Central Coast Composites

Supermileage Seat and Wheel Development and Production

Final Report

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1 INTRODUCTION

The intent of this document is to detail the design and fabrication efforts of the Cal Poly senior project team Central Coast Composites (CCC). The project being undertaken is the development of three products for Cal Poly's Supermileage club team. Currently Cal Poly Supermileage is developing two vehicles for Shell's annual Eco-marathon competition, their high mileage Prototype Vehicle (PV) and their fuel conscious Urban Concept Vehicle (UCV). CCC has been commissioned by Supermileage to develop three products, a seat for the Urban Concept Vehicle, and a wheelset each for the Urban Concept Vehicle and Prototype Vehicle. Materials, funding, and design requirements for these products is being provided by Supermileage.

Because each product to be developed has unique requirements the project will be carried out in three stages. In the first stage, the UCV seat will be designed and built. The design of the seat has been chosen as the first completion deadline because, in comparison to the wheels, its analysis and manufacture will be relatively straightforward and its fabrication will give CCC much needed experience working with composites. The second stage will consist of the design and manufacture of wheels for the UCV. Whereas initially the plan was to produce wheels for the PV first, Supermileage ultimately decided that, since the PV already has a set of functioning wheels, the preference was for completion of UCV wheels first. Completion of the UCV's wheels is to be prior to the end of March, 2010 when the Shell Eco-marathon is held. Finally the third stage of the project will be the development of wheels for the PV that will outperform the vehicles existing wheels. Manufacture of the PV wheels will be completed on a time permitting basis.

2 BACKGROUND

Before getting started with designing a seat and wheels, the rules of the Shell Eco-marathon and current available designs must be considered. The rules are important so that contestants know what kinds of components are necessary and legal for the competition. Existing seat and wheel designs are examined in order to determine what designs may or may not work. The rules are summarized in more detail and existing seats and wheels are compared in the following sub-sections.

2.1 Shell Eco-marathon

The Shell Eco-marathon began in Europe in 1939 when Shell's employees began arguing about who could get better gas mileage. The argument developed into a competition and in 2006 the competition was brought from Europe to the United States making this year's competition the 4th annual Shell Eco-marathon held in the US. The goal of the Shell Eco-marathon is twofold: to design and build the world's most fuel-efficient vehicles and to do so while producing the fewest emissions. Two vehicle categories exist for the American competition: The Prototype Vehicles, which are streamlined vehicles that are designed to reduce drag and maximize vehicle efficiency, and the Urban Concept Vehicles, which are built to more conventional 4-wheel user-oriented criteria.

The objectives of the Shell Eco-marathon are:

- To encourage and foster innovation and ideas about fuel-efficiency and the future of modern transport
- To help technical institutions
- To secure talent for their professional technical courses
- To promote technical careers among young people all over the world

Shell has competition rules and information available online (See **Appendix A**). According to Shell's rules, the wheels must be either 16" or 17" for the Urban Concept Vehicle, but no such restrictions exist for the Prototype Vehicle. From a rules standpoint, there are no other restrictions exclusively applicable to the wheel design.

Because of the long history of the Shell Eco-marathon, a large amount of information regarding the development of fuel efficient vehicles is available. The team that holds the current world record in fuel economy, ETH Zürich, has published a book on their design [(1)]. Their success makes their literature an important component of the design of the Cal Poly Supermileage Vehicles.

2.2 Existing Seat Designs

In order to learn more about seat designs, some current designs were examined. Those seats are the Recaro Profi SPA, the Ribtect carbon fiber go cart seat, the Ford Reflex Concept seat, the Cal Poly sit ski seats, and recumbent bicycle seats. Size, weight, support, adjustability, and comfort were taken in to consideration.

2.2.1 Recaro Profi SPA Bucket Seat

The Recaro Profi SPA [(2)] is an aftermarket racing bucket seat. It is made out of a carbon-kevlar fiber. It weighs 8.8 pounds without a seat track. There is padding and fabric on the seat in order to make it comfortable. It accommodates a five point harness by utilizing holes which allow the harness to pass through. The dimensions can be seen in Figure 1 and Table 1. The main concerns about a seat such as the Recaro Profi SPA is that it will weigh more than the target weight of 7.5 pounds, it may not fit into the Urban Concept Vehicle, and it is expensive at about $2200. Also, seat tracks are not included with the Recaro Profi SPA, so additional weight and cost would be added.

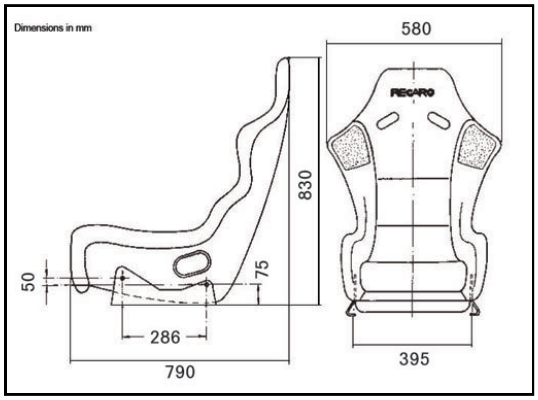


Figure 1: Recaro Profi SPA seat dimensions. [2]

Table 1: Recaro Profi SPA specifications [2]

Product Specs	Description
Height	830 mm (32.7 inches)
Shoulder width	580 mm (22.8 inches)
Seat width	395 mm (15.6 inches)
Gross weight	8.8 lbs.
Material	Carbon-Kevlar® fibre

2.2.2 Ribtect Go Cart Seat

The next seat which was examined is the Ribtect [3] carbon fiber go cart seat seen in Figure 2. The main benefit of this seat is that it weighs less than 6 pounds. Also, the seat is contoured for comfort, but lacking padding for additional comfort. The one piece design is simple, which makes it easier to manufacture. There is sufficient lateral support for the driver and the Ribtect seat is small enough to fit into the Urban Concept. The main drawback of this seat is the need for additional hardware for installation and adjustability.

Figure 2: Ribtect carbon fiber go cart seat. [3]

2.2.3 Ford Reflex Concept Seat

The next seat examined was the seat in the Ford Reflex Concept [4] vehicle as seen in Figure 3. The Ford Reflex Concept is a concept vehicle designed by Ford to showcase a variety of fuel saving features. One of those is the simple and light weight seats. Specifications are not readily available for the Ford Reflex seats because they are part of a concept vehicle. The benefit of the design is mainly the weight reduction. The centers of the seat back and seat bottom have been replaced with a net-like mesh to reduce weight and material requirements. The use of the net material also provides comfort for the driver by acting as a cushion would. While specifications are not available, the design of the seat may be used in the Urban Concept to save weight, while remaining comfortable. Adjustability and cost requirements are unknown at this time.

Figure 3: Seats in the Ford Reflex concept vehicle. [4]

2.2.4 Sit Ski Seat

Cal Poly has a history of working with paraplegic athletes in designing custom skis for paralympic competition. As part of their project scope, the engineers must create a custom seat that holds the skier in place, while not adding too much additional weight. The Sit Ski Team's seat molds and experience with constructing composite seats will be helpful in determining the best way to approach the design of the Urban Concept Vehicle's composite seat. Additionally, the Sit Ski molds could potentially be reused on the Urban Concept Vehicle.

2.2.5 Recumbent Bike Seats

Recumbent bicycle have an actual chair shaped seat unlike traditional bicycles which have saddles. The idea behind a recumbent bicycle is that instead of the majority of the weight of the rider being carried by the legs, arms and hands, the chair will support much of the load. A recumbent bicycle seat, seen in Figure 4, is usually a mesh stretched over a frame or a solid shell seat covered with soft foam which adds comfort to the rider. The seats on a recumbent bicycle are light weight but still strong enough to hold the weight of the rider and the force the rider transmits. Many recumbent seats are ergonomically designed for the comfort of the rider. Most recumbent bicycle seats are custom made and the retail prices are between $100 and $250.

Figure 4: Recumbent bike seat.(5)

2.3 Existing Urban Concept Vehicle Wheel Designs

2.3.1 Weds Sport

The Weds Sport wheel in Figure 5 is the first all carbon wheel to be released by a wheel manufacturer. [6] The information on this wheel was minimal because it was displayed in Japan and technical information was not abundant. Weds uses a dry method to make these wheels as opposed to a wet method. [6] These wheels present a very light weight package and are aesthetically pleasing. While a wheel similar to these would be a good choice for the UCV, these wheels are expensive at $2500 to $4000 a piece. Also, Cal Poly may not have the facilities necessary to produce wheels like these.

Figure 5: Weds Sport full carbon wheel. [7]

2.3.2 Dymag Carbon Magnalium

Dymag is a car and motorcycle wheel manufacturer that manufactures two piece carbon and magnalium wheels seen in Figure 6. The hoop is carbon fiber and the center is magnalium. [8]

They are very light weight and have been produced longer than the Weds wheels. They are, however, too expensive to purchase. Cal Poly also lacks facilities to manufacture wheels similar to these.

Figure 6: Dymag two piece carbon and magnalium car wheel.

2.3.3 Dymag Motorcycle wheels

Dymag also produces motorcycle wheels such as the one seen in Figure 7. The benefits of these wheels are that they are light weight, rigid, approved for standard road use, and available in a narrow enough size for the UCV. [9] The drawback of these wheels is that they are expensive at roughly $3000 per set. [10] These wheels would be difficult to manufacture at Cal Poly, but due to the one piece design and less intricate shape, would be easier to manufacture than a wheel like the Weds Sport wheel.

Figure 7: Dymag 5-spoke motorcycle wheel. (Dymag)

2.3.4 Rivers Carbon Racing Wheels

Another potential design is that of Rivers Carbon's racing wheels. These wheels, seen in Figure 8 and Figure 9, are designed for drag racing and have been tested to 12,000 ft-lbs of torque [11]. This design is a fairly simple two piece design with the center being a solid disk. Of the several wheels previously shown, these would be the easiest to manufacture. They are also overbuilt for the UCV, so a smaller design that is not as strong as these racing wheels could work for the

UCV. The drawbacks of these specific wheels are that they are custom made by Rivers Carbon and are most likely expensive, and Rivers Carbon is located in New Zealand (11).

Figure 8: Rivers Carbon racing wheels.

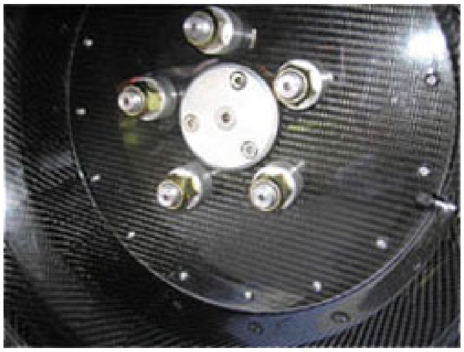


Figure 9: Detail of the center of a Rivers Carbon racing wheel.

2.3.5 Other Urban Concept Vehicle Wheel Designs

Other potential designs for the UCV wheels are similar to potential designs for the Prototype vehicle. Since the UCV does not need wheels as large as standard automobile wheels, any of the potential Prototype wheel designs could work, but on a larger scale. For each of these potential designs, similar problems are present for use or manufacturing for the UCV.

2.4 Existing Prototype Vehicle Wheel Designs

The market for custom wheels is very large, but is mainly centered on full sized road bike wheels and aftermarket rims for production street vehicles. Comparable products to Supermileage's request do exist; however, they are underdeveloped and costly. The following section explains how current custom products can help Central Coast Composites create custom wheels that meet the needs of Supermileage.

2.4.1 Formula SAE Vehicle Wheels

The Cal Poly Formula SAE teams have made several attempts at designing and building successful carbon fiber wheels as seen in Figure 10. (12) Their project reports are available on

Microfiche in the Cal Poly library. Relevant manufacturing techniques and test data from their report could prove useful in the designing of the Supermileage wheels. The latest Formula SAE wheels are also an important case study because they failed before they even made it to the track. The inflation pressure from the tires was sufficient to separate and crack the wheels. A close look at the failure mode of these wheels will be important in preventing another Cal Poly wheel mishap.

Figure 10: Cal Poly Formula SAE composite wheels. (12)

2.4.2 Recumbent Bicycle Wheels

There is a large market for recumbent bicycle racing wheels such as the one in Figure 11. The top of the line products serve as a benchmark for the Prototype Vehicle wheels. The standard recumbent bicycle wheels are the correct size for the Prototype Vehicle. Composite full disk wheels already exist on the market, but are expensive. Central Coast Composites aims to attain similar performance to existing racing wheels while offering them to the Supermileage team at a lower cost.

Figure 11: Recumbent Bicycle Wheel. (13)

2.4.3 Zipp Wheels

Zipp is a performance road bike wheel manufacturer. They manufacture full disk and carbon hoop spoke wheels seen in Figure 12. Wind tunnel tests done by Zipp have shown that the full disk is the most aerodynamic design. Zipp also manufactures dimples into the surface of the wheels to break the boundary layer of air on the wheels, thus reducing drag. The main drawbacks of Zipp wheels are that they are expensive and too large for the Prototype Vehicle.

Figure 12: Zipp full disk rear and front spoke composite wheels. [14]

2.4.4 Mavic Cosmic Carbone Ultimate Wheel

Mavic manufactures a wheel that has a carbon hoop with unilateral elliptical carbon spokes that appear to be bonded to the hoop and full carbon hub as seen in Figure 13. They are some of the lightest road bike wheels available and take advantage of the properties of carbon fiber. The problem with these wheels is that, like the Zipp wheels, they are expensive and too large for the Prototype Vehicle.

Figure 13: Mavic Cosmic Carbone Ultimate wheel. [15]

2.4.5 Current Prototype Wheels

The current Prototype wheels are Alex DX32 rims, Figure 14, with Sturmey Archer XFD front hubs. The rear hub is a standard bmx type hub. These wheels are light weight for a low price, durable, and easily serviceable due to readily available parts. The drawbacks of these wheels are that they weigh more than the designed competition weight, and have high rotational inertia compared to composite wheels.

Figure 14: Rim from current Supermileage Prototype. (16)

2.5 Composite Materials

Composite materials are known for their high strength-to-weight ratio. In order to minimize the weight on the Supermileage Vehicles, it is crucial for us to consider which type of composite materials and what orientations will provide the greatest strength and the least amount of weight for the seat and wheels. The two main types of composites considered for this project are fiberglass and carbon fiber. Table 2 below shows a comparison between the two materials and adds aluminum and steel as a reference.

Table 2: Material Properties Comparison (17)

	Unit	Fiberglass (0°/90°)	Carbon Fiber (0°,90°)	Carbon Fiber (Uni)	Aluminum	Steel
Density, ρ	lb_f/in^3	.08	.05	0.05	0.098	0.282
Modulus of Elasticity, E	Mpsi	3.6	10.5	20.8	10.4	30.0
Modulus of Rigidity, G	Mpsi	0.6	0.7	0.7	3.9	11.5
Poisson's Ratio, ν	-	0.2	.01	0.2	0.333	0.292

Because of the higher modulus of elasticity and lower density for carbon fiber, it is the preferred composite material. However, carbon fiber is much more expensive than fiberglass.

Composites like carbon fiber are strong in tension, but in compression, the fibers are prone to failure. Because of this, it is crucial to orient the fibers in such a way that they take mostly a tensile load. Often times, fibers are oriented in a 0°/90° pattern in order to withstand varying loads. Furthermore, rotating the fibers to a ±45° pattern increases torsional stiffness. Most carbon suppliers offer the material in a uni-directional sheet, or in 0°/90° sheets known as cloth. Carbon cloth also has its own varieties, with common variants being standard weave, twill, and satin patterns. The differences are shown in Figure 15: Standard Twill and Satin weave carbon fiber cloth..

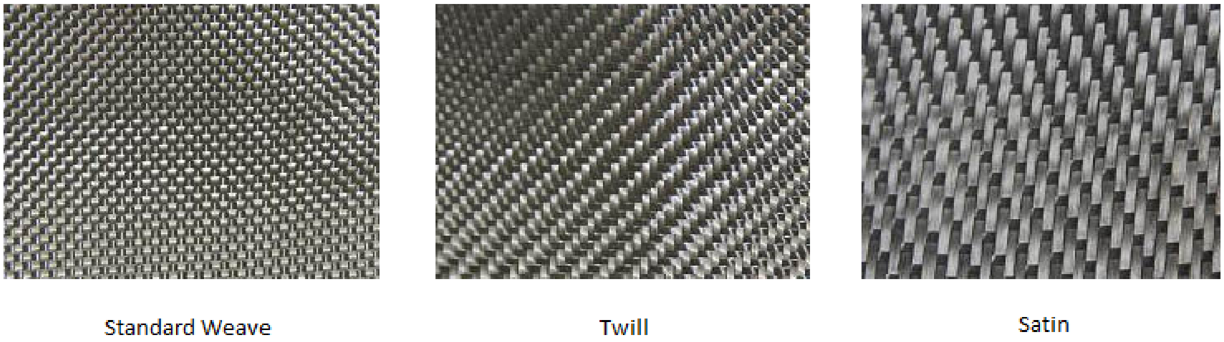


Figure 15: Standard Twill and Satin weave carbon fiber cloth. [17]

Standard weave is the cheapest cloth, followed by twill and then satin. Twill offers the greatest flexibility, making it easier to drape over 3D surfaces. Satin is generally thicker and provides a visually appealing surface finish since all fibers are oriented in the same direction on the visible layer.

2.5.1 Composite Resins

In cloth form, carbon fiber is very flexible and prone to losing shape. By adding in a plastic resin matrix, the cloth is able to retain its shape. Resins come in a large variety of mixtures and properties. Some resins cure at room temperature, while others require being heated to high temperatures in order to cure. Also, different resins have different work times and dry times. It is crucial to find the resin compound that works best for our application. A ratio of 50/50 carbon to resin is typical. Adding additional resin will increase the weight and decrease the material's strength-to-weight ratio. The process of adding resin to a dry cloth is known as a wet layup.

Some cloth comes pre-impregnated with resin. These cloths are known as carbon fiber prepreg. Because the resin is already impregnated in the cloth, it needs to be kept frozen to prevent the resin from setting. Prepreg is preferred over wet layup because the carbon/resin ratio is optimized and the resin is evenly distributed. Prepreg comes in most standard weave patterns, but often costs twice the amount as dry cloth. Wet layup techniques prove to save much more money, but are messier to work with and are more difficult to achieve optimal resin ratios.

2.5.2 Composite Construction

Carbon fiber parts are difficult to produce in comparison to metals. Because metals have uniform properties, they can be machined easily. Carbon fiber's strength is dependent on the fibers. If fibers are cut, then it creates a weakness in the part. This makes it impossible to create a solid block of carbon fiber and machine it down to the given dimensions. On top of this, the plastic resin that is required to harden the carbon cloth is very hard. This makes it difficult to machine or even drill unless carbide tips are used.

A common way of constructing carbon fiber parts is to use molds and lay the cloth over or into a mold. Molds typically are created using fiberglass material and smoothing out the surface with Duratec, a polyester surface primer. Foam can also be used to create a male plug in which the cloth can be wrapped around. The foam can be left inside the carbon to increase the compression strength and to eliminate the difficult process of removing the foam. Figure 16 shows an example of a female composite mold and the resulting carbon fiber part. Molds can also be waxed to aid in the removal of the carbon fiber part after curing.

In order to keep the cloth in the shape of the mold, a vacuum is applied by surrounding the part in a vacuum bag. Because the bag sticks to the resin impregnated cloth, a release agent or film must be placed between the vacuum bag and the cloth. To prevent the bag from sealing and creating uneven pressure distribution, a breather cloth is also added, allowing the vacuum pressure to remain constant across the entire surface of the part. This breather cloth also doubles as an absorber cloth for any excess resin.

Figure 16: Female Composite Mold and Resulting Carbon Fiber Part [19]

The vacuum must be maintained until the resin cures. For parts that need to be baked in an autoclave, it is necessary to check that all parts entering the autoclave are able to withstand the high temperatures.

2.6 Design Tools

A number of design tools are available to Central Coast Composites on the Cal Poly campus. These various programs will prove useful in simulating the loading conditions for the Supermileage vehicles, ultimately leading to an optimized design. Some tools will include Finite Element Analysis software (FEA), namely Abaqus 6.7-3 and Pro-Engineer based Pro-Mechanica

Wildfire 4, as well as the solid modeling programs Pro-Engineer Wildfire 4 and Solidworks 2009 SP4.0.

3 PROJECT OBJECTIVES

The major objectives of this project have been broken into three separate parts. Each objective will be given individual consideration in this section, as each has its own requirements, deadlines, and goals. The three portions are therefore treated each as individual sub-projects of the overall Senior Project Goal.

For each sub-project, customer needs were determined through dialog with the customer, Cal Poly Supermileage. These needs were than analyzed using a Quality Function Deployment matrix (QFD) to determine the relevant and necessary engineering specifications required to meet those needs (see **Appendix B**). This was accomplished by analyzing the customer needs and using engineering judgment to propose a list of specifications to meet the needs. Each need was then weighted based on its relative importance to the success of the final product. Needs that were absolutely necessary were given higher weighting than those that were less, or not necessary for success. After weighting, each need was compared to each specification and given a correlation factor. For instance, if the customer need is a lightweight product and the specification is cost, the need and specification are given a medium correlation because it is expected that a decrease in weight is correlated to an increase in cost. Finally the weight factor for each need was distributed to each correlation factor to determine how well each need was being met by the chosen specifications. The QFD matrix ensures that all of the needs that must be met have a measurable specification that can be tested against in the final product.

We plan to design, manufacture and install a seat in the Urban Concept Vehicle. The planned terminus of the seat project is the end of Fall quarter of 2009. As of the writing of this report the seat has been designed and manufactured. Currently the seat needs a mounding bracket to be fabricated before it can be installed. The bracket will be fabricated and the seat installed prior to the car going to the Shell Eco-marathon in late March. Further, we plan to design, manufacture, and test four wheels for the Urban Concept Vehicle. The planned terminus of the UCV wheel project is before the 2010 Shell Eco-marathon competition which is in the last week of March, 2010. Finally we plan to begin the design of the Prototype Vehicle wheels after successful completion of the UCV wheels. Manufacture of PV wheels will be performed on a time permitting basis.

3.1 Urban Concept Seat Specifications

Our objective with the urban concept seat is to design, fabricate and install a seat in the developing Cal Poly Urban Concept Vehicle such that the needs and desires of the Cal Poly Supermileage Team are met to the team’s satisfaction. When taken in the context of the overall project, the objective of the seat portion is to garner as much practical knowledge of the process of designing and fabricating with composites as possible. It is our intent to use this experience and knowledge to assist in the design and fabrication of the Prototype wheels, as well as the design of the Urban Concept Wheels, time permitting.

Based on input from the Supermileage team, a set of customer needs were determined. Enumerated in Table 3, the customer needs have been assessed using a QFD matrix (see **Appendix B**) which translates these needs into measurable engineering specifications or targets. Table 3 also presents the assessed risk of not successfully achieving each engineering target. It also shows our planned method of approach in certifying that our final product has met our specifications. At this time the assessed risk is defined to be the risk perceived by the team based on a Gantt chart of completion deadlines.

Table 3: Urban Concept Seat specification requirement and assessment.

Item Number	Specification	Engineering Target	Target Tolerance	Assessed Risk	Certification approach
1	Weight	7.5 lbs	± 0.5 lbs	Medium	T
2	Dimension	See cabin dimensions	N/A	Low	N/A
3	Cost	~ $350	± $50	Low	I
4	Seatbelt compatibility	Two upper slots, room for crotch strap	N/A	Low	I,T
5	Frame compatibility	See cabin dimensions	N/A	Low	I,T
6	Weight capacity	150 to 200 lbs	± 25 lbs	Low	T
7	Comfort	Subjective	N/A	Medium	I
8	Manufacturability	N/A	N/A	Medium	I
9	Adjustable range	4 inches	2 inch increments	Medium	T

Assesed risk is the risk level that exists for reaching that particular goal. High risk is for a specification that will be hard to reach. Medium risk will be feasible to reach. Low risk is easy to reach. Non-applicable is "n/a." Certification approaches include **A** for analysis, **T** for test, **S** to similarity, and **I** for inspection. Non-applicable is "n/a."

3.2 Urban Concept Vehicle Wheel Specifications

Our objective with the Urban Concept Vehicle Wheels is to design, fabricate four wheels for the developing Cal Poly Urban Concept Vehicle such that the needs and desires of the Cal Poly Supermileage Team are met to the team's satisfaction. The development of the UCV wheels constitutes the bulk of the senior project.

Like the UCV seat a set of customer needs were determined based on input from the Supermilage team. Enumerated in

Table 4, the customer needs have been assessed using a QFD matrix (see Appendix B) which translates these needs into measurable engineering specifications or targets.

Table 4 also presents the assessed risk of not successfully achieving each engineering target. It further shows our planned method of approach in certifying that our final product has met our specifications. At this time the assessed risk is defined to be the risk perceived by the team based on a Gantt chart of completion deadlines.

Table 4: Urban Concept Vehicle Wheel Specification requirement and assessment.

Item Number	Specification	Engineering Target	Target Tolerance	Assessed Risk	Certification approach
1	Tire Pressure	50 psi	Max	Low	A,T
2	Weight	3 lbs/wheel	±0.5 lbs/wheel	Medium	A,T
3	Tire Compatibility	95/80R16	N/A	Medium	T,I
4	Frame Compatibility	100mm hub spacing	±1mm	Low	T,I
5	Lateral Force	Undetermined	FOS: 2	High	A,T
6	Axial Force	Undetermined	FOS: 2	Medium	A,T
7	Rotor Compatibility	180mm Diameter	±1mm	Low	I
8	Concentric with Axle	N/A	N/A	Medium	T,I
9	Cost	Undetermined	N/A	Medium	I

Assesed risk is the risk level that exists for reaching that particular goal. High risk is for a specification that will be hard to reach. Medium risk will be feasible to reach. Low risk is easy to reach. Non-applicable is "n/a."
Certification approaches include **A** for analysis, **T** for test, **S** to similarity, and **I** for inspection. Non-applicable is "N/A."

