Project Number: MQF221

A Major Qualifying Project

Submitted to the Faculty

of the

WORCESTER POLYTECHNIC INSTITUTE

in partial fulfillment of the requirements for the

Degree of Bachelor of Science

EMS Surgical Sponge for Containment of Physiological Fluids and Vibration Dampening

By

Aarik Devenger	Shaaz Shuttari	Abdul Zerguine	Paul Aguiar

April 15, 2011

Approved by

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Prof. M. S. Fofana, Advisor, PhD

Mechanical Engineering Department

Abstract

Emergency Medical Services are challenged with maintaining clean equipment and a sanitary environment, which are compromised every time a patient loses biological fluids inside the ambulance. The goal of this MQP project was to develop a super-absorbent sponge that is compatible with ambulatory stretchers. The sponge should absorb, contain, and isolate biological fluids from ambulatory patients. The sponge should be applicable to any patient. It was designed to resist road vibrations. A class of materials was examined in order to gain a better understanding of fluid absorbance and containment capabilities. The selected materials were incorporated into the designing of the sponge and tested on absorption of impact forces by application of AMTI AccuSway force platform. Vibration measurements were conducted to evaluate the range of vibration amplitudes and frequencies that were suppressed by the surgical sponge.

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Acknowledgments

We would like to take this opportunity to humbly thank our two co-advisors Dr. Mustapha Fofana and Dr. Krystyna Gielo-Perczak for their consistent guidance throughout this four-term MQP design project. It has been an absolute pleasure and blast to work with such a friendly and brilliant group of students, who in the end have come together to be a cohesive team. We would like to thank UMASS Emergency Medical Service's Chief Mr. Steve Haines for allowing our team access to their vehicles and equipment. Without Mr. Haines and his team we could not have completed our project. Finally, we would like to thank Tredegar Film Products for sending our team several hundred feet of aperture film for no cost to help us reach our goal. We are thrilled to have been able to work on this project, and have grown from all the experiences and challenges we faced during the completion of the MQP.

Authorship

The completion of this project would not have been possible without all four team members. The Surgical Sponge MQP team is a close-knit, well-oiled machine that has attacked the problem head on and worked tirelessly until it was solved. Each team member contributed evenly to the overall effort, each bringing to the table a certain skill set crucial to solving the problem. Paul Aguiar dedicated countless hours to becoming proficient in SolidWorks CAD software to model our final design. Abdul Zerguine was crucial in designing and executing most of the wettability and absorbance testing. Shaaz Shuttari studied static and dynamic force plate analysis in order to test our final design and quantify its improvements from a control. Aarik Devenger was integral in visualizing the final design and defining what materials the team would need and what each materials specific functions were. He also took lead on contacting actual companies to query them for recommendations as well for any contribution of materials to the MQP. Each team member wrote multiple sections of the final paper. All team members contributed an equal 25 percent to the successful completion of the project, and stood by each other through weekly presentations with Professor Fofana and daily, humbling critique sessions with Professor Gielo-Perczak. We are thankful for all of their help.

Detailed Authorship

Chapter 1 - EMS and Life Saving Practices (S. Shuttari)

Chapter 2 – Literature Review

2.1 EMS and Patient-Centric Quality Care(S. Shuttari, A. Zerguine)

2.2 The Potential Need of the Surgical Sponge(S.Shuttari, A.Zerguine, P.Aguiar, A. Devenger)

Chapter 3- Project Approach and Specific Aims(S. Shuttari, A. Zerguine)

Chapter 4- Alternative Designs(P.Aguiar, A.Zerguine)

Chapter 5- Final Design

5. 1- Selected Engineering Design(P.Aguiar, A. Devenger)

5.2- Methods(S.Shuttari, A.Zerguine)

5.3- Results and Discussion(S.Shuttari, A.Zerguine)

Chapter 6: Recommendations for Future Development(A. Devenger)

Chapter 7: Concluding Remarks(A.Devenger)

Chapter 1 - EMS and Life Saving Practices

1.1 Introduction

The purpose of this project is to create a spongy system that will collect, capture, and retains physiological fluids from a patient of any size, and that's compatible with most hospital based stretchers for the EMS squad. The current need for EMS personnel is to have a cloth protector that can capture physiological fluids, so no types of contamination or infection can be passed onto other members of the EMS team or other resources within the confines of the ambulance. This system has to be placed over the mattress of the EMS stretcher and must be able to withstand numerous forces applied by the patient and other background influences.

Some of the major objectives needed to be achieved by this sponge system covering are that it must be able to absorb and not leak out any content of physiological fluid, fit any type of patient, withstand any external environments, resist vibrations, easy to clean, be compatible with EMS procedures on patient, and cheap to sell and produce. The surgical covering must be one hundred percent absorbable, in the sense that any liquid, such as blood or urine, will not leak into the mattress and will be contained within the confines of the surgical covering. The surgical covering must be able to fit any patient, which means that this covering must have a mechanism to attach and completely cover any sized patient in terms of length and width. The surgical covering must be able to be used in any type of environment, such as rain or snow like conditions, and provide comfort for the patient as he/she will be transferred from an outdoor to a more contained ambulance environment. The surgical covering must be able to resist any vibrations that may come from rough conditions when the ambulance is in motion, as well as from the transportation process of being transferred from the ambulance to the hospital.

Vibrations are known to cause discomfort for the patient and might alter some of the procedures being ran on the patient. The surgical covering will be able to be cleaned by removing a layer of the covering and cleaning the rest of the covering with basic cleaning solutions. The surgical covering will be compatible to be used with any medical devices being attached to the patient, such as a line for IV fluid or leads for an electrocardiogram, and will not interfere with the principle functions that the covering is intended to perform. The surgical covering will also be produced from low costing materials that are of high quality, in order for any type of EMS personnel to use upon their stretchers.

The order of this report will be presented in the following format. The table of contents will list all the major pages that are available to find each section within this report. The list of figures will entail all the major figures in the report, as well as captions and an available page number. The list of tables will entail all the major tables in the report, as well as captions and an available page number. The abstract will be a short description of this project and will also convey the problem, needs, constraints, objectives, solutions, results, and conclusions for this project. Chapter 1 will present the basic objectives and purpose for why this product should be mass produced. Chapter 2 will present the literature review content that showed the importance of EMS personnel and the improvement that our final design will have upon EMS. Chapter 3 will showcase the overall project approach on how our group will attempt to go about our project. Chapter 4 will entail our three alternative designs and aspects that make them different from one another. Chapter 5 will display the aspects for choosing our final design and show the methods of proving the effectiveness of the final design. Chapter 6 will outline future recommendations for future tests and other factors that will benefit our project. Chapter 7 will go over some concluding remarks on our group's overall impression of the project. The

references will include all outside material used for the background information and of this report. The appendix section was used to list any SolidWorks models, and simulation and results based on the overall description of final prototype for this project.

Chapter 2 – Literature Review

2.1 EMS and Patient-Centric Quality Care

The field that the Surgical Sponge dealt with involved personnel within Emergency Medical Services (EMS). The EMS squad provides medical care outside of the hospital or medical office setting. On a daily basis, people call EMS when they have an accident or experience a medical emergency. Emergencies might include heart attack, difficult breathing, falls, accidents, drowning, cardiac arrest, stroke, drug overdose, and acute illnesses. EMS services may provide both basic and advanced medical care at the scene of an emergency and en route to a hospital. EMS is much more than an ambulance service. The delivery of emergency medical care comprises of many parts called the EMS system. The EMS system includes the call center, police officers, firefighters, an ambulance transportation team of Emergency Medical Technicians (EMTs) or Paramedics, physicians, nurses, air medical services, hospital receiving facilities, governmental and medical oversight (Moore [30]).

When a person becomes ill or injured and dials 911 or another emergency phone number, an EMS dispatcher answers the call. The dispatcher also gives the caller patient care instructions while sending emergency responders to the scene of the emergency. Depending on the severity within the scene of emergency, different types of EMS responders will attend to the scene. First Responders have about 40 hours of training and EMT-Basics have about 110 hours of training. These two types of EMS personnel will respond to minor emergencies, such as helping a choking victim or applying sutures to a patient with various cuts. EMT-Intermediates have about 200-400 hours of training and Paramedics have about 1,000 or more hours of training. These two types of EMS personnel will respond to either minor or major emergencies, such as traffic accidents or wounded patients. The training level of responders is a local decision based upon local resources and those who fund the EMS system. Each of these levels of EMS responders are trained to perform different kinds of skills to assist the patient (Moore [30]).

In order for an EMT to treat patients, he or she must be proficient in CPR, and treating life-threatening emergencies outside the hospital environment. An EMT learns the basics of how to handle cardiac arrest, heart attacks, seizures, diabetic emergencies, and respiratory problem. He or she also learns how to manage traumatic injuries such as falls, fractures, lacerations, and burns. An EMT must also learn patient assessment, history taking, and obtaining vital signs. EMS responders work under protocols approved by a physician medical director. Many of these medical directors are members of the National Association of EMS Physicians. The medical director oversees the care of patients in the EMS system, and he or she is knowledgeable about patient care interventions. EMS medical directors work in conjunction with local EMS leaders to assure quality patient care (Martinez [29]).

The purpose of having EMS centered care works on the basic tenets of first aid. These tenets are to promote recovery, prevent further injury, and preserve life. A common logo seen on many EMS ambulances is named the star of life. The star of life upholds EMS personnel to follow six main points of care before the patient can enter a hospital type of setting. The first point is early response, and this point is important because the earlier EMS personnel can attend to a medical situation, the more likely they can save a patient's life. The second point is early detection, which refers to the ability of EMS personnel to find and attend to the medical emergency. The third point is early reporting, which refers to the ability of common citizens to call 911 and tell an EMS representative all possible details of the medical emergency. The fourth point is that all EMS personnel must observe well on scene care, which means that EMS uses their time efficiently and orderly enough to treat any type of patient emergency. The fifth point is that EMS personnel must be able to transfer the patient to a proper medical institution with a trained emergency department. The sixth point is that EMS personnel must have the proper care items to use on the patient while the ambulance is in motion, and must ensure complete comfort and ease of treatment for the patient (Moore [30]).

The overall model of EMS care is based on the Anglo-American model system. This model system focuses on bringing patients as quickly as possible to the emergency room of the hospital..

Physicians do not travel on board inside the ambulance to aid the EMS team with various patient cases. Instead paramedics and highly trained EMTs lead the EMS team to aid with patients, and can lead to physician help via radio frequency transmission. This system also focuses on using of land and road based ambulances, as opposed to ambulances that run in the air via use of a helicopter and water based ambulances. Countries, such as America, whom use this system tend to put a big focus on emergency medicine as a major specialization within hospital based systems. These countries also have far more developed and organized emergency room units than most countries who do not implement the Anglo-American system. Also these countries involve police and fire department personnel, to aid the EMS team in many different types of medical emergencies. Countries emphasizing the Anglo-American system are United States, Canada, New Zealand, Sultanate of Oman and Australia (Al-Shaqsi [5]).

All EMS squad organizations run on the advanced life support (ALS) system, which focuses on the ABCs of every patient. ABC represents an acronym that all EMS personnel must demonstrate within various medical situations. The A of ABC stands for airway, and refers for the patient's ability to have an airway that is not constricted. The B of ABC stands for breathing, and refers to the patient's ability to breathe in and out. The C of ABC stands for circulation and refers to the patient's ability to have proper heart conditions within the body, in order to pump blood at an efficient rate.

Some of the components of the ALS system include cardiac monitoring, cardiac defibrillation, and intravenous cannulation (IV) access into the body via needle connection. Specific algorithms with the ALS system assume principles of basic life support, such as administering compressions. This system aroused from conditions found within a heart attack, where cardiac monitoring of the electrical signals from the heart results. Administering cardiac medications or defibrillating the heart can aid in many cardiac conditions similar to arrhythmia. Specific medications such as adrenaline, atropine, bicarbonate, and saline can all improve the circulation volume of blood flowing in and out of the cardiac system. The process of intubation can apply to the thoracic cavity to administer oxygen to regions of the lungs that are

low in oxygen. Cardiopulmonary resuscitation (CPR) is a very important practice within ALS regulations and applies to any medical situation (ACLS [2]).

Unfortunately with any type of EMS system, there is always the risk of negative feedback by patients treated by EMS personnel. Many hospitals run a survey based system to patients treated by EMS staff members. This was identified the main source of complaints against EMS personnel. Also the survey worked on improving overall quality and performance within various members of the EMS staff. A previously ran study took a total of 286 complaints during a 6 year time frame, with an average of 48 complaints per year. The study found that the most common complaints were patients (53%), rude behavior (23%), technical skills (20%), medical personnel (19%), transport problems (18%), loss of belongings (13%), and family members or friends (12%). Identifying these areas will allow for programs to be set up for programs that will bring about performance improvement and quality changes. (West [40]).

This study recorded patient complaint and complied these statements from hospitals within the Denver metropolitan area within a six year time span. The Denver area is described to be a city of around 500,000 residents, and represents all major ethnic and income groups. Paramedics within this area tend to about 54,000 requests for EMS to pick up patients and transport them to the emergency room. About 35,000 of these patients were transported to hospitals in the Denver area. Two paramedics were in attendance during the ambulance transportation of patients and mostly all the resources were available with Advanced Life Support (ALS) services (West [40]).

Complaints were gathered from experienced EMS paramedics, and did not include information from basic level EMTs. All levels of complaints were identified by the EMS medical director and were stored within a personalized computer database. The paramedics were

listed as 84% male and had at least six years of training experience. From treatment of paramedics upon their patients, about 286 complaints were generated within the 6-year study period. A higher number of complaints were filed during the summer and spring seasons, as opposed to the relatively colder seasons of fall and winter, due to the high level of calls during these warmer seasons. The overall complaint rate was much higher during the warmer months, as compared to the colder months. The rate went from 9.8 per 10,000 responses within the warmer months, as compared to 7.3 per 10,000 responses within colder months (West [40]).

The ALS system assume principles of basic life support, such as administering compressions within the chest and distributing a bag full of oxygen for the patient to inhale and exhale from. This system aroused from conditions found within a heart attack, where cardiac monitoring of electrical signals from the heart resulted. Administering cardiac medications or defibrillating the heart can aid in solutions to arrhythmia. Specific medications such as adrenaline, atropine, bicarbonate, and saline can all improve problems with circulation volume of blood flowing in and out of the cardiac system. The process of intubation can be applied to the thoracic cavity to administer oxygen to regions of the lungs that lack oxygen. Figure 1 lists the number of patient complaints versus the number of ambulance responses to medical situations from 1993-1998. From 1993-1998, patient complaints have risen from about 30 complaints to about 40 complaints over 5 years. The number of ambulance responses raised from a value around 49,000 responses to about 54,000 responses over 5 years. Peaks in complaint values were seen at about 80 complaints in 1997, and peaks in ambulance responses were seen at about 54,000 responses in 1998 (West [40]).

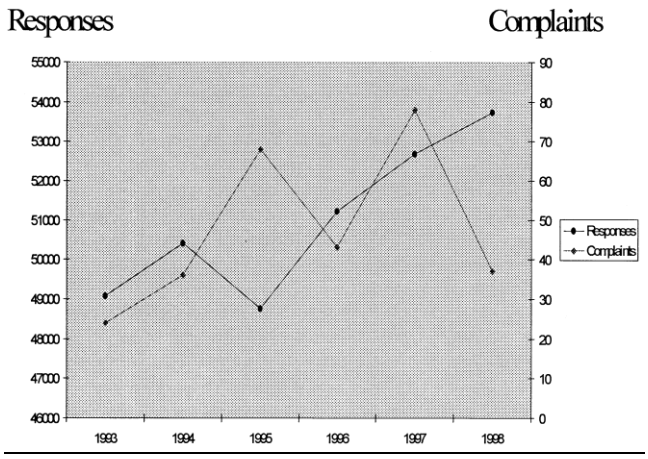


Figure 1- Distinction of Patient Complaints vs. Ambulance Responses over 6 years

Figure 2 displays the overall complaints for paramedics during the cooler and warmer seasons during a five year time span. From 1993-1998, patient complaints during the spring/summer seasons had increased from 6-7 complaints over 6 years. During the fall/winter seasons, patient complaints increased from about 3-7 complaints over 6 years. Peaks in complaint values resulted at about 15 complaints in 1995 during the fall/winter seasons, and about 13 complaints from 1995 to 1997 (West [40]).

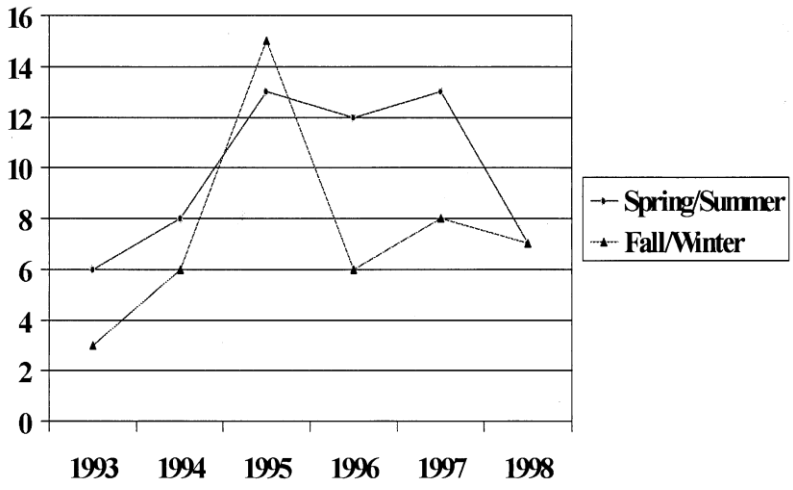


Figure 2- Number of Complaints during the warm and cold seasons over 6 years

Figure 3 shows the originators of generated complaints against EMS personnel. The three highest complaint sources were patients (53%), medical staff such as nurses and physicians (19%), and people directly related to the patient such as family and friends (12%) (West [40]).

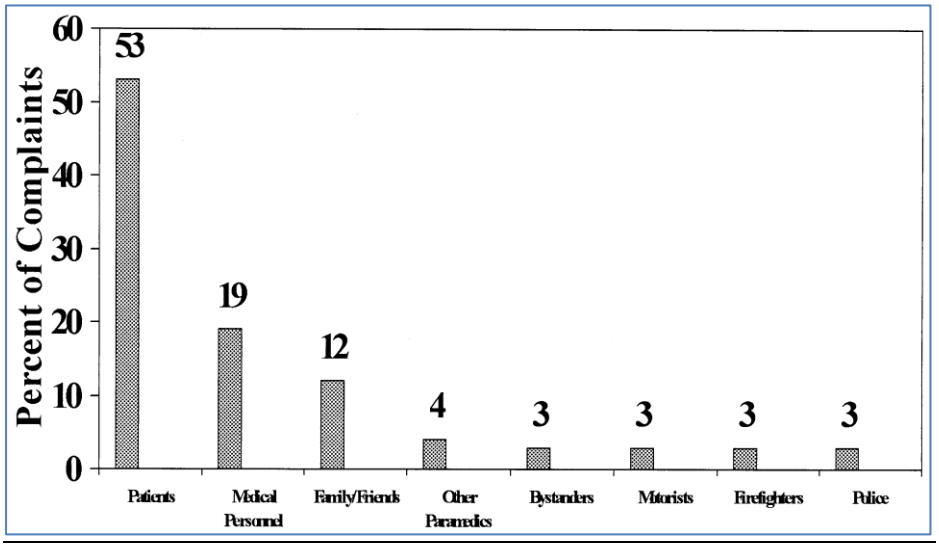


Figure 3- Total Percentages of Complaints by Personnel Associated with EMS

Amongst all complaints, categories sought out to identify and classify all types of reported complaints. Within the 12 categories of complaints, 4 particular behaviors were identified as the cause for 75% of the overall complaints. One of the main categories was rude or inappropriate behavior, which resulted in 27% of all recorded complaints. Reasons such as EMS telling a patient with a broken ankle can lead to the pattern of rude behavior complained upon members within the EMS squad. Another source of complaints dealt with improper behavior based on history and physical taking skills. This complaint resulted in 20% of overall patient complaints. Instances such as miscommunication and understanding the medical problems of the patient would lead to the source of this complaint. Transport problems resulted in 18% of patient overall complaints, and could result by the lack of care by EMS personnel.

Loss of belongings results in 13% of overall patient complaints, and could result in instances where EMS personnel forget to bring a patient's wallet or personal keepsake. Driving skills and timeliness resulted in 5% of overall patient complaints, and can both coincide with each other to make the patient feel angry or unpleased. Personal and billing disputes, as well as excessive force resulted in 4% of overall patient complaints. Any type of small argument or disagreement could lead up over time to feelings of mistrust and hatred of patients upon the EMS personnel. Excessive force, such as forcing an intubator down a patient's throat, can lead to mistrust and scared feelings of patients upon EMS personnel (West [40]).

Table 1 sums up the entire study done on examining patient complaints upon EMS personnel. The Colwell et al column of Table 1 highlights the recent study conducted from 1993-1998. This column compares to a previously conducted study, Curka et al, during the 1990-1992 year period. More incidents of complaints resulted in the Coldwell study as opposed to the Curka et al study. Other categories, such as medical treatment and transport complaints, significantly rose from the Curka et al study. A percentage total of 7 categories rose in the Colwell et al study compared to the Curka et al study (West [40]).

Table 1- Comparison of complaint patterns from Colwell and Curka et al studies

	Colwell et al	Curka et al
Duration of study	6 years (1993–1998)	3 years (1990–1992)
Total number of complaints	286	371
Incidence of complaints	9.3/10,000 encounters	9/10,000 encounters
Unprofessional/rude behavior complaints	27% (Combined rude/excessive force)	34%
Medical treatment/care related complaints	20%	13%
Transport problems (destination) related complaints	18%	8%
Complaints related to Non-transport of patients	1%	18%
Complaints of lost/damaged property	13%	11%
Complaints related to driving skills	5%	6%
Complaints related to response times	5%	2%
Patient as the source of the complaint	53%	31%
Patient´s family member as the source of the complaint	12%	39%
Medical personnel as the source of the complaint	19%	8%

In order to assess the effectiveness of EMS treatment upon patients, a study from the University of Washington was used to see the success rates of EMS personnel treating hypoglycemic patients without any transport methodology. This study aimed to compare the effectiveness of the work of Emergency Medical Technicians (EMTs) over Paramedics. The

EMTs were responsible for the treatment of stable conditioned hypoglycemic patients without the aid of higher ranked Paramedics, and were responsible for keeping the patients in stable condition before admission into the hospital. The significance of the study, dealt with the fact that EMTs lacked proper traineing in performing tests that measure glucose. It was usually determined that Paramedics dealt with patients who were suffering from hypoglycemia. In 2003, The State of Washington Office of Emergency Medical and Trauma ran an experimental program for EMTs to learn and assess patients with hypoglycemic symptoms. Results from this program proved beneficial for EMTs to assess patients with hypoglycemia. A plan of action developed for treating hypoglycemic patients. The EMT glucometrics program became a standard within the curriculum of basic EMTs in 2005. The main goal of this study was to assess the overall success rate of EMTs treating hypoglycemic patients with completion of the EMT glucometrics program. The treatment provided by Paramedics for hypoglycemic patients was the gold standard that was compared to the same treatment provided by EMTs (Strote [36]).

The design of the study compared the treatment of hypoglycemic patients by EMTs and Paramedics in Kings County, Washington. The area had a population of 1.2 million inhabitants, and the study took place from June 1, 2005 to May 31, 2006. The area was also predominantly Caucasian, representing 65% of the overall population. Amongst the minority groups, 11% were Asian, 6% were Hispanic, and 5% were African-American (Strote [36]). The overall EMS treatment system dealt with a two-tier system, where the first-tier comprised basic EMTs from the fire department who were described to have training in various facets of basic life support, such as Cardiopulmonary Resuscitation (CPR) and suturing up wounds. The second-tier comprised of Paramedic highly trained in advanced life saving skills. Normally first-tier responders arrive first on the scene to assist patients. If patients are in very serious condition, the

main fire department EMT within the first-tier may request backup from Paramedics within the second-tier. When dealing with hypoglycemic patients, it is not prescribed that first-tier EMTs can use glucometrics procedures to control blood sugar within kids who are 5 years old or younger. It's usually the job of a Paramedic to give a written protocol on the amount of insulin needed to control a patient's blood sugar. The Paramedic would proceed to instruct the patient to call their physician before the next insulin dosage. Also these Paramedics would have to check blood sugar on an hourly basis. If the condition of the patient worsens, Paramedics would call 911 for further assistance (Strote [36]).

Considering the cases of hypoglycemia, this study dealt with non-transported patients with low blood sugar. Two cases were involved, one that took the use of only EMT personnel to treat patients and another case who involved Paramedics. Because EMS services responded to the two-tier system, most of the hypoglycemic patient cases did involve the aid of Paramedics to transport patients to the Emergency Department of any area hospital. Patients would then be able to respond to a post-treatment questionnaire, which assessed the overall satisfaction of patient treatment by EMS personnel. Some of the questions included if someone observed the patient after six hours of treatment by EMS personnel and if insulin dosage changed after the presence of hypoglycemia. The main independent variable that would have an influence on the study was the overall EMS participation with treatment of the patient. The involvement of EMT personnel or Paramedics would have an influence in the overall satisfaction of each patient (Strote [36]). Table 2 displayed the common factors for patients not responding to the post-treatment questionnaire. There were more unresponsive answers with patients treated by EMTs as opposed to Paramedics (Strote [36]).

Table 2- Common Reasons for Not Responding to Post-Treatment Questionnaire

Reason	EMT (n = 111)	Paramedic (n = 88)
No answer	79 (71.2%)	54 (61.4%)
Wrong number	20 (18.0%)	19 (21.0%)
No English	5 (4.5%)	3 (3.4%)
Refused	6 (5.4%)	9 (10.2%)
Deceased	1 (0.9%)	3 (3.4%)

Table 3 listed the common questions that were enlisted on the post-treatment questionnaire for patients that underwent treatment from either EMTs or Paramedics. The X2 column represented the chi-square distribution in statistics, where two variables would be compared against one another for similarities. The P column represented the probability that a test statistic as one that's proved to be observed, as long as the null hypothesis holds true. All answers represented "yes" responses by the patient to the questions (Strote [36]).

Table 3- Patient Responses after Treatment by EMTs or Paramedics

	Yes (n)	Yes (%)	$\chi 2$	P
1. Did you call your PCP?			0.41	.52
EMT	58	56		
Paramedic	53	61		
2. Did you change your insulin dose?			1.73	.42
EMT	51	49		
Paramedic	48	53		
3. Were you observed for 6 h?			1.84	.18
EMT	98	91		
Paramedic	88	96		
4. Did you call 911 again?			0.98	.32
EMT	3	3		
Paramedic	5	8		
5. Did you have another low sugar?			0.64	.42
EMT	8	8		
Paramedic	10	11		
6. Did you go to the hospital?			0.021	.88
EMT	9	8		
Paramedic	7	8		
7. Do you recall receiving instructions?			1.02	.31
EMT	57	58		
Paramedic	40	50		

When considering the two-tier system of EMS care in the state of Washington, EMT service may be the only source of treatment for numerous patients in emergency situations. If treated patients in locations are far from urban medical centers, local EMTs would be the only personnel to provide immediate treatment for the patient. Most EMTs lack skills to apply a proper treatment regimen upon patients with hypoglycemia; however, this result implies that more EMT personnel should understand the skills necessary to treat hypoglycemic patients. The

low glucose levels seen by patients by Paramedics showed that Paramedics than EMTs most likely treated more critically ill patients. This also showed the validity of the two-tier system, which showed that patients were first assessed by EMTs and then Paramedics. Results from the follow-up questionnaire and patient satisfaction showed that EMTs in the state of Washington had the same upstanding level of treatment as Paramedics. Benefits such as reducing work for Paramedics and maintaining consistent resources within a hospital's emergency department could help out with the treatment process of patients by Paramedics. Some limitations of the study included the fact that not all cases of hypoglycemia and the two-tier EMS system in Washington may not be replicable within other EMS systems across the United States (Strote [36]).

The compartmentalization of the ambulance is a very important consideration if the desired outcome is a more patient-centered ambulatory service. Moreover, the paramedics are an integral part of this health service. Special care seems to provide the paramedics maximum efficiency and comfort when performing their job. Ferreira et al performed a study that included observing paramedics over a period of 130 hours (Ferreira et al [17]). The most performed tasks were checking blood oxygen level, oxygen administration, blood pressure, and monitoring heart condition. The paramedic must have an efficient way to obtain the tools to perform these tasks. The distance between them and the tools should be shorter, in a way that they could easily reach them. The current ambulance design could be improved and emphasize on the efficiency and convenience of the paramedics.

Paramedics suffer from high incidences of musculoskeletal problems. This is mainly due to the handling of loads (Boocock et al [6]). A survey has reported that the ambulance staff manually handles and carries excessive loads at a rate of 18% (Boocock et al [6]). This presents

18% risk of musculoskeletal injury. The injuries that the ambulance workers are exposed are mainly due to the following: heavy lifting and force exertion, improper working posture, body vibration, and physical exhaustion. Doormaal et al said that in non-emergency calls, 24% of observed postures of paramedics is improper and leads to injury. This percentage went up to 56% in emergency calls (Doormaal et al [13]). Letendre et al reported that the most difficult tasks are performing cardiopulmonary resuscitation (CPR), accessing the patient, accessing the needed equipment, loading the stretcher, and working from the seats (Letendre [27]).

Paramedics respond to various calls, some are urgent and not highly urgent. The type of injuries differs, but one can categorize the different injuries and their frequency. One does not expect to make the ambulance design ideal and efficient for every task. Using the collected data, one can prioritize and rate the different features, to optimize the ambulance's limited space at providing clinical efficiency and paramedic's safety. Louis-Smith et al suggested that the design priorities should be the following (Louis-Smith [28]):

1. Facilitate CPR by providing proper restraints for equipment and paramedics. Also, it should provide easy access to equipment.

2. Improve the comfort of ambulance by providing better seats and reducing noise levels.

3. Reduce obstructions and clutter

4. Make equipment locations easy to access.

Ferreira et al conducted a study to get details about the nature of calls, the treatment given, and the frequency of the different clinical tasks. In an average shift (8 hours), the paramedic responds to about 5 calls and spends about 2 hours (25% of the shift) giving treatment to the

patient. The paramedic is giving treatment 30% of their time to the patient in stationary conditions, and 70% while the ambulance is moving (Ferreira et al [17]). The rating of the frequency of the clinical tasks is rated as the following (Table 4):

1. Using pulse-oximeter to check the pulse and blood oxygen level-51% of calls.
2. Administrating oxygen-27% of calls.
3. Monitoring the heart-23% of calls.
4. Measuring blood pressure- 21% of calls.

Table 4- Frequency distribution of the various clinical tasks (Table 2 from Ferreira et al)

Task	Percentage each task occurred (total number of calls=71)
Check pulse/blood oxygen saturation	**51**
Administer oxygen	**27**
Monitor ECG pattern/use cardiac monitor	**23**
Check blood pressure	**21**
Administer drugs/IV fluids	18
Patient transfer from chair to stretcher	16
Check blood glucose concentration	16
First aid treatment (e.g. clean wounds)	7
Cardiac massage	1

This data is a good starting point to set up an optimum ambulance design. Moreover, it is important to know the different interactions that occur between the paramedics and the patient.

Tests on seat B occurred 71% of the time. The paramedics treated the patients by sitting on the stretcher 14% of the time. Testing for seat A occurred 11% of the time. The paramedic box resulted in usage of 2% of the time. The criteria that determined the implemented location depended on the type of call, the number of patients transported, and the patient's injury type and its location (Ferreira et al [17]). It is important to know the clinical tasks frequency, and their relationship to the improper postures of the paramedic (Table 5).

Table 5- Detail of clinical tasks done by paramedics, and their influence on the paramedics' injury (adopted from Table 5 from Ferreira et al)

Task	***N***	**AC=1 (%)**	**AC=2 (%)**	**AC=3 (%)**	**AC=4 (%)**
Writing on clipboard	297	94	6	—	—
Interaction with patient	292	70	30	—	—
Idle	194	100	—	—	—
Interaction with care givers	74	82	16	—	2
Accessing equipment[a]	56	41	54	3	2
Using cardiac monitor[a]	55	60	40	—	—
Using pulse-oximeter	51	67	27	4	2

Task	*N*	AC=1 (%)	AC=2 (%)	AC=3 (%)	AC=4 (%)
Loading/unloading patient	45	62	27	7	4
Other[a]	38	47	50	3	—
Cannulation/drug administration[a]	31	32	68	—	—
Blood pressure check[a]	30	57	43	—	—
Blood glucose check[a]	26	58	42	—	—
Rubbish/sharps disposal[a]	23	9	91	—	—
Oxygen administration[a]	17	59	41	—	—
Non-specific motion	16	75	25	—	—
Talking to driver/ on phone[a]	12	25	75	—	—
First aid treatment[a]	11	57	43	—	—
Transferring patient[a]	9	11	22	56	11
Listening with stethoscope[a]	8	50	50	—	—

[a] Indicates tasks with at least 40% of paramedics' improper postures.

