Process & Equipment Design of Frozen Car Project

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ABSTRACT

The purpose of this project is to create a public art display that consists of a car suspended within a block of ice. The full-scale project will be constructed in the fall of 2007 and will be displayed in either Ann Arbor or Detroit in the winter of 2008. The project should involve the public throughout every step of the process from freezing the water to the car emerging from the ice. The goal of the ME450 group is to design a safe and efficient process that will be used to create a proof-of-concept scaled prototype taking into account heat transfer, manufacturing, and structural aspects of the design.

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INTRODUCTION

This project, Project 22: Process and Equipment Design for Frozen Car Public Art Exhibit, entails freezing a 1978 Chevrolet Nova in a block of ice and displaying it in a public location for public viewing. The sponsors are Sue Wrbican, Professor of Photography at George Mason University, and Mary Carothers, Professor of Photography at the University of Louisville. It is our responsibility to take their artistic vision of the car being encased or preserved in ice and developing it into a feasible process and design. Our sponsors requested that the ice be crystal clear, the car be positioned in an upward bank curve, the freezing process be safely visible to the public, and the process be environmentally friendly. The project will be placed on display beginning next winter 2007/2008. The team has developed a design and process that will fit our sponsors' needs and will be mechanically feasible.

INFORMATION SEARCH

The project posed several engineering problems which we thoroughly researched and analyzed. First we obtained the dimensions of the 1978 4-door Chevrolet Nova and found the density of ice. [1,2] Next, we investigated ways in which to freeze a volume of water similar in size to a backyard swimming pool. It is also important that the ice is clear and can be preserved once put on display. We attended the 25th Annual Plymouth Ice Spectacular on January 20, 2007 to gain some insight into the problem. While the artists at the show did not actually create the ice blocks themselves, we learned that they were provided by the Department of Commerce of the City of Plymouth. We made contact with the department and obtained estimate prices for the ice blocks from their supplier Home City Ice in Romulus, Michigan.

We researched the possibility of freezing the water similar to the way water is frozen for an ice hockey rink. For this we took a tour of Yost Ice Arena and observed their freezing system first hand. This system entailed piping filled with glycol that ran under the ice. The piping was connected to a cooling system the consisted of a compressors, condensers, pumps, throttle valves, and evaporators. Also, our sponsors provided us with a website about an artist, Tavares Strachan [3]. Strachan removed a four ton block of ice from the Arctic Circle and put it on display in the Bahamas, keeping it frozen using energy from solar panels. We have researched this possible technique as well but will not utilize it due to high cost.

A second problem we have researched involves the tank in which the car and water will be contained during freezing. The final tank will need to hold a volume of about 10,000 gallons of water and completely contain the car. Our sponsors would like for the walls of the tank to be clear so that the car can be visible during freezing. We have researched several different material possibilities for the tank walls including, Plexiglas, steel, sheet metal, and wood. The tank will also be disassembled once the ice is completely frozen for display purposes. We have researched several methods of disassembly using both bolts and waterproof caulking as a sealant on the tank.

Our sponsors' vision is for the car to be completely suspended in the ice at a tilt so that it appears to be going uphill on a banked curve. This means the car cannot simply sit in the tank as the water freezes; it must be suspended in this position. The current plan for supporting the car is to use four jack stands as seen on the website [6]. A mounting base will be welded to the base of the car to which the jack stands will be attached at the base of each wheel. The base of each stand will also be fastened to the base of the tank to ensure stability.

One of the world's most complete Giant Squids ever found is currently on display in a 3,500 kg block of ice in the Melbourne Aquarium in Australia [7]. The ice is one of the largest man made ice blocks ever constructed and has been frozen with exceptional clarity. This would have been an invaluable resource which could potentially provide us with insight on freezing processes, tank construction, and ice preservation. We unsuccessfully attempted to contact the museum curator, Nicholas Kirby, for more information regarding this project.

CUSTOMER REQUIREMENTS AND ENGINEERING SPECIFICATIONS

After talking to our sponsors, we used a Quality Function Deployment (QFD) diagram, located in Appendix A, to organize our customer requirements and engineering specifications for our projects. Benchmarking is difficult in our specific project because of the uniqueness to the art concept and design.

CUSTOMER REQUIREMENTS The majority of our customer requirements are based on aesthetics and safety of the final product. The most important requirements we found were aesthetic appeal and ice clarity. Ice clarity is very important so that the car can be clearly seen suspended in the ice. The sponsors described this as wanting it to look like the car was "preserved in a block of ice." The length of time that the block of ice lasts is a critical issue since the display will be outside and thus subject to variable conditions. Our sponsors would like the block to melt slowly until spring. Thickness of ice, which is another critical requirement, will be varied in order to adjust the lifetime, cost of frame construction and transportation, and energy required to freeze the ice. The position of the car is important because the sponsors have requested a tilted position so that the car looks like it's going around a banked curve. This will help increase the visibility of the inside of the car. Another aesthetic requirement is the final shape of the ice.

As far as cost requirements, we were given $1000 for the prototype, and the budget for the final project will be around $10,000. The final project will be paid for by grants and fundraiser so this number might change according to the success of the fundraising. However, both sponsors are very aware of the budgetary constraints on this project. We also have environmental requirements on the project. We were told to use an environmentally safe liquid to freeze the ice avoiding harmful substances such as Freon whenever possible. The sponsors also had a request to make this project viewable to the public and would like the entire process to take place where it can be seen. This includes the assembly process of positioning the car and freezing the ice. They also mentioned that the car did not need to be drivable after the project ends; therefore, parts that do not affect aesthetics such as the engine can be removed. However, the seats and steering wheel should remain intact.

ENGINEERING SPECIFICATIONS We have two different sets of technical engineering requirements for this project which are heat transfer related elements and structural related elements. The relationship between these areas will also be examined. For the heat transfer management requirements, we are considering ice clarity, freezing process, heat loss management, and block shape/dimensions. The ice clarity is going to be affected by the external conditions such as precipitation and temperature for both the freezing and melting processes. This will be measured by the distance that can be seen through the ice. The freezing process will need to account for outdoor conditions and public safety. The heat loss management will be incorporated in our design once we determine the length of time that the block will last. If this is found to be too short of a time period, we can work on ways to reduce the amount of heat that the ice absorbs. The block shape and dimensions will also have an affect on the lifetime of the project. The larger the ice block the longer the block will last. We will calculate how long it would take for this volume of liquid to freeze and melt.

Engineering Specifications
Visibility through ice
Freezing process
Water drainage quantity
Support system
"Ice tray" material strength
Heat loss dependent on temperature
Block shape and dimensions
Lifting the car – Piston strength and size
Stresses on car and walls
Public safety – Distance of interaction with structure

Table 1: Engineering Specifications

For the structural specifications, we are taking into account the support system, ice melt drainage, lifting the car, block shape/dimensions, and stresses on the car caused by the ice during freezing and melting. The support system will hold the car and ice in place throughout the duration of the project. For safety reasons, the drainage water from the melting ice will need to be controlled and removed from the surrounding area. This design can be incorporated into the structural support. The purpose of lifting the car would be to position it at an angle. The block shape and dimensions will affect the way that the structure is designed, the payload of the project, and the transportation process of the ice.

QFD ORGANIZATION As was previously mentioned, we used a QFD, attached in Appendix A, to organize our customer requirements and our engineering specifications. The customer requirements are located in the left column and are weighted on a scale from 1 to 10 with 10 being the maximum importance. These requirements are determined from direct conversation with our sponsors. The engineering specifications are located across the top of the chart below the triangular section. These allow us to list the technical elements needed to complete the project.

The central section of the QFD is the relationship matrix. This is where we determined the correlation between the customer requirements and the engineering specifications. The scale is 0 for no correlation, 1 for low correlation, 3 for medium correlation, and 9 for strong correlation. This allows us to see the interaction between the goal and the means to get there. The group agreed on all of these values after careful reasoning and evaluation. Some requirements and specifications that have strong correlations are ice clarity and visibility through ice, safety and "ice tray" material strength, and lifetime of the ice and heat loss. Some pairs that have weak correlations are the position of the car and "ice tray" material strength, environmental friendliness and heat loss, and aesthetic appeal and heat loss. These correlation values are then multiplied by the customer importance and summed vertically. The larger the value is the greater the importance to the engineering specification. We found that the most important specification was the ice clarity followed by the structural support system.

The correlation matrix, the triangular portion of the QFD, tells us how the engineering specifications are related amongst each other. The symbols used in this section are "++" to represent a strong positive correlation, a "+" to represent a weak positive correlation, a "-" to represent a weak negative correlation, and a "--" to represent a strong negative correlation. We determined that the ice clarity will be strongly dependent on the method that is used to freeze the ice. Bubbles need to be reduced during the freezing process to ensure optimum clarity. We also decided that the support system had strong correlations with the ice tray material, the block shape/dimensions, and the stresses on the car/walls. Another strongly correlated relationship will be the heat loss management and the block shape. This relationship is relevant because the larger the ice block, the longer it will take to melt. Therefore, fewer measures will need to be taken to prevent ice melting.

CONCEPT GENERATION

FAST DIAGRAM AND MORPHOLOGICAL CHART After brainstorming, we came up with some initial concept designs. A Function Analysis System Technique (FAST) diagram was used to generate the functions of these designs. The main goal of the project is to exhibit a frozen car. This car exhibit will be achieved by: 1) setting up the exhibit, 2) displaying the exhibit, and 3) disassembling the exhibit all while taking into account the visual appeal and assuring dependability and convenience. This process is shown in the FAST diagram located in Appendix C. A morphological chart, Figure 1, was used to generate and classify concepts.

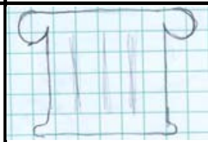
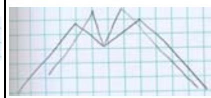
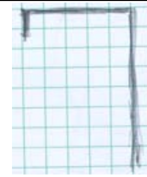
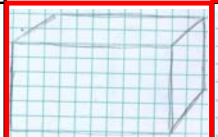
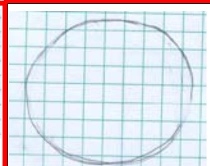
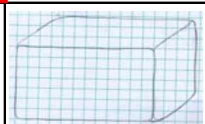
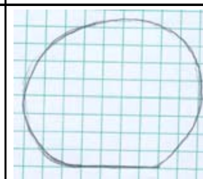
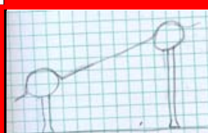
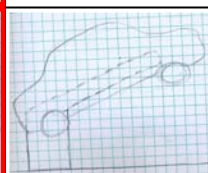
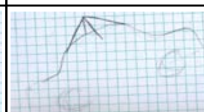
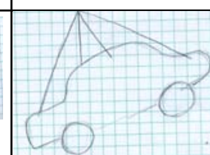
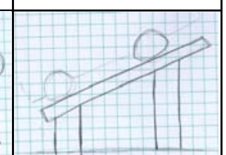
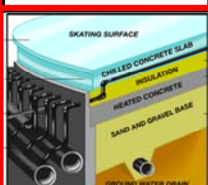
Sub Function	Working Principle 1	Working Principle 2	Working Principle 3	Working Principle 4	Working Principle 5
1. Base	 **Pedistal** similar to a ancient greek column	 **Cement Platform**	 **Cement raised platform**	 **Poles and suspension cables**	 **Pole**
2. Shape of the Ice	 **Prism**	 **Sphere**	 **Prism with Rounded Edges**	 **Sphere with Flat Bottom**	
3. Car Supports	 **Jacks** fastened to the car behind each wheel	 **Cantevleer Beam** running through the car with it only sticking out at one end.	 **Suspension** with the cables attached to the roof of the car	 **Suspension** with the cables attached to the body of the car	 **Platform**
4. Freezing Process	 **Chillers** running through the base, similar to an ice rink	**Giant Freezer**	**Tubes of coolant** on top and sides of tank	**Freeze Small Block** then assembly around the car	**Natural Freezing** based on the cold winter weather
5. Type of Tank	**Metal Tank**	**Plexi-glas Tank**	**Fish Tank** that is bigger then the block of ice the car is in	**Plastic Tank**	

Figure 1: Morphological Chart

Setting up the exhibit will entail preparing the site foundation to make sure there is enough support to prevent sinking of the project and to make sure that there is enough power supplied for the cooling system to run constantly. Then we will need to create the base for the project. This base will be made of a sturdy and strong material. The base height should be elevated to bring up the level of the project to the observers eye. Also, the base should integrate a cooling system to prevent the ice from melting. The base should also provide enough structural support for the car. The next step will be to elevate the car. This will require lifting the car to the appropriate tilted angles to simulate an upward sloping banked curve. The mechanism used to elevate the car must be blended with the ice to reduce its visibility. We must then assemble the tank around the car. The tank must be collapsible so welds and seals will need to be created at all the joints to prevent water leakage. The public must be able to view the process. Next, the tank will need to be filled with water being careful not to create bubbles in the ice. We will then use the cooling system to freeze the water, and once frozen, the tank will then be removed. The main component of the removable tank again is the walls can be taken apart and the materials will be easy to remove. Finally the car will be ready to be exhibited.

Displaying the exhibit will require monitoring of structural supports and surrounding areas for safety.

Disassembling the exhibit will require the car to be lowered and removed from the base. We will also need the cooling system to be removable. The coolant will need to be taken out carefully so that it does not spill because it could be an environmental hazard. The base will need to be able to be demolished or removed from the site.

To create the appropriate visual appeal, we must clarify the ice to allow it to be visible, angle the car for dramatic effect, and hide the supports creating a feeling of being suspended within the ice. Clarifying the ice will involve freezing in a continuous process by utilizing a constant flow of water, removing the bubbles by inserting a tube to release them after freezing, and to purify the water so that there is no dirt or debris. Angling the car will involve using four separate adjustable legs. By making these legs individually adjustable, we will be able to achieve the artists' desired angles so that the car will appear on an inclined banked curve. Hiding the supports will involve decreasing the size and width so that it decreases the visibility to the spectator. Also, painting the supports white will help to camouflage the structure and make the car feel like it is being suspended and preserved in a block of ice.

To ensure dependability, we need to prioritize safety by guiding the car to the ground throughout the melting process. This will require us to control the motion of the car with adjustable supports that can move so that the car doesn't place abnormal stresses on the system. We also need to be able to control the melt off from the ice so that it doesn't pool around the display causing hazards for spectators. We will achieve this by making the melt off flow away from the design using a piping system. Along with safety, we would like to increase the life of the ice. Since ambient temperature will not be controllable, we would like to use chillers to reduce the temperature variability.

To insure convenience, we would like to make the project approachable and accessible to spectators. This would be achieved by decreasing the size of the supports so that people can be close to the project. Another goal we have is to involve the public through out the entire project including the freezing and melting process. For the freezing process, this would involve constructing a removable tank so that the freezing can be done on sight.

CONCEPT EVALUATION AND SELECTION

We were able to narrow down to our final concept because of one major factor: feasibility. We generated all of our concepts with sponsor feedback solely based on aesthetic appeal. Once we took a step back and looked at the concepts from the engineering perspective, we were able to determine that only one out of five designs was feasible.

We again used the morphological chart, Figure 1, to mix and match different parts together to generate our five concepts. There are many factors as to why the four concepts were not feasible: cost, lifting limitations and support limitations. The weight of the ice for these four designs would have been too large for this project. Our final concept design has the simplest shape block of ice and a simple support for the ice, which decreases the cost and weight. We will freeze the block of ice on the base so that lifting will not be required.

Also, to ensure that we had chosen the correct design we made a Pugh chart, Table 2. The criteria is based on our design requirements and engineering specifications. They were all ranked on a scale of 1-10, 10 being the most important. Then each concept design was evaluated based on how they incorporated each of the criteria. The design concept that had the highest total was the design concept that best fit into our criteria. Design concept 1, Appendix D, was the final selected design because safety, cost, and size wise it was going to be the most feasible. Out of the five designs, concept 1 used the least amount of water, would take half the time to construct, and would dramatically decrease the cost of the project. The other criterion rating for concept 1 met or was only slightly below the rating of the other concepts.

Criteria	Importance Rating	Concept 1	Concept 2	Concept 3	Concept 4	Concept 5
	Rating 1-10					
Ice Clarity	9	90	81	90	90	90
Position of Car	6	60	10	60	60	60
Clearance from Ice	2	20	10	20	20	20
Length of time it lasts	7	56	56	42	42	42
Controllability	7	35	70	0	0	0
Surface Area/Volume Ratio	7	35	35	56	56	56
Cost	6	42	6	6	18	18
Environmentally Friendly	8	64	72	56	40	40
Viewable to the Public	4	36	10	36	36	36
Condition of Car	4	32	28	28	28	28
Aesthetic Appeal	10	60	90	90	80	80
Safety	10	80	90	20	20	20
Construction Time	6	54	42	24	30	30
Total		608	544	486	478	478

10 is a positive contribution to the desgin
1 is the least positive contribution to the design
0 has no effect

Table 2: Pugh Chart

SELECTED CONCEPT

The selected concept, Figure 2, consists of the car positioned in a block of ice on a solid pedestal. The car, a 1978 Chevrolet Nova, is 16.4 ft. long, 6.0 ft. wide and 4.5 ft. tall. It will be positioned on a banked curve at a 10 degree upward angle and a 30 degree banked angle with the front of the car at the highest position. These angles were selected through trial and error and what would give the car the most aesthetic appeal, while remaining within a safe stability range. Everything will be removed from under the hood of the car and from the trunk. The windows and windshield will also be removed. The car will consist of a metal frame, four rubber tires, and cloth seats.

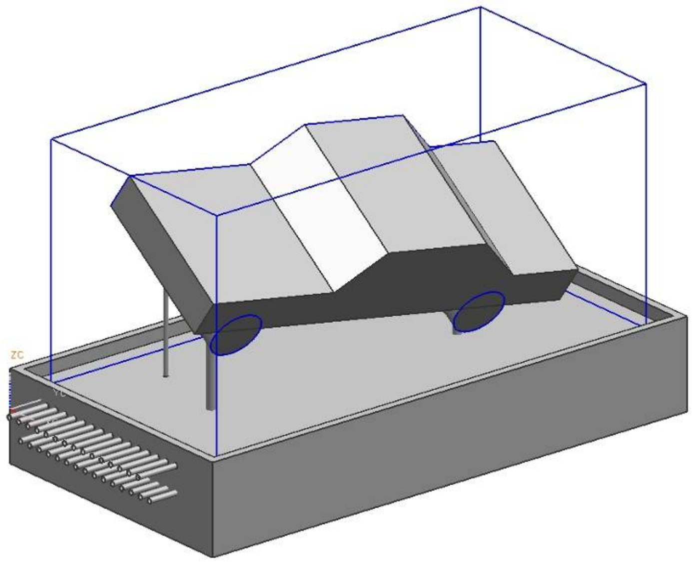


Figure 2: CAD Model of Base and Ice

The block will be dimensioned at 19 ft. long, 9 ft. wide and 9 ft. tall. These dimensions were selected after the car was positioned at the correct angle in the CAD drawing. Our sponsors requested that a two foot ice wall surround the car. The thicker the ice is the longer the melting time. Therefore, to maximize time while minimizing ice dimensions we selected the former dimensions rounded to the nearest foot for construction convenience. The block of ice will be frozen at a constant rate to avoid imperfections. The freezing will take place in a wood and Plexiglas constructed container with drainage for the melted water out of the bottom. The Plexiglas panels will allow for viewing of the freezing process and drainage will allow the ice to remain frozen longer.

The base is dimensioned at 21 ft. long, 11 ft. wide, and 3 ft. tall. This will allow a one foot clearance on all sides of the block to help with drainage and for safety purposes. The base is made of cooled concrete with a hollow center that will be filled with sand and copper piping. The tank walls for the block will have a rubber seal around the base that will butt up against the concrete base. The tank will be held in position by wood clamps attached to the concrete base, Figure 26. The piping for the cooling system will run through the concrete base and insulation, sand, will be placed around them, Figure 3. Copper pipes will be used with a glycol cooling agent. The pipes will connect to a chiller located on the outside of the tank, which will be accessible in a concealed chiller house. This is a very similar concept to the freezing processes of an ice rink. The chiller will simulate that same system used in an ice rink, bring the glycol down to a temperature of 10 degrees Fahrenheit.

