MET 2023

ETTG 1035: Technical Project and Report

CONVERTING EXTRUDER NO. 3 BARREL FROM WATER-COOLED TO AIR-COOLED SYSTEM AT INTEPLAST BAGS & FILMS CORPORATION

by

Bryan Mendoza

2023

Technical Project REPORT

Mechanical Engineering Technology (MET) PROGRAM

Engineering Technologies DEPARTMENT

NEW BRUNSWICK COMMUNITY COLLEGE—SAINT JOHN CAMPUS
950 Grandview Avenue, Saint John, NB, Canada   E2J 4C5

Phone: (506) 658-6600 Fax: (506) 658-6578

www.nbcc.ca

Bryan G. Mendoza
2-58 Sewell Street,
Saint John, New Brunswick E2L 3A4
April 10, 2023

Mr. Robert Linden
MET/STR Coordinator
New Brunswick Community College
950 Grandview Avenue
Saint John, N.B E2J 4C5

Dear Mr. Linden,

I am submitting my Senior Technical Report, "Converting Extruder No. 3 Barrel from Water-Cooled to Air-Cooled System at Inteplast Bags & Films Corporation," for your evaluation.

This Senior Technical Report was initiated in September 2022. It was made possible through the authorization of the NBCC Mechanical Engineering Technologies Department and the cooperation of my project sponsor, Mr. Ron Loughery of Inteplast Bags and Films Corporation. This project aimed to improve the efficiency of the extruder by converting its barrel cooling system from water-cooled to air-cooled.

This project applies what I learned in school, especially in Mechanical Engineering, to a real industry problem. By applying engineering principles and thorough research through the guidance of my advisor and my project sponsor, I was able to design a solution that could improve the efficiency of the extrusion process with a total cost of $ 17,431.08. The project involves technical calculations such as sizing blowers and heater bands and designing fins to ensure efficient heat transfer.

Thank you for providing me with the technical writing knowledge and guidance to make this report successful.

Enclosed is my Senior Technical Report, which includes all methodologies for achieving the solution with a summary of the results and recommendations for Inteplast Bags and Films Corporation. Please let me know if you have any questions or require additional information. I am available for further discussion or clarification through my email:bgmendoza.nb@gmail.com.

Sincerely,

Bryan G. Mendoza
Enclosure: Senior Technical Project

Bryan G. Mendoza
2-58 Sewell Street,
Saint John, New Brunswick E2L 3A4
April 10, 2023

Mr. David Fletcher, P.Eng.
Senior Technical Project Advisor
New Brunswick Community College
950 Grandview Avenue
Saint John, N.B E2J 4C5

Dear Mr. Fletcher

I am submitting my Senior Technical Report, "Converting Extruder No. 3 Barrel from Water-Cooled to Air-Cooled System at Inteplast Bags & Films Corporation," for your evaluation.

This Senior Technical Report was initiated in September 2022. It was made possible through the authorization of the NBCC Mechanical Engineering Technologies Department and the cooperation of my project sponsor, Mr. Ron Loughery of Inteplast Bags and Films Corporation. This project aimed to improve the efficiency of the extruder by converting its barrel cooling system from water-cooled to air-cooled.

This project applies what I learned in school, especially in Mechanical Engineering, to a real industry problem. Through your guidance, I was able to design a new air-cooled system. The project's total cost is $ 17,431.08, which involves equipment such as a three-phase centrifugal blower with a capacity of 489 CFM, 2000-Watts heater bands with a width of 2 inches and a proposed design of fins to improve the heat transfer efficiency.

Thank you for sharing your technical knowledge and providing advice and insights to lead me in the right direction for the project.

Enclosed is my Senior Technical Report, which includes all methodologies for achieving the solution with a summary of the results and recommendations for Inteplast Bags and Films Corporation. Please let me know if you have any questions or require additional information. I am available for further discussion or clarification through my email:bgmendoza.nb@gmail.com.

Sincerely,

Bryan G. Mendoza
Enclosure: Senior Technical Project

Bryan G. Mendoza
2-58 Sewell Street,
Saint John, New Brunswick E2L 3A4
April 10, 2023

Mr. Ron Loughery
Maintenance Head
Inteplast Bags and Films Corporation
291 Industrial Drive
Saint John NB E2R 1A4

Dear Mr. Loughery,

I am pleased to submit my Senior Technical Report, "Converting Extruder No. 3 Barrel from Water-Cooled to Air-Cooled System at Inteplast Bags & Films Corporation," for your evaluation.

This Senior Technical Report was initiated in September 2022. It was made possible through the authorization of the NBCC Mechanical Engineering Technologies Department and the cooperation of my project sponsor, Inteplast Bags and Films Corporation. This project aimed to improve the efficiency of the extruder by converting its barrel cooling system from water-cooled to air-cooled.

The project involves technical calculations such as sizing blowers and heater bands and designing fins to ensure efficient heat transfer. Upon doing this project, I recommended using a three-phase centrifugal blower with a capacity of 489 CFM, 2000-Watts heater bands with a width of 2 inches and a proposed design of fins to improve the heat transfer efficiency. The necessary materials for this project cost $ 17,431.08 for the whole conversion.

I want to thank you for providing me access to your facility to do the study and for your invaluable support and guidance throughout the project. Your insight and suggestions have been beneficial to the project's success. Your willingness to make yourself available to answer my questions and provide me with the necessary data and resources was instrumental in making this project possible.

Enclosed is my Senior Technical Report, which includes all methodologies for achieving the solution with a summary of the results and recommendations for Inteplast Bags and Films Corporation. Please let me know if you have any questions or require additional information. I am available for further discussion or clarification through my email:bgmendoza.nb@gmail.com.

Sincerely,

Bryan G. Mendoza
Enclosure: Senior Technical Project

NBCC
COLLEGEWORKS

Faculty Advisors in Mechanical Engineering Technology
NBCC Saint John Campus
950 Grandview Avenue
Saint John, NB E2J 4C5

Winter 2023

Senior MET Students
New Brunswick Community College
Saint John Campus
950 Grandview Avenue
Saint John, NB E2J 4C5

SUBJECT: Authorization for Senior Technical Project & Report (STR)

Dear Senior MET Student:

The Mechanical Engineering Technology Department formally authorizes you to carry out the necessary research and application work to complete the program requirement of an STR for ETTG 1035.

This Engineering Technology Project, Report, and Presentation are required by the MET program (TAC-accredited) at NBCC Saint John Campus. The project must address a program-related problem chosen by the individual student and approved by Department Faculty. Requirements include determining a set of deliverables, preparing a formal report, and completing a formal technical presentation. Current guidelines for the project are outlined in the "MET Handbook: Guidelines for Report and Presentation."

On 6 April 2023, please upload two digital copies of the final report to the ETTG 1035 Brightspace Assignment Dropbox. Engineering Technology Faculty (including the Faculty Advisors listed below) will assess the technical content of the report. Communication Faculty will assess format and style. Presentations (i.e. the public oral defense of the projects) will take place after the report is submitted.

The final mark on the full project combines the report marks—both Engineering and Communication—and the presentation mark, less any penalties incurred.

MET Faculty encourages you to consult with them regularly as you research, analyze, and document this technical investigation. As the culmination of your two-year program, this rigorous capstone project provides evidence of the technical knowledge and the professional workplace communication skills you have built.

Best wishes for a successful report and presentation that demonstrate the range of skills you have worked hard to develop within the MET programs at NBCC Saint John Campus.

Regards,

Colin Bastow	Mauricio Hernandez
Dana Betts	Shannon Milutin
Bill Chamberlain	Graham Moore
Jay Fletcher	
Ted White	Rob Linden
(Engineering Technologies Department Chair)	(MET STR Project Coordinator)

CONVERTING EXTRUDER NO. 3 BARREL FROM WATER-COOLED TO AIR-COOLED SYSTEM AT INTEPLAST BAGS & FILMS CORPORATION

CONVERTING EXTRUDER NO. 3 BARREL FROM WATER-COOLED TO AIR-COOLED SYSTEM AT INTEPLAST BAGS & FILMS CORPORATION

NAME: BRYAN MENDOZA

ADVISOR: JAY FLETCHER

COURSE: ETTG- SENIOR TECHNICAL PROJECT

SPONSOR: INTEPLAST BAGS & FILMS CORPORATION

DATE: APRIL 10, 2023

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EXECUTIVE SUMMARY

Inteplast Bags and Films Corporation is a plastic manufacturing company in Saint John, New Brunswick, that uses an extrusion process at the beginning of production. Extruder barrel No. 3 runs with a water-cooled system with aluminum cast-in heaters. The pump runs continuously even if cooling is not needed. Furthermore, frequent clogging and scaling on pipes cause inefficiencies in the system. Glycol is also used as a heat exchange medium from the plant's temperature-controlled factory, adding to the operating costs.

The report addressed those issues by converting the existing water-cooled into an air-cooled system. Throughout this project, a detailed study of the following was conducted, and calculations were made to achieve the desired solution:

- Heat load calculations to determine the required cooling capacity.
- Sizing up the blower for each zone.
- Selection of heater bands.
- Design of cooling fins for better heat transfer.
- Design of shroud for better airflow distribution.

The report recommends purchasing a three-phase blower to ensure efficient operation with a flow rate of 489 CFM. Additionally, installing five 2-inch heater bands with a heating capacity of 2000W would provide the required heating for each zone with the minimum surface area covered. Furthermore, the fabrication and installation of cooling fins between the heaters were recommended to improve heat transfer efficiency. Lastly, upper and lower shrouds with baffles and louvres were proposed to improve airflow.

The conversion cost $17,431.08 worth of materials with taxes, but the savings from the conversion were significant. Based on calculations, the conversion could save $4,672.68 annually, with an expected return on investment of under four years.

1.0 INTRODUCTION

This report gives detailed design recommendations for converting a water-cooled system into an air-cooled system, as requested by the project sponsor. The introduction includes the background of the study, purpose, scope, and methodology.

1.1 BACKGROUND OF STUDY

Inteplast Bags and Films Corporation is a plastic manufacturing company in Saint John, New Brunswick, that uses a blown film extrusion process at the beginning of its production. Part of this process is the extruder barrels that need constant heating and cooling to maintain the desired operating temperature. This extruder has five separate "Zones," which allow a different heat profile to be adjusted along the length of the barrel. These controllers have independent outputs that turn on the heat or cool to maintain the desired temperature setpoint. The heat output energizes a contactor, turning on a resistive heating element when the actual temperature is below the desired temperature. The cool output energizes a solenoid valve which permits the cooling water to flow through the existing barrel heat/cool unit when the actual temperature exceeds the desired temperature.

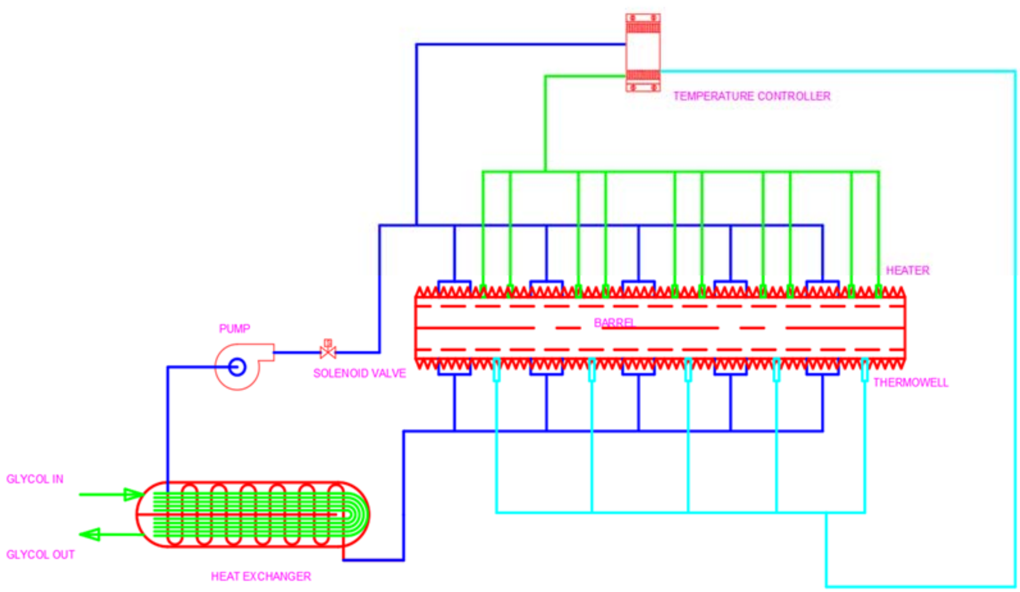

Figure 1 Existing Process

Source: Original

The barrel on extruder number 3 uses a water-cooled cooling system with a single pump and a reservoir with distilled water as the cooling medium. The heating and cooling were integrated into single-cast aluminum, as shown in Figure 1. The system also uses glycol from the temperature-controlled factory process system as a heat exchange medium for the water.
Mr. Ron Loughery, maintenance head of the company, is currently experiencing problems with the setup since clogging and scaling frequently occur along the pipes, which causes a significant setback in the plant operation. Furthermore, the pump runs continuously even if cooling is unnecessary, making it inefficient and adding all up results in higher maintenance costs and loss in production opportunities of the plant during the shutdown.

1.2 PURPOSE

The purpose of this project is to design an air-cooled cooling system and heating system that will replace the existing setup of extruder No. 3 and improve the following:

- Plant's energy efficiency by eliminating continuous equipment running and having a blower for each zone.
- Reduce operating costs by eliminating distilled water and glycol as the cooling mediums.
- Maximize the energy using an improved airflow diffuser integrated into the shroud design.
- Heat transfer efficiency by designing fins for better heat transfer.

1.3 PROJECT SCOPE/OUT OF SCOPE

This project aims to include heat load calculations of the existing setup and the design of an air-cooled system to replace the current setup with better efficiency. This consists of the following items:

- Conductive and convective heat rates needed to dissipate heat along the barrel.
- Sizing of a blower.
- Design fins for better heat transfer.
- Sizing of heater bands as the heating medium.
- Integration of the existing controls into newly installed equipment.

The project's scope is only limited to the design of the air-cooled system and heating system. It does not take into consideration the noise created by the equipment. Furthermore, the effect on the temperature rise inside the plant is also not part of the study, as warm air will be dissipated into the atmosphere after the cooling process. Further investigation to develop a ducting system to redirect the heat to specific areas might be needed.

1.4 METHODOLOGY

The report aims to design a setup that can replace the pump and cast-in heaters with properly sized blowers that can remove the excess heat and install heater bands to give additional heat to the process when needed. This includes a selection of blower for each zone, installation of heater bands along the barrel, design of a shroud system to contain the air and arrangement of fins for better heat transfer.

The report used different areas of Mechanical Engineering disciplines to develop the optimum design. In-depth research on each topic in heat transfer, fluid mechanics, and materials engineering was needed for the project's success. Furthermore, utilizing the expertise of Mr. Ron Loughery and Mr. Jay Fletcher regarding the subject matter gave more precise directions in achieving the project's success.

2.0 PRELIMINARY REVIEW

In a plastic extrusion process, heat is generated by friction between the plastic pellet resin and the walls of the extruder through shear force. This action causes the plastic to melt and flow into the desired output. However, if the temperature is too high, the resin will degrade and can be out of specification. Inversely, if the temperature is too low, the polymer may not fully melt and cannot flow properly, thus blocking the die at the end of the extrusion. This is why cooling and heating are introduced into the system to balance the heat and, therefore, can achieve the optimal temperature.

Furthermore, closed-loop temperature control was used with standard equipment such as a heat source, cooling medium, sensor, and controller. The heat was added and removed from the system using a central controller based on temperature readings from the thermocouple (McGwire). This section focuses on the current heating and cooling setup of extruder No 3.

2.1 CURRENT COOLING AND HEATING SETUP

Brampton Engineering supplied extruder 3 with 4-1/2" 24:1 specification, which has aluminum cast-in fins that operates in a water-cooled system with a 1/2-inch-thick shell and 7/8 inches fins for cooling. Appendix D shows the detailed drawing for the barrel and pump setup. Cooling pipes run through the bottom of the cast-in heater and exit on the other side. The pump uses distilled water to minimize scaling and clogging. It runs continuously so water does not flash to steam, which can cause instability in the process (McGwire). The average change in temperature of the water exiting each barrel was around 87.46 ^{o}F (48.59 ^{o}C) to maintain the process temperature at 380-400 ^{o}F. Table 1 shows the temperature profile for each zone with the inlet and outlet temperature of the cooling water. The data was obtained using FLIR thermal camera. Appendix E shows the recorded temperature in each zone.

Table 1 Temperature Profile of each Zone

Zone	Temperature of the barrel	Inlet temperature of water	Outlet temperature of water	Change in Temperature (ΔT)	
1	380	125	213	88	^{o}F
2	400	134	200	66	^{o}F
3	400	99	170	71	^{o}F
4	390	103	203	100	^{o}F
5	390	97.7	210	112.3	^{o}F
Average	392	111.74	199.2	**87.46**	**^{o}F**
	200	44.30	92.89	**48.59**	**^{o}C**

Source: Original

Figure 2 shows the current piping setup with the cast-in aluminum heaters of Extruder 3. Leaks were very evident at the bottom of the barrel.

Figure 2 Current setup of Extruder 3

Source: Original

2.2 CURRENT HEATING SETUP

The current heating setup for the extruder barrel involves electric heaters integrated into the aluminum cast-in heaters. The thermocouple sends a signal to the control system to activate the heaters. The heaters are connected in series and supply 9000W of energy whenever heating is needed. Since the pump has a continuous supply, part of the heat given off by the heaters is being cooled. Thick cast-in heaters also add up to the heat required by the heaters. Figure 3 shows one zone with a series of heaters connected and integrated into the cast-in aluminum fins. Note that thermocouples are located in the middle of each zone.

Figure 3 Heater series configuration

Source: Original

3.0 HEAT LOAD CALCULATIONS

Heat load calculations were essential in determining the cooling requirements for an extrusion process. It involved determining the amount of excess heat that needs to be dissipated and the air volume flow rate required for cooling. This section considers the factors in calculating heat transfer rates and how they relate to sizing the blower and selecting the appropriate accessories. Relevant literature and industry standards were used to provide detailed calculations.

3.1 FACTORS IN DETERMINING HEAT TRANSFER RATE

Many factors were needed to calculate the excess heat that needed to be dissipated on the barrel. This calculation assumes the system was in a steady state condition and had no external work interactions. Calculation of excess heat needs to be dissipated by a cooling medium with one inlet and one exit with negligible changes in kinetic and potential energies (Cengel, Heat Transfer A Practical Approach 46)

$$\dot{Q} = \dot{m}C_p(T_2 - T_1)$$

Where:

Q= excess heat that needs to be dissipated in BTU/hr

Cp= specific heat of plastic at constant pressure

m= maximum mass flow rate of the plastic

T_2 = maximum temperature of the barrel without cooling

T_1 = operating temperature setpoint of the barrel

The project sponsor provided the initial data needed for this computation. The maximum mass flow rate of melted LDPE/LLDPE production is around 850 lb/hr, with a specific heat of 0.52 to 0.57 BTU/lb-F (Vlachopoulos and Strutt).

The equipment does not have any historical data on the maximum temperature of the barrel without cooling; however, relative to the other extrusion process inside the plant that does not have any cooling, the temperature can reach up to 550ºF. The operating temperature setpoint of the barrel ranges from 370 ºF to 410ºF as the mean value.

This resulted in a total of 84,150 BTU/hr (24.662 kW) excess heat that needed to be dissipated to maintain the setpoint temperature. Table 2 shows the summary of data collected and the total amount of heat that needs to be removed from the system for cooling.

Table 2 Summary of Collected Data

Mass flow rate	m	850 lbs/hr
Maximum Temperature	T_2	550ºF
Setpoint Temperature	T_1	390ºF
Specific heat of LLDPE	C_p	0.55 BTU/lb-ºF
Excess heat	Q	84,150.0 BTU/hr (24.662 Kw)

Source: Original

3.2 DETERMINATION OF VOLUME FLOW RATE OF BLOWER

The aim of sizing a blower is to determine the volumetric flow of air needed to dissipate the excess heat in each barrel zone. Using the following formula and applying the same principle in determining the excess heat:

$$Q_{excess\ heat} = Q_{needed\ to\ dissipate\ by\ air} = m_{air} Cp_{air} (T_1 - T_\infty)$$

Where:

m_{air}= mass of air

T_1 = operating temperature setpoint of the barrel

T_∞= average air temperature

C_p= specific heat of air

Since the excess heat was already known, the mass flow rate of air needed to dissipate the same heat can be calculated. Using the properties of air from Appendix F, the specific heat of air at constant pressure is 1007 J/kg-K or 0.24 BTU/lb-F. For this calculation, an average temperature of 30ºC or 86ºF and humidity of 53% account for the worst conditions, as the hottest month in New Brunswick is July (Climate and Average Weather Year Round in New Brunswick).

Using all the available data, the air's volume flow rate can be calculated using the density formula (Cengel, Boles and Kanoglu, Thermodynamics An Engineering Approach).

$$\dot{v_{air}} = \frac{\dot{m_{air}}}{\rho_{air}}$$

The specific volume can be obtained using the Psychrometric chart in Appendix F with a value of $13.6 ft^3/lb$. This gives a density of $0.0735\ lb/ft^3$

.

Table 3 Sizing of Blower (CFM)

Process Capacity	Maximum Temperature Without Controlled Cooling								
	400	450	500	550	600	650	700	750	800
lbs/hr	**CFM of blower needed for each zones**								
100	5.49	14.63	23.78	32.92	42.07	51.21	60.36	69.50	78.65
150	8.23	21.95	35.67	49.38	63.10	76.82	90.54	104.25	117.97
200	10.97	29.26	47.55	65.85	84.14	102.43	120.72	139.01	157.30
250	13.72	36.58	59.44	82.31	105.17	128.03	150.89	173.76	196.62
300	16.46	43.90	71.33	98.77	126.20	153.64	181.07	208.51	235.94
350	19.20	51.21	83.22	115.23	147.24	179.24	211.25	243.26	275.27
400	21.95	58.53	95.11	131.69	168.27	204.85	241.43	278.01	314.59
450	24.69	65.85	107.00	148.15	189.30	230.46	271.61	312.76	353.92
500	27.44	73.16	118.89	164.61	210.34	256.06	301.79	347.52	393.24
550	30.18	80.48	130.78	181.07	231.37	281.67	331.97	382.27	432.57
600	32.92	87.79	142.66	197.54	252.41	307.28	362.15	417.02	471.89
650	35.67	95.11	154.55	214.00	273.44	332.88	392.33	451.77	511.21
700	38.41	102.43	166.44	230.46	294.47	358.49	422.51	486.52	550.54
750	41.15	109.74	178.33	246.92	315.51	384.10	452.68	521.27	589.86
800	43.90	117.06	190.22	263.38	336.54	409.70	482.86	556.03	629.19
850	46.64	124.37	202.11	279.84	357.58	435.31	513.04	590.78	668.51
900	49.38	131.69	214.00	296.30	378.61	460.92	543.22	625.53	707.83
Source:	*Original*								

Table 3 shows the amount of air needed in ft^3/min (CFM) on each process capacity in lb/hr over the temperature difference of the process setpoint temperature and the temperature without cooling. For the data above, 279.84 CFM of air was needed to keep cooling. However, blowers should operate within 80% of their rated capacity. This ensures an adequate bearing and seal life and provides room for heat/ metal expansion (Newton). Accounting for 10% air losses on design and 1.20 factor of safety accepted in the industry, the blower size needed will be around 481 CFM (Goslin) . Refer to Appendix G for detailed calculations.

$$volume\ flow\ rate\ CFM = \frac{Calculated\ CFM\ x\ Factor\ of\ safety\ x\ Air\ losses}{efficiency}$$

$$volume\ flow\ rate\ CFM = \frac{279.84\ CFM\ x\ 1.20\ x\ 1.1}{0.8}$$

$$volume\ flow\ rate = 461.7\ CFM$$

3.3 BLOWER SELECTION

Since the volume flow rate has been calculated, determining the actual size of the blower would be the next step. Blowers for industrial use were usually sized up on the capacity and the amount of static pressure generated.

Centrifugal fans are typically used in industry due to their efficiency. Figure 4 shows an overview configuration of a centrifugal blower with casing and impeller blades. In addition, they are easy to maintain or repair due to minimal parts. They can also deliver maximum airflow with higher pressure than axial fans (Pelonis).

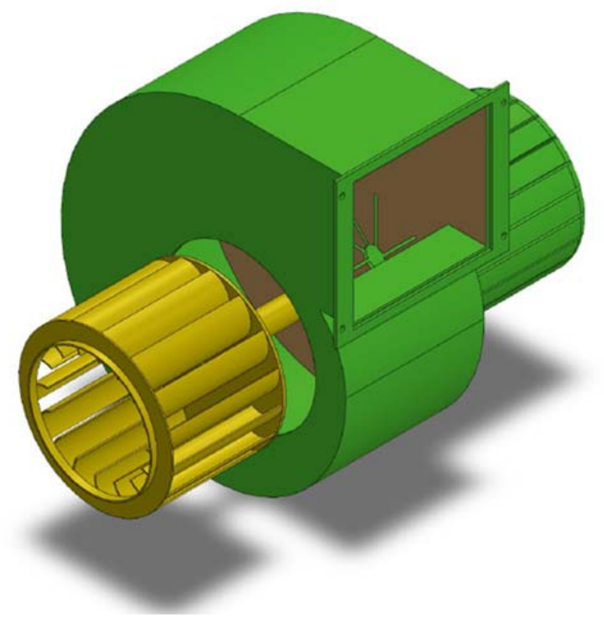

Figure 4 Typical Centrifugal Blower

Source: Original

For this application, the typical static pressure generated by the shroud was around 0.45" – 0.55" (11.43mm-12.7mm) of water, reducing the blower rating (Goslin). Appendix H is the list of blowers supplied by Motor-Pump-Ventilation.

Another consideration is the selection of the blower motor to be used. For this project, a three-phase motor blower was utilized. One of the advantages of a three-phase motor is power efficiency. It consumes 40% less current than a single phase to deliver the same power output. It also has fewer points of failure, thus, longer equipment life (Davis). Though a three-phase motor costs slightly more than a single phase, the cost will offset the long-term use of the equipment.

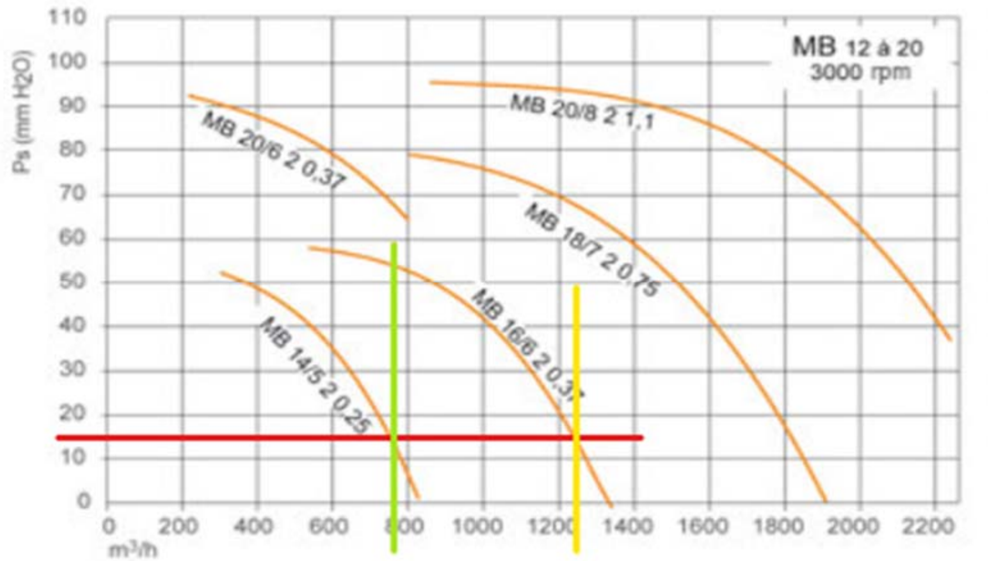

Figure 5 Blower Curve of MB 14/5 T2

Source: https://www.motor-pump-ventilation.com/merchant/product/centrifugal-fan-mb-3000-rpm-three-phase

Figure 5 shows the blower curve performance of MB 14/5 T2 0,25 by universal three-phase centrifugal blowers supplied by Motor-Pump-Ventilation with a rated capacity of 830 m^3/hr (489 CFM). This shows that at 0.45 inches of water gauge pressure, the blower can deliver 785 m3/hr (463 CFM) of air, almost similar to the computed volume flow rate needed for cooling under atmospheric conditions. Refer to Appendix H for the calculated blower curve.

3.4 HEATER BAND SELECTION

The barrel is a 180 inches pipe divided into five zones requiring constant heating or cooling. Figure 6 shows the typical process inside an extruder wherein the screw creates a shear force to melt the plastic pellets from the hopper feed (McGwire). Though the barrel screw can generate heat, it is not enough to maintain the temperature needed for the plastic to melt homogeneously. The heater band would replace the bulky aluminum cast-in heater to supply 9000W of heat for each zone.

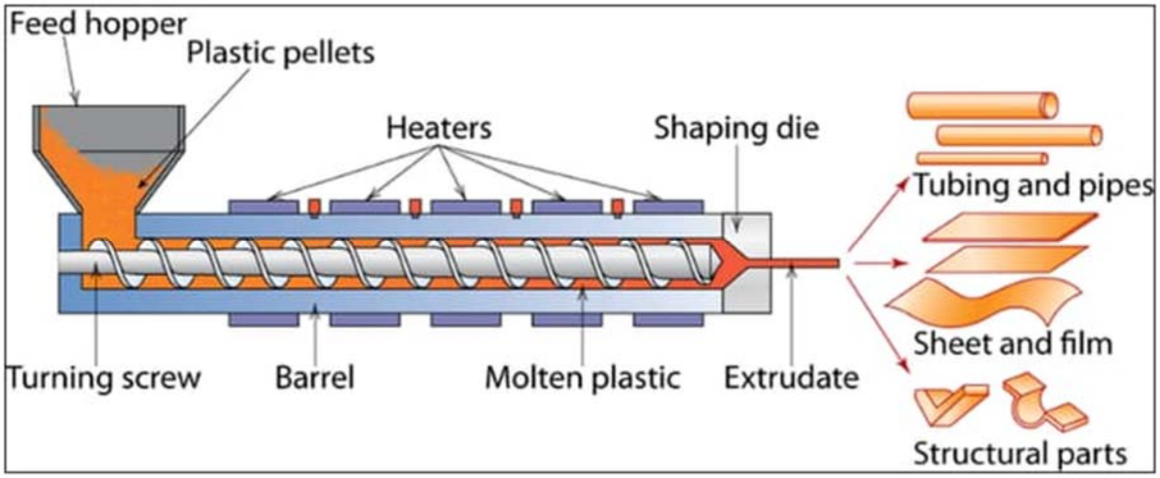

Figure 6 Simple Plastic Extrusion Process
Source: https://www.rapiddirect.com/blog/plastic-extrusion-process/

The ceramic heater bands were chosen to be used in this project over different kinds of heater bands, such as mica bands and mineral-insulated bands, for the following reasons:

- Efficient heat transfer.
- Minimizes unwanted change in temperature along the barrel.
- Simplified wiring.
- Flexible design for easy installation and removal for maintenance. (Heat and Sensor Technology)

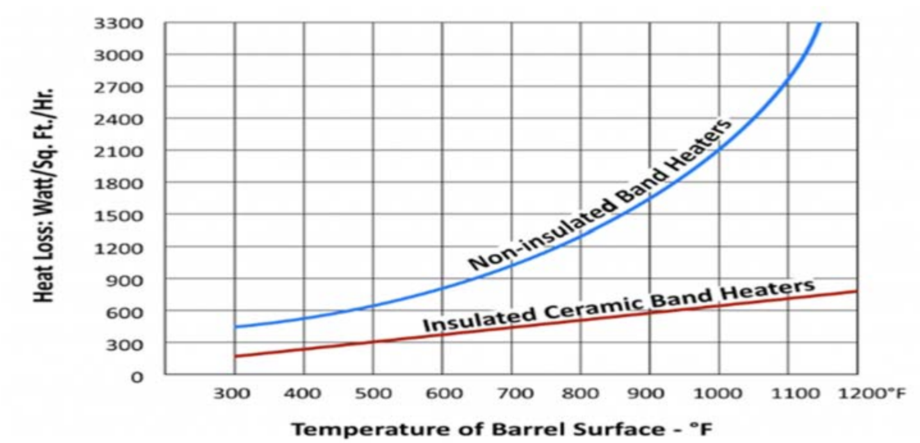

Figure 7 Heat Loss Comparison Chart
Source: https://heatandsensortech.com/products/ceramic-heaters/

Figure 7 compares heat loss for insulated ceramic band heaters and non-insulated band heaters. This indicates minimal heat loss value for insulated ceramic band heaters with a gradual increase in slope.

Another design consideration in selecting heater bands is the heat surface ratio that the heater bands occupy on the barrel. Since cooling was also needed in the system, sufficient exposed surface area to allow proper cooling should be considered. Each zone along the 8-inch barrel was 20 inches long with a total surface area exposed of 502.65 in^2. Appendix I is the catalogue of different ceramic heater band products from Tempco for different barrel diameters with widths and wattages. Since a 230V 60Hz electrical supply powers extruder No. 3, the selection may be narrowed down with Table 4.

Table 4 Surface Area for Cooling and Heating for Ceramic Heater Bands

Inside Diameter (Inches)	Width (Inches)	Wattage	Heater Band per Zone	Total Wattage	Total Surface Area per Zone in^2	Surface Area for Heating in^2	Surface Area for Cooling in^2	Percentage
8	1.5	770	12	9240	502.65	452.39	50.27	90%
8	2	2000	5	10000	502.65	251.33	251.33	50%
8	4	3000	3	9000	502.65	301.59	201.06	60%
8	6	3500	3	10500	502.65	452.39	50.27	90%

Source: Original

Each barrel needs at least 9000 Watts of heat to maintain process requirements. Table 4 shows that five ceramic heater bands with a width of 2 inches will generate 10,000W of heat, only occupying 50% of the surface area, leaving 251.33 in^2 for cooling. Since the barrel consists of 5 zones, a total of 25 of the 2-inch heater bands were needed and appropriately spaced to maintain the desired heat. Figure 8 shows the heater bands' basic parts: ceramic fibre insulation, threaded stud terminals, barrel nut clamp and stainless-steel case.

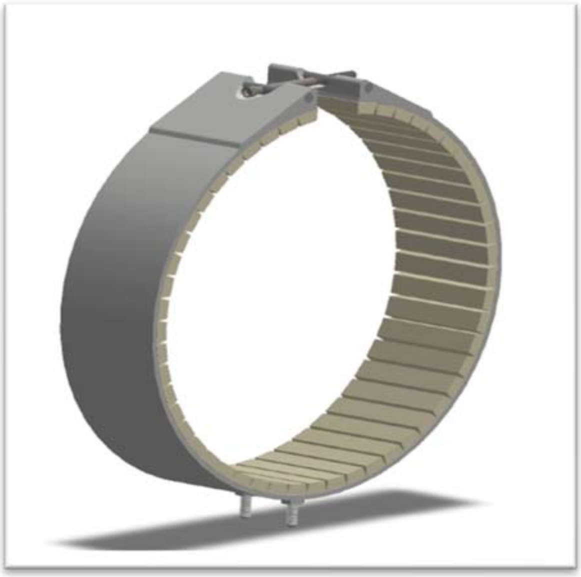

Figure 8 Typical Ceramic Heater Band

Source: Original

4.0 COOLING FINS DESIGN AND CALCULATION

This section includes the design of cooling fins. Calculations of length and spacing were discussed, and the convective heat transfer coefficient of air was determined. The report came up with two designs, and recommendations were made based on the ease of fabrication. Material selection of the fin was also discussed in this section.

4.1 COOLING FIN WRAP-AROUND DESIGN

Cooling fins are commonly used in the industry to dissipate heat faster as it increases the surface area of the material to be heated or cooled. Fins extending from the wall into the surrounding fluid will increase the forced draft blower's convection rate (Incropera, Dewitt and Bergman 139). For a 20-inches long zone section, 50% will be allotted for fins. For equally spaced 2-inch heaters bands, an optimum fin width design must be determined to maximize heat transfer.

4.2 CONVECTIVE HEAT TRANSFER COEFFICIENT OF AIR

Air's convective heat transfer coefficient was determined to calculate fin characteristics. For this application, the approximated value of the heat transfer coefficient for airflow may be determined using the below empirical formula (Convective Heat Transfer).

$$h_{cW} = 12.12 - 1.16v + 11.6v^{\frac{1}{2}}$$

Since the formula was derived using SI units, air velocity was determined using Table 5 below. Appendix J shows the detailed calculation for the convective heat transfer coefficient of air.

Table 5 Air and Barrel Characteristics

Variable	Definition	Values	
Do	Diameter of the Barrel	0.203	m
L	Length of Barrel per section	0.508	m
q	Flow rate of Air	0.2179	m^3/s
A	Flow area of Air	0.324	m^2
V	Velocity of Air	0.672	m/s
h_{cw}	Convective Heat Transfer Coefficient	20.849	W/m^2-C

Source: Original

4.3 SIZING OF FINS

The next step is to determine the length of the fins. It is essential to consider the proper fin length L for the design. Figure 9 shows the efficiency curve of circular fins of length L at constant thickness with respect to a geometrical parameter on the x-axis. The longer the fin, the larger the heat transfer area, but there are drawbacks such as weight, fluid friction and price.

