Glue Gun Automation Final Report:

Semi-Automated Glass Mat Splice Operation for Asphalt Shingle Line

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Abstract

The following report details the senior project sponsored by GAF Materials Corporation, Shafter, CA in regards to semi-automating a glass-mat splicing table for asphalt roofing shingle production. Herein includes details, research, design, and analysis regarding the semi-automation of the gluing processes for the splicing table. A working prototype was manufactured and tested for the future implementation onto GAF's production line or further senior project involvement.

Introduction

Sponsor Background and Need

GAF Materials Corporation, located in Shafter, CA is a roofing shingle manufacturer looking to update their current asphalt shingle production line. For this reason, they have chosen to sponsor this Cal Poly senior project design team in order to help them achieve this goal.

The production of asphalt shingles requires that one end of a fiberglass mat roll be spliced and mated to the beginning of another roll multiple times during a shift in order to achieve continuous operation. Currently GAF employs two operators to perform the fiberglass mat splicing procedure. The key functions of the procedure include feeding a new roll of fiberglass mat into the splicing area, cutting both fiberglass mats, aligning the two fiberglass mats, applying hot melted glue, and pressing the two fiberglass mat ends together. Figure 1 depicts the current splice table used at GAF. A new process is needed that will allow a single operator to perform all steps of the splicing process. The new process should have a degree of automation and produce consistent splices that are as reliable if not more reliable than those produced by the current process.

Figure 1. GAF's Current Splice Method.

The initial objective of this project was to analyze, design, and produce an offline prototype that performs the splicing process. The prototype was to be tested with intentions to fully develop and integrate into GAF's asphalt shingle production line.

The team spent the first quarter of the project researching and outlining the problem. At the conclusion of winter quarter (March 21, 2014) the team determined that the initial scope of the project was much too large to be accomplished in the given amount of time. Therefore, it was agreed upon by the team, sponsor, and project advisor that the project be narrowed down to the current scope presented in this document. For all analysis and documentation of the project

prior to this revision of the problem statement refer to the attached document; 'Concept Design Review I: Semi-Automated Glass Mat Splice Operation for Asphalt Shingle Line'.

Problem Definition and Objectives

GAF roofing currently employs a semi-automated system in order to splice together two separate glass mats. The current system requires two operators to manually cut, glue, and align the mat and hydraulic press. The system exposes users to sharp objects, hot glue, and a hazardous press. GAF needs a more efficient, reliable, and consistent system to splice together two separate glass mats.

The objective of this project will be to analyze, design, and produce an offline prototype that performs the gluing process. The prototype is to be tested with the intention to integrate the new design into GAF's current splice table.

Customer Requirements:

- The system must be operable by a single operator.
- The system should use electric servo motors to move the glue gun.
- The system must apply glue in a consistent and timely manner.
- The system must perform as good if not better than the current system.
- The new system must decrease safety hazards to operator.
- The new system must employ hands-off operation outside of initial activation.
- The design must be compatible with GAF's current glue gun and splice table.
- The system must be capable of future automation.
- The system should prevent overspray.
- The assembly must be rigid, durable and shock proof.
- The system must be able to accommodate inconsistent mat placement and various mat sizes.
- The system must operate in a high fiberglass particulate environment.
- The system should utilize Thomson Linear products where applicable.

The automation of the system can be accomplished by any means necessary, but emphasis should be placed upon utilizing linear motion electric servos. GAF will supply the components and programming to automate the system.

The new system must also have sufficient splice strength for the downstream process comparable or better than the current splice strength. The target splice break reduction rate for the new system will be 20% less than the current system.

The new system must reduce exposure to hot glue as well as reduce potential ergonomic hazards towards the operator.

The new system will benefit GAF roofing by increasing efficiency, the system operator by reducing safety risks, and the customer by ensuring a quality product.

Preliminary engineering design and analysis of the system as well as an offline prototype of the gluing system are expected to be completed so that the system can be tested for safety, quality, and efficiency targets.

The project will be accomplished by first researching current solutions as well as analyzing the current systems design. Based upon this research, a new system will be designed based upon the above stated constraints.

Engineering Specifications

Table 1 contains the engineering specifications developed for the project. These specifications are based upon the customer's requirements as understood by the design team. These requirements are listed in Table 2 as well as in the Quality Function Deployment (QFD) tool found in Appendix A. The engineering specifications were derived through the use of a QFD tool, in this case a 'house of quality'. The house of quality is a tool used to analyze the customer requirements and help narrow down the specific engineering requirements that correlate with achieving each requirement. Furthermore, the house of quality is used to compare the various engineering requirements and weigh them based upon the customer's specifications. The house of quality also allows for the logical progression from engineering requirements to measurable targets in order to determine the success or failure of meeting each requirement. After determining the engineering requirements and measurable targets, the current system is analyzed for effectiveness of meeting these requirements. Appendix B has a general house of quality diagram for reference.

As can be seen from the QFD, the highest weighted engineering requirements are those which have numerical targets associated with their success. These requirements are the most crucial to the design because they cannot be easily achieved and must be verified through both testing and analysis. Furthermore, these requirements correlate to those features which are currently not included in GAF's current glass mat splice table.

Based upon this analysis, the problem statement in the objectives section was derived with the final outcome being a working offline prototype with the capacity to be easily automated.

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Table 1. GAF Fiberglass mat splice table formal requirements.

Spec. #	Parameter Description	Requirement or Target	Tolerance	Risk*	Compliance**
1	Sufficient Traverse Speed	79 fpm	±5 fpm	M	A, T
2	Adequate Safety Shielding	No direct contact with glue gun	NA	M	I, T
3	Retrofit Design	Mounts to press plate assembly	NA	M	I, T
4	Sensitive Component Protection	Operating Temperature < 160°F	±5°F	M	A, T
5	Uniform Process	20% reduction from current splice breaks	≤20%	H	I, T
6	Auto-Alignment Capabilities	Allows incorporation of sensor	TBD	L	T
7	Utilize Existing Glue Gun	Yes or No	NA	L	I,T
8	One Man Adjustability	Total Weight < 200lb	NA	L	T

*__H__igh, **M**edium, **L**ow
__A__nalysis, **Test, **S**imilarity/Existing **D**esign, **I**nspection

Table 2. GAF Fiberglass mat splice table customer requirements.

Customer Requirement #	Customer Requirement
1	One Man Operation
2	Compatible with Current Design
3	Consistency
4	Quick Process
5	Safety
6	Reliable
7	Splice Break Reduction
8	Compatible with multiple mat sizes
9	Capable of Automation
10	Easy Maintenance
11	No Overspray
12	Shock Resistant

Background

Existing/Similar Products

Research for existing products was conducted to find what was commercially available. Any existing products would help us develop potential solutions toward fulfilling our sponsor's requirements.

Fisnar Inc. specializes in manufacturing various types of automatic fluid dispensers for markets. The Fisnar Industrial Robot series are automatic dispensing machines that discharge fluid onto a working area. As seen in figure 2, the system has a 3 or 4 traversing axis systems that allows for automatic precise movement across the work area. Unfortunately, it has a small working area and is unable to handle high temperatures. These characteristics prevent the Fisnar F9600 from fulfilling the needs of GAF.

Figure 2. Fisnar F9600 robot.

Another similar product is made by Industrial Robot Supply, Inc. who manufactures industrial robotic arms. The robotic arms have the capability of grabbing a piece of work and moving that piece from one point to another. The robotic arms can also be outfitted with adhesive dispensing units. Figure 3 shows a Fancu M16i/Arcmate 120i RJ3 robotic arm.

Figure 3. Fanuc M16i/ Arcmate 120i RJ3.

Additionally, gluing mechanism patent searches were done to determine any limitations on design. The majority of searches yielded patents related to the robotic arm concept of gluing. US patent 2011012805 pertains to an angle adjusting glue dispenser for a Cartesian robot arm. Also, US patent 5893490 describes a hose mount for a robot arm dispenser system. Both patents are currently active.

Design Development

Idea Generation/Brainstorming

The initial steps of the brainstorming process began by defining the major components of the glue gun design.

Glue Gun System Components:

- **Supply Line Holder**: A system to support the air and power lines that need to be supplied to the glue gun. The system needs to be able to allow the air and power lines to move back and forth as the glue gun traverses across the table.

- **Carriage Height Adjustment**: A system is needed to adjust the height of the glue gun nozzle from the glass mat.
- **Linear Traverse System**: A system is needed to move the glue gun across the table quickly and smoothly.
- **Mounting system**: A system is needed to mount the new design onto the current splice table.