The incidence of the improper paramedic posture is higher in emergency calls than non-emergency calls. Also, the incidence of improper paramedic posture is higher in a moving ambulance than a stationary ambulance (Ferreira et al [17]). The data presented above is important in optimizing the best ambulance design. This MQP group wants to meet our objective of providing patient and paramedic safety while enhancing efficiency. A redesign of the ambulance is an integral part of the overall transition.

2.2 The Potential Need of the Surgical Sponge

2.2.1- The Harms of EMS Exposure to Contaminants and Physiological Fluids

One of the essential problems for EMS personnel within the ambulance is the issue of exposure to contaminants. These contaminants can be exposed by physical contact or through airborne means. Physiological fluids, such as blood and urine, are commonly found on the uniforms and bodies of EMS personnel. Due to time constraints and efforts to keep the patient in stable condition, EMS personnel can't really safeguard themselves against these potential contaminants. If EMS personnel get infected through physical contact, they will not have the available time to clean off and disinfect the area of contaminant contact. Airborne contaminants are spreadable due to the issue that EMS personnel don't have proper face and nose protection. Thus there is a need to have an effective product that can protect EMS personnel from infectious physiological fluids and airborne pathogens.

In a previous study in the *Journal of Emergency Medicine*, it highlights that there's a slight increase in the exposures of EMS to the blood of their patients. With exposure to patient blood, EMS personnel have a higher chance of contracting blood borne pathogens, such as hepatitis C virus. The purpose of this study was to generate the number of Paramedics exposed to blood, based on how the blood infected the bodies of the Paramedics (Leiss [26]). An investigation took place amongst two groups of Paramedics. One group was comprised of Paramedics from all over the United States and another group comprised of Paramedics from California. Since California has the largest number of Paramedics, researchers decided to give examine California to the rest of the nation. Most health studies show that health care workers, such as nurses and doctors, are at the highest risk for blood exposure and fail to mention any data based on EMS personnel or Paramedics. This study tried to detail the reality that Paramedics are exposed to blood at high rates and only one previous study documented statistics/data for Paramedics. This previous study was somewhat biased for urban based paramedics and not all the

methods of exposure were considered for Paramedics coming into contact with blood from the patient (Leiss [26]).

To collect data from all Paramedics in the study, The National Study to Prevent Blood Exposure in Paramedics created a mail survey during the years of 2002 to 2003. The total number of paramedics questioned for this study was 6500, with a number around 1500 who were from the state of California. The generated survey asked questions relating to current work status and previous experiences with blood. The responses were based on the number of times per day that each Paramedic was exposed to blood during a 12-month period from specific methods of exposure to the body. The five exposure methods were from blood in the eyes, mouth, or nose. Blood exposure routes also accounted from cuts from sharp objects, insect bites, blood on non-cut skin, and needle pricks (Leiss [26]). Results from the study showed that 3778 questionnaires resulted from 6142 Paramedics. The overall sample size ranged to around 2664, in which 78.9% met the credentials enough to participate within the study. Other characteristics explained that the sample size was comprised of Caucasian males. More than 70% were 30-49 years of age and more than 60% had more than 5 years of EMS experience (Leiss [26]).

Table 6 illustrates the percentage of Paramedics that had some sort of contact with blood. Age groups ranged from ages 19 to over 50. The gender of each of the Paramedics was listed as either Caucasian or Non-Hispanic. The years of experience for each certified Paramedic was 2-11 years. The highest percentage of incidents were seen for Paramedics aged 30-39 years at 95% for Caucasians, 82% for male Paramedics, and 45% for Paramedics aged 30-39 (Leiss [26]).

Table 6- The percentage of blood related incidences of 2664 Paramedics (Leiss [26])

TABLE 1. Characteristics of respondents to the National Study to Prevent Blood Exposure in Paramedics, United States, 2002 to 2003 (n = 2664)

Characteristic	n	%
Age (years)*		
19	1	
20–29	540	21
30–39	1182	45
40–49	714	28
50+	209	8
Male	2171	82
White or Caucasian	2397	95
Non-Hispanic	2414	92
Years since paramedic certification		
≤2	433	16
3–5	539	20
6–10	733	28
11+	928	35

Table 7 displays the 12-month exposure rate of all nationwide Paramedics to blood. Two different categories considered to generate data related to route of exposure, and calculated either per 10,000 calls or 10,000 patients. There were five routes of exposure listed. The highest number of cases of exposure to blood results with contact to non-intact skin. Thus the highest rates per paramedics results with contact to non-intact skin within the two different categories. The 95% confidence interval represented the upper and lower limits of each route of exposure. The highest 95% confidence interval shows for patients with non-intact skin exposure to blood in Table 7. The total number of exposures totaled 895 patients (Leiss [26]).

Table 7- Twelve-month incidence rates for nationwide Paramedics based on different routes of exposure per 10,000 calls and per 10,000 patients (Leiss [26])

TABLE 2. Twelve-month incidence rates for exposure to blood by route of exposure and two different denominators, The National Study to Prevent Blood Exposure in Paramedics, United States, 2002 to 2003

	Per 10,000 calls		Per 10,000 patients		
Route of exposure	Rate	95% CI	Rate	95% CI	n
Needlestick	1.3	0.5–2.0	0.8	0.3–1.3	132
Cut from sharp objects	0.5	0.1–1.0	0.3	0.1–0.6	83
Eyes, nose, mouth	1.1	0.8–1.4	0.7	0.5–0.8	147
Nonintact skin	3.0	1.7–4.2	1.8	1.0–2.7	508
Bite	0.1	0.1–0.2	0.1	0.0–0.1	25
Total	6.0	3.9–8.1	3.7	2.4–5.0	895

CI = confidence interval.

Table 8 displays the 12-month exposure rate of all California Paramedics to blood. Two different categories were considered to generate data related to route of exposure, which were calculated either per 10,000 calls or 10,000 patients. There were five routes of exposure listed. The highest number of cases of exposure to blood results with contact to non-intact skin. Thus the highest rates per paramedics results with contact to non-intact skin within the two different categories. The 95% confidence interval represented the upper and lower limits of each route of exposure. The highest 95% confidence interval results for patients with non-intact skin exposure to blood in Table 8. The total number of exposures totaled 183 patients (Leiss [26]).

Table 8- Twelve-month incidence rates for California Paramedics based on different routes of exposure per 10,000 calls and per 10,000 patients

TABLE 3. Twelve-month incidence rates for exposure to blood by route of exposure and two different denominators, California paramedics only, National Study to Prevent Blood Exposure in Paramedics, 2002 to 2003

	Per 10,000 calls		Per 10,000 patients		
Route of exposure	Rate	95% CI	Rate	95% CI	n
Needlestick	0.3	0.2–0.4	0.2	0.1–0.3	19
Cut from sharp objects	0.3	0.1–0.4	0.2	0.1–0.3	19
Eyes, nose, mouth	0.6	0.4–0.8	0.4	0.3–0.5	41
Nonintact skin	1.5	0.9–2.2	1.0	0.6–1.4	102
Bite	0.0	0.0–0.1	0.0	0.0–0.0	2
Total	2.7	2.0–3.5	1.8	1.3–2.3	183

CI = confidence interval.

As Tables 6-8 have presented, paramedics within California and nationwide have encountered some type of blood borne contact. It shows that in past studies that involved Paramedics, needle-stick contact was the main method which Paramedics incur blood borne contact. However this study shows that methods, such as blood contact by the eyes, nose, and mouth and contact with non-intact skin, factor in for Paramedics to catch infection by blood borne means. With the highest rates of blood borne contact found on non-intact skin, this could suggest that Paramedics do not pay too much attention to cover these areas to prevent blood contact. This could be an underlining reason of why Paramedics get infected with common blood borne illnesses, such as Hepatitis B or HIV. The use of facemasks and goggles should be looked in future research studies to see if these types of equipment could be used to lower the overall rates of blood borne pathogens (Leiss [26]).

The rate of contact for Paramedics through the eyes, nose, and mouth was similar to contact rates for patients with needle-stick contact. Also the blood borne contact generated from bites and cuts from sharp objects attributed for about 15% of all cases, and these cases should be looked in preventative manners to reduce overall Paramedic cases. The overall needle-stick contact rates from California accounted for about one quarter of the nationwide cases, and are a hazard that should stop future

Paramedic occurrences. The needle-stick preventative injury law for California Paramedics should enforce prevention of future cases, in which Paramedics would properly encase needles to prevent accidental contact (Leiss [26]).

The outlined study displayed accurate data to show the accidental occurrence of blood exposure for Paramedics. The results show that EMS squads and Paramedics should have more preventative measures to avoid blood borne contact. This study also shows that their lacks a method or device that can fully contain the splashes of blood from a patient. Creating the Surgical Sponge should decline the number of incidences of Paramedic contact with the blood from a patient.

2.2.2 -Current Methods of Ambulance Cleaning and Contamination Reduction

Currently, there is no mechanism to collect a patient's excretions on the stretcher. A linen sheet is placed on top of the stretcher pad. The linen sheet is a poor absorbent for bodily liquids. It allows the penetration of excretions to the stretcher pad, and it can eventually spread to the rest of the ambulance. These sheets are washed to be reused (EMS [16]). Their reusability should be further scrutinized. Some bacterial cannot wash off.

Cleaning an ambulance after it has carried a patient is an important process to follow, and the Surgical Sponge group would like to offer solutions in facilitating this task. Cleaning an ambulance after use requires time, money, and patience. For example, in England, there are claims that flawed infection-prevention techniques have resulted in the creation of a superbug (Bradshaw [8]). Solutions such as a roll-through cleaning method have been offered, which prevent EMT's from using any ambulance that has not completed a cleaning circuit. Another costly solution is simply to hire staff whose purpose is to clean the ambulances instead of the EMT's. Currently, there is a drastic need to reduce the time required to properly and efficiently disinfect an entire ambulance down to the stretcher that it utilizes for transporting patients.

An ambulance must also let disinfectants sit on surfaces for 10 minutes if the vehicle has been contaminated with infections like Strep and Staph. “Blood and other bodily fluids must be thoroughly cleaned from surfaces and objects before the application of the disinfectant (Bradshaw[8]).” Paper towels wipe up these fluids and later disposed in biohazard containers. EMTs are only required to wear gloves and eye protection. These are the standards that exist, and staff do not all properly follow them through (Bradshaw [8]).

A report released in April of 2010 claimed that 42 of 167 trusts in England failed the standards of the NHS (National Health Service of England), including 4 ambulance trusts (Search [35]). The common problems occurring were a result of there not being specified areas to decontaminate equipment. A sourced list of ambulance cleaning procedures demonstrates that they should have a designated area where contaminated equipment results in disposure. Contaminated equipment is first hosed and then disinfected for a half of a minute to up to ten minutes for certain types of bacterial and viral strains to be eliminated. Ambulances are taking the blame for the spread of MRSA and Clostridium difficile (2). This is a direct result of improperly disinfecting an ambulance. Bacteria and viruses continue harvesting when germs result from improper cleaning protocols (Kempt [25]).

A patient will be exposed to germs on this piece of equipment and inhale any bacteria that may be growing inside of it after an improper cleaning. It is quick and easy to put off leaving disinfectant on a surface for ten minutes. When considering inconvenient factors, like the potent scent of a disinfectant and the amount of time it takes to properly use it, there are many ways to explain why infections and viruses are spreading in ambulances. One example of what these factors lead to is a very expensive epidemic called HAIs (US Annual HAI [20]). With HAIs (hospital-acquired infections) costing the United States an annual $11 billion, ambulance cleanliness is a concern that is severely costing citizens. The ambulance has always been contributing greatly to HAIs. On average, 2 million people a year obtain an HAI, and 150,000 of them die from it. There is no statistic to determine how many HAIs resulted by ambulance trips, but ambulances are a major contributing factor. No one can determine the cleanliness of these

ambulances given the nature of the patients who ride in them. Even insurance companies will save money with decreased HAIs, since insurers pay $45,600 more for HAI victims on average than a non-HAI hospitalized patient (US Annual HAI [20]). Inspections resulted to assure and reinforce cleanliness standards. Ambulances are a great place to start due to the chronological order in which patients are treated. An increasing need for successful cleaning of ambulances remains, and implies that more labor is the only way to disinfect ambulances.

Moreover, there are no specialized mechanisms that are included in the ambulance to collect liquids like vomit, blood, saliva, and other bodily fluids. Steve Haynes, head chief of UMass EMS, reported that blood catches inside the screws and inner pipes of the stretcher (EMS Umass[16]). Kayla Gonzalez, an EMT from Oxford, MA reported that any part of the uniform that gets infected with blood will have to be disposed of (Gonzalez [18]). This will add to the burden of cost on the budget of these facilities. In their newer addition of the ambulance stretcher, Stryker made insignificant changes to aid in maintaining sterility (Stryker EMS[15]).

2.2.3 Vibration Effect on Patient Safety and Care in the Ambulance

Vibration still continues to be a health risk in the ambulance today. Dr. Bourne from Meharry Medical College reported that a major complaint of patients while on the stretcher and in the ambulance is that of excessive vibration (Bourne [7]). Several studies have indicated that vibration is a health-risk (Helmut et al [23]). A thorough understanding of the stretcher used will greatly contribute to an overall understanding of patient ambulance vibration. Different aspects of the stretcher need more analysis in respect with the project's functionality. These components are the mattress, cover sheet, and supportive skeletal structure. Stretchers evolved as technology evolved. Automated and technologically involved stretchers have been designed. The progression toward force-free use did not include novel techniques for vibration dampening (EMS [15]).

The mattress is an important aspect of the stretcher. It should provide the core of the comfort that patient needs in such critical situations. The type of material of the inner core of the mattress is crucially important. Stryker uses a combination of cotton and other synthetic materials (EMS [15]). The spring arrangement is even more important. Almost all mattresses contain springs within them to assist in the support. The spring material chosen supports significant loads and various mechanical properties. Most springs result from placement in a vertical manner. The arrangement of the springs ideally should support more force and apply the necessary reaction force needed for comfort. According to Dr. Fofana from Worcester Polytechnic Institute, being creative with spring arrangement can be very useful in offering more comfort. One of the reasons that Stryker's stretchers aren't used through UMass Medical Center is the low standard of comfort of the stretcher mattress (Haynes [21]).

For a better comfort on the ambulance stretcher we must deal with the vibration. Many patients complain about vibration as they are transferred by the stretcher (Bourne [7]). While the patient is in the ambulance, the WPI Ambulance Project attempted to solve this problem by integrating a multi-spring system as part of the ambulance structure. The WPI Ambulance Stretcher group wants to integrate a system of shocks to minimize this vibration. Also, the wheels in the existing stretcher are non-deformable. A change of wheels, to a more proper type of wheels that absorbs shock, has been considered by the WPI Stretcher group. A vibration dampening system within the stretcher itself can prevent vibration when patients go through the process of transport from their house to the ambulance. However, these systems have not made it to the market yet.

2.2.4 The Superabsorbent Pad

2.2.4.1Key components of super-absorbent pads

Super-absorbent pads are far more involved than one may understand by simple inspection. Engineers have already discovered what materials are ideal for absorbency, water-wicking, avoiding leakages, adhesives, and comfort. In order to design a stretcher component with maximum liquid retention and minimal leakage, use of the appropriate combination of materials is paramount.

The responsibility for maximum absorbency is delegated to the sodium polyacrylate powder. However, SPA cannot simply sit in a cloth basin and be expected to function perfectly. The SPA is housed in multiple layers of cloth and other plastics. As a sponge, it is necessary to achieve maximum absorbency while also avoiding any leakage from unwanted areas. To meet this specification, a thin but impermeable layer should lie gravitationally below the sponge layer. This can be a host of materials but a simple, cost effective choice is polyethylene (PE). PE comes in many varieties depending upon its branching characteristics and its molecular weight. Examples of these are UHMWPE, or Ultra High Molecular Weight Polyethylene, and its brother ULMWPE, or Ultra Low Molecular Weight Polyethylene. The type most suitable to a diaper or an impermeable layer beneath a sponge is LDPE, or low-density polyethylene. This is commonly found used on rigid containers and plastic film wraps, perfect for use beneath a spongy layer. It does not have a particularly high tensile strength, but as simply a protective layer, it bears little load. As with plastic bags, the LDPE has hydrophobic character and will not allow liquid through its highly branched structure (Diapers [12]).

It is also necessary in super-absorbent systems to have a system to contain the SPA. Ideal conditions for the powder are not satisfied if the SPA sits freely within the space above the LDPE. Therefore, a tissue is needed to create the actual sponge feature of a system. Related tissues generally range between two types of material. One is a special tissue that has a higher wet strength and elasticity then normal tissue paper or bathroom tissue. It can be substituted with nonwoven material as well which serves the same purpose; a wrap around the super-absorbent core. This is safe to place directly next to the LDPE (Diapers [12]).

In order to secure the pad to the LDPE and other surround materials, industry has discovered that "hot melts" are useful. In essence, they are very simple adhesives made of resins and oils that are delivered in a molten phase. "Construction adhesives" are used to attach the absorbent pad, made of SPA wrapped in tissue or nonwoven material, with the back LDPE sheet. A second type of adhesive, called "pad integrity adhesive" is sometimes used directly on the absorbent pad to increase its strength when it has begun to absorb its fluids. This keeps the pad from sheering under force of impact when it is wet. Stitching may have adverse effects on the pad's integrity, as it would introduce point- weaknesses (Diapers [12]).

It may be necessary to have area of a super-absorbent pad to have hydrophobic properties, or properties that tend to repel water. A perfect example of this material is found on the elastic leg bands on diapers so when fluids come into contact with it, the fluids repel back towards its origin preventing leakages. Hydrophobic properties can be given to a nonwoven material by adding certain resins with phobic character; a good example of this is a polypropylene resin. Water will simply bead from this newly phobic material back to the pad (Diapers [12]).

If there is a bottom sheet of LDPE, it only makes sense to include a material with the sole purpose usher the liquid through itself and away from its origin, an example being a human being. For materials of this nature, hydrophilic character is desired. Hydrophilic materials attract water and are capable of pulling it away from its source and avoiding regurgitation of the liquid. Action of this nature is not uncommon in sports gear to move sweat away from the athlete. This is also found in absorbent pads like diapers and is found on top of the absorbent padding. Its purpose is to move sweat and urine away from the human (Diapers [12]).

How a hydrophilic material functions is very simple and models through materials science. "Wetting," is the degree to which a liquid will cover a surface or will maintain a droplet form a likely bead. The closer the contact angle, Ø theta, approaches 180 degrees the less wetting will occur and the water droplets will tend to stay in bulged up. A material has high wettability as the angle approaches zero. This makes sense because as the liquids tangential angle with the surface gets smaller, the droplet is occupying more area on the surface. It is just the opposite with a very large contact angle; an angle at 90 degrees would resemble the shape a penny covered in drops of water would take. The drops are bulged upward due to surface tension between the water molecules and the penny. As the angle approaches 180 degrees, the droplet stays theoretically entirely intact and does not spread at all over the surface. This is referred to as "perfectly non-wetting" character and is almost impossible to attain, as the liquid would be a sphere. The idea of wetting is important because a hydrophilic material is one that minimizes the contact angle that augments its absorbing ability (Diapers [12]).

Again, hydrophilic character can be attained in a similar manner to achieving hydrophobic properties, a surfactant treatment on nonwoven material. This surfactant allows and actually beckons liquids to fully wet the nonwoven material, pass through it, and become trapped

in the SPA. The material should be soft and comfortable since most times it is this layer that is in contact with tissue of a human. In diapers, even vitamins and other skin-friendly oils are included in this layer so as to treat the skin when the skin comes into contact with the fabric. This is simply a novelty and is not necessary for effective fluid absorption (Diapers [12]).

To preliminarily sum the aforementioned subject matter, it will be critical to use the correct combination of materials in order to achieve and ensure maximum absorbency while minimizing leakage. Hydrophilic and hydrophobic surfactants, woven and nonwoven fabrics, and polyethylene can be purchased directly from suppliers all over the United States and the world. A few examples of these companies are Tredegar Film Products, Fibered, General Nonwovens, Consolidated Fibers, and Advanced Fabrics SAAF.

2.2.4.2 The Specific Layers of the Diaper System

Layers of the Diaper

Polyethylene: The Bottom Layer

The bottom layer of the diaper, or any absorbent system for that matter, is generally a very thin sheet of polyethylene. These polymers are made up of many mers of ethylene, a very hydrophobic compound. This is an ideal material as it is impermeable to water and other fluids. This characteristic is necessary for waste retention systems as it does not allow any fluids to flow through the back of the absorbent core. Without this layer, fluids would drip through the bottom of the diaper or pad and would contaminate everything around it (Diapers [18]).

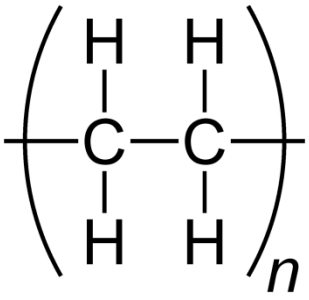


Figure 4-The basic "mer" of the polymer polyethylene

In Figure 4, this is the basic "mer" of the polymer polyethylene. This unit can be repeated n times to form very long and relatively strong chains, depending on the molecular weight and the density with which it is packed (Philips [24]).

Low- density polyethylene (LDPE) is common choice for the back sheet of diapers and other pads because it is light, thin, and still impermeable to fluids. Also, using as little possible polymer helps to save money and resources, so it is important that LDPE is strongly considered for any back sheet application. Typically the LDPE is only about 1 mil, or 25 micrometers in thickness. There also exists High Density Polyethylene (HDPE) and Ultra-high Molecular Weight Polyethylene (UHMWPE), which are used in other applications that require more rigid character in their application. In the case of the diaper, this is the opposite of desirable as the sheets must be light and pliable to move dynamically with the diaper and body of its wearer (Diapers [18]).

Figure 5-A thin layer of polyethylene back- sheeting

In Figure 5, this shows what a typical thin layer of polyethylene back- sheeting looks like. It is very thin, and often comes with designs drawn upon its surface to make the outside of the diaper more aesthetically pleasing. It is easily bonded to the inner core of the diaper by using hot melt adhesives.

The Absorbent Core

The absorbent core of the diaper is made of two main components: the pulpy matrix and the superabsorbent polymer. Both are crucial in a diaper's ability to absorb all of the fluids excreted by a human. Cellulose is a fibrous material that originates from pine trees that is effective at absorbing fluids inside the small spaces between wood fibers. It typically can absorb about 10 cubic centimeters of liquid per gram of pulp, but is found to release about 80 percent of its fluid content when subjected to even minor loads. The cellulose is soft and fluffy in texture and works as a matrix for the sodium polyacrylate as well as to give bulk and integrity to the diaper core. It is not effective as the sole medium into which fluids are trapped but works very well as a complement its main absorbing sister, sodium polyacrylate.

Sodium polyacrylate is a superabsorbent polymer that has the ability to trap up to 300 times its own weight in water. Since blood is nearly completely water, it is a viable option as a medium to trap biological fluids. During the manufacturing process, the SPA mixes into the cellulose fluff and gives the mixture an astounding ability to absorb fluids and retain them under pressure (Richer Investment [41]).

The core is wrapped tightly in a nonwoven fabric. Nonwoven fabrics are typically polypropylene polymer that is drawn out into fibers or filaments and are bonded physically or chemically into webs. These are called "Spun bonded Nonwovens." Nonwoven fabrics are not knitted or woven like typical linens. The plastic is able to perform this way because it is made molten, not dissimilar from glass, and hardens into place. The sheeting is porous which is ideal for letting fluids through. However, polypropylene is hydrophobic in nature and tends to repel water. Therefore, this material is generally treated with a surfactant that adheres to the surface of

the fabric. The purpose is to lower the contact angle between the fluids molecules and the surface, allowing for increased "wettability," or the ability for the fluids to spread out and cover the surface. By doing this, the fluid can pass through the polymer and enter the cellulose-SPA mixture. Nonwoven fabrics provide a host of characteristics that are ideal for a variety of purposes. The fabrics can exhibit different levels of resilience, toughness, softness, liquid or biological repellency, strength, and cushioning (About Nonwovens [1]).

Figure 6- A spun bonded nonwoven fabric

In Figure 6, the above figure shows spun bonded nonwoven fabric. It is an extremely common fabric used in the core of diapers as it allows fluids to pass through when treated with a surfactant. The consistency of this material is soft, and is easily pliable for use with diapers.

The top layer: Acquisition Distribution Layer

The top layer of most diapers is the acquisition distribution layer (ADL). This is a relatively new material being used in diaper systems today, and is still being researched and developed to augment its already important function. One of the major problems associated with

diaper systems is rewetting of the top sheet surface. Once fluids pass through the top layer, they should be limited to the greatest extent possible from regurgitating back to the person's skin. This causes irritation of the skin and an overall feeling of discomfort for the user. Also, before the advent of the ADL, fluids that passed through the top sheet tended to pool directly below its point of entry into the core because the core could not absorb the fluids at a rapid enough rate. The ADL assists in dispersion of liquids over a greater portion of the absorbent core so more fluids can be absorbed. Fluids are also able to pool in the ADL and drain with a slower velocity into the core allowing for more full absorption and retention by the core (ADL [4]).

To combat all of these very real issues with the diaper, the ADL was developed. Three dimensional aperture film constructs most ADL. The apertures on this film are located between a soft, nonwoven top sheet and the absorbent core. Aperture film functionality stems from its highly numerous apertures, or small cone-like structures. The cones allow fluids to pool in their wide entrance zones that face the direction of the person excreting fluids. When the cones fill with fluids, the fluids can literally overflow into other cones allowing for a distribution effect to occur giving the fluid greater access to areas of the absorbent core, that have not already been insulted with liquids. The open ends of the cones account for a large surface area compared to the small holes at the opposite (bottom) side of the cones. Once fluid has passed through the small hole at the bottom of the cone, sometimes as small as less than 100 microns in diameter, it becomes very difficult for the fluid to regurgitate back through to the voluminous cone space thus back towards the skin. During manufacturing of the aperture film, a variety of ratios of cone entrance areas to exit areas can be set to achieve desired pass-through velocities versus regurgitation amounts (WIPO [3]).

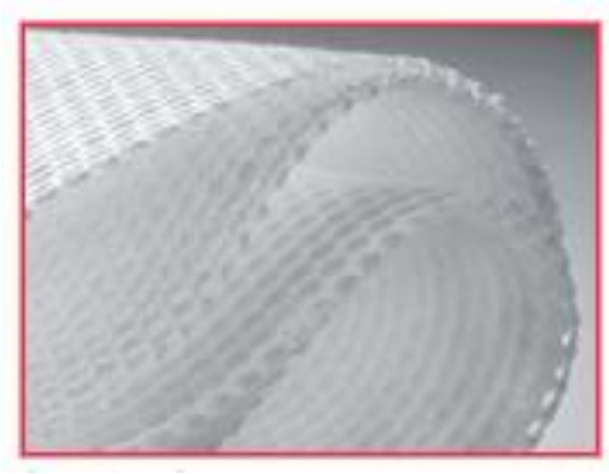


Figure 7- An example of Tredegar Film Product's "Comfort Quilt" Aperture Film

In Figure 7, the above figure shows an example of Tredegar Film Product's "Comfort Quilt" Aperture Film. This particular film specializes in reducing rewetting of the top sheet while maintaining the highest standard of comfort. Diaper systems and other special absorbent systems are most effective when user comfort, core entrance distribution, as well as wetness management is optimized.

An absorbent system is only as effective as the combination of all of its various elements. In order for an iteration of previous absorbent systems to be developed for new applications, known structures of past products should be investigated fully and aspects of each should necessarily be reapplied to the new, novel system. Absorbent systems should include impermeable back sheets, a superabsorbent core whenever possible, and a soft top sheet complemented with an acquisition distribution layer.

2.5.4 Sodium Polyacrylate

Sodium polyacrylate (SPA) is a chemical compound that polymerizes from its base unit acrylic acid called a "mer." When more than one molecule of acrylic acid form long chains, they then can be designated as a "polyacrylate," literally means multiple acrylates. By varying methods and strategies of synthesis, synthetic chemists and engineers can create long chains of a compound, or even sheets, which are then used for numerous applications in biomaterials, plastics, and other engineering interests.

Figure 8-Sodium polyacrylate powder after absorbance

One of Sodium Polyacrylate's striking functional uses is its extreme fluid absorbency. The polymer is known to be able to absorb up to 300 percent of its own weight in water (United Nuclear [39]). This makes it extremely useful as a means to absorb large quantities of water or other liquids without needing a great amount of polymer. Physically, SPA is a fine, white, odorless powder that is commonly found embedded within commercial infant and adult diapers to quickly and efficiently trap, dry, and wick away any liquid waste from its source. It is generally encapsulated by a nonwoven shroud and contains several grams of SPA powder. As

liquid leaks through the highly permeable cotton later, the liquid becomes captured and forms a gel prohibiting any liquids from leaking out of the capsule. This phenomenon is what makes the diaper so efficient at controlling the escape of urine, sweat, and feces. SPA is also used in the "MAG" or the Maximum Absorbency Garment used by NASA's astronauts in absorbing urine and feces during long space missions where the specially designed space suits cannot be removed.

According to the Material Safety and Data Sheet (MSDS) for SPA, the polymer is a very common and safe substance. It has undergone extensive testing to prove its usefulness and safety, two paramount areas of focus when discussing medical applications of a chemical. The Emerging Technologies Inc. released an MSDS for SPA, which outlines its hazards. SPA was deemed to have virtually no susceptibility to catching fire and its melting point is greater than 390 degrees Fahrenheit. Short-term exposure to skin will cause no adverse effects, but is known to exacerbate preexisting skin conditions with prolonged exposure due to the polymer's dehydrating character. The manufacturer deemed SPA as non-harmful when inhaled, but ingestion should be avoided, as it will induce vomiting. Finally, SPA is federally recognized as a non-hazardous material (Super-Absorbing Polymer Powders [37]).

SPA's chemical formula is $(C_3H_3NaO_2)_n$. The "n" represents the polymerizing character of the SPA. The molecule unit is simply what is found within the parentheses and it can be repeated "n" times until the chains become too long and are no longer stable under their own steric hindrance or torque forces experienced by the molecules growing weight.

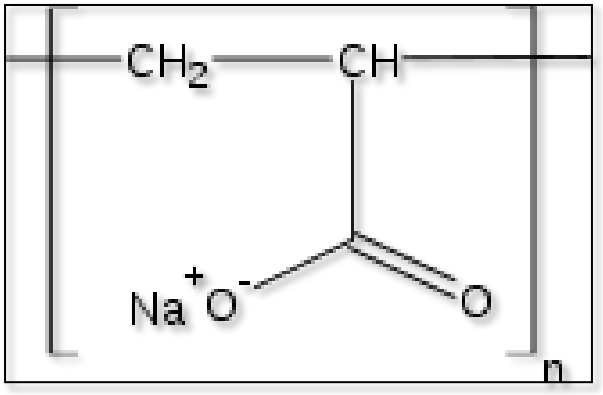


Figure 9- Molecular structure of sodium polyacrylate

As molecules become too long and bulky, they will become to break down or become weaker. The polymers in the case of SPA form fine, white crystals that are very easy with which to work and manipulate.

SPA, also known as "water-lock" for its gel-forming character, functions mechanistically in the following manner. SPA forms what is known as a "partially neutralized polyacrylate" with incomplete cross-linking between units. The "COOH" units on the main chain are converted to sodium salts, but only between 50 and 70 percent, hence the "incomplete" cross-linking. Sodium atoms between each chain hold the long carbon chains together. When the presence of water becomes apparent, the water enters into the chains via osmosis, a process by which water moves to equalize salt concentrations. When there is the same amount of water within the molecules as there is outside, the absorption ceases. However, by now the polymers have swollen greatly to form slippery gels.

Water can be released from the gel confines by applying pressure, which physically forces the water out of the polymer and into the surroundings. This is one method by which

diapers are prone to leak liquids. Also, since urine is not pure water, one cannot expect the SPA to be as effective against an influx of pure water. Urine, especially the more yellow and odorous it is, contains many salts. These salts hinder the waters absorption because the sodium ion concentrations will not balance quickly enough, causing fluid to not be assimilated. This effect is predominantly seen in diapers that have just received heavily concentrated urine (Helmenstine [22]).

