Saimaa University of Applied Sciences

Technology, Lappeenranta

Degree Programme in Mechanical Engineering

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PORTABLE BEVERAGE CAN COOLER

Bachelor’s Thesis 2010

ABSTRACT

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The reason to make a portable beverage can cooler is that all the other products in the market are heavy, expensive and all use electricity from the wall plugs. Also regular refrigerators take a long time to properly cool a beverage can. So it was decided to make a portable beverage can cooler which can keep a beer cool during outdoor activities like picnics, hiking etc. More so, since it will be portable it will be smaller and therefore cheaper.

The main user group targeted with this product (PBCC) is people interested in outdoor activities, like picnics, camping, festivals, cyclists etc. This product can also be useful for people working in places without refrigerator.

How to create a beverage can cooler which can be carried along since it stores energy. Since a regular refrigerator takes over an hour to cool a beverage from room temperature, the product should be able to cool a can in less than twenty minutes. Without the cans it should weigh less than 5 kg and still be affordable; also it could cool a maximum of four cans at a time.

The purpose of this project was to create a product which helps people in their everyday lives by cooling beverages quickly.

Keywords: portable beverage, cooler, material selection

CONTENTS

1 PROBLEM FORMULATION 5

2 DELIMITATION...5

3 CHOICE OF MODEL AND METHOD PROCEDURE 6

4 SCENARIO FOR THE BEVERAGE CAN COOLER 10

5 MIND MAPPING OF BEVERAGE CAN COOLER PRODUCT 12

6 MORPHOLOGICAL CHART 12

7 WORK FLOW DESIGN OF BEVERAGE CAN COOLER 13

8 SELECTION OF THE MATERIAL FOR BEVERAGE CAN COOLER.........14

8.1 Preliminary selection stage of material 14

8.2 Step of preparing a property profile 15

9 MATERIALS...16

9.1 Cooling Materials 16

9.2 Insulation 17

9.3 Cover materials...17

10 TESTING 18

10.1 Peltier Element 19

10.2 Refrigeration 20

11 TYPE OF PELTIER ELEMENT..20

12 COOLING CALCULATIONS..22

13 ELECTRICAL CONNECTIONS 23

14 FINAL DESIGN OF BEVERAGE CAN COOLER......................................25

15 INSULATION CALCULATIONS...27

16 CALCULATION OF BATTERY 28

17 DESIGN SELECTION 29

18 IMPROVEMENT IN THE FUTURE 31

18.1 Waste Heat Recovery 31

18.2 Process 32

18.3 Different Power Source 33

18.4 Automation and Temperature Control 33

19 CONCLUSIONS 33

20 REFERENCES 34

1 PROBLEM FORMULATION

Power Source

The design wants to find out which power source will be used. Information in gathered from books, internet and also from renewable energy course teacher and other teachers.

Material- Aesthetics -Cost

The purpose is to find out which materials will be used, since it affects costs, aesthetics and portability; information will be mainly acquired from the project supervisor.

Shape and Size

The decision must be made on how many cans it cools at once, since it affects costs, usability, weight and size. This problem will be solved through a series of calculations and tests.

Time

The last thing to solve is the time needed for the cooling, since it has a big effect on usability.

Easily use.

The can cooler must be designed as small as possible. The operation for the can cooler must be simple.

2 DELIMITATION

Using any other type of energy is not needed but existing energy sources like solar, regular, mechanical or chemical.

According to materials expensive, heavy and brittle materials are delimitated, because the product must be affordable, portable and durable.

Cooling cans is the only purpose; therefore we exclude bottles and other beverage vessels are excluded. Cooling times over twenty minutes are excluded.

3 CHOICE OF MODEL AND METHOD PROCEDURE

What Problem	Why	Which Method	How
Power Source	Needed to generate energy for cooling		Calculations and consulting
Materials	Affects cooling, costs and portability	From tables and consultants	Comparison
Shape and Size	Affects usability	Sketching & Drawing	Using software
Cooling time	Affects usability	Tests and calculations	Testing and calculation
Costs	Affects affordabilit y	Calculations	Summing up the costs

Sketches designed of beverage can cooler

There are 6 kinds of beverage can coolers. Figure 1 shows a telescope model that could put 3 cans inside. Figure 2 and figure 3 show a briefcase model that could put 2 cans inside and each can take half space of the beverage can cooler. Figure 4 shows a sphere model that could contain one can. Figure 3 shows an oven model of the beverage can cooler but this design wastes so much space. Figure 4 shows a fridge model that could contain 4 cans.

Figure 5 shows a cube model that could contain 4 cans and it really saves the space because the target of the design is a portable beverage can cooler. In these 6 methods the last cube model could contain the most cans and the space is the smallest. In saving space and the capacity of the beverage can cooler the cube model is the best.

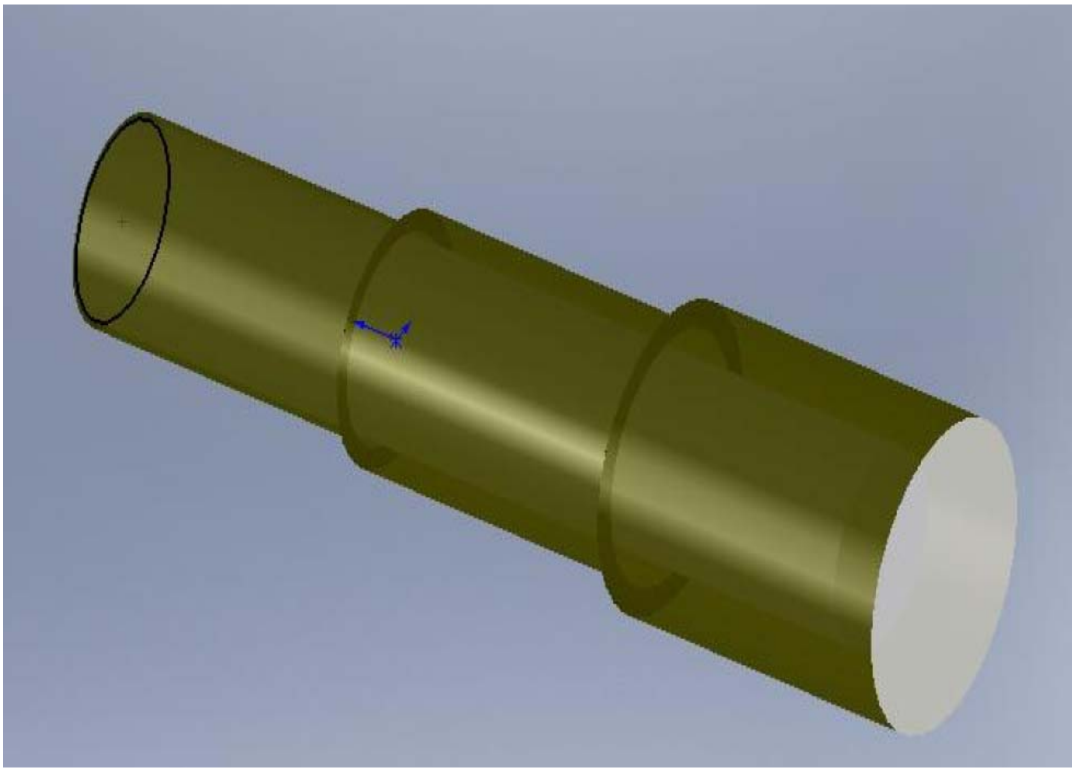


Figure 6 The first sketch design on how the beverage can cooler is going to look like – Telescope

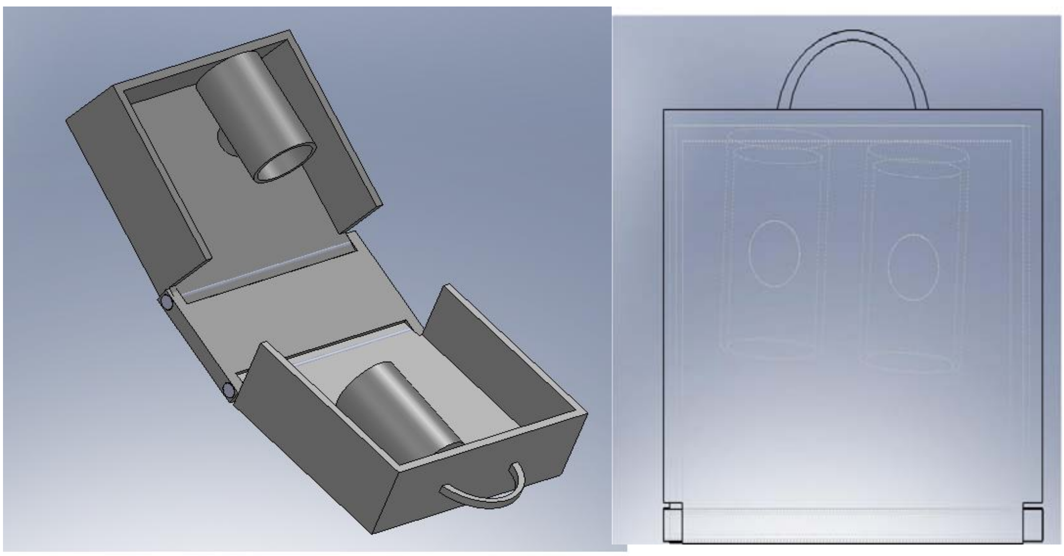


Figure 7 Open and close view second sketch designs on how the beverage can cooler is going to look like.