The team came together and held an individual brainstorming session for each of the above listed categories in order to generate solutions for each component.

Supply Line Holder Brainstorming Results:

- Spring
- Hang from ceiling/bracket
- Coiled plastic air hose
- Plastic linked cage
- Retractable winding roll

Mounting System Brainstorming Results:

- Clamps
- Bolt on
- Weld

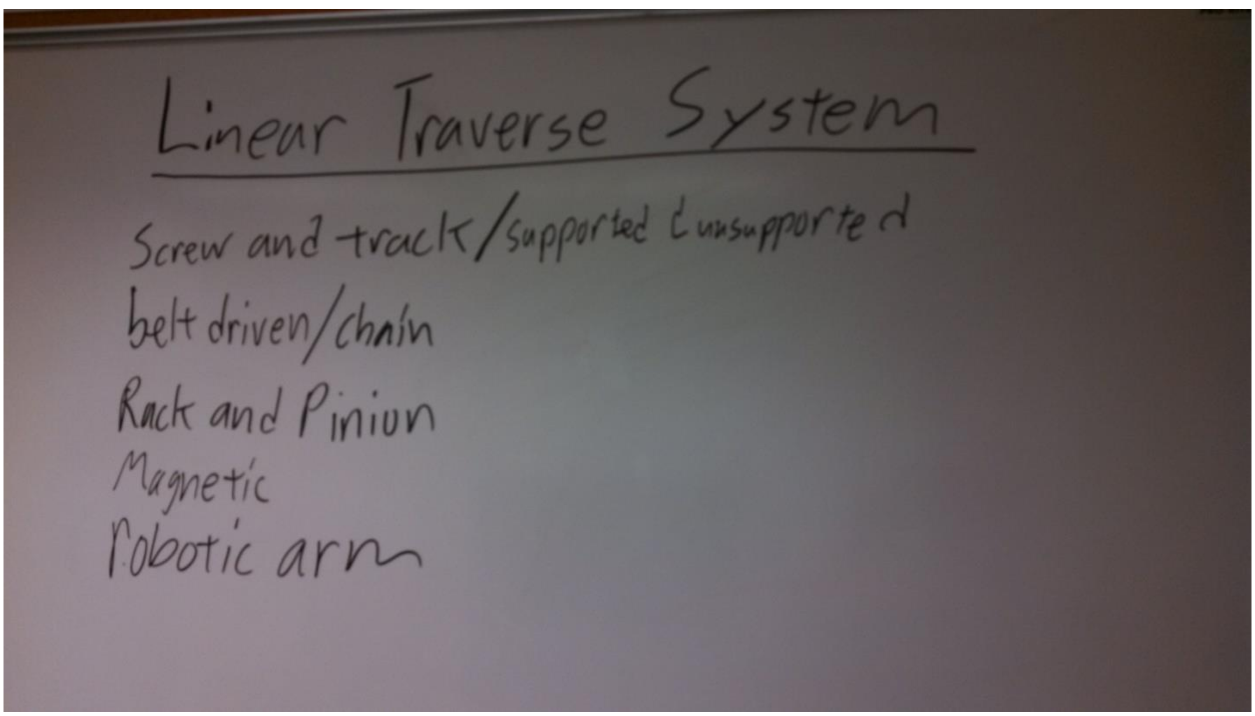


Figure 4. Linear traverse system brainstorming results.

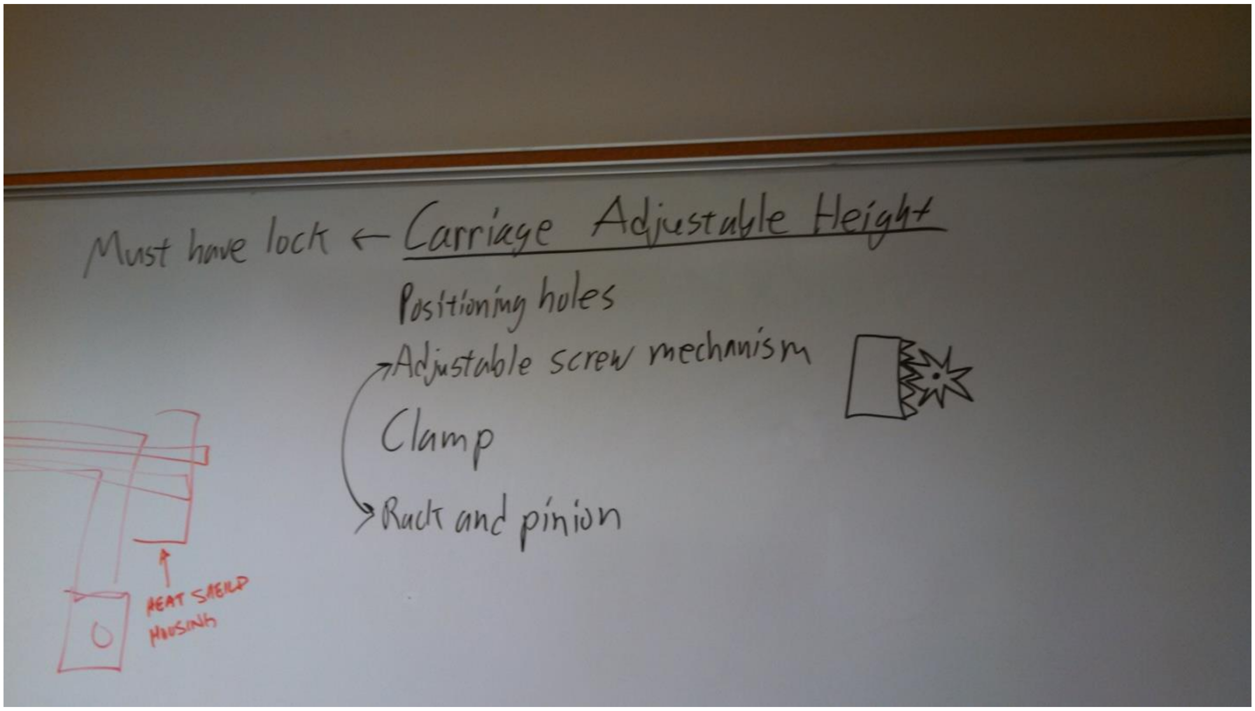


Figure 5. Carriage adjustable height brainstorming results.

With ideas generated for each of the glue gun components, the team then revisited each category and eliminated those ideas they deemed the weakest. The team then devised an overall solution for the glue gun system based upon the remaining ideas. These ideas are highlighted in Table 3.

Table 3. Glue gun system overall idea.

Component	Idea
Supply Line Holder	Plastic Linked Cage (Cable Chain)
Carriage Height Adjustment	Positioning Holes with bolts
Linear Traverse System	*Lead screw/belt drive
Mounting System	Bolt on

*Note: the team had originally chosen a belt driven design, however the sponsor later required the design utilize a lead screw.

The following figures (figures 6-9) are basic representations of the initial glue gun concept design derived from the brainstorming process. Figure 4 is an exploded view of the concept with each component labeled.

