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Executive Summary

Design Objective:

Our company has identified a potential market for a temperature-controlled unit for shipping bio-specimens between hospitals and laboratories. Our team has been tasked with creating a cooling system that can cool a bio-specimen to a temperature of -70^{o}C within ten minutes and then keep it there for a twelve-hour delivery. Power consumption should not exceed 72W since the car battery only outputs 12V and 6amps. This portable cooling system must be of minimal weight and size as well as function in extreme temperatures of ranging from -63^{o}C to 79^{o}C. Also, the cooling system must be cheap and reasonable to manufacture as the goal is world-wide distribution.

Design Alternatives Considered:

From the beginning we felt that a cooling mechanism utilizing dry ice would be the best choice due to its sublimating temperature and cheap cost. The first iteration of our design was a free convection based system. We thought we could take advantage of the fact that CO_2 is denser than air. The design allowed the sublimated CO_2 to fall down and surround our specimen container before exiting through pressure release valves. However, we determined through our calculations and research that free convection was one of the worst forms of heat transfer we could use, and that controlling the temperature with such an inconsistent mode of heat transfer would be almost impossible. We therefore abandoned the idea.

Conduction, on the contrary, was one of the best forms of heat transfer we could use. That was the inspiration for our second iteration, which was a basic conduction-based system. The conduction based system would allow for a more constant surface temperature along the wall of the specimen container**.** This design utilized a steel vacuum-insulated container that makes convection and conduction from the outside environment negligible. Insulation between the aluminum dry ice compartment and outside of the steel container reduces the rate of sublimation of the dry ice. Separating the dry ice container and the specimen container is a heater that will warm the specimen container if it gets too cold. The main flaw in this iteration was that once the dry ice melted around the walls of the container, the system would be in only free convection which is something we want to avoid.

Chosen Design:

After considering the sublimation of the dry ice, we added a copper fin section to our design to create our third and final iteration. The addition of copper fins and the usage of crushed dry ice will eliminate the problem of having no dry ice touch the container walls. Also, the fins result in a more consistent specimen container temperature. We also added insulation between the dry ice container and the specimen container to reduce temperature fluctuation. This system will be able to cool the specimen container to -70^{o}C in less than ten minutes and required very little power from the vehicle. This system needs to cool he specimen container to -70^{o}C even under extreme temperatures.

Highlights of Expected Performance:

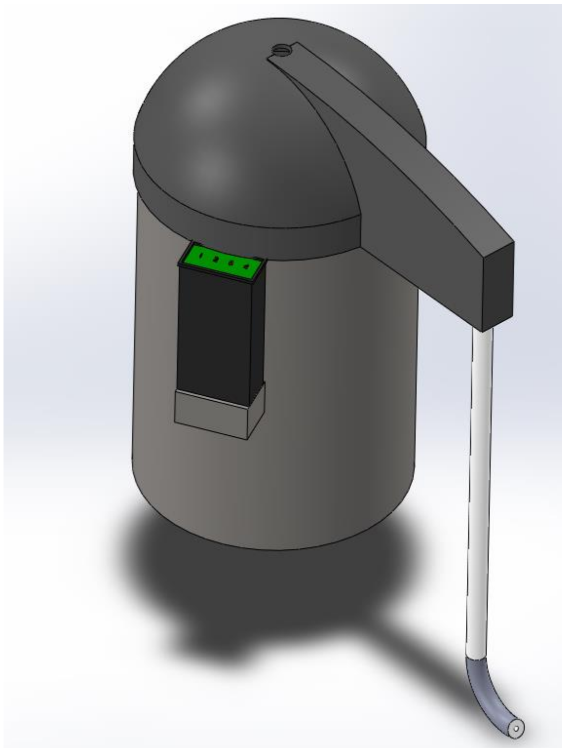
Firstly, we expect outer environmental conditions ranging from -63°C to 57°C to have a small impact on our middle CO2 layer thanks to a tightly sealed outer vacuum shield. Secondly, the middle CO2 layer will maintain at exactly -78°C during sublimation. Finally, through a process of conduction and electrical heating, the inner wall shall be maintained at -70°C for the 12 hour shipment.

Key Numbers:

Ultimately, the heater will need to output only 23 W of power to keep the specimen container at the desired temperature. The total cost of the system will be $632.88 for the first unit. Extra material left over can be used for subsequent units cutting cost to $183.69.
Expected Machine Shop Hours: 1hr.

Detailed Design

Figures 1 & 2: Fully Assembled Cooling System



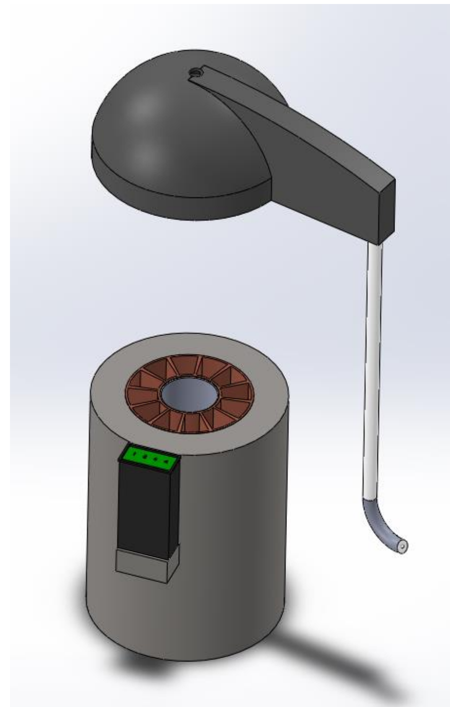


Figure 3: Exploded View of Cooling System

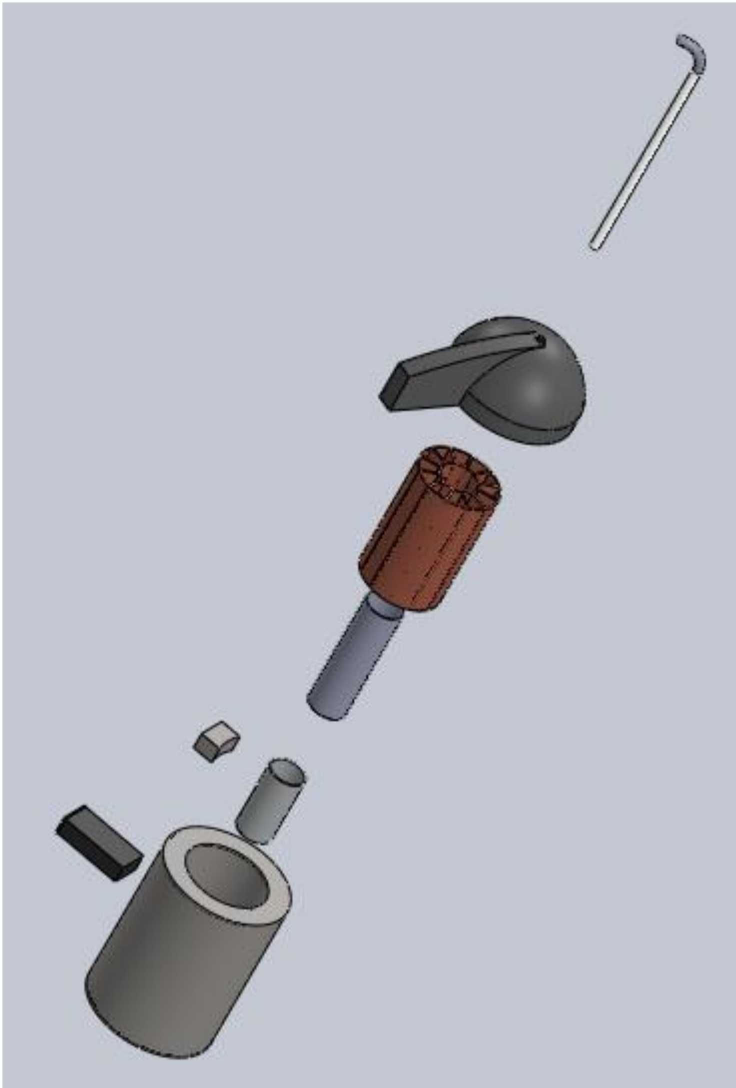


Figure 4: Assembly of Cooling System

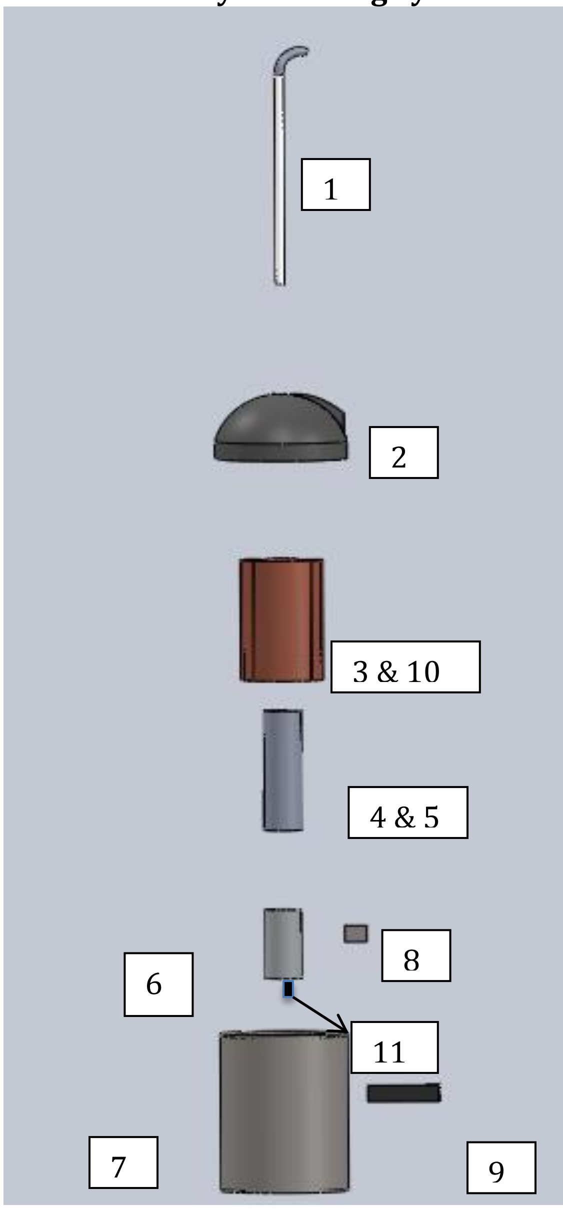
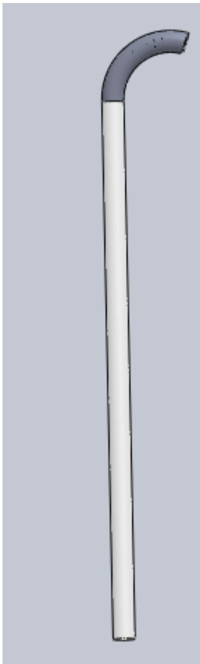


