Rapid Beverage Cooling System

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Abstract:

The basis of this project originates from the idea that many beverages (especially canned beverages) are meant be consumed at a temperature much lower than room temperature (about 20° Celsius or 70° F) and usually close to the water freezing point (0° C and 32° F). Maintaining this temperature level may not be possible due to lack of space in your cooling mechanism, but often drinks must be served on demand when they are not at optimal serving temperature. The traditional method of cooling a canned beverage involves placing it in a cold environment, such as an ice chest or a refrigeration system, and waiting for the cold environment to passively absorb the energy from the can, resulting in the beverage becoming cold. This process takes a considerable amount of time due to the passive nature of it, and the time involved could be greatly decreased if some sort of active process was used to cool the beverage. The goal of this project is to provide a much quicker way of cooling a canned beverage, by taking the time involved for cooling from about an hour, to no more than 5 minutes. The definition of "cool," or the final temperature of the can, should be no more than 40° F after the 5 minute time limit is expired. The physical footprint of the device should be as small/portable as possible, and it should not require an exorbitant amount of energy to accomplish the goal.

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Definition of Problem

The basis of the problem is almost entirely thermodynamically based. The classic example of a cooling problem would involve a heated object with a defined specific heat capacity, placed into an environment at a much lower temperature with a defined specific heat capacity. The environment would act as a temperature sink, changing its temperature very little as compared to the object placed in the environment. The process invariably takes a long time because of the way that energy is transferred through heat from a high temperature to a low temperature, moving toward an equilibrium point. The air immediately around the object would heat up first, leading to a temperature difference in the air, and the energy would slowly be diffused throughout the environment until the object and the environment reach an equilibrium temperature.

Simply adding a fan into the process would decrease the amount of time because of the ability for "new" unsaturated (with heat) air to be continuously in contact with the object, reducing the need for diffusion to be needed as much as in the first scenario. This idea that the process is no longer passive, but rather now active, leads one to believe that there is much more that can be done through careful analysis of the problem.

Problem Statement

I would like to create a way to cool down a canned beverage to slightly above 32° F (maximum 40° F) in the quickest manner possible (5 minutes maximum).

Need Statement

Remove maximum amount of energy from a canned beverage at highest rate possible.

Primary Function

Primary Constraint

Gathering Information

After the recognition that this project is very thermodynamically dependent, informational resources needed to be gathered in order to make the most educated design decisions, and to accurately address the functions that the system must accomplish.

Through the use of the textbook *Thermodynamics: An Engineering Approach (Seventh Edition)* By Yunus A. Cengel, we can quickly gain a fairly comprehensive and accurate understanding of the physical laws immediately being addressed, and some thermodynamic device concepts that would be beneficial to exploit in the design concept process.

The most obvious physical laws in play are the fundamental laws of Thermodynamics:

The *zeroth law of thermodynamics* defines the idea of thermal equilibrium, by stating that two bodies are in thermal equilibrium if both have the same temperature reading even if they are not in contact.

- This idea will be important to us because it defines the moment at which cooling will no longer be effective, thus giving us a stopping point on our process timeline. A major constraint on the project is reducing the amount of time required to cool an object, so a definite end point of the process is very useful in achieving and regulating that goal.

The *first law of thermodynamics* is an expression of the conservation of energy, and defines energy as a thermodynamic property.

- This idea is important because it defines energy, which we are effectively trying to remove from the canned beverage, and informs us that we cannot simply destroy the energy, but we must rather displace it into another medium, because it is still conserved. This is an important concept to understand so that we can exploit the idea of maximizing the heat capacity of the medium the energy is being transferred to.

The *second law of thermodynamics* gives energy properties such as quality and quantity, and asserts that real processes (that is ones that occur in the natural world) occur in the direction of decreasing the quality of energy.

- While we are not necessarily concerned about reusing the energy removed from the beverage, thus the decreased quality is not our concern, we are interested in the direction of decreasing quality, thus the direction the energy would flow. Being that entropy increases as heat moves from a hot object to a cold object, we can infer that the quality is decreasing because the exergy (useful energy destroyed, or quality decreased)- which is defined as X=S(T) where S is the amount of entropy, and T is the average temperature between the two objects- is maximized as entropy is maximized. This gives us a concrete direction of which way energy will naturally move, which is very important to the process, being that our primary function is to remove the energy from the object. It is important to note that the receiving medium of the energy needs to be a lesser temperature than the beverage, and the more the temperature difference, the higher the exergy will be, making the flow of energy to the medium quicker. Because the rate of our energy removal happens to be the primary constraint, this idea is of upmost importance to us.

The *third law of thermodynamics* gives entropy an initial, constant value at T=0K, which is important to note that as the energy leaves the beverage, the entropy of the liquid will decrease, but being that we are going be very far away from 0K, we are not concerned too much with this law.

Function Structure

Functions

With the information acquired in research of the thermodynamic principals applied to the scenario, we now need to delegate specific functions that our system must address, and the constraints that will limit the solutions to these functions.

We will start with our primary function that was clear from the problem statement, and confirmed in our research:

- To remove the maximum amount of energy possible

Through research of basic thermodynamic principles, we were able to define certain aspects that this process would require, and in that, we can add a few more functions that should be accomplished for the design to perform optimally:

- To create as much of a temperature difference between the beverage and receiving medium as possible
- To stop using energy when the beverage reaches the equilibrium point (thus giving a solid stop point on a timeline)
- To create as much heat capacity in the receiving medium as possible

Constraints

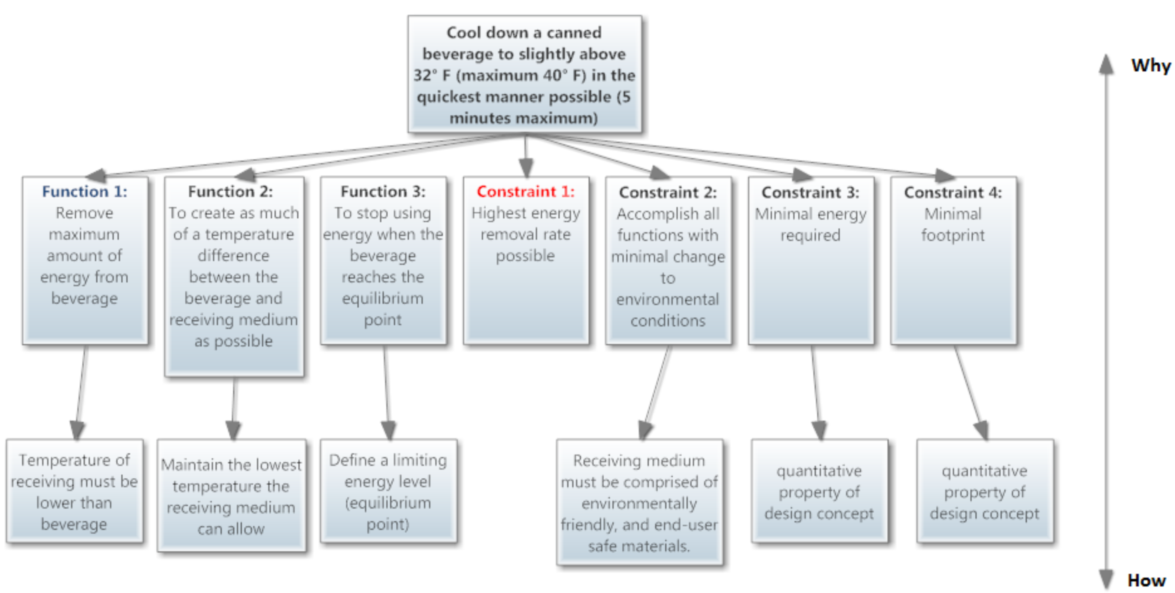
We then must limit the solutions to only acceptable designs based on moral and ethical issues that may arise as well as cost efficiency, and keeping the project goal oriented. Obviously solving the original problem is the most important, thus we will start with our primary constraint:

- To remove the maximum amount of energy possible *at the highest rate possible* (thus minimizing the time required.)
    - We will make this a quantitative goal rather than a qualitative by attaching a maximum time limit of 5 minutes to the process.
    - We also will set a quantitative goal of as close to 32° F as possible within the time limit and we will use this property of each system to compare possible design concepts.