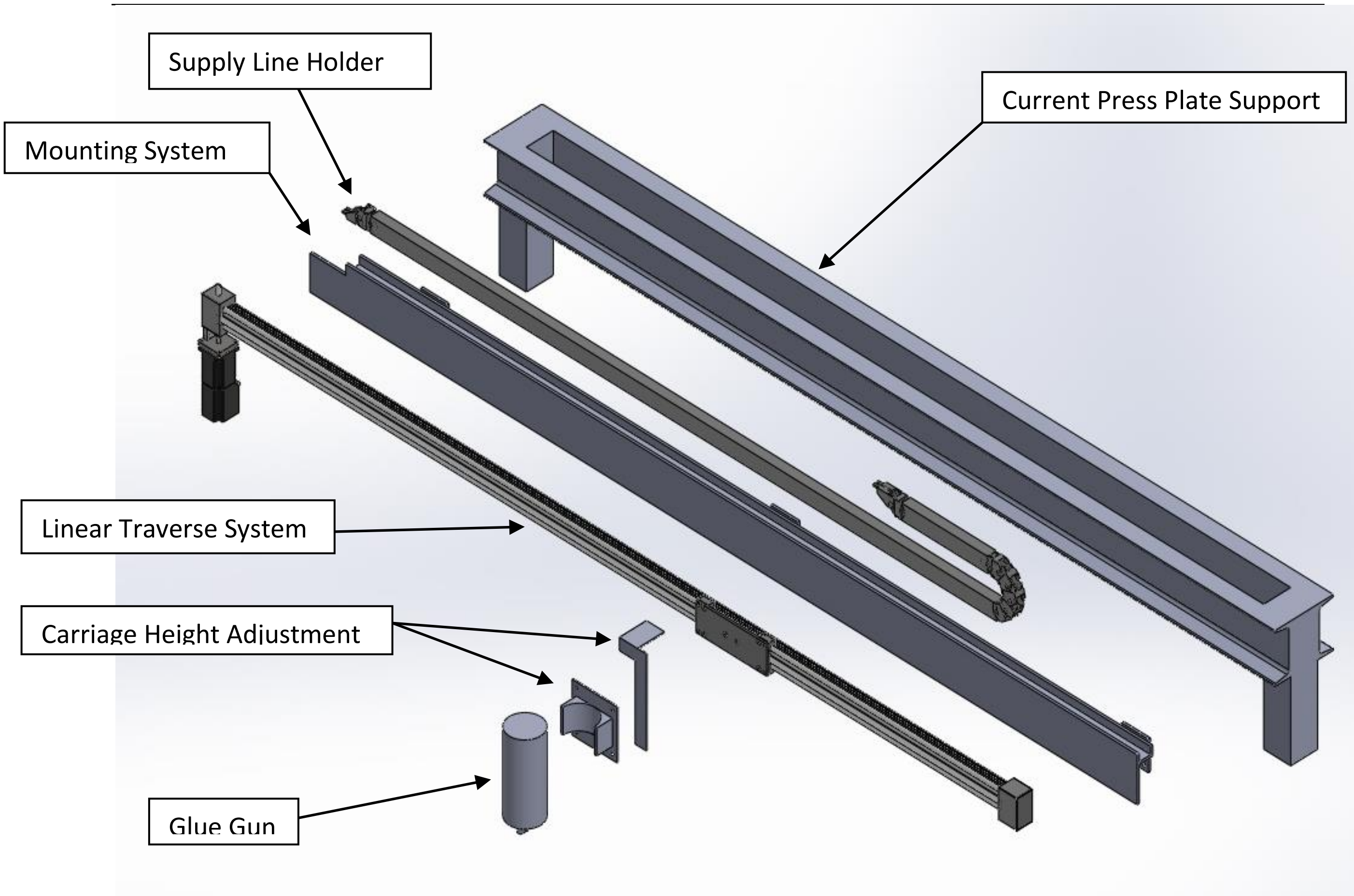


Figure 6. Basic glue gun concept.

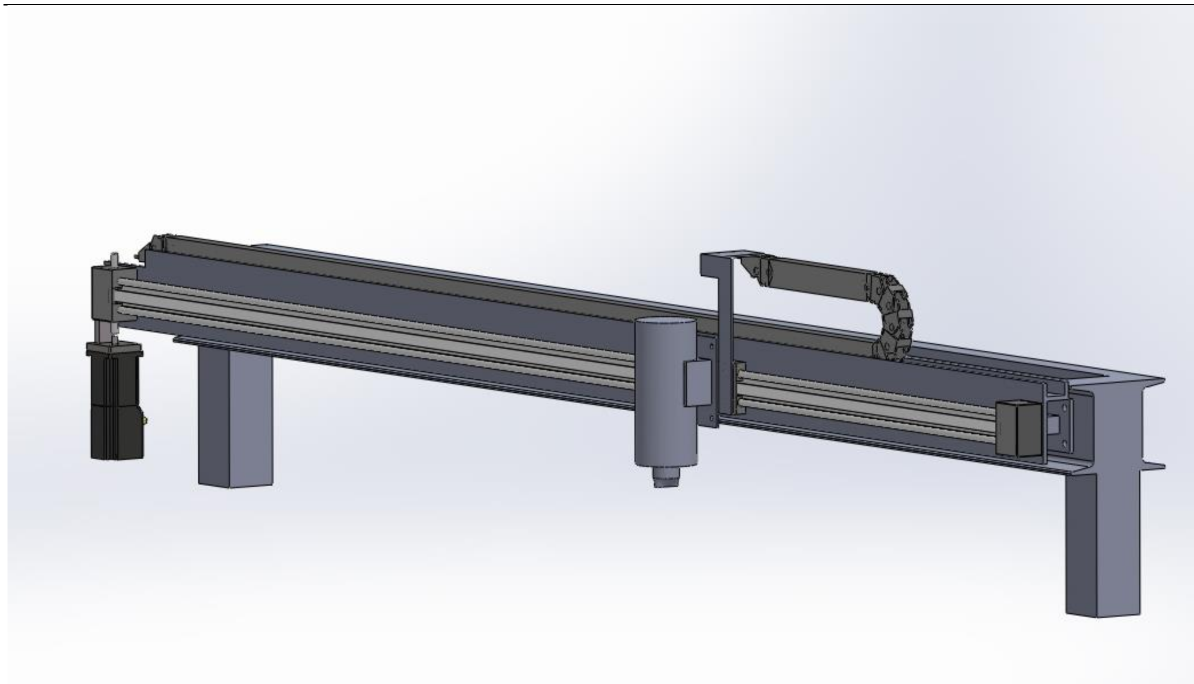


Figure 7. Basic glue gun concept view 1.

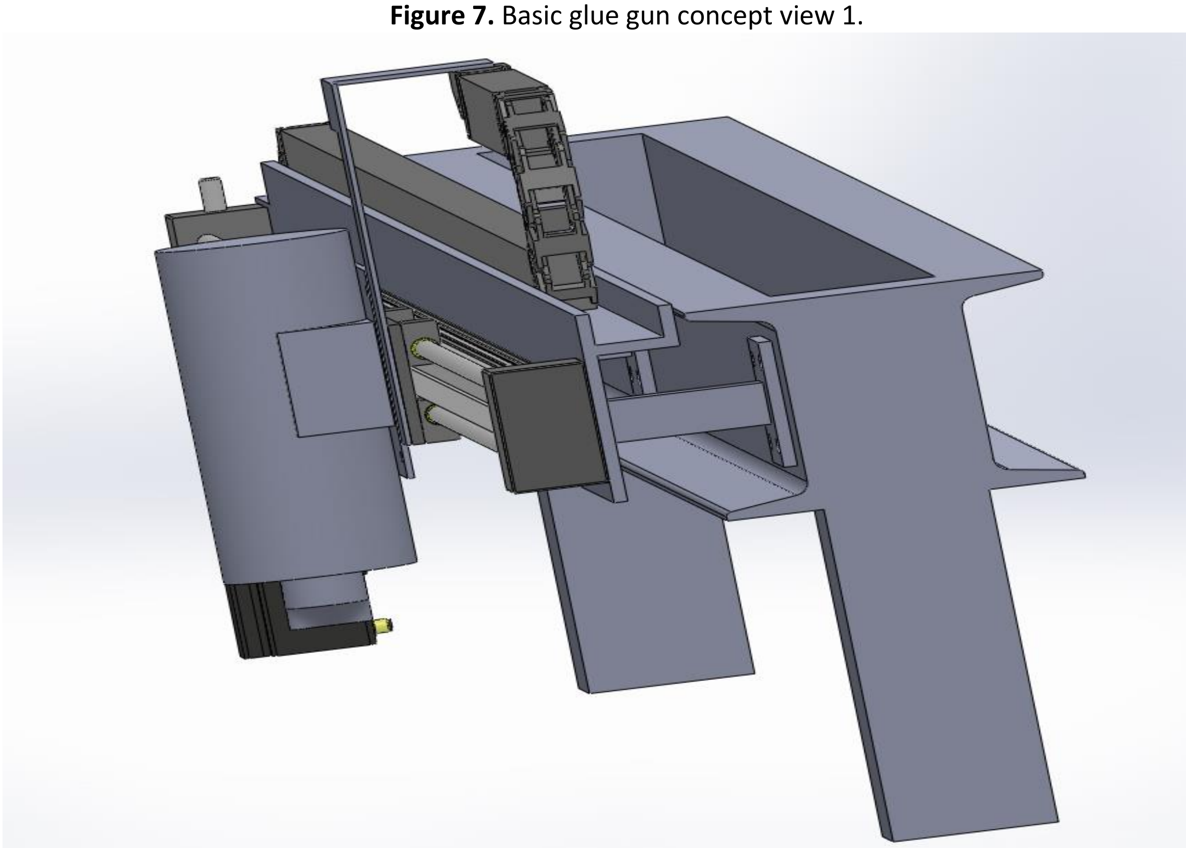


Figure 8. Basic glue gun concept view 2.