- Briefcase

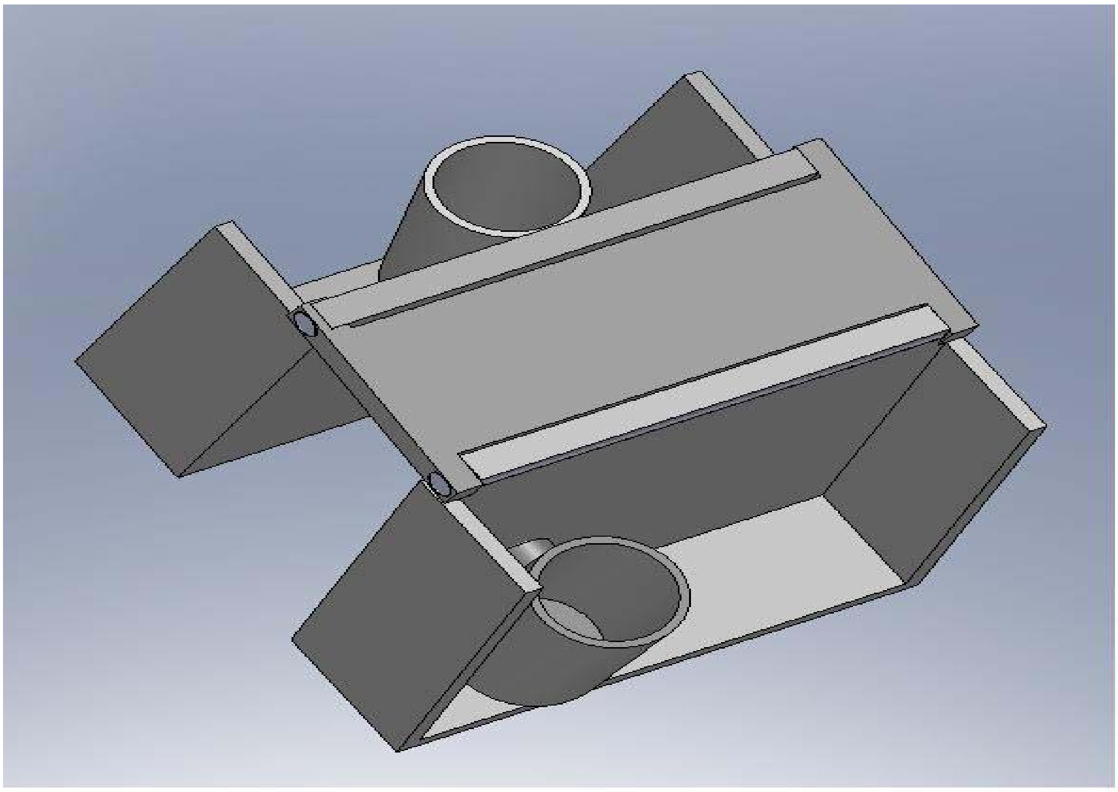
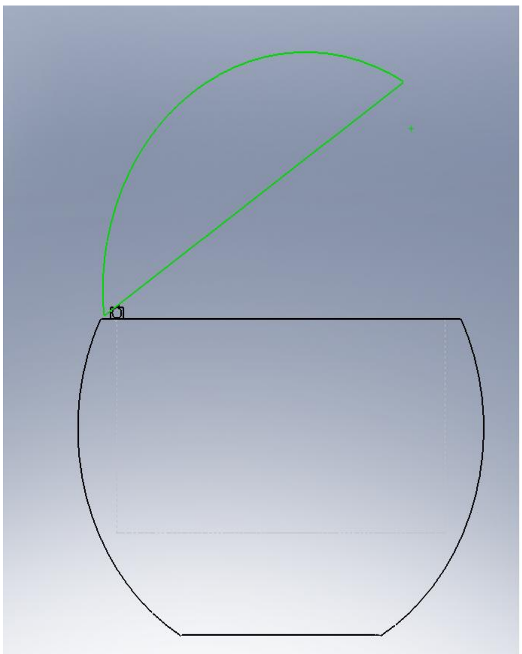


Figure 8 Totally open sketch design on how the beverage can cooler is going to look like



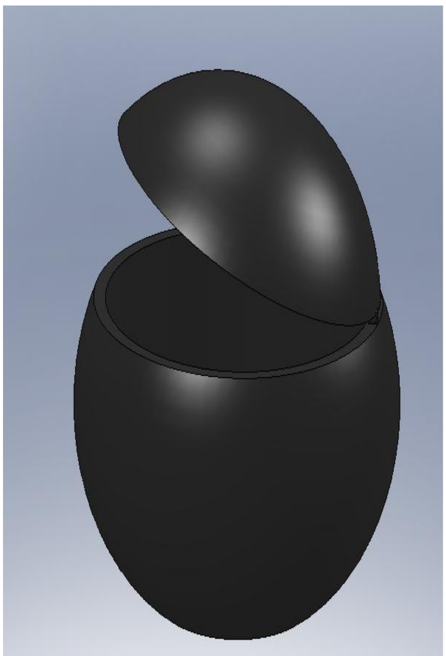


Figure 9 The third sketch design on how the beverage can cooler is going to look like - Sphere

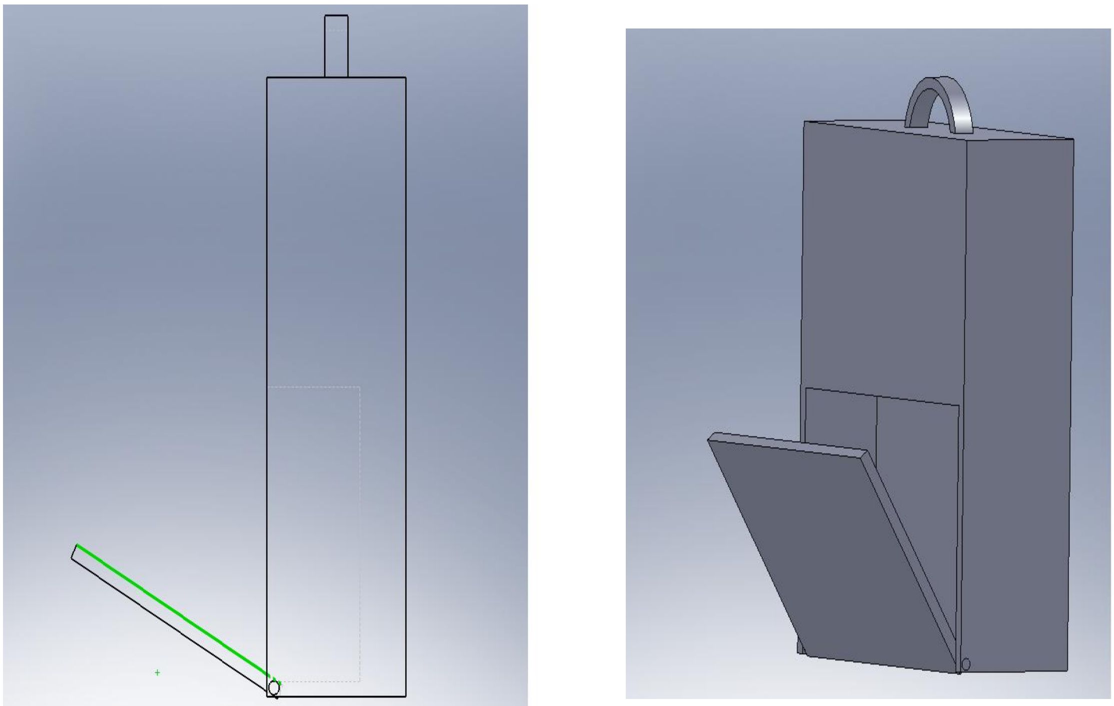


Figure 10 The fourth sketch design on how the beverage can cooler is going to look like - Oven

