\ \mathrm{N}$$

Reaction Forces on Bearing 2:

$$Ry2 := Fld + Frd - Ry1 = 1275.3\ \mathrm{N}$$

$$Rz2 := Fg - Rz1 = 78.7292\ \mathrm{N}$$

Singulartiy Equations

$$Si(x, a, n) := \begin{array}{l} \text{if } ((x-a) > 0) \wedge (n \ge 0) \\ \quad (x-a)^n \\ \text{else} \\ \quad 0 \end{array}$$

Moment and Shear Equation(x-y plane)

$$qy(x) := Ry1 \cdot Si(x, 0\ \mathrm{mm}, -1) - Frd \cdot Si(x, Lrd, -1) - Fld \cdot Si(x, Lld, -1) + Ry2 \cdot Si(x, Lt, -1)$$

$$Vy(x) := Ry1 \cdot Si(x, 0\ \mathrm{mm}, 0) - Frd \cdot Si(x, Lrd, 0) - Fld \cdot Si(x, Lld, 0) + Ry2 \cdot Si(x, Lt, 0)$$

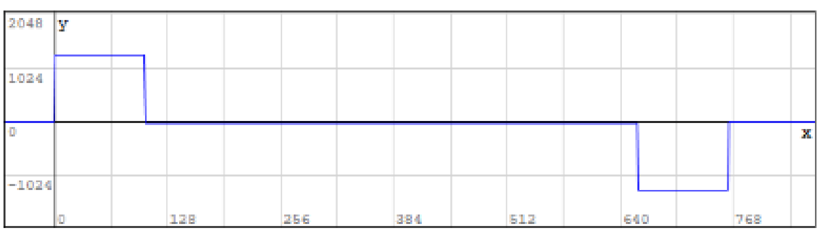
$$Mz(x) := Ry1 \cdot Si(x, 0\ \mathrm{mm}, 1) - Frd \cdot Si(x, Lrd, 1) - Fld \cdot Si(x, Lld, 1) + Ry2 \cdot Si(x, Lt, 1)$$

Moment and Shear Equation(x-z plane)

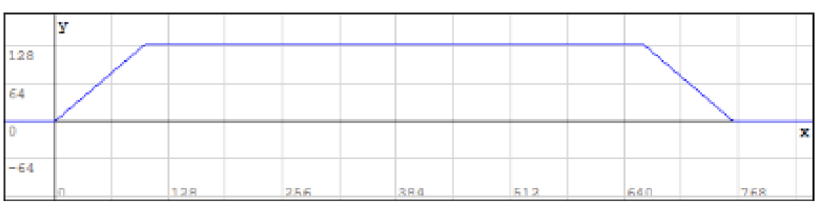
$$qz(x) := Rz1 \cdot Si(x, 0\ \mathrm{mm}, -1) - Fg \cdot Si(x, Lg, -1) + Rz2 \cdot Si(x, Lt, -1)$$

$$Vz(x) := Rz1 \cdot Si(x, 0\ \mathrm{mm}, 0) - Fg \cdot Si(x, Lg, 0) + Rz2 \cdot Si(x, Lt, 0)$$

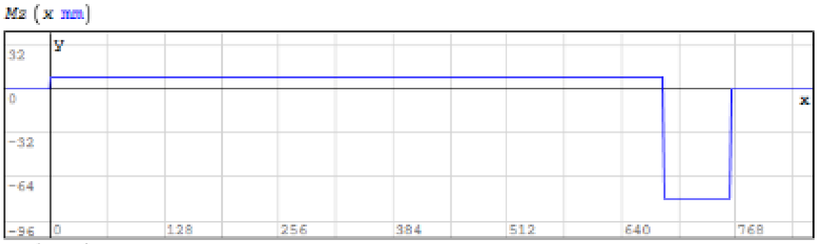
$$My(x) := Rz1 \cdot Si(x, 0\ \mathrm{mm}, 1) - Fg \cdot Si(x, Lg, 1) + Rz2 \cdot Si(x, Lt, 1)$$



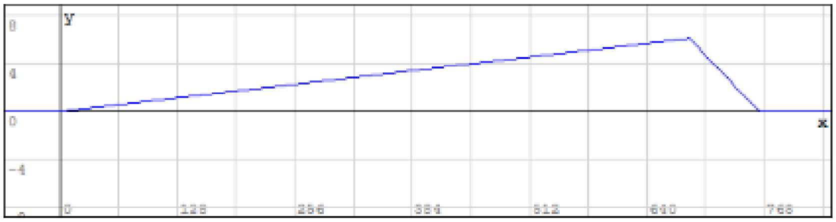
$Vy(x\ \mathrm{mm})$



$Mz(x\ \mathrm{mm})$



$Vz(x\ \mathrm{mm})$



$My\left(x\ mm\right)$

Slope and Deflection Equation (x-y plane)

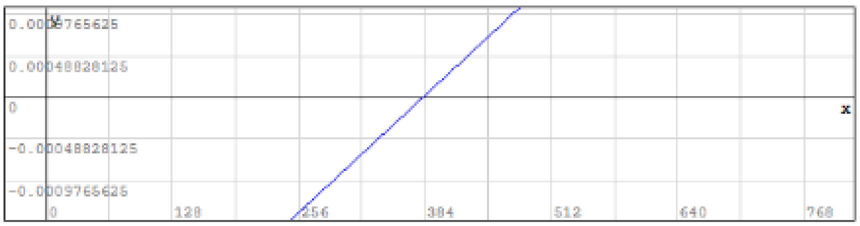
Use Boundary condtions to determine two constants. Boundary condtions are θ(0)=θ(Lt)=0

$$Cy2 := 0$$

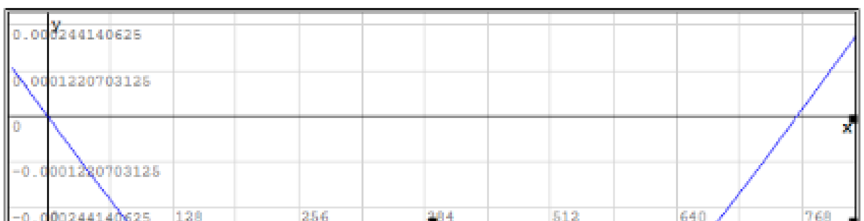
$$Cy1 := -\frac{\left(Ry1\cdot Si\left(Lt, 0\ mm, 3\right) - Frd\cdot Si\left(Lt, Lrd, 3\right) - Fld\cdot Si\left(Lt, Lld, 3\right) + Ry2\cdot Si\left(Lt, Lt, 3\right)\right)}{6\cdot E\cdot I\cdot Lt} = 0$$

$$\theta y\left(x\right) := \frac{1}{2\cdot E\cdot I}\cdot\left(Ry1\cdot Si\left(x, 0\ mm, 2\right) - Frd\cdot Si\left(x, Lrd, 2\right) - Fld\cdot Si\left(x, Lld, 2\right) + Ry2\cdot Si\left(x, Lt, 2\right)\right) + Cy1$$

$$\delta y\left(x\right) := \frac{1}{6\cdot E\cdot I}\cdot\left(Ry1\cdot Si\left(x, 0\ mm, 3\right) - Frd\cdot Si\left(x, Lrd, 3\right) - Fld\cdot Si\left(x, Lld, 3\right) + Ry2\cdot Si\left(x, Lt, 3\right)\right) + Cy1\cdot x + Cy2$$



$\theta y\left(x\ mm\right)$



$\delta y\left(x\ mm\right)$

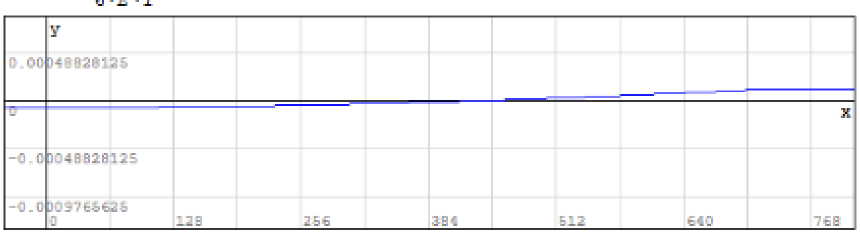
Slope and Deflection Equation (x-z plane)

$$Cz2 := 0$$

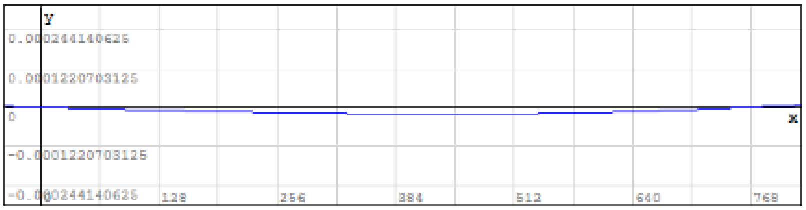
$$Cz1 := -\frac{\left(Rz1\cdot Si\left(Lt, 0\ mm, 3\right) - Fg\cdot Si\left(Lt, Lg, 3\right) + Rz2\cdot Si\left(Lt, Lt, 3\right)\right)}{6\cdot E\cdot I\cdot Lt} = -6.89\cdot 10^{-5}$$

$$\theta z\left(x\right) := \frac{1}{2\cdot E\cdot I}\cdot\left(Rz1\cdot Si\left(x, 0\ mm, 2\right) - Fg\cdot Si\left(x, Lg, 2\right) + Rz2\cdot Si\left(x, Lt, 2\right)\right) + Cz1$$

$$\delta z\left(x\right) := \frac{1}{6\cdot E\cdot I}\cdot\left(Rz1\cdot Si\left(x, 0\ mm, 3\right) - Fg\cdot Si\left(x, Lg, 3\right) + Rz2\cdot Si\left(x, Lt, 3\right)\right) + Cz1\cdot x + Cz2$$



$\theta z\left(x\ mm\right)$



$\delta z\,(x\ \mathrm{mm})$

Slope and Deflection Combined

$$\theta(x) := \sqrt{\theta y(x)^2 + \theta z(x)^2}$$

$$\delta(x) := \sqrt{\delta y(x)^2 + \delta z(x)^2}$$

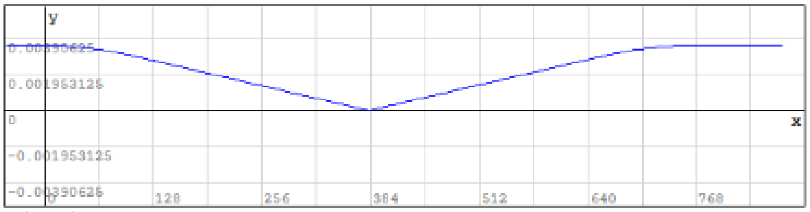
Shaft Twist

$$\theta twist := \frac{T}{J \cdot G} = 0.0002 \cdot \frac{1}{\mathrm{m}}$$

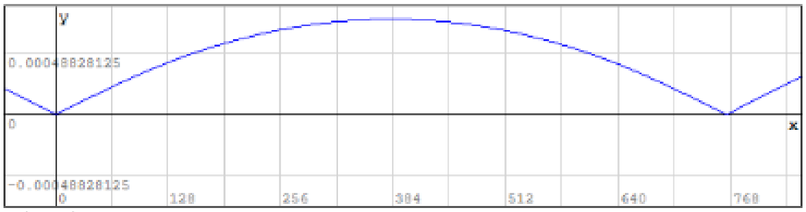
deflection at gears < 0.000127 m

slope at gears < 0.004 rad = 0.2292 deg

angle of twist < 3 deg/m



$\theta\,(x\ \mathrm{mm})$



$\delta\,(x\ \mathrm{mm})$

Alternating and Mean Stress

Assume Fully Reversed Bending:

X Y Plane:

$Ma1 := Mz(Lrd) = 129.5705\ \mathrm{N\,m}$

X Z Plane:

$Mb1 := My(Lrd) = 5.777\ \mathrm{N\,m}$

$Mmax := \sqrt{Ma1^2 + Mb1^2} = 129.6992\ \mathrm{N\,m}$ — Maximum Moment

$Mmin := -Mmax = -129.6992\ \mathrm{N\,m}$ — Minimum Moment

$Ma := Mmax = 129.6992\ \mathrm{N\,m}$ — Alternating Moment

$Mm := 0\ \mathrm{N\,m}$ — Mean Moment

$Ta := 0\ \mathrm{N\,m}$ — Alternating Torque

$Tm := T = 2.6243\ \mathrm{N\,m}$ — Mean Torque

$\sigma Max := \frac{Mmax \cdot (dshaft)}{2 \cdot I} = 4.0633 \cdot 10^{7}\ \mathrm{Pa}$ — Maximum Bending Stress

$\sigma Min := \frac{Mmin \cdot (dshaft)}{2 \cdot I} = -4.0633 \cdot 10^{7}\ \mathrm{Pa}$ — Minimum Bending Stress

$\sigma an := \frac{\sigma Max - \sigma Min}{2} = 4.0633 \cdot 10^{7}\ \mathrm{Pa}$ — Alternating Bending Stress

$\sigma mn := \dfrac{\sigma Max + \sigma Min}{2} = 0$ Mean Bending Stress

$\tau mn := \dfrac{Tm \cdot dshaft}{2 \cdot J} = 4.1108 \cdot 10^{5}\ Pa$ Mean Shear

$Kfm := \text{if } Kf \cdot |\sigma Max - \sigma Min| > 2 \cdot Sy$

    0

  else

    if $Kf \cdot |\sigma Max| < Sy$

      Kf

    else

      $\dfrac{Sy - Kf \cdot \sigma an}{|\sigma mn|}$

$Kfsm := \text{if } Kfs \cdot |\tau mn| > 2 \cdot Sy$

    0

  else

    if $Kfs \cdot |\tau mn| < Sy$

      Kfs

    else

      $\dfrac{Sy - Kfs \cdot \tau an}{|\tau mn|}$

$Kfm = 1.84$

$Kfsm = 2.5$

Assume Steady Torsion therefore τa=0

$\sigma a := Kf \cdot \sigma an = 7.4766 \cdot 10^{7}\ Pa$ Maximum Alternating Stress

$\sigma m := Kfm \cdot \sigma mn = 0$ Maximum Mean Stress

$\tau m := Kfsm \cdot \tau mn = 1.0277 \cdot 10^{6}\ Pa$

Von Mises Equivalent Stresses

$$\sigma' = \frac{1}{\sqrt{2}}\left[(\sigma_{xx}-\sigma_{yy})^2 + (\sigma_{yy}-\sigma_{zz})^2 + (\sigma_{zz}-\sigma_{xx})^2 + 6(\tau_{xy}^2 + \tau_{yz}^2 + \tau_{zx}^2)\right]^{1/2}$$

$\sigma a' := \dfrac{1}{\sqrt{2}} \cdot \sqrt{2 \cdot \sigma a^{2}} = 7.4766 \cdot 10^{7}\ Pa$ Alternating Von Mises Stress

$\sigma m' := \dfrac{1}{\sqrt{2}} \cdot \sqrt{2 \cdot \sigma m^{2} + 6 \cdot \tau m^{2}} = 1.78 \cdot 10^{6}\ Pa$ Mean Von Mises Stress

Safety Factor

$$\eta f := \sqrt{\frac{1}{\left(\frac{\sigma a'}{Se}\right)^2 + \left(\frac{\sigma m'}{Sy}\right)^2}} = 2.2593$$

Minimum Diameter

$$d := \left(\frac{16 \cdot n}{\pi} \cdot \sqrt{\frac{4 \cdot (Kf \cdot Ma)^2 + 3 \cdot (Kfs \cdot Ta)^2}{Se^2} + \frac{4 \cdot (Kf \cdot Mm)^2}{Sy^2} + \frac{3 \cdot (Kfs \cdot Tm)^2}{Sy^2}}\right)^{\frac{1}{3}} = 1.084378\ in$$

References:

MEC E 360 Course Notes

Conclusion:

In conclusion, the minimum diameter of each roller was calculated to be 1.11 inches given an applied torque of 43.19 Nm on each sprocket and the diameter from the sourced conveyor. With this minimum diameter value, the safety factor was determined to be 6.2.

Appendix A2: Finite Element Analysis

Appendix A2.1: Normal Conditions

Name: Adam Dumanowski

Date: Nov 22, 2019

Introduction

The purpose of this experiment was to determine how the roller functions when placed under the normal functioning scenario. The roller that is being analyzed can be seen in Figure A1. The external force applied to the roller was equal to 635 N and was placed on the two areas highlighted in Figure A2.1. The fixture forces were selected to occur in the shown areas due to the bearings that are there in the actual rollers.

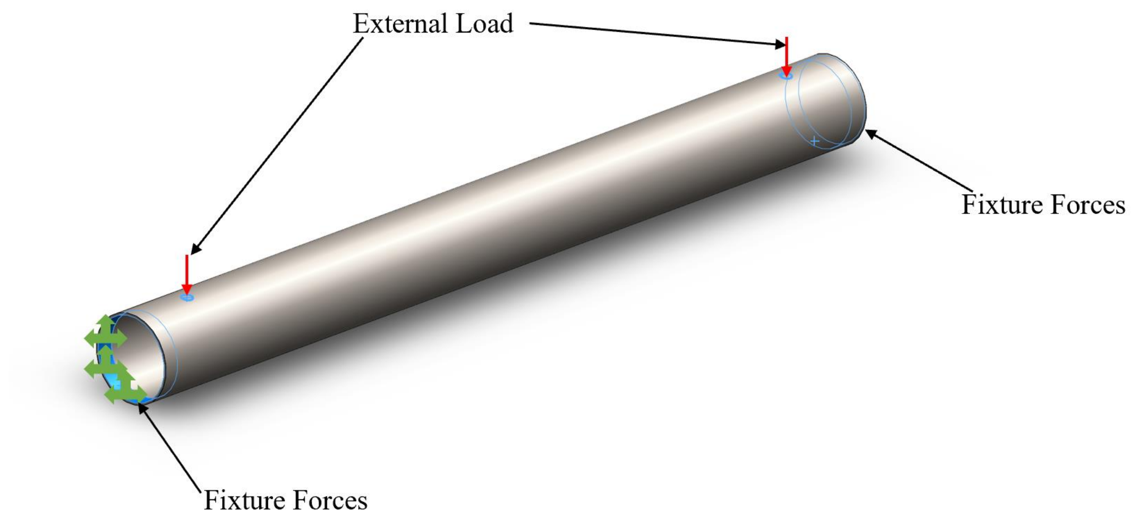


Figure A2.1: Annotated figure of the roller with the external load and fixture forces applied to the roller.

Simulation

The purpose of this simulation was to complete a mesh analysis of the normal functioning scenario of the roller. To create this simulation, multiple assumptions were made, which include:

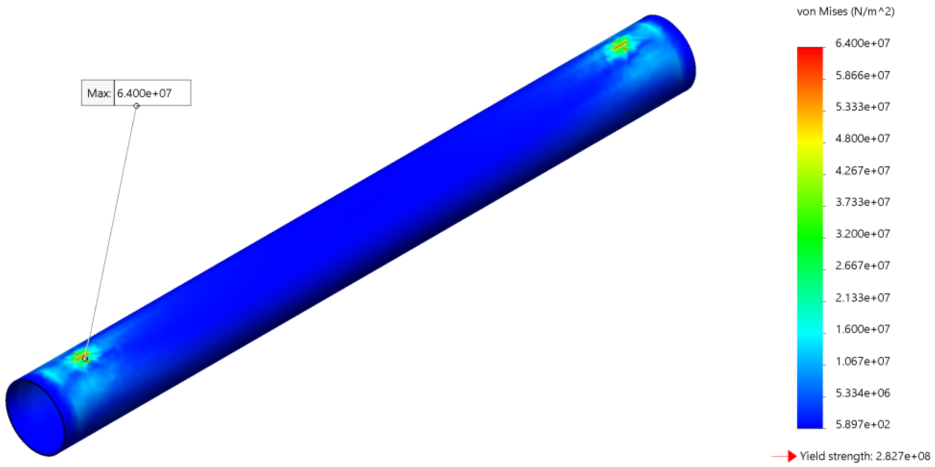
- External load of 635 N applied to the two areas that the drum is in contact with
- External load is directed vertically down
- External load is a static load
- Material properties are constant
- Bearings apply fixture forces on area at the edge of the internal diameter of the roller
- Corrosion does not occur

The simulation was completed by applying the external load and fixture forces that are shown in Figure A2.1.

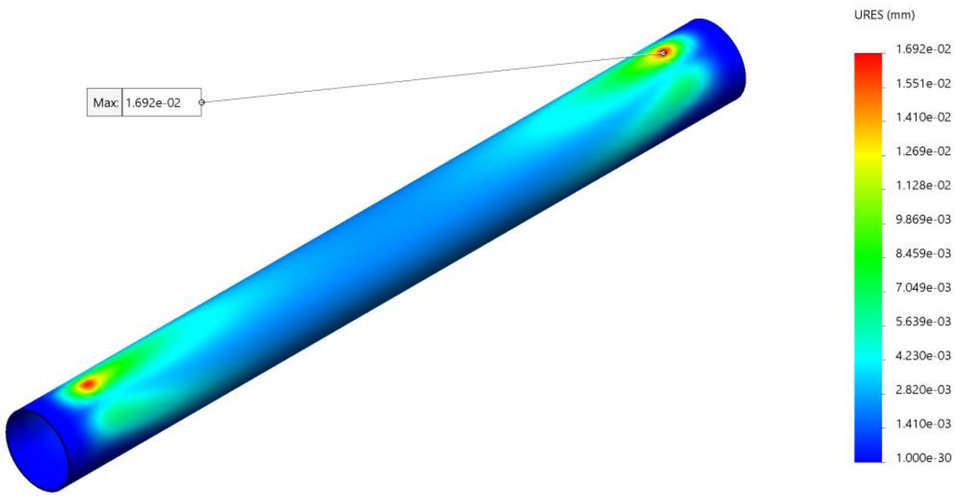
Results

Finite Element Analysis

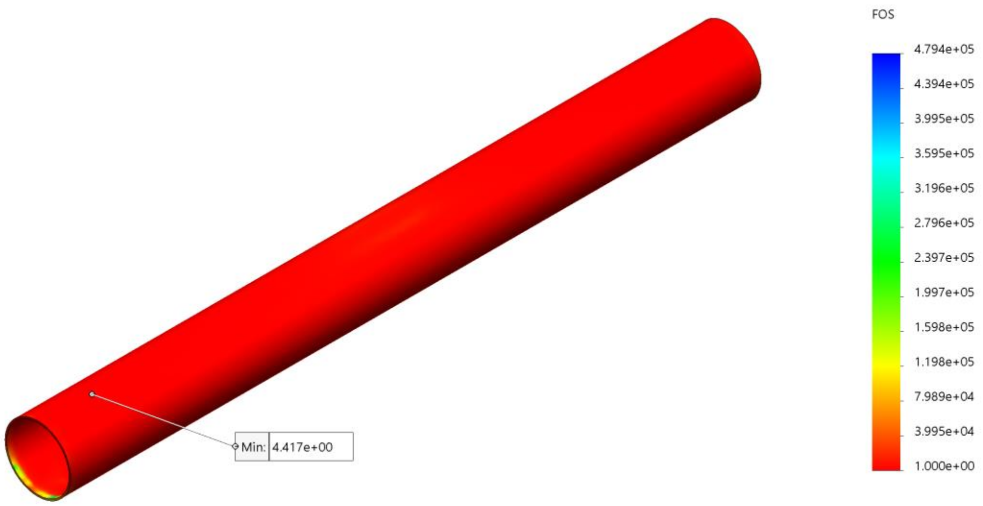
A finite element analysis was completed using the dimensions of the roller that is going to be purchased for the project. This means that the inner diameter was 60.325 mm. Using this inner diameter, the maximum vonMises, maximum deflection, and minimum factor of safety can be seen in Figure A2.2 for the initial mesh.



(a)



(b)



(c)

Figure A2.2: Figure of the (a) vonMises stress, (b) displacement, and (c) factor of safety on roller after FEA.

Since the minimum factor of safety was larger than 1, this means that the roller will be able to function under the normal functioning scenario load. A mesh analysis was next completed to verify the results.

Mesh Analysis

A mesh analysis was completed to verify that the roller functions under the normal loading. The finite element analysis was completed multiple times with the mesh size being decreased for each simulation. It can be seen from Figure A2.3 from the slope of the minimum factor of safety line and vonMises stress line that the mesh size being decreased did not affect the simulation after around 50000 elements were used in the simulation.

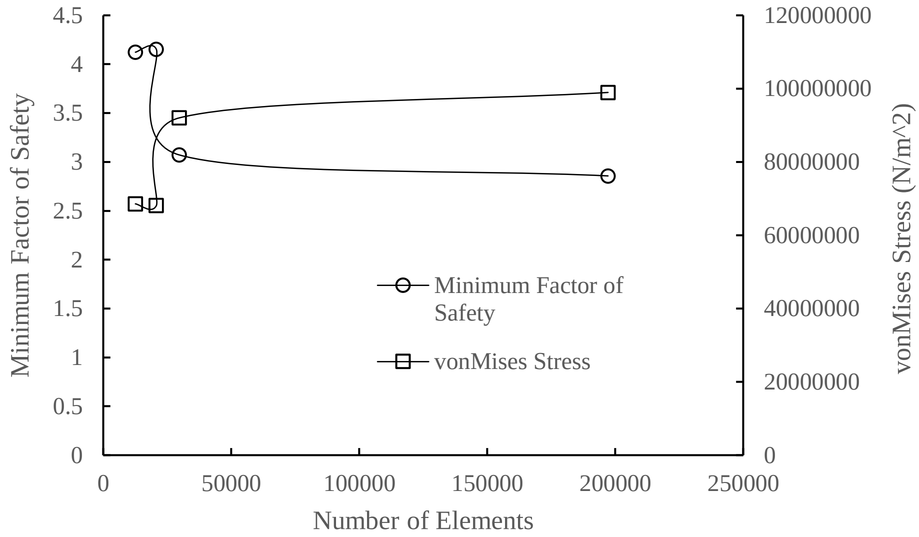


Figure A2.3: Plot of minimum factor of safety and vonMises stress against the number of elements in the mesh.

Figure A2.3 shows that the minimum factor of safety decreases by 1 through the mesh analysis and the vonMises stress increases by 20000000 N/m^2.

Table A2.1: Table of the values found during the mesh analysis

Number of Elements	vonMises (N/m^2)	Displacement (mm)	Minimum Factor of Safety
9112	57150000	0.1414	4.946
12555	68560000	0.01724	4.123
20740	68090000	0.0197	4.152
29668	92020000	0.02096	3.072
197196	98960000	0.02255	2.857

Conclusion

In conclusion, a finite element analysis was completed on the purchased roller dimensions to determine if it would function or fail under the normal functioning scenario loading. External load was placed on two areas of the roller where the drum would be in contact with the roller and fixture forces were placed on the inside of the roller where the bearings would be. After the simulation was ran, it was determined that the minimum factor of safety was 4.417. This ensures that the roller would not fail under the normal functioning scenario loading. A mesh analysis was completed to ensure that the simulated values were correct given the initial mesh. The mesh analysis determined that the actual minimum factor of safety was 2.857 instead of 4.946 from the initial mesh. Also, after around 50000 number of elements in the mesh, the values are accurate.

Appendix A2.2: Worst Case Condition

Appendix A2.2: Worst Case Condition

Name: Adam Dumanowski

Date: Nov 22, 2019

Introduction

The purpose of this experiment was to determine if the purchased roller would be able to function without failure under the worst-case scenario. The roller that is being analyzed can be seen in Figure A2.12.4. The external force applied to the roller was equal to 2540 N and was placed on the two areas highlighted in Figure A2.1A2.4. The fixture forces were selected to occur in the shown areas due to the bearings that are there in the actual rollers. The manufacturer claimed that the roller would be able to support a maximum of 600 lbf, so the force of 2540 N should function without failure. The roller that the manufacturer suggested for purchase had an inner diameter of 60.325 mm and an outer diameter of 63.5 mm. To find the optimum roller thickness size, a range of values were used in a design study to determine the point of failure.

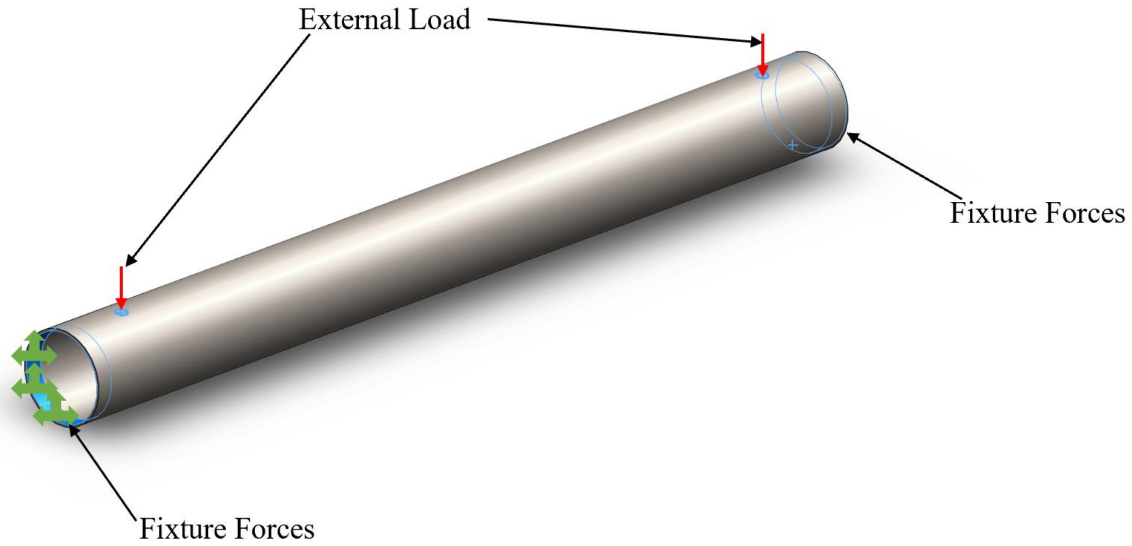


Figure A2.4: Annotated figure of the roller with the external load and fixture forces applied to the roller.