2.2.5 Velcro

Attaching it to a Stretcher

When we came to a conclusion for the final design of our Surgical Sponge, a decision had to be made on how this would attach to a stretcher. Furthermore, this needs to attach to just about any stretcher, not just one specific stretcher. We began by writing down a few solutions. Among these were magnets, zippers, a pull-tight skirt, seatbelts and Velcro. Below are several of our solutions and thought processes and how they led us to choose Velcro.

Magnets are an innovative solution to our problem. They hold simply by putting one surface to another surface, and are easily removed simply by pulling them apart. They have the advantage of keeping things simple in the hustle and bustle of everyday ambulance use. They are not very expensive either. For two 2x1/2x1/8 inch magnets that will pull 13 pounds on each other, it will cost $2.38 (Rare, [25]). Unfortunately, magnets become a complication due to their electro-magnetic fields. Patients with pace-makers and other metal devices that help them live

may encounter interference from the magnets, and thus taking a trip in an ambulance could prove fatal for certain patients. A metal solution without electro-magnetic fields exists.

Next we considered the use of zippers. Zippers are strong; they do not slacken or weaken when they become wet. Zippers are fundamental in closing things temporarily, and do not emit electro-magnetic fields. The only nuisance with zippers is getting things caught in them and starting them sometimes requires a moment. They are inexpensive, a foot of which only costs $0.72. They are, however, not as easy to remove as magnets are. They require dragging the zipper all the way down the sleeve and un-feeding the end of one side to completely open, which regularly jams. For this reason, and knowing that EMTs will mercilessly cut through 1500 dollar equipment when it gets in the way, we will consider this an option in the case that nothing better comes around.

A skirt with an elastic chord to pull it tight underneath the stretcher mattress is another viable solution. An example of this would be most barstools. Although we did not decide on the material for this design, this solution is simple enough for practical use, but again is not the easiest to remove. We decided to look for a solution with an easier ability to remove afterwards before looking further into the pros and cons of a pull-tight skirt. Strapping the product down with seatbelt style belts and plastic buckles is another viable option that falls under the category of not-fast-enough. Gluing the product to the mattress will definitely give it the strength it needs, but this “permanent” solution is not an option right now, especially for a new product. EMTs will not risk adding something permanently to their stretcher that may have too many design flaws to continue using. After our product has been tried, proven, and recommended, permanent solutions may become an option.

Lastly, we considered the use of Velcro. Velcro includes all the advantages of magnets, being easy to attach and easy to detach, being simple enough to not cause any problems in attaching and detaching, and being a non-permanent attachment. Velcro does not include the con of magnets, being an aggravator of pacemakers and other mechanical devices. Velcro is also a very cheap solution, lightweight, and easy to replace when necessary. Velcro's few cons include the "ripping" noise when detaching, which may be annoying but otherwise harmless. Also, over time, the Velcro will capture lint and other small fabrics which will lower its performance. Statistics show that Velcro will fail around 5000 cycles of application and removal (Conductive Hook [11]). This is a very practical solution to placing the product on a stretcher. This solution will need little to no variation between different stretcher designs. Also, we believe that its simplicity in removal, just pulling the Velcro apart, will discourage EMTs from destroying it in an emergency situation. Conclusively, we need not look into the previous ideas because Velcro is the obvious solution in every category besides for modern appeal.

Chapter 3- Project Approach and Specific Aims

The group used a combination of engineering expertise and efficient teamwork to accomplish the goals of this project. Both qualitative and quantitative experiments were conducted to achieve our aims. Also, communication and collecting feedback from clients, users, and Engineering firms have been integral to the success of the project. Good teamwork was an essential component that had a positive impact on the project.

The team consisted of Biomedical Engineering and Mechanical Engineering students. To allow for a maximum yield in the project, each group member was matched to an aspect of the project that he had had a knowledge depth in. All along, the team applied a cohesive effort to combine everyone's contributions to satisfy the project's objectives. A combination of qualitative and quantitative experiments was completed to complete this project. Data was collected from the materials' absorbance experiments. Moreover, vibration was stimulated and computed on our final design, a control, and selected materials. Force-plate experiments and analysis reinforced the vibration data.. Direct communication with the clients and users of the product has been an essential part of the project. The group conducted interviews with EMS personnel and ambulance companies, and contacted several materials' companies. Moreover, having an in-depth knowledge of the current technology used helped us to innovate and create our product.

On a daily basis, EMS personnel face grave challenges transporting patients from one location to the next. The constant fear of not having the proper resources to protect EMS personnel from the foreign substances and materials of a patient still remain for current EMS

members. Current EMS personnel don't have the required time and effort to follow proper protocol that would enable them to prevent exposure to fluids from the patient. The use of a more protective outfit for EMS would be a good fit to avoid EMS squad from the patient's fluids; however the budget of numerous EMS squads across the nation would not be very affordable. To fully sanitize an ambulance, a period around an hour would be required to clean and disinfect all regions of the ambulance. Cleaning of the ambulance environment is also a hard task to accomplishment, since EMS squad responders must be ready 24 hours a day and 7 days a week to respond to any type of patient related emergency. Thus, an absorbent device would be preferred to prevent any physiological fluids from spraying all over the ambulance and onto the skin and uniforms for EMS personnel. This device design would be long enough to cover the mattress region of the stretcher and would be innovative enough to prevent any patient fluids from coming into contact with the EMS personnel. This design would also eliminate the time it would take to clean the ambulance, since this product would absorb and not let out any fluids or excretions from the patient onto other regions of the ambulance.

The initial project statement is to design a spongy system to collect, capture, and retain physiological fluids from a patient of any size, and that is compatible with most stretchers and litter-platforms.

From interviews with the UMass EMS squad, they would like this absorbent sponge within certain constraints. First, the EMS personnel said that they would like something that's easy to be strapped onto the mattress of the stretcher and isn't too complicated to be attached or taken off the stretcher. Second, the sponge must allow for seatbelts to cross the sponge and allow for proper patient security on the stretcher. Third, the sponge should have some open space that would allow for EMS personnel to work on the patient's arm, so critical items like IV

lines and blood pressure monitors to attach to the arm region. Fourth, a member of the EMS squad responded that the largest areas of bleeding within the body could be observed within the head region of the patient. Thus the region of the sponge around the head should highly superabsorbent and potentially have higher concentrations of sodium polyacrylate than other regions.

Objectives for the sponge are that it should be easy to clean, disposable, able to absorb any type of physiological fluid or biological contaminant, be adjustable to fit the length of any type of patient, and resist vibrations. The two main objectives that this sponge should adhere to are its ability to contain any of the contaminants that may come out of the patient and resisting vibrations that impact the mattress of the stretcher. The sponge would be easy to clean, in the sense that only the top layer of the sponge would have to be removed if any physiological fluid comes into contact with this layer. The sponge should also be disposable, in which this sponge would be manufactured at the lowest rate possible to ensure that this design is highly affordable for any EMS squad company to purchase. The intent is that EMS squads across the country would buy these sponges in high bulk, and they could dispose of the sponge in case any contaminants come out of the patient. No matter what viscosity or thickness of the physiological fluid, this sponge device would have the layers necessary to absorb all contains of the fluid and would not allow any fluids to come out in case any loads or forces will be applied onto the sponge. The sponge design intent is to be adjustable of fitting a patient of heights up to 7 feet and a weight capacity of 250 lbs., which fit many of the common characteristics of common patients. Since many patients complain of uncomfortable experiences when being placed on a stretcher, a vibration dampened layer will be placed on the bottom layer of the sponge to

suppress vibrations from coming onto the mattress of the stretcher and ensure comfortable and stable conditions for the patient when the stretcher is in motion.

The major constraints facing the design of the sponge range from the overall scale of the sponge, money that's provided to make the design, and the time frame to make a full scale and marketable design. With the budget of $120 allowed by the mechanical engineering department for each MQP student, there isn't much money required to make our prototype life-sized. The budget will allow for all the materials to be purchased and for proper experimentation to take place with the overall design. A life-sized model will take more money and time to produce, and perhaps another MQP group for next year could continue working on our current design to make it marketable and realistic. With the limited manufacturing knowledge of each of the teammates and limited workspace, the sponge will probably not be as well represented as originally thought. With the lab space, budget, and materials that the MQP team is currently provided with, the team constructs a small scale prototype. Connecting the layers of the sponge may not be as professional as once thought, but the use of materials within the MQP group lab space should be enough to connect all the layers together.

A more revised project statement emphasizes that the final product will be a small-scaled prototype of a larger and marketable sponge. The final design will serve two main purposes, which are to contain any of the physiological fluids or excretions that may come out from a patient and resist any harmful vibrations that may affect the overall health and comfort level of the patient. To accommodate the absorption of the contaminants of the patient, a superabsorbent polymer and non-woven materials will be embedded into the sponge to allow for the absorption of physiological fluids upon contact onto the sponge. Sections inside the sponge will have to be hydrophilic to allow fluids to come into the sponge and other regions will have to be

hydrophobic to prevent fluids from leaving the sponge. Vibrations will be minimized with Akton viscoelastic polymer, which will be used on the bottom of the sponge to be shock absorbing and vibration dampening. Through these two purposes, the spread of diseases and infections of patients to EMS squad will be minimized and the comfort and stability of patient within the mattress will greatly improve.

The overall project approach for the final design of our surgical sponge will incorporate a multi-layer design. Each layer will serve an overall importance towards the maintenance and adherence of all other layers upon the sponge. The first layer will be an acquisition distribution layers (ADL), which will also contain a holding position for a typical linen sheet that is used to transport the patient to the actual mattress of the stretcher. This sheet will be used because it is inexpensive and can be disposed of if any physiological fluid comes out of the patient. The outer surface of this layer would be hydrophilic to attract the fluid, and the inner surface would hydrophobic to maintain the fluids inside. The second layer of the sponge will be the middle layer and will contain sodium polyacrylate, cellulose, and non-woven materials that will be used in absorbing materials that will come through the first layer. This layer will not be disposed of and any fluid that comes into this layer is expected to turn into gel. The third layer will be a polyethylene sheet that will prevent the further penetration of any fluids to the mattress. The fourth layer will be an Akton viscoelastic polymer to suppress vibrations that may originate from the stretcher onto the mattress. This polymer is found to have shock-absorbing and vibration reducing properties, as well as the fact that this polymer doesn't support the growth of bacteria. This layer should add to the comfort level of the patient, by reducing overall vibrations and preventing the mattress from moving at a high rate during the movement of the stretcher. Velcro will be placed under the surgical sponge to securely and effectively attach the sponge to the

mattress. The overall goal of this sponge is to make a low cost and reusable sponge system that can serve the purposes of reducing any possible vibrations and containing any fluids that may come into contact of EMS personnel.

Chapter 4- Alternative Designs

The following is a brief description of our alternative designs which we decided against as our project progressed. One design, known as the funnel design, guided all released fluids into one of several holes, which channeled into an inclined funnel and is contained in a bottle at the end of the ramp. A practical rejected design was the cartridge design, unique for using a cartridge lined with Sodium Polyacrylate. Our most promising design which we have put aside, our three layer system, was a simpler version of our current design. Our intent was to collect the good things from our previous designs and use them to better our next design. You will see how we kept the good features we took from each design and incorporated them into the next.

4.1 Design Iteration 1: The Cartridge

Cartridge Design

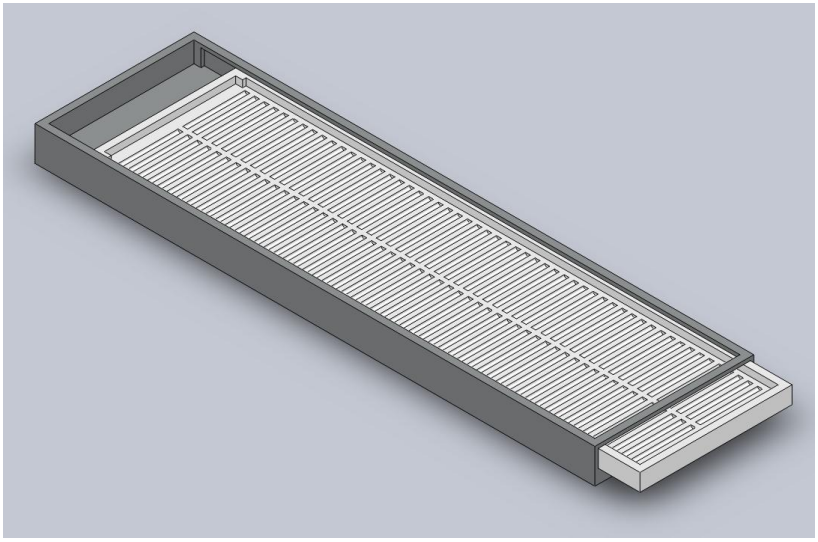


Figure 10- Isometric view of the cartridge design- cartridge containing sodium polyacrylate

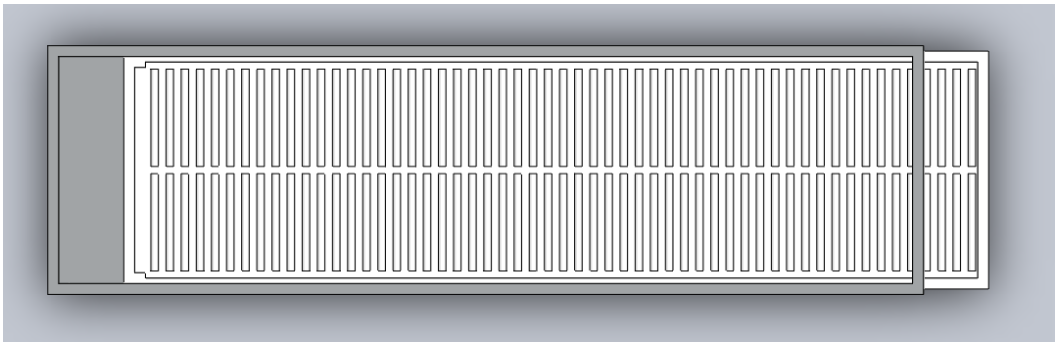


Figure 11- Top view of the cartridge design with cartridge partially ejected

Shown above are a couple pictures of our cartridge design [Figure 10, Figure 11]. We decided, moving on from the Funnel design, that there is no use in collecting the physiological fluids: After hitting the air physiological fluids are no longer sterile, and would most likely just leave a bottle of fluids that must be disposed of in a special manner and is not reusable anyway. We decided, instead, to try a design with one primary part that is permanent and a couple of disposable parts that would completely trap the bodily fluids and then be disposed of. The design is rather simple: A cartridge, with ridges covered in Sodium Polyacrylate (SPA), slides into the permanent attachment which sits on top of the stretcher mattress. Ideally, there would be a thin sheet on top to only allow fluids to pass through, but we moved on to a new design before developing that portion of this design. A necessary test for this design would be how much SPA will absorb as much blood as a person can lose before dying.

Sources state that after losing 40% of your blood, you will die (Blood, [10]). The average human being contains 10 pints of blood, so therefore a human being will die after losing approximately 4 pints of blood (56, [1]). Using the density of blood, 1060 kg/m3, and converting 4 pints of blood into 0.001892 m3, we calculate that 4 pints of blood weighs 2.005 kg (Shmukler, [40]). Since SPA can hold 300 times its own weight for non-distilled liquids, we would require

6.685 grams of SPA to absorb that amount of blood (Super-Absorbing, [43]). Although we did many wettability tests for SPA within certain materials, they do not apply to this design because the cartridge has SPA and it does not cover the pit at all, besides for a thin film separating the patient from touching the SPA: It is a simple pit of absorbent powder. Assuming 4 pints of blood will not spread out evenly throughout the entire cartridge, a safety factor of 2 or 3 would be necessary. Assuming we would place 20 grams of SPA in each cartridge, we calculate the price of SPA per cartridge as follows: 5 pounds of SPA costs $44.95, so 20grams/50pounds * $44.95 = 39.7 cents per cartridge (Superabsorbent, [42]). This is extremely cheap, and it is up to the disposable cartridge to decide if this design is worth the price.

Choosing a material for the cartridge will be tricky. Most likely the cartridge would be injection molded in mass production. Taking a look at Polyethylene Terephthalate (PET), a highly recyclable thermoplastic, we can make a cost analysis of designing it out of this material. Sources show that PET is an injection moldable material: This is ideal because these cartridges will be in high demand since they replace after use (Plastic, [34]). In the US economy, PET costs $0.8871 per pound (Polyethylene, [35]). Using a density of 1.37g/cm3, and a volume of 2648 in3 from our SolidWorks file, we have 131.061 pounds (Polyethylene, [35]). Not only will each cartridge cost $116.27 in raw PET, the weight of it is ridiculously out of proportion: no EMT in their right mind would put this on their stretcher. Also, the cost of Injection Molding Capital is around $80,000 (the cheap end of the spectrum), according to CES Edupack 2010. With no regard to the material used for the permanent outer structure of the design, this is already too expensive and will need to significantly reduce. We had intended to use the linen sheet that EMS always have with their stretchers as the cover-all for the design, although we never decided how to fill the gap in the top of the design so that the patient laying on it would be reasonably

comfortable on it. The cartridge would need to thin significantly in order to make this design viable.

Lastly, we will discuss the pros and cons of this alternative design. To begin, the thing we like most about this design is the simplicity: just slide a cartridge in, take it out when it gets dirty. It requires no training; it is quite simply plug-and-play. Again, we have no moving parts and no magnets or electronics. It is easy to work with, and the cartridge should not lock in or need to lock in. The use of SPA is an idea that has stuck with us through the entirety of this project since this design. SPA will hold 800 times its weight in distilled water; 300 times otherwise (Super-Absorbing, [43]). On the adverse side, we did not consider the necessary thickness for the cartridge involved in the design: Making it very thick, we did not consider how thick it needed to be in the design process: Consider the strength of a plastic soda bottle, which is only 0.010 ± 0.0005 in. The bottle is easily strong enough to not burst open through dropping or punching, so we can conclude that for a slightly more rigid cartridge a good thickness would be approximately 0.020 ± 0.0005 in. This should significantly reduce the cost of the cartridge, since we designed it to be approximately half an inch thick. This would be approximately a 92.3% decrease in thickness, and now that we have realized the thickness is so out of proportion, the cartridge should most likely be affordable when designed to this thickness. Lastly, this design does not seem to have any hope in the comfort aspect of capturing physiological fluids, since it is made of rigid plastics and not having developed supports for floating above the pit.

We chose to keep several key components from this design. For one, the disposable piece of this design is highly recyclable. This is important because the medical field is not very eco-friendly: Any help in the recycling department of the medical field is a must-have. We plan to keep disposable portions of our designs highly recyclable. Also, SPA is cheap enough for our

intentions in this design, so we assume it will not grow much more expensive in alternate designs. This design was also a wake-up call for us about comfort, and how keeping shapes simpler and not using hard materials will give us the comfortable design we strive for.

4.2 Design Iteration 2: Funnel Design

Funnel Design

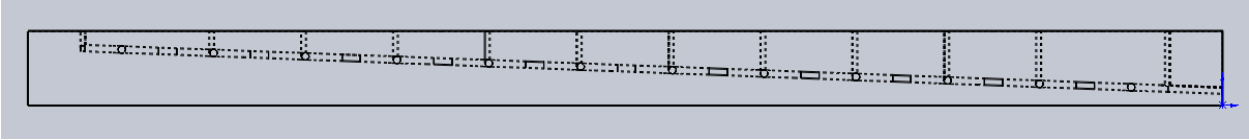


Figure 12- Side view of the funnel design- internal angled piping system uses gravity to funnel fluids downward

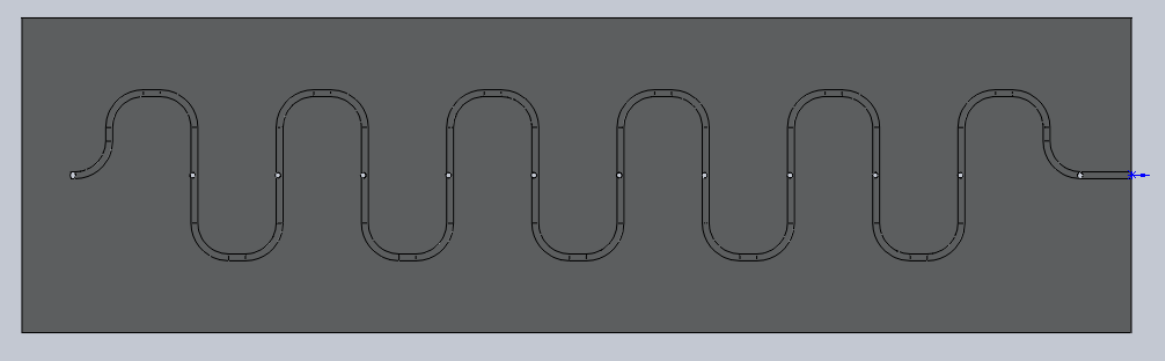


Figure 13- Top view of the funnel design

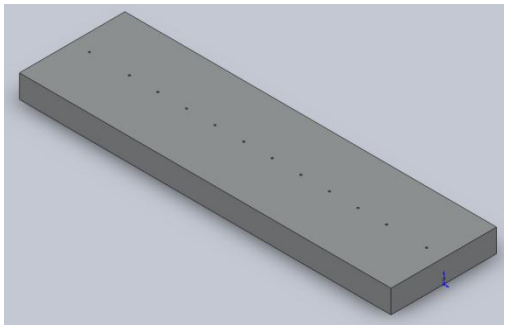


Figure 14- Isometric, solid view of the cartridge design showing pin holes

The three pictures shown are of the funnel design [Figures 12, 13, 14]. Put simply, there are holes in the surface of the design that will lead fluids to the sloping funnel which is set at approximately a 4 degree angle, heading towards the foot of the mattress. Although this design sounds like fun, many things needed to be tested and it was quite possibly out of our reach. We needed to test the 4 degree angle to see if it was steep enough to lead the water along. We also realized when going from side to side, the short way, there is no ramp for the water to go down. Thus, instead of connecting U's to make our ramp, we should have done zigzag's, connecting V's for instance: It would insure that the liquid is never stagnant and always on an incline. This was not our only setback, as this one could be simply redesigned and fixed: Our largest concern was how much weight the tubes could handle before they press shut.

Although this problem will be complex to solve in a very proper scientific experiment, there are ways we could assure it will work: An easy test of its effectiveness would be, for instance, pouring Y mL through each hole in the top surface and measuring how much returns in the bottle (Z) while a person weighing X lays on top of the mattress. We would then graph (12Y - Z) Vs. X. Notice this formula uses 12Y because there are 12 holes with which to pour Y mL into. We would consider our results poor if (1 - Z/12Y)*100 was 5 or greater, meaning at least 5% of the fluid did not make it out of the tubes. If this were the case, we would make it out of a

stronger material that hopefully does not compromise too much comfort. Where materials come into play, the chosen tube material would simply be medical tubing: it is relatively cheap and if it does not pinch under the pressure, it is the simplest material for the job. Choosing a material for the mattress would be slightly more complicated, for the tubing structure within clearly will interfere with the springs of a normal mattress. After considering options that would be applicable to the situation, the only practical solution was a custom fitted memory foam mattress.

Using the price of a queen mattress and a volume ratio, we estimate that a mattress 23"x81"x5" would cost $71.61 (Sarah [33]). Assuming that dissection of the mattress to input the tubing does not diminish the effectiveness of the mattress, it would not be extremely expensive to make. Doing some quick math, we would use approximately 12 feet of rubber tubing, 10 feet of which only costs $8.84 (Tygon [10]). Therefore, the total cost would be $82.22. Lastly, it would require a waterproof covering so that the memory foam cannot stain from body fluids. Although many solutions exist for wrapping the mattress, not many of them are comfortable to lie on. With this in mind, we searched for a waterproof blanket and found a few created for picnicking. A rough formula for the surface area to cover would be: 2*(L*W + L*H + W*H) + (-12*.4*pi + 12*.4*pi) [subtracting the circular tube cutouts, then adding an inch deep cylinder cut to attach to the tubing] = 4766 in2. A 5'x7' blanket costs $89: thus it would cost us $84.16 to wrap the mattress. This material has fleece on one side and soft waterproof nylon on the other.

In total, it would cost us $166.38 to create an entire funnel mattress. As far as cleaning goes, the cover is machine-washable. It should never stain by either blood or puke, for it is waterproof. As long as the nylon side remains outside, the cover should only ever need disinfectant between uses. The memory foam should never dirty and the only replacement of any part would be the cover if it rips. The cover is rugged enough for outdoor use, so we believe it

will only rip after many uses, or an accidental puncture. One good thing about this design is that there are no moving parts, or magnets for the matter. It is extremely simple, and essentially works completely through the use of ramps. It is durable, and there is no common replacement of any part in the assembly. On second thought, the bottle used to catch the fluids would need replacement, but under the right circumstances could cost nothing, for instance if recyclable 16.9oz plastic water bottles are usable. The worst thing about this design is, despite its simplicity, it costs $166 dollars to make. Although it is completely reusable and lasts a long time, $166 is a price the medical field might not like. When shown the long-run expenses, they assure that $166 is cheaper than $50 and replacement parts that add up fast. Recommendations for this design would be to find a cheaper solution to wrap the mattress, since it accounts for more than half of the entire price. Alternatively, the memory foam mattress is the second most expensive, and not by far.

4.3 Design Iteration 3: The Three Layer Design

Three Layer Design

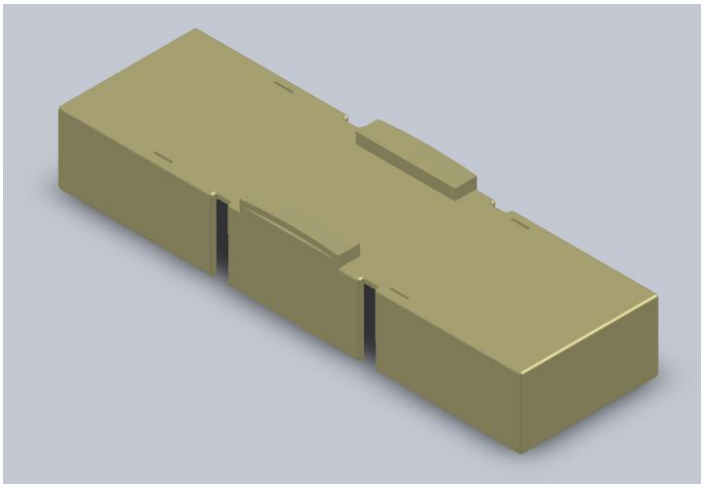


Figure 15- Solid Isometric view of the three layer design showing flaps and rail covers

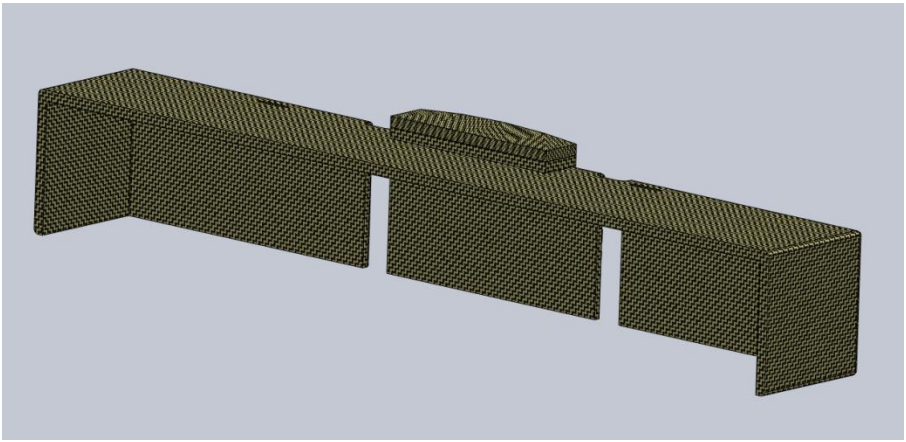


Figure 16- Longitudinal cutaway model of the three layer design

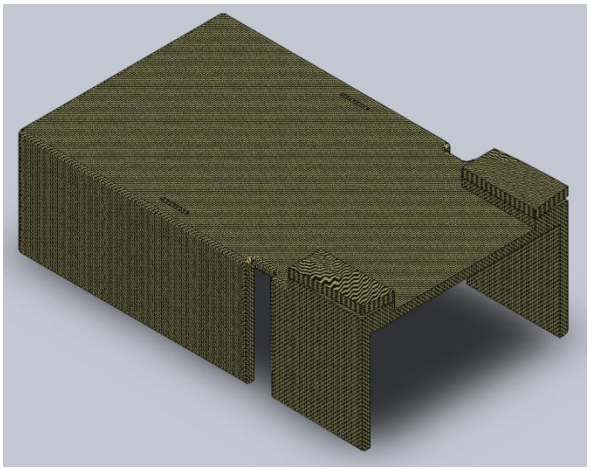


Figure 17- Latitudinal cutaway model of the three layer design

Shown above are some pictures of our final, and most promising, rejected design [Figures 15, 16, 17]. We call it the Three-Layer design quite simply because it contains three main components. The top layer is very thin, an acquisition distribution layer (ADL), and separates the patient from the absorbent layer (Tredegar [38]). It allows fluids to pass through and into the absorbent layer, but does not allow fluids to come back through to the patient. It is disposed of every time a patient lays on it. This layer is significant in the success of our design because it spreads liquid over the surface before the liquid passes through and enters the absorbent layer. The absorbent layer is, broadly, cotton wrapped around Sodium Polyacrylate (SPA). The cotton is able to contain some fluid by itself, and anything that made it through the top portion of cotton catches within SPA. After this, the bottom layer of cotton will catch anything left, and beyond that is the third layer. We believe that this second layer can absorb more than any patient could release. This second layer is disposed of when it absorbs physiological fluids from a patient, and ideally is broken up into several pieces so that most of the second layer is recoverable after a patient dirties a section of it.

The third layer is made of a heavy duty material called Gore-Tex. Gore-Tex is waterproof, so anything which did not absorb into the absorbent layer would pool above the Gore-Tex and fall to the floor before dirtying the stretcher (Gore-Tex [19]). We feel this design will be comfortable because there are no plastics involved: it is simply ADL, cotton, and Gore-Tex sheets, which individually are all flexible, placed on top of the stretcher mattress. A main goal for this design is to have skirts that cover over the EMTs arm-bars that can alternatively tuck underneath in case they prove to be obstructive to the EMTs job in moving the stretcher. Another design goal is to have flaps, stitched to the top of the top layer, that pull up and slide down over the arm-bars to protect those from fluids as well. This arm-bar cover does two things: it removes an uncomfortable cold metal surface; it gives the patient something soft to rest their arm on. Keep in mind this design does not intend to obstruct, in any way, the EMT's access to the patient's arms or head. You will notice four thin slits in the top of our design: These are gaps for the seat belts to pass through the assembly and secure the patient the way seat belts intend. In no way do we think we have the right to neglect EMS protocol or safety measures.

There are also gaps in the skirt of our design. These gaps intend to allow the middle skirt to tuck in underneath the arm-bar and above the mattress. In this case, a flaw in our SolidWorks file shows the flaps stitched to the top of the assembly should be to the far edges of those gaps in order to wrap around the arm-bars. The secondary purposes of the gaps in the skirt are for the points where the stretcher can fold: Tension will form along the bottom of the skirt when the stretcher folds to allow the patient to sit up. Using our SolidWorks file we find a surface area of 6.149 m2, which we can cut in half to estimate the area for each portion of our design. The price of ADL is very private: We are currently inquiring from two different sources about the cost of the material (ADL [6]). Cotton rolls also inquiry-only for pricing. Using the calculations from

the cartridge design, we can assume the same amount of blood loss, requiring the same amount of SPA, and spending 39.7 cents per absorbent layer on SPA. The cost of Gore-Tex (ePTFE) is also inquiry only, and the only things with listed prices are extremely thin membranes of 1 thousandth of an inch or less (Philips [24]).

A substitute material that represents our design intention in place of Gore-Tex is Tarpaulin, better known as Tarp, being waterproof and rugged as our intention had been. A 12'x20' tarp costs $24.18, and thus approximately half the surface of area of our design will require tarp: This much tarp will cost $3.38 (Dry Top [14]). Assuming there are no real issues with substituting ePTFE with Tarp, especially since the patient never touches it, the price of this bottom layer is extremely low. Due to the lack of sources for pricing of these materials, it is easy to say that the cost for this product may shoot up fast. Due to our lack of pricing, a pricing function should be in order: a formula for the cost of maintaining this design is P (in USD) = 3.38 + (.397+x)*a + y*b such that: x is the price of 6.149m2 of Absorbent Cotton Rolls; y is the price of 3.0745m2 of ADL; a is the amount of patients who release physiological fluids onto our product; b is the total amount of patients who use the stretcher. Until further notice, the price of this product is looking like it will be reasonably cheap, mostly thanks to how reusable it is.