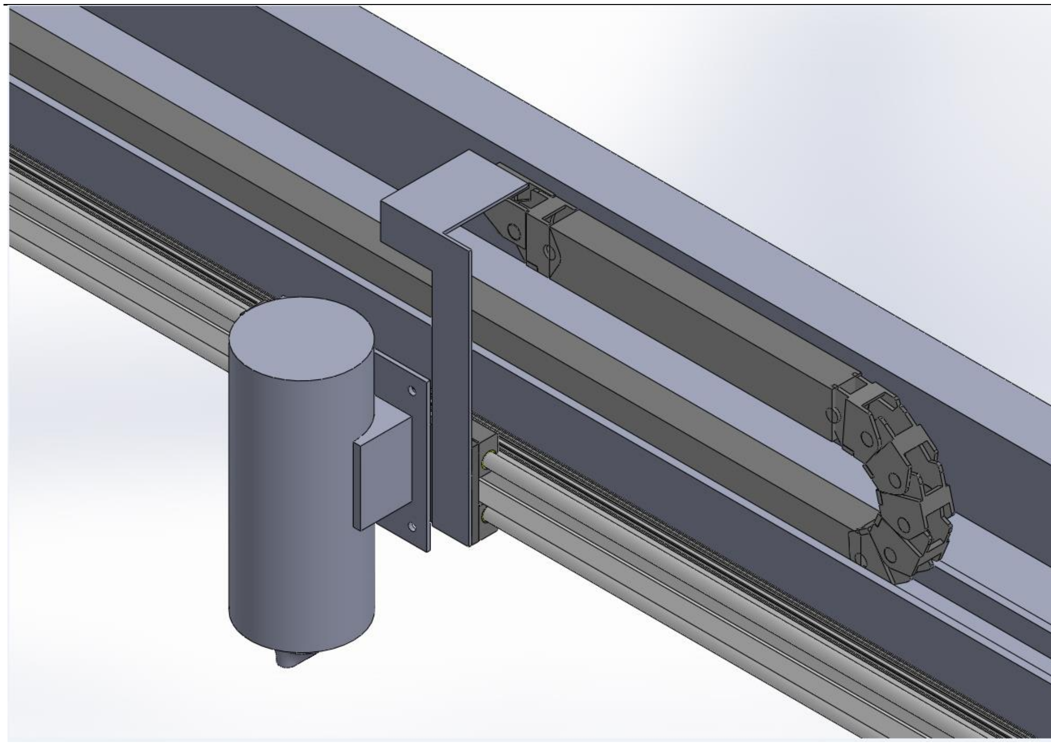


Figure 9. Basic glue gun concept view 3.

Concept Designs

GAF expressed a desire to be presented with 3 concept designs based upon a price range of high, medium and low. The team then set out to define a concept design for each price range with the most expensive option being the top of the line model and the least expensive model being the most cost effective design that would still fulfill the requirements of the project. These concepts were nicknamed Rolls Royce, Toyota, and Chevy; with the Rolls Royce being the top of the line design and the Chevy being the cheapest option. Figure 10 shows the results of a brainstorming session held by the team to generate these 3 concept designs.

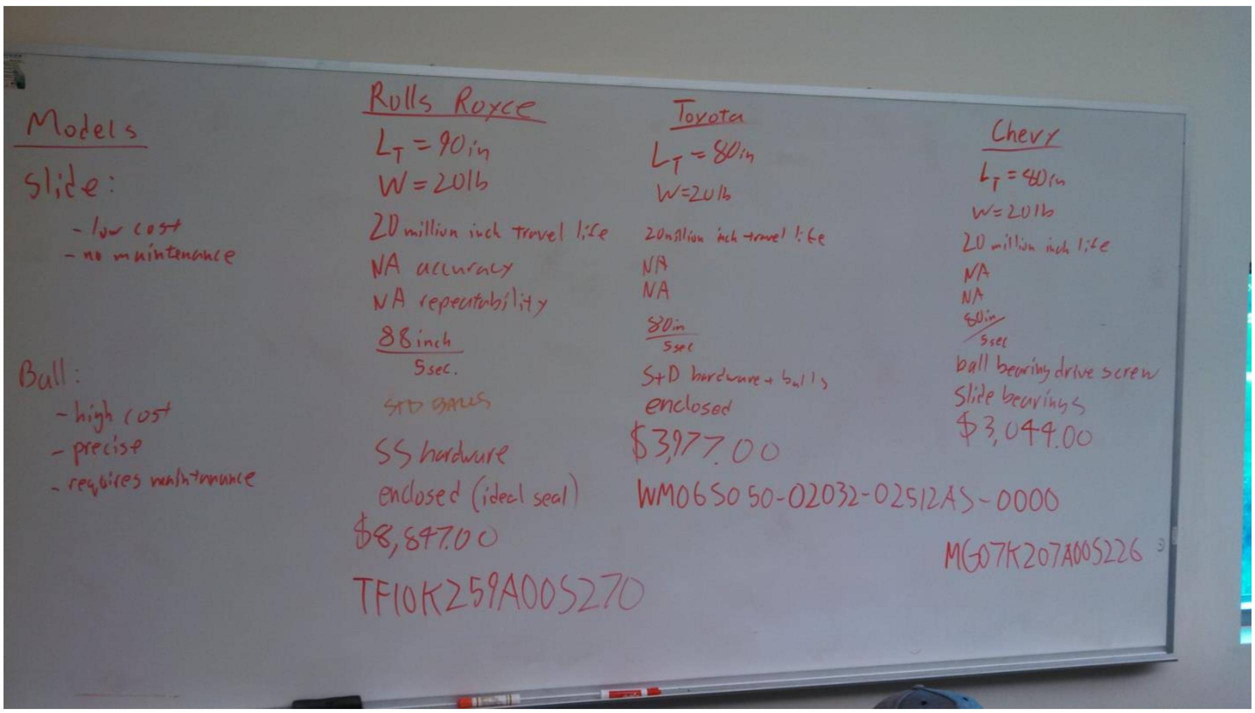


Figure 10. Price based concept design brainstorming results.

After generating ideas for the 3 concepts during a brainstorming session, the team determined that the primary determining factor in cost was the choice of linear traverse system. Therefore, the team focused their efforts on researching this component of the glue gun system. The components; carriage height adjustment, supply line holder, and mounting system were all held constant for the 3 price based concept designs.

Rolls Royce

The top of the line model utilizes a Thomson Linear MF07K series linear motion system. The highlights of this system are:

- Ball screw driven carriage with ball guided carriage.
- Self-adjusting stainless steel cover band that protects internal components.
- High load, high stiffness, low friction, high thrust, and long stroke capabilities.

- Stainless steel components and hardware.

The features of note for this option include the stainless steel hardware and components as well as the stainless steel cover band. This option is also fully enclosed and exceeds the load requirements of the project. Appendix D contains the technical data for the Thomson Linear M75 which is cross listed as the MF07K. The MF series is also identical to the TF series except for the fact that the MF series pertains to metric units whereas the TF series pertains to imperial units. Technical data for the TF series can be found in appendix C. Figure 11 shows the MF07K linear system.

Basic Cost estimate: $4,000.00 (Supplied by Thomson Linear online)