We then focus on all other concerns that should be addressed in order to make this a marketable and usable product:

- We must accomplish all functions with minimal change to environmental conditions
    - This applies to the medium used to receive the energy, as it must be environmentally friendly, and not dangerous to the end-user.
- With minimal energy required
    - This will remain as a qualitative constraint and will be used later quantitatively in comparing possible design concepts
- With a minimal footprint
    - Again, we will later quantitatively compare the volumes of each system, and use them in our analysis of design concepts.

With the absolute minimum of functions and constraints required to accomplish the goal set forth in the problem statement, we will now assemble a function structure that can be used to visualize the answers to the WHY, HOW, and WHEN questions that should be asked during the design process:



Concept Generation

In order to maximize the possible number of solutions, and thus come up with the best solution available, we must broaden thought spectrum from a solution based analysis, to a concept based analysis. There are many ways to accomplish this, but a simple word association brainstorming exercise is chosen as an example. We are trying to accomplish cooling an object, so we will list as many different words that are associated to the word "cold" as possible to give us a broad range of topics to choose from:

- Ice
- Freezer
- Refrigerator
- Air conditioner
- Ice cream
- Snow
- Winter
- Refrigerant
- Fan
- Popsicle
- Icicle
- Wind

Using these words, we can begin to research possible concepts that are linked with each of these, that could be applied to our solution.

Four concepts that are immediately apparent as viable concepts that could be used are:

Refrigerants

- Refrigerants are materials (almost always in the liquid/gas state) that have very good heat conductivity properties, and thus can be used to absorb heat from our beverage, and because of their fluid state, can be routed away from the beverage for cooling and recycling their use. Common refrigerants include water and R-134a. Water is abundantly available and environmentally safe, but it does have a rather high temperature freezing point, which would limit the minimum temperature we could keep it at. R-134a has a much lower freezing point (well beyond our scope of use) and is relatively easy to acquire, however, it has many environmental and safety issues that could be of concern if improperly implemented.

Heat Exchangers

- A heat exchanger is a thermodynamic device that maximized the amount of energy exchange between two objects, by actively moving the coolant fluid (and if the object being cooled is in the form of a fluid, the fluid will be moved as well) so as to continually allow "fresh" coolant to come into contact with the heated substance. Heat exchangers could also be viewed at in the reverse manner of a heated substance raising the temperature of the cooled substance, however, in our application we will focus on cooling an object with a thermal exchanger, with minimal regard to the temperature raising capabilities.

Thermoelectric Materials

- Thermoelectric materials are typically two different metals, joined at a point that take advantage of the Seebeck Effect. Essentially, the Seebeck Effect describes how, because of the difference in properties (mainly electrical conductivity) of two metals joined, when heat is added, current flows continuously in the circuit. Curiously enough, the reverse will also be true, where if a current is flowing through the circuit, heat is absorbed by the metals. This idea would allow us to use a thermoelectric device, apply current to it, and create a low temperature object that could be used to absorb heat from the beverage.

Capillary Tubes

- A capillary tube is a thermodynamic device that is used to decrease pressure, increasing velocity, and keeping the enthalpy of the fluid relatively the same (ideally it the enthalpy entering is the same as the enthalpy leaving). This results in the fluid dropping in temperature (because of the pressure drop) and is the basis of most refrigeration and air conditioning systems. The advantage of using a capillary tube is it would require very little external energy, however, the beverage would need to be removed from the can. While it is not a constraint that the beverage must remain in the can throughout the cooling process, it will definitely play a role in the usability and overall analysis of the final design concepts.

Critical Parameter Identification

In order to correctly use the concepts above to generate useful design concepts, we need to identify our Critical Parameter, or the make-or-break factor in our problem. Throughout the analysis of the problem, and the development of the functions and constraints, there is one gradient that clearly is the most important factor in the system, which is the rate of heat exchange (or energy removal) from the beverage.

In order to find a solution that addresses the heat exchange rate most effectively, we first need to know what factors play a role in heat exchange rate. After further research, we are able to identify several factors that play a role in heat exchange rate:

- Temperature difference
- Material properties (heat transfer coefficient)
- Area
- Thickness (distance heat must travel)

Additionally, we are able to find a formula using these variables to calculate a quantitative rate:

$$Rate = \frac{kA(T_1 - T_2)}{d}$$

Using qualitative analysis of the formula, and the idea of limiting values, we can make the following assumptions:

- The more we decrease the distance the heat needs to travel (thickness of the beverage) the higher the heat transfer rate will be
- The higher the value of the heat transfer coefficient (which classifies a thermal conductor) the higher the heat transfer rate will be
- The more surface area exposed to the temperature difference, the higher the heat transfer rate will be
- The bigger the temperature difference, the higher the heat transfer rate will be. This is also effected by our ability to maintain our low temperature of the coolant, or else the low temperature would rise as the high temperature drops, raising the minimum temperature of our system.

After a careful examination of the assumptions above, it is clear that there are two design paths that will yield very different results, but depend solely on the customer specifications. The deviation is found when we ask whether or not the beverage can be removed from the can or not.

If the beverage is removed, we would have much more control over the area exposed, and thickness of the beverage. It would eliminate the extra material of the aluminum can that would also have energy that would need to be removed (thus wasting the effort of solving the problem which is to cool the *beverage*). However this method introduces some inconveniences to the end user that could possibly diminish the usability of the product. The issue of cleaning the product of residue of the beverage after use would now come into play. Also, considering the fact that many people prefer to drink canned beverages straight from the can could lose customers because they dislike the need to have to dispose of the can and use a glass.

If we were to keep the beverage in the can, we would preserve the traditional method of consuming a canned beverage, however we have very little ability to exploit the properties of heat transfer, and would only have control over the temperature difference.

In order to move passed this crucial decision in the design process, we would consult with the customer. Methods of doing this would include focus groups, surveys, and product testing. If it was found that there is little difference in consumers' minds about the loss of the use of the can, then it would make logical sense to pursuit the path of removing the beverage from the can thus controlling almost all of the variables that contribute to heat transfer. If it is found that there is a significant decrease in the enjoyment of using the product because of the loss of the ability to use the can, then it would make little sense to develop a product that would eliminate the can.

Because this project is for demonstration purposes only, we are going to neglect the preference to can vs. no can and focus on the problem at hand, which is to cool the *beverage* as quickly as possible. Thus we will move forward designing with the idea of removing the beverage from the can. This isn't necessarily a bad decision either, because now it opens the possibility of cooling many different fluids, whether they were initially canned, bottled, or packaged in some other medium.

Design Goals

Using the idea that heat exchange rate is the top priority, and taking the assumptions of the equation into consideration, in order to maximize the heat exchange rate, we should try to design with the following goals in mind, to the best of our ability:

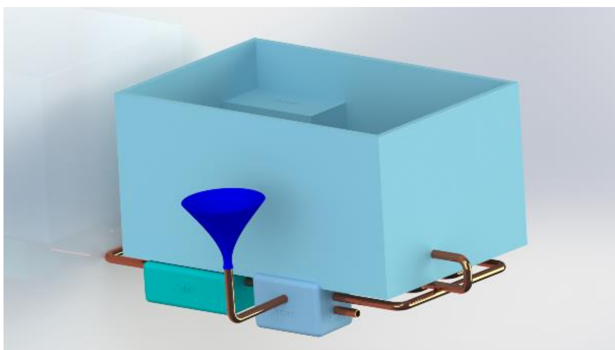
- Spread the beverage as thin as possible, so as to decrease the distance the heat has to travel and increase the amount of surface area available to be cooled
- Keep the temperature difference between the beverage and the coolant as high as possible. Because the initial temperature of the beverage is not decided by us, our only option is to lower the coolant temperature as much as possible.
- Keep the heat transfer coefficient as high as possible. Because the beverage is not a material that we are able to control, again the coolant is the only option we have in this regard. Because heat transfer from the beverage will equal the heat transfer to the coolant, it would make sense to maximize the heat transfer coefficient of the coolant as much as possible while still remaining within the constraints.