Simulation

The purpose of this simulation was to ensure that the object would not fail under the worst-case scenario. To create this simulation, multiple assumptions were made, which include:

- External load of 2540 N applied to the two areas that the drum is in contact with
- External load is directed vertically down
- External load is a static load

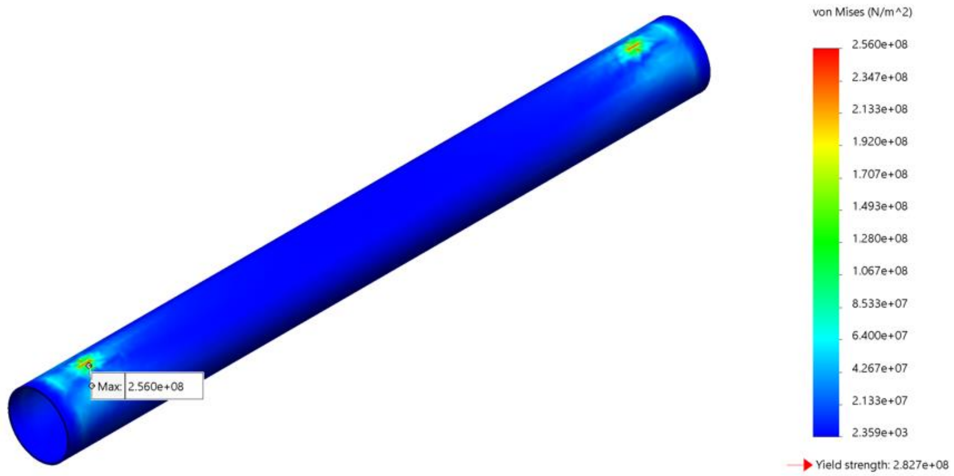
- Material properties are constant
- Bearings apply fixture forces on area at the edge of the internal diameter of the roller
- Corrosion does not occur

The simulation was completed by applying the external load and fixture forces that are shown in Figure A2.4. The external loads were applied in a general circular split line. Since the drums may not all be identical used during function, there is a possibility that the stress concentrations may be larger if the rim of the drum in contact with the rollers is smaller. Due to the possibility, a protective outer layer may need to be added to the rollers depending how the drums are shaped.

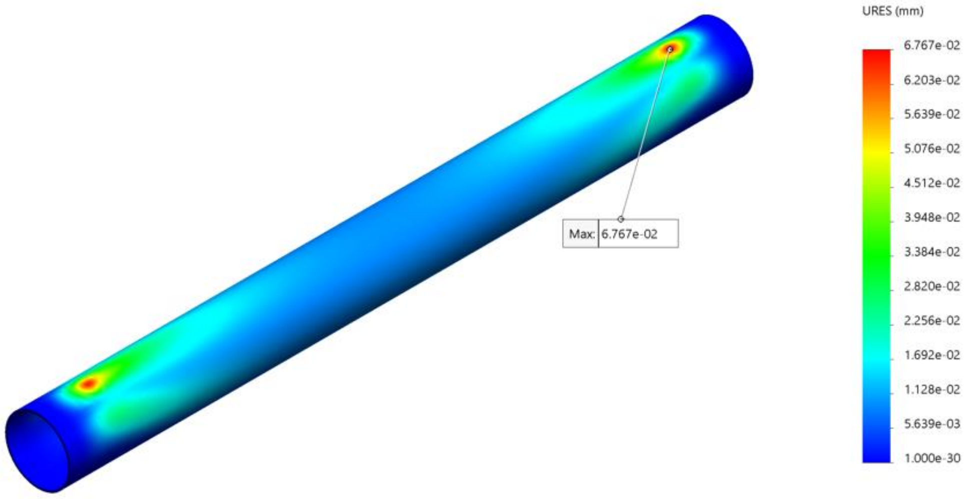
Results

Initial Finite Element Analysis

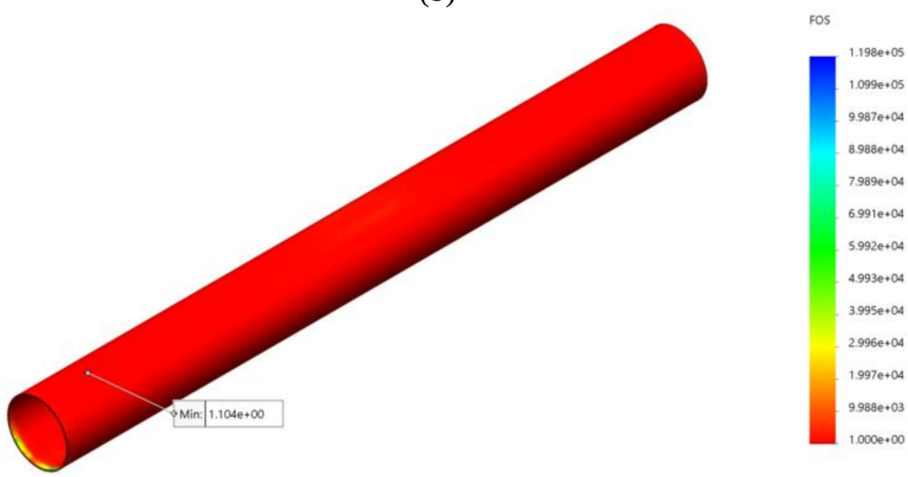
An initial finite element analysis was completed using the dimensions of the roller that is going to be purchased for the project. This means that the inner diameter was 60.325 mm. Using this inner diameter, the maximum vonMises was 256000000 N/m^2, maximum deflection was 0.06767 mm, and minimum factor of safety was 1.104 as seen in Figure A2.2A2.5.



(a)



(b)



(c)

Figure A2.5: Figure of the (a) vonMises stress, (b) displacement, and (c) factor of safety on roller after FEA.

Since the minimum factor of safety was larger than 1, this means that the roller will be able to function under the worst-case scenario load. To determine the point at which the roller stops functioning under the worst-case scenario load, a design study took place.

Design Study

A design study took place that changed the inner diameter of the roller to determine the smallest it can be before the roller fails. Due to this being the wanted outcome, the variable was selected to be the inner diameter that was set to be a range from 59 mm – 62 mm with a step of 0.5 mm. The constraint of the design study was that the minimum factor of safety had to be larger than 1 and the goal of the study was set to minimize mass. This design study created 7 different scenarios.

The results of this design study can be seen in Figure A2.6. The values that were used to make Figure A2.6 can be seen in Appendix A2.

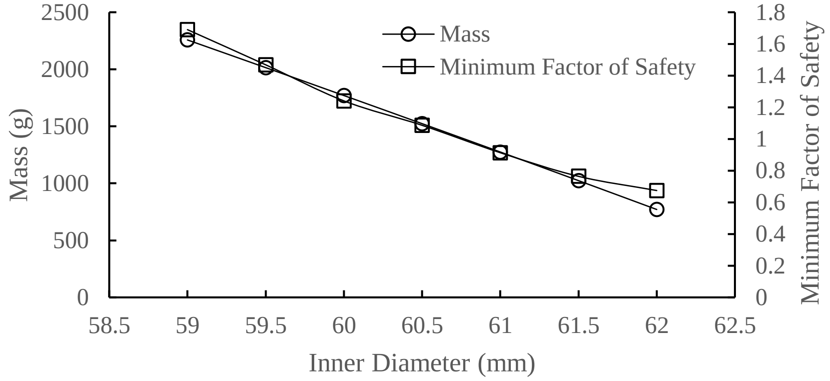


Figure A2.6: Plot of roller mass and minimum factor of safety against inner diameter.

Figure A2.6 shows that the inner diameter of 60.5 mm is the ideal inner diameter because it is the point that has a minimum factor of safety greater than 1 with the smallest mass.

Table A2.2: Table of the values found from the design study.

Parameter	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6	Scenario 7
Inner Diameter (mm)	59	59.5	60	60.5	61	61.5	62
Minimum Factor of Safety	1.69001	1.46812	1.24052	1.08624	0.91316	0.76414	0.67453
Mass (g)	2257	2014.4	1769.8	1523.1	1274.4	1023.6	770.754

Conclusion

In conclusion, a finite element analysis was completed on the purchased roller dimensions to determine if it would function or fail under the worst-case scenario loading. External load was placed on two areas of the roller where the drum would be in contact with the roller and fixture forces were placed on the inside of the roller where the bearings would be. After the simulation was ran, it was determined that the minimum factor of safety was 1.104. This ensures that the roller would not fail under the worst-case scenario loading. A design study was completed to ensure that the selected roller to be purchased was the optimum design for the worst-case scenario. By having a goal to minimize mass of the roller while maintaining a minimum factor of safety larger than 1, the inner diameter was altered until the optimum value was selected. The purchased roller's inner diameter was 60.325 while the design study determined that the optimized inner diameter was 60.5 mm. This means that the purchased roller is the best roller that could have been purchased.

Appendix A3: Flow and Time Analysis

Time Calculations

by Cameron Fenske
November 29, 2019

Objectives:

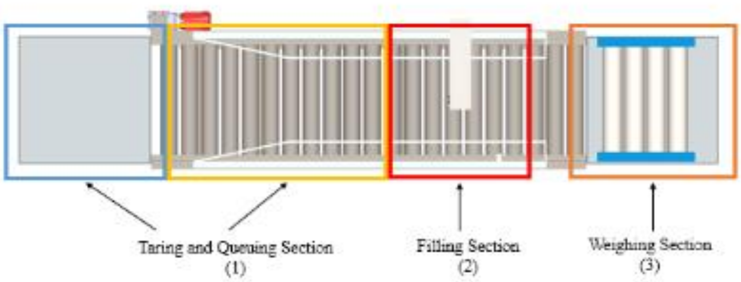
1) To determine the limiting time step (i.e. the step that will limit how fast the machine will operate).
2) The rate at which drums will be filled.
3) Determine the point at which the filling process will be the limiting stage.
4) Determine the point at which the filling process will limit the operation to 30 drums/hr
5) Determine the required time for each drum to move through the process.
6) Determine the maximum number of drums that can be filled before refilling the tank.
7) Determine the time required to empty an entire tank of honey.

Assumptions:

The key steps in the design are:

1) Taring and setting on conveyor
2) Moving drum into position and filling drum
3) Reweighing drum, calculating net weight, applying label, and removing drum
4) Honey is assumed as incompressible
5) Properties of honey are constant throughout

Diagram 1:



Analysis:

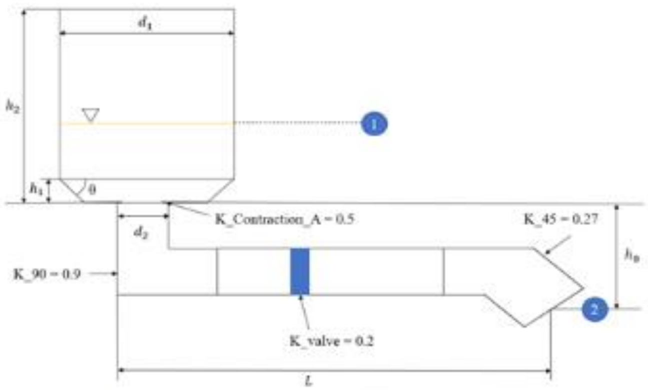
Step 1: Taring and setting on conveyor

Action	Estimated time
1a) setting drum on scale	$t_{1a} := 5\ s$
1b) waiting for scale to calculate tare weight	$t_{1b} := 5\ s$
1c) removing drum from scale and putting on conveyor	$t_{1c} := 5\ s$

Total Time: $t_1 := t_{1a} + t_{1b} + t_{1c} = 15\ s$

Step 2: Moving drum into position and filling drum

Diagram 2:



Defining the variables given by the tank and piping geometry:

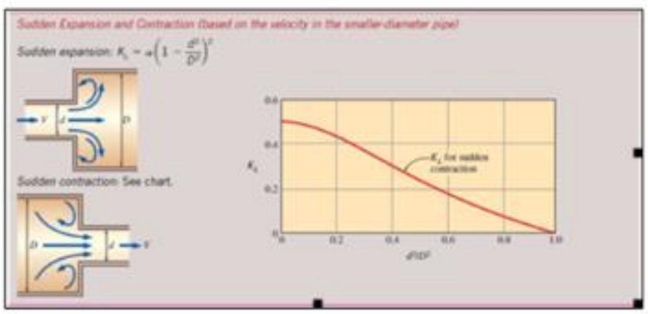
Defining the variables given by the tank and piping geometry:

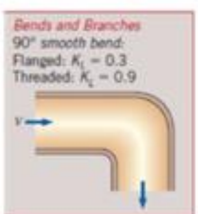
$g := 9.81\ \frac{m}{s^2}$	gravitational constant
$\rho := 1415\ \frac{kg}{m^3}$	density of honey
$\mu := 10.9\ Pa\ s$	dynamic viscousity of honey at 21 degrees celcius
$V_{tank} := 10\ m^3$	Volume of tank
$h_0 := 279.4\ mm$	height difference from bottom of tank to valve outlet
$h_2 := 3337\ mm$	height of the tank
$d_1 := 2000\ mm$	diameter of the top of the tank
$d_2 := 101.6\ mm$	diameter of valve outlet
$d_3 := 500\ mm$	diameter of the base of the tank
$\theta := 20\ deg$	angle of the slope of the tank towards it's base
$L_{pipe} := 2.25\ m$	estimated length of 4" pipe section

Solving for dependant variables:

$h_1 := \left(\frac{d_1}{2} - \frac{d_3}{2}\right) \cdot \tan(\theta) = 272.9777\ mm$ height above tank base where tank ceases to slope.

Minor Loss coefficients:





Gate valve, fully open: $K_L = 0.2$
$\frac{1}{4}$ closed: $K_L = 0.3$
$\frac{1}{2}$ closed: $K_L = 2.1$
$\frac{3}{4}$ closed: $K_L = 17$

$k_{ctr} := 0.5$	Loss coefficient for the constraction at the tank exit
$k_{90} := 0.9$	Loss coefficient for a 90 degree smooth elbow
$k_{45} := 0.27$	Loss coefficient for a 45 degree smooth elbow
$k_{valve} := 0.2$	Loss coefficient for the solinoid valve

To calculated the total time for step 2, the filling time as a function of tank head will need to be found.

First use generalized Bernoulli to describe the energy differences between the upper surface and the orifice outlet:

$$\frac{P_1}{\rho g} + \frac{v_1^2}{2g} + z_1 = \frac{P_2}{\rho g} + \frac{v_2^2}{2g} + z_2 + \sum h_L + \frac{\Delta P_\mu}{\rho g}$$

The pressure at both points can be assumed to be atmospheric pressure and will therefore cancel out of the equation:

$$P_1 = P_2 = P_{atm}$$

Using the law of conservation of mass and assuming the density at both points are the same, the velocity at point one in terms of point 2 is given as:

$$\dot{m}_1 = \dot{m}_2$$

$$\rho v_1 A_1 = \rho v_2 A_2$$

$$v_1 = v_2\left(\frac{A_2}{A_1}\right)$$

The area of the orifice outlet is easily determined from its diameter. However, the area of the tank surface is given as a function of head, y:

$$A_2 = \frac{\pi}{4}{d_2}^2$$

$$A_1 = \frac{\pi}{4}d(y)^2$$

Using the dimensions outlined in diagram 2, the area of the upper surface as a function of head is calculated in piecewise form as:

$$d(y) = \begin{cases} d_1 & for\ y \in h_2 \\ d_3 + y\cot(\theta) & for\ y \in h_1 \end{cases}$$

$$A_1 = \begin{cases} \frac{\pi}{4}{d_1}^2 & for\ y \in h_2 \\ \frac{\pi}{4}(d_3 + y\cot(\theta))^2 & for\ y \in h_1 \end{cases}$$

The difference in height between the upper surface of the tank and the orifice is also given as a function of head as:

$$z_1 - z_2 = y + h_0$$

Finally the head losses due to the contraction, bend, and valve is given by:

$$\sum h_L = (k_{ctr} + k_{90} + k_{valve})\frac{{v_2}^2}{2g}$$

The viscous effects are going to have a significant effect on the flow rate. The viscous pressure effects is, as defined by Poiseuille flow, is given as:

$$\Delta P_\mu = \frac{32 L_{pipe}\mu v_2}{d_2^2}$$

Putting all the simplifications back into the generalized Bernoulli Equation, it resolves down to:

$$\frac{v_2^2}{2g}\left(1 - \left(\frac{A_2}{A_1}\right)^2 + k_{90} + k_{ctrg} + k_{valve}\right) + \frac{32 v_2 \mu L_{pipe}}{\rho g d_2^2} - (y + h_0) = 0$$

Let: $A(y) := \text{if } (y \ge h_1) \wedge (y \le h_2)$

$$\frac{1}{2\cdot g}\cdot\left[1 - \left(\frac{d_2}{d_1}\right)^4 + k_{90} + k_{ctr} + k_{valve} + k_{45}\right]$$

else

$\text{if } (y \ge 0) \wedge (y < h_1)$

$$\frac{1}{2 \cdot g} \cdot \left[1 - \left(\frac{d_2}{d_3 + \frac{y}{\tan(\theta)}} \right)^4 + k_{90} + k_{ctr} + k_{valve} + k_{45} \right]$$

else
"outside the interval"

$$B := \frac{32 \cdot \mu \cdot L_{pipe}}{\rho \cdot g \cdot {d_2}^2}$$

$$C(y) := -\left(y + h_0\right)$$

This simplifies the expression to:

$$Av_2^2 + Bv_2 + C$$

Solving the quadratic equation for v.2, this yields:

$$v_2(y) := \frac{1}{2 \cdot A(y)} \cdot \left(-B + \sqrt{B^2 - 4 \cdot A(y) \cdot C(y)}\right)$$

From the outlet velocity equation, the volumetric flow rate, Q, into the drums can be calculated using the following equation:

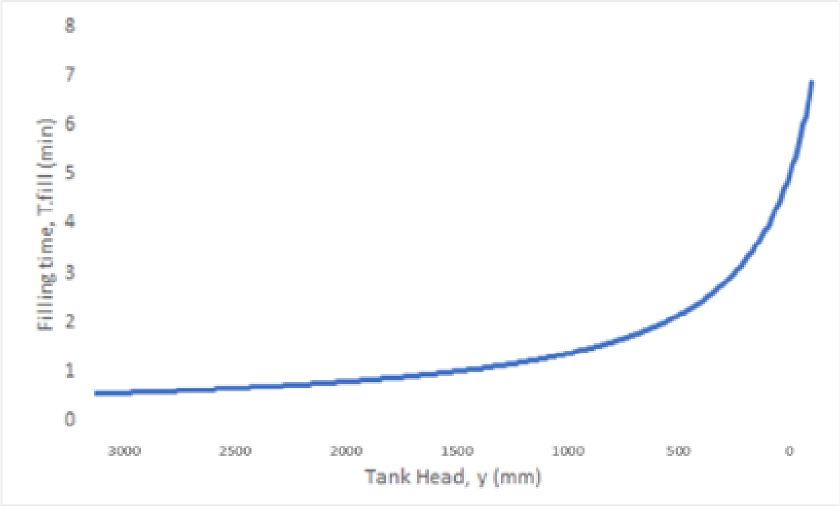
$$Q(y) = v_2(y) * A_2 = v_2(y) * \frac{\pi}{4} d_2^2$$

The time, T.fill, to fill each drum can be further calculated by:

$$T_{fill}(y) = \frac{V}{Q(y)} = \frac{V}{v_2(y) * \frac{\pi}{4} d_2^2}$$ where $V_{drum} := 45 \frac{gal}{drum}$ (volume of drums filled)

$$T_{fill}(y) := \frac{V_{drum}}{v_2(y) \cdot \frac{\pi}{4} \cdot {d_2}^2}$$

This equation is graphed from a maximum head of y = 3.337m to an empty tank, y = 0:



The slowest filling time will occur when the tank is closest to being empty. This will result in a minimum filling rate of: $\boxed{T_{fill}(0\,m) = 6.874 \frac{min}{drum}}$

Calculating the time for each drum to fill as the tank empties:

The total number of drums, N.maxdrums, that can be filled by one tank is given as:

$$N_{maxdrums} := \frac{V_{tank}}{V_{drum}} = 58.7049 \text{ drum}$$

Rounding down, this gives a maximum of 55 drums that can be filled from a full tank. The flow rate at which the drums are filled is given as:

$$Q(y) = -\frac{dV(y)}{dt}$$

Where V(y) is the volume in the tank as a function of head height. The sign is negative because as the volume in the tank decreases, the volume in the drums increases. Then, subsituting in area and head for dV gives:

$$dV(y) = A(y)dy$$

$$Q(y) = -\frac{A(y)dy}{dt}$$

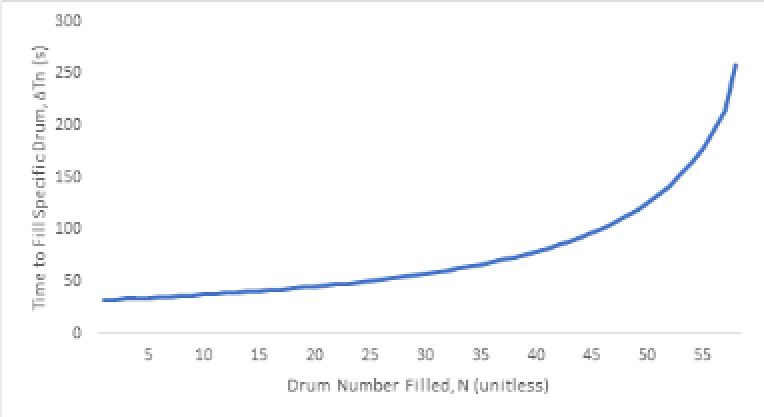
Applying an integral over Q(y), we return the time required to fill each drum. Where n = [0,58].

$$\int_{t_1}^{t_2} dt = -\int_{y_1}^{y_2} \frac{A(y)}{Q(y)} dy$$

$$\int_{T_n}^{T_{n+1}} dt = -\int_{y(V_n)}^{y(V_{n+1})} \frac{A(y)}{Q(y)} dy$$

$$\Delta T_n = -\int_{y(V_n)}^{y(V_n - 45gal)} \frac{A(y)}{Q(y)} dy$$

Graphed is the result of this integral for each drum from 0 to 58.

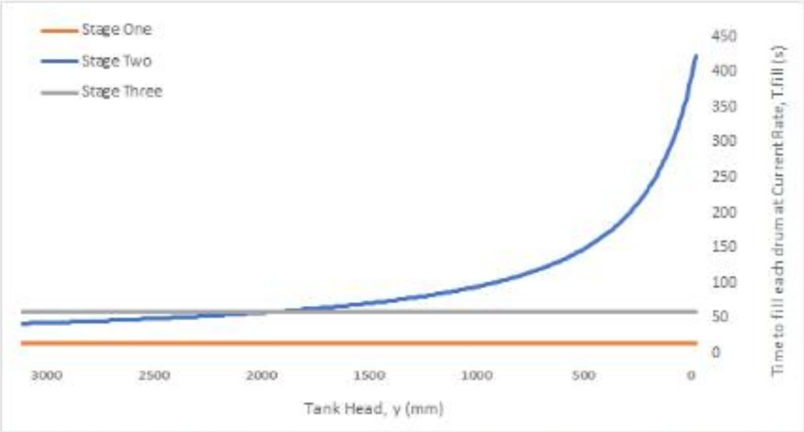


Action	Estimated time
2a) move drum into position	$t_{2a} := 10\ s$
2b) Fill drum to 45gal	$t_{2b}(y) := T_{fill}(y)$
Total	$t_2(y) := t_{2a} + t_{2b}(y)$

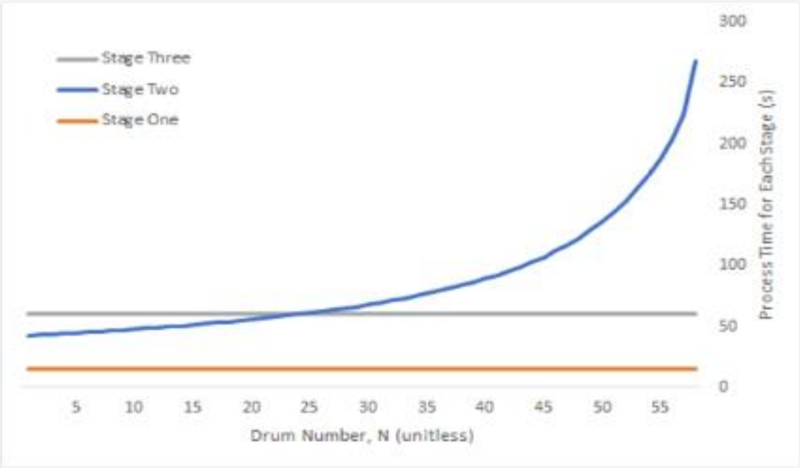
Step 3: Reweighing drum, calculating net weight, applying label, and removing drum

Action	Estimated time
3a) move drum from filling section to second scale	$t_{3a} := 10\ s$
3b) apply lid to drum	$t_{3b} := 15\ s$
3c) Waiting for scale to calculate gross and net weight	$t_{3c} := 5\ s$
3d) Print and apply label to side of drum	$t_{3d} := 15\ s$
3e) Remove drum from second scale	$t_{3e} := 15\ s$
Total	$t_3 := t_{3a} + t_{3b} + t_{3c} + t_{3d} + t_{3e}$ $t_3 = 60\ s$

Because the drums can be simultaneously at different sections of the filling process, the rate of drums per hour will be limited by the slowest step in the process. The three steps are graphed below as a function of head in the tank.



The filling time is also graphed as a function of drum number. Note the reason the time is less for the latter drums is because the tank has a tapered bottom which decreases the amount of time it fills at a very slow instantaneous rate.



To calculate the total time for the process to empty the entire tank, an integral is taken over the graph (that is, the time for whichever stage is limiting).

$$T_{total} = \int_0^n \Delta T_n \, dn$$

This yields a total time of $T_{total} := 5238\ s = 87.3\ min$

To calculate this as a rate, the filling process will empty a whole tank as:

$$Rate := \frac{N_{maxdrums}}{T_{total}} = 40.347 \frac{drum}{hr}$$

The total amount of time for one drum to complete the entire process will be limited by the time for the slowest stage in the process. Assuming the worst case scenerio (ie the time for the last drum to fill, the total filling time will be equal to:

$$T_{perdrum_{max}} = \Delta T_{56} + \Delta T_{57} + \Delta T_{58}$$

$$T_{perdrummax} := 204\ s + 224\ s + 268\ s = 11.6\ min$$

Conclusion:

- The limiting stage in the filling process will be the weighing, labeling, and unloading step while the head within the tank is above 2.04m. At which point, the filling stage will be the limiting step.
- The time required to empty a full tank of honey into 58 drums was determined to be 87.3min. This results in a filling rate of 40 drums/hr
- The filling rate will drop below the minimum rate of 30drums/hr when the head is allowed to fall below 0.77m. Bee Mechanical recommends keeping the head height above that to improve operation speed.
- The maximum time for one drum to pass through the whole process is 11.6 minutes.

Appendix A4: Circuit Code

```
//Variable definition
volatile int pulseCount; //This integer needs to be set to volatile to ensure it updates correctly during the interrupt process
int sensorInterrupt = 0;  //interrupt 0
int flowsensorPin       = 2; //Digital Pin 2 connects to the output of the flow sensor
int solenoidValve = 5; // Digital pin 5 connects to the input of the solenoid valve
unsigned int SetPoint = 45; //45 gallons is the point when the solenoid valve closes

//The flow sensor outputs pulses per second per gallon/minute of flow

float calibrationFactor = 7.5; //Frequency=7.5*Q (gal/min)
float flowRate = 0.0;
unsigned int flowvolume = 0;
unsigned long totalvolume = 0;
unsigned long oldTime = 0;

//Interrupt Service Routine
void pulseCounter()
{
  // Increment the pulse counter
  pulseCount++;
}

void SetSolenoidValve()
{
  digitalWrite(solenoidValve, LOW); //closes solenoid valve
}

void setup()
{

  // Initialize a serial connection for reporting values to the host
  Serial.begin(9600);
  pinMode(solenoidValve, OUTPUT); //solenoid valve recieves output
  pinMode(flowsensorPin, INPUT_PULLUP); //Arduino receives flow rate input from flow sensor
  digitalWrite(flowsensorPin, HIGH);
  digitalWrite(solenoidValve, HIGH);

  /*The flow sensor is connected to pin 2 which uses interrupt 0. Configured to trigger on a RISING state change (transition from LOW
  state to HIGH state)*/
  attachInterrupt(sensorInterrupt, pulseCounter, RISING); //Configures interrupt 0 (pin 2 on the Arduino Uno) to run the function "Flow" when the pin goes from LOW to HIGH
}

void loop()
{

   if((millis() - oldTime) > 1000)    // Only process counters once per second
```

```
  {
    // Disable the interrupt while calculating flow rate and sending the value to the
host
    detachInterrupt(sensorInterrupt);

    // Because this loop may not complete in exactly 1 second intervals we calculate
the number of milliseconds that have passed since the last execution and use that to
scale the output. We also apply the calibrationFactor to scale the output based on
the number of pulses per second per units of measure (litres/minute in this case)
coming from the sensor.
    flowRate = ((1000.0 / (millis() - oldTime)) * pulseCount) / calibrationFactor;

    // Note the time this processing pass was executed. Note that because we've
    // disabled interrupts the millis() function won't actually be incrementing right
    // at this point, but it will still return the value it was set to just before
    // interrupts went away.
    oldTime = millis();

    // Divide the flow rate in gallons/minute by 60 to determine how many gallons
have
    // passed through the sensor in this 1 second interval
    flowvolume = (flowRate / 60);

    // Add the gallons passed in this second to the cumulative total
    totalvolume += flowvolume;

    //Print the flow rate for this second in gallons / minute
    Serial.print("Flow rate: ");
    Serial.print(flowvolume, DEC);  // Print the integer part of the variable
    Serial.print("gal/min");
    Serial.print("\t");

    //Print the cumulative total of gallons flowed since start
    Serial.print("Output Liquid Quantity: ");
    Serial.print(totalvolume,DEC);
    Serial.println("gal");
    Serial.print("\t");

    if (totalvolume > SetPoint)
    {
    SetSolenoidValve();
    }
// Reset the pulse counter so we can start incrementing again
    pulseCount = 0;

    // Enable the interrupt again now that we've finished sending output
    attachInterrupt(sensorInterrupt, pulseCounter, RISING);
  }
}
```

Appendix B: Cost Analysis

Appendix B1: Price Breakdown of Each Component

Table B1: Price breakdown of each component

Subsystem	Part Name	Number of Units	Single Unit Cost (USD)	Single Unit Cost (CAD)	Total Cost (CAD)	Link
Roller Conveyor	Roller Conveyor	1	$3,664.00	$4,836.48	$4,836.48	Quote from Titan Conveyor is shown below
Roller Conveyor	Steel Guard Rail Kit	1	$570.00	$752.40	$752.40	
Roller Conveyor	Photoelectric Sensor	1	$489.00	$645.48	$645.48	
Roller Conveyor	Conveyor Emergency Stop	1	$322.00	$425.04	$425.04	
Weighing	Weighing Scale	1		$1,190.35	$1,190.35	https://www.kern-sohn.com/en/IFB
Weighing	Roller Conveyor YRO	1		$1,574.96	$1,574.96	https://www.kern-sohn.com/shop/en/components/platforms/YRO/
Labelling	Thermal Label Printer	1	$215.00	$283.80	$283.80	https://www.thermalprinteroutlet.com/product/zebra-tlp2844-thermal-ribbon-label-printer-tlp-2844-plus-driver-manual/?gclid=Cj0KCQjwjOrtBRCcARIsAEq4rW58ljYGFUJ9NxIOadYAOdB_d-kH_jT79cO-qmpqyGe6EjcDk0qcCkoaApl3EALw_wcB