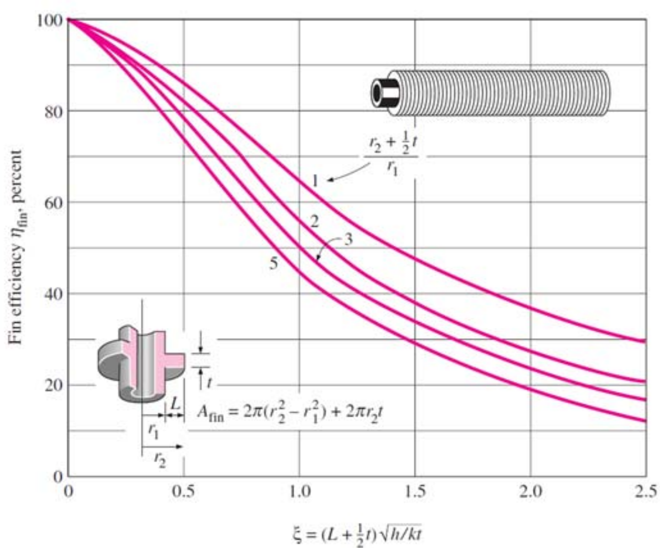

Figure 9 Efficiency of circular fins of Length L and constant thickness t

Source: Cengel, Heat Transfer A Practical Approach, pp. 162

Typically, "the efficiency of most fins in practice is above 90 percent" (Cengel, Heat Transfer A Practical Approach 163). For this calculation, 92% efficiency was used to determine the length L of the fin.

Since the table was derived in SI units, the following data in Table 6 were used:

Table 6 Fin Characteristics

Parameters	Values
r_1	0.127794 m
r_2	0.1143+L m
t	0.0008128 m
Efficiency	92 %
Efficiency curve	1.2

Source: Original

A Gauge 20 material with an equivalent thickness of 0.8128 mm was used in the project. The thickness was selected for ease of fabrication and weight consideration. An efficiency curve was determined by trial and error to match the calculated length "L" to the estimated value of "L" on the geometrical parameter (x-axis). Appendix K shows the detailed calculations of fin size.

Using the formula from Figure 9:

$$Efficiency\ Curve = \frac{r_2 + 0.5t}{r_1}$$

Where calculated L is 0.0247 m or approximately 1 inch.

Checking for the value of L using the following formula for thermo-geometrical parameter:

$$\varepsilon = (L + \frac{1}{2}t)\sqrt{\frac{h}{kt}}$$

Where:

Table 7 Calculated Thermo-geometrical parameter.

ξ from table	0.19	
L	0.02515235	m
h	20.84949675	W/m^2-C
k	401	W/m-C
ξ calculated	0.2044	

Source: Original

Table 7 shows the value of the thermo-geometrical parameter from the graph and the value from the above calculation. The graph analysis reveals that the value of the thermo-geometrical parameter closely matches the calculated value. Moreover, the calculated Length L falls within an acceptable range of the value obtained from the graph.

4.4 FIN DISTANCE

To maximize the cooling effects of fins, the optimum distance must be determined. "Fins that are closely packed will have greater surface area for heat transfer; however, because of the extra resistance on the additional fins, it reduces the heat transfer coefficient of the fluid" (Cengel, Heat Transfer A Practical Approach 474).

Using the formula:

$$S_{optimum} = 2.714(\frac{L}{Ra_L^{0.25}})$$

Where:

$$R_{aL} = \frac{g\beta(T_S - T_\infty)L^3}{\nu^2}$$

Table 8 Physical Characteristics of Air and fin design

Parameter	Definition	Values	Units
g	Gravity	9.81	m/s^2
β	coefficient of volume expansion 1/Tf for ideal gas	0.00231541	ºC
Tf	Film Temperature	158.8888889	ºC
Ts	Process Temperature	287.78	ºC
T∞	Ambient Temperature	30	ºC
L	Length	0.960988688	m
v	Kinematic Viscosity	0.00001608	m^2/s
Pr	Prandtl Number	0.7282	
Ra_L	Rayleigh Number	14634431778	

$S_{optimum}$	0.007498668 m	0.295 in

Source: Original

Table 8 shows the physical characteristics of air from Appendix F. From the calculations optimum distance was around 3/8 inch. Appendix K includes detailed calculations for fin distance.

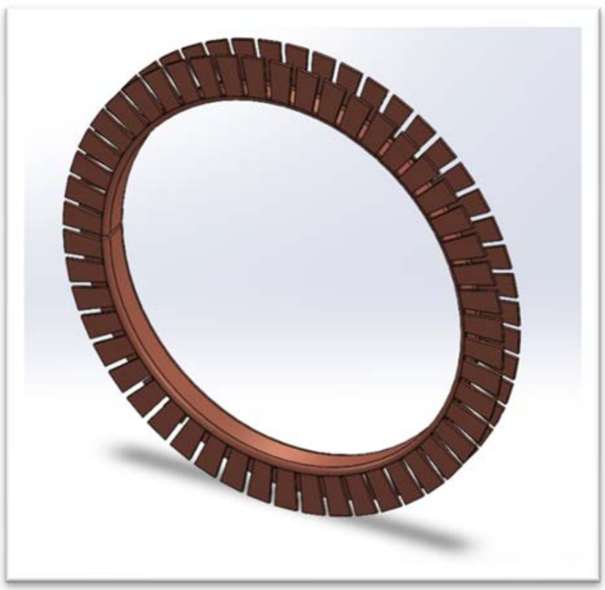

Figure 10 Fin Design
Source: Original

4.5 FIN DESIGN

For this project, two fin types were designed to maximize heat dissipation. Refer to Appendix L for the fin design variation with dimensions. However, Figure 10 was chosen because of its effectiveness and ease of fabrication. Each zone would need 12 fins to maximize the surface area designed for cooling. The fins would be tightened securely by a locking mechanism fabricated to hold them firmly in place. Appendix L shows the detailed drawing for the annular fins and locking mechanism, which can be fabricated in-house. Installation of these fins should be staggered on each slot to allow maximum airflow in between.

4.6 MATERIAL SELECTION

Due to their thermal conductivity, aluminum and copper are two of the most typical materials commonly used in fin manufacturing. Table 9 shows the comparison of the two metals with their respective properties.

Table 9 Copper and Aluminum Comparison

Characteristics	Copper	Aluminum
Thermal Conductivity (W/m-K)	401	237
Density (kg/m^3)	8933	2702
Price/ metric ton (as of December 2022)	$8,375.40	$2,401.69
Melting Point (K)	1358	933

Sources: Heat Transfer: A Practical Approach (Cengel)
https://ycharts.com/

Though copper's thermal conductivity almost doubled by aluminum's value, their price was a significant factor in the project's design.

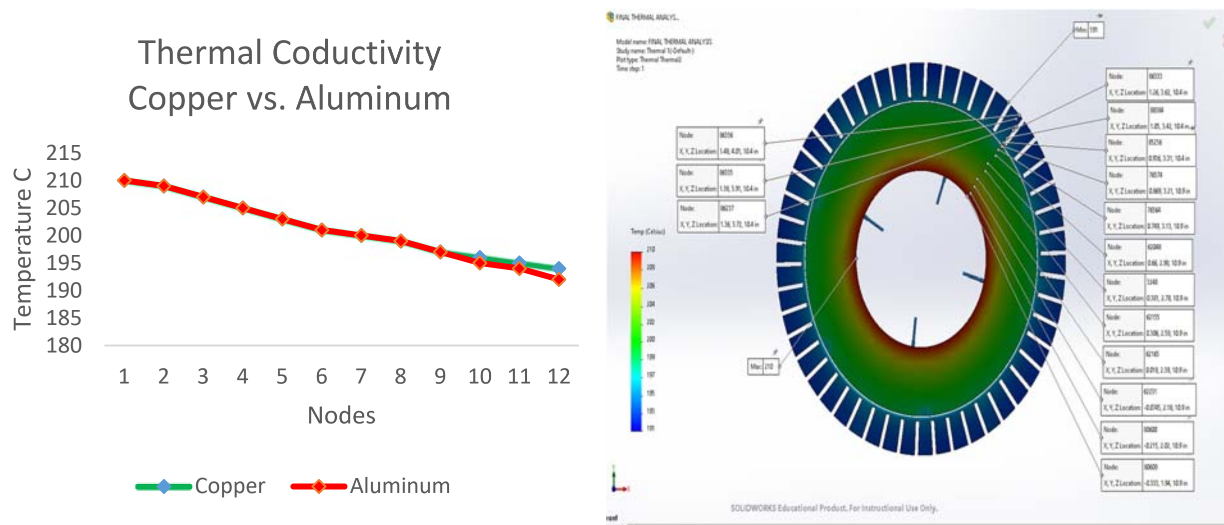

Figure 11 Thermal Analysis of Copper and Aluminum
Source: Original

Using Computer-Aided Design (SolidWorks), thermal analysis between copper and aluminum has been simulated using peak temperatures inside the barrel. Figure 11 shows the temperature profile on each node taken across the barrel and the fins. From this result, copper has a higher average temperature conducted through natural convection over aluminum. The simulation was conducted in a steady state condition with 405ºF (210ºC) as the maximum temperature inside the barrel. The average temperature on the tip of the fins was 191ºC for copper and 186 for aluminum. Since time delay in cooling and heating is very critical for the application of the project, copper fins were recommended to be used. Though copper is more expensive than aluminum, it would offset the price by the cost of operation over time by reducing the time for cooling, thus saving energy in running the blowers.

5.0 SHROUD DESIGN

This section covers the design of the blower shroud and the process of choosing the suitable material. Thermal and flow simulation was done to come up with the optimal design.

5.1 DESIGN CONSIDERATION AND MATERIAL SELECTION

One of the most important design considerations for the project was the blower shroud. The shroud channels the forced air from the blower to the barrel and fin's exposed surface area. It is also essential for safe operation since the shroud covers the hot barrel preventing any exposed hot surfaces. This project's design comprises an upper and lower shroud connected by a socket head cap screw in between for faster installation and troubleshooting. Figure 12 shows the upper shroud with equal space slots to allow maximum air retention time of air inside, thus facilitating better heat transfer. Louvres were installed on the air outlet, which opens when the blower operates, directs the air out, and closes when it turns off. This would decrease the heat loss due to natural convection and radiation when the system needs heating and heater bands are activated.

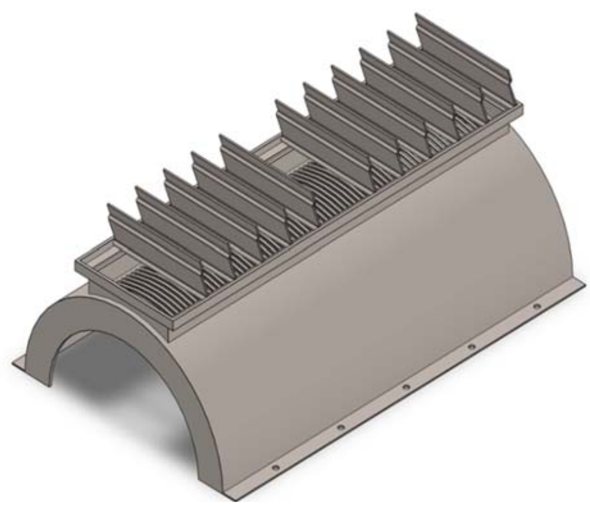

Figure 12 Upper Shroud Assembly

Source: Original

On the other hand, the lower shroud would be connected to the main blower, housing the electrical components of the heater bands on the side. Slotted holes were made with just enough room for wires. This enhances the airflow rate by minimizing losses coming out of the side of the shroud and then being covered by a plate flange. Baffles were also designed at the entrance of the air coming out of the blower to direct the flow of air to maximize forced convection. Figure 13 shows the cross-sectional drawing of the lower shroud. Guage-11 or 0.125" thick 304 Stainless Steel was chosen to fabricate the upper and lower shroud and electrical slots. Stainless steel is suitable for this application due to its corrosion resistance. Aside from the ease of fabrication when dealing with stainless steel plates, SS304 is 40% lower in price than its counterpart SS316. For the application of products not exposed to chemicals or marine environments, 304 is a practical and economical choice (Geise). Appendix M shows the detailed drawing for the upper and lower shrouds.

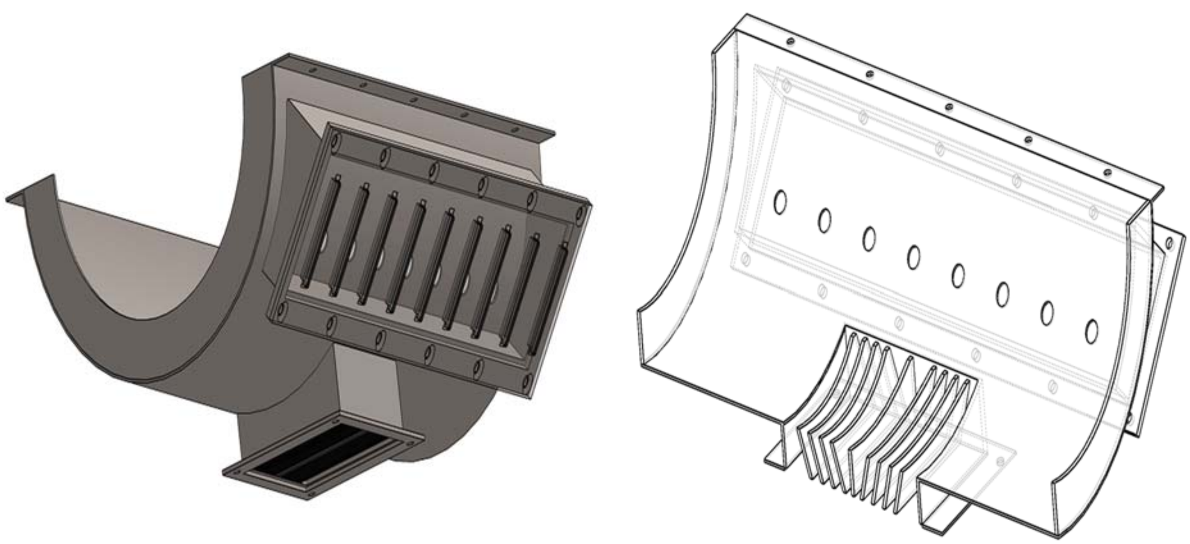

Figure 13 Lower Shroud Design

Source: Original

5.2 EQUIPMENT CONFIGURATION

Each zone comprises five 2-inch ceramic heater bands spaced evenly along the barrel. The approximate distance for each heater band was 2 inches. The cooling fins fill those gaps, three for each space and 12 fins for each zone. Four copper clamps hold the whole assembly and tighten securely by socket head screw. The upper shroud consists of slotted airways along the top and 12 flappers for the airways. Note that the middle was intentionally left without a flapper to make room for the thermocouple. The lower shroud has nine air baffles to direct the air, especially to the side of the assembly. Finally, a cover for the lower shroud for the electrical access must be installed with nine slots to ensure minimal air loss and dissipate heat accumulated by the heater wires. Figure 14 shows the exploded view of one of the barrel zones. This configuration would be the same for all five zones along the barrel.

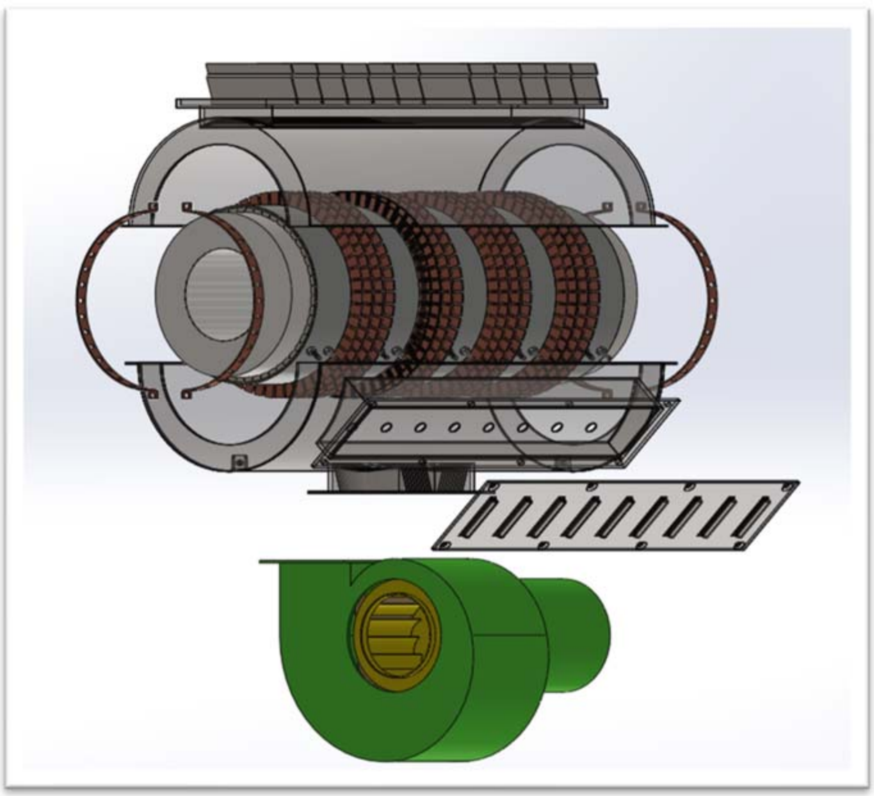

Figure 14 Exploded view.
Source: Original

5.3 THERMAL AND FLOW SIMULATION DESIGN

Using Computational Fluid Dynamics (CFD) to determine the behaviour of parameters such as airflow and temperature profile of the barrel, a test was conducted for the actual condition of the barrel. For the simulation, one barrel zone was used for the study and the maximum temperature of 405ºF (207ºC) for the molten plastic. A temperature of 30ºC (85ºF) for air was used for the simulation, which is the average temperature during summer. Figure 15 shows how forced air distribution dissipates heat in the barrel zone at a given time. Red areas show the average temperature of the air at 83.29ºC and a 53.29ºC change in temperature from the air inlet to the air outlet. Furthermore, the heat transfer rate of the barrel was 3,486.877 Watts, and the convective heat transfer of air around the barrel was around 611.011 watts.

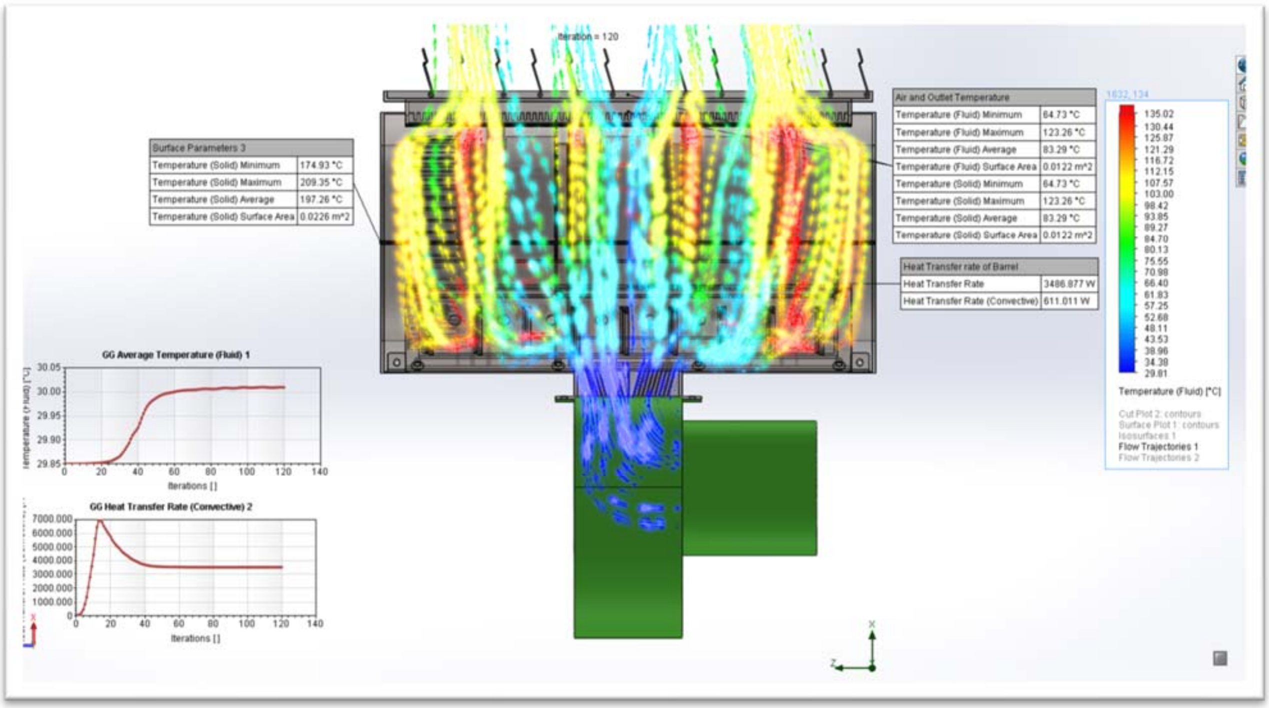

Figure 15 CFD Analysis

Source: Original

A detailed study conducted using CFD and flow simulation is found in Appendix R. As a comparison for the analysis, for the same boundary conditions of a single zone, Figure 16 shows the temperature gradient on the cross-sectional area of the barrel with and without fin conditions. This confirms the effectivity of the copper fins along the barrel, as the temperature on the outer surface is much lower than those without fins.

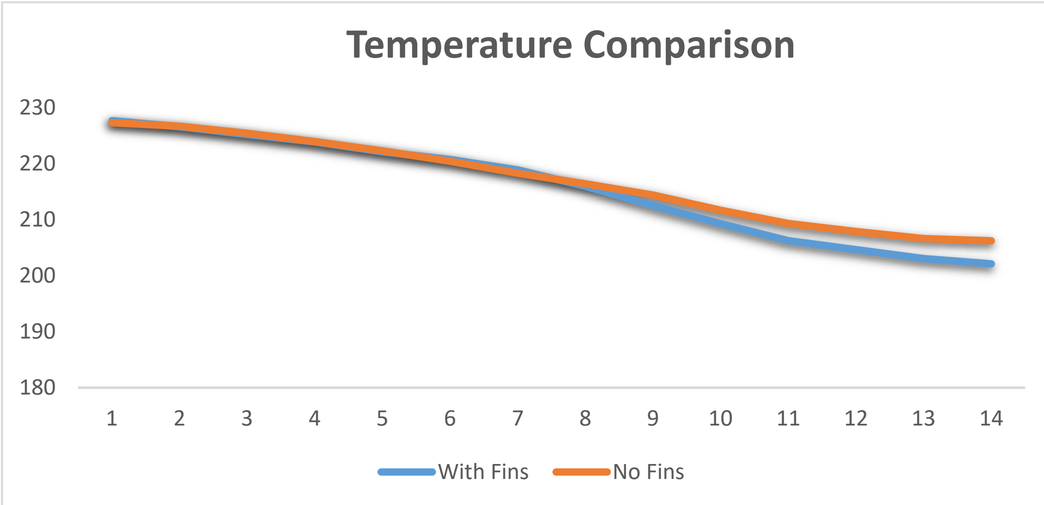

Figure 16 Temperature Condition Comparison

Source: Original

6.0 MOUNTING DESIGN AND CALCULATION

Since most of the materials used were stainless steel, the bolts were also stainless steel for the same reason stated in the shroud section. A standard 5/16" socket head cap screw was used for initial calculations.

6.1 SHROUD

For this calculation, the identified critical component for the fastener would be the barrel clamp shown in Figure 17. The detailed specifications for fabricating copper clamps to hold the assembly can be found in Appendix M. For this setup, if the upper shroud is removed, only four bolts would hold the entire assembly along the barrel. Basing all shear stress calculations for the bolt on this location would be ideal.

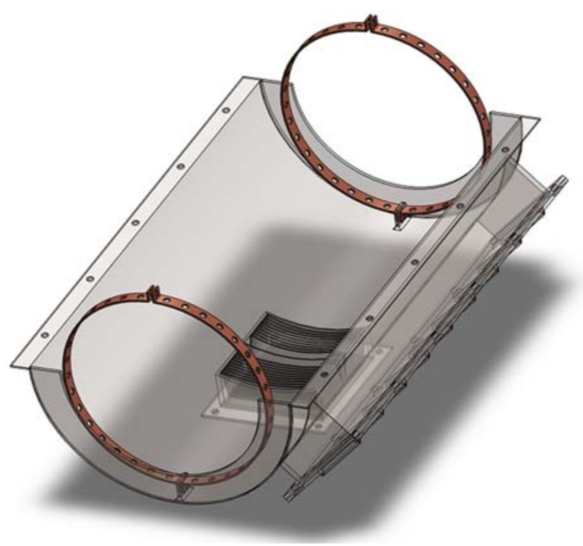

Figure 17 Copper Clamp Assembly

Source: Original

This arrangement was a single shear due to the single cross-section area of the bolt applied in shearing force (Mott and Untener 34). Using the formula for direct shear stress below, the shear stress of 231 psi and way less than the allowable shearing stress of the bolt from Appendix N. Table 10 summarizes the calculation for the direct shear stress of a single bolt.

$$\textit{Direct shear stresses } \boldsymbol{\tau} = \frac{\textit{Force}}{\textit{Shear area}} = \frac{F}{A_s}$$

Table 10 Shear Stress Calculation

SHEAR			
Force F	Weight of the lower shroud and blower	35.435	lbs
Area	Shear area of the bolt	0.0767	in^2
Direct Shear	Two bolts carrying the load	231	psi
Maximum Shear	Maximum allowable shear strength	3450	psi
Decision		SAFE	

Source: Original

A ¼"-standard socket head screw was used for the lower shroud cover since minimal load or force is acting. Appendix N also recommends tightening torque for each bolt at 170 in-lbs.

6.2 BLOWER

Bolts on the blower would be subjected to tensile load since they carry the actual weight of the blower. The vibration created by the equipment was also considered for the design. Using the same formula for the stress, Table 11 shows the tensile stress calculation.

Table 11 Tensile Stress Calculation

TENSILE			
Force F	Weight of the blower	15.435	lbs
Area	Area of the bolt (Minimum Diameter)	0.07321	in^2
Direct Shear	Four bolts carrying the load	52.7112	psi
Maximum Shear	Maximum allowable tensile strength	4200	psi
Decision		SAFE	

Source: Original

It was also recommended to use nuts and washers and tighten them according to the correct specification to ensure bolts do not loosen during operation.

7.0 ELECTRICAL AND INSTRUMENTATION

This section covers Electrical and Instrumentation aspects related to integrating the new equipment into an existing setup. It provides a detailed schematic wiring diagram for each zone, showing the connection for each piece of equipment integrated into the existing controllers. Meanwhile, the instrumentation diagram examines the controllers used to regulate temperature setpoints and how the controller reacts to temperature changes in each zone. Figure 18 shows the existing configuration of the controllers. This setup remains since it has provisions to change from a water pump to a set of blowers.

Figure 18 Control Panel Configuration
Source: Original

7.1 ELECTRICAL DIAGRAM

Figure 19 shows the schematic wiring diagram of each zone integrated with the existing setup. Primarily, the thermocouple sends the signal to the model 2208e controller, which then dictates if it needs to activate the heater through the power regulator controller or turn on the motor blowers. Heaters run into a single phase, while the blowers run in a three-phase system. Blowers need magnetic contactors for ease of installation and the operator's safety (Aaron Lee; Chad Flinn). The diagram was referenced from the Installation and Operation Handbook of 2208e and 2204e Controller provided by the project sponsor.

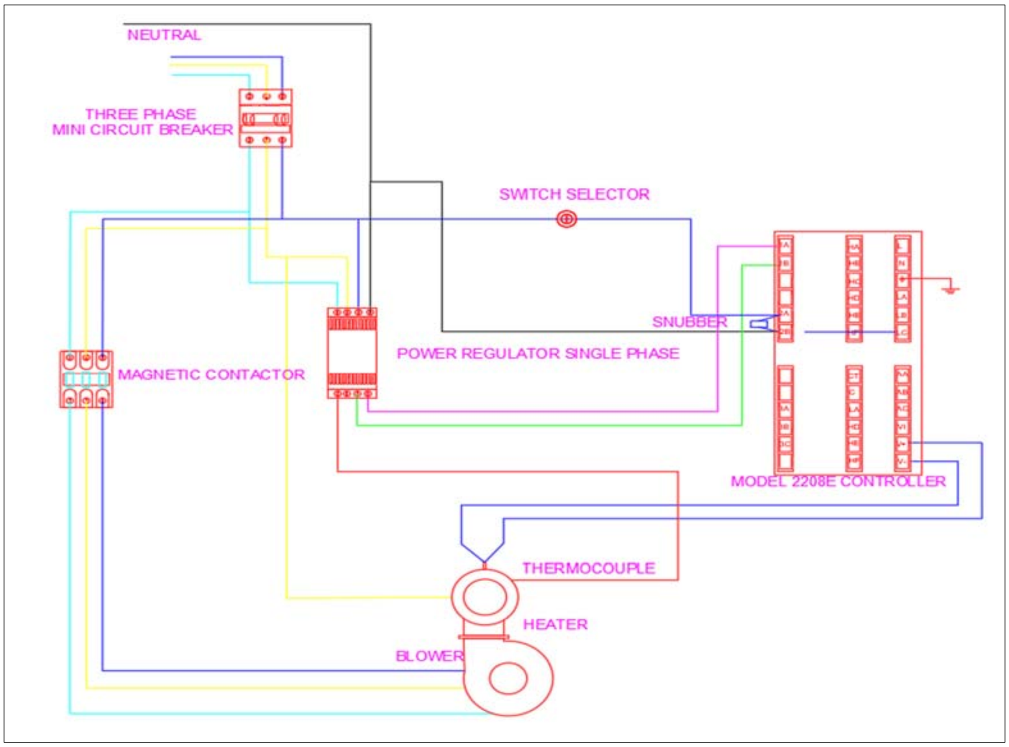

Figure 19 Electrical Diagram per Zone
Source: Original

7.2 INSTRUMENTATION DIAGRAM

For controlling temperature setpoints and operation of the blowers and heaters, 'EUROTHERM' model 2204e is currently used in the same equipment running into a water-cooled system. The current instrumentation controllers can be integrated into the new design, and the diagram below shows the current setup and the modification needed for the new setup. These controllers do not need any coding and can be manually installed. Figure 20 shows the block diagram of the controller for the new setup. The design was patterned to the old process and adapted to the proposed project. The process starts on the thermocouple that sends the signal to the controller. The control then decides what error must be corrected. From then, PID controls whether it is for cooling or heating. This cycle continues and turns the blower and heater bands on and off until the desired temperature is achieved.

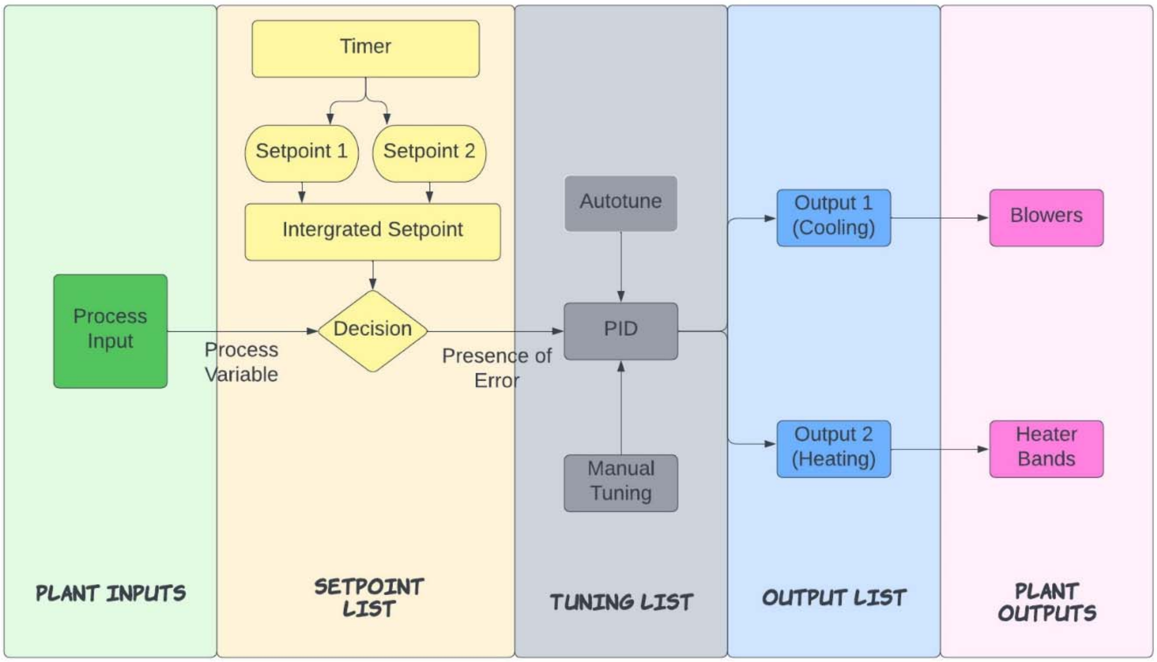

Figure 20 Process Flow Diagram
Source: Original

8.0 PROJECT DESIGN COST

The cost of materials can be divided into three parts: shroud and accessories, heater bands fins and clamp, and blowers and accessories. Since this project was a major conversion, the initial cost of procuring all the materials was relatively high.

8.1 SHROUD

The upper and lower shroud must be fabricated using Stainless Steel 304 material. Due to its complex design and the limitations of tools, shrouds cannot be fabricated in-house; therefore, they must be outsourced. Tempco offers fabrication of existing designs for upper and lowers shrouds for an average of USD 975.00 each or CAD 1,327.80 (Goslin). Table 12 shows the summary of the cost for the shroud and accessories.

Table 12 Cost of Shroud and Accessories

EQUIPMENT	QUANTITY	PRICE/UNIT	TOTAL PRICE
Shrouds	5	$ 1,327.80	$ 6,639.00
Bolts 5/16"	20	$ 0.69	$ 13.80
Nuts 5/16"	20	$ 0.17	$ 3.40
Washer 5/16"	20	$ 0.11	$ 2.20
Bolts 1/4"	90	$ 0.57	$ 51.30
Nuts 1/4"	90	$ 0.12	$ 10.80
Washer 1/4"	90	$ 0.14	$ 12.60
Total			$ 6,733.10
Grand Total with Tax			**$ 7,743.07**

Source: Original

8.2 HEATER BAND, FINS, AND CLAMP

Fins and Barrel clamps can be fabricated in-house at the workshop using basic tools. Appendix M shows the dimensions for each design. For this calculation, manpower hours and consumables were not included in the computation. A total of 4510.0 in^2 or 31.32 ft^2 of the copper plate was needed to manufacture all fins, clamps and locking mechanisms.

A 2"-2000Watts heater has been selected for the heater band. Since mounting and bolts were included in the package, they were not included in the cost calculation. Table 13 shows the cost of each material.

Table 13 Cost for Copper and Heater Bands

EQUIPMENT	QUANTITY	PRICE/UNIT	TOTAL PRICE
Copper Sheet (8x4ft)	2	$ 612.99	$ 1,225.98
Heater Band (CEH-BCH00086)	25	$ 141.29	$ 3,532.25
Total			$ 4,758.23
Grand Total with Tax			**$ 5,471.96**

Source: Original

8.3 BLOWER AND ACCESSORIES

Table 14 shows the cost of blowers and auxiliaries needed for the conversion. Commercially available blowers can be purchased within the specifications required for each zone. Referring to Figure 16, only the Model 2208e controller can be reused for the existing setup; therefore, all the equipment on the proposed configuration must be purchased. Insulated copper wire with 16 to 22 AWG (American Wire Gauge) must be used per the manufacturer's recommendations.

Table 14 Cost for Blower and Accessories

EQUIPMENT	QUANTITY	PRICE/UNIT	TOTAL PRICE
Blower	5	$ 432.40	$ 2,162.00
Three-Phase Mini Circuit Breaker	5	$ 76.52	$ 382.60
Magnetic Contactor	5	$ 56.75	$ 283.75
Power Regulator Single Phase	5	$ 54.76	$ 273.80
Switch Selector	5	$ 28.00	$ 140.00
Copper Wire	2	$ 202.29	$ 404.58
Bolts 5/16"	20	$ 0.69	$ 13.80
Nuts 5/16"	20	$ 0.17	$ 3.40
Washer 5/16"	20	$ 0.11	**$ 2.20**
Total			$ 3,666.13
Grand Total with Tax			**$ 4,216.05**

Source: Original

This sums up to $ 17,431.08 of material cost to complete the project. Appendix P is the list of websites for the price reference of each item.

9.0 COST ANALYSIS

The focus of this section is to evaluate the cost associated with converting a water-cooled system into an air-cooled one. This section discusses the financial implications of the project and how this project would be beneficial for the company in the long term.

9.1 COST-BENEFIT ANALYSIS

As stated above, the conversion cost for this project was $ 17,431.08. While the initial investment required for this conversion was significant, long-term benefits and operational efficiency improvement could lead to substantial cost savings over time. This section focuses on the running cost comparison between the two setups. Assuming the pump runs 350 days a year, 24 hours a day. The remaining days were assigned for scheduled pump maintenance. Plant record also shows that they consume around 1.5 gallons of water daily and must top up. Since the whole plant has a central factory for glycol, this cannot be quantified on a daily basis. However, a 10% glycol consumption based on distilled water has been assigned for this calculation. Prices were sourced from Appendix P.