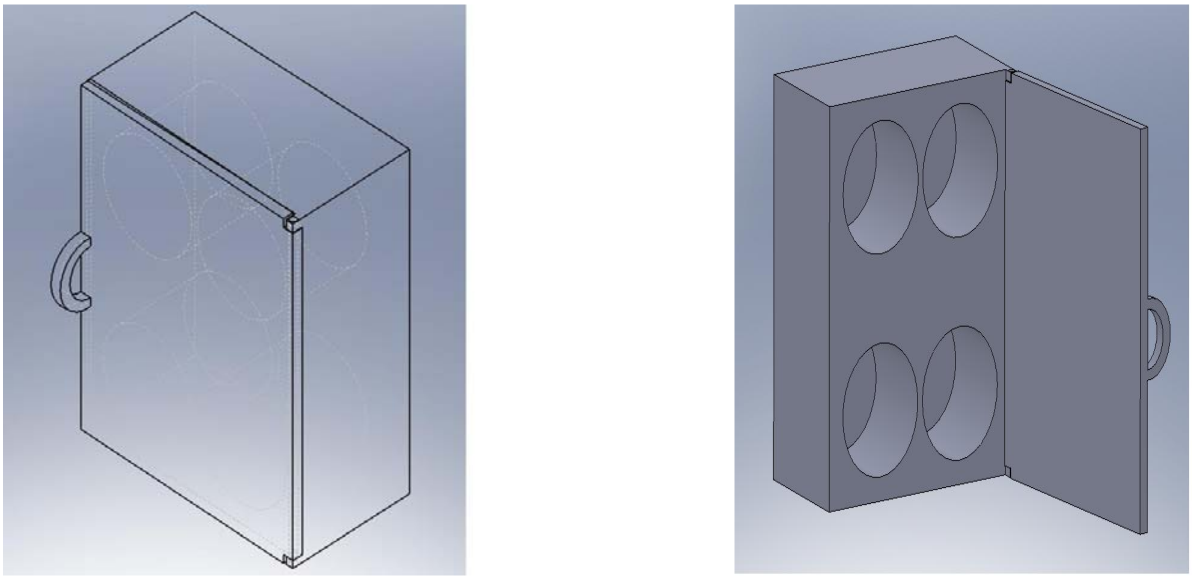


Figure 11 The fifth sketch design on how the beverage can cooler is going to look like - Fridge

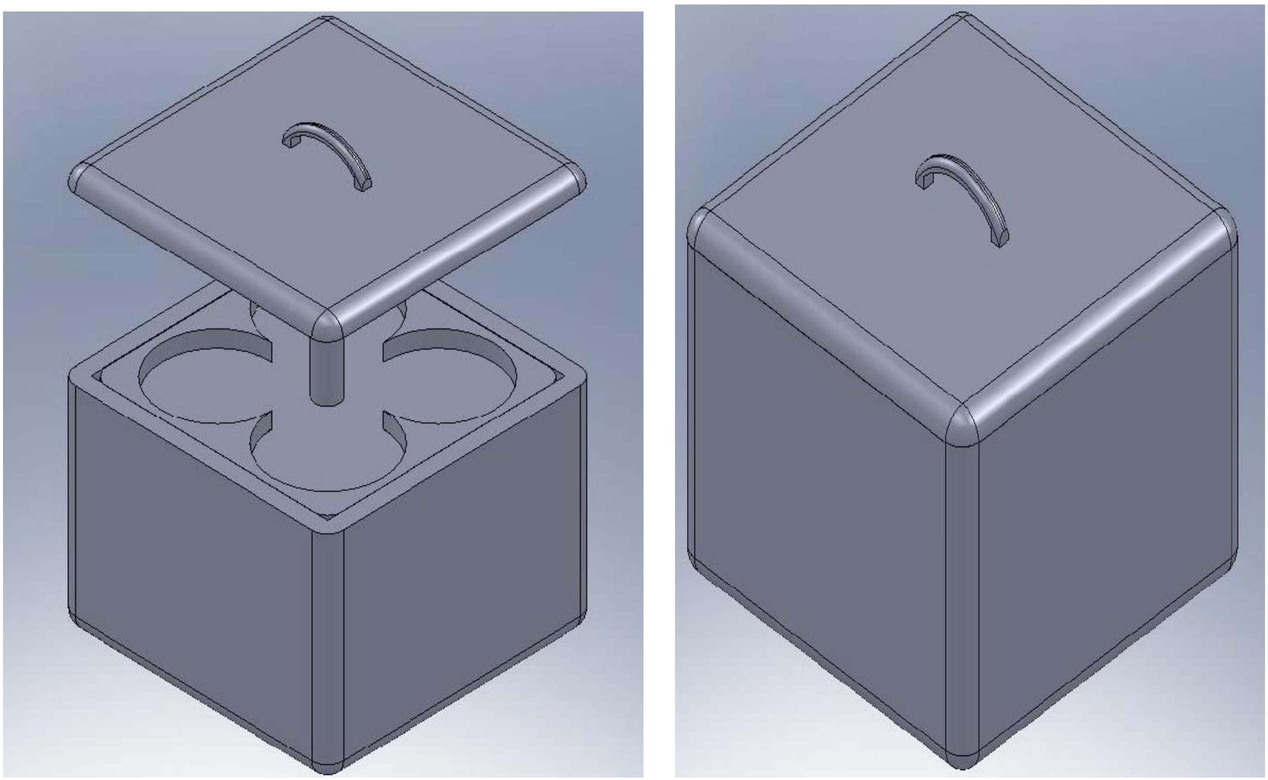


Figure 12 The sixth design for how the beverage can cooler is going to look like

4 SCENARIO FOR THE BEVERAGE CAN COOLER

Portability

Considering outdoor activities nowadays, these include picnic, hiking, travelling, camping, group activities, different sport and other alike. Along the way and during these activities people would want to have a break of drinking some cold beverages or other canned drinks, but even if you cool your drinks at home, they will warm up during the activities especially if it is a sunny day.

When families travel by car they often pack snacks along so the kids stay busy and father can concentrate on the road. But if the kids have warm soda, they are going to complain about it and you are going to have to stop so you can buy cold beverages. This wastes time and money, and in addition all the stops you make are bad for the environment. So if you had a beverage cooler in your car mother could cool the sodas for the children. And later on the whole family could enjoy some cool beverages on the picnic ground.

Fast Cooling

Sometimes you have big events where you need to serve cold beverages and it is not convenient to bring a fridge. So, for these events you would need to cool your beverages at home. But if you have a portable beverage cooler which can cool a beverage quickly you could serve all the visitors without forming too long queues.

Luxury Item

When you book a stay at a 5-star hotel, you expect a very high level of luxury and sophistication, to get a good value for your money. Now, if the hotel has a high-tech beverage cooler it makes the visitors feel like they get something special and unique.

http://www.youtube.com/watch?v=nS32QN3s_2o&feature=channel_page

http://www.cybercandy.co.uk/aaasmt/index.php/url_indprod?xlc=945

http://www.cooldesignideasblog.net/2009/09/14/mini-beverage-fridge.html

5 MIND MAPPING OF BEVERAGE CAN COOLER PRODUCT

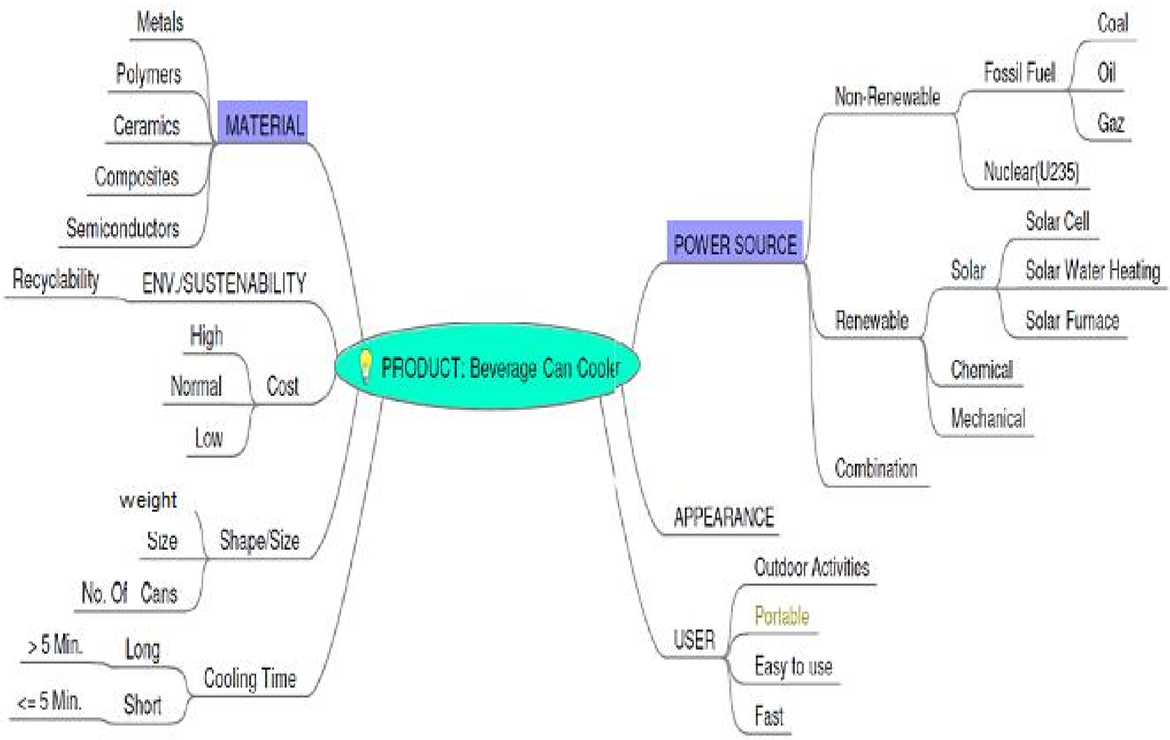


Figure 13 Mind mapping

This figure shows what should be considered in the project. It looks like a WBS （work break down system）for the whole project considering.