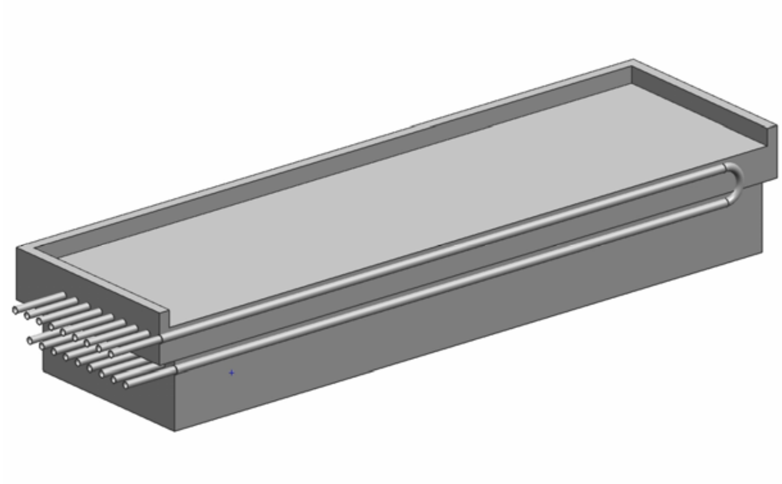


Figure 3: Base with Piping and Chiller Connection

Jacks will be used to support the car during the freezing process and ensure the safety of the exhibit visitors. The jacks will be hidden behind the wheels and will be painted white to make them less conspicuous. The jacks will be welded directly to the car so during the melting process the car will not slip from its original position.

ENGINEERING ANALYSIS

The engineering analysis required system breakdowns of the safety precautions, the prototype tank design, the full scale tank design, the car support system, the full scale base design, the manufacturability, and the environmental affects.

PROCESS FMEA Since our project is continuously on display to the public and is supporting extremely large load, we have made safety a priority in our designs. In order to identify potential safety hazards, we used the program DesignSafe to create a process failure mode error analysis (FMEA) chart shown in Appendix E. The purpose of the FMEA is to identify possible hazardous situations that will arise during the process.

We have defined the necessary people to carry out the project as well as the tasks that they will perform. To process will begin with a set-up person. This person will be responsible for setting up the base of the project. During this setup, this person could encounter hazards such as: crushing due to the heavy weight overhead objects, head bumping due to overhead objects, machine instability from the support system, falls from elevated work, falls from instability during construction, excessive force with high loads, ergonomic worries from lifting, ergonomic concerns with deviations from safe work practices and interaction between people. The person also must be aware of the fact that the base is going to be very cold. We are also requiring the set-up person to perform the demonstration of the support system and to check the alignment of the jacks supporting the car. Possible hazards for this are mechanical crushing, head bump on overhead objects, and instability of the support system.

The next person that we would require would be a maintenance technician. This person would be responsible for quality testing and routine maintenance. The potential hazard for this person would be improper wiring.

Another person that we will require is an electrician that will be responsible for connecting lines and wires to run the cooling system as well as inspecting the equipment after installation. This person should be aware of improper wiring, lack of grounding, and overloading.

The material handlers are responsible for bring the material to the project site and removing the tank after the freezing process is complete. They should be careful due to excessive weight and motor vehicle movement.

The engineer that is assigned to this project serves the critical function of conducting the tests to ensure safety, troubleshooting, communicating with supervisors, and inspecting the machinery. While the engineer is carrying out their required tasks, he or she should be aware of mechanical crushing, head bump on overhead object, machine instability, improper wiring, slipping on melt water, falling due to elevated work, excessive lifting, deviations from safe work practices, severe cold, and fluid leakage in the cooling system.

The remover will be responsible for disassembling the metal tank and preparing the equipment to be taken away by the material handlers. This task could encounter the following hazards: crushing, head bump from overhead objects, break up during the freezing process, machine instability, improper wiring, fall from elevated work, excessive lifting, deviations from safe work practices, severe cold, and fluid leakage from the cooling system.

There also needs to be precautions taken to protect the observer of the art display. The main hazard that they would face would be slipping on melt water. The other hazards have been minimized due to the timing and distance that they will be allowed to view the project. Once the melting begins the observer will be restricted from the immediate area.

The final process is material output by a maintenance technician. This technician would be responsible for disassembly of the remaining structure.

To ensure the highest safety, we have identified risk reduction for all of the previously mentioned failure modes. This information is located in Appendix E. A few of the high and moderate risk items will be listed in this paragraph along with a brief explanation of the solution. The first issue is crushing due to the large weight of the ice and the car located on the supports. This will be dealt with by the design engineer during the initial design phase. By adding a safety factor of 1.5 to each of the jack supports it should allow the system to support a much higher load. Another major concern is that the load would become unstable throughout the melting process. This will be addressed by having a daily maintenance technician monitor the display and document any issues concerning the load. The daily maintenance person will also be responsible for monitoring the support system after the freezing process has occurred and through out the melting process. This person should document any damage to the structure caused during freezing that may reveal itself once the ice has melted. Another important person for project safety is the electrician. The electrician will be responsible for covering any wires and making sure that the site has the capability to support the cooling system/chillers.

After making the additional safety measure above, most of the risk levels were reduced to low risk. The structural damage of the support system during the freezing was still at a moderate risk level mainly due to the unpredictability of the large scale freezing. This portion of the project will have to be watched meticulously and if the structural integrity of the exhibit is compromised in any way, the exhibit will need to be closed to the public until it is fixed.

PROTOTYPE TANK The 2:19 ratio prototype tank design consists of a base and four walls as five separate pieces. We chose this scaling factor so that the largest dimension would be able to fit inside the industrial freezer that we were using for the prototype. The walls consist of four 0.1 inch thick aluminum plates – two plates are 2′ X 1′ while the others are 1 ft square. The walls are joined at the corners using L-brackets and machine screws. The details of the tank construction can be seen in the prototype testing section. The bottom edge of the walls has a caulk seal to prevent leakage when secured to the base plate. The tank walls are supported by 2″ X 4″ wood pieces. These supports are attached to the base at the bottom and connect with a cross piece over the top of the tank. This is to provide support against the water pressure and keep the walls firmly pressed against the caulk seal. The supports are at the midpoint of the longer walls. Once the tank is fully assembled, the prototype car will be mounted in place before being placed in an industrial freezer and filled with water. Once the water is completely frozen, the walls are removed by first removing the machine screws and L-brackets.

The benefit of the design is that it can be reused many times to create several prototype ice blocks. This will allow us and the sponsors to get a better idea of how the ice will melt under different conditions. It will also let us test different ways of making clear ice without bubbles or cracks.

Figure 4 shows a finite element analysis using Altair Hypermesh. The analysis was completed before the prototype construction and confirmed the strength of the walls. The maximum displacement is 1.0 mm located at the midpoint of the smaller walls. The maximum Von Mises stress in the tank is 14.1 MPa. The analysis confirms that the wall displacement is minimal and that the safety factor for yielding in the walls is greater than ten.

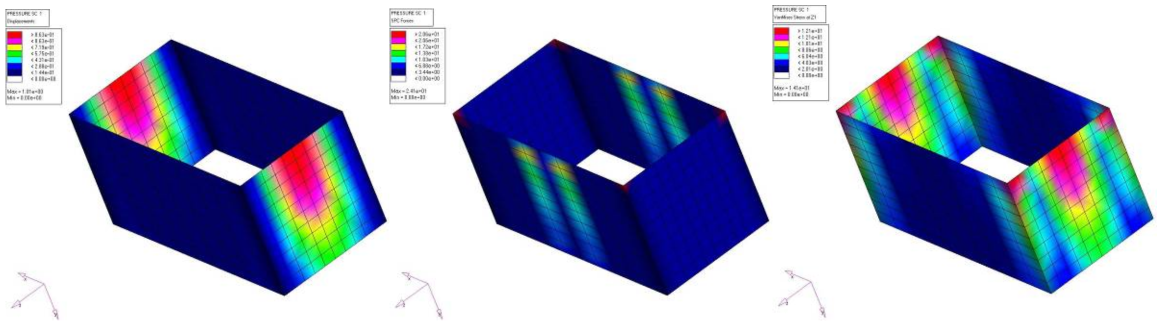


Figure 4: Finite element analysis shows prototype displacements, forces, and stresses

FULL SCALE TANK ANALYSIS The panel and frame size, material, and thicknesses were selected to ensure the strength of the tank as well as reduce costs. Table 3 shows the maximum stresses and displacements that each panel type and beam would experience if the tank was completely filled with water giving a maximum water pressure of 26.9 kPa. The locations of these extremes occur in the bottom panels and can be viewed in Figure 5. The process plan is to fill the tank slowly so that the ice forms from the bottom up. This means that the tank will not actually have to support a full load of water because the ice will form along the walls. However, it is important that the tank structure be strong so that it forces the ice to expand upwards rather than outwards. The analysis shows that the panels and frame are sufficiently strong with minimal displacements under the most severe conditions.

Material	Bending Yield Strength	Maximum Bending Stress	Safety Factor	Maximum Displacement
Aluminum	193 MPa	134 MPa	1.44	39.9 mm
Plexiglas	110 MPa	14.7 MPa	7.48	34.3 mm
Plywood	60 MPa	8.3 MPa	7.23	5.1 mm
4 X 6 beams	80 MPa	13.1 MPa	3.05	1.2 mm

Table 3: The tank is sufficiently safe to support a full tank of water.

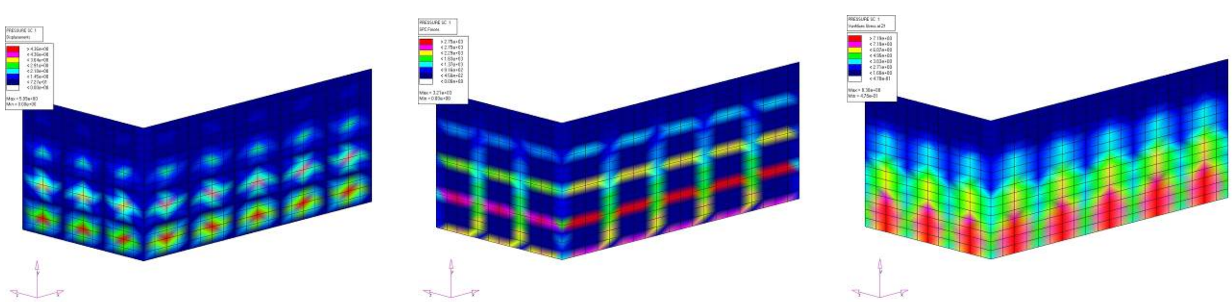


Figure 5: Displacements, forces, and Von Mises stresses of the tank filled with water.

The finite element analysis was conducted on the tank design using Altair Hypermesh and MD Nastran 2006 to get an idea of the locations and magnitudes of stresses and displacements in the walls. The water pressure is calculated using the formula $P = \rho g d$ where ρ is the density of water, g is gravitational acceleration and d is the water depth. Over one hundred point forces are applied to each wall to mimic the forces due to water pressure. Each point force represents the total force of the water pressure for the small area.

The analysis reported only the loads experienced by the tank frame rather than the stresses. The maximum stress experienced in the frame was calculated using beam theory and the load per unit length determined in the analysis.

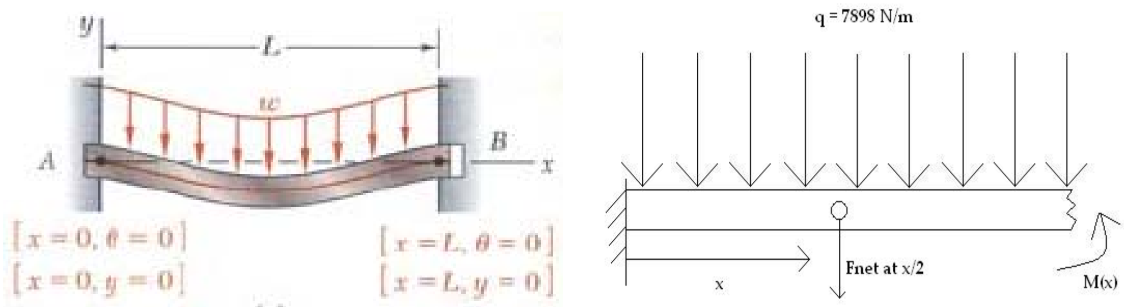


Figure 6: Load and stress analysis of the water pressure on the frame.

The deflection of the frame at its maximum load is found using the beam deflection equation:

$$EI\frac{d^2y}{dx^2} = M(x) = 2407.5xNm \qquad \textbf{Eq. 1}$$

$$EI\frac{dy}{dx} = EI\theta(x) = \int M(x)dx + A = \frac{2407.5}{2}x^2 + 0 \text{ (No angle deflection at joint)} \qquad \textbf{Eq. 2}$$

$$y(x) = \frac{1}{EI}\int(\int M(x)dx + A)dx + B = \frac{1}{EI}[\frac{2407.5}{6}x^3 + 0] \text{ (No deflection at joint)} \qquad \textbf{Eq. 3}$$

$$y(x = mid) = \frac{1}{EI}[\frac{2407.5}{6}x^3] = .0012m \qquad \textbf{Eq. 4}$$

Where E = 9.0 GPa (for pine timber) and I = $bh^3/12$ with b = 5.5″ (.1397 m) and h = 3.5″ (.0889 m). The value for x is taken at the midpoint of the beam section, or L/2.

The maximum bending stress in the frame is found at the outer edge of the beam, c = .04445 m:

$$\sigma = \frac{Mc}{I} = 13.1MPa \qquad \textbf{Eq. 5}$$

TANK FRAME CONSTRUCTION Each wall of the frame can be assembled independently. For the longer walls, the vertical beams are nine feet long while the horizontal beams are 19 feet long (see CAD, Figure 24 for detailed dimensions). For the shorter walls, the vertical beams are nine feet long while the horizontal beams are 10 feet long. Bolt the bottom beam of each wall to the base. Attaching supports across top of the tank can offer further reinforcement but should not be necessary.

The final weights of the constructed walls are 625 lb and 360 lb for one large and small wall, respectively.

NOTE: Prior to the joining of the four frame walls, the outside edge panels on the shorter walls must be fastened to the frame. The outer edge of these panels will be part of the four butt joints. All other panels can be added after the assembly of the four walls.

To maximize strength, we recommend using the following joining techniques for the various joints in the frame [12].

1. Cross halving - Used for intermediate framework. Half the thickness is removed from both pieces of timber where they cross. Mark out the width and depth of the recess in both pieces of timber and cut squarely to the depth line with a tenon saw. Use a chisel or pre-set router to remove the surplus material from between the cuts. Fasten timber pieces at cross with two screws or bolts. Twelve cross halving joints per long wall, six cross halving joints per short wall. The horizontal beams are on the outside.

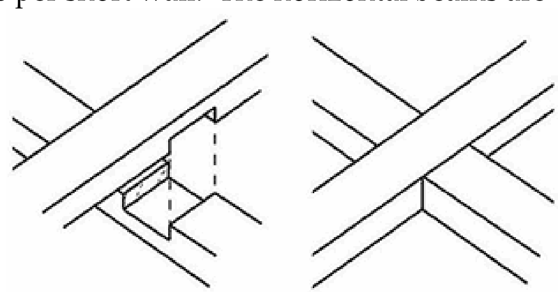


Figure 7: Demonstration of cross halving

2. Dove Tail - Mark out the width and depth of the recess in the edge timber. Then mark the angle for the dove tail, this can be achieved by using an adjustable square or by measurement. Cut the angled sides of the dovetail down to the depth line with a tenon saw. Use a chisel or pre-set router to remove the surplus material from between the cuts. Mark and cut the other piece as if it were for a corner halving joint. Then mark each side of the projecting piece with the same dove tail angle down to the shoulder line. With the timber secured in a vice, carefully cut the angle down each side to the shoulder line, reposition the timber and cut the sides along the shoulder line to remove the waste material. Fasten timber pieces at joint with two screws or bolts. This technique offers substantial increase in strength over a simple T joint. Fourteen dove tail joints per long wall, ten dove tail joints per short wall. The horizontal beams are on the outside.

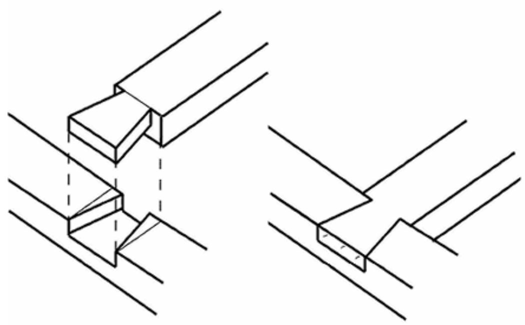


Figure 8: Demonstration of dove tail joint

3. Corner halving - Carefully mark out the end of each piece of timber including the depth. Make all cuts using a tenon saw. Secure the timber to a bench when cutting across the timber and place it in a vice when cutting from the end. Fasten timber pieces at joint with two screws or bolts. Four corner halving joints for each wall. Horizontal beams on the outside.

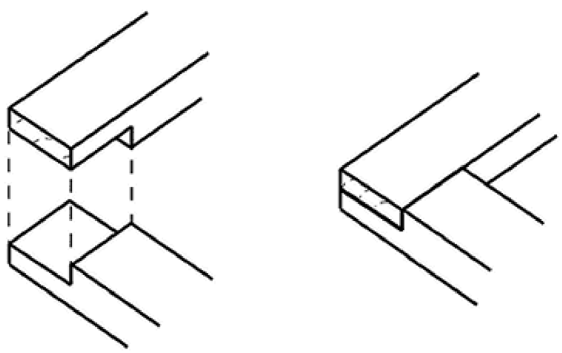


Figure 9: Demonstration of corner halving

4. Butt joint - The joining of the four walls consists of the longer walls "butting" into the shorter walls. Fasten the joint with approximately 30 screws. These are the final joints and complete the construction of the tank frame.

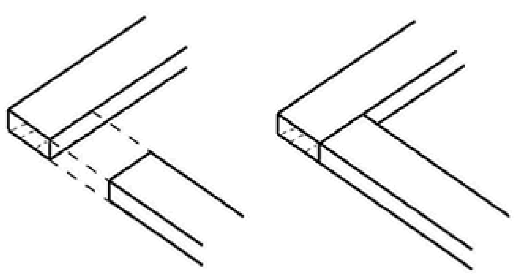


Figure 10: Demonstration of butt joint

PANEL ATTACHMENTS The frame is designed such that any of the 64 panels can be either ½″ plywood, 1/8″ 5052-Aluminum, or 3/8″ Plexiglas acrylic sheet. The final panel selection is at the discretion of the sponsors, but each aluminum or Plexiglas panel used will increase costs (see Table 9 on page _). We recommend using plywood for the bottom panels to maximize strength and minimize costs. The remaining panels can be attached as the water/ice level rises. Leaving the higher panels off initially will allow easy access to the ice for inspection and upkeep. We recommend using the aluminum panels at the higher levels if the chillers in the base are insufficient to freeze the water to higher levels and additional chillers are needed on the walls. The Plexiglas panels will allow the public to view the freezing of the car as requested by the sponsors.

The panels will be fastened to the frame by using 4-inch, round headed screws. The screws will pass through pre-drilled holes in the frame with the final half-inch of the screw tapping into the plywood panel. The panel will be pulled snug against the inside of the frame with the screw in tension by the head against the washer on the outside of the frame. Machine screws will be used for the aluminum and Plexiglas panels. Pre-drilled holes will have to be tapped in the panels before fastening. Using this technique will allow the panels to be detached from the outside. It does not matter if any of the screw tips should penetrate entirely through the panel. This should not happen but will not affect the final product if it does.

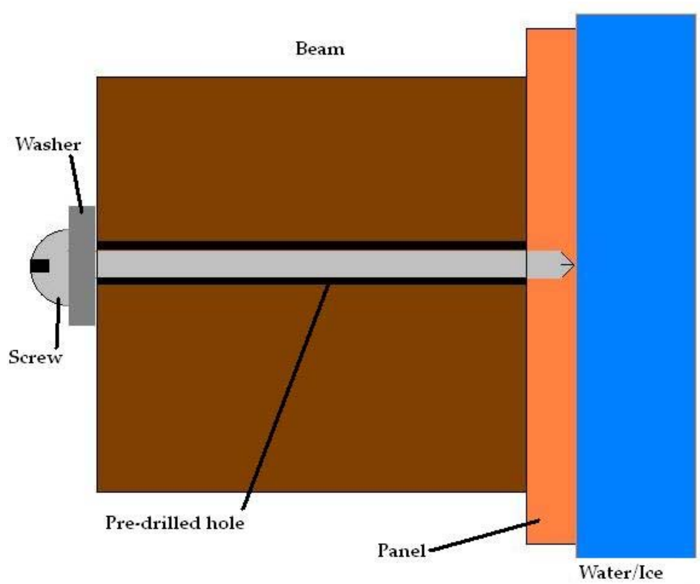


Figure 11: Demonstration of attaching the panels to the frame

After attaching the panels to the frame, we recommend lining the entire inside of the tank with 1-mm thick plastic drop sheets. This will prevent any leaking at joints, cracks, or through the wood panels/supports. During prototype testing, this method was much easier and more effective than attempting to use caulk and sealants to keep the tank watertight. The final benefit to the plastic lining is that it prevents the panels from sticking to the ice and allows easy removal.