Subsystem	Part Name	Number of Units	Single Unit Cost (USD)	Single Unit Cost (CAD)	Total Cost (CAD)	Link
Flow Control	4" Electrical Butterfly Valve D971X-10S	1	$424.52	$560.37	$560.37	https://www.alibaba.com/product-detail/Serviceable-4-inch-electrical-water-valve_60749508141.html?spm=a2700.7724857.normalList.24.59e25c1eOPaGSV&s=p
Flow Control	Flow Sensor FTS100-1002	1	$939.00	$1,239.48	$1,239.48	https://www.automationdirect.com/adc/shopping/catalog/process_control_-a-_measurement/flow_sensors/thermal_flow_sensors/fts100-1002
Flow Control	Arduino UNO	1	$22.00	$29.04	$29.04	https://store.arduino.cc/usa/arduino-uno-rev3
Flow Control	AC to DC Transformer	1	$13.58	$17.93	$17.93	https://www.digikey.ca/product-detail/en/triad-magnetics/WSU240-0500/237-1459-ND/3094985
Flow Control	Power Cord	1	$6.95	$9.17	$9.17	https://www.digikey.ca/product-detail/en/tensility-international-corp/11-00081/839-1268-ND/5977826
Flow Control	5V Relay Module	1	$5.50	$7.26	$7.26	https://www.amazon.com/Tolako-Arduino-Indicator-Channel-Official/dp/B00VRUAHLE
Flow Control	Emergency Shut-off Button	1		$10.63	$10.63	https://www.amazon.ca/Uxcell-a14041700ux0692-Push-Button-Switch/dp/B00MJVMV32/ref=pd_sbs_469_6/136-5185873433960?_encoding=UTF8&pd_rd_i=B00MJVMV32&pd_rd_r=a78df574-28f3-471a-85d8-b8a46cec10c7&pd_rd_w=T0BnD&pd_rd_wg=6DNMP&pf_rd_p=0602d3b5-e536-4dc4-9e55-dd650b3d14d4&pf_rd_r=08A9NKCJR09K239TPC2K&psc=1&refRID=08A9NKCJR09K239TPC2K

Subsystem	Part Name	Number of Units	Single Unit Cost (USD)	Single Unit Cost (CAD)	Total Cost (CAD)	Link
Flow Control	USB A to B	1	$3.95	$5.21	$5.21	https://www.sparkfun.com/products/512
Flow Control	Wires	1		$6.59	$6.59	https://www.amazon.ca/Solderless-Breadboard-Professional-Universal-Motherboard/dp/B081FF4YQW/ref=sr_1_10?keywords=jumper+wire&qid=1574114739&s=hi&sr=1-10
Flow Control	Standard Steel I Beam	1	$102.01	$134.65	$134.65	https://www.metalsdepot.com/steel-products/steel-beams
Electronics Housing	DB9 Panel-Mount 9-pin Serial Coupler	2	$5.95	$7.85	$15.71	https://www.datapro.net/products/db9-panel-mount-9-pin-serial-coupler.html
Electronics Housing	USB Port	1		$6.63	$6.63	https://www.amazon.ca/AmazonBasics-USB-2-0-Cable-Male/dp/B00NH11KIK/ref=sr_1_3?gclid=CjwKCAiA8ejuBRAaEiwAn-iJ3nr13-Yl9aMu0gDDJBothQX9aeMx_iWWI6e9YAAdbh8kF8hB4mhy2hoCjLQQAvD_BwE&hvadid=208380738652&hvdev=c&hvlocphy=9001384&hvnetw=g&hvpos=1t1&hvqmt=b&hvrand=10505270063073681134&hvtargid=kwd-296266699829&hydadcr=1498_9454457&keywords=arduino+usb&qid=1574629491&sr=8-3
Electronics Housing	Housing	1	$207.69	$274.15	$274.15	Quotes from Protocase is shown below

Subsystem	Part Name	Number of Units	Single Unit Cost (USD)	Single Unit Cost (CAD)	Total Cost (CAD)	Link
Electronics Housing	RM3X8MM-2701	4	$0.57	$0.57	$0.57	https://www.mouser.ca/ProductDetail/APM-HEXSEAL/RM3X8MM-2701?qs=sGAEpiMZZMtFmYSM%2FWUJwlhkne%252BDBEKK%252B65ranfRaceJ92KtXpsnUw%3D%3D
Electronics Housing	SM3X6MM-2701	4	$0.57	$0.57	$0.57	https://www.mouser.ca/ProductDetail/APM-HEXSEAL/SM3X6MM-2701?qs=sGAEpiMZZMtFmYSM%2FWUJwr2ujiBzdnsjUo9tbQQ4fMA%3D
Electronics Housing	M3 Flat Head Countersunk Screw Kit,M3 4mm	4	$0.10	$0.10	$0.10	https://www.amazon.ca/Countersunk-Stainless-Machine-ScrewsFastener/dp/B072DVJQNB/ref=sr_1_4_sspa?gclid=jwKCAiA5o3vBRBUEiwA9PVzaiKMWZ9e1VXbEFJMFuU8L08IetGDuPQ7_Iw56ZlUpU76mnUytTGBoC5NAQAvD_BwE&hvadid=324877661926&hvdev=c&hvlocphy=9001384&hvnetw=g&hvpos=1t1&hvqmt=e&hvrand=12355671817089327143&hvtargid=aud-749198100220%3Akwd-61392664269&hydadcr=11266_10103180&keywords=m3+mm+screw&qid=1575242578&sr=8-4-spons&psc=1&spLa=ZW5jcnlwdGVkUXVhbGlmaWVyPUExTEc4WUowT1dFWUM4JmVuY3J5cHRlZElkPUEwOTk2MzkzR1k3Ulk1WFA0UDVQJmVuY3J5cHRlZEFkSWQ9QTA4NjE0NjFWVERNTTQzWDVCRlUmd2lkZ2V0TmFtZT1zcF9hdGYmYWN0aW9uPWNsaWNrUmVkaXJlY3QmZG9Ob3RMb2dDbGljaz10cnVl

Subsystem	Part Name	Number of Units	Single Unit Cost (USD)	Single Unit Cost (CAD)	Total Cost (CAD)	Link
Electronics Housing	Metric hex nuts, Stainless steel 18-8 (A-2), 3mm x 0.5mm	12	$0.05	$0.05	$0.05	https://www.boltdepot.com/Product-Details.aspx?product=4773
Electronics Housing	M4-0.7 x 5 mm. Phillips-Square Flat-Head Machine Screws	8	$0.19	$0.19	$0.19	https://www.homedepot.com/p/Crown-Bolt-M4-0-7-x-5-mm-Phillips-Square-Flat-Head-Machine-Screws-3-Pack-06878/203539944
Electronics Housing	HN-M4-79/RPC3083-ND	8	$0.41	$0.41	$0.41	https://www.digikey.ca/productdetail/en/essentracomponents/HNM479/RPC3083ND/391783?utm_adgroup=&utm_source=google&utm_medium=cpc&utm_campaign=Shopping_Hardware%2C%20Fasteners%2C%20Accessories&utm_term=&mkwid=sbTD170fw&pcrid=314866257804&pkw=&pmt=&pdv=c&productid=391783&slid=&gclid=CjwKCAiA5o3vBRBUEiwA9PVzahSd7tzq4ybiYl6maesCcmkeLv578RgpODcvI0cbOeuzcJ_KNEq9BoCsKYQAvD_BwE
Total Cost					**$11,109.43**	

Pricing Quote for the Roller Conveyor, Steel Guard Rail, Emergency Stop and Photoelectric Sensor (Titan Conveyors)

TITAN CONVEYORS
735 Industrial Loop Road, New London, WI 54961
www.titanconveyors.com
Phone: (920) 982-6600 Fax: (920) 982-7750

PROPOSAL

PAGE 1

PRINT DATE 10/31/2019

PHONE:
FAX:

TO:

UNIVERSITY OF ALBERTA - CANADA
ATTN: ADAM DUMANOWSKI
REF: CAPSTONE PROJECT

QUOTE NO.	QUOTE DATE	CUSTOMER NO.	LOC.	SALES	
00104124	10/31/2019	999999	01	JAN	Thank you for allowing us to quote your conveyor needs.

QUANTITY	ITEM NO. / DESCRIPTION	UOM	UNIT PRICE	EXTENDED PRICE
	Please contact Jeff Nienhaus if you have any questions regarding your quote. Drawing delivery: 1 week(s). Equipment ship date: 4 week(s) after receipt of approved drawings. Credit Terms: 50% down at time of order. 50% down at time of shipment. Shipping Terms: FOB New London, WI; Freight Collect. Please Note: The price shown is your net cost in USD, and is valid for 30 days. Cancellation charges apply after an order is received. Sales quotations and orders are subject to Titan's Standard Terms and Conditions available at www.titanconveyors.com.. Buyers purchase order constitutes acceptance of such Terms and Conditions.			
1	0 525X00099 Prom: 10/31/2019 MODEL 525 CHAIN DRIVEN LIVE ROLLER CONVEYOR CONVEYOR WIDTH IS: 24.0000" E.W. CONVEYOR LENGTH IS: 6.00 FEET .0000 INCHES	EA	3,664.00	3,664.00

*** Continued On The Next Page ***

By ______________________________

TITAN CONVEYORS
735 Industrial Loop Road, New London, WI 54961
www.titanconveyors.com
Phone: (920) 982-6600 Fax: (920) 982-7750

PROPOSAL

PAGE
2

PRINT DATE
10/31/2019

PHONE:
FAX:

TO:

UNIVERSITY OF ALBERTA - CANADA
ATTN: ADAM DUMANOWSKI
REF: CAPSTONE PROJECT

QUOTE NO.	QUOTE DATE	CUSTOMER NO.	LOC.	SALES	
00104124	10/31/2019	999999	01	JAN	Thank you for allowing us to quote your conveyor needs.

QUANTITY	ITEM NO. / DESCRIPTION	UOM	UNIT PRICE	EXTENDED PRICE
	SPEED: VARIABLE SPEED VARIABLE SPEED OF 3-30 F.P.M. MOTOR: 1 HP 230/460 VOLT INVERTER DUTY MOTOR REDUCER: GROVE GRG BMQ DRIVE SPROCKET: 50B DRIVEN SPROCKET: 50A18 TOP/SIDE MOUNT DRIVE 4 3/8" ROLLER CENTERS ROLLERS SET HIGH ROLLERS: 2 1/2" DIA. X #11 GA. 11/16" CF 1018 HEX BEARINGS: GREASED PACKED STANDARD #7 GA. FORMED FRAME FRAME: #7 GAUGE FORMED-STANDARD PAINT: STANDARD TITAN GRAY SPECIAL SUPPORT DESCRIPTION: TWO PAIR OF SUPPORTS FOR 8" TOP OF ROLLER. REVERSING VFD, 115V: WITH INTEGRATED PUSH BUTTONS, FOR USE WITH 230/3/60 MOTORS AND 115/1/60 INCOMING POWER. CORD W/110V PLUG: 10' LONG			

*** Continued On The Next Page ***

By ______________________________

TITAN CONVEYORS

735 Industrial Loop Road, New London, WI 54961
www.titanconveyors.com
Phone: (920) 982-6600 Fax: (920) 982-7750

PROPOSAL

PAGE
3

PRINT DATE
10/31/2019

PHONE:
FAX:

TO:

UNIVERSITY OF ALBERTA - CANADA
ATTN: ADAM DUMANOWSKI
REF: CAPSTONE PROJECT

QUOTE NO.	QUOTE DATE	CUSTOMER NO.	LOC.	SALES	
00104124	10/31/2019	999999	01	JAN	Thank you for allowing us to quote your conveyor needs.

QUANTITY	ITEM NO. / DESCRIPTION	UOM	UNIT PRICE	EXTENDED PRICE
	MOUNTING & WIRING INFORMATION: MOUNT CONTROL NEAR DRIVE PACKAGE AND WIRE TO MOTOR NO OPTIONS REQUIRED NO POP-UP CHAIN TRANSFER			
		Total for Order:		3,664.00

By ______________________________

---------- Forwarded message ---------
From: **Jeff Nienhaus** <JeffN@titanconveyors.com>
Date: Mon, Nov 18, 2019 at 8:30 AM
Subject: RE: Roller Conveyor Quote
To: Adam Dumanowski <adumanow@ualberta.ca>

Adam,

Adjustable siderails would add $570.00 to net price per unit
Siderails at the beginning would be tapered to direct material to center.

Adding a photo eye will add $489.00 to net price
Adding a e-stop will add $322.00 to net price.

Thanks,

Jeff Nienhaus
Sales Engineer
Direct (920)250-6121
Office (920) 982-6600
Fax (920) 982-7750
www.titanconveyors.com

Pricing Quote for the Housing (Protocase)

Protocase Designer Checkout

Estimate Information

This is your price estimate for **Quote # 244633**.

You may close this browser window and return to Protocase Designer at any time.

Quote # 244633

Quantity to update quantity, enter the amount, then click "Update", and note the change in the Price Quote section below.

Quantity: 1 Update

Price Quote # 244633

Quantity:	Item:	Unit:	Price in: USD
1	U-Shape Template	$167.69	$167.69
1	Setup Fee:	$40.00	$40.00
		Sub-Total Price:	**$207.69**

Taxes are Extra.

Please add $18 for shipping to Canada and the continental United States and $40 USD charge will apply outside these regions.

Summary for Quote # 244633

Customer Name:		Enclosure Style:	U-Shape Template
Company:		Quantity:	1
Phone:			
Email:	0		
Country:			

Appendix B2: Price Breakdown of the Assembly Cost of Each Subsystem

The assembly of the design can be completed by the employees at Worker Bee Honey who are currently getting paid $20/hr. The time it takes for two employees to assemble the design was estimated based on the complexity of the subsystem so that the total assembly cost could be calculated. The assembly cost for each subassembly can be seen in Table B2.

Table B2: Hours and cost of assembly

Subsystem	Hours of assembly	Assembly Cost (CAD)
Roller Conveyor	2.0	$80
Weighing	0.5	$20
Labelling	0.5	$20
Flow Control	2.0	$80
Electronic Housing	1.0	$40
Total	6.0	$240.00

Appendix B3: Breakeven and Savings Analysis

A savings analysis was done to find the breakeven point and the accumulated savings after 10 years if Worker Bee Honey implemented our Automated Filling Machine. Based on the client's needs, the most drums that needs to be filled in year is 1500 drums. The filling process in a honey farm is usually done in an 8-week period, working 5 days a week for 2 hours a day. This means that the maximum hours of operations per year 80 hours. The number of drums per hour that the two employees can fill is approximately 19 per hour. These employees are getting paid approximately $20 /hr. Table B3 shows the wage expenses that is spent each year for 10 years, assuming a 2% inflation rate.

Table B3: Expenses per year without filling machine

Year	Wage expenses per year with inflation	Drums Filled
1	$3,200	1500
2	$3,264.00	1500
3	$3,329.28	1500
4	$3,395.87	1500
5	$3,463.78	1500
6	$3,533.06	1500
7	$3,603.72	1500
8	$3,675.79	1500
9	$3,749.31	1500
10	$3,824.30	1500
Total	**$35,039**	**15000**

Implementing the filling machine would increase filling production to 40 drums per hour and it can be achieved by a single worker. There would be an increase in maintenance hours and electricity cost. There would be an additional 5 hours of maintenance, which is based on the numbers of weeks and months worked. This can be seen below in Figure B1 There is an hour added for each week of operation and an additional hour at the end of each month. The hours of operation will be cut down to 38 hours per year, which means that Worker Bee Honey only needs to operate for 4 weeks a year. The electricity cost was estimated based on a rate of $0.09 /kWh. Table B4 shows the overall expenses that is spent each year for 10 years, assuming a 2% inflation rate if Worker Bee Honey implemented the automated filling machine.

Table B4: Expenses per year with filling machine

Year	Filling Machine Cost (CAD)	Wage Expenses (CAD)	Maintenance Cost (CAD)	Operation cost (i.e. electric cost) (CAD)	Total Expenses (CAD)	Drums Filled
1	$11,350	$760	$200	$108.21	$12,418	1500
2		$775	$204	$110	$1,090	1500
3		$791	$208	$113	$1,111	1500
4		$807	$212	$115	$1,134	1500
5		$823	$216	$117	$1,156	1500
6		$839	$221	$119	$1,179	1500
7		$856	$225	$122	$1,203	1500
8		$873	$230	$124	$1,227	1500
9		$890	$234	$127	$1,252	1500
10		$908	$239	$129	$1,277	1500
Total	$11,350	$760	$200	$108.21	$12,418	1500

Chain Installation and Maintenance

Maintenance Schedule

A typical maintenance schedule is laid out below. This should be adapted to suit each specific application, based on the local conditions and duty cycle.

Typical Maintenance Schedule

EVERY WEEK
- Check lubrication and lubricate if necessary.

FIRST MONTH'S RUNNING
- Check chain take-up and adjust if necessary.
- Check for unusual wear and identify cause and rectify.

EVERY 3 MONTHS
- Check chain take-up and adjust if necessary.
- Check unusual wear and identify cause and rectify.

AFTER 3 MONTHS
- Check chain adjustment and rectify if necessary.
- Change oil, oil filter and clear the sump, if lubrication system fitted

ANNUALLY
- Carry out the above checks.
- Check for wear on side plates.
- Check for chain elongation.
- Check cleanliness of components.
  - Remove any accumulation of dirt or foreign materials.
- Check for shaft and sprocket alignment.
- Check for wear on sprockets.
- Check the condition of the lubricant.
- Check the lubrication system.

Lubrication

Effective lubrication of the chain bearing surfaces is essential to obtain optimum performance in addition to minimising power absorption, rate of wear, probability of corrosion and noise.

For normal conditions a good quality mineral oil with medium viscosity, for example SAE 20W50, is recommended where operating temperatures are normal.

The standard treatment given to every Renold chain before leaving the factory, unless otherwise requested, is to immerse the chain in a grease which, when solidified, will act as a protection and preliminary lubricant for the chain. Re-lubrication should be carried out immediately after installation of the chain with a suitable lubricant and at regular intervals thereafter. The following selection procedure for conveyor chain lubrication is designed to give users an idea of the types of lubrication to be used in conditions where normal lubricants would be inadequate. (See Fig 11).

Figure B1: Maintenance Schedule

Appendix C: Data Sheets

Roller Conveyor Data Sheet

MODEL 525

CHAIN DRIVEN LIVE ROLLER

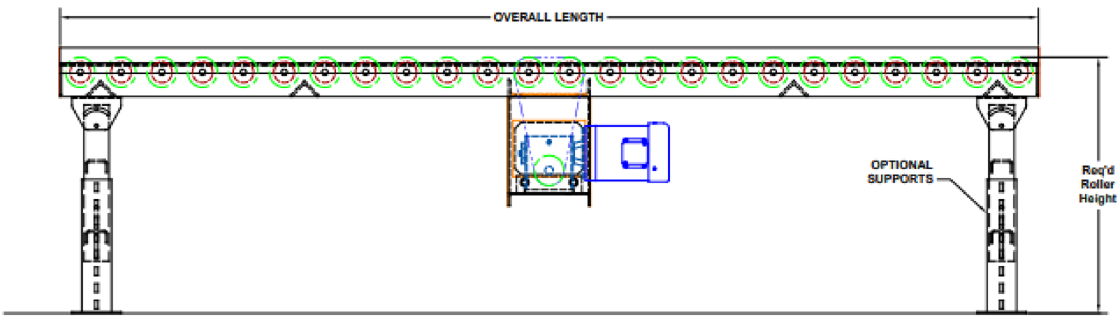
TITAN™ CONVEYORS

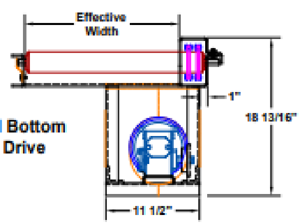
The **Model 525 Chain Driven Live Roller conveyor** from Titan Industries is designed to handle heavy loads such as pallets, skids or drums. The unit incorporates a number 50 chain with a roll-to-roll drive. The frame is a heavy formed 7 gauge construction with a one piece chain guard. Rollers are 2-1/2" diameter x 11 gauge (**580 lb. capacity**). The standard drive is a 3/4 H.P. for 30 F.P.M. roller speed. A wide range of standard effective widths are available. Standard roller spacings are 2-13/16", 3-7/16", 4-3/8", 5", and 5-15/16". Floor supports are optional. The Model 525 comes in lengths to suit with a minimum length of 4' long.
Consult the factory for further details.

MODEL 525 CHAIN DRIVEN LIVE ROLLER CONVEYOR SPECIFICATIONS		
	Standard	**Options**
Effective Widths	15" to 72"	Specify up to 40" E.W.
Lengths	5' min.	3' min., max. based on application
Roller Size	2 1/2" Dia. x 11 ga. with 11/16" hex shaft - 580 lb. roller cap.	
Roller Center	5"	2-13/16", 3-7/16", 4-3/8", 5", 5-15/16", 10"
Frame	Formed 7 ga.	
Drive	3/4 H.P. 230/460/3/60	1, 1-1/2, 2, 3 H.P. 230/460/3/60, severe duty, inverter duty, brake motor
Chain Drive	#50	#60 available
OPTIONAL		
Roller Space - Consult factory, Roller Center - Consult Factory, Drive locations: as needed, Galvanized or stainless construction, H. P. , Speeds, Variable speed, Controls, Coated rollers, Paint, 2, 3 or 4 strand chain transfers, Pallet lifts, Pallet jack plates for side or end load, "C" Face brake and Fixed end stop, Pallet pusher, Walk plates,Rollers set low, UHMW sleeves, Accumulation sleeves, Urethane sleeves, Knee braces, Air operated blade stop, Supports - 6" @ #8.2 structural channel		

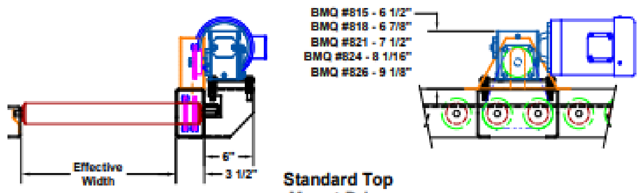
NOTE: Specifications subject to change without notice

MODEL 525
CHAIN DRIVEN LIVE ROLLER CONVEYOR

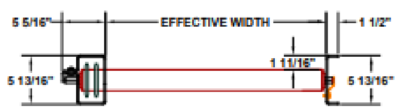




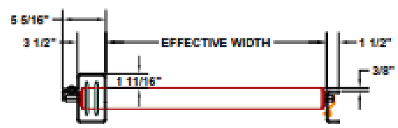
Standard Bottom Mount Drive



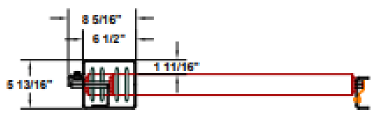
Standard Top Mount Drive



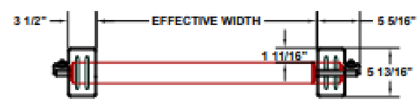
ROLLERS SET LOW



ROLLERS SET HIGH



DOUBLE WIDE CHAIN GUARD
(STANDARD CENTERS - 3 7/16")



DOUBLE DRIVE GUARD
(STANDARD CENTERS - 2 13/16")

TITAN CONVEYORS

735 Industrial Loop Road • New London, WI 54961-9612
920-982-6600 • Fax 920-982-7750 • Toll Free 800-558-3616
Website: www.titanconveyors.com • Email: sales@titanconveyors.com

Bulletin 0619_525GH

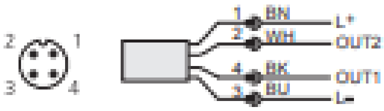
Flow Sensor Data Sheet

ProSense FTS Series (-1002) Liquid / Air Thermal Flow Sensors

ProSense FTS Series (-1002) Thermal Flow Sensors Specifications Continued		
Model	*FTS100-1002*	*FTS200-1002*
	Operating Conditions	
Ambient temperature	-40 to 176°F (-40 to 80°C)	
Storage temperature	-40 to 212°F (-40 to 100°C)	
Protection	IP 65; IP 67	
	Tests / Approvals	
EMC	DIN EN 60947-5-9	
Shock resistance	DIN EN 60068-2-27 @ 50 g (11 ms)	
Vibration resistance	DIN EN 60068-2-6 @ 5 g (10 to 2000 Hz)	
UL approval	E320401	
CE	EMC; RoHS II	
	Mechanical Data	
Weight	0.65 lb (295.5 g)	
Material	Stainless steel (1.4404 / 316L); PBT-GF20; PBT-GF30	
Materials (wetted parts)	Stainless steel (1.4404 / 316L)	
Process Connection	Diameter 8mm	
	Displays / Operating Elements	
Display	Display Unit: 5 x LED, green (fps, gpm, cfm, °F, 10ⁿ)	
	Measured values: alphanumeric display, red/green 4-digit, 9mm character height	
	Electrical Connection	
Connector	1 x M12	
Contacts	Gold plated	

Note: Check the chemical compatibility of the sensor's wetted parts with the medium to be measured.

Wiring Diagram



Cable Assembly Wiring Colors:
Pin 1 - Brown
Pin 2 - White
Pin 3 - Blue
Pin 4 - Black

Colors to DIN EN 60947-5-2

For additional wiring details see individual product manuals.

Note: Wiring colors are based on AutomationDirect CD12L and CD12M 4-pole cable assemblies.

Output Function Selections

Models:
FTS100-1002, FTS200-1002
Output 1:
Analog output Temperature monitoring

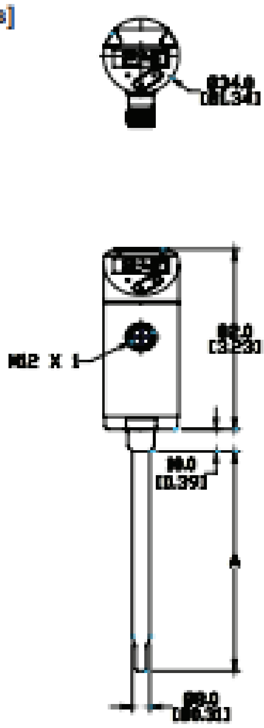
Output 2:
Analog output Volumetric flow rate monitoring

For the latest prices, please check AutomationDirect.com.

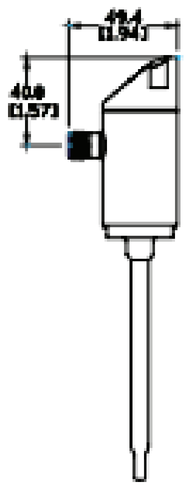
prosense FTS Series Liquid / Air Thermal Flow Sensors

Dimensions

mm [inches]



Dimensions mm [inches]	
Part No.	A
FTS100-100x	100mm [3.94 in]
FTS200-100x	200mm [7.87 in]



See our website www.AutomationDirect.com for complete Engineering drawings.

proSense® FTS Series Liquid / Air Thermal Flow Sensors

Liquid Flow Conversions

To convert from flow velocity to flow rate, use the following formula:

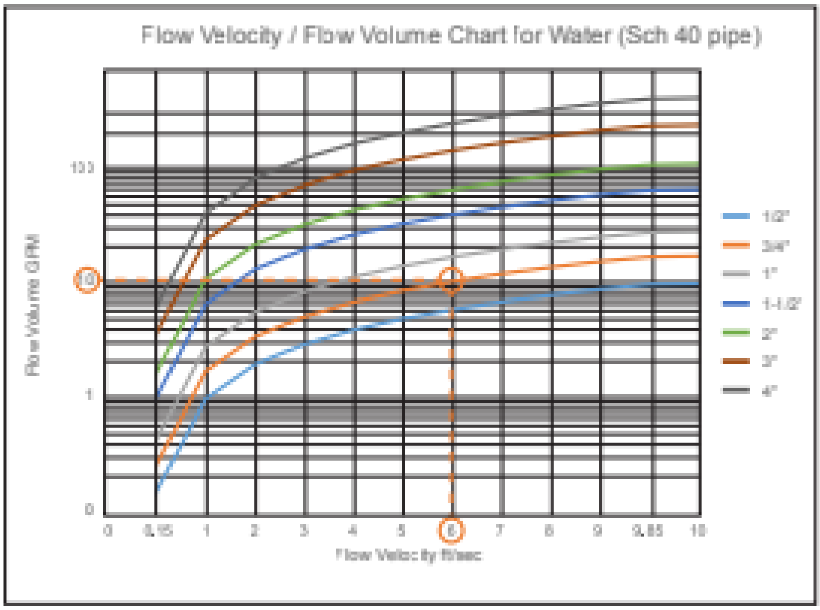
$$V = v \times A$$

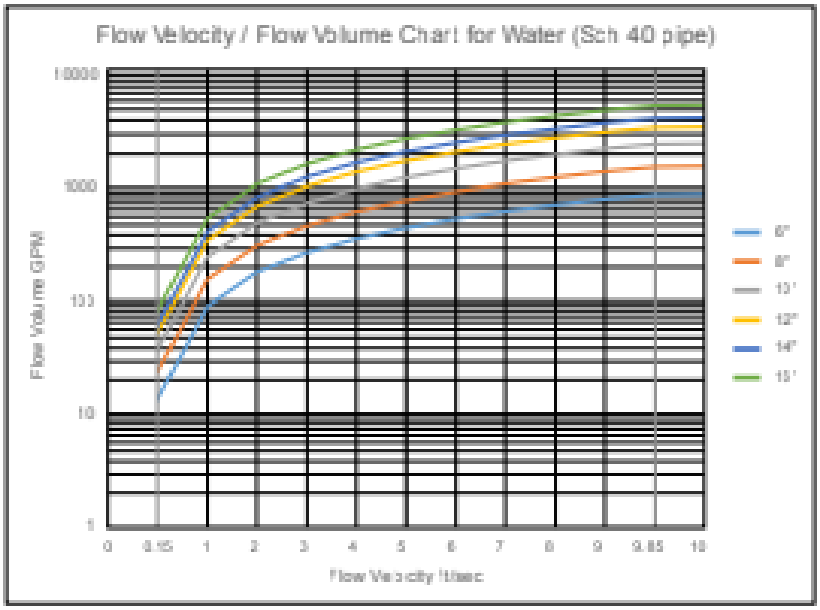
Where V = volumetric flow rate

v = flow velocity

A = cross sectional area of the pipe

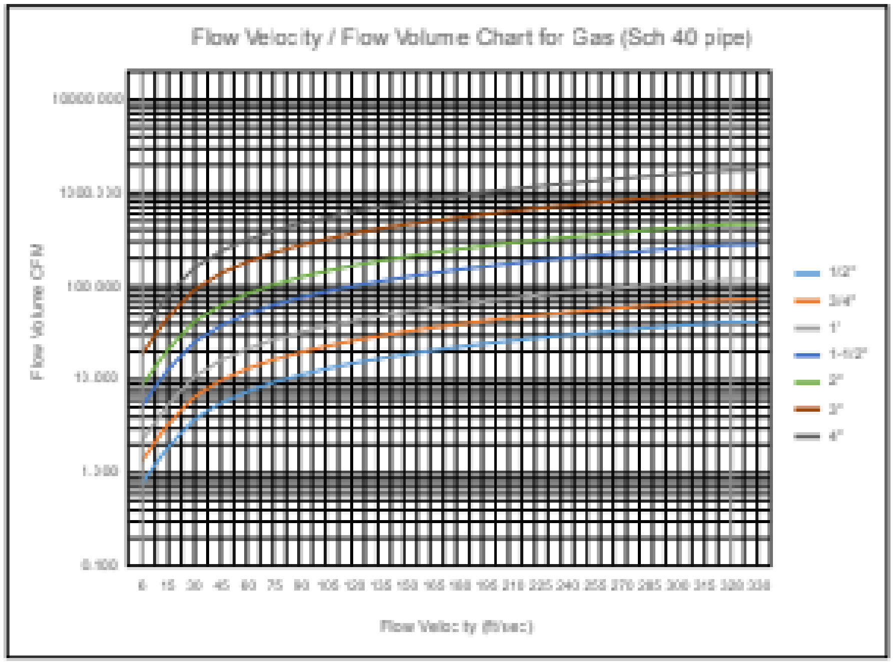
Take care to ensure all the units of measure are consistent. The following charts can be used in lieu of the calculation for round pipes. Find the volumetric flow rate on the y-axis. (Example: 10 GPM) Follow the line horizontally until it intersects the line for pipe diameter. (Example: 3/4" pipe diameter). From the intersection point, drop straight down to read the x-axis to find the given flow velocity. (Example: 6 ft/sec)





proSense® FTS Series Liquid / Air Thermal Flow Sensors

Gas Flow Conversions



ProSense FTS Series Liquid / Air Thermal Flow Sensor Accessories

FTS Series Liquid / Air Flow Sensor Accessories

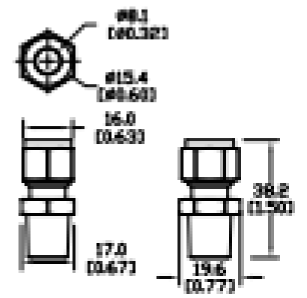
CF08-25N

CF08-50N

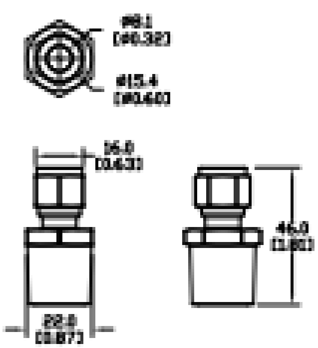
Part No.	Description	Pcs/Pkg	Weight (lbs)	Price
CF08-25N	ProSense compression fitting, stainless steel, 1/4in male NPT process connection. For use with 8mm outside diameter sensor probes.	1	0.1	$25.00
CF08-50N	ProSense compression fitting, stainless steel, 1/2in male NPT process connection. For use with 8mm outside diameter sensor probes.	1	0.2	$25.00

Dimensions

mm [inches]



CF08-25N



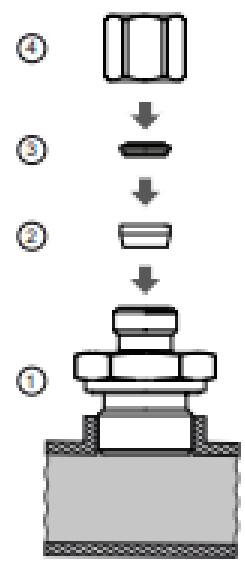
CF08-50N

See our website www.AutomationDirect.com for complete Engineering drawings.