Table 1: Assembly of Cooling System Parts List

1	Rubber CO_2 Exhaust Hose
2	Stainless Steel Vacuum-Insulated Lid
3	Thermal Fins
4	Thermal Insulation
5	Heater
6	Specimen Container
7	Stainless Steel Vacuum-Insulated Container
8	Controller Mount
9	Temperature Controller
10	Dry Ice
11	Thermocouple

Component List

Figure 5: Rubber CO_2 Exhaust Hose

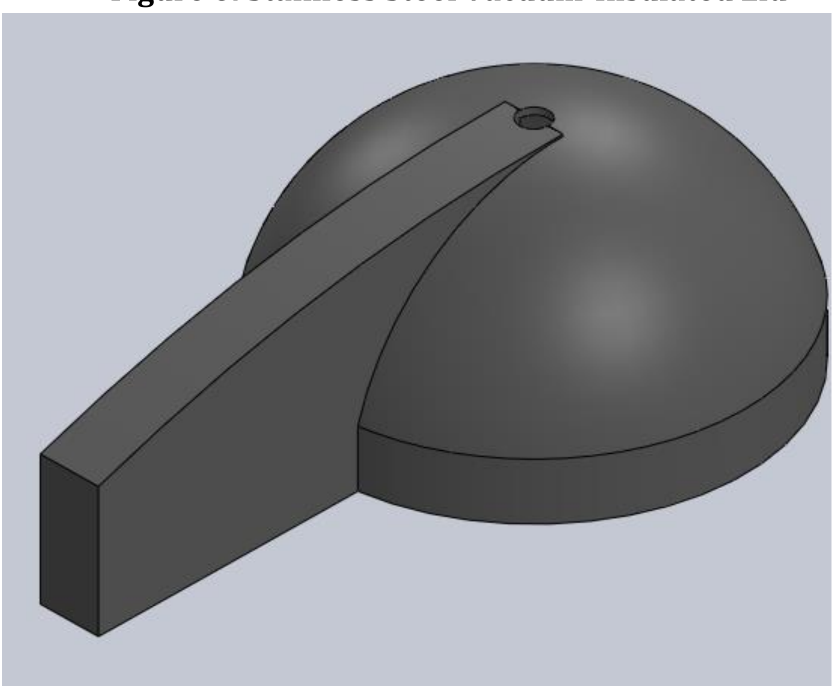


Component Number: 1

Component Name: Rubber CO_2 Exhaust Hose
Dimensions: Diameter = 1.59 cm
Length= 1.5m

Purpose: Lead the Carbon Dioxide safely out of the vehicle

Figure 6: Stainless Steel Vacuum-Insulated Lid



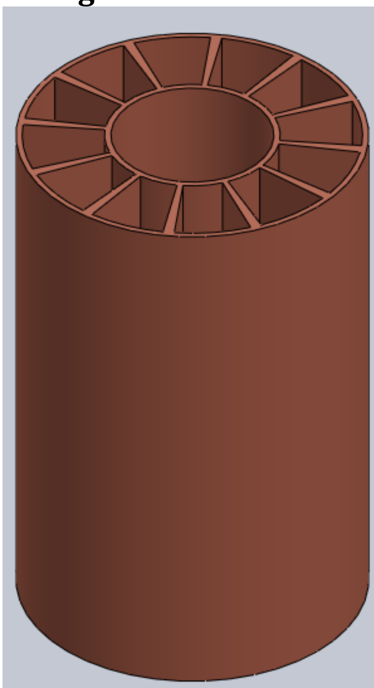
Component Number: 2

Component Name: Stainless Steel Vacuum-Insulated Lid

Dimensions: Diameter = 18 cm
Tail Length = 20.3 cm,
Tail Thickness = 2.5 cm

Purpose: Closes the system to prevent convection. Comes with the vacuum-insulated system we purchased. Since it is a coffee container originally, the tube (component 1) can be inserted into the existing spout.

Figure 7: Thermal Fins



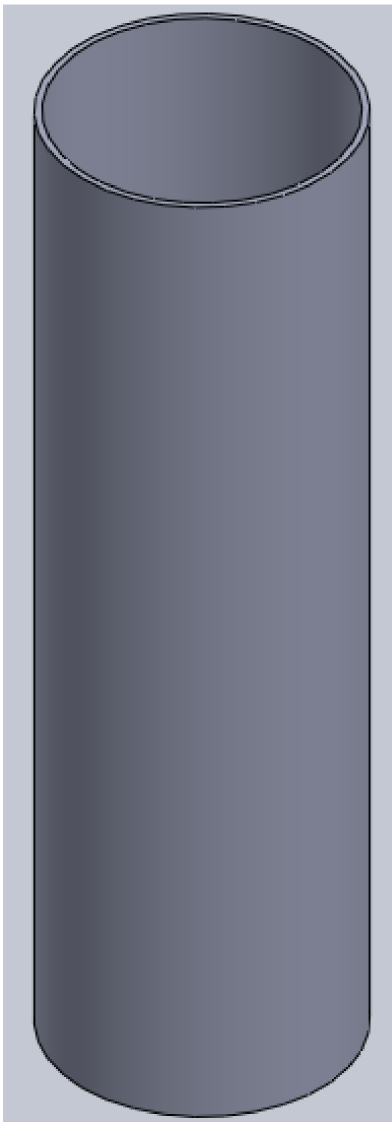
Component Number: 3

Component Name: Thermal Fins

Dimensions: OD = 11.35 cm,
ID = 5.5 cm, Length = 17.9 cm,
Thickness = 0.2 cm

Purpose: Copper fins that contain the dry ice allow for conduction throughout copper system, and a more uniform sublimation of the dry ice.

Figure 8: Thermal Insulation



Component Number: 4

Component Name: Thermal Insulation

Dimensions: ¼ cm thickness, ID = 5cm, OD = 5.5 cm, 17.4 cm length

Purpose: ¼ cm of foam rubber insulation is used as thermal insulation between the copper fins and the heater. This reduces the effect of the heater on sublimation of the dry ice to conserve dry ice. Our thin heater is located on the inside of foam.

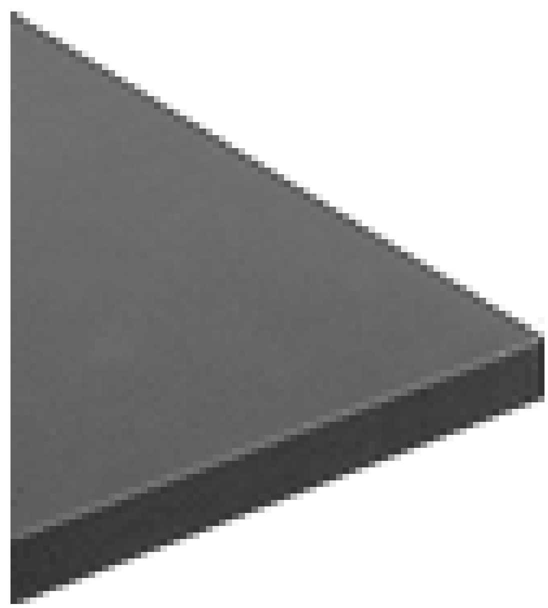


Figure 9: Heater

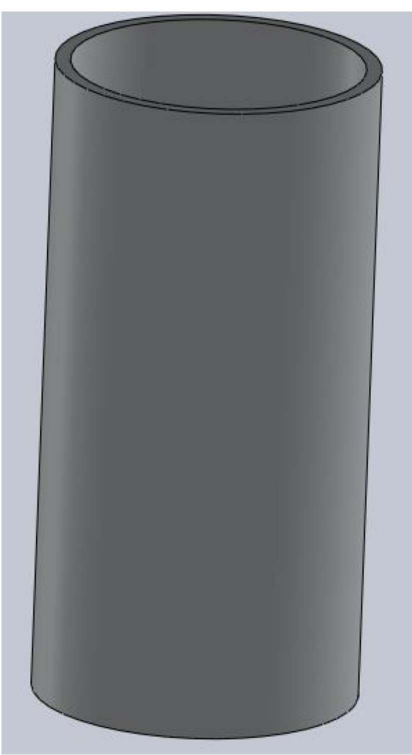
Component Number: 5

Component Name: Heater (Nichrome wire)

Dimensions:
Thickness = 0.0635 cm
Length = 4 m
A wire of length 4m will wrap 25 times around the specimen container. 12V from the car battery will be run through the wire, creating 27W heat output.

Purpose: Used to heat the specimen container if it gets too cold. This resistance heater lies between the insulation and the specimen container. It can function at temperatures as low as -195°C, making it ideal for the situation.

Figure 10: Specimen Container



Component Number: 6

Component Name: Specimen Container

Dimensions: 5cm diameter, 10cm length

Purpose: Location of the specimen to be cooled. The inside of this aluminum cylinder must reach -70^{o}C within 10 minutes and stay there for a twelve hour trip. This container will be provided with the specimen, so is not included in our cost estimation.