TANK DISASSEMBLY Once the ice is completely frozen and ready to be displayed the tank can be disassembled. First, remove all screws attaching panels and joints. The horizontal beams will be the first removed on all walls from the top down. Next the vertical beams can be taken down. Finally, the panels can be peeled from the ice to reveal the ice and car.

CAR SUPPORT SYSTEM To determine the load each jack stand will support, we first calculated the center of gravity (C.G.) of the car. The dimensions and weights of the 1978 Chevrolet Nova were obtained from the website novaresource.org. The axle loads of a functional Nova were given, along with engine weights. The longitudinal C.G. was determined using a moment balance with the axle loads and wheelbase. The vertical C.G. was estimated using values from a data library of similar sedans found in the computer program, CarSim. The lateral C.G. is assumed to be in the center of the car.

We made a conservative estimate that 750 total pounds of parts including the 600 pound engine would be removed from under the hood once it is "gutted". Since the C.G. for the removed parts is unknown, and we do not have the actual car to make measurements, we estimate its location to be 20 cm behind the front axle and 55 cm above the ground. Considering this, the C.G. of the car after it is gutted is shifted back and up with no change to the lateral position. Table 4 and Figure 13 show the location of the C.G. of the car before and after removing the parts. The longitudinal position is measured behind the front axle, the vertical is from the ground, and the lateral is from the wheel center or car frame.

	Mass (pounds)	Longitudinal C.G. (cm)	Vertical C.G. (cm)	Lateral C.G. (cm)
Functional Nova	3182	126.9	60.4	77.9
Gutted Nova	2432	159.9	62.1	77.9

Table 4: Location of the car center of gravity.

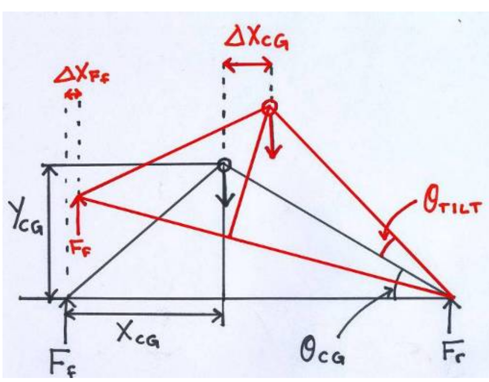


Figure 12: Free Body Diagram of the jacks.

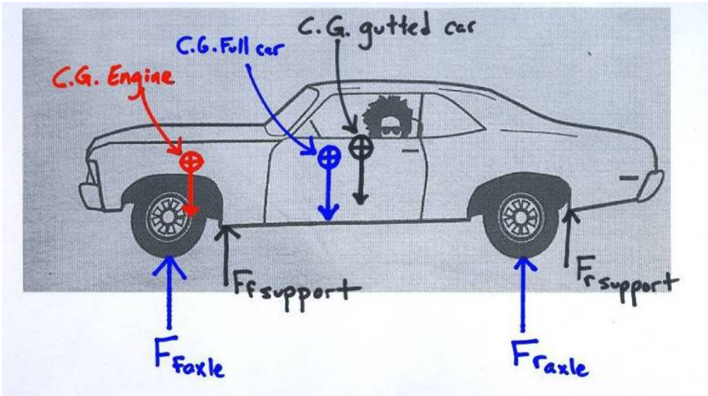


Figure 13: Free Body Diagram of the car.

The design for the car support system consists of four high capacity jack stands attached to the car frame behind each wheel approximately 29 cm from each axle. The specifications of the jack stands are included in Table 5. The jack stand models were selected based on safety, height, and appearance. The load supported by each stand was determined using moment balance equations after recalculating the horizontal shift of the car's C.G. laterally and longitudinally based on the degree of tilt. Since the car C.G. is higher than the locations of the supports, the C.G. will shift towards the lower end of the tilted car. This shift is more extreme laterally due to the 30 degree roll tilt as opposed to the 10 degree pitch tilt.

Location	Model	Height (inches)	Load (pounds)	Capacity (pounds)
Driver (low) rear	Ranger Rolling Stand	30	804	36,000
Passenger (high) rear	Ranger High Stand	60	367	1,650
Driver front	Ranger Rolling Stand	50	972	36,000
Passenger front	Ranger High Stand	80	289	1,650

Table 5: Height, load, and capacity of jacks at each wheel location

HEAT TRANSFER One of the major engineering aspects to consider for this project was the heat transfer and the thermodynamics in the system. This helped us to determine if this project was feasible and economical. We had to figure out if the system that we proposed would be able to handle the requirements. The first concept was to let the ice freeze naturally. It was thought that since Michigan is naturally cold that we would be able to freeze the ice by leaving the water out long enough. To analyze this issue, we looked at an average temperature plot for the City of Detroit, shown in Figure 14, where we took the temperatures every 3 hours for the past 4 years. From this plot, we were concluded that due to the fluctuations, we would not be able to freeze using a natural process, so an alternate process had to be designed.

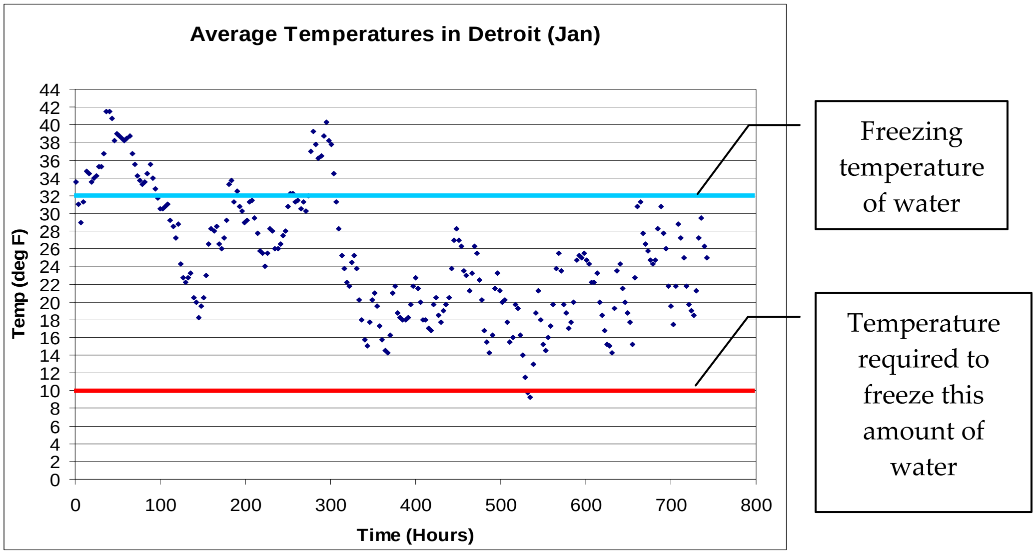


Figure 14: Average temperatures for the city of Detroit for the month of January.

Chiller In order to freeze a block of ice this size, a considerable amount of energy needed to go into the system. One of the specifications of this project was to make the process completely visible to the public from start to finish. When deciding how to freeze the water, we looked at different systems that could be used outdoors. The first idea was a system that is used in ice rinks, but we did not know if it would provide the amount power that would be required to freeze such a large quantity of water.

First, we needed to mimic the construction of an ice rink within our own base. This includes running copper pipes through the concrete and also using proper insulation so that we would not lose too much energy while still getting ample energy out of the system. Figure 15 shows a schematic of how the base would be constructed with these different layers.

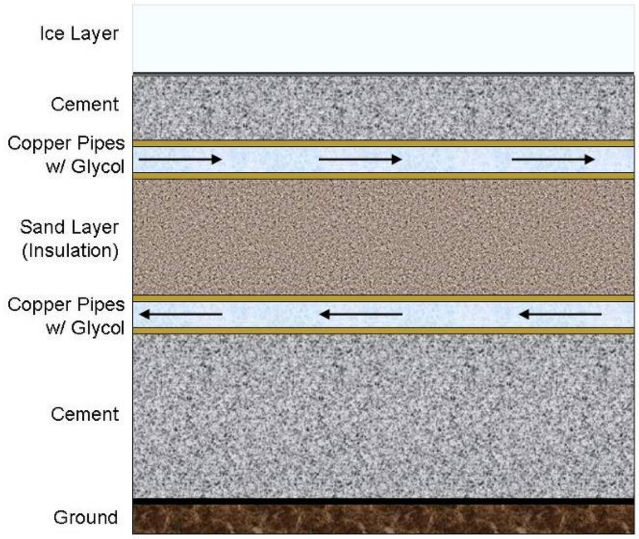


Figure 15: Detailed cut-away of the base with each layer.

From this concept, we were able to look at it from a heat transfer perspective. In order to fully understand the system, we drew a thermal circuit diagram, including all of the intermediate temperatures, thermal resistances, and heat sources. This is shown in Figure 16.

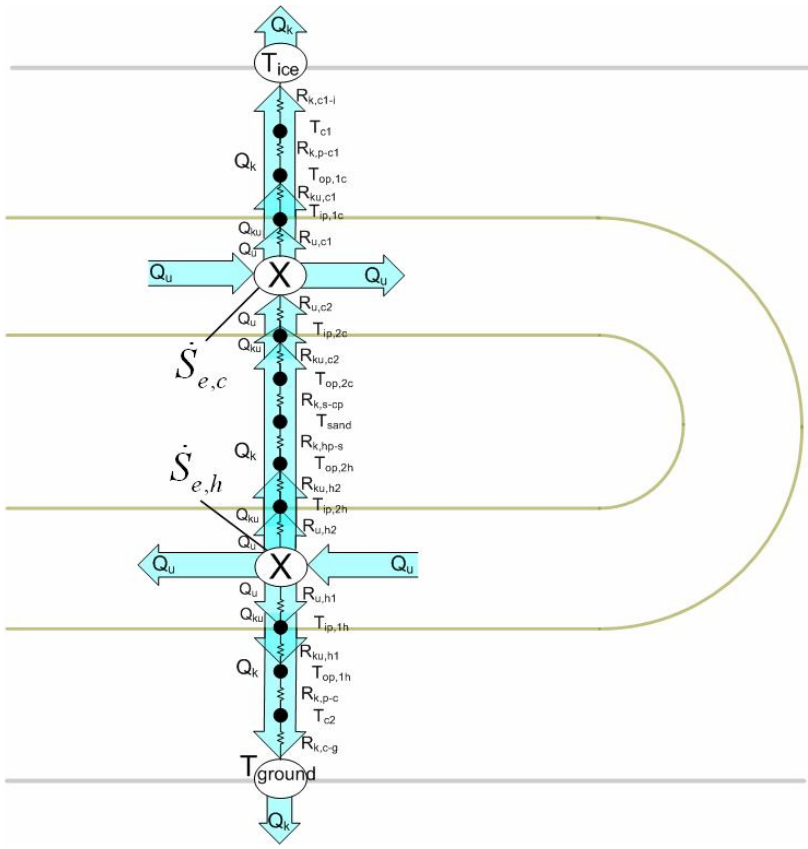


Figure 16: Thermal Circuit Diagram for base chiller system.

Assumptions Before we started any of the calculations, we made assumptions based on the nature of this problem to help simplify the calculations. First, we assumed that the insulation between the top pipe and bottom pipe perfectly insulated both pipes so that no heat was transferred between the two. Some of our initial calculations of the system showed that the energy leaving the bottom tube, traveling through the layer of sand and entering the top tube was small compared to the entire system. Second, based on our research of similar systems, we made the assumption that the difference in temperature between the glycol coming into the system and the glycol leaving the system was 10° F. The third assumption that was made about the pipe system is that the flow within the pipes was fully turbulent. This was safely made because we calculated the Reynolds number for the system and got a number higher than the crucial value. We assumed that it would have already reached this stage by the time the glycol came from the chiller to the base and entered the cement. There would be ample time and space for the glycol to get to its turbulent state. This was so that we did not have to include the small amount of time that the glycol will have laminar and transitional flow. When doing the calculations for the chiller, we assumed that the edge of cement was at 32°F. We felt confident making this assumption based on the fact that the cement will be outside for a considerable amount of time prior to starting the freezing process. Some other assumptions that we made included all of the constant properties and ideal gas behavior. Also, we assumed that we were operating under steady state conditions, the glycol was an incompressible liquid with negligible viscous dissipation, and that we were operating under a pressure of 1 atmosphere. Finally, all of these calculations were done without the car in the system. Having the car within the ice, added a level of complexity that was not necessary for the calculations and would have little effect on the outcome.

Selecting a Chiller We knew that we wanted to purchase a chiller and not construct our own because of the size of the project. After research, we found a 20-ton chiller that we felt would work best in our case. We picked out the chiller before starting the calculations so that we would know how much energy is going to be entering the system. We started with the largest chiller of 20 tons, but kept in mind that if we did not get the results we were expecting, then we could either decrease the size or add multiple chillers.

Calculations Knowing the energy being transferred into the system, the initial speed and temperature of the glycol entering the system, and the temperature drop through the pipes, we are able to apply equations 6-9 to calculate the heat being transferred out of the pipes. The temperature at the inside surface of the tube would be 18.17°F is the input temperature of the glycol is 15°F.

Reynolds Number

$$\mathrm{Re}_D = \frac{\rho u_m D}{\mu} \qquad \textbf{Eq. 6}$$

Friction factor

$$f = (0.790 \ln \mathrm{Re}_D - 1.64)^{-2} \qquad \textbf{Eq. 7}$$

Nusselt's Number

$$Nu_D = \frac{(f/8)(\mathrm{Re}_D - 1000)\,\mathrm{Pr}}{1 + 12.7(f/8)^{1/2}(\mathrm{Pr}^{2/3} - 1)} \qquad \textbf{Eq. 8}$$

Temperature of inside surface of copper tube

$$T_{ip} = T_{in} + \frac{Q_{in}}{Nu_D * \frac{k_{gly}}{D}} \qquad \textbf{Eq. 9}$$

After the external temperature of the pipes was obtained, we used the thermal circuit diagram to calculate the resistance through which the heat would have to travel to reach the top surface using equation 10. The total thermal resistance through the top of the cement base is 0.05 °C/W

$$\Sigma R = \frac{\ln(\frac{r_o}{r_i})}{2\pi k_{cop} L} + \frac{\ln(\frac{r_{cem}}{r_o})}{2\pi k_{cem} L}$$ **Eq. 10**

Using the resistance and the known temperatures, we were able to calculate the energy being transferred out of the top of the base from equation 11. The total energy that will come out of the base is 44.09 W.

$$Q = \frac{T_{op} - T_{ice}}{\Sigma R}$$ **Eq. 11**

Mass Flow of Water In order to freeze such a large quantity of water, we have to regulate how much water is actually in the system at a given time. Using the properties of water and our understanding of heat transfer and thermodynamics, we were able to calculate a flow rate of water into the system that would ensure that the water would freeze at approximately the same rate that it would flow into the system. Using equations 12-14, we took the energy that would be coming into our system and optimized it to find the mass flow rate into the system. A diagram of this system can be seen in Figure 17.

$$\frac{\delta m_{CV}}{\delta t} = \dot{m}_i$$ **Eq. 12**

$$\frac{\delta E_{CV}}{\delta t} = \dot{Q}_1 - \dot{Q}_2 + \dot{m}_i h_i = 0$$ **Eq. 13**

$$\frac{\delta S_{CV}}{\delta t} = \frac{\dot{Q}_1}{T_{ICE}} - \frac{\dot{Q}_2}{T_{amb}} + \dot{m}_i s_i = 0$$ **Eq. 14**

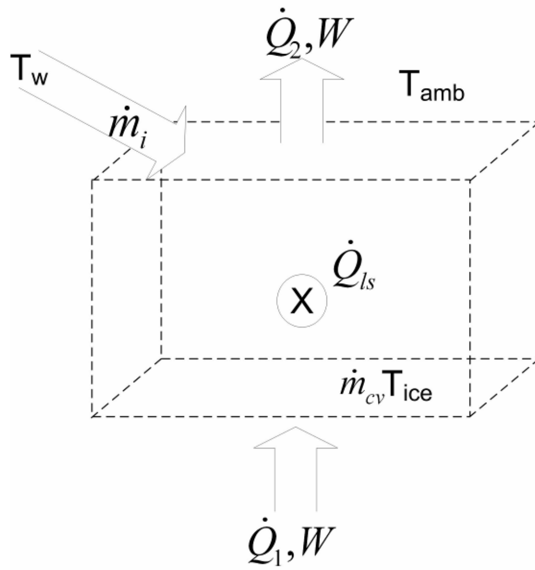


Figure 17: Energy flow diagram for the water into the tank.

Assumptions In order to do these calculations, we had to make some additional assumptions. A main assumption that we made is that as the water freezes to ice, fusion energy will be released from the system. We also assumed that this was a perfect system with no heat loss. This, in reality, could be simulated if a thermal blanket was put over the top of the tank. This will keep all of the cold air created by the chillers within the system and all of the warmer, ambient air out.

Calculations For this system we know that Q_1= 44.09 Watts, T_{amb}=44.6 degrees Fahrenheit and T_{ice}= 19.4 degrees Fahrenheit. We are assuming that the system is in steady-state meaning Eq. 13 and 14 are equal to zero. We are also assuming that S_{gen}=0 and that Pressure = .8721 kPa. Therefore, a value of h_i= 20.98 kJ/kg*K and s_i= .0761 kJ/kg*K can be found using the phase charts for liquid water. You can then plug these values into Eqs. 12, 13, 14 and obtain Q_2= 58.378 Watts and m_1= 0.56 kg/s.

Melting of the Ice To better estimate how long it would take for the ice to melt, we first had to understand the temperature of the ice. This gave us a clear understanding of all the different temperatures of the ice block. We used these temperatures to complete a finite-difference analysis of the block. The block was broken into 8 sections horizontally and 6 vertically, as shown in Figure 18.

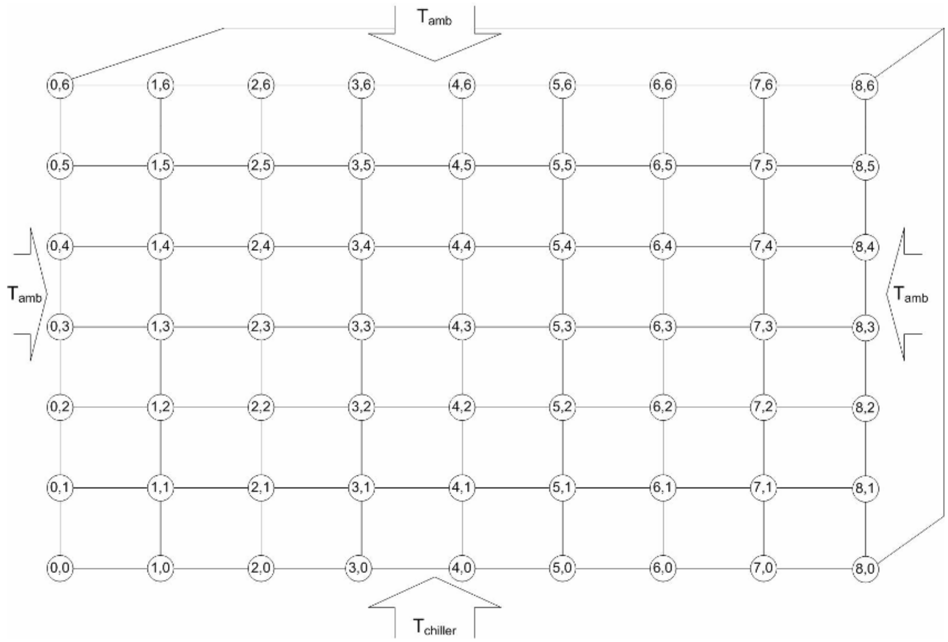
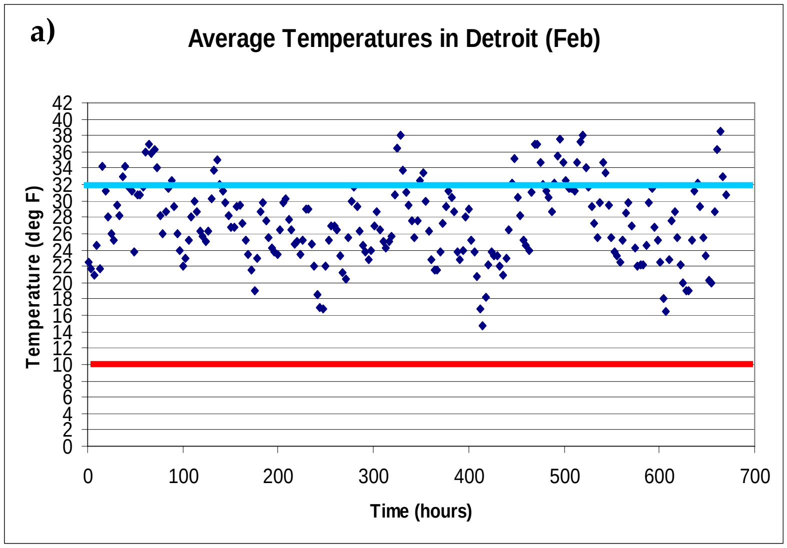


Figure 18: Finite-Difference Analysis numbering system of the block of ice.