3.3 Prototype Vehicle Wheel Specifications

Our objective with the Prototype wheels is to design and, time permitting, manufacture and test three wheels (two front and one rear) for the Cal Poly Supermileage team's Prototype Vehicle such that the needs and desires of the Cal Poly Supermileage Team are met to the team's satisfaction. This includes benchmarking of the current wheels to determine engineering targets for aerodynamic drag, weight, and stiffness. Existing data from Zipp Wheels shows how wind angles affect the drag force on four different types of wheels shown in Figure 17. This data will be used in lieu of performing wind tunnel tests to decide the most appropriate design for the Prototype Vehicle.

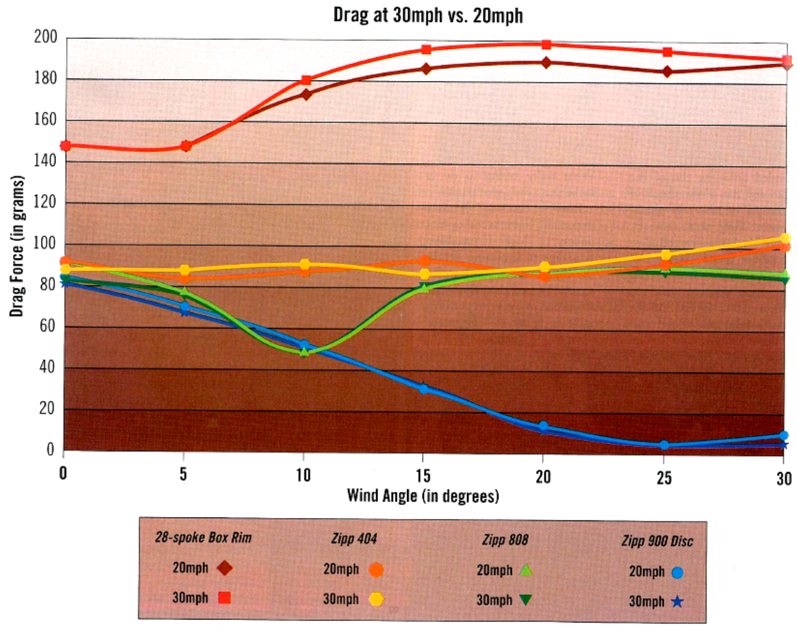


Figure 17: Zipp Wheels wind angle and drag force on wheels. [20]

As with the Urban Concept Seat and wheels, Table 5 details the engineering specifications for the Prototype Vehicle Wheels as determined using a QFD matrix (see **Appendix B**). Again the assessed risk and certification approach are detailed in order to outline our proposal for final product approach and to ensure completion of high-risk items.

Table 5: Prototype Wheels engineering requirement and assessment.

Item #	Specification	Engineering Target	Target Tolerance	Assessed Risk	Certification approach
1	Tire pressure	100 psi	±5 psi	Low	T
2	Weight	700 g/wheel	±5%	High	A,T
3	Tire compatibility	16” tire diameter	±0.05 in	Low	I
4	Frame compatibility	100 mm hub	±0.05 mm	Low	A,T
5	Lateral force	Undetermined	FOS: 2	High	A,T
6	Axial force	Undetermined	FOS: 2	Medium	A,T
7	Drum compatibility	70 mm drum	±0.05 mm	Low	I
8	Axle compatibility	28 mm	±0.01mm	Low	I
9	Drag force	Undetermined	FOS: 2	Medium	S
10	Cost	Undetermined	N/A	Medium	I
11	Valve accessible	N/A	N/A	Low	I

Assessed risk is the risk level that exists for reaching that particular goal. High risk is for a specification that will be hard to reach. Medium risk will be feasible to reach. Low risk is easy to reach. Non-applicable is “n/a.”
Certification approaches include **A** for analysis, **T** for test, **S** to similarity, and **I** for inspection. Non-applicable is “n/a.”

4 METHOD OF APROACH

The method of approach to design and build the composite wheels and seat is separated into three portions. These portions are the seat, the urban concept wheels, and the prototype wheels. For each of those, there will be design, analysis, building, and testing.

The design and building of the seat will act as a training mechanism for designing and building the composite wheels. First, the seat will be designed. Ideas will be gathered from existing seat designs, including current and past composite sit ski seats. Once the type of seat is chosen, analysis will be done to determine the dimensions of the seat. These dimensions include material thickness, composite weave direction, type of cloth to use, shape, and user fit. Once these dimensions are derived, a 3D model will be made to show what the seat will look like. From the 3D model, the seat will be made. This will be done using one of the many existing composite layup techniques. The technique will be chosen based on the shape of the seat. Once the seat is built, it will be installed in the Urban Concept Vehicle to check for fit. If the seat meets the design requirements, it will be finished. This is also where any adjustments will be made to suit the drivers.

The urban concept wheels will follow a similar method of approach as the seat, but with more analysis. First, existing designs will be examined. These include carbon disk wheels, carbon hoop/traditional spoke wheels, carbon spoke wheels, carbon automobile wheels, and carbon motorcycle wheels. Based on existing data, one of these designs will be chosen. Once the design is chosen, a 3D model will be made. Along with existing wheel aerodynamics data, dynamic and static analysis will be done, as well as any additional aerodynamics testing, to make sure the design is structurally sound. Once the design meets failure criteria, the wheels will be built. The build will consist of laying the carbon fiber using a predetermined technique, installing the hubs and brakes, and installing the tire. Next, the wheels will be installed on the Urban Concept vehicle to be checked for fit and function. Any necessary adjustments will be made until the wheels meet the design requirements.

The Prototype Vehicle wheels will be designed and built based on remaining time after completing the seat and Urban Concept wheels. The design will start with choosing a wheel type based on existing wheel designs. These include carbon disk wheels, carbon hoop/traditional spoke wheels, and carbon spoke wheels. Existing data will help to determine the optimal wheel design. Once a design is chosen, a 3D model will be made to determine and show dimensions of the wheels. Based on the design, any necessary analysis will be done to determine material thickness, weave direction, cross sectional areas and shapes, and profiles of surfaces on the wheel. The analysis will focus on static and dynamic loading and aerodynamics. After the analysis is done, changes to the design will be made so that the design is optimized. If there is enough time available, the Prototype wheels will be constructed for the team.

5 CONCEPT GENERATION

For the most part, the three projects undertaken are not new to engineering design. There are established methods for designing, analyzing and building both seats and wheels. Both seats and wheels have been successfully constructed out of numerous materials, in almost limitless shapes and sizes and for varying applications. For this reason the goal was not to "reinvent the wheel" or the seat for that matter, but instead to choose an effective and established design and manufacturing process and optimize them to the application.

Driving all of our concepts was a need to create lightweight products. One of the main factors affecting fuel economy is the amount of weight that must be moved around. For this reason many materials and process were not considered even in initial concept generation. However, even given that the goal was to model an established product and process, initial concept generation was left somewhat open to unconventional materials, methods and designs through the use of morphological attribute lists.

Morphological attribute lists are designed to yield all of the possible design concepts attainable given lists of usable parameters for various attributes of the product to be designed. In this way the list yields possibilities which are normally outside of the realm of ideas typically considered. The hope is that an "out of the box" solution will present itself and be a better solution than existing ideas and products. For example, the attributes of a wheel would be material, size, manufacturing process, and configuration. Each attribute would have a list of all possible parameters that could reasonably be associated with the attribute. For the example above, the material list might include such entries as wood, aluminum, carbon fiber, ceramic and so on. The parameters in the list need not be typically associated with the given product being designed but only reasonable possibilities. The lists of attributes are placed side by side and then random connections are created across the lists by drawing lines connecting various entries in each list. Each line represents a concept possibility that must be considered no matter how outlandish it may initially seem. For a graphical example of this process see **Appendix D**.

Morphological attribute lists were used to generate seat and wheel concepts. Each concept was then evaluated against the design specifications. The top six concepts for each project, UCV seat and wheels and PV wheels were then selected for further consideration and concept selection.

6 DESIGN PROCESS AND CONCEPT SELECTION

From the morphological attributes list six concepts were chosen for each project. These six concepts were then evaluated against one another with respect to the design specifications in order to determine the top three concepts. This was accomplished through decision matrices. The decision matrix weighs each concepts performance against each design specification. Additionally the specifications are weighted based on their relative necessity for a successful product. The weight factors for the specifications must add up to one(1) insuring that the engineer take a serious look at what is most important and what is least important. In other words all of the weights cannot have the same value thus giving each specification equal importance. Furthermore, for each project a benchmark product was selected and each concept was evaluated with respect to each specification based on how it compared to the benchmark. If the concept exceeded the benchmark for a given specification it was given a plus(+) if it fell short of the benchmark it received a minus(-) and if it was similar to the benchmark it received an evaluation of similar(s). In tabulating the total for each entry a plus(+) is given a value of +1, a minus(–) a value of -1 and an s a value of zero(0). These values were multiplied by the weighted value for the specifications they related to and the columns for each concept were totaled. The three concepts with the highest scores for each project were selected for further analysis and consideration. Decision Matrices for the Urban Concept Vehicle seat can be found in Table 6, for the Urban Concept wheels Table 7, and Table 8 for the Prototype Vehicle wheels.

Table 6: Decision Matrix for Urban Concept Vehicle seat concepts.

Specification	Weight Factor	Recaro Car Seat	Single rail w/ dual Pan	Frame w/ fabric support	Saddle	Suspended	Single Piece Lower Pan	Single Piece Ergo
Weight	0.3	0	+	+	+	s	+	+
Size	0.1	0	s	s	-	-	+	+
Cost	0.15	0	+	+	+	+	+	+
Seatbelt Compatibility	0.05	0	s	s	-	-	-	s
Frame Compatibility	0.075	0	s	s	s	-	s	s
Weight Capacity	0.075	0	s	s	-	-	s	s
Comfort	0.1	0	-	+	-	s	-	-
Adjustability	0.15	0	-	-	-	-	-	-
TOTAL	1	0	.2	.4	-.025	-.45	.25	.3

Table 7: Decision Matrix for Urban Concepet Vehicle wheels.

Specification	Weight Factor	Bicycle Spoked Wheel	Full Disc	Carbon Hoop w/metal center	Carbon Reinforced Plastic Wheel	5-spoke Carbon Motorcycle Style wheel	Plastic Injection Molded
Weight	0.3	s	+	s	-	+	-
Tire Compatibility	0.05	-	s	s	s	s	s
Frame Compatibility	0.075	s	s	s	s	s	-
Drag Force	0.1	s	+	s	-	s	-
Cost (vs purchasing Custom)	0.2	+	+	+	+	+	+
Manufactur-ability	0.2	s	s	-	-	-	s
Valve Accessibility	0.075	+	s	s	s	s	s
TOTAL	1	.225	.6	0	-.4	.3	-.275

Table 8: Decision Matrix for Prototype Vehicle wheel concepts.

Specification	Weight Factor	Current Wheels	Aero Spoke	Full Disc	Carbon Hoop/Hub w/ st. spokes	Carbon Hoop/Hub w/ Carbon Spokes	STD w/ Carbon Hoops	PIM
Weight	0.3	0	+	+	+	+	s	-
Tire Compatibility	0.05	0	s	s	s	s	s	s
Frame Compatibility	0.075	0	s	s	s	s	s	-
Drag Force	0.1	0	+	+	s	s	s	-
Cost (vs purchasing Custom)	0.2	n/a	+	+	+	+	+	+
Manufactur-ability	0.2	n/a	-	0	+	0	+	0
Valve Accessibility	0.075	0	+	-	s	s	s	s
TOTAL	1	0	.475	.525	.7	.575	.4	-.275

As can be seen from the decision matrices, the top PV wheel concepts for further consideration are a full carbon disc design, a carbon fiber hoop and hub with steel spokes, and a carbon fiber hoop and hub with carbon fiber spokes. These designs are similar to those pictured in Figure 12 and Figure 13. Similarly, the top UCV seat concepts for further consideration are a single piece ergonomic half profile design, a single piece ergonomic full profile seat, and a full profile framed seat utilizing fabric support for bottom and back panels. Sketches for these concepts can be seen in Figure 18, Figure 19 and Figure 20.

Figure 18: UCV single piece half profile seat concept.

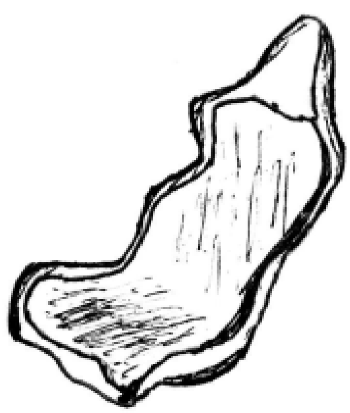


Figure 19: UCV single piece full profile seat concept.

Figure 20: UCV full profile framed seat utilizing fabric support for bottom and back panels.

7 DESIGN DEVELOPMENT

7.1 Meeting Design Targets

One of the biggest concerns in the execution of these projects is that the finished products be lightweight. Producing a seat and wheels having all of the required functionality, while maintaining a specified design weight, is therefore a top goal. Other goals include creating products that perform as desired and, perhaps most important to Cal Poly Supermileage, are completed prior to competition. Individually the projects each have separate goals which need to be met in order for the finished products to be successful.

The three goals driving the overall scope of these projects are weight, cost and completion date. The weight goals will be accomplished through appropriate materials selection. The seat, currently under construction, is the single piece full profile carbon fiber version created by wrapping a thin lightweight foam core in several layers of carbon fiber. The wheels will similarly be constructed out of light weight materials, namely carbon fiber and aluminum. To meet completion deadlines, all necessary project tasks have been outlined in a gant chart (see **Appendix C**) to insure the project is well organized and on schedule. Furthermore, manufacturability has been chosen as an important parameter in selecting appropriate design concepts. Concepts involving difficult and time consuming construction were weeded out to prevent the projects from running past their completion deadlines. Finally cost goals are being met by attempting to procure as much material as possible through sponsor donation. To ensure that the final products have met these goals they will be weighed and compared with current or expected product weights and the cost and completion date will be inspected.

Individually each project has goals necessary for its success. The goals with the seat are to create something which is comfortable and aesthetically pleasing while being rigid enough to provide support to the driver and accommodating a five point safety harness. The comfort and aesthetics goals will be accomplished by hand shaping the mold for the seat until each team member can sit comfortably in it and deems it to look “cool.” The free form design with soft flowing curves lends an organic and graceful appearance to the overall design. Rigidity will be accomplished by using a carbon fiber wrapped foam core. Calculations have been performed to estimate forces on the seat and the required layers of carbon fiber to withstand those forces (see Analysis Results section and **Appendix E**) and accommodation for the safety harness will be accomplished by cutting reliefs in the seat for the straps to pass through. The acid test for comfort and aesthetics will be the opinion of Cal Poly Supermileage, and rigidity and harness compatibility will be tested via an installation test.

Individual goals relating to the wheel projects include frame compatibility, tire compatibility and lateral and axial stiffness. Frame and tire compatibility will be met by designing the wheels in and solid modeling program, assembling them to their frame and tire components and running an interference check. Testing for compatibility will be accomplished by installing the tires to the wheels and then the wheels to the frame assembly. In order to reach stiffness goals, calculations will be performed to estimate maximum loads (see Analysis Results Section) and FEA software will be utilized to check theoretical deflections. Testing to insure that stiffness requirements have been met will consist of installing the wheels and tires and driving the vehicles under expected operating conditions.

8 FINAL DESIGN DESCRIPTION

8.1 Detailed Design Description

8.1.1 Urban Concept Vehicle Seat

The Urban Concept Vehicle seat is a carbon fiber wrapped high-density-foam-core design. Its design was shear-form so a solid model does not exist. Its shape was a product of team members subjective opinions of comfort and visual aesthetics as well as geometric requirements as detailed by the Supermileage Team, see Figure 21. Pictures of the completed seat are detailed in Figure 22 . Further ABAQUS models for the seat can be found in section 8.2.1.

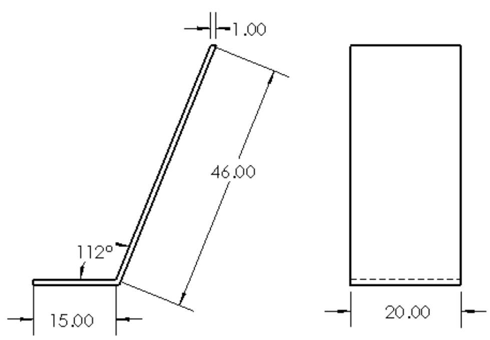


Figure 21: UCV required seat geometry.

Figure 22: UCV completed seat.

8.1.2 Urban Concept Vehicle Wheels

The Urban Concept Vehicle wheels will be a single-sided full disc carbon fiber design utilizing a separate central hub made of aluminum. The Carbon fiber portion will be bolted to the hub using six 1/4” button-head cap-screws. Further six aluminum inserts will be bonded into the carbon fiber portion of the wheel to prevent the screws from crushing or marring the carbon fiber. Part and assembly level drawings for the wheels can be found in **Appendix Q.**

8.1.3 Prototype Vehicle Wheels

Initial design for the Prototype Vehicle wheels is in progress and unknown at this time. It is most likely that the design for the Prototype Vehicle wheels will follow the top choices as decided by the decision matrix as detailed in section 6, Table 8 of this report.

8.2 Analysis Results

8.2.1 Urban Concept Vehicle Seat Load Analysis

The first analysis (see **Appendix E)**, a preliminary step to the FEA model, is an estimation of the expected loads the seat will experience during heavy use. These calculations also include a preliminary estimation of the number of composite cloth layers needed to give sufficient strength to safely withstand these loading conditions. These calculations were used as a starting point but were not used for the final design. For an accurate model, see the FEA calculations section below, section 8.2.2.

8.2.2 Urban Concept Vehicle Seat Mechanical Analysis

To create an accurate model of the seat, ABAQUS, a Finite Element Analysis(FEA), program implemented. The model was constructed by creating the back side of the seat, the sides of the seat and the bottom brackets (see Figure 23). Each one of these parts were created as a shell. The back piece and the sides of the seat were then assigned section properties of two layers of cloth thickness 0.01 inch then a layer of foam 1 inch then another two layers of cloth. The bottom brackets were assigned a cross section of three layers of cloth but no foam. The seat was then fixed using the holes cut out of the bottom bracket. A load of 250 lbs was then distributive across the back side of the seat. This can be seen in the picture below.

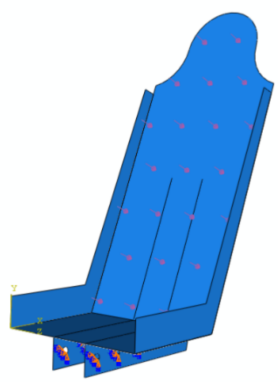


Figure 23: ABAQUS seat model

After assigning section properties and creating an assembly of the parts they were meshed and then submitted for analysis. The results can be seen below in Figure 24.

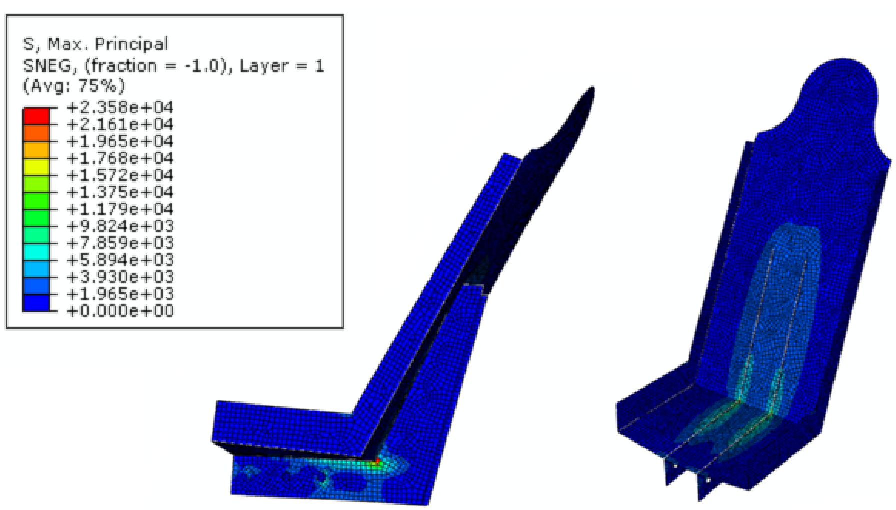


Figure 24: ABAQUS model showing maximum principal strains.

The greatest stress that the seat will experience will be where the bottom brackets are bonded to the back side of the seat. Even then the model shows very minimal deflection and stress compared to the allowable sigma of 90 ksi. This gives a safety factor of $n = \frac{90\ ksi}{23.5\ ksi} = 3.8$.

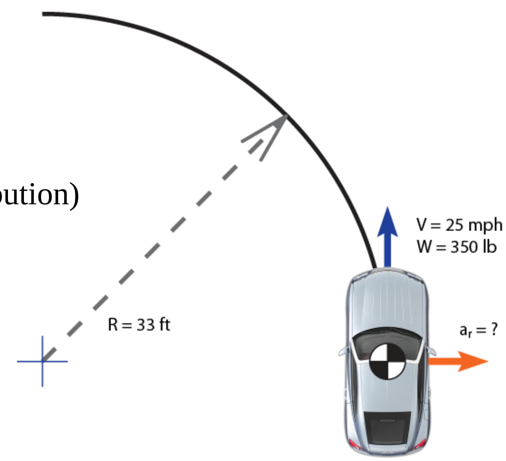
8.2.3 Urban Concept Vehicle Wheel Load Analysis

Dynamic Cornering Loads:

The following calculations help in determining the maximum cornering loads the vehicle will see during competition. Dynamic cornering loads in the Urban Concept Vehicle differ from the loads seen on the Prototype Vehicle since the Urban Concept is a four-wheeled vehicle. A few assumptions must be made in determining these loads because the vehicle is not completely designed and the track geometry is still not confirmed by the track officials. Also, track conditions are still unknown, such as weather conditions, surface roughness of the track, and whether surfaces change at different portions of the track. Most of these will remain unknown until competition.

Assumptions:

- 40 in Front Track Width
- 32 in Rear Track Width
- 60 in Wheelbase
- 350 lb car with driver (40/60 weight distribution)
- 15 in CG height
- No suspension
- μ_s = 1.0 for tires on asphalt
- 33 ft cornering radius
- 25 mph max cornering speed
- Tires do not slide



$$a_r = \frac{v^2}{r}$$

$$a_r = \left(\frac{(25\frac{mi}{\not{h}r})^2}{33ft}\right) * \left(\frac{5280\ ft}{1\ mi}\right)^2 * \left(\frac{1\ \not{h}r}{3600\ sec}\right)^2$$

$$a_r = 40.741\frac{ft}{s^2}$$

Based on these conditions, the total lateral forces on the car are as follows:

$$F_l = ma_r$$

$$F_l = \left(\frac{350\ lb}{32.2\frac{ft}{s^2}}\right) * \left(40.741\frac{ft}{s^2}\right)$$

$$F_l = 442.837\ lb$$

This lateral force equates to 1.26 lateral G's. If we assume that the dynamic loading on the tires will always total 350 lb of normal force, then the theoretical grip limit will be

$$F_f = N\mu_s = 350\ lb * 1.0 = 350\ lb$$

However, during cornering, the dynamic loading is based upon the tire track width, wheel base, weight distribution, CG height, lateral G's, and stiffness of the vehicle. These calculations can be lengthy, but fortunately, an excel program called *Optimum G* is able to calculate dynamic loading. The user needs only to input the variables mentioned above to yield the dynamic cornering loads. The program allows the addition of suspension spring rates, but those values were set to 8000 lb/in to simulate a rigid frame.

Using the *Optimum G* program, the dynamic cornering loads of the Urban Concept vehicle during a 1.26 G turn are shown in Table 9 below.

Table 9: Dynamic Corner weights for a 1.26G turn.

Dynamic Corner Weight (lb)	
-5.4	145.4
-7.4	217.4

The quadrants correspond to each corner of the vehicle during a left-hand turn. The top-left quadrant is the front-left tire. Based on these numbers, we see that the left side of the vehicle is actually off the ground. This is because the program is also assuming that the vehicle is able to maintain grip and not slide during the cornering. When this case occurs, the program is only useful in determining that not all 4 wheels of the vehicle are in contact with the ground. All dynamic loading numbers are no longer accurate.

Since the coefficient of static friction is assumed to be μ_s=1.0, then the total lateral load supported by these tires is the summation of the dynamic cornering loads. The maximum cornering loads seen by the vehicle would be when the total lateral load due to cornering is equal to the total lateral load supported by the tires. Using *Optimum G* and excel, this value was determined to be 1.0 G. Beyond this, the tires will begin to slide. During a 1.0 G turn, the loads are shown in Table 10 below.

Table 10: Dynamic Corner Weights for a 1.0G turn.

Dynamic Corner Weight (lb)	
10.1	129.9
15.8	194.2

Fortunately, all wheels are still in contact with the ground and the maximum vertical and lateral load seen by the vehicle's wheels will be 194.2 lb. The dynamic cornering loads depend largely upon the CG height. With a lower CG height, the vehicle remains stable and cornering loads are distributed more evenly from right to left. With a higher CG height, the vehicle begins to tip before the wheels slide. According to the *Optimum G* calculations, with a 1.0 G turn, the vehicle will tip with a CG height of greater than 16.9 in. If the CG height exceeds this value, then the loading conditions will change and the vehicle will be more susceptible to tipping. Although these conditions are unlikely, they must be considered as plausible during design of the wheels.

Loading Conditions

The vehicle during cornering has four types of loading that need to be addressed during the design phase of the wheels. Figure 25 illustrates the different loading conditions.