Figure 11: Stainless Steel Vacuum-Insulated Container

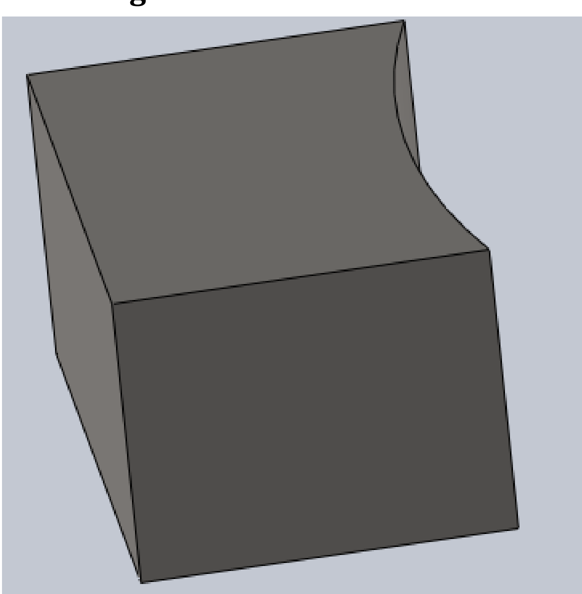
Component Number: 7

Component Name: Stainless Steel Vacuum-Seal Container

Dimensions: 2.5L container, ID = 11.4 cm, OD = 17.50 cm, Length = 23 cm

Purpose: Outer most layer of protection from ambient temperatures. Its reflective coat makes radiation negligible. Contains Parts #3-6. Drastically reduces the sublimation rate of the dry ice. This component and the Stainless Steel Vacuum-Insulated Lid are purchased together (they are a coffee carafe).

Figure 12: Controller Mount



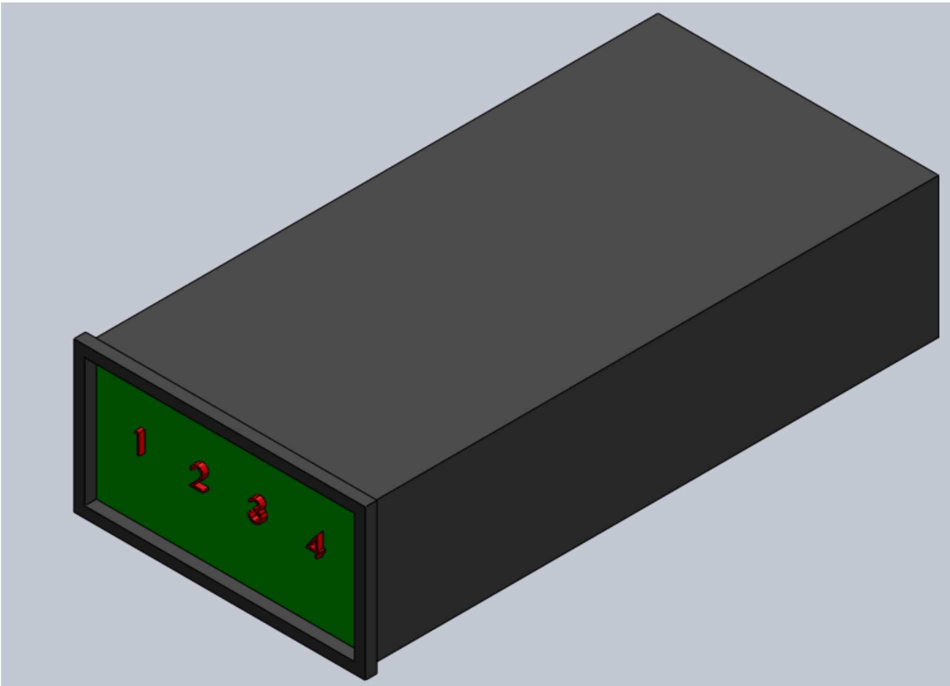
Component Number: 8

Component Name: Controller-Container Adapter

Dimensions: Diameter = 17.5 cm, Length = 4.8cm, Thickness =

Purpose: PVC part attaches the controller to the assembly. The inside surface models the cylinder while the outside surface fits the temperature controller. It attaches to the container and the controller by Epoxy.

Figure 13: Temperature Controller



Component Number: 9

Component Name: Temperature Controller

Dimensions: Length = 9.8 cm, Width = 4.8cm, Thickness = 4.8 cm

Purpose: Takes the thermocouple temperature as an input. If the input reads below -70^{o}C, its output is on/off to connect the car battery to the heater. The heater then warms the system until the specimen container is slightly above -70 ^{o}C. If the input temperature reads above -70^{o}C, the power to the heater is cut off.

Figure 14: Dry Ice

Component Number: 10

Component Name: Dry Ice
Dimensions: 10lbs

Purpose: For a 12-hour delivery, we only need 2.5-5lbs of dry ice. Because our system can hold 2.5L and the density of dry ice is only 1.4 g/cm^3, we have enough space for 10lbs of dry ice. This will allow our system to run at conduction throughout the delivery. The dry ice is crushed so when it sublimates the crumbles will collapse on itself and touch the walls at all times.

Manufacturing Drawings

Figure 15: Manufacturing Drawing of Thermal Fins

Component Number: 3
Note: Slots along the center have the same dimensions

Manufacturing Drawing will be sent to GindreCopper so that thermal fin can be manufactured. It will be manufactured by an extrusion process, so once the process is completed once, it will be easy to reproduce using the same extrusion mold.

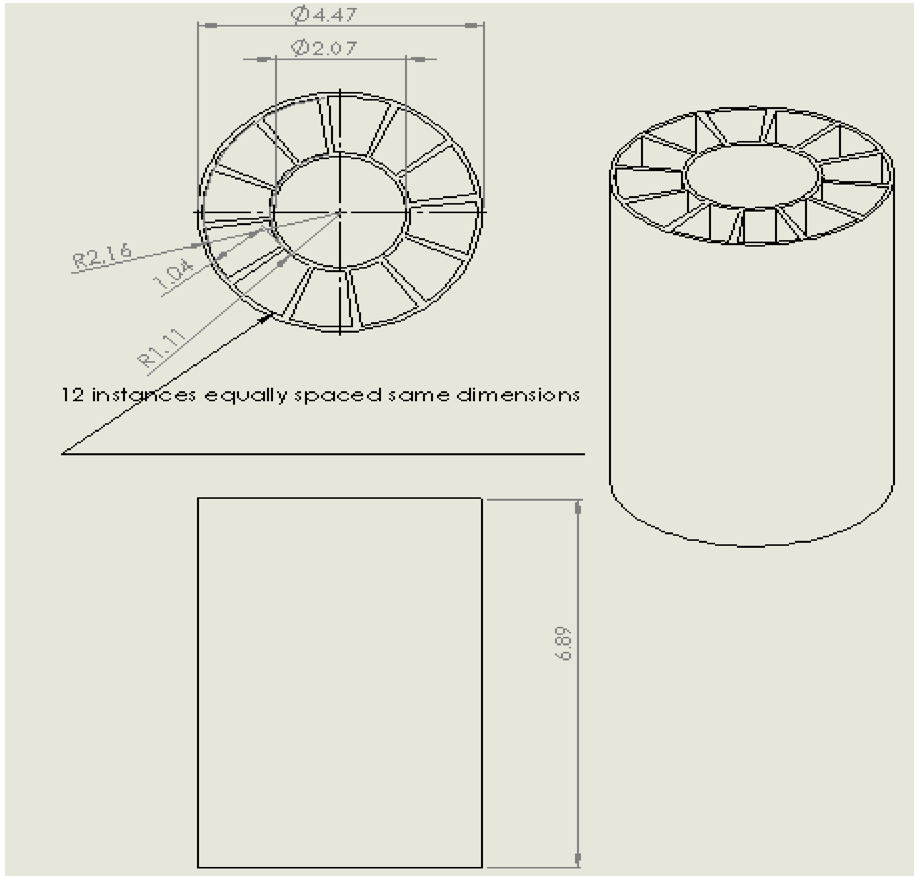
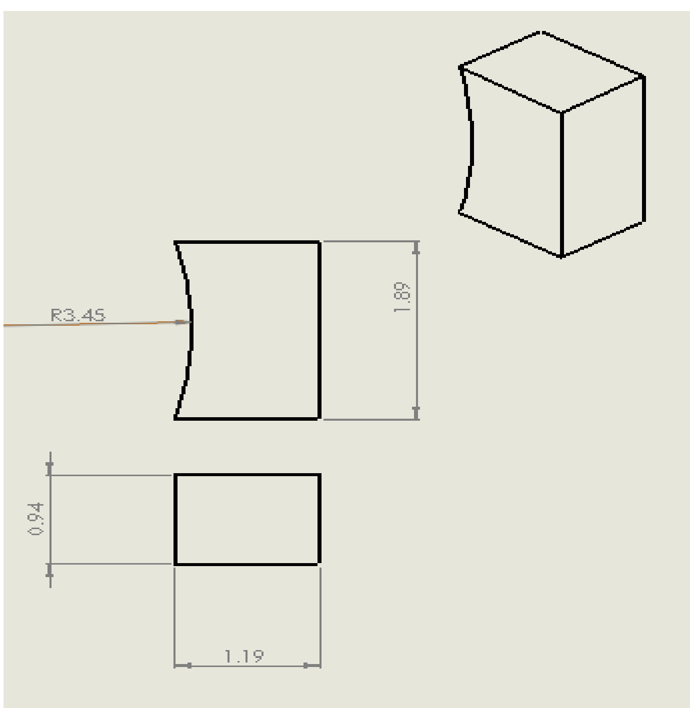


Figure 16: Manufacturing Drawing of Controller Mount



Component Number: 6
Note: Controller mount is attached to the container and temperature controller by Epoxy.