One of the biggest factors in understanding how the ice would melt is to understand the ambient conditions at the site. To do this, we did extensive research and analysis on the past weather history of the city of Detroit. The two main months that we did an analysis on were February and March. We used these months because they make up the majority of the projects freezing and melting durations. We looked at temperature readings that were taken every 3 hours during these months and looked over four years. We were able to plot the average temperatures of each of the months by hour and these plots can be seen in Figure 19.



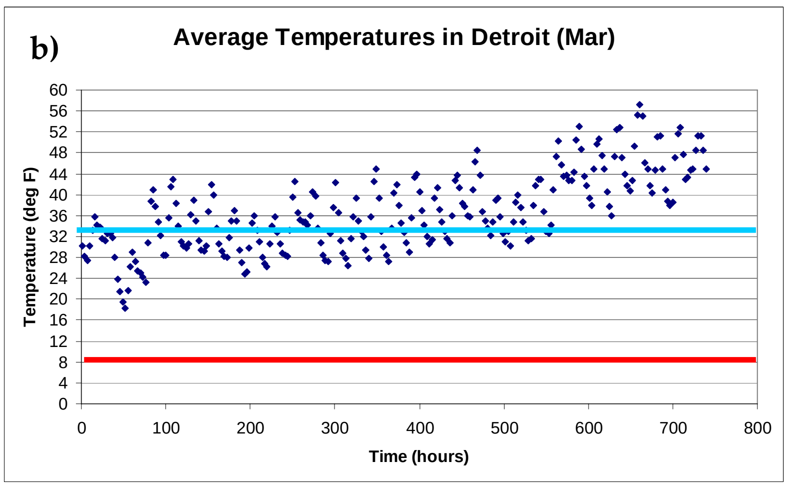


Figure 19: Average Temperatures for the city of Detroit in the months a) February and b) March.

From these graphs, we were able to find the ambient temperatures at the time when we would start to melt the ice. Along with this information, we used a similar analysis on the wind speeds. Using the average wind speeds, we calculated the average air convection heat transfer coefficient using Equation 15. The values of this analysis are shown in Figure 20.

$$h = 0.6 + 0.00318V_{air} \quad \textbf{Eq. 15}$$

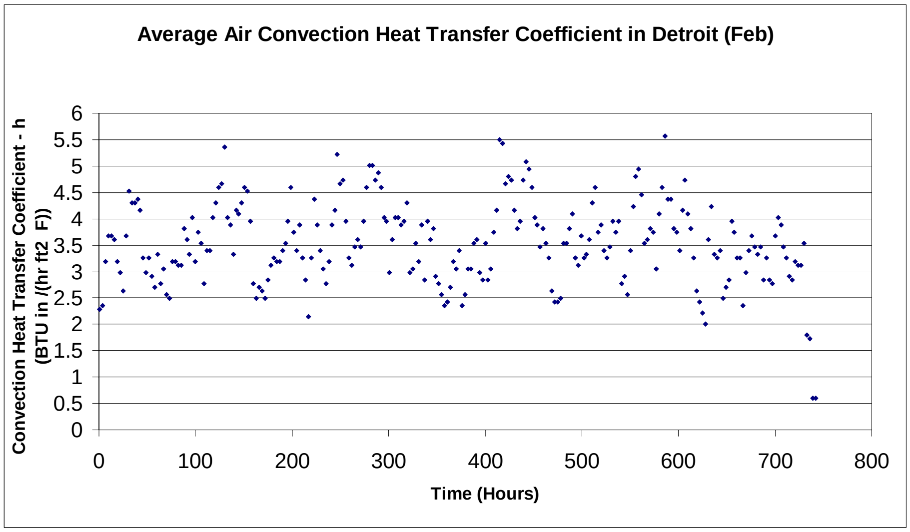


Figure 20: Average Air Convection Heat Transfer Coefficient for the city of Detroit in the month of February.

After we understood the ambient conditions that the ice would be melting during, we could do the calculations of the finite-difference analysis to get the specific temperature at each given point of the block. At each point, we did the sum of all of the heat transfer rates entering each node. The analysis was only done on a two-dimensional level to help decrease the complexity of the problem. A sample of a point can be seen in Figure 21.

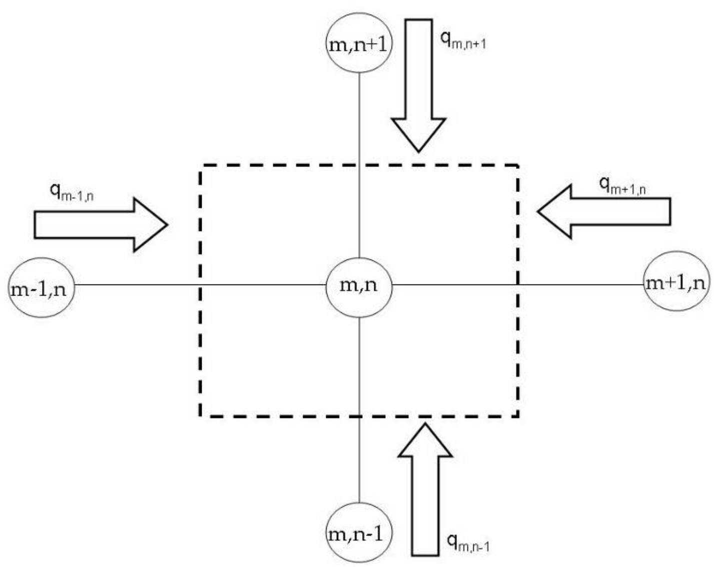


Figure 21: Example of finite-difference calculation.

Once we understood that initial temperature at each individual point (Appendix G), we could start to analyze how the block would melt. From Equation 14, we were able to calculate that the melting of this block of ice would generate 7.05 kW of energy. We also determined that it will give off about 2.9 W/hr. With that we can estimate it will take 101 days to melt. All of this is according to the average ambient temperature data that we have, so it could easily fluctuate depending on the ambient conditions at the time this is project is completed.

CONCRETE BASE We performed a force analysis on the concrete base to determine if the base will support the weight of the ice and car. A force diagram of the base is designed in Figure 22. The weight of the car and ice equals 44,890 lbs and the concrete has a compressive strength of 20.7 MPa. The cross sectional area of the supports is equal to 171 sq. ft. Therefore, there is 262.5 lbs/sq. ft. making F1=262.5 lbs/sq. ft. The compressive force is 0.0472 MPa, which is substantially less than the concrete compressive force. The sand and the piping should have no significant effect on the forces of the base. The base will still support the weight of the car and ice and has been proven by the Energy Management Manual for Arena and Rink Operations. This shows that the sand insulation layer is standard practice in ice rinks and will not cause issues with compression. The piping is very small in comparison to the rest of the base thickness. This allows us to neglect the pipes in our calculations. Thus, our base with the piping and sand will be able to support the exhibit.

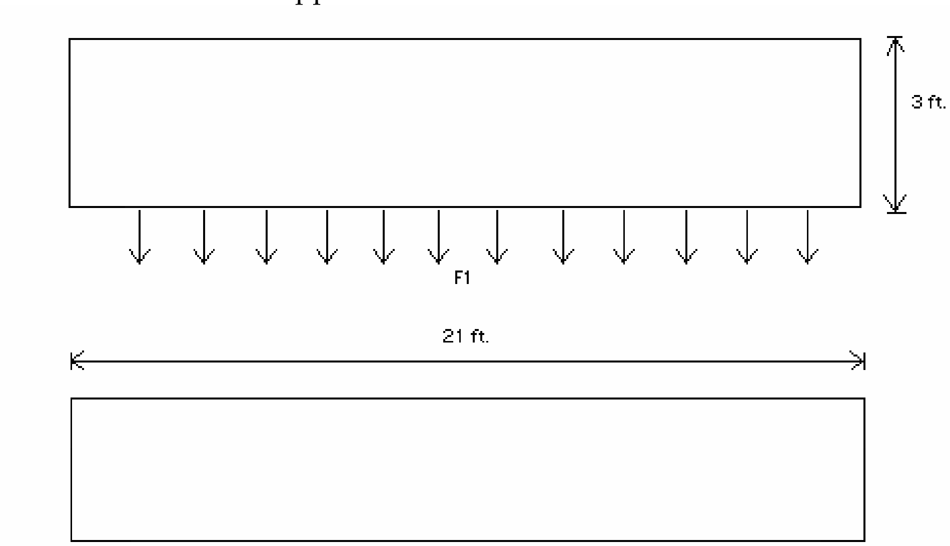


Figure 22: Free-body diagram of concrete base.

DESIGN FOR MANUFACTURING AND ASSEMBLY (DFMA) Principles of Design for Manufacturing and Assembly are important for cost minimization and improvement of quality of our process design. Budgets for the prototype and full scale design were created in order to see which aspect of the project cost the most. Materials for construction of the exhibit were evaluated and trade-offs were made to exclude unnecessary materials in order to minimize cost. Smart design of the art display components minimized the number of parts and maximized quality of the process. Design guidelines were created and heavily focused on when tank, base, and cooling system processes were formulated as shown in Table 6. This method guaranteed process designs that complied with customer requirements as well as engineering specifications.

Trade-offs: Functionality vs. Cost The process designs of all components were made to be simple yet efficient. This ensures that functionality is maximized while cost is minimized due to uniform parts throughout. Purchasing materials in bulk will lower cost. Functionality will change less than cost as they both increase.

Trade-offs: Cost of Manufacturing vs. Cost of Assembly Due to the simple assembly of all components, the cost to construct the tank, base, and cooling system, will be low. Manufacturing costs will also be low due to use of materials already being sold on the market. Chillers and other machinery that are expensive to purchase can be rented for reduced cost. There is a direct relationship between costs of manufacturing and assembly. Increase in one factor causes and increase in the other.

Component	Guidelines
Tank	Assembly o All tank panels and screws are standardized and uniform o Assembly of panels will be in open spaces o Tank cage and panels are symmetrical o Assembly performed mostly on the outside of cage o Easy access for tools to fasten screws Manufacturing o Small holes for screws o No sharp corners for brackets
Base	Assembly o Minimized variety of materials leads to high functionality and low cost o Simple, symmetric design Manufacturing o Mold process: pour and cure
Cooling System	Assembly o Insulated for efficiency of overall system o Easy access and controlled remotely, above ground o Uniform, bent pipes
Ice Block	Manufacturing o Constant flow rate of water allows for faster freezing o Will freeze upwards minimizing forces on tank walls

Table 6: Guidelines for DFMA

DESIGN FOR ENVIRONMENT In planning the process for the exhibit, eco-design principles were utilized. These concepts aided in making the process more efficient and environmentally friendly. Waste material will be minimized by reusing the water from the ice block. The site location and sponsors' inputs are important factors in how this water will be reused, and therefore, this step will be determined at the sponsors' discretion. The gutted car parts can also be checked for reusability.

Designing for easier disassembly will also make recycling at the end of the exhibit more cost-effective. The tank panels will be easily removable from the cage-like frame that we designed. The car will also stay intact as the ice melts because it is secured by the jacks, and the ice pressure will even out from freezing on the inside and outside of the car.

Safety precautions will also be taken in order to prevent accidents and harm to visitors and the environment. The coolant material that we have chosen is the less toxic of the glycols available, propylene glycol. The cooling system tubes will be hidden in the concrete base at all times and controlled above ground for easy access. The fluid will be monitored and the system will be shut off when not needed. Disposal of the propylene glycol should also be planned with safety in mind.

Component	Guidelines
Tank	o Easy disassembly of panels o Recyclable parts
Base	o Minimized number of materials: concrete and sand (insulation) o Reuse ground concrete
Cooling System	o Use less toxic glycol – propylene glycol o Constantly monitored for safety o Easy, above ground access to system controllers o Use chillers only when needed to reduce energy consumption
Ice Block	o Reuse water to reduce waste o Drain water safely
Car	o Reuse gutted parts to reduce waste o Recycle car frame after ice block melts

Table 7: Guidelines for Eco-design

FINAL DESIGN

ENGINEERING DRAWINGS The engineering drawings are of the full-scale project. Figure 23 shows the base and ice dimensions. The ice is evenly centered on the base with a one foot clearance on all sides. The car is positioned in the ice at an upward slope of 10 degrees and a banked slope of 30 degrees. Figure 24 shows the tank dimensions. Each beam has a cross-section of 5.5″x 3.5″. The same drawings were followed for the prototype construction with a scale of 19 ft=2ft.

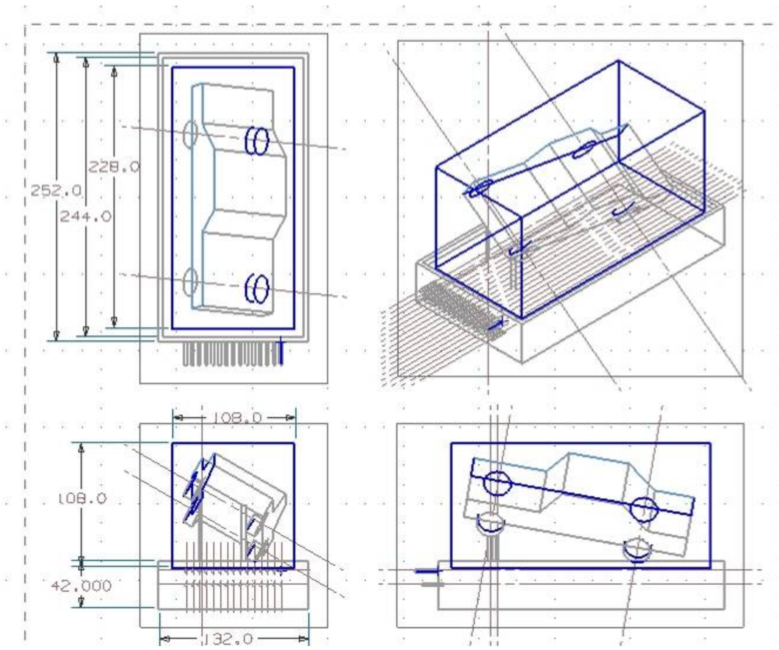


Figure 23: Base and Ice Engineering Drawings

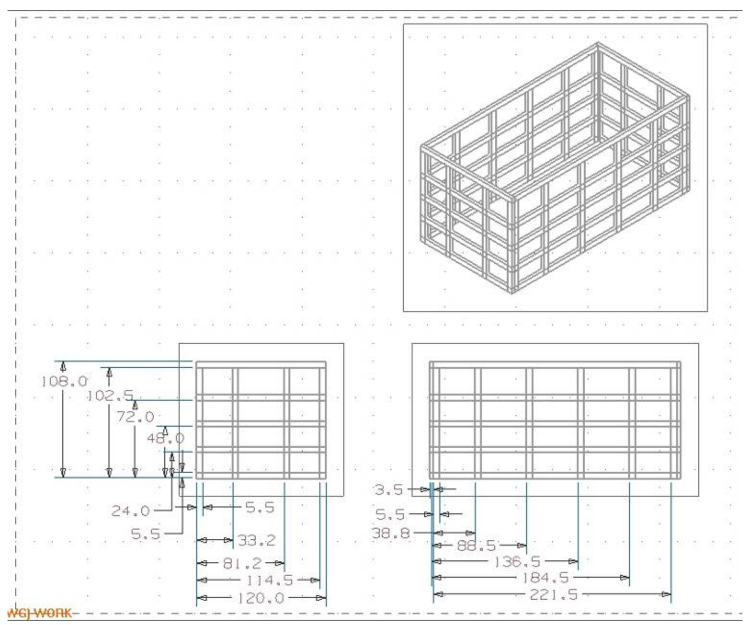


Figure 24: Tank Engineering Drawing

FINAL PROCESS The final design process begins with the site selection. Since this is still undecided, we are preparing for two different options. The first option is located on pavement and would allow us to begin construction directly on the pavement. The second option would be soft ground, grass or dirt, where we would need to create a foundation below the structure before beginning construction. This would allow the display to be adequately supported and prevent sinking when the ground is saturated in the spring.

The next step would be constructing and filling the mold for the concrete base. This will require adequate time for the concrete to cure, and may need to be adjusted according to ambient temperature. The base and mold are described in Concrete Base section of Engineering Analysis. We would then install the cooling system consisting of piping running through the concrete base along with a pump. This system is described in the Selected Concept Section. The system would then be sealed and filled with glycol. Depending on the final site location, an electrician would be required to run a power supply out to support the cooling system.

After the base and the cooling system are assembled, we can install the jacks that will be used to support the car at an angle. A lift will be used to place the car at the appropriate heights. The jacks will then be attached to the car frame and the car base located behind each wheel. The jacks will be adjusted to appropriate heights resulting in correct angles. These attachments will have to allow for pivoting in order to angle the car.

Once the car is properly supported by the jacks the tank can then be assembled. The tank is described in further detail in the Tank Analysis section. We will bolt the tank directly to the concrete base. This will apply pressure to the seal located on the bottom of the tank walls. All of the seals will require leak testing to assure that there are no leaks before filling the tank with water.

After the tank is inspected, we can then begin to fill the tank with water. The key to obtaining clear ice is to fill the water slowly to prevent air bubbles from freezing into the ice and to freeze the water continuously to prevent the appearance of layers. It is important to remove the surface layer of ice that forms to prevent cracking and bubbles. Once the ice is entirely frozen, which should be visible due to the continuous freezing process, we can carefully disassemble the tank walls.

PROTOTYPE BILL OF MATERIALS We are allotted $1000 to purchase and to construct our prototype. The bill of materials is shown below. The majority of the cost was incurred by purchasing the metal for the tank prototype walls and wood for the concrete base mold. We are currently significantly below budget.

Quantity	Part Description	Purchased From	Price
1	Concrete for base	Home Depot	$3.38
2	Trowel for concrete work	Home Depot	$7.86
3	2x4 for base and tank support	Home Depot	$9.96
4	MDF for base and tank	Home Depot	$15.76
9 lbs	Aluminum for tank walls + Plexiglass for window	Alro Metals	$74.97
3	Sheet metal for tank base	Home Depot	$38.45
5	Copper Piping for cooling system	Home Depot	$16.05
2	Screws for prototype assembly	Home Depot	$13.44
1	Glue for prototype assembly	Home Depot	$6.97
1	Black Spray paint for frozen object	Home Depot	$0.99
1	Tubing for tank seal	Home Depot	$15.87
1	Angle gauge metal for tank assembly	Home Depot	$8.96
1	Caulk Gun	Home Depot	$2.08
1	Caulk for sealing	Home Depot	$3.29
1	Nails for prototype assembly	Home Depot	$3.76
1	Silicone for sealing	Home Depot	$7.77
4	Handles for tank	Home Depot	$13.16
4	L-bracket	Home Depot	$3.92
1	Foam Insulation wrap	Ace Hardware	$5.97
4	Foam Panels	Ace Hardware	$5.69
1	Caulk	Ace Hardware	$3.19
1	L-bracket	Ace Hardware	$4.48
1	2 x 4	Ace Hardware	$2.30
1	Bag of Cement	Fingerle Lumber	$5.87
42	Rubber seal o-rings	Stadium Hardware	$18.34
1	Caulk Rope For Seal	Ace Hardware	$2.19
1	Round File	Ace Hardware	$6.99
1	Thermometer	Ace Hardware	$6.99
1	Pipe Insulation for Seal	Ace Hardware	$2.99
1	Repair Cement	The Home Depot	$2.48
4	Handles for concrete base	The Home Depot	$13.16
2	Model car for prototype	Target	$30.00
		Total Tax:	$13.69
		Total:	**$370.97**

Table 8: Prototype Bill of Materials

PROJECT BUDGET The project budget for the frozen car ice display process was originally designated at $10,000. This budget is included in Appendix F. In order to verify where we were incurring the majority of the cost, we separated the process into subsystems. The majority of the cost is tied up in labor and in the cooling system. We are currently over the projected budget.