6 MORPHOLOGICAL CHART

Control Operation	Automatic	Timer	Complex Automation	Simple Switch		
Power Source	Solar	Normal Electricity	Mechanical			

Component s for Cooling System	Burning of gases	Peltier Element	Compresso r			
Cooling of Heating part	Liquid	Fan	ventilation			
Design	Sphere	Fridge	Telescope	Briefcas e	Cub e	Ove n

Table 1 Morphological chart

7 WORK FLOW DESIGN OF BEVERAGE CAN COOLER

The work flow defines as how the system works step by step.

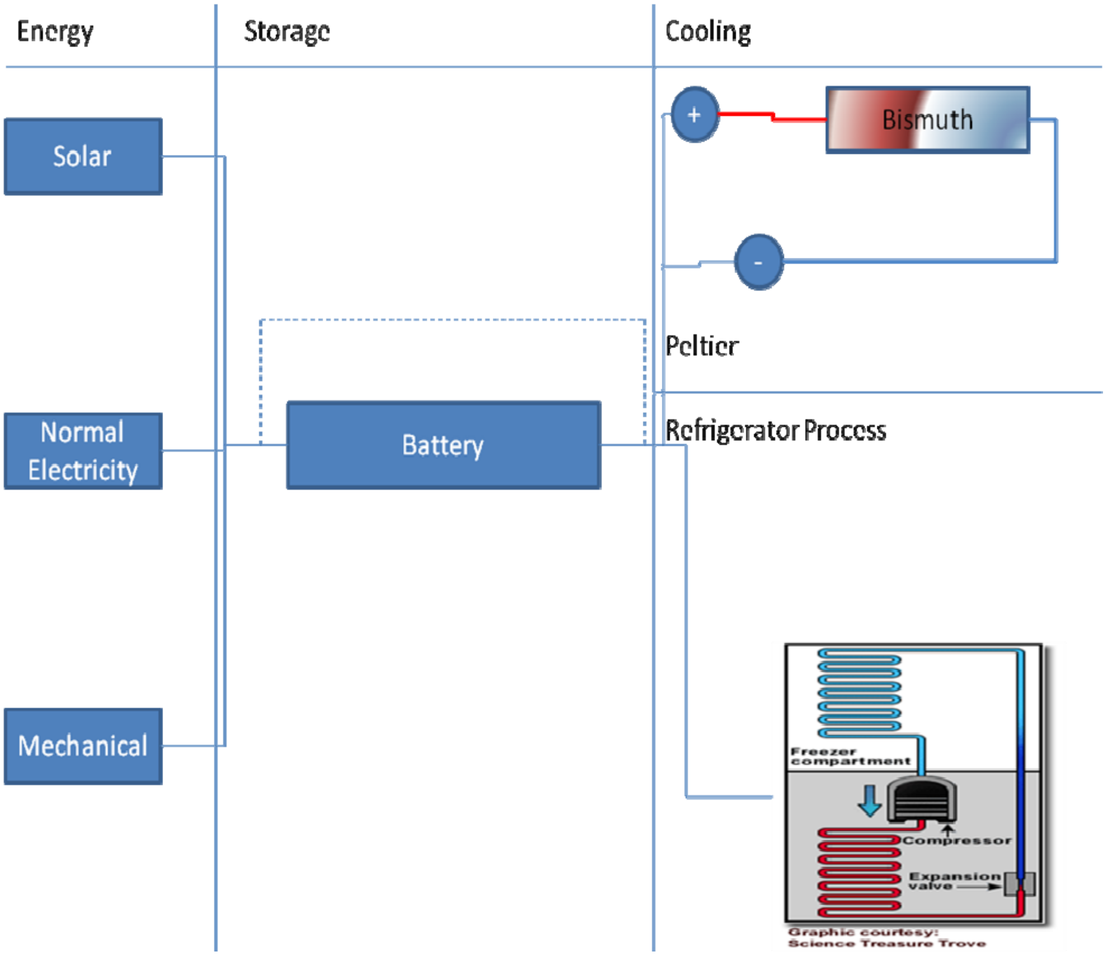


Figure 14 Work flow of refrigerator and design for beverage can cooler

8 SELECTION OF THE MATERIAL FOR BEVERAGE CAN COOLER

Selecting material is a part of the process which aims to fulfill the requirement of the design product (beverage can cooler), also in selecting material it must fulfill the demanded function with low costs in the pre-determined environment, the desired period or time and the product to be manufactured.

8.1 Preliminary selection stage of material

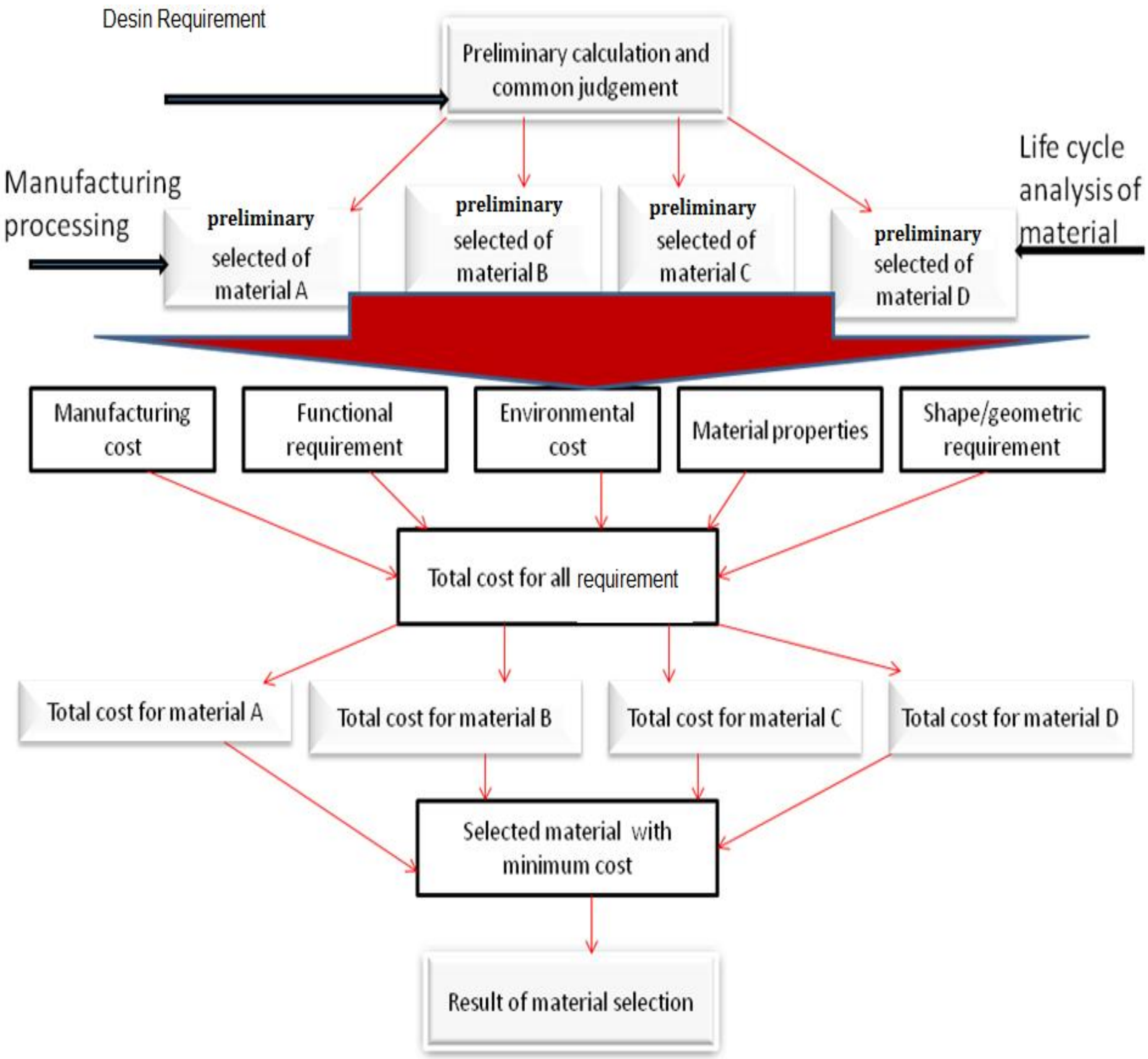


Figure 15 Preliminary selection stage of material

8.2 Step of preparing a property profile

Demand --->properties

Properties-->materials to be consider

Performance factors considering the fuction of the product, order of importance

Shape requires	Hardness, density, coefficient of heat expansion, module of elasticity
Weight capacity	Yield strength, module of elasticity and rigidity
Stress concentrations	Ductility, notch sensitivity
Dynamic load	Fatigue strength,fatigue of notch factor
Impact load	Impact strength, transition temperature
Wear	Hardness, coefficient of friction
Processibility	Castability: melting temperature, fluidity Machinability: hardness, microstructure Weldability: carbon content, alloying

Table 2 Profile to know about the material properties in selecting the material for the desired product