Table 15 Pump operational Cost

Yearly Operating Cost of Pump			
	Quantity (gal)	**Price/Unit**	**Total Cost**
Glycol	52.5	36	$ 1,890.00
Distilled Water	525	3.63	$ 1,905.75
Running Cost			$ 1,337.25
		Total	**$ 5,133.00**
Grand Total with Tax			**$ 5,902.95**

Source: Original

Table 15 summarizes the operational cost of running the water-cooled system and auxiliaries. It includes using distilled water and glycol and running the pump annually. On average, Saint John Energy charges around 10.67 cents per kWh (Saint John Energy Rates). The operating costs do not include the glycol cooling in the central cooling factory, which will add up to the cost reduction after conversion. Additionally, there was a significant energy cost difference between the two systems. Studies show that air cooling systems save between 7 percent to 80 percent of electricity compared to water cooling (McGwire). On a conservative assumption of 20% saving, the cost to operate an air-cooled system is around $ 1,069.8, significantly lower than operating a water-cooled system. Table 16 shows that an annual saving of 79.2% in terms of operating costs can be achieved by switching to an air-cooled system.

Table 16 Operational Cost Comparison

Yearly Operating Cost of Blowers	
Running Cost	$ 1,230.27
Savings	
Overall Saving	$ 4,672.68
Annual Saving Percentage	**79.2%**

Source: Original

9.2 RETURN ON INVESTMENT

The analysis of the ROI for this project was focused on cost savings. This project aimed to reduce the opportunity lost in production due to frequent shutdowns. Extruder 3 can generate $18,000 of profit in a 24-hour operation, provided that no unforeseen shutdown may hinder production. In addition, the company lost $750 per hour every time there was a problem with the water-cooled system.

Moreover, pump systems for industrial setup commonly have a lifespan of 15 to 20 years (U.S. Department of Energy). Considering that Extruder 3 has been in use since 1992 and has been operational for almost 31 years, the company should upgrade the equipment to meet the demand. In contrast, a high-quality fan may last up to fifty years, provided it receives regular service and maintenance schedule (What is an industrial fan's life span?).

As mentioned, the expected annual cost savings is $4,672.68 per year. Doing the calculation would result in the following:

Payback period: $ 17,431.08 /$ 4672.68 = 3.73 years

Total expected cost savings over equipment life: $4,672.68/year x 50 years (life expectancy of blowers) = $233,634.

Total Expected Return on Investment (ROI): ($233,634/ $17,431.08) x 100% = 1,340.33%

Based on the calculations above, the project was economically doable, with a payback period of around three and a half years. Over the lifespan of the blowers, the expected ROI was 1,340.33%, indicating that the project has excellent potential to provide significant returns in terms of savings. Note that the computation does not include income generated by the machine due to equipment upgrades. The project is a wise investment with relatively short payback and significant potential profits.

10.0 CONCLUSION AND RECOMMENDATION

This project focuses on converting water cooled system into an air-cooled system. As stated in this study, conversion has many benefits, such as cost-effectiveness, less maintenance, and energy efficiency. This also eliminates the need for distilled water and glycol as part of the water-cooled system.

This report can be summarized into four categories.

- Determining the size of the blower based on heat calculations.
- Proper selection of heater bands for heat load demand
- Designing a shroud that can improve the airflow.
- Installation of fins for better cooling.

Based on the calculations, purchasing a three-phase blower was recommended since it draws less current when starting. Furthermore, five heater bands with a heating capacity of 2000W must be installed along the barrel to meet the maximum heat demand of 9000 W when in need. The 2" heater band was chosen because it has the best surface area ratio for cooling and heating. Installation of fins would help the heat transfer, thus saving energy in running the blowers. It is recommended to fabricate the fins in-house to minimize the cost of production. Finally, a shroud design with baffles to direct the airflow and flappers on the air outlet to minimize natural convection and radiation would add to a more economical design.

Further study is recommended to add variable frequency drives (VFD) for each blower. The installation of VFDs can help regulate the speed of the blowers, resulting in significant energy savings instead of just turning them on or off. In addition, a study to capture the heat dissipated and redirect it to the areas where it can be useful can add up to the plant's overall efficiency.

It is also recommended that the new equipment assembly be installed during the equipment schedule maintenance shutdown so as not to disrupt the regular operation.

At a total cost of $ 17,431.08 for the whole assembly of the conversion, Inteplast Bags & Films Corporation could maximize the equipment's capacity by increasing throughput and decreasing downtime. Overall, the project shows a return on investment in less than four years and a 1,340.33% return on savings over the equipment's life span, which aligns with the company's goal for continuous improvement.

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APPENDIX A: STR APPROVAL FORM

Source: Original

Project Approval Form

Student Information

Name: Bryan G. Mendoza

Program & Date: Mechanical Engineering Technology, September 24, 2022

Email & Phone: bgmendoza.nb@gmail.com & (506) 566-4858

Update to Proposal: No

Advisor & Sponsor Information

Department Advisor & Assigned Difficulty Level: Jay Fletcher & 3.5

Project Sponsor & Liaison: Ron Loughery & Maintenance

Project Site: Inteplast Bags & Films Corp., 291 Industrial Drive, Saint John N.B. E2L 4C3

Project Email & Phone: rloughery@bssj.inteplast.com & (506) 633-8101

Project Description

1. Describe the current problem that needs to be addressed (who/what/where/when/why)

- Inteplast Bags and Films Corporation is a plastic manufacturing company in Saint John New Brunswick that uses a blown film extrusion process at the beginning of its production. Extruder barrels need to heat & cool to maintain the desired operating temperature. Currently, extruder number 3 uses a water-cooled system using a pump and a reservoir that runs continuously even if the unit does not need cooling. The barrel temperature is currently automatically controlled by temperature controllers. This particular extruder has 5 separate "Zones" which allow a different heat profile to be adjusted along the length of the barrel. These controllers have separate outputs which turn on either heat or cool output to maintain desired temperature setpoint. The heat output energizes a contactor which turns on a resistive heating element when the actual temperature is below the desired temperature. The cool output energizes a solenoid valve which permits the cooling water to flow through the existing barrel heat/cool unit when the actual temperature exceeds the desired temperature. The amount of cooling water allowed to flow through the heat/cool unit is manually adjusted with a needle valve by the operators. This is to prevent the thermal shock of the controlled zone. The pump also uses distilled water as a cooling medium and passes through a heat exchanger and uses glycol on the colder side. The glycol is supplied from a temperature-controlled factory process system. Furthermore, the breakdown of either pump or the motor will cause the whole unit to shut down.

2. State the Objective of your project (what/why)

- The objective of this project is to study the heat and mass transfer of the extruder 3 and convert the existing water-cooled barrel of the extruder into an air-cooled type using a series of blowers and use automation controls for the blowers to turn on or off depending on the desired temperature. This is to eliminate unscheduled shutdown due to pump or motor malfunction. Also, to increase the energy efficiency of the barrel cooling. The cooling pump runs continuously, and the distilled water is an ongoing expense due to evaporation and leakage.

Project Deliverables

List the concrete elements that you will produce to achieve the Objective of the Project (e.g., CAD drawings, load calculations, specifications, ROI, test data for systems, flow diagrams, recommendations....)

- Any drawing required including
  - 2D and 3D CAD for the existing setup
  - 2D and 3D CAD **drawings/models** for the proposed modification **& assembly**
  - Electrical diagram and instrumentation controls diagram, **P&ID**
- Tables and charts and diagrams that are needed especially for temperature profiling.
- Computation of the project design cost
- All heat and mass load calculations, equipment rating, flow rates, material specifications and the like.
- Cost Benefit Analysis and future cost-effectiveness of the project
- ROI Analysis
- Mounting Calculations

Signature & Dates

Student: [signature] **Date:** October 03,2022

Sponsor: Ron Lonqhurz [signature] **Date:** OCT 12/22

STR Coordinator: Rob Linden **Date:** 10/25/2022

APPENDIX B: STR FORMAL PROPOSAL

Source: Original

TO: Jay Fletcher
COPIES: Rob Linden
FROM: Bryan Mendoza - MET
DATE: 27 November 2022

SUBJECT: **FORMAL PROPOSAL for NBCC-SJ Senior Technical Project and Report —MET Project Title: Converting Extruder No. 3 Barrel from Water-Cooled to Air-Cooled System at Inteplast Bags & Films Corp.**

ATTACHMENTS: **Appendix A – List of Project Deliverables**
Appendix B – Weekly Work Plan Schedule
Appendix C – Available Project Resources

BACKGROUND TO PROJECT

Plastic extrusion is a process in a manufacturing plant wherein plastic materials are fed from a silo into the barrel of an extruder. The plastic material is gradually melted using external heat and the friction between the screw and the barrel itself and is divided into different zones. These zones need to maintain a specific temperature to run smoothly.
Inteplast Bags and Films Corporation is a plastic manufacturing company in Saint John, New Brunswick, that uses a blown film extrusion process at the beginning of its production. Extruder barrels need to heat & cool to maintain the desired operating temperature.
Currently, extruder number 3 uses a water-cooled system using a single pump and a reservoir that runs continuously even if the unit does not need cooling. Though the system uses distilled water for the cooling system, clogging and scaling along the line causes the cooling to be inefficient. Furthermore, glycol is supplied from the temperature-controlled factory process system as a heat exchange medium for the water, which adds to the unit's operating cost. All this causes a significant setback in the operation of the plant, including maintenance of the pump and motor, which results in a consequent loss in the production opportunities of the plant.

As a mechanical engineering technology student at NBCC, I have acquired knowledge through my instructors to develop the skills necessary for this project. This project is suitable for applying engineering subjects such as heat transfer, fluids and machinery, cooling using force draft blowers, design, blueprint reading, AutoCAD and SolidWorks, and communication skills. To solve the stated problem and come up with a suitable solution within specifications and costs, I will need to apply all necessary knowledge with the support of my instructors, my advisor, and my project sponsor.

PROJECT DESCRIPTION / SCOPE

This project aims to convert the existing water-cooled barrel for extruder 3 to an air-cooled system at Inteplast Bags & Film Corp. and improve the following:

- Improve overall plant efficiency by eliminating equipment running (in this case, pump and motor) even not in use
- Reduce operating costs by eliminating the use of glycol as a heat exchange medium.
- Maximize the use of energy through the use of an improved airflow diffuser along the barrel.

This project includes heat calculations of the existing setup and the design of an air-cooled system that will replace the current setup with better efficiency. The success will be evaluated by the efficiency and cost of the project.

a) Project Deliverables

A list of project deliverables is included in Appendix A: "List of Project Deliverables." To be able to achieve the desired outcome of the project, I will need to:

- Study the overall plant setup and operation.
- Included CAD models for proposed modification and assembly
- Calculating heat dissipated by the extruding barrel and the heat transfer from the barrel to the water-cooling system.
- Using the calculated heat flow rate, compute the required airflow needed to dissipate the same amount of heat.
- Sizing of blowers/blowers for each zone on the barrel
- Mounting calculations and design recommendations on how to install the blowers/blowers
- Integrate existing Process Logic Control into the newly installed equipment.
- Design costs and cost-benefit analysis

b) Schedule

This project requires frequent plant visits to gather information necessary for preliminary design concepts. Company-owned devices such as thermal cameras, measuring tools, and mechanical means will be needed to access hidden parts required for this project. Thorough Research is also essential on the subject matter to fully understand the concept and apply it in this project. Attached is Appendix B: "Weekly Action Plan Schedule," which gives an overview of the timeline needed to complete the project.
Significant milestones for this project include:

- Having a clear and concise calculation of heat transfer for the existing setup, which provides for data collection, actual measurements, and applying engineering formulas
- Sizing up equipment such as blowers and their auxiliaries
- Design an airflow system that will maximize the transfer of heat
- Final recommendation and suggestions for suppliers in the market that suits the best quality yet at an economical price

FEASIBILITY

a) Personal Credentials:

With my experience working in the oil and gas industry for the past years, I've gained skills such as critical thinking and attention to detail that I needed to complete this project. I am immersed in different kinds of mechanical equipment, such as stationary and static, and relate those experiences to the actual design. Furthermore, with my current job as a restaurant server, I have gained soft communication skills, which are very important for the field I am in right now. Lastly, New Brunswick Community College has taught me all the technical knowledge needed to be competent and fit to finish this project.

b) Resources:

I will utilize a variety of resources to guarantee the timely and effective execution of this project. Appendix C: "Available Project Resource" summarizes tools needed to finish this project promptly. In addition to the resources already mentioned, my advisor, Jay Fletcher, will help me understand the concepts and put them into practice through his expertise on the subject.

REQUEST FOR AUTHORIZATION

With all the documents presented and all the plans set in place, I hope this will be satisfactory to convince you that I am fit for this project. With this, please accept my proposal and give me the authorization to begin my project at Inteplast Bags & Films Corp.

The experience and knowledge I will gain in this project will significantly help the company and improve the skills I can use to find an employer.

Regards,

Bryan Mendoza
MET-2 Student

Appendix A: List of Project Deliverables **Date: 27 November 2022**
Name, Program: Bryan Mendoza-MET
Project Title: Converting Extruder No. 3 Barrel from Water-Cooled to Air-Cooled System at Inteplast Bags & Films Corp.
Sponsor: Ron Loughery-Maintenance at Inteplast Bags & Films Corp., Saint John

Project Deliverables

The following project deliverables will be included in the final submission of the report.

- Any drawing required, including
  - 2D and 3D CAD for the existing setup
  - 2D and 3D CAD drawings/models for the proposed modification & assembly
  - Electrical diagram and instrumentation controls diagram, P&ID
- Tables and charts, and diagrams that are needed, especially for temperature profiling.
- Complete bill of materials on the latest equipment prices available
- Computation of the project design cost
- All heat and mass load calculations, equipment ratings, flow rates, material specifications and the like.
- Cost Benefit Analysis and future cost-effectiveness of the project
- ROI Analysis
- Mounting Calculations

Appendix B: Weekly Work Plan Schedule **Date: 27 November 2022**
Name, Program: Bryan Mendoza-MET
Project Title: Converting Extruder No. 3 Barrel from Water-Cooled to Air-Cooled System at Inteplast Bags & Films Corp.
Sponsor: Ron Loughery-Maintenance at Inteplast Bags & Films Corp., Saint John

Weekly Work Plan Schedule
All STR Project ***DELIVERABLES*** are mentioned at appropriate times in the following Work Plan.

Previous Work Completed

- Plant Visit and overall operation
- Meeting with Ron Loughery concerning the project
- Establish a structured daily Logbook

November 7-13

- **Start the Project Proposal and Weekly Workplan**
- **November 10th** Meet with Project Sponsor on-site—take notes on proposed work-plan schedule/restrictions…
- Review plant rules and production
- Establish CAD requirements
- Gather background information on the topic/company
- Begin review of background data on the problem
- Consult with my Technical Advisor regarding the proposed work plan

November 14-20

- Complete review of background information
- Gather field data for the project, including temperature profiling on each zone of the barrel
- Calculation of heat dissipated by the extruding barrel and the heat transfer from the barrel to the water-cooling system

November 21-27

- The initial design of air flow ducting wrapped around the barrel to maximize heat dissipation from the barrel to the atmosphere
- Computation for the volumetric flow rate required to size up the blowers needed
- **November 27th -**Submit formal STR Proposal and Weekly Workplan with all required Appendices to the Assignment Dropbox COMM & ETTG ***DELIVERABLE***
- Communicate with the project sponsor for additional data needed for the computation

November 28-December 4

- Meet with Project Sponsor to approve the project schematic and review the data
- Begin literature review
- Discuss project solutions with Technical Advisor
- Begin to compile a list of options and recommendations

December 5-11

- Finalize existing project schematic on CAD
- Prepare a draft list of recommendations/options for discussion with the Project Sponsor ***DELIVERABLE***
- Meet with Ron Loughery for any suggestions about the progress of the project
- Review SolidWorks and begin to model the design
- Review AutoCAD and begin to model the existing setup
- Update the logbook from time to time

December 12-18

- Start doing all CAD drawings for the existing setup and proposed modification and assembly

December 19-January 1

- Christmas Break
- Continue doing CAD drawings for the existing setup and proposed modification and assembly

January 2-8

- Finalizing CAD drawings and having Graham Moore take a look at the files ***DELIVERABLE***
- Research electrical diagrams and instrumentation, and controls needed for the project
- Research on mounting calculations for the modified design to the existing setup
- Start Researching vendors for suitable equipment needed and suppliers for possible fabrication of design.

January 9-15

- Design for the Electrical Diagram and instrumentation control diagram
- Design the mounting of the proposed modification to the existing setup
- Finalizing the equipment and the inventory of all materials needed for the project, ie. Bolts, fasteners, clamps, wires etc.
- Update the logbook from time to time

January 16-22

- Finalizing Design for Electrical Diagram and instrumentation control diagram ***DELIVERABLE***
- Finalizing the mounting design of the components. ***DELIVERABLE***
- **January 22nd-** Submission of Progress Report to the Assignment Dropbox by 11:59 pm; email advisor to request a meeting via teams and include Rob Linden in the correspondence to review progress ***DELIVERABLE***

January 23-29

- Research topics on cost-benefit analysis and rate of investment using collected data
- Research on the computation of project design costs

January 30-February 5

- Start computation for the cost-benefit analysis and rate of investment using the collected data
- Putting up together all reports and starting drafting for the STR by the standards

February 6-12

- Finalizing computation for cost-benefit analysis and investment rate using the collected data and the project design costs. ***DELIVERABLE***
- Going back to all sessions that are helpful for the STR, such as video recordings of Rob Linden and Sarah Wilson

February 13-19

- Finalizing the report and having someone take a look at it. (possibly other instructors and/or my advisor if there is any point missing, additional data to be added etc.)
- Meet with Rob Linden for the formatting of the STR

February 20-26

- Final checking of the report before submission.
- **February 26th**- Submit the initial Submission to the Assignment Dropbox by 11:59 pm ***DELIVERABLE***

February 27-March 5

- Meet with Ron Loughery for any additional input on the initial submitted STR
- Meet with Jay Fletcher for any revisions on the project

March 6-12

- Finalize report
- Completion of the front matter of the report

March 13-19

- Start working on the PowerPoint slide presentation
- Start proofreading the report

March 20-26

- Continue working on the slides and start preparation for the STR presentation
- Finalize report and start printing final STR (if there is no revision)

March 27-April 2

- Finalize PowerPoint slides and prepare some answers to possible questions that might be asked
- Final touch-up on the report and have it ready on original hard copy, digital e-copy, flash drive

APRIL 3-10

- **April 10th** Submit copies of the Senior Technical Report as outlined in class ***DELIVERABLE***
- Practice STR presentation
- Invite Sponsor to attend Presentation (date/time/NBCC E2001)

APRIL 11-14

- Prepare and practice STR Presentation
- Presentation are 12,13, 14th in the PEF (E-2001)

Appendix C: Available Project Resources **Date: 27 November 2022**
Name, Program: Bryan Mendoza-MET
Project Title: Converting Extruder No. 3 Barrel from Water-Cooled to Air-Cooled at Inteplast Bags & Films Corp.
Sponsor: Ron Loughery-Maintenance at Inteplast Bags & Films Corp., Saint John

List of People Contacted or to be Contacted:

- Jay Fletcher
- Joshua Murray
- Dana Betts
- Shannon Milutin
- Graham Moore
- Rob Linden
- Ron Loughery

Topics to be Researched:

- Heat transfer
- Fluid Mechanics
- Plastic Manufacturing/Plastic Extrusion
- Process Heating: Water vs. air cooling in plastic manufacturing.

Resources (equipment) used in your Research:

- AutoCAD
- Solid works
- Thermal Camera
- Measuring tools, ie. Vernier calliper, tape measure
- Microsoft office
- Calculator

Sources (websites & books) used in your Research:

- https://www.iqsdirectory.com/articles/plastic-extrusion.html
- https://www.process-heating.com/articles/91919-water-vs-air-cooling-during-plastics-manufacturing
- https://www.youtube.com/c/PaulsonTraining
- https://www.engineeringtoolbox.com/convective-heat-transfer-d_430.html
- https://nbcc.libguides.com/mechaniclengineeringtechnology

APPENDIX C: PROGRESS REPORT

Source: Original

TO: Jay Fletcher
COPIES: Rob Linden
FROM: Bryan Mendoza
DATE: 22 January 2023
ATTACHMENT: Appendix A: Weekly Work Plan (Deliverables and Target Dates)
SUBJECT: **NBCC-SJ MET2 Senior Technical Report - Progress Report**
Project Title: Converting Extruder No. 3 Barrel from Water-Cooled to Air-Cooled System at Inteplast Bags & Films Corp.
Period Covered: 27 November 2022 – 22 January 2023

PROJECT OBJECTIVE/OVERVIEW

Inteplast Bags and Films Corporation is a plastic manufacturing company in Saint John, New Brunswick, that uses a blown film extrusion process at the beginning of its production. Extruder barrels need to heat & cool to maintain the desired operating temperature.

Currently, extruder number 3 uses a water-cooled system using a single pump and a reservoir that runs continuously even if the unit does not need cooling. Though the system uses distilled water for the cooling system, clogging and scaling along the line causes the cooling to be inefficient. Furthermore, glycol is supplied from the temperature-controlled factory process system as a heat exchange medium for the water, which adds to the unit's operating cost. All this causes a significant setback in the operation of the plant, including maintenance of the pump and motor, which results in a consequent loss in the production opportunities of the plant.

The project's main objective is to convert water-cooled barrels into air-cooled ones and design a system that works better than the current setup.

I selected this subject because it covers a vast mechanical engineering knowledge such as design, heat and mass calculations.

I will apply the knowledge I learned in the program to this project. Deep research on the topic is essential in successfully designing an air-cooled system. I can also reach out to some technical people who are knowledgeable about this topic in academic and industrial setups.

With the preliminary measurement I did together with some research and keeping in touch with my project sponsor Ron Loughery and my project advisor Jay Fletcher, I did with the first stage of the design, which is the calculations and worked on the second stage, which is the design and drawing of the proposed project.

WORK COMPLETED

Since I have very little knowledge of the topic, I did preliminary research online on how the plastic industry works. Luckily, my project sponsor gave me a detailed tour of their plant and discussed each process. I also contacted some of the sectors for similar applications. I had a few exchange emails with Tempco, a US-based company that provides a wide variety of products in heating and cooling products. I also talked to Walter Smith of Xaloy, which supplies barrels for Inteplast Bags and Films Corporation, to get some information about the barrel. I also made some inquiries with Durex industries for similar products.

The sizing of blowers for each zone was calculated using some of the insights that are acceptable in the industry given by Zach Goslin of Tempco, as well as some efficiencies on their products. I also used the book Heat Transfer: A Practical Approach by Yunus Cengel for my other heat transfer calculations.

For the progress of the project, I have completed the following calculations:

- ✓ Sizing of Blowers
- ✓ Convective heat transfer of Air
- ✓ Sizing of Fins
- ✓ Radial Conduction of heat
- ✓ Sizing of heater bands

Background Material Collected:

a) Original mechanical drawings, such as barrel dimensions and existing setup configurations, were given to me by my project sponsor Mr. Ron Loughery.

b) Check out books from the NBCC library as well as online books and came across the following, which are of a big help in doing my calculations:
   - Heat Transfer: A Practical Approach by Yunus A. Cengel
   - Fundamentals of Heat and Mass Transfer by Frank P. Incropera et. al.

c) Other websites that are also I also found very interesting are as follows:
   - https://web.mit.edu/16.unified/www/FALL/thermodynamics/notes/node128.html
   - https://designerdata.nl/materials/plastics/thermo-plastics/low-density-polyethylene
   - https://www.engineeringtoolbox.com/convective-heat-transfer-d_430.html

Original Drawings:

Drawings that are needed for this project using a combination of AutoCAD and Solidworks, which were taught in college. The list below is the drawings needed for the project.

- 2D and 3D drawing of the current setup-80% complete
- Drawing for the fin design-100% complete
- Drawing for the heater band design-100% complete
- Drawing for the shroud design-in progress
- Drawing for the fan specification design- in progress
- 2D and 3D drawings of the proposed design-in progress
- Electrical block diagram- not yet started
- Instrumentation block diagram- not yet started

Data Collected:

Data collected were a combination of measured data and data provided by the project sponsor from the equipment manufacturers handbook and based on the years of experience operating the equipment. Some of the data that were given to me by my project sponsor are as follows:

1. Maximum operating temperature without cooling- **570°F**
2. Mass flow rate of the melted plastic in lb/hr. **850 lb/hr**
3. Setpoint temperature (which I believe is 390F?) Typically, **370-410°F**
4. Feed- **HDPE/LLDPE leaning more towards LLDPE**

I also got some data on fan and band heaters manufacturer, which gave me the following valuable data:

1. Typical Static Pressure Range for Shrouds- **0.45-0.55" of H_2O**
2. Efficiency of Standard Blowers- **75-85%**
3. Factor of Safety they use for the industry- **25%**
4. Frictional air losses due to baffles and air restrictions- **10%**

PROBLEMS ENCOUNTERED

I have had an opportunity to visit the plant regularly since I started this project and did some measurements, such as collecting data for the existing setup. I also made some comparisons to their units that are factory built air-cooled and got some ideas.

With the current development of the project, there are many issues that arise which, in fact, necessary for the project. Many design considerations should be based on assumptions and must be proven in mathematical solutions or known facts that need to be researched. Some of the required values are the following:

- Factor of Safety
- Rate of cooling and heating that will be used in material selection
- Mounting calculations

Some of these issues affect the timeline for project deliverables. I am still working on those issues by reading and asking questions that are experts in this field. This gives me better ideas on how to tackle problems correctly. Although I am a bit behind in my proposed schedules on project deliverables, I am confident that I can address all issues on time.

WORK TO BE COMPLETED

Having almost all the data needed for my computation, I can proceed with the following work items remaining to finish the project:

- Finalize calculation and selection of the blowers at the rated capacity needed for the project
- Finalize all the drawings
- Get quotations on how much the project will eventually cost
- Finalize design for electrical and instrumentation block diagrams
- Finalize mounting calculations

See attached Appendix A for a detailed Weekly Work Plan with Target Dates.

CONCLUSION

I have gone through much development since I started this project, from the planning stage to brainstorming and researching. Though unforeseen events slightly delay my schedule for the project, I am confident that I can finish it on time and will complete all my deliverables as planned. With the help and guidance of my project sponsor and my technical advisor, I am now on the right track to completing this project.

Appendix A: Weekly Work Plan **Date: 22 January 2022**
Name, Program: Bryan Mendoza, MET
Project Title: Converting Extruder No. 3 Barrel from Water-Cooled to Air-Cooled System at Inteplast Bags & Films Corp.
Sponsor: Ron Loughery-Maintenance at Inteplast Bags & Films Corp., Saint John

All STR Project ***DELIVERABLES*** are mentioned at appropriate times in the following Work Plan.
All completed project items are indicated in orange, checkmark on the side, and green fonts are work in progress.

Previous Work Completed

- Plant Visit and overall operation
- Meeting with Ron Loughery concerning the project
- Establish a structured daily Logbook

November 7-13

- ✓ **Start the Project Proposal and Weekly Workplan**
- ✓ **November 10th** Meet with Project Sponsor on-site—take notes on proposed work-plan schedule/restrictions…
- ✓ Review plant rules and production
- ✓ Establish CAD requirements
- ✓ Gather background information on the topic/company
- ✓ Begin review of background data on the problem
- ✓ Consult with my Technical Advisor regarding the proposed work plan

November 14-20

- ✓ Complete review of background information
- ✓ Gather field data for the project, including temperature profiling on each zone of the barrel
- ~~Calculation of heat dissipated by the extruding barrel and the heat transfer from the barrel to the water-cooling system~~. **(Ruled out of the work item)**

November 21-27

- ✓ The initial design of air flow ducting wrapped around the barrel to maximize heat dissipation from the barrel to the atmosphere
- ✓ Computation for the volumetric flow rate required to size up the blowers needed
- ✓ **November 27th -**Submit formal STR Proposal and Weekly Workplan with all required Appendices to the Assignment Dropbox COMM & ETTG ***DELIVERABLE***
- ✓ Communicate with the project sponsor for additional data needed for the computation

November 28-December 4

- ✓ Meet with Project Sponsor to approve the project schematic and review the data
- ✓ Begin literature review
- ✓ Discuss project solutions with Technical Advisor
- ✓ Begin to compile a list of options and recommendations

December 5-11

- ✓ Finalize existing project schematic on CAD
- ✓ Prepare a draft list of recommendations/options for discussion with the Project Sponsor ***DELIVERABLE***
- ✓ Meet with Ron Loughery for any suggestions about the progress of the project
- ✓ Review SolidWorks and begin to model the design
- ✓ Review AutoCAD and begin to model the existing setup
- ✓ Update the logbook from time to time

December 12-18

- ✓ Start doing all CAD drawings for the existing setup and proposed modification and assembly

December 19-January 1

- ✓ Christmas Break
- ✓ Continue doing CAD drawings for the existing setup and proposed modification and assembly

January 2-8

- o Finalizing CAD drawings and having Graham Moore take a look at the files ***DELIVERABLE***
  - ✓ Research electrical diagrams and instrumentation, and controls needed for the project
  - ✓ Research on mounting calculations for the modified design to the existing setup
  - ✓ Start Researching vendors for suitable equipment needed and suppliers for possible fabrication of design.

January 9-15

- o Design for the Electrical Diagram and instrumentation control diagram
- o Design the mounting of the proposed modification to the existing setup
- o Finalizing the equipment and the inventory of all materials needed for the project, ie. Bolts, fasteners, clamps, wires etc.
  - ✓ Update the logbook from time to time

January 16-22

- o Finalizing Design for Electrical Diagram and instrumentation control diagram ***DELIVERABLE***
- o Finalizing the mounting design of the components. ***DELIVERABLE***
- o **January 22nd-** Submission of Progress Report to the Assignment Dropbox by 11:59 pm; email advisor to request a meeting via teams and include Rob Linden in the correspondence to review progress ***DELIVERABLE***

January 23-29

- o Research topics on cost-benefit analysis and rate of investment using collected data
- o Research on the computation of project design costs

January 30-February 5

- o Start computation for the cost-benefit analysis and rate of investment using the collected data
- o Putting up together all reports and starting drafting for the STR by the standards

February 6-12

- Finalizing computation for cost-benefit analysis and investment rate using the collected data and the project design costs. ***DELIVERABLE***
- Going back to all sessions that are helpful for the STR, such as video recordings of Rob Linden and Sarah Wilson

February 13-19

- Finalizing the report and having someone take a look at it. (possibly other instructors and my advisor if there is any point missing, additional data to be added etc.)
- Meet with Rob Linden for the formatting of the STR

February 20-26

- Final checking of the report before submission.
- **February 26th**- Submit the initial Submission to the Assignment Dropbox by 11:59 pm ***DELIVERABLE***

February 27-March 5

- Meet with Ron Loughery for any additional input on the initial submitted STR
- Meet with Jay Fletcher for any revisions on the project

March 6-12

- Finalize report
- Completion of the front matter of the report

March 13-19

- Start working on the PowerPoint slide presentation
- Start proofreading the report

March 20-26

- Continue working on the slides and start preparation for the STR presentation
- Finalize report and start printing final STR (if there is no revision)

March 27-April 2

- Finalize PowerPoint slides and prepare some answers to possible questions that might be asked
- Final touch-up on the report and have it ready on original hard copy, digital e-copy, flash drive

APRIL 3-10

- **April 10th** Submit copies of the Senior Technical Report as outlined in class ***DELIVERABLE***
- Practice STR presentation
- Invite Sponsor to attend Presentation (date/time/NBCC E2001)

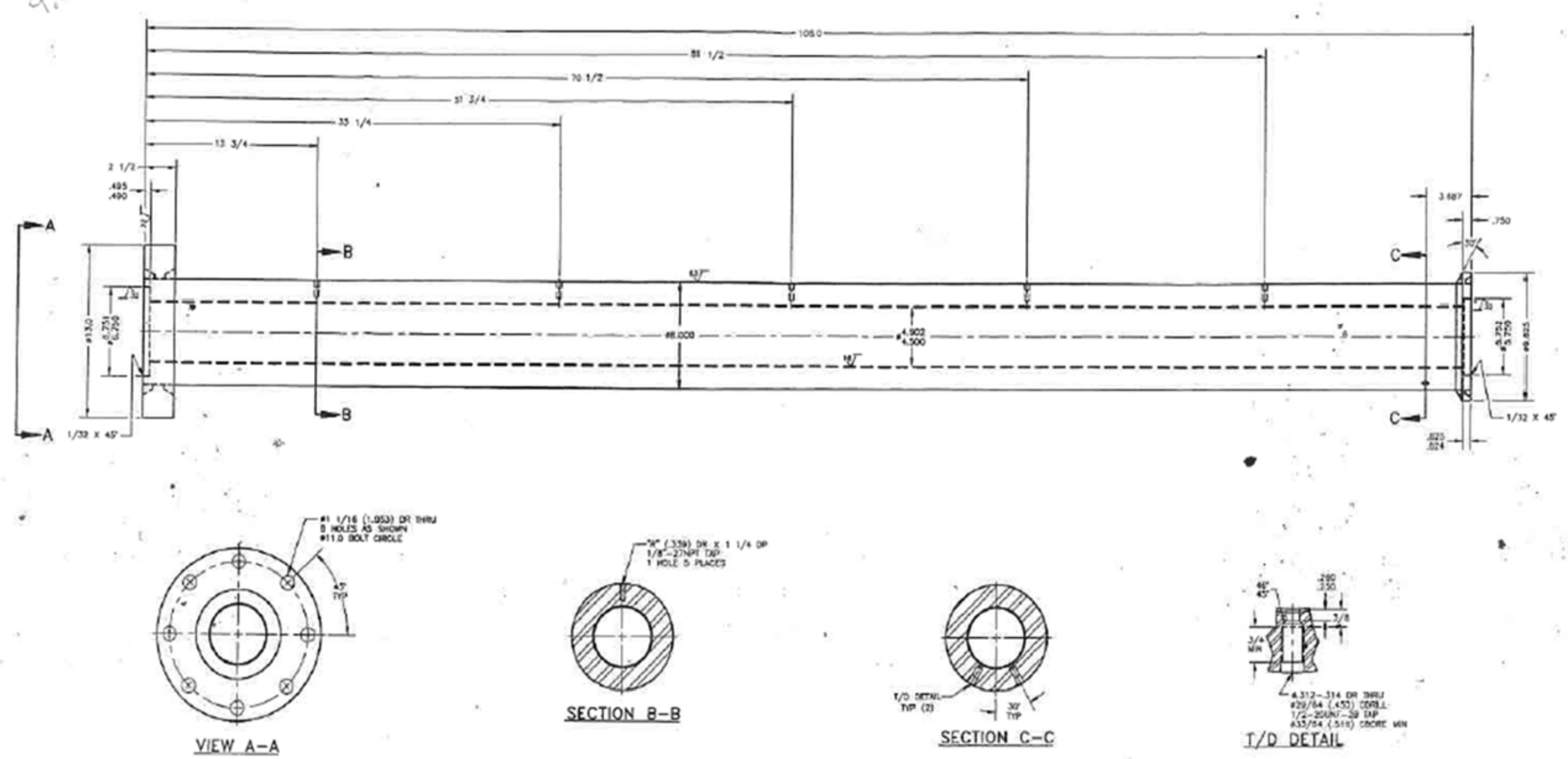
APRIL 11-14

- Prepare and practice STR Presentation
- Presentation are 12,13, 14th in the PEF (E-2001)

APPENDIX D: DETAILED DRAWING OF THE BARREL

Source: Ron Loughery of Inteplast Bags and Plastics Corp

13" I 3.375
9.625 (85.73mm)



PART NO:	INLAY TYPE	BACKING STEEL
51096	X-800	BM32

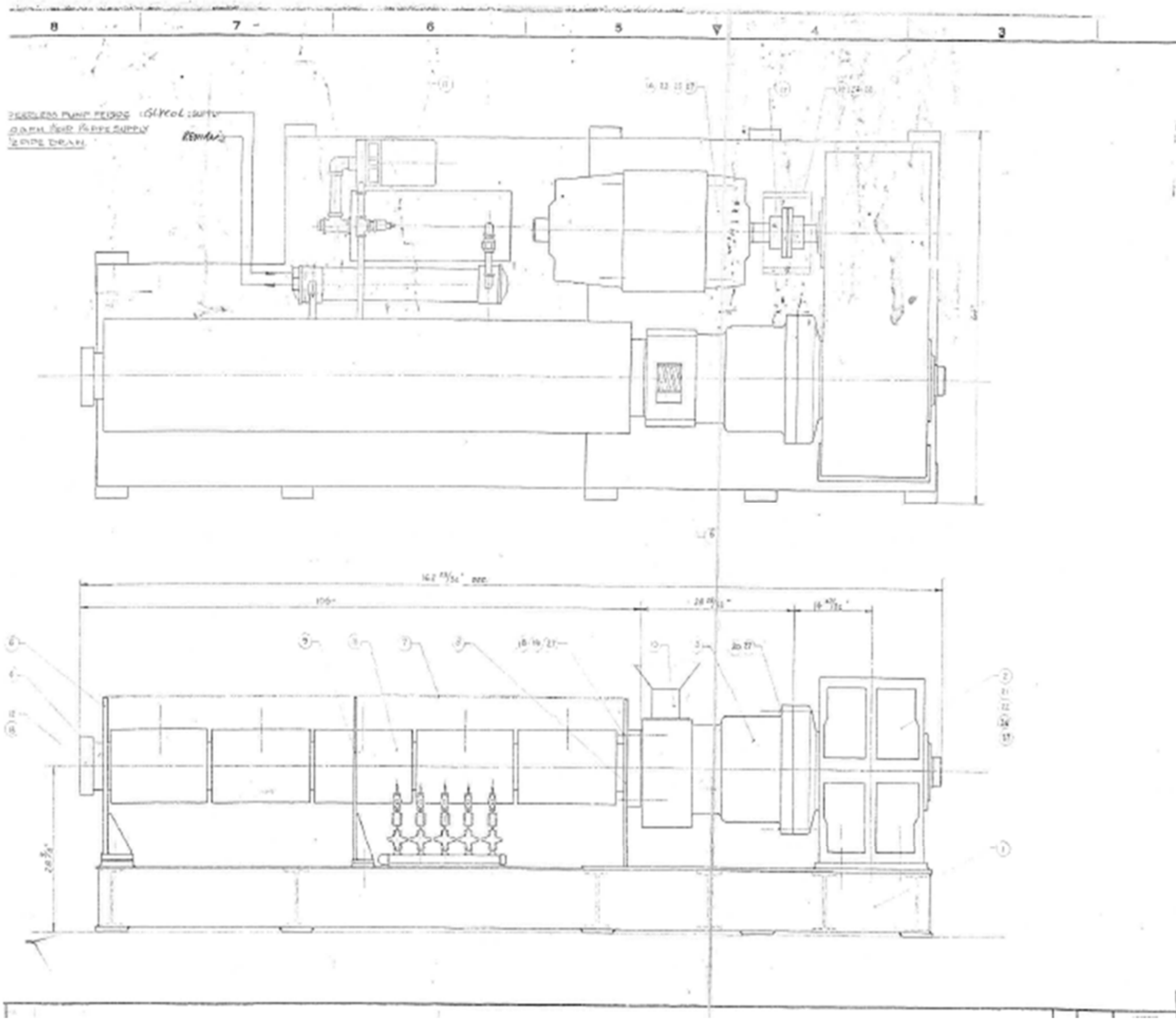
NO.	REVISION DESCRIPTION	DATE	CHK.