We used company quotes to estimate the cost for the majority of the projects. The cost for the water was estimated by using an estimate cost per gallon provided by the City of Ann Arbor, MI. We received a quote from Connelly Crane in Detroit, MI for positioning the car at the appropriate angles. This quote is a “flex-rate” quote meaning they would position the car on a stand with a crane and then remove the stand when the positioning is eventually completed. This was a much cheaper alternative to crane rental for the entire week, and this will provide adequate spacing to attach the jacks using welding. The cost of the chiller that was included was for a brand new 20-ton chiller from Econochill, a company from Wayne, PA. A representative from Econochill recommended renting a chiller for this project in order to save cost. He was unable to give us an estimate for this due to the length of time between now and the time where a chiller is required. He has requested that a project sponsor contact him closer to the start date of the freezing at 1-800-942-9249 for a more accurate cost estimate. The cost of glycol was estimated using information from Dow Chemical on price of glycol per pound. The cost of the tank is derived using the orientation of the panels designated in the tank cost section in Table 9. Labor has been separated into specific functions including jack stand positioning, tank set-up, tank tear down, and project tear down. The largest amount of labor cost comes in with the tank assembly and set-up at roughly $2,200. These labor costs were based on average contractor hourly wages and an estimated length of completion time per task. Energy costs to freeze the water and to run the cooling system is approximately $589. The energy cost was based on a report done by the Energy Information Administration in 2003 which estimates the cost of energy per kilowatt hour in Michigan [9]. The $650 car shipment cost was obtained from a quote from Door-to-Door Car Shipping. This quote included all fees and taxes.

We have come up with suggestions to help reduce the cost of the project. The first suggestion would be to drive the car to Michigan instead of having the car shipped. The only cost that would be required to do this would be gas cost which would be roughly $150. This is a $500 savings. Another suggestion would be to rent or buy used chillers instead of purchasing them. This results in significant savings. One way that will save energy cost is to vary the project start date to coincide exactly with the coldest weather. Our suggested timeline incorporates the average temperatures which can vary year to year. This has potential for significant savings. There is also a possibility of having local businesses sponsor portions of the project. This will greatly reduce the cost of labor and supplies.

TANK COST Table 9 details the materials needed for the construction of the tank with plywood panels. It also includes each material’s cost, the number of each item needed, and a local source for the item. The total cost of the tank materials is $1,473 including sales tax.

Item	Price per item	Number	Total Cost	Source
4″ X 6″ X 10′ beams	$11.68	34	$421	Fingerle Lumber
4″ X 6″ X 20′ beams	$37.84	10	$401	Fingerle Lumber
½″ X 4′ X 8′ plywood	$21.39	20	$454	Fingerle Lumber
Screws/washers	$81.90/1000	2000	$174	Boltdepot.com
10′ X 20′ Plastic drop sheets	$4.25	5	$23	Hardware store

Table 9: Tank material criteria

Table 10 shows the cost of replacing a plywood panel with aluminum or Plexiglas. The estimate is for replacing a 24 inches x 48 inches panel, the most common panel size on the tank.

Panel Type	Price Increase per Panel	Source
1/8″ Aluminum	$100	ASAP source/ALRO Steel
3/8″ Plexiglas	$146	ASAP source/ALRO Steel

Table 10: Extra material cost for replacing plywood panels

MANUFACTURING

MANUFACTURING PLAN Our prototype will be a scaled down version about two nineteenths of the full-scale product. For this reason, some methods of manufacturing the prototype will be different from the actual exhibit. As described above in the Final Process section, a base will need to be manufactured for a site that is not supported. The mold for this part will be made by nailing pieces of wood to the designated shape. After the concrete is poured, it will take a few days to dry and harden completely. Copper pipes will be incorporated into this base to show how the cooling system piping will fit in. The base is very heavy and therefore will not be used in the actual freezing process of our ice block for ease of maneuverability and safety. Instead, we will use a temporary base of a flat piece of wood with edges that will hold the tank described below.

We will manufacture a tank made of sheet metal that will actually be used to freeze the ice. It can be clamped down onto the temporary base with a wood and screw system. The sheet metal will be bent or welded at the corners of the tank. After its use for freezing it will also be fitted onto the concrete base by using clamps and sealant. This will be to demonstrate how the actual full scale product should look.

For the prototype, we imitated the real exhibit. We purchased a car and painted it black in order to simulate the effect that the actual black car will have on the block of ice as it receives sunlight. Small scale stands were used to simulate the jacks that will support the real car. Then the water was added by methods described below in the Testing section.

Much of this project entails assembly rather than manufacturing. After each part is made, how they are put together is the most critical aspect. We will need to seal the connecting edges well in order to prevent and leaking of water as it freezes and as it melts. The tank assembly is described in further detail in the engineering analysis section.

The full scale product will be manufactured similar to our prototype. Our smaller scale parts are accurate examples of how the full scale product will look.

PROTOTYPE TANK To create a proof-of-concept design for the scaled prototype, we used removable panel walls made of quarter inch aluminum metal. The mechanism that connects the tanks corners consist two L-brackets. One would be place on the outside and the other on the inside of the tank. A bolt was placed through the inside L-bracket, the tank wall, and the outside L-bracket. The diagram for the corner tank assembly is shown in Figure 25. The nut is located on the outside of the tank so that it can be removed when the ice is frozen inside. The picture of the tank is shown in Figure 26. The full-scale project will consist of 64 panels; however, due to space constraints and practicality of disassembling the prototype, we were unable to make an exact replica of the tank. The basic concept mechanism used to connect the panels will be the same on the prototype as the full-scale display. This mechanism used for wall removal is shown in Figure 27. The removed tank panel is shown in Figure 28.

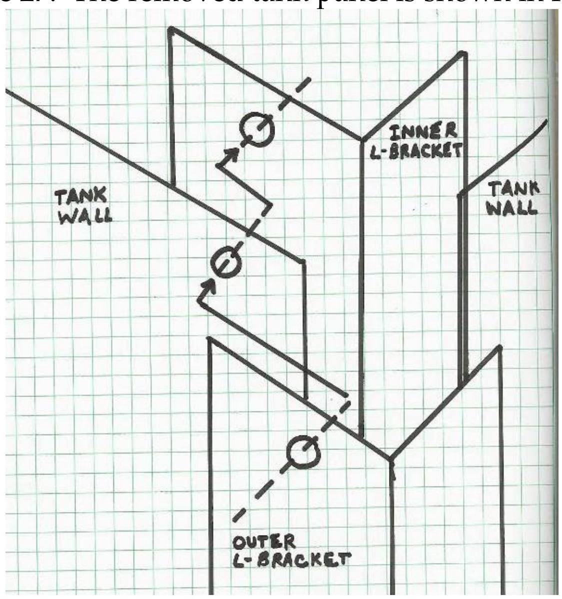


Figure 25. Prototype tank corner assembly.

Figure 26. Prototype tank and wooden support base.

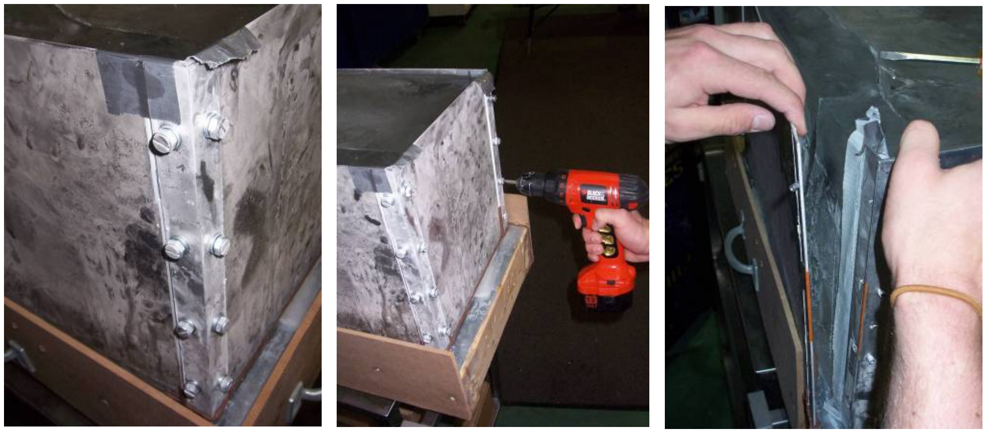


Figure 27. The removal process of the tank walls.

Figure 28. The tank wall removed from ice block.

We also created a wood base to support the metal tank shown in Figure 26. This base will not be constructed when creating the full scale design. This base is strictly to assist us in moving the prototype. It includes a tray and level base with 4 handles. There are 4 boards that are positioned vertically specifically 2 are located on each of the two long walls of the tank. This mimics the large scale clamping that will be used on the final project.

PROTOTYPE BASE The prototype base will be made of concrete in order to support the weight of the ice block and car.

Construction of the base first required making a frame to pour the concrete mix. The materials used for this step are a base board, wood planks, caulk, screws, and nails. The outer edges of the mold were made in a rectangular shape with dimensions 2 feet long, 1 foot wide, and approximately 4 inches high. The lip of the base was created by adding another perimeter of 1 in. x 1 in. cross sectional wood on the inside of the first set. Copper tubes were also placed into the frame before the concrete was poured. This served to simulate what the actual cooling system would look like. When all of the crevices were caulked, the concrete was ready to be poured.

A wooden board was pressed into the wet concrete of the prototype in order to make edges so that the ice block will not move around when placed on top. This step was completed within a few hours so that the board would be easily taken out and the base left to cure in that final shape. It took about a week for the base to cure completely.

The base was very heavy and therefore was not used in the actual set up process of our ice block for ease of maneuverability and safety.

FULL SCALE BASE Much of the full scale base construction depends on the location of the exhibit. If the site is on paved ground, the wood mold will be assembled directly on the area. However, if the site has no foundation to begin with, the ground will have to be strengthened to support the heavy weight.

The mold will be constructed with a perimeter of wood being 21 feet long, 11 ft. wide, and 3 ft. high. An initial layer of concrete will be created in order to support the three groups of curved copper cooling pipes that will be set up in parallel to and in contact with each other. Between the three sets of pipes, two strip of concrete will be made for extra support in the middle of the base. This is shown in Figure 29.   Then, sand insulation will be packed in firmly between the pipes. This sand layer is the same type of insulation used in ice rinks and can support the pipes [10]. The top layer of cement will then be poured and an inner lip will be formed with slanted adjacent sides that will lead melted water to the two drainage holes located diagonally across from each other. This is presented in Figure 30. The full scale base will take much more time than the prototype. Ambient temperatures should be considered when estimating the total time to cure the base; however, the estimated cure time is one month.

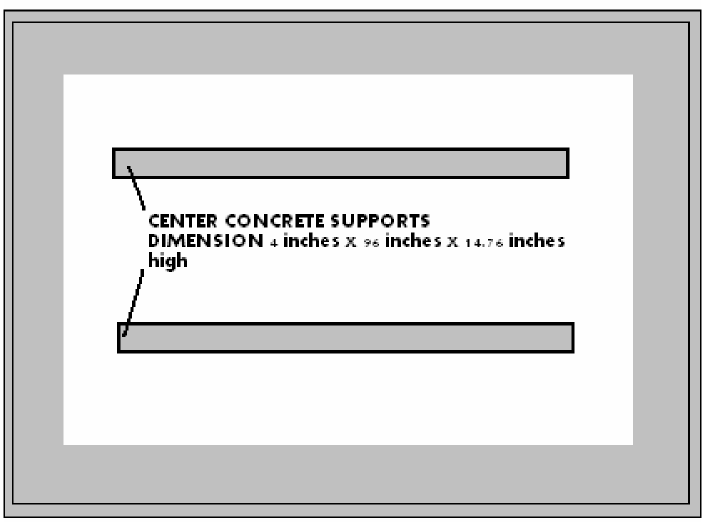


Figure 29: Center Concrete Supports

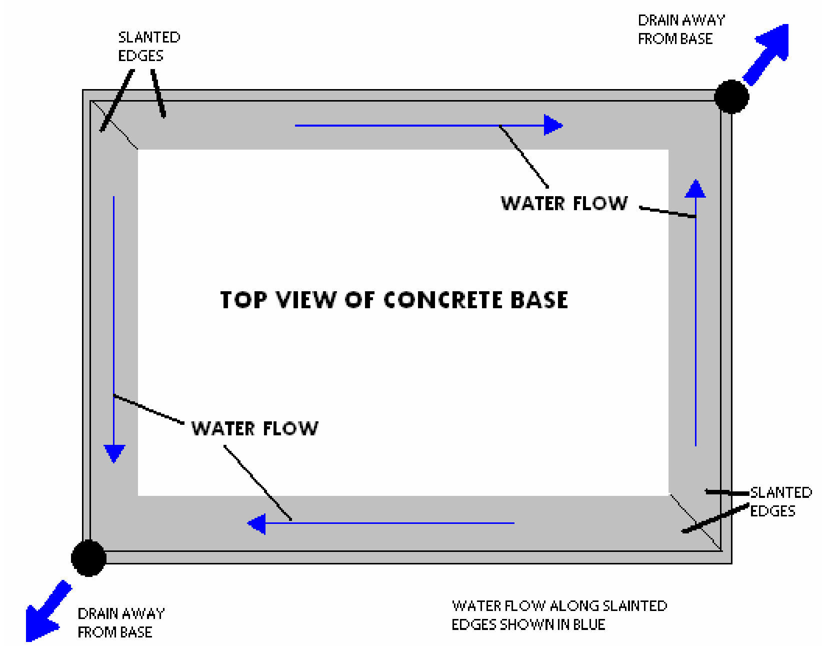


Figure 30: Base Drainage System

PROJECT PLAN

The first step taken in mid-January for the creation of our frozen car prototype was to brainstorm ideas about the setup and processes required. These ideas have been researched and finalized according to our sponsors' ideas and vision in early February. After the optimal design along with the most efficient cooling and draining methods were chosen, CAD drawings and process plans were created. These plans and concepts will be continually monitored and tailored to aid in the compilation of the actual prototype to be finished in the first week of April. Careful consideration will be taken so that the total cost of the full scale project will remain cost effective and that the overall cost of prototyping will not exceed $1000. We have summed up an estimate of costs in order to confirm these limits. All tasks are divided up amongst the team members and allocations are shown in the Gantt chart in the Appendix B.

TIMELINE We have created a timeline so that proper steps can be implemented with adequate timing to achieve the final exhibit. The timeline is included in Appendix H. To start we will need to prepare the site. This will include creating the proper foundation to support the weight of the exhibit. Depending on the site that is finally chosen, sand or fill dirt may need to be utilized below the exhibit. We will also need to have power supply at the location for running the chillers. The materials should be ordered for the construction of the base mold, and the car will be shipped to the site. These materials include 2 x 4 boards, plywood, copper piping, insulation, and cement. During this step, the Nova should be gutted and the windows will be removed. These preparation events will occur on October 1, 2007. The base will the need to be assembled on October 7, 2007.

The cement needs to be poured at the exhibit site by October 17, 2007. This date was chosen because the weather will be warm enough for the concrete to cure properly. This allows enough time to cure before the next step needs to be taken. This next step is to secure the car into position. This step will occur on December 7, 2007. This timing was chosen so that the concrete could have sufficient time to cure. To position the car, a lift moves the car to the appropriate inclined bank curve. The selected jack stands will then be welded to the bottom of the car behind each wheel. These jacks can then be fastened to the concrete base. The car will then be completely supported without the help of the ice.

The next step is to assemble the tank frame around the car. This will occur on December 14, 2007. This timing was chosen so that we could have the project ready to start filling by January 1, 2008. Once the wood frame is positioned and reinforced, the panels can be inserted into the frame. This assembly is described in the tank frame construction under the engineering analysis section. The panels will need to be sealed and leak tested to assure that no water can escape. On January 1, 2008, we will begin filling the tank slowly with water. This date was chosen to allow for the freezing to occur over the coldest 6 week period. The water flow rate should be efficiently slow so that pooling of water should not occur. The freezing will also occur at the same time as the filling of the tank. The simultaneous freezing and filling will improve clarity by reducing the bubble formation and increasing the continuity of the ice.

Our heat transfer calculations show that the freezing process will take approximately 6 weeks. On February 14, 2008, the block will be completely frozen, and the tank can then be removed. This will require unbolting the panels from the frame and removing them. The frame will then have to be taken apart and removed. Since the tank will not need to be reassembled, the condition of the tank after removal is not important. Once the tank is taken apart the exhibit can then be allowed to melt for the exhibit. A daily safety inspection will occur once the melting occurs to assure that there is not load shifting.

Our heat transfer calculations predict that the melting will takes approximately 101 days. The cooling system installed below should assist in delaying the melting in case of warmer than expected weather.

Once the car is exposed in 2008, the car can be lowered and removed from the site. The concrete base can be demolished and taken away. The whole base removal is expected to take approximately one week.

ETHICAL CONCERNS The ethical issues for this project were mainly considered during the safety planning. Since this project is for public viewing and involves deadly loads, we addressed the need to provide additional safety measures to prevent hazardous situations. These safety procedures are described with the FMEA on page 12.

If our cooling system were to leak, this would contaminate the environment. To prevent leaking, we designed this system be closed and sealed with in the concrete. If leaking does occur, city officials should be contacted immediately, and the public should be not allowed to view the exhibit until proper clean up has occurred.

Another ethical situation that this project poses is the waste of materials. We are proposing that all necessary material be recycled in various manners. The concrete can be ground up and reused in roads. The metal can be recycled for many different uses. The water can be reused in a form yet to be determined by the sponsor.

TESTING

TEST PROCEDURE We will produce two blocks of ice by the method described above. Each block will be frozen in a different manner to observe the effects of the ice on the car, the freezing process on the ice clarity, and the freezing process on the ice quality. The first way that we will freeze the block is filling the tank completely with water and freezing it all at once. The second way that we will freeze the block is in intervals where we fill the tank a few inches at a time and allow that section to freeze.

We will also allow a sample ice block to melt outside over time. We will document the ways that ice melts as far as progressive shape of the ice and ice clarity over time. We want to observe if there is going to be ice support issues. Another key conclusion from this melting test can be how the elements affect rate of melting and ice clarity. These various test methods will be used to assess which conditions are best for the final full-scale product.

FREEZING PROCESS The general freezing process used to test the prototype started by placing the tank and the base in a freezer at the University of Michigan indoor track. The freezer was held at a constant 16°F. We then filled the tank with water and allowed the tank to freeze over the course of a few days. The block of ice that was created is 2 feet long by 1 foot wide by 1 foot deep. The tank was lined with a plastic bag and duct tape was used to provide leak protection to joints. The bag was used as a way to separate the ice from the metal to prevent sticking. The bag also assisted in preventing leaking water from escaping the tank. We were not able to utilize a similar method of freezing as the large-scale display because of the cost of equipment. It would have been impossible to scale down piping and other components of the design.

TANK FREEZING FILLED AT ONE TIME For the first attempt at freezing the water, we filled the tank all at once. In this trial, we did not freeze a car. This was an initial experiment to examine the freezing capacity of our set-up. The freezer was at a constant temperature of 16°F throughout all freezing processes. We allowed the ice to freeze over the course of 3 days, and the results were checked intermittently over the course of freezing.

After three days, we removed the prototype and examined the block. At first, the block appeared to be completely frozen. Upon removal of the block, we noticed that the internal section of the block was still liquid. The unfrozen section of the block was approximately 3 inches wide, 12 inches long and 4 inches deep. These results are shown in Figure 31. We are concerned that this problem could occur in the full-scale design. In order to correct this error, we would like to freeze the water in intervals. This would improve the completeness of freezing due to the reduced thickness of the ice. This interval freezing would also allow us to better see if the ice is completely frozen.

Figure 31: Hollow center of prototype ice.