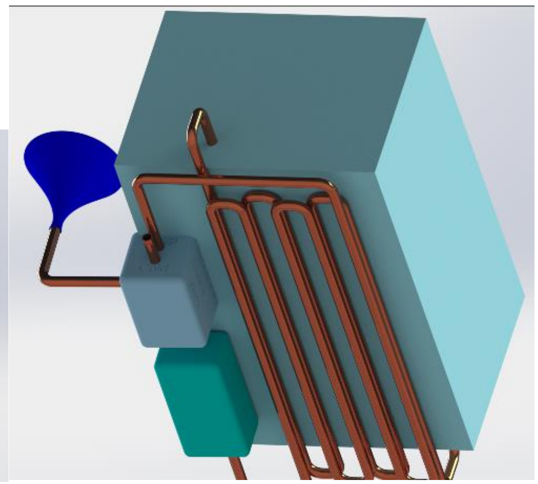
With these goals, and the physical concepts found after brainstorming, we can begin designing systems that would solve our problem efficiently.

Design 1:

Design 1 uses a combination of refrigerants, and a heat exchanger to accomplish the goals. The beverage would be poured into the system, and a small pump would begin to circulate the beverage in a loop of piping, that is directly in contact with a loop containing iced water flowing in the opposite direction. A temperature monitoring system would keep track of the change in temperature per unit time, and as the rate levels off, the system would determine it was relatively close to the equilibrium temperature, thus breaking the loop and dispensing the liquid, adding a definite end point to the time line.

- The opposite flow direction would allow the coolant to always be moving to a higher energy portion of the beverage at all times
- The loops of each fluid would be as long as possible, allowing for each fluid to be spread out as much as possible, increasing the rate of heat transfer that will take place.
- There will be an ice reservoir that the water will flow through that will continually cool the water that was heated from the beverage.
- The use of water makes it extremely environmentally friendly, as well as easy to operate, and design. If we were to use a more commercial refrigerant such as R-134a, there would be environmental and health concerns, as well as the complexity of the system would increase dramatically, as we would need to design a way to cool the R-134a effectively.
- The temperature control system would monitor the effectiveness of the cooler, which would allow for the system to only operate at times of maximum efficiency, thus limiting energy usage, and decreasing the overall time to cool the beverage, rather than having a set amount of time.

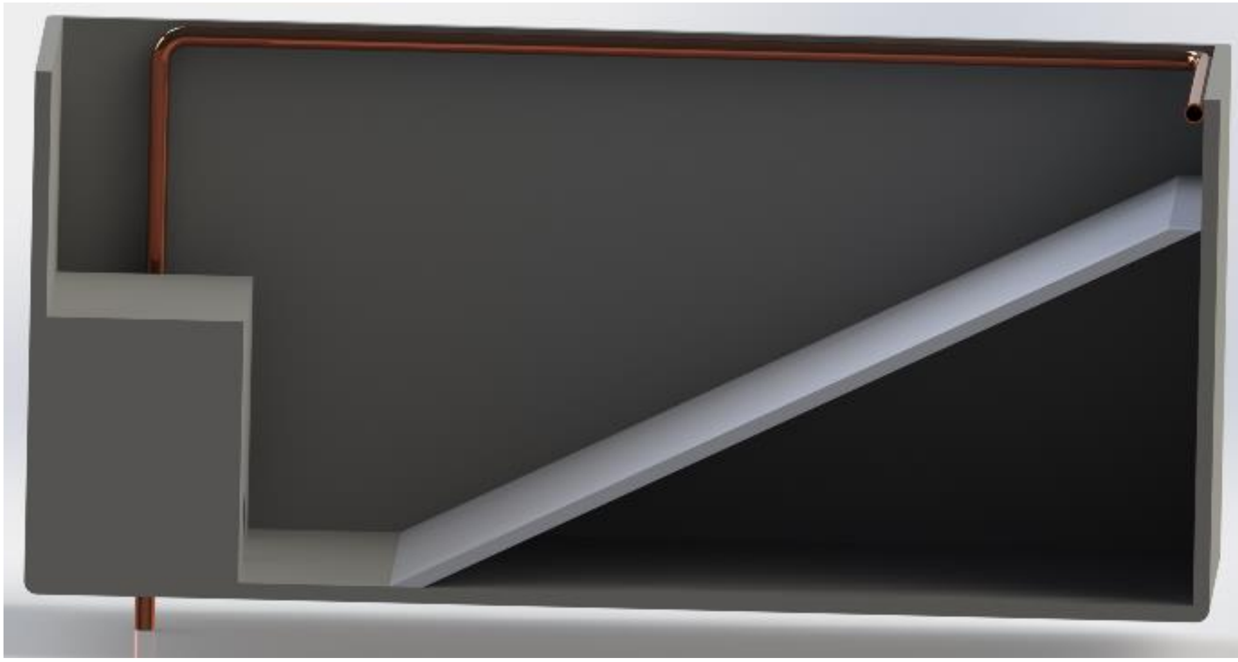




Design 2:

Design 2 uses the idea of a thermoelectric device, along with maximum surface area in order to cool the beverage. The beverage would be poured into a reservoir with a pump that would continually move the beverage up a chute, and allow it to fall back into the reservoir along a path made of the thermoelectric device. This design would employ the same temperature control system as Design 1.

- The simplicity of the design allows for a very small footprint.
- The design uses one pump rather than two
- The temperature of the thermoelectric device will remain the same as long as the same amount of current is applied through it
- Thermoelectric devices can operate as low as -60°C
- This design's efficiency depends almost solely on the efficiency of the thermoelectric device
- Because of the thermoelectric device's properties, the polarity could be reversed, causing the device to heat to as high as 180° C, and the same device could easily be used to reheat liquids, with almost no additional design effort.