Manufacturing Time: 1 hour

1d. Assembly Instructions

1	Rubber CO_2 Exhaust Hose
2	Stainless Steel Vacuum-Insulated Lid
3	Thermal Fins
4	Thermal Insulation
5	Heater
6	Specimen Container
7	Stainless Steel Vacuum-Insulated Container
8	Controller Mount
9	Temperature Controller
10	Dry Ice
11	Thermocouple

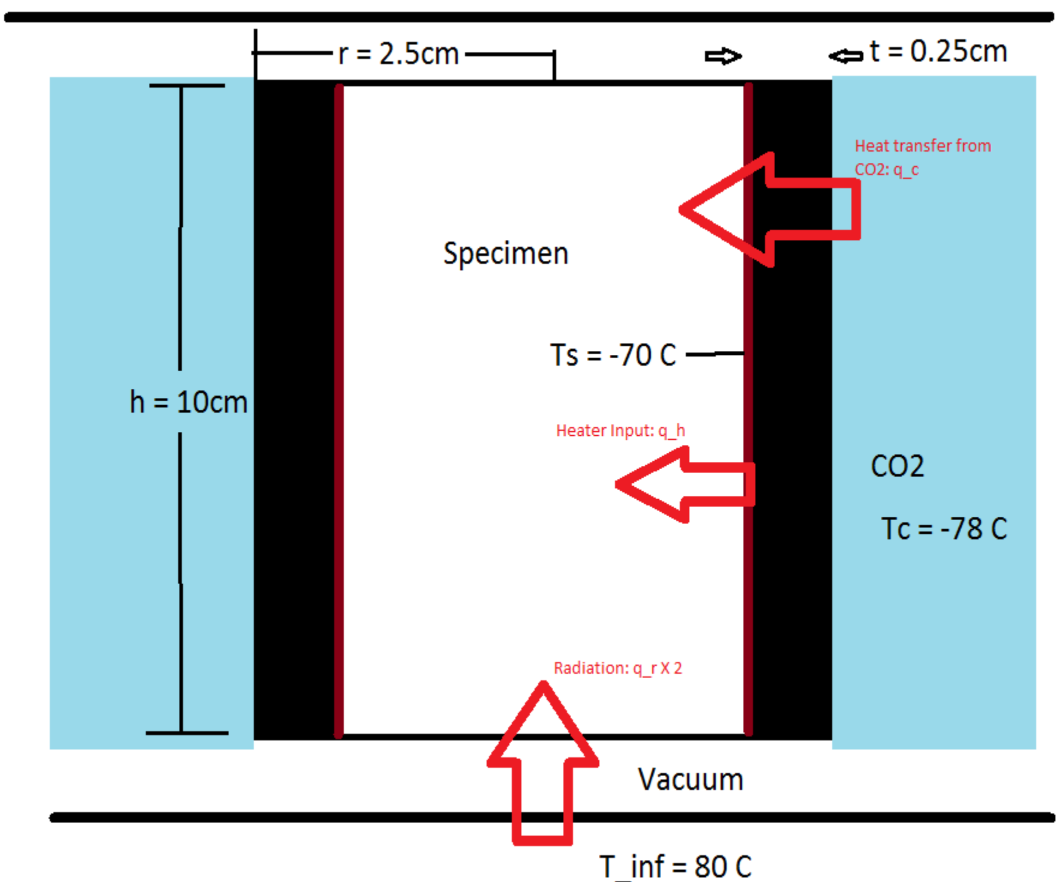
1. For the assembly, begin by attaching the Thermocouple [11] to the inner surface of the Specimen Container [6]. Take the Nichrome Wire Heater [5], and wrap it around the Specimen Container [6] twenty-five times evenly. Finally, wrap the Thermal Insulation [4] around the heater/container [5,6] assembly.
2. Proceed by inserting the Thermal Fins [3] into the Stainless Steel Vacuum-Insulated Container [7]. Once the Thermal Fins [3] are fully inserted, slide the insulation/heater/container [4,5,6] assembly into inner cylinder of the Thermal Fins [3].
3. Attach the Controller Mount [8], with Epoxy, to the outer surface of the Stainless Steel Vacuum-Insulated Container [7].
4. Insert the Temperature Controller [9] into the Controller Mount [8] and connect its input wires to the thermocouple and output wires heater through the top of the assembly.
5. Once the Controller is connected to the thermocouple and heater, put 2.55 lbs of dry ice blocks [10] into the compartments of the Thermal Fins.
6. Input 12V into the Controller, which will deliver 12V output into the heater.
7. Insert the specimen into the Specimen Container and fasten the Stainless Steel Vacuum-Insulated Lid [2] onto the assembly (the thermocouple and heater wires will be insulated between the lid and the container). Once fastened, feed the rubber CO2 Exhaust hose [1] into the hole located on the top of the Stainless Steel Vacuum-Insulated Lid.
8. Steps 1-3 will be completed by manufacturer before distribution. For subsequent uses of the unit, the customer will only steps 4-6 need to be completed, because the assembly can remain intact.

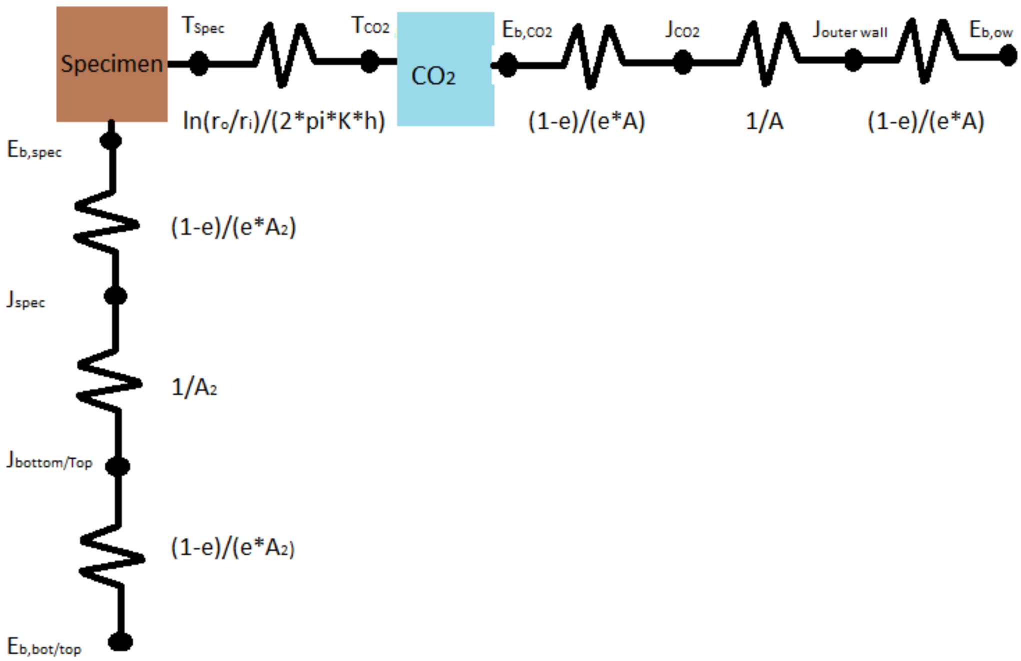
Detailed Analysis

Assumptions

- Steady state
- Constant Properties
- Large Surroundings
- Negligible contact resistance
- Extreme temperature analyzed
- 1-D conduction for calculations
- Heater has negligible thermal resistivity
- Copper fin insert has negligible thermal resistivity

Figure 17: Diagram on Cooling System





Equations

We considered three types of heat transfer in our system when performing thermal analysis. They were conduction throughout the system to the specimen container, natural convection from the ambient air and the sublimated CO2, and radiation from the surroundings. The system was evaluated at the most extreme ambient temperatures. The inside of the dry ice containers that touched the dry ice was said to be the same temperature as the dry ice. In order to run the Solidworks thermal analysis, we needed to calculate the surface temperatures of all our parts.

Hand Calculations of Heat Transfer into Specimen

To estimate the heater power necessary to keep our specimen at -70 C, we used the following equations to calculate the heat transfer into the specimen at steady state, and to keep a steady temperature we said the total $q_{specimen}$ needed to be zero. Please refer to the figure above, and the notes in Appendix B.

$$q_c = \frac{2\pi h K_{ins}(T_c - T_s)}{ln(\frac{2.75}{2.5})} = -13.185\ W \quad ** K_{ins} = 0.25\ \frac{w}{m*K} \tag{1}$$

$$q_r = \frac{\sigma \pi r^2 (T_\infty^4 - T_s^4)}{\frac{2}{\varepsilon} - 1} = 0.15\ W \quad ** \varepsilon_{Al} = 0.18 \tag{2}$$

Hot Environment: Radiation important

$$q_{specimen} = q_c + q_r = -13.035\ W \quad (3)$$

At steady state:

$$q_{specimen} - q_h = 0 \rightarrow\ q_h = 13.035\ W \quad (4)$$

Cold Environment: Radiation negligible

$$q_{specimen} = q_c = -13.035 \quad (5)$$

At steady state:

$$q_{specimen} - q_h = 0 \rightarrow\ q_h = 13.185\ W \quad (6)$$

Nichrome Heater Calculations:

One of our alternative heater options was a nichrome resistance heater with a current passing through it. To determine the gauge of the wire, we used the following equations.

$$P_{max} = 13.185\ W * FOS(2) = 27\ W \quad (7)$$

$$P_{elec} = \frac{V^2}{R} = \frac{V^2}{\rho\frac{l}{A}} \quad (8)$$

We wanted the wire to wrap 25 times around the cylinder (circumference 0.157), so we needed 3.927m of wire.

Using the above equation, we determined the diameter of the wire needs to be 0.001m = 0.025inches.