Pros and cons for this design are here as well. One of the best things about this design is the fact that there are no rigid parts to it, and should then be very comfortable. There is no question that this design should absorb everything a patient can throw at it. The use of SPA makes this design absorb 13.2 pounds of physiological fluids by itself. The slits in the skirts are a great idea for utilizing the product despite the mechanical movements of the stretcher: The small tabs that will cover the arm-bars are great for keeping the patient off a cold metal bar as well as protecting the arm-bars from physiological fluids. In the unlikely event that some physiological

fluids make it through both cotton rolls and the SPA, it will be stuck on top of the Tarp and will remain there, find a spot to absorb into the bottom cotton roll, or will roll off and onto the floor, although not touching the stretcher. The slits for the seat belts are important for safety as well. Things that need to be improved in this design include the size of the seat belt slits, for we feel that no EMT is going to have the patience to fumble with the buckle trying to feed it through a slit that is the same size as the buckle itself: We need to make them longer and account for the fact that the seatbelt can slide along the bar and is not fixed. Our tab system for covering the arm-bars is weak: We feel that under a moderate amount of stress it will rip. The skirt that will be sliding underneath the arm-bar might me more hassle than it is worth. We think eliminating the arm-bar cover and using the piece of skirt in question in replace of it will be more effective. This concludes the things we feel are good and bad about the Three Layer Design.

Lastly we would like to close with a couple suggestions about continuations for this design. The first and easiest would be to make each seatbelt slit an inch longer on each side. Next, we suggest removing the middle part of the skirt, or making a small skirt that will go up and over the arm-bar and get rid of the arm-bar covering flaps. We also feel that the absorbent layer design is a bit sketchy. It is simply SPA wrapped in cotton rolls: We suggest doing further research into diaper technology and finding a stronger solution to the problem.

Chapter 5- Final Design

5. 1 -Selected Engineering Design

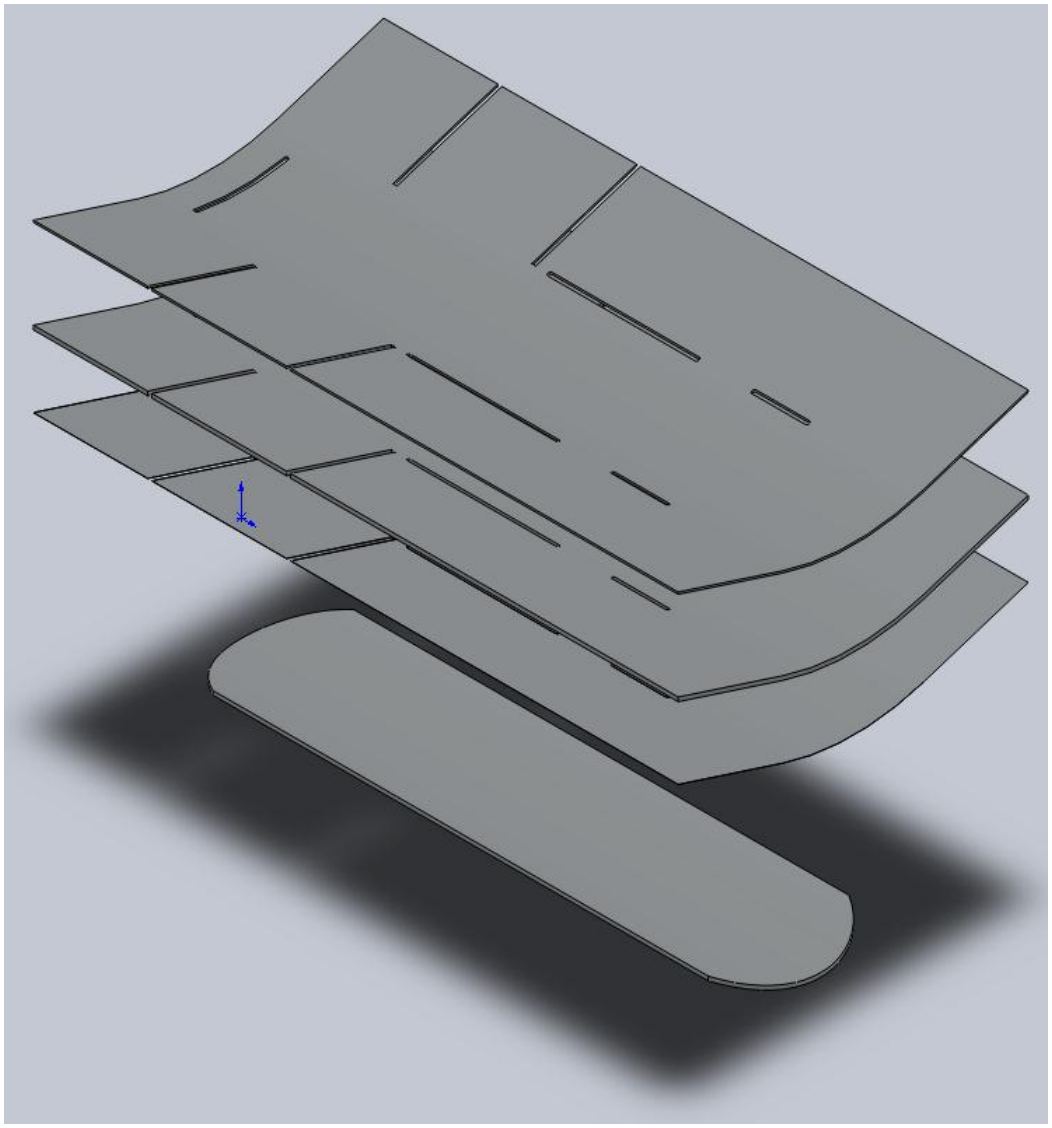


Figure 18 Exploded view of final surgical sponge design

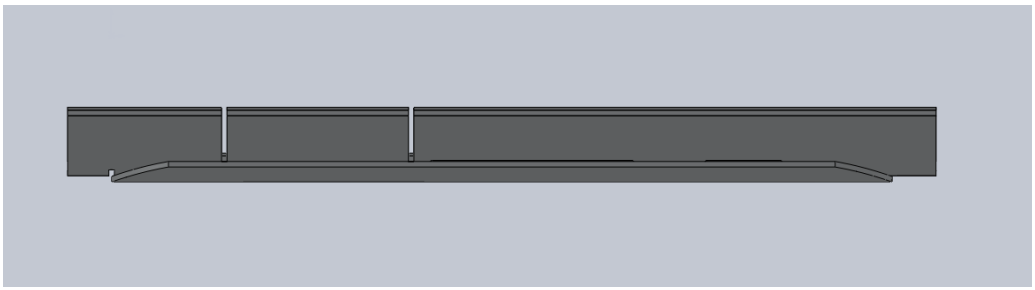


Figure 19- Side view of final surgical sponge design

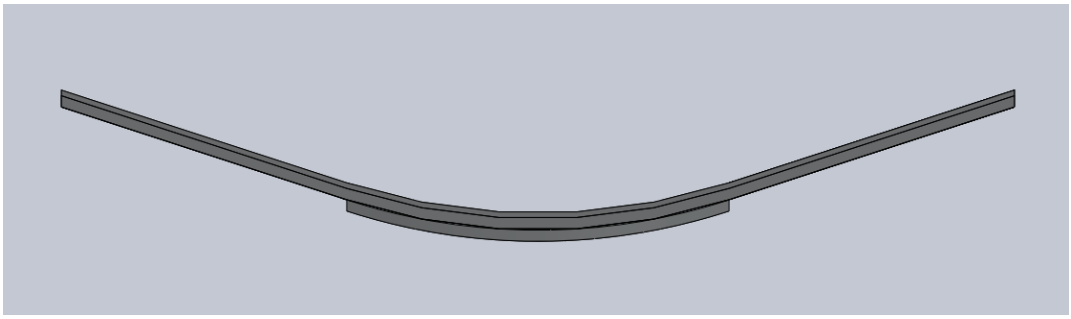


Figure 20- Front view of the collapsed final surgical sponge design

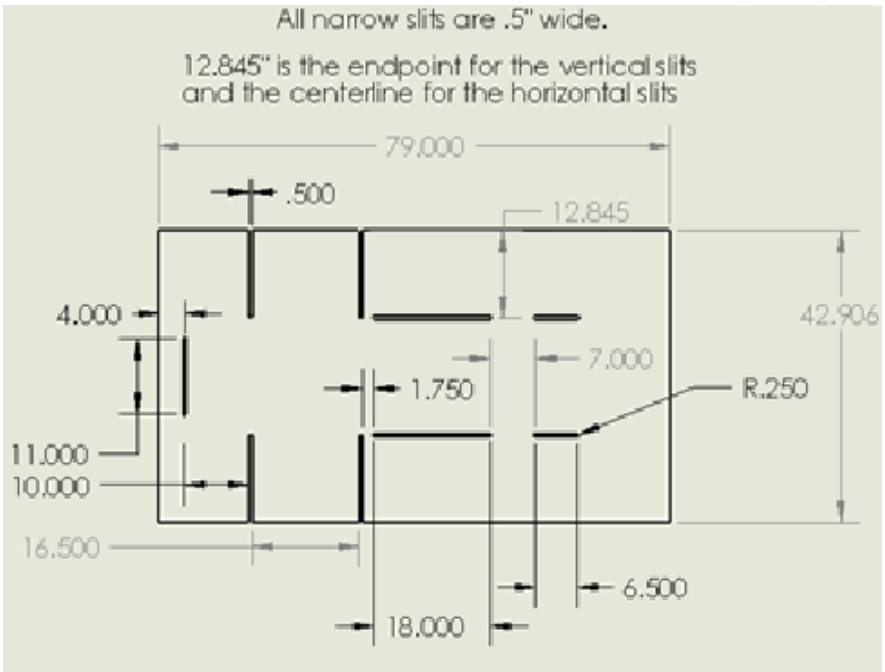


Figure 21- A dimensioned top view of the three top layers of the Surgical Sponge design

The following is a detailed account of the design intentions found in the Surgical Sponge Final Design. Our final design consists of four layers that sit on top of the stretcher mattress. The bottom-most layer of the Final Design is Akton, a vibration dampening pad which is shaped to fit on top of the mattress perfectly once laid on. Above the Akton is a layer of Polyethylene, a super-thin sheet at approximately 5 mils thick, preventing any fluids from passing into the Akton layer. Above the Polyethylene layer we have an absorbent core which is constructed of Under-pads which have been stuffed with extra cellulose and Sodium Polyacrylate for increased absorbency. The top layer is constructed from Acquisition-Distribution Layer, a generally thin polymer, which takes the liquid it contacts, and spreads it out before dropping it through and into the absorbent core, trapping it underneath the top layer with cone-shaped pores (Tredegar [38]). The Surgical Sponge Final Design consists of the best of our alternative designs with a few differences of its own. In fact, we have wet-ability experiments and vibration data on this design.

We began by deciding what things we would take from our old designs to incorporate into this Final Design. The Cartridge System used Sodium Polyacrylate which will increase absorbency significantly. 20 grams of Sodium Polyacrylate will hold 13.2 pounds of blood, and only costs about 39 cents. The idea to incorporate vibration dampening into our project stemmed from the memory foam mattress found in our funnel design: Recall the wine cup tests of the memory foam mattress on television, a glass of wine at one corner of the bed and a person jumping up and down on the bed at the other end and yet the wine glass would not tip over, showing its vibration dampening capabilities. Although, wanting to incorporate vibration dampening, we found the memory foam was too thick for our Final Design and had to find a thinner solution. Action Manufacturing was kind enough to send us a sample of their Akton

viscoelastic polymer, and it works quite perfectly for our purposes, being only about half an inch thick (About Nonwovens [1]).

We chose to keep the multiple layer idea from the Three Layer design. We kept the seatbelt slits from that design, because seatbelts are mandatory, save lives, and will help strap down our product and keep it from slipping: although we feel the Akton bottom surface is porous enough to hold itself in place against the stretcher mattress. We decided to keep rigid parts out of our design, as we do not want to hinder comfort in any way. We decided to incorporate a spin-off from the skirt feature: wings off to the sides and overhang at the head and foot. The skirt-slits feature is also required for this design, although with more intent. We decided the intent of the arm-bar covers should be taken care of in this design: having the arm-bars covered over to keep the patient from a cold metal surface and the arm-bars from physiological fluids. We liked the idea that anything making it through the absorbent layer would pool on top of the Gore-Tex, although we felt we could find a more suitable material for the job.

During our last visit to the EMS station on Wells St in Worcester, MA, we took many dimensions of a Ferno stretcher in order for our SolidWorks file to fit that particular stretcher. We decided during that visit that our Three Layer design needs to be thrown out. The arm-bar covers were complicated and feeding the skirt through the arm-bars would be a hassle. We took dimensions so that we could model the stretcher mattress in SolidWorks. We then made an oval-shaped pad that would represent the Akton layer, covering the surface of the mattress. This layer was designed to perfectly cover the mattress while it is being laid on, not when it is resting. On top of that would be the following three layers, identical to each other yet with different thicknesses that would hang over the sides of the stretcher: four inches at the head and the foot; thirteen and a half inches on the sides. We plan on the left and right wings being able to be

closed, either with buttons or with Velcro. Looking at the cross section of the stretcher mattress we added the length across the top peaks (3.875*2+9.75) to create a diameter, and taking a quarter of that circumference, we rounded the value up to thirteen and a half inches.

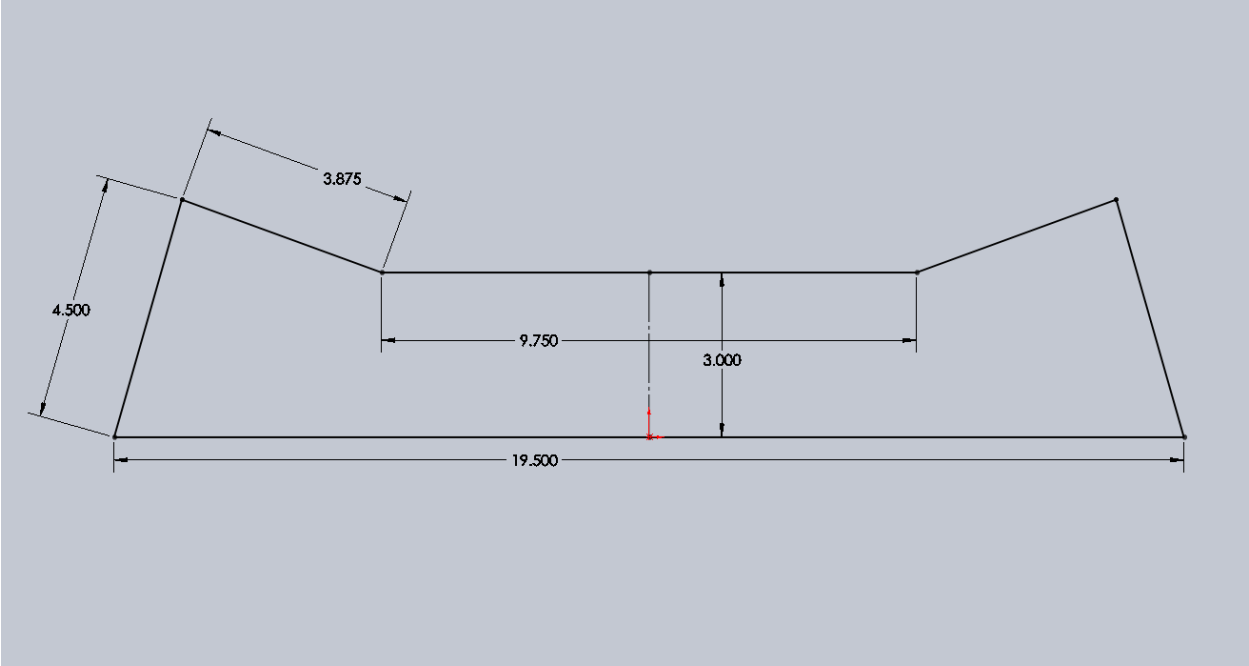


Figure 22- A sketch of the cross section of the stretcher mattress

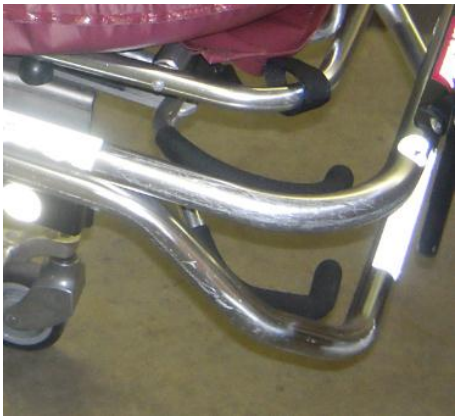


Figure 23- The levers at the foot of the stretcher

Other design intents we need to abide by include allowing the EMTs to still access their levers for performing certain functions with the stretcher. There are two levers in the right foot

corner of the stretcher: Although we planned on working around it we feel that our design does not obstruct these levers at all. There is also a lever underneath the right-hand arm-bar: Although technically the wing there will obstruct it the wing is very flexible and can easily be lifted in order to access the lever. We have made the seatbelt slits nice and long so that the seatbelts can easily be fed through, and can also slide along to their extremes since the seatbelts are not anchored to one spot. Slits in the wings were necessary for increased flexibility of the design. There is one slit about level with an adult's bellybutton for which the stretcher can fold up without causing tension in the wing.

Figure 24- Upper body portion of the stretcher

The picture above shows the mechanical feature of the stretcher to incline up so the patient may be sitting up. There is a second slit in the wing roughly level with the neck. This slit is placed there so that if the wings were closed up to wrap around the person, their face would not be covered up as well. It also allows the top wing, level with the head, to be used as a wipe if the person is bleeding from the face or vomiting.

Figure 25- A closer look at the seatbelts and how they are not anchored along the bar

With the Three Layer design we felt that EMTs would not care to fumble around getting each seatbelt through the narrow slit: We decided to add an inch at each end so there would be plenty of room to open the slits. All seatbelts have slits and should be available for use in conjunction with our Sponge System. We assume EMTs will actually feed the seatbelts through each slot after replacement of a dirty liner so that the seatbelts will be ready to be closed as soon as the patient lies on it. One thing we did not embrace prior to our last EMS station visit was the fact that the seatbelts are not planted in place. In the picture at the bottom of the previous page you will see that the seatbelt to the left can slide seven inches back and forth and the other two seatbelts have a twenty-one and a half inch span which they can slide along: We decided for these seatbelts we would leave a gap equal to these lengths to allow the seatbelts to not be obstructed by the Sponge System at any spot along its swing-arm. There are two seatbelts that come from the head of the stretcher and cannot slide which we have made a good sized slit in the top layers for. We plan for the use of the seatbelts, which is mandatory, to hold the Sponge System in place, although we strongly feel the Akton layer will make enough friction to hold it in place on its own.

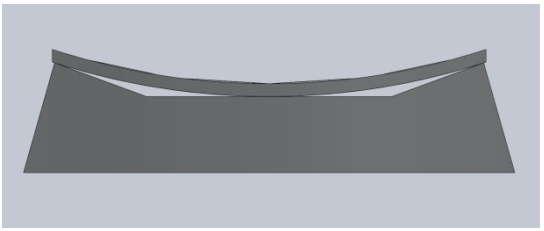


Figure 26- Right view of the stretcher mattress and the Akton Layer on top

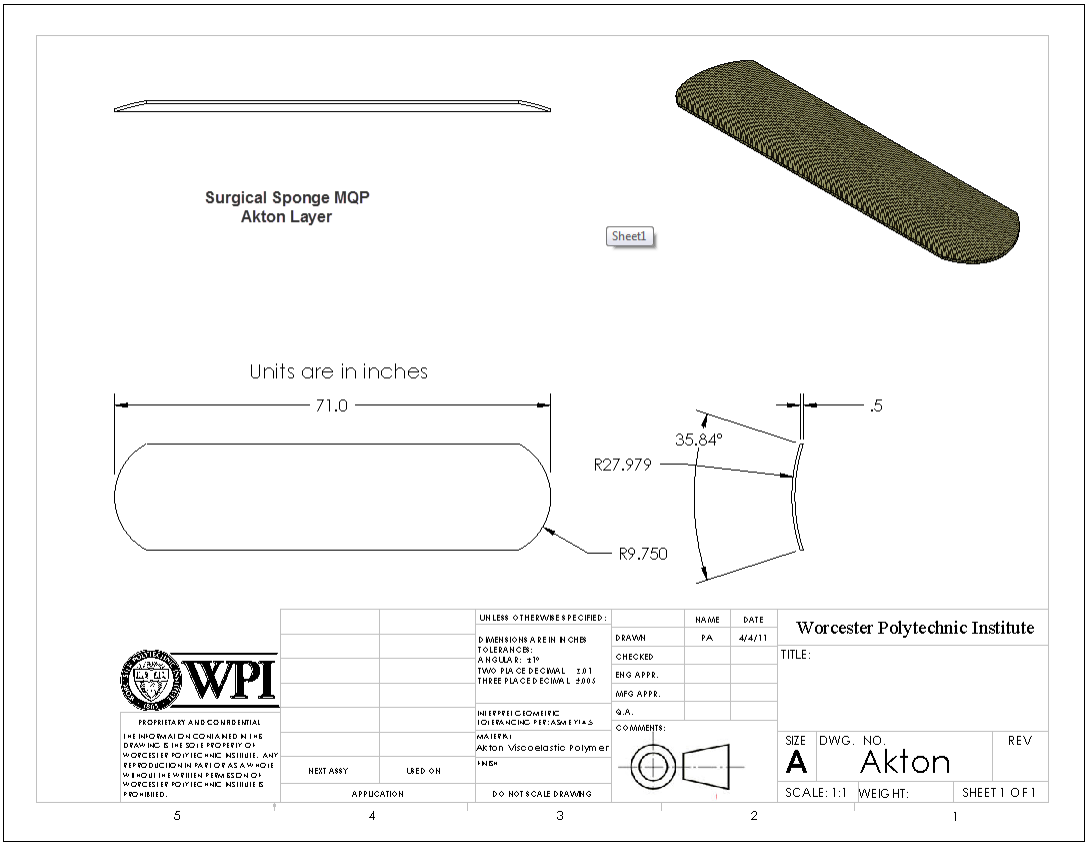


Figure 27- Dimensioned drawing of the Akton layer

We would also like to address the SolidWorks file. In order to keep things simple, yet still realistic, we chose to make the Akton layer as if it were perfectly curved, as you can see in the picture above. In reality, the Akton is just heavy enough so that it would sag down into those gaps shown. In reality we can assume that, if someone were laying on this, the Akton would be pressured into filling those gaps entirely. With this in mind we wanted to make sure, under the condition that those gaps are filled, that the Akton layer will continue to cover the entire top

surface of the stretcher. In order to do so we took the length of that top surface of the stretcher (again, 9.75+3.875*2) and made sure that the circumference of the Akton layer was equal to it. You will notice a small amount of overhang of the Akton layer in the SolidWorks file because of this concept. The Akton layer is cut to be circular at either end in order to match the top surface of the stretcher mattress. Above that we added the Polyethylene layer, by construction-lining the old Akton sketch, making a copy of the Akton layer only five mils thick, which you can see in the picture below. We then added the wings that spread out thirteen and a half inches and are tangent to the arc.

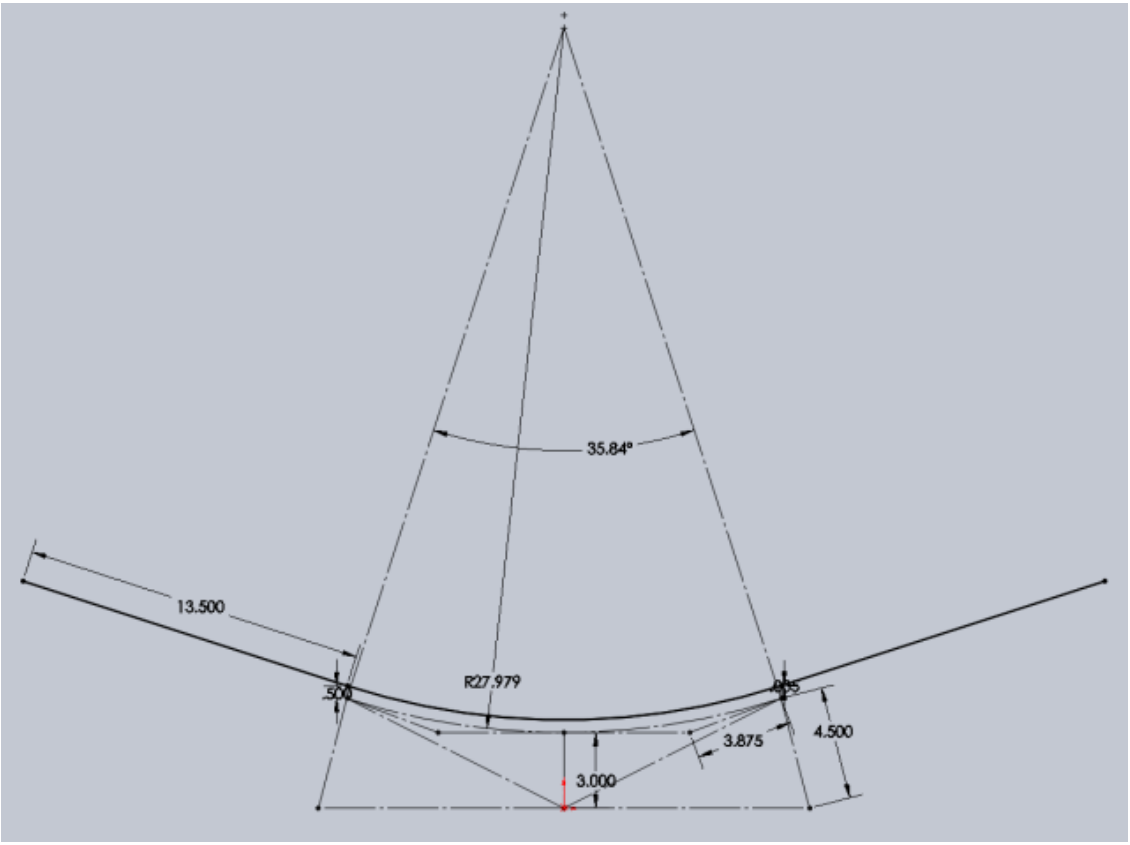


Figure 28- SolidWorks sketch of the Polyethylene Layer, built over the previous layer's sketch

We repeated this process, copying the previous sketch and turning them into construction lines, to make the next two layers: the Absorbent Core being half an inch thick, and the

Acquisition-Distribution Layer being approximately a quarter of an inch thick. From there we began plotting out the slits in the wings and for the seatbelts, shown in the picture below.

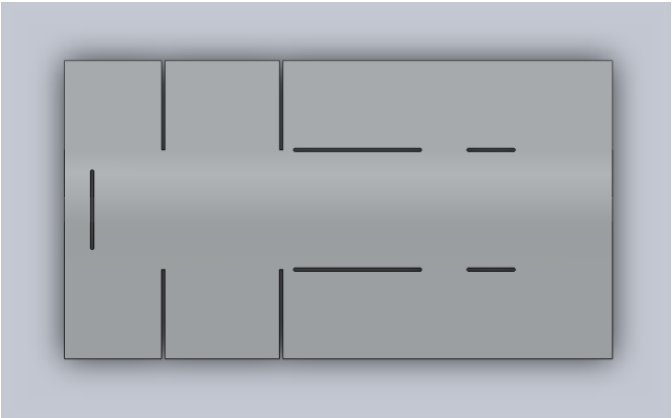


Figure 29- Top view of the Sponge System, showing skirt slits and seatbelt slits

The vertical slit to the far left is for the seatbelts that come down from around the head: Since we designed it to have four inches of overhang on that side it is positioned four inches from the edge and is eleven inches wide, as per our measurements of the seatbelts there. The next two slits from the left are the wing slits to separate the head-wing section and the torso-wing section, in order to not cover the face when covering the chest: The slits move from the edge towards the center thirteen and a half inches so to stop at the Akton Layer. The next pair of slits in the wing separates the torso-wing from the leg-wing. These serve two purposes: they make a gap for EMTs to access the patient's arms despite being wrapped up; they allow the stretcher to be shifted to the upright position without causing tension in the wing. The following two horizontal slits are for the seatbelts found underneath the arm-bar. They can slide back and forth between the twenty-one inch span that the arm-bar takes up and thus the slit is twenty-one inches long. Lastly, the lower leg seatbelt spans seven inches, and the last two horizontal slits correspond to them.

We would like to discuss several design flaws we have found minor solutions or no solution to. The first thing we would like to point out is that, without regular cleaning, the Akton layer may begin to smell foul. As of right now there are no reviews on the material whatsoever so this may only be found after integration of our product onto the medical field. If the Akton layer fails in this way, or if somehow it has an early failure rate, it will not cripple our product because it simply absorbs vibrations and is not vital to the utility of the product, only added comfort. We have no current solution for using our product in rain or snow, besides for closing it up completely so that the precipitation will only hit the Polyethylene layer which is waterproof and will prevent use of our product on the weather conditions. In the event that fluid does not get absorbed into the Absorbent Core and pools on top of the Polyethylene, it will likely roll off at the foot of the Sponge System and may dirty the EMTs stretcher handle. Lastly, EMTs regularly require using a linen sheet in order to lift the patient onto the stretcher: This would result in the linen sheet being in between the patient and our product, and would lessen its utility. Currently we are not developing anything that would allow our product to be used as a lifting sheet, but it is a possibility for future advancements and would require extensive research.

Next we would like to discuss the advantages of using this product as compared to not using it. On day one of the Surgical Sponge our goal was, and still is, to capture and isolate the physiological fluids released by a patient on an ambulance stretcher. We feel that our product will be cheap enough to replace the hours of labor required to clean an ambulance after every vomit or bleeding incident. On the note of saving money we also feel that our product will prevent splashing of physiological fluids which leads to too many replaced EMT uniforms. By increasing the average life of EMT uniforms we will save the medical field a lot of money. We feel that, although we localize a lot of bacteria to the stretcher itself, we will reallocate a lot of

existing bacteria from elsewhere in the ambulance to our product for disposal, directly removing the majority of any bacteria and viruses that enter the ambulance. We do not think this product will eliminate cleaning certain parts of the ambulance, nor do we encourage it, unless proper experiments show it is safe to do so. This is regulated by a higher power and is not for us or our product to decide. We feel that our product will take some weight off EMS shoulders by giving their patients a smoother ride: As of right now, the conditions are grim due to State and Federal standards on the structure of an ambulance. This product will also make patients more comfortable by absorbing the fluid and removing it from the patient: A dry patient is always happier than a wet patient. We feel that our idea for the product wrapping around the patient will help keep them warm and dry from physiological fluids and precipitation. Our product can also be used as a large towel for wiping off the patient as well.

We would like to share with you a few future developments for our Surgical Sponge. We believe, as it is currently designed, our product will not be able to support the weight of a patient when not against the stretcher: This would be a great development since EMTs currently have to use linen sheets to lift patients to the stretcher, which disrupts the use of our product when the linen sheet is between the patient and our product: If we can add strong fibers underneath the Polyethylene layer, we may be able to strengthen it to carry patients and also stay with the patient until they are released from the hospital. Another small improvement would be a channel system, in the case that the Absorbent Core does not gather all physiological fluids, grooved into the Polyethylene layer that leads to the foot of the stretcher and leads into a bottle, similar to our Funnel Design. Since we worry that the Akton layer may begin to smell foul after being used for a long time some sort of spray adhesive of chemical process to coat the Akton layer without diminishing its flexibility or vibration absorbance may be an option for us to improve our

product. If our product is absorbing physiological fluids in an inefficient way, such as the fluids not spreading out as much as we expect them to which causes more fluid than we plan to leak through to the Polyethylene layer, then, upon further cost analysis, we will consider adding a second Absorbent Core to our product. Another improvement, if our product does not catch most vomit, would be to redesign the head wings of the product to be shaped more like a bowl in order to catch vomit more effectively.