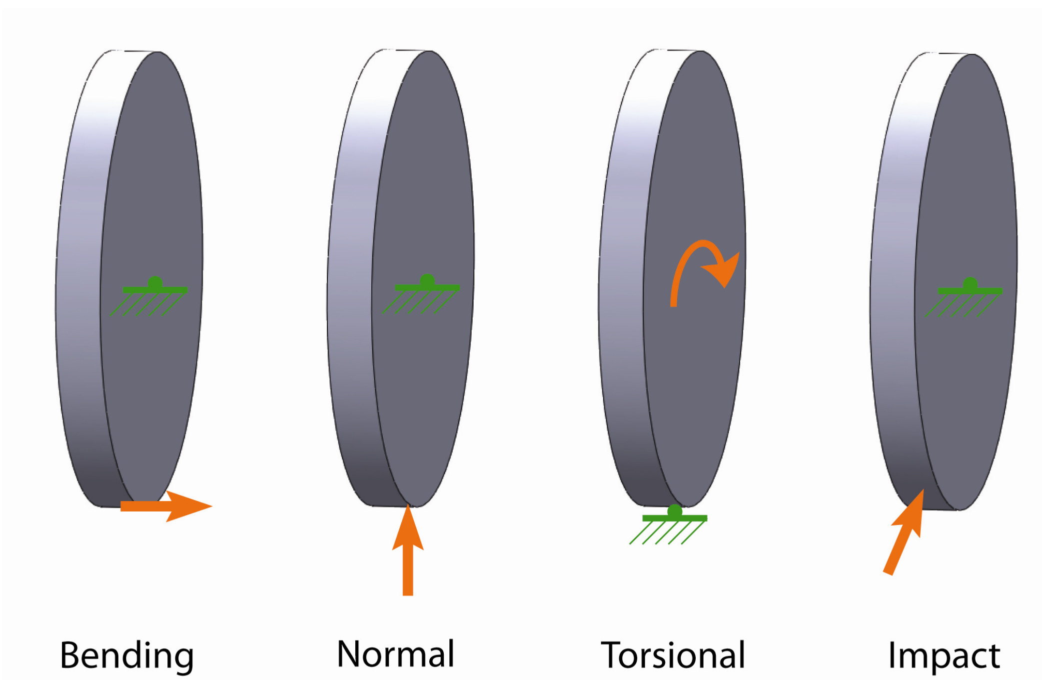


Figure 25: Loading conditions for the Urban Concept Vehicle

Axial and Bending Loads

Lateral force generated during cornering at the tire contact patch is transferred to the axles. If the hub and the portion that connects the hub to the hoop (whether it ends up being a full disk or spokes) are not rigid enough, the hub could separate from the hoop. Any bonds must also be able to withstand the axial loading. Also, the hub must be strong enough to support the compressive load of the lug nuts during mounting.

The lateral forces also create a moment about the hub. This moment can cause the hoop to deform during high cornering loads. Because the hoop will be significantly thicker than the other portions of the wheel, it will provide the majority of the bending support. The hoop must be rigid enough to withstand any bending forces. The maximum bending force is equal to the maximum cornering load; 194.2 lb_f (assuming $\mu_s = 1.0$ for tires on asphalt).

Normal Loads

During rest as well as during rotation, the normal forces acting due to the corner weights cause the upper disk/spokes of the wheel to be in tension, while the lower disk/spokes will be in compression. Composite fibers must be orientated such that the loads will be carried most efficiently. Normal loads can also cause deformation and buckling. As stated above, the maximum normal load is 231.1 lb_f.

Torsional Loads

Fibers must also be able to withstand the torsional loads applied during heavy breaking and acceleration. The worst loading conditions would be just when the brakes lock during a high-speed turn. Weight redistributes toward a front corner of the car and prior to sliding, the frictional force is a maximum. For the Urban Concept vehicle, the engine produces only around 2 ft-lb_f of torque. With a 12:1 gear ratio, the wheels see a maximum of about 24 ft-lb_f of torque. If the front wheels lock during braking and cornering, the following can be used to calculate the torque generated.

Assumptions: Same as dynamic cornering loads

Conditions: 1.0 G braking and 1.0 G cornering

Optimum G was used again to calculate the combined braking and cornering loads.

Table 11: Dynamic Corner Weights for 1.0 G of Braking and 1.0 G of Cornering

Dynamic Corner Weight (lb)	
82.4	125.1
34.1	68.37

$$T_b = F_b + r = (125.14\ lb_f) * (\frac{11\ in * ft}{12\ in})$$

$$T_b = 114.7\ ft * lb_f$$

$$Where\ T_b = Braking\ Torque,\ F_b = Braking\ Force, and\ r = radius$$

Since the torque generated by the motor is so small, the acceleration loads are less than 1/4th of the braking loads.

Impact Loads

In ideal circumstances, track conditions are smooth. Many race tracks maintain their asphalt well to eliminate any potholes or irregularities in surface. However, urban environments are less controlled and potholes and surface irregularities are common. In the automobile industry, it is commonly assumed that impact force is 3 G's. This is much higher than any of the dynamic loads of the vehicle and thus should be the primary concern when designing the wheels. Lateral impacts are uncommon but not impossible. The vehicle could slide during a turn and the wheels could hit a bump or pothole, resulting in lateral impact loads. Maximum impact loads could be as high as 582.6 lb_f using this assumption.

8.2.3 Urban Concept Vehicle Wheel Mechanical Analysis

An FEA model was created of the proposed wheel design, to help us better understand how the wheels of the urban concept vehicle will behave under working loads. From that model, we can get an approximation of the number of layers of carbon cloth needed to support the loading conditions. The wheel model was built using three different parts. The first part modeled is a revolved shell profile of the rim seen in Figure 26. Next small solid studs were created that would be bonded to the bolt holes cut out on the rim Figure 26. For the final part a shell disk was created that would be attached to the back of the rim to give added stability Figure 26.

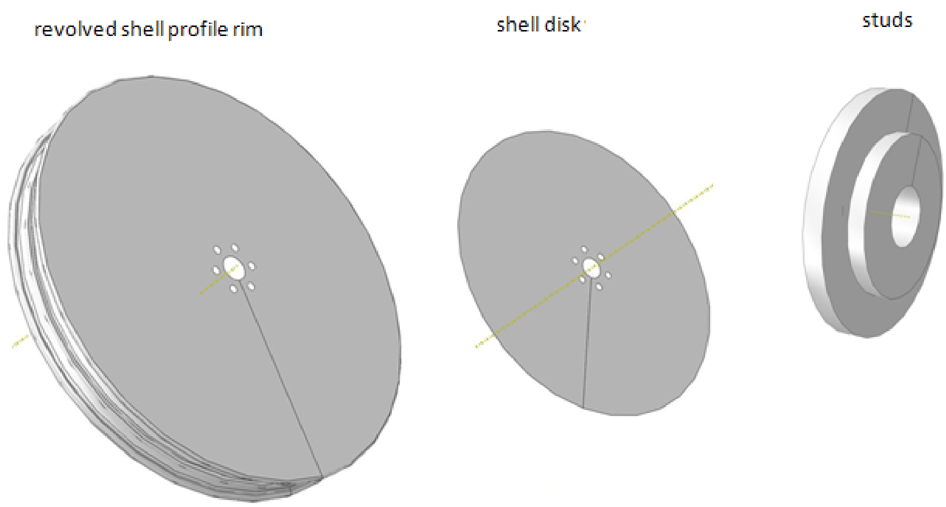


Figure 26: ABAQUS model components.

Next, three materials were created. These are the carbon composite cloth, aluminum, and a foam core material. Each part was then assigned a material section. The studs were assigned aluminum. The shell disk was assigned a quarter of an inch of the foam core material and five layers of the carbon composite cloth on top of it. The central rim was assigned 10 layers of the carbon composite cloth. After the materials were created and sections had been assigned, the rim assembly could be created. The disk was tied to the back of the central rim, and the aluminum studs were then tied into the bolt holes. Once the final assembly was done, the model needed to be fixed and then loaded. This can be seen in Figure 27.

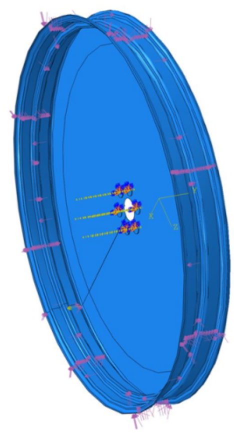


Figure 27: ABAQUS model load placement.

To accurately represent how the wheel would behave, the rim was fixed at the six locations of the bolt holes studs. A pressure load of 50 psi was placed uniformly about the rim. A normal force of 87.5 lbs was applied at the base of the rim, as well as a lateral force of 220lbs. After applying the load conditions, the part was meshed and the simulation was run. The results can be seen below in Figure 28.

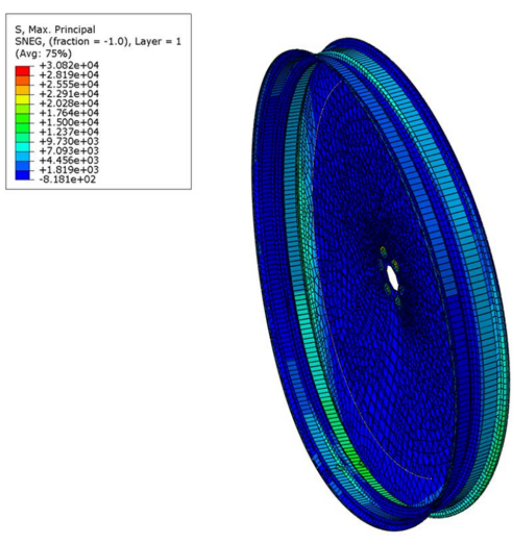


Figure 28: ABAQUS model max principal stress under predicted loading conditions.

The final stress seen in the whole part was 31 ksi. This gives us an allowable safety factor of 3.

8.2.4 Prototype Vehicle Wheels Analysis

Preliminary load analysis for Prototype Vehicle wheels has been performed and can be found in ***Appendix S.***

8.3 Cost Analysis

8.3.1 Urban Concept Vehicle Seat

For the Urban Concept seat, the material cost was approximately $400.00. These materials included enough 3k 5.8 oz 2x2 twill carbon fiber cloth to cover the seat core with 2 layers of cloth. There was also leftover cloth of which the quantity has yet to be determined. For a breakdown of individual costs see the bill of materials in Table 12.

Table 12: UCV seat B.O.M.

Line Item	Item	Qty	Cost (for needed quantity)	Part #	Supplier
1	Foam	1	$0.00	N/A	Cal Poly Supermileage
2	50 in 3k 5.8 oz 2x2 twill carbon fiber cloth	10 yd	$315.00	FG-CFT5750	US Composites
3	Medium Cure Epoxy Resin & Hardener	1 gal	$61.00	EPOX-635314	US Composites
4	Vacuum Bag	3 yd	$12.00	VB-VF02110	US Composites
5	Peel Ply	3 yd	$15.00	VB-PEF1548	US Composites
6	Sealant Tape (25 ft roll)	1	$7.00	VB-BT25	US Composites
7	Breather Cloth	3 yd	$12.00	VB-BLE060	US Composites
	Shipping (estimated)	1	$20.00	N/A	US Composites
	Total:		$442.00		

8.3.2 Urban Concept Vehicle Wheels

For the Urban Concept Wheels, if 3k 284 5.8 oz 2x2 twill carbon fiber cloth is used, the cost will be $590.00 for the cloth alone. The calculations for this can be seen in **Appendix L**. Since the wheels are relatively small compared to the widths of cloth available, the smallest width of 50 inches is the best to use because it is less expensive than wider cloth. Also, by calculating the amount of resin needed, we found that we do not need to purchase any more resin or hardener due to the amount that is leftover from construction of the seat. The calculations for resin and hardener volumes can also be seen in **Appendix L**.

Besides the carbon fiber, there are other materials needed. Aluminum blocks are needed to machine wheel hubs out of. Along with the blocks, bolts are needed to attach the hubs to the wheels. These bolts are stainless steel 1/4 -20 x 1 ½ bolts. Also, material for making molds is needed. This material is primarily high temperature casting resin. Also, a motorcycle rim is needed to use it for making the mold.

There is a possibility that cost for 3k 5.8 oz 2x2 twill carbon fiber cloth will be eliminated. If we are able to use and obtain uni ply carbon fiber, the cost will be greatly reduced due to a corporation that is willing to donate an amount of pre-preg uni ply that is larger than we would need. This would bring the cost down to the combined cost of mold making materials and hubs. Without needing to purchase carbon fiber, the estimated total cost would be $494.92.

The items, quantities, costs, and total costs for the seat and wheels can be found in below.

Table 13: UCV Wheels B.O.M.

Line Item	Item	Qty	Cost (for needed quantity)	Part #	Supplier
8	50 in 3k 5.8 oz 2x2 twill carbon fiber cloth	N/A	$0.00	FG-CFT5750	US Composites
9	1/4" carbide end mill	2	$35.68	88815A44	McMaster-Carr
10	1/4-20 Stainless Steel Hex Bolts	24	$10.26	92240A546	McMaster-Carr
11	Motorcycle Rim	1	$59.99	2000000	J&P Cycles
12	Pre Preg Carbon Fiber Cloth	N/A	$0.00	N/A	Cal Poly Supermileage
13	6061-T6 Aluminum Rod 1 inch dia.	2 ft	$7.54	N/A	Online Metals
14	6061-T6 Aluminum Rod 4 inch dia.	2 ft	$102.45	N/A	Online Metals
15	Vacuum Bag	N/A	$0.00	VB-VF02110	Cal Poly Supermileage
16	Peel Ply	3 yd	$15.00	VB-PEF1548	US Composites
17	Sealant Tape (25 ft roll)	1	$7.00	VB-BT25	US Composites
18	Breather Cloth	3 yd	$12.00	VB-BLE060	US Composites
19	High-Temp Aluminum Filled Casting Series (can substitute for Line Item 18)	2 gal	$205	EC-433	Adtech Plastic Systems
	Shipping (estimated)	1	$40.00	N/A	
	Total:		$494.92		

8.3.3 Prototype Vehicle Wheels

As it is undetermined at this time whether or not Prototype Vehicle wheels will be manufactured, a cost analysis for them has not been performed.

8.4 Manufacturing Procedure

8.4.1 Urban Concept Vehicle Seat

After considering many possible fabrication processes, we decided to construct the seat by using a series of steps that enabled completion of the first part of our project. We began by creating an ABAQUS model which carefully incorporated safety designs that satisfied minimum safety requirements which were previously calculated. We also considered other design limits including driver size, vehicle size, and competition rules for the vehicle. To insure that our seat design met geometric constraints a template was constructed out of paper. This template was used to insure that the proportions of the seat were in accordance with the specifications provided by the Supermileage team as well as insure that the overall dimensions were proportional an aesthetically appealing. This template further assisted in tracing the correct shape of the seat into a block of high density foam which was provided by the Supermileage team. After tracing the template, a rough cut of the foam was made using a carpenter's saw. This was done incrementally, making progressive rough cuts with the carpenters saw, removing big pieces of unwanted foam until we reached a size and shape that was close to the template. After achieving a rough shape, hand tools such as scrapers, sanding block, and planes were used to get within a very close distance of the trace line. The hand tools allowed us to shape the contours of the seat and achieve an organic and comfortable shape. The foam core was continually tested for relative comfort by sitting in it and then reshaping problematic areas. This process was continued until every team member could sit in the seat comfortably. Getting to the trace line was accomplished by the use of sand paper. We used a coarse grit of 80 for the first pass over the seat to get exact contours and a second pass with a finer grit of 150 to get all the rough surfaces and edges smooth and even.

After finishing the foam core mold the remaining materials needed to complete construction of the seat were ordered. We waited to order material until completion of the foam core in order to get a better estimate of the amount of carbon fiber required. We decided to use a twill weave cloth because it drapes better than a plain weave cloth. Along with the cloth we ordered absorber cloth, resin, release cloth vacuum bag and vacuum bag tape. The release cloth we decided to use was a perforated plastic type. The perforated plastic creates a smooth shiny finish while allowing excess resin to be drawn through the perforations. The material took about one week to reach us during which time we received a quick lesson in the vacuum bagging process used to bond resin and fiber to the contours of the seat. Vacuum bagging is used in both wet-layup and pre-preg applications to insure that the fiber conforms to the shape of the mold. For the seat we decided to go with a wet-layup because wet cloth drapes better than pre-preg and does not require the part to be cured in an auto-clave. This last point was important because we were unsure of how our foam would act at elevated temperatures and did not have the time required to perform proper testing on the foam. After receiving the material we began our lay-up process by creating a template of the finished foam core. This was done by draping a piece of dry fiberglass cloth over the back of the foam core. This template was then transferred to the carbon fiber cloth. The boundaries of the template were traced out and scotch tape was placed on the tracing. This is necessary to prevent the cloth from fraying and unraveling when it is cut. The tape can be left on indefinitely provided the taped side is placed facing down against the foam, however the inelastic tape prevents the cloth from draping properly. A better solution is to remove the tape once the cloth has been wetted with resin. Once the cloth is wetted out it does not fray and unravel as readily as dry cloth if care is taken to not disturb the edges.

The next step was to prepare the other materials required for vacuum bagging. A piece of breather cloth was cut such that it would wrap completely around the seat. A vacuumed bag was prepared by sealing three sides with vacuum bagging tape. The fourth side was left open and the sticky tape was placed along one side of the open edge. The sticky tape has a wax paper cover on one side similar to a sticker. This paper was left on so the tape would not prematurely stick to anything. The bag was prepared in this manner so that the seat could be quickly transferred into the bag after the cloth was applied. This is important because the resin has a relatively quick cure time and having everything ready before hand insures a quick and smooth process. Finally a vacuum valve was added to the bag to allow a compressor to pull a vacuum on the bag once the bag was sealed. It is important to place the valve somewhere on the bag where it is not going to be in contact with the wet carbon fiber or the result will be a circular imprint on the finished product resulting from the metal valve base pressing into the wet cloth. After these items were prepared we began the process of vacuum bagging. First we mixed the resin with a ratio of three to one as specified in the resins' instructions. Note that different resin systems require different ratios so careful reading is required. The cloth was laid on a piece of vacuum bag and the resin was poured over the cloth. A second sheet of vacuum bag was placed on top of the cloth and plastic scrapers were used to spread the resin evenly into the cloth and then squeegee the excess resin out. A second sheet of cloth was draped over the back of the mold and resin was spread through the cloth using plastic scrapers. Once the cloth on the back of the seat was evenly wetted the cloth prepared in the vacuum bag was laid on top of this first layer. The cloth was then covered in the perforated release cloth, then the breather cloth, and the whole assembly was placed into the vacuum bag. The bag was sealed and a compressor was used to draw the air out of the bag. It is important to insure that the vacuum bag does not wrinkle in any areas containing carbon fiber as a vacuum is drawn. If the bag wrinkles it will tend to draw cloth into the wrinkle and result in a wrinkled final product. It is also important to insure that the release cloth does not fold, pleat or wrinkle as this will have the same result. This can be avoided by cutting the release cloth into thin overlapping strips and placing them carefully so that they do not wrinkle.

Once the vacuum was drawn on the bag, the compressor was allowed to run for four hours after which time it was turned off and the seat was allowed to cure for an additional day inside of the vacuum bag after which time it was removed and the release and breather cloth were removed. This entire process was repeated for the top portion of the seat with one exception. Instead of placing one layer of cloth directly on the seat for resin infusion, both layers were laid one on top of the other and placed on the vacuum bag. Resin was then distributed to both layers simultaneously as described above. This worked much better as the cloth was much easier to handle and manipulate.

8.4.2 Urban Concept Vehicle Wheels

Wheel Centers and Inserts

The wheel centers and inserts are to be machined out of 6061-T6 aluminum. The wheel centers will be made on a CNC-Mill. The inserts will be hand turned on a lathe. Both parts will be made per their respective solid models, the geometry for which is defined in the part level drawings in **Appendix Q.**

Carbon Fiber Hoop Mold Construction

The mold used to manufacture the carbon fiber rims is a two piece mold. It was constructed using a motorcycle rim to achieve the desired rim profile. The motor cycle rim was first prepped for mold construction by sealing the spoke holes using a strip of aluminumized ducting tape and then coating the surface of the rim in carnauba wax to assist in the rim releasing from the mold making material, a high temperature aluminum filled casting resin.

The next step was to create a concentric sheet metal hoop for the rim to be centered in. The hoop was created using 6-inch wide rain gutter flashing and an aluminum plate for a base, see Figure 29. The 90 degree bends in the hoop were formed using a press-break.

Figure 29: Concentric sheet metal hoop for mold construction.

The rim was placed into the sheet metal hoop and both the rim and the hoop were sealed to the aluminum plate using high temperature aluminum filled caulking. Two thin sheet metal dividers were then placed radially 180 degrees apart between the rim and the concentric sheet metal hoop to create a parting line in the mold. These dividers were also sealed to the rim, base and hoop using the high temperature caulking, see Figure 30 and Figure 31.

Figure 30: Rim placed in sheet metal hoop with parting line dividers.

Figure 31: Detail of Rim placed in sheet metal hoop with parting line dividers.

High temperature aluminum filled casting resin was then poured into the space between the rim and the concentric hoop on both sides of the parting line inserts thus creating a mold of the rim profile with a parting line in the middle. See Figure 32 and Figure 33.

Figure 32: Pouring the casting resin into the mold for the mold.

Figure 33: Detail of casting resin being poured. Resin is best worked with at warm temperatures as it has an extremely low viscosity.

The resin was allowed to cure for 24 hours at room temperature at which point it was pre-cured in an autoclave at 150 degrees F. At this point the sheet metal hoop was removed, the mold separated and the rim removed from the center. The two halves were then post-cured in the autoclave according to the curing schedule as outlined in the technical literature for the resin system as found in **Appendix R.**

After curing the mold was sanded and any imperfections in the surface were filled using Bondo filler. After filling the imperfections the mold was sanded until smooth again.

Carbon Fiber Wheel Center Mold Construction

The second mold constructed was the mold for the carbon fiber wheel centers. It was also constructed using the motorcycle rim. A sheet of MDP was cut into a circle and placed inside of the motorcycle rim such that it rested on the drop-center portion. A circular sheet of half inch honeycomb was then placed on top of the MDP. Finally, two layers of carbon fiber were laid up on top of the honeycomb and the rim was vacuum bagged while curing. This created a mold that could be used to lay up the wheel centers to obtain an edge profile that matches with the edge profile of the carbon fiber rims being created, thus creating a male and female mating surface for bonding. The center mold can be seen in Figure 34.

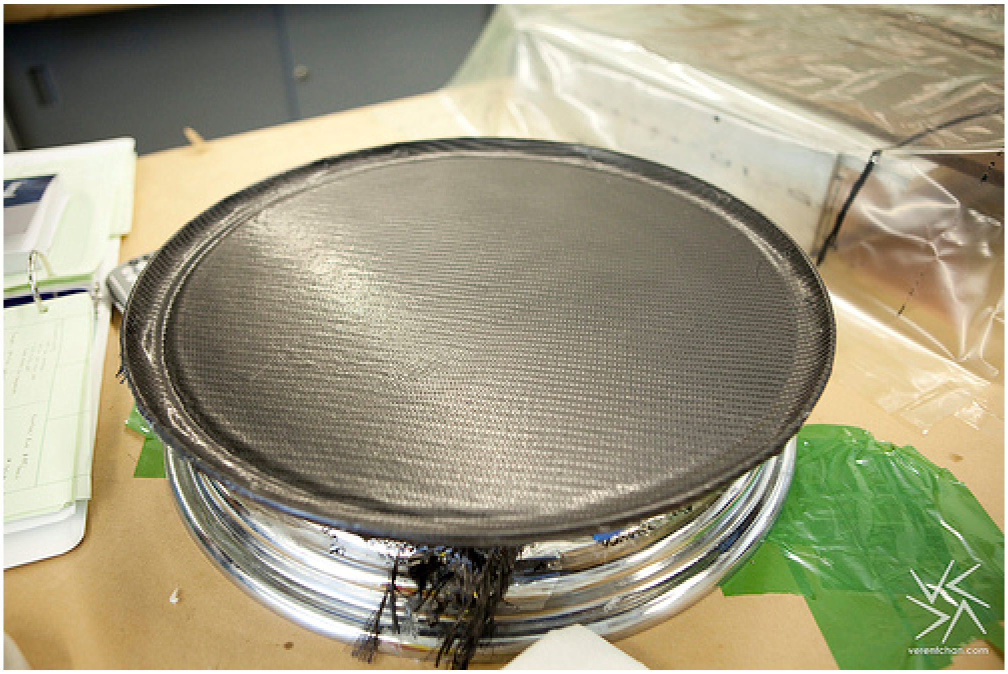


Figure 34: Completed center mold. Notice the scalloped profile around the edge which matches with the finished rim shape to create male and female surfaces for bonding.

Wheel Construction

The carbon fiber hoop was created by layering seven sheets of pre-preg carbon fiber into the mold cavity. The strips were cut in a pattern such that when laid into the mold their edges would line up and not overlap. The joints formed by the strips were staggered such that the seams were not aligned. After the pre-preg is placed a razor blade was used to trim the excess material. After the pre-preg was laid in, strips of Teflon release cloth were cut and used to line the mold, see Figure 35.

Figure 35: Hoop mold with carbon fiber Pre-preg laid in and Teflon strips being placed. The Teflon strips are the light tan seen in the right portion of the image.

After the Teflon release cloth, a layer of breather cloth was wrapped around the mold and the entire mold was placed in a vacuum bag, see Figure 36.

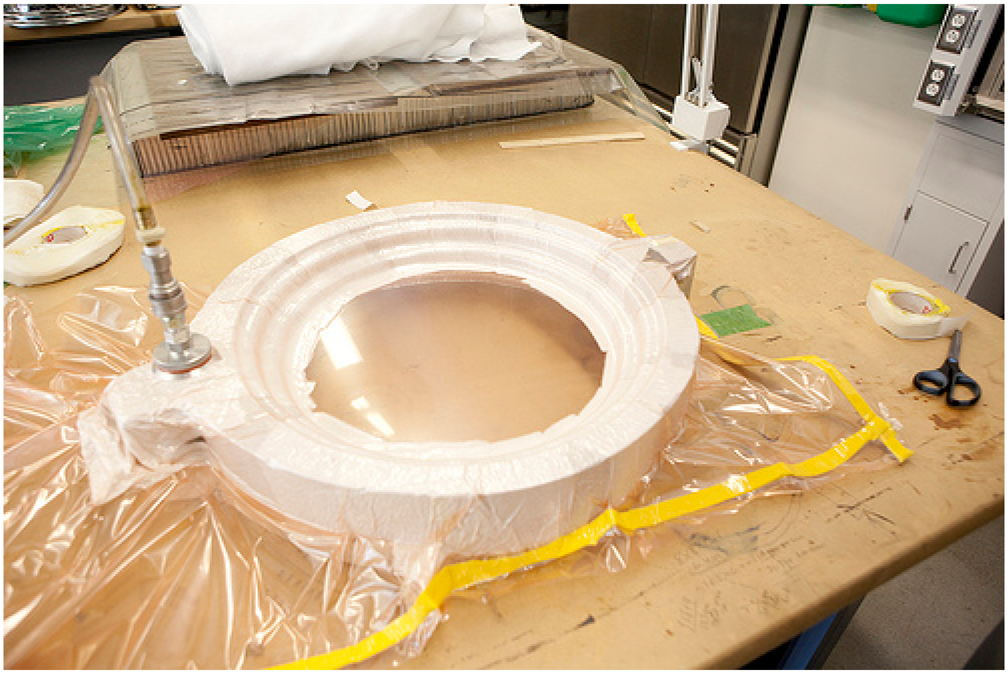


Figure 36: Mold placed in a vacuum bag. The vacuum bag material used was stretchy so that it would conform to the inner surface of the rim.