SolidWorks Analysis

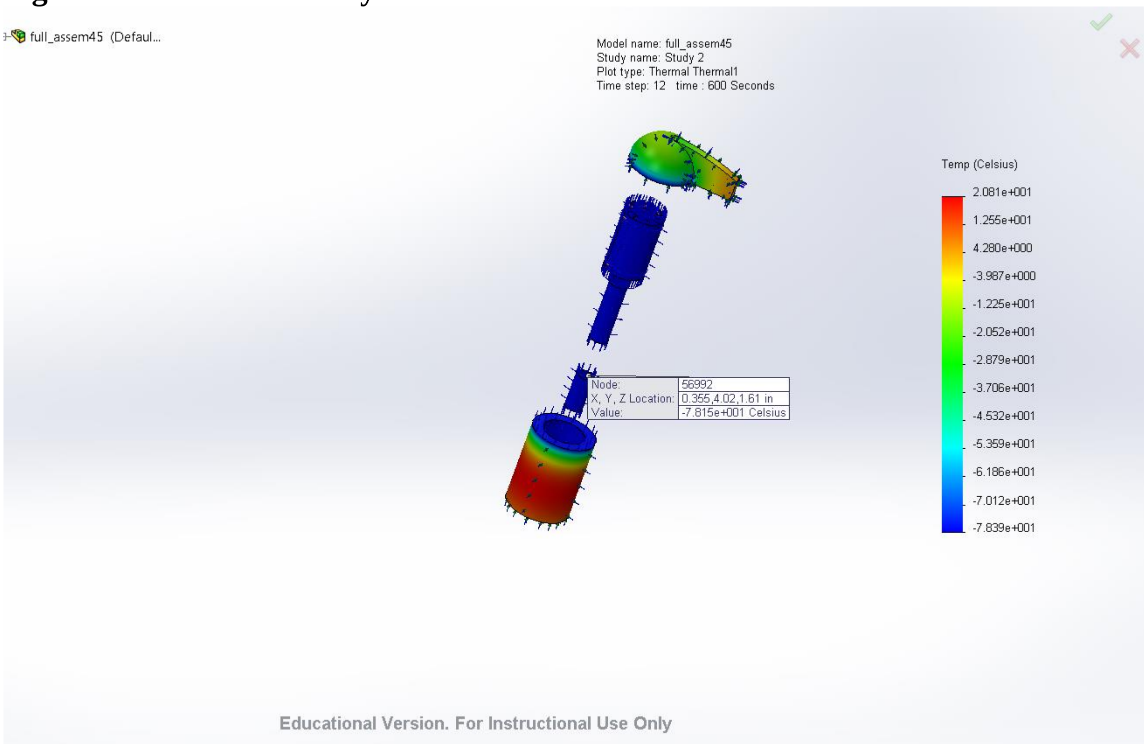
Assumptions

- Steady state
- Constant Properties
- Large Surroundings
- Negligible contact resistance
- Extreme temperature analyzed
- 1-D conduction for calculations
- Radiation negligible

Transient Analysis

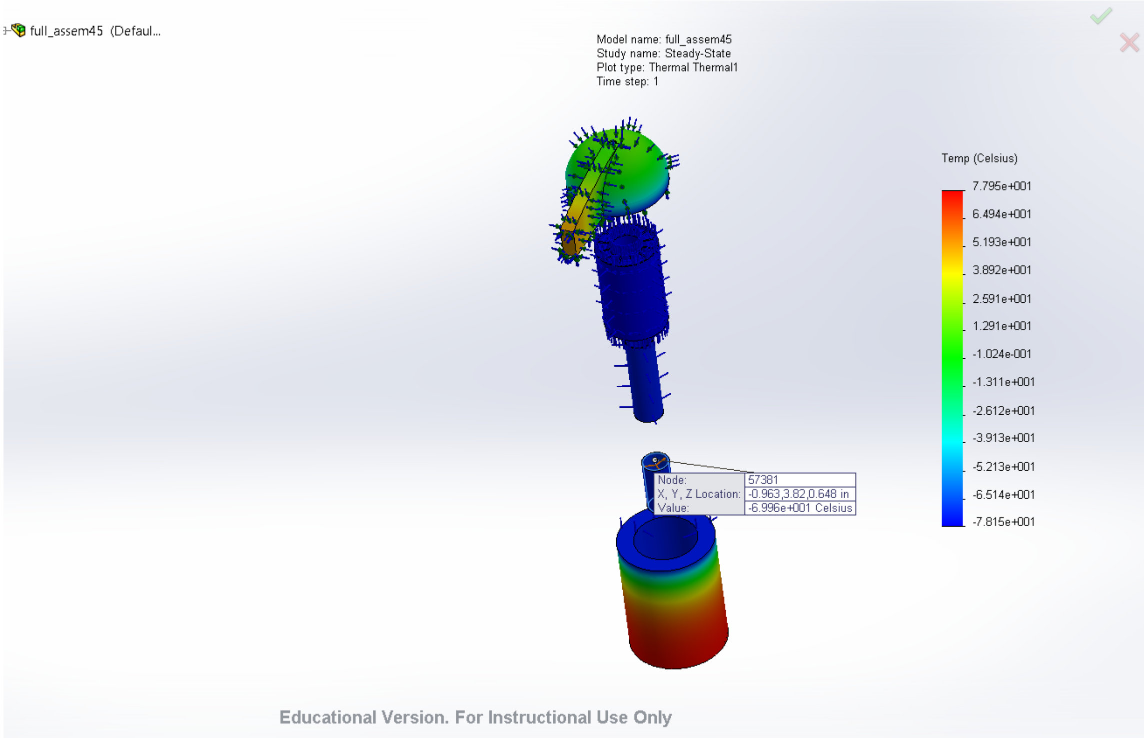
In our detailed analysis, we performed a transient analysis on our system. The parts that we needed to model under transient heat transfer are the stainless steel vacuum system, copper fins, heater, insulation and aluminum specimen container. The inside of our specimen container must reach a temperature of -70^{o}C in less than ten minutes and then remain at -70^{o}C for a twelve-hour trip. For our transient analysis, we will set our initial parameters on the system and let the transient analysis run for ten minutes. We set the initial temperatures of the copper fin pockets to be -78.15^{o}C because that is the temperature of dry ice. The rest of the system we set an initial temperature of room temperature, or 23^{o}C. If the inside of the specimen container reaches a temperature of -70^{o}C or below, then we can determine that our system will work for the previously stated conditions.

Figure 18: Transient Analysis



The coolest area of our system is found inside the copper fins. This makes intuitive sense because our dry ice is located within each of the compartments. The high thermal conductivity of copper makes the fins roughly the same temperature of the dry ice it is in contact with. The overall temperature of the inside of the specimen container is -78.15^{o}C after ten minutes of running without any power from our heater. This means that our goal of reaching -70^{o}C within ten minutes will be achieved. Our steady state thermal analysis determined that -70^{o}C could be maintained if the heater is powered at 23W. The temperature controller will turn on the heater when the inside of the specimen container is a temperature lower than -70^{o}C. This analysis is taken for a system in extreme heat (79^{o}C), so if it can function in this heat then it can function in all ambient temperature scenarios.

Figure 19: Steady-State Analysis with Air = 79^{o}C



Our copper fins can hold more than twice as much dry ice than we need for the full twelve-hour cycle. Because of this, we can assume our steady-state analysis is a good representation of a twelve-hour delivery. This is because at all times the dry ice level will be higher than 10cm, making the respective copper surface it touches to be in conduction. Therefore, the 10cm tall specimen container will mostly be affected by conduction and not the free convection of the sublimated CO_2.

Figure 20: Steady-State Analysis with Air = -63°C & Full Dry Ice

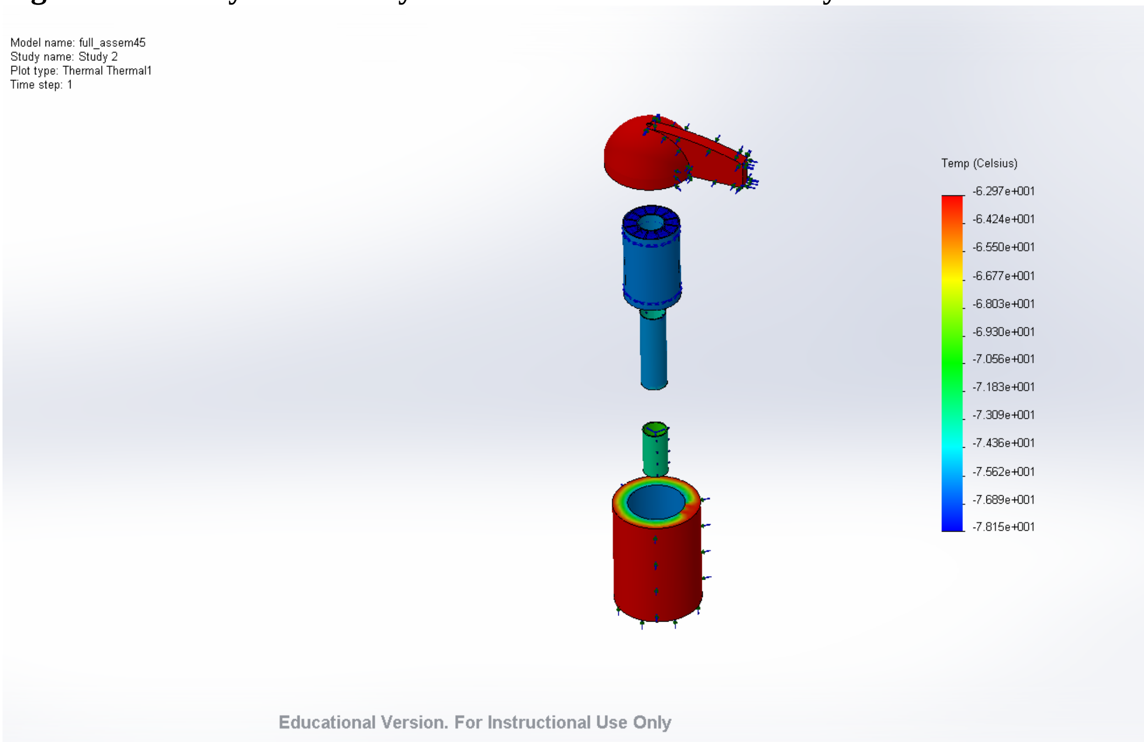
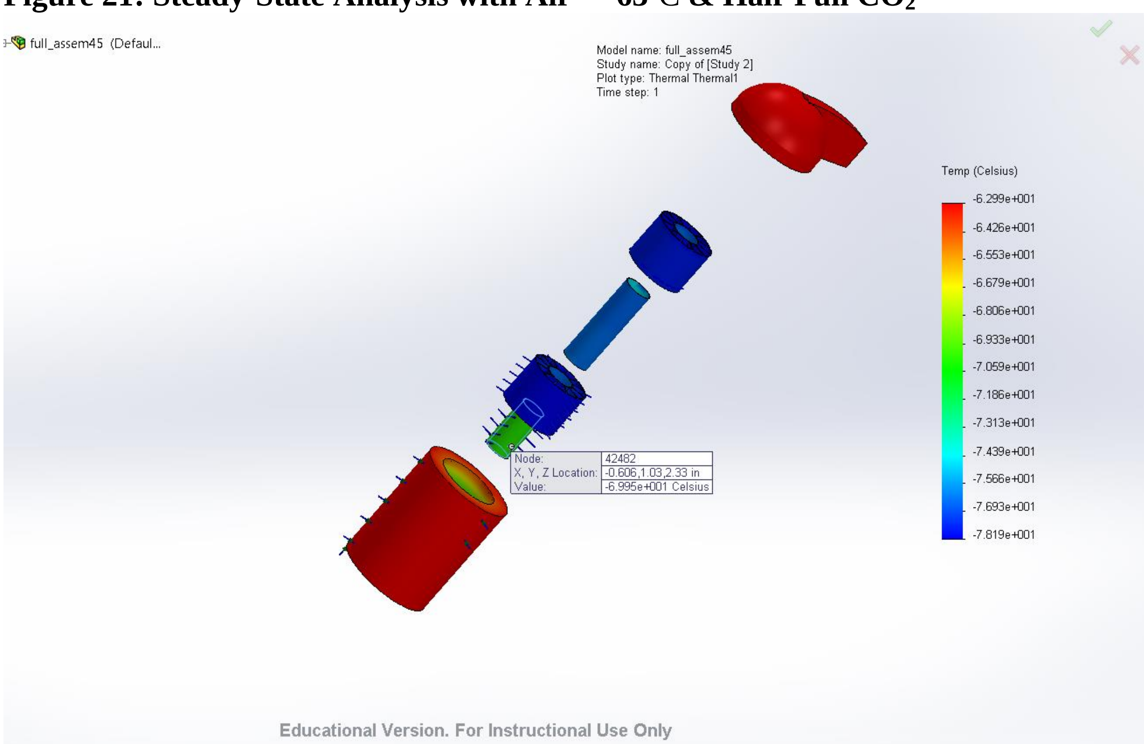