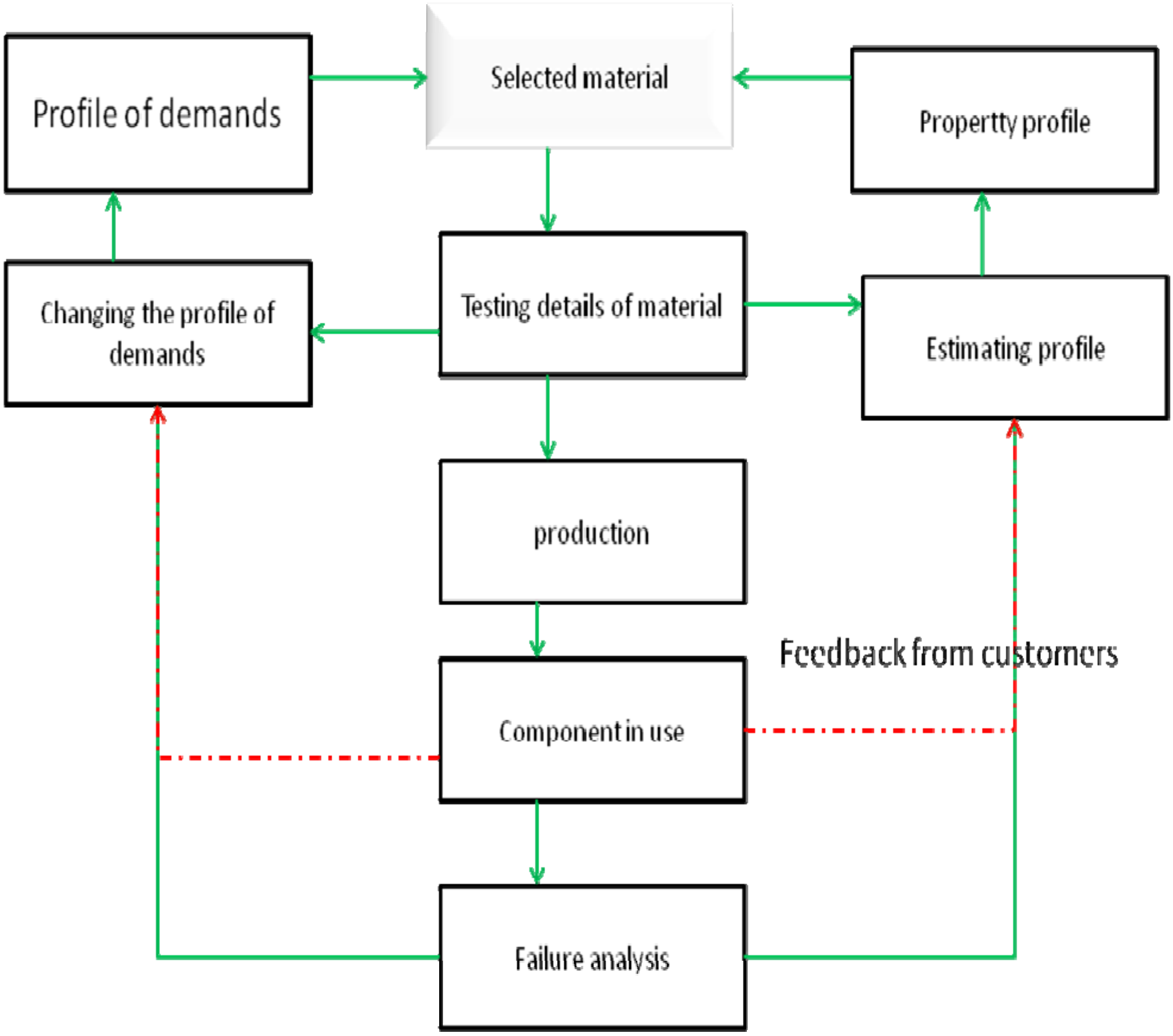


Figure 16 Diagram step in selecting the final material to be used

9 MATERIALS

9.1 Cooling Materials

The needed material is light, cheap and has a high thermal conductivity.

Material	Thermal Conductivity [W/m K]	Density [g/cm3]	Price [USD/Kg]	Process ability	Recyclability
Aluminium	205	2.7	1.87	++	+++
Copper	385	8.3-9	6.4	++	+
Diamond	1000	3.53	>10 000	-	+++
Gold	314	19.3	1085.5	+	++
Polyethylene	0.4	0.9	1	++	+++
ABS	0.19	1.04	2	+++	+++

Table 3 Material selected

Based on this study it was decided to select aluminum. Even though it has the lowest thermal conductivity, it still meets the requirements. Further, due to the low life-cycle costs and the weight, it is the best selection. It is also very recyclable.

9.2 Insulation

One of the key things when considering insulation is layers; for good insulation many layers are needed. The so called tri-lam insulation is chosen. It is a combination of foil, polyethylene foam and high density polyethylene film. The foil reflects the heat, foam keeps the temperature constant and the film provides tear resistance. The price for the insulation of one unit is about 1 $.

9.3 Cover materials

The inside and outside of the system needed a material that is strong, processable, recyclable, lightweight and cheap. Therefore ABS plastic was chosen.

http://foamconverting.com/

10 TESTING

Cooling time test in a refrigerator

Figure 17 Refrigerator test

This test uses two cans of beer in the refrigerator and tested the temperature of the cans. After 30 minutes, there was no noticeable change in the temperature, after 70 minutes the beverage was starting to cool but it was not really cold. After 160 minutes the beverages were finally cold enough to drink.

Selection of Cooling Element

Studying all sorts of different cooling elements is the beginning, but in the end it came down to two: The Peltier element and the refrigeration. The Peltier element, due to reasons stated below, was chosen.

http://home.howstuffworks.com/refrigerator.htm

10.1 Peltier Element

How it works

The cooling in a Peltier element is created by two highly conductive wires (like copper) and a piece of bismuth or iron wire. When the conducting wires are connected to the bismuth and a battery, there is a temperature difference between the two conductive wires. The wire in which the current is flowing to the bismuth will increase in temperature and the wire in which the current is flowing from the bismuth will decrease in temperature; thus creating a cooling effect.

Why Peltier?

- Low costs
- Small size & weight
- Safety
- Precise temperature control
- Solid state, no liquids
- No moving parts → High reliability (Life cycle over 20 years)
- Heat generated can be recycled to create energy

10.2 Refrigeration

How it works

Refrigerator uses a compressor to pressurize a gas to create a temperature change in the gas. The cold gas then flows in the back of the refrigerator until it condenses into liquid and then it flows to the compressor again and the process restarts.

Why not refrigeration?

- Heavy
- Noisy
- Moving parts → Vibrations
- Requires a liquid, which can leak
- Expensive

11 TYPE OF PELTIER ELEMENT

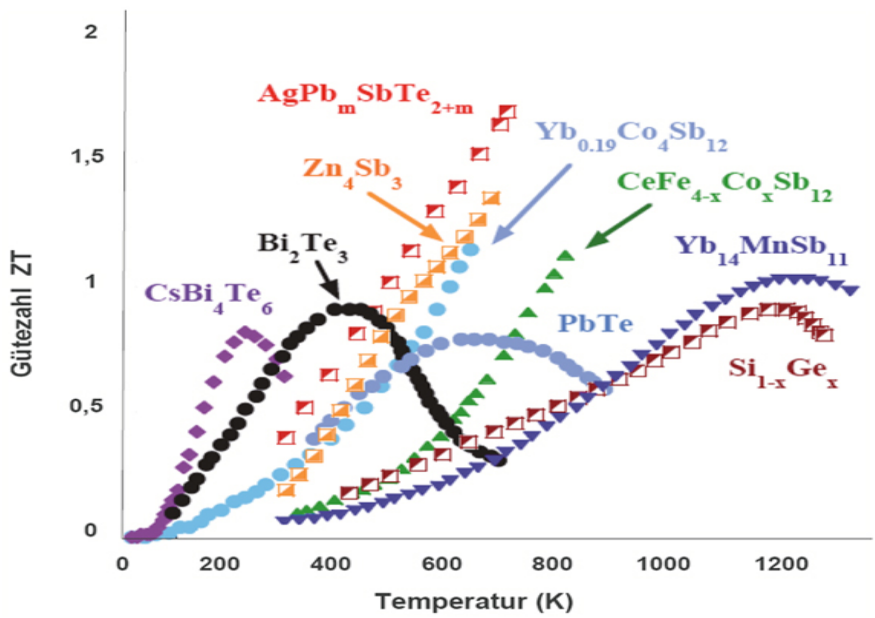


Figure 18 Chart for diversity of Peltier element material

The Zt value is calculated using the formula:

Z = S2 Σ x T/K
Where:
T = absolute temperature
S = Seebeck coefficient
Σ = electrical conductivity
K = thermal conductivity

Material	**Price**
Bismuth Telluride(Bi_2Te_3)	
Lead Telluride (PbTe)	
Silicon Germanium (SiGe)	

Table 4 Price for Peltier material

Design of Peltier element

- High mechanical strength
- Low shear stress
- All interfaces between components must be flat, parallel, and clean

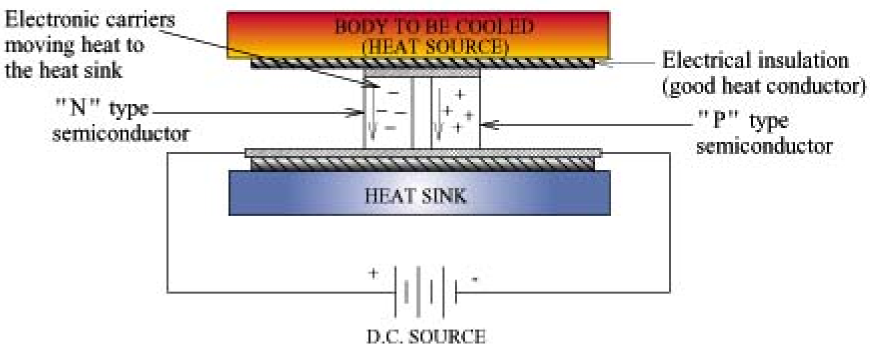


Figure 19 Cross section of peltier element view

http://www.melcor.com/tec_intro.html

A choice of different Peltier elements in different categories is High Performance, High Temperature, Micro, Multi-Stage, Special Shapes, series-parallel connection and Standard. From these it is possible to immediately eliminate High Temperature, Multi-Stage, Micro, Series-Parallel connection and Special Shapes, due to over design to the requirements and costs. Therefore, selection is made between High Performance and Standard.