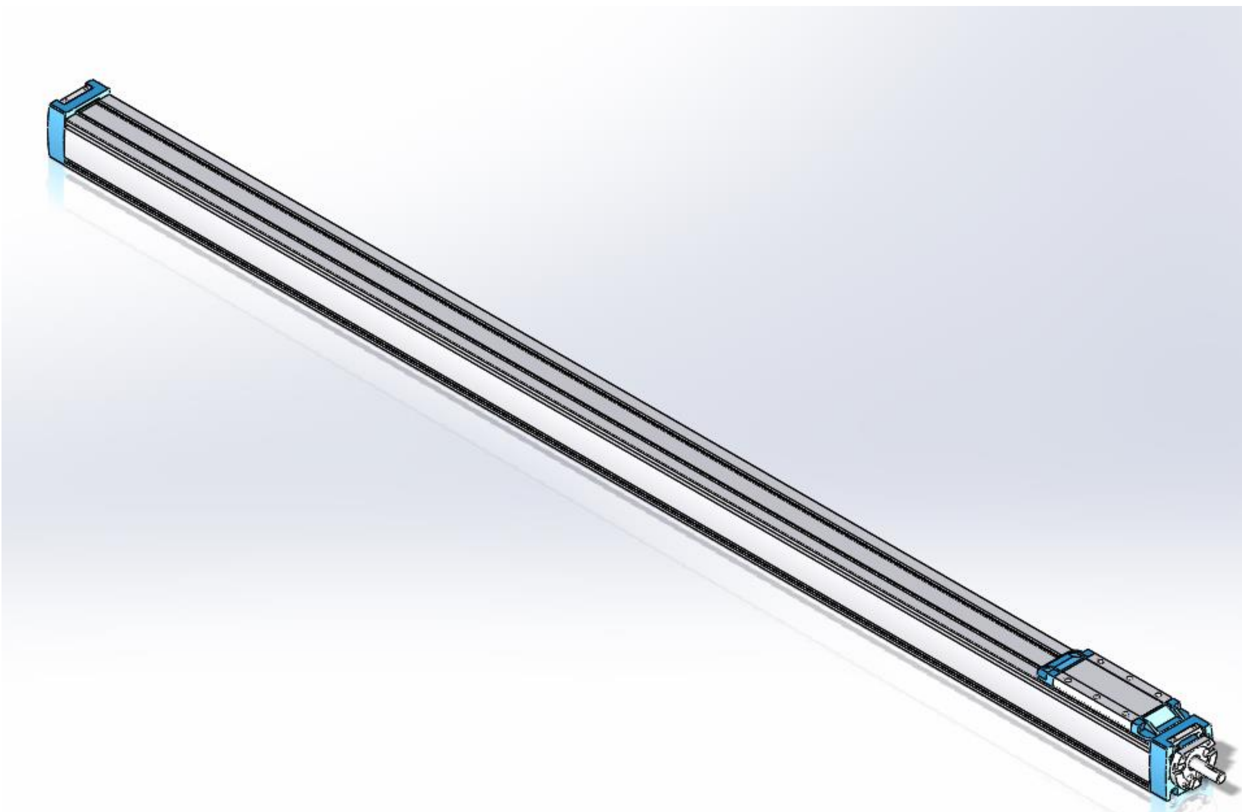


Figure 11. Thomson Linear MF07K207A00S200.

Toyota

The middle class concept utilizes a Thomson Linear WM60S linear motion system. The highlights of the system are:

- Ball screw driven carriage with ball guided carriage.
- Ball guided carriage supports.
- Self-adjusting plastic cover band.

The primary difference between the WM60s and the MF07K is the WM has a cover band made of plastic rather than stainless steel and the fact that the MF is constructed using stainless steel hardware. However, it should be noted that the WM linear system has a greater load capacity than the MF series. The WM series has a maximum dynamic load of 2800 N (629 lbs) and the MF has a maximum dynamic load of 2500 N (562 lbs). Furthermore, the WM series has a maximum drive shaft torque of 35 Nm (25 ft-lbs) and the MF series only has a maximum drive shaft torque of 30 Nm (22 ft-lbs). Figure 12 shows the WM60S linear system. The technical data for the WM series linear system can be found in Appendix E.

Basic Cost Estimate: $3,200.00 (Supplied by Thomson Linear online)

Figure 12. Thomson Linear WM60S050-02000-02480AS-0000.

Chevy

The cheapest option utilizes an Igus DryLin ZLW linear motion system. The highlights of this system are:

- Belt Drive Carriage.
- Igus iglide J lubrication-free bearings.
- Anodized aluminum profile with plastic end housings.

The primary difference between this system and the other two systems is the fact that this system uses a metal reinforced belt to pull the carriage across the track. Furthermore, unlike the other two systems which use lubricated ball bearings, this system uses Igus iglide bearings which are plastic, lubrication free slide bearings. Furthermore, the igus system is not completely enclosed and makes more use of plastic components. Figure 13 shows an exploded view of the Igus DryLin ZLW linear motion system. The technical data for the Igus DryLin ZLW linear motor can be found in Appendix F.

Basic Cost Estimate: $1,253.44 (See Appendix F)

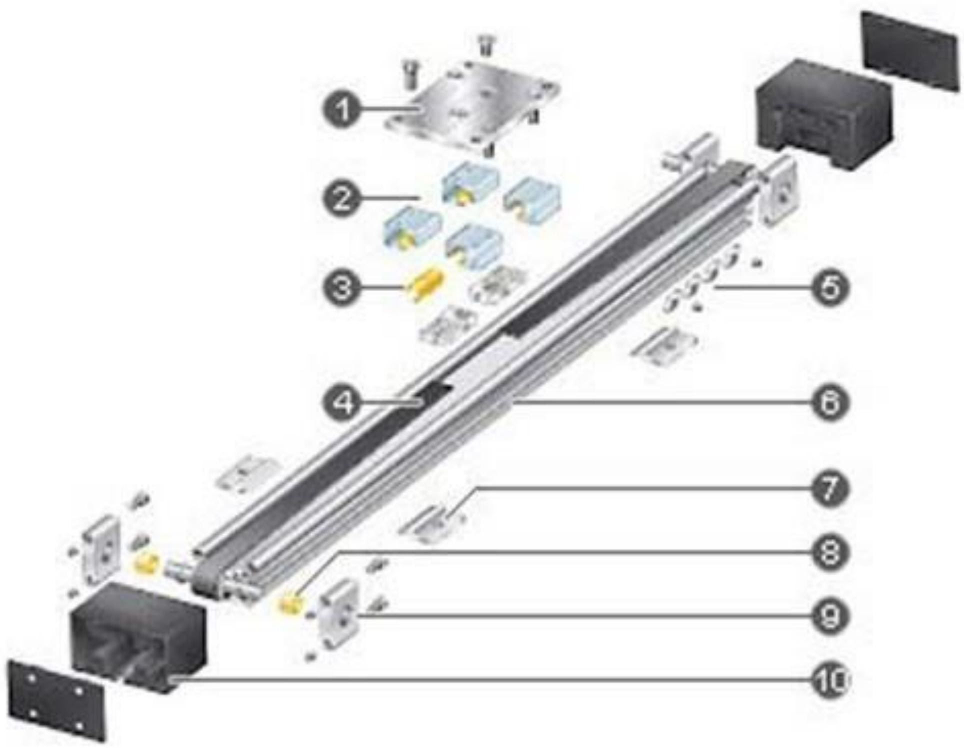


Figure 13. Igus DryLin ZLW-1040-02-S-200-L linear motion system.

As stated earlier the 3 price based concept designs were developed with only variations to the linear motion system. All of the price based concepts utilize the same supply line holder, glue gun height adjustment system, and mounting system. The specifics of these systems are outlined later in the component design description section.

Weighted Decision Matrix

A weighted decision matrix was used to evaluate the glue gun system concept. The weighted decision matrix in Appendix G lists the design criterions derived from the customer requirements (Table 2) and the three glue gun system concepts derived by the team. The matrix identifies how well each concept fulfills the various design criterions based upon a weighted and non-weighted factor. The non-weighted factor is a numerical representation of how well the concept meets the design criterion. This representation is based upon an arbitrary scale from 0 to 100 with 100 meaning that the concept fulfills the design criterion perfectly and 0 meaning that the concept does not fulfill the criterion whatsoever. The weighted decision matrix also contains a weighting factor column. This column numerically rates each criterion's importance in regards to the overall system. The sum of the values in the weighting factor table is 1. This means that a criterion with a higher weighting factor value is more important to the overall

performance of the system. The weighting factor was determined based upon the team's interpretation of each criterion's importance.

The weighted satisfaction for each criterion is the product of the weighting factor and the non-weighted score of the respective criterion. The sum of the weighted satisfaction is the measure of how effectively the given system meets the overall design criterion. A perfect system would have an overall weighted satisfaction of 100.

The results of the decision matrix revealed that the 'Rolls Royce' was the most effective design. This result was not surprising when taking into account the fact that the 'Rolls Royce' system utilized the top of the line linear system.

Description of Final Design

Overall Description

The overall final concept design is shown on Figure 14. The components of the assembly are shown in the figure. Figures 15-17 are alternative views of the final design.