The vacuum bagged mold was then placed into the autoclave to cure. After curing the mold was unclamped and the hoop removed. The completed hoop can be seen in Figure 37.

Figure 37: First completed carbon fiber hoop.

The Carbon Fiber centers were created by layering seven sheets of carbon fiber into the center mold, placing in a single layer of honeycomb, and then layering seven more layers of carbon fiber on top of the honeycomb. To cure, a sheet of release cloth was placed on top of the mold followed by a sheet metal plate. Two cinderblocks were then placed on top of the plate to compress the carbon fiber and honeycomb while curing. After 24hours curing at room temperature the blocks and plate were removed. Excess carbon fiber was then trimmed off of the center using a pneumatic cutoff wheel.

The wheel was assembled by bonding the center into the hoop using 3M Scotch Weld Epoxy Adhesive DP-460 NS. The completed wheel was then drilled to accept the aluminum wheel centers and a valve stem. The valve stem and wheel centers were then bolted in to complete the wheel.

8.4.3 Problems Encountered During Wheel Production

Mold Finish

Our initial problem with the hoop mold arose out of the casting resin used to create it. Because of the low viscosity of the resin, air which is introduced when mixing the resin is not able to escape. Entrapped air that settled next to the finished surface (next to the motorcycle rim) resulted in small cavities. These cavities had to be filled with Bondo in order to achieve the desired finish on the finished hoop. Unfortunately the resin system in the pre-preg carbon fiber used has an affinity for Bondo and when the hoop is removed from the mold after curing it pulls all of the Bondo off of the mold. The end result is that the mold must be re-Bondoed and re-sanded after every hoop is created. The procedure to prep the mold surface is extremely time intensive and each subsequent prepping result in an increasingly diminished mold surface.

Thermal Expansion of the Hoop Mold- Mismatched CTE's

The major problem which ultimately prevented our team from seeing this project through to completion was the material which the mold was made out of. Initially we believed that we were going to be receiving pre-preg carbon fiber with a cure temperature of 150˚F. Because of this relatively low cure temperature we did not heavily weight the impact of thermal expansion of the mold during curing. In the long run we ended up receiving carbon fiber which needed to be cured at 300˚F. This elevated temperature caused our mold to exhibit unforeseen behavior.

As the mold heats up in the autoclave it expands radially and the circumference of the mold grows appreciably. Because the resin in the carbon fiber is still fluid at this point and the mold is in a vacuum bag, the carbon fiber gets pulled into the larger mold circumference. As the resin cures at elevated temperature the carbon fiber becomes rigid. The problem arises when the mold is cooled off. Since the carbon fiber has set up and is rigid, it tries to keep the circumference of the heated mold which is larger than that of the cooled mold. As the mold cools it tries to shrink back to its original size and because the carbon fiber's coefficient of thermal expansion is much less than the casting resin used to create the mold it does not shrink at the same rate. The result is the mold begins to shrink and puts the carbon fiber hoop into compressive hoop stress.

The problem is that the cured carbon fiber hoop is much stronger than the resin mold, and as the mold tries to shrink around the hoop it begins to fail. So much hoop stress is generated as the mold cures that it was sufficient to bend three of the ¼ inch bolts used to secure the mold together and shear off the fourth. Unfortunately, even with the fasteners yielding the amount of stress developed was sufficient enough to begin cracking the mold after only two trips through the autoclave cure cycle.

Oversized Hoop resulting from Thermal Expansion of the Mold.

The critical dimensions on the wheel are the ones that match up with the tire. These dimensions are the shape and circumference of the bead-seat surface. When the carbon fiber set up in the thermally expanded mold it created a bead-seat circumference that was larger than the specified tires are designed for. Despite this we were able to mount the tire to the rim, albeit with great difficulty. However, when we attempted to seat the beads of the tire to the rim they would not pop onto the bead seat surface because it was too large. At the operating pressure of the rim, neither of the beads would seat. When the pressure was increased significantly one bead popped while the other bead popped partially, the bead seat surface being too large for it to seat completely. As the pressure was incrementally increased in an attempt to get the remainder of the bead to seat, the eccentric load as well as the increase operating pressures caused the rim to fail. The rim failed without the bead seating at a pressure somewhere between 70psi and 80psi, well beyond the design operating pressure of either the tire or the rim. Had the rim not been oversized it is our opinion that the tire would have mounted and inflated successfully.

8.4.4 Wheel Production Solutions and Future Manufacturing Recommendations

It is our opinion that the general manufacturing procedure that we have developed will yield successful wheels if the construction of the mold is corrected. Because all of our failures arose out of the inadequate mold design, creating a better mold will solve all of the problems we encountered.

We suggest that in the future the Supermileage Vehicle Team take the following steps to create a new hoop mold:

- Purchase a new 16x3 inch motorcycle rim similar to the one currently used in the center mold.
- Using the same pre-preg carbon fiber as will be used for the production of hoops, create a two piece mold similar in design to the current hoop mold using the new motorcycle rim.

Because a mold made out of the same carbon fiber as the hoops will have the same coefficient of thermal expansion the mold, the mold will not be compromised by the heat cycles it experiences in the autoclave. Additionally, because carbon fiber has an extremely low coefficient of thermal expansion, a carbon fiber mold will result in a finished hoop that is extremely close to the dimensions of the motorcycle rim and therefore optimum geometry for successful tire mounting and inflation.

We further suggest that the team re-evaluate the number of layers used for the carbon fiber hoops. Our initial analysis suggested that 10 layers was the optimum number for balancing weight and performance, however we ultimately went with only 7 layers because of a shortage of available pre-preg carbon fiber.

8.5 Maintenance and Repair and FMEA

8.5.1 Urban Concept Vehicle Seat

In order to limit the need for maintenance and repair, a failure mode and effects analysis (FMEA was performed for the final seat design to ensure that the likelihood of failure and the resulting need for maintenance and repair was minimized. An FMEA for the UCV seat is contained in **Appendix N.**

Despite the efforts to minimize failure maintenance should be performed on the seat at least once a month. This will include wiping the seat clean of any dirt or dust that accumulates by using any clean rag. To help with stubborn dirt, dust or liquid stains a cleaning agent may be used. This cleaning agent can be any house hold cleaning product however solvents or toxic agents should not be used. It is also possible for the owner to have the seat refinished if he or she desires. This will require removal of the seat and sanding off the old finish with sand paper. A new coat of resin can then be applied. Refinishing will keep the seat looking new and help the user keep the seat clean.

The seat should be inspected regularly for any surface cracks and the number of inspections depends on the amount of usage the seat receives. If the seat receives a daily usage, an inspection of once a week is recommended. If used less, we recommend an inspection of once every two to three weeks. The inspections can be visual and if the user desires a more detailed inspection he or she can perform a feel test. This type of test requires the inspector to run their hand around the seat feeling for any small cracks or scratches. If any cracks or scratches are found the user can easily repair the defect by purchasing resin and filling the defect. Any extremely large tears or cracks should be repaired by a professional. However if the defect is too large a replacement seat may be necessary because the seat may be unsafe under any external forces.

8.5.2 Urban Concept/Prototope Vehicle Wheels

In order to limit the need for maintenance and repair, a failure mode and effects analysis (FMEA was performed for the final whel design to ensure that the likelihood of failure and the resulting need for maintenance and repair was minimized. An FMEA for the UCV seat is contained in **Appendix M.**

Despite efforts to minimize failure of the components maintenance is mandatory and should be preformed regularly on the wheels. This is important because foreign matter may damage the wheels by puncturing or tearing parts. Debris also adds unwanted weight which will reduce the efficiency of the vehicle. We recommend the wheels be checked and cleaned before each use. Cleaning consists of wiping the wheels free from foreign debris and any house-hold cleaning agent may be used to assist with cleaning stubborn stains so long as it contains no solvents. Toxic cleaning materials with solvents are not recommended as they may damage or weaken structural parts of the wheels. Removal of the wheels is recommended every three to five hours of use to ensure the wheels are free of defects. The pressure in the tire should also be checked at least once a week and kept between proper pressures at all times to prevent any unsafe situations.

During maintenance the owner should inspect the wheels for any cracks or deep scratches. A team member must also periodically check the wheels for any visual deformations during use. If a deficiency should occur the vehicle must be immediately stopped. Quickly finding a defect is extremely important because the defect could cause structural failure of the wheel during use. Failure of a wheel could cause harm to the driver and or spectator near the vehicle. If a defect is found the wheel should not be used under any circumstances until it has been repaired or replaced. Large defects that penetrate multiple layers of cloth should not be repaired. If such a defect is detected the wheel shall be destroyed so it cannot be used again, and the wheel replaced.

8.6 Design Verification and Testing

8.6.1 Urban Concept Vehicle Seat

The Urban Concept Vehicle Seat was verified and tested as prescribed in the UCV seat DVPR found in **Appendix O.** A summary of the test plan is contained in

Table 14 below. The seat was verified to meet Item Numbers 1,5 and 7 in Table 14. The remaining Item Numbers have been left to the Cal Poly Supermileage Team to complete as the vehicle is not currently in a state in which the remaining tests can be carried out.

Table 14: UCV Seat test plan summary.

PROTOTYPE SEAT TEST PLAN									
Item No	Specification or Clause Reference	Test Description	Acceptance Criteria	Test Responsibility	Test Stage	SAMPLES TESTED		TIMING	
						Quantity	Type	Start date	Finish date
1	Weight	Weight seat on scale accurate to +/- 1 oz	7.5±0.5 lbs	CCC	PV	1	C	2/24/2010	2/24/2010
2	Seatbelt Compatibility	Driver sits in seat with seatbelts attached	No Interference	CCC	PV	1	C	2/24/2010	2/24/2010
3	Frame Compatibility	Mount seat on frame and check dimensions	No Interference	CCC	PV	1	C	2/24/2010	2/24/2010
4	Weight Capacity	Load seat to 250lb	No Failure	CCC	PV	1	C	2/24/2010	2/24/2010
5	Adjustable Range	Move seat forward and backward	3 locations 2 inches apart	CCC	PV	1	C	2/24/2010	2/24/2010
6	Bending Test	Load seat back with 250lb distributed load	No Failure	CCC	PV	1	C	2/24/2010	2/24/2010
7	Comfort	Driver evaluates comfort for 45 min	No Discomfort	CCC	PV	1	C	2/25/2010	2/25/2010

CCC = Central Coast Composites PV = Product Verification C = Product Validation

8.6.2 Urban Concept Vehicle Wheels

The Urban Concept Vehicle wheels were tested as prescribed in the UCV wheel DVPR form found in **Appendix P.** A summary of the test plan is contained in The wheels failed when attempting to mount the tire. Because of manufacturing issues as described in this report, an inflation pressure greater than the designed pressure was used in an attempt to seat the bead of the tire to the rim. In doing so the rim failed at a pressure of somewhere between 70-80psi. Further testing was precluded because there was not another viable wheel available for testing. It is the responsibility of the Cal Poly Supermileage team to ensure that future wheels are tested to the specification outlined in the DVPR contained in this report.

Table 15 below. The wheels failed when attempting to mount the tire. Because of manufacturing issues as described in this report, an inflation pressure greater than the designed pressure was used in an attempt to seat the bead of the tire to the rim. In doing so the rim failed at a pressure of somewhere between 70-80psi. Further testing was precluded because there was not another viable wheel available for testing. It is the responsibility of the Cal Poly Supermileage team to ensure that future wheels are tested to the specification outlined in the DVPR contained in this report.

Table 15: UCV wheel test plan summary.

URBAN CONCEPT WHEEL TEST PLAN									
Item No	Specification or Clause Reference	Test Description	Acceptance Criteria	Test Responsibility	Test Stage	SAMPLES TESTED		TIMING	
						Quantity	Type	Start date	Finish date
1	Tire Compatibility	Mount tire and inflate	Holds Pressure	CCC	PV	1	C	3/1/2010	3/1/2010
2	Tire Pressure	Inflate to 60 psi	No Failure	CCC	PV	1	C	3/1/2010	3/1/2010
3	Weight	Weigh wheel on a scale with ±1 oz resolution	3±0.5 lbs	CCC	PV	1	C	3/1/2010	3/1/2010
4	Frame/Rotor Compatibility	Mount wheel on axle, check clearances	No Interferenc e	CCC	PV	1	C	3/1/2010	3/1/2010
5	Lateral Force	Place car on inclined ramp to produce 125% of theoretical maximum cornering loads	No Failure	CCC	PV	1	C	3/1/2010	3/1/2010
6	Axial Force	Raise one wheel to create artificial uneven weight distribution	No Failure	CCC	PV	1	C	3/1/2010	3/1/2010
7	Concentric with Axle	Spin wheel, use gauge to determine alignment	±0.0625" Deflection	CCC	PV	1	C	3/1/2010	3/1/2010

8	Impact Loading	Drive vehicle into uneven pavement	No Failure	SMVT	PV	1	C	3/1/2010	3/1/2010
9	Bolt Inspection	Remove Bolts, check for corrosion and wear	No Irregularities found	SMVT	PV	1	C	3/1/2011	3/1/2011

CCC = Central Coast Composites SMV = Supermileage Vehicle Team PV = Product Verification C = Product Validation

9 SAFETY CONSIDERATIONS

The scope of the projects and the nature of the products being developed is such that, should any of them fail, there is a significant chance of the driver and/or observers being injured or even killed. Safety considerations are therefore paramount in mitigating such failures and preventing injuries. Should the safety requirements specified here and in future documents fail to be met, the products being developed for Supermileage shall not be used until such a time as they can be shown safe.

For the design and development of all three products, calculation of maximum theoretical loads shall be performed and peer reviewed. An appropriate factor of safety shall be applied to calculated loads. Computer generated solid models will be created and analyzed using FEA software with the factor of safety corrected theoretical loads. Once desired performance is obtained from the model the products will be manufactured to modeled specification. Prior to use, all products will undergo static testing. In the case of the wheels, dynamic testing will be performed at moderate speeds under controlled conditions after the wheels have successfully passed static testing.

9.1 Material Properties and Safe Use:

5.7oz Graphite 3K 2x2 Twill Weave

For cloth properties, see *Appendix F* [21]

For 3K tow properties, see *Appendix G* [22]

For cloth MSDS, see *Appendix H* [23]

635 Epoxy Resin

For MSDS, see *Appendix I* [24]

3:1 Epoxy Hardener

For MSDS, see *Appendix J* [25]

Adtech El-325-1 HTTC Epoxy composite tooling compound

For MSDS, see *Appendix S* [26]

10 MANAGEMENT

After the formation of our group, our team soon made a list of responsibilities that would be required to successfully complete our project. Every individual in the group was assigned one or more of these responsibilities that he or she must complete. These responsibilities range from short assignments to long assignments that can take a few months for completion. Our group came to an agreement that the division of these responsibilities should be decided mainly on who had the most experience in certain areas and the strengths of each individual. After our agreement, our group listed all the responsibilities our project would require and divided these responsibilities equally amongst the group. A timeline was also made after the responsibilities were assigned and it shows dates that certain tasks must be started as well as deadlines for those tasks.

Casey Alvernaz is in charge of group meetings. In the group meeting, Mr. Alvernaz will keep an agenda of what is discussed. This will include all topics, ideas, and the length of time the group meets. All of the information discussed and recorded in the group meeting will be available to our sponsor or group for future reference if requested. Mr. Alvernaz also has access to all of his group members' calling numbers and is in charge of notifying each group member of an upcoming meeting. He will also use the contact numbers to share any important information discussed in previous meetings in the event that a group member is absent.

Verent Chan is primarily in charge of research. His research will be done predominantly by corroborating with the Cal Poly team and with our sponsor. He will also be referring to many research books made by the previous Cal Poly team. Mr. Chan will also frequently refer to research books about how to optimize seat and wheel designs. Mr. Chan will report his finding to the group members during meetings and the group will keep all of his information. The group can then incorporate Mr. Chan's information when designing and constructing the seat and wheels.

Brian Hamstrom is accountable for any written documents from the group. He is the technical writer and editor of any written documents the group must present to the Cal Poly Supermileage Team. He must receive all papers written from our group and arrange them in order and make sure these documents are free from most errors. He must also make sure that all documents are cited correctly. Mr. Hamstrom is also responsible for double checking that information written is correct and the document shows where the information was obtained. Mr. Hamstrom will keep any written documents and present them to anyone that is apart of the project upon request.

David Lewis is responsible for procurement of materials and is the vendor contact. He will obtain any materials needed to construct the composite seat and wheels. Mr. Lewis will primarily obtain materials through the Cal Poly Supermileage Team's supplies and if need, will obtain any other material by ordering from a supplier, or purchasing through local stores. He also can obtain certain materials from instructors that have extra materials available. Mr. Lewis will be the main contact person for anyone who is providing or selling us the material and he will provide these vendors or suppliers with his email and contact number.

James Sciaini is liable for the coordination of the group. He is also obligated to keep track of the design our group decides to construct. Mr. Sciaini is required to make sure the group works on separate parts of the project and that each part of the project will be finished on time. He must check that all parts meet the requirements that the Cal Poly Supermileage Team has specified to our group. A timeline, seen in **Appendix C,** will be used by Mr. Sciaini to ensure everything is on track and that everything gets completed on or before deadlines. Some of these deadlines are as follows:

Completion of seat by November 25, 2009
Complete Urban Concept Vehicle wheel design by November 29, 2009
Complete Urban Concept Vehicle wheel fabrication by March 4, 2010

On the timeline, each color signifies a different stage in the overall project:

Blue represents the Urban Concept Vehicle seat.
Red signifies the Prototype Vehicle wheels.
Green is the development of the Prototype Vehicle wheels and the Urban Concept Vehicle seat.
Purple represents the Urban Concept Vehicle wheels.

11 CONCLUSION

The goal of Central Coast Composites was to utilize the resources at Cal Poly to successfully design and build an Urban Concept seat as well as wheels for the Urban Concept Vehicle. Although at times it appeared as though Cal Poly's available resources were insufficient to complete the task at hand, with some hard work and ingenuity we were able to overcome these barriers and develop innovative manufacturing processes to accomplish our goals. Had it not been for some unforeseen supply issues that could neither be avoided nor helped and the resulting mismatch between our designed and actual manufacturing process we would have completed four wheels successfully. We believe that our design and process are both sound and that given a little more time we could have presented Cal Poly Supermileage Team with four outstanding and high performance carbon fiber wheels.

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13 APPENDICIES

The appendix contains relevant project information referenced in the body of the report.

Appendix A: Shell Eco-marathon® Rules [21]

The following section dictates the importance of certain Shell Eco-marathon® rules to the design of the Urban Concept Vehicle Seat and the wheels for both the Urban Concept and the Prototype Vehicles. A full copy of the rules is available on the Shell Eco-marathon® website. The rules mentioned below are taken word-for-word from the Shell Eco-marathon® official rules.

General Rules

> ***Article 21b:*** *Drivers of the Urban Concept Vehicles must weigh at least 70 kg in full driving gear.*
>
> > The seat for the Urban Concept Vehicle must be designed to support the full load of the driver while the vehicle is stationary and while it is in motion. Forces generated during cornering and hard braking are expected to be the largest loads.
>
> ***Article 22:*** *Drivers must wear protective helmets that comply with the safety standards specified in Chapter II of the Official Rules of each Shell Eco-marathon® Event.*
>
> > The helmet size will be taken into consideration during seat design to ensure the drivers' head is positioned comfortably and to minimize discomfort to the back and neck.

Prototype Rules

> ***Article 26g:*** *The maximum vehicle weight without the Driver is 140kg.*
>
> > Even though the current Prototype Vehicle weighs 96 lbs without the driver, it is possible for the vehicle's weight to change. The rules place a limit on the car's weight. In the event that Cal Poly's Prototype Vehicle increases in weight, the wheels should be able to support the static and dynamic loads of the vehicle.
>
> ***Article 37a,b:*** *All types of wheels are allowed. Any type of wheel rim may be used. Rims must be compatible with the dimensions of the selected tires in order to satisfy safety standards….The wheel axles must be designed for cantilever loads.*
>
> > This rule removes any requirement for off-the-shelf wheels to be purchased. However, it does place restrictions on how the wheels must be designed.

Urban Concept Rules

> ***Article 47a:*** *Urban Concept Vehicles must have exactly four wheels.*

Central Coast Composites is required to develop four wheels.

Article 48h: *The maximum vehicle weight (excluding the Driver) must be 160kg.*

Similar to the Prototype Vehicle, the wheels must be able to support the dynamic and static loads of the Urban Concept Vehicle. Since the Urban Concept Vehicle's official weight is still unknown, load calculations should account for possible max vehicle weight until more information is known.

Article 54a: *The Driver's seat must be fitted with an effective safety harness having at least five mounting points to maintain the Driver in his/her seat. The mounting point(s) for the crotch straps must be below the Driver's torso to prevent the Driver from slipping forward. The 5 independent belts must be firmly attached to the vehicle's main structure and be fitted into a single buckle, specifically designed for this purpose.*

The seat design must allow for the crotch strap to securely hold the driver from sliding forward. Since the safety belts will be attached to the vehicle's chassis, it is not necessary for the seat to support any additional loads other than the driver.

Article 55: *It is imperative for Drivers, fully harnessed, to be able to vacate their vehicles at any time without assistance in less than 10 seconds.*

Easy access in and out of the vehicle should not be limited by the seat design.

Article 57: *The rims must be 16 or 17 inches in diameter.*

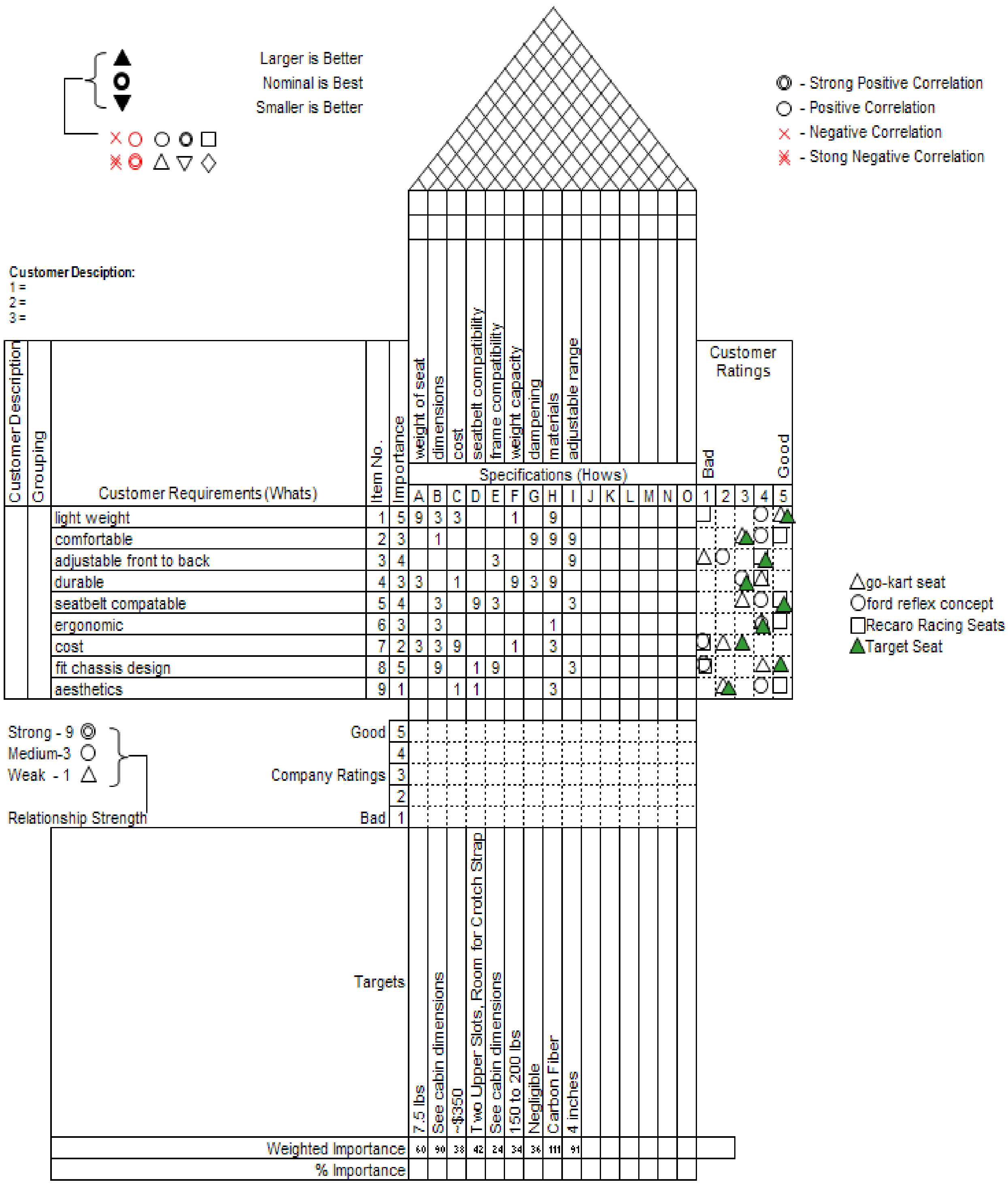
The wheel diameter is to be designed as stated.

Article 58: *All tire types are allowed as long as they are fitted on the type and size of rims recommended by their manufacturers. The tire/rim assembly must have a minimum width of 80mm, measured from sidewall to sidewall. The width is measured with the tire fitted on its rim at its rated pressure.*

Tire and rim fitment is crucial to safe operation of the vehicle. Since the tires are already selected, the Urban Concept wheels will be designed to meet the required rim profile of the tire manufacturer. The minimum width is measured from the tire sidewalls, but the tire sidewall width is directly affected by the width of the rim.