TOLERANCES UNLESS OTHERWISE SPECIFIED
INCHES

TITLE: ø4 1/2" BRAMPTON TYPE EXTRUDER BARREL

DWN BY: Mahon	DATE: 3/01/88
CHK BY: DOUGLAS SWECKER	DATE: 3/02/88
SCALE: .27=1	SHEET: 1 OF 1
DWG NO: 006124	REV NO: 00

XALOY® INCORPORATED



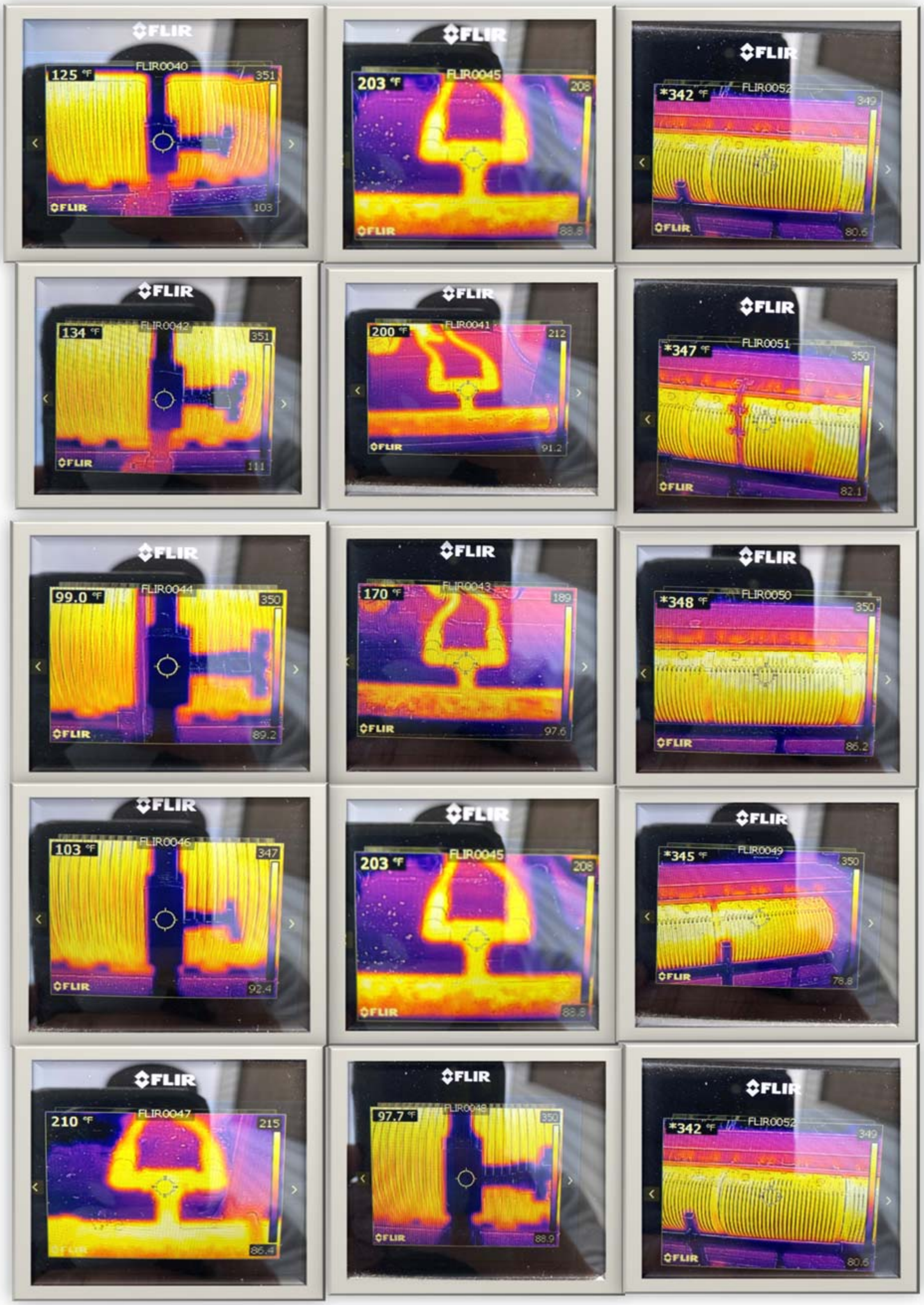
BRAMPTON ENGINEERING

ITEM	QTY	DESCRIPTION	PART NO. / SPEC.
1	1	[illegible]	E-3500-285
4	1	[illegible]	[illegible]
2	1	[illegible] THRUST HOUSING ASSY	E-78-2324-026
3	1	[illegible]	E-78-0000-041
5	1	FEED SECTION	
6	1	BARREL SUPPORT	E-78-2607-001
7	1	BARREL LINER	E-78-2607-031
8	1	BARREL LINER SUPPORT	E-78-2607-001
9	1	[illegible]	[illegible]
10	1	HOPPER	300.0030
11	1	[illegible]	E-78-2607-001
12	1	BREAKER PLATE	E-78-2607-081
13	1	SPACER RING	E-78-2607-021
14	1	COUPLING GUARD	E-78-2607-021
15	8	HEATING / COOLING JACKET	E-78-0000-028
16	1	DRIVE	'RELIANCE' [illegible] FRAME [illegible]
17	1	COUPLING	'FALK' [illegible]
18	6	SOC. HD. CAP SCREW	'UNBRAKO' 1" NC x 4 1/2" [illegible]
19	2	SOC. HD. CAP SCREW	'UNBRAKO' 1" NC x 5" LG.
20	12	SOC. HD. CAP SCREW	'UNBRAKO' 1" NC x 5" LG.
21	8	HEX. HD. SCREW	1/2" NC x 3/4" LG.
22	2	HEX. HD. SCREW	1" NC x 3 1/2" LG.
23	4	HEX. HD. SCREW	1" NC x 2 1/4
24	8	HEX. HD. SCREW	3/8" NC x 3/4" LG.
25	4	HEX NUT	1" NC
26	8	LOCKWASHER	1/2"
27	24	LOCKWASHER	1"
28	8	LOCKWASHER	3/8"

BRAMPTON ENGINEERING

APPENDIX E: TEMPERATURE PROFILE

Source: Original


FLIR
125 °F
FLIR0040
351
103
FLIR
203 °F
FLIR0045
208
88.8
FLIR
*342 °F
FLIR0052
349
80.6
FLIR
134 °F
FLIR0042
351
111
FLIR
200 °F
FLIR0041
212
91.2
FLIR
*347 °F
FLIR0051
350
82.1
FLIR
99.0 °F
FLIR0044
350
89.2
FLIR
170 °F
FLIR0043
189
97.6
FLIR
*348 °F
FLIR0050
350
86.2
FLIR
103 °F
FLIR0046
347
92.4
FLIR
203 °F
FLIR0045
208
88.8
FLIR
*345 °F
FLIR0049
350
78.8
FLIR
210 °F
FLIR0047
215
86.4
FLIR
97.7 °F
FLIR0048
350
88.9
FLIR
*342 °F
FLIR0052
349
80.6

APPENDIX E: PROPERTIES OF AIR

Source: Cengel, Yunus A. Heat Transfer A Practical Approach. Texas: Mcgraw-Hill, 2003. Book.

https://www.engineeringtoolbox.com

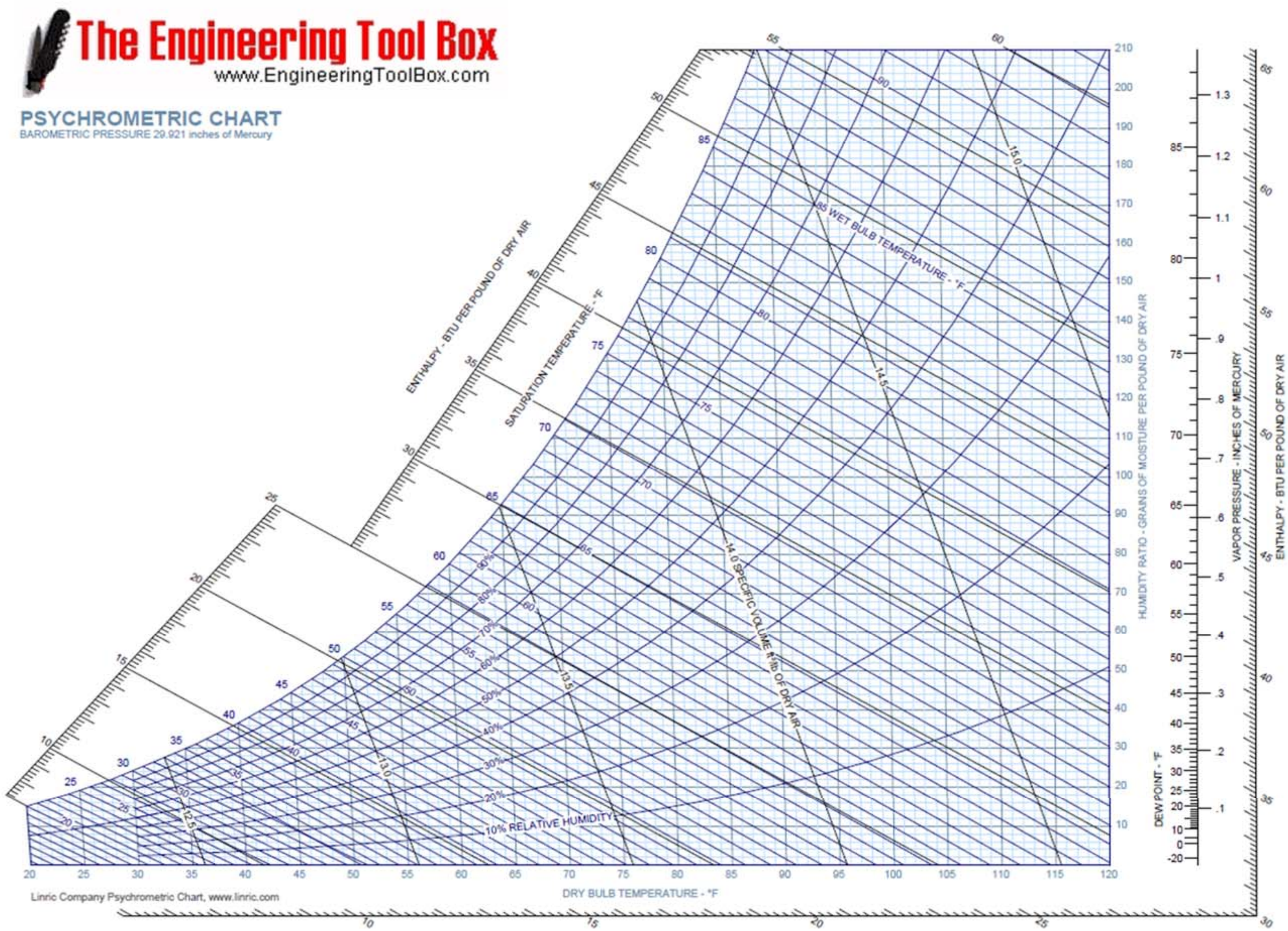
TABLE A–15

Properties of air at 1 atm pressure

Temp. T, °C	Density ρ, kg/m^3	Specific Heat c_p, J/kg·K	Thermal Conductivity k, W/m·K	Thermal Diffusivity α, m^2/s	Dynamic Viscosity μ, kg/m·s	Kinematic Viscosity ν, m^2/s	Prandtl Number Pr
−150	2.866	983	0.01171	4.158×10^{-6}	8.636×10^{-6}	3.013×10^{-6}	0.7246
−100	2.038	966	0.01582	8.036×10^{-6}	1.189×10^{-5}	5.837×10^{-6}	0.7263
−50	1.582	999	0.01979	1.252×10^{-5}	1.474×10^{-5}	9.319×10^{-6}	0.7440
−40	1.514	1002	0.02057	1.356×10^{-5}	1.527×10^{-5}	1.008×10^{-5}	0.7436
−30	1.451	1004	0.02134	1.465×10^{-5}	1.579×10^{-5}	1.087×10^{-5}	0.7425
−20	1.394	1005	0.02211	1.578×10^{-5}	1.630×10^{-5}	1.169×10^{-5}	0.7408
−10	1.341	1006	0.02288	1.696×10^{-5}	1.680×10^{-5}	1.252×10^{-5}	0.7387
0	1.292	1006	0.02364	1.818×10^{-5}	1.729×10^{-5}	1.338×10^{-5}	0.7362
5	1.269	1006	0.02401	1.880×10^{-5}	1.754×10^{-5}	1.382×10^{-5}	0.7350
10	1.246	1006	0.02439	1.944×10^{-5}	1.778×10^{-5}	1.426×10^{-5}	0.7336
15	1.225	1007	0.02476	2.009×10^{-5}	1.802×10^{-5}	1.470×10^{-5}	0.7323
20	1.204	1007	0.02514	2.074×10^{-5}	1.825×10^{-5}	1.516×10^{-5}	0.7309
25	1.184	1007	0.02551	2.141×10^{-5}	1.849×10^{-5}	1.562×10^{-5}	0.7296
30	1.164	1007	0.02588	2.208×10^{-5}	1.872×10^{-5}	1.608×10^{-5}	0.7282
35	1.145	1007	0.02625	2.277×10^{-5}	1.895×10^{-5}	1.655×10^{-5}	0.7268
40	1.127	1007	0.02662	2.346×10^{-5}	1.918×10^{-5}	1.702×10^{-5}	0.7255
45	1.109	1007	0.02699	2.416×10^{-5}	1.941×10^{-5}	1.750×10^{-5}	0.7241
50	1.092	1007	0.02735	2.487×10^{-5}	1.963×10^{-5}	1.798×10^{-5}	0.7228
60	1.059	1007	0.02808	2.632×10^{-5}	2.008×10^{-5}	1.896×10^{-5}	0.7202
70	1.028	1007	0.02881	2.780×10^{-5}	2.052×10^{-5}	1.995×10^{-5}	0.7177
80	0.9994	1008	0.02953	2.931×10^{-5}	2.096×10^{-5}	2.097×10^{-5}	0.7154
90	0.9718	1008	0.03024	3.086×10^{-5}	2.139×10^{-5}	2.201×10^{-5}	0.7132
100	0.9458	1009	0.03095	3.243×10^{-5}	2.181×10^{-5}	2.306×10^{-5}	0.7111
120	0.8977	1011	0.03235	3.565×10^{-5}	2.264×10^{-5}	2.522×10^{-5}	0.7073
140	0.8542	1013	0.03374	3.898×10^{-5}	2.345×10^{-5}	2.745×10^{-5}	0.7041
160	0.8148	1016	0.03511	4.241×10^{-5}	2.420×10^{-5}	2.975×10^{-5}	0.7014
180	0.7788	1019	0.03646	4.593×10^{-5}	2.504×10^{-5}	3.212×10^{-5}	0.6992
200	0.7459	1023	0.03779	4.954×10^{-5}	2.577×10^{-5}	3.455×10^{-5}	0.6974
250	0.6746	1033	0.04104	5.890×10^{-5}	2.760×10^{-5}	4.091×10^{-5}	0.6946
300	0.6158	1044	0.04418	6.871×10^{-5}	2.934×10^{-5}	4.765×10^{-5}	0.6935
350	0.5664	1056	0.04721	7.892×10^{-5}	3.101×10^{-5}	5.475×10^{-5}	0.6937
400	0.5243	1069	0.05015	8.951×10^{-5}	3.261×10^{-5}	6.219×10^{-5}	0.6948
450	0.4880	1081	0.05298	1.004×10^{-4}	3.415×10^{-5}	6.997×10^{-5}	0.6965
500	0.4565	1093	0.05572	1.117×10^{-4}	3.563×10^{-5}	7.806×10^{-5}	0.6986
600	0.4042	1115	0.06093	1.352×10^{-4}	3.846×10^{-5}	9.515×10^{-5}	0.7037
700	0.3627	1135	0.06581	1.598×10^{-4}	4.111×10^{-5}	1.133×10^{-4}	0.7092
800	0.3289	1153	0.07037	1.855×10^{-4}	4.362×10^{-5}	1.326×10^{-4}	0.7149
900	0.3008	1169	0.07465	2.122×10^{-4}	4.600×10^{-5}	1.529×10^{-4}	0.7206
1000	0.2772	1184	0.07868	2.398×10^{-4}	4.826×10^{-5}	1.741×10^{-4}	0.7260
1500	0.1990	1234	0.09599	3.908×10^{-4}	5.817×10^{-5}	2.922×10^{-4}	0.7478
2000	0.1553	1264	0.11113	5.664×10^{-4}	6.630×10^{-5}	4.270×10^{-4}	0.7539

Note: For ideal gases, the properties c_p, k, μ, and Pr are independent of pressure. The properties ρ, ν, and α at a pressure P (in atm) other than 1 atm are determined by multiplying the values of ρ at the given temperature by P and by dividing ν and α by P.

Source: Data generated from the EES software developed by S. A. Klein and F. L. Alvarado. Original sources: Keenan, Chao, Keyes, Gas Tables, Wiley, 1984; and Thermophysical Properties of Matter. Vol. 3: Thermal Conductivity, Y. S. Touloukian, P. E. Liley, S. C. Saxena, Vol. 11: Viscosity, Y. S. Touloukian, S. C. Saxena, and P. Hestermans, IFI/Plenun, NY, 1970, ISBN 0-306067020-8.



The Engineering Tool Box
www.EngineeringToolBox.com
PSYCHROMETRIC CHART
BAROMETRIC PRESSURE 29.921 inches of Mercury
ENTHALPY - BTU PER POUND OF DRY AIR
SATURATION TEMPERATURE - °F
WET BULB TEMPERATURE - °F
SPECIFIC VOLUME ft³/lb OF DRY AIR
10% RELATIVE HUMIDITY
HUMIDITY RATIO - GRAINS OF MOISTURE PER POUND OF DRY AIR
DEW POINT - °F
VAPOR PRESSURE - INCHES OF MERCURY
ENTHALPY - BTU PER POUND OF DRY AIR
DRY BULB TEMPERATURE - °F
Linric Company Psychrometric Chart, www.linric.com

APPENDIX G: SIZING OF BLOWERS CALCULATION

Source: Original (Calculation)

http://www.polydynamics.com/fra_library.htm (Plastic Properties)

STR

BRIAN MENDOZA
5059633
MET-2

CALCULATING THE AMOUNT OF HEAT GENERATE BY THE PROCESS IN TERMS OF THE CONTROLLED SETPOINT & THE MAXIMUM TEMPERATURE WITHOUT COOLING.

USING FORMULA

$$Q = m C_p \Delta T$$

WHERE m = mass flow rate = $850 \frac{lb}{hr}$

T_2 = MAXIMUM TEMPERATURE WITHOUT COOLING = 550°F

T_1 = SETPOINT TEMPERATURE
= 370°F - 410°F (DEPENDING ON THE MATERIAL TO BE USED)

* FOR THIS CALCULATION, I WILL USE 370°F FOR EXTREME CONDITION

C_p = LDPE / LLDPE MATERIAL BEING USED
= 2300 J/kg-K
= $0.55 \frac{Btu}{lb\text{-}°F}$

$$Q = m C_p \Delta T$$
$$= 850 \frac{lbs}{hr} \cdot 0.621 \frac{Btu}{lb\text{-}°F} (550 - 370)$$
$$Q = 84{,}150 \frac{Btu}{hr}$$

STR

BRYAN MENDOZA
5059633
ME7-2

AMBIENT TEMPERATURE INSIDE THE BUILDING (EXTREME)
80°F
SPECIFIC VOLUME (PSYCHROMETRIC CHART)

$\dot{v} = 13.6\ ft^3/lb$ $\qquad C_{p\,air} = 0.24\ \frac{BTU}{lb\cdot°F}$

$\rho = 0.07353\ lb/ft^3$

$Q = \dot{m}_{air}\, C_{p\,air}\, (\Delta t)$ $\qquad \rho = \frac{\dot{m}}{\dot{V}}$

WHERE

Δt → TEMPERATURE DIFFERENCE BETWEEN THE SETPOINT & THE INDOOR TEMPERATURE

$84{,}150\ \frac{BTU}{hr} = \dot{V}\left(0.0735\ \frac{lb}{ft^3}\right)\left(0.24\ \frac{BTU}{lb\cdot°F}\right)(370-80)$

$\dot{V} = \frac{84{,}150\ \frac{BTU}{hr}}{0.0735(0.24)(370-80)} \times \frac{1hr}{60min}$ = **279.84 CFM**

ACCOUNTING FOR:
FACTOR OF SAFETY = 1.2
EFFICIENCY : 80%
AIR LOSSES : 10%

BLOWER SIZE CFM $= \frac{279.84}{0.8} \times 1.2 \times 1.1 =$ **461.7 CFM**

Table 3

Selected Thermal Properties.

Polymer	Solid Density* ρ (g/cm^3)	Glass Transition T_g	Melting Point T_m	Usual Melt Processing Range	Melt Density* ρ (kg/m^3)	Thermal Conductivity k (W/m °C) (Btu/h ft °F)	Heat Capacity Cp (J/kg °C) (Btu/lb_m °F)	Heat of Fusion ΔH (J/kg) (Btu/lb)
HDPE	0.941-0.967	-130°C -202°F	130-137°C 266-278°F	160-240°C 320-464°F	780	0.25 0.145	2200-2400 0.52-0.57	210,000-300,000 90-130
LDPE	0.915-0.935	-130°C -202°F	106-112°C 223-234°F	160-240°C 320-464°F	760	0.20 0.115	2200-2400 0.52-0.57	190,000-240,000 80-100
LLDPE	0.910-0.925	-130°C -202°F	125°C 257°F	160-240°C 320-464°F	760	0.20 0.115	2200-2400 0.52-0.57	190,000-240,000 80-100
PP	0.890-0.910	-20°C -4°F	165°C 329°F	180-240°C 356-464°F	730	0.18 0.10	2000-2200 0.48-0.52	210,000-260,000 90-110
PVC (Rigid)	1.30-1.58	80°C 176°F	175°C 347°F	165-205°C 329-401°F	1250	0.17 0.10	1000-1700 0.24-0.41	170,000-190,000 70-80
PS	1.04-1.10	100°C 212°F	amorphous**	180-240°C 356-464°F	1000	0.15 0.09	1300-2000 0.31-0.48	amorphous**
PMMA	1.17-1.20	105°C 221°F	amorphous**	180-230°C 356-446°F	1050	0.19 0.11	1400-2400 0.33-0.57	amorphous**
PET	1.34-1.39	80°C 176°F	265°C 509°F	275-290°C 527-554°F	1160	0.18 0.10	1800-2000 0.43-0.48	120,000-140,000 50-60
ABS	1.01-1.04	105-115°C 221-239°F	amorphous**	200-290°C 392-554°F	990	0.25 0.145	1300-1700 0.31-0.41	amorphous**
Nylon-66	1.13-1.15	90°C 194°F	265°C 509°F	275-290°C 527-554°F	980	0.20 0.115	2400-2600 0.57-0.62	190,000-205,000 80-88
PC	1.2	140°C 284°F	amorphous**	250-305°C 482-581°F	1050	0.22 0.13	1300-2200 0.31-0.52	amorphous**

* Melt densities have been estimated for roughly the mid-temperature of the processing range. See Mark [9] for expressions in the form $\rho = A - BT \pm CT^2$.

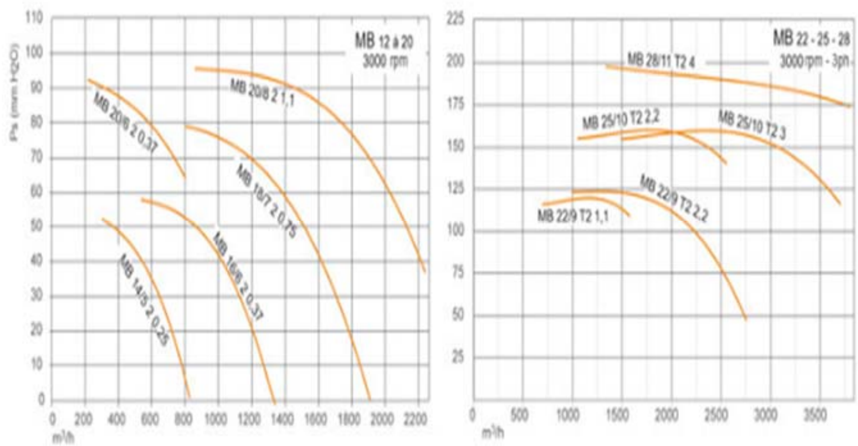
APPENDIX H: BLOWER SPECIFICATIONS

Source: *https://www.motor-pump-ventilation.com/merchant/product/centrifugal-fan-mb-3000-rpm-three-phase*

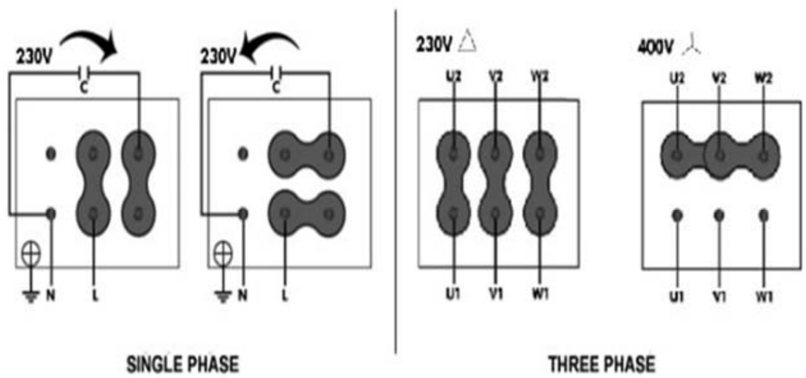
Blower curve: *Original*

Done through Excel and plot digitizer

Construction | **Technical data** | Dimensions | Operating instructions

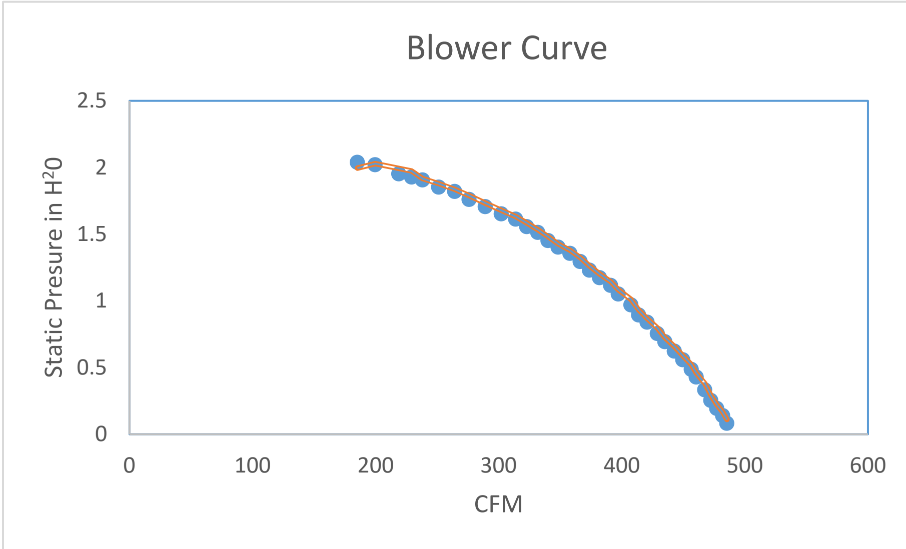


Construction | Technical data | Dimensions | **Operating instructions**

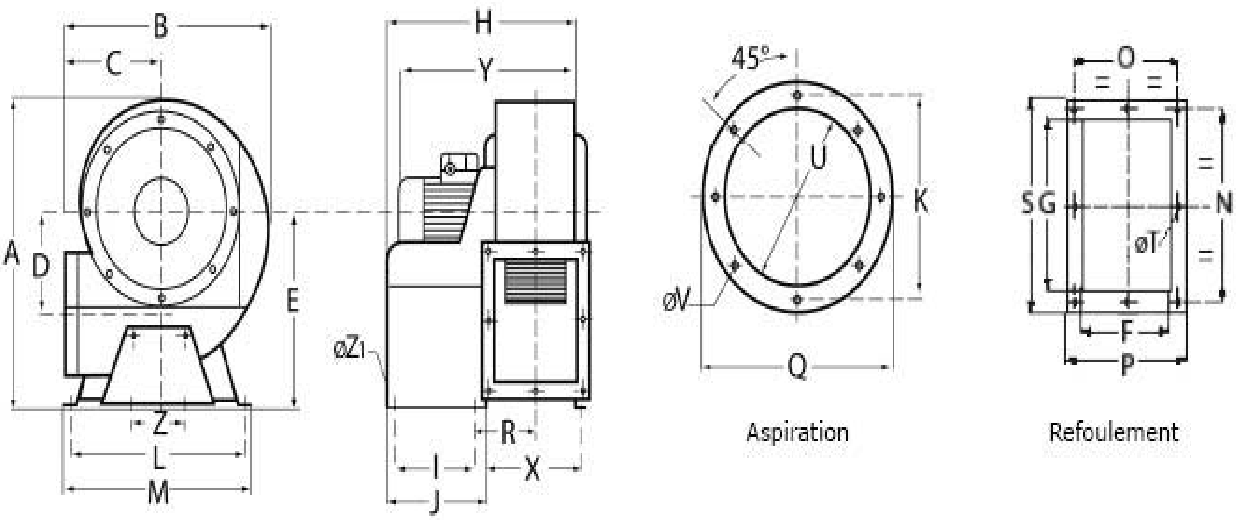


Related Products

CFM	in H^2O
218.903403	1.95194228
185.192228	2.03763571
199.635633	2.01982795
229.222878	1.92695118
238.166376	1.9055311
251.242614	1.85192402
264.314061	1.81979157
276.016747	1.75901803
289.093009	1.70541102
302.169265	1.65180394
313.867101	1.61250496
322.818633	1.5552937
331.766963	1.5123989
340.031678	1.45160433
348.294015	1.40154724
357.93074	1.35507756
366.195455	1.29428291
373.773394	1.2299052
382.037355	1.17268984
390.988858	1.11547862
397.191585	1.05109244
407.52395	0.96883594
413.729113	0.89371252
420.617056	0.84006783
428.887439	0.75421965
435.089377	0.6934126
442.668929	0.62187665
449.559291	0.55749469
456.451243	0.48595455
460.589651	0.42871409
467.487235	0.33212024
472.318034	0.25340934
477.144848	0.19259394
481.970003	0.13893674
485.420805	0.08169208



Type	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T/V	U	Y	Z	Z1
													MB 12 à 20 sans support											
MB 12/5M2-T2	203	180	85	67	116	72	85	225	-	-	135	-	-	105	93	106	150		118	7	92,5	-	-	-
MB 12/5 M4-T4	203	180	85	67	116	72	85	220	-	-	135	-	-	105	93	106	150		118	7	92,5	-	-	-
MB 14/5 M2-T2	249	222	100	91	147	80	105	280	-	-	162	-	-	128	105	123	175		147	7	105	-	-	-
MB 16/6 M2-T2	293	254	118	107	171	100	120	340	-	-	180	-	-	147	128	153	214		172	7	127	-	-	-
MB 16/6 M4-T4	293	254	118	107	171	100	120	310	-	-	180	-	-	147	128	153	214		172	7-9	127	-	-	-
MB 18/7 M2-T2	347	302	128	133	203	115	140	355	-	-	214	-	-	169	146	169	237		192	9	141	-	-	-
MB 20/6 M2-T2	347	300	128	146	203	105	100	335	-	-	230	-	-	128	134	159	255		153	9	161	-	-	-
MB 20/8 M4-T4	375	321	138	136	222	130	160	350	-	-	230	-	-	189	160	184	255		213	9	161	-	-	-
MB 20/8 M2-T2	375	321	138	136	222	130	160	380	-	-	230	-	-	189	160	184	255		213	9	161	-	-	-
													MB 22 à 45 avec support											
MB 22/9 T4 T2 1,1	452	386	181	134	280	140	216	381	50	110	256	220	290	256	180	204	280	100	282	9	180	-	-	11
MB 22/9 T2 2,2	452	386	181	134	280	140	216	429	50	110	256	220	290	256	180	204	280	100	282	9	180	-	-	11
MB 25/10 T4	501	425	197	144	310	165	250	429	74	134	282	228	315	290	205	229	306	113	314	9	203	-	-	13
MB 25/10 T2	501	425	197	144	310	165	250	447	74	134	282	228	315	290	205	229	306	113	314	9	203	-	-	13
MB 28/11 T2	553	471	216	152	340	180	300	515	95	144	320	245	348	340	220	244	348	120	364	9	228	-	-	13
MB 28/11 T4	553	471	216	152	340	180	300	493	95	144	320	245	348	340	220	244	348	120	364	9	228	-	-	13
MB 31/12 T4	644	528	246	182	406	198	319	538	240	290	355	457	482	360	240	274	382	171	395	11	257	538	-	13
MB 35/14 T4	718	584	267	243	451	224	280	564	240	290	394	449	524	318	266	300	422	184	356	11	289	564	-	13
MB 40/16 T4	795	649	300	273	499	250	320	595	240	290	438	560	590	370	300	336	464	192	406	11	325	595	200	13
MB 45/18 T4	885	728	326	305	553	280	360	625	250	300	489	602	632	404	328	356	515	207	436	11	365	625	200	13



Aspiration

Refoulement

APPENDIX I: HEATER BANDS CATALOG

Source*: https://www.tempco.com/Tempco/Products/Electric-Heaters-and-Elements/Band-Heaters.htm*

Made in USA

Standard (Non-Stock) Ceramic Bands

Continued from previous page...