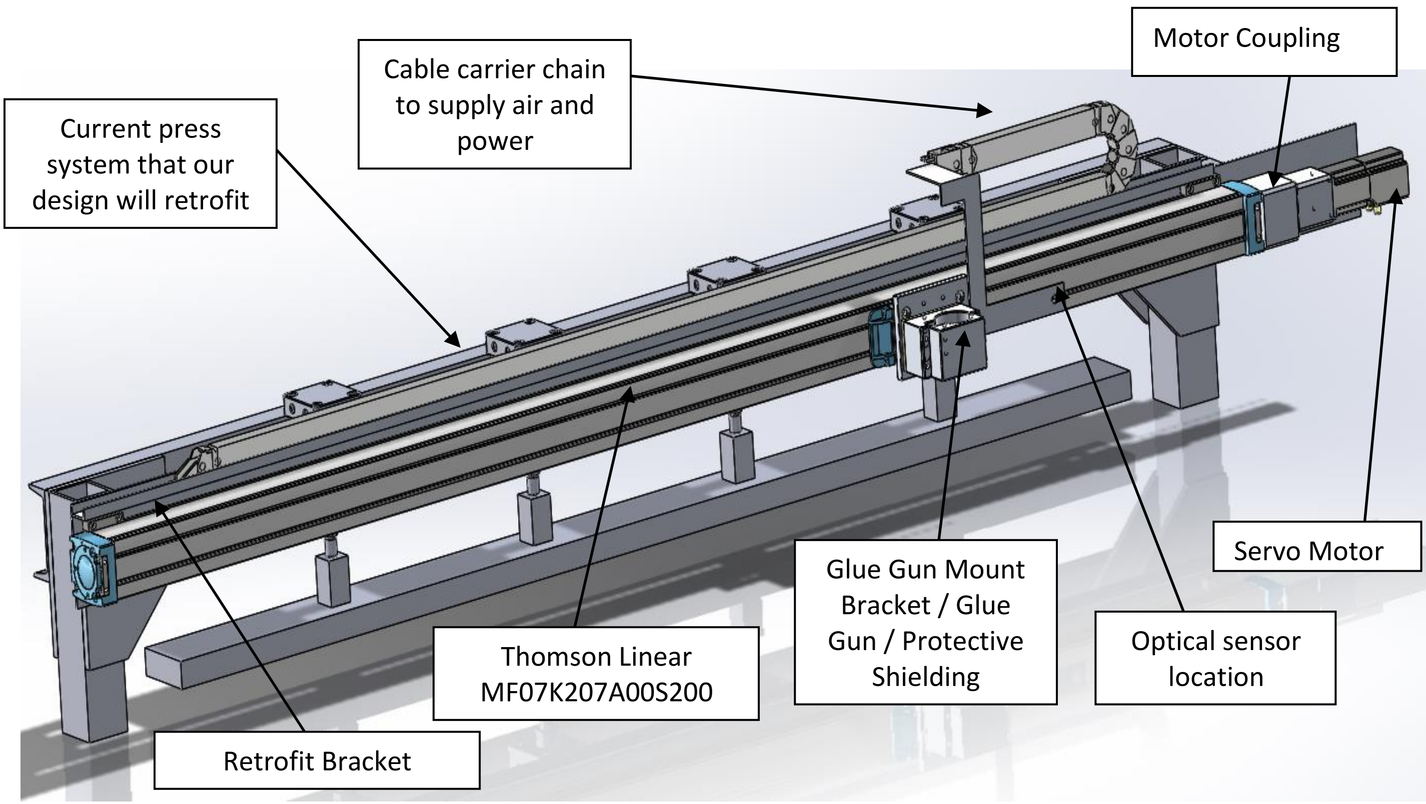


Figure 14. Final design concept for glue gun system.

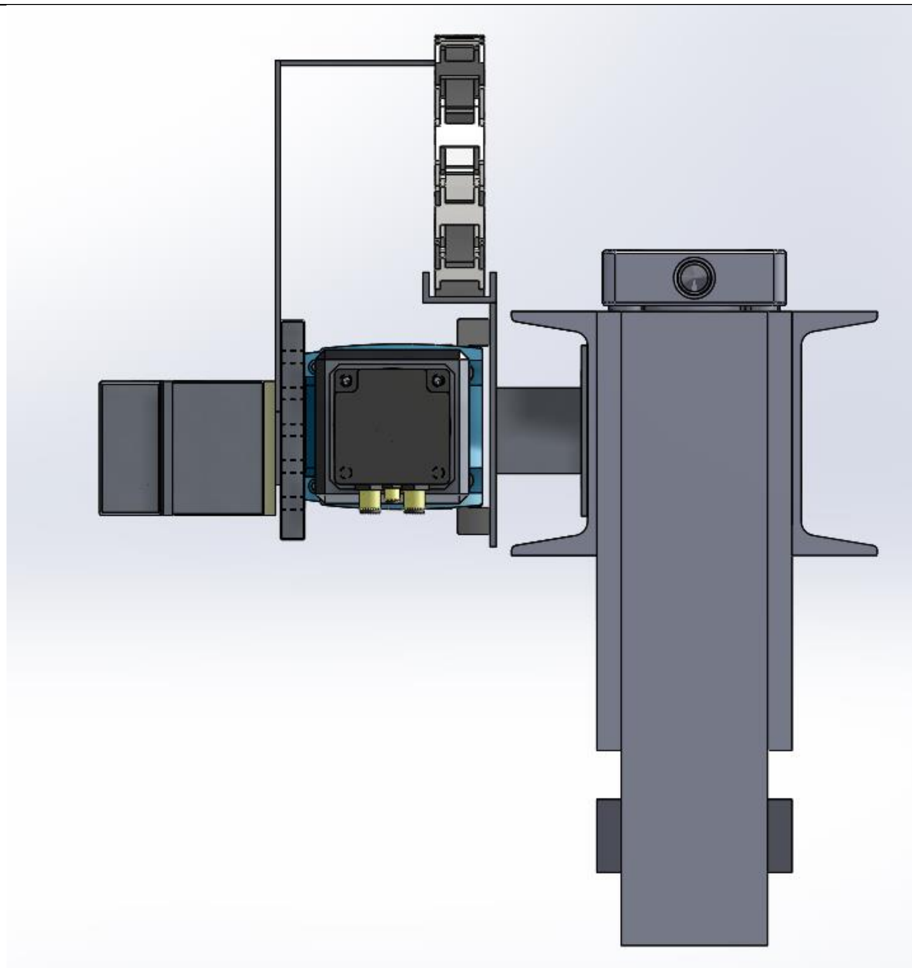


Figure 15. Side view of final design assembly.

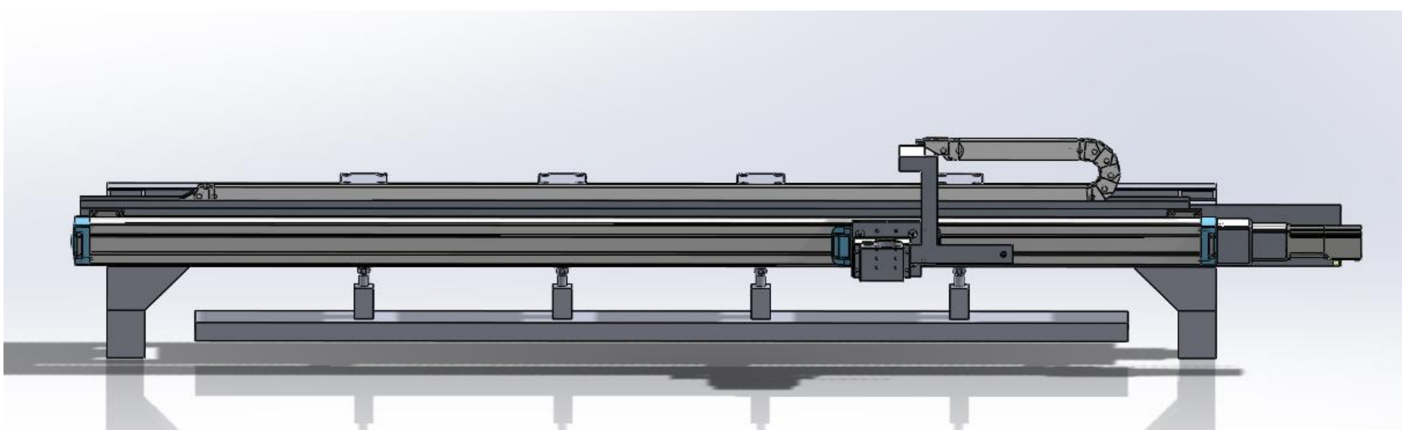


Figure 16. Front view of final design assembly.