Fitting Illustration

The CF compression fittings consist of four parts:

1. Screw fitting
2. First clamping ring
3. Second clamping ring
4. Coupling nut



Note: Once the FTS series unit is inserted to the correct depth and the coupling nut is tightened down, the first and second clamping rings will be joined together, compressed onto to the FTS probe and cannot be removed without damaging the unit probe. The coupling nut however can be loosened after compressing allowing for the FTS probe, clamping rings and coupling nut to be removed for FTS probe cleaning.

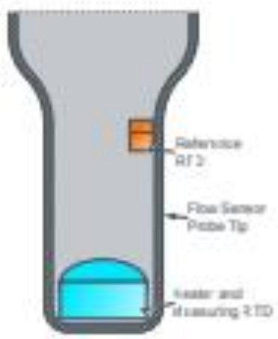
prosense FTS Series Liquid / Air Thermal Flow Sensors

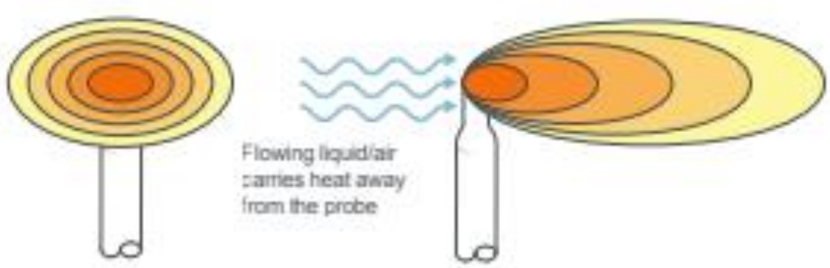
Thermal Flow Meter Measuring Principle

Thermal dispersion or thermal flow sensing technology is based on the principle of heat transfer and relies on the cooling effect of a flowing fluid or gas to monitor flow rate. The tip of a thermal flow sensor probe typically contains two RTD temperature sensors and a heater element. One RTD sensor located on the inside cylindrical wall of the thermal flow sensor probe measures the temperature of the fluid or gas and is used as a reference temperature. The second RTD sensor is located in the end of the sensor probe with the heater element. Electrical power is applied to the heater element which raises the temperature measured by the second RTD sensor creating a temperature difference with the reference RTD sensor. As fluid or gas flows, heat will be carried away from the sensor probe tip. Faster flow will transfer more heat resulting in a smaller temperature difference between the two RTD sensors. Slower flow will transfer less heat resulting in a greater temperature difference between the two RTD sensors. The difference in temperature between the two RTD sensors is used to determine the velocity or flow rate of the fluid or gas flowing past the sensor probe.

Applications

- Liquid or gas flow or no flow detection
- Flow rate monitoring for process control
- Pump run dry protection
- Cooling water or air
- Relief valve monitoring
- Combustion air flow
- Compressed air flow





ProSense FTS Series Thermal Flow Sensors Selection Guide								
Model	**Price**	**Process Connection**	**Probe Length**	**Flow Range**	**Temperature Range**	**Display Units**	**Output 1**	**Output 2**
FTS100-1001	$235.00	None Use CFOB-25N or CFOB-50N for mounting (purchased separately)	100mm	Liquid: 0.15 to 9.85 ft/sec Air: 6 to 328 ft/sec	-4 to 212°F (-20 to 100°C)	5 x LED, green (fps, gpm, cfm, °F, 10⁶) Switching status: 2 x LED, yellow Measured values: alphanumeric display, red/green 4-digit	Flow switch PNP/NPN, N.O./N.C. selectable or flow monitoring frequency signal	Flow / temp. switch PNP/NPN, N.O./N.C. selectable or flow / temp. monitoring 4-20 mA or frequency signal
FTS200-1001	$245.00		200mm					
FTS100-1002	$235.00		100mm			5 x LED, green (fps, gpm, cfm, °F, 10⁶) Measured values: alphanumeric display, red/green 4-digit	Temp. monitoring 4-20 mA	Flow monitoring 4-20 mA
FTS200-1002	$245.00		200mm					

Butterfly Valve Data Sheet

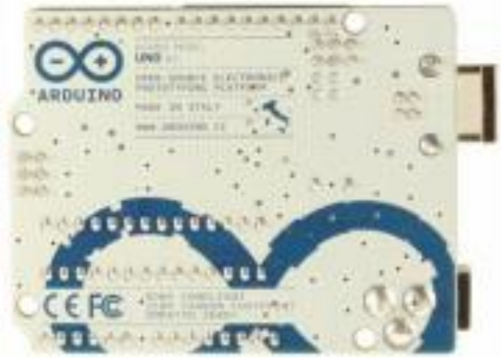
The electric total fluorine valve switch and intelligent two,butterfly valve and electric actuator,the input control signal (4-20mA or 1-5VDC) and single-phase power supply to control operation,has strong function,small volume,light and pleasant,reliable performance,simple matching,large flow capacity,the electric total fluorine valve is especially suitable for in the medium is thick,containing particles,fiber nature of the occasion.At present,the electric control valve is widely used in food,environmental protection, light industry, petroleum, paper, chemical,teaching and research equipment,power and other industries in the industrial automatic control system.

Product Name		High quality China electric actuator butterfly valve D971X-10S
Model		D971X-10S
Power		Electric
DN(mm)		50~500
PN(MPa)		0.6~1.0
Final controlling element		KLA1, KLB2, KLB3
Control mode		Electric switch, Regulate
Power pressure		AC220V, AC380V, DC24V
Main parts	Valve body	Cast steel; Stainless steel; 304
	Valve Disc	PTFE
	Sealing ring	PTFE
Connection Type		Wafer

Arduino Data Sheet

Arduino Uno

Arduino Uno R3 Front



Arduino Uno R3 Back

Arduino Uno R2 Front

Arduino Uno SMD

Arduino Uno Front

Arduino Uno Back

Overview

The Arduino Uno is a microcontroller board based on the ATmega328 (datasheet). It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.
The Uno differs from all preceding boards in that it does not use the FTDI USB-to-serial driver chip. Instead, it features the Atmega16U2 (Atmega8U2 up to version R2) programmed as a USB-to-serial converter.
Revision 2 of the Uno board has a resistor pulling the 8U2 HWB line to ground, making it easier to put into DFU mode.
Revision 3 of the board has the following new features:

- 1.0 pinout: added SDA and SCL pins that are near to the AREF pin and two other new pins placed near to the RESET pin, the IOREF that allow the shields to adapt to the voltage provided from the board. In future, shields will be compatible both with the board that use the AVR, which operate with 5V and with the Arduino Due that operate with 3.3V. The second one is a not connected pin, that is reserved for future purposes.
- Stronger RESET circuit.
- Atmega 16U2 replace the 8U2.

"Uno" means one in Italian and is named to mark the upcoming release of Arduino 1.0. The Uno and version 1.0 will be the reference versions of Arduino, moving forward. The Uno is the latest in a series of USB Arduino boards, and the reference model for the Arduino platform; for a comparison with previous versions, see the index of Arduino boards.

Summary

Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V

Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328) of which 0.5 KB used by bootloader
SRAM	2 KB (ATmega328)
EEPROM	1 KB (ATmega328)
Clock Speed	16 MHz

Schematic & Reference Design

EAGLE files: arduino-uno-Rev3-reference-design.zip (NOTE: works with Eagle 6.0 and newer)
Schematic: arduino-uno-Rev3-schematic.pdf
Note: The Arduino reference design can use an Atmega8, 168, or 328, Current models use an ATmega328, but an Atmega8 is shown in the schematic for reference. The pin configuration is identical on all three processors.

Power

The Arduino Uno can be powered via the USB connection or with an external power supply. The power source is selected automatically.
External (non-USB) power can come either from an AC-to-DC adapter (wall-wart) or battery. The adapter can be connected by plugging a 2.1mm center-positive plug into the board's power jack. Leads from a battery can be inserted in the Gnd and Vin pin headers of the POWER connector.
The board can operate on an external supply of 6 to 20 volts. If supplied with less than 7V, however, the 5V pin may supply less than five volts and the board may be unstable. If using more than 12V, the voltage regulator may overheat and damage the board. The recommended range is 7 to 12 volts.
The power pins are as follows:

- **VIN.** The input voltage to the Arduino board when it's using an external power source (as opposed to 5 volts from the USB connection or other regulated power source). You can supply voltage through this pin, or, if supplying voltage via the power jack, access it through this pin.
- **5V.**This pin outputs a regulated 5V from the regulator on the board. The board can be supplied with power either from the DC power jack (7 - 12V), the USB connector (5V), or the VIN pin of the board (7-12V). Supplying voltage via the 5V or 3.3V pins bypasses the regulator, and can damage your board. We don't advise it.
- **3V3.** A 3.3 volt supply generated by the on-board regulator. Maximum current draw is 50 mA.
- **GND.** Ground pins.

Memory

The ATmega328 has 32 KB (with 0.5 KB used for the bootloader). It also has 2 KB of SRAM and 1 KB of EEPROM (which can be read and written with the EEPROM library).

Input and Output

Each of the 14 digital pins on the Uno can be used as an input or output, using pinMode(), digitalWrite(), and digitalRead() functions. They operate at 5 volts. Each pin can provide or receive a maximum of 40 mA and has an internal pull-up resistor (disconnected by default) of 20-50 kOhms. In addition, some pins have specialized functions:

- **Serial: 0 (RX) and 1 (TX).** Used to receive (RX) and transmit (TX) TTL serial data. These pins are connected to the corresponding pins of the ATmega8U2 USB-to-TTL Serial chip.
- **External Interrupts: 2 and 3.** These pins can be configured to trigger an interrupt on a low value, a rising or falling edge, or a change in value. See the attachInterrupt() function for details.
- **PWM: 3, 5, 6, 9, 10, and 11.** Provide 8-bit PWM output with the analogWrite() function.

- **SPI: 10 (SS), 11 (MOSI), 12 (MISO), 13 (SCK).** These pins support SPI communication using the SPI library.
- **LED: 13.** There is a built-in LED connected to digital pin 13. When the pin is HIGH value, the LED is on, when the pin is LOW, it's off.

The Uno has 6 analog inputs, labeled A0 through A5, each of which provide 10 bits of resolution (i.e. 1024 different values). By default they measure from ground to 5 volts, though is it possible to change the upper end of their range using the AREF pin and the analogReference() function. Additionally, some pins have specialized functionality:

- **TWI: A4 or SDA pin and A5 or SCL pin.** Support TWI communication using the Wire library.

There are a couple of other pins on the board:

- **AREF.** Reference voltage for the analog inputs. Used with analogReference().
- **Reset.** Bring this line LOW to reset the microcontroller. Typically used to add a reset button to shields which block the one on the board.

See also the mapping between Arduino pins and ATmega328 ports. The mapping for the Atmega8, 168, and 328 is identical.

Communication

The Arduino Uno has a number of facilities for communicating with a computer, another Arduino, or other microcontrollers. The ATmega328 provides UART TTL (5V) serial communication, which is available on digital pins 0 (RX) and 1 (TX). An ATmega16U2 on the board channels this serial communication over USB and appears as a virtual com port to software on the computer. The '16U2 firmware uses the standard USB COM drivers, and no external driver is needed. However, on Windows, a .inf file is required. The Arduino software includes a serial monitor which allows simple textual data to be sent to and from the Arduino board. The RX and TX LEDs on the board will flash when data is being transmitted via the USB-to-serial chip and USB connection to the computer (but not for serial communication on pins 0 and 1).
A SoftwareSerial library allows for serial communication on any of the Uno's digital pins.
The ATmega328 also supports I2C (TWI) and SPI communication. The Arduino software includes a Wire library to simplify use of the I2C bus; see the documentation for details. For SPI communication, use the SPI library.

Programming

The Arduino Uno can be programmed with the Arduino software (download). Select "Arduino Uno from the **Tools > Board** menu (according to the microcontroller on your board). For details, see the reference and tutorials.
The ATmega328 on the Arduino Uno comes preburned with a bootloader that allows you to upload new code to it without the use of an external hardware programmer. It communicates using the original STK500 protocol (reference, C header files).
You can also bypass the bootloader and program the microcontroller through the ICSP (In-Circuit Serial Programming) header; see these instructions for details.
The ATmega16U2 (or 8U2 in the rev1 and rev2 boards) firmware source code is available . The ATmega16U2/8U2 is loaded with a DFU bootloader, which can be activated by:

- On Rev1 boards: connecting the solder jumper on the back of the board (near the map of Italy) and then resetting the 8U2.
- On Rev2 or later boards: there is a resistor that pulling the 8U2/16U2 HWB line to ground, making it easier to put into DFU mode.

You can then use Atmel's FLIP software (Windows) or the DFU programmer (Mac OS X and Linux) to load a new firmware. Or you can use the ISP header with an external programmer (overwriting the DFU bootloader). See this user-contributed tutorial for more information.

Automatic (Software) Reset

Rather than requiring a physical press of the reset button before an upload, the Arduino Uno is designed in a way that allows it to be reset by software running on a connected computer. One of the hardware flow control lines (DTR) of the ATmega8U2/16U2 is connected to the reset line of the ATmega328 via a 100 nanofarad capacitor. When this line is asserted (taken low), the reset line drops long enough to reset the chip. The Arduino software uses this capability to allow you to upload code by simply pressing the upload button in the Arduino environment. This means that the bootloader can have a shorter timeout, as the lowering of DTR can be well-coordinated with the start of the upload.
This setup has other implications. When the Uno is connected to either a computer running Mac OS X or Linux, it resets each time a connection is made to it from software (via USB). For the following half-second or so, the bootloader is running on the Uno. While it is programmed to ignore malformed data (i.e. anything besides an upload of new code), it will intercept the first few bytes of data sent to the board after a connection is opened. If a sketch running on the board receives one-time configuration or other data when it first starts, make sure that the software with which it communicates waits a second after opening the connection and before sending this data.
The Uno contains a trace that can be cut to disable the auto-reset. The pads on either side of the trace can be soldered together to re-enable it. It's labeled "RESET-EN". You may also be able to disable the auto-reset by connecting a 110 ohm resistor from 5V to the reset line; see this forum thread for details.

USB Overcurrent Protection

The Arduino Uno has a resettable polyfuse that protects your computer's USB ports from shorts and overcurrent. Although most computers provide their own internal protection, the fuse provides an extra layer of protection. If more than 500 mA is applied to the USB port, the fuse will automatically break the connection until the short or overload is removed.

Physical Characteristics

The maximum length and width of the Uno PCB are 2.7 and 2.1 inches respectively, with the USB connector and power jack extending beyond the former dimension. Four screw holes allow the board to be attached to a surface or case. Note that the distance between digital pins 7 and 8 is 160 mil (0.16"), not an even multiple of the 100 mil spacing of the other pins.

Appendix D: Sustainability

Lifetime Calculations of rollers

Cameron Fenske
November 19, 2019

First, calculate the number of loading cycles needed to ensure a warranty garauntee of 10 years.

Number of loaded roller rotations per drum:

$D_{drum} := 558.4\ \text{mm}$

$D_{rollers} := 63.5\ \text{mm}$

From geometry,

$C_{rollers} := \pi \cdot D_{rollers}$

$N_{perdrum} := \dfrac{D_{drum}}{C_{rollers}} = 2.7991$

Number of drums in 10 years assuming factory produces 1500 drums/year:

$Time := 10\ \text{yr}$

$N_{drums} := Time \cdot \dfrac{1500}{\text{yr}}$

Number of load bearing roller rotations in 10 years:

$N_{warranty} := N_{drums} \cdot N_{perdrum}$

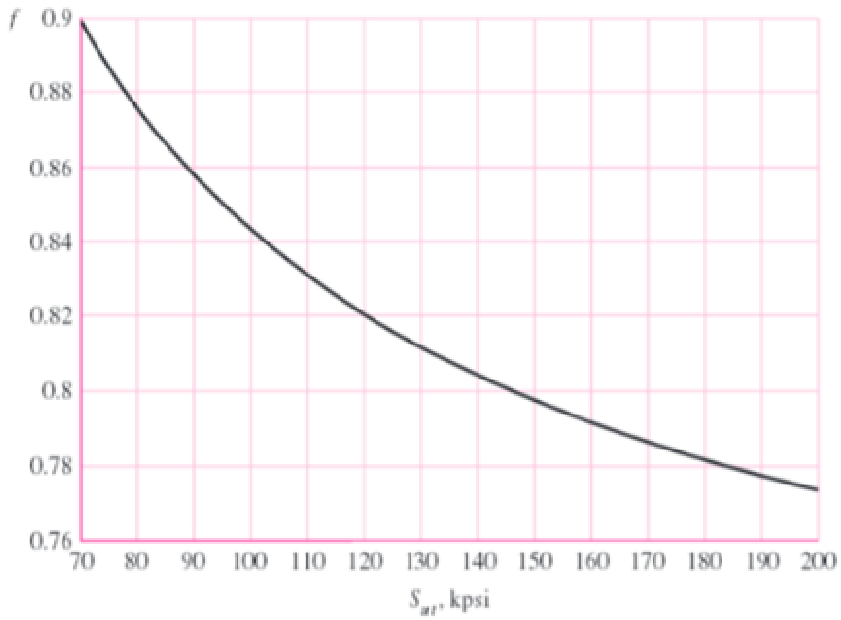
$\boxed{N_{warranty} = 41986.8285}$

Next, calculate the maximum allowable loading rotations given the ultime strength of of the rollers and the von Mises stresses:

$S_{ultimate} := 540\ \text{MPa}$

$S_e := 158.26\ \text{MPa}$ from previous calculations

For high cycle fatigue domain (1000 --> 1000000 cycles)



$f := 0.879$ from above graph, given Sut = 540MPa (78.3 kpsi)

$$a := \frac{\left(f \cdot S_{ultimate}\right)^2}{S_e}$$

$$b := \left(-\frac{1}{3}\right) \cdot \left(\log_{10}\left(\frac{f \cdot S_{ultimate}}{S_e}\right)\right)$$

from previous equations, the von Mises stresses are given as:

$\sigma_a := 25.59\ \text{MPa}$ alternating stress

$\sigma_m := 0.604\ \text{MPa}$ mean stress

$$\sigma_{VM} := \left|\sigma_a\right| + \left|\sigma_m\right|$$

$$N_{max} := \left(\frac{\sigma_{VM}}{a}\right)^{\frac{1}{b}}$$

$$\boxed{N_{max} = 8.1827 \cdot 10^{10}}$$

$N_{max} >> N_{warranty}$

Conclusion: the mimimum number of cycles that the that the rollers must be able to withstand is about 420 000 loading cycles. This would allow for a warranty of 10 years. Baseed on the imposed stresses and strength of the rollers under cyclic loading, the maximum number of cycles is well in excess of the required number.

Appendix E: Revised Design Specification Matrix

Appendix E1: Client Approval of Design Specification Changes

The table below shows the revisions made on the design specification matrix from Phase I report. The changes were made based on the additional details given by the Peter Awram. Please provide a signature beside each revision if they align with the specifications necessary for the design.

Revision	Description	Client Approval (signature)	Date
1	Budget was changed to 15,000 from 10,000.		Nov 2, 2019
2	Aesthetic of design was removed.		Nov 2, 2019
3	Accuracy of aiming was removed since the drums are open top instead of having a lid with a small hole for filling		Nov 2, 2019
4	System must be able to fill thirty or more 55-gallon drums to 45 gallons per hour. Importance of speed was increased from 4 to 5.		Nov 2, 2019
5	The design must be operated by a single user		Nov 2, 2019
6	The design must be integrated specifically into Worker Bee Honey's current facility		Nov 2, 2019
7	Design must be able to determine the gross weight of the drum with lid, tare weight of the empty drum and lid and net weight of honey. The tolerance of the weight is 0.2 kg		Nov 2, 2019
8	Labels must be generated and printed. Placing label on the drum is a desirable extra but not mandatory. Must be CFIA complaint		Nov 2, 2019
9	Design must be able to generate a log of drums filled that can be exported to a CSV file or similar		Nov 2, 2019

Connie Phillips
Nov 22 2019

Appendix F: Task Tracker

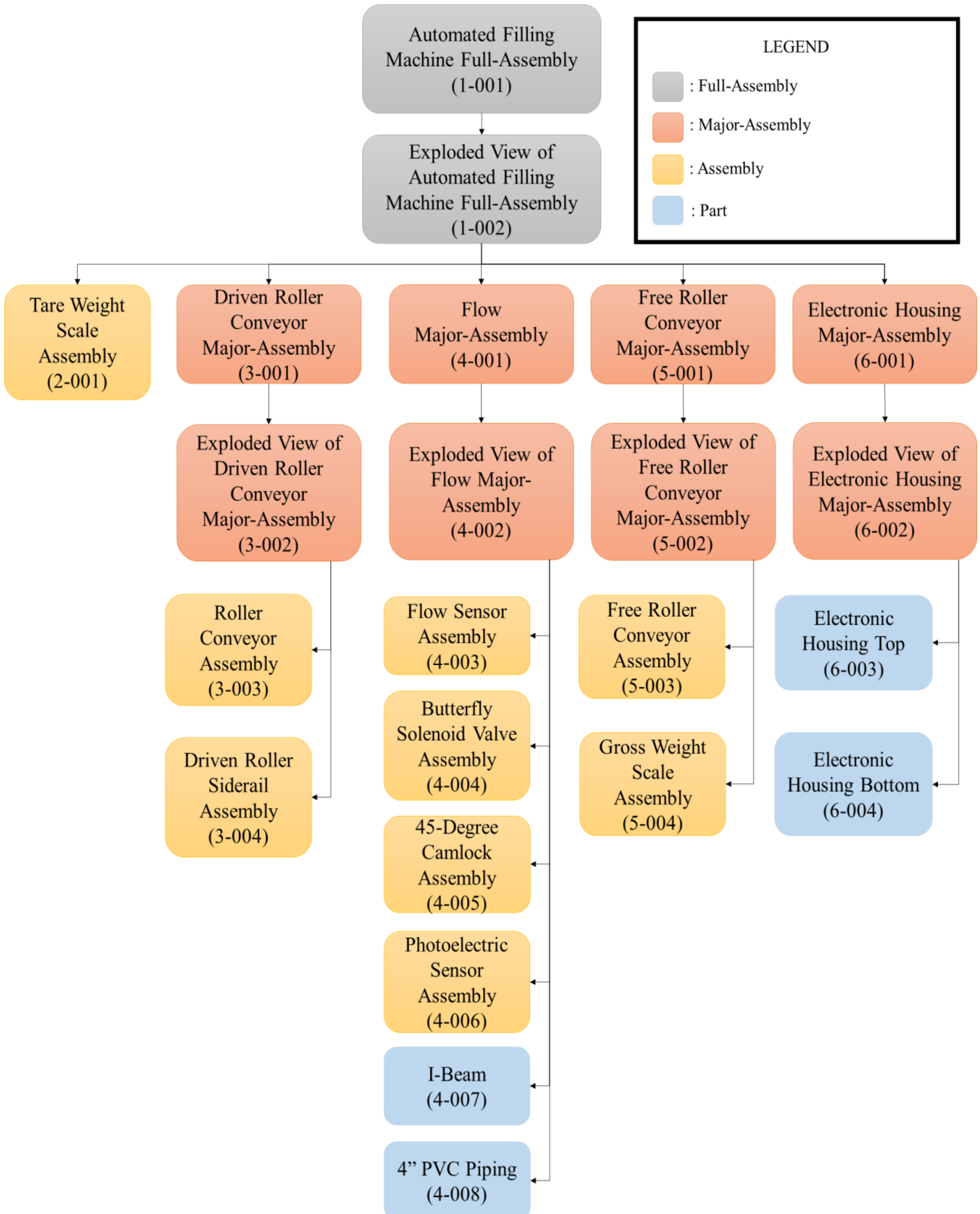
Mec E 460 Group 6						Name					
Phase	**Task**	**Estimated Time Required (hr)**	**Actual Time Taken (hr)**	**Assigned Person**	**Status**	**Adam**	**Cameron**	**Dustin**	**Hannah**	**Jaeyoung**	**Victor**
Pre-Project	Deciding Top 5 Projects (Decision Matrix)	4	3	ALL	Completed	0.5	0.5	0.5	0.5	0.5	0.5
	Group Meetings	18	24	ALL	Completed	4	4	4	4	4	4
	Writing Letter of Intent	2	1	DE	Completed			1			
	Collecting Electronic Signatures for Members	0.5	0.5	AD	Completed	0.5					
	List Tasks to be Done for Phase 1 (Sticky Notes)	2	1	CF, VH	Completed		0.5				0.5
	Final Editing and Submitting the Letter of Intent	1	1	JN	Completed					1	
Total Time Taken for Pre-Project		**27.5**	**30.5**	ALL		**5**	**5**	**5.5**	**4.5**	**5.5**	**5**
Phase 1	Meetings with the Client	6	4.5	ALL	Completed	1	0.5	0.5	1	1	0.5
	Communicating with the Client & Advisor (Email, Texting, etc.)	4	3	CF, JN	Completed		1			1	
	Setting Up Questions to Ask to the Client	4	4	ALL	Completed	0.5	1	0.5	0.5	1	0.5
	Contact and Meet the Advisor	6	12	ALL	Completed	2	2	2	2	2	2
	Group Meetings	30	18	ALL	Completed	3	3	3	3	3	3
	Creating Gantt Chart	2	3.5	AD	Completed	3.5					
	Defining Scopes	2	3	CF	Completed		3				
	Setting Up Achievement Goals	4	3	ALL	Completed	0.5	0.5	0.5	0.5	0.5	0.5
	Brain Storming	12	12	ALL	Completed	2	2	2	2	2	2
	Patent Search (Research of Similar Projects)	3	5	VH	Completed						5
	Standards and Regulation Research	3	5	AD, HL, VH	Completed	1			3		1
	Cost Estimates	2	3	CF, JN, VH	Completed		1			1	1
	Researching Possible Materials & Manufacturing Process	3	2.5	ALL	Completed	0.5	0	0	0	0.5	1.5
	Design Specification Matrix	2	5.5	ALL	Completed	1	0.5	0.5	2	1	0.5
	Tracking Cost	2	2	JN	Completed					2	
	Cost Verification	1	4.5	AD, JN	Completed	3.5				1	
	Creating Task Tracker and Maintain it	4	5	JN, DE	Completed			3		2	
	Writing Phase One Report	24	27	ALL	Completed	2	5	7	6	4	3
Total Time Taken for Phase 1		**114**	**122.5**	ALL		**20.5**	**19.5**	**19**	**20**	**22**	**20.5**