Figure 21: Steady-State Analysis with Air = -63°C & Half-Full CO_2



We ran a thermal analysis of the system when the compartments of dry ice were completely filled and when they were half of the way filled since that is the result of the twelve-hour delivery. For the half-filled compartments, we analyzed as if the top half of the copper fins were affected by the natural convection while the bottom half was affected by conduction. The results were very similar, which means that our steady-state conduction model is valid.

Steady-State Scenarios in which the system will work as expected

To determine if our system will work in all temperature scenarios, we tested our system under the extreme temperature conditions of a parked car found in Death Valley, CA. This temperature we found to be as hot as 79^{o}C. The logic is that our system will be heating the dry ice, so if our system runs in the ambient temperature of 79^{o}C, it will surely run fine at colder ambient temperatures. The effectiveness of our insulation and the power capacity of our heater allow our system to handle any ambient temperature it experiences. After running a Solidworks thermal analysis, we determined our system would successfully do the task.

The steady-state thermal analysis was mostly used to determine two things. The first was the power our heater needed to run in order for the system to be successful. The second was to determine the ambient temperatures effects on the sublimation of the dry ice. After running our Solidworks thermal analysis, we determined that our heater needed to run at 23W in order to keep the specimen container at a steady state temperature of -70^{o}C. This is similar to the power found in our numerical calculations. The stainless steel vacuum does an excellent job insulating the copper fins from the ambient temperature. The ambient temperature still has an effect on the sublimation rate of the dry ice though, as the system isn't perfect. However, this changing sublimation rate is not significant enough that all of our dry ice sublimates. In fact, we lose less than half of the dry ice in our container. This can be backed by our numerical calculations as well as research we did on dry ice sublimation.

Cost Estimation

Table 2. Table Illustrating List of Components and whether they are purchased or manufactured.

Reference Number	Component	Manufactured/ Purchased
1	Rubber CO_2 Exhaust Hose	Purchased
2	Stainless Steel Vacuum-Insulated Lid	Purchased
3	Thermal Fins	Purchased (Custom Part)
4	Thermal Insulation	Purchased
5	Heater	Purchased
7	Stainless Steel Vacuum-Insulated Container	Purchased
8	Controller Mount	Manufactured
9	Temperature Controller	Purchased
10	Dry Ice	Purchased
11	Thermocouple	Purchased

Table 3. Purchased Components

Reference Number	Component	Quantity	Price $/unit	Cost $
1	Rubber CO_2 Exhaust Hose	1	$18.00	$18.00*
2 & 7	Stainless Steel Vacuum-Insulated Lid Stainless Steel Vacuum-Insulated Container	1	$48.21	$48.21
3	Thermal Fins	1	$349.00	$349.00*
4	Thermal Insulation	1	$17.48	$17.48*
5	Heater	1	$13.06	$13.06*
9	Temperature Controller	1	$99.0	$99.00
10	Dry Ice	1	$0.6/lb	$1.53
11	Thermocouple	1	$34.95	$34.95
			Total	**$581.23**

Table 4. Custom Components

Reference Number	Component	Material	Material Price $/lb	Quantity	Material Cost	Machining Time	Machining Cost $50/hr	Cost $
8	Controller Mount	Rigid PVC	$0.55/lb	3lbs	$1.65	1hr	$50.00	$51.65*
				Total	**$1.65**	**2hr**	**$50.00**	**$51.65**

Grand Total= $632.88*

***These costs will yield considerable extra material, which can be reused for the production of many more units. For subsequent iterations, only the Stainless Steel Vacuum-Insulated Lid, Stainless Steel Vacuum-Insulated Container, Temperature Controller, and Thermocouple will need to be purchased again, cutting the cost to $183.69.

Conclusion

Based on the results of our Solidworks thermal analysis along with our calculations, we determined that our system would successfully cool our specimen container to -70^{o}C within ten minutes and keep it at -70^{o}C for a twelve-hour delivery. This can mostly be attributed to the high thermal conductivity of the copper fins as well as the insulation and heater that were chosen. The heater we will use is able to generate enough power under the extremely cold conditions. Because our design will succeed under the most extreme conditions, we can conclude it can operate effectively during normal conditions.

Appendix A

1	Rubber CO_2 Exhaust Hose
2 & 7	Stainless Steel Vacuum-Insulated Lid Stainless Steel Vacuum-Insulated Container
3	Thermal Fins
4	Thermal Insulation
5	Heater
9	Temperature Controller
10	Dry Ice
11	Thermocouple

Reference Number 1

Vibrant Performance Reinforced Silicone Heater Hoses 20445

Large Image

Image is a representation of this item. Actual item may vary.

$18.00

1 + Cart

+ Wish List
+ Compare

Heater Hose, Silicone, Black, 5/8 in. Diameter, 5.0 ft. Length, Each

Check Application

Estimated Ship Date: Today

Would you rather pick it up? Select Location

Curtir Seja o primeiro de seus amigos a curtir isso.

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Vibrant Performance Reinforced Silicone Heater Hoses

Part Type: Hoses, Heater

Vehicle: Find out if this fits your vehicle

Overview Applications Show All

Large Image

Brand:	Vibrant Performance
Manufacturer's Part Number:	20445
Part Type:	Hoses, Heater
Product Line:	Vibrant Performance Reinforced Silicone Heater Hoses
Summit Racing Part Number:	VPE-20445
Hose Inside Diameter (in):	0.625 in.
Hose Length (in):	60.000
Hose Length (ft):	5.000
Hose Adapters Included:	No
Hose Material:	Silicone
Hose Finish:	Black
Hose Clamps Included:	No
Hose Clamp Covers Included:	No
Quantity:	Sold individually.
Free Catalog	Request a Catalog from the World's Speed Shop

Vibrant Performance reinforced silicone heater hoses are very flexible. Designed to withstand elevated temperatures, these hoses are nylon-reinforced. Vibrant silicone heater hoses have a temperature range of -65 degrees F to +350 degrees F, making them well-suited to oil and coolant fluid service. These gloss black hoses are available in three lengths--2 ft., 5 ft., and 20 ft.--and in several inner diameters to fill your application needs. Plumb your ride with the quality and performance of Vibrant Performance reinforced silicone heater hoses.

http://www.summitracing.com/parts/vpe-20445/all

Reference Number 2 & 7

Restaurant Equipment | Kitchen Supplies | Dinnerware | Disposables | Bar | Catering | Janitorial | Office | Food | Parts | Specials

Instawares › Restaurant Equipment › Beverage Service › Coffee › Airpots › 84 oz Airpots › BUN-32125

BUNN Airpot Stainless Steel 2.5 Liter

$48.21

Qty 1 Add to cart

Sold As 1 EA Packed As 1
Usually ships within 1 to 2 business days
Request Volume Pricing
Buy 2, Get 3% Off
Buy 3, Get 5% Off

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More from Bunn Coffee

Customers Also Bought

Bunn CWT15-APS Coffee Maker Airpot Automatic
$606.24

Bunn EasyClear Quick Change Water Filter
$61.51

Bunn Two Pot Universal Airpot Rack Assembly
$67.42

Recently Viewed

Description

BUNN Airpot Stainless Steel 2.5 Liter
List Price: $63.90

BUNN 32125.0000 chrome airpot can hold up to 2.5 liters (84 ounces) at one time. This airpot features a brew through insert where you can just shut the lid when brewing is finished. BUNN designed this airpot to have stainless steel lining that keep beverages hot. This airpot comes with an attractive, chrome finish with black trim. The 2.5 liter lever action airpot has a convenient black handle that makes it easy to transport.