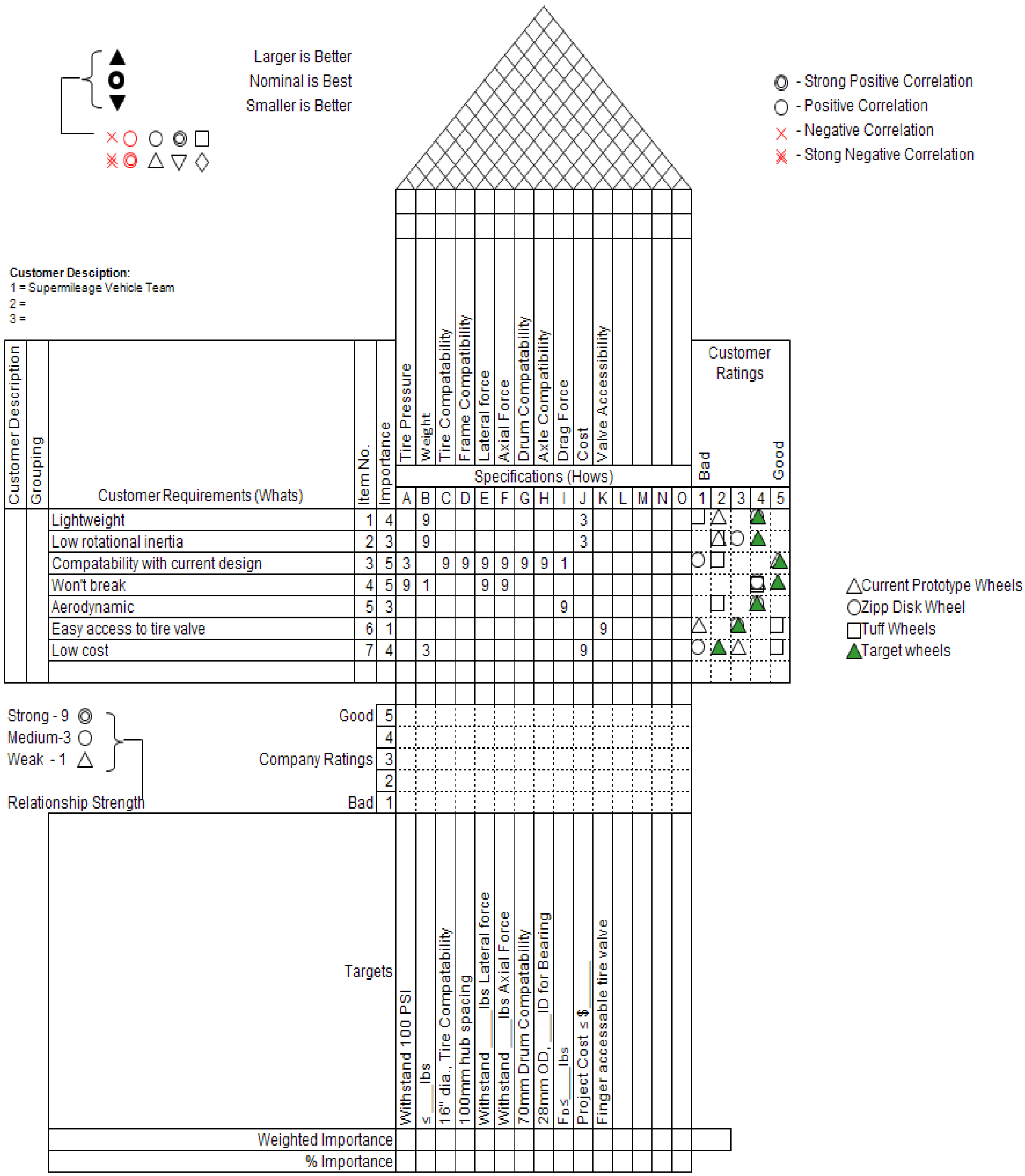
Appendix B: QFD matrices for Urban Concept Seat, Prototype Wheels

Urban Concept Seat QFD



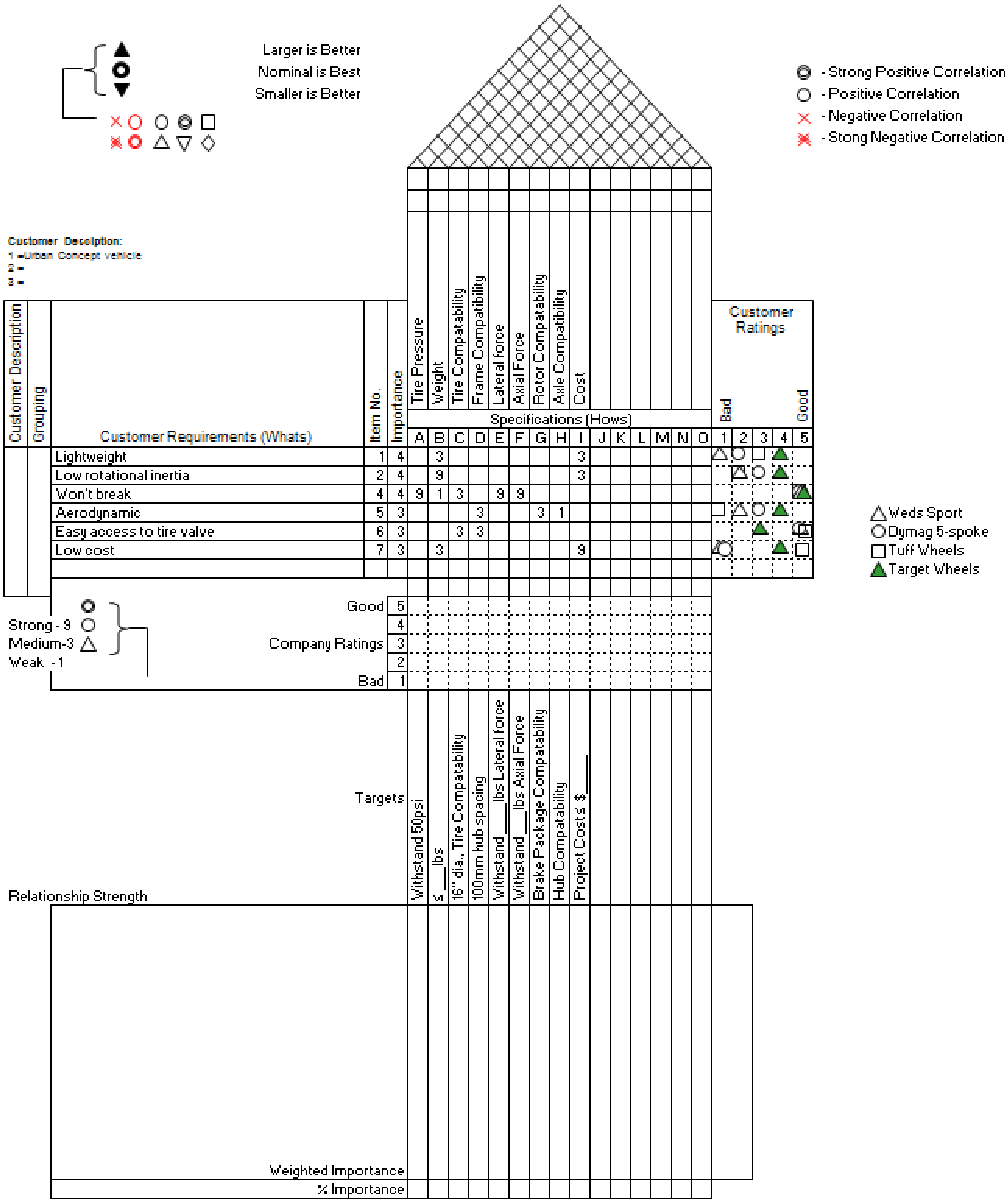
Item No.	Customer Requirements (Whats)	Importance	A weight of seat	B dimensions	C cost	D seatbelt compatibility	E frame compatibility	F weight capacity	G dampening	H materials	I adjustable range	J	K	L	M	N	O
1	light weight	5	9	3	3			1		9							
2	comfortable	3		1					9	9	9						
3	adjustable front to back	4					3				9						
4	durable	3	3		1			9	3	9							
5	seatbelt compatable	4		3		9	3				3						
6	ergonomic	3		3						1							
7	cost	2	3	3	9			1		3							
8	fit chassis design	5		9		1	9				3						
9	aesthetics	1			1	1				3							
	Targets		7.5 lbs	See cabin dimensions	~$350	Two Upper Slots, Room for Crotch Strap	See cabin dimensions	150 to 200 lbs	Negligible	Carbon Fiber	4 inches						
	Weighted Importance		60	90	38	42	24	34	36	111	91						
	% Importance																

Prototype Vehicle wheels QFD



Customer Requirements (Whats)	Item No.	Importance	A Tire Pressure	B Weight	C Tire Compatability	D Frame Compatibility	E Lateral force	F Axial Force	G Drum Compatability	H Axle Compatibility	I Drag Force	J Cost	K Valve Accessibility	L	M	N	O
Lightweight	1	4		9								3					
Low rotational inertia	2	3		9								3					
Compatability with current design	3	5	3		9	9	9	9	9	9	1						
Won't break	4	5	9	1			9	9									
Aerodynamic	5	3									9						
Easy access to tire valve	6	1											9				
Low cost	7	4		3								9					

Urban Concept Vehicle wheels QFD

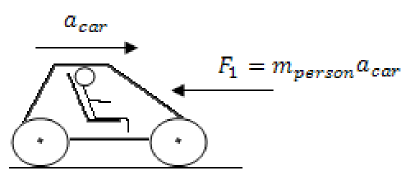


Appendix C: Project Timeline

The Project Timeline is more readily attached in a paper copy. For electronic copies the project timeline will be sent as an additional file.

Appendix E: Load Calculations for UCV seat.

Force on the Seat



Max acceleration seen by person in the car.

$$a_{car} = \frac{v - v_o}{t}$$

$$a = \left(\frac{35\ miles}{hr} - \frac{0\ miles}{hr}\right) * \left(\frac{1}{10s}\right) * \left(\frac{5280\ ft}{mile}\right) * \left(\frac{1\ hr}{3600s}\right) = 5.133\frac{ft}{s^2}$$

We will be looking at the force on the back of the seat so when calculating the mass of the person we will only look at half the weight on the back and half on the bottom of the seat.

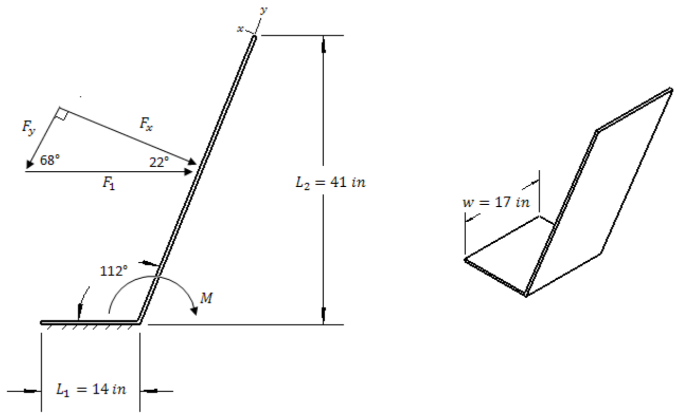
$$m_{person} = \frac{150\ lbs}{2 * 32.2\frac{ft}{s^2}} = 2.33\ lbs$$

$$F_1 = m_{person}a_{car}$$

$$F_1 = 2.33\ lbs * 5.133\frac{ft}{s^2} = 11.95\ lbs$$

As a factor of safety we will double the force.

$$F_1 = 2 * 11.95\ lbs = 23.9\ lbs$$



$$F_x = \cos 22 * \mathrm{F}_1$$

$$F_x = \cos 22 * 23.9 \text{ lbs}$$

$$F_x = 22.159\ lbs$$

$$F_x = \sin 22 * \mathrm{F}_1$$

$$F_y = \sin 22 * 23.9\ lbs$$

$$F_y = 8.453$$

Force in the F_x is used to find the moment at the bottom of the seat.

$$M = F_x * \frac{1}{2} * \left(\frac{41}{\cos 22}\right)$$

$$M = 22.159\ lbs * 22\ in$$

$$M = 487.5\ lbs - in$$

$$\sigma = \frac{6M}{wt^2}$$

Rewrite the stress equations in terms of the thickness of the seat t.

$$t = \sqrt{\frac{6M}{w\sigma}}$$

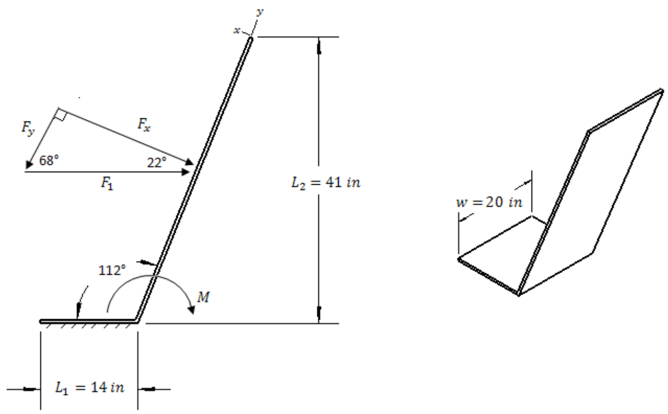
$$t = \sqrt{\frac{6 * 487.5\ lbs - in}{17\ in * 100 \times 10^3\ \frac{lbs}{in^2}}}$$

$$t = .042\ in$$

Divide by the thickness of the cloth to get approximation of the number of layers

$$number\ of\ cloth = \frac{.042}{.012} = 3.5$$

Or Alternatively using a max theoretical load on the back of the seat as F_1= 250 lbs.



Simplified seat model for determination of number of layers of carbon fiber cloth required to meet safety requirements.

$$F_x = \cos 22 * \mathrm{F}_1$$

$$F_x = \cos 22 * 250\mathrm{lbs}$$

$$F_x = 231.8\ lbs$$

$$F_x = \sin 22 * \mathrm{F}_1$$

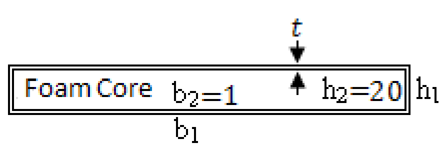
$$F_y = \sin 22 * 250\ lbs$$

$$F_y = 93.7$$

Force in the F_x is used to find the moment at the bottom of the seat.

$$M = F_x * \frac{1}{2} * \left(\frac{41}{\cos 22}\right)$$

$$M = 5125.1\ lbs - in$$



Seat back side cut away.

$$I = \frac{b_1 * h_1^3}{12} - \frac{b_2 * h_2^3}{12}$$

$$c = \frac{h_1}{2}$$

$$t = \frac{h_1 - h_2}{2}$$

$$h_1 - h_2 = b_1 - b_2$$

$$\sigma = 90\ ksi$$

$$\sigma = \frac{Mc}{I}$$

$$number\ of\ cloth = \frac{t}{.01} = .28$$

Actual cloth used

$$t_{used} = 4$$

$$I = \frac{b_{1sf} * h_{1sf}^3}{12} - \frac{b_{2sf} * h_{2sf}^3}{12}$$

$$c = \frac{h_{1sf}}{2}$$

$$t_{used} = \frac{h_{1sf} - h_{2sf}}{2}$$

$$h_{1sf} - h_{2sf} = b_{1sf} - b_{2sf}$$

$$\sigma_{sf} = \frac{Mc}{I}$$

$$\sigma_{sf} = 5840$$

$$safty\ factor = \frac{90000}{5840} = 15.4$$

Appendix G: Carbon Fabrics 284 Technical Data Sheet

284
Carbon Fabrics
Product Data

STYLE 284

Type of yarns	*Warp Yarn* *Fill Yarn*	3K Carbon, 33 MSI 3K Carbon, 33 MSI
Fabric Weight	5.8 197	*(oz/yd²)* *(g/m²)*
Weave Style	2/2 Twill	

CONSTRUCTION

Nominal Construction yarns/inch	*Warp Count* *Fill Count*	12.5 12.5
Fabric Thickness	8.7 0.22	*(mils)* *(mm)*
Breaking Strength	n/a n/a	*(lbf/in)* *(lbf/in)*
Markets	*Aeronautics/Aerospace, Recreational*	
Applications	*Low Pressure Composites, Aircraft Advanced Composites*	

IMPORTANT

All information is believed to be accurate but is given without acceptance of liability. Users should make their own assessment of the suitability of any product for the purpose required. All sales are made subject to our standard terms of sales which include limitations on liability and other important terms. The fabric style listed may not be available from inventory, and minimum order quantities may apply.

FOR FURTHER INFORMATION, PLEASE CONTACT US

Appendix H: HexTwo AS2C Technical Data Sheet

HexTow® AS2C
Carbon Fiber
Product Data

HexTow® AS2C carbon fiber is a continuous, high strength, high strain, PAN based fiber available in 3,000 (3k) filament count tows. This fiber has been surface treated and can be sized to improve its interlaminar shear properties, handling characteristics, and structural properties, and is suggested for use in weaving.

Typical Fiber Properties	U.S. Units	SI Units
Tensile Strength	644 ksi	4,440 MPa
Tensile Modulus (Chord 6000-1000)	32 Msi	221 GPa
Ultimate Elongation at Failure	1.9%	1.9%
Density	0.0650 lb/in^3	1.80 g/cm^3
Weight/length 3k	11.2 x 10^{-6} lb/in	0.200 g/m
Approximate yield 3k	7,442 ft/lb	5.00 m/g
Tow cross-sectional area 3k	1.72 x 10^{-4} in^2	0.11 mm^2
Filament Diameter	0.270 mil	6.9 microns
Carbon Content	94.0%	94.0%
Twist	Never Twisted	Never Twisted

Carbon Fiber Certification

This carbon fiber is manufactured to Hexcel industrial grade specification HS-CP-3000. A copy of this specification is available upon request. A Certificate of Conformance will be provided with each shipment.

Available Sizing

Sizing compatible with various resin systems, based on application are available to improve handling characteristics and structural properties. Please see additional information on available sizes on our website or contact our technical team for additional information.

Packaging

Standard packaging of HexTow® AS2C is as follows:

Filament Count	Nominal Weight (lb)	Nominal Weight (kg)	Nominal Length (ft)	Nominal Length (m)
3k	4.0	1.8	29,770	9,070

Other package sizes may be available on request. The fiber is wound on a 3-inch ID by 11-inch long cardboard tube and overwrapped with plastic film.

Safety Information

Obtain, read, and understand the Material Safety Data Sheet (MSDS) before use of this product.

Appendix I: MSDS Fibre Glast 1069 5.7oz Twill cloth

FIBRE GLAST DEVELOPMENTS CORP.
385 Carr Drive
BROOKVILLE, OH 45309

TELEPHONE: (937) 833-5200
FAX: (937) 833-6555
FOR CHEMICAL EMERGENCY
CALL (800) 424-9300 24 HRS.

SECTION 1 - PRODUCT IDENTIFICATION

PRODUCT: PART #1069 5.7oz Graphite 3K 2x2 Twill Weave

Synonyms: All Product Grades
Chemical Family: Carbon
Molecular Formula: Polymer
Molecular Wgt: Polymer

SECTION 2 - COMPOSITION/INFORMATION ON INGREDIENTS

WHMIS Regulated Components:

COMPONENT	CAS. NO.	%(W/W)	TWA/CEILING:	REFERENCE
Carbon Fiber (As Carbon Fiber)	007440-44-0	100	not established 3 fibers/cc	CYTEC

SECTION 3 –HAZARDS IDENTIFICATION

EMERGENCY OVERVIEW
Appearance and Odor: Odorless black fiber

Statements of Hazard:
Warning: Electrically conductive fibers
Airborne fibers can short circuit electrical equipment
Airborne fibers may cause mechanical irritation of eyes, skin, nose and throat.

POTENTIAL HEALTH EFFECTS
Effects of Exposure: The acute oral (rat) and dermal (rabbit) LD50 values are estimated to be greater than 5,000 mg/kg and greater than 2,000 mg/kg, respectively.

Direct contact with this material may cause mild eye and skin irritation.

Refer to Section 11 for toxicology information on the regulated components of this product.

SECTION 4 – FIRST AID MEASURES

If swallowed, call a physician immediately. Only induce vomiting at the instructions of a physician. Never give anything by mouth to an unconscious person. In case of skin contact, wash affected areas of skin with soap and water. In case of eye contact, immediately irrigate with plenty of water for 15 minutes. If vapor or dust of this material is inhaled, remove from exposure. Administer oxygen if there is difficulty in breathing. Obtain medical attention immediately if necessary.

SECTION 5 – FIRE FIGHTING MEASURES

FLAMMABLE PROPERTIES

FLASH POINT: Not applicable
FLAMMABLE LIMITS
(% BY VOL): Not applicable
AUTOIGNITION TEMP: Not available
DECOMPOSITION TEMP: Not available
MECHANICAL/STATIC SENSITIVITY: None

EXTINGUISHING MEDIA AND FIRE FIGHTING INSTRUCTIONS

This material will not burn readily. Use an extinguishing media appropriate for the surrounding fire. Wear self-contained, positive pressure breathing apparatus.

SECTION 6 – ACCIDENTAL RELEASE MEASURES

STEPS TO BE TAKEN IN CASE MATERIAL IS RELEASED OR SPILLED

Sweep up spills and place in a waste disposal container. Flush area with water.

SECTION 7 – HANDLING AND STORAGE

Keep container closed.
Maintain good housekeeping to control dust accumulations.
IMPORTANT! Airborne fibers are electrically conductive and may cause short circuits. Do not let fibers come in contact with electrical equipment.

SECTION 8 – EXPOSURE CONTROLS/PERSONAL PROTECTION

ENGINEERING CONTROLS AND PERSONAL PROTECTIVE EQUIPMENT (PPE)
Engineering controls are not usually necessary if good hygiene practices are followed. Before eating, drinking, or smoking, wash face and hands thoroughly with soap and water. Avoid unnecessary skin contact. Impervious gloves are recommended to prevent prolonged skin contact. For operations where eye or face contact can occur, eye protection is recommened.

SECTION 9 – PHYSICAL AND CHEMICAL PROPERTIES

APPEARANCE AND ODOR:	Odorless black fiber
BOILING POINT:	Not applicable
MELTING POINT:	>5000 F, 2760 C
VAPOR PRESSURE:	Not applicable
SPECIFIC GRAVITY:	1.6
VAPOR DENSITY:	Not applicable
% VOLATILE (BY WT):	Not applicable
pH:	Not applicable
SATURATION IN AIR (% BY VOL):	Not applicable
EVAPORATION RATE:	Not applicable
SOLUBILITY IN WATER:	Negligible
VOLATILE ORGANIC CONTENT:	Not applicable
ODOR THRESHOLD:	See section 2 for permissible exposure limits.

SECTION 10 – STABILITY AND REACTIVITY

STABILITY:	Stable
CONDISITONS TO AVOID:	None known
POLYMERIZATION:	Will not occur
CONDITIONS TO AVOID:	None known
INCOMPATIBLE MATERIALS:	No specific incompatibility

HAZARDOUS DECOMPOSITION/COMBUSTION PRODUCTS: Oxides of carbon

SECTION 11 – TOXICOLOGICAL INFORMATION

Toxicological information for the product is found under Section 3. HAZARDS IDENTIFICATION. Toxicological information on the regulated components of this product is as follows:

Carbon fibers may cause mechanical irritation of the eyes, skin, nose and throat. Airborne carbon fibers are not considered respirable. A typical carbon fiber may be characterized as having a diameter of 5-7 microns and a length greater than 100 microns. Fibers with diameters greater than 3.5 microns are not considered respirable.

SECTION 12 – ECOLOGICAL INFORMATION

No aquatic LC50, BOD, or COD data available.
OCTANOL/H_2O PARTITION COEF: Not applicable

SECTION 13 – DISPOSAL CONSIDERATIONS

Fibre Glast Developments Corporation encourages the recycle, recovery and reuse of materials, where permitted, as an alternative to disposal as a waste. Fibre Glast Developments Corporation recommends that organic materials classified as hazardous waste according to the relevant local or national regulations be disposed of by thermal treatment or incineration at approved facilities. All local and national regulations should be followed.

SECTION 14 – TRANSPORT INFORMATION

This section provides basic shipping classification information. Refer to appropriate transportation regulations for specific requirements.

	TRANSPORT CANADA	ICAO/IATA
SHIPPING NAME:	NOT APPLICABLE/NOT REGULATED	NOT APPLICABLE/ NOT REGULATED
HAZARD CLASS:	Not Applicable	Not Applicable
SUBSIDIARY CLASS:	Not Applicable	Not Applicable
UN/ID NUMBER	Not Applicable	Not Applicable
PACKING GROUP:	Not Applicable	Not Applicable
TRANSPORT LABEL REQUIRED:	Not Applicable	Not Applicable
PACKING INSTR:	Not Applicable	PASSENGER: Not Applicable CARGO: Not Applicable
MAX NET QTY:	Not Applicable	PASSENGER: Not Applicable CARGO: Not Applicable
SHIPPING NAME:	D.O.T. SHIPPING INFORMATION NOT APPLICABLE/NOT REGULATED	IMO SHIPPING INFORMATION NOT APPLICABLE/NOT REGULATED
D.O.T. HAZARDOUS SUBSTANCES:	(Product Reportable Quantity) Not Applicable	Not Applicable
TRANSPORT LABEL REQUIRED:	None Required	None Required
ADDITIONAL TRANSPORT INFORMATION		
TECHNICAL NAME (N.O.S.)	Not Applicable	

SECTION 15 – REGULATORY INFORMATION

This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations and this Material Safety Data Sheet contains all the information required by the Controlled Products Regulations

WHMIS CLASSIFICATION: NOT WHMIS CONTROLLED

INVENTORY INFORMATION

CANADA DSL: Components of this product have been reported to Environment Canada in accordance with subsection 25 of the Canadian Environment Protection Act and are included on the Domestic Substance List.

US TSCA: All components of this product are included on the TSCA inventory in compliance with the Toxic Substances Control Act, 15 U.S.C. 2601 et. Seq.