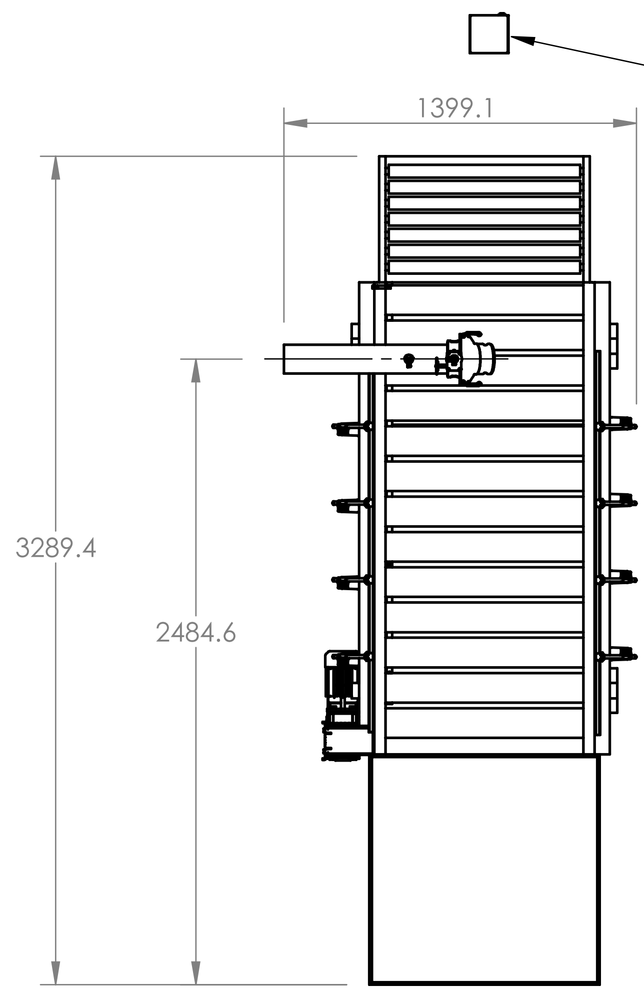
LEGEND	
AD	Adam Dumanowski
CF	Cameron Fenske
DE	Dustin Evangalista
HL	Hannah Liang
JN	Jaeyoung Nam
VH	Victor Hua

Mec E 460 Group 6						Name					
Phase	**Task**	**Estimated Time Required**	**Actual Time Taken (hr)**	**Assigned Person**	**Status**	**Adam**	**Cameron**	**Dustin**	**Hannah**	**Jaeyoung**	**Victor**
	General										
	Concept Brainstorming	6	6	ALL	Completed	1	1	1	1	1	1
	Communicating with the Client & Advisor (Email, Texting, etc.)	6	4	ALL	Completed	0	1	0	1	1	1
	Group Meeting	24	18	ALL	Completed	3	3	3	3	3	3
	Desgin Evaluation Matrix for 3 Designs	12	14	ALL	Completed	2	2	4	2	2	2
	Meetings with the Client	12	12	ALL	Completed	2	2	2	2	2	2
	Meetings with the Advisor	12	16	ALL	Completed	3	2	3	3	2	3
	Setting Up Questions to Ask the Client for Scope Details	6	7	ALL	Completed	1	1	1	2	1	1
	Task Tracking and Gantt Chart	4	4	JN, AD	Completed	2				2	
	Writting Phase 2 Report - Abstract, Executive Summary, Introduction	4	4	ALL	Completed	0	2	0	2	0	0
	Writting Phase 2 Report - Body	8	8.5	ALL	Completed	0	1.5	2	1	2	2
	Writting Phase 2 Report - Conclusion	5	4.5	ALL	Completed	0	0	0	3	1	0.5
	Writting Phase 2 Report - Appendicies	7	7	ALL	Completed	1	1	2	1	0	2
	Final Editing & Formatting of Report	12	13	ALL	Completed	0	0	7	4	2	0
	Concept 1 (Cameron, Victor)										
	Material Research for Concept 1 Equipment	8	6	CF, VH	Completed		2				4
	Manufacturing Procedure Research	3	4	CF, VH	Completed		2				2
	3D CAD - Sheet Metal (guide rails)	2	2	VH	Completed						2
	3D CAD - Conveyor Belt	2	2	VH	Completed						2
	3D CAD - Geneva Wheel System	4	4	VH	Completed						4
	3D CAD - Assemble Parts	3	2	VH	Completed						2
	3D CAD - Assembly Renders (exploded & unexploded)	2	2	VH	Completed						2
	Calculation - Load (Free Body Diagram)	2	3	CF	Completed		3				
	Calculation - Friction	3	3	CF	Completed		5				
Phase 2	Calculation - Torque	6	6	CF, VH	Completed		5				1
	Calculation - Roller Diameter	5	5	CF	Completed		5				
	Cost Analysis of the Design	2	2	VH	Completed						2
	Concept 2 (Dustin, Adam)										
	Material Research for Concept 2 Equipment	2	6	AD, DE	Completed	3		3			
	Manufacturing Procedure Research	4	3	AD, DE	Completed	2		1			
	3D CAD - Chain Driven Roller Conveyor	3	4	AD	Completed	4					
	3D CAD - Guide Rails	1	1	AD	Completed	1					
	3D CAD - Free Rotation Conveyor	2	2	AD	Completed	2					
	3D CAD - Sensors	2	0.5	AD	Completed	0.5					
	3D CAD - Assemble Parts	3	2.5	AD	Completed	2.5					
	3D CAD - Assembly Renders (exploded & unexploded)	2	1.5	AD	Completed	1.5					
	Calculation - Torque	5	5	AD, DE	Completed	3		2			
	Calculation - Bending Moment for shaft	3	3.5	AD, DE	Completed	0.5		3			
	Calculation - Deflection for shaft	3	3.5	AD, DE	Completed	0.5		3			
	Cost Analysis of the Design	7	7	AD, DE	Completed	5		2			
	Concept 3 (Hannah, Jaeyoung)										
	Material Research for Concept 3 Equipment	6	7	HL, JN	Completed				4	3	
	Manufacturing Procedure Research	2	1	JN	Completed					1	
	3D CAD - Frame	2	3.5	JN	Completed					3.5	
	3D CAD - Diverter	6	8	JN	Completed					7.5	
	3D CAD - Assemble Parts	3	4	JN	Completed					4	
	3D CAD - Assembly Renders (exploded & unexploded)	3	4	HL	Completed				4		
	Calculation - Load (Free Body Diagram)	2	3	HL	Completed				3		
	Calculation - Fluid Flow	2	2	JN	Completed					2	
	Cost Analysis of the Design	2	4	HL, JN	Completed				3	1	
	Total Time Taken for Phase 2	**225**	**235**	**ALL**		**40.5**	**38.5**	**39**	**39**	**41**	**38.5**

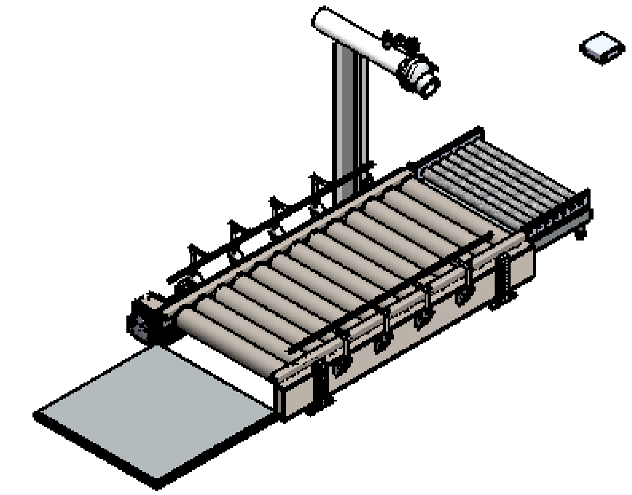
Mec E 460 Group 6						Name					
Phase	Task	Estimated Time Required	Actual Time Taken (hr)	Assigned Person	Status	Adam	Cameron	Dustin	Hannah	Jaeyoung	Victor
Phase 3	**General**										
	Group Meeting	30	36	ALL	Completed	6	6	6	6	6	6
	Meetings with the Client	12	0	ALL	Completed	0	0	0	0	0	0
	Communicating with the Client & Advisor (Email, Texting, etc.)	6	4	ALL	Completed	0	0	1	1	2	0
	Meeting with the Advisor	18	18	ALL	Completed	3	3	3	3	3	3
	Final Design Discussion	6	6	ALL	Completed	1	1	1	1	1	1
	Additional Material Research	12	12	ALL	Completed	2	2	1	2	2	3
	Additional Manufactoring Procedure Research	12	5	ALL	Completed	1	0	0	2	1	1
	Detailed 3D CAD - Part Development	10	10	AD, VH, JN	Completed	3				3	4
	Detailed 3D CAD - Assembly	10	6	AD, VH, JN	Completed	2				1	3
	Detailed 3D CAD - Rendering Images	6	4	AD, JN	Completed	1				3	
	Finite Element Analysis	10	5	AD	Completed	5					
	Detailed CAD Drawings - Whole Assembly (Exploded & unexploded)	5	8	AD, VH, JN	Completed	3				3	2
	Detailed CAD Drawings - Sub Assemblies Drawings	5	6	AD, VH, JN	Completed	2				2	2
	Detailed CAD Drawings - Significant Parts Drawings	6	3	AD, VH, JN	Completed	1				1	1
	Detailed CAD Drawings - Small Parts Drawings	6	5	AD, VH, JN	Completed	2				2	1
	Detailed Calculation - Life Cycle Assessment/Sustainability	4	5	CF	Completed		5				
	Detailed Calculation - Flow Analysis	6	12	CF	Completed		12				
	Cost Analysis & Bill of Material	4	7	AD,CF,DE	Completed	1	2	4			
	Design Compliance Matrix (Edition & Confirmation from Client)	10	9	ALL	Completed	1	1	3	2	1	1
	Writting Phase 3 Report - Abstract, Executive Summary, Introduction	6	5	ALL	Completed	0	0	2	3	0	0
	Writting Phase 3 Report - Body	8	15	ALL	Completed	1	2	4	5	1	2
	Writting Phase 3 Report - Conclusion	6	8	ALL	Completed	0	0	2	4	0	2
	Writting Phase 3 Report - Appendicies	10	13	ALL	Completed	1	1	4	4	1	2
	Final Editing & Formatting of Report	12	14	ALL	Completed	1	3	5	4	0	1
	Design Conference										
	Making a PowerPoint for the Presentation	18	8	ALL	Completed	1	1	1	3	1	1
	Practice for the Presentation	12	12	ALL	Completed	2	2	2	2	2	2
	Creating a Poster	12	10	ALL	Completed	0	0	2	0	6	2
	Setting Up Expected Questions and Prepare	12	8	ALL	Completed	2	2	1	1	1	1
Total Time Taken for Phase 3		**244**	**254**	**ALL**		**42**	**43**	**42**	**43**	**43**	**41**
Total Time Taken (As of Today)		**610.5**	**642**	**ALL**		**66**	**63**	**63.5**	**63.5**	**68.5**	**64**

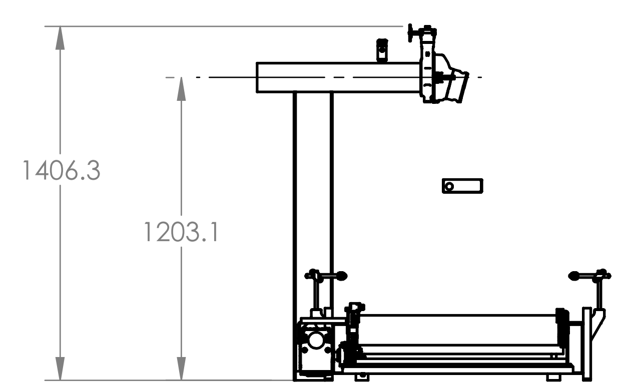
Appendix G: Drawing Package





Note: Electronic Housing will be on a pre-existing table beside automated filling machine.





MEC E 460

Instructor: **Dr. Kajsa Duke**
Fall 2019
Group Number: **Group 6**
Project Name: **Automated Filling Machine**

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MM
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X = ± 0.5
X.X = ± 0.1
X.XX = ± 0.025
SURFACE FINISH 0.6 µm

DRAWN BY: **Adam Dumanowski**
SM By **Adam Dumanowski**
Reviewed By **Jaeyoung Nam**

Saturday, November 30, 2019 3:24:13 PM
Tuesday, November 19, 2019 4:37:41 PM

The Department of Mechanical Engineering
UNIVERSITY OF ALBERTA

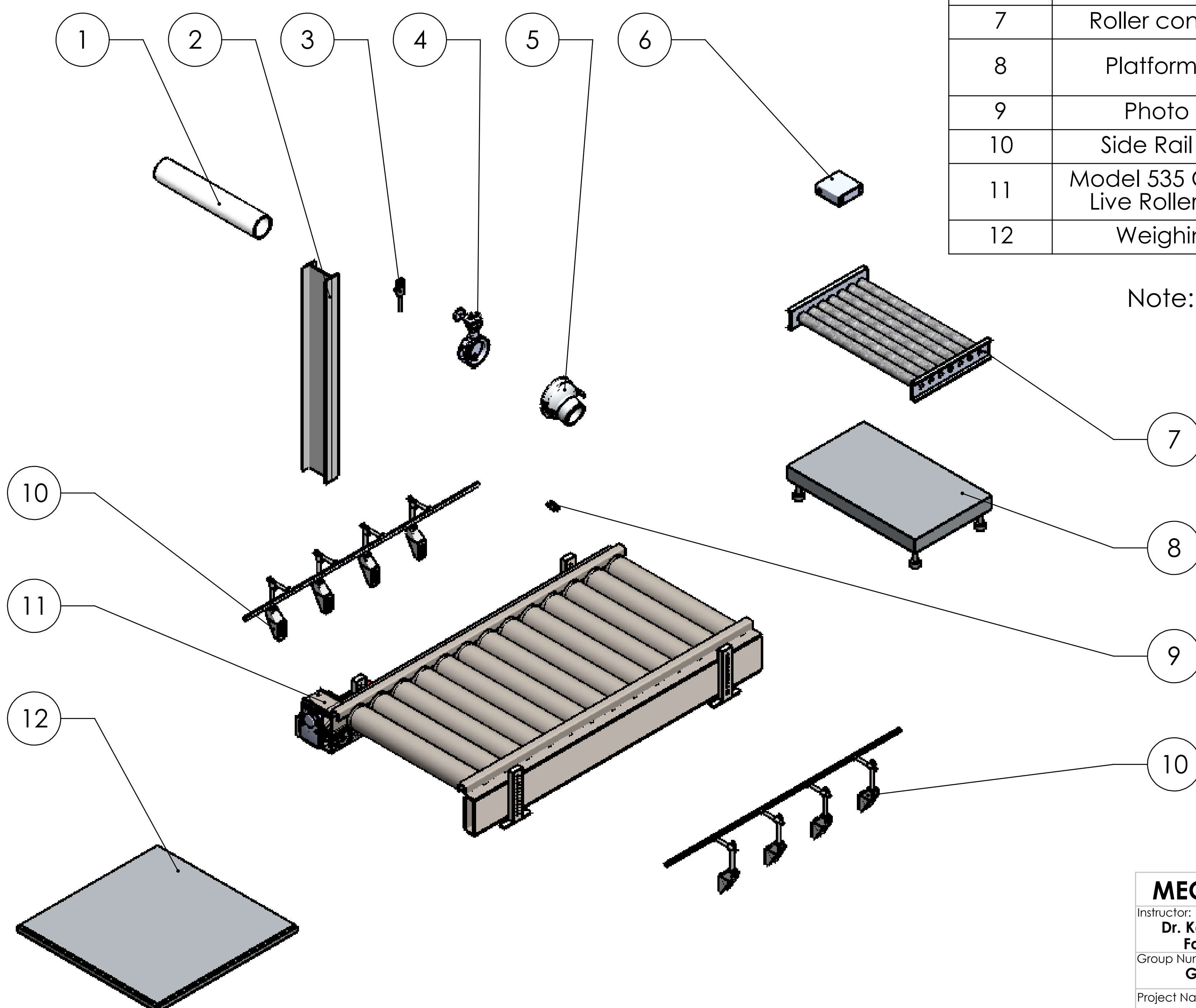
TITLE:
Automated Filling Machine Full-Assembly

SIZE **B** REV 1

MATERIAL: Various
FILE NAME: FinalDesign
SCALE: 1:50
Drawing Number: 1-001
SHEET 1 OF 1

ITEM NO.	PART NAME	MANUFACTURER	DESCRIPTION	QTY.
1	4PVC	N/A	4" piping from the honey storage tank	1
2	8003K156	MetalsDepot	I-Beam	1
3	FTS100-1002	AutomationDirect	Flow Sensor	1
4	4" Electrical Butterfly Valve D971X-10S	Yuanda Valve	4" Electric Butterfly Valve	1
5	Liquip-API-MC100	N/A	4" 45-degree camlock (similar CAD sourced from 3D Content Central)	1
6	Electronic Housing	PROTOCASE	Main casing for electronics	1
7	Roller conveyor YRO	KERN	Free roller conveyor	1
8	Platform scale IFB	KERN	High-resolution scale for industrial application	1
9	Photo Sensor2	Titan Conveyors	Photoemitter sensor	1
10	Side Rail Assembly	Titan Conveyors	Side rail of the driven roller conveyor	2
11	Model 535 Chain Driven Live Roller Conveyor	Titan Conveyors	Chain driven roller conveyor	1
12	Weighing Scale	N/A	Tare Weight Scale	1

Note: Parts that do not have a manufacturer are currently owned by the client.



MEC E 460
Instructor: Dr. Kajsa Duke
Fall 2019
Group Number: Group 6
Project Name: Automated Filling Machine

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MM
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X = ± 0.5
X.X = ± 0.1
X.XX = ± 0.025
SURFACE FINISH µm 0.6

DRAWN BY: Adam Dumanowski
SM By Adam Dumanowski
Reviewed By Jaeyoung Nam

The Department of Mechanical Engineering
UNIVERSITY OF ALBERTA

TITLE: Exploded View of Automated Filling Machine Full-Assembly

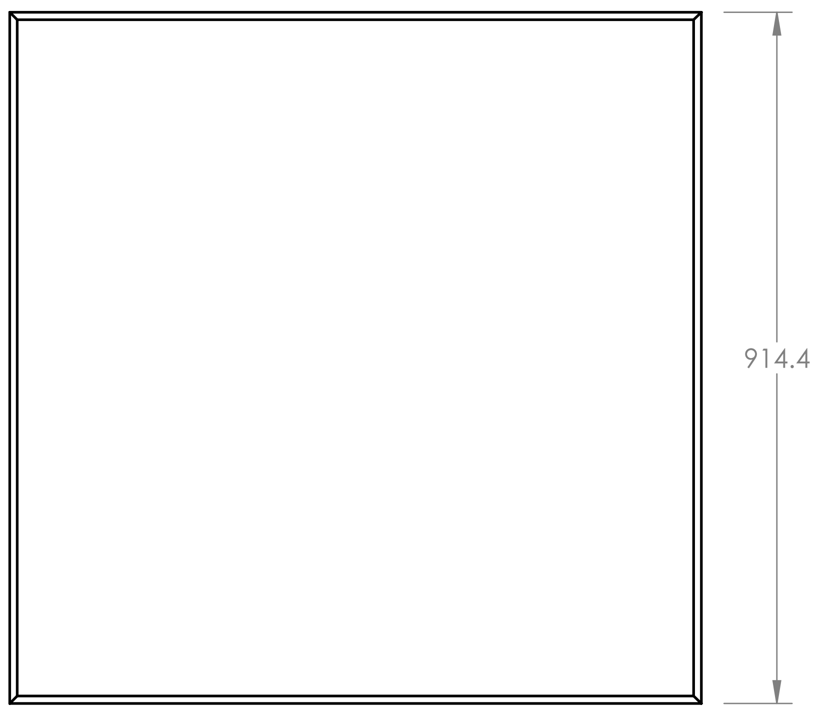
SIZE B | REV 1

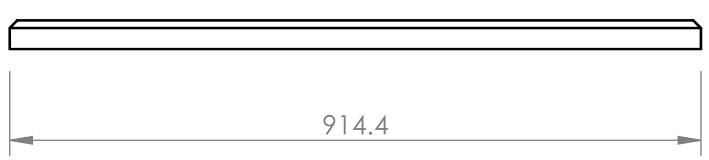
MATERIAL: Various

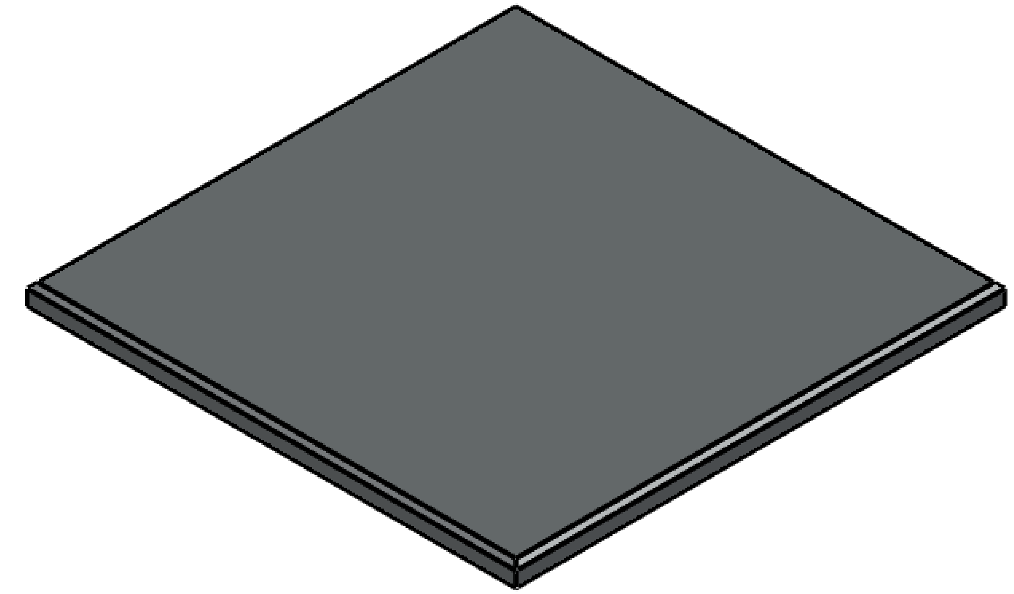
Saturday, November 30, 2019 3:24:13 PM
Tuesday, November 19, 2019 4:37:41 PM

FILE NAME: FinalDesign

SCALE: 1:50 | Drawing Number: 1-002 | SHEET 1 OF 1

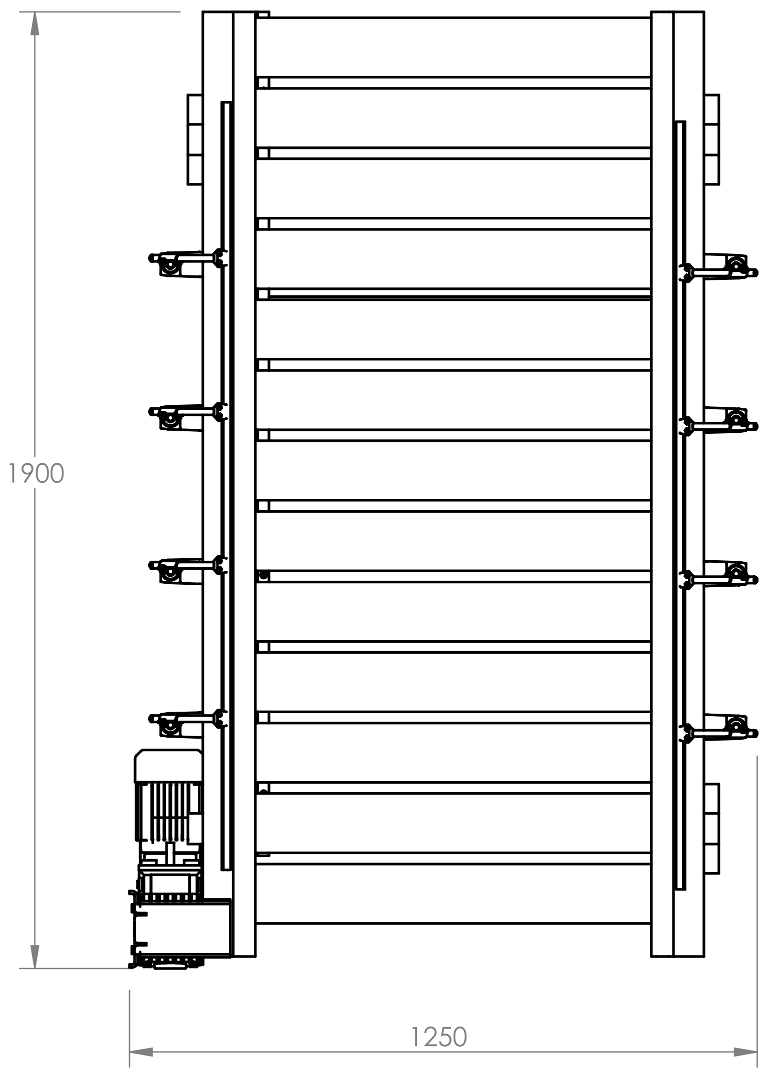


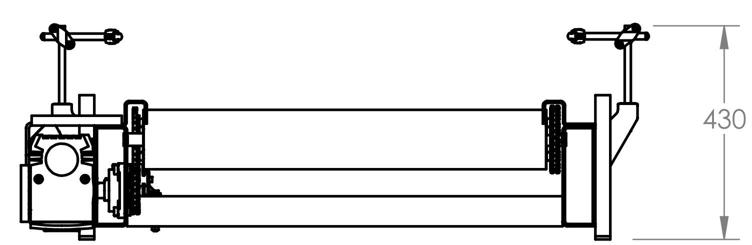


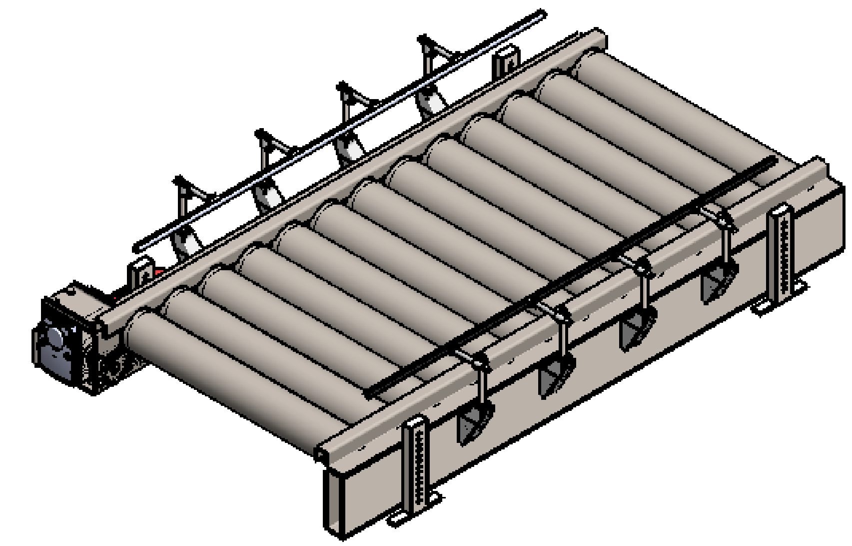


NOTE: Only known dimensions provided by the client are annotated in this drawing

MEC E 460 Instructor: **Dr. Kajsa Duke Fall 2019** Group Number: **Group 6** Project Name: **Automated Filling Machine**	UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MM TOLERANCES: ANGULAR: ± 0.5° LINEAR X = ± 0.5 X.X = ± 0.1 X.XX = ± 0.025 SURFACE FINISH µm 0.6	DRAWN BY: **Jaeyoung Nam** SM By **Adam Dumanowski** Reviewed By **Victor Hua**	The Department of Mechanical Engineering UNIVERSITY OF ALBERTA TITLE: Tare Weight Scale Assembly
MATERIAL: Chrome Stainless Steel		Monday, November 18, 2019 3:10:25 PM Sunday, October 27, 2019 9:35:00 PM	SIZE **B** REV 1
FILE NAME: WeighingScale		SCALE: 1:10	Drawing Number: 2-001 SHEET 1 OF 1







Note: Assembly dimensions may change due to unspecified dimensions for conveyor because of confidentiality

MEC E 460

Instructor: **Dr. Kajsa Duke**
Fall 2019

Group Number: **Group 6**

Project Name: **Automated Filling Machine**

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MM
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X = ± 0.5
X.X = ± 0.1
X.XX = ± 0.025

SURFACE FINISH µm 0.6

MATERIAL: Various

FILE NAME: DrivenConveyor

DRAWN BY: **Adam Dumanowski**

SM By **Adam Dumanowski**

Reviewed By **Jaeyoung Nam**

Wednesday, November 27, 2019 3:07:30 PM
Monday, November 25, 2019 2:14:10 PM

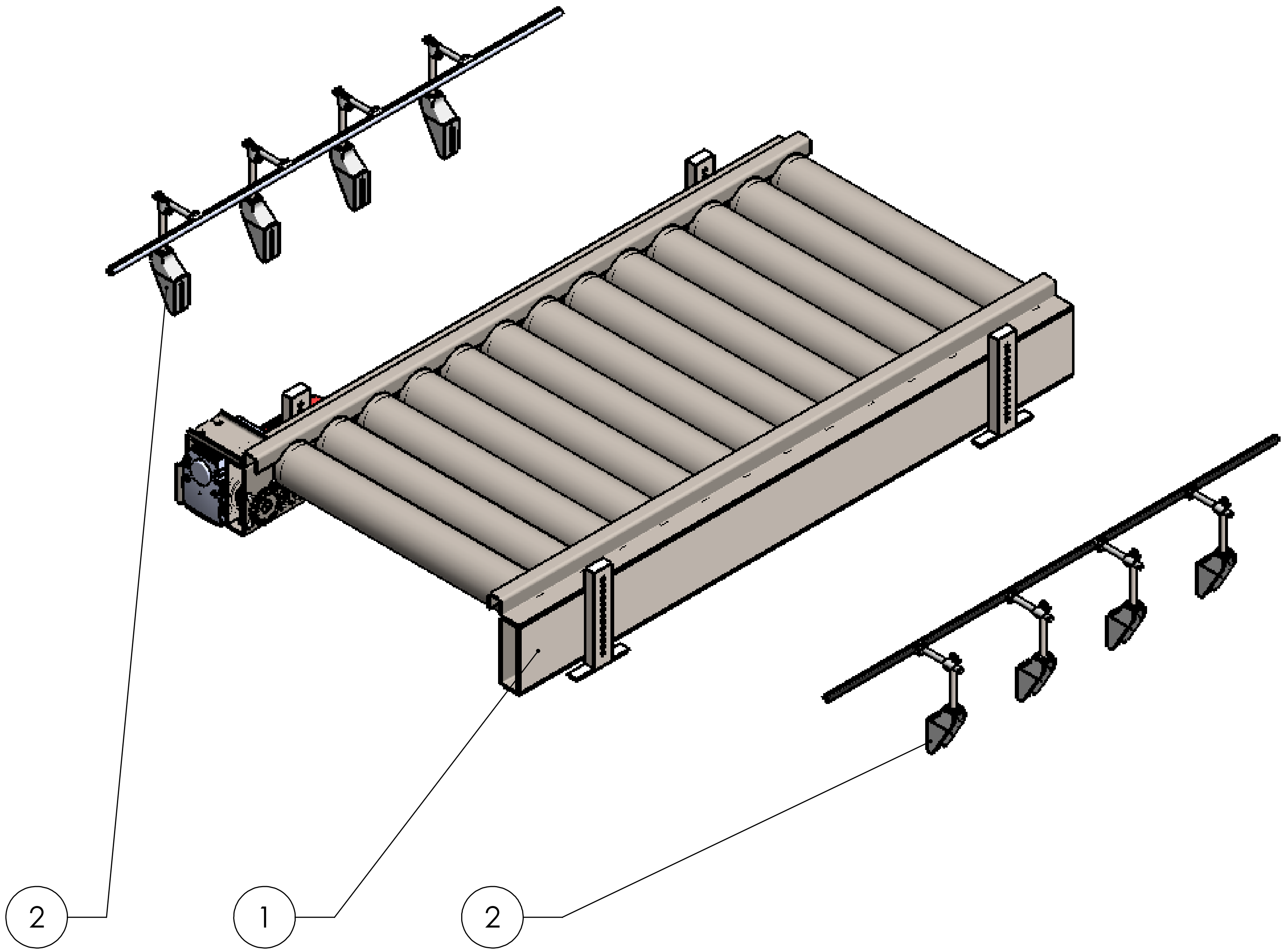
The Department of Mechanical Engineering
UNIVERSITY OF ALBERTA