12 COOLING CALCULATIONS

The basis for these calculations is a cooling time for four cans from room temperature to five degrees, with a heat energy removal of 85 W, which comes from the chosen Peltier element. Since beverages have different compositions of ingredients it is difficult to get the specific heat capacity for different beverages, because all beverages are mostly water it is assumed that the specific heat capacity to be the same as water. It is assumed that there is a direct contact between the Peltier element and the can, so it does not consider the effect of the materials between the Peltier and the cans. These calculations do not assume heat transfer from the hot side of the Peltier element to the beverage to be cooled.

With these calculations a value for the time that it takes to cool the beverages was found.

$t = (m*C_p*dT)/Q$

t = Time (s)

m = Mass of object (kg)

C_p = Specific heat capacity (J/kg K)

dT = Temperature change of object (K)

Q = Heat Energy Removed (W)

Mass of Object = 1.33 kg. The mass for one can with content was measured to be 0, 33 kg, so four cans will have the mass of 1,33 kg.

C_p of water = 4186 (J/kg K)

dT = 15K Temperature difference from room temperature to desired temperature from 293,15K to 278,15K

Q = 85 W

And from these calculations we can find a cooling time for four cans by one Peltier element as 16 min. And since we will be using two elements, the time will be halved.

So, the selected Peltier element will be HP-199-1,4-0,8 from TE Technology, Inc.

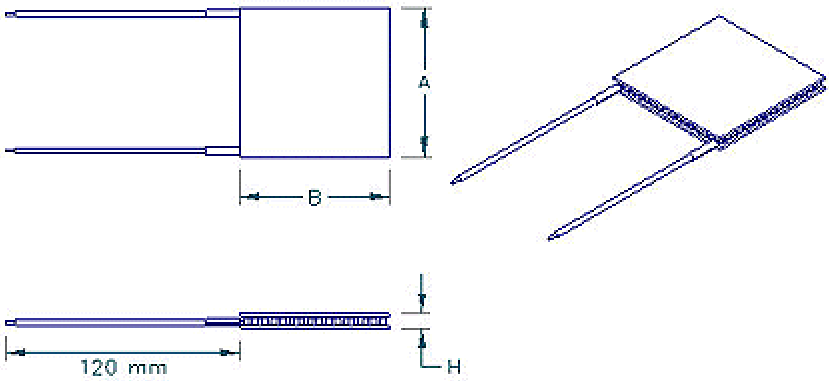


Figure 20 Schematic for Peltier element

http://www.tetech.com/Peltier-Thermoelectric-Cooler-Modules/High-Performance.html

A = 40mm

B= 40mm

H= 3,2mm

Price = 30$

13 ELECTRICAL CONNECTIONS

Trying to use two Peltier elements for more efficient cooling, it must be decided how they are connected.

Parallel

- Low Voltage
- High Current
- More Reliable

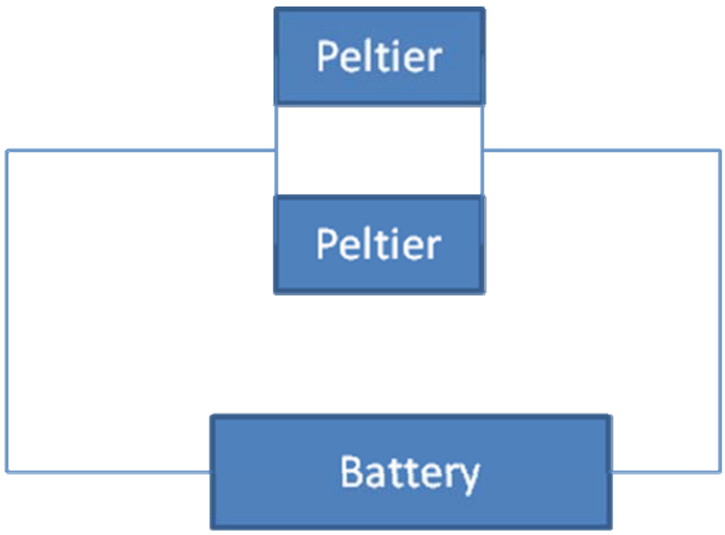


Figure 21 Parallel connection of Peltier element

Series

- High Voltage
- Low Current
- If one malfunctions, all malfunction

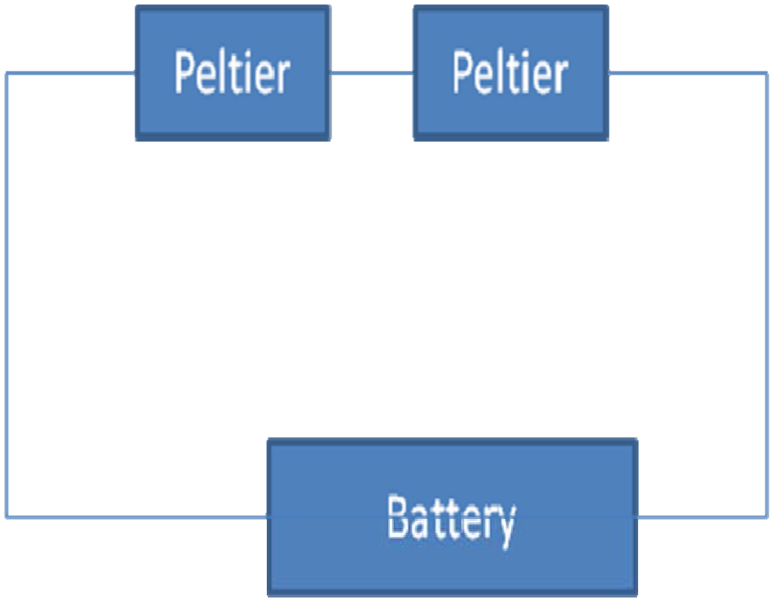


Figure 22 Series connection of Peltier element

14 FINAL DESIGN OF BEVERAGE CAN COOLER

In the final design of the beverage can cooler the cube model is the decided model because it suited for the product requirements and technology requirements.

There are three figures showing the parts and the whole model of the cube model.

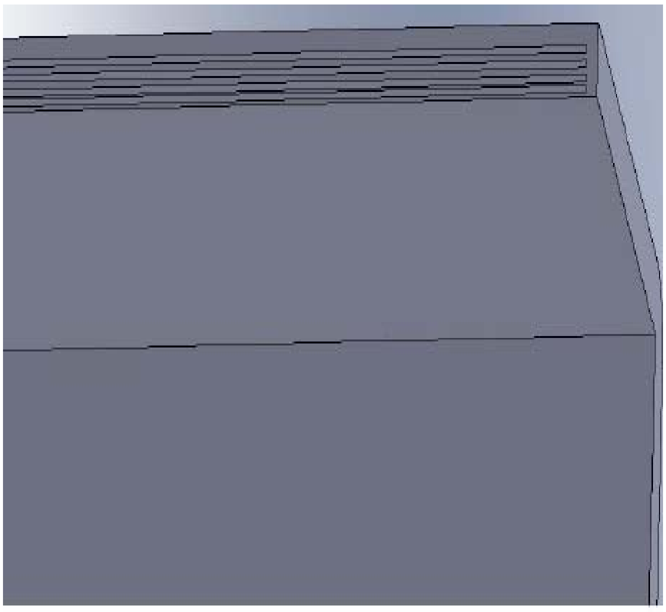


Figure 18 One part of the cube model, the sockets help the parts assembly

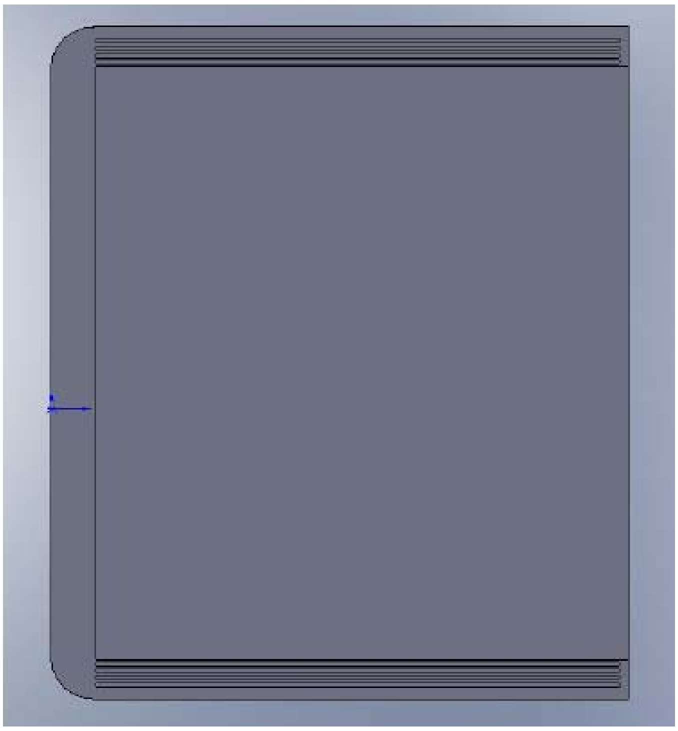


Figure 19 The base part of the cube model.