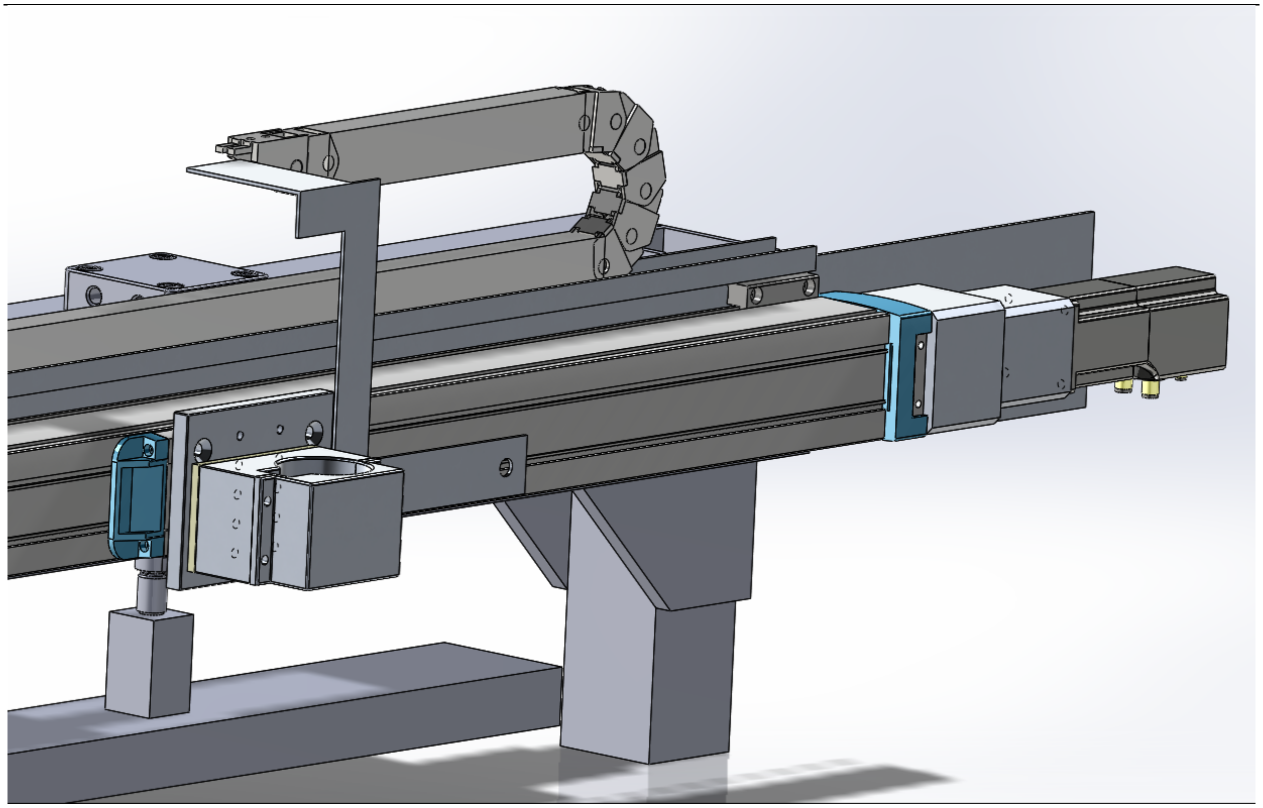


Figure 17. Close up view of the gluing mechanism.

Component Design Description

Thomson Linear System

The linear motion system used in the design is the Thomson Linear MF07K207A00S200. This linear system utilizes a single nut ball screw drive and carriage that rides along an extruded aluminum track on ball bearings. The ball screw and bearings are enclosed within the aluminum rail system and are protected by a stainless steel cover band. The stainless steel cover band is composed of two pieces held together magnetically. As the carriage runs across the linear tracks, the cover band separates and snaps back together as the carriage goes past.

The system is rated for use in high particulate environments and has a wash down option available. The wash down option includes more stainless steel mounting hardware. The wash down option was not included in the final design because of the fact that the option only adds stainless steel mounting hardware to the linear system which is not essential to the overall design. The linear system would have a total length of 81 inches and a stroke length of 70 inches. The screw is supported internally and the carriage is attached to the lead screw with a single nut. See Appendix H for a diagram of the single nut and screw support design. Figure 11 is a graphical representation of the Thomson Linear MF07K207A00S200. The technical data

regarding the Thomson Linear MF07K207A00S200 can be found in Appendix D as well as the simplified table in figure 18.

Rapidtrak T•07K		TF07K		TG07K	
		0702	2020	0702	2020
Max. speed	Ft/s(m/s)	2 (0.63)	3.3 (1)	2 (0.63)	3.3 (1)
Repeatability	in(mm)	± 0.002 (± 0.05)		± 0.004 (± 0.1)	
Ambient temperature		-4°F(-20°C) +158°F(+70°C)			
Linear movement / shaft revolution	in(mm)	0.50 (12.7)	0.79 (20)	0.50 (12.7)	0.79 (20)
Max. input speed	rpm	3000			
Weight with A-saddle	lb	(7.1(L* x .03281))+14.1		(5.5(L* x .03281))+11.7	
Weight with A-saddle	kg	(10.5(L* x 0.01))+6.4		(8.2(L* x0.01))+5.3	
Weight with C-saddle	lb	(7.1(L* x .03281))+23.8		(5.5(L* x .03281))+19	
Weight with C-saddle	kg	(10.5(L* x 0.01))+10.8		(8.2(L* x0.01))+8.6	
Weight per pair screw supports	lb(kg)	3.53 (1.6)			

**See figure 1, L = inches for pound calculations or cm for kg calculations*

Figure 18. Simplified table of Thomson Linear MF07K data.

Retrofit Bracket

The retrofit bracket is composed of a large flat rectangular piece that will be mounted to the press plate frame at four positions. The bracket will be bolted to the press plate frame using the existing bolt locations. A second, smaller rectangular piece will be affixed to the top of the first rectangular piece at a 90° angle. This second plate will serve as a guide for the cable chain which will guide the electrical and pneumatic lines to the glue gun as it tracks across the table. Figures 19 and 20 show the retro-fit bracket with key features noted.

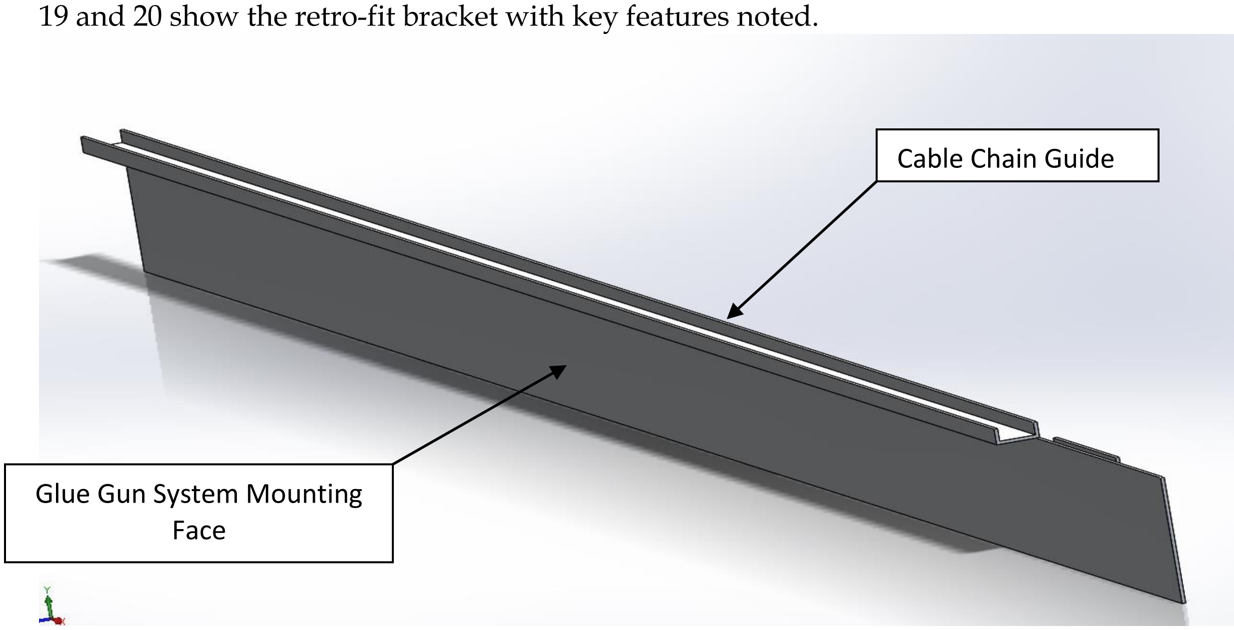


Figure 19. Retro-fit bracket.