In our vision our product will be used with every patient who rides in the ambulance. For patients who will not bleed or vomit it may be a smart alternative to lay down the linen sheet on top of the Sponge System in order to not waste it. EMTs will have less cleaning responsibilities so that they can focus on their training and be exposed to cleaning chemicals much less often. EMTs will take inventories on Sundays and Thursdays and always be stocked for at least seven days in the event that a delivery truck cannot come on either Monday or Friday: We feel that Monday through Thursday may require the same amount of stock, or less, as Friday through Sunday. The medical field will be saving money on labor with our product which can be used for other important studies. Our product could be incorporated with a machine for fast DNA matching by using a very small sample with blood on it. We also see our product finding many other practical uses, such as a child's blanket to help them not dirty their bed as severely at a young age. Depending on our product's absorbance limits we may be able to make paper towel rolls out of this assembly for bars and homes for everyday spills and cleanup. We can also see our product in the sports industry: some sports arenas forbid spitting; there is a lot of bleeding in sports such as Lacrosse and Hockey. Any situation which currently uses a towel or paper towel can use our product.

The following are a few closing words on our product. Our product will soak up physiological fluids from stretcher patients and prevent the ambulance from getting dirty. The top layers of the Sponge System, the Acquisition\Distribution Layer and the Absorbent Core, are disposable and the Polyethylene Layer is recyclable. Our product outsources labor costs of cleaning ambulances into buying our product and saving the medical field money in the process. Our product doubles as a blanket and also dampens vibrations with the Akton Layer

Figure 30- The bottom of the prototype: Wings and the Akton layer

Figure 31- The top of the prototype: Wing and seat belt slits, ADL

Our prototype was created using the same materials we had tested throughout the year. The one exception is that we had run out of Underpads with which to insert Sodium Polyacrylate as the absorbent core. Instead we used baby diapers, which we feel is a good representation of our second and third layers of our product, since it has an absorbent core on top and polyethylene on the backside. We trimmed off the stretchy parts, as well as the ends of the diaper that stick to each other, in order to get the absorbent core of the diaper we were looking for. We super-glued three of these absorbent cores to each other, and then super-glued this to the top of top of a trimmed piece of Akton. We trimmed a piece of ADL and placed it on top, closing off the perimeters with some masking tape. We then cut slits into the sides and the middle using a knife and scissors, lining the wing slits with tape as well. Although we could not effectively line the seatbelt slits with tape, we did highlight them with a sharpie to make them more visible. Although the slits are not to scale with the actual engineering drawing, the entire prototype is approximately 10.5" by 11.5" and is a perfectly good visual representation of our final product.

5.2- Methods

5.2.1 AMTI Biomechanics Force Plate

In order to exposure our final design to different forces and moments, the ATMI Biomechanics Force Plate was used to analyze and quantify the force and moment values in the x, y, and z directions. These values are measured at the four corners of the force platform by proprietary load cells attached to strain gages. These strain gages have six Wheatstone bridges with four arms attached across eight or more gages within each Wheatstone bridge. Three of the output signals are proportional to the moments about the x, y, and z axes and another three output signals are proportional to the x, y, and z axes (Letendre [27]).

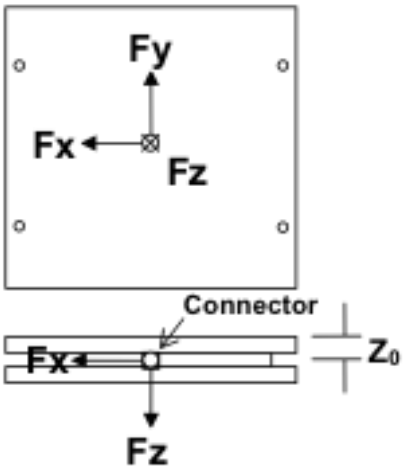


Figure 32- Location of the true origin and components of forces and moments

Figure 36 displays the origin and three different force directions for the components of the forces and moments. The positive z-axis points into the force platform, the positive x-axis points to the left of the origin and the positive y-axis points up towards the upper region of the force platform. The true origin lies at a point Z_0, which is the area under the top plate of the force platform. Calibrating the force platform helps to determine the origin within the top area

of the top plate (Letendre [27]).

When a force is placed upon the top surface of the force plate, the force components will be in the Fx, Fy, and Fz directions, but the moment components are Mx equaling Fx*0 - Fy*Z0 + Fz*Y + Tx, My equaling Fx*Z + Fy*0 - Fz*X + Ty , and Mz equaling - Fx*Y +Fy*X + Fz*0 + Tz, where the T components represent moments upon the top surface of the force platform. The moment components Tx and Ty do not apply physically upon general conditions, so both Tx and Ty equal out to zero. Once the true origin Z0 is found from calibrating the force plate and Mx, My, and Mz are also found , then the X-Y location of the resultant force and the moment applied upon the top surface of the force platform, Mz, can be found as well. Thus to find Mx and My will result from the multiplication of the force within the z-axis and the corresponding x and y directions. The moment Mx equals Fz times Y, My equals –Fz times X. From those two equations, the X component is My divided by Fz and the Y component quantifies as Mx divided by Fz. These four overall equations can help find Mz, which equals –Fx times Y plus Fy times X plus Tz or the moment within the top of the force plate within the z direction (Legendre [27]).

The overall calibration process of the force platform involves the use of the precision calibration stand within the force platform. The sensitivity within each of the six output channels applied to various components of load is calibrated. From this process, loads can be applied with the x, y, and z-axes and outputs within the six output channels can then be recorded. The true origin results from calibration, as the physical center within the x, y, and z-axes of the top plate of the force platform (Legendre [27]).

Figure 37 displays the sensitivity matrix used within the calibration report of the force platform. This calibration report is represented as a 6 x 6 matrix that labels all the force channels

of sensitivity within components of the force platform. Within the matrix, the input load is displayed within the top row of the matrix and outputs from all of the sensitivity channels are shown in the left column of the matrix. All the middle entries represented by S displayed the sensitivity values of each channel (Letendre [27]).

SENSITIVITY MATRIX
S(I,J)

	Fx	Fy	Fz	Mx	My	Mz
Fx'	S_{11}	S_{12}	S_{13}	S_{14}	S_{15}	S_{16}
Fy'	S_{21}	S_{22}	S_{23}	S_{24}	S_{25}	S_{26}
Fz'	S_{31}	S_{32}	S_{33}	S_{34}	S_{35}	S_{36}
Mx'	S_{41}	S_{42}	S_{43}	S_{44}	S_{45}	S_{46}
My'	S_{51}	S_{52}	S_{53}	S_{54}	S_{55}	S_{56}
Mz'	S_{61}	S_{62}	S_{63}	S_{64}	S_{65}	S_{66}

Figure 33-Sensitivity Matrix of the calibration report of all the force and moment components of the force platform (Hsieh[32])

For the users of the force platform to understand its operations and functions, Table 9 displays a table of various channels that explain a different function. The maximum excitation voltage for each channel is 10 VDC. The pin indicates the specific function and location of each channel within the force platform. Each channel either produces an excitation or an output, or is represented by the function column of Table 9 as also a negative or positive overall charge. The three components of force and moment are illustrated as different channels within the force platform (Letendre [27])

Table 7-The list of six channels and their specific function within the force

Pin	Function	Channel	Pin	Function	Channel
A	+ Excitation	Fx	N	+ Excitation	Mx
B	- Excitation	Fx	P	- Excitation	Mx
C	- Output	Fx	R	- Output	Mx
D	+ Output	Fx	S	+ Output	Mx
E	+ Excitation	Fy	T	+ Excitation	My
F	- Excitation	Fy	U	- Excitation	My
G	- Output	Fy	V	- Output	My
H	+ Output	Fy	W	+ Output	My
J	+ Excitation	Fz	X	+ Excitation	Mz
K	- Excitation	Fz	Y	- Excitation	Mz
L	- Output	Fz	Z	- Output	Mz
M	+ Output	Fz	a	+ Output	Mz
			b	No Connection	
			c	No Connection	

When considering the issue of mounting, the force platform must be positioned in a certain manner to obtain data of the various forces that are applied onto the platform. The top plate of the force platform serves as the sensor that senses different moments and forces applied to the platform. The overall force platform should be placed on a smooth and even surface that won't allow the platform to move in any type of matter that might alter the data readings. Situations involve dynamic forms of movement, such as running and jumping, should enable the testers to mount the platform in order to obtain the most accurate data possible. To achieve this goal, the platform could be fastened to a flat plate that is placed within a solid and stable structure. Any type of rocking or other unforeseen motions may alter data patterns and skew the overall shape of each data recording (Letendre [27]).

To properly for the force platform to get the most accurate readings possible, the top plate should be fastened to the base plate with four different sensing plates found in between the top and base plates. Forces applied to the top plate should distribute into the remaining sensing plates, in order for the base plate to receive accurate readings. Not mounting the base plate of the force platform may result in a non-linear loading pattern with respect to overall data recordings. Dismounting the base plate may also result in inaccurate data from dynamic testing, due to the occurrence of unforeseen vibrations within the base plate that could travel into each of the different components of the force platform. The base platform should be at a moderately rigid connection to the whole force platform, but tightly fastened to the mounting surface of the force platform. The overall connections between each component of the force plate should be linearly elastic and solid in nature. Any non-linearity within the force components of the force platform will lead to errors in data recordings. Thus fastening the force platform to a surface that's not flat will enable the recording of stresses within the plate's sensing components. Vibrations should be felt within the mounting surface because the platforms will act like accelerometers and generate outputs due to vibrations felt within the floor (Letendre [27]).

The illustration of the force platform within Figure 38 shows the mounting process of the force platform. As observed, a rigid mass is usually mounted under the force platform and contains a solid base such as concrete. The solid base should have a depth of about 6-18 inches under the mounting plate and force platform layer. About 1-2 mm should be spaced out between the force platform and its surrounding surface, in order for the platform to pick up accurate measurements (Letendre [27])

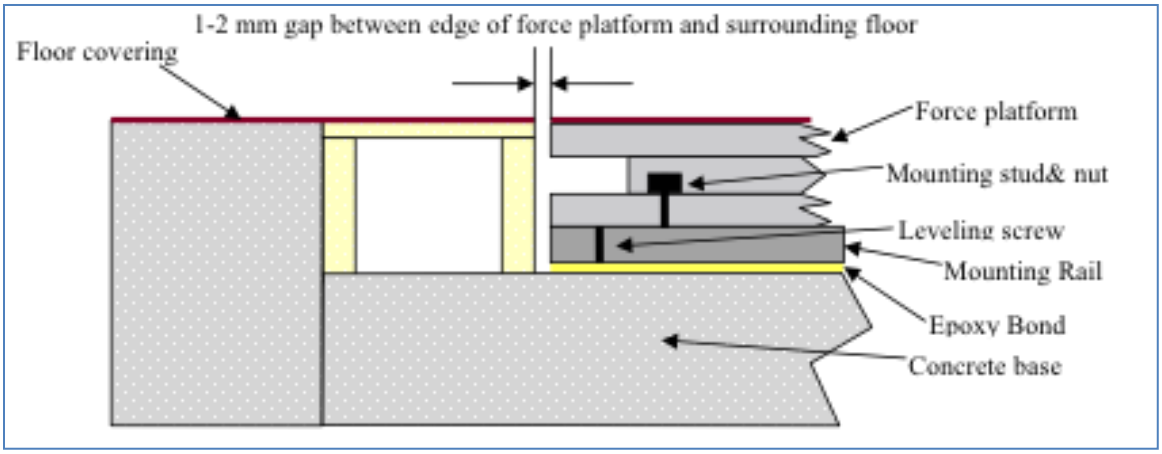


Figure 34-Mounting Process of Force Platform to the surrounding floor environment (Hsieh [32])

5.2.1.2 Protocol for Force-Plate Analysis

The goal of using this type of analysis was to have statistical and representative data that can show the validity of our group's final design. This analysis used a force plate to collect measurements based on the applied force placed onto the plate. There were two types of tests applied to the force plate, which were lying down and sitting upon the force plates. Forces were measured at both static and dynamic states during the sitting and lying down patterns of the subject. Data recordings took place within the Netforce data program and statistical analysis was produced within the Bioanalysis data program. These experiments took place with two of the group members. One of the group members was the test subject and the other test member handled the data measurements on the computer.

The first part of the FEA took results of comparing the force properties of the Akton polymer vibration-dampening layer versus a plain linen sheet. This part of the experiment involved the sitting process of the test subject on the force plate. Before starting the Netforce

program, all connections were checked from the force plate to the computer in order for proper measurements to take place. One group member then started the Netforce program within the computer. Before the test subject could sit down on the force plate, a group member had to zero out the plate and initially check if data recording was taking place. Once this process was complete, the test subject was able to sit upon the vibration-dampening layer with diaper middle layer prototype and linen sheet for data to be generated.

The first procedure implemented the use of the vibration-dampening layer with diaper middle layer prototype upon the force plate. This test was completed with the test subject being in static equilibrium and then proceeded to sit within the middle of the force plate, about 6 inches from the front of the force plate. Then the test subject slowly put his hands on top of his knees. The position remained constant, as the Netforce program would collect force data within a time frame of 30-45 seconds. This process was repeated two more times for the sake of repetition and for variation amongst the data.

The same procedure listed above was almost identically followed for the use of a linen sheet upon the force plate. This test was completed in a static state, in which the test subject remained still during the data recording process. The test subject proceeded to sit within the middle of the force plate, about 6 inches from the front of the force plate. Then the test subject would slowly put his hands on top of his knees. The position remained constant, as the Netforce program collected force data within a time frame of 30-45 seconds. This process was completed two more times, in order to compare these three trials to all the trials with use of the vibration-dampening layer.

The next test was performed using a dynamic testing technique. The main objective was for the test subject to hold itself over the force plate by placing his hands to the sides of the force plate and was instructed to place its gluteus maximus about 6 inches from the front of the force plate. When the group member was about to start the Netforce program, he shouted, "start" and this was the indication for the test subject to put its gluteus maximus on the force plate. Then the test subject proceeded to put its gluteus maximus on top of the force plate. Shortly after the test subject placed his arms over his knees and remained still for about 5 seconds. The Netforce software took this data recording over the 5-second time frame. Three trials following this protocol were performed on the vibration-dampening layer with diaper middle layer prototype and linen sheet respectfully. All results turned into statistical data with the use of Bioanalysis software.

The force plate was used within a setting for a model stretcher that would be placed upon the surface of a table. Three wooden blocks and one force plate represented the four positions of the stretcher. During different trials, the force plate was placed within each of the four positions. The head, upper back, thigh, and leg regions were represented by each of the force plate recordings.

During the first trial of the force plate, this plate was placed within the head region of the test subject. The subject was orientated in a way where the middle of the leg region was where the subject should align his legs. The subject was prepared for testing by crossing its arms across the chest region and remained in a still and stable position for a test time of about 30-45 seconds. The other group member said, "start" and data collection would take place by Netforce software. Then that same group member said, "relax" to indicate that the data recording has stopped. This procedure was repeated two more times.

During the second trial of the force plate, this plate was placed within the upper back region of the test subject. The subject was orientated in a way where the middle of the upper region was where most of the subject's force should be applied. The subject prepared for testing by crossing its arms across the chest region and remained in a still and stable position for a test time of about 30-45 seconds. The other group member said, "start" and data collection took place by Netforce software. That same group member said, "relax" to indicate that the data recording had stopped. This procedure was repeated two more times.

During the third trial of the force plate, this plate was placed within the thigh region of the test subject. The subject was orientated in a way where the middle of the thigh region was where most of the subject's force should be applied. The subject prepared for testing by crossing its arms across the chest region and remained in a still and stable position for a test time of about 30-45 seconds. The other group member said, "start" and data collection took place by Netforce software. That same group member said, "relax" to indicate that the data recording had stopped. This procedure was repeated two more times.

During the fourth trial of the force plate, this plate was placed within the lower leg region of the test subject. The subject was orientated in a way where the middle of the lower leg region was where most of the subject's force should be applied. The subject prepared for testing by crossing its arms across the chest region and remained in a still and stable position for a test time of about 30-45 seconds. The other group member said, "start" and data collection took place by Netforce software. That same group member said, "relax" to indicate that the data recording had stopped. This procedure was repeated two more times.

5.2.2 Vibration Application

In order to obtain information about the presence of vibration upon our group's design, an application was bought on the iPhone store for the iPhone 3Gs. The application was called Vibration, and this program is intended to measure vibrations within the x, y, and z directions for our final design.

Vibration uses an internal accelerometer within the structure of the iPhone, which can allow a program to analyze the patterns of vibration placed upon the iPhone. This application is known to use a generation of times series data to eliminate any type of DC signal and uses alongside a Hammering window to produce a range of frequency values by a Fast Fourier Transform. The accelerometer has a three channel sensitivity value around 0.02g and a range of values around ±2g. The main vibration graph lists three time form graphs measuring the root mean square within the x, y, and z directions (Rare Earth Magnets [31]).

Within the time series option of the Vibration application, three graphs measure acceleration over a range of time values over the span of three accelerometers. The root mean square is the measure of magnitude of waveform activity within the negative and positive directions. The overall root means square magnitude is given, along with magnitude values within the Y direction. The sample button is the way to collect data onto the Vibration app. A time series from about 128-256 values in the time series can be shown as real time progress within the graphs, but series longer than 256 will present a progress bar and a long time frame to collect data. Between each length of sample vibrations within each direction, the sample rate can be compared to the realistic sample length that the iPhone truly generates. The iPhone can automatically show a warning message if the time sample has a percent error more than 5%. Any record of data must be pressed by the sample button. The abort button is known to stop any

recording process of data only when acquisition of data has commenced. The snapshot button is known to take a picture of each of the frequency and time series tabs, which is placed within the photo album of the iPhone. The send CSV button displays an e-mail window to send the frequency time frame graph, amplitude time frame graph, and a Microsoft Excel file that documents all the amplitude and frequency values within the x, y, and z directions over different time values to any specified e-mail address. The settings button can be used to adjust numerous specific parameters related to the rate of how the Vibration app will collect and generate data. One can also touch any part of the screen of the time series graph display of the root means square (RMS) X, Y, and Z graphs, in order to trace specified values of the specific time and the specific position within the X, Y, or Z graphs (Rare Earth Magnets [31]).

In Figure 39 below, a screenshot shows the time series page of the Vibration app for the iPhone. A sample range of values has been taken within the three accelerometers of this iPhone program. Specific frequency values have been taken for the root means square within the x, y, and z axis. The magnitudes of the RMS values are above, along with two values in the Y direction. The sample, abort, snapshot, CSV, and settings buttons are displayed on the top region of the time series graph (Rare Earth Magnets [31]).

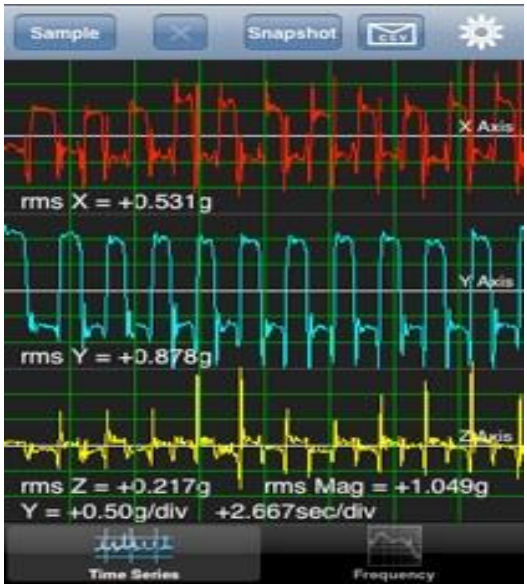


Figure 35-Snapshot of a trial run performed on time series menu of the iPhone Vibration App

Specifically, the time series graph has a settings option that has various options to choose from. The sample rate can be taken from 10-100 Hz and is the value that the accelerometer can acquire data at. The sample delay can range from 0-20 seconds and allows there to be a delay time before the actual accelerometer starts collecting data. The acquisition time can range from 1.28-102.40 seconds and sets in place the total number of data points being used during the data acquisition process. A low frequency pattern can be observed if the total data acquisition time is placed at a high number. The time series vertical scale can trigger the scaling process of time specific values and can range from 0.05-1.0 units. The DC removal switch can be used to regulate the removal of each average value from each specific data set. The calibrate button is used to scale and zero in each specific accelerometer. The trigger button works to control the overall rate of triggering. The "?" button is linked to the table of contents button of the Vibration app within Internet Explorer (Rare Earth Magnets [31]).

Within Figure 40, a screenshot is generated to outline the options displayed on the settings button of the time series menu. The sample rate slider is displayed at a rate of 100 Hz. The sample delay is displayed at 4 seconds. The acquisition time is highlighted at 2.56 seconds and a time series vertical scale is highlighted at .5 seconds. The "?" button is labeled in green, as well as DC remove is labeled “ON.” The "calibrate", "done", and "triggering" buttons are all shown at the bottom of the settings menu (Rare Earth Magnets [31]).

Figure 36-Snapshot of a trial run performed on the settings menu of the iPhone Vibration App

The second main tab on the Vibration app was the frequency display window. This tab was used to measure various amplitudes of the range of frequencies of the three channels for

accelerometers. The main difference between this tab and times series tab is that data sampling and capturing images aren't possible within the Frequency tab. The settings button allowed for frequency to be controlled by certain parameters within the program. Tracing data points are allowed within the frequency tab by the use of a cursor. Amplitude and frequency values can be traced within this tab for the three accelerometer channels and change for different positions where the cursor is placed upon the graph. The integration button allows for the frequency tab data to be integrated and turn into velocity values in mm/sec and in/sec, or be integrated again to turn into a range of displacement values in mm/in. The differentiation button allows the data to be assessed by the displacement to velocity alteration or the velocity to acceleration alteration (Rare Earth Magnets [31]).

Figure 41 shows a data recording in which the frequency tab was highlighted. The vibrations within the x, y, and z axes are highlighted by various spikes and dips within a specific time frame. The velocity range is from 0.01 mm/s-100 mm/s over the frequency range of 0.10 Hz-10 Hz for the three accelerometer channels. The settings tab, differentiation, and integration buttons are found to the extreme right of the graph (Rare Earth Magnets [31]).

Figure 37-Snapshot of a trial run performed on the frequency tap menu of the Vibration App

As a separate button within the frequency display menu, the frequency display settings can help adjust specific parameters within the three accelerometer graphs of frequency. The three axes display various plots within the x, y, and z directions, which allow the tester to switch on and off separate frequency plots within the x, y, and z directions. As long as one of the two axes of the frequency plots are operating within the Log mode, the axis display switches will be able to be visible. Switches that turn on within Linear mode, three plots will be display separate information in one connected and enabled plot. The log plot switches interpreted rather the axis that these graphs are frequency graphs are plotted against are either in linear or log mode. When log plot switches are off, the three separate plots are placed together on each other. The Hz/Rpm switch allows for units to be established within the frequency axis graphs, with Hz measured in cycles/second and rpm measured in revolutions/minute. The frequency scale option sets into place the vertical scale of the frequency plots once the y direction plot is in linear mode

5.2.2.1- Vibration Experimental Protocol

The purpose of this testing procedure was to see a substantial difference in the frequency and amplitude graphs of the Akton vibration-damping layer versus the linen sheet. The software used was an iPhone App called Vibration, which used an internal accelerometer to measure and identify vibrations within the x, y, and z planes. A total of twelve trials were performed within the time span of about 25 seconds per trial. The car used to generate vibrations was a 2010 Honda Accord LX. This car was to go travel through two different types of road surfaces, which were an urban bumpy road and an urban smooth road. A group member was the driver of the vehicle, and another group member would place down both the linen sheets and vibration-dampening layers and commence the Vibration program within the iPhone.

The first test was performed on an urban bumpy road with a linen sheet being used to collect data from. The first step was setting up the linen sheet on the floor of the front passenger side, when the car was not in motion. The Vibration App was turned on from the iPhone, and the following settings would be set up. The gear button within the app was pressed and various settings were put into place. The sample rate was set to 7 Hz. The sample delay was set to 2 seconds. The acquisition time was set to 25 seconds. The time series vertical scale was set to .5 and the DC remove option was set to ON. The sample rate was the pace that the accelerometer receives data into the iPhone app. The sample delay was the rate that the iPhone was delayed from the generation of collecting and obtaining data. The acquisition time was the total time that the Vibration app actually recorded data. The time series vertical scale represented the scaling of the time series graph. The DC remove switch was used to control the instantaneous withdrawal of the average value from the set of data points. Each trial was calibrated to ensure accuracy within range of measurements. Once all options were selected within this section, the sample button was pressed within the iPhone. Once pressing the sample button, this gave the group

member 2 seconds to place the iPhone on top of the linen sheet. The other group member would slowly drive the vehicle at a constant speed of 7 miles per hour down the bumpy urban road. The total time of 25 seconds was reflected within the graphs, as x, y, and z directional vibration data was generated. A range of frequency and wavelength values were produced and collected as data within an Excel spreadsheet. These data values were created as a graph for all the data points over the 25 second time frame. The same procedure was followed for the same two remaining trials of linen sheet vibrations over an urban bumpy road.

The second test was performed on an urban bumpy road with a vibration-dampening layer being used to collect data from. The first step was setting up the vibration-dampening layer on the floor of the front passenger side, when the car was not in motion. The Vibration App was turned on from the iPhone, and the following settings were set up. The gear button within the app was pressed and various settings would be put into place. The sample rate was set to 7 Hz. The sample delay was set to 2 seconds. The acquisition time was set to 25 seconds. The time series vertical scale was set to .5 and the DC remove option was set to ON. Each trial was calibrated to ensure accuracy within range of measurements. Once all options were selected within this section, the sample button was pressed within the iPhone. Once pressing the sample button, this gave the group member 2 seconds to place the iPhone on top of the linen sheet. One group member would say, "start" when he was ready to start data acquisition. The other group member would slowly drive the vehicle at a constant speed of 7 miles per hour down the bumpy urban road. The total time of 25 seconds would be reflected within the graphs, as x, y, and z direction vibration data would be generated. A range of frequency and wavelength values were produced and collected as data within an Excel spreadsheet. These data values were created as a graph for all the data points over the 25 second time frame. The same procedure was followed

for the same two remaining trials of the vibration-dampening layer over an urban bumpy road.

The third test was performed on an urban smooth road with a linen sheet being used to collect data from. The first step was setting up the linen sheet on the floor of the passenger side seat, when the car was not in motion. The Vibration App was turned on from the iPhone, and the following settings would be set up. The gear button within the app was pressed and various settings would be put into place. The sample rate was set to 7 Hz. The sample delay was set to 2 seconds. The acquisition time was set to 25 seconds. The time series vertical scale was set to .5 and the DC remove option was set to ON. The sample rate is the pace that the accelerometer receives data into the iPhone app. Each trial was calibrated to ensure accuracy within range of measurements. Once all options were selected within this section, the sample button was pressed within the iPhone. Once pressing the sample button, this gave one group member 2 seconds to place the iPhone on top of the linen sheet. The other group member slowly drove the vehicle at a constant speed of 7 miles per hour down the smooth urban road. The total time of 25 seconds was reflected within the graphs, as x, y, and z directional vibration data would be generated. A range of frequency and wavelength values were produced and collected as data within an Excel spreadsheet. These data values were created as a graph for all the data points over the 25 second time frame. The same procedure was followed for the same two remaining trials of linen sheet vibrations over a smooth urban road.

The first trial was performed on an urban bumpy road with a linen sheet being used to collect data from. The first step was setting up the linen sheet on the floor of the passenger seat, when the car was not in motion. The Vibration App was turned on from the iPhone, and the following settings were set up. The gear button within the app would be pressed and various settings were put into place. The sample rate was set to 7 Hz. The sample delay was set to 2

seconds. The acquisition time was set to 25 seconds. The time series vertical scale was set to .5 and the DC remove option was set to ON. Each trial was calibrated to ensure accuracy within range of measurements. Once all options were selected within this section, the sample button was pressed within the iPhone. Once pressing the sample button, this gave the group member 2 seconds to place the iPhone on top of the linen sheet. The other group member slowed the vehicle at a constant speed of 7 miles per hour down the bumpy urban road. The total time of 25 seconds were reflected within the graphs, as x, y, and z directional vibration data was generated. A range of frequency and wavelength values were produced and collected as data within an Excel spreadsheet. These data values were created as a graph for all the data points over the 25 second time frame. The same procedure was followed for the same remaining two trials of linen sheet vibrations over an urban smooth road.

Results from all 12 trials of measurement of vibrations within the vibration-dampening layer and linen sheet testing mediums were sent via e-mail by the CSV button on the Vibration app program. A frequency vs. time graph, amplitude vs. time graph, and Excel data sheet were all created from the Vibration iPhone app. The Excel data sheets for all 12 trials enlisted frequency and amplitude measurements over time, within the x, y, and z directions of vibrational generation. Further statistical and quantitative analysis could be made based on the data collected from the Vibration iPhone app over the specified 12 trials.

5.2.3-Absorbance Testing and Procedure of Absorbance Experiments

One of the important objectives of this device is to absorb bodily fluid excretions of patient on the ambulance. On this basis, our approach to satisfy this objective evolved to offer the best solution. Wettability absorbance experiments were devised to test the effectiveness of our product. The two major considerations of the superabsorbent layer are: maximum absorbance

capacity (MAC) and maximum pressure sustained (MPS). Within our product, the main variables that control the aforementioned considerations are: Sodium Polyacrylate (SPA), and cellulose.

The major component of most bodily fluid excretions is water. Water will be used as the capacity load in these experiments. The water load will be varied according to the testing procedure. When measuring the maximum absorbance capacity (MAC), the tests will determine the material's MAC of water.

The maximum pressure sustained (MPS) will be determined via applying weights on a known cross sectional area. An increase of weight and a decrease of area in which the weight is applied will yield a greater pressure on the material. The properties of MAC and MPS are related and dependent on each other. The following test results will show this relationship.

Sodium polyacrylate (SPA) is a big contributor to the pad's absorbance ability. A relationship between the added SPA and the MAC was investigated. The group investigated if an increase of 2 g to the absorbent pad will significantly increase the MAC of the pad. Cellulose is another major component in the absorbance ability of the pad. Similarly, the relationship between the amount of cellulose added and MAC was studied. Also, the group investigated if an increase of 5 g of cellulose to the absorbent pad will significantly increase the MAC of the pad.

There were five materials tested under a uniformed pressure of about 2000 Pa and a varying water load. The first material that was tested is linen sheet, and it acted as a control. Linen sheet is the material currently used to cover the ambulance stretcher mattress. The second material tested was a cellulose absorbent pad. The third material tested was a cellulose absorbent pad reinforced with 2 grams of SPA. The fourth material tested was a cellulose absorbent pad

reinforced with an additional 5 grams of cellulose. The fifth material tested was a developed superabsorbent SPA (1 gram) diaper pad (FD). In addition to cellulose, it contains ADL which aids in the distribution of the fluid upon absorbance. Moreover, the group investigated if the FD product will have significantly higher MAC compared to the control and the cellulose pad. Moreover, the group investigated if the FD product will have significantly higher MAC compared to the control and the cellulose pad.

The first experiment tested for absorbance. The experiment was to determine how much water leaked from the material under a uniformed pressure, and varying water load. The following procedure was followed to do the first experiment:

1. The five different materials were cut into uniformed length and width dimensions (15cm x 15cm). These will act as testing materials
2. The first testing material was weighed using a digital weight scale.
3. A water load, 10 grams, was added to the testing material.
4. A load of 1 kg (pressure= 1960 Pa) was applied on the testing material for a period of 20 seconds
5. An absorbing towel was put on top of the surface of the testing material. A load of 1 kg was applied on the testing material for 20 seconds.
6. The testing material was weighed, and the weight difference was noted.
7. Repeat steps 1-6 two more times, to do 3 trials of the same material and the same water load.
8. Repeat steps 2-7, using a water load of 50grams instead.
9. Repeat steps 2-7, using a water load of 100 grams instead.
10. Repeat steps 2-9, using the second material instead.

11. Repeat steps 2-9, using the third material instead.
12. Repeat steps 2-9, using the fourth material instead.
13. Repeat steps 2-9, using the fifth material instead.

The second absorbance experiment tested for two quantities. The first quantity was determining how much water leaked from the material under a uniformed pressure, and varying water load. The second quantity was determining the adhesiveness of the surface of the material to water. The following procedure was followed to do the first experiment:

1. The five different materials were cut into uniformed length and width dimensions (15cmX15cm). These will act as testing materials
2. The first testing material was weighed using a digital weight scale.
3. A water load, 200 grams, was added to the testing material.
4. A load of 1 kg (pressure= 1960 Pa) was applied on the testing material for a period of 20 seconds
5. The testing material was picked up in a way that it is perpendicular to the ground surface for a period of 20 seconds or until water drops stop. The water drops, if any, were collected in a beaker.
6. The testing material was weighed again, and the weight was recorded. The weight difference was noted.
7. The testing material was returned to the testing area. An absorbing towel was put on top of the surface of the testing material. A load of 1 kg was applied on the testing material for 20 seconds.
8. The testing material was weighed again, and the weight difference was noted.
9. Repeat steps 2-8 twice, to do 3 trials of the same material and the same water load.