TANK FREEZING FILLED IN INTERVALS For the second trial, we filled and froze the tank in intervals. The advantageous concept of interval freezing was that the ice would have an easier time freezing all the way through if it was done with thinner layers. We found that the ice continues to freeze from the outside inwards until the internal pressure from freezing expansion causes the ice to crack. The cracked ice is shown in Figure 32. To prevent cracking, any ice which forms on the water surface must be removed to prevent internal pressure. This will allow the ice to expand vertically upwards. Layers of surface ice left in the prototype resulted in bubbles and cloudiness. The ice froze with a noticeable slant at the top of the ice block. This shape was the same slant as the car. We are not concerned about this section of the ice block being at a slant because it will not be visible to the public at ground level. This section does not support a load either so the slanted surface does not introduce any safety hazards. We would recommend having an ice sculptor level off the top of the block if the chosen site would make the top of the block visible. The prototype after this freezing is shown in Figure 33.

Figure 32: The ice crack occurred during the freezing.

Figure 33: Prototype after interval freezing (top view).

PROTOTYPE MELTING After freezing the prototype, we wanted to observe the way in which it would melt to evaluate possible safety hazards and new design problems. We allowed the prototype ice block to melt outdoors for 3 days. The initial ice block is shown in Figure 34. The clarity is high with the entire profile of the car visible, and the shape is rectangular.

Figure 34: The prototype initially before melting begins.

The next observation came 6 hours into the melting process, Figure 35. During this portion of the test, the ice was located in the sun. The clarity had been greatly reduced due to cloudiness in the ice. The melting also results in ice cracking which also reduces clarity. One recommendation to improve clarity and delay the melting would be to construct a canopy to provide shade to the ice. Another possibility is to choose a site that would be located in shade.

Figure 35: The prototype ice is shown after 6 hours.

The ice was then observed 12 hours later shown in Figure 36. At this point, the edges appear to melting into a more rounded shape. The cracks that had formed during the freezing are melting faster than the rest of the block and appear to be opening up. This could potentially cause stress issues with full scale block because of the inadvertent load bearing aspect of the ice. We also observed that the car was exposed to the outside.

Figure 36: The prototype ice with rounded corners and exposed car.

The final observation of the prototype came on day 3 of the melting shown in Figure 37. At this point, we observed the car to be almost entirely exposed. The parts that were exposed were directly around the black parts of the car. This is because the melting is accelerated in these areas due to the absorption of sunlight from the black color. This may cause a large portion of the ice to be left on top of the car without any support of the ice. To reduce the effects of the car color, we recommend changing it to a medium shade color that would be dark enough to see against the contrasting ice color; however, the color would be lighter than black to reduce the absorption. Another recommendation is to chip off any unsupported ice so that it does not cause hazardous conditions for the observers.

Figure 37. Prototype ice with exposed car.

DISCUSSION FOR FUTURE IMPROVEMENTS

FUTURE WORK A major step that is still needs to be completed is obtaining more accurate cost estimates for the final budget. The estimates that we were given for the project are based on past history of similar capacity projects given to us by companies in the appropriate fields. We were not able to get official quotes due to the length of time between now and the actual task being completed.

Another task would be to complete a more thorough heat transfer model of the system. We recommend a more complex modeling system to obtain more accurate freezing and melting conditions. We also would recommend researching the use of chillers along the walls to facilitate more thorough freezing.

RECOMMENDATIONS One of the major contributing factors that has yet to be determined is the exact location of the project. The sponsors have selected the Detroit area as the leading candidate city. For the specific site, we would recommend considering a site that has good shade, a solid foundation, drainage opportunities, and electricity hook-ups available. Choosing a site that has the designated characteristics above will simplify the set-up.

The budget for the project is one of the major constraints that we have had to consider. The proposed project is over budget; however, we have identified potential ways that the project cost can be reduced. These savings opportunities are: driving the car up to the project site instead of shipping the car, having some of the tasks sponsored by local companies that are completing the work, and freezing the block at the time that coincides with the coldest days.

Another recommendation that we have is to paint the car a different color than black. Despite the fact that black has the most contrast with the ice, we found that the color black also decreases the time that it takes for the ice to melt. The shorter melting time is due to the high sun absorption of the color itself. A lighter color may help lengthen the projects life; however, when selecting a color, contrast between the ice color and the car color should be considered. This problem can also be remedied by placing the exhibit in a shaded area as was previously mentioned.

We also recommend recycling the materials used to construct the project. This will help increase the environmentally friendly nature of the project itself. We recommend recycling the metal used for the tank walls, the concrete in the base, and the water from the melting ice.

For the cooling system we recommend using a thermal blanket to cover the open tank during freezing. This will help to prevent heat from entering the system and should shorten freezing time. It will also prevent debris from entering the tank which will help to maintain ice clarity.

CONCLUSIONS

The project that we are working on is a visual sculpture project, in which we have been asked to freeze a car in a block of ice to be put on display starting next winter. After speaking with our sponsors we have agreed upon an angle and block shape for our design. We have calculated stresses on the car supports, completed tank wall finite element analysis, calculated the stress that will be applied to the base, identified potential failure modes, and investigated a potential cooling system. We have successfully completed prototype construction. Our prototype included a scaled version of the concrete base and the aluminum tank. We also ran two prototype freezing trials and observed the melting process.

A full scale version of our prototype can be successfully constructed and exhibited. Our analysis shows that the recommended concrete base design will support the loads applied. The cooling system has the capacity to freeze the required amount of water needed for the project. Tank analysis showed that the tank walls will support the force of the water and ice. The jack stand leverage will support the weight of the car and the ice with in a large safety factor, throughout the entire process. The project was designed to ensure the safety of all visitors and workers. Certain precautions may need to be taken as noted in the proceeding report. Most importantly the ice will need to be monitored constantly to identify any hazards.

ACKNOWLEDGEMENTS

We have had a lot of help over the course of completing this project. We would like to express our gratitude to both our sponsors Mary Carothers, Assistant Professor of Photography at the University of Louisville, and Sue Wrbican, Assistant Professor of Art and Technology at George

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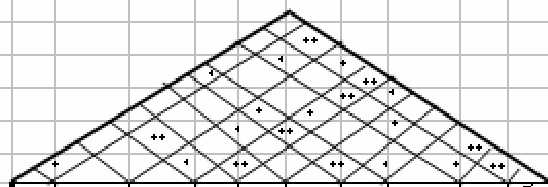
Appendix A: QFD Diagram

Appendix A: Quality Function Development (QFD)

Relationships

++	Strong Positive
+	Medium Positive
-	Medium Negative
- -	Strong Negative



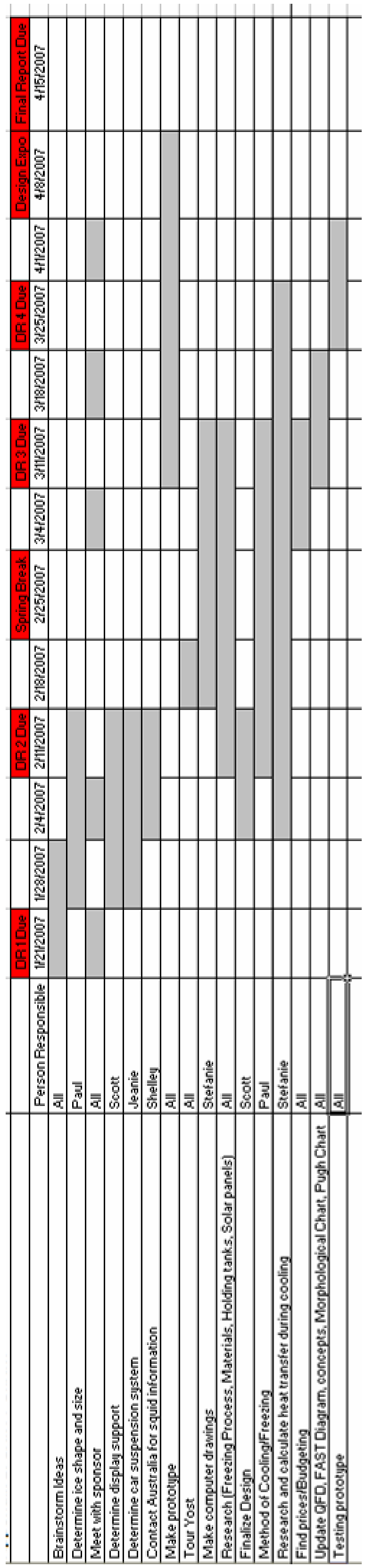
(+) => more is better
(-) => less is better

	Weight	Visibility through ice	Freezing Rate	Water drainage quantity	Weight of system to be supported	"Ice tray" material strength	Heat loss dependent on temperature	Block Shape and Dimensions	Lifting the car - Jack Strength & Size	Stresses on car and walls	Public Safety - Distance of interaction with structu	Benchmarks Frozen Squid	Strachan
Ice Clarity	9	9	9									5	1
Position of Car	6					1		1	9	9	9	3	1
Clearance from Ice	2					1	3	1	9	9		3	1
Length of time it lasts	7	1		1			9	1				4	5
Cost	6	3	3	3	9	9	3	3			3	3	2
Environmentally Friendly	8		9	9	3		3	3		3	9	1	1
Viewable to the Public	4	9	1	9	9	9						5	5
Condition of Car	4											1	1
Shape of Ice	2				1	9		9	1	1		5	2
Aesthic Appeal	10	9		3	9	1	1	3				4	3
Safety	10		9	9	9	9			9	9	9	4	2
Measurement Unit		Ft	Watts	gal	tons	MPa	mm/min	m³	kg & m	MPa	Ft		
Target Value		2	40	10,000	4	400	0.25	45	3500 & 1.5	40	0-∞		
Total		232	265	253	296	216	121	105	164	188	234	197	109
Normalized		0.11	0.13	0.12	0.14	0.10	0.06	0.05	0.08	0.09	0.11	0.64	0.36

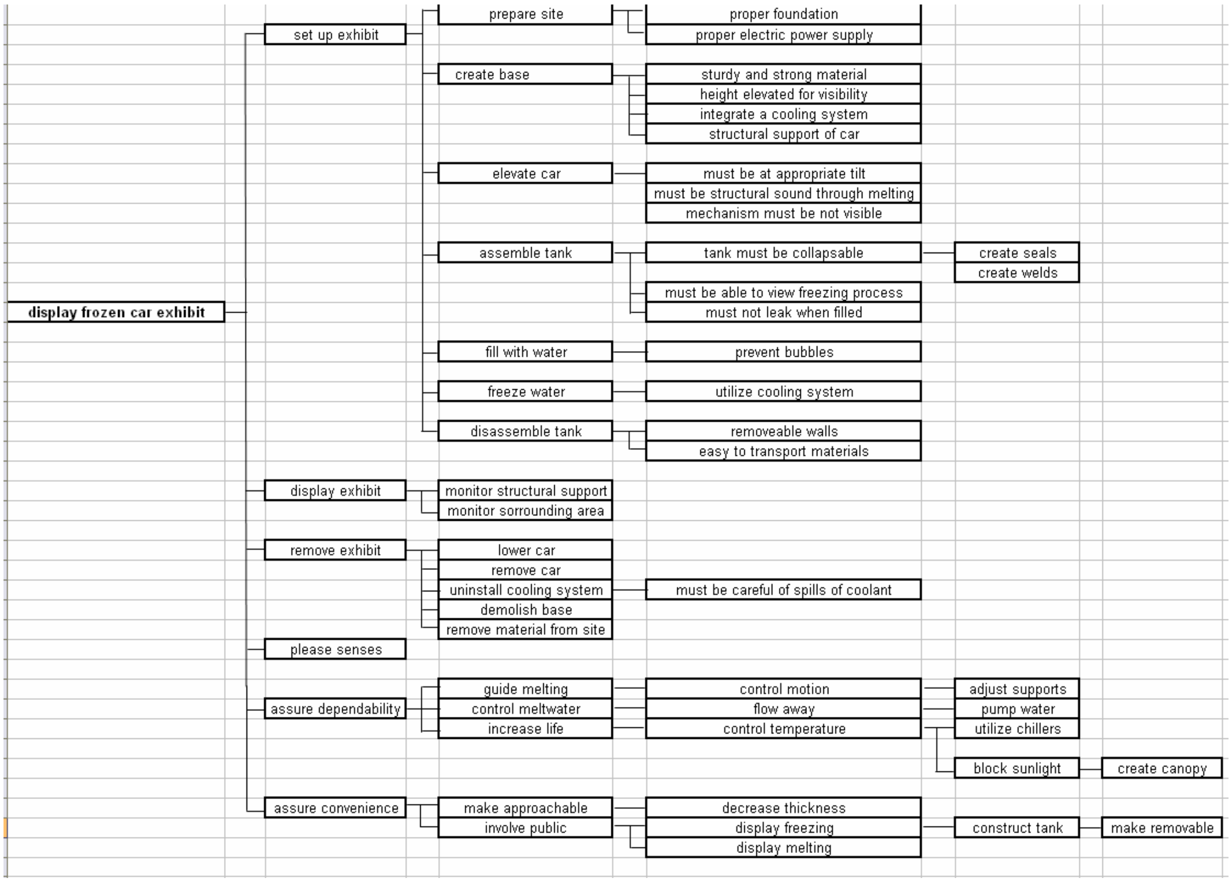
Key:
9 => Strong Relationship
3 => Medium Relationship
1 => Small Relationship
(blank) => Not Related

***Weights are figured on a scale of 1 to 10**
(ten being most important)

Appendix B: Gantt Chart

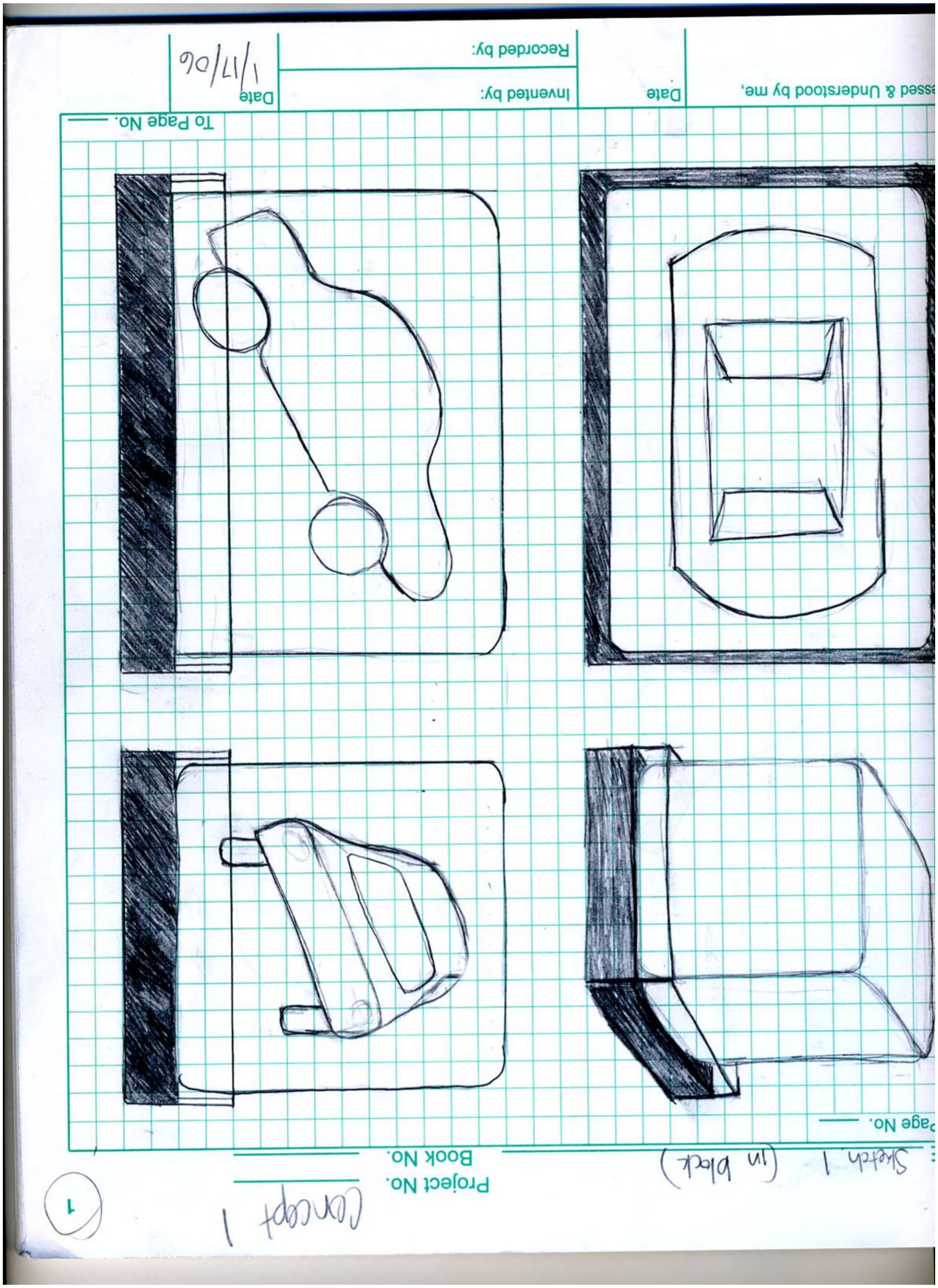


Appendix C: Fast Chart

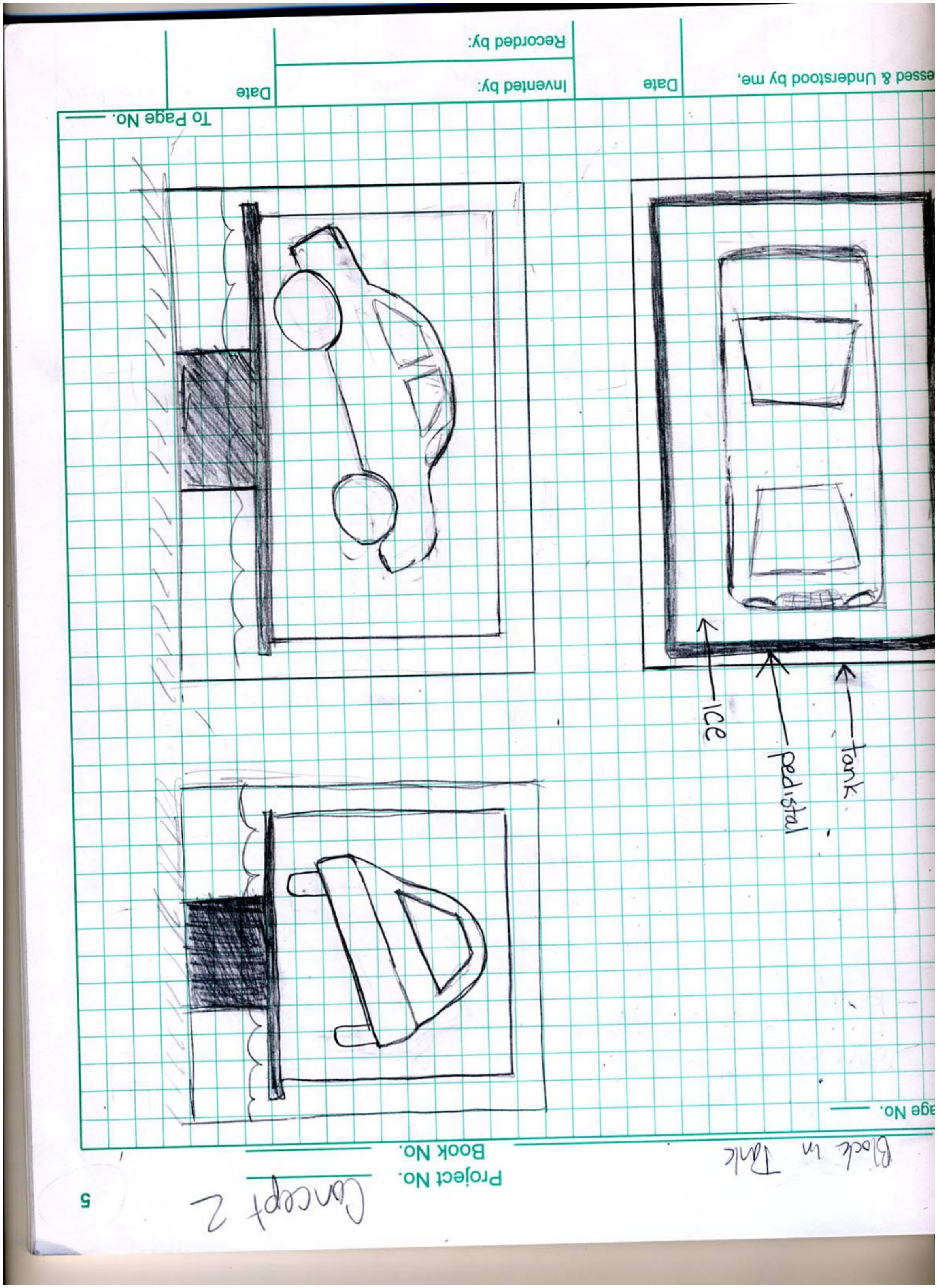


Appendix D: Design Concepts

Concept 1:



Concept 2: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Invented by:
Date
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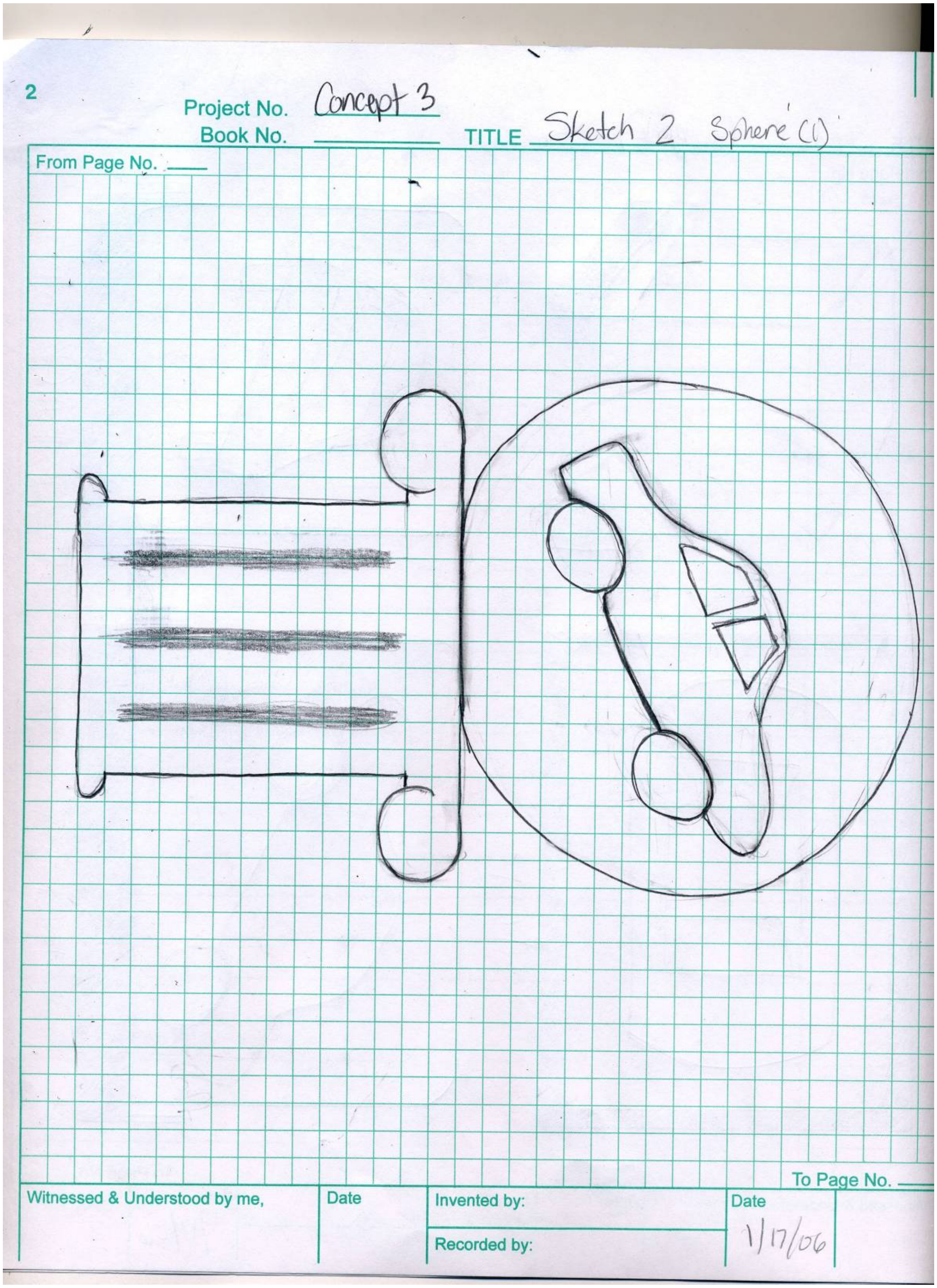
ice
pedistal
tank
Block in Tank
Book No.
Project No.
Concept 2
5

Concept 3: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Book No.
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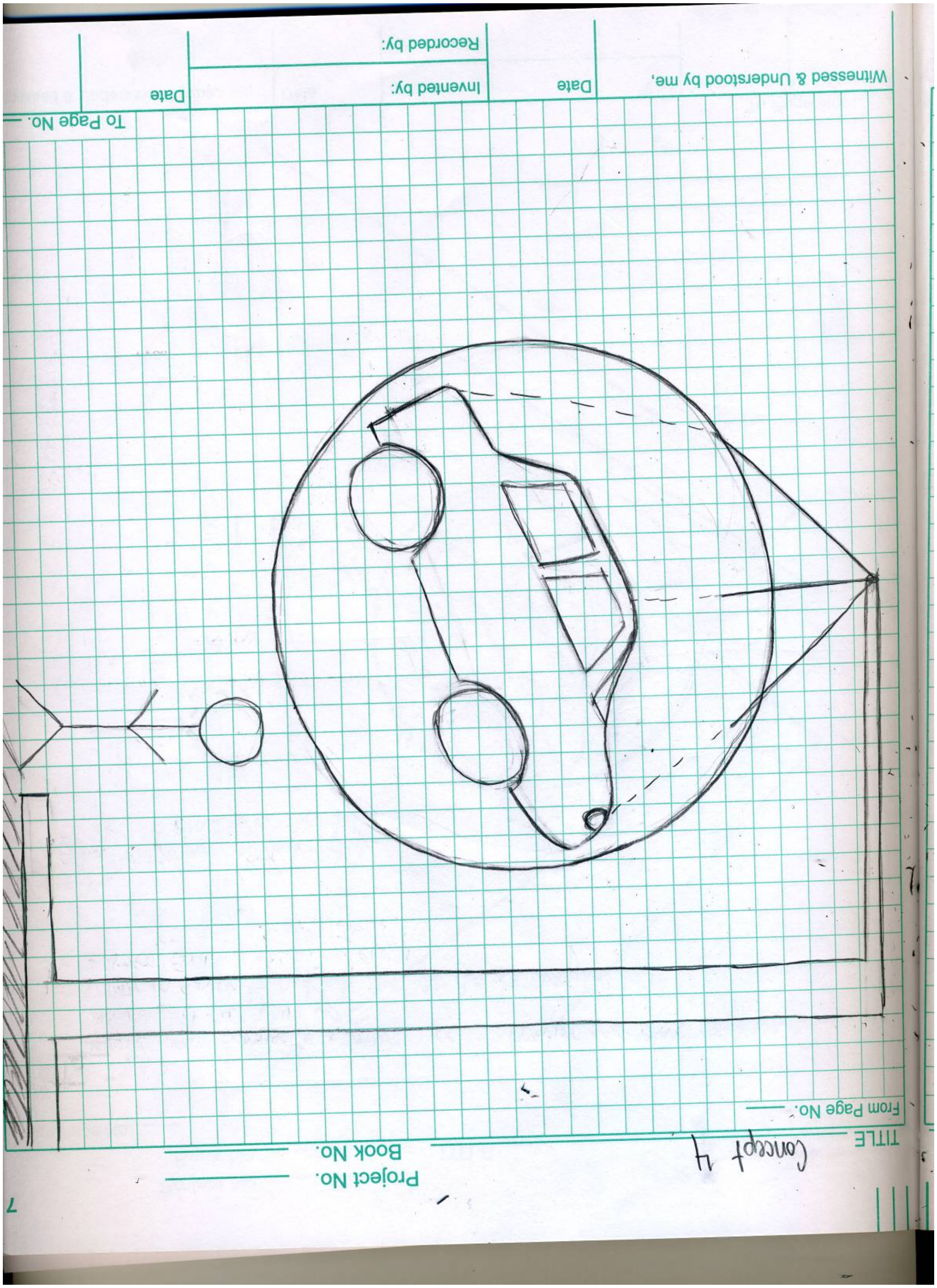
Date
1/17/06

Concept 4: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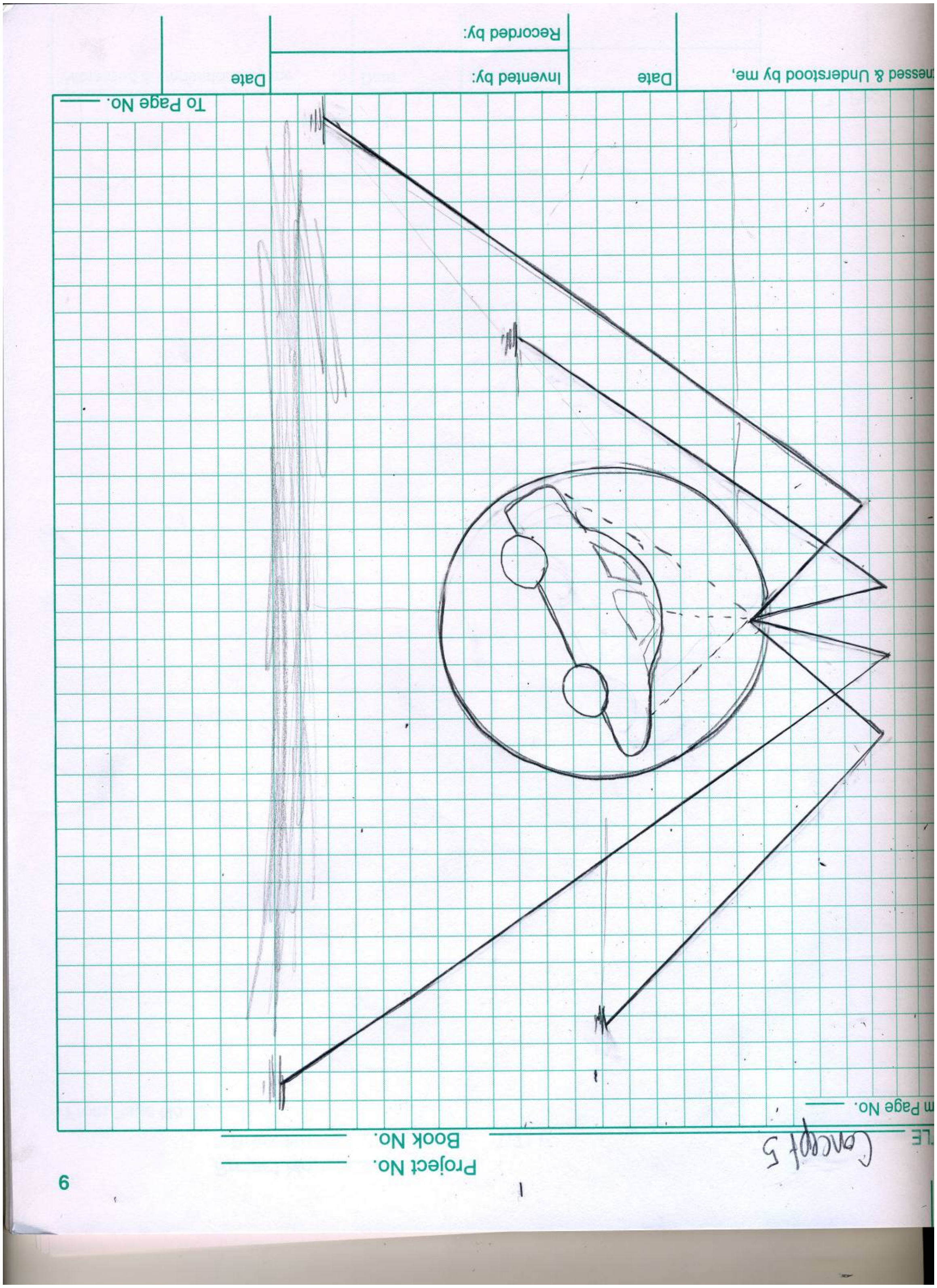
Concept 4
Book No.
Project No.

Concept 5: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Invented by:
Date
Date
To Page No.
Book No.
Project No.
Concept 5

Appendix E: PROCESS FMEA REPORT

designsafe Report

Application: Frozen Car Process Design
Description:
Product Identifier:
Assessment Type: Detailed
Limits:
Sources:

Analyst Name(s):
Company:
Facility Location:

Guide sentence: When doing [task], the [user] could be injured by the [hazard] due to the [failure mode].

Sub-process / User / Task	Hazard / Failure Mode	Initial Assessment Severity Exposure Probability	Risk Level	Risk Reduction Methods /Comments	Final Assessment Severity Exposure Probability	Risk Level	Status / Responsible /Reference
Material input set-up person set-up or changeover	mechanical : crushing Load of Ice/Car too much for support	Catastrophic Occasional Unlikely	High	utilize a safety factor of 1.5 during design to assure sufficient strength	Slight Remote Unlikely	Low	In-process design engineer
Material input set-up person set-up or changeover	mechanical : head bump on overhead objects working around lifted car	Minimal Remote Possible	Low	utilize safety equipment- hard hat	Minimal Remote Negligible	Low	On-going [Daily] woker
Material input set-up person set-up or changeover	mechanical : break up during operation Damage of Structural support during freezing	Catastrophic Remote Possible	High	daily visual inspection of ice load	Serious Remote Unlikely	Moderate	On-going [Daily] daily maintenance
Material input set-up person set-up or changeover	mechanical : machine instability Load unstable atop support jacks	Serious Remote Unlikely	Moderate	monitor ice melt on a daily basis once tank is removed to assure sufficient support	Minimal Remote Unlikely	Low	On-going [Daily] daily maintenance
Material input set-up person set-up or changeover	slips / trips / falls : slip melt water from day refreezing on cold nights	Minimal Remote Negligible	Low	inspect surrounding area and use salt accordingly	Minimal None Negligible	Low	On-going [Daily] daily maintenance
Material input set-up person set-up or changeover	slips / trips / falls : fall hazard from elevated work fall when installing tank and car	Minimal Remote Unlikely	Low	use safe work practices	Minimal None Unlikely	Low	On-going [Daily] worker
Material input set-up person set-up or changeover	slips / trips / falls : instability difficult angles to apply leverage during installation	Minimal Remote Unlikely	Low	use safe work practices	Minimal None Unlikely	Low	On-going [Daily] worker
Material input set-up person set-up or changeover	ergonomics / human factors : excessive force / exertion heavy materials to elevate	Minimal Remote Unlikely	Low	use safe work practices	Minimal None Unlikely	Low	On-going [Daily] worker

Sub-process / User / Task	Hazard / Failure Mode	Initial Assessment Severity Exposure Probability	Risk Level	Risk Reduction Methods /Comments	Final Assessment Severity Exposure Probability	Risk Level	Status / Responsible /Reference
Material input set-up person set-up or changeover	ergonomics / human factors : lifting / bending / twisting injury during lifting materials for construction	Minimal Remote Possible	Low	use safe work practices	Minimal None Unlikely	Low	On-going [Daily] worker
Material input set-up person set-up or changeover	ergonomics / human factors : deviations from safe work practices not wearing proper safety equipment	Minimal Remote Unlikely	Low	use safe work practices and wear proper protective equipment	Slight None Unlikely	Low	On-going [Daily] worker
Material input set-up person set-up or changeover	ergonomics / human factors : interactions between persons not communicating issues about equipment	Slight Remote Possible	Moderate	make sure technicians and engineers are aware of potential hazards defined in FMEA and are able to communicate with proper authority	Slight Remote Unlikely	Low	On-going [Daily] daily maintenance and engineer
Material input set-up person adjust controls / settings	heat / temperature : severe cold contact with the cooled glycol or piping	Minimal Remote Unlikely	Low	wear insulated gloves when working with cooling system	Minimal Remote Unlikely	Low	On-going [Daily] worker
Material input set-up person demonstration	mechanical : crushing Load of Ice/Car too much for support	Catastrophic Occasional Unlikely	High	utilize a safety factor of 1.5 during design to assure sufficient strength	Slight Remote Unlikely	Low	In-process design engineer
Material input set-up person demonstration	mechanical : head bump on overhead objects working around lifted car	Minimal Remote Possible	Low	utilize safety equipment- hard hat	Minimal Remote Unlikely	Low	On-going [Daily] worker
Material input set-up person demonstration	mechanical : machine instability Load unstable atop support jacks	Serious Remote Unlikely	Moderate	monitor ice melt on a daily basis once tank is removed to assure sufficient support	Serious Remote Unlikely	Moderate	On-going [Daily] daily maintenance
Material input set-up person installation	<None>						
Material input set-up person check alignment	mechanical : crushing Load of Ice/Car too much for support	Catastrophic Occasional Unlikely	High	utilize a safety factor of 1.5 during design to assure sufficient strength	Slight Remote Unlikely	Low	In-process design engineer
Material input set-up person check alignment	mechanical : head bump on overhead objects working around lifted car	Minimal Remote Possible	Low	utilize safety equipment- hard hat	Minimal Remote Unlikely	Low	On-going [Daily] worker

Sub-process / User / Task	Hazard / Failure Mode	Initial Assessment Severity Exposure Probability	Risk Level	Risk Reduction Methods /Comments	Final Assessment Severity Exposure Probability	Risk Level	Status / Responsible /Reference
Material input set-up person check alignment	mechanical : machine instability Load unstable atop support jacks	Serious Remote Possible	Moderate	monitor ice melt on a daily basis once tank is removed to assure sufficient support	Slight Remote Unlikely	Low	On-going [Daily] daily maintenance
Material input maintenance technician periodic maintenance	<None>						
Material input maintenance technician quality testing	electrical / electronic : improper wiring dangerous wires running from cooling system to power supply	Serious Remote Unlikely	Moderate	do not leave wires exposed during wiring process	Slight Remote Unlikely	Low	TBD electrician
Material input electrician / controls technician connect lines / wires	electrical / electronic : improper wiring dangerous wires running from cooling system to power supply	Serious Remote Unlikely	Moderate	do not leave wires exposed during wiring process	Slight Remote Unlikely	Low	TBD electrician
Material input electrician / controls technician inspect machinery / equipment	electrical / electronic : lack of grounding (earthing or neutral) on wires from power supply	Serious Remote Negligible	Low	identify ground before installing wiring	Minimal None Negligible	Low	TBD electrician
Material input electrician / controls technician inspect machinery / equipment	electrical / electronic : improper wiring dangerous wires running from cooling system to power supply	Slight Remote Negligible	Low	do not leave wires exposed during wiring process	Minimal Remote Unlikely	Low	TBD electrician
Material input electrician / controls technician inspect machinery / equipment	electrical / electronic : overloading cooling system consumes more power, or needs to work more than expected	Slight Remote Negligible	Low	define site capability before installing wiring	Minimal None Negligible	Low	TBD electrician
Material input materials handler drive to / from locations	material handling : excessive weight heavy construction materials	Minimal Occasional Unlikely	Low	use safe work practices	Minimal Remote Unlikely	Low	On-going [Daily] worker
Material input materials handler deliver materials / products	material handling : movement to / from storage car will be shipped from storage out of state	Minimal Remote Unlikely	Low	use safe work practices	Minimal Remote Unlikely	Low	On-going [Daily] worker