TITLE:
Driven Roller Conveyor Major-Assembly

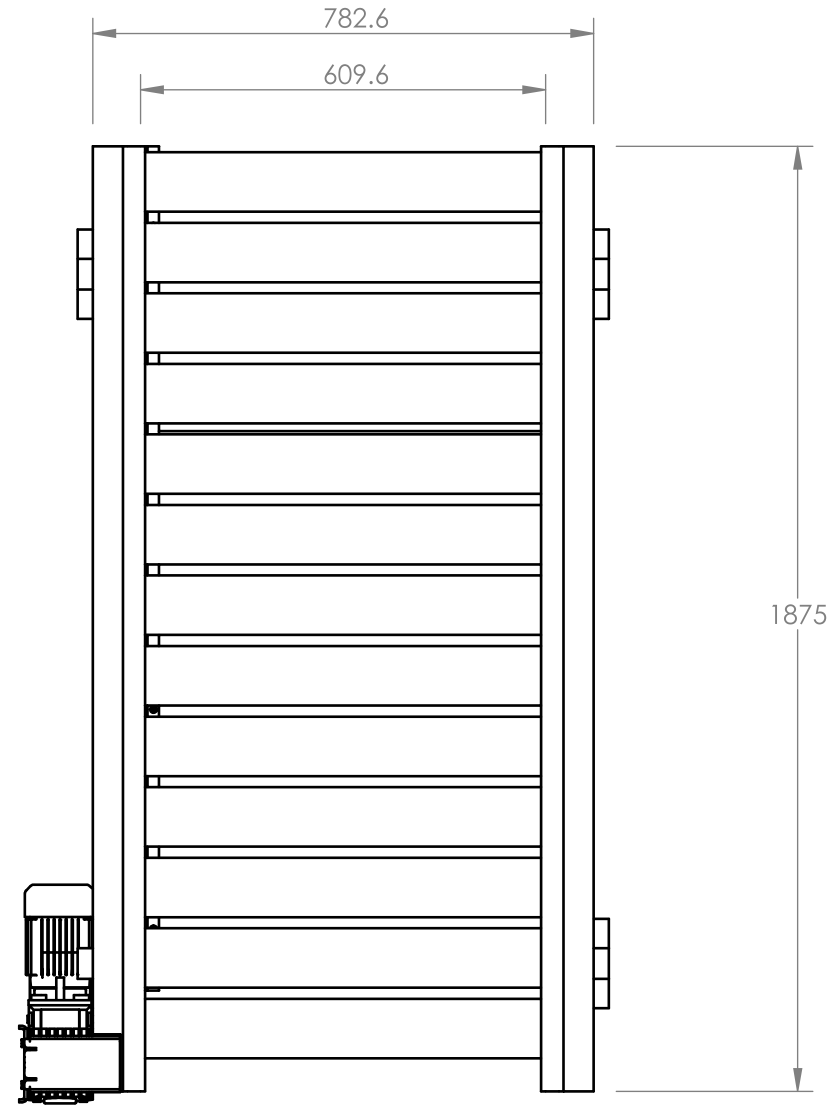
SIZE **B** REV 1

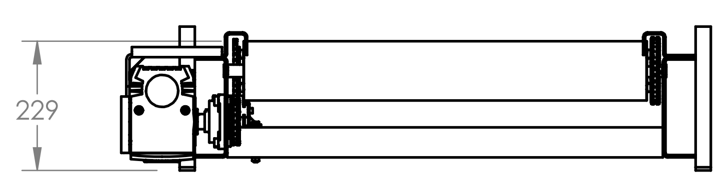
SCALE: 1:20 | Drawing Number: 3-001 | SHEET 1 OF 1

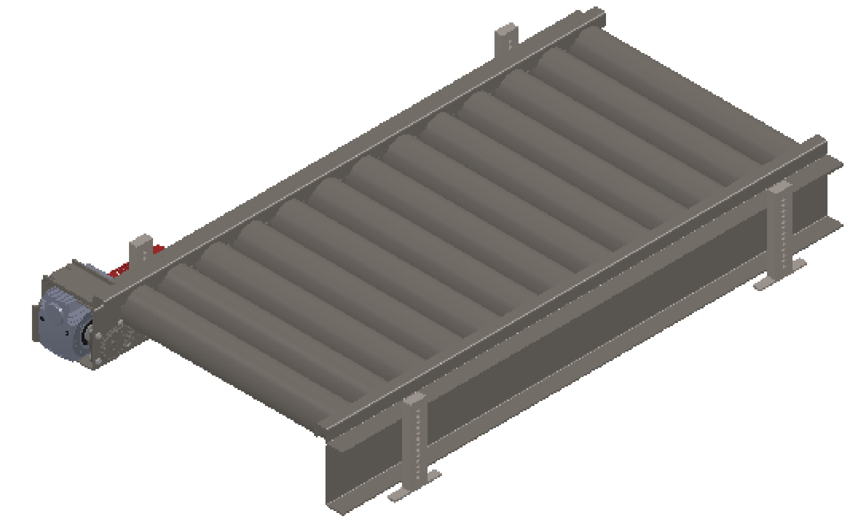
ITEM NO.	PART NAME	MANUFACTURER	DESCRIPTION	QTY.
1	Model 535 Chain Driven Live Roller Conveyor	Titan Conveyors	Chain driven roller conveyor	1
2	Side Rail Assembly	Titan Conveyors	Side rail of the driven roller conveyor	2



MEC E 460 Instructor: Dr. Kajsa Duke Fall 2019 Group Number: Group 6 Project Name: Automated Filling Machine	UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MM TOLERANCES: ANGULAR: ± 0.5° LINEAR X = ± 0.5 X.X = ± 0.1 X.XX = ± 0.025 SURFACE FINISH µm 0.6	DRAWN BY: Adam Dumanowski SM By: Adam Dumanowski Reviewed By: Jaeyoung Nam	The Department of Mechanical Engineering UNIVERSITY OF ALBERTA TITLE: Exploded View of Driven Roller Conveyor Major-Assembly
MATERIAL: Various		Wednesday, November 27, 2019 3:07:30 PM Monday, November 25, 2019 2:14:10 PM	SIZE: B REV: 1
FILE NAME: DrivenConveyor		SCALE: 1:20	Drawing Number: 3-002 SHEET 1 OF 1







Note: CAD was modified from "Chain driven roller conveyor" model found on GrabCad due to CAD not being able to be supplied by roller conveyor mannufacturer used in this project.

MEC E 460

Instructor: **Dr. Kajsa Duke**
Fall 2019

Group Number: **Group 6**

Project Name: **Automated Filling Machine**

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MM
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X = ± 0.5
X.X = ± 0.1
X.XX = ± 0.025

SURFACE FINISH μm 0.6

MATERIAL: Various

FILE NAME: AssemF3

DRAWN BY: **Adam Dumanowski**

SM By **Adam Dumanowski**

Reviewed By **Jaeyoung Nam**

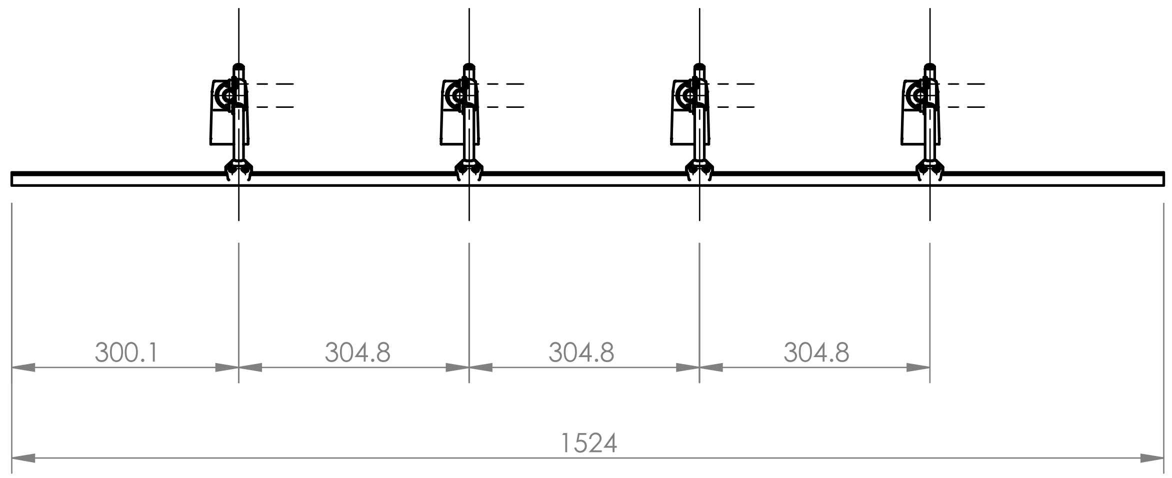
Saturday, November 30, 2019 7:37:40 PM
Monday, November 18, 2019 2:49:03 PM

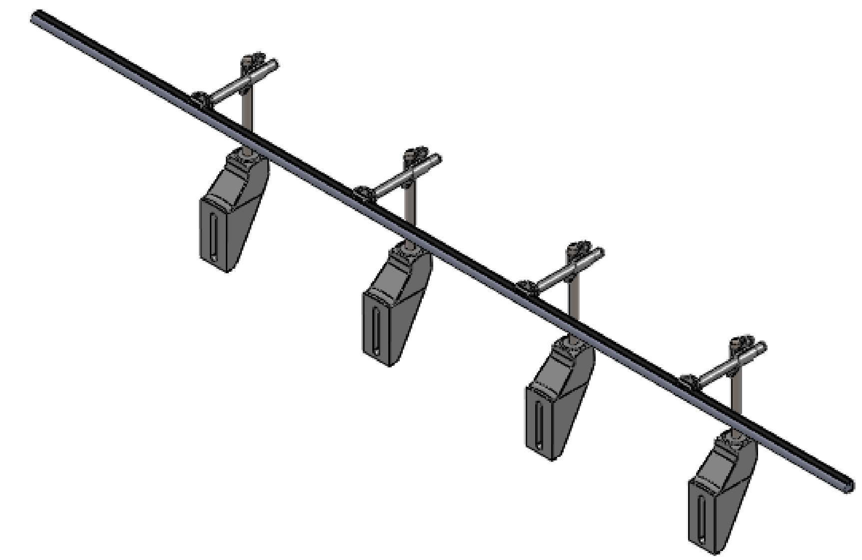
The Department of Mechanical Engineering
UNIVERSITY OF ALBERTA

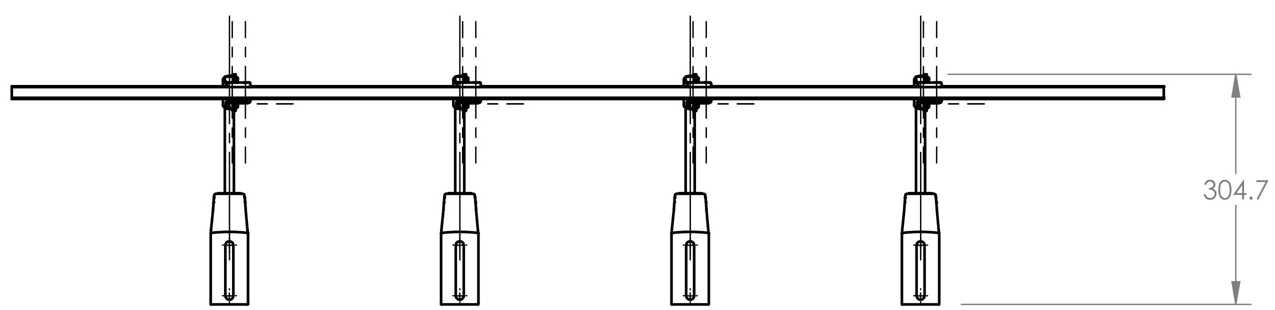
TITLE: Roller Conveyor Assembly

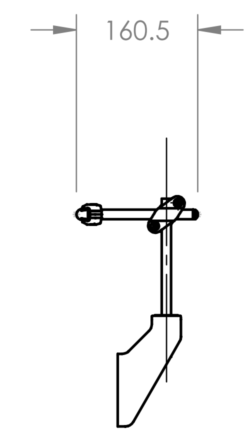
SIZE B | REV 1

SCALE: 1:20 | Drawing Number: 3-003 | SHEET 1 OF 1



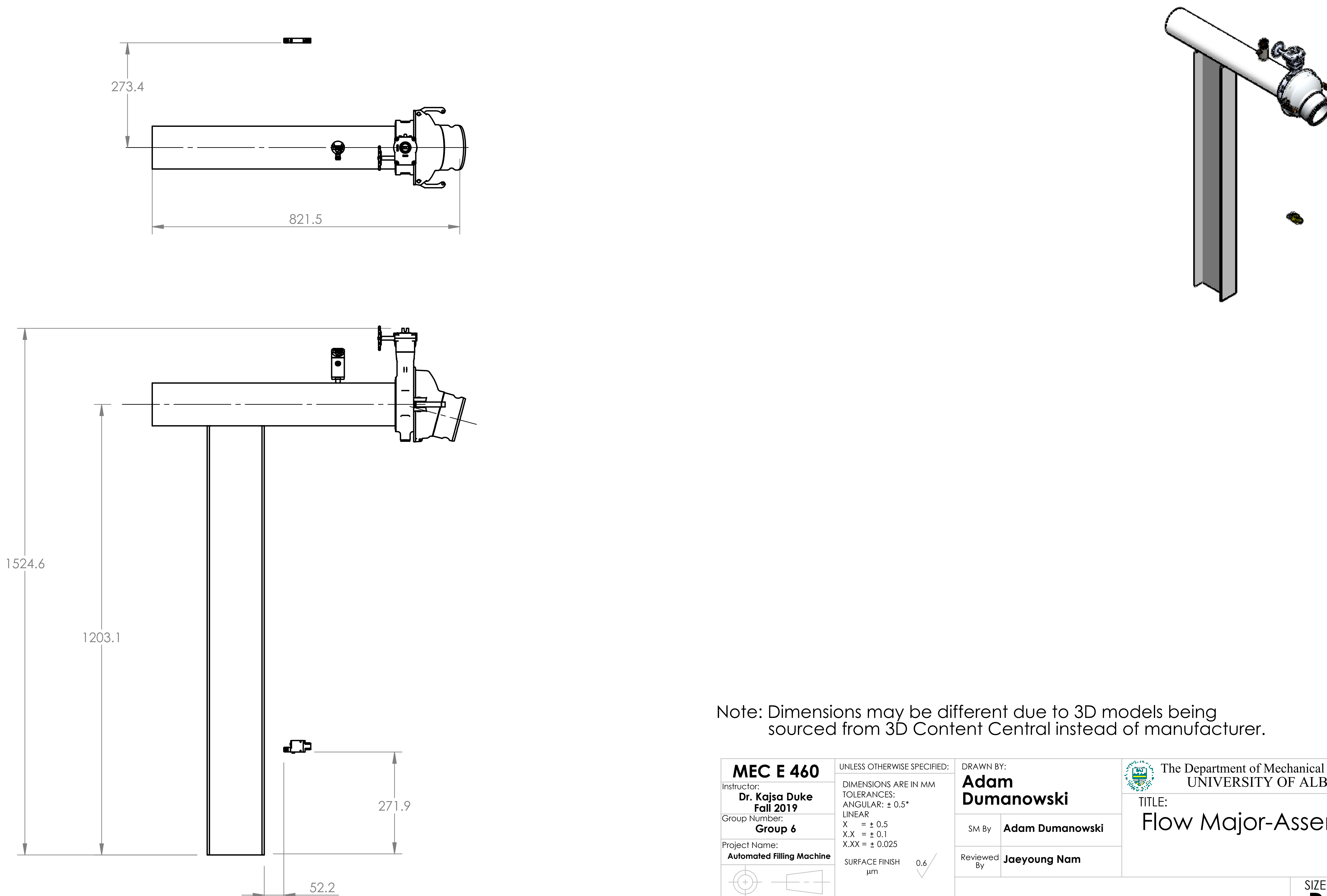






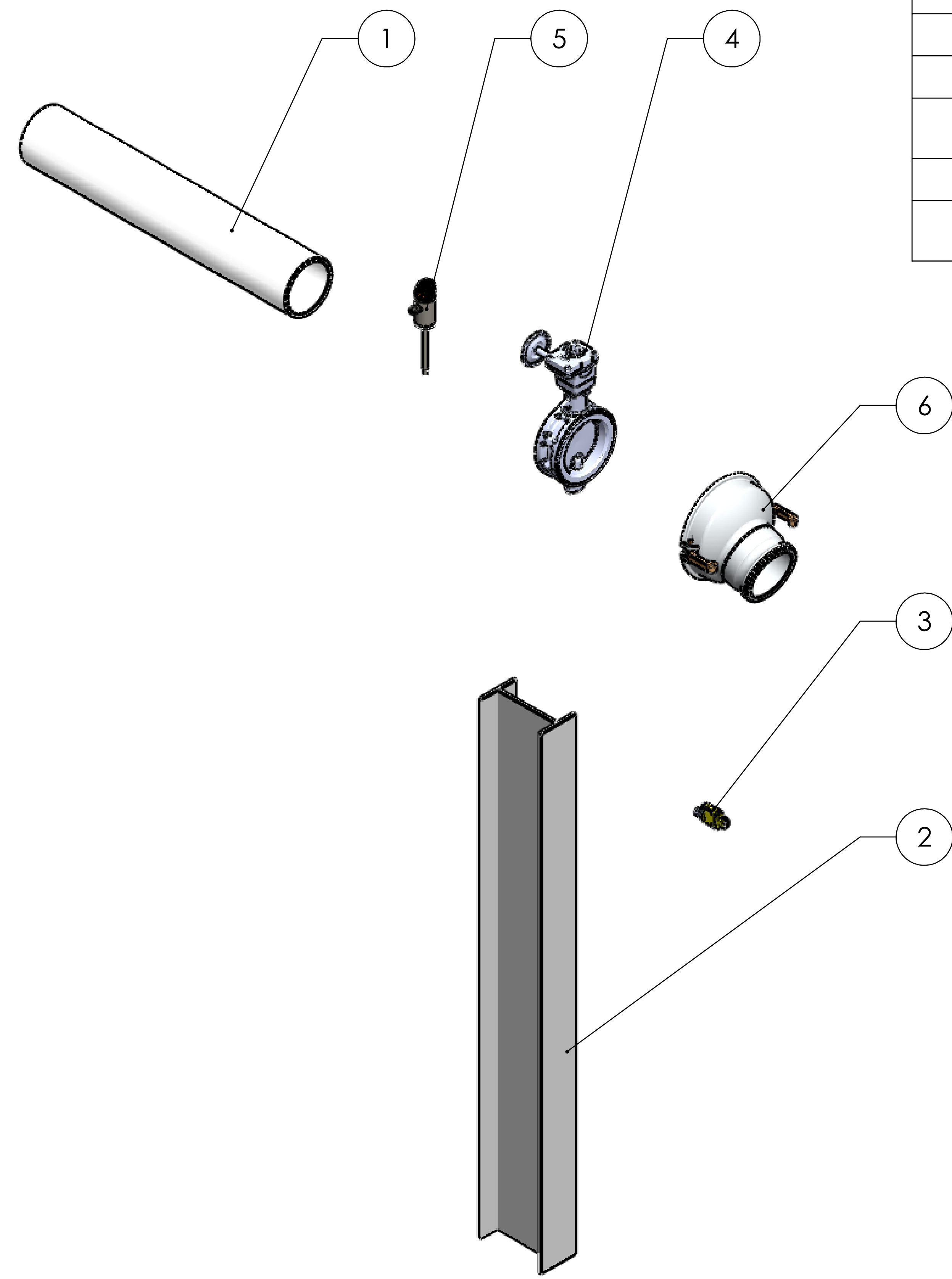
NOTE: Dimensions are configurable for client's needs as the assembly is adjustable.

MEC E 460 Instructor: Dr. Kajsa Duke Fall 2019 Group Number: Group 6 Project Name: Automated Filling Machine	UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MM TOLERANCES: ANGULAR: ± 0.5° LINEAR X = ± 0.5 X.X = ± 0.1 X.XX = ± 0.025 SURFACE FINISH μm 0.6	DRAWN BY: Jaeyoung Nam SM By Jaeyoung Nam Reviewed By Victor Hua	The Department of Mechanical Engineering UNIVERSITY OF ALBERTA TITLE: Driven Roller Side Rail Assembly
MATERIAL: Various		Sunday, December 1, 2019 1:13:13 PM Monday, November 18, 2019 4:26:22 PM	SIZE B REV 1
FILE NAME: Side_Rail_Assembly		SCALE: 1:10	Drawing Number: 3-004 SHEET 1 OF 1



Note: Dimensions may be different due to 3D models being sourced from 3D Content Central instead of manufacturer.

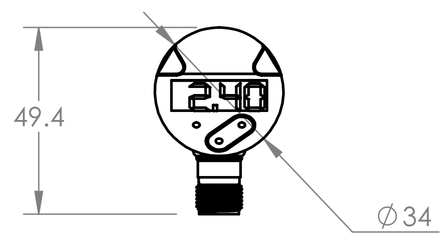
MEC E 460 Instructor: **Dr. Kajsa Duke** **Fall 2019** Group Number: **Group 6** Project Name: **Automated Filling Machine**	UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MM TOLERANCES: ANGULAR: ± 0.5° LINEAR X = ± 0.5 X.X = ± 0.1 X.XX = ± 0.025 SURFACE FINISH µm 0.6	DRAWN BY: **Adam Dumanowski** SM By **Adam Dumanowski** Reviewed By **Jaeyoung Nam**	The Department of Mechanical Engineering UNIVERSITY OF ALBERTA TITLE: Flow Major-Assembly
MATERIAL: Various		Wednesday, November 27, 2019 3:23:52 PM Monday, November 18, 2019 6:18:05 PM	SIZE **B** REV 1
FILE NAME: Flow3		SCALE: 1:20	Drawing Number: 4-001 SHEET 1 OF 1

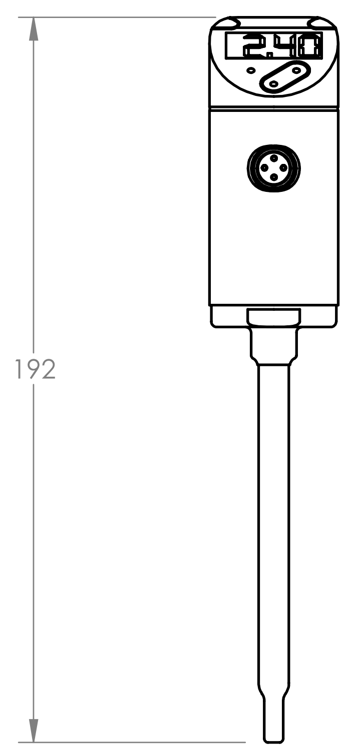


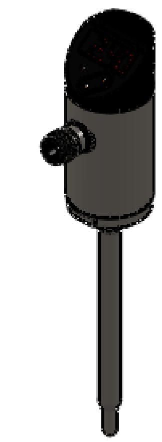
ITEM NO.	PART NAME	MANUFACTURER	DESCRIPTION	QTY.
1	4PVC	N/A	4" piping from the honey storage tank	1
2	8003K156	MetalsDepot	I-Beam	1
3	Photo Sensor2	Titan Conveyors	Photoemitter sensor	1
4	4" Electrical Butterfly Valve D971X-10S	Yuanda Valve	4" Electric Butterfly Valve	1
5	FTS100-1002	AutomationDirect	Flow Sensor	1
6	Liquip-API-MC100	N/A	4" 45-degree camlock (similar CAD sourced from 3D Content Central)	1

Note: Parts that do not have a manufacturer are currently owned by the client.

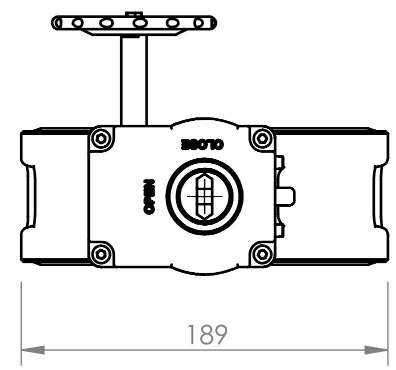
MEC E 460 Instructor: **Dr. Kajsa Duke Fall 2019** Group Number: **Group 6** Project Name: **Automated Filling Machine**	UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MM TOLERANCES: ANGULAR: ± 0.5° LINEAR X = ± 0.5 X.X = ± 0.1 X.XX = ± 0.025 SURFACE FINISH µm 0.6	DRAWN BY: **Adam Dumanowski** SM By **Adam Dumanowski** Reviewed By **Jaeyoung Nam**	The Department of Mechanical Engineering UNIVERSITY OF ALBERTA TITLE: Exploded View of Flow Major-Assembly
MATERIAL: Various		Wednesday, November 27, 2019 3:23:52 PM Monday, November 18, 2019 6:18:05 PM	SIZE **B** REV 1
FILE NAME: Flow3		SCALE: 1:20	Drawing Number: 4-002 SHEET 1 OF 1

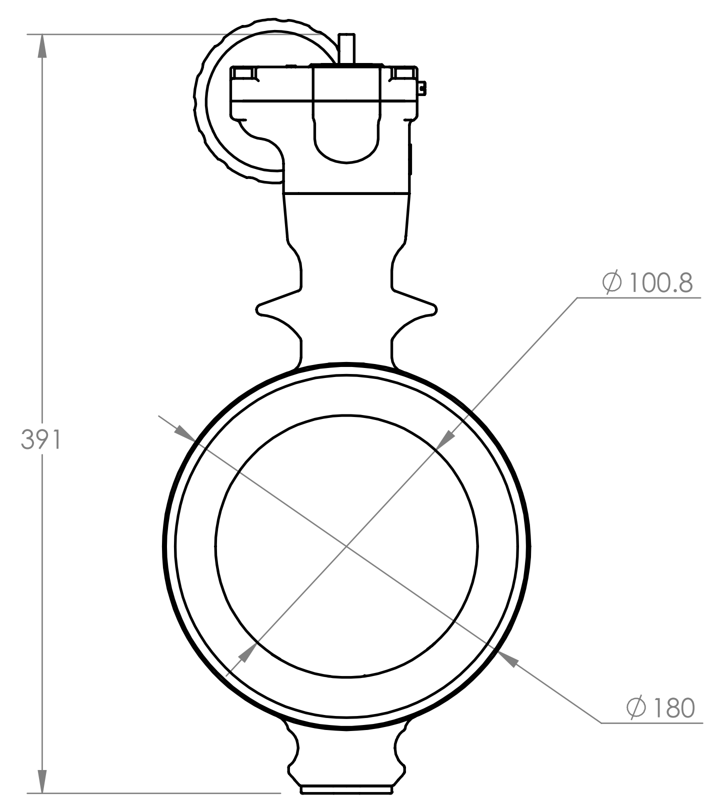


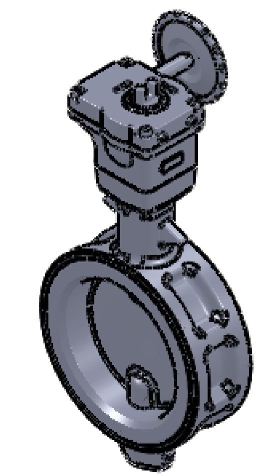




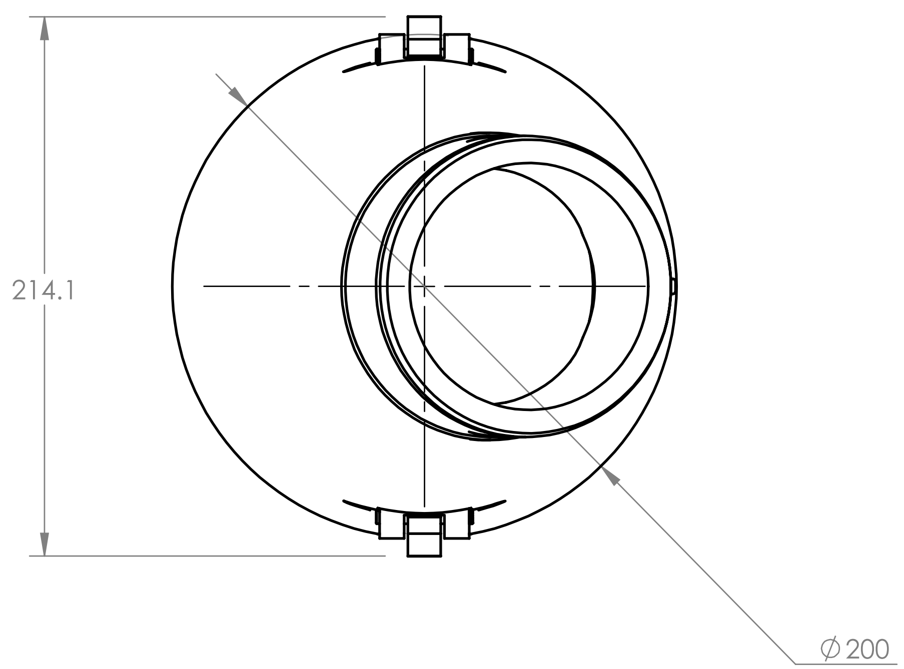
MEC E 460	UNLESS OTHERWISE SPECIFIED:	DRAWN BY: Adam Dumanowski	The Department of Mechanical Engineering UNIVERSITY OF ALBERTA
Instructor: Dr. Kajsa Duke Fall 2019	DIMENSIONS ARE IN MM TOLERANCES: ANGULAR: ± 0.5° LINEAR X = ± 0.5 X.X = ± 0.1 X.XX = ± 0.025	SM By ProSense	TITLE: Flow Sensor Assembly
Group Number: Group 6	SURFACE FINISH μm 0.6	Reviewed By Jaeyoung Nam	
Project Name: Automated Filling Machine		Monday, November 25, 2019 9:28:17 PM Monday, November 25, 2019 9:20:40 PM	SIZE B REV 1
MATERIAL: Various			
FILE NAME: FTS100-1002		SCALE: 1:2	Drawing Number: 4-003 SHEET 1 OF 1