ID		Width		Wattage	Watt Density		Terminal	Part Number			
in	mm	in	mm		W/in²	W/cm²		120V	240V	480V	240/480V
6	152.4	1½	38.1	950	35	5.5	T2	BCH00010	BCH00062	—	—
6	152.4	2	50.8	1900	53	8.2	T3	—	BCH00063	BCH00129	—
6	152.4	2½	63.5	1600	36	5.6	C2A	—	BCH00064	BCH00130	—
6	152.4	3	76.2	1400	26	4.1	T3	—	—	—	BCH00167
6	152.4	4	101.6	1300	18	2.8	T3	BCH00011	BCH00065	—	—
6	152.4	5	127.0	1600	18	2.8	C5E	—	—	—	BCH00168
6	152.4	5½	139.7	2000	20	3.2	T3	—	—	—	BCH00169
6	152.4	6	152.4	2000	19	2.9	T3	—	—	—	BCH00170
6	152.4	6	152.4	3000	28	4.3	T3	—	BCH00066	—	—
6	152.4	6	152.4	4000	37	5.8	T3	—	BCH00067	—	—
6¼	158.8	4	101.6	2430	33	5.1	T3	—	BCH00068	—	—
6¼	158.8	6	152.4	4600	41	6.4	T3	—	—	BCH00131	—
6½	165.1	1½	38.1	1000	34	5.3	T2	—	BCH00069	—	—
6½	165.1	2	50.8	1600	41	6.4	T3	—	BCH00070	—	—
6½	165.1	3½	88.9	1800	26	4.1	T3	BCH00012	BCH00071	—	—
6½	165.1	5	127.0	2500	26	4.0	T3	—	BCH00072	—	—
6½	165.1	5½	139.7	4200	39	6.1	T3	—	—	BCH00132	—
6½	165.1	6	152.4	2000	17	2.7	C5E	—	—	—	BCH00171
6½	165.1	6½	165.1	3700	29	4.5	T3	—	BCH00073	—	—
6⅝	168.3	4½	114.3	3300	37	5.7	T3	—	—	BCH00133	—
6¾	171.5	1½	38.1	1000	33	5.1	T2	BCH00013	BCH00074	—	—
6¾	171.5	5	127.0	2500	25	3.8	C5E	—	BCH00075	—	—
7	177.8	2	50.8	1400	33	5.2	C2A	—	—	BCH00134	—
7	177.8	3	76.2	1650	26	4.1	T3	—	BCH00076	—	—
7	177.8	3½	88.9	1300	18	2.7	T3	BCH00014	BCH00077	—	—
7	177.8	4	101.6	3500	42	6.5	T3	—	BCH00078	BCH00135	—
7	177.8	5½	139.7	2000	17	2.7	C5E	—	BCH00079	—	BCH00172
7	177.8	6	152.4	5400	43	6.6	T3	—	BCH00080	—	—
7½	190.5	2	50.8	1900	42	6.5	T3	—	BCH00081	—	—
7½	190.5	3	76.2	1800	27	4.1	T3	—	BCH00082	BCH00136	—
7½	190.5	4½	114.3	2000	20	3.1	T3	—	—	—	BCH00173
7½	190.5	4½	114.3	2000	20	3.1	T3	BCH00015	BCH00083	—	—
7½	190.5	5	127.0	2500	22	3.4	C2A	—	BCH00084	—	—
7½	190.5	5½	139.7	2500	20	3.1	T3	BCH00016	—	—	BCH00174
7½	190.5	7	177.8	6500	41	6.4	T3	—	—	—	BCH00175
7½	190.5	9	228.6	5710	28	4.4	T3	—	—	BCH00137	—
8	203.2	1½	38.1	770	21	3.3	T2	—	BCH00085	BCH00138	—
8	203.2	1½	38.1	1000	28	4.3	T2	—	—	BCH00139	—
8	203.2	2	50.8	2000	41	6.4	T3	—	BCH00086	—	—
8	203.2	2½	63.5	1000	17	2.6	T2	—	—	BCH00140	—
8	203.2	3	76.2	1900	26	4.1	T3	—	—	—	BCH00176
8	203.2	4	101.6	3000	31	4.8	T3	—	BCH00087	—	—
8	203.2	6	152.4	3500	24	3.7	T3	—	BCH00088	—	—
8	203.2	6	152.4	4500	31	4.8	T3	—	—	BCH00141	—
8	203.2	6½	165.1	2600	17	2.6	C5E	—	—	—	BCH00177
8¹⁄₁₆	204.8	4	101.6	2100	22	3.3	T3	—	—	BCH00142	—
8¹⁄₁₆	204.8	4	101.6	2800	29	4.5	T3	—	—	BCH00143	—
8¹⁄₁₆	204.8	9	228.6	4900	22	3.5	T3	—	—	BCH00144	—
8¼	209.6	3	76.2	2300	31	4.8	C5E	—	BCH00089	—	—
8¼	209.6	7½	190.5	3100	17	2.6	C5E	—	—	—	BCH00178
8⁷⁄₁₆	214.3	3	76.2	3000	39	6.1	T3	—	—	BCH00145	—
8⁷⁄₁₆	214.3	3½	88.9	2800	31	4.9	T3	—	BCH00090	BCH00146	—
8⁷⁄₁₆	214.3	3½	88.9	3255	36	5.7	T3	—	—	BCH00147	—
8⁷⁄₁₆	214.3	4	101.6	3400	33	5.2	T3	—	BCH00091	BCH00148	—
8⁷⁄₁₆	214.3	5½	139.7	3800	27	4.2	T3	—	—	BCH00149	—
8½	215.9	1½	38.1	1250	32	5.0	C2A	—	BCH00092	—	—
8½	215.9	4½	114.3	3890	34	5.2	T3	—	BCH00093	—	—
8¾	222.3	9	228.6	4100	17	2.7	C5E	—	—	—	BCH00179
9	228.6	1½	38.1	1100	27	4.2	T2	—	—	BCH00150	—
9	228.6	2	50.8	2300	42	6.5	T3	—	BCH00094	—	—
9	228.6	2½	63.5	2800	41	6.4	T3	—	BCH00095	—	—
9	228.6	3	76.2	2200	27	4.2	T3	—	—	—	BCH00180
9	228.6	5	127.0	2500	18	2.8	T3	—	—	—	BCH00181
9	228.6	5½	139.7	3000	20	3.1	T3	—	BCH00096	—	BCH00182
9	228.6	8½	215.9	3900	17	2.6	C5E	—	—	—	BCH00183

Standard (Non-Stock) Ceramic Bands

Continued from previous page…

ID in	ID mm	Width in	Width mm	Wattage	Watt Density W/in²	Watt Density W/cm²	Terminal	Part Number 120V	Part Number 240V	Part Number 480V	Part Number 240/480V
9 7/16	239.7	3	76.2	2500	29	4.5	T3	—	BCH00097	BCH00151	—
9½	241.3	1½	38.1	1200	28	4.3	T2	—	—	BCH00152	—
9½	241.3	3	76.2	2200	25	3.9	T3	—	—	—	BCH00184
9¾	247.7	10	254.0	5200	18	2.7	C5E	—	—	—	BCH00185
10	254.0	1½	38.1	600	13	2.0	T2	—	BCH00098	—	—
10	254.0	2	50.8	1800	30	4.6	C2A	—	BCH00099	—	—
10	254.0	3	76.2	2400	26	4.1	T3	—	—	—	BCH00186
10	254.0	4	101.6	1500	12	1.9	C2A	—	BCH00100	—	—
10	254.0	5	127.0	2800	18	2.9	C5E	—	—	—	BCH00187
10	254.0	5½	139.7	2500	15	2.3	T3	—	BCH00101	—	—
10	254.0	6	152.4	3000	16	2.5	C2A	—	BCH00102	—	—
10½	266.7	4½	114.3	5000	35	5.4	C2A	—	BCH00103	—	—
11	279.4	3	76.2	2600	26	4.0	T3	—	—	—	BCH00188
11	279.4	5	127.0	4000	24	3.7	T3	—	—	—	BCH00189
11 1/16	281.0	4	101.6	4000	30	4.6	T3	—	—	BCH00153	—
12	304.8	2	50.8	2000	27	4.2	C2A	—	BCH00104	—	—
12	304.8	3	76.2	2000	18	2.8	C2A	—	—	—	BCH00190
12	304.8	6	152.4	4000	18	2.8	T3	—	—	—	BCH00191
12	304.8	12	304.8	2000	5	0.7	T3	—	BCH00105	—	—
12½	317.5	4	101.6	1950	13	2.0	C2A	—	BCH00106	—	—
12½	317.5	4	101.6	2600	17	2.6	T3	—	BCH00107	—	—
13	330.2	2	50.8	2000	25	3.9	C5E	—	BCH00108	—	—
13	330.2	3	76.2	4200	35	5.4	T3	—	—	—	BCH00192
13	330.2	6	152.4	4000	17	2.6	T3	—	BCH00109	—	—
14½	368.3	3	76.2	2300	17	2.7	T3	—	—	BCH00154	—
15¼	387.4	2	50.8	3000	32	5.0	C2A	—	BCH00110	—	—
16	406.4	2	50.8	1500	15	2.4	C2A	—	BCH00111	—	—
16	406.4	3	76.2	5000	34	5.2	C2A	—	BCH00112	—	—
16½	419.1	2	50.8	3000	30	4.6	C2A	—	BCH00113	—	—
16½	419.1	3	76.2	5400	35	5.5	C2A	—	BCH00114	—	—
16½	419.1	3½	88.9	1800	10	1.6	C2A	—		BCH00155	—
16½	419.1	3½	88.9	2500	14	2.2	T3	—	BCH00115	—	—
16½	419.1	4	101.6	3500	17	2.7	C2A	—	BCH00116	—	—
16½	419.1	5	127.0	4350	17	2.7	T3	—	BCH00117	—	—
17½	444.5	1½	38.1	825	10	1.6	C2A	—	BCH00118	—	—
19¼	489.0	2½	63.5	5000	34	5.2	C2A	—	BCH00119	—	—
21	533.4	4½	114.3	5039	17	2.7	C2A	—	—	BCH00156	—
21	533.4	6	152.4	5600	14	2.2	T3	—	—	BCH00157	—
21½	546.1	3½	88.9	3000	13	2.0	T3	—	—	BCH00158	—
26	660.4	5	127.0	6800	17	2.6	C2A	—	—	BCH00159	—
28	711.2	4½	114.3	6600	17	2.6	T3	—	—	BCH00160	—
28	711.2	5	127.0	5750	13	2.0	T3	—	—	BCH00161	—
32½	825.5	3½	88.9	3000	8	1.3	C2A	—	—	BCH00162	—

Ordering Information

Standard Heaters

Select a Ceramic Insulated Band Heater from pages 1-63 through 1-65. Each heater's Termination Type is indicated.

Type L1 has 10" long leads.

Type W1 has 12" long leads with 10" wire braid.

Type R2A has 12" long leads with 10" galvanized steel armor cable.

Custom Engineered/Manufactured Heaters

Understanding that an electric heater can be very application specific, for sizes and ratings not listed **TEMPCO** will design and manufacture a Ceramic Insulated Band Heater to meet your requirements. ***Standard lead time is 3 weeks.***

Please Specify the following:

- ❑ Inside Diameter
- ❑ Width
- ❑ Wattage
- ❑ Voltage
- ❑ Termination (see pages 1-68 through 1-74)
- ❑ Lead Cable/Braid Length
- ❑ Construction style (see page 1-66)
- ❑ Clamping variation (see page 1-67)

APPENDIX J: CONVECTIVE HEAT TRANSFER OF AIR CALCULATION

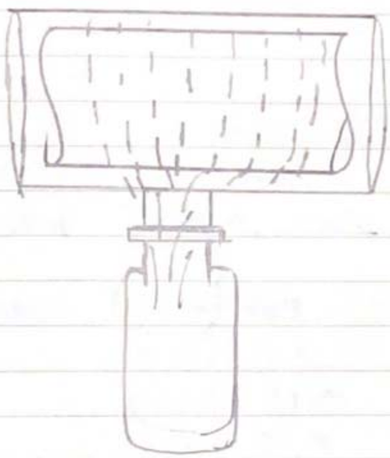
Source: Original

SAR

BRYAN MENDOZA
5059633
MET-2

AIR PROPERTIES

DETERMINATION OF CONVECTIVE HEAT TRANSFER COEFFICIENT OF AIR.



USING THE EMPIRICAL FORMULA:

$$h_{cw} = 12.12 - 1.16V + 11.6V^{1/2}$$

where:
h_{cw} - heat transfer coefficient $\frac{W}{m^2\,°C}$

Diameter of barrel = 8 in = 0.203 m
Length of barrel per section = L = 20 in = 0.508 m
FLOW RATE OF AIR = 461.7 CFM =

$$461.7\ \frac{ft^3}{min} \times \frac{1\ min}{60\ s} \times \left(\frac{1\ m}{3.28\ ft}\right)^3 = 0.218\ m^3/s$$

FLOW AREA: $A = \pi D h$
$$= \pi(0.203)(0.508) = 0.324\ m^2$$

VELOCITY: $Q = AV$
$$V = \frac{Q}{A} = \frac{0.218\ m^3/s}{0.324\ m^2} = 0.672\ m/s$$

$$h_{cw} = 12.12 - 1.16(0.672) + 11.6(0.672)^{1/2} = 20.8495\ \frac{W}{m^2\,°C}$$

APPENDIX K: FIN CALCULATION

Source: Original

STR

BRYAN MENDOZA

5059633

MET-2

SIZING OF FIN.

USING TRIAL AND ERROR TO CALCULATE THE LENGTH OF EACH FIN

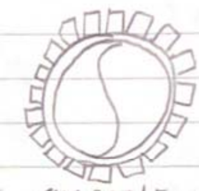
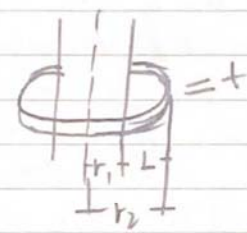


FIGURE 3.43 ON PAGE 162 ON HEAT TRANSFER; A PRACTICAL APPROACH BY CENGEL. SHOWS ANNULAR FINS SIMILAR ON THE CURRENT SETUP

PARAMETERS	VALUES
r_1	0.12779 m
r_2	0.1143 + L m
t	0.00081 m
EFF.	92%
EFF. CURVE	1.2



0.00081 m → GUAGE 20 COPPER SHEET

1.2 → TRIAL & ERROR TO GET "L."

USING

$$\text{EFF CURVE} = \frac{r_2 + 0.5t}{r_1}$$

$$1.2 = \frac{r_2 + 0.5t}{r_1}$$

$$1.2 = \frac{(0.1143 + L) + 0.5(0.0081)}{0.12779\,m}$$

$$L = 0.02515\ m \approx 0.99025\ in$$

STR

BRIAN MENDOZA
5059633
MET-2

SIZING OF FIN.

CHECKING THE CALCULATED VALUE OF "L" USING THE THERMO GEOMETRICAL PARAMETER ON THE X-AXIS OF THE GRAPH.

$$\xi = (L + \tfrac{1}{2} t) \sqrt{h/kt}$$

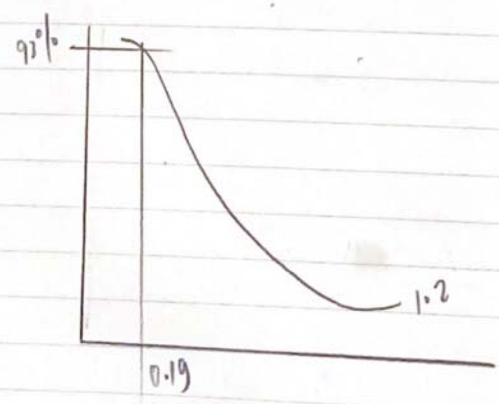
WHERE

$L = 0.025\ m$
$h = 20.85\ W/m^2\text{-}°C$
$k = 401\ \frac{W}{m\text{-}°C} \rightarrow$ COPPER

$$\xi = \left(0.02515 + \tfrac{1}{2}(0.0008128m)\right)\left(\sqrt{\frac{20.85}{401(0.0008128m)}}\right)$$

$\xi = 0.204 \rightarrow$ CALCULATED

ACTUAL FROM TABLE ∴ 0.19 ≈ 0.204



STR

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505 96 33
MET-2

COMPUTATION FOR FIN SPACING

USING THE FORMULA

$$Ra = \frac{g\beta (T_s - T_\infty) L^3}{v^2} Pr$$

EQ. 9-30 pp. 479 ON HEAT TRANSFER BY CENGEL.

USING TABLE A-15 :

Parameters	Definition	Values
g	gravity	9.81 m/s^2
β	coefficient OF volume expansion	0.00231 $/°C$
T_f	Film temperature	158.5°C
T_s	Process temperature	550F or 287°C
T_∞	Ambient Temp	30° C
L	Length	0.96 m
v	kinematic viscosity	1.6×10^{-5} m^2/s
Pr	Prandtl number	0.7282

$$\beta = \frac{1}{T_f} \; ; \; T_f = \frac{1}{2}(T_s + T_\infty)$$

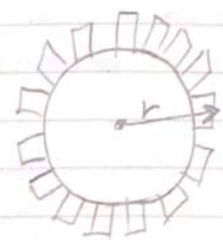
$$T_f = \frac{1}{2}(287°C + 30°C) = 158.5 °C$$

$$\beta = \frac{1}{T_f} = \frac{1}{158.5°C} = 0.00231 °C$$

STR

BRYAN MENDOZA
B059633
MET 2

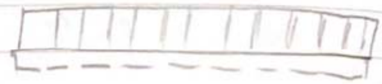
FIN SPACING



$L = 2\pi r$

$L = 2\pi(0.1529\ m)$

$L = 0.96098\ m$



Applying the formula

$$Ra_L = \frac{g\beta(T_s - T_\infty)L^3}{\nu^3} Pr$$

$$Ra_L = \frac{9.81(0.00231)(287.78-30)(0.96098)^3}{(1.608\times10^{-5})^3} \times 0.7282$$

$Ra_L = 146,34,431,778 \approx 1.46\times10^{10}$

USING FORMULA Soptimum

$$S_{optimum} = 2.714\left(\frac{S^3 L}{Ra_S}\right)^{0.25} = 2.714\frac{L}{Ra_L^{0.25}}$$

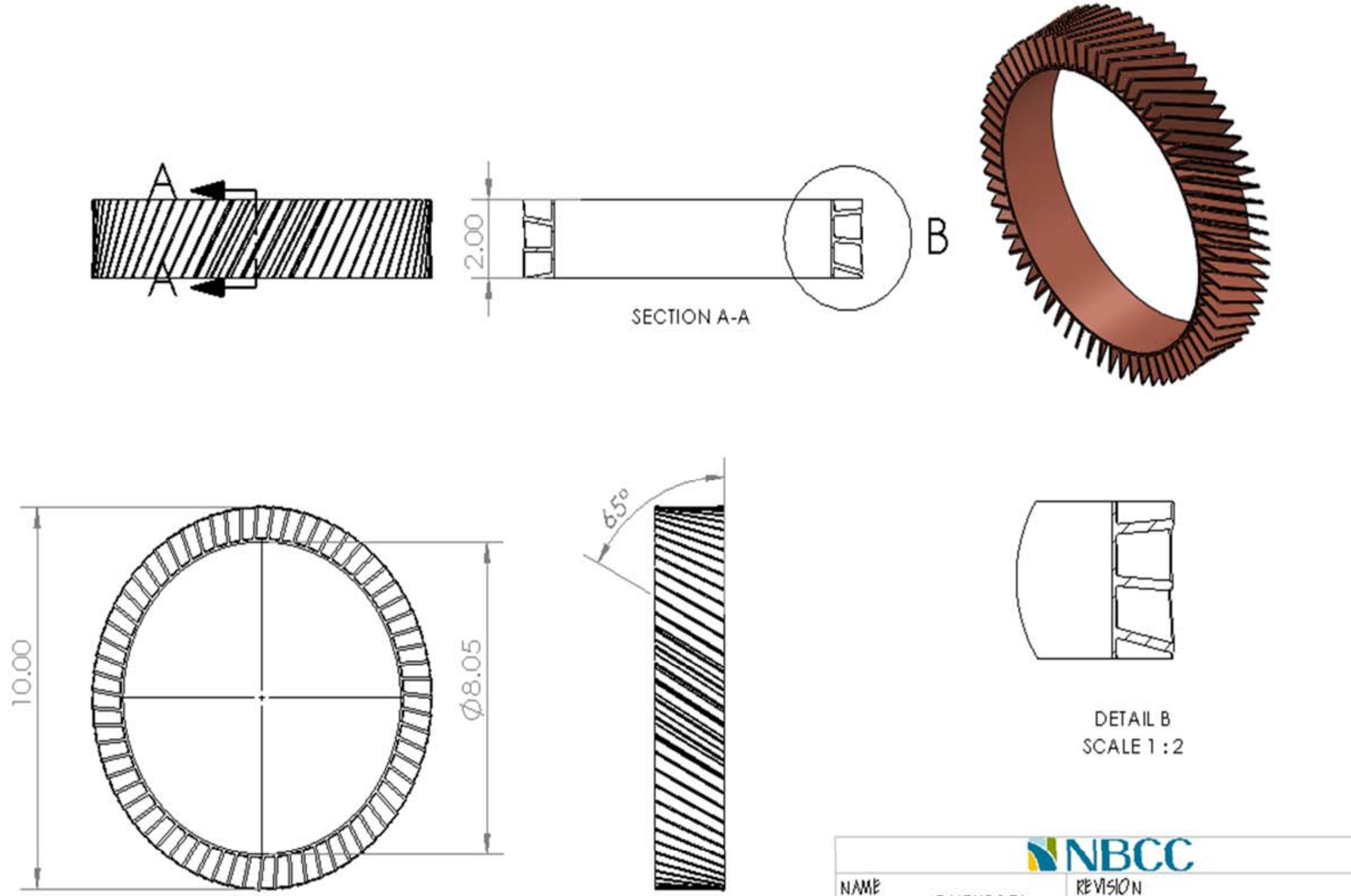
$$S_{optimum} = 2.714\left[\frac{0.96098}{(1.46\times10^{10})}\right]$$

$S_{optimum} = 0.0075m$

$= 0.295in \approx 3/8\ in$

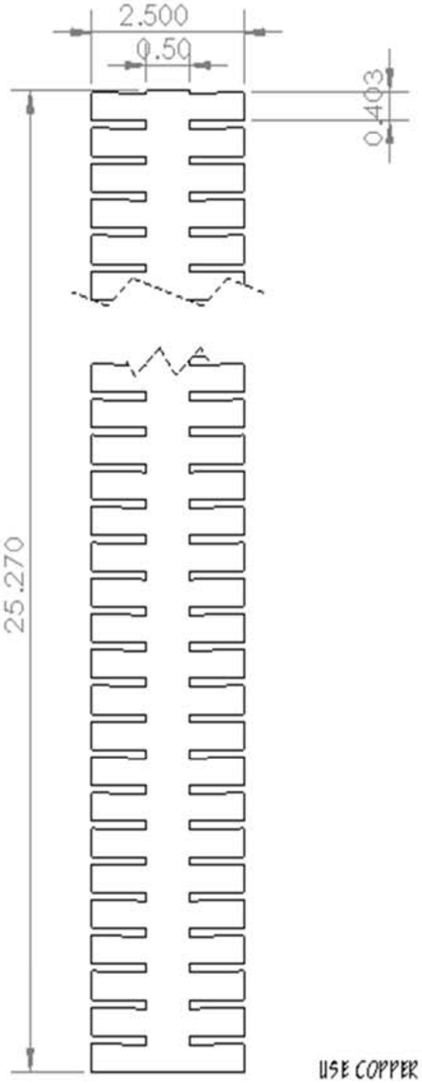
APPENDIX L: FIN DESIGN

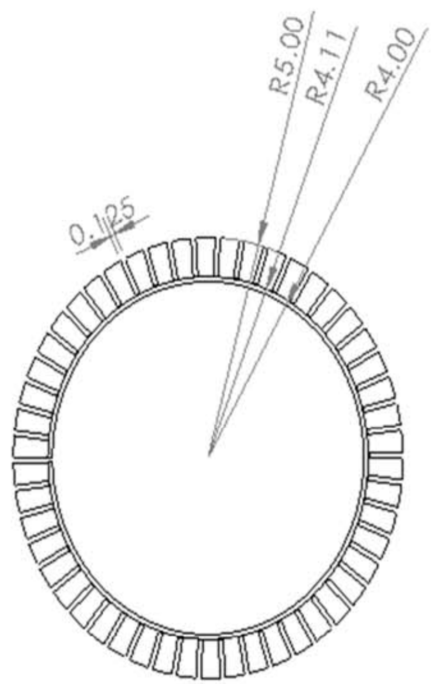
Source: Original

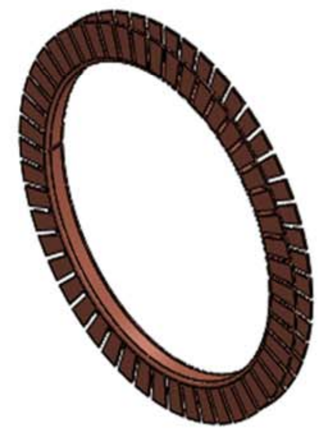


NBCC

NAME	B.MENDOZA	REVISION	
CHK'D BY	J.FLETCHER	SCALE NTS	DATE 03/01/2023
DWG NAME	COPPER FINS V.2	DWG NO.	CF-02



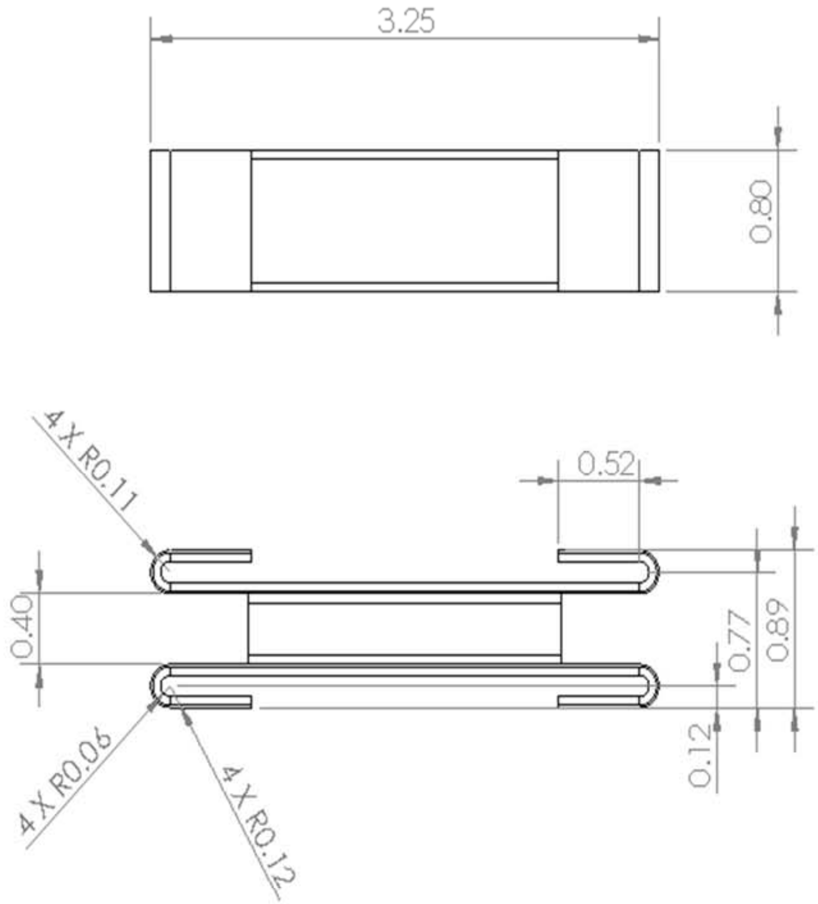


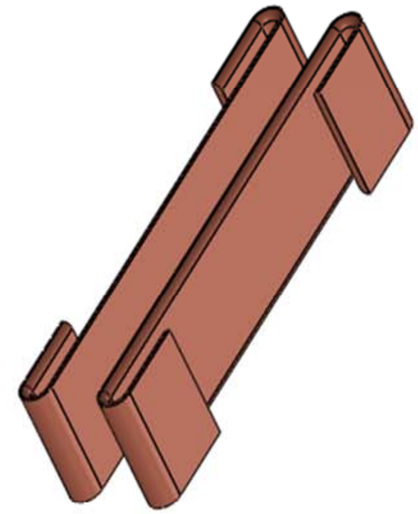


USE COPPER SHEET WITH GUAGE 20 OR 0.032" THICKNESS FOR FABRICATION

NBCC

NAME B.MENDOZA	REVISION		
CHK'D BY J. FLETCHER	SCALE NTS	DATE 03/01/2023	
DWG NAME COPPER FIN		DWG NO CF-01	



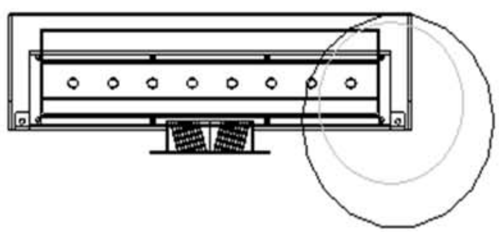


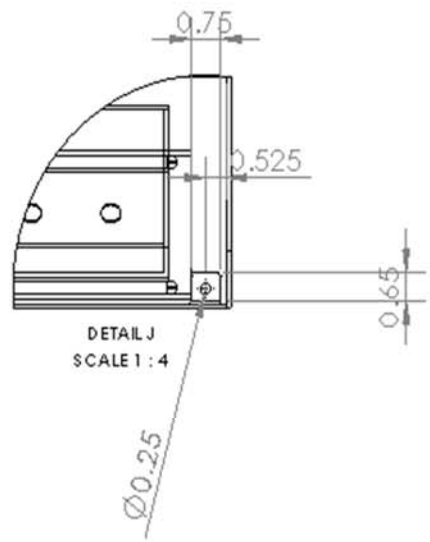
NBCC

NAME	B.MENDOZA	REVISION	
CHK'D BY	J. FLETCHER	SCALE NTS	DATE 03/01/2023
DWG NAME	LOCKING MECHANISM	DWG NO.	LM-01

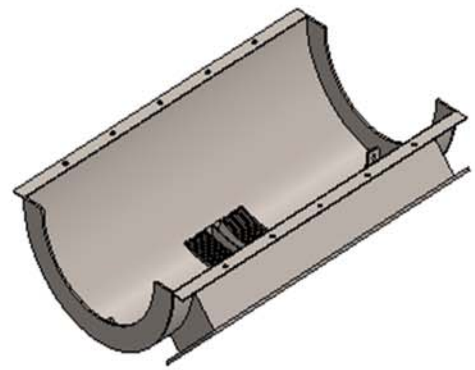
APPENDIX M: UPPER AND LOWER SHROUD DESIGN, FLAPPER, AND CLAMP

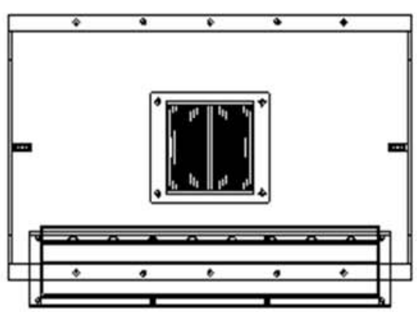
Source: Original





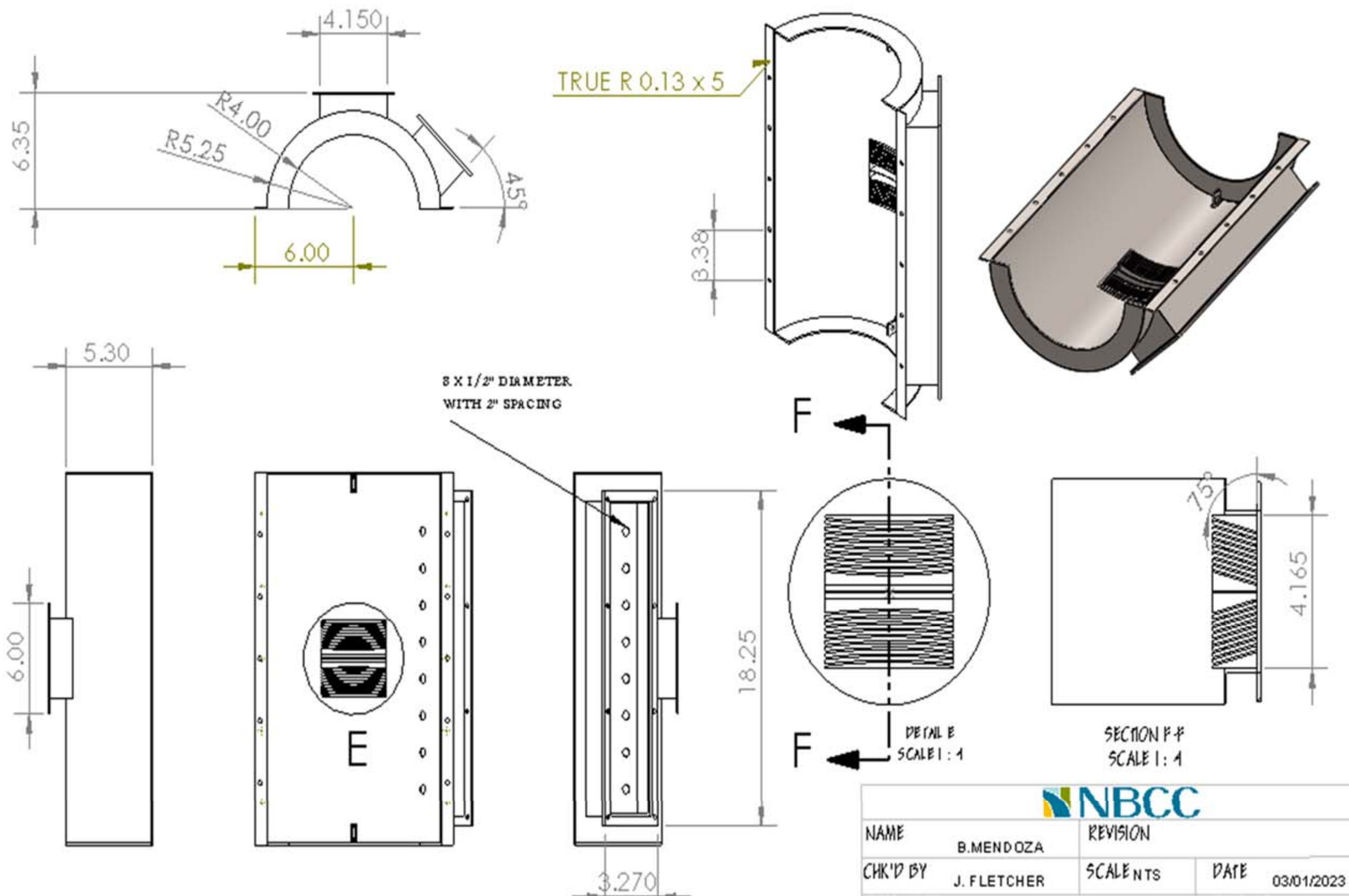
DETAIL J
SCALE 1 : 4





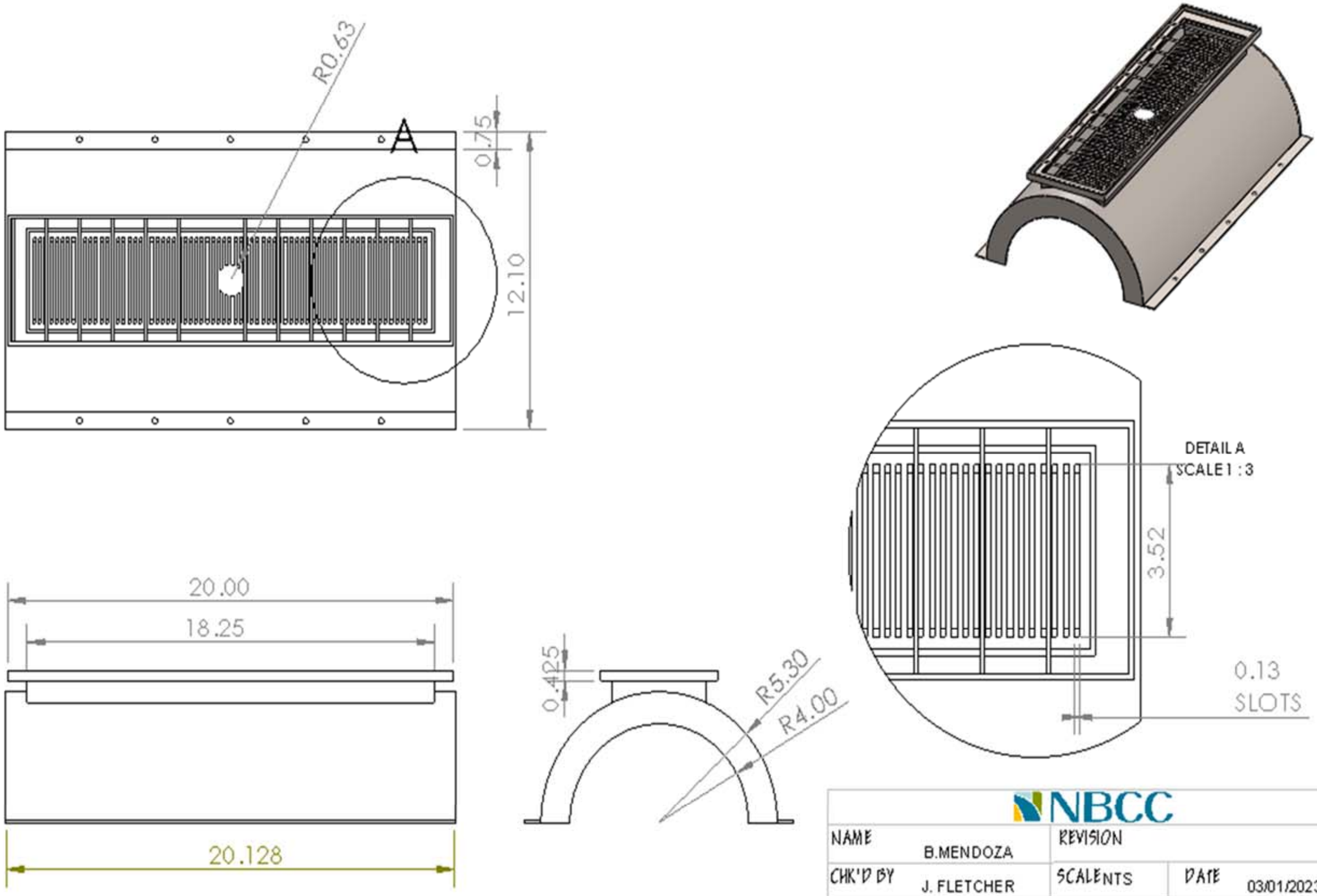
NBCC

NAME	B.MENDOZA	REVISION	
CHK'D BY	J. FLETCHER	SCALE NTS	DATE 03/01/2023
DWG NAME	LOWER SHROUD		DWG NO. LS-01



NOTE: MATERIAL USED IS SS304 GAUGE 11 (0.125" THICK)