EEC EINECS: All components of this product are included in the European Inventory of Existing Chemical Substances (EINECS) in compliance with Council Directive 67/548/EEC and its amendments.

SECTION 16 – OTHER INFORMATION

NFPA HAZARD RATING (National Fire Protection Association)
Fire: Materials that must be preheated before ignition can occur.
Health: Materials that under emergency conditions, can cause significant irritation.
Reactivity: Materials that in themselves are normally stable, even under fire exposure conditions.

Fire
1

Health 1 0 Reactivity

___
Special

SECTION 17 - COMMENTS

PDCT-MSDS-00111-C-12/08-RR

The information accumulated herein is believed to be accurate but is not warranted to be, whether originating with Fibre Glast Developments or not. Recipients are advised to confirm in advance of need that the information is current, applicable, and suitable to their circumstances.

Appendix J: MSDS Reichhold 635 thin epoxy resin

Reichhold, Inc.
Corporate Headquarters
P.O. Box 13582
Research Triangle Park, NC 27709-3582

8am to 5pm Phone: 1-800-275-6353
24-Hour Emergency Phone: 1-800-424-9300

Street Address:
2400 Ellis Road, Durham, NC 27703

Distributed by:
US Composites (561) 588-1011 www.uscomposites.cc

Effective Date: 8/15/07 **Material Safety Data Sheet**

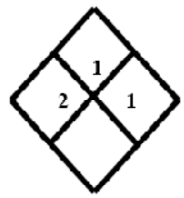
1. PRODUCT IDENTIFICATION

Trade Name: 635 THIN EPOXY RESIN

Material Code: 37127-00

Chemical Family: Epoxy Resin

Intended Use: Coatings



NFPA RATING

Health:	2*
Flammability:	1
Reactivity:	1
Personal Protection:	

HMIS RATING

2. COMPOSITION / INFORMATION ON INGREDIENTS

OSHA	CAS No.	CHEMICAL IDENTITY	EXPOSURE LIMITS					CARCINOGEN STATUS		
			ACGIH		OSHA		MFR.	IARC	NTP	OSHA
			TWA	STEL	PEL	STEL				
*	25085-99-8 Common Name: Concentration	Diglycidyl ether of bisphenol A homopolymer Epoxy Resin 80.00 - 82.00 wt%	NE	NE	NE	NE	NE	NR	NR	NR
*	68609-97-2 Concentration	Alkyl glycidyl ether 18.00 - 20.00 wt%	NE	NE	NE	NE	NE	NR	NR	NR

NE = Not Established NR = Not Reviewed * = OSHA Hazardous Ingredient

Reference Notes: Refer to Section 8, Subheading "Exposure Guidelines", for additional information concerning exposure limits.

3. HAZARDS IDENTIFICATION

Emergency Overview: Appearance: Straw Colored Liquid Mild Odor

May cause skin and respiratory sensitization.

Route(s) of Entry: Eye contact, ingestion, inhalation, and skin contact. Skin absorption.

Acute Exposure: SKIN: Contact may cause skin sensitization, an allergic reaction which becomes evident on re-exposure to this material. Contact causes skin irritation. Harmful if absorbed through skin.

EYES: Direct contact with this material may cause eye irritation including tearing and redness.

INHALATION: Low volatility makes vapor inhalation unlikely. Aerosol can be irritating. May cause respiratory sensitization in susceptible individuals.

INGESTION: Single dose oral toxicity is low. Swallowing small amounts during normal handling is not likely to cause harmful effects; swallowing large amounts may be harmful. Ingestion is not an anticipated route of exposure for this material in industrial use.

Chronic Exposure: Prolonged or repeated exposure may cause respiratory sensitization, an allergic reaction that becomes evident on re-exposure to this material.

Carcinogenicity: This material does not contain 0.1% or more of any chemical listed by the International Agency for Research on Cancer (IARC), the National Toxicology Program (NTP), or regulated by the Occupational Safety and Health Administration (OSHA) as a carcinogen.

4. FIRST AID MEASURES

Eye Contact: Immediately flush eyes with large quantities of clean water for at least 15 minutes. Get immediate medical attention.

Skin Contact: Wash skin with soap and water. Remove contaminated clothing. Get medical attention if irritation develops or persists. Wash contaminated clothing before reuse. Solvents should not be used to clean hands or skin because they increase the penetration of the material into the skin. Remove and dispose of all contaminated leather goods, including shoes.

Ingestion: Do not induce vomiting. Give the victim one or two glasses of water or milk to drink. Never give anything by mouth to an unconscious person. Seek medical advice. In general, no adverse effects are anticipated by this route of exposure incidental to proper industrial handling.

Inhalation: Remove affected individual(s) to fresh air. Seek medical attention if breathing difficulty develops.

5. FIRE FIGHTING MEASURES

Flash Point:	> 300° F (> 149 ° C)
Flash Point Method Used:	SetaFlash Closed Cup
Flammable Limits in Air (Lower):	Not applicable
Flammable Limits in Air (Upper):	Not applicable
Autoignition:	Not applicable

General Hazards: Containers of this material may build up pressure if exposed to heat (fire). Use water spray to cool fire-exposed containers.

Fire Fighting Extinguishing Media: Use carbon dioxide, foam, dry chemical or water fog to extinguish fire.

Fire Fighting Equipment: Wear self-contained breathing apparatus (SCBA) and full fire-fighting protective clothing. Thoroughly decontaminate all protective equipment after use.

Fire Fighting Instructions: Evacuate all persons from the fire area to a safe location. Move non-burning material, as feasible, to a safe location as soon as possible. Fire fighters should be protected from potential explosion hazard while extinguishing the blaze. Use water spray to cool fire-exposed containers.

Fire and Explosion Hazards: This material may polymerize (react) when its container is exposed to heat (as during a fire). This polymerization increases pressure inside a closed container and may result in the violent rupture of the container.

Hazardous Combustion Products: The by-products expected in incomplete pyrolysis or combustion of epoxy resins are mainly phenolics, carbon monoxide and water.

6. ACCIDENTAL RELEASE MEASURES

Accidental Release Measures: FOR SMALL SPILLS: Absorb spill with inert material (e.g., dry sand or earth), then place in a chemical waste container.

LARGE SPILL: Persons not wearing protective equipment (see Section 8) should be excluded from the area of the spill until clean-up has been completed. Prevent spilled material from 1) contaminating soil, 2) entering sanitary sewers, storm sewers, and drainage systems, and 3) entering bodies of water or ditches that lead to waterways. Shut off the leak when it is safe to do so, dike and pump the liquid into waste containers. Residual resin may be removed using steam or hot soapy water.

7. HANDLING AND STORAGE

Signal Word: W A R N I N G

Handling Information: Avoid contact with eyes, skin, and clothing. Wash hands thoroughly after handling and before eating or drinking. Remove and wash contaminated clothing before reuse. Use with adequate ventilation.

Empty drums should be completely drained, properly bunged, and promptly returned to a drum reconditioner or properly disposed.

Storage Information: Keep container closed when not in use. Warm storage (130°F/54°C to 150°F/65.5°C) is recommended. This resin may crystallize during extended storage or when stored at low temperatures. Resin which has crystallized can be melted by warming at 130°F - 150°F until all crystals have melted. Remelting of resin has no negative effects on performance.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

Exposure Guidelines: There are no Occupational Safety and Health (OSHA) Permissable Exposure Limits (PEL) or American Conference of Governmental Industrial Hygenists (ACGIH) Threshold Limit Values (TLV) or Short Term Exposure Limits (STEL) established for the component(s) of this product.

Engineering Controls: Good general ventilation should be sufficient to control airborne levels of irritating vapors. Local ventilation may be required during certain operations.

Eye Protection: Wear safety glasses with side shields or goggles. Facilities storing or utilizing this material should be equipped with an eyewash station and safety shower.

Skin Protection: Wear chemical resistant gloves. If splashing is likely, wear impervious clothing and boots to prevent repeated or prolonged skin contact. Consult your supplier of personal protective equipment for additional instructions on proper usage.

Respiratory Protection: If material generates fumes when heated, a NIOSH/MSHA approved air-purifying respirator with organic vapor cartridge or canister may be used to minimize exposure. A respiratory protection program that meets OSHA's 29 CFR 1910.134 and ANSI Z88.2 requirements must be followed whenever workplace conditions warrant a respirator's use. Protection provided by air purifying respirators is limited. Use a positive pressure air-supplied respirator if 1) there is any potential for an uncontrolled release, 2) exposure levels are not known, or 3) during other circumstances where air purifying respirators may not provide adequate protection.

9. PHYSICAL AND CHEMICAL PROPERTIES

Color:	Straw colored
Odor:	Mild
Odor Threshold:	Not available
Physical State:	Liquid
Solubility in Water:	Insoluble at 20°C (68 °F)
Viscosity:	500 - 800 cps at 25°C (77 °F)

Vapor Pressure:	Not applicable
Specific Gravity:	1.09 - 1.11 (Water = 1) at 25°C (77 °F)
Boiling Point:	Not available
Freezing Point:	Not available
% Volatile:	18 - 20 % by weight
VOC Content:	209 grams/liter (calculated)product as supplied
pH:	Not applicable

10. STABILITY AND REACTIVITY

Stability: Stable at normal temperatures and storage conditions.

Incompatibility: Avoid contact with strong oxidizing agents, mineral acids, and strong mineral and organic bases, especially primary and secondary aliphatic amines.

Hazardous Decomposition Products: Thermal decomposition may produce various hydrocarbons and irritating, acrid vapors.

Hazardous Polymerization: Hazardous polymerization will not occur. Reaction with some curing agents may produce considerable heat. Run-a-way cure reactions may char and decompose the resin system, generating unidentified fumes and vapors which may be toxic.

Conditions to Avoid: Contamination by those materials referred to under Incompatability. Potentially violent decomposition can occur above 350° C (662° F).

11. TOXICOLOGICAL INFORMATION

Acute Eye Toxicity: No information is available.

Acute Skin Toxicity: Diglycidyl Ether of Bisphenol A: dermal LD50 (rabbit), 20,000 mg / kg. Alkyl Glycidyl Ether: dermal LD50 (rabbit), > 2000 mg / kg; Draize (rabbit, 24 hr.), 3.4 - 5.7.

Acute Inhalation Toxicity: No information is available.

Acute Oral Toxicity: Diglycidyl Ether of Bisphenol A: oral LD50 (rat), > 5,000 mg / kg. Alkyl Glycidyl Ether: oral LD50 (rat), > 2,000 mg / kg.

Chronic/Carcinogenicity: The International Agency for Research on Cancer (IARC) has classified diglycidyl ether of bisphenol A in Group 3, the agent is not classifiable as to its carcinogenicity to humans.

Many studies have been conducted to assess (DGEBPA) based epoxy resins. In one of these, a DGEBPA-based resin (containing high levels of several impurities, including a known animal carcinogen) was reported to produce a weak carcinogenic response in the skin of one of two strains of mice tested. Recent studies have suggested slight increases in two systemic tumor types following repeated application of certain DGEBPA-containing resins (or pure DGEBPA), although the response was not uniform among practically identical resins. Based on the cause-effect relationship between DGEBPA treatment and these tumor increases is questionable.

Teratology: Diglycidyl ether of bisphenol A did not cause birth defects or other adverse effects on the fetus when pregnant rabbits were exposed by skin contact, the most likely route of exposure, or when pregnant rats or rabbits were exposed orally.

Reproduction: In animal studies, diglycidyl ether of bisphenol A has been shown not to interfere with reproduction.

Mutagenicity: Diglycidyl ether of bisphenol A has proved to be inactive when tested by in-vivo mutagenicity assays. It has shown activity by in-vitro microbial mutagenicity screening and has produced chromosomal aberrations in cultured rat liver cells. The significance of this information to man is unknown.

12. ECOLOGICAL INFORMATION

Ecotoxicity: Diglycidyl Ether of Bisphenol A: material is moderately toxic to aquatic organisms on an acute basis LC50 (Daph magna), 1.3 mg / L; LC50 (fathead minnow), 3.1 mg / L.

Environmental Fate: The bioconcentration potential for diglycidyl ether of bisphenol A is moderate. Potential for mobility in is low. Biodegradation under aerobic laboratory conditions is below detectable limits.

13. DISPOSAL CONSIDERATIONS

Waste Disposal Method: Not a RCRA hazardous waste. Disposal of this material is not regulated under RCRA. Consult fede state and local regulations to ensure that this material and its containers, if discarded, is disposed of in compliance with all regulatory requirements.

"Empty containers", as defined under 40 CFR 261.7 or other applicable state or provincial regulations or transportation regulatio are not classified as hazardous wastes.

RCRA Hazard Class: NOT A RCRA HAZARDOUS WASTE: When discarded in its purchased form, this material would no regulated as a RCRA Hazardous waste under 40 CFR 261.

14. TRANSPORT INFORMATION

DOT / IATA / IMDG / TDG: Bulk and Non Bulk
Proper Shipping Name: NOT REGULATED

15. REGULATORY INFORMATION

Occupational Safety and Health Act (OSHA): This material is classified as a hazardous chemical under the criteria of the US Occupational Safety and Health Administration (OSHA) Hazard Communication Standard, 29 CFR 1910.1200.

SARA Title III: Section 302 - Extremely Hazardous Substances (EHS): This product does not contain any chemicals regula under Section 302 (40 CFR 355) as extremely hazardous substances.

SARA Title III: Section 304 - CERCLA: Reportable Quantities have not been established for any of this material's componen

SARA Title III: Section 311/312 - Hazard Communication Standard (HCS): This material is classified as an IMMEDIATE HEALTH HAZARD and DELAYED HEALTH HAZARD under the US Superfund Amendment and Reauthorization Act (Secti 311/312).

SARA Title III: Section 313 Toxic Chemical List (TCL): This product does not contain any chemicals for routine annual tox chemical release reporting under Section 313 (40 CFR 372).

TSCA Section 8(b) - Inventory Status: All components of this material are listed on the US Toxic Substances Control Act (TSCA) inventory.

TSCA Section 12(b) - Export Notification: This material does not contain any components that are subject to the US Toxic Substances Control Act (TSCA) Section 12(b) Export Notification requirements.

Australian Inventory Status: This product contains only chemicals which are currently listed on the Australian Inventory of Chemical Substances.

Canadian Inventory Status: All components of this material are listed on the Canadian Domestic Substances List (DSL).

Canadian WHMIS: This material is classified by the Canadian Workplace Hazardous Material Information System as: D2A (materials causing other toxic effects, very toxic material) D2B (materials causing other toxic effects, toxic material)

European Inventory Status (EINECS): All components are either listed or are exempt from being listed, on the EINECS chemical inventory.

Korean Inventory Status: This product contains only chemicals which are currently listed on the Korean Chemical Substances List.

Additional International Information: This product contains only chemicals that are currently listed on the Chinese Inventory of Existing Chemical Substances.

This product contains only chemicals that are currently listed on the Philippine Inventory of Chemicals and Chemical Substances.

This product contains one or more chemicals currently not on the Japanese Inventory of Existing and New Chemical Substances.

California Proposition 65: W A R N I N G: This material contains a chemical known to the State of California to cause cancer and birth defects or other reproductive harm. Epichlorohydrin (CAS# 106-89-8)

Additional Canadian Regulatory Information: This product does not contain a substance present on the WHMIS Ingredient Disclosure List (IDL) which is at or above the specified concentration limit.

This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations and the MSDS contains all the information required by the Controlled Products Regulations.

16. OTHER INFORMATION

MSDS No:	
Reason Issued:	General update
Prepared By:	Product Safety & Compliance Department
Approved Date:	08/15/07
Supersedes Date:	04/15/04

Disclaimer: This information is provided in good faith and is correct to the best of Reichhold's knowledge as of the date hereof and is designed to assist our customers; however, Reichhold makes no representation as to its completeness or accuracy. Our products are intended for sale to industrial and commercial customers. We require customers to inspect and test our products before use and to satisfy themselves as to suitability for their specific applications. Any use which Reichhold customers or third parties make of this information, or any reliance on, or decisions made based upon it, are the responsibility of such customer or third party. Reichhold disclaims responsibility for damages, or liability, of any kind resulting from the use of this information. THERE ARE NO WARRANTIES OR REPRESENTATIONS, EXPRESS OR IMPLIED, INCLUDING THOSE OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE WITH RESPECT TO THIS INFORMATION OR TO THE PRODUCT IT DESCRIBES. IN NO EVENT SHALL REICHHOLD BE LIABLE FOR SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES.

Appendix K: MSDS Reichhold 556 epoxy Hardener

REICHHOLD

Material Safety Data Sheet

Revision Date: 22 Aug 2009

Distributed by:
US Composites
(561) 588-1011
www.uscomposites.com

1. PRODUCT AND COMPANY IDENTIFICATION

Product Description:	**556 Epoxy Hardener (3:1)**
SAP ID(s):	6708; 6709; 181313
Material Code:	
Chemical Family:	Modified Polyamine
Intended Use:	Epoxy Resin Curing Agent

Manufacturer/Supplier:
Reichhold, Inc.
Corporate Headquarters
P.O. Box 13582
Research Triangle Park, NC 27709
USA
Tel +1-919-990-7500
Fax +1-919-767-8602

Emergency Telephone (Chemtrec) 1-800-424-9300

Email: ProdSafe@reichhold.com

2. HAZARDS IDENTIFICATION

Emergency Overview:

DANGER!
Corrosive
Causes skin and eye burns
Harmful by inhalation
May cause irritation of respiratory tract
May cause sensitization by skin contact
May cause allergic respiratory reaction
May be harmful if swallowed

Appearance: Straw Colored **Physical State:** Liquid **Odor:** Amine

Primary Routes of Entry	Skin contact, Ingestion, Inhalation, Eye contact, Skin absorption.
Acute Effects	
Eyes:	Corrosive to the eyes and may cause severe damage including blindness.
Skin:	Corrosive. Causes burns. Severe skin irritation. May cause sensitization by skin contact. Can be absorbed through skin.
Inhalation:	Harmful if inhaled and may cause delayed lung injury. Severe respiratory irritant. May cause allergic respiratory reaction.
Ingestion:	Moderately toxic. May be harmful if swallowed. Aspiration into lungs may cause chemical pneumonia and lung damage. Ingestion causes burns of the upper digestive and respiratory tracts. Ingestion is not an anticipated route of exposure for this material in industrial use.
Chronic Effects:	May cause sensitization by inhalation. This material does not contain 0.1% or more of any chemical listed by the International Agency for Research on Cancer (IARC), the National Toxicology Program (NTP), or regulated by the Occupational Safety and Health Administration (OSHA) as a carcinogen. Exposure to organic solvents during pregnancy may cause an increased risk of birth defects.
Target Organ(s):	Lungs, Eyes, Skin.

HMIS: **Health:** 3* **Flammability:** 1 **Reactivity:** 1

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3. COMPOSITION/INFORMATION ON INGREDIENTS

Component	CAS-No	Weight %	Status
Poly(oxypropylene)diamine	9046-10-0	45.5 - 47.5	Hazardous
4-Nonyl phenol, branched	84852-15-3	33 - 35	Hazardous
Phenol, 4,4"-(1-methylethylidene)bis-, polymer with (chloromethyl)oxirane and 1-piperazineethanamine	68391-18-4	11.5 - 13.5	Hazardous
1-Piperazineethanamine	140-31-8	6 - 8	Hazardous

4. FIRST AID MEASURES

Skin Contact: Wash off immediately with plenty of water for at least 15 minutes. Remove and wash contaminated clothing before re-use. Get medical attention if irritation develops or persists.

Eye Contact: Move individual away from exposure. Immediately flush eyes with large quantities of clean water for at least 15 minutes. Get immediate medical attention.

Inhalation: Remove victim to fresh air. Keep warm and quiet. If not breathing, give artificial respiration. If breathing is difficult, give oxygen by trained personnel. GET IMMEDIATE MEDICAL ATTENTION.

Ingestion: Do not induce vomiting without medical advice. CORROSIVE. ASPIRATION HAZARD. Never give anything by mouth to an unconscious person. GET IMMEDIATE MEDICAL ATTENTION.

5. FIRE-FIGHTING MEASURES

Flammability: No data available

Suitable Extinguishing Media: Carbon dioxide (CO_2), Foam, Dry chemical, Water spray, Do not use a solid water stream as it may scatter and spread fire.

Hazardous Combustion Products: Carbon dioxide (CO_2), Carbon monoxide, Nitrogen oxides (NO_x), Ammonia.

Fire/Explosion Hazard: Closed containers may rupture when exposed to extreme heat.

Protective Equipment and Precautions for Firefighters: Wear self-contained breathing apparatus (SCBA) and full fire-fighting protective clothing. Thoroughly decontaminate all protective equipment after use. Evacuate all persons from the fire area to a safe location. Move non-burning material, as feasible, to a safe location as soon as possible. Fire fighters should be protected from potential explosion hazard while extinguishing the blaze. Use water spray to cool fire-exposed containers.

NFPA Rating: **Health** 3 **Flammability** 1 **Instability** 0

6. ACCIDENTAL RELEASE MEASURES

Personal Precautions: Use personal protective equipment. Ensure adequate ventilation. Keep people away from and upwind of spill/leak.

Environmental Precautions: Prevent further leakage or spillage if safe to do so. Prevent product from entering drains. Do not flush into surface water or sanitary sewer system.

Methods for Containment: Prevent spilled material from 1) contaminating soil, 2) entering sanitary sewers, storm sewers, and drainage systems, and 3) entering bodies of water or ditches that lead to waterways. Prevent spreading over a wide area (e.g. by containment or oil barriers).

Methods for Clean-up: Soak up with inert absorbent material (e.g. sand, silica gel, acid binder, universal binder,

7. HANDLING AND STORAGE

Handling: Avoid breathing vapors or mists. Avoid contact with skin, eyes and clothing. Remove and wash contaminated clothing before re-use. Wash hands before breaks and immediately after handling the product. Ensure adequate ventilation.

Storage: Keep containers tightly closed in a dry, cool and well-ventilated place.

8. EXPOSURE CONTROLS / PERSONAL PROTECTION

Exposure limits
Contains no substances with occupational exposure limit values

Engineering Controls: Ensure adequate ventilation, especially in confined areas. Local ventilation may be required during certain operations.

Personal Protective Equipment

Eye/face Protection: Wear safety glasses with side shields and a faceshield or goggles and a faceshield. Ensure that eyewash stations and safety showers are close to the workstation location.

Skin Protection: Gloves made of butyl rubber. Chemical resistant apron. Boots.

Respiratory Protection: In case of inadequate ventilation wear respiratory protection.

9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance:	Straw Colored
Odor:	Amine
Odor Threshold:	Not available
Physical State:	Liquid
pH:	Not applicable
Flash Point:	> 93°C / > 200°F
Flash Point Method:	Seta closed cup
Autoignition Temperature:	Not available
Boiling Point/Range:	> 200°C / < 392°F
Freezing point:	Not available
Flammability Limits in Air	
Lower:	Not available
Upper:	Not available
Specific Gravity:	0.964 - 0.988 @ 25°C
Solubility:	Insoluble
Evaporation Rate:	Not available
Vapor Pressure:	Not available
Vapor Density:	> 1 (Air = 1)
Percent volatile:	Not applicable
VOC Content:	Not available
Viscosity:	200 - 400 cps @ 25°C

10. STABILITY AND REACTIVITY

Chemical Stability: Stable under normal conditions.

Conditions to Avoid: Keep away from open flames, hot surfaces and sources of ignition. Contamination by those materials referred to under Incompatible materials. Temperatures above 300°C.

Incompatible Materials: Strong oxidizing agents. Acids. Halogenated compounds. Aldehydes. Copper. Copper alloys.

Hazardous Decomposition Products: Carbon monoxide. Carbon dioxide (CO_2). Hydrocarbons. Nitrogen oxides (NO_x). Ammonia.

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Hazardous Polymerization: Hazardous polymerisation does not occur.

11. TOXICOLOGICAL INFORMATION

Acute Toxicity

Poly(oxypropylene)diamine	
LD50 Oral	2855 mg/kg - rat
LD50 Dermal	2980 mg/kg - rabbit
4-Nonyl phenol, branched	
LD50 Oral	1300 mg/kg - rat
1-Piperazineethanamine	
LD50 Oral	2140 mg/kg - rat
LD50 Dermal	894 mg/kg - rabbit

Irritation and corrosion Corrosive to eyes. Corrosive to skin.
Sensitization: May cause sensitization by inhalation and skin contact.

Chronic Toxicity

Target Organ(s): Lungs, Eyes, Skin.

12. ECOLOGICAL INFORMATION

Marine Pollutant: NONYL PHENOL.

Ecotoxicity
Ecotoxicity effects: Harmful to aquatic organisms. May cause long-term adverse effects in the aquatic environment.
Bioaccumulation: No information available.

Poly(oxypropylene)diamine	
Freshwater Fish	LC50 (96h) > 220 - < 460 mg/l (golden orfe)
1-Piperazineethanamine 556 Epoxy Hardener (2:1)	
Toxicity to Aquatic Invertebrates	EC50 (48h) 32 - 58 mg/l (daphnia magna)

13. DISPOSAL CONSIDERATIONS

Waste Disposal Method: NOT A RCRA HAZARDOUS WASTE: When discarded in its purchased form, this material would not be regulated as a RCRA Hazardous waste under 40 CFR 261.

Contaminated Packaging: Empty containers should be taken for local recycling, recovery or waste disposal.

US EPA Waste Number: Not applicable.