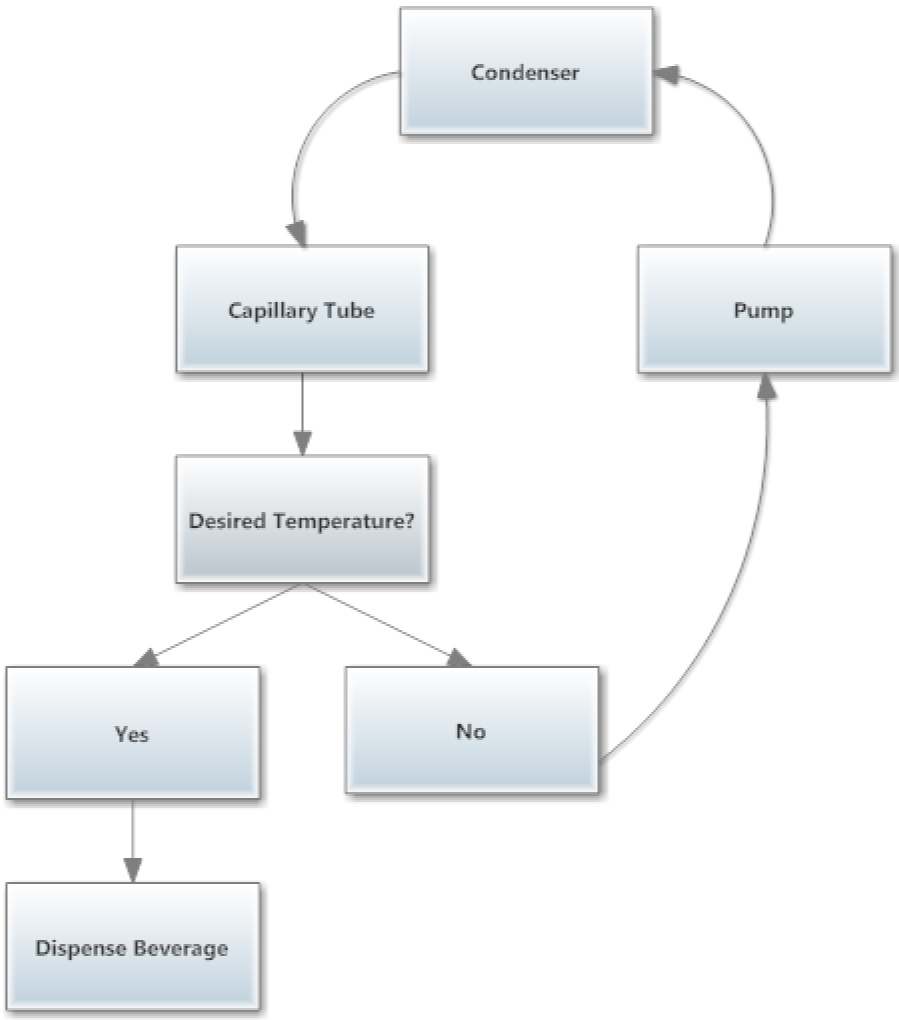


Design 3:

Design 3 uses the idea of a capillary tube in the same way that a simple refrigeration cycle would. In a simple refrigeration cycle, a refrigerant is pressurized through a pump, raising its temperature dramatically. It is then routed to a condenser which could also effectively be a heat exchanger running a separate refrigerant. After the refrigerant in the first loop is condensed to a saturated liquid, it is run through a capillary tube where the pressure is decreased, and the temperature is dropped. The refrigerant is then exposed to the heat source and the process is repeated.

Rather than re-expose the beverage to a heat source at the end, the beverage would be rerun through the system continuously until the lowest temperature possible could be achieved.

- This process could potentially create a very cold beverage very quickly
- This process is much more complex and would cost a substantial amount of money to develop as well as produce
- This process requires much more equipment and would have a very large footprint
- The amount of energy required to run a pump that could turn a partially cooled beverage into a superheated vapor through pressure alone would be massive.
- The pressures involved in this process could potentially be very dangerous.
- Strongly alcoholic beverages could have the potential of igniting if placed under enough pressure
- The pressure required could potentially change the physical properties of the beverage, altering the taste of the beverage.



Improvement Matrix (Pugh Chart)

In order to evaluate the ideas effectively, we will use a Pugh chart, comparing each design concept the datum example of the refrigerator.

	Refrigerator	Design 1	Design 2	Design 3
Energy Required	D	+	+	S
Time Required	A	+	+	+
Environmentally Friendly/Safe	T U	+	+	-
Initial Cost	M	+	+	S
Foot print		S	+	S
Total +		4	5	1
Total -		0	0	1

We can then combine the results with weighted criteria.

Weights / 100	**Criteria**
25	Energy Required
30	Time Required
10	Environmentally Friendly/Safe
15	Initial Cost
20	Footprint

	Refrigerator	Design 1	Design 2	Design 3
Energy Required x25	D	+	+	S
Time Required x30	A	+	+	+
Environmentally Friendly/Safe x10	T	+	+	-
Initial Cost x15	U	+	+	S
Foot print x20	M	S	+	S
Total		80	100	20

As we can see, Designs 1 and 2 are much better than the original solution to the problem, which was using a refrigerator. Design 3 solves the problem of speeding up the process, but due to its complicated and unsafe way, it does not fair very well when compared to the first two design options. Design 1 and 2 remain relatively the same until the footprint criteria, where Design 2 fairs much better. Because of the amount of piping required in design 1, it has a rather large footprint that would be comparable to something such as a mini-refrigerator. Design 2 is condensed into a very small box design, with very minimal piping, which would decrease production costs radically, as well as decrease the overall footprint. Design 1 could be improved by making the loops much more condensed, however this would increase production costs even *more* which again confirms the idea that Design 2 is inherently the better design.

Embodiment Design

Product architecture

The physical layout of Design 2 is already basically modeled above when it was introduced. The system will consist of minimal components:

- A box shaped frame that will likely be injection molded from ABS plastic to reduce costs, several thermoelectric cooling pads
- Some sort of barrier that can withstand extreme temperatures so as to protect the thermoelectric cooling pads but also allow for them to effectively use their thermal properties (likely made of a cheap, highly conductive metal such as aluminum)
- Some sort of plumbing to allow for the beverage to be routed from the reservoir to the top of the chute
- A pump to move the beverage from the reservoir to the top of the chute

- A "black-box" temperature control module that can be used to regulate when the beverage has reached its optimal drinking temperature and dispense it accordingly.

Configuration Design

Specialty Components

Because of the need of a temperature control module, which is highly intensive on electrical components, I will leave this component as a "black-box" special purpose part; the temperature control module would be designed by an electrical engineer rather than bought, however, because I am a mechanical engineer I will treat the component as an input vs. output device.

Other specialty components include the frame, which will be injection molded to shape, and the barrier between the beverage and the thermoelectric devices, which is simply ¼" sheet metal that has been prepped to food preparation standards and shaped to fit the application. Drawings of each of these parts are provided below in the Drawings section.

Because the thermoelectric devices easily allow for it, the circuit designed by the electrical engineer should be easily switched polarity by the end user to allow for the device to serve a double function, which is to heat up a beverage. This requires no extra design on the mechanical part as long as the temperatures are within the safe values of the ABS plastic materials, and very little change in design for the electrical engineer (usually a simple switching circuit would be employed).

Standard (Purchased) Components

The most obvious standard component in the system are the thermoelectric devices. There will be multiple included in the design because their surface area is minimal. The electrical engineer will also create a circuit with these devices that allows them to operate at 75% maximum power. This is to provide a sufficient temperature gradient, but not have the devices running at maximum power all of the time, decreasing the life and safety of the product.

Addition standard components would include any hardware that would be needed, as well as any electrical components such as switches and wiring that would be needed by the electrical engineer.

A bilge pump is necessary to move the beverage through the loop. It is much more beneficial to buy one than to try and design one.

Parametric Design

ABS plastic (Acrylonitrile Butadiene Styrene) is chosen as the frame and plumbing materials because of its low cost, ease of manufacturing, relatively high melting point (221° F and 105° C) that can be increased with simple chemistry, strength, and durability. It will be molded in an injection molding process into the following parts: frame, pump/temperature control unit housing, and plumbing.

Aluminum is selected as the material to be used as a barrier between the thermoelectric devices and the beverage because of its low cost, ease of manufacturing, and relatively high heat transfer coefficient (k=237). This will allow for the thermoelectric devices to be separated from moisture, increasing the safety of the product, while still allowing for heat transfer to take place between the beverage and devices.