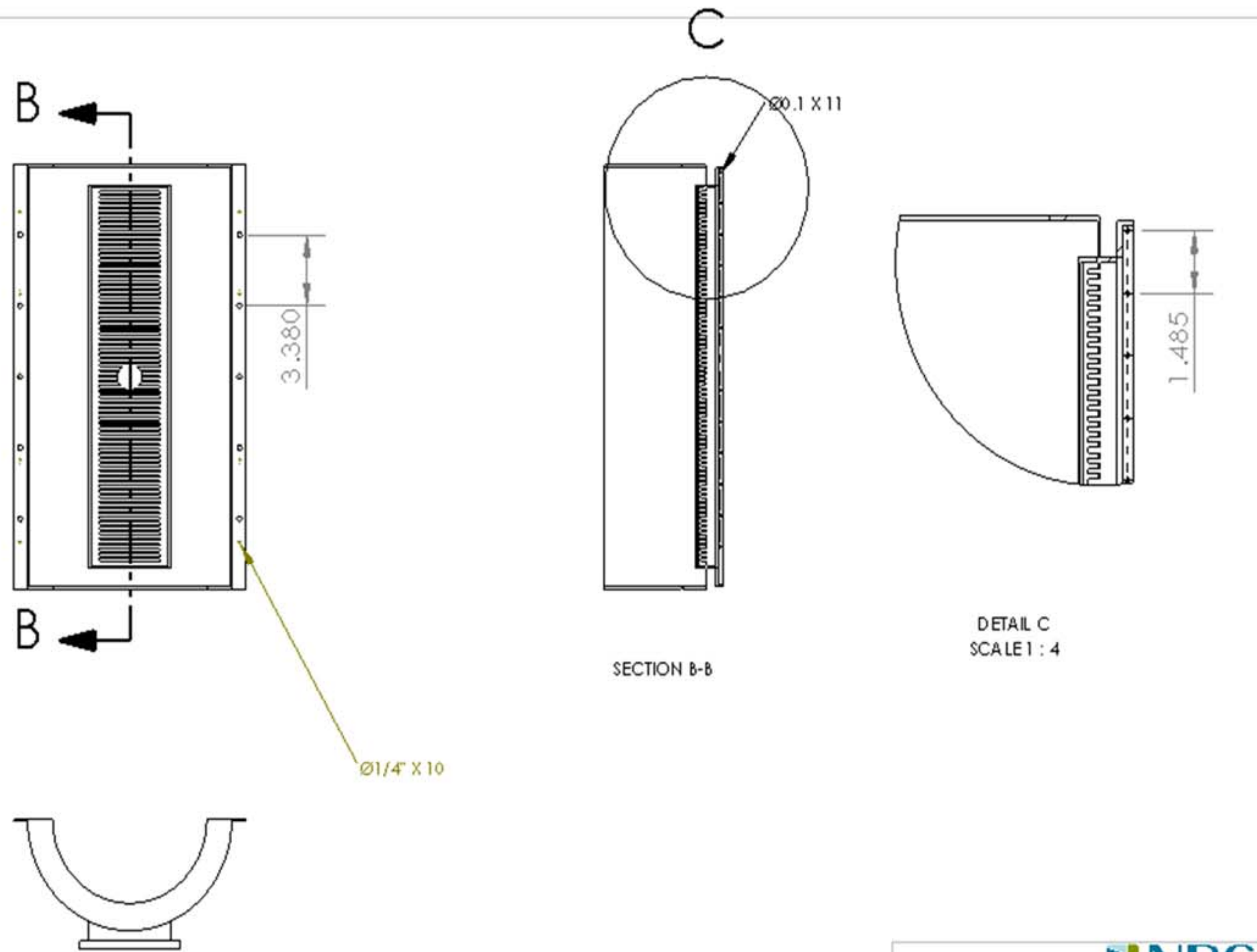
NBCC			
NAME B.MENDOZA	REVISION		
CHK'D BY J. FLETCHER	SCALE NTS	DATE 03/01/2023	
DWG NAME LOWER SHROUD		DWG NO. LS-02	



USE STAINLESS STEEL 304 GUAGE 11 (0.125" THICK) PLATE FOR FABRICATION

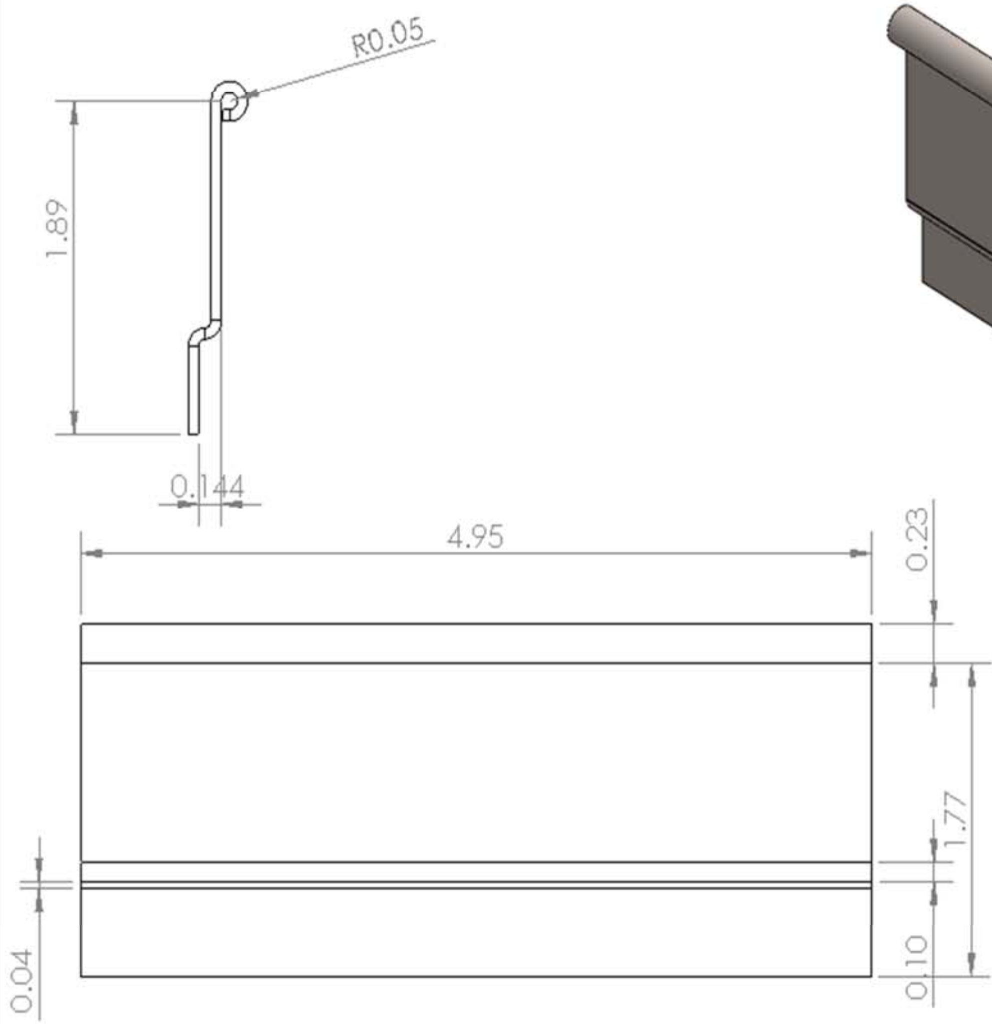
NBCC

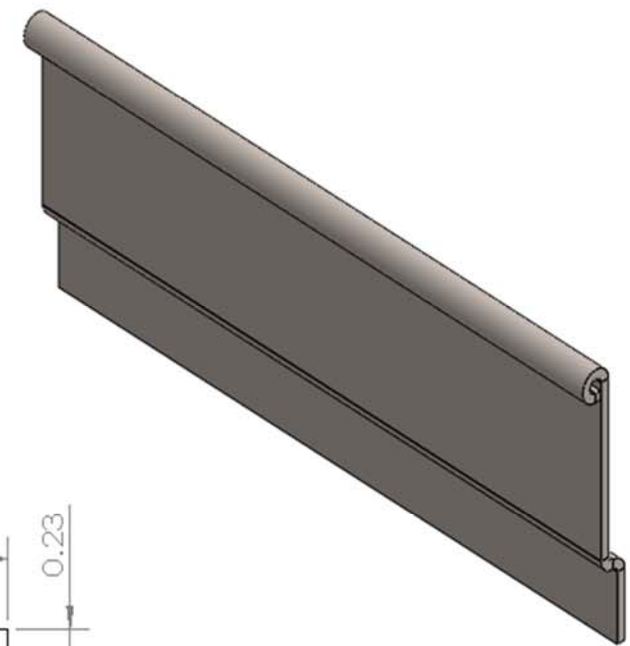
NAME	B.MENDOZA	REVISION	
CHK'D BY	J. FLETCHER	SCALE NTS	DATE 03/01/2023
DWG NAME	UPPER SHROUD	DWG NO.	US- 01



NBCC

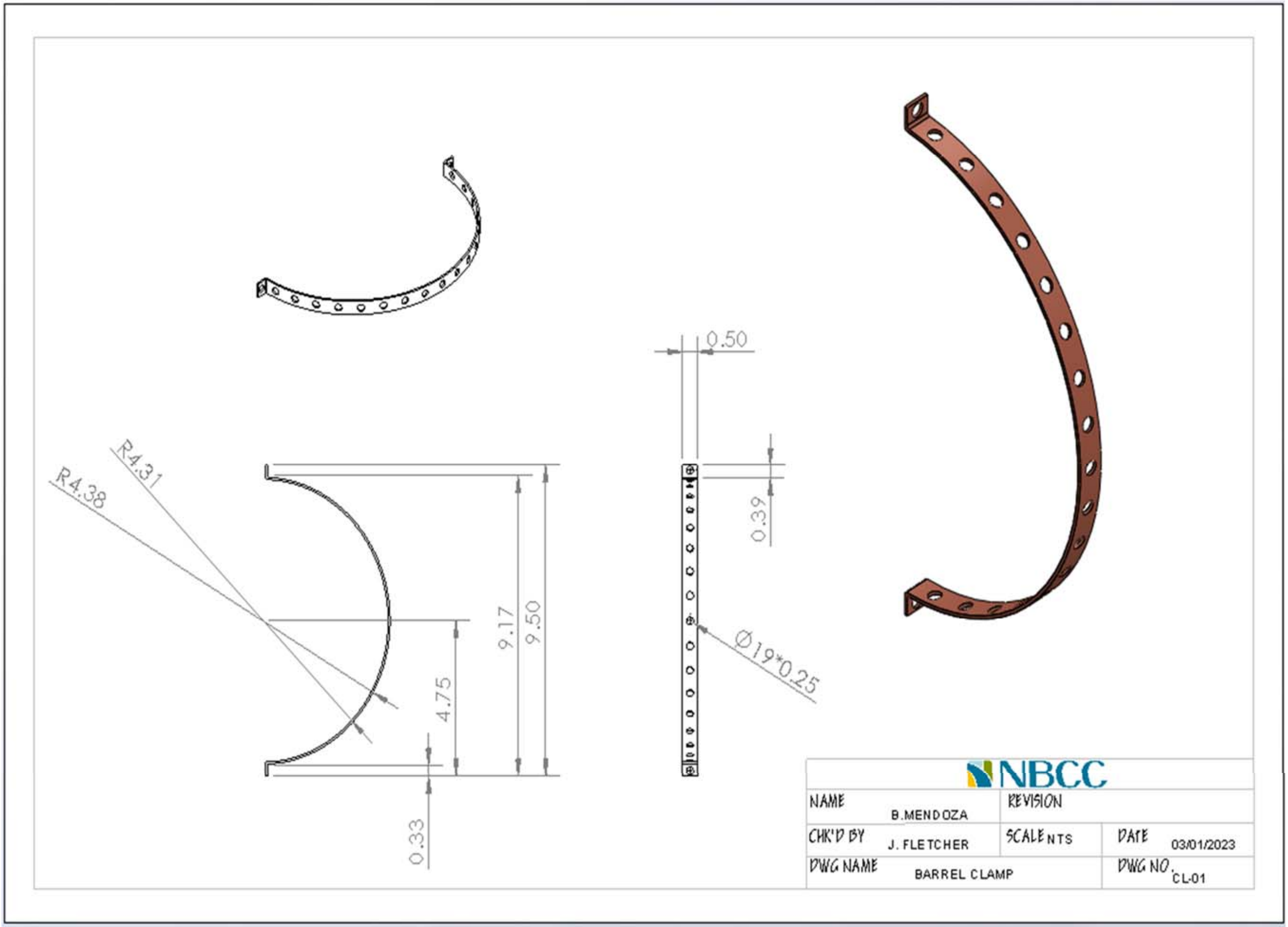
NAME	B.MENDOZA	REVISION	
CHK'D BY	J. FLETCHER	SCALE NTS	DATE 03/01/2023
DWG NAME	UPPER SHROUD	DWG NO.	US-02

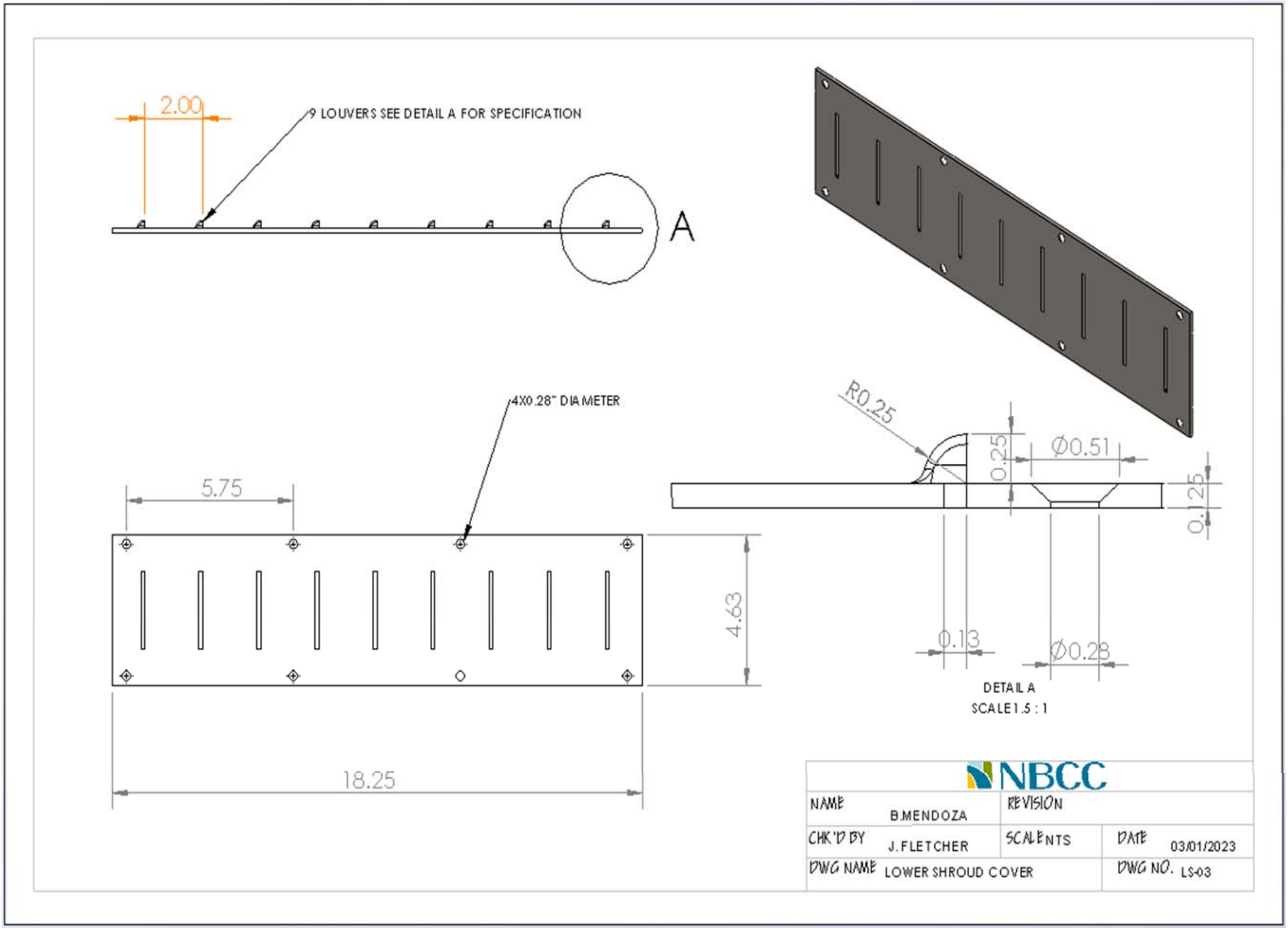




NBCC

NAME	B.MENDOZA	REVISION	
CHK'D BY	J. FLETCHER	SCALE NTS	DATE 03/01/2023
DWG NAME	FLAPPER		DWG NO. UP-01

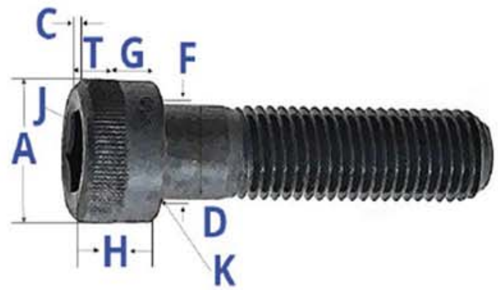

0.50
R4.31
R4.38
0.39
9.17
9.50
4.75
Ø19*0.25
0.33
NBCC
NAME B.MENDOZA
REVISION
CHK'D BY J. FLETCHER
SCALE NTS
DATE 03/01/2023
DWG NAME BARREL CLAMP
DWG NO. CL-01


2.00
9 LOUVERS SEE DETAIL A FOR SPECIFICATION
A
4X0.28" DIAMETER
5.75
4.63
18.25
R0.25
0.25
Ø0.51
0.125
0.13
Ø0.28
DETAIL A
SCALE 1.5 : 1
NBCC
NAME B.MENDOZA
REVISION
CHK'D BY J.FLETCHER
SCALE NTS
DATE 03/01/2023
DWG NAME LOWER SHROUD COVER
DWG NO. LS-03

APPENDIX N: BOLT CHART

Source*: https://store-gdy1ehz.mybigcommerce.com/content/Socket%20Head%20Cap%20Screws%20Dimensions%20%26%20Specs%20_%20AFT%20Fasteners%202022.pdf*

Socket Head Cap Screws: Dimensions and Specifications



Standard Socket Head Cap Screw Dimensions (Alloy & Stainless Steel) ASME B18.3-2003

Basic Screw Diameter	Body Diameter (D)		Head Diameter (A)		Head Height (H)		Top Chamfer or Radius (C)	Hex Socket Size (J)	Fillet Juncture Diameter at Bearing Surface (F)		Key Engagement (T)	Wall Thickness (G)	Bottom Chamfer or Radius (K)
	Max	Min	Max	Min	Max	Min	Max	Nom	Max	Min	Min	Min	Max
0	0.0600	0.0568	0.096	0.091	0.060	0.057	0.004	0.050	0.074	0.062	0.025	0.020	0.007
1	0.0730	0.0695	0.118	0.112	0.073	0.070	0.005	1/16	0.087	0.075	0.031	0.025	0.007
2	0.0860	0.0822	0.140	0.134	0.086	0.083	0.008	5/64	0.102	0.090	0.038	0.029	0.007
3	0.0990	0.0949	0.161	0.154	0.099	0.095	0.008	5/64	0.115	0.102	0.044	0.034	0.007
4	0.1120	0.1075	0.183	0.176	0.112	0.108	0.009	3/32	0.130	0.117	0.051	0.038	0.008
5	0.1250	0.1202	0.205	0.198	0.125	0.121	0.012	3/32	0.145	0.132	0.057	0.043	0.008
6	0.1380	0.1329	0.226	0.218	0.138	0.134	0.013	7/64	0.158	0.144	0.064	0.047	0.008
8	0.1640	0.1585	0.270	0.262	0.164	0.159	0.014	9/64	0.188	0.172	0.077	0.056	0.008
10	0.1900	0.1840	0.312	0.303	0.190	0.185	0.018	5/32	0.218	0.202	0.090	0.065	0.008
1/4	0.2500	0.2435	0.375	0.365	0.250	0.244	0.025	3/16	0.278	0.261	0.120	0.095	0.010
5/16	0.3125	0.3053	0.469	0.457	0.312	0.306	0.033	1/4	0.347	0.329	0.151	0.119	0.010
3/8	0.3750	0.3678	0.562	0.550	0.375	0.368	0.040	5/16	0.415	0.397	0.182	0.143	0.010
7/16	0.4375	0.4294	0.656	0.642	0.438	0.430	0.047	3/8	0.484	0.465	0.213	0.166	0.015
1/2	0.5000	0.4919	0.750	0.735	0.500	0.492	0.055	3/8	0.552	0.531	0.245	0.190	0.015
5/8	0.6250	0.6163	0.938	0.921	0.625	0.616	0.070	1/2	0.689	0.664	0.307	0.238	0.015
3/4	0.7500	0.7406	1.125	1.107	0.750	0.740	0.085	5/8	0.828	0.800	0.370	0.285	0.015
7/8	0.8750	0.8647	1.312	1.293	0.875	0.864	0.100	3/4	0.963	0.932	0.432	0.333	0.020
1	1.0000	0.9886	1.500	1.479	1.000	0.988	0.114	3/4	1.100	1.068	0.495	0.380	0.020
1-1/4	1.2500	1.2336	1.875	1.852	1.250	1.236	0.144	7/8	1.370	1.333	0.620	0.475	0.020
1-1/2	1.5000	1.4818	2.250	2.224	1.500	1.485	0.176	1	1.640	1.601	0.745	0.570	0.020

Mechanical Properties of Socket Cap Screws - Alloy and Stainless Steel																
Nominal Size	Tensile Strength (lbs., min)				Yield Strength (lbs., min)				Body Section		Tightening Torque (in. - lbs.)					
	UNRC		UNRF		UNRC		UNRF		Single Shear Strength (lbs., min.)		UNRC		UNRF			
	Alloy	Stainless	Alloy	Stainless	Alloy	Stainless	Alloy	Stainless	Alloy	Stainless	Alloy	Stainless	Alloy	Stainless		
0	-	-	320	145	-	-	290	72	305	130	-	-	2.6	1.4		
1	475	-	500	220	425	-	450	111	450	190	4.5	-	4.8	2.3		
2	665	295	710	-	600	185	635	-	625	260	7.5	3.8	8.0	-		
3	875	-	940	-	790	-	845	-	830	-	11.0	-	12.0	-		
4	1,090	480	1,190	-	975	240	1,070	-	1,060	350	16.0	6.0	18.0	-		
5	1,430	-	1,490	-	1,290	-	1,345	-	1,325	-	24.0	-	24.0	-		
6	1,640	725	1,825	-	1,470	363	1,645	-	1,615	375	30.0	15.0	34.0	-		
8	2,520	1,120	2,650	-	2,270	560	2,385	-	2,280	670	55.0	28.0	58.0	-		
10	3,150	1,400	3,600	1,600	2,835	701	3,240	800	3,060	950	79.0	40.0	90.0	46.0		
1/4	5,725	2,550	6,550	2,910	5,150	1,273	5,900	1,455	5,295	2,200	200.0	95.0	230.0	109.0		
5/16	9,430	4,200	10,440	4,645	8,490	2,100	9,395	2,230	8,285	3,450	415.0	170.0	460.0	188.0		
3/8	13,950	6,100	15,805	7,025	12,555	3,100	14,225	3,510	11,910	4,970	740.0	301.0	845.0	341.0		
7/16	19,135	-	21,365	-	17,220	-	19,230	-	16,200	-	1,190.0	-	1,305.0	-		
1/2	25,540	11,350	28,780	-	22,990	5,675	25,905	-	21,175	8,840	1,800.0	750.0	2,065.0	-		
5/8	38,400	-	43,500	-	34,550	-	39,150	-	31,300	-	3,400.0	-	3,800.0	-		
3/4	56,750	-	63,400	-	51,100	-	57,050	-	45,050	-	6,000.0	-	6,750.0	-		
7/8	78,500	-	86,500	-	70,700	-	77,850	-	61,350	-	8,250.0	-	9,200.0	-		
1	103,000	-	112,700	-	92,700	-	101,450	-	80,100	-	12,500.0	-	13,000.0	-		
1-1/4	164,700	-	182,400	-	148,250	-	164,150	-	125,100	-	25,000.0	-	27,750.0	-		
1-1/2	238,800	-	268,800	-	215,950	-	241,900	-	180,200	-	43,500.0	-	49,000.0	-		

APPENDIX O: BOLT STRESS CALCULATION & COPPER SURFACE AREA

Source: Original

SIR

BRYAN MENDOZA
5059633
MET-2

BOLT SHEAR STRESS CALCULATION

DIRECT SHEAR STRESS $\tau = \frac{\text{Force}}{\text{Shear Area}} = \frac{F}{A_\tau}$

SINGLE SHEAR

F = 33.435 lbs (SHROUD + BLOWER)
(20 lbs + 15.435 lbs)

AREA : $\frac{\pi}{4} D^2 = \frac{\pi}{4}\left(\frac{5}{16}\right)^2 = 0.0767$

$\tau = \frac{33.435\,lbs}{0.0767} = 435.92$ psi

SINCE 2 BOLTS CARRYING THE LOAD $\tau = \frac{435.92}{2}$

$\tau = 217.96$ psi SAFE!!

MAXIMUM ALLOWABLE SHEAR : 4200 psi

(B) BLOWER

DIRECT TENSILE STRESS

F = WEIGHT OF BLOWER : 15.43 lbs

$A_{min} = \frac{\pi}{4} D^2 = \frac{\pi}{4}(0.3053)^2 = 0.07321\ in^2$

$\delta = \frac{F}{A} = \frac{15.43\,lbs}{0.07321\ in^2} = 210.764$ psi

SINCE 4-BOLT CARRYING THE LOAD

$\delta = \frac{210.764}{4} = 52.717$ psi

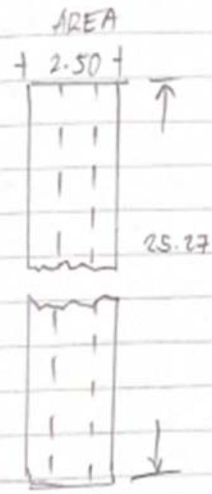
SAFE !!

MAXIMUM ALLOWABLE TENSILE STRENGTH OF THE MATERIAL : 4200 psi

STR

BRYAN MENDOZA
50594633
MET-2

COPPER FINS
CLAMPS
LOCKING MECHANISM



A = 2.5 x 25.27

A = 63.175 in²

NO. OF FINS IN TOTAL = 12 x 5 = 60
NO. OF CLAMPS IN TOTAL : 4 x 5 = 20
NO OF LOCKING MECHANISM : 12 x 5 = 60

A = 2πr x t

A : π(4.38) x 0.5 = 6.88 in²

A : 0.4 + 2(0.8) x (3.25 + 2(0.8))
A : 2 x 4.85 = 9.7 in²

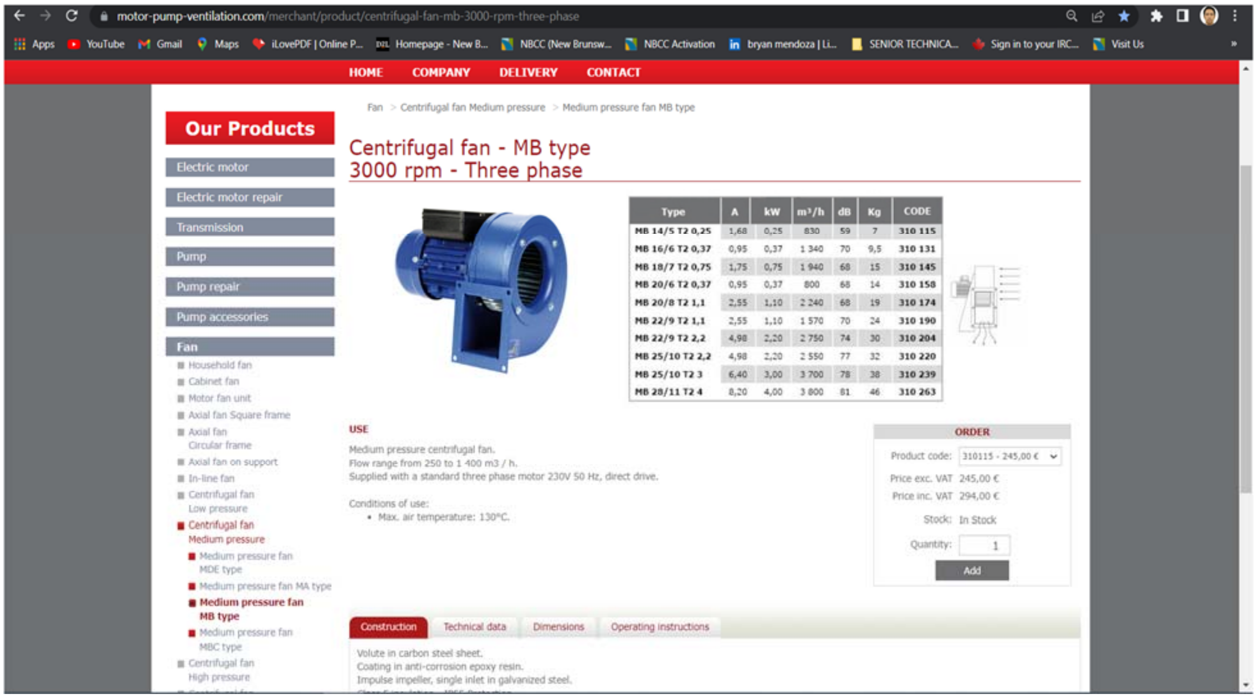
60 x 63.175 in² : 3790.5
20 x 6.88 in² = 137.6
60 x 9.7 in² = 582
4510.1 in² x 1ft² / 144in²

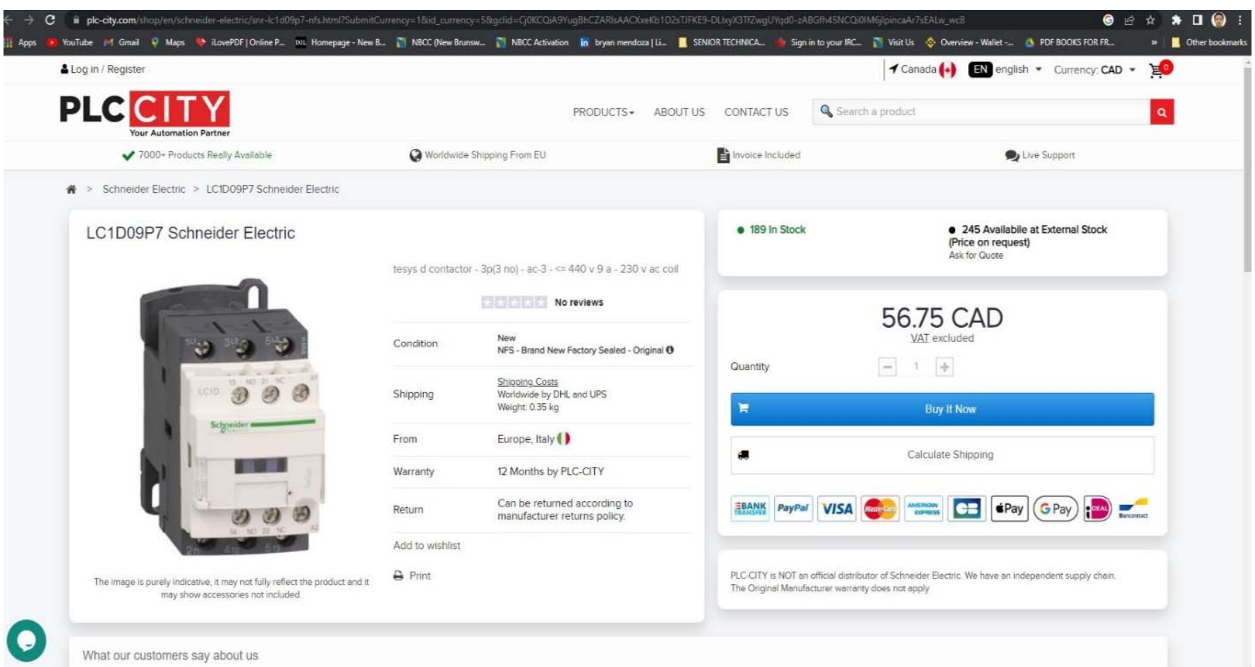
= 31.32 ft²

APPENDIX P: BILL OF MATERIALS

Sources:

Blower
https://www.motor-pump-ventilation.com/merchant/product/centrifugal-fan-mb-3000-rpm-three-phase
Three Phase Mini Circuit Breaker-
https://www.grainger.ca/en/product/p/GGE5ZUU9?cm_mmc=PPC:+Google+PLA&gclid=Cj0KCQiA9YugBhCZARIsAACXxeLgly3IetOpeEDj1VstkLYa5WXOaWkQH4AvzVX_cbO7JHkRmBvyY4QaAhevEALw_wcB&gclsrc=aw.ds
Magnetic Contactor:
https://www.plc-city.com/shop/en/schneider-electric/snr-lc1d09p7-nfs.html?SubmitCurrency=1&id_currency=5&gclid=Cj0KCQiA9YugBhCZARIsAACXxeKb1D2sTJFKE9-DLIxyX3TfZwgUYqd0-zABGfh45NCQi0IM6jIpincaAr7sEALw_wcB
Power Regulator Single Phase
https://www.itm.com/product/watlow-din-a-mite-c-single-phase-scr-power-controller-dc10-12p0-0010
Switch Selector
https://www.itm.com/product/altech-2as2-3-22-mm-non-illuminated-selector-switch?ksearch_click=selector%2Bswitch
Copper Wire
https://www.digikey.ca/en/products/detail/belden-inc./9916%2520002100/7389104?utm_adgroup=Single%20Conductor%20Cables%20%28Hook-Up%20Wire%29&utm_source=google&utm_medium=cpc&utm_campaign=Shopping_Product_Cables%2C%20Wires&utm_term=&productid=7389104&gclid=Cj0KCQiA9YugBhCZARIsAACXxeIM807zhaNHIZXAQ8X0UwCWt90k23sv9mjwzpNxnGOI7TK0MI814RAaAnO2EALw_wcB
Copper Sheet (8x4ft)
https://basiccopper.com/20-gauge-copper-sheet-32-mil-36-x-10/#:~:text=This%20copper%20sheet%20is%2020,99.9%25%20pure%20copper%20alloy%20110%20.
Heater Band (CEH-BCH00086)
https://mpimorheat.store/store/stock-heaters/stock-ceramic-band-heaters/
Bolts and Nuts
https://www.boltdepot.com
Glycol
https://www.dynalene.com/product/ethylene-glycol-dynalene-eg/
Distilled Water
https://www.chemworld.com/ChemWorld-Distilled-Water-s/196062.htm


motor-pump-ventilation.com/merchant/product/centrifugal-fan-mb-3000-rpm-three-phase
HOME COMPANY DELIVERY CONTACT
Our Products
Electric motor
Electric motor repair
Transmission
Pump
Pump repair
Pump accessories
Fan
Household fan
Cabinet fan
Motor fan unit
Axial fan Square frame
Axial fan Circular frame
Axial fan on support
In-line fan
Centrifugal fan Low pressure
Centrifugal fan Medium pressure
Medium pressure fan MDE type
Medium pressure fan MA type
Medium pressure fan MB type
Medium pressure fan MBC type
Centrifugal fan High pressure
Fan > Centrifugal fan Medium pressure > Medium pressure fan MB type
Centrifugal fan - MB type
3000 rpm - Three phase
Type | A | kW | m³/h | dB | Kg | CODE
MB 14/5 T2 0,25 | 1,68 | 0,25 | 830 | 59 | 7 | 310 115
MB 16/6 T2 0,37 | 0,95 | 0,37 | 1 340 | 70 | 9,5 | 310 131
MB 18/7 T2 0,75 | 1,75 | 0,75 | 1 940 | 68 | 15 | 310 145
MB 20/6 T2 0,37 | 0,95 | 0,37 | 800 | 68 | 14 | 310 158
MB 20/8 T2 1,1 | 2,55 | 1,10 | 2 240 | 68 | 19 | 310 174
MB 22/9 T2 1,1 | 2,55 | 1,10 | 1 570 | 70 | 24 | 310 190
MB 22/9 T2 2,2 | 4,98 | 2,20 | 2 750 | 74 | 30 | 310 204
MB 25/10 T2 2,2 | 4,98 | 2,20 | 2 550 | 77 | 32 | 310 220
MB 25/10 T2 3 | 6,40 | 3,00 | 3 700 | 78 | 38 | 310 239
MB 28/11 T2 4 | 8,20 | 4,00 | 3 800 | 81 | 46 | 310 263
USE
Medium pressure centrifugal fan.
Flow range from 250 to 1 400 m3 / h.
Supplied with a standard three phase motor 230V 50 Hz, direct drive.
Conditions of use:
Max. air temperature: 130°C.
ORDER
Product code: 310115 - 245,00 €
Price exc. VAT 245,00 €
Price inc. VAT 294,00 €
Stock: In Stock
Quantity: 1
Add
Construction
Technical data
Dimensions
Operating instructions
Volute in carbon steel sheet.
Coating in anti-corrosion epoxy resin.
Impulse impeller, single inlet in galvanized steel.