14. TRANSPORT INFORMATION

DOT

UN-No	UN2735
Proper Shipping Name:	POLYAMINE, LIQUID, CORROSIVE, N.O.S.
Technical Name:	NONYL PHENOL POLYOXYALKYLENE AMINES

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Revision Date: 22 Aug 2009

14. TRANSPORT INFORMATION

Hazard Class	8
Packing Group	III
Marine Pollutant:	NONYL PHENOL
NAERG:	153

TDG

UN-No	UN2735
Proper Shipping Name	POLYAMINES, LIQUID, CORROSIVE, N.O.S.
Technical Name:	NONYL PHENOL POLYOXYALKYLENE AMINES
Hazard Class	CLASS 8
Packing Group	PG III
NAERG:	153

IATA

UN-No	UN2735
Proper Shipping Name	POLYAMINES, LIQUID, CORROSIVE, N.O.S.
Technical name:	NONYL PHENOL POLYOXYALKYLENE AMINES
Hazard Class	8
Packing Group	III
Packing Instructions	818, 820
NAERG:	153

IMDG/IMO

UN-No	UN2735
Proper Shipping Name	POLYAMINE, LIQUID, CORROSIVE, N.O.S.
Technical Name:	NONYL PHENOL POLYOXYALKYLENE AMINES
Hazard Class	CLASS 8
Packing Group	PG III
EmS No.	F-A, S-B
NAERG:	153

15. REGULATORY INFORMATION

International Inventories

TSCA Inventory Status:	All components of this material are listed on the US Toxic Substances Control Act (TSCA) inventory.
Canadian Inventory Status:	All components of this material are listed on the Canadian Domestic Substances List (DSL).
Australian Inventory Status:	This product contains only chemicals which are currently listed on the Australian Inventory of Chemical Substances.
Korean Inventory Status:	This product contains only chemicals which are currently listed on the Korean Chemical Substances List.
Philippine Inventory:	This product contains one or more chemicals currently not on the Philippine Inventory of Chemicals and Chemical Substances.
Japan ENCS:	This product contains only chemicals that are currently listed on the Japanese Inventory of Existing and New Chemical Substances.
Chinese IECS:	This product contains only chemicals that are currently listed on the Chinese Inventory of Existing Chemical Substances.

New Zealand Inventory: This product contains only chemicals which are currently listed on the New Zealand Inventory of Chemicals.

U.S. Federal Regulations

SARA 313

Section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1986 (SARA). This product does not contain any chemicals which are subject to the reporting requirements of the Act and Title 40 of the Code of Federal Regulations, Part 372.

SARA 311/312 Hazardous Categorization

Acute Health Hazard	Yes
Chronic Health Hazard	Yes
Fire Hazard	No
Sudden Release of Pressure Hazard	No
Reactive Hazard	No

TSCA 12(b) - Export Notification:

This material does not contain any components that are subject to the US Toxic Substances Control Act (TSCA) Section 12(b) Export Notification requirements.

Clean Air Act, Section 112 Hazardous Air Pollutants (HAPs) (see 40 CFR 61)

This product does not contain any HAPs.

CERCLA

This product does not contain components that have been assigned reportable quantities.

State Regulations

California Proposition 65

This product does not contain any Proposition 65 chemicals.

Canada

This product has been classified in accordance with the hazard criteria of the Controlled Products Regulations (CPR) and the MSDS contains all the information required by the CPR.

WHMIS Hazard Class D2A Very toxic materials
E Corrosive material

Component	CAS-No	WHMIS Ingredient Disclosure List
1-Piperazineethanamine	140-31-8	1%

16. OTHER INFORMATION

Prepared By: Reichhold Product Regulatory Department

Revision Date: 22 Aug 2009

Revision Number: 1

Revision Summary None

Former date: 6 September 2002

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End of MSDS

Appendix L: Urban Concept Wheel Calculations for Materials Required and Cost

Notes:

All prices from www.uscomposites.com

$$y_c = yard\ of\ carbon\ cloth$$

Based on the materials used for the sea:

$$\left(1.3353\ {y_c^2}/{layer}\right)(4\ layers) = 5.34129\ y_c^2$$

$$\left(\frac{5.34129\ y_c^2}{3\ lb}\right)\left(\frac{3\ lb}{1\ wheel}\right)\left(\frac{5\ wheels}{1\ wheel\ set}\right) = 26.70645\ {y_c^2}/{wheel\ set}$$

For 3K 5.7 oz 2x2 twill cloth:

Using width, w = 60 in = 1.66667 y

$$A = lw$$

$$A = 26.70645\ y_c^2$$

$$26.70645\ y_c^2 = 1.66667 y_c * l$$

$$l = 17\ y_c$$

$$17 y_c \left(\frac{\$40.50}{y_c}\right) = \$688.50 + shipping\ \&\ handling$$

Using width, w = 50 in = 1.38889 y

$$26.70645\ y_c^2 = 1.28889\ y_c * l$$

$$l = 20\ y_c$$

$$20 y_c \left(\frac{\$29.50}{y_c}\right) = \$590 + shipping\ \&\ handling$$

For resin required:

$$\left(\frac{567\,ml}{3\,lb}\right)\left(\frac{15\,lb}{wheel\ set}\right) = 2835\,ml$$

Due to the 3:1 resin to hardener ratio:

$$0.75(2835\,ml) = 2126.25 = 0.5617\ gal\ of\ resin$$

$$0.25(2835\,ml) = 708.75\,ml = 23.97\ fl\ oz\ of\ hardener$$

We had 1 gallon of hardener and 42.6 fl oz of hardener that was purchased for the seat.

We used 0.1849 gallons of resin and 10.1442 fl oz of hardener on the seat.

So:

$$(0.5617 + 0.1849) gal\ of\ resin = 0.7466\ gal\ \le 1\ gallon$$

$$(10.1442 + 23.97)\ fl\ oz\ of\ hardener = 34.1142\ oz\ \le 42.6\ fl\ oz$$

Appendix M: UCV Wheel FMEA

Part	Function	Failure mode	Failure Effect(s)	S	Failure Cause(s)	O	Current controls	D	RPN	Recommended actions	Responsibility and Target Completion Date	Action taken
Aluminum Center	Tightening wheel on	Crushes under bolt load	Permanent deformation leading to imbalance and misalignment	3	Excessive tightening torque	1	Torque Wrench	2	6	None	None	None
	Acceleration	Center Seizes with Hub	Difficult to remove wheel from hub, permanent damage resulting in replacement of components	6	Excessive torque at the wheel	1	3 petal spline design, minimal clearance between hub and center	3	18	None	None	None
Bolts	Static Loading	Shearing bolt	Reduced support of lateral loads	6	Bolt diameter too small	1	Use larger bolts	2	12	None	None	None
	Tightening Bolts	Strip head pattern	Inability to further tighten or loosen bolt	4	Improper driver size or over-torqued	4	Use star or hex key heads	1	16	None	None	None
	Normal Operation	Corrosion	Weakening of bolt material	6	Exposure to high moisture levels or acidic environments	5	Use Stainless Steel or coated bolts	5	150	Check bolts for corrosion annually	Cal Poly Supermileage Vehicle Team	None
		Loosening	Bolt falls out or does not support the loading	7	Excessive vibration	5	Use Lock-tight on bolts and torque to 60 lb-ft	2	70	None	None	None
	Tightening Bolts	Fatiguing	Loss of strength in bolt	4	Excessive mounting and removal of bolt	2	None	6	48	Check bolts annually for signs of fatiguing	Cal Poly Supermileage Vehicle Team	None
Vertical Carbon Disk	Tightening Bolts	Crack Propagation	Cracks developing and spreading during operation of the wheel	8	Excessive torque during tightening	4	Torque to 60 lb-ft	4	128	Static testing prior to completion of production run, listen for cracking sound during tightening of bolts	James Scaini, 3/1/2010	None
	Normal Operation	Buckling	Vertical loads cause bottom portion of carbon to buckle	8	Higher vertical dynamic loads than calculated	2	None	3	48	Load wheel to 125% of maximum calculated vertical dynamic loads during testing	David Lewis, 3/1/2010	None
	Cornering	Excessive deflection	Loss of driver response to road	4	Higher lateral dynamic loads than calculated	2	None	3	24	Load wheel to 125% of maximum calculated lateral dynamic loads during testing	David Lewis, 3/1/2010	None

S = Severity Rating (1 = No Danger, 10 = Critical Danger)
O = Occurance Rating (1 = Rare, 10 = Frequently)
D = Detection Rating (1 = Low Chance To Escape Detection, 10 = High Chance)
RPN = Risk Priority Number (Desired Value < 80)

Carbon Rim	Tire Mounting	Denting or cracking	Dents or cracks that affect fiber strength on the outer rim portion	3	High concentrated loads on rim edge	3	Use tire mounting device that has minimal contact with rim surface	2	18	None	None	None
	Cornering	Excessive deflection	Rim profile shifts, tire loses pressure	5	Higher vertical dynamic loads than calculated	2	None	4	40	Load wheel to 125% of maximum calculated vertical dynamic loads during testing	David Lewis, 3/1/2010	None
	Impacts	Crack Propagation	Cracks develop due to impacts with sharp objects or	7	Impact with sharp objects or potholes	5	None	3	105	Tire will absorb much of the impact loading and distribute it over the wheel	None	None

S = Severity Rating (1 = No Danger, 10 = Critical Danger)
O = Occurance Rating (1 = Rare, 10 = Frequently)
D = Detection Rating (1 = Low Chance To Escape Detection, 10 = High Chance)
RPN = Risk Priority Number (Desired Value < 80)

Appendix N: UCV seat FMEA

Function	Failure mode	Failure Effect(s)	S	Failure Cause(s)	O	Current controls	D	RPN	Recommended actions	Responsibility and Target Completion Date	Action taken
Hard Braking	Back of Seat Buckles	Seat no longer structural, need replacement	8	Too much weight on back of seat	1	None	9	72	Rest seat against rear firewall	Casey Alvernaz, 3/1/2010	None
	Bracket punctures seat bottom	Loss of rigidity, driver discomfort during operation, detachment of seat	8	Sharp bracket corners, too much weight on back of seat	2	Rest seat back against rear fire wall	5	80	Use large brackets that extend up the back wall of the seat, eliminate any sharp edges where the bracket could puncture	Casey Alvernaz, 3/1/2010	None
	Cracks form in carbon	Crack propagation leading to structural failure of part	7	Puncture in carbon layer, excessive stress causing resin to yield	1	Use of twill weave cloth, no sharp objects in contact or near seat	2	14	None	None	None
Sitting in seat	Foam crushes	Air gaps introduced, delamination of carbon from foam	2	Too much weight on bottom or back of seat, carbon deflecting too much	5	None	2	20	None	None	None
Hard Cornering	Seat twists	Too much driver movement, loss of responsive feel to driver	2	Fiber orientation incorrect, seatbelts don't hold driver back in seat correctly	2	Seat Belts	3	12	None	None	None

S = Severity Rating (1 = No Danger, 10 = Critical Danger)

O = Occurance Rating (1 = Rare, 10 = Frequently)

D = Detection Rating (1 = Low Chance To Escape Detection, 10 = High Chance)

RPN = Risk Priority Number (Desired Value < 80)

Appendix O: UCV seat DVPR

CUSTOMER: Cal Poly Supermileage Vehicle Team	DVP+R NUMBER: 101		DEPT.
PART NAME: Seat	REPORT DATE: 1/22/2010		PLAN ORIGINATOR: Verent Chan
MODEL YEAR: 2010	COMPONENT / ASSEMBLY: Seat		MANAGER: Sarah Harding
			REPORTING ENGINEER:

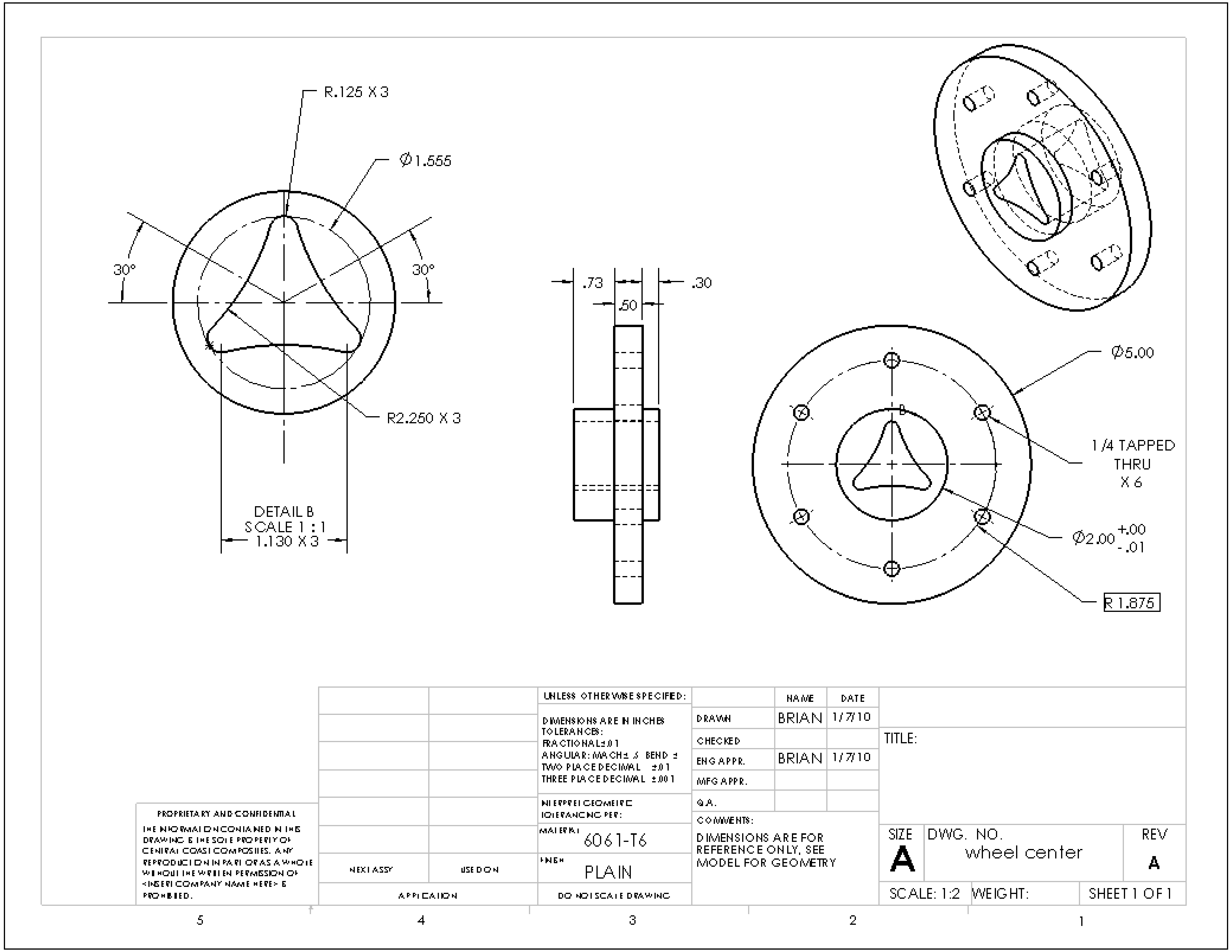
TEST PLAN										TEST REPORT			
Item No	Specification or Clause Reference	Test Description	Acceptance Criteria	Test Responsibility	Test Stage	SAMPLES TESTED		TIMING		TEST RESULTS			NOTES
						Quantity	Type	Start date	Finish date	Test Result	Quantity Pass	Quantity Fail	
1	Weight	Weight seat on scale accurate to +/- 1 oz	7.5±0.5 lbs	CCC	PV	1	C	2/24/2010	2/24/2010	P	1	0	
2	Seatbelt Compatibility	Driver sits in seat with seatbelts attached	No Interference	SMVT	PV	1	C	2/24/2010	2/24/2010	N/A	N/A	N/A	
3	Frame Compatibility	Mount seat on frame and check dimensions	No Interference	SMVT	PV	1	C	2/24/2010	2/24/2010	N/A	N/A	N/A	
4	Weight Capacity	Load seat to 250lb	No Failure	SMVT	PV	1	C	2/24/2010	2/24/2010	N/A	N/A	N/A	
5	Adjustable Range	Move seat forward and backward	3 locations 2 inches apart	SMVT	PV	1	C	2/24/2010	2/24/2010	N/A	N/A	N/A	
6	Bending Test	Load seat back with 250lb distributed load	No Failure	CCC	PV	1	C	2/24/2010	2/24/2010	P	1	0	
7	Comfort	Driver evaluates comfort of seat for 45 minutes	No Discomfort	CCC	PV	1	C	2/25/2010	2/25/2010	P	1	0	
8													
9													
10													
11													

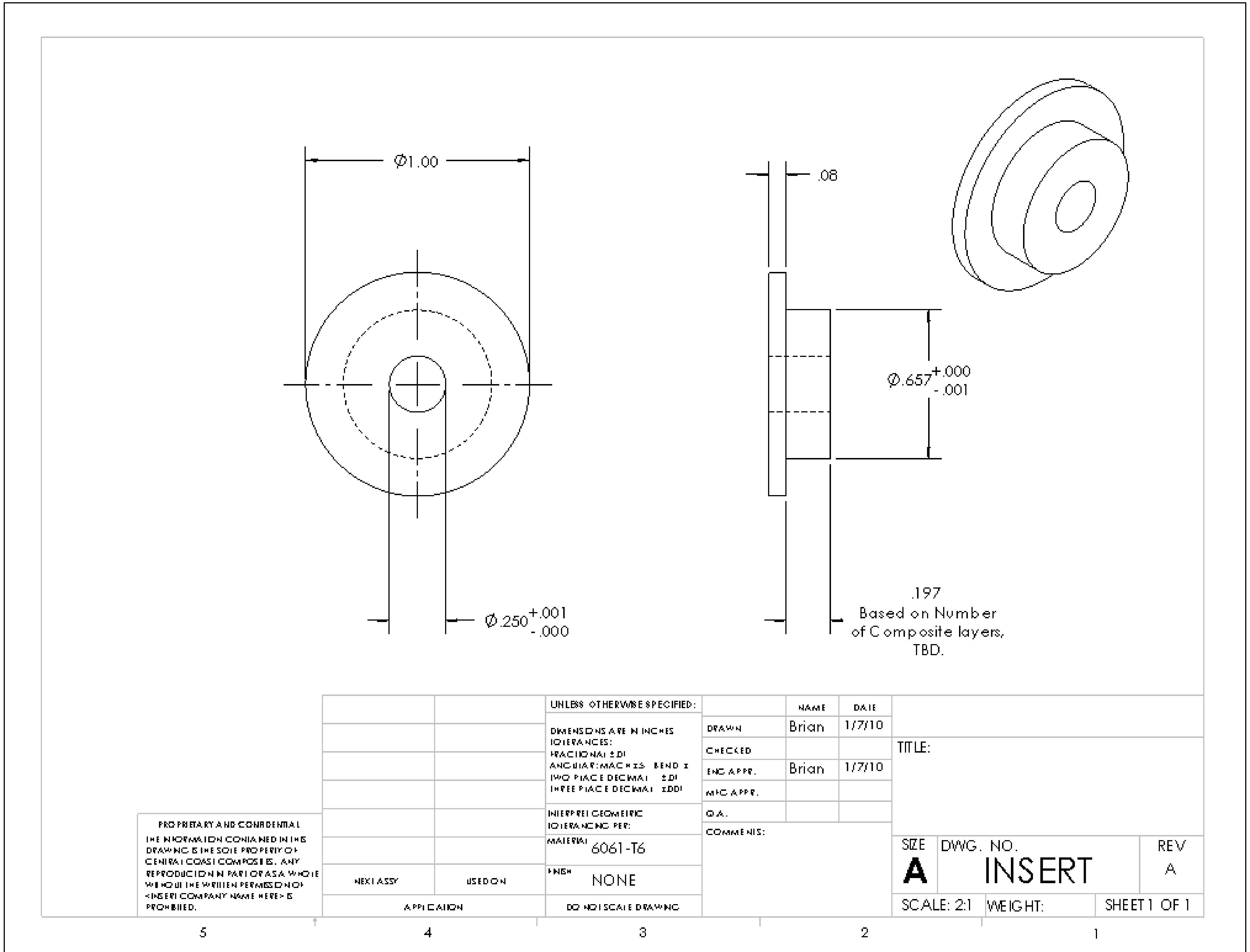
Appendix P: UCV Wheel DVPR

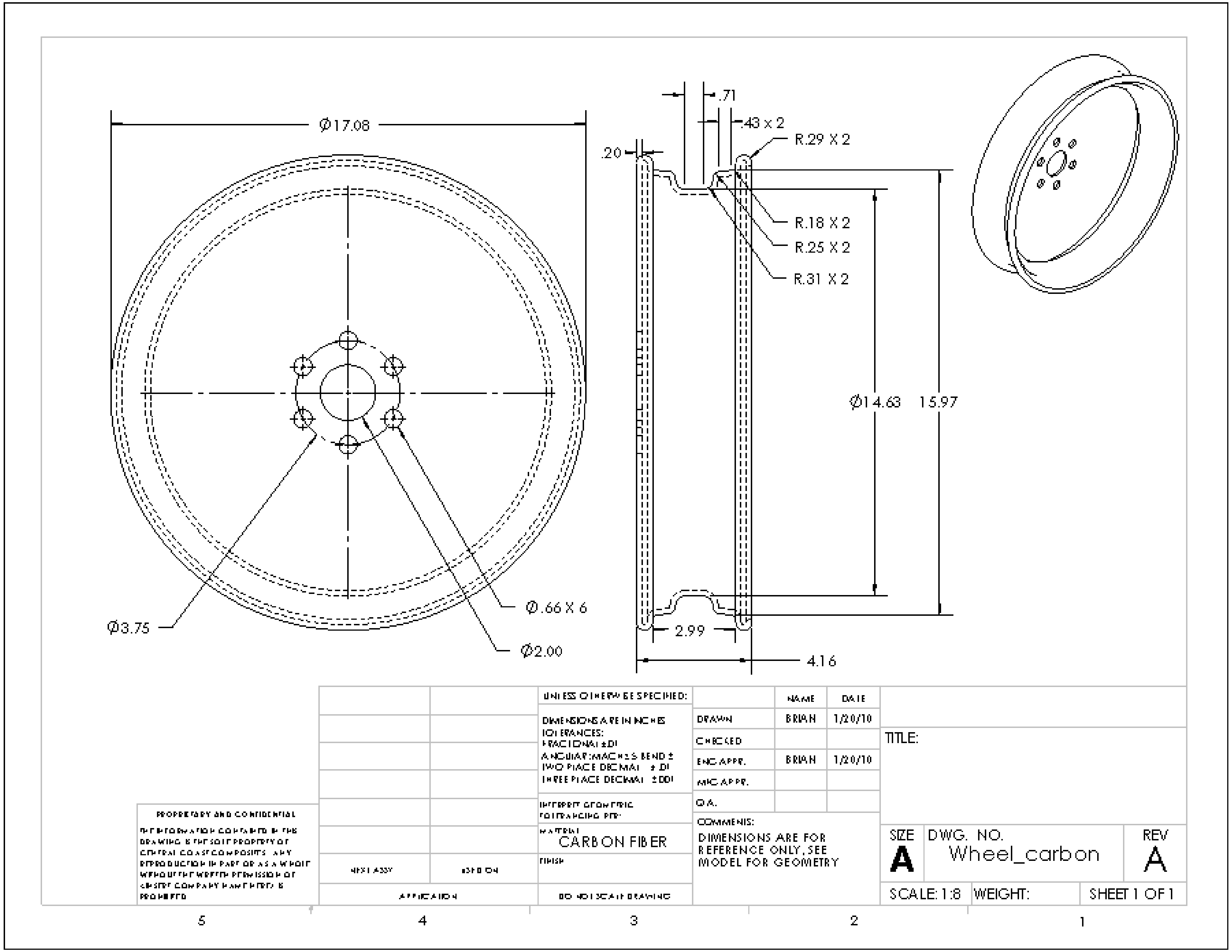
CUSTOMER: Cal Poly Supermileage Vehicle Team	DVP+R NUMBER: 101		DEPT.
PART NAME: Wheel	REPORT DATE: 1/22/2010		PLAN ORIGINATOR: Verent Chan
MODEL YEAR: 2010	COMPONENT / ASSEMBLY: Wheel		MANAGER: Sarah Harding
			REPORTING ENGINEER:

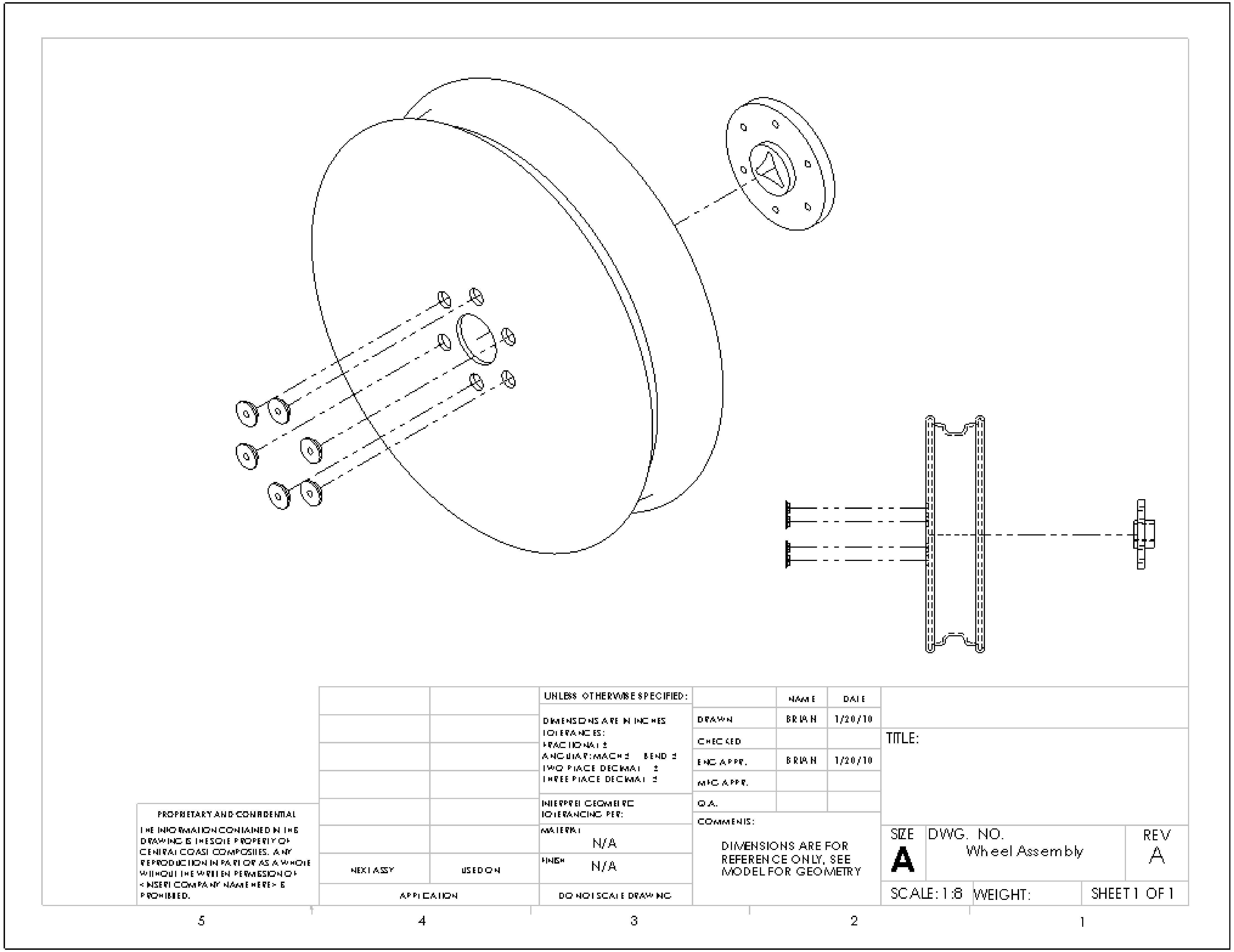
TEST PLAN										TEST REPORT			
Item No	Specification or Clause Reference	Test Description	Acceptance Criteria	Test Responsibility	Test Stage	SAMPLES TESTED		TIMING		TEST RESULTS			NOTES
						Quantity	Type	Start date	Finish date	Test Result	Quantity Pass	Quantity Fail	
1	Tire Compatibility	Mount tire and inflate	Holds Pressure	CCC	PV	1	C	3/1/2010	3/1/2010	F	0	1	Tire would not seat at specified pressure
2	Tire Pressure	Inflate to 60 psi	No Failure	CCC	PV	1	C	3/1/2010	3/1/2010	P	1	0	Tire not seated at 60 psi
3	Weight	Weigh wheel on a scale with ±1 oz resolution	3±0.5 lbs	CCC	PV	1	C	3/1/2010	3/1/2010	F	0	1	Weight =4.4lbs
4	Frame/Rotor Compatibility	Mount wheel on axle, check clearances	No Interference	CCC	PV	1	C	3/1/2010	3/1/2010	N/A	N/A	N/A	
5	Lateral Force	Place car on inclined ramp to produce 125% of theoretical maximum cornering loads	No Failure	CCC	PV	1	C	3/1/2010	3/1/2010	N/A	N/A	N/A	
6	Axial Force	Raise one wheel to create artificial uneven weight distribution	No Failure	CCC	PV	1	C	3/1/2010	3/1/2010	N/A	N/A	N/A	
7	Concentric with Axle	Spin wheel, use gauge to determine alignment	±0.0625" Deflection	CCC	PV	1	C	3/1/2010	3/1/2010	N/A	N/A	N/A	
8	Impact Loading	Drive vehicle into uneven pavement	No Failure	SMVT	PV	1	C	3/1/2010	3/1/2010	N/A	N/A	N/A	
9	Bolt Inspection	Remove Bolts, check for corrosion and wear	No Irregularities found	SMVT	PV	1	C	3/1/2011	3/1/2011	N/A	N/A	N/A	
10													
11													
12													

Appendix Q: UCV Wheel Model Drawings:




Ø1.00
.08
Ø.657 +.000 -.001
Ø.250 +.001 -.000
.197
Based on Number of Composite layers, TBD.
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL 6061-T6
FINISH NONE
DO NOT SCALE DRAWING
NAME
DATE
DRAWN Brian 1/7/10
CHECKED
ENG APPR. Brian 1/7/10
MFG APPR.
Q.A.
COMMENTS:
TITLE:
SIZE A
DWG. NO. INSERT
REV A
SCALE: 2:1
WEIGHT:
SHEET 1 OF 1
PROPRIETARY AND CONFIDENTIAL
THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF CENTRAL COAST COMPOSITES. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF <INSERT COMPANY NAME HERE> IS PROHIBITED.
NEXT ASSY
USED ON
APPLICATION
5
4
3
2
1


Ø17.08
.71
.43 x 2
R.29 X 2
.20
R.18 X 2
R.25 X 2
R.31 X 2
Ø14.63
15.97
Ø.66 X 6
Ø3.75
Ø2.00
2.99
4.16
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
NAME
DATE
DRAWN
BRIAN
1/20/10
CHECKED
ENG APPR.
BRIAN
1/20/10
MFG APPR.
Q.A.
COMMENTS:
DIMENSIONS ARE FOR REFERENCE ONLY, SEE MODEL FOR GEOMETRY
TITLE:
PROPRIETARY AND CONFIDENTIAL
MATERIAL
CARBON FIBER
FINISH
NEXT ASSY
USED ON
APPLICATION
DO NOT SCALE DRAWING
SIZE
A
DWG. NO.
Wheel_carbon
REV
A
SCALE: 1:8
WEIGHT:
SHEET 1 OF 1
5
4
3
2
1


UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
INTERPRET GEOMETRIC TOLERANCING PER:
MATERIAL
N/A
FINISH
N/A
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
BRIAN
1/20/10
CHECKED
ENG APPR.
BRIAN
1/20/10
MFG APPR.
Q.A.
COMMENTS:
DIMENSIONS ARE FOR REFERENCE ONLY, SEE MODEL FOR GEOMETRY
TITLE:
SIZE
A
DWG. NO.
Wheel Assembly
REV
A
SCALE: 1:8
WEIGHT:
SHEET 1 OF 1
NEXT ASSY
USED ON
APPLICATION
PROPRIETARY AND CONFIDENTIAL
5
4
3
2
1

Appendix R: Molding Resin Technical Data Sheet

PRODUCT BULLETIN

EL-325-1 HTTC
EPOXY COMPOSITE
TOOLING COMPOUND
SLOW WORK LIFE
LIGHT-WEIGHT, HIGH TEMP

ADTECH Plastic Systems

www.CASSpolymers.com 800.344.7776 ADTECH@CASSpolymers.com
31200 Stephenson Hwy Madison Heights MI 48071 Ph 248.588.2270 Fax 248.588.5909

DESCRIPTION

EL-325-1 HTTC is an epoxy "Composite Tooling Compounds" designed for the construction of tools, jigs, models and other tooling that will see elevated temperatures. This system had a slower working life that the standard EL-325 HTTC. Use of EL-325-1 HTTC allows a considerable time and labor saving in tool construction. The neutral resin and black hardener give a uniform dark gray color when thoroughly mixed that is pliable and can be applied to the tool surface without crumbling or cracking.

Tools constructed with EL-325-1 HTTC maintain a very high degree of dimensional stability, are light weight, can be machined as well as drilled and tapped. All of these qualities allow EL-325-1 HTTC to be used in a variety of tooling applications. EL-325-1 HTTC offers the toolmaker a safer alternative to standard epoxy laminates since both resin and hardener are syntactic, therefore, eliminating splash hazards. EL-325-1 HTTC does not contain MDA or VCHD, however, the hardener is corrosive and gloves should be worn when handling.

HANDLING CHARACTERISTICS @ 25°C/77°F	**EL-325-1 HTTC**
Mix Ratio (parts by weight)	100R/29H
Mix Ratio (parts by volume)	3.8R/1H
Density (mixed)	5.29 lbs/gal
Density (mixed)	0.023 lbs/cu in
Specific Gravity	0.633 gms/cc
Viscosity	Syntactic Dough
Work Life	3 hours
Demold Time	16-24 hours
Mixed Color	Dark gray
Peak Exotherm (1 lb mass, 6" deep)	115°F
Shelf Life Resin & Hardener (in original unopened container)	1 year

PHYSICAL PROPERTIES (Cast Bar: 5" x ½" X ½")

Ultimate Flexural Strength (ASTM D-790.92)	9,600 psi
Flexural Modulus (ASTM D-790.92)	540,000 psi
Ultimate Compressive Strength (ASTM D-695.91).	4,900 psi
Coefficient of Thermal Expansion (ASTM-696.91)	0.9×10^{-5} in/in °F
Heat Deflection Temperature (ASTM D-648.82)	218°C/425°F
Hardness	65-70 Shore D

APPLICATION GUIDELINES

NOTE: The following abbreviated construction sequence will vary depending on intended application.

Apply any ADTECH High Temp Epoxy Surface Coat to prepared model. Allow to tack. Apply a second surface coat and allow to tack. Apply ADTECH High Temp Laminating system to surface coat. Laminate 3 layers 10 oz. tooling cloth. Prepare EL-325-1 HTTC. Mix catalyzed EL-325-1 HTTC with catalyzed laminating system at 50/50 parts-by-volume. Brush this bond coat onto the laminate (this helps to ensure an air free tool). Press compound out in all directions until you get the desired thickness. Add new tooling compound to existing tooling compound, therefore, eliminating any possible air pockets. Let the tooling compound firm up (3 hrs) then proceed to brush ADTECH High Temp Laminating system on top of the tooling compound. Apply an additional 3 layers of 10 oz. cloth forming a sandwich construction. Allow to cure/post cure and de-mold.

Continued on next page

PRODUCT BULLETIN CONT.

POST CURE SCHEDULE

PRELIMINARY CURE SCHEDULE

On Model Cure for 24 hours @ 25°C/77°F
+ 6 hours 66°C/150°F

You may attach support structure and demold tool after this schedule is completed.

POST CURE SCHEDULE

After completing the Preliminary Cure Schedule, complete the following:

1 hour @ 93°C/200°F
1 hour @ 121°C/250°F
1 hour @ 149°C/300°F
3 hours @ 177°C/350°F

Install thermocouples to monitor the mold temperature throughout the post cure process.

HEATING AND COOLING RATES DURING POST CURE

Always allow tools made with ADTECH high temp systems to gel at room temperature before subjecting them to post cure (24 hours is usually sufficient). This will prevent excessive exotherm and shrinkage from occurring.

When oven curing laminated molds, always place the mold in a room temperature oven increasing the temperature at a rate of no more than 13°C/25°F per hour. When finished, allow molds to remain in the heated oven, decreasing the temperature at a rate of no more than 27°C/50°F per hour. Never remove the mold from the oven until temperature has been lowered to less than 38°C/100°F.

Once a mold has been heat cured and conditioned, during the production curing cycles of composite parts you can revert to the heating/cooling rates prescribed for the production pre-preg or two component resin.

Appendix S: MSDS EL-325-1 Epoxy composite tooling compound

MATERIAL SAFETY DATA SHEET

1. IDENTIFICATION OF THE SUBSTANCE/PREPARATION AND OF THE COMPANY

PRODUCT NAME: EL-325-1 HTTC Resin

CHEMICAL NAME: Epoxy Resin Blend, Bisphenol A/F reaction products with Epichlorhydrin.

MANUFACTURER: CASS POLYMERS OF MICHIGAN, INC.
815 WEST SHEPHERD STREET
CHARLOTTE MI 48813 USA

INFORMATION PHONE: (248) 588-2270
EMERGENCY PHONE: (703) 527-3887(Call Collect)

2. COMPOSITION/INFORMATION ON INGREDIENTS

Hazardous Materials Information System (United States)

Health	2
Flammability	1
Physical Hazard	0

Hazard Codes: *=Chronic Hazard 0=Minimal Hazard, 1=Slight Hazard, 2=Moderate Hazard, 3=Serious Hazard, 4=Severe Hazard

Material Composition

Component	CAS.NO	EINECS/ELINCS No.	Percent
Reaction Product of Bisphenol-A and Epichlorhydrin	25068-38-6	Polymer	20% - 25%
Tris-Hydroxyphenylethanetriglycidyl ether	87093-13-8	Not Available	4% - 5%
Neopentyl Glycol Diglycidyl Ether	17557-23-2	Not Available	1% - 5%
Reaction product of Phenol-Formaldehyde Novolac with Epichlorohydrin	28064-14-4	Polymer	5% - 9%
Aluminum Oxide	1344-28-1	Not Available	50% - 60%
Sodium Borosilcate Glass	65997-17-3	Not Available	1% - 5%

Hazardous Materials are listed if present in concentrations of 1.0% or higher. Materials posing a possible Chronic Health Risk are listed at concentrations of 0.1% or higher. Materials listed in section 2 are not necessarily hazardous. See section 8-Exposure Controls/Personal Protection, and section 11-Toxicological Information for complete hazard/exposure limit information

3. HAZARDS IDENTIFICATION

****Emergency Overview****

Moderate skin irritant. Mild eye irritant. Mild respiratory tract irritant. May cause skin sensitization.

EC Classification(s): Xi-Irritant
Risk Phrases: R36/38: Irritating to eyes and skin
R43: May cause sensitization with skin contact
(See Section 15-REGULATORY INFORMATION for complete risk phrases.)

ROUTES OF EXPOSURE
Eye Contact
Skin Contact
Ingestion

EXPOSURE STANDARDS
No standards established for the product. Maintain air contaminant concentrations in the workplace at the lowest feasible levels.

HEALTH HAZARDS
Moderate skin irritant.
Mild eye irritant.
Mild respiratory tract irritant.
May cause skin sensitization.

TARGET ORGANS
Skin

SIGNS AND SYMPTOMS OF EXPOSURE (Acute effects)

Contact with eyes may cause mild irritation and discomfort. Contact with skin causes irritation, redness and discomfort which is transient. Inhalation of mists may cause irritation in the respiratory tract. Inhalation of vapors from heated material may cause irritation in the respiratory tract. Coughing and chest pain may result.

SIGNS AND SYMPTOMS OF EXPOSURE (Possible Longer Term Effects)

Repeated and/or prolonged exposure may cause allergic reaction/sensitization. Repeated and/or prolonged exposures may result in: adverse skin effects (such as rash, irritation or corrosion).

MEDICAL CONDITIONS GENERALLY AGGRAVATED BY EXPOSURE

Skin disorders and Allergies

CARCINOGENS UNDER OSHA, ACGIH, NTP, IARC, OTHER

This product contains no carcinogens in concentrations of 0.1 percent or greater.

4. FIRST AID MEASURES

Never give fluids or induce vomiting if patient is unconscious or is having convulsions.

Inhalation

Move effected persons to fresh air; if effects occur, consult a physician.

Skin Contact

Continued and thorough washing in flowing water for at least 15 minutes is imperative while removing contaminated clothing. Prompt medical consultation is essential. Wash clothing before reuse. Destroy contaminated leather items.

Eye Contact

Wash immediately and continuously with flowing water for at least 15 minutes. Remove contact lenses after the first 5 minutes and continue washing. Obtain prompt medical consultation, preferably from an ophthalmologist.

Ingestion

If swallowed, call a physician immediately. Remove stomach contents by gastric suction or induce vomiting only as directed by a physician or medical personnel. Do not give anything by mouth to an unconscious person.

Note to Physician

No specific antidote. Treatment of exposure should be directed at the control of symptoms and the clinical condition of the patient.

5. FIRE FIGHTING PRECAUTIONS

Extinguishing Media

Water fog or fine spray. Carbon dioxide. Alcohol resistant foam. Dry chemical fire extinguishers.

Hazardous Combustion Products

May generate toxic or irritating combustion products. Sudden reaction and fire may occur if product is mixed with an oxidizing agent.

Protection of Firefighters

Wear positive-pressure self-contained breathing apparatus and protective fire fighting clothing (includes fire fighting helmet, coat, trousers, boots and gloves.)

6. ACCIDENTAL RELEASE MEASURES

Personal Precautions

Wear adequate personal protective equipment, see Section 8, EXPOSURE CONTROLS/PERSONAL PROTECTION.

Methods of Cleaning Up

Large spills: Contain with dike. Pump into suitable and properly labeled containers.
Small spills: Dilute with water and recover or use non-combustible absorbent material/sand and shovel into appropriate containers.

7. HANDLING AND STORAGE

STORAGE

Keep away from: oxidizers. Keep in cool, dry, ventilated storage areas and in closed containers.

HANDLING

Avoid contact with skin or eyes. Avoid breathing of vapors. Handle in well-ventilated workspace. When handling, do not eat, drink, or smoke.

OTHER PRECAUTIONS

Emergency showers and eye wash stations should be readily accessible. Adhere to work practice rules established by government regulations (e.g. OSHA).

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Hazardous Component Control Parameters –

Component	CAS. No.	EINECS	Percent	Exposure Limits	Source
Sodium Borosilcate	65997-17-3	Not	1% - 5%	5mg/m^3 TWA respirable dust,	OSHA

Glass		Available		5 mg/m^3 TWA total inhalable dust	ACGIH
Aluminum Oxide	1344-28-1	Not Available	50% - 60%	15mg/m^3 TWA respirable dust, 10 mg/m^3 TWA total inhalable dust	OSHA ACGIH

-No Further Data Available-

EYE PROTECTION

Chemical safety glasses. A full-face shield and vapor respirator is recommended for operations involving spraying or other operations placing this material under pressurized conditions.

HAND PROTECTION

Neoprene rubber gloves. Impermeable gloves. Nitrile rubber gloves. The breakthrough time of the selected glove(s) must be greater than the intended use period.

RESPIRATORY PROTECTION

Not required under normal conditions and in a well-ventilated workplace. At elevated temperatures, a cartridge mask National Institute for Occupational Safety and Health (NIOSH) approved for organic vapors may be appropriate

PROTECTIVE CLOTHING

Long sleeved clothing.

ENGINEERING CONTROLS

No specific controls needed. Heated material

WORK AND HYGIENIC PRACTICES

Provide readily accessible eye wash stations and safety showers. Wash at the end of each work shift and before eating, smoking or using the toilet.

NOTICE: The selection of a specific glove for a particular application and duration of use in a workplace should also take into account all requisite workplace factors such as, but not limited to: Other chemicals which may be handled, physical requirements (cut/puncture protection, dexterity, thermal protection), as well as the instructions/specifications provided by the glove supplier.

9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance :	Thixotropic Paste
Color:	Brown to Tan
Odor:	Epoxy Odor
Specific gravity :	0.69 – 0.82
Vapor pressure:	Not Determined
Boiling point/range :	Not Determined
Freezing point/range :	Not Determined
Water solubility :	Liquid Components are Not Readily Soluble in Water
pH :	Not Determined
Flash point :	Not Determined
Auto-ignition temp. :	>300 deg.C
Flammability-LFL :	Not Determined
Flammability-UFL :	Not Determined
% volatile:	0 g/L (0%)

10. STABILITY AND REACTIVITY

CHEMICAL STABILITY

Stable

CONDITIONS TO AVOID (if unstable)

Not applicable

INCOMPATIBILITY (Materials to Avoid)

Oxidizing Agents (i.e. perchlorates, nitrates etc.). Sodium or Calcium Hypochlorite. Reaction with peroxides may result in violent decomposition of peroxide possibly creating an explosion.

HAZARDOUS DECOMPOSITION PRODUCTS (from burning, heating, or reaction with other materials).

Carbon Monoxide in a fire. Carbon Dioxide in a fire. Irritating and toxic fumes at elevated temperatures.

HAZARDOUS POLYMERIZATION

Will not occur

CONDITIONS TO AVOID (if polymerization may occur)

Not applicable

11. TOXICOLOGICAL INFORMATION

Acute toxicity

This finished product has not been tested to determine individual toxicological/ecological limits. Individual components of this mixture have been independently tested by the raw material manufacturers and any known results have been presented below. The results for the individual components may not be representative of the toxicity of this finished product.

Glass		Available		5 mg/m^3 TWA total inhalable dust	ACGIH
Aluminum Oxide	1344-28-1	Not Available	50% - 60%	15mg/m^3 TWA respirable dust, 10 mg/m^3 TWA total inhalable dust	OSHA ACGIH

-No Further Data Available-

EYE PROTECTION

Chemical safety glasses. A full-face shield and vapor respirator is recommended for operations involving spraying or other operations placing this material under pressurized conditions.

HAND PROTECTION

Neoprene rubber gloves. Impermeable gloves. Nitrile rubber gloves. The breakthrough time of the selected glove(s) must be greater than the intended use period.

RESPIRATORY PROTECTION

Not required under normal conditions and in a well-ventilated workplace. At elevated temperatures, a cartridge mask National Institute for Occupational Safety and Health (NIOSH) approved for organic vapors may be appropriate

PROTECTIVE CLOTHING

Long sleeved clothing.

ENGINEERING CONTROLS

No specific controls needed. Heated material

WORK AND HYGIENIC PRACTICES

Provide readily accessible eye wash stations and safety showers. Wash at the end of each work shift and before eating, smoking or using the toilet.

NOTICE: The selection of a specific glove for a particular application and duration of use in a workplace should also take into account all requisite workplace factors such as, but not limited to: Other chemicals which may be handled, physical requirements (cut/puncture protection, dexterity, thermal protection), as well as the instructions/specifications provided by the glove supplier.

9. PHYSICAL AND CHEMICAL PROPERTIES

Appearance :	Thixotropic Paste
Color:	Brown to Tan
Odor:	Epoxy Odor
Specific gravity :	0.69 – 0.82
Vapor pressure:	Not Determined
Boiling point/range :	Not Determined
Freezing point/range :	Not Determined
Water solubility :	Liquid Components are Not Readily Soluble in Water
pH :	Not Determined
Flash point :	Not Determined
Auto-ignition temp. :	>300 deg.C
Flammability-LFL :	Not Determined
Flammability-UFL :	Not Determined
% volatile:	0 g/L (0%)

10. STABILITY AND REACTIVITY

CHEMICAL STABILITY

Stable

CONDITIONS TO AVOID (if unstable)

Not applicable

INCOMPATIBILITY (Materials to Avoid)

Oxidizing Agents (i.e. perchlorates, nitrates etc.). Sodium or Calcium Hypochlorite. Reaction with peroxides may result in violent decomposition of peroxide possibly creating an explosion.

HAZARDOUS DECOMPOSITION PRODUCTS (from burning, heating, or reaction with other materials).

Carbon Monoxide in a fire. Carbon Dioxide in a fire. Irritating and toxic fumes at elevated temperatures.

HAZARDOUS POLYMERIZATION

Will not occur

CONDITIONS TO AVOID (if polymerization may occur)

Not applicable

11. TOXICOLOGICAL INFORMATION

Acute toxicity

This finished product has not been tested to determine individual toxicological/ecological limits. Individual components of this mixture have been independently tested by the raw material manufacturers and any known results have been presented below. The results for the individual components may not be representative of the toxicity of this finished product.

OSHA Hazard Communication Standard (29CFR1910.1200) hazard class(es)

Irritant. Sensitizer.

EPA SARA Title III Section 312 (40CFR370) hazard class

Immediate Health Hazard. Delayed Health Hazard.

EPA SARA Title III Section 313 (40CFR372) toxic chemicals above "de minimis" level are

None

STATE REGULATIONS

PROPOSITION 65 SUBSTANCES (component(s) known to the State of California to cause cancer and/or reproductive toxicity and subject to warning and discharge requirements under the "Safe Drinking Water and Toxic Enforcement Act of 1986")

None

NEW JERSEY TRADE SECRET REGISTRY NUMBER(S)

None

CANADIAN REGULATIONS

DSL

Included on Inventory.

WHMIS HAZARD CLASSIFICATION

Class D Division 2B

WHMIS INGREDIENT DISCLOSURE LIST

None

WHMIS TRADE SECRET REGISTRY NUMBER(S)

This product has been classified in accordance with the hazard criteria of the CPR and the MSDS contains all the information required by the CPR.

None

WHMIS SYMBOLS

EUROPEAN ECONOMIC COMMUNITY (EEC)

EINECS/ELINCS MASTER INVENTORY

Included on EINECS inventory or polymer substance, monomers included on EINECS inventory or no longer polymer.

CHIP 3 REGULATIONS

CHIP 3 regulations have been applied

Hazard symbol(s):

Xi

EU Labeling Classification:	Xi-Irritant	
Risk Phrases:	R36/38:	Irritating to eyes and skin
	R43:	May cause sensitization with skin contact
Safety Phrases:	S24:	Avoid contact with skin.
	S37:	Wear suitable gloves.

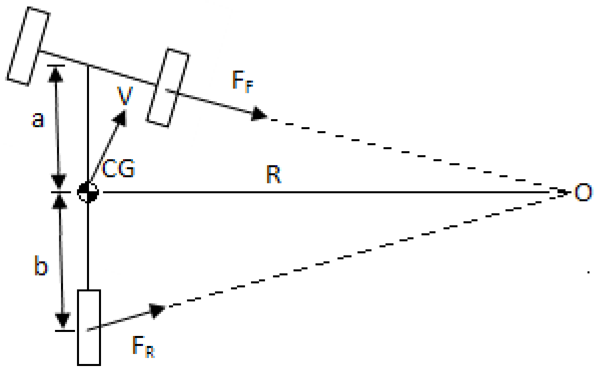
16. OTHER INFORMATION

No Other Information

To the best of our knowledge, the information contained herein is accurate. Final determination of the suitability of any material is the sole responsibility of the users. All materials may present unknown hazards and should be used with caution. Although certain hazards are described herein, we cannot guarantee that these are the only hazards which exist.

Appendix S: Prototype Vehicle Wheel Preliminary Load Analysis.

Forces on a three wheel car.



W_f = Weight on the font wheels

W_R = Weight on the rear wheel

V= Velocity of the car

R= Radius of the turn

G= Gravity

F_F=Lateral force on the front wheels

F_R=lateral force on the rear wheels

$$Total\ weight\ of\ car\ and\ person\ w = 230\ lbs$$

$$W_F = \frac{2w}{3} = \frac{2 * 250\ lbs}{3} = 152.33\ lbs$$

$$W_R = \frac{w}{3} = \frac{250\ lbs}{3} = 76.67\ lbs$$

$$V = 35\ mph \rightarrow \frac{35\ mile}{1\ hr} * \frac{1\ hr}{60\ min} * \frac{1\ min}{60\ s} * \frac{5280\ ft}{mile} = 51.33\ \frac{ft}{s}$$

$$F_F = \frac{W_F}{g} * \frac{V^2}{R} = \frac{153.33\ lbs * \left(51.33\ {}^{ft}/_{s}\right)^2}{32.2\ {}^{ft}/_{s^2} * 33ft} = 380.1\ lbs$$

$$F_R = \frac{W_R}{g} * \frac{V^2}{R} = \frac{76.67\ lbs * \left(51.33\ {}^{ft}/_{s}\right)^2}{32.2\ {}^{ft}/_{s^2} * 33ft} = 190.1\ lbs$$