10. Repeat steps 2-9, using the second material instead.
11. Repeat steps 2-9, using the third material instead.
12. Repeat steps 2-9, using the fourth material instead.
13. Repeat steps 2-9, using the fifth material instead.

The third absorbance experiment investigated the relationship between MAC and MPS. A uniformed water load of 50 grams was applied to the 2nd material. The applied weight varied: 1kg, 5kg, and 10kg. The following procedure was followed:

1. A length and width dimension of 15cmX 15cm of the second material was used as the testing material.
2. The testing material was weighed using a digital weight scale.
3. The water load, 50 grams, was added to the testing material.
4. An absorbing towel was put on top of the surface of the testing material. A load of 1kg (pressure= 1960 Pa) was applied on the testing material for 30 seconds.
5. The testing material was weighed again, and the weight difference was noted.
6. Repeat steps 1-5 three more times, to do 3 trials of the same pressure and the same water load.
7. Repeat steps 1-6 , using the same water load and an applied load of 5 kg(pressure= 9800 Pa)
8. Repeat steps 1-6, using the same water load and an applied load of 10 kg (pressure =.19600 Pa)

5.3- Results and Discussion

In this section, the various quantitative analyses executed to design and test the surgical sponge pad were done. The goals of the tests were to prove the validity of our project and to provide consistent, accurate data to show quantifiable improvements from the current conditions within the ambulance environment. The tests included vibration testing, impact and static force plate analysis, and absorbance experiments.

5.3.1 Vibration Testing

Vibration results were compared on the basis of frequency and amplitudes. The group with the lower amplitudes and frequency ranges determined rather or not each material is effective in reducing vibrations. The amplitude is defined as the height of each individual wave over a time period. The frequency is defined as the number of cycles divided by time length.

The first set of trials was conducted on a bumpy urban road. Figure 42 displayed the time vs. frequency graph of the linen sheet being tested over a 25-second time frame on a bumpy urban road surface. Figure 43 displayed the time vs. frequency graph of the Akton polymer being tested over a 25-second time frame on a bumpy urban road surface. The amplitude was found to be higher within the time frequency graph of the linen sheet compared to the Akton polymer. The amplitude of the linen sheet frequency vs. time graph was 2.25 cm, and amplitude of the Akton polymer frequency vs. time graph was 1.65 cm. The frequency of the entire frequency vs. time graph for the linen sheet was: f =30 cycles/25 sec= 1.20 Hz. The frequency of the entire frequency vs. time graph for the Akton polymer was: f= 27 cycles/25 sec= 1.08 Hz.

Figure 38-Frequency vs. Time graph of 1st trial on bumpy road with linen

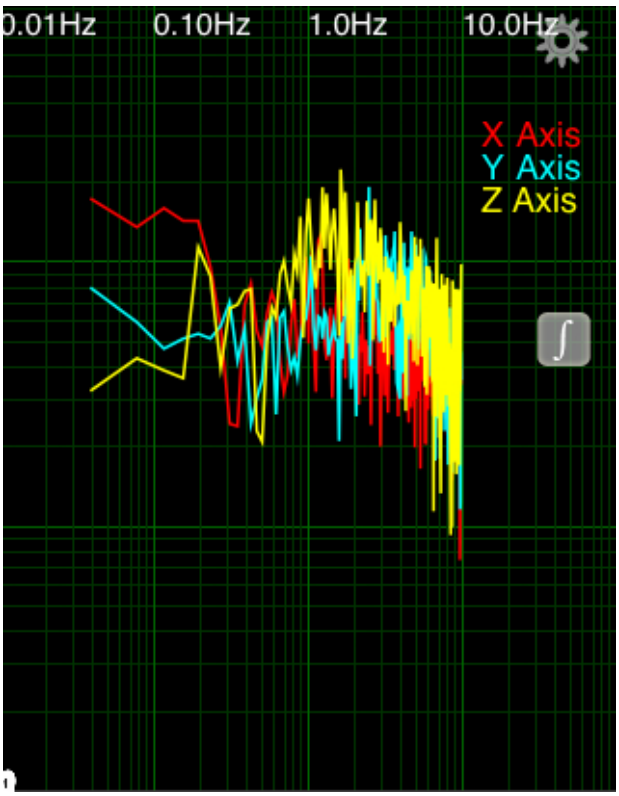


Figure 39-Frequency vs. Time graph of 1st trial on bumpy road with Akton polymer

The second set of trials was conducted on a bumpy urban road. Figure 44 displayed the time vs. frequency graph of the linen sheet being tested over a 25-second time frame on a bumpy urban road surface. Figure 45 displayed the time vs. frequency graph of the Akton polymer being tested over a 25-second time frame on a bumpy urban road surface. The amplitude was found to be higher within the time frequency graph of the linen sheet compared to the Akton polymer. The amplitude of the linen sheet frequency vs. time graph was 2.50 cm, and amplitude of the Akton polymer frequency vs. time graph was 1.70 cm. The frequency of the entire frequency vs. time graph for the linen sheet was: f =29 cycles/25 sec= 1.16 Hz. The frequency of the entire frequency vs. time graph for the Akton polymer was: f= 21 cycles/25 sec= 0.84 Hz.

Figure 40-Frequency vs. Time graph of 2nd trial on bumpy road with linen sheet

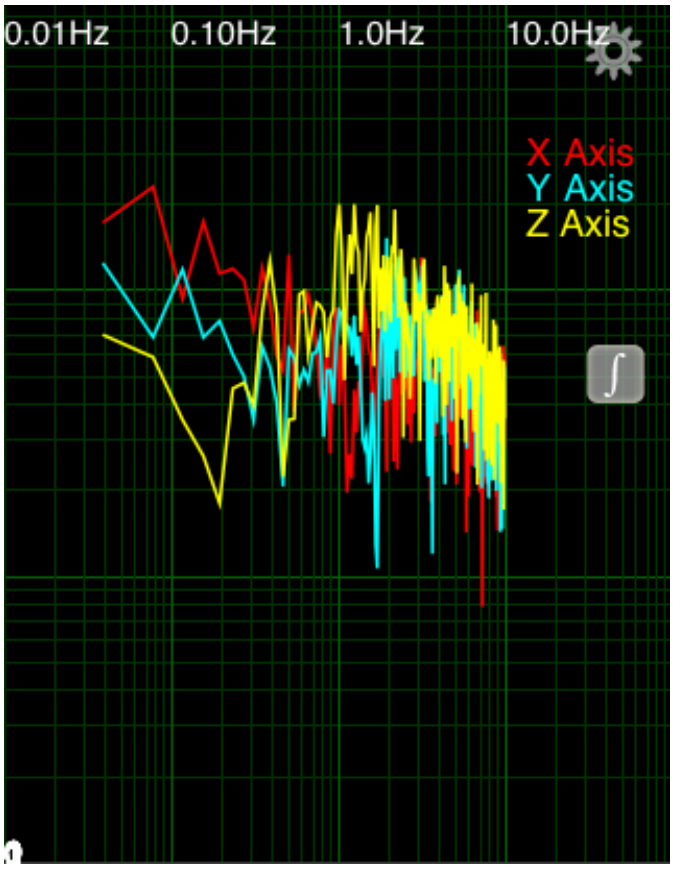


Figure 41-Frequency vs. Time graph of 2nd trial on bumpy road with Akton polymer

The third set of trials was conducted on a bumpy urban road. Figure 46 displayed the time vs. frequency graph of the linen sheet being tested over a 25-second time frame on a bumpy

urban road surface. Figure 47 displayed the time vs. frequency graph of the Akton polymer being tested over a 25-second time frame on a bumpy urban road surface. The amplitude was found to be higher within the time frequency graph of the linen sheet compared to the Akton polymer. The amplitude of the linen sheet frequency vs. time graph was 2.60 cm, and amplitude of the Akton polymer frequency vs. time graph was 2.15 cm. The frequency of the entire frequency vs. time graph for the linen sheet was: f =28 cycles/25 sec= 1.12 Hz. The frequency of the entire frequency vs. time graph for the Akton polymer was: f= 24 cycles/25 sec= 0.96 Hz.

Figure 42-Frequency vs. Time graph of 3rd trial on bumpy road with linen sheet

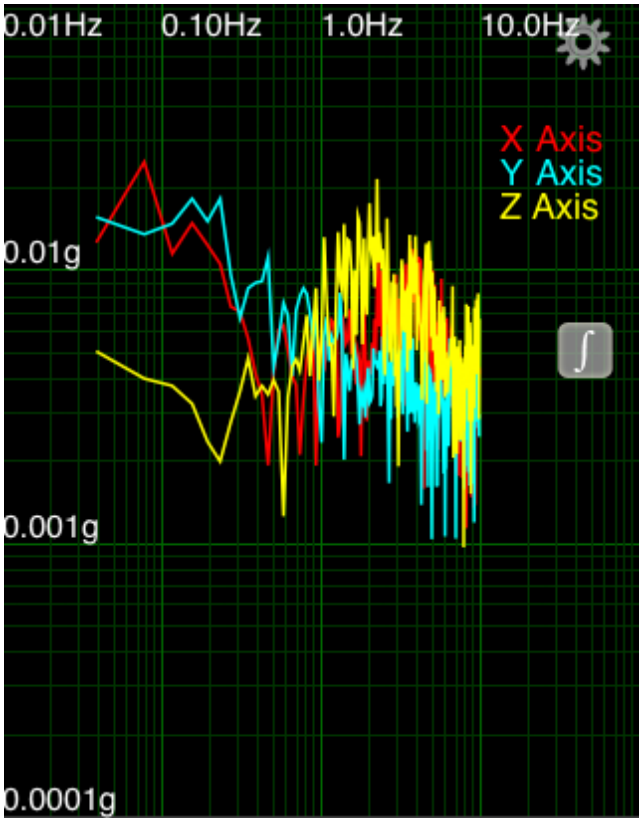


Figure 43-Frequency vs. Time graph of 3rd trial on bumpy road with Akton polymer

The fourth set of trials was conducted on a smooth urban road. Figure 48 displayed the time vs. frequency graph of the linen sheet being tested over a 25-second time frame on a smooth urban road surface. Figure 49 displayed the time vs. frequency graph of the Akton polymer being tested over a 25-second time frame on a smooth urban road surface. The amplitude was found to be higher within the time frequency graph of the linen sheet compared to the Akton polymer. The amplitude of the linen sheet frequency vs. time graph was 2.05 cm, and amplitude of the Akton polymer frequency vs. time graph was 1.60 cm. The frequency of the entire frequency vs. time graph for the linen sheet was: f =23 cycles/25 sec= 0.92 Hz. The frequency of the entire frequency vs. time graph for the Akton polymer was: f= 18 cycles/25 sec= 0.72 Hz.

Figure 44-Frequency vs. Time graph of 1st trial on smooth road with linen sheet

Figure 45-Frequency vs. Time graph of 1st trial on smooth road with Akton polymer

The fifth set of trials was conducted on a smooth urban road. Figure 50 displayed the time vs. frequency graph of the linen sheet being tested over a 25-second time frame on a smooth urban road surface. Figure 51 displayed the time vs. frequency graph of the Akton polymer being tested over a 25-second time frame on a smooth urban road surface. The amplitude was found to be higher within the time frequency graph of the linen sheet compared to the Akton polymer. The amplitude of the linen sheet frequency vs. time graph was 2.15 cm, and amplitude of the Akton polymer frequency vs. time graph was 1.55 cm. The frequency of the entire frequency vs. time graph for the linen sheet was: f =22 cycles/25 sec= 0.88 Hz. The frequency of the entire frequency vs. time graph for the Akton polymer was: f= 18 cycles/25 sec= 0.72 Hz.

Figure 46- Frequency vs. Time graph of 2nd trial on smooth road with linen sheet

Figure 47-Frequency vs. Time graph of 2nd trial on smooth road with Akton Polymer

The sixth set of trials was conducted on a smooth urban road. Figure 52 displayed the time vs. frequency graph of the linen sheet being tested over a 25-second time frame on a smooth urban road surface. Figure 53 displayed the time vs. frequency graph of the Akton polymer being tested over a 25-second time frame on a smooth urban road surface. The amplitude was found to be higher within the time frequency graph of the linen sheet compared to the Akton polymer. The amplitude of the linen sheet frequency vs. time graph was 2.20 cm, and amplitude of the Akton polymer frequency vs. time graph was 1.70 cm. The frequency of the entire frequency vs. time graph for the linen sheet was: f =23 cycles/25 sec= 0.92 Hz. The frequency of the entire frequency vs. time graph for the Akton polymer was: f= 19 cycles/25 sec= 0.76 Hz.

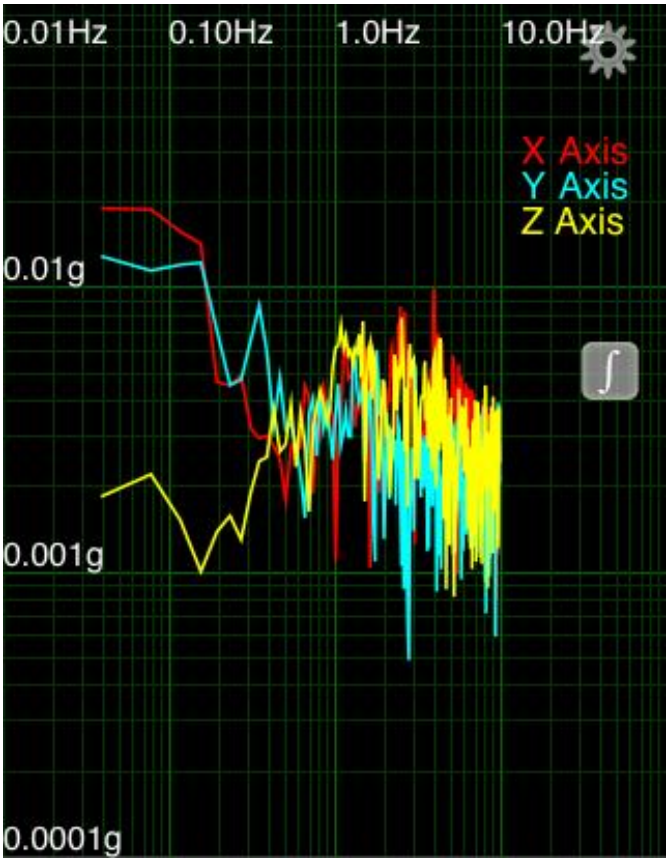


Figure 48- Frequency vs. Time graph of 3rd trial on smooth road with linen sheet

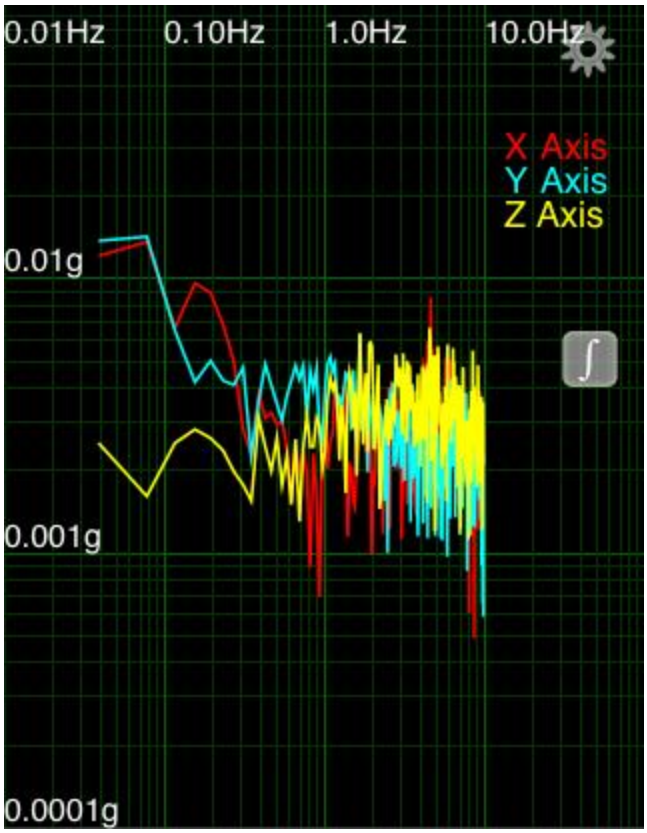


Figure 49- Frequency vs. Time graph of 3rd trial on smooth road with Akton Polymer

Percentage differences were calculated to generate the difference in comparison to the vibration suppressing properties of the Akton Polymer over the linen sheet. To calculate this figure, the amplitude and frequency values of the Akton polymer and linen sheet for both bumpy and smooth road surfaces were the figures for comparison.

The first set of trials performed on a bumpy road was considered as a basis of comparison for the Akton Polymer and linen sheet models. The amplitude for the Akton polymer was 1.65 cm and the amplitude of the linen sheet was 2.25 cm. The frequency for the Akton Polymer was 1.08 Hz and frequency for the linen sheet was 1.20 Hz.

Finding % difference for amplitudes:

= (Akton amplitude/Linen Sheet amplitude) x 100

= (1.65 cm/ 2.25 cm) x 100 = 73.3

= 100 – 73.3 = **26.7 % difference of the Akton polymer over the linen sheet**

Finding % difference for frequencies:

= (Akton frequency/Linen Sheet frequency) x 100

= (1.08 Hz / 1.20 Hz) x 100 = 90.0

= 100 – 90.0 = **10.0 % difference of the Akton polymer over the linen sheet**

The second set of trials performed on a bumpy road was considered as a basis of comparison for the Akton Polymer and linen sheet models. The amplitude for the Akton polymer was 1.70 cm and the amplitude of the linen sheet was 2.50 cm. The frequency for the Akton Polymer was 0.84 Hz and frequency for the linen sheet was 1.16 Hz.

Finding % difference for amplitudes:

= (Akton amplitude/Linen Sheet amplitude) x 100

= (1.70 cm/ 2.50 cm) x 100 = 68.0

= 100 – 68.0 = **32.0 % difference of the Akton polymer over the linen sheet**

Finding % difference for frequencies:

= (Akton frequency/Linen Sheet frequency) x 100

= (0.84 Hz / 1.16 Hz) x 100 = 72.4

= 100 – 72.4 = **27.6 % difference of the Akton polymer over the linen sheet**

The third set of trials performed on a bumpy road was considered as a basis of comparison for the Akton Polymer and linen sheet models. The amplitude for the Akton polymer was 2.15 cm and the amplitude of the linen sheet was 2.60 cm. The frequency for the Akton Polymer was 0.96 Hz and frequency for the linen sheet was 1.12 Hz.

Finding % difference for amplitudes:

= (Akton amplitude/Linen Sheet amplitude) x 100

= (2.15 cm/ 2.60 cm) x 100 = 82.7

= 100 – 82.7 = **17.3 % difference of the Akton polymer over the linen sheet**

Finding % difference for frequencies:

= (Akton frequency/Linen Sheet frequency) x 100

= (0.96 Hz / 1.12 Hz) x 100 = 85.7

= 100 – 72.4 = **14.3 % difference of the Akton polymer over the linen sheet**

The other main set of trials was performed within a smooth urban road. The first set of trials performed on a smooth road was considered as a basis of comparison for the Akton Polymer and linen sheet models. The amplitude for the Akton polymer was 1.60 cm and the amplitude of the linen sheet was 2.05 cm. The frequency for the Akton Polymer was 0.92 Hz and frequency for the linen sheet was 1.12 Hz.

Finding % difference for amplitudes:

= (Akton amplitude/Linen Sheet amplitude) x 100

= (1.60 cm/ 2.05 cm) x 100 = 78.0

= 100 – 78.0 = **22.0 % difference of the Akton polymer over the linen sheet**

Finding % difference for frequencies:

= (Akton frequency/Linen Sheet frequency) x 100

= (0.72 Hz / 0.92 Hz) x 100 = 78.3

= 100 – 78.3 = **21.7 % difference of the Akton polymer over the linen sheet**

The second set of trials performed on a smooth road was considered as a basis of comparison for the Akton Polymer and linen sheet models. The amplitude for the Akton

polymer was 1.55 cm and the amplitude of the linen sheet was 2.15 cm. The frequency for the Akton Polymer was 0.72 Hz and frequency for the linen sheet was 0.88 Hz.

Finding % difference for amplitudes:

= (Akton amplitude/Linen Sheet amplitude) x 100

= (1.55 cm/ 2.15 cm) x 100 = 72.1

= 100 – 72.1= **27.9 % difference of the Akton polymer over the linen sheet**

Finding % difference for frequencies:

= (Akton frequency/Linen Sheet frequency) x 100

= (0.72 Hz / 0.88 Hz) x 100 = 81.8

= 100 – 81.8= **18.2 % difference of the Akton polymer over the linen sheet**

The third set of trials performed on a smooth road was considered as a basis of comparison for the Akton Polymer and linen sheet models. The amplitude for the Akton polymer was 1.70 cm and the amplitude of the linen sheet was 2.20 cm. The frequency for the Akton Polymer was 0.76 Hz and frequency for the linen sheet was 0.92 Hz.

Finding % difference for amplitudes:

= (Akton amplitude/Linen Sheet amplitude) x 100

= (1.70 cm/ 2.20 cm) x 100 = 77.3

= 100 – 77.3= **22.7 % difference of the Akton polymer over the linen sheet**

Finding % difference for frequencies:

= (Akton frequency/Linen Sheet frequency) x 100

= (0.76 Hz / 0.92 Hz) x 100 = 82.6

= 100 – 82.6 = **17.4 % difference of the Akton polymer over the linen sheet**

5.3.2- Balance and Impact Force-Plate Testing

In order to get an accurate recollection of all the forces and moments applied onto the body, the AMTI force plate was used for both our tested prototype and control factor. The tested prototype consisted of a bottom Akton polymer vibration damping layer with a top layer of cellulose and sodium polyacrylate glued on top. The control factor just consisted of a linen sheet. A balance Netforce analysis was performed since static conditions were considered.

Figures 54 and 55 show the experimental construct of where the force plate was located. This figure represents the four different regions of a model stretcher. The first region was regarded as the spot for the head, second region was placed for the torso and back areas, third region was allocated as the thigh and upper part of the lower leg area, and the fourth region was formulated at the area for the lower region of lower leg and feet area. For each trial run, the AMTI force plate was changed to each of the four regions and the remaining three regions would have wooden blocks placed amongst the model stretcher. All situations involved around 45 seconds of data recording by the Netforce computer program and the test subject had to be in a static and stable lying down position during data recording.

Figure 50- Overview of the four regions of the model stretcher

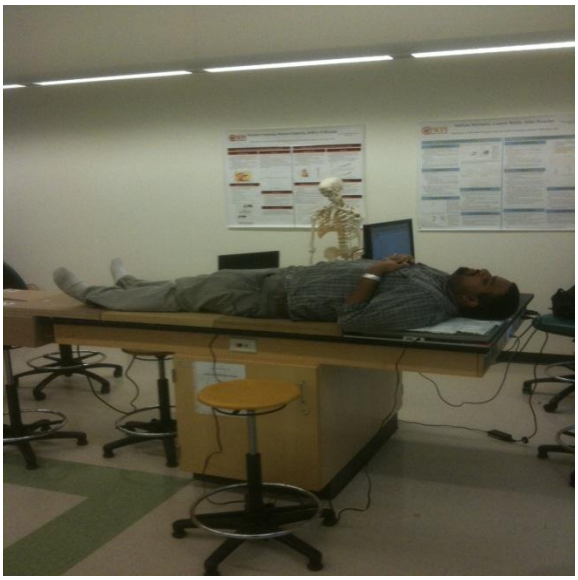


Figure 51- Outlining of test subject on model stretcher with force plate set up upon the first region

Two programs were used to analyze the various force and moment components within the four regions of the model stretcher. The first program was Netforce, which was used to generate force and moment readings in real time in accordance to the force plate. The second program was Bioanalysis, which gave statistics and data points comparing relationships to the area of applied pressure within the force plate.

Tables 10 and 11 below, label statistics that were generated from the force plate being placed within the first region of the model stretcher. Three trial runs were performed on the linen sheet region within the force plate. Three more trial runs were performed on the tested prototype region within the force plate. The three main pieces of information that were compared with the linen sheet and tested prototype were the 95% ellipse area, average velocity, and length values.

Table 8- Bioanalysis results from three trials of force plate analysis of the linen sheet within the first region of the stretcher

Parameters	Max	Min	Avg	SD
COP-X Avg (in.)	5.535	5.469	5.502	0.046
COP-Y Avg (in.)	0.186	0.148	0.167	0.027
COP-X Max (in.)	0.083	0.066	0.074	0.012
COP-X Min (in.)	-0.064	-0.071	-0.067	0.005
COP-Y Max (in.)	0.035	0.032	0.033	0.002
COP-Y Min (in.)	-0.033	-0.034	-0.034	0.001
Standard Deviation - X COP	0.028	0.027	0.027	0.001
Standard Deviation - Y COP	0.011	0.011	0.011	0
Avg. Displacement along X (in.)	0.023	0.022	0.023	0.001
Avg. Displacement along Y (in.)	0.009	0.008	0.009	0
Avg. Radial Displacement (in.)	0.026	0.026	0.026	0
Standard Deviation - Radial Disp	0.015	0.012	0.014	0.002
Corelation Coefficient	0.089	-0.08	0.004	0.119
95% Ellipse Slope	2.43	-2.195	0.118	3.27
SD - Major Axis of 95%Ellipse	0.028	0.027	0.027	0.001
SD - Minor Axis of 95%Ellipse	0.011	0.011	0.011	0
95% Ellipse Area (in..in.)	0.006	0.005	0.006	0
Avg Velocity (ft/sec)	1.327	1.303	1.315	0.016
Length (in.)	26.532	26.066	26.299	0.33

Table 9- Bioanalysis results from three trials of force plate analysis of the tested prototype within the first region of the stretcher

Parameters	Max	Min	Avg	SD
COP-X Avg (in.)	5.161	5.109	5.135	0.036
COP-Y Avg (in.)	1.026	0.961	0.993	0.046
COP-X Max (in.)	0.097	0.054	0.076	0.031
COP-X Min (in.)	-0.058	-0.081	-0.07	0.017
COP-Y Max (in.)	0.035	0.035	0.035	0.001
COP-Y Min (in.)	-0.025	-0.031	-0.028	0.004
Standard Deviation - X COP	0.035	0.021	0.028	0.01
Standard Deviation - Y COP	0.011	0.008	0.01	0.003
Avg. Displacement along X (in.)	0.029	0.018	0.023	0.008
Avg. Displacement along Y (in.)	0.01	0.006	0.008	0.002
Avg. Radial Displacement (in.)	0.032	0.02	0.026	0.009
Standard Deviation - Radial Disp	0.018	0.011	0.015	0.005
Corelation Coefficient	-0.18	-0.543	-0.361	0.257
95% Ellipse Slope	-4.428	-10.998	-7.713	4.646
SD - Major Axis of 95%Ellipse	0.035	0.021	0.028	0.01
SD - Minor Axis of 95%Ellipse	0.009	0.008	0.009	0.001
95% Ellipse Area (in..in.)	0.006	0.003	0.005	0.002
Avg Velocity (ft/sec)	1.13	1.039	1.084	0.064
Length (in.)	22.592	20.774	21.683	1.286

From Tables 12 and 13, the 95% ellipse area, average velocity, and length values were compared. The values from the average column were analyzed. The overall average velocity and length values were smaller from the tested prototype as compared to the linen sheet. The 95% ellipse areas were about the same for both the tested prototype and linen sheet. The smaller length of the tested prototype suggests that the overall range of pressure was smaller in the prototype as compared to the linen sheet. The smaller velocity of the tested prototype persuades that there was more movement within the force plate of the linen sheet as compared with the tested prototype.

Table 10- Bioanalysis results from three trials of force plate analysis of the linen sheet within the second region of the stretcher

Parameters	Max	Min	Avg	SD
COP-X Avg (in.)	0.402	0.348	0.372	0.039
COP-Y Avg (in.)	1.021	0.991	1.004	0.022
COP-X Max (in.)	0.066	0.043	0.056	0.017
COP-X Min (in.)	-0.035	-0.047	-0.043	0.01
COP-Y Max (in.)	0.028	0.019	0.024	0.006
COP-Y Min (in.)	-0.02	-0.024	-0.022	0.003
Standard Deviation - X COP	0.023	0.014	0.02	0.007
Standard Deviation - Y COP	0.008	0.006	0.007	0.002
Avg. Displacement along X (in.)	0.019	0.012	0.016	0.006
Avg. Displacement along Y (in.)	0.007	0.005	0.006	0.002
Avg. Radial Displacement (in.)	0.02	0.015	0.018	0.005
Standard Deviation - Radial Disp.	0.013	0.007	0.011	0.005
Corelation Coefficient	-0.146	-0.509	-0.376	0.284
95% Ellipse Slope	-6.33	-10.994	-8.258	3.443
SD - Major Axis of 95%Ellipse	0.024	0.014	0.02	0.007
SD - Minor Axis of 95%Ellipse	0.008	0.005	0.007	0.002
95% Ellipse Area (in..in.)	0.003	0.002	0.002	0.001
Avg Velocity (ft/sec)	0.67	0.64	0.659	0.024
Length (in.)	13.402	12.804	13.187	0.471

The similar range of statistics in the previous two tables was measured for Tables 12 and 13. The values from the average column were analyzed. The 95% ellipse area, average velocity, and length values were again all compared for the second region of the model stretcher. The

95% ellipses were again the same in value for the linen sheet compared to the tested prototype. A smaller range of pressure values was observed for the tested prototype over the use of the linen sheet. Also the smaller range of velocity values seen in the tested prototype as compared to the linen sheet means that less motion is seen within the tested prototype.

Table 11- Bioanalysis results from three trials of force plate analysis of the tested prototype within the second region of the stretcher

Parameters	Max	Min	Avg	SD
COP-X Avg (in.)	-0.148	-0.225	-0.178	0.058
COP-Y Avg (in.)	-1.253	-1.308	-1.278	0.039
COP-X Max (in.)	0.059	0.031	0.042	0.021
COP-X Min (in.)	-0.025	-0.053	-0.041	0.02
COP-Y Max (in.)	0.019	0.012	0.016	0.005
COP-Y Min (in.)	-0.019	-0.021	-0.019	0.001
Standard Deviation - X COP	0.023	0.011	0.015	0.009
Standard Deviation - Y COP	0.007	0.005	0.006	0.001
Avg. Displacement along X (in.)	0.017	0.009	0.012	0.006
Avg. Displacement along Y (in.)	0.006	0.004	0.005	0.001
Avg. Radial Displacement (in.)	0.019	0.011	0.014	0.006
Standard Deviation - Radial Disp.	0.014	0.006	0.009	0.006
Corelation Coefficient	0.213	-0.193	-0.028	0.302
95% Ellipse Slope	9.014	-6.492	0.3	11.214
SD - Major Axis of 95%Ellipse	0.023	0.011	0.015	0.009
SD - Minor Axis of 95%Ellipse	0.007	0.005	0.006	0.001
95% Ellipse Area (in..in.)	0.002	0.001	0.002	0.001
Avg Velocity (ft/sec)	0.567	0.512	0.534	0.042
Length (in.)	11.344	10.235	10.678	0.831

The same range of Bioanalysis statistics were analyzed within Tables 14 and 1 5. These tables illustrate the 95% ellipse area, average velocity, and length values. These values were taken from the third section of the model stretcher, in which an extra wooden plank would have to be applied to that region for data to be generated. Inaccurate values were found when no extra plank was placed on the third region. This could be caused by the reduction of applied load for the force plate to recognize forces and moments by the upper portion of the lower leg. The values from the average column were analyzed. The two reoccurring patterns are seen in regards to average velocity and length. Both values are seen to decrease with use of the tested prototype

over using a linen sheet. This means that a lower range of pressure values and motion values will be observed by the test subject. This can also mean that better control and stability can be found in regards to pressure and comfort with the tested prototype over use of the linen sheet.