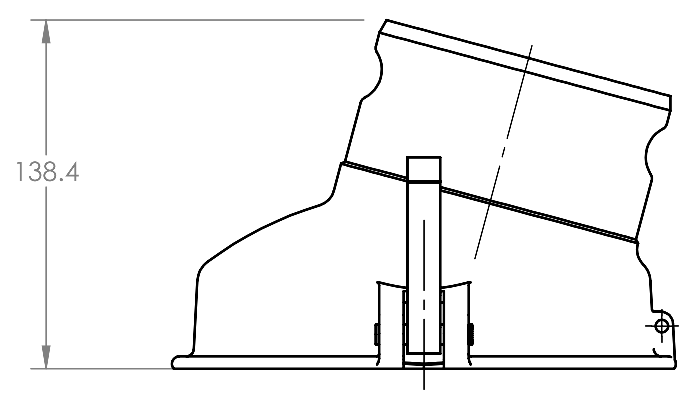


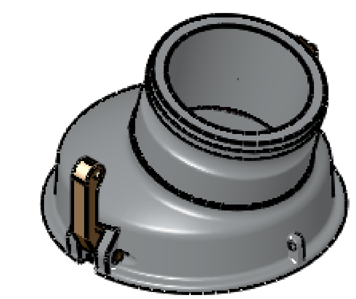




MEC E 460 Instructor: **Dr. Kajsa Duke** **Fall 2019** Group Number: **Group 6** Project Name: **Automated Filling Machine**	UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MM TOLERANCES: ANGULAR: ± 0.5° LINEAR X = ± 0.5 X.X = ± 0.1 X.XX = ± 0.025 SURFACE FINISH µm 0.6	DRAWN BY: **Adam Dumanowski** SM By **Apasipep** Reviewed By **Jaeyoung Nam**	The Department of Mechanical Engineering UNIVERSITY OF ALBERTA TITLE: Butterfly Solenoid Valve Assembly
MATERIAL: Various		Wednesday, November 27, 2019 7:39:11 PM Monday, November 25, 2019 9:40:19 PM	SIZE **B** REV 1
FILE NAME: valve		SCALE: 1:5	Drawing Number: 4-004 SHEET 1 OF 1







MEC E 460

Instructor:
Dr. Kajsa Duke
Fall 2019
Group Number:
Group 6
Project Name:
Automated Filling Machine

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MM
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X = ± 0.5
X.X = ± 0.1
X.XX = ± 0.025
SURFACE FINISH µm 0.6

DRAWN BY:
Adam Dumanowski
SM By **3D Content Central**
Reviewed By **Jaeyoung Nam**

The Department of Mechanical Engineering
UNIVERSITY OF ALBERTA

TITLE:
45-Degree Camlock Assembly

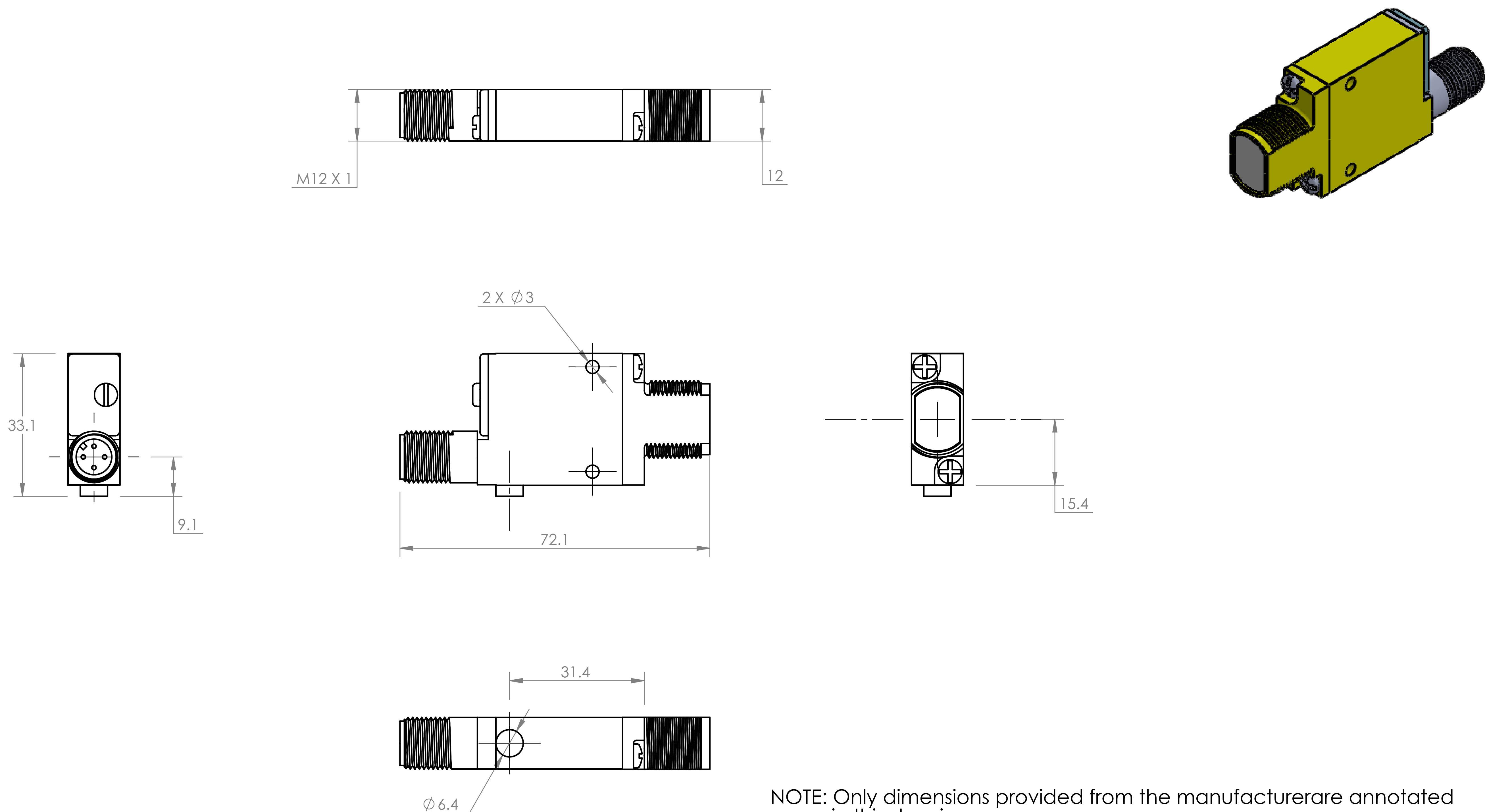
MATERIAL:
Various

Wednesday, November 27, 2019 7:48:19 PM
Monday, August 23, 2010 10:58:42 PM

SIZE **B** REV 1

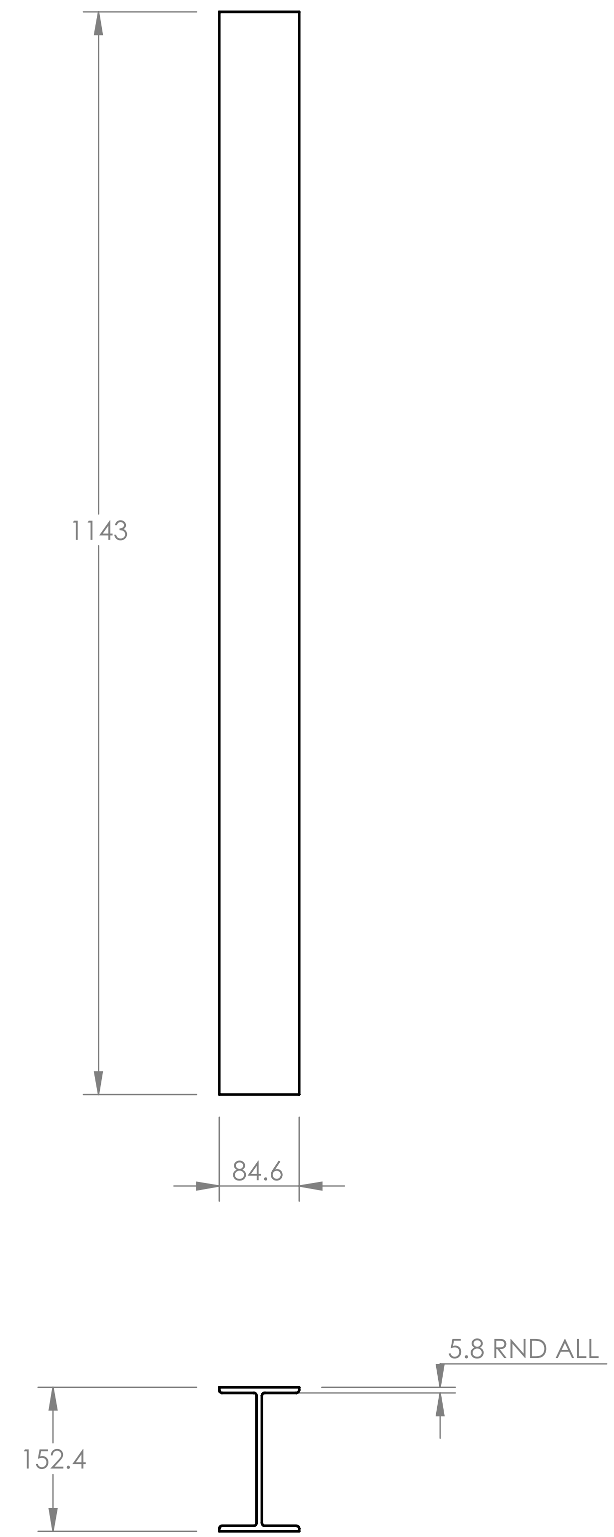
FILE NAME:
Liquip-API-MC100

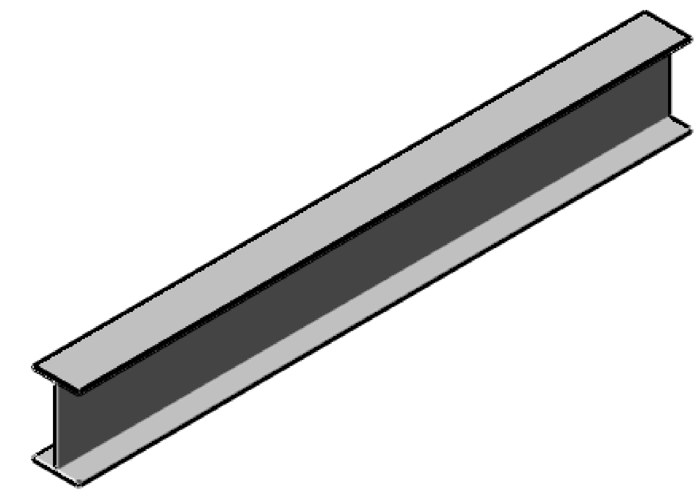
SCALE: 1:5 | Drawing Number: 4-005 | SHEET 1 OF 1



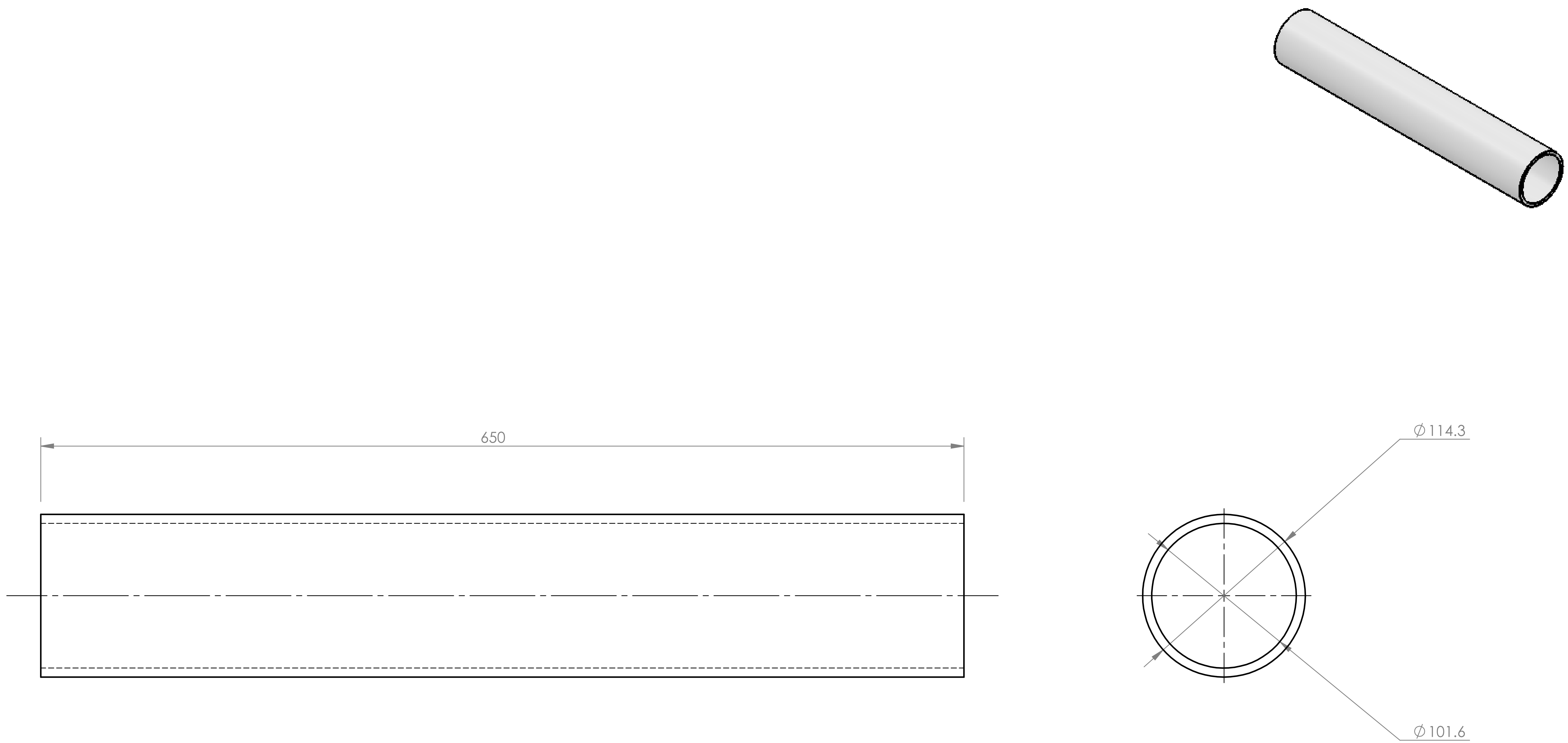
NOTE: Only dimensions provided from the manufacturerare annotated in this drawing

MEC E 460 Instructor: **Dr. Kajsa Duke Fall 2019** Group Number: **Group 6** Project Name: **Automated Filling Machine**	UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MM TOLERANCES: ANGULAR: ± 0.5° LINEAR X = ± 0.5 X.X = ± 0.1 X.XX = ± 0.025 SURFACE FINISH µm 0.6	DRAWN BY: **Jaeyoung Nam** SM By **BANNER** Reviewed By **Victor Hua**	The Department of Mechanical Engineering UNIVERSITY OF ALBERTA TITLE: Photoelectric Sensor Assembly
MATERIAL: Various		Sunday, December 1, 2019 4:43:17 PM Monday, November 18, 2019 3:17:05 PM	SIZE **B** REV 1
FILE NAME: Photo Sensor		SCALE: 1:1	Drawing Number: 4-006 SHEET 1 OF 1

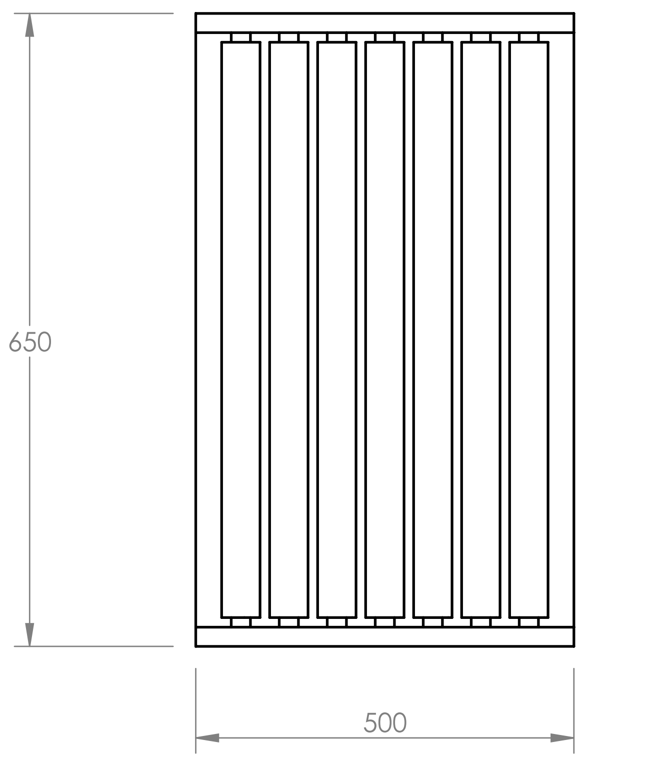


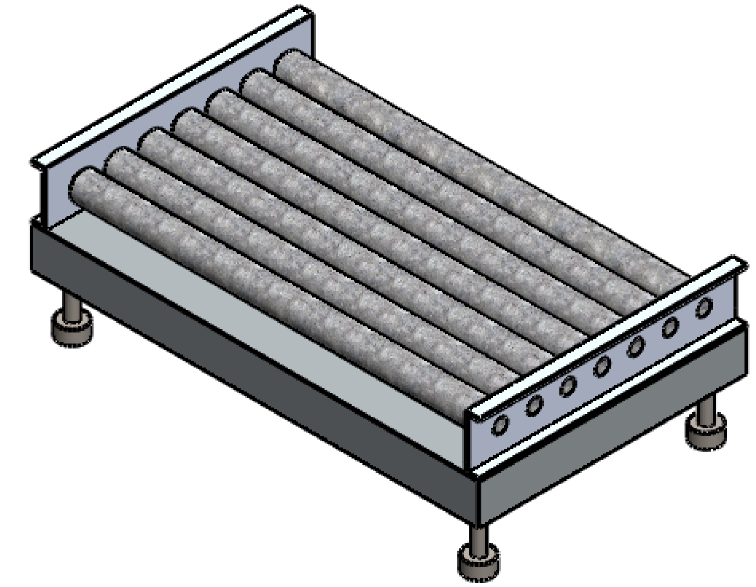


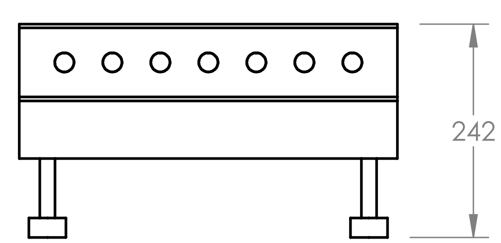
MEC E 460 Instructor: Dr. Kajsa Duke Fall 2019 Group Number: Group 6 Project Name: Automated Filling Machine	UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MM TOLERANCES: ANGULAR: ± 0.5° LINEAR X = ± 0.5 X.X = ± 0.1 X.XX = ± 0.025 SURFACE FINISH µm 0.6	DRAWN BY: Adam Dumanowski SM By: Adam Dumanowski Reviewed By: Jaeyoung Nam	The Department of Mechanical Engineering UNIVERSITY OF ALBERTA TITLE: I-Beam
MATERIAL: ASTM A992/A572-50 (Grade 50)		Wednesday, November 27, 2019 7:25:43 PM Wednesday, August 20, 2014 6:41:40 AM	SIZE: B REV: 1
FILE NAME: 8003K156_6061 ALUMINUM I-BEAM		SCALE: 1:10	Drawing Number: 4-007 SHEET 1 OF 1

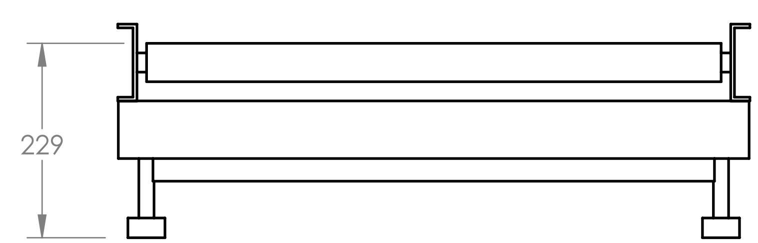


MEC E 460 Instructor: **Dr. Kajsa Duke Fall 2019** Group Number: **Group 6** Project Name: **Automated Filling Machine**	UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MM TOLERANCES: ANGULAR: ± 0.5° LINEAR X = ± 0.5 X.X = ± 0.1 X.XX = ± 0.025 SURFACE FINISH µm 0.6	DRAWN BY: **Adam Dumanowski** SM By **Adam Dumanowski** Reviewed By **Jaeyoung Nam**	The Department of Mechanical Engineering UNIVERSITY OF ALBERTA TITLE: 4" PVC Piping
MATERIAL: PVC 0.007 Plasticized		Wednesday, November 27, 2019 7:31:06 PM Monday, November 18, 2019 5:43:21 PM	SIZE **B** REV 1
FILE NAME: 4PVC		SCALE: 1:5	Drawing Number: 4-008 SHEET 1 OF 1



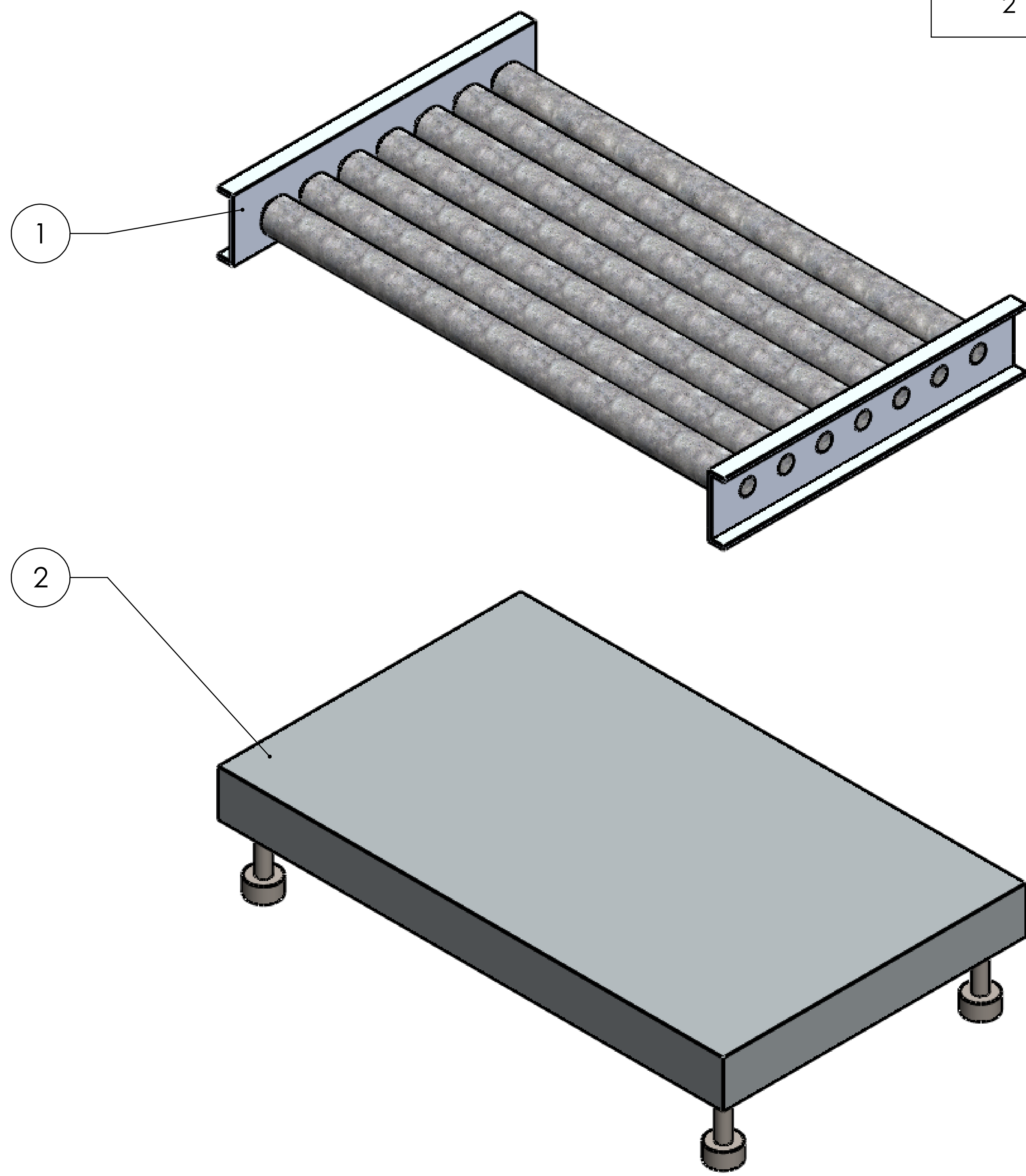




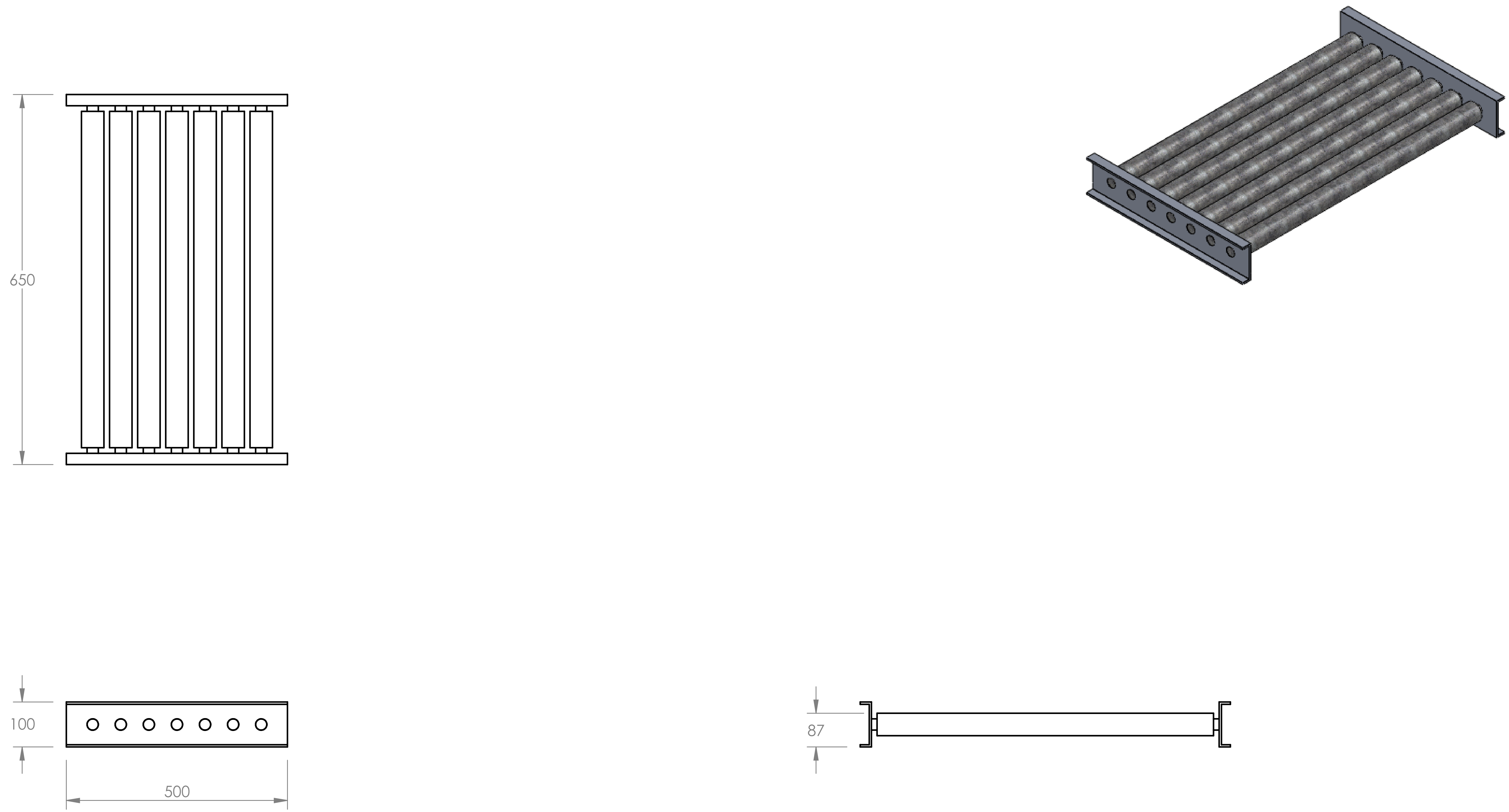


MEC E 460 Instructor: **Dr. Kajsa Duke** **Fall 2019** Group Number: **Group 6** Project Name: **Automated Filling Machine**	UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MM TOLERANCES: ANGULAR: ± 0.5° LINEAR X = ± 0.5 X.X = ± 0.1 X.XX = ± 0.025 SURFACE FINISH µm 0.6	DRAWN BY: **Jaeyoung Nam** SM By **Adam Dumanowski** Reviewed By **Adam Dumanowski**	The Department of Mechanical Engineering UNIVERSITY OF ALBERTA TITLE: Free Roller Conveyor Major-Assembly
MATERIAL: Various		Monday, November 25, 2019 3:07:24 PM Monday, November 25, 2019 1:54:57 PM	SIZE **B** REV 1
FILE NAME: FreeRollerAssembly		SCALE: 1:10	Drawing Number: 5-001 SHEET 1 OF 1

ITEM NO.	PART NAME	MANUFACTURER	DESCRIPTION	QTY.
1	Roller conveyor YRO	KERN	Free roller conveyor	1
2	Platform scale IFB	KERN	High-resolution scale for industrial application	1