plc-city.com/shop/en/schneider-electric/snr-lc1d09p7-nfs.html
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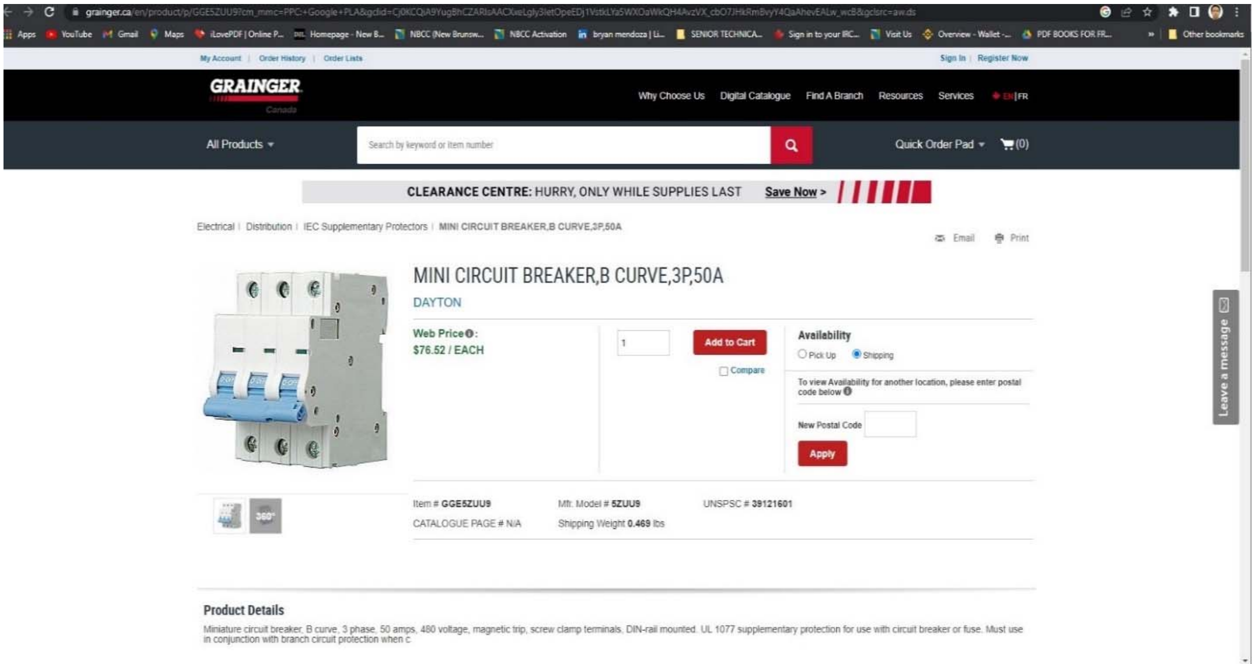
Invoice Included
Live Support
Schneider Electric > LC1D09P7 Schneider Electric
LC1D09P7 Schneider Electric
tesys d contactor - 3p(3 no) - ac-3 - <= 440 v 9 a - 230 v ac coil
No reviews
Condition
New
NFS - Brand New Factory Sealed - Original
Shipping
Shipping Costs
Worldwide by DHL and UPS
Weight: 0.35 kg
From
Europe, Italy
Warranty
12 Months by PLC-CITY
Return
Can be returned according to manufacturer returns policy.
Add to wishlist
Print
The image is purely indicative, it may not fully reflect the product and it may show accessories not included.
189 In Stock
245 Available at External Stock
(Price on request)
Ask for Quote
56.75 CAD
VAT excluded
Quantity
Buy It Now
Calculate Shipping
PLC-CITY is NOT an official distributor of Schneider Electric. We have an independent supply chain.
The Original Manufacturer warranty does not apply
What our customers say about us


grainger.ca/en/product/p/GGE5ZUU9
My Account | Order History | Order Lists
Sign In | Register Now
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Digital Catalogue
Find A Branch
Resources
Services
All Products
Quick Order Pad
CLEARANCE CENTRE: HURRY, ONLY WHILE SUPPLIES LAST
Save Now >
Electrical | Distribution | IEC Supplementary Protectors | MINI CIRCUIT BREAKER,B CURVE,3P,50A
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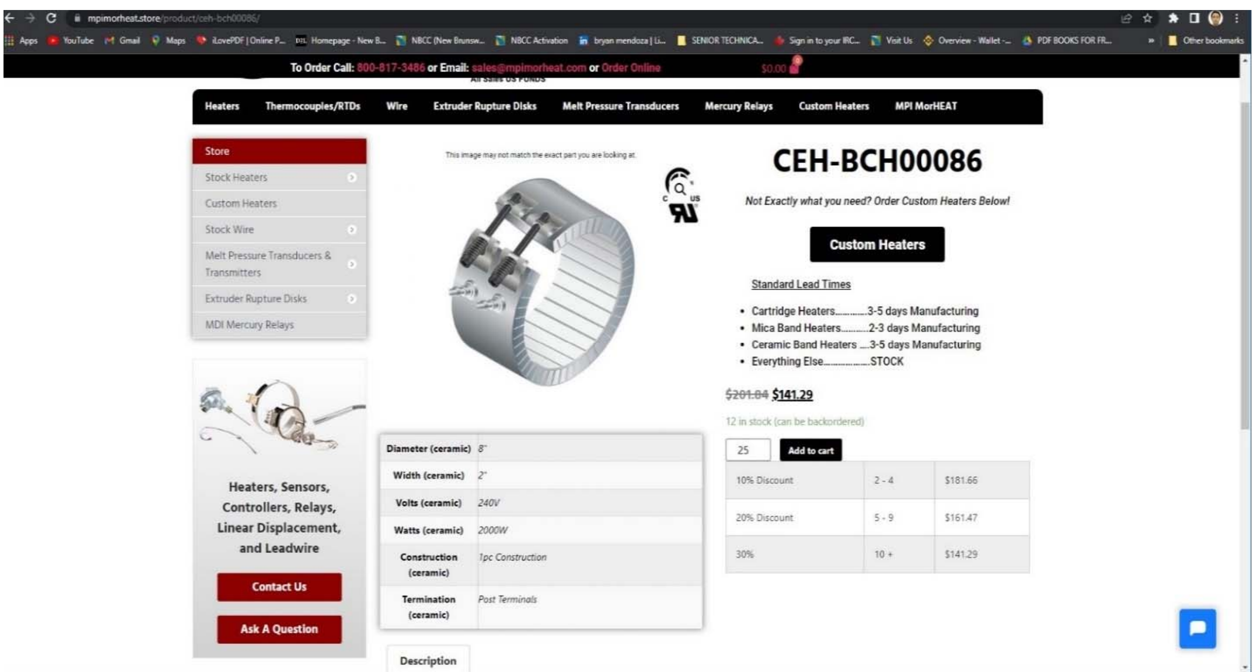
Print
MINI CIRCUIT BREAKER,B CURVE,3P,50A
DAYTON
Web Price:
$76.52 / EACH
Add to Cart
Compare
Availability
Pick Up
Shipping
To view Availability for another location, please enter postal code below
New Postal Code
Apply
Item # GGE5ZUU9
Mfr. Model # 5ZUU9
UNSPSC # 39121601
CATALOGUE PAGE # N/A
Shipping Weight 0.469 lbs
Product Details
Miniature circuit breaker, B curve, 3 phase, 50 amps, 480 voltage, magnetic trip, screw clamp terminals, DIN-rail mounted. UL 1077 supplementary protection for use with circuit breaker or fuse. Must use in conjunction with branch circuit protection when c
Leave a message


mpimorheat.store/product/ceh-bch00086/
To Order Call: 800-817-3486 or Email: sales@mpimorheat.com or Order Online
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Thermocouples/RTDs
Wire
Extruder Rupture Disks
Melt Pressure Transducers
Mercury Relays
Custom Heaters
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Store
Stock Heaters
Custom Heaters
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Melt Pressure Transducers & Transmitters
Extruder Rupture Disks
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Not Exactly what you need? Order Custom Heaters Below!
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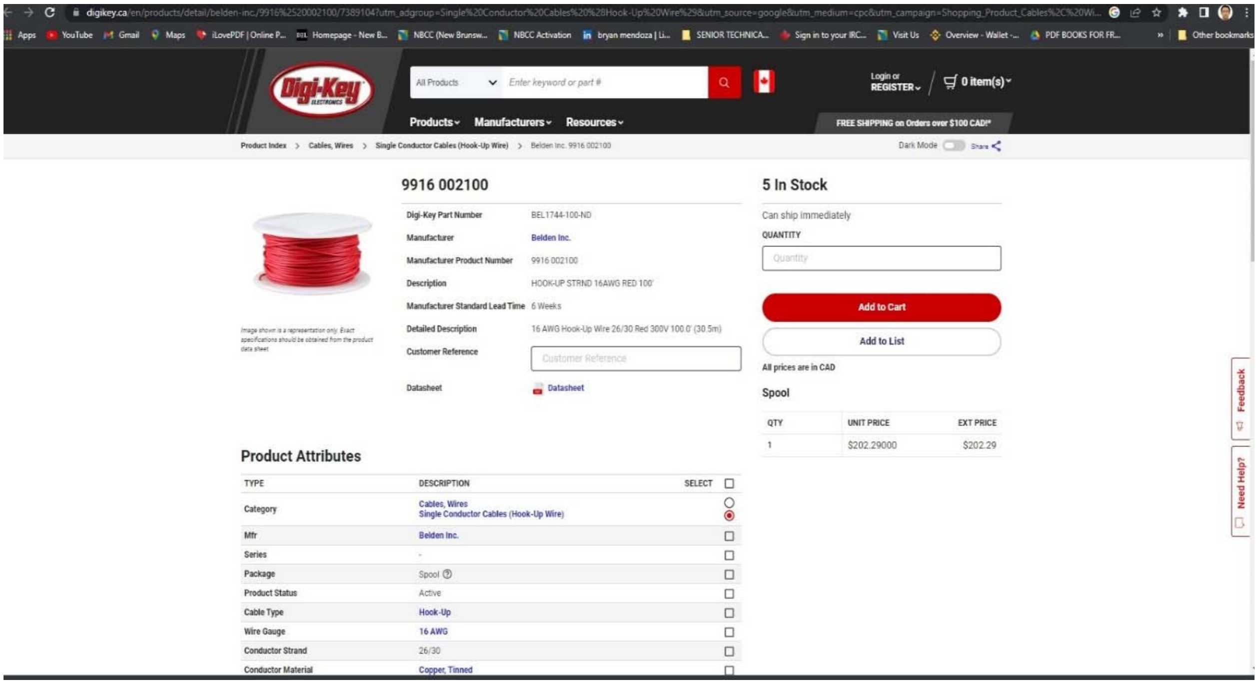
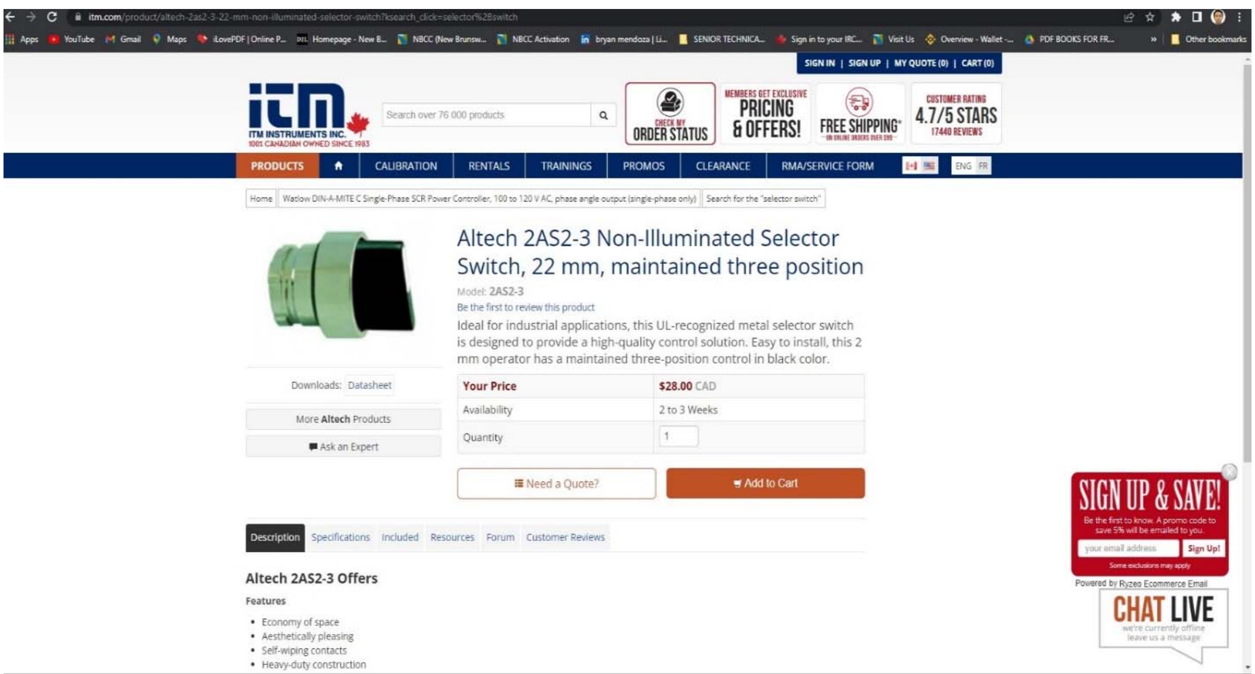
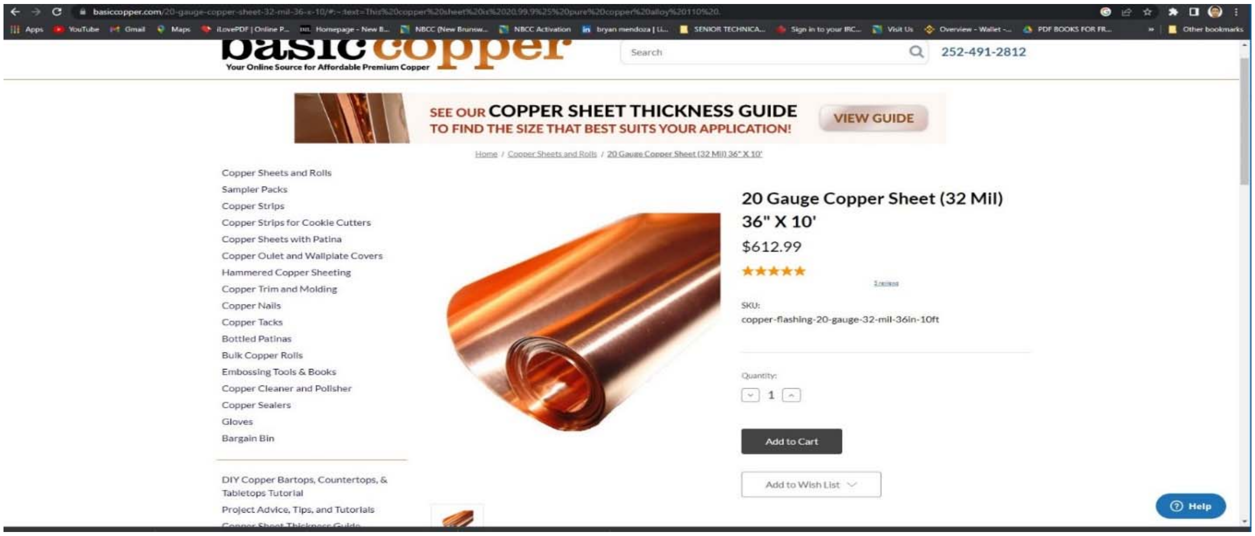
Standard Lead Times
Cartridge Heaters............3-5 days Manufacturing
Mica Band Heaters..........2-3 days Manufacturing
Ceramic Band Heaters ....3-5 days Manufacturing
Everything Else................STOCK
$201.84 $141.29
12 in stock (can be backordered)
25
Add to cart
10% Discount | 2 - 4 | $181.66
20% Discount | 5 - 9 | $161.47
30% | 10 + | $141.29
Diameter (ceramic) | 8"
Width (ceramic) | 2"
Volts (ceramic) | 240V
Watts (ceramic) | 2000W
Construction (ceramic) | 1pc Construction
Termination (ceramic) | Post Terminals
Description
Heaters, Sensors, Controllers, Relays, Linear Displacement, and Leadwire
Contact Us
Ask A Question

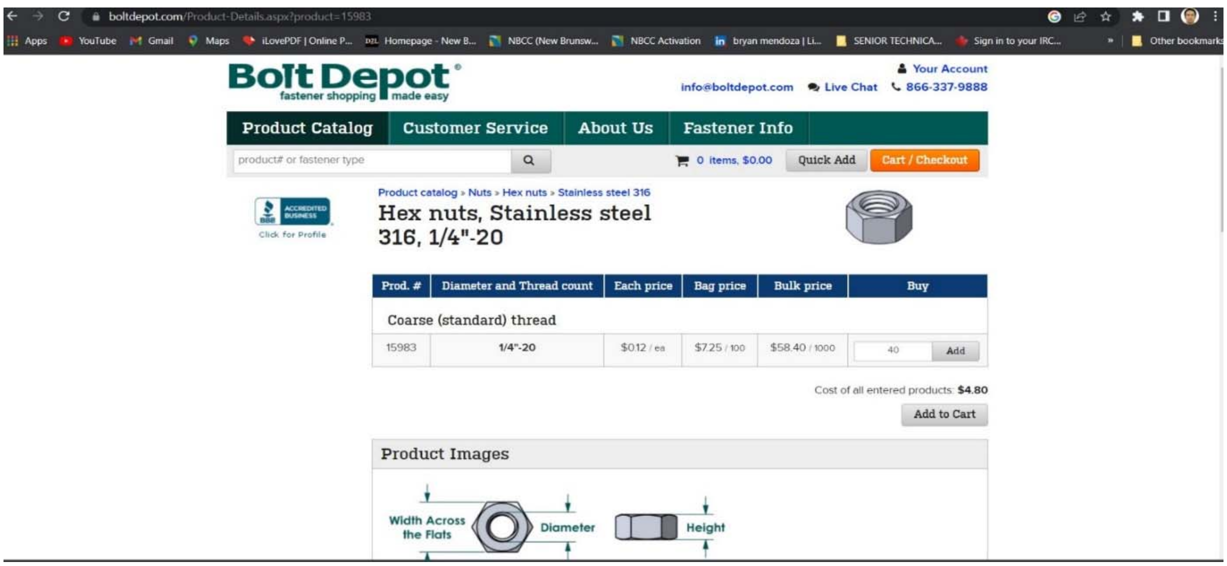


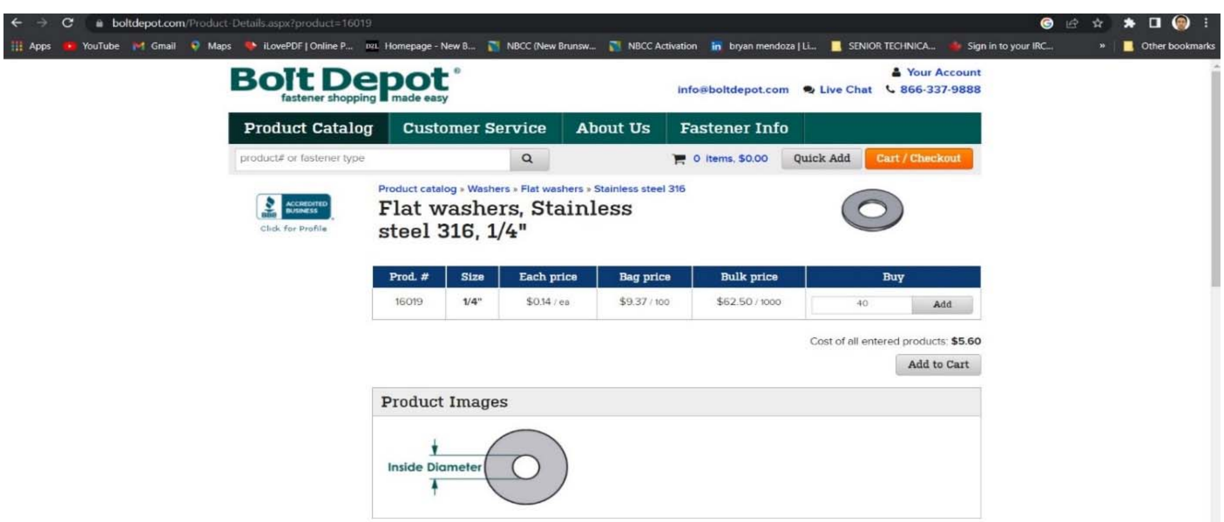
Products Manufacturers Resources
FREE SHIPPING on Orders over $100 CAD!*
Product Index > Cables, Wires > Single Conductor Cables (Hook-Up Wire) > Belden Inc. 9916 002100
9916 002100
Digi-Key Part Number BEL1744-100-ND
Manufacturer Belden Inc.
Manufacturer Product Number 9916 002100
Description HOOK-UP STRND 16AWG RED 100'
Manufacturer Standard Lead Time 6 Weeks
Detailed Description 16 AWG Hook-Up Wire 26/30 Red 300V 100.0' (30.5m)
Customer Reference
Datasheet
5 In Stock
Can ship immediately
QUANTITY
Add to Cart
Add to List
All prices are in CAD
Spool
QTY UNIT PRICE EXT PRICE
1 $202.29000 $202.29
Product Attributes
TYPE DESCRIPTION SELECT
Category Cables, Wires Single Conductor Cables (Hook-Up Wire)
Mfr Belden Inc.
Series -
Package Spool
Product Status Active
Cable Type Hook-Up
Wire Gauge 16 AWG
Conductor Strand 26/30
Conductor Material Copper, Tinned



SIGN IN | SIGN UP | MY QUOTE (0) | CART (0)
ITM INSTRUMENTS INC.
PRODUCTS CALIBRATION RENTALS TRAININGS PROMOS CLEARANCE RMA/SERVICE FORM
Home | Watlow DIN-A-MITE C Single-Phase SCR Power Controller, 100 to 120 V AC, phase angle output (single-phase only) | Search for the "selector switch"
Altech 2AS2-3 Non-Illuminated Selector Switch, 22 mm, maintained three position
Model: 2AS2-3
Be the first to review this product
Ideal for industrial applications, this UL-recognized metal selector switch is designed to provide a high-quality control solution. Easy to install, this 2 mm operator has a maintained three-position control in black color.
Downloads: Datasheet
More Altech Products
Ask an Expert
Your Price $28.00 CAD
Availability 2 to 3 Weeks
Quantity 1
Need a Quote?
Add to Cart
Description Specifications Included Resources Forum Customer Reviews
Altech 2AS2-3 Offers
Features
Economy of space
Aesthetically pleasing
Self-wiping contacts
Heavy-duty construction
SIGN UP & SAVE!
CHAT LIVE


basiccopper.com
basic copper
Your Online Source for Affordable Premium Copper
252-491-2812
SEE OUR COPPER SHEET THICKNESS GUIDE
TO FIND THE SIZE THAT BEST SUITS YOUR APPLICATION!
VIEW GUIDE
Copper Sheets and Rolls
Sampler Packs
Copper Strips
Copper Strips for Cookie Cutters
Copper Sheets with Patina
Copper Outlet and Wallplate Covers
Hammered Copper Sheeting
Copper Trim and Molding
Copper Nails
Copper Tacks
Bottled Patinas
Bulk Copper Rolls
Embossing Tools & Books
Copper Cleaner and Polisher
Copper Sealers
Gloves
Bargain Bin
DIY Copper Bartops, Countertops, & Tabletops Tutorial
Project Advice, Tips, and Tutorials
20 Gauge Copper Sheet (32 Mil) 36" X 10'
$612.99
SKU:
copper-flashing-20-gauge-32-mil-36in-10ft
Quantity:
1
Add to Cart
Add to Wish List
Help


boltdepot.com/Product-Details.aspx?product=15983
Bolt Depot
fastener shopping made easy
Your Account
info@boltdepot.com
Live Chat
866-337-9888
Product Catalog
Customer Service
About Us
Fastener Info
product# or fastener type
0 items, $0.00
Quick Add
Cart / Checkout
Product catalog » Nuts » Hex nuts » Stainless steel 316
Hex nuts, Stainless steel 316, 1/4"-20
Prod. #
Diameter and Thread count
Each price
Bag price
Bulk price
Buy
Coarse (standard) thread
15983
1/4"-20
$0.12 / ea
$7.25 / 100
$58.40 / 1000
40
Add
Cost of all entered products: $4.80
Add to Cart
Product Images
Width Across the Flats
Diameter
Height


boltdepot.com/Product-Details.aspx?product=16019
Bolt Depot
fastener shopping made easy
Your Account
info@boltdepot.com
Live Chat
866-337-9888
Product Catalog
Customer Service
About Us
Fastener Info
product# or fastener type
0 items, $0.00
Quick Add
Cart / Checkout
Product catalog » Washers » Flat washers » Stainless steel 316
Flat washers, Stainless steel 316, 1/4"
Prod. #
Size
Each price
Bag price
Bulk price
Buy
16019
1/4"
$0.14 / ea
$9.37 / 100
$62.50 / 1000
40
Add
Cost of all entered products: $5.60
Add to Cart
Product Images
Inside Diameter

product# or fastener type | 0 items, $0.00 | Quick Add | Cart / Checkout

Product catalog » Socket screws » Socket cap » Zinc plated alloy steel » Coarse (standard) thread » 5/16"-18

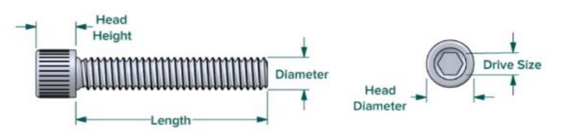
Socket cap, Zinc plated alloy steel, 5/16"-18 x 1"

Prod. #	Length	Each price	Bag price	Bulk price	Buy
15104	1"	$0.69 / ea	$47.46 / 100	$404.00 / 1000	120 Add

Cost of all entered products: **$56.95**

Add to Cart

Product Images

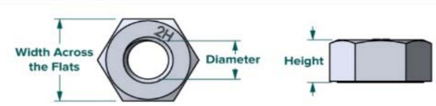


Prod. #	Diameter and Thread count	Each price	Bag price	Bulk price	Buy
Coarse (standard) thread					
27295	5/16"-18	$0.17 / ea	$11.10 / 100	$102.00 / 1000	120 Add

Cost of all entered products: **$13.32**

Add to Cart

Product Images



Product details

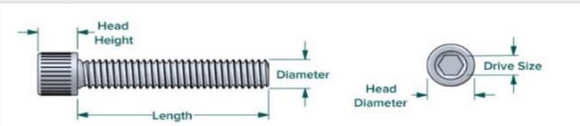
Bolt Depot product#	27295
Units	US
Category	Nuts Nuts have internal machine threads, for use with machine thread bolts and screws.

Prod. #	Length	Each price	Bag price	Bulk price	Buy
16536	1/2"	$0.57 / ea	$43.23 / 100	$366.00 / 1000	40 Add

Cost of all entered products: **$22.80**

Add to Cart

Product Images



Product details

Bolt Depot product#	16536
Units	US
Category	Socket screws Screws with an Allen wrench drive.
Head style	Socket cap

boltdepot.com/Product-Details.aspx?product=2957

Click to go back, hold to see history | Maps | iLovePDF | Online P... | Homepage - New B... | NBCC (New Brunsw... | NBCC Activation | bryan mendoza | Li... | SENIOR TECHNICA... | Sign in to your IRC... | Other bookmarks

ACCREDITED BUSINESS
Click for Profile

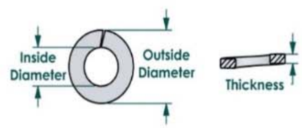
Lock washers, Stainless steel 18-8, 5/16"

Prod. #	Size	Each price	Bag price	Bulk price	Buy
2957	5/16"	$0.11 / ea	$6.07 / 100	$53.20 / 1000	120 Add

Cost of all entered products: **$7.28**

Add to Cart

Product Images



Product details

Bolt Depot product#	2957
Units	US
Category	Washers Used to spread the load of a bolt or screw over a larger area or to help prevent loosening under

RE: Air-cooled extruder barrel inquiry

ZG Zach Goslin <ZachGoslin@tempco.com>
2023-03-01 10:35 AM

To: Mendoza, Bryan

This email was generated outside of NBCC, please use caution when replying.

Hi Bryan,

These numbers pulled are *from a few years* back so pricing would probably be higher now except for the blowers.

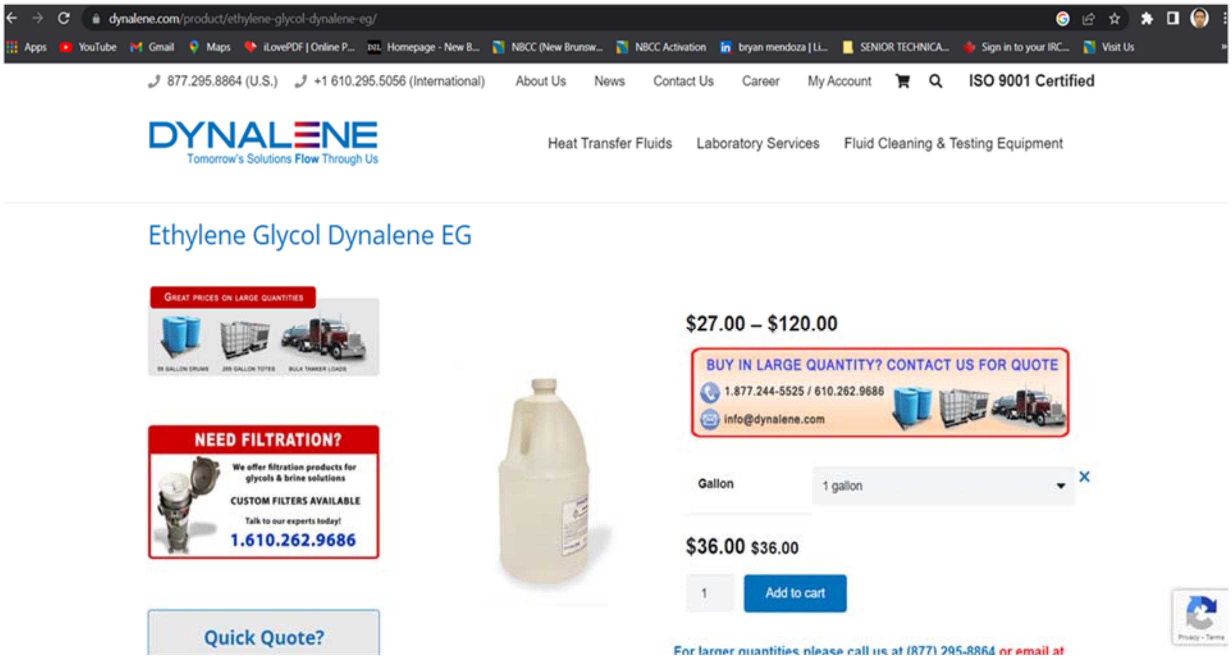
1 shroud ASJ00330 = US $975.00 each

5 shrouds ASJ00330 = US $706.00 each

1 Blower (MTR-102-107, 550 CFM) = US $340 each

Thanks,

Zach Goslin | Territorial Sales Manager
Tempco Electric Heater Corporation
607 N. Central Ave. Wood Dale, IL 60191
Direct: 630.477.3214 Corp: 630.350.2252
TEMPCO SINCE 1972


dynalene.com/product/ethylene-glycol-dynalene-eg/
877.295.8864 (U.S.)
+1 610.295.5056 (International)
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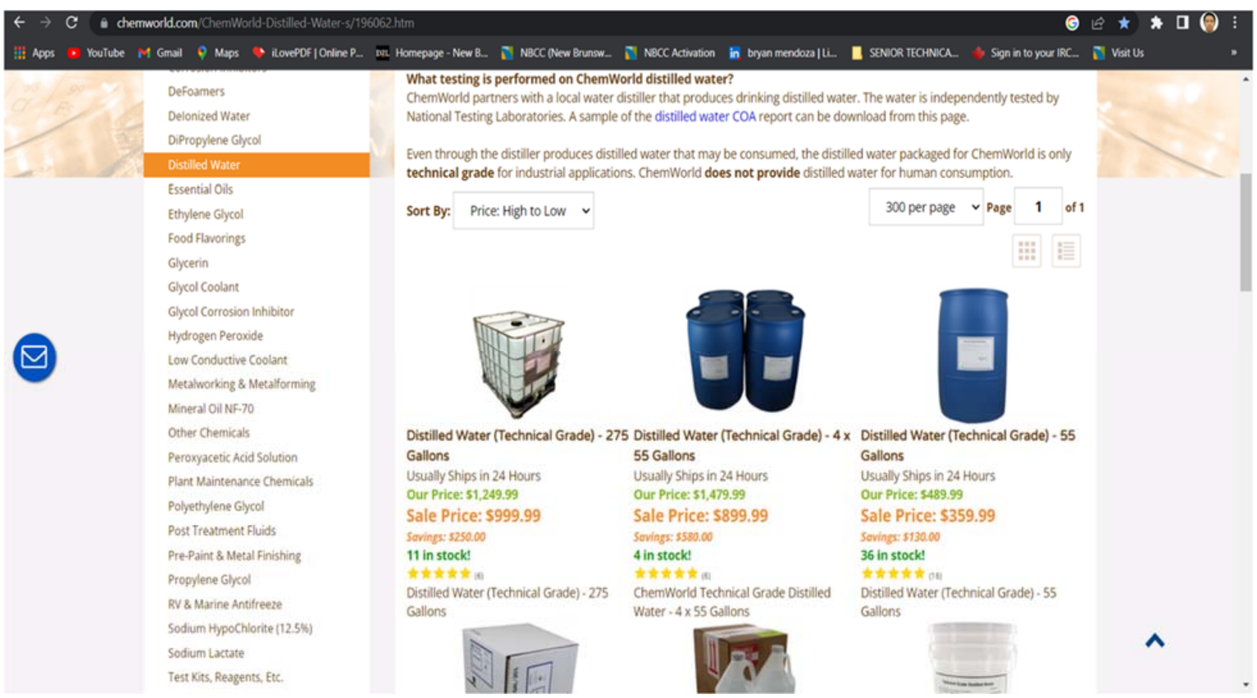
My Account
ISO 9001 Certified
DYNALENE
Tomorrow's Solutions Flow Through Us
Heat Transfer Fluids
Laboratory Services
Fluid Cleaning & Testing Equipment
Ethylene Glycol Dynalene EG
NEED FILTRATION?
We offer filtration products for glycols & brine solutions
CUSTOM FILTERS AVAILABLE
Talk to our experts today!
1.610.262.9686
Quick Quote?
$27.00 – $120.00
BUY IN LARGE QUANTITY? CONTACT US FOR QUOTE
1.877.244-5525 / 610.262.9686
info@dynalene.com
Gallon
1 gallon
$36.00 $36.00
Add to cart


chemworld.com/ChemWorld-Distilled-Water-s/196062.htm
DeFoamers
Deionized Water
DiPropylene Glycol
Distilled Water
Essential Oils
Ethylene Glycol
Food Flavorings
Glycerin
Glycol Coolant
Glycol Corrosion Inhibitor
Hydrogen Peroxide
Low Conductive Coolant
Metalworking & Metalforming
Mineral Oil NF-70
Other Chemicals
Peroxyacetic Acid Solution
Plant Maintenance Chemicals
Polyethylene Glycol
Post Treatment Fluids
Pre-Paint & Metal Finishing
Propylene Glycol
RV & Marine Antifreeze
Sodium HypoChlorite (12.5%)
Sodium Lactate
Test Kits, Reagents, Etc.
What testing is performed on ChemWorld distilled water?
ChemWorld partners with a local water distiller that produces drinking distilled water. The water is independently tested by National Testing Laboratories. A sample of the distilled water COA report can be download from this page.
Even through the distiller produces distilled water that may be consumed, the distilled water packaged for ChemWorld is only technical grade for industrial applications. ChemWorld does not provide distilled water for human consumption.
Sort By: Price: High to Low
300 per page
Page 1 of 1
Distilled Water (Technical Grade) - 275 Gallons
Usually Ships in 24 Hours
Our Price: $1,249.99
Sale Price: $999.99
Savings: $250.00
11 in stock!
Distilled Water (Technical Grade) - 275 Gallons
Distilled Water (Technical Grade) - 4 x 55 Gallons
Usually Ships in 24 Hours
Our Price: $1,479.99
Sale Price: $899.99
Savings: $580.00
4 in stock!
ChemWorld Technical Grade Distilled Water - 4 x 55 Gallons
Distilled Water (Technical Grade) - 55 Gallons
Usually Ships in 24 Hours
Our Price: $489.99
Sale Price: $359.99
Savings: $130.00
36 in stock!
Distilled Water (Technical Grade) - 55 Gallons

APPENDIX Q: RETURN ON INVESTMENT CALCULATION

Source: Original

STR

BRYAN MENDOZA
5059633
MET-2

PUMP ELECTRIC CONSUMPTION

MOTOR PUMP RATING: 2hp

POWER CONSUMPTION IN (KW) : Power input x conversion factor

$= 2hp \times 0.746 \frac{kW}{hp}$

$= 1.492$ kW

ELECTRICITY CONSUMED FOR ENTIRE YEAR

SAINT JOHN ENERGY : 10.67 cents /kw-h
= \$0.1067 / kw-h

$1.492 \text{ kW} \times \frac{\$0.1067}{\text{kw-hr}} \times \frac{24 \text{ hrs}}{1 \text{ day}} \times \frac{350 \text{ day}}{\text{year}} = \$1337.35$

WITH TAX: \$1337.25 x 1.15 = 1,537.841

DISTILLED WATER

$1.5 \frac{gal}{day} \times \frac{350 \text{ days}}{1 yr} \times \$ \frac{3.63}{gal} = \$1,905.75$

WITH TAX: \$1,905.75 x 1.15 = 2191.61

GLYCOL

10% OF WATER CONSUMPTION

$1.5 \frac{gal}{day} \times 0.1 \times \frac{350 \text{ days}}{1 yr} \times \$ \frac{36}{gal} = \$1,905.75$

WITH TAX 1,905.75 x 1.15 = 2,191.61

STR

BRYAN MENDOZA
5059633
MET-2

BLOWER OPERATING COST & SAVINGS.

RUNNING COST : 20% LESS THAN PUMP

$ 1337.25 × 0.8 × 1.5 = $1,230.27

OVERALL SAVING IN OPERATIONAL COST PER YEAR

$ 1,890 + $ 1,905.75 + 1,337.25 = 5,133.00

with tax

$ 5,133.00 × 1.15 = 5902.95

OVERALL SAVING:

$ 5902.95 − $1,230.27 = $ 4,672.68

SAVING IN PERCENTAGE:

$$\frac{\$\,4,672.68}{\$\,5,902.95} = 79.2\%$$

RETURN ON INVESTMENT

OVERALL SAVINGS PER YEAR $ 4,672.68

PAYBACK PERIOD: $ 17,431.08 → COST TO PURCHASE
$ 4,672.68 → SAVINGS PER YEAR

= 3.73 years

STR

BRYAN MENDOZA
5059633
MET-2

RETURN ON INVESTMENT

TOTAL EXPECTED COST SAVING OVER EQUIPMENT LIFE

$ 9,672.68/yr × 30 yrs = $ 233,639

TOTAL EXPECTED RETURN ON INVESTMENT (ROI)

$$\frac{\$233,639}{\$17,431.08} \times 100\% = 1,340.33\%$$

GREAT RETURN OVER THE EXPECTED LIFE OF EQUIPMENT.