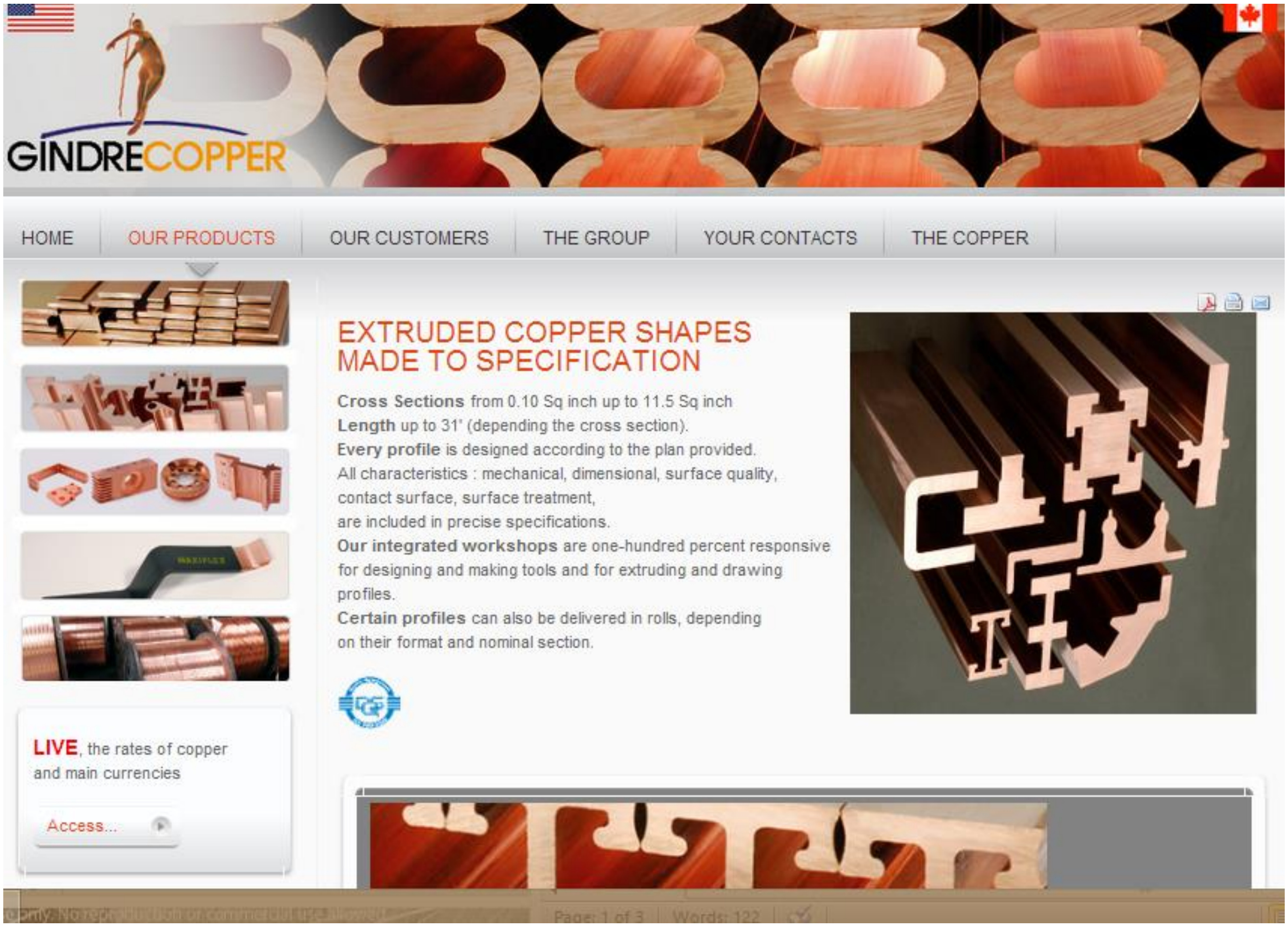
- Lever action
- Stainless steel liner
- Chrome finish with black trim
- NSF listed
- Holding Capacity: 2.5 liters (84 ounces)

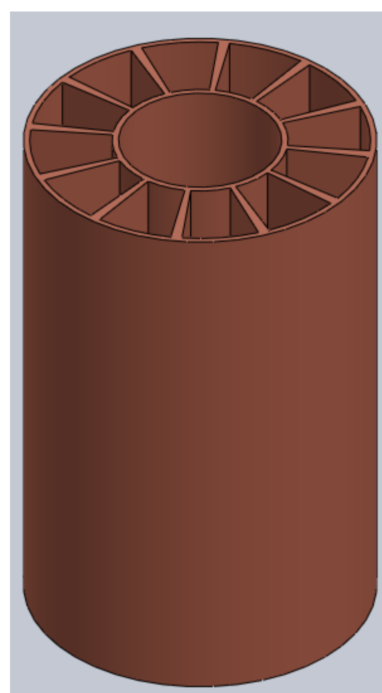
Specifications

Name	BUNN Airpot Stainless Steel 2.5 Liter
Manufacturer	Bunn Coffee
Product ID	BUN-32125
Manufacturer ID	32125.0000
Equivalents	32125.0000, 32125
Material	Chrome
Dimensions (LxWxH)	9 x 9 x 14.5
Product Cube	0.68
Product Weight	5 lbs
Shipping Weight	6 lbs

http://www.instawares.com/bunn-32125-0000-2-5-liter-lever-action-airpot.bun-32125.0.7.htm?s_cseid=AMZN

Reference Number 3

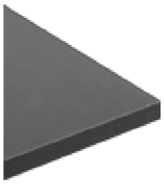




GindreCopper is a company that manufactures custom designed extruded copper shapes. Upon inquiry of the manufacturing of our custom thermal fin we received a quote of 349.00$. http://www.gindrecopper.com/copper-products/extruded-shapes-made-to-specification.html

Reference Number 4

Ultra-Flexible Foam Rubber Insulation



- Temperature Range: Plain back: -295° to 220° F; Adhesive Back: 20° to 180° F
- Heat Flow Rate (K-Factor) @ 75° F: 0.25
- Density Range: 3-6 lbs./cu. ft.
- Color: Black

Soft Buna-N/PVC foam creates an extremely flexible insulation sheet. The material is elastomeric and has a closed-cell construction for moisture resistance. Can be used outdoors if coated with latex paint (sold separately). Meets ASTM E84 25/50 for flame and smoke. Install plain-back insulation with contact adhesive (sold separately).

White latex paint is compliant under all state VOC rules in effect on November 1, 2011. **Contact adhesive** is compliant under all state VOC rules in effect on November 1, 2011.

			Plain Back	
Thick.	Wd.	Lg., ft.		Each
1/4"	36"	4	**9349K9**	$17.48

Catalog Page | Bookmark

Ultra-Flexible Foam Rubber Insulation Plain Back, 1/4" Thick, 36" X 48" Sheet, Black

Each

ADD TO ORDER

In stock

3/8"	36"	4	9349K1	23.11
1/2"	36"	4	9349K2	24.27
3/4"	36"	4	9349K3	32.60
1"	36"	4	9349K4	46.34
1 1/2"	36"	4	9349K5	90.60

McMaster #9349K9

http://www.mcmaster.com/#thermal-insulation/=mocbgp

Reference Number 5

High-Temperature Nickel Wire

Nickel wire withstands high temperatures and is corrosion resistant.

View a wire gauge conversion chart.

Nickel Chromium—Bright Finish

- Bend-and-stay wire (soft temper)
- Meets ASTM B267 and B344

Made of nickel chromium, commonly referred to as Chromel C, this wire is often used for heating elements, resistance windings, and hot wire cutters. Diameter tolerance is ±0.0002" for diameters up to 0.020"; ±0.0006" for diameters 0.025" and larger. Maximum temperature is 1850° F.

Warning! Temperature is not guaranteed and is intended only as a basis for comparison.

	1/8-lb. Spools			1/4-lb. Spools			1-lb. Spools		
Wire Dia.	Ft./Spool		Each	Ft./Spool		Each	Ft./Spool		Each
0.025"	62	8880K77	$13.06	120	8880K19	$26.15	495	8880K49	$72.47

McMaster #8880K77

http://www.mcmaster.com/#nickel-chromium-(nichrome)-wire/=mocj0e

Reference Number 9

DUAL DISPLAY TEMPERATURE CONTROLLERS

This new range of powerful and versatile yet low cost PID controllers have a dual 4 digit display of process and set values and can be ranged by the user for a variety of inputs and alarms. These auto tuning controllers also feature continuous self tuning which in the majority of applications sets the controller up for optimum performance.

- PID Auto tuning or On/Off can be selected
- 1/16 DIN (1.88"x1.88"x3.93" deep) 1/8 DIN (3.78"x1.88"x3.93" deep) 1/4 DIN (3.78"x3.78"x3.93" deep)
- 4 digit dual LED display
- Accuracy: Typically better than ±0.3% FSV
- 100-240V AC as standard
- Customer rangeable for Type K J T N E R S and B thermocouple or RTD Pt100 inputs
- Temperature (process or deviation) alarms can be easily configured
- Relay or Solid State Relay drive (SSR)
- Non volatile memory
- 2 year warranty

The following types are available:

1/16 DIN - 1.88" x 1.88" x 3.93" deep
1/8 DIN - 3.78" x 1.88" x 3.93" deep
1/4 DIN - 3.78" x 3.78" x 3.93" deep

1/16 DIN - 1.88" x 1.88" x 3.93" deep

Order Code	Description	Price:1-4	Price:5-9	Price:10-19	Buy	
304-100	2 alarms - Relay output	$99.00	$94.00	$89.00	Buy	0
304-103	2 alarms - SSR output	$99.00	$94.00	$89.00	Buy	0

1/8 DIN - 3.78" x 1.88" x 3.93" deep

Order Code	Description	Price:1-4	Price:5-9	Price:10-19	Buy	
304-200	2 alarms - Relay output	$109.00	$104.00	$99.00	Buy	0
304-203	2 alarms - SSR output	$109.00	$104.00	$99.00	Buy	0

Order Code: 304-100
http://www.tcdirect.com/deptprod.asp?deptid=100/91

Reference Number 10

The ICE FACTORY

"The Iceman Cometh"

231 Landing Road, Landing, NJ 07850 · 973-770-1396 · f.schuld@yahoo.com

- Home
- About Us
- Price List
- Cubed Ice
- Dry Ice
- Shot Luges
- Cold Packaging
- Halloween-Fog Effects
- Hours of Operation
- Related Links
- Solar Energy Making Ice Cubes With The Sun

Retail Price List

< Previous Tour Next >

Retail Delivery Not Available
CASH ONLY

DRY ICE

1 Block (approximately 50 lbs.)...........................$30.00
½ Block...$16.00
¼ Block...$10.00
Pelletized ice available upon request.