Sub-process / User / Task	Hazard / Failure Mode	Initial Assessment Severity Exposure Probability	Risk Level	Risk Reduction Methods /Comments	Final Assessment Severity Exposure Probability	Risk Level	Status / Responsible /Reference
Material input materials handler deliver materials / products	material handling : excessive weight heavy construction materials	Minimal Occasional Unlikely	Low	use safe work practices	Minimal Remote Unlikely	Low	On-going [Daily] worker
Material input materials handler deliver materials / products	material handling : motor vehicle movement trucks will be required to deliver materials specifically cement and tank materials, worker injured by motor vehicle	Minimal Remote Negligible	Low	use safe work practices	Minimal Remote Unlikely	Low	On-going [Daily] worker
Material input materials handler transport materials	material handling : excessive weight heavy construction materials	Minimal Occasional Unlikely	Low	use safe work practices	Minimal Remote Unlikely	Low	On-going [Daily] worker
Material input materials handler transport materials	material handling : motor vehicle movement trucks will be required to deliver materials specifically cement and tank materials, worker injured by motor vehicle	Minimal Remote Negligible	Low	use safe work practices	Minimal Remote Unlikely	Low	On-going [Daily] worker
Material input engineer conduct tests	mechanical : crushing Load of Ice/Car too much for support	Catastrophic Occasional Unlikely	High	utilize a safety factor of 1.5 during design to assure sufficient strength	Slight Remote Unlikely	Low	In-process design engineer
Material input engineer conduct tests	mechanical : head bump on overhead objects working around lifted car	Minimal Remote Possible	Low	utilize safety equipment- hard hat	Minimal None Unlikely	Low	On-going [Daily] worker
Material input engineer conduct tests	mechanical : machine instability Load unstable atop support jacks	Catastrophic Remote Possible	High	monitor ice melt on a daily basis once tank is removed to assure sufficient support	Slight Remote Unlikely	Low	On-going [Daily] daily maintenance
Material input engineer conduct tests	electrical / electronic : improper wiring dangerous wires running from cooling system to power supply	Serious Remote Unlikely	Moderate	do not leave wires exposed during wiring process	Minimal Remote Unlikely	Low	TBD electrician
Material input engineer conduct tests	slips / trips / falls : slip melt water from day refreezing on cold nights	Minimal Remote Unlikely	Low	inspect surrounding area and use salt accordingly	Minimal None Negligible	Low	On-going [Daily] daily maintenance

Sub-process / User / Task	Hazard / Failure Mode	Initial Assessment Severity Exposure Probability	Risk Level	Risk Reduction Methods /Comments	Final Assessment Severity Exposure Probability	Risk Level	Status / Responsible /Reference
Material input engineer conduct tests	slips / trips / falls : fall hazard from elevated work fall when installing tank and car	Slight Remote Unlikely	Low	use safe work practices	Minimal Remote Unlikely	Low	On-going [Daily] worker
Material input engineer conduct tests	ergonomics / human factors : lifting / bending / twisting injury during lifting materials for construction	Slight Remote Unlikely	Low	use safe work practices	Minimal Remote Unlikely	Low	On-going [Daily] worker
Material input engineer conduct tests	ergonomics / human factors : deviations from safe work practices not wearing proper safety equipment	Minimal Remote Unlikely	Low	use safe work practices	Minimal Remote Unlikely	Low	On-going [Daily] worker
Material input engineer conduct tests	heat / temperature : severe cold contact with the cooled glycol or piping	Minimal None Unlikely	Low	wear insulated gloves when working with cooling system	Minimal Remote Unlikely	Low	On-going [Daily] worker
Material input engineer conduct tests	fluid / pressure : fluid leakage / ejection Glycol fluid leaks from cooling system	Minimal Remote Unlikely	Low	wear insulated gloves when working with cooling system	Minimal Remote Unlikely	Low	On-going [Daily] worker
Material input engineer trouble shooting	<None>						
Material input engineer communicate with / supervise others	<None>						
Material input engineer inspect machinery	mechanical : crushing Load of Ice/Car too much for support	Catastrophic Occasional Unlikely	High	utilize a safety factor of 1.5 during design to assure sufficient strength	Slight Remote Unlikely	Low	In-process design engineer
Material input engineer inspect machinery	mechanical : head bump on overhead objects working around lifted car	Minimal Remote Possible	Low	utilize safety equipment- hard hat			On-going [Daily] worker
Material input engineer inspect machinery	slips / trips / falls : slip melt water from day refreezing on cold nights	Minimal Remote Unlikely	Low	inspect surrounding area and use salt accordingly			On-going [Daily] daily maintenance

Sub-process / User / Task	Hazard / Failure Mode	Initial Assessment Severity Exposure Probability	Risk Level	Risk Reduction Methods /Comments	Final Assessment Severity Exposure Probability	Risk Level	Status / Responsible /Reference
Material input remover disassemble equipment	mechanical : crushing Load of Ice/Car too much for support	Catastrophic Occasional Unlikely	High	utilize a safety factor of 1.5 during design to assure sufficient strength	Slight Remote Negligible	Low	In-process design engineer
Material input remover disassemble equipment	mechanical : head bump on overhead objects working around lifted car	Minimal Remote Possible	Low	utilize safety equipment- hard hat	Slight Remote Unlikely	Low	On-going [Daily] worker
Material input remover disassemble equipment	mechanical : break up during operation Damage of Structural support during freezing	Catastrophic Remote Possible	High	daily visual inspection of ice load	Serious Remote Unlikely	Moderate	On-going [Daily] daily maintenance
Material input remover disassemble equipment	mechanical : machine instability Load unstable atop support jacks	Serious Remote Unlikely	Moderate	monitor ice melt on a daily basis once tank is removed to assure sufficient support	Slight Remote Unlikely	Low	On-going [Daily] daily maintenance
Material input remover disassemble equipment	electrical / electronic : improper wiring dangerous wires running from cooling system to power supply	Serious Remote Unlikely	Moderate	do not leave wires exposed during wiring process	Slight Remote Unlikely	Low	TBD electrician
Material input remover disassemble equipment	slips / trips / falls : fall hazard from elevated work fall when installing tank and car	Slight Remote Unlikely	Low	use safe work practices	Slight Remote Unlikely	Low	On-going [Daily] worker
Material input remover disassemble equipment	ergonomics / human factors : excessive force / exertion heavy materials	Slight Remote Unlikely	Low	use safe work practices	Slight Remote Unlikely	Low	On-going [Daily] worker
Material input remover disassemble equipment	ergonomics / human factors : lifting / bending / twisting injury during lifting materials for construction	Slight Remote Unlikely	Low	use safe work practices	Slight Remote Unlikely	Low	On-going [Daily] worker
Material input remover disassemble equipment	ergonomics / human factors : deviations from safe work practices not wearing proper safety equipment	Slight Remote Unlikely	Low	use safe work practices	Slight Remote Unlikely	Low	On-going [Daily] worker
Material input remover move / remove components	mechanical : crushing Load of Ice/Car too much for support	Catastrophic Occasional Unlikely	High	utilize a safety factor of 1.5 during design to assure sufficient strength	Slight Remote Unlikely	Low	In-process design engineer

Sub-process / User / Task	Hazard / Failure Mode	Initial Assessment Severity Exposure Probability	Risk Level	Risk Reduction Methods /Comments	Final Assessment Severity Exposure Probability	Risk Level	Status / Responsible /Reference
Material input remover move / remove components	mechanical : head bump on overhead objects working around lifted car	Slight Remote Unlikely	Low	utilize safety equipment- hard hat	Slight Remote Unlikely	Low	On-going [Daily] worker
Material input remover move / remove components	electrical / electronic : improper wiring dangerous wires running from cooling system to power supply	Serious Remote Unlikely	Moderate	do not leave wires exposed during wiring process	Slight Remote Unlikely	Low	TBD electrician
Material input remover move / remove components	ergonomics / human factors : excessive force / exertion heavy materials to remove from high elevatation	Slight Remote Unlikely	Low	use safe work practices	Slight Remote Unlikely	Low	On-going [Daily] worker
Material input remover move / remove components	ergonomics / human factors : lifting / bending / twisting injury during lifting materials for construction	Slight Remote Unlikely	Low	use safe work practices	Slight Remote Unlikely	Low	On-going [Daily] worker
Material input remover move / remove components	material handling : excessive weight heavy construction materials	Slight Remote Unlikely	Low	use safe work practices	Slight Remote Unlikely	Low	On-going [Daily] worker
Material input remover prepare for shipment	mechanical : crushing Load of Ice/Car too much for support	Catastrophic Occasional Unlikely	High	utilize a safety factor of 1.5 during design to assure sufficient strength	Slight Remote Unlikely	Low	In-process design engineer
Material input remover prepare for shipment	slips / trips / falls : fall hazard from elevated work fall when installing tank and car	Slight Remote Unlikely	Low	use safe work practices	Minimal Remote Unlikely	Low	On-going [Daily] worker
Material input remover prepare for shipment	ergonomics / human factors : excessive force / exertion heavy materials	Slight Remote Unlikely	Low	use safe work practices	Minimal Remote Unlikely	Low	On-going [Daily] worker
Material input remover prepare for shipment	ergonomics / human factors : lifting / bending / twisting injury during lifting materials for construction	Slight Remote Unlikely	Low	use safe work practices	Minimal Remote Unlikely	Low	On-going [Daily] worker
Material input passer-by / non-user walk near machinery	fluid / pressure : fluid leakage / ejection Glycol fluid leaks from cooling system	Minimal Remote Unlikely	Low	wear insulated gloves when working with cooling system	Minimal Remote Unlikely	Low	On-going [Daily] worker

Sub-process / User / Task	Hazard / Failure Mode	Initial Assessment Severity Exposure Probability	Risk Level	Risk Reduction Methods /Comments	Final Assessment Severity Exposure Probability	Risk Level	Status / Responsible /Reference
Material output maintenance technician periodic maintenance	heat / temperature : severe cold contact with the cooled glycol or piping	Minimal Remote Unlikely	Low	wear insulated gloves when working with cooling system	Minimal Remote Unlikely	Low	On-going [Daily] worker
Material output maintenance technician periodic maintenance	fluid / pressure : fluid leakage / ejection Glycol fluid leaks from cooling system	Minimal Remote Unlikely	Low	wear insulated gloves when working with cooling system	Minimal Remote Unlikely	Low	On-going [Daily] worker

Appendix F: PROJECTED BUDGET FOR FROZEN CAR ICE DISPLAY PROCESS

Cement Base	Quantity	Unit Price	Cost
Cement	600 cubic ft	n/a	$2,500.00
ABS Piping	200 ft	n/a	$200.00
Insulation	6 rolls	$30.00	$180.00
2 ton jack stands (short)	4 jacks	$158.00	$316.00
2 ton jack stands (tall)	2 jacks	$84.00	$168.00
Ply Wood	10 sheets	$25.00	$250.00
Car lifting and positioning	n/a	n/a	$600.00
2 x 4 lumber	10 boards	$3.00	$30.00
		Subsystem Cost:	**$4,244.00**

Cooling System	Quantity	Unit Price	Cost
20-ton chillers	2	4000	**$18,000.00*
Glycol	150 gal (1297lb)	$1.31 per pound	$1,699.07
		Subsystem Cost:	**$19,699.07**

Metal Tank	Quantity	Unit Price	Cost
Tank materials	n/a	n/a	$1,473.00
2 x 4 lumber	30 boards	$3.00	$90.00
Plexiglas Window	*1 Sheet (dime)*	*n/a*	*$500.00*
Plywood	15 sheets	$15.00	$225.00
Insulation	10 rolls	$30.00	$300.00
		Subsystem Cost:	**$2,588.00**

Miscellaneous	Quantity	Unit Price	Cost
Screws	20 boxes	$6.00	$120.00
Sealant	10 tubes	$7.77	$77.70
Water	11,500 gal	$0.0067 per gallon	$80.00
Electrician	4 hours	$19 per hour	$76.00
Base set-up labor	60 hours	$19 per hour	$1,140.00
Jack stand positioning labor	30 hours	$19 per hour	$570.00
Tank set-up labor	120 hours	$19 per hour	$2,280.00
Tank tear down labor	60 hours	$19 per hour	$1,140.00
Project tear down labor	80 hours	$19 per hour	$1,520.00
Energy Costs	7,052 kW hours	$0.0835 per kilawatt-hour	$588.84
Engine removal/car prep. labor	16 hours	$19 per hour	$304.00
Shipping the car to site	n/a	n/a	$650.00

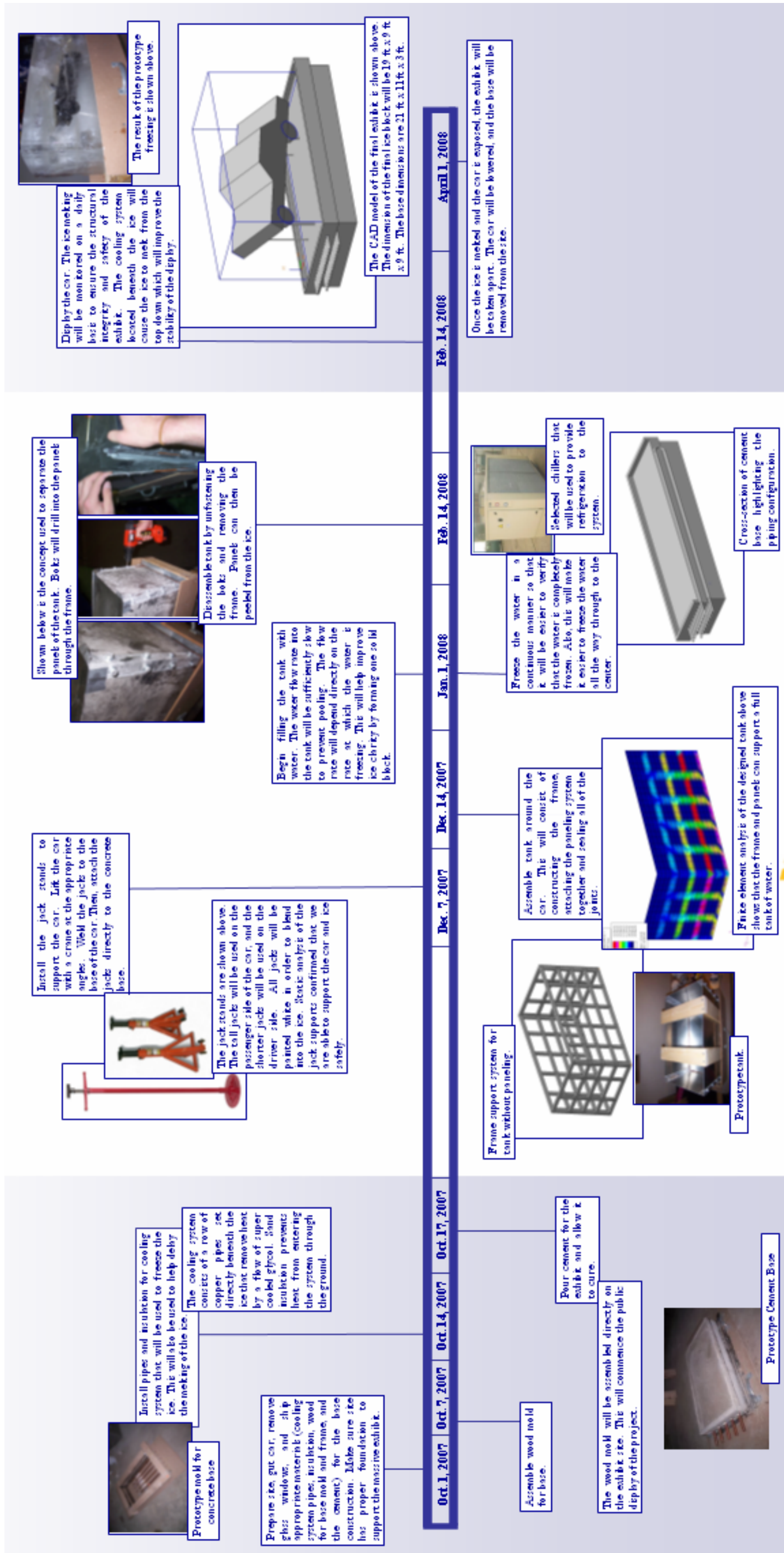
TOTAL COST	**$35,077.61**

**Cost of a brand new chiller. A rental or used chiller is recommended and will be significantly cheaper.*

Appendix G: Finite Difference Temperature Results

Point (m,n)	Temperature (F)	Point (m,n)	Temperature (F)
0,0	29.45106	5,0	29.45106
0,1	-9.51552	5,1	46.88334
0,2	-7.1154	5,2	46.68264
0,3	0.3672	5,3	45.01494
0,4	13.72338	5,4	37.4364
0,5	33.95448	5,5	29.0619
0,6	9.38772	5,6	-34.3539
1,0	15.33258	6,0	41.33232
1,1	46.88334	6,1	47.03292
1,2	42.51564	6,2	47.30472
1,3	39.29472	6,3	43.67538
1,4	44.30808	6,4	36.79776
1,5	37.6083	6,5	32.36256
1,6	-34.3539	6,6	-18.90522
2,0	13.56282	6,7	9.38772
2,1	46.79946	7,0	44.30808
2,2	42.81282	7,1	47.30472
2,3	42.19092	7,2	47.03292
2,4	45.80244	7,3	42.81282
2,5	32.36256	7,4	37.4364
2,6	-42.0579	7,5	37.6083
3,0	15.33258	8,0	20.64906
3,1	46.77174	8,1	41.33232
3,2	43.67538	8,2	33.95448
3,3	45.80244	8,3	13.72338
3,4	42.19092	8,4	0.3672
3,5	29.0619	8,5	-7.1154
3,6	-44.39448	8,6	-18.90522
4,0	20.64906		
4,1	46.79946		
4,2	45.01494		
4,3	46.68264		
4,4	39.29472		
4,5	27.9396		
4,6	-42.0579		

Appendix H: Timeline



Appendix I: TEAM BIOS

JEANIE CHUN Jeanie Chun is 21 year old senior in Mechanical Engineering at the University of Michigan. She was born and raised in Queens, New York. Her family of five includes her mother, father, a younger sister, and her grandmother. She went to high school at the Bronx High School of Science and graduated in 2003. Her interests include bowling, singing, making jewelry, and cooking. In high school, Jeanie realized that she enjoyed her technical drawing class and fixing things that were broken. She knew that her hobby of making things even origami combined with her science and technology-oriented mind would help her in Mechanical Engineering. She enjoys her design classes in Mechanical Engineering the most. In the summer of 2006, Jeanie interned at HanJin Shipping Company and learned to use various programs to design performance reports. In the future, Jeanie hopes to be working for a company as a design engineer. She would like to use her computer drawing and problem solving skills in order to improve products and create new products that will make daily events easier.

SCOTT MITCHELL Scott Mitchell is a senior in Mechanical Engineering at the University of Michigan. He is originally from Grand Blanc, MI near Flint. He has always been interested in mechanical engineering in some form because he enjoys the problem solving and resulting design process that it entails. He plays IM sports such as soccer and basketball and is a peer mentor. He has worked five internships 3 of which were at Delphi in Flint, one at 3M in Minneapolis, and one at the Boeing Company in Seattle. Three of these internships were in manufacturing and two were in design. Recently, he has accepted a job with 3M in Minneapolis working as a process engineer for their optical systems division and will begin this summer.

PAUL SARANTOS Paul Sarantos was born and raised in Portage, Michigan, and always wanted to attend the University of Michigan. His ambition to study mechanical engineering comes from a love of solving problems and creating hands-on projects. He also likes the wide range of possible occupations available to a mechanical engineer. As of yet, Paul does not have any particular interest in one occupation, but would like to be able to travel both domestically and internationally. He also plans on going back to school in a few years to get an MBA. Paul spends a majority of his time at Michigan competing in sports. He played defensive end on the football team from 2002 to 2005 and was part of two Big Ten Championship and Rose Bowl teams.

He also throws shot put, discus, and hammer for the track team and is currently in his final season. Last summer, Paul spent his first summer free of football to run the archery area at Camp Michigania, a Michigan alumni family camp. In his free time, he enjoys playing the harmonica, cooking, and playing beach volleyball.

SHELLEY SZALAY Shelley Szalay is from East Lansing, Michigan and has lived there all her life. Shelley applied to the University of Michigan Engineering school in 2003, due impart to her interest in math and science. She later declared a major in Mechanical Engineering. Shelley has spent her last three years attending the University of Michigan and working on private residential construction sites. In the fall 2006, Shelley worked a semester at Toyota Technical Center in Ann Arbor, Michigan. In the future, she plans to work at a top level engineering design firm and will later return to school for her MBA. In her free time, Shelley enjoys playing sports, traveling, skiing, and spending time with friends. She is a member of Alpha Delta Pi Sorority.

STEFANIE THEIS Stefanie is a fourth year Mechanical Engineer at the University of Michigan. She is native to Michigan and can to the University from Holland, MI. She found herself in the Mechanical Engineering program after her first year at the University when she wanted to take her passion for art and design and math and science and find a program that fit both of these. While at the University Stefanie has been involved in numerous organizations but the most notable is the campus chapter of Circle K, which is an international collegiate service organization. This year she serves as the club’s president. During her time with the club she has done over 900 hours of service. Because of all the work that she has done out in the community she has developed a real desire to work and serve people. This leads to her long term goal which is to take the knowledge she has acquired in the engineering program and her passion for helping people to start her own non-profit organization designing and manufacturing wheelchairs and other equipment for people with disabilities. While this is a very long term goal, the short term plan is to find a job after graduation that will allow her to work in this same area.