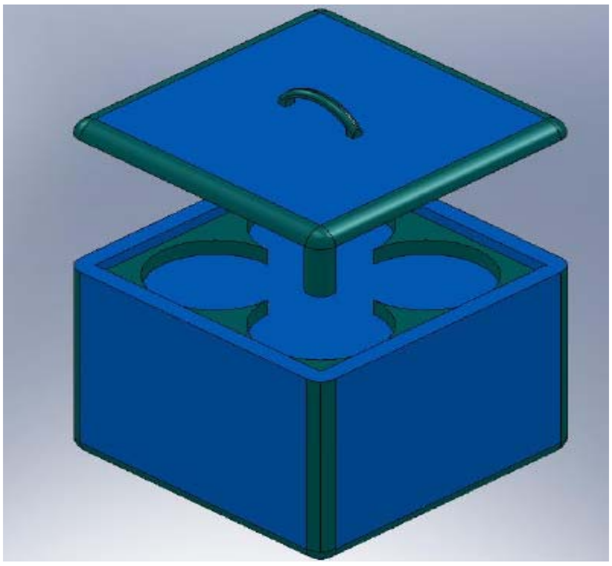


Figure 20 The whole cube model

15 INSULATION CALCULATIONS

Heat transfer is from a high temperature object to a lower temperature object. It changes the internal energy of both systems involved according to the first law of thermodynamics

Conservation of energy principle

$\Delta u = Q – W$

Δu = change in internal energy

Q = heat added to the system

W = work done by the system

The rate of heat loss is given by $Q/t = (KA\,(T_{heat}-T_{cold}))/D$

K = thermal conductivity ($W/M^{o}C$) of the barrier

A = area

D = thickness

16 CALCULATION OF BATTERY

The following calculations were made to find out the required battery capacity to cool a hundred cans without recharging. Since it takes eight minutes to cool four cans it will take 200 minutes to cool a hundred cans.

$E = C * V$

E = Energy Stored in Battery [Watt – Hours]

C = Capacity [Amp – Hours]

V = Voltage [V]

The system should draw 9 amperes for 200 minutes, because each of the two Peltier elements draws 4, 5 amperes.

$C = I * t$

t = Time [Hours]

I = Current [A]

t = 3,3 hrs

I = 9 amp

Using these values a capacity (C) was found out as 30 ampere – hours.

To increase battery life it is not good to fully discharge the battery for each charge cycle. Instead only 80% of its charge should be used.

C' = C/0,8 = 37,5 amp – hours

C' = New capacity where life cycle is considered

To change this value into watt – hours it needs to be multiplied with the voltage.

C' * V = 345 Watt – Hours

http://www.powerstream.com/battery-capacity-calculations.htm

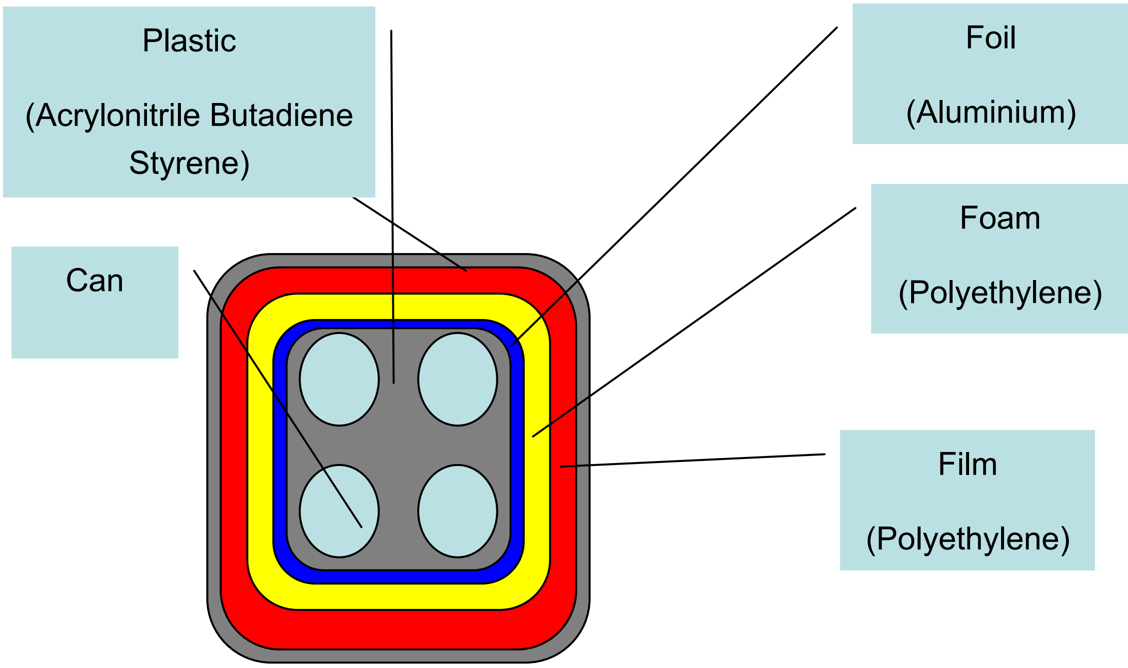


Figure 21 Layers of beverage can cooler

17 DESIGN SELECTION

There are 6 designs to choose from, and from these the cube shaped was selected. Because the Peltier element is rectangular, the cylindrical shaped designs were eliminated. The cube has no joints, so it is more durable in that respect. It is also in the shape of a cube, so it is easy to fit anywhere.

Final Work Flow

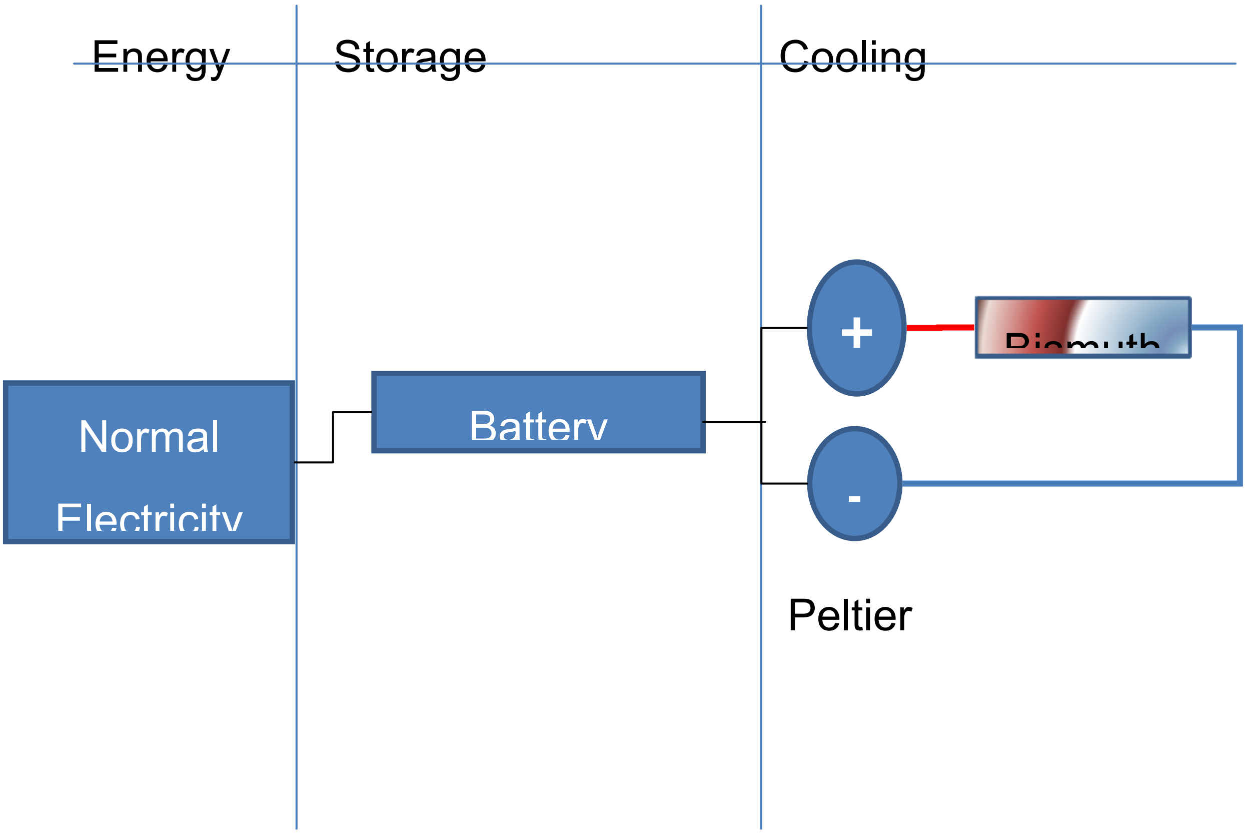


Figure 22 Final work flow of beverage can cooler

The current comes from the plug to the battery and from there the Peltier gets the needed current to operate.