Table 12- Bioanalysis results from three trials of force plate analysis of the linen sheet within the third region of the stretcher with an added wooden plank

Parameters	Max	Min	Avg	SD
COP-X Avg (in.)	0.076	0.027	0.05	0.035
COP-Y Avg (in.)	-2.168	-2.224	-2.192	0.041
COP-X Max (in.)	0.042	0.035	0.038	0.006
COP-X Min (in.)	-0.027	-0.034	-0.032	0.006
COP-Y Max (in.)	0.065	0.039	0.055	0.02
COP-Y Min (in.)	-0.058	-0.085	-0.068	0.021
Standard Deviation - X COP	0.013	0.012	0.013	0.001
Standard Deviation - Y COP	0.021	0.016	0.019	0.004
Avg. Displacement along X (in.)	0.011	0.01	0.011	0.001
Avg. Displacement along Y (in.)	0.017	0.013	0.015	0.003
Avg. Radial Displacement (in.)	0.022	0.018	0.02	0.003
Standard Deviation - Radial Disp	0.012	0.01	0.011	0.002
Corelation Coefficient	0.278	-0.173	0.109	0.347
95% Ellipse Slope	73.896	-80.445	22.426	125.991
SD - Major Axis of 95%Ellipse	0.016	0.013	0.014	0.002
SD - Minor Axis of 95%Ellipse	0.021	0.015	0.018	0.004
95% Ellipse Area (in..in.)	0.005	0.004	0.005	0.001
Avg Velocity (ft/sec)	1.715	1.67	1.691	0.032
Length (in.)	34.292	33.404	33.82	0.631

Table 13- Bioanalysis results from three trials of force plate analysis of the tested prototype within the third region of the stretcher with an added wooden plank

Parameters	Max	Min	Avg	SD
COP-X Avg (in.)	0.554	0.418	0.478	0.098
COP-Y Avg (in.)	-2.709	-2.846	-2.798	0.109
COP-X Max (in.)	0.044	0.041	0.042	0.003
COP-X Min (in.)	-0.031	-0.044	-0.036	0.009
COP-Y Max (in.)	0.07	0.054	0.061	0.012
COP-Y Min (in.)	-0.064	-0.118	-0.088	0.038
Standard Deviation - X COP	0.014	0.012	0.013	0.002
Standard Deviation - Y COP	0.03	0.024	0.026	0.004
Avg. Displacement along X (in.)	0.011	0.01	0.011	0.001
Avg. Displacement along Y (in.)	0.022	0.019	0.02	0.002
Avg. Radial Displacement (in.)	0.026	0.023	0.024	0.002
Standard Deviation - Radial Disp	0.019	0.013	0.016	0.004
Corelation Coefficient	-0.161	-0.492	-0.372	0.259
95% Ellipse Slope	-71.391	-83.967	-76.995	9.049
SD - Major Axis of 95%Ellipse	0.027	0.012	0.017	0.012
SD - Minor Axis of 95%Ellipse	0.026	0.019	0.023	0.005
95% Ellipse Area (in..in.)	0.006	0.005	0.006	0.001
Avg Velocity (ft/sec)	1.515	1.453	1.476	0.047
Length (in.)	30.294	29.064	29.524	0.949

A consistent pattern of statistics were compared and contrasted from Tables 16 and 17 from the Bioanalysis software. In order to get measurable data measurements, an additional wooden plank would have to be applied to the fourth section of the model stretcher. If an extra wooden plank wasn't placed upon this area, then no measurable statistics would be produced. This event can result from the reduction of applied force from the lower region of the lower legs and feet for the force plate to recognize. The values from the average column were analyzed. The 95% ellipse area was somewhat smaller in the tested prototype compared to the linen sheet,

meaning there was a little more balance control from use of the tested prototype. Decreased values were observed in terms of average velocity and length of the tested prototype versus the linen sheet. This means that a lower range of pressure values and motion values will be observed by the test subject. This can also mean that better control and stability can be found in regards to pressure and comfort with the tested prototype over use of the linen sheet.

Table 14- Bioanalysis results from three trials of force plate analysis of the linen sheet within the fourth region of the stretcher with an added wooden plank

Parameters	Max	Min	Avg	SD
COP-X Avg (in.)	1.009	0.989	0.998	0.014
COP-Y Avg (in.)	4.714	4.653	4.693	0.049
COP-X Max (in.)	0.054	0.049	0.051	0.004
COP-X Min (in.)	-0.038	-0.059	-0.05	0.016
COP-Y Max (in.)	0.07	0.067	0.069	0.002
COP-Y Min (in.)	-0.062	-0.082	-0.073	0.015
Standard Deviation - X COP	0.018	0.016	0.017	0.002
Standard Deviation - Y COP	0.021	0.018	0.02	0.002
Avg. Displacement along X (in.)	0.015	0.012	0.013	0.003
Avg. Displacement along Y (in.)	0.018	0.012	0.015	0.004
Avg. Radial Displacement (in.)	0.025	0.02	0.023	0.003
Standard Deviation - Radial Disp	0.014	0.012	0.013	0.002
Corelation Coefficient	-0.089	-0.272	-0.164	0.135
95% Ellipse Slope	-52.702	-78.918	-67.502	18.994
SD - Major Axis of 95%Ellipse	0.021	0.016	0.019	0.004
SD - Minor Axis of 95%Ellipse	0.019	0.017	0.018	0.001
95% Ellipse Area (in..in.)	0.007	0.006	0.006	0.001
Avg Velocity (ft/sec)	2.684	2.279	2.466	0.288
Length (in.)	53.672	45.584	49.326	5.767

Table 15- Bioanalysis results from three trials of force plate analysis of the tested within the fourth region of the model stretcher with an additional wooden plank

Parameters	Max	Min	Avg	SD
COP-X Avg (in.)	0.795	0.684	0.749	0.082
COP-Y Avg (in.)	3.554	3.317	3.433	0.168
COP-X Max (in.)	0.042	0.038	0.04	0.003
COP-X Min (in.)	-0.039	-0.044	-0.041	0.004
COP-Y Max (in.)	0.059	0.043	0.049	0.012
COP-Y Min (in.)	-0.039	-0.063	-0.051	0.017
Standard Deviation - X COP	0.014	0.013	0.013	0.001
Standard Deviation - Y COP	0.019	0.017	0.018	0.002
Avg. Displacement along X (in.)	0.012	0.01	0.011	0.001
Avg. Displacement along Y (in.)	0.016	0.012	0.014	0.003
Avg. Radial Displacement (in.)	0.021	0.017	0.02	0.003
Standard Deviation - Radial Disp	0.012	0.008	0.01	0.003
Corelation Coefficient	0.388	-0.024	0.198	0.294
95% Ellipse Slope	72.495	-86.096	16.932	126.313
SD - Major Axis of 95%Ellipse	0.016	0.014	0.015	0.002
SD - Minor Axis of 95%Ellipse	0.019	0.015	0.017	0.003
95% Ellipse Area (in..in.)	0.005	0.004	0.004	0.001
Avg Velocity (ft/sec)	2.336	1.744	2.045	0.418
Length (in.)	46.716	34.888	40.908	8.367

Additional analysis can be performed to see the overall percent difference between usages of our tested prototype compared to the linen sheet. Since all 95% ellipse values were near in value in all sections of the model stretcher for the tested prototype and linen sheet, percent differences were not calculated. Each of the average velocity and length values within use of the tested prototype and linen sheet were compared using the percent difference equation.

The first section of the model stretcher would be compared in regards to average velocity of the linen sheet versus the tested prototype. The average velocity value for the tested prototype was 1.084 ft/s and the linen sheet was 1.315 ft/s. Thus finding percent difference:

((1.084 ft/s) / (1.315 ft/s)) x 100% = 82.43

% difference= 100% - 82.43%= **17.57%**, this value implies that there's a 17.57% difference within the tested prototype compared to the linen sheet in terms of reducing motion.

Similarly, the first section of the model stretcher would be compared in regards to length of the linen sheet versus the tested prototype. The length value for the tested prototype was 21.683 in. and the linen sheet was 26.299 in. Thus finding percent difference:

21.683 in. / (26.299 in.) x 100% = 82.45

% difference= 100% - 82.45%= **17.55%**, this value implies that there's a 17.55% difference within the tested prototype compared to the linen sheet in terms of reducing the length of applied pressures.

The second section of the model stretcher would be compared in regards to average velocity of the linen sheet versus the tested prototype. The average value for the tested prototype was 0.534 ft/s and the linen sheet was 0.659 ft/s. Thus finding percent difference:

((0.534 ft/s) / (0.659 ft/s)) x 100% = 81.03%

% difference= 100% - 81.03%= **18.97%**, this value implies that there's an 18.97% difference within the tested prototype compared to the linen sheet in terms of reducing motion.

Similarly, the second section of the model stretcher would be compared in regards to length of the linen sheet versus the tested prototype. The length value for the tested prototype was 10.678 in. and the linen sheet was 13.187 in. Thus finding percent difference:

10.678 in. / (13.187 in.) x 100% = 80.97

% difference= 100% - 80.97%= **19.03%**, this value implies that there's a 19.03% difference

within the tested prototype compared to the linen sheet in terms of reducing the length of applied pressures.

The third section of the model stretcher would be compared in regards to average velocity of the linen sheet versus the tested prototype. The average value for the tested prototype was 1.476 ft/s and the linen sheet was 1.691 ft/s. Thus finding percent difference:

((1.476 ft/s) / (1.691 ft/s)) x 100% = 87.29%

% difference= 100% - 87.29%= **12.71%**, this value implies that there's a 12.71% difference within the tested prototype compared to the linen sheet in terms of reducing motion.

Similarly, the third section of the model stretcher would be compared in regards to length of the linen sheet versus the tested prototype. The length value for the tested prototype was 29.524 in. and the linen sheet was 33.820 in. Thus finding percent difference:

29.524 in. / (33.820 in.) x 100% = 87.30

% difference= 100% - 87.30%= **12.70%**, this value implies that there's a 12.70% difference within the tested prototype compared to the linen sheet in terms of reducing the length of applied pressures.

The fourth section of the model stretcher would be compared in regards to average velocity of the linen sheet versus the tested prototype. The average value for the tested prototype was 2.045 ft/s and the linen sheet was 2.466 ft/s. Thus finding percent difference:

((2.045 ft/s) / (2.466 ft/s)) x 100% = 82.93%

% difference= 100% - 82.93%= **17.07%**, this value implies that there's a 17.07% difference within the tested prototype compared to the linen sheet in terms of reducing motion.

Similarly, the fourth section of the model stretcher would be compared in regards to length of the linen sheet versus the tested prototype. The length value for the tested prototype was 40.908 in. and the linen sheet was 49.326 in. Thus finding percent difference:

40.908 in. / (49.326 in.) x 100% = 82.93%

% difference= 100% - 82.93%= **17.07%**, this value implies that there's a 17.07% difference within the tested prototype compared to the linen sheet in terms of reducing the length of applied pressures.

Another type of analysis performed was a dynamic test of a subject sitting down over a specified time frame. The subject would hold their arms out against the corners of the force plate, and hold their weight over the platform as the Netforce computer program was turned on. Then when the tester on the computer signified for the subject to sit down, the test subject would slowly sit down on the tested prototype or the linen sheet. The type of analysis used was an impact analysis, because movement was involved during the test run.

As shown in Figure 56, the test subject is complying with the test conditions of performing a dynamic gait analysis. The test subject would hold his weight for about 5 minutes and once the tester at the computer would say, "sit down," the test subject's hands would be placed on the knees and concentration would be applied to one point so swaying of the body would not occur.

Figure 52- Test subject performing dynamic impact analysis using Netforce software and force plate

Center of pressure values were observed within Tables 1 8 and 19. Values were produced during the dynamic gait analysis of the test subject sitting down over a thirty- second time frame. The values compared the dynamic analysis of sitting down on a linen sheet versus sitting down on the tested prototype. The center of pressure values for length, maximum velocity, and average velocity were the targeted measures for comparative analysis. In both cases, the center of pressure length value was smaller for the tested prototype than for the linen sheet. This means that the range of pressure is lower for the tested prototype than the linen sheet, ensuring more comfort for the test subject. The center of pressure maximum and average velocities of the tested prototype were both smaller in value than the linen sheet, which suggests

that the tested prototype will not experience as much motion over a range of movement than a linen sheet will sense.

Table 16- Bioanalysis results from three trials of dynamic gait force plate analysis of the linen sheet

Parameters	Max	Min	Avg	SD
Heel Strike (sec)	2.55	1.94	2.27	0.436
Toe Off (sec)	7.91	6.31	7.01	1.158
Stance Time (sec)	5.36	3.99	4.74	0.982
Fz Max (lbs.)	172.487	157.045	167.312	12.575
Fz Max @Time (sec)	2.72	2.05	2.45	0.5
Fz Avg (lbs.)	149.134	142.271	145.855	4.867
Fz Impulse (lb.-sec.)	797.743	566.102	691.353	165.416
Fz Max Deceleration (lbs.)	172.487	157.045	167.312	12.575
Fz Max Deceleration @Time (sec)	2.72	2.05	2.45	0.5
Fz Max Deceleration Impulse (lb.-sec.)	26.497	12.842	20.118	9.718
Fz Mid Stance (lbs.)	149.242	144.561	146.504	3.45
Fz Mid Stance Time (sec)	5.31	4.9	5.04	0.331
Fz Mid Stance Impulse (lb.-sec.)	435.729	367.721	405.537	48.987
Fz Max Accl. (lbs.)	153.021	146.203	149.653	4.822
Fz Max Accl. @Time (sec)	7.9	6.3	7	1.158
Fz Max Accl. Impulse (lb.-sec.)	0	0	0	0
Fy Max (lbs.)	23.182	16.038	18.932	5.318
Fy Max @Time (sec)	2.66	2.2	2.457	0.332
Impulse : t=0,Tfymax (lb.-sec.)	3.761	0.931	2.173	2.046
Fy Min (lbs.)	-0.639	-2.555	-1.325	1.51
Fy Min @Time (sec)	3.75	3.18	3.417	0.42
Impulse : t=0,Tfymin (lb.-sec.)	9.214	6.077	7.485	2.253
Fy Avg. (lbs.)	2.075	0.827	1.629	0.984
Fx Max (lbs.)	2.404	2.282	2.364	0.099
Fx Max @Time (sec)	3.24	2.81	3.007	0.307
Impulse : t=0,Tfxmax (lb.-sec.)	-0.944	-1.986	-1.417	0.747
Fx Min (lbs.)	-5.377	-11.948	-9.509	5.088
Fx Min @Time (sec)	2.7	2.05	2.42	0.473
Impulse : t=0,Tfxmin (lb.-sec.)	-0.437	-0.595	-0.502	0.117
Fx Avg	0.13	-0.018	0.045	0.108
Torque Max (in-lbs.)	28.944	21.06	24.17	5.936
Torque Max @Time (sec)	3.23	2.03	2.527	0.885
Torque Min (in-lbs.)	1.162	-11.645	-3.562	9.946
Torque Min @Time (sec)	3.46	2.17	2.84	0.914
Torque Avg (in-lbs.)	11.314	8.266	9.608	2.2
COP: Heel Strike X (in.)	-2.495	-5.155	-3.662	1.923
COP: Heel Strike Y (in.)	-10.557	-14.378	-12.969	2.968
COP: Toe Off X (in.)	0	0	0	0
COP: Toe Off Y (in.)	0	0	0	0
COP: Min along Y-Axis X (in.)	-2.495	-5.155	-3.662	1.923
COP: Min along Y-Axis Y (in.)	-10.557	-14.378	-12.969	2.968
COP: Max along Y-Axis X (in.)	0	-0.24	-0.08	0.196
COP: Max along Y-Axis Y (in.)	3.915	0	1.305	3.197
COP: Excursion along Y-Axis (in.)	17.886	10.557	14.274	5.184
COP: Min along X-Axis X (in.)	-2.495	-5.155	-3.662	1.923
COP: Min along X-Axis Y (in.)	-10.557	-14.378	-12.969	2.968
COP: Max along X-Axis X (in.)	0.514	0.363	0.454	0.113
COP: Max along X-Axis Y (in.)	-1.023	-2.71	-1.858	1.193
COP: Excursion along X-Axis (in.)	5.669	2.858	4.116	2.02
COP: Avg X (in.)	0.153	0.064	0.118	0.067
COP: Avg Y (in.)	-1.082	-2.823	-1.961	1.231
COP: Length (in.)	26.584	15.75	19.827	8.335
COP: Max Velocity (ft/sec)	573.473	364.179	438.346	165.759
COP: Avg Velocity (ft/sec)	4.96	3.234	4.164	1.231

Table 17- Bioanalysis results from three trials of dynamic gait force plate analysis of tested prototype

Parameters	Max	Min	Avg	SD
Heel Strike (sec)	3.61	2.66	3.093	0.679
Toe Off (sec)	7.4	6.2	6.8	0.849
Stance Time (sec)	4.14	3.19	3.707	0.679
Fz Max (lbs.)	181.604	176.265	178.483	3.934
Fz Max @Time (sec)	4.19	3.3	3.61	0.711
Fz Avg (lbs.)	164.754	159.827	162.375	3.49
Fz Impulse (lb.-sec.)	671.196	508.134	600.664	118.408
Fz Max Deceleration (lbs.)	181.604	176.265	178.483	3.934
Fz Max Deceleration @Time (sec)	4.19	3.3	3.61	0.711
Fz Max Deceleration Impulse (lb.-sec.)	93.706	35.357	69.379	42.933
Fz Mid Stance (lbs.)	168.627	163.781	165.998	3.463
Fz Mid Stance Time (sec)	6.02	4.04	4.773	1.535
Fz Mid Stance Impulse (lb.-sec.)	393.665	190.83	267.086	156.108
Fz Max Accl. (lbs.)	170.105	166.409	167.723	2.922
Fz Max Accl. @Time (sec)	6.31	5.4	5.737	0.706
Fz Max Accl. Impulse (lb.-sec.)	459.923	380.355	427.708	59.239
Fy Max (lbs.)	16.584	13.886	15.046	1.963
Fy Max @Time (sec)	3.96	2.98	3.427	0.701
Impulse : t=0,Tfymax (lb.-sec.)	2.809	2.577	2.685	0.165
Fy Min (lbs.)	0.521	-0.941	0.034	1.194
Fy Min @Time (sec)	4.19	3.62	3.957	0.422
Impulse : t=0,Tfymin (lb.-sec.)	8.06	0	5.323	6.52
Fy Avg. (lbs.)	3.217	2.691	2.998	0.387
Fx Max (lbs.)	1.235	1.121	1.159	0.093
Fx Max @Time (sec)	5.27	3.98	4.563	0.925
Impulse : t=0,Tfxmax (lb.-sec.)	-0.464	-2.169	-1.319	1.206
Fx Min (lbs.)	-4.638	-10.34	-6.877	4.302
Fx Min @Time (sec)	3.87	2.83	3.323	0.738
Impulse : t=0,Tfxmin (lb.-sec.)	-0.392	-1.098	-0.656	0.544
Fx Avg	0.108	-0.442	-0.239	0.428
Torque Max (in-lbs.)	25.114	14.665	18.167	8.509
Torque Max @Time (sec)	5.38	3.5	4.3	1.373
Torque Min (in-lbs.)	-0.961	-7.053	-4.718	4.647
Torque Min @Time (sec)	4.01	3.06	3.41	0.738
Torque Avg (in-lbs.)	13.246	3.122	8.342	7.17
COP: Heel Strike X (in.)	-1.061	-1.835	-1.373	0.577
COP: Heel Strike Y (in.)	-4.424	-5.492	-4.91	0.764
COP: Toe Off X (in.)	0	0	0	0
COP: Toe Off Y (in.)	0	0	0	0
COP: Min along Y-Axis X (in.)	-1.061	-1.835	-1.373	0.577
COP: Min along Y-Axis Y (in.)	-4.424	-5.492	-4.91	0.764
COP: Max along Y-Axis X (in.)	0	0	0	0
COP: Max along Y-Axis Y (in.)	0	0	0	0
COP: Excursion along Y-Axis (in.)	5.492	4.424	4.91	0.764
COP: Min along X-Axis X (in.)	-1.061	-1.835	-1.373	0.577
COP: Min along X-Axis Y (in.)	-4.424	-5.492	-4.91	0.764
COP: Max along X-Axis X (in.)	0.471	0	0.213	0.338
COP: Max along X-Axis Y (in.)	0	-1.521	-0.84	1.093
COP: Excursion along X-Axis (in.)	1.835	1.391	1.586	0.321
COP: Avg X (in.)	0.259	-0.363	-0.04	0.441
COP: Avg Y (in.)	-1.135	-1.738	-1.399	0.436
COP: Length (in.)	7.673	6.788	7.105	0.697
COP: Max Velocity (ft/sec)	152.976	100.418	119.171	41.485
COP: Avg Velocity (ft/sec)	2.128	1.656	1.936	0.351

During the dynamic impact analysis of sitting, the percent difference could be found in regards to the length of the linen sheet versus the tested prototype. The average value for the

tested prototype was 7.105 in. and the linen sheet was 19.827 in. Thus finding percent difference:

((7.105 in.) / (19.827 in.) x 100% = 35.83%

% difference= 100% - 35.83%= **64.17%**, this value implies that there's a 64.17% difference within the tested prototype compared to the linen sheet in terms of reducing the overall range of pressure.

During the dynamic impact analysis of sitting, the percent difference could be found in regards to the maximum velocity of the linen sheet versus the tested prototype. The average value for the tested prototype was 119.171 ft/s and the linen sheet was 438.346 ft/s. Thus finding percent difference:

((119.171 ft/s) / (438.346 ft/s) x 100% = 27.19%

% difference= 100% - 27.19%= **72.81%**, this value implies that there's a 72.81% difference within the tested prototype compared to the linen sheet in terms of reducing the overall maximum range of motion.

During the dynamic impact analysis of sitting, the percent difference could be found in regards to the average velocity of the linen sheet versus the tested prototype. The average value for the tested prototype was 1.936 ft/s and the linen sheet was 4.164 ft/s. Thus finding percent difference:

((1.936 ft/s) / (4.164 ft/s) x 100% = 46.49%

% difference= 100% - 46.49%= **53.51%**, this value implies that there's a 53.51% difference within the tested prototype compared to the linen sheet in terms of reducing the overall average range of motion.

5.3.3- Absorbance Testing

The following tables were used to record the results of the first experiment:

Table 18- Absorbance results of the five materials under uniformed pressure and varying water volume.

First Material Trial	Weight of dry material(g)	Weight of water added(g)	Total weight-water+ material (g)	Weight of material after (g)	Total water leaked(g)
1	2.9	10.0	12.9	4.9	8.0
2	3.0	10.0	13.0	3.1	9.9
3	3.1	10.0	13.1	3.5	9.6
4	2.8	50.0	52.8	5.3	47.5
5	3.0	50.0	53.0	4.1	48.9
6	2.9	50.0	52.9	4.7	48.2
7	2.9	100.0	102.9	5.9	97.0
8	3.0	100.0	103.0	7.2	95.8
9	3.0	100.0	103.0	6.9	96.1
Second Material Trial					
1	3.8	10.0	13.8	8.9	4.9
2	3.8	10.0	13.8	8.2	5.6
3	3.9	10.0	13.9	9.6	4.3
4	3.8	50.0	53.8	15.4	38.4
5	3.7	50.0	53.7	13.4	40.3
6	3.9	50.0	53.9	15.1	38.8
7	3.8	100.0	103.8	22.6	81.2
8	4.0	100.0	104.0	19.6	84.4
9	3.9	100.0	103.9	24.1	79.8
Third Material Trial					
1	5.8	10.0	15.8	14.7	1.1
2	5.7	10.0	15.7	12.9	2.8
3	5.1	10.0	15.1	13.9	1.2
4	6.1	50.0	56.1	52.1	4.0

5	5.7	50.0	55.7	49.9	5.8
6	5.9	50.0	55.9	50.1	5.8
7	6.1	100.0	106.1	87.9	18.2
8	5.9	100.0	105.9	85.1	20.8
9	5.8	100.0	105.8	81.7	24.1
Fourth Material Trial					
1	9.3	10.0	19.3	18.1	1.2
2	9.7	10.0	19.7	16.2	3.5
3	10.1	10.0	20.1	17.9	2.2
4	9.9	50.0	59.9	52.1	7.8
5	9.7	50.0	59.7	50.4	9.3
6	9.6	50.0	59.6	48.2	11.4
7	10.1	100.0	110.1	70.2	39.9
8	10.2	100.0	110.2	65.4	44.8
9	9.8	100.0	109.8	67.6	42.2
Fifth Material Trial					
1	12.8	10.0	22.8	21.0	1.8
2	12.4	10.0	22.4	21.6	0.8
3	11.9	10.0	21.9	20.1	1.8
4	12.2	50.0	62.2	60.1	2.1
5	11.3	50.0	61.3	59.8	1.5
6	13.1	50.0	63.1	59.2	3.9
7	12.8	100.0	112.8	108.2	4.6
8	11.7	100.0	111.7	107.7	4.0
9	12.8	100.0	112.8	105.1	7.7

The following tables were done for statistical analysis for the first experiment:

Table 19- Statistical results representing all five materials with uniform pressure and changing water volume derives from absorbance experiment results in Table 20.

First Material

Average Leakage(g)	Max(g)	Min(g)	STD	%Absorbance
9.2(T1-3)	9.9	8.0	0.8	28.9
48.2(T4-6)	48.9	47.5	0.6	8.7
96.3(T7-9)	97.0	95.8	0.5	6.4

Second Material

Average Leakage(g)	Max	Min	STD	%Absorbance
4.9(T1-3)	5.6	4.3	0.5	64.3
39.2(T4-6)	40.3	38.4	0.8	27.2
81.8(T7-9)	84.4	79.8	1.9	21.2

Third Material

Average Leakage(g)	Max	Min	STD	%Absorbance
1.7(T1-3)	2.8	1.1	0.8	89.2
5.2(T4-6)	5.8	4.0	0.8	90.7
21.0(T7-9)	24.1	18.2	2.4	80.2

Fourth Material

Average Leakage(g)	Max	Min	STD	%Absorbance
2.3	3.5	1.2	0.9	88.1
9.5	11.4	7.8	1.5	84.1
42.3	44.8	39.9	2.0	61.6

Fifth Material				
Average Leakage(g)	**Max**	**Min**	**STD**	**%Absorbance**
1.5	1.8	0.8	0.5	93.6
2.5	3.9	1.5	1.0	96.0
5.4	7.7	4.0	1.6	95.2

The following tables were used to record the results of the second experiment:

Table 20- Absorbance and surface adhesion results for the five materials under uniformed pressure and using 200 g of water.

First Material Trial	Weight of dry material(g)	Weight of water added(g)	Total weight-water+ material (g)	Weight of material after step 5 (g)	Weight Difference(g): Total weight-Weight of material after step 5	Weight after applying absorbing towel(g)	Weight of ejected water after pat (g)	Total water leaked(g) : column 6+ 8
1	3.1	200.1	203.2	11.4	191.8	5.5	5.8	197.6
2	3.1	200.2	203.3	14.2	189.1	7.2	7.0	196.1
3	3.1	199.9	203.0	13.9	189.1	8.2	5.7	194.8
Second Material Trial								
1	3.8	200.0	203.8	68.2	135.6	41.6	26.6	162.2
2	3.7	200.1	203.8	74.2	129.6	38.9	35.3	164.9
3	4.0	200.0	204.0	71.6	132.4	36.7	34.9	167.3
Third Material Trial								
1	5.6	200.1	205.7	160.3	45.4	146.4	14.0	59.4
2	5.9	200.0	205.9	163.3	42.6	153.2	10.1	52.7
3	5.1	199.9	205.0	159.3	45.7	150.2	9.1	54.8
Fourth Material Trial								
1	9.1	200.0	209.1	140.4	68.8	105.7	34.7	103.4
2	9.8	200.0	209.8	135.9	73.9	98.6	37.3	111.2

3	10.3	200.0	210.3	136.3	74.0	96.9	39.4	113.4
Fifth Material Trial								
1	11.2	200.1	211.3	209.1	2.2	202.1	7.0	9.2
2	12.4	200.0	212.4	210.1	2.3	205.2	4.9	7.2
3	11.9	200.0	211.9	209.8	2.1	203.1	6.7	8.8

The following tables were done for statistical analysis for the second experiment:

Table 21- Statistical results for the five materials under uniform pressure and using 200 g of water derive from results in table 22.

First Material				
Average Leaked(g)	**Max(g)**	**Min(g)**	**STD(g)**	**%Absorbance**
196.2	197.6	194.8	1.2	3.4
Second Material				
Average Leaked(g)	**Max(g)**	**Min(g)**	**STD(g)**	**%Absorbance**
164.8	167.3	162.2	2.1	19.1
Third Material				
Average Leaked(g)	**Max(g)**	**Min(g)**	**STD(g)**	**%Absorbance**
55.6	59.4	52.7	2.8	73.0
Fourth Material				
Average Leaked(g)	**Max(g)**	**Min(g)**	**STD(g)**	**%Absorbance**
109.3	113.4	103.4	4.3	47.7
Fifth Material				
Average Leaked(g)	**Max(g)**	**Min(g)**	**STD(g)**	**%Absorbance**
8.4	9.2	7.2	0.9	96.0

The following tables were used to record the results of the third experiment:

Table 22- Absorbance experiment results for the second material, using 50 of water, and changing applied pressure.

Trial-Second Material(50 g water added)	Load applied(kg) Surface area=0.005 m^2	Weight of Material(g)	Weight of Material + water before(g)	Weight of Material +water after step 4 (g)	Weight Difference(g)
1	1.0	3.9	53.9	20.3	33.6
2	1.0	3.7	53.7	17.2	36.5
3	1.0	3.9	53.9	21.5	32.4
4	5.0	4.0	54.0	15.3	38.7
5	5.0	3.8	53.8	13.4	40.4
6	5.0	3.9	53.9	15.2	38.7
7	10.0	3.9	53.9	11.9	42.0
8	10.0	4.1	54.1	9.1	45.0
9	10.0	3.9	53.9	12.7	41.2

The following tables were done for statistical analysis for the third experiment:

Table 23- Statistical results for the second material, using 50 g of water, and under changing pressure derive from results in table 24.

Average Leaked(g)	Max	Min	STD	%Absorbance
34.2(T1-3)	36.5	32.4	1.7	36.6
39.3(T4-6)	40.4	38.7	0.8	27.3
42.7(T7-9)	45.0	41.2	1.6	20.7

The absorbance experiments presented in Tables 20-23 have given us some interesting results. These experiments maintained a uniformed pressure, and various water volumes were tested. In Table 11, the absorbance of the fiver materials were tested. According to Table 21, the fifth material had significantly higher absorbance than all five materials, with over 90% absorbance for all three water volumes used. The first material, linen, had the poorest absorbance, with below 10% absorbance for two water volumes used. Interestingly, the third and fourth material had similar absorbance results for the 10 g and 50 g water capacity, but under100g water, the third material had about 20% more absorbance (80.2% vs. 61.6%) than the fourth material. From Table 23, using 200g water capacity, the absorbance percentage difference was even higher, about 25% (73.0% vs. 47.7%).

From Table 21, the third material seems to have better adhesion to water compared to the fourth. This is possibly due to the nature of the gel forming SPA. The third material has more SPA than the fourth and fifth material (2g vs. 0g (4)1g (5)). The gel forms immediately after contact with water. Patting and applying pressure with an absorbent towel will likely retrieve less liquid than the fourth material because the water is already locked in the gel structure. Some water remained on the surface in the third material; the material did not properly facilitate its spread to all surface area. This decreased the percent absorbance of the third material.

Table 24 and 25 presented results for an experiment in which the water capacity was kept constant, but pressure changed. Interestingly, percent absorbance decreased more dramatically, when moving from 5kg to 10 kg, than 1 kg to 5 kg.

The fifth material, which contains both cellulose and SPA, was tested and had a maximum water capacity of 800 g. It is possible that from 0-100g interval both SPA and

cellulose were equally contributing to absorbance. Beyond 100 g, SPA took the leading role. The role of cellulose is important too. Besides contributing to absorbance, it gives structural support to the formed gel, which makes the material contain more. It is possible that the absorbance percent can be increased even further in the fifth material if additional SPA and cellulose are added.

Chapter 6: Recommendations for Future Development

6.1 Introduction

Throughout the development of the novel surgical sponge pad, the team reached numerous road blocks and experienced varying degrees of limitations due to time, resources available, and budget constraints. A full-scale engineering design project requires resources that are not readily available to undergraduate college students, but tend to be available to sizable companies with research and development budgets and work spaces. However, areas for improvement are consistently encountered and documented so teams with future vested interest in the project can understand where to focus their attention to augment our work. In the case of the surgical sponge, the vast majority of the project was based on CAD modeling and primitive prototype construction. Largely serving as the pilot study for the absorbent pad for ambulatory application, the projects next logical phases are construction of full-scale prototypes and the implementation of field and functionality testing.