The overall size of the device should be large enough to hold at least 12 oz of liquid in the reservoir, while minimizing the overall size to reduce the footprint as well as lower material costs.

$$(12\ oz)\left(\frac{29.57\ ml}{1oz}\right)\left(\frac{1cm^3}{1ml}\right)\left(\frac{1in}{2.54cm}\right)^3 = 21.65in^3$$

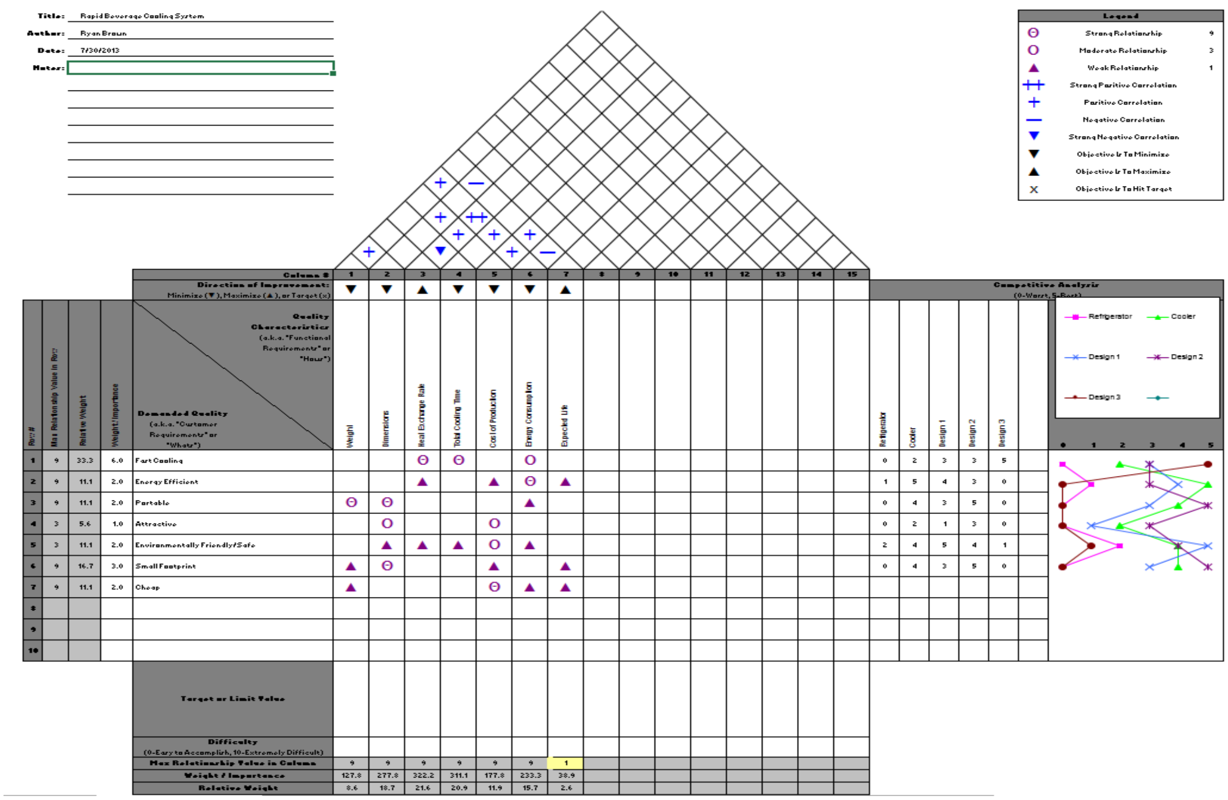
We chose to use 4 thermo electric devices, in order to keep the price manageable, and offer as much coverage of the chute as possible.

32 .01" holes are drilled in the Main Tube in order to provide an even distribution of the beverage on the chute. There are 2 rows of 16 holes, spaced .1" apart.

The pump we chose is a 500GPM bilge pump, which when run at partial speed should be more than enough to move the small amount of beverage throughout the loop.

House of Quality Matrix

We can also form a House of Quality matrix, which allows us to see the relationships and tradeoffs between criteria and functions, as well as allows us to weigh the more important options to focus on:



The HOQ also allows us to see that the heat exchange rate is the most important parameter in the design project, and it is followed closely by overall time required to cool the beverage, which happens to directly influence the heat exchange rate. The third most important design option is the physical dimensions of the system, which is congruent with Design 2 winning out in the Pugh Chart.

As an added benefit, we can rate each design in terms of how they satisfy the customer requirements. For this matrix we also added the method of cooling the beverage with a cooler (ice chest), which faired quite well with Designs 1 and 2, but overall was defeated by Design 2 as well, due to its ability to cool the beverage more rapidly, which is the main design requirement.

Detail Design

Bill of Materials

Item	Quantity	Price
ABS Plastic for injection Molding	1.25 lbs per unit	$2.42 per pound
1060 Aluminum Sheet Metal	80 square inches per unit	$.11 per square inch
500 Gallon Bilge Pump	1 per unit	$29.99
Thermoelectric Cooling Module	4 per unit	$11.20 each
¼” 20 UNC Screws	4 per unit	$.10 each
Total		$87.02 per unit