WET ICE

7 lb. Bag Cubed Ice..$1.75
20 lb. Bag Cubed Ice..$4.50
40 lb. Bag Cubed Ice..$8.00

SHOT LUGES

PLEASE CALL TO ORDER

Shot Luge..$75.00
Shot Luge w/insert.....(Your Supplied Image)......$90.00
Shot Luge w/insert......(Our Created Image).....$100.00
Drip Tray...$20.00

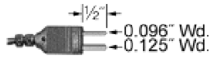
INSULATED SHIPPING CONTAINERS

	Box	Box w/Dry Ice
Small Box (10 x 10 x 10)	$12.00	$17.00
Medium Box (12 x 12 x 12)	$14.00	$19.00
Large Box (14 x 14 x 14)	$16.00	$21.00

http://www.icefactoryonline.com/Prices.htm

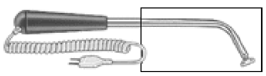
Reference Number 11

Surface-Contact Thermocouple Probes with Flat-Pin (Mini) Connector

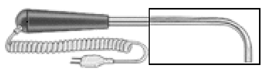


Flat-Pin (Mini) Connector

1



2



3

4

5

6

7

Designed for measuring surface temperatures, these probes are a useful addition to your thermocouple thermometer. All have a male flat-pin (mini) connector.

Note: Response times listed below are approximate.

Styles 1-3—Straight, 60°, and 90° Probes

Probe Type	Temp. Range	Probe Lg.	Response Time, sec.	Max. Cable Temp.		Each
(1) Type 304 SS Straight Probes (7/16" dia.) with 4-ft. PVC Cable						
J	+32° to +1202° F	4"	1	176° F	3861K36	$94.95
K	−40° to +1202° F	4"	1	176° F	3861K37	94.95
T	−40° to +752° F	4"	1	176° F	3861K311	94.95
(2) Type 304 SS 60° Probes (11/16" dia.) with 4-ft. PVC Cable						
J	+32° to +500° F	4 1/2"	4	176° F	3861K631	91.68
K	−40° to +500° F	4 1/2"	4	176° F	3861K632	91.68
T	−40° to +500° F	4 1/2"	4	176° F	3861K633	91.68
(3) Type 304 SS 90° Probes (7/16" dia.) with 4-ft. PVC Cable						
J	+32° to +1202° F	5"	1	176° F	3861K321	104.53
K	−40° to +1202° F	5"	1	176° F	3861K322	104.53

Style 4—Hook-and-Loop Probes

Probe Type	Temp. Range	Strap Lg.	Response Time, sec.	Max. Cable Temp.		Each
(4) Nylon Probes (1" wide strap) with 10-ft. PVC Cable						
J	−310° to +250° F	8"	10	250° F	37045K191	$34.95
K	−418° to +250° F	8"	10	250° F	37045K192	34.95

Style 5—Hose-Clamp Probes

Probe Type	Temp. Range	Clamp Dia.	Response Time, sec.	Max. Cable Temp.		Each
(5) Type 301 SS Probes with 10-ft. Type 304 SS Cable						
J	+32° to +250° F	11/16"–1 1/4"	5	900° F	37045K511	$25.39
J	+32° to +250° F	13/16"–1 1/2"	5	900° F	37045K521	28.44
J	+32° to +250° F	1 5/16"–2 1/4"	5	900° F	37045K531	30.47
K	+32° to +250° F	11/16"–1 1/4"	5	900° F	37045K512	25.39
K	+32° to +250° F	13/16"–1 1/2"	5	900° F	37045K522	28.44
K	+32° to +250° F	1 5/16"–2 1/4"	5	900° F	37045K532	30.47

Styles 6 & 7—2" Long Clip-On Probes

Probe Type	Temp. Range	Jaw Size	Response Time, sec.	Max. Cable Temp.		Each
(6) Chrome-Plated Brass Probes with 5-ft. Coiled PVC Cable						
J	−310° to +250° F	3/8"	5	250° F	6443T211	$30.51
K	−418° to +250° F	3/8"	5	250° F	6443T212	30.51
(7) Chrome-Plated Brass Probes with 10-ft. Type 304 SS Cable						
J	−310° to +850° F	3/8"	5	900° F	6443T811	42.72
K	−418° to +850° F	3/8"	5	900° F	6443T812	42.72

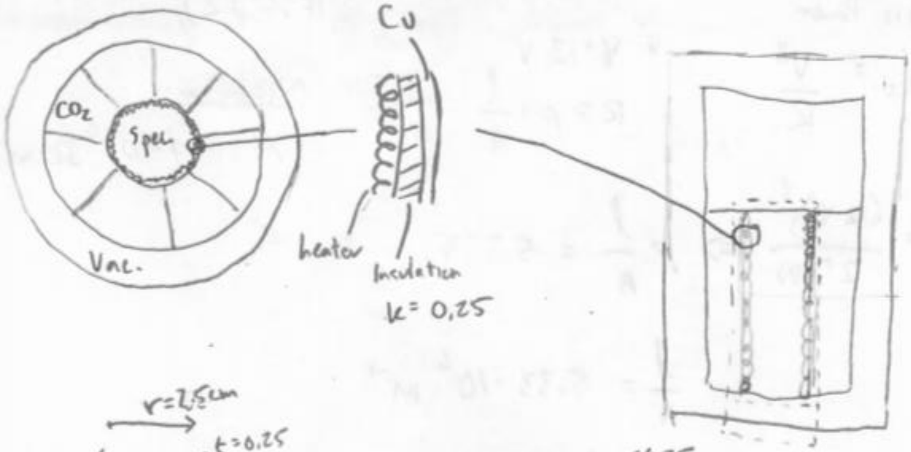
McMaster #37045K191

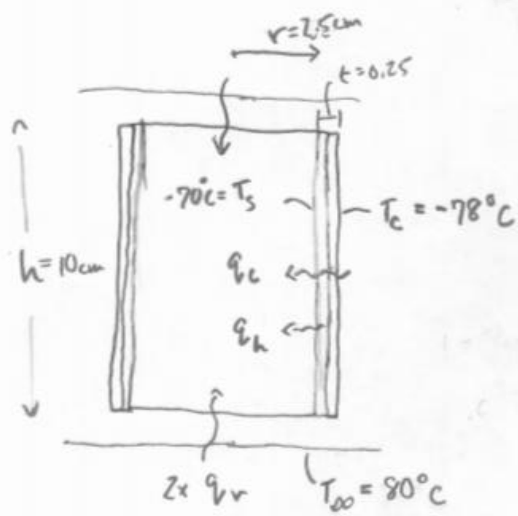
http://www.mcmaster.com/#surface-thermocouples/=moc9z3

Appendix B: Hand Calculations

Simplified Calculations of Heat Into Specimen

* Determine Heater input at steady state.





$k_{ins} = 0.25$

$$q_c = \frac{2\pi h k (T_c - T_s)}{\ln\left(\frac{r+0.25}{r}\right)}$$

$$q_c = \frac{2\pi(0.1\,m)(0.25\,\frac{W}{mK})(-78+70)K}{\ln\left(\frac{2.75}{2.5}\right)}$$

$q_c = -13.185\ W$

$$q_r = \frac{\sigma \cdot \pi r^2 \left(T_\infty^4 - T_s^4\right)}{\frac{2}{\varepsilon} - 1} \quad * \varepsilon_{Al} = 0.18$$

$$q_r = \frac{\left(5.67 \cdot 10^{-8}\,\frac{W}{m^2K^4}\right)\left(\pi \cdot 0.025^2\,m^2\right)\left(353^4 - 203^4\right)}{\frac{2}{0.18} - 1}$$

$q_r = 0.15\ W$

* If Cold Environment

$q_r = 0\ W$

Hot environment:

Heater off:

$q_{specimen} = q_r + q_c = -13.035$

Heater on: (s.s.)

$q_{specimen} = 0 = q_h + q_r + q_c$

$\Rightarrow$ $q_h = 13.035\ W$

Cold Environment:

Heater Off:

$q_{specimen} = q_c = -13.185\ W$

Heater On: (s.s.)

$q_{specimen} = 0 = q_h + q_c \Rightarrow$ $q_h = 13.185\ W$

<u>Max heater input needed:</u> 13.185 W $\Rightarrow P_{max} = 13.185 \cdot FOS = 27\ W$

(FOS of 2)

Electric Power:

$P_{elec} = \frac{V^2}{R}$ * V = 12 V $R = \rho \cdot \frac{l}{A}$

<u>Nichrom:</u>

$\rho = 1 \cdot 10^{-6}\ \Omega \cdot m$

$R = \frac{(12V)^2}{27W} \Rightarrow \rho \frac{l}{A} = 5.333$

$\frac{l}{A} = 5.33 \cdot 10^{6}\ m^{-1}$

$C_{cyl} = 2\pi r = 0.157\ m$

25 wraps of wire $\Rightarrow$ 3.927 m

$\frac{3.927\ m}{5.33 \cdot 10^{6}\ m^{-1}} = A = \pi (r)^2$

<u>$r = 0.0005\ m$</u>

$d = 0.001\ m \Rightarrow 0.025''$ Nichrome wire

1/8-lb spool (62')

$13.06 (MM# 8880K77)

References

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