APPENDIX R: CFD ANALYSIS

Source: Original

[NBCC]

SOLIDWORKS

[New Brunswick Community College
Saint John, New Brunswick
Mechanical Engineering Technology

Fluid Flow Simulation Project Report

Bryan Mendoza
MET-2
bgmendoza.nb@gmail.com
(506) 566-4858

GENERAL INFORMATION

Objective: This simulation aims to show the material's thermal properties and airflow dynamics. It shows how specific parameters which are relevant to the projects. Key parameters include the temperature of the air, the temperature of solids, flow velocity, and the effectiveness of the design.

ANALYSIS ENVIRONMENT

Software Product:	Flow Simulation 2022 SP2.0. Build: 5593
CPU Type:	Intel(R) Core(TM) i5-10300H CPU @ 2.50GHz
CPU Speed:	2496 MHz
RAM:	16251 MB / 1344 MB
Operating System:	Windows 10 (or higher) (Version 10.0.19045)

MODEL INFORMATION

Model Name:	THERMOFLOW SIMULATION.SLDASM
Project Name:	WITH FINS

PROJECT COMMENTS:

Unit System:	Custom Units
Analysis Type:	External (not exclude internal spaces)

SIZE OF COMPUTATIONAL DOMAIN

Size

X min	-1.506 m
X max	2.178 m
Y min	-1.491 m
Y max	1.972 m
Z min	-1.541 m
Z max	2.048 m
X size	3.685 m
Y size	3.464 m
Z size	3.589 m

SIMULATION PARAMETERS

MESH SETTINGS

BASIC MESH

Basic Mesh Dimensions

Number of cells in X	38
Number of cells in Y	36
Number of cells in Z	36

ANALYSIS MESH

Total Cell count: 146478
Fluid Cells: 100118
Solid Cells: 46360
Partial Cells: 36611
Trimmed Cells: 0

ADDITIONAL PHYSICAL CALCULATION OPTIONS

Heat Transfer Analysis: Heat conduction in solids: OnHeat conduction in solids only: Off
Flow Type: Laminar and turbulent
Time-Dependent Analysis: Off
Gravity: Off
Radiation: Off
Humidity: Off

Default Wall Roughness: 0 micrometre

MATERIAL SETTINGS

Material Settings

Fluids

Air

Solids

Aluminum 6061
Plain Carbon Steel
LLDPE
Copper
Alumina (Typical)

INITIAL CONDITIONS

Ambient Conditions

Thermodynamic parameters	Static Pressure: 101325.00 Pa Temperature: 29.85 °C
Velocity parameters	Velocity vector Velocity in X direction: 0 m/s Velocity in Y direction: 0 m/s Velocity in Z direction: 0 m/s
Solid parameters	Default material: Aluminum 6061 Initial solid temperature: 29.85 °C
Turbulence parameters	Turbulence intensity and length Intensity: 2.00 % Length: 4.800e-04 m

BOUNDARY CONDITIONS

Fans

External Inlet Fan 1

Default Wall Roughness: 0 micrometre

MATERIAL SETTINGS

Material Settings

Fluids

Air

Solids

Aluminum 6061
Plain Carbon Steel
LLDPE
Copper
Alumina (Typical)

INITIAL CONDITIONS

Ambient Conditions

Thermodynamic parameters	Static Pressure: 101325.00 Pa Temperature: 29.85 °C
Velocity parameters	Velocity vector Velocity in X direction: 0 m/s Velocity in Y direction: 0 m/s Velocity in Z direction: 0 m/s
Solid parameters	Default material: Aluminum 6061 Initial solid temperature: 29.85 °C
Turbulence parameters	Turbulence intensity and length Intensity: 2.00 % Length: 4.800e-04 m

BOUNDARY CONDITIONS

Fans

External Inlet Fan 1

Default Wall Roughness: 0 micrometre

MATERIAL SETTINGS

Material Settings

Fluids

Air

Solids

Aluminum 6061
Plain Carbon Steel
LLDPE
Copper
Alumina (Typical)

INITIAL CONDITIONS

Ambient Conditions

Thermodynamic parameters	Static Pressure: 101325.00 Pa Temperature: 29.85 °C
Velocity parameters	Velocity vector Velocity in X direction: 0 m/s Velocity in Y direction: 0 m/s Velocity in Z direction: 0 m/s
Solid parameters	Default material: Aluminum 6061 Initial solid temperature: 29.85 °C
Turbulence parameters	Turbulence intensity and length Intensity: 2.00 % Length: 4.800e-04 m

BOUNDARY CONDITIONS

Fans

External Inlet Fan 1

ENGINEERING GOALS

Goals

Global Goals

GG Average Temperature (Fluid) 1

Type	Global Goal
Goal type	Temperature (Fluid)
Calculate	Average value
Coordinate system	Global Coordinate System
Use in convergence	On

GG Heat Transfer Rate (Convective) 2

Type	Global Goal
Goal type	Heat Transfer Rate (Convective)
Coordinate system	Global Coordinate System
Use in convergence	On

GG Average Temperature (Solid) 3

Type	Global Goal
Goal type	Temperature (Solid)
Calculate	Average value
Coordinate system	Global Coordinate System
Use in convergence	On

Nodal Goals

FG External Inlet Fan 1 Volume Flow Rate

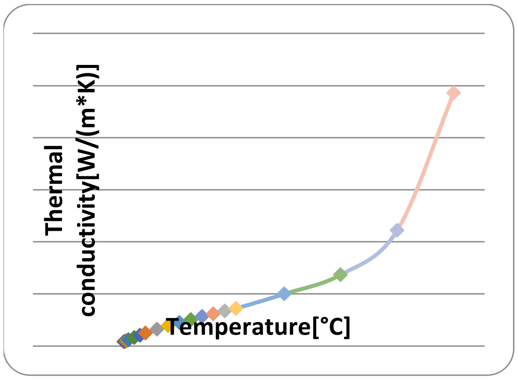
Type	Nodal Goal

c

Min/Max Table

Name	Minimum	Maximum
Density (Fluid) [kg/m^3]	0.73	1.17
Density (Solid) [kg/m^3]	925.00	8960.00
Pressure [Pa]	101278.73	101901.52
Temperature [°C]	29.81	210.00
Temperature (Fluid) [°C]	29.81	210.00
Temperature (Solid) [°C]	30.05	210.00
Velocity [m/s]	0	16.442
Velocity (X) [m/s]	-8.734	15.099
Velocity (Y) [m/s]	-11.202	13.195
Velocity (Z) [m/s]	-10.385	13.859
Axial Velocity [m/s]	-10.385	13.859
Circumferential Velocity [m/s]	-15.752	10.091
Mach Number [ ]	0	0.05
Radial Velocity [m/s]	-9.430	12.122
Velocity RRF [m/s]	0	16.442
Velocity RRF (X) [m/s]	-8.734	15.099
Velocity RRF (Y) [m/s]	-11.202	13.195
Velocity RRF (Z) [m/s]	-10.385	13.859
Distributed Force [Pa]	101288.76	101849.27
Relative Pressure [Pa]	-46.27	576.52
Shear Stress [Pa]	0	13.40
Bottleneck Number [ ]	0	1.0000000
Heat Flux [W/m^2]	0	5039988.066
Heat Flux (X) [W/m^2]	-855925.479	359598.447
Heat Flux (Y) [W/m^2]	-799674.537	4943230.969
Heat Flux (Z) [W/m^2]	-295399.787	982498.255
Heat Transfer Coefficient [W/m^2/K]	3.998e-05	543.428
Overheat above Melting Temperature [K]	-1666.068	85.150
ShortCut Number [ ]	0	1.0000000
Surface Heat Flux [W/m^2]	-587272.646	587272.646
Surface Heat Flux (Conductive) [W/m^2]	-587272.646	587272.646
Surface Heat Flux (Convective) [W/m^2]	-29143.547	82591.313
Total Enthalpy Flux [W/m^2]	-1682264.307	1062255.467
Acoustic Power [W/m^3]	0	1.591e-06

Thermal conductivity



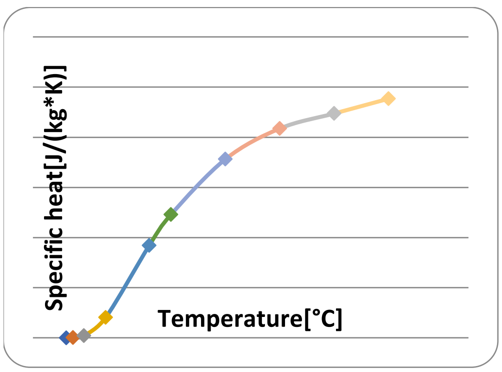
Solids

Aluminum 6061

Path: Solids Pre-Defined\Alloys

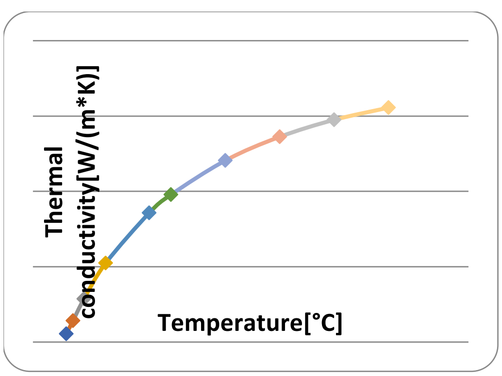
Density: 2700.00 kg/m^3

Specific heat



Conductivity type: Isotropic

Thermal conductivity



Electrical conductivity: Conductor

Resistivity: 3.7000e-08 Ohm*m

Radiation properties: No

Melting temperature: Yes

Temperature: 582.00 °C

Plain Carbon Steel

Path: Solids User Defined\THERMOFLOW SIMULATION.SLDASM\Default

Density: 7800.00 kg/m^3

Specific heat: 440.0 J/(kg*K)

Conductivity type: Isotropic

Thermal conductivity: 43.0000 W/(m*K)

Electrical conductivity: Dielectric

Radiation properties: No

Melting temperature: No

LLDPE

Path: Solids User Defined\THERMOFLOW SIMULATION.SLDASM\Default

Density: 925.00 kg/m^3

Specific heat: 2400.0 J/(kg*K)

Conductivity type: Isotropic

Thermal conductivity: 0.2000 W/(m*K)

Electrical conductivity: Dielectric

Radiation properties: No

Melting temperature: Yes

Temperature: 124.85 °C

Copper

Path: Solids Pre-Defined\Metals

Density: 8960.00 kg/m^3

Electrical conductivity: Conductor

Resistivity: 3.7000e-08 Ohm*m

Radiation properties: No

Melting temperature: Yes

Temperature: 582.00 °C

Plain Carbon Steel

Path: Solids User Defined\THERMOFLOW SIMULATION.SLDASM\Default

Density: 7800.00 kg/m^3

Specific heat: 440.0 J/(kg*K)

Conductivity type: Isotropic

Thermal conductivity: 43.0000 W/(m*K)

Electrical conductivity: Dielectric

Radiation properties: No

Melting temperature: No

LLDPE

Path: Solids User Defined\THERMOFLOW SIMULATION.SLDASM\Default

Density: 925.00 kg/m^3

Specific heat: 2400.0 J/(kg*K)

Conductivity type: Isotropic

Thermal conductivity: 0.2000 W/(m*K)

Electrical conductivity: Dielectric

Radiation properties: No

Melting temperature: Yes

Temperature: 124.85 °C

Copper

Path: Solids Pre-Defined\Metals

Density: 8960.00 kg/m^3

Specific heat: 765.0 J/(kg*K)

Conductivity type: Isotropic

Thermal conductivity: 16.0000 W/(m*K)

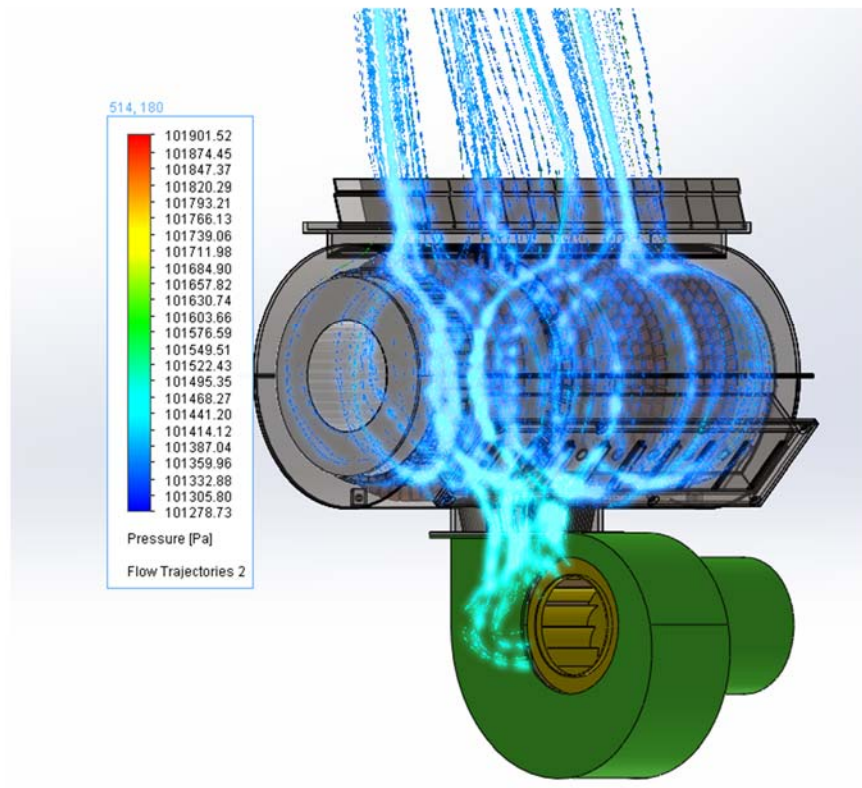
Electrical conductivity: Dielectric

Radiation properties: No

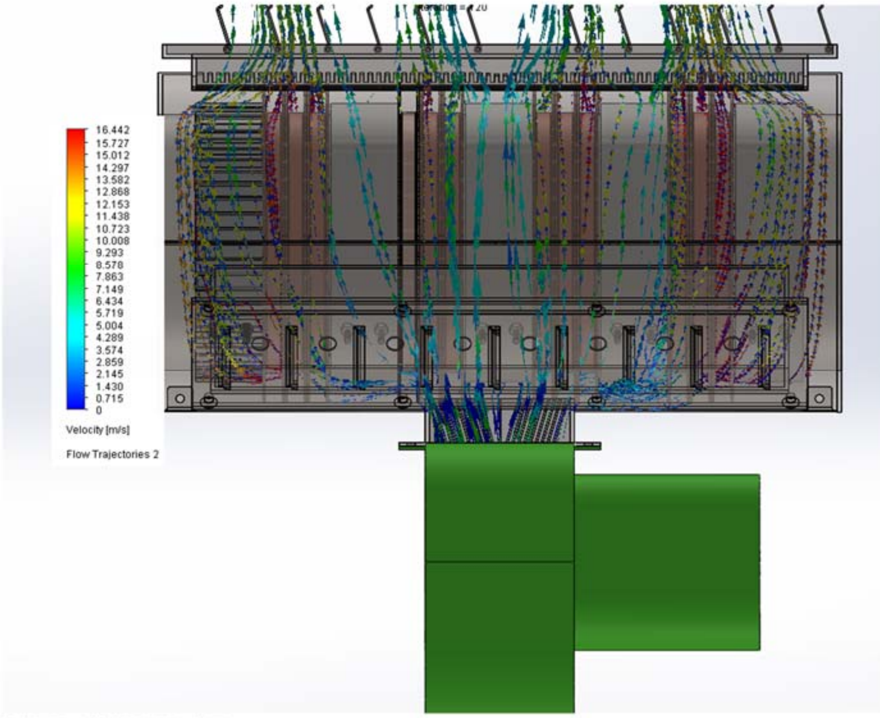
Melting temperature: Yes

Temperature: 1700.00 °C

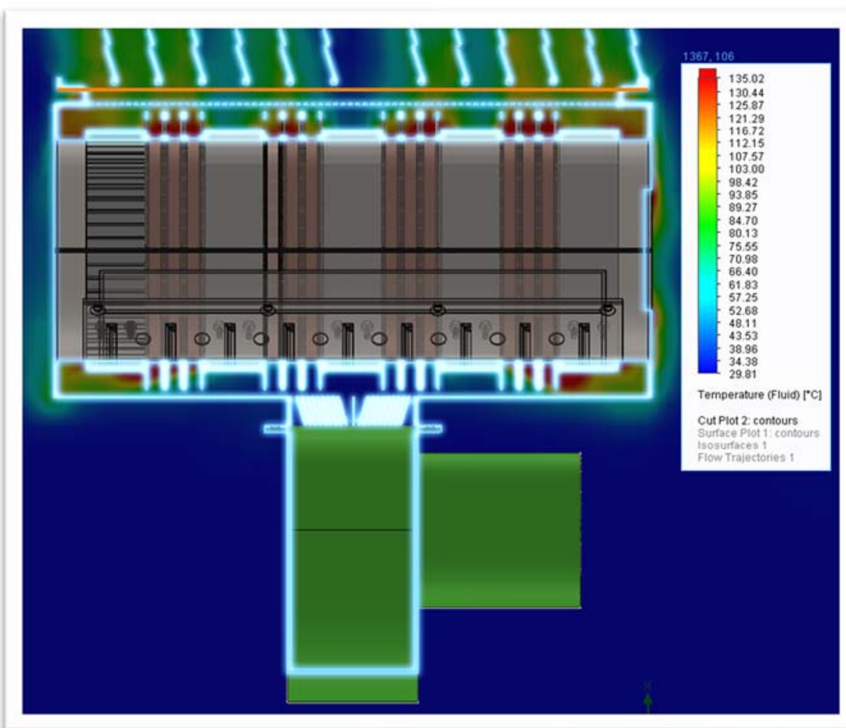
PRESSURE:

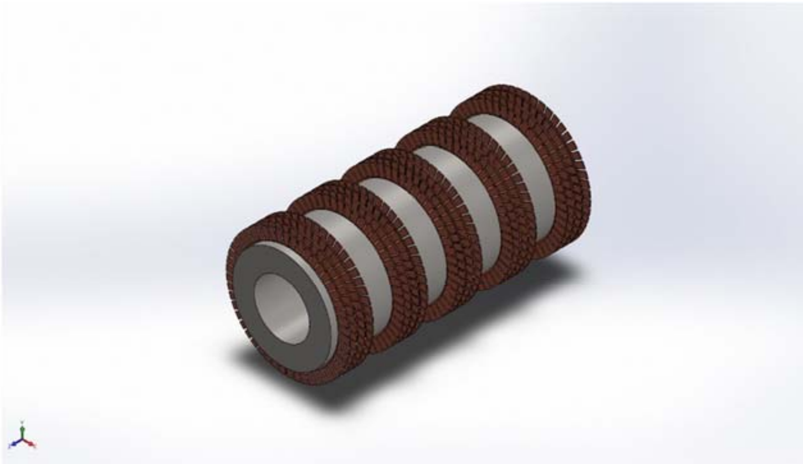


VELOCITY



TEMPERATURE CUT PLOT





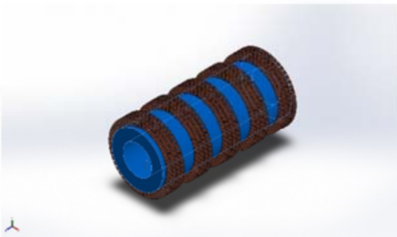
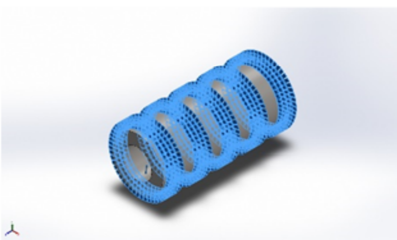
Simulation of FINAL THERMAL ANALYSIS

Date: April 3, 2023
Designer: Bryan Mendoza
Study name: Thermal 1
Analysis type: Thermal(Steady state)

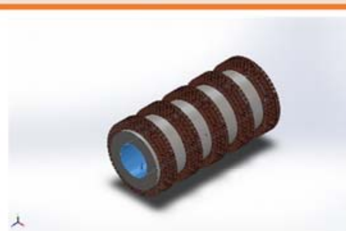
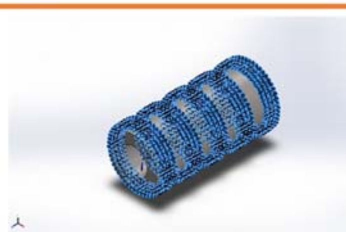
DESCRIPTION

Copper Fins

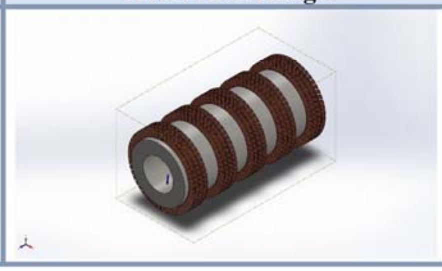
MATERIAL PROPERTIES

Model Reference	Properties	Components
	Name: **Plain Carbon Steel** Model type: **Linear Elastic Isotropic** Default failure criterion: **Unknown** Thermal conductivity: **0.000575114 BTU/(in.s.F)** Specific heat: **0.105112 Btu/(lb.F)** Mass density: **0.281793 lb/in^3**	**SolidBody 1(Boss-Extrude1)(BARELL EXPERIMENT-1)**
Curve Data: N/A		
	Name: **Copper** Model type: **Linear Elastic Isotropic** Default failure criterion: **Max von Mises Stress** Thermal conductivity: **0.00521615 BTU/(in.s.F)** Specific heat: **0.0931677 Btu/(lb.F)** Mass density: **0.321533 lb/in^3**	**SolidBody 1(CirPattern1)(FINS FOLDABLE-1), SolidBody 1(CirPattern1)(FINS FOLDABLE-10), SolidBody 1(CirPattern1)(FINS**

THERMAL LOADS

Load name	Load Image	Load Details
Temperature-1		**Entities** **1 face(s)** **Temperature: 410 Fahrenheit**
Convection-1		**Entities: 6285 face(s)** **Convection Coefficient: 23 W/(m^2.K)** **Time variation: Off** **Temperature variation: Off** **Bulk Ambient Temperature: 303 Kelvin** **Time variation: Off**

INTERACTION INFORMATION

Interaction	Interaction Image	Interaction Properties
Global Interaction		**Type:** **Bonded** **Components:** **1 component(s)** **Options:** **Independent mesh**

MESH INFORMATION

Mesh type	Mixed Mesh
Mesher Used:	Standard mesh
Automatic Transition:	Off
Include Mesh Auto Loops:	Off
Jacobian points for High-quality mesh	16 Points
Jacobian check for shell	On
Element Size	0.416783 in
Tolerance	0.0208391 in
Mesh Quality	High
Remesh failed parts independently.	Off

MESH INFORMATION – DETAILS

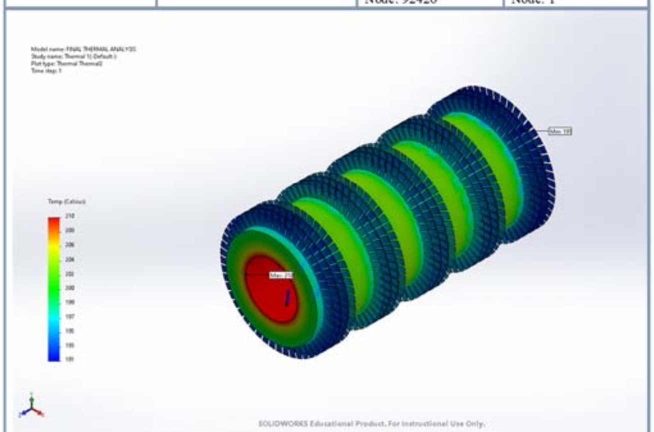
Total Nodes	136420
Total Elements	75402
Time to complete mesh(hh;mm;ss):	00:03:44

MESH INFORMATION – DETAILS

Total Nodes	136420
Total Elements	75402
Time to complete mesh(hh;mm;ss):	00:03:44
Computer name:	BRYAN-MENDOZA

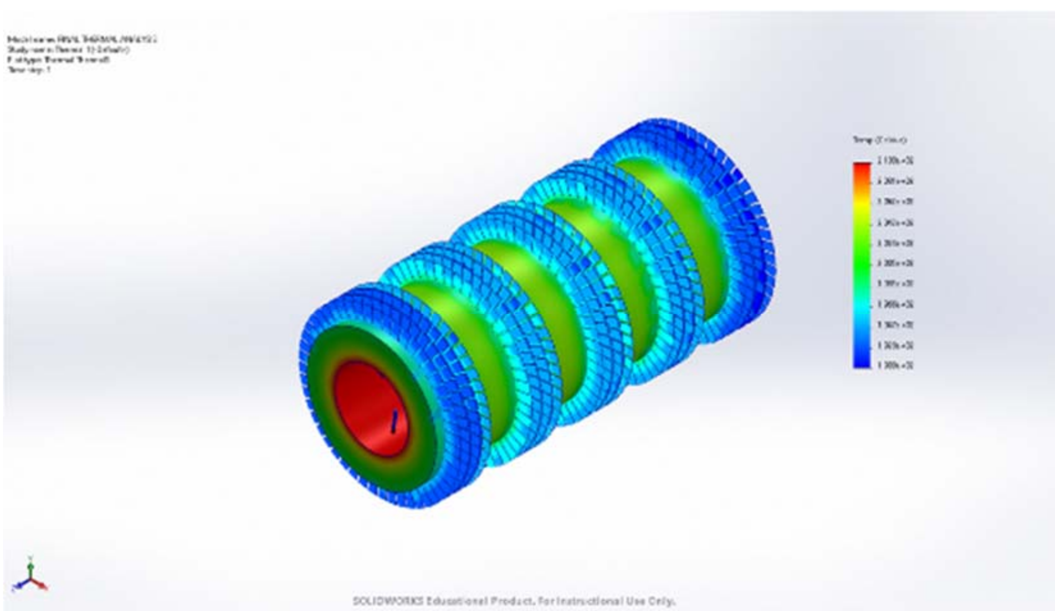
STUDY RESULTS

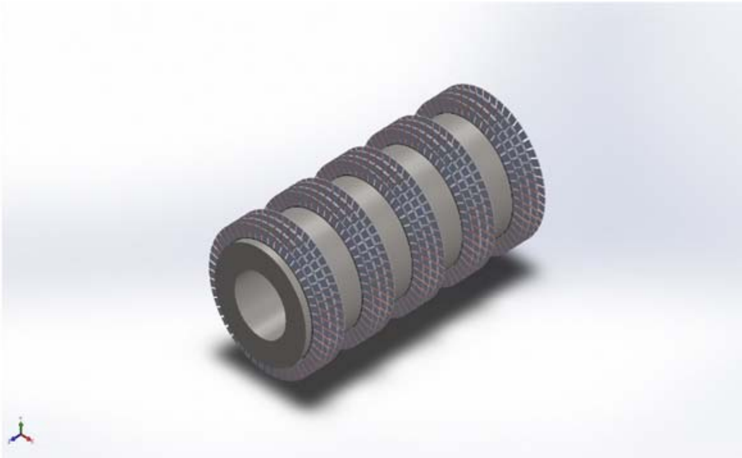
Name	Type	Min	Max
Thermal2	TEMP: Temperature	191Celsius Node: 92426	210Celsius Node: 1



FINAL THERMAL ANALYSIS-Thermal 1-Thermal-Thermal2

Name	Type	Min	Max
Thermal3	TEMP: Temperature	1.909e+02Celsius Node: 92426	2.100e+02Celsius Node: 1



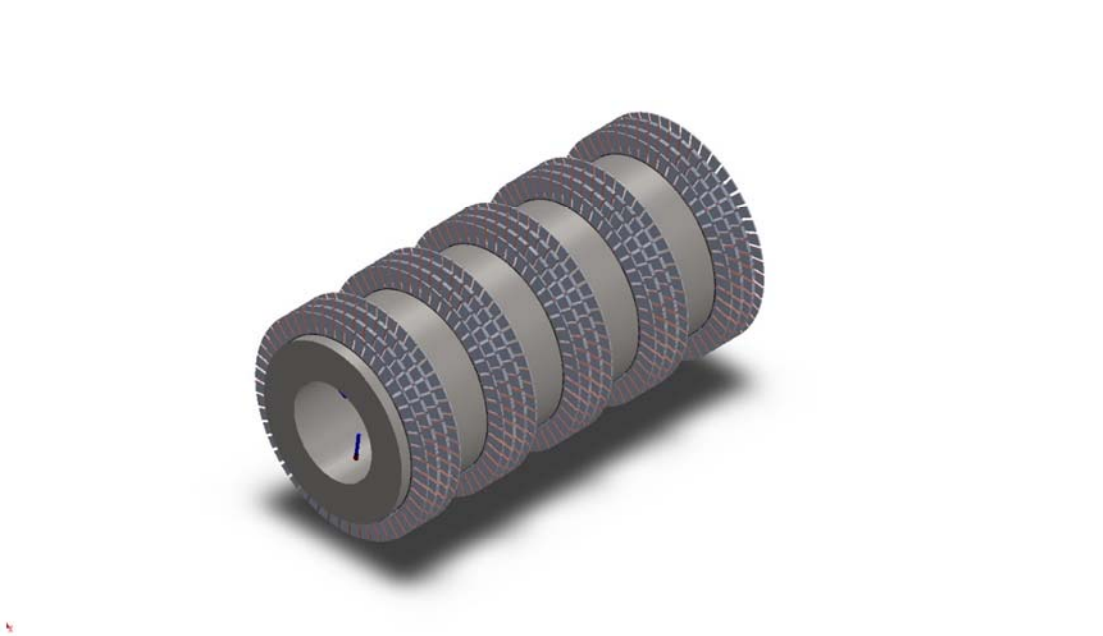


Simulation of FINAL THERMAL ANALYSIS

Date: April 3, 2023
Designer: Solidworks
Study name: Thermal 1
Analysis type: Thermal(Steady st

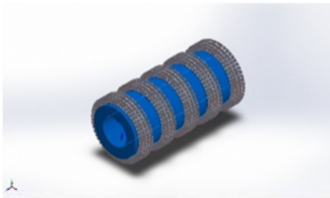
DESCRIPTION
Aluminum

MODEL INFORMATION

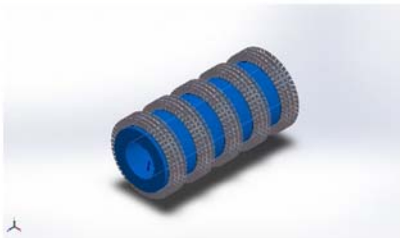


Model name: FINAL THERMAL ANALYSIS
Current Configuration: Default

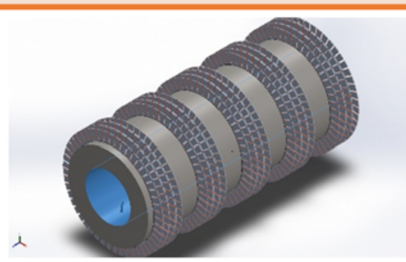
Solid Bodies

Document Name and Reference	Treated As	Volumetric Properties	Document Path/Date Modified
Boss-Extrude1 	Solid Body	Mass:196.075 lb Volume:695.814 in^3 Density:0.281793 lb/in^3 Weight:195.942 lbf	C:\Users\BRYAN\OneDrive - NBCC\Desktop\SUBJECTS\WINTER 2023\ETTG\SOLIDWORKS COMPONENTS\ASSMEBLY FOR TEST\BARELL EXPERIMENT.SLDPRT Mar 3 23:46:10 2023

MATERIAL PROPERTIES

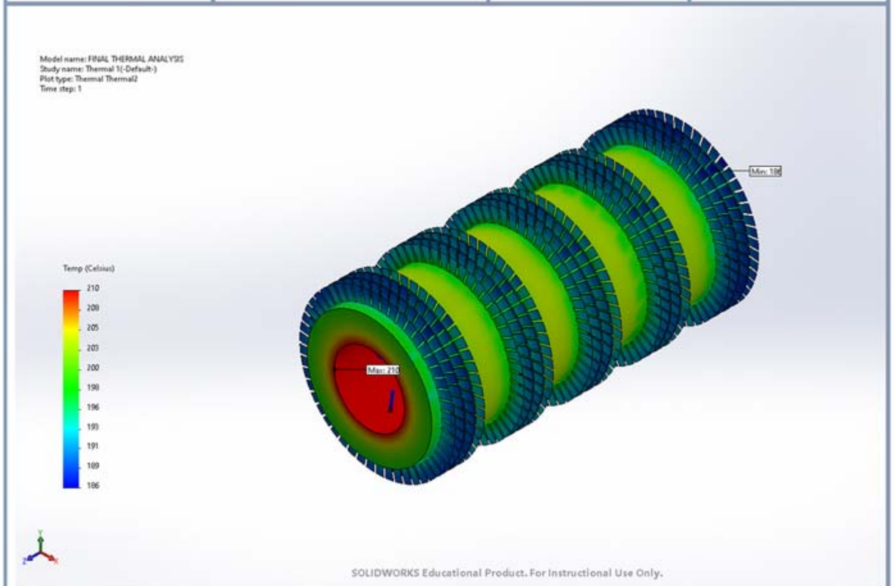
Model Reference	Properties	Components
	Name: **Plain Carbon Steel** Model type: **Linear Elastic Isotropic** Default failure criterion: **Unknown** Thermal conductivity: **0.000575114 BTU/(in.s.F)** Specific heat: **0.105112 Btu/(lb.F)** Mass density: **0.281793 lb/in^3**	**SolidBody 1(Boss-Extrude1)(BARELL EXPERIMENT -1)**
Curve Data: N/A		
	Name: **3003 Alloy** Model type: **Linear Elastic Isotropic** Default failure criterion: **Max von Mises Stress** Thermal conductivity: **0.00227371 BTU/(in.s.F)** Specific heat: **0.238892 Btu/(lb.F)** Mass density: **0.0975437 lb/in^3**	**SolidBody 1(CirPattern1)(FINS FOLDABLE-1), SolidBody 1(CirPattern1)(FINS**
Curve Data: N/A		

THERMAL LOADS

Load name	Load Image	Load Details
Temperature-1		**Entities:** **1 face(s)** **Temperature:** **410 Fahrenheit**
Convection-1		**Entities:** **6285 face(s)** **Convection Coefficient:** **23 W/(m^2.K)** **Time variation:** **Off** **Temperature variation:** **Off** **Bulk Ambient Temperature:** **303 Kelvin** **Time variation:** **Off**

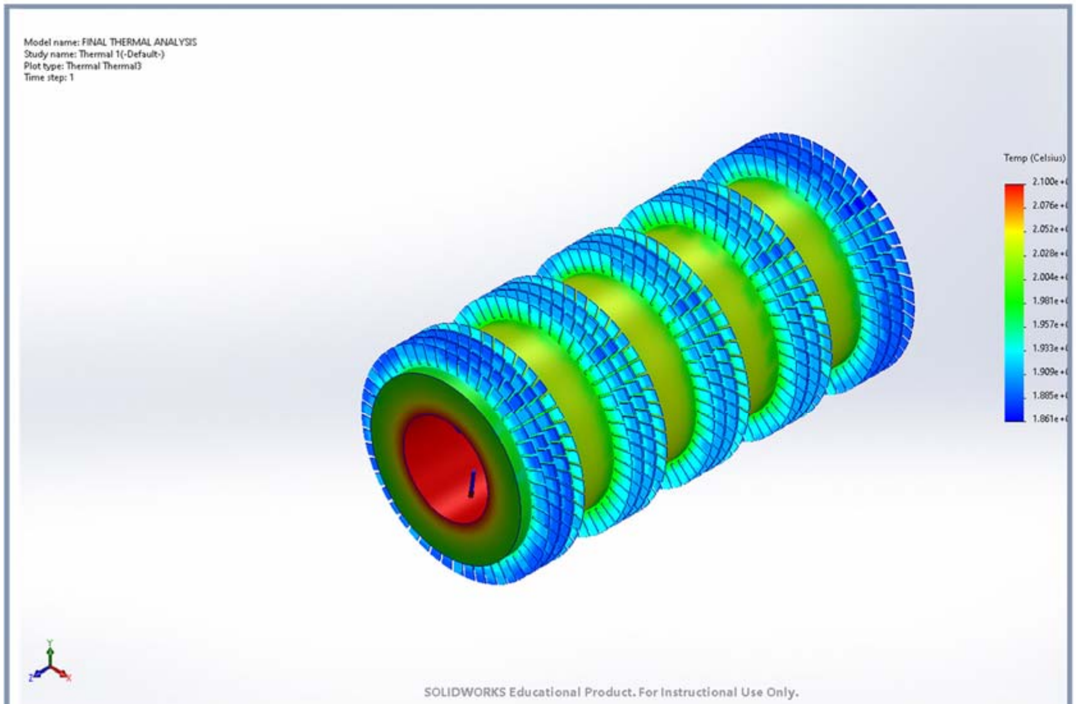
STUDY RESULTS

Name	Type	Min	Max
Thermal2	TEMP: Temperature	186Celsius Node: 92426	210Celsius Node: 1



FINAL THERMAL ANALYSIS-Thermal 1-Thermal-Thermal2

Name	Type	Min	Max
Thermal3	TEMP: Temperature	1.861e+02Celsius Node: 92426	2.100e+02Celsius Node: 1



FINAL THERMAL ANALYSIS-Thermal 1-Thermal-Thermal3