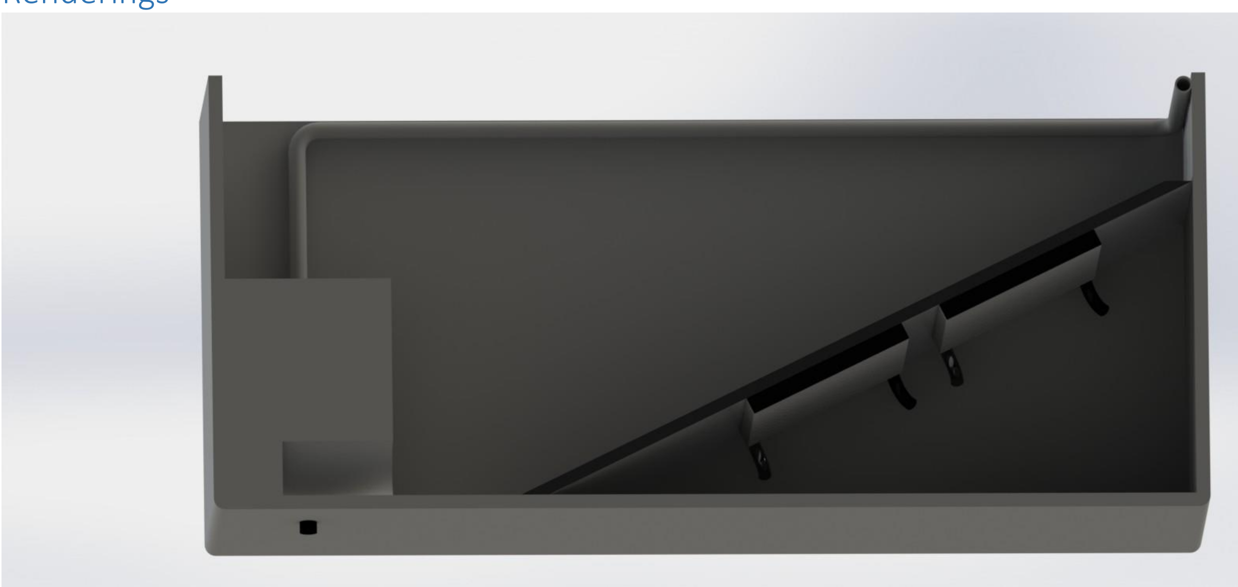
Drawings

Drawings are included at the end of this document

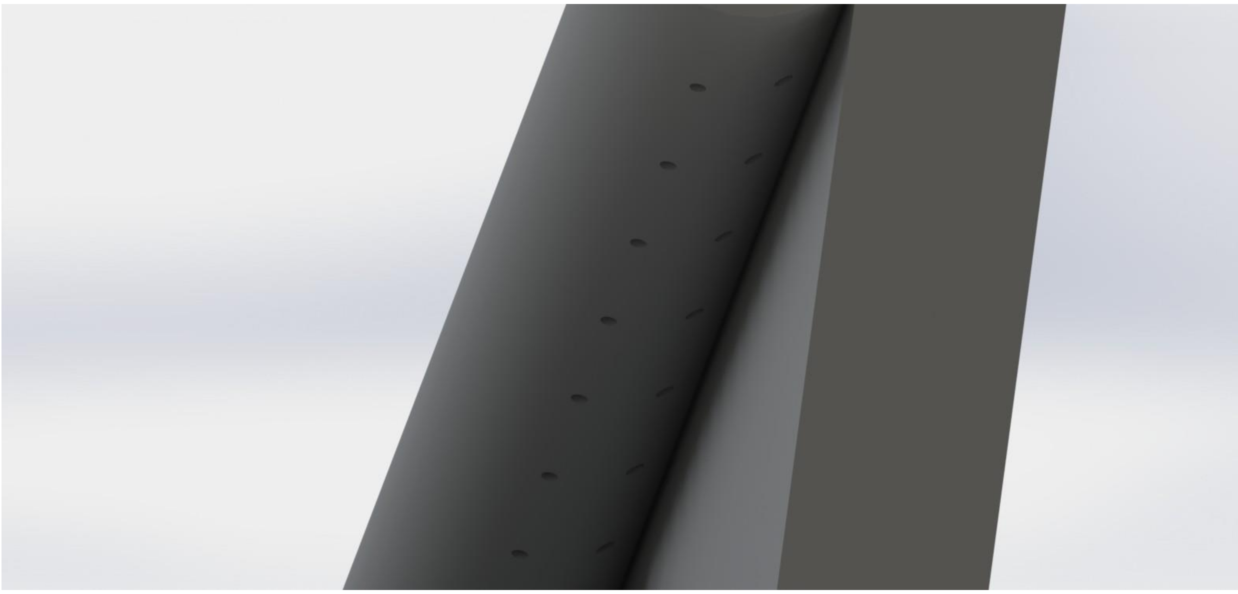
Conclusion

After running through the entire design process, and using QFD techniques to choose the best design option available, Design 2, the design with the thermoelectric devices was used. The product has been modeled in SolidWorks, and dimensioned to offer optimal production costs. Each unit (when produced in bulk) costs about $87.02 to produce. This leaves room for a healthy markup percentage in order to make a profit on the product. Below are renderings of certain features that may have been unclear in the verbal descriptions above.

Renderings



(Cutaway image of design 2 with thermoelectric modules in place)



(Small holes allow for a pressure to be higher than atmospheric, allowing an even spray and thus even coverage of the beverage on the chute)

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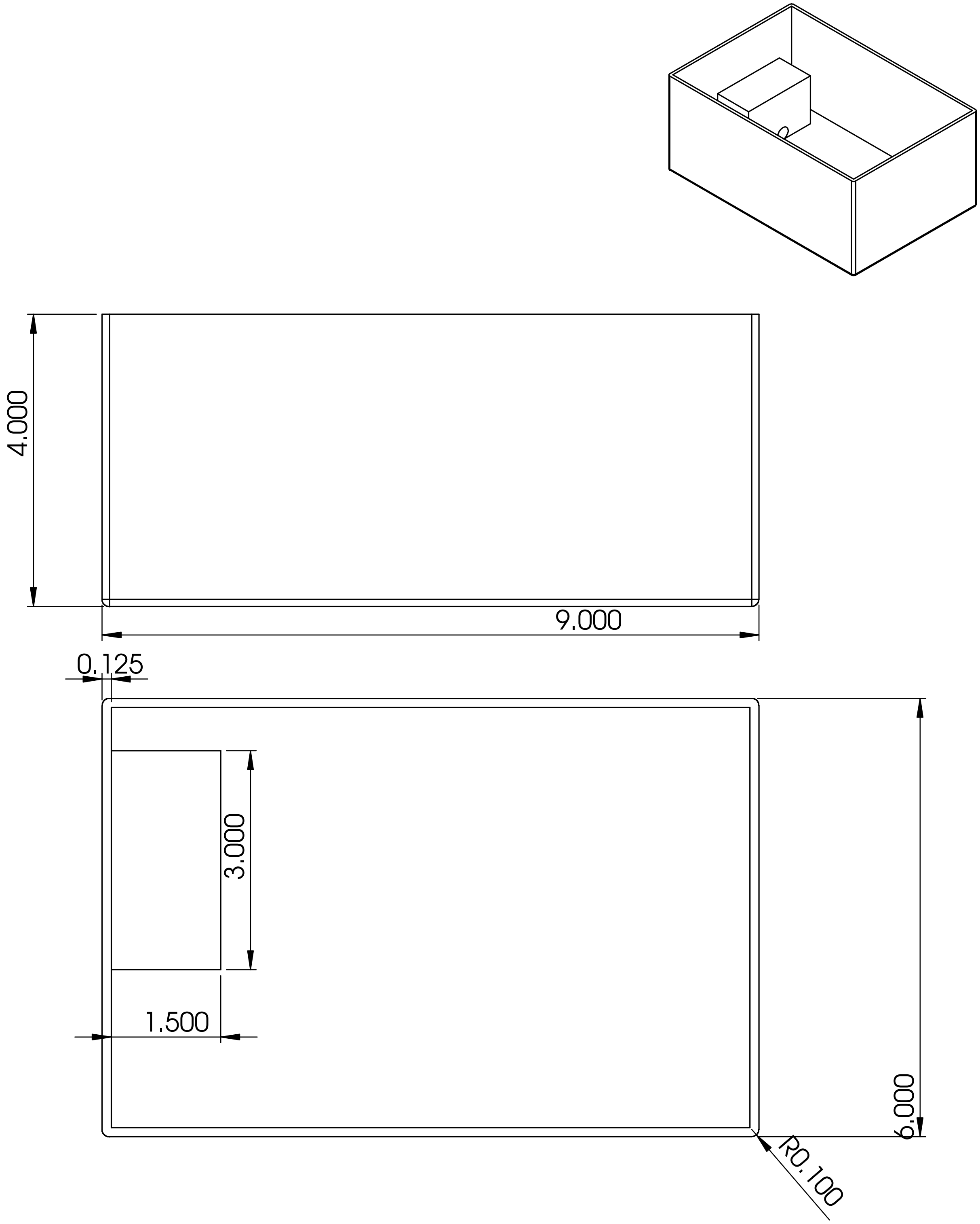

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:

FINISH: Injection Molded

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION 01

	NAME	SIGNATURE	DATE
DRAWN			
CHK'D			
APPV'D			
MFG			
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TITLE: Reservoir