6.2 Constructing the Full-Scale Prototype

Following the CAD design of the surgical sponge pad, the team set out to create a basic prototype. The team faced many challenges in the said construction since most absorbent systems, specifically the diaper, are manufactured on large scale machines with mechanical elements such as presses, folding devices, hot melt adhesive applicators, and precise robotic mechanisms to create perfectly proportioned products. As undergraduate students without the necessary access to facilities such as the aforementioned, the team was forced to adapt and use currently existing materials to model its final design. To do this, materials such as diapers,

Underpads, sodium polyacrylate powder, cellulose fluff, and acquisition distribution layers were obtained. Some of the materials were purchased using the project's budget, and some were acquired by contacting companies and presenting our case. One company in particular took interest in the development of the surgical sponge pad, and sent the team several hundred feet of acquisition distribution layer nonwovens for free. This particular company was Tredegar Film Products, a company that specializes in nonwoven fabrics for medical and hygienic applications. The representatives from Tredegar were extremely helpful and gladly sent materials to enhance the quality of the team's prototypes.

For future development of the prototypes, all of the various materials within the absorbent sponge pad should be purchased. There materials were described in section 2.5.2. The polyethylene back sheet, the spun bond nonwoven fabric shrouding of the superabsorbent core containing SPA and cellulose, the top acquisition distribution layer, hydrophilic surfactant coating to apply to the nonwoven core housing, and hot melt adhesives should all be purchased and applied to create a full-scale, industry standard prototype. Since these materials were not all available to the students, development of the said prototype was limited to materials found in the Biomedical laboratories. In order for a team in the future to take this project to the next level, a full prototype compatible with the Ferno stretchers should be created in order to conduct field testing. Protocols from sections 3.2.1, 3.2.2 and 3.2.3 can be reproduced using the full prototype as opposed to a small, basic model of the final design.

6.3 Optimizing Amount of Materials

When examining the diaper system or the Underpad, it is important to know that the engineers who study the systems aim to make the products as cost efficient as possible while still maintaining the minimum standards they have set to ensure the products function properly. It is common knowledge to understand the notion of optimization. By minimizing the amount of material used to construct a final product, the more a company will save on raw materials. This is crucial in allowing the company to make a profit while still keeping their prices low enough in order to cause a demand for the product. This applies directly to the surgical sponge pad. Since it involves the use of specialized fabrics such as 3-D aperture film, special superabsorbent polymers, and viscoelastic polymers, cost will be a significant factor in determining the pad's success in the market.

This area of the project was not significantly studied and requires further investigation to determine exactly how much of each material is necessary to maintain absorbent and vibration-dampening functionality while minimizing the cost of the final product. This will be a key point in setting design parameters industrial engineers will use to create the perfectly competitive product. There are several design aspects of the surgical sponge pad that can be optimized with further research. First is the amount of the acquisition distribution layer. Since this material is specialized and expensive relative to polyethylene and spun bond nonwoven, it must be optimized. Recall the purpose of the ADL which is to spread the influx of fluids to the core over a greater area to ensure a higher absorbance as well as to reduce regurgitation of fluids from the core towards the patient. Since the patient will not be lying on the entire sponge pad at any given time, the ADL should only be present in areas that will experience the most wetting of biological

fluids. This can be determined experimentally by creation of a prototype, applying it to a stretcher, and simulating wetting of fluids by modeling wounds in different parts of the body. By using dyed fluids, exact travel patterns of the fluids can be predicted allowing engineers to determine where the ADL should be optimally applied on the surface of that pad. Using this method, use of the ADL can be minimized resulting in saved money, less material used, and more products created.

Secondly the amount of SPA should be optimized within the absorbent core. There is no need to put pounds of SPA into a single sponge pad since it can absorb 300 times of its own mass in fluids, while the amount of fluids available is constrained to the amount of fluids in the human body. Upon further investigation, proper ratios of masses of SPA to cellulose per unit area of sponge pad core space can be obtained and implemented across the entire core. In this manner, only the minimum amount of SPA and cellulose will be used, again saving money and materials for the manufacturer. Akton polymer is a control in the design of the project and will not need to be minimized as its design parameter is to cover the entire stock stretcher mattress pad. In this manner, a flat rate can be determined for each stretcher based upon mattress top surface area in regards to how much it will cost to coat in viscoelastic polymer.

6.4 Functionality Testing and Surveying Among EMS

Despite whether or not the surgical sponge pad system performs exactly as it was designed, its qualifications will mean little unless Emergency Medical Services approve of the product. EMT's operate at a grueling pace and have zero time and tolerance for new procedures and equipment that in any way inhibit their ability to provide crisis care to injured and sick patients. Therefore, the surgical sponge pad must in every way complement the EMT's ability to

provide quality care. By testing, future groups will be able to determine if the surgical pad will function as a superabsorbent system; however, this tells engineers nothing about how the EMT's interact with the product. Therefore, future work on the project will require actual prototypes to be delivered to EMT's for field use. The EMT's will take the surgical sponge pad on various emergency responses and evaluate its cohesion with the emergency services. Interviews and questionnaires can be conducted and filled out following each call to determine the opinions of the EMT's, as well as to accept first hand criticisms and areas for potential improvements. In this manner of research, the surgical sponge pad can be improved for better EMT/product cohesion which will inevitably increase its allure to other EMS around the world. By being easy to use and replace, and while isolating contaminants to maintain a more sanitary environment as well as cut down sanitization time, the surgical sponge can be optimized to be an asset to the EMT.

Chapter 7: Concluding Remarks

The Surgical Sponge MQP presented the team with a real life problem that Emergency Medical Services face each and every day. Emergency medical technicians are forced to execute their intensely grueling occupational duties in the presence of numerous hazards within the ambulance environment. Primarily, these hazards are physical injury stemming from contact with the internal environment of the ambulance compartment. However, EMTs expose themselves to biological fluids which may flow from a patient onto the stretcher and onto the floor or walls of the ambulance, not to mention the EMTs themselves. Spread of biological contaminants can pose health concerns for the EMT's as the fluids may be unsanitary and carry disease. The fluids also require extensive time and methods to clean once the fluids have been released.

Patients also experience discomfort within the ambulance as they are exposed to relentless and uncontrolled vibrations. These vibrations propagate from the ground, through the ambulance chassis, through the stretcher and into the patient. Patients are also exposed to their own biological fluids and are forced to lie in their own blood, or vomit. This is highly unsanitary, uncomfortable, and cannot be considered part of quality care. Patients deserve to be comfortable in the environment of the ambulance; simply the idea of being in such a vehicle under the circumstances is enough to cause stress in an individual which is counterproductive to their treatment.

Therefore, it was the goal of the Surgical Sponge MQP team to assess the problem from an engineering standpoint and apply critical thinking to create a solution to the main issues. The team's goals were to develop an absorbent pad to absorb as much biological fluids as possible

within the ambulance setting, as well as to dampen vibrations propagating through the stretcher to inevitably augment comfort. Its secondary goals were to keep this pad easily replaceable, maintain the ability to reuse it if its primary absorbent function does not utilize, and to use as little materials as possible. To do this, the team visited UMASS Memorial EMS and investigated medical stretchers to understand their shape, dynamics, functions, dimensions, uses, and other properties that would better assist the team in finding a solution to the problem.

The team decided that the absorbent pad should be modeled from the common diaper as the diaper system utilizes exceptional materials and technology to maximize its ability to absorb and retain biological fluids. After investigation and research, a theoretical design was created based on the diaper. First, impenetrable polyethylene back sheet would be used to block all fluids from passing through the bottom of the pad. Next an absorbent core of sodium polyacrylate super-absorbent polymer in a cellulose matrix should be used as the primary mode with which to absorb fluids, and finally a top layer called an acquisition distribution layer would be used to spread fluids out as they entire the core maximize absorption and minimize the fluids ability to regurgitate back toward the patient causing discomfort. Using CAD, the team then designed a three dimensional, correctly-dimensioned model through a design iteration process until satisfied with a final product that is compatible with most common stretchers, more specifically the Ferno stretchers used by UMASS EMS.

Next, the team tested this design using quantitative analyses. These tested the final design's ability to provide quantifiable benefits to the EMT's and patients. Using static force plate data to determine center of pressure (COP) and various properties associated with the COP, it was determined there was an 18.97 percent difference in average velocities. The slower the COP was shown to move, the less fierce and jarring movements are when experienced through

the Akton viscoelastic polymer and absorbent core combination as opposed to simply a linen sheet. This figure shows a significant decrease in velocity, indicative of a quantifiable increase in comfort. Next was the impact force plate data involving a group member sitting down onto the force plate first with a linen sheet covering the plate only and then finally with the Akton polymer. Here the team calculated a 53.51 percent decrease in average velocity, even more indicative of increased comfort. The team was pleased with these results as it was a primary goal to decrease motions to in turn increase the comfort of the patient.

The team then investigated vibrations experienced while driving in a car at seven MPH. The test used a linen sheet only as a control, and finally with the Akton polymer and absorbent core combination. The road chosen was a smooth, urban road to ensure the safety of the team and accuracy of the data collected. To conduct the test, the "Vibration" application for IPhone was downloaded, utilizing the internal accelerometer of the IPhone 3GS. It was shown the Akton polymer dampened vibrations by 35 percent when using the viscoelastic polymer as opposed to simply a linen sheet. The team was pleased with these results since another of the primary goals was to dampen vibrations experienced through the stretcher and into a patient.

Finally, wettability and absorbance tests were conducted using the linen sheet as a control and comparing its water absorbencies to the final design, which included both cellulose and SPA, the key components of the diaper. The team was astounded with the results, as the final design combination of materials showed an incredible 92.6 percent more absorbance capacity than the linen sheet alone. This value is critical to proving to EMS as well as the interested consumers that this product functions exceptionally as a superabsorbent pad. The team was also able to show that the inclusion of SPA into the absorbent core instead of simply using cellulose alone, not unlike the Underpad, gave over 21 percent more absorbance capacity alone. The team feels

strongly the primary goals of the project were reached from the attainment of the aforementioned numerical figures.

The Surgical Sponge MQP team members were able to grow immensely from the opportunity to challenge this project. The problem at hand was dynamic and applicable to current day EMS that the team had to be constantly vigilant of new technology and using the best possible materials and software to solve the problem. The project enabled us to work with accomplished faculty, other student groups such as the Stretcher Canopy group, and representatives from large scale global companies including Tredegar Film Products and Mogul. Speaking to representatives from companies allowed the team to mature into engineers who must communicate effectively project goals and issues so as to gain the solutions needed in order to progress with the project. Overall, the project was an excellent success in the eyes of the team members and hope our project will be continued in the future so the Surgical Sponge may be implemented into the EMS workforce in the near future.

Glossary

Impact Parameters

Heel Strike (HS) - Point in time when the heel hits the ground at the beginning of the stance phase, in seconds.

Toe Off (TO) - Point in time when toe lifts off the ground at the end of the stance phase, thus starting the swing phase, in seconds

Stance Time- Point in time between heel strikes (HS) and toe off (TO), the time when foot is in contact with the ground, in seconds

Fz Maximum- Maximum force along the vertical axis, in pounds or Newtons

Fz Max @ Time- Time at which the maximum force occurs, in seconds

Fz Average- Average force on the vertical axis, in pounds or Newtons

Fz Max Impulse- The area under the force (z-axis) vs. time curve from 0 to Fz maximum, in pounds per second or newtons per second

Fz Max Deceleration (MD) - The force corresponding to the maximum deceleration (MD) on the Force (z-axis) vs. time plot, in Newtons or pounds

Fz Max Deceleration @ Time- The time at which the maximum deceleration (MD) on the Force (z-axis) vs. time plot, in seconds.

Fz Max Deceleration Impulse- The area under the Force (z-axis) vs. time curve from 0 to the maximum deceleration, in pounds per second or Newtons per second

Fz Mid Stance- The force corresponding to Mid Stance (MS) on the Fz vs. Time plot, in pounds or Newtons

Fz Mid Stance @ Time- The time at which Mid Stance on the Force (z-axis) vs. time plot occurs, in seconds

Fz Mid Stance Impulse- The area under the Force (z-axis) vs. Time curve from 0 to Mid Stance, in pounds per second or Newtons per second

Fz Maximum Acceleration- The force corresponding to the maximum acceleration (MA) on the Fz vs. Time plot, in pounds or Newtons

Fz Maximum Acceleration Impulse- The area under the Force (z-axis) vs. Time curve from 0 to maximum acceleration, in pounds per second or Newtons per second

Fy Maximum- The maximum force along the y-axis, in pounds or Newtons

Fy Maximum @ Time- The time at which the maximum force along the y-axis occurs, in seconds

Fy Maximum Impulse- The area under the Force (y-axis) vs. Time curve from to 0 to Fy maximum, in pounds per second or Newtons per second

Fy Minimum- The minimum force along the y-axis, in pounds or Newtons

Fy Minimum @ Time- The time at which the minimum force along the y-axis occurs, in seconds

Fy Minimum Impulse- The area under the Force (y-axis) vs. Time curve from 0 to minimum acceleration, in pounds per second or Newtons per second

Fy Average- The average force along the y-axis, in pounds or Newtons

Fx Maximum- The maximum force along the x-axis, in pounds or Newtons

Fx Maximum @ Time- The time at which the maximum force along the X-axis occurs

Fx Maximum Impulse- The area under the Force (x-axis) vs. Time curve from to 0 to Fx maximum, in pounds per second or Newtons per second

Fx Minimum- The minimum force along the x-axis, in pounds or Newtons

Fx Minimum @ Time- The time at which the minimum force along the x-axis occurs, in seconds

Fx Minimum Impulse- The area under the Force (x-axis) vs. Time curve from 0 to Fx minimum, in pounds per second or Newtons per second

Fx Average- The average force along the x-axis, in pounds or Newtons

Torque Maximum- The maximum vertical torque, in inches per pounds or Newtons per centimeters

Torque Maximum @ Time- The time of the maximum vertical torque, in seconds

Torque Minimum- The minimum vertical torque, in inches per pounds or Newtons per centimeters

Torque Minimum @ Time- The time of the minimum vertical torque, in seconds

Torque Average- The average vertical torque, in inches per pounds or Newtons per centimeters

COP: Heal Strike X- The X coordinate of the COP at heal strike, in inches or centimeters

COP: Heal Strike Y- The Y coordinate of the COP at heal strike, in inches or centimeters

COP: Toe Off X: The X coordinates of the COP at toe off, in inches or centimeters

COP: Toe Off Y: The Y coordinates of the COP at toe off, in inches or centimeters

COP: Minimum Along Y-Axis X : The X coordinates of the COP at the minimum point along the Y-axis, in inches or centimeters

COP: Minimum Along Y-Axis Y : The Y coordinates of the COP at the minimum point along the Y-axis, in inches or centimeters

COP: Maximum Along Y-Axis X : The Y coordinates of the COP at the minimum point along the Y-axis, in inches or centimeters

COP: Maximum Along Y-Axis Y : The Y coordinates of the COP at the maximum point along the Y-axis, in inches or centimeters

COP: Excursion Along Y-Axis- The distance traveled along the y axis, in inches or centimeters

COP: Minimum Along X-Axis X : The X coordinates of the COP at the minimum point along the X-axis, in inches or centimeters

COP: Minimum Along X-Axis Y : The Y coordinates of the COP at the minimum point along the X-axis, in inches or centimeters

COP: Minimum Along X-Axis: The Y coordinates of the COP at the minimum point along the X-axis, in inches or centimeters

COP: Excursion Along X-Axis- The COP‘s total distance traveled in the X direction, in inches or centimeters

COP: Average X- The COP’s average distance in the X direction, in inches or centimeters

COP: Average Y- The COP’s average distance in the Y direction, in inches or centimeters

COP: Length: The length of the total distance traveled by the COP, in inches or centimeters

COP: Maximum Velocity- The maximum velocity traveled by the COP, in inches per second or centimeters per second

COP: Average Velocity- The average velocity traveled by the COP, in inches per second or centimeters per second

Center of Pressure (COP): Point of application of all the ground reaction forces within a force plate

Balance Parameters

COP: X Average- The average position of the x coordinate of the center of pressure, in inches or centimeters

COP: Y Average- The average position of the y coordinate of the center of pressure, in inches or centimeters

COP- X Maximum- The maximum coordinate of the COP along the x-axis, in inches or centimeters

COP- X Minimum- The minimum coordinate of the COP along the x-axis, in inches or centimeters

COP- Y Maximum- The maximum coordinate of the COP along the y-axis, in inches or centimeters

COP- Y Minimum- The minimum coordinate of the COP along the y-axis, in inches or centimeters

Standard Deviation- X COP: Standard deviation of the COP along the x-axis

Standard Deviation- Y COP: Standard deviation of the COP along the y-axis

Average Displacement along X: Average displacement of the x coordinates of the COP

Average Displacement along Y: Average displacement of the y coordinates of the COP

Average Radial Displacement: Calculated for each frame. These numbers are added together and divided by the total number of frames

Standard Deviation (Radial Displacement) - The Standard deviation of the radial displacement of the COP

Correlation Coefficient: The correlation coefficient of X and Y, as $cov(x, y)/SD_x*SD_y$

SD- Major Axis of 95% Ellipse: Standard deviation along the major axis

SD- Minor Axis of 95% Ellipse: Standard deviation along the minor axis

95% Ellipse Area- Area of the 95% confidence ellipse, where 95% of the data lies within the area of the ellipse, in in^2 or cm^2

Average Velocity- The total length of the path of COP divided by the number of frames times the change in time, in inches per second or centimeters per second

Length: Total length of the path of COP, in inches or centimeters

Center of Pressure (COP): Point of application of all the ground reaction forces within a force plate

Vibration Testing

Amplitude- The maximum displacement of a vibrating particle or body from its position of rest, in inches or centimeters

Frequency- The number of occurrences of a repeating vibrational event per unit time

References

[1] About Nonwovens. (2010). Retrieved April 2, 2011, from Inda Association of the Nonwoven Fabrics Industry: http://www.inda.org/about/nonwovens.html

[2] ACLS: Principles and Practice. (2003). Dallas: American Heart Association.

[3] Acquisition distribution layer having void volumes for an absorbent article. (2002). Retrieved April 2, 2011, from World Intellectual Property Organization: http://www.wipo.int/pctdb/en/wo.jsp?WO=2002024133&IA=US2001029394&DISPLAY=STATUS

[4] ADL acquisition distribution layer. (2010). Retrieved March 30, 2011, from Alibaba.com: http://www.alibaba.com/product-gs/237374934/ADL_acqusition_distribution_layer.html

[5] Al-Shaqsi, S. (2010). Model of International Emergency Medical Services (EMS) systems. OMJ, 320-323.

[6] Boocock, M., Gray, I., & Williams, S. (2002). Patient Handling in the Ambulance Services. Contemporary Ergonomics, 33-38.

[7] Bourne, C. (2011, January 31). Ambulance Stretcher. (A. Zerguine, Interviewer)

[8] Bradshaw. (2007, November). Dirty Ambulances blamed for spread of killer superbugs. Retrieved February 9, 2011, from London Ambulance Service: http://www.dailymail.co.uk/health/article-496423/Dirty-ambulances-blamed-spread-killer-superbugs.html

[9] Clean EMS - Lifesaving Practices in Ambulance Cleaning. (2009, May). Retrieved February 9, 2011, from Fire EMS Blogs: http://lifeunderthelights.com/2009/05/clean-ems-%E2%80%93-lifesaving-practices-in-ambulance-cleaning/

[10] Clear Tygon S-50-HL Medical Tubing. (2011). Retrieved March 28, 2011, from Amazon.com, Inc.: http://www.amazon.com/Tygon-S-50-HL-Medical-Tubing-Length/dp/B000FOYKX4

[11] Conductive Hook and Loop Tape. (2011). Retrieved February 14, 2011, from Domanet Inc.: http://www.hookandloop.com/site/product.cfm?id=electrically_conductive_hook_and_loop

[12] Diapers. (2011). Retrieved April 2, 2011, from Dow Chemical Company: http://www.dow.com/polyethylene/ap/en/application/hygiene/diapers.htm

[13] Doormaal, M., Driessen, A., & Landerweerd, M. (1995). Physical Workload of ambulances' assistants. Ergonomics, 361-376.

[14] Dry Top 12x20' Tarp. (2011). Retrieved March 30, 2011, from Amazon.com, Inc.: http://www.amazon.com/Dry-Top-312201-20-Foot-Heavy-Duty/dp/B000FH4III

[15] EMS Medical Supplies: Stryker. Web. 25 Apr. 2011.http://www.ems.stryker.com

[16] EMS, Umass, interview by Abdul Zerguine. (November 20, 2010).

[17] Ferreira, J., & Hignett, S. (2005). Reviewing ambulance design for clinical efficiency and paramedic safety. Applied Ergonomics, 97-105.

[18] Gonzalez, Kayla, interview by Abdul Zerguine. (December 12, 2010).

[19] Gore-Tex Properties. (2011). Retrieved March 30, 2011, from W. L. Gore & Associates: http://www.gore-tex.com/remote/Satellite/home

[20] HAI Calculator. (2010). Retrieved February 9, 2011, from Advanced Disinfection Technologies: http://www.adtecbio.com/Calculators/HAICostCalculator1.xls

[21] Haynes, C. (2010, December 10). Ambulance Contaminants. (A. Zerguine, Interviewer)

[22] Helmenstine, A. M. (2011). How Do Disposable Diapers Work? Retrieved February 15, 2011, from http://chemistry.about.com/od/howthingsworkfaqs/f/diapers.htm

[23] Helmut, W., & Alexander, V. (2009). Whole-body vibration knowledge survey of U.S. occupational safety and health. Journal of Safety Research, 171-176.

[24] Item # MBX1004, Ultra-Thin ePTFE Membrane. (n.d.). Retrieved March 30, 2011, from Phillips Scientific Inc.: http://egotex.thomasnet.com/item/all-categories/eptfe-membrane/mbx1004?

[25] Kempt, Charles. "Clean EMS – Lifesaving practices in Ambulance Cleaning." Fire EMS. 2009. http://lifeunderthelights.com/2009/05/clean-ems-%E2%80%93-lifesaving-practices-in-ambulance-cleaning/ (accessed December 2010).

[26] Leiss J, Ratcliffe J, Lyden J, Sousa S, Orelien J, Boal W, Jagger J. Blood exposure among paramedics: incidence rates from the National Study to Prevent Blood Exposure in Paramedics. Annals of Epidemiology 2006(Sept.); 16(9):720-5.

[27] Letendre, J., & Robinson, D. (2000). EMS Evaluation of paramedic's tasks and equipment to control the risk of musculoskeletal injury. CUPE Internal Report, 873.

[28] Louis-Smith, E. (1986). Human engineering concern in ambulance interior design. Human Factors Society 30th Annual Meeting. Santa Monica.

[29] Martinez, R. (1998). New vision for the role of emergency medical services. Ann Emerg Med, 594-599.

[30] Moore, L. (1999). Measuring quality and effectiveness of pre-hospital EMS. Prehosp Emerg Care, 325-331.

[31] Rare Earth Magnets. (2011). Retrieved February 14, 2011, from Applied Magnets & WindMax Wind Turbines: http://www.magnet4less.com/product_info.php?cPath=1&products_id=54

[32] Rothman, R & Hsieh, M. "Communicable Respiratory Threats in the ED: Tuberculosis, Influenza, SARS, and Other Aerosolized Infections." Emergency Medicine Clinics of North America 24.4 (2006): 989-1017.

[33] Sarah Peyton Memory Foam Bed. (2011). Retrieved March 28, 2011, from CSN Stores LLC: http://www.csnstores.com/asp/superbrowse.asp?clid=46&caid=&sku=CQQ1000&PiID=3964037&refid=FR49-CQQ1000_3964037

[34] Schueller, R. (2011). Disposable Diaper. Retrieved April 2, 2011, from http://www.madehow.com/Volume-3/Disposable-Diaper.html

[35] Search, D. (2010, April). Quarter of NHS trusts failing hygiene tests. Retrieved February 9, 2011, from Health Direct: http://www.healthdirect.co.uk/2010/04/quarter-of-nhs-trusts-failing-hygiene-tests.html

[36] Strote, J., Simons, R., & Eisenburg, M. (2008). Emergency Medical Technician Treatment of Hypoglycemia Without Transport. American Journal of Emergency Medicine, 291-295.

[37] Super-Absorbing Polymer Powders. (2009). Retrieved March 28, 2011, from Colloids, Polymers and Surfaces Program Outreach Project: http://gelfand.web.cmu.edu/scimodules/1._Super-Absorbing_Polymer_Powder.html

[38] Tredegar Acquisition Distribution Layers. (2008). Retrieved March 30, 2011, from Tredegar: http://www.tredegarfilms.com/Markets/PersonalCare/BabyCare4.aspx

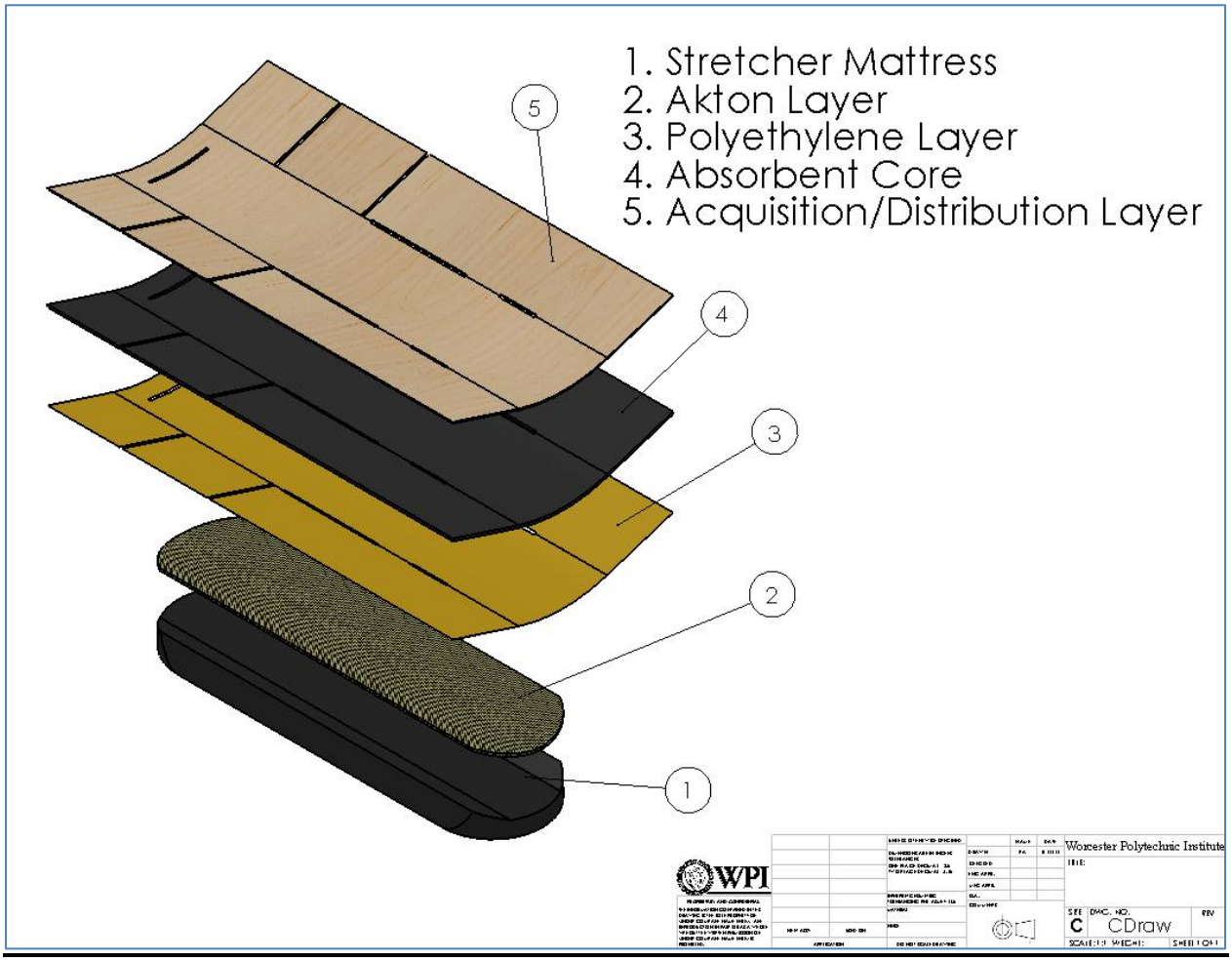
[39] United Nuclear Scientific Instruments and Supplies. (2011). Retrieved February 14, 2011, from http://www.unitednuclear.com/index.php?main_page=index&cPath=16_17_69

[40] West, K. (2000). After the call, The latest post-exposure medical management info. J Emerg Med Serv, 42-44.

[41] What are the Components of a Disposable Diaper? (2007). Retrieved 2 April 2011, 2011, from Richer Investment Diaper Consulting Services: http://www.disposablediaper.net/faq.asp?1

Appendices

Appendix A:

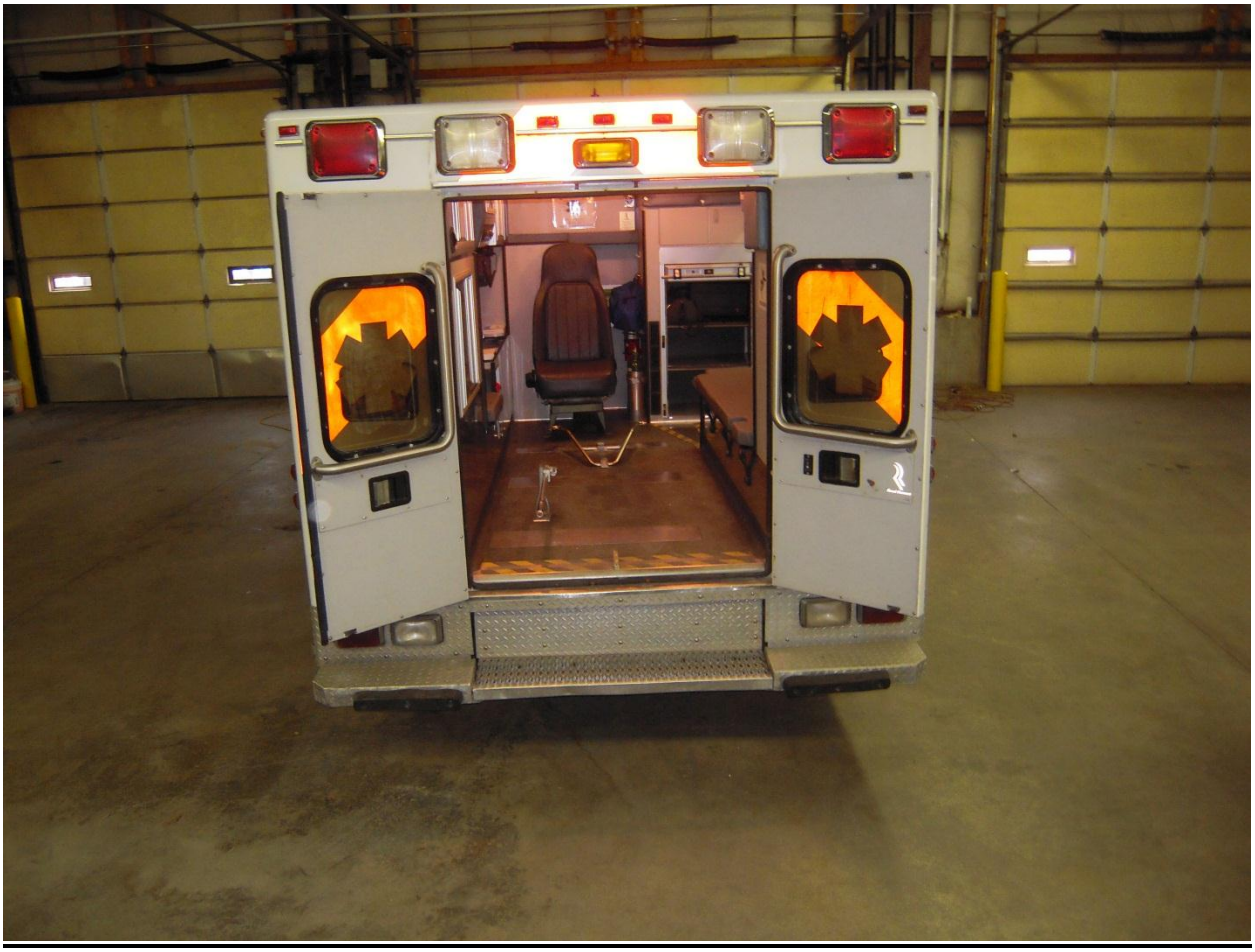


Exploded, color-coded, annotated CAD model of the Surgical Sponge Final Design

Appendix B:

Surgical Sponge MQP team at the UMASS EMS headquarters in Worcester, MA

Appendix C:



The internal compartment of a UMASS EMS Ambulance

Appendix D:

Professor Fofana, the Surgical Sponge MQP Team, and UMASS EMT's