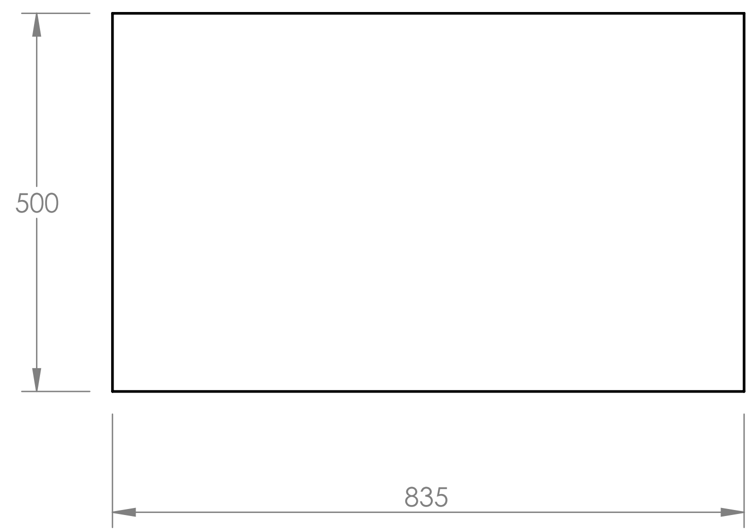


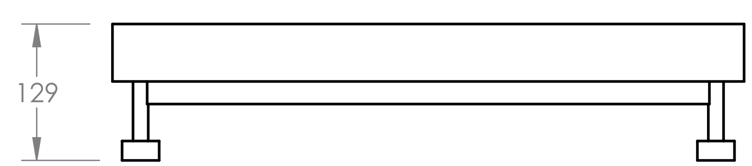
MEC E 460 Instructor: Dr. Kajsa Duke Fall 2019 Group Number: Group 6 Project Name: Automated Filling Machine	UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MM TOLERANCES: ANGULAR: ± 0.5° LINEAR X = ± 0.5 X.X = ± 0.1 X.XX = ± 0.025 SURFACE FINISH µm 0.6	DRAWN BY: Jaeyoung Nam SM By Adam Dumanowski Reviewed By Adam Dumanowski Monday, November 25, 2019 3:07:24 PM Monday, November 25, 2019 1:54:57 PM	The Department of Mechanical Engineering UNIVERSITY OF ALBERTA TITLE: Exploded View of Free Roller Conveyor Major-Assembly SIZE B REV 1
MATERIAL: Various FILE NAME: FreeRollerAssembly		SCALE: 1:7	Drawing Number: 5-002 SHEET 1 OF 1

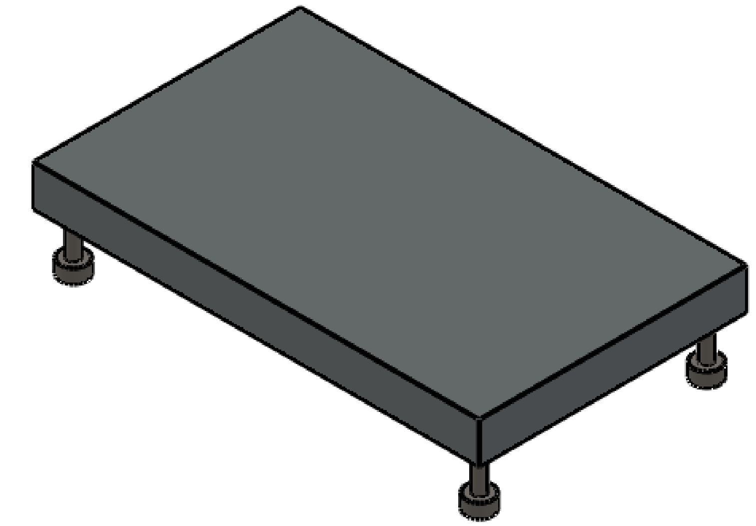


NOTE: Only known dimensions provided by the manufacturer are annotated

MEC E 460 Instructor: Dr. Kajsa Duke Fall 2019 Group Number: Group 6 Project Name: Automated Filling Machine	UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MM TOLERANCES: ANGULAR: ± 0.5° LINEAR X = ± 0.5 X.X = ± 0.1 X.XX = ± 0.025 SURFACE FINISH µm 0.6	DRAWN BY: Jaeyoung Nam SM By: Adam Dumanowski Reviewed By: Adam Dumanowski	The Department of Mechanical Engineering UNIVERSITY OF ALBERTA TITLE: Free Roller Conveyor Assembly
MATERIAL: Various		Monday, November 18, 2019 4:22:15 PM Monday, November 18, 2019 4:06:04 PM	SIZE B REV 1
FILE NAME: FreeRoller1		SCALE: 1:10	Drawing Number: 5-003 SHEET 1 OF 1







MEC E 460

Instructor:
Dr. Kajsa Duke
Fall 2019

Group Number:
Group 6

Project Name:
Automated Filling Machine

MATERIAL:
Various

FILE NAME:
FreeScale

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN MM
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X = ± 0.5
X.X = ± 0.1
X.XX = ± 0.025

SURFACE FINISH µm 0.6

DRAWN BY:
Jaeyoung Nam

SM By **Adam Dumanowski**

Reviewed By **Adam Dumanowski**

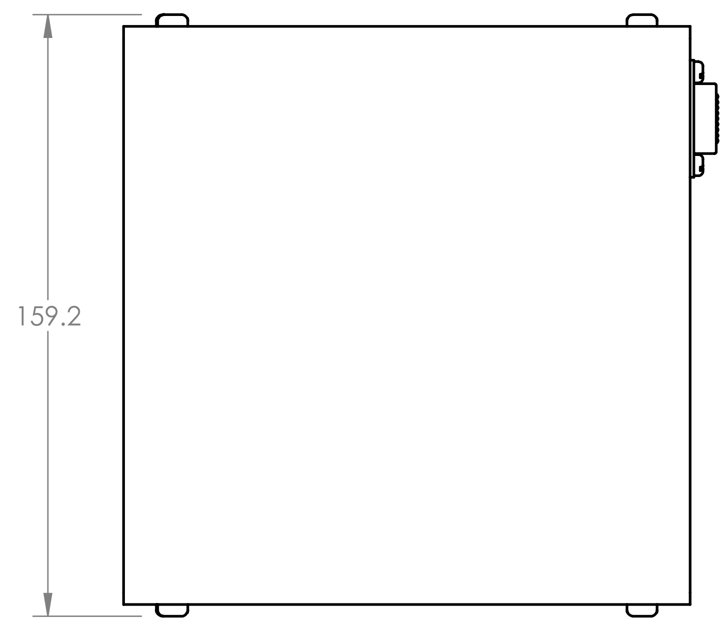
Sunday, November 24, 2019 4:15:57 PM
Monday, November 18, 2019 4:39:20 PM

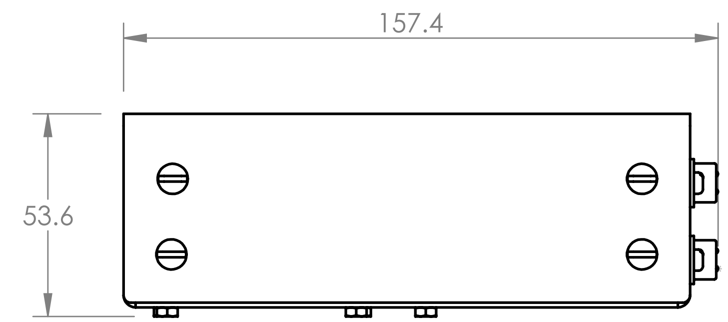
The Department of Mechanical Engineering
UNIVERSITY OF ALBERTA

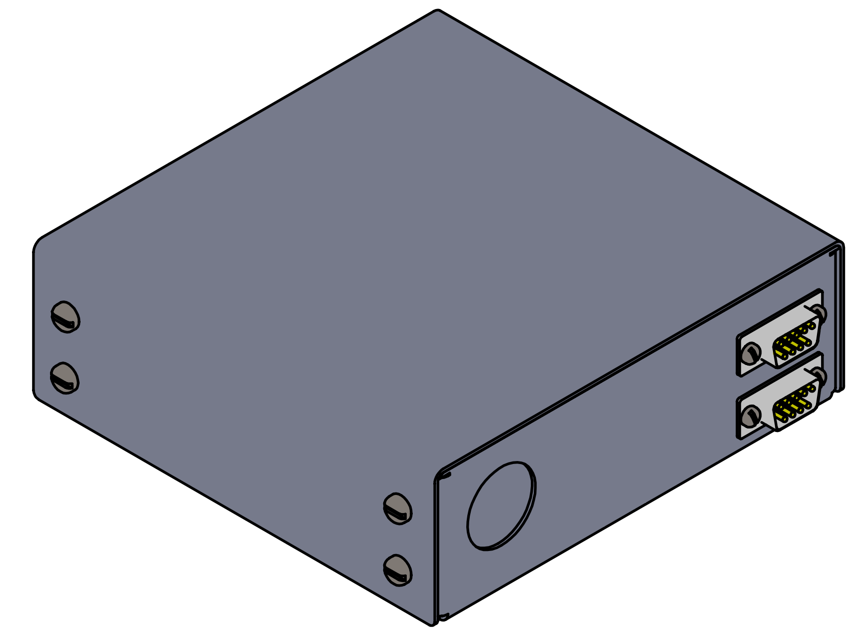
TITLE:
Gross Weight Scale

SIZE	REV
B	1

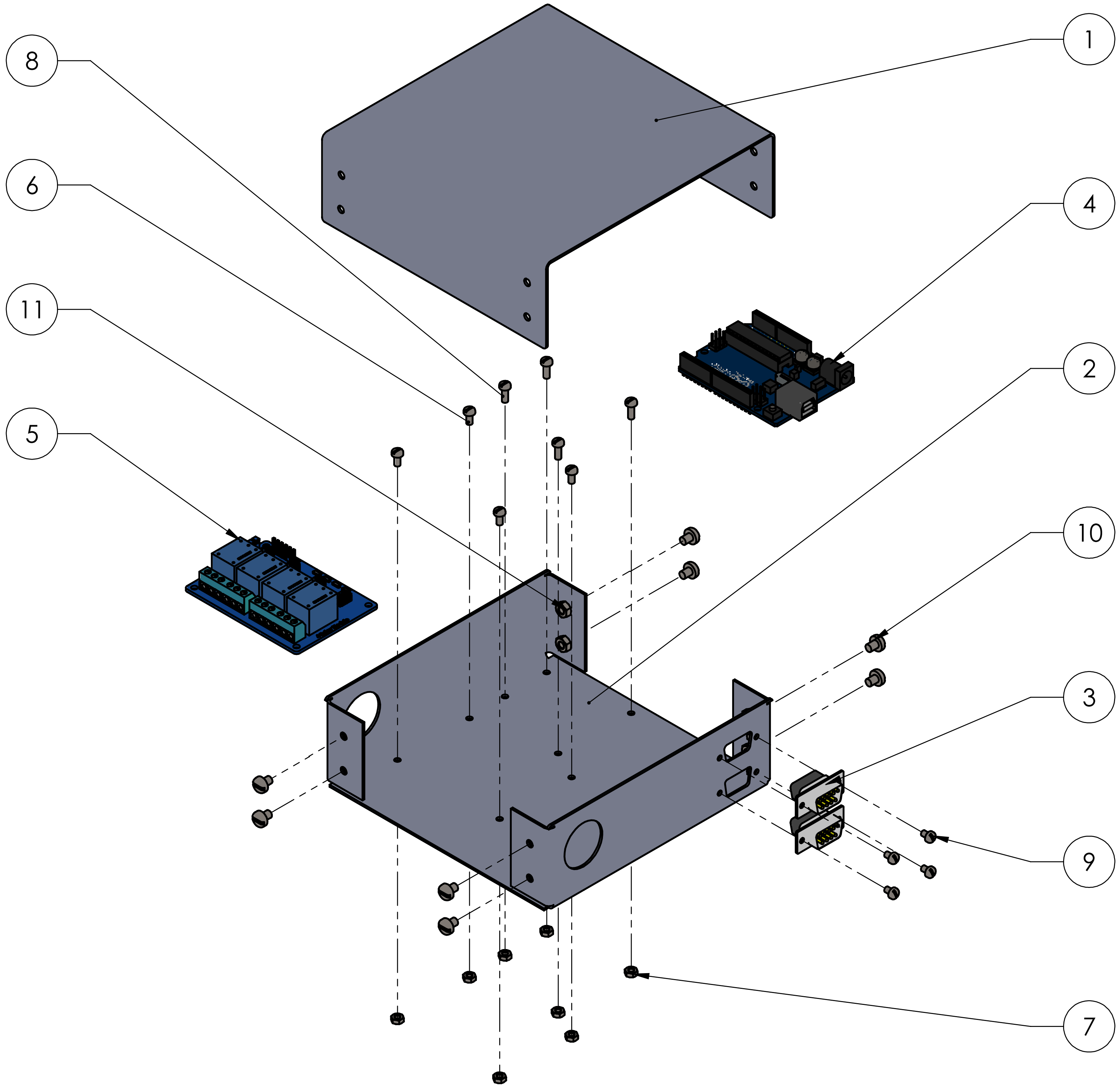
SCALE: 1:10 | Drawing Number: 5-004 | SHEET 1 OF 1







MEC E 460 Instructor: **Dr. Kajsa Duke** **Fall 2019** Group Number: **Group 6** Project Name: **Automated Filling Machine**	UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MM TOLERANCES: ANGULAR: ± 0.5° LINEAR X = ± 0.5 X.X = ± 0.1 X.XX = ± 0.025 SURFACE FINISH µm 0.6	DRAWN BY: **Jaeyoung Nam** SM By **Victor Hua** Reviewed By **Adam Dumanowski**	The Department of Mechanical Engineering UNIVERSITY OF ALBERTA TITLE: Electronic Housing Major-Assembly
MATERIAL: Various		December 1, 2019 10:59:29 AM November 21, 2019 2:31:57 PM	SIZE **B** REV 1
FILE NAME: housing		SCALE: 1:2	Drawing Number: 6-001 SHEET 1 OF 1



ITEM NO.	PART NAME	MANUFACTURER	DESCRIPTION	QTY.
1	Electronic housing top	PROTOCASE	Housing for electronics	1
2	Electronic housing bottom	PROTOCASE	Housing for electronics	1
3	DB9_pins	GUMP Trade	Female to male head	2
4	Arduino UNO	ARDUINO	The main processor for the whole system	1
5	Relay module	Lysignal	Turning on and off a circuit	1
6	SM3X6MM-2701	APM HEXSEAL	Bolt to hold in Relay Module	4
7	Metric hex nuts, Stainless steel 18-8 (A-2), 3mm x 0.5mm	Bolt Depot	Nuts to secure the Botls	12
8	RM3X8MM-2701	APM HEXSEAL	Bolts to hold in Arduino	4
9	M3 Flat Head Countersunk Screw Kit,M3 4mm	Walfront	Bolts to hold in 9 pins connector	4
10	M4-0.7 x 5 mm. Phillips-Square Flat-Head Machine Screws	Home Depot	Bolts to hold housing together	8
11	RPC3083-ND	Essentra Components	Nuts to secure the bolts and housing	8

MEC E 460
Instructor: Dr. Kajsa Duke
Fall 2019
Group Number: Group 6
Project Name: Automated Filling Machine

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MM
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X = ± 0.5
X.X = ± 0.1
X.XX = ± 0.025
SURFACE FINISH µm 0.6

DRAWN BY: **Victor Hua**
SM By: Victor Hua
Reviewed By: Jaeyoung Nam

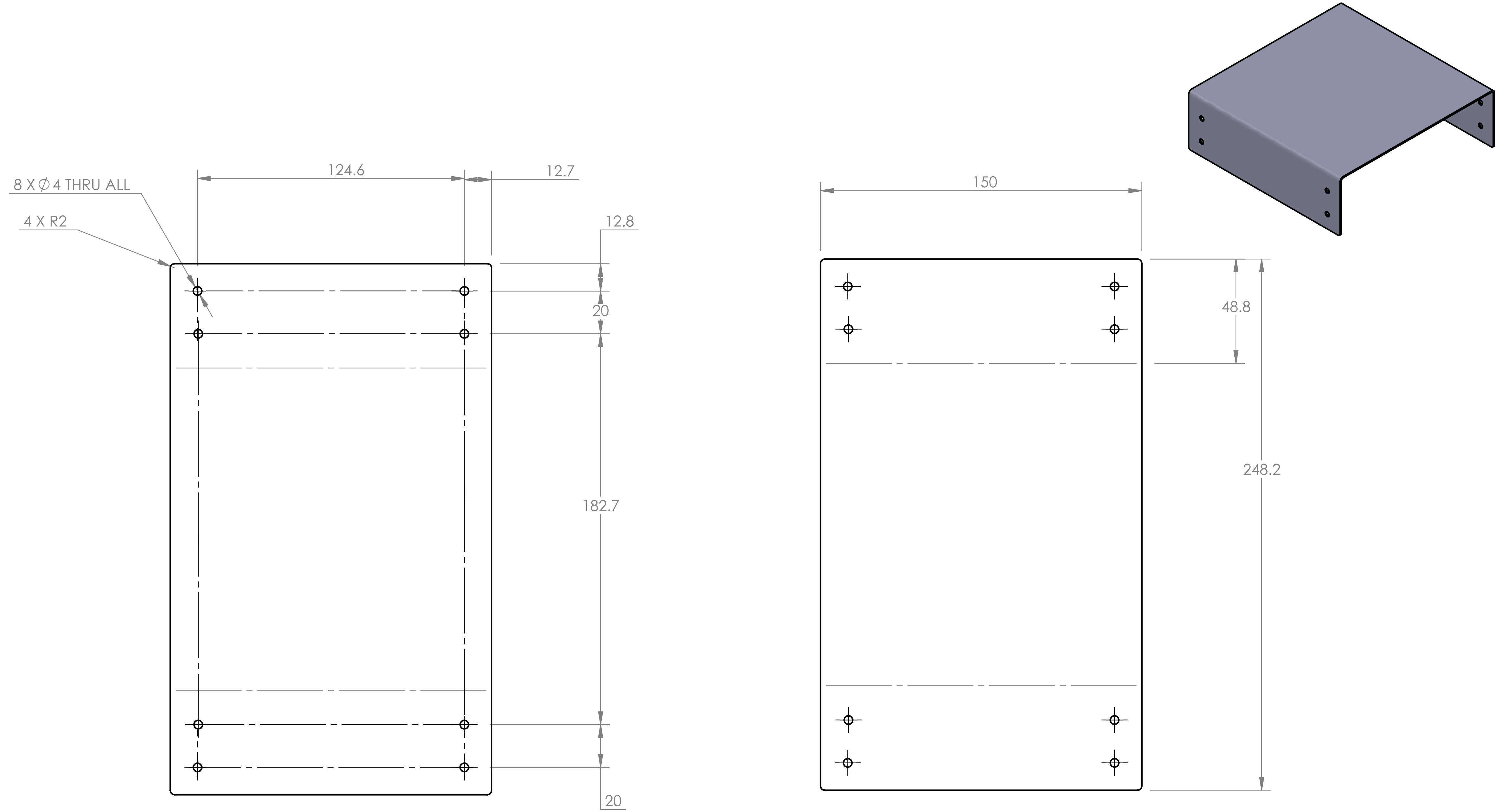
The Department of Mechanical Engineering
UNIVERSITY OF ALBERTA

TITLE: Exploded View of Electronic Housing Major-Assembly

MATERIAL: Various
FILE NAME: housing

December 1, 2019 10:59:29 AM
November 21, 2019 2:31:57 PM

SIZE: **B** | REV: 1
SCALE: 1:2 | Drawing Number: 6-002 | SHEET 1 OF 1



MEC E 460

Instructor:
Dr. Kajsa Duke
Fall 2019

Group Number:
Group 6

Project Name:
Automated Filling Machine

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MM
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X = ± 0.5
X.X = ± 0.1
X.XX = ± 0.025
SURFACE FINISH µm 0.6

DRAWN BY:
Victor Hua

SM By **Victor Hua**

Reviewed By **Jaeyoung nam**

The Department of Mechanical Engineering
UNIVERSITY OF ALBERTA

TITLE:
Electronic Housing Top

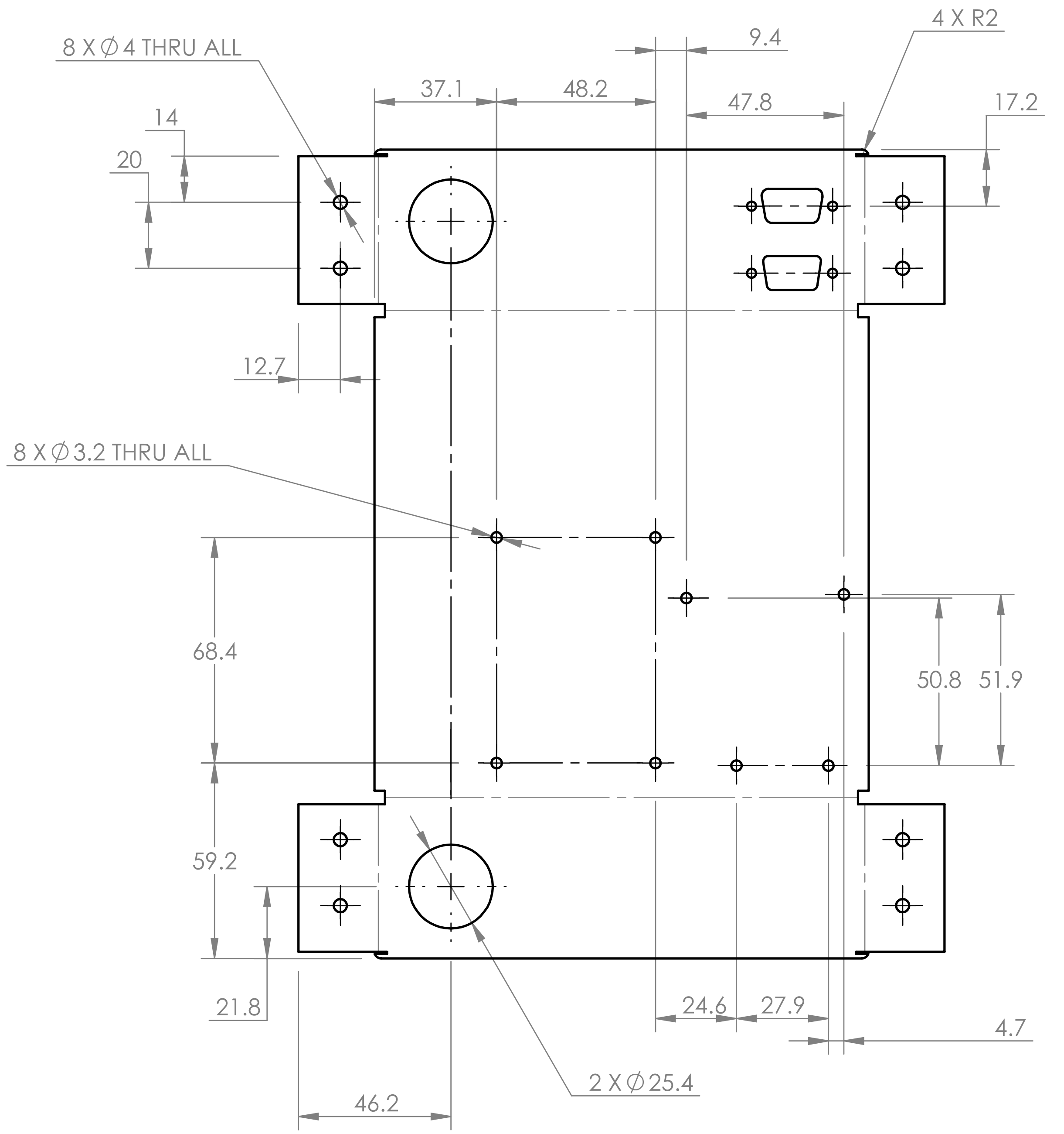
MATERIAL:
Cold Rolled Steel (CRS A1008 CS TP B)

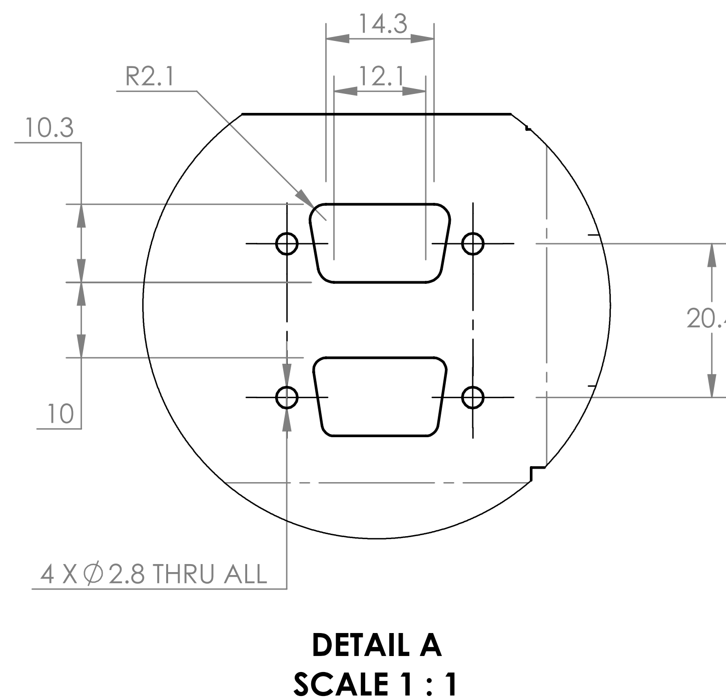
November 30, 2019 4:12:41 PM
November 21, 2019 2:03:30 PM

SIZE **B** REV 1

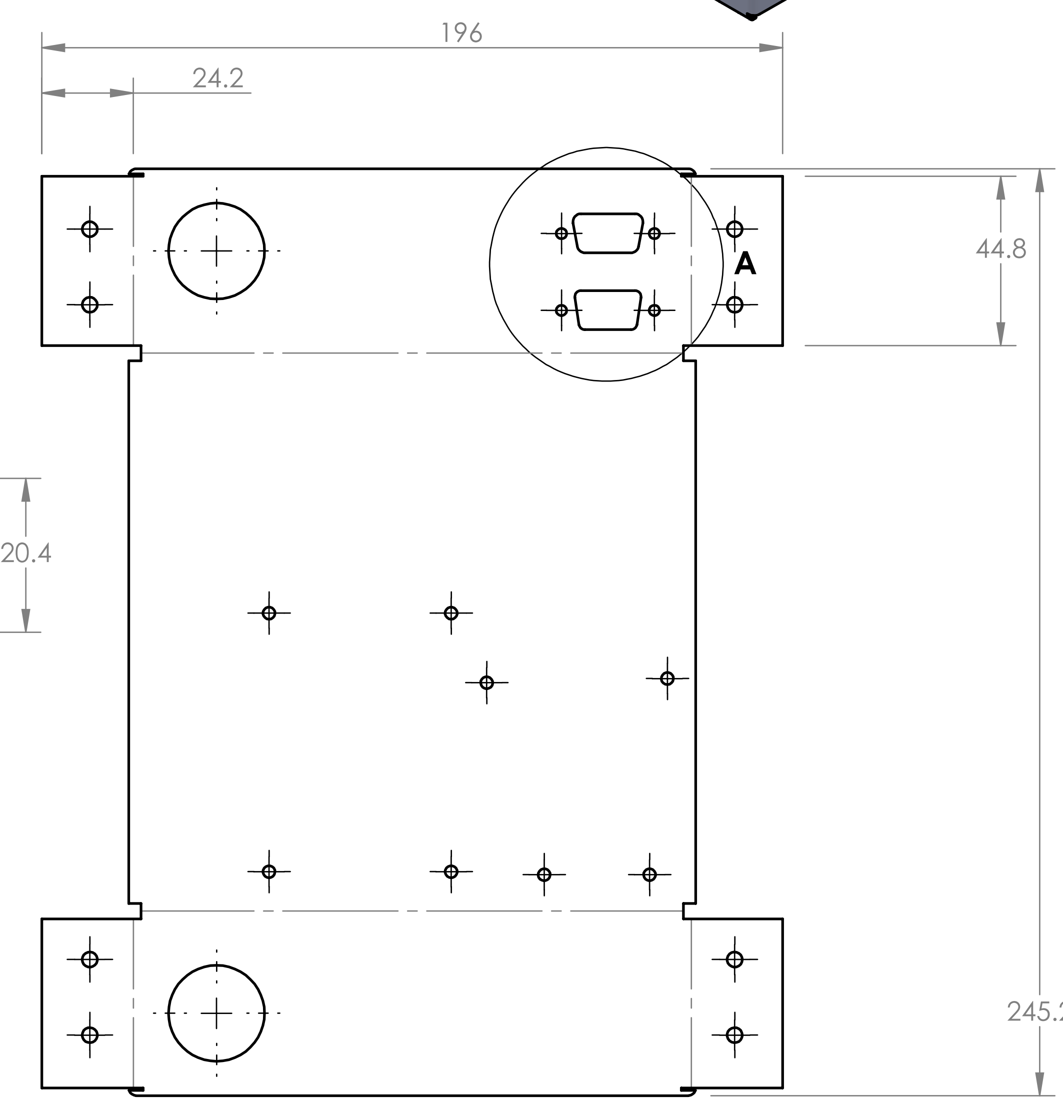
FILE NAME:
housing top

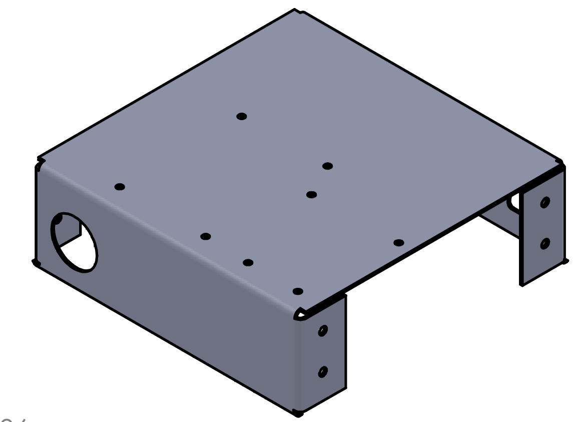
SCALE: 1:2 | Drawing Number: 6-003 | SHEET 1 OF 1





DETAIL A
SCALE 1 : 1





NOTE: Dimensions and locations of holes on the bottom may vary depding on where holes are located in Arduino Uno or relay module

MEC E 460

Instructor:
Dr. Kajsa Duke
Fall 2019
Group Number:
Group 6
Project Name:
Automated Filling Machine

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MM
TOLERANCES:
ANGULAR: ± 0.5°
LINEAR
X = ± 0.5
X.X = ± 0.1
X.XX = ± 0.025
SURFACE FINISH µm 0.6

DRAWN BY:
Victor Hua
SM By **Victor Hua**
Reviewed By **Jaeyoung Nam**

The Department of Mechanical Engineering
UNIVERSITY OF ALBERTA

TITLE:
Electronic Housing Bottom

SIZE **B**
REV 1

MATERIAL:
Cold Rolled Steel (CRS A1008 CS TP B)

November 30, 2019 4:12:40 PM
November 21, 2019 2:03:30 PM

FILE NAME:
housing bottom

SCALE: 1:2
Drawing Number: 6-004
SHEET 1 OF 1