MATERIAL: ABS Plastic

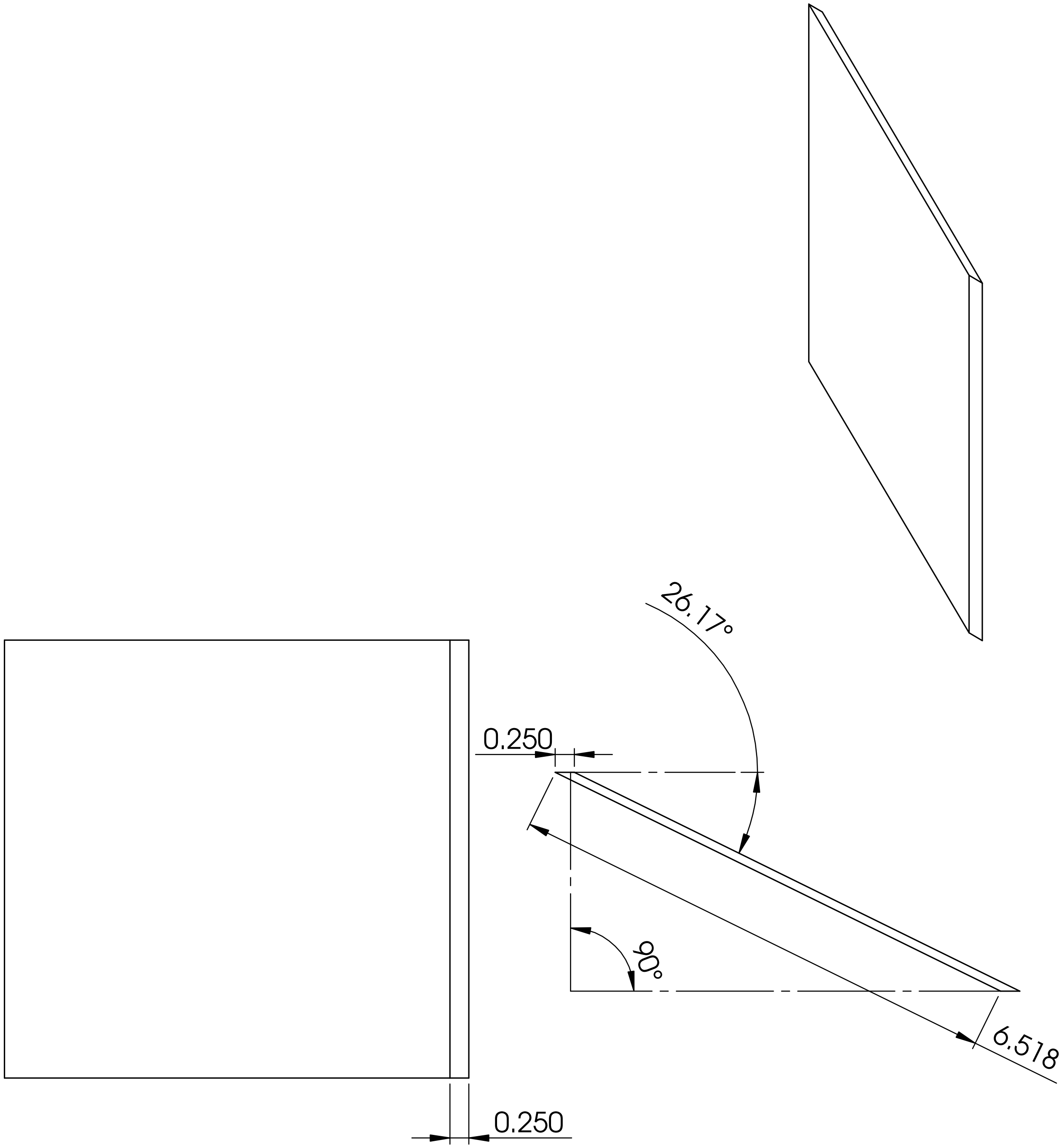
DWG NO. 001

A4

WEIGHT:

SCALE:1:5

SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:

FINISH: Food Preperation Standards

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION 01

	NAME	SIGNATURE	DATE
DRAWN			
CHK'D			
APPV'D			
MFG			
Q.A			

TITLE: Chute

MATERIAL: 0 Alluminum

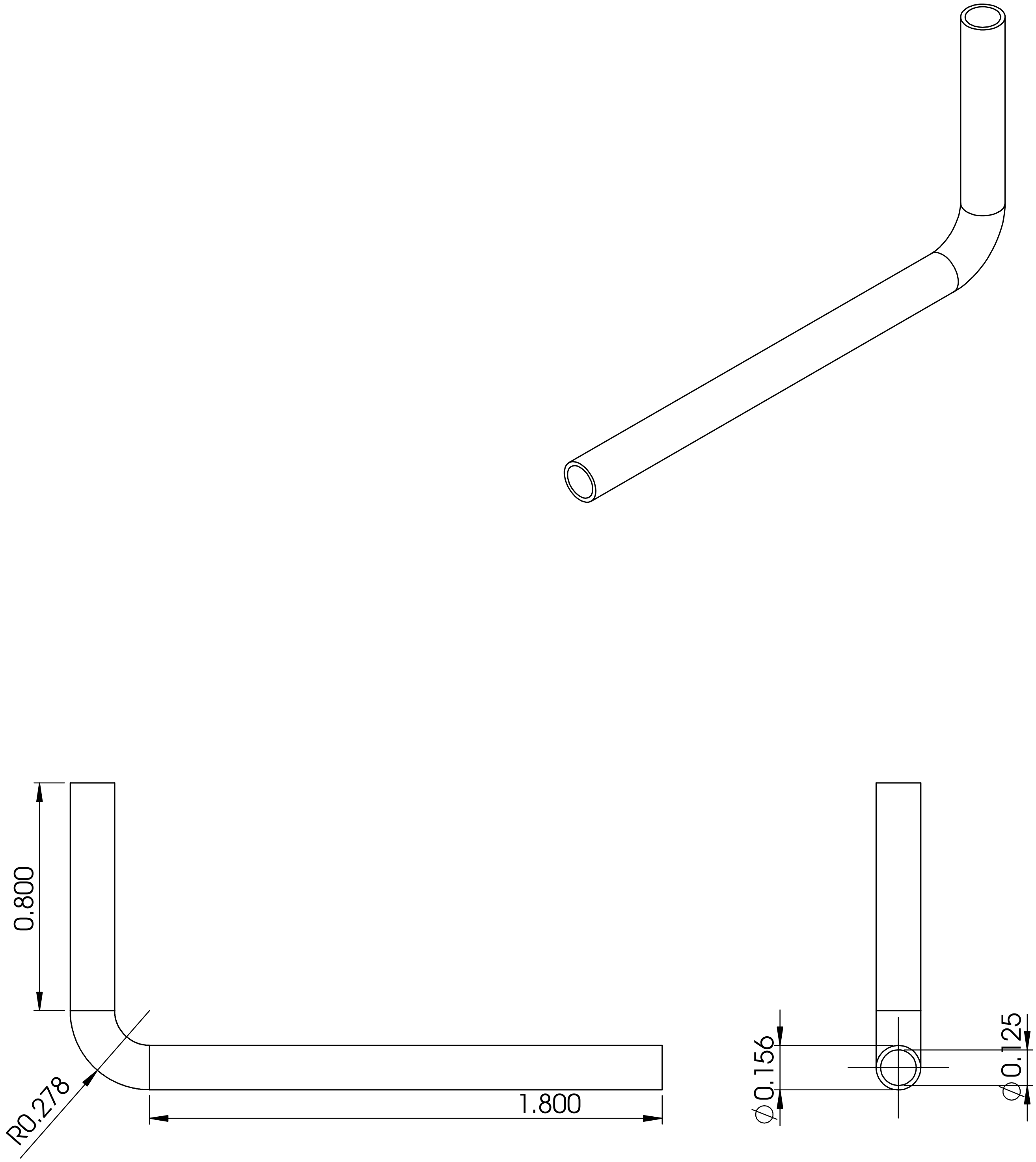
WEIGHT:

DWG NO. 002

A4

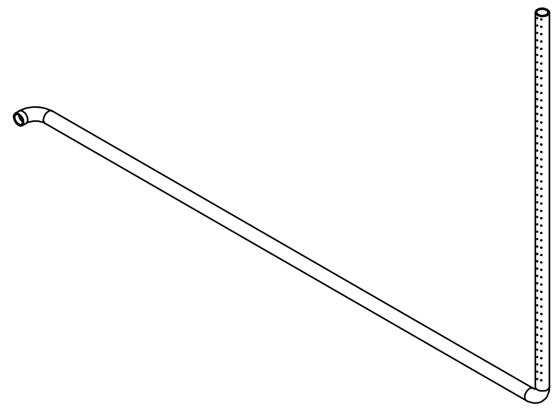
SCALE:1:2

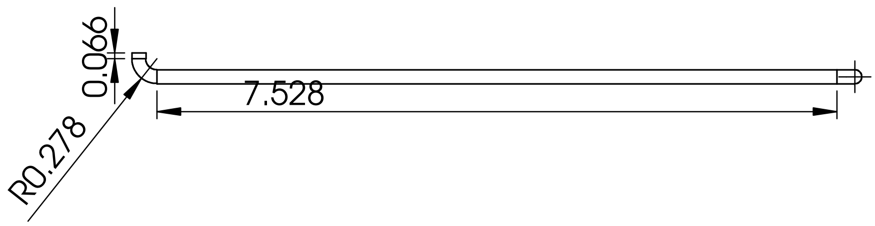
SHEET 1 OF 1



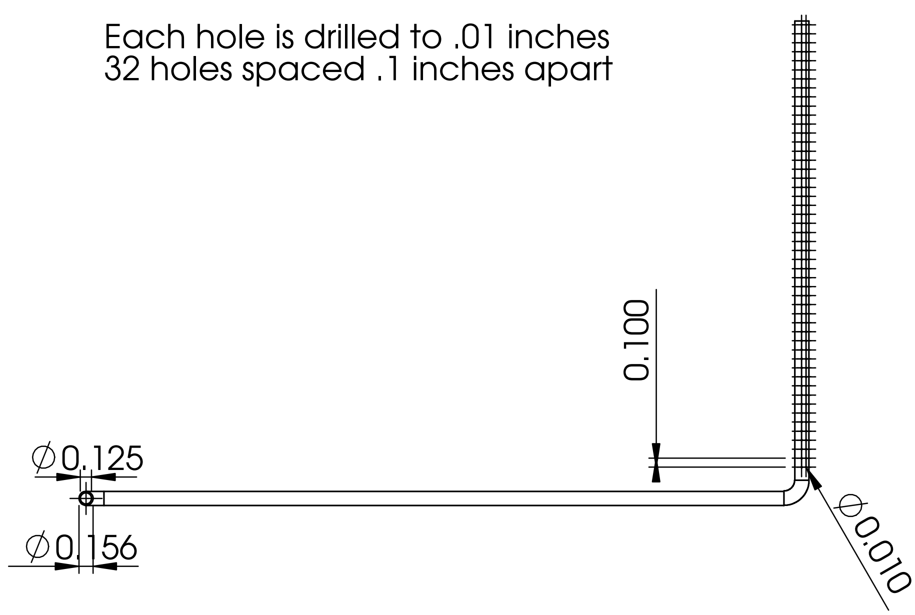
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:	FINISH: Injection Molded	DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING — REVISION 01

	NAME	SIGNATURE	DATE				TITLE:
DRAWN							Inlet tube
CHK'D							
APPV'D							
MFG							
Q.A				MATERIAL: ABS Plastic			DWG NO. 003 — A4
				WEIGHT:			SCALE:2:1 — SHEET 1 OF 1





Each hole is drilled to .01 inches
32 holes spaced .1 inches apart



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:	FINISH: Injection Molded	DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING — REVISION 01

	NAME	SIGNATURE	DATE
DRAWN			
CHK'D			
APPV'D			
MFG			
Q.A			

TITLE:

Main Tube

MATERIAL: ABS Plastic

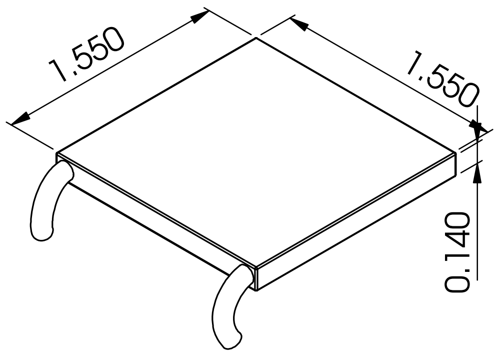
WEIGHT:

DWG NO. 004

A4

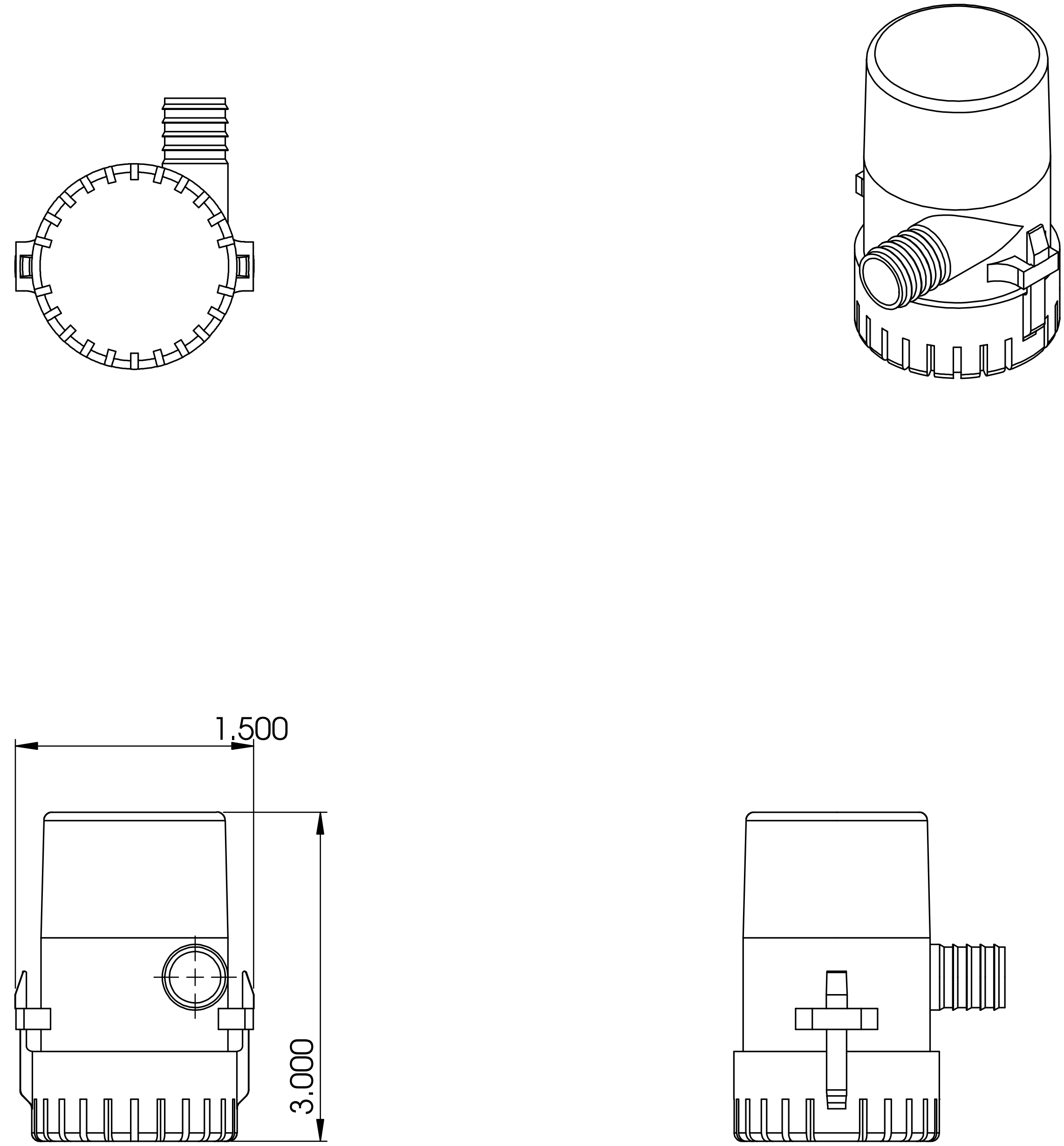
SCALE:1:2

SHEET 1 OF 1



Purchased Part (F30345)

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:		DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION	
	NAME	SIGNATURE	DATE		TITLE: Thermoelectric Cooling Module (F30345)		
DRAWN							
CHK'D							
APPV'D							
MFG							
Q.A				MATERIAL:	DWG NO. 005		A4
				WEIGHT:	SCALE:1:1	SHEET 1 OF 1	



Purchased Part
(B-700021)

UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:	FINISH: Purchased	DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION 01

	NAME	SIGNATURE	DATE		
DRAWN					
CHK'D					
APPV'D					
MFG					
Q.A				MATERIAL:	
				WEIGHT:	

TITLE:

Bilge Pump

DWG NO. 006 A4

SCALE:1:2 SHEET 1 OF 1