Ventilation for Peltier elements and battery

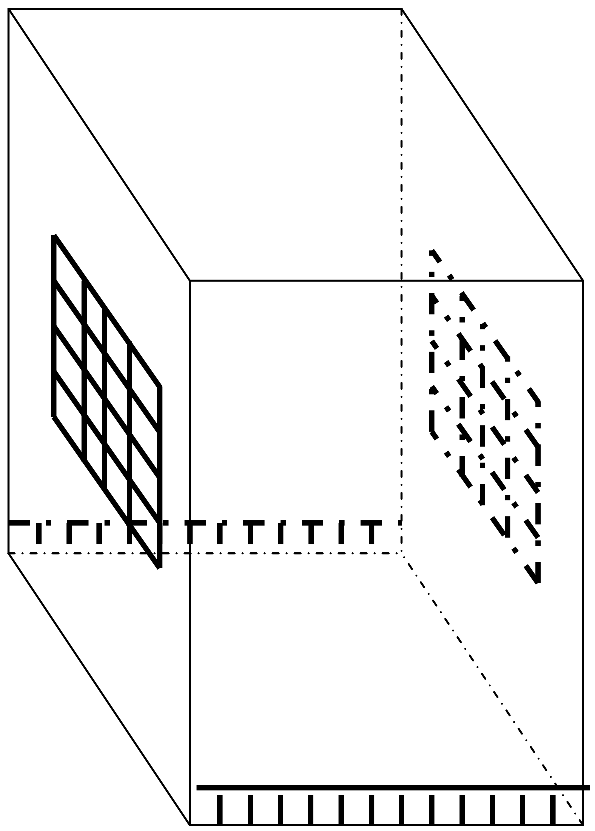


Figure 23 Ventilation of beverage can cooler

The Peltier elements and the battery will require cooling to prevent overheating. Since the Peltiers will be placed on the sides, the best place for the ventilation is just behind them. The Peltiers will also have aluminum plates as heat sinks. The battery will be placed at the bottom of the beverage can cooler, and its ventilation will be on the lower part.

18 IMPROVEMENT IN THE FUTURE

18.1 Waste Heat Recovery

Thermoelectric materials can be used for either cooling or power generation. Since they have no moving parts compared to conventional energy technologies, they are more reliable and durable.

In the beverage cooler, Peltier element was used to produce a refrigeration effect by a process known as “Peltier effect”. A heat sink comprised of thin aluminum plates was used to dissipate the heat produced on the hot side of the Peltier element into atmosphere. It would be more efficient if the heat energy was converted to electrical energy, which would in turn be used for battery charging or for other purpose, using thermoelectric power generation technology.

18.2 Process

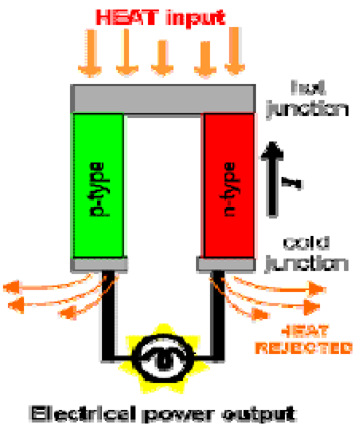


Figure 24 Peltier element for waste recovery

Thermoelectric generators are based on materials that are special types of semiconductors. When coupled, they function as a heat pump: a temperature gradient is applied across a sample, electrons diffuse from the hot to cold part due to the larger thermal speed of the electrons in the hot region, a charge difference then builds up between the hot and cold region, creating a voltage and producing an electric current.

In this case of the beverage cooler, the small amount of heat energy would not be enough to produce enough current because of the fact that in nowadays thermoelectric material power generation, current devices have a low conversion efficiency of around 10 per cent.

Researchers are studying on possible special thermoelectric devices that can be used as thermoelectric generator to recover waste heat and convert it more efficiently into more usable electrical energy.

In the near future thermoelectric waste heat recovery will make a significant contribution, over a wide range of applications, in reducing fossil fuel consumption and global warming.

18.3 Different Power Source

Once renewable energy technology advances enough it may become possible to make a system that uses solar energy, or other type of clean energy. The solar energy battery could be used in the power source design. This kind of solar energy battery does not have a high efficiency but it could be developed in the future. A kind of electric hand torch gives another way that uses the human power to get the energy. But it does not suit the design because that it is not portable.

18.4 Automation and Temperature Control

The system could be developed to have automation for temperature sensors to stop the cooling when the beverage reaches the desired temperature. Remote controlled systems, or voice activation could also be developed. In this part a temperature sensor could work as a switch. The temperature sensor is in the normal closed state. When the temperature reaches the desired temperature the sensor is working in an open state, the cooling will be stopped.

19 CONCLUSIONS

Portable beverage can cooler was designed step by step. The first step was to design the model of the portable beverage can cooler then choose the best one from the portable side. The second step is to divide can cooler to many components and deign each part. The third step is to choose the suitable material for each part. The fourth step is to calculate something about the battery and the cooling then find the best model from the technology side. To choose the cooling method is suitable for the product requirements(For example, low noise, the weight is light and the product is small)

We learned the advantages and disadvantages for the different ways and how to calculate the cooling and battery. We used the knowledge of material selection to help us in materials of part choosing.

Component of layout

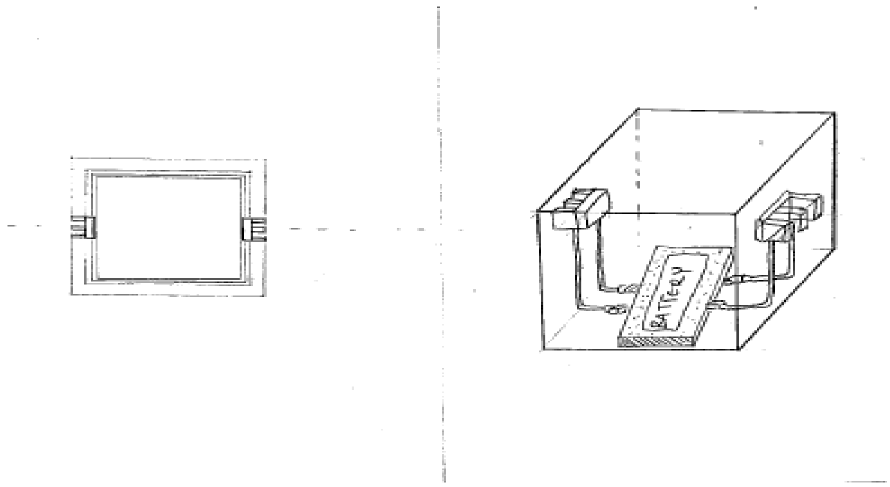


Figure 25 Peltier component layout view

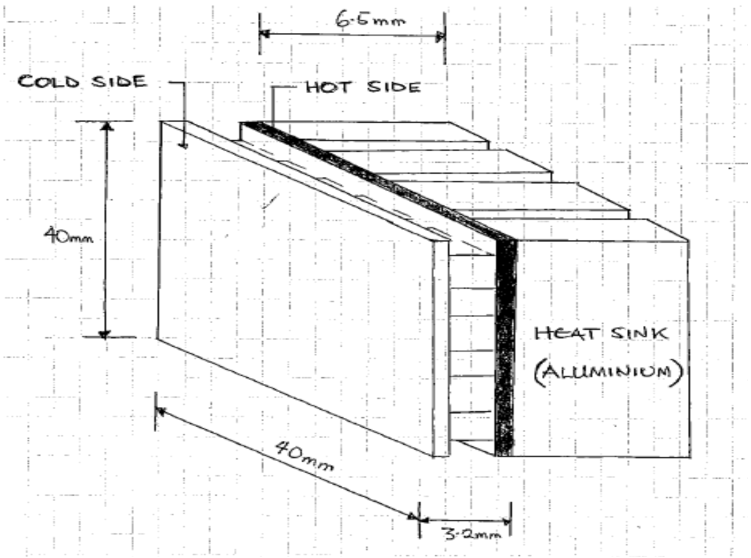


Figure 26 Peltier layout

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