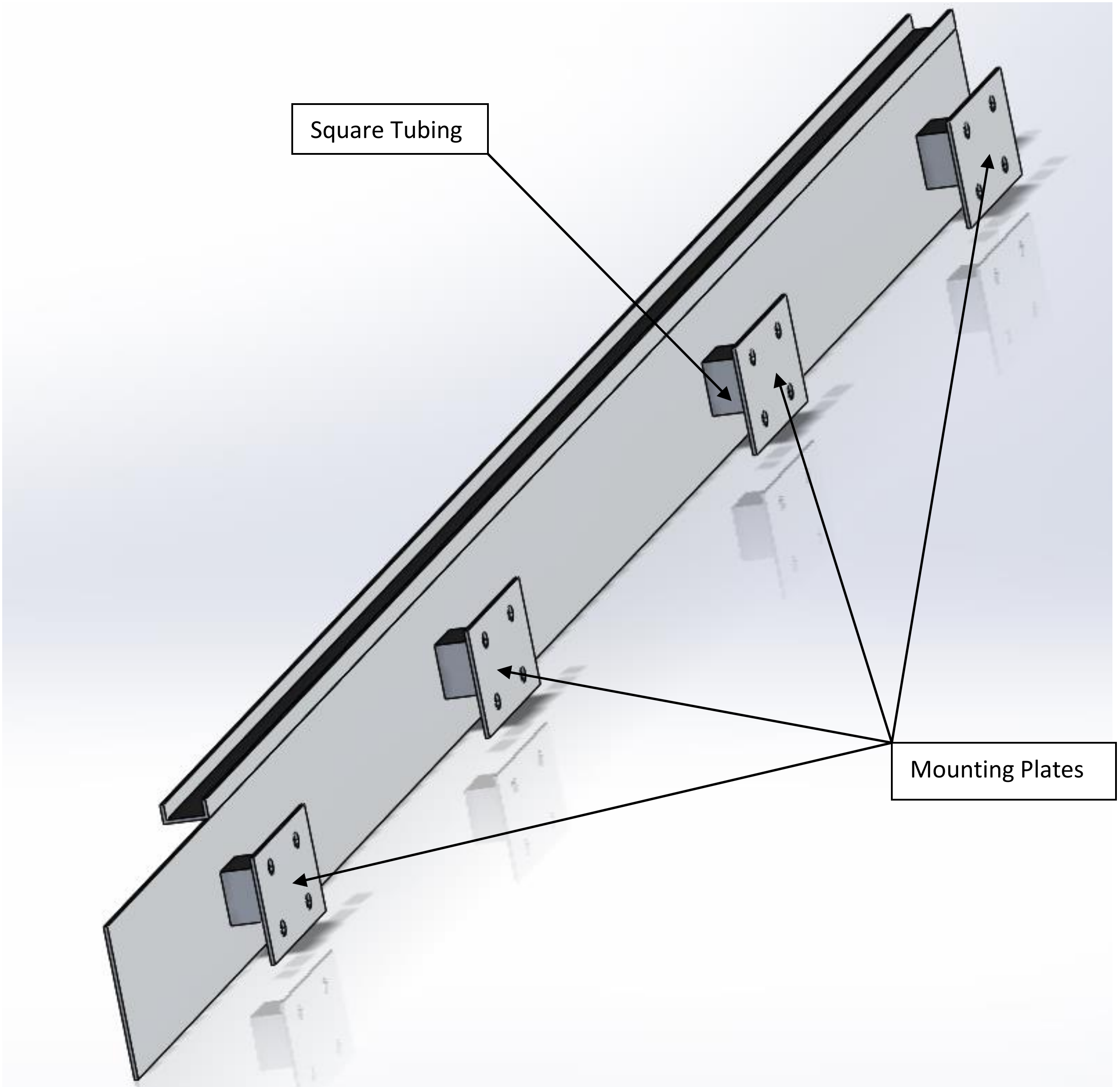


Figure 20. Rear view of retro-fit bracket.

The retrofit bracket is made from 1/8 in thick AISI 1018 steel. This steel was chosen because it is cheap, readily available and has high weld ability and is easy to work with. Most importantly, AISI 1018 steel meets the strength requirements of the design. The analysis results section contains a detailed description of how these strength requirements were determined and verified against the strength of AISI 1018 steel. The major point of concern and thus analysis in this design was the sizing of the square tubing used to support the weight of not only the bracket itself, but the entire linear motion system to be attached to the bracket.

The bolts used to affix the bracket to the press plate bracket are not yet specified. As previously mentioned, the retrofit bracket will bolt onto the existing press plate bracket using the existing bolts on the press plate bracket. These bolts will likely remain the same size but be upgraded to stainless steel. There is little concern for bolt failure with this design. Figure 21 is a close up of the existing bolt pattern on the press plate bracket.

Figure 21. Bolt pattern on current press plate bracket.

Cable Chain

The pneumatic air lines and the electrical lines for the glue gun will be guided to the gun through a cable chain. A cable chain is a hollow flexible tube like system made of rigid plastic and composed of multiple links, like a chain. The pneumatic airline and electrical lines are fed through this chain which rests on the top of the retrofit bracket. This ensures that as the glue gun moves across the table, the lines do not become tangled or interfere with the rest of the system. Figure 22 shows an example of a cable chain.

Figure 22. Cable chain from McMaster-Carr.

Servo Motor and Motor Coupling

The servo motor to be used in the design will be an electric servo motor supplied by GAF. This motor will be selected using the motor specifications detailed in the analysis results section of this report.

The motor coupling is the interface between the output shaft of the electric servo motor and in the input shaft of the lead screw of the Thomson linear system. The motor coupling will be a custom ordered part from Thomson built specifically to work with whatever motor GAF chooses to supply for the system.

It should be noted that the inclusion of a gearbox between the motor and the input shaft of the lead screw was considered. However, the Thomson Linear tech support service advised that the same results could be selecting the proper size lead for the lead screw in the Thomson linear system. The detailed analysis and selection of this lead is outlined in the analysis results section of this report.

Glue Gun Mounting Bracket Assembly

GAF requested that the new design must be able to incorporate and utilize a Bühnen HB500EHT hot melt applicator gun. This is the current glue gun that the operators use during the splice process. It was important that we did not change the actual gluing process as GAF has performed it successfully for many years, but reduce the required operator input to the process.

The glue gun was intended for handheld use so the team disassembled a HB500EHT to determine how it could be mounted to the carriage of the linear motion system. The team determined that a custom designed mounting bracket would be necessary to fully meet the design requirements. These design requirements are as follows:

- The bracket needs to be very rigid in order to not allow the glue gun to move when the whole system experiences shocks due to quick stops back and forth both in the direction of the glue gun travel as well as perpendicular.
- The outer surface of the glue can reach temperatures as high as 500°F. The mounting bracket must take into account possible heat transfer from the gun and ensure the linear motion system will not experience temperatures above its rated working temperature.
- The design must include safety guards to protect from the hot glue gun and other possible dangers.

To rigidly mount the glue gun, a two-piece bracket that utilizes part of the current glue gun mounting points and fully surrounds the tubular body of the gun was designed. The bracket spans roughly one-third the length of the glue gun body. While the bracket was designed to squeeze the ceramic mounting block of the glue gun, the circular portion that encapsulates the tubular body was designed to allow for roughly a one-quarter inch thick fibrous insulation to be wrapped around the tubular body of the gun. The amount of insulation wrapped on the gun can be varied to achieve the correct amount of compressive force required to keep the glue gun rigid. The two-piece bracket is held together using four standard M6x20mm socket head cap screws, two on each side.

The two-piece mounting bracket is then bolted to a mounting plate. This mounting plate serves two purposes, interfacing between the carriage of the linear motion system and providing vertical adjustment for the glue gun. The glue gun mounting bracket is bolted to the plate using four M6x40mm socket head cap screws. The plate is mounted to the carriage of the linear motion system using four counter-sunk M8x25mm flat head screws, as specified by Thompson Linear.

In order to reduce the amount of heat transfer through the glue gun mounting assembly, the team implemented a couple different features within the design. The first heat consideration was directly around the tubular body of the glue gun which was mentioned above. The glue gun will be wrapped with high-temperature fibrous wrap. The planned material has a thermal conductivity of 0.05 W/m-K. This will greatly reduce the amount of heat that is transferred to

the mounting bracket and with also insulate the glue gun which will allow the gun to run more efficiently and maintain more precise temperatures. Next, the M6x40mm bolts will utilize Nylon 6.6 sleeves and insulating fiberglass washers to prevent direct contact between the bolt and bracket and reduce heat transfer to the mounting plate. Morgan Thermal Ceramics BTU-BLOCK Board will also be placed between the mating surfaces of the mounting plate and mounting bracket to further reduce heat transfer. Heat transfer analysis has been completed and can be found in the Analysis Results section. Analysis concluded that the back side of the mounting plate will be well within the temperature range of the linear motion system with worse-case assumptions used. Figure 23 shows the glue gun mounting assembly with added thermal reduction features described above. Figure 24 shows the resultant temperature gradient across the glue gun mounting assembly from the heat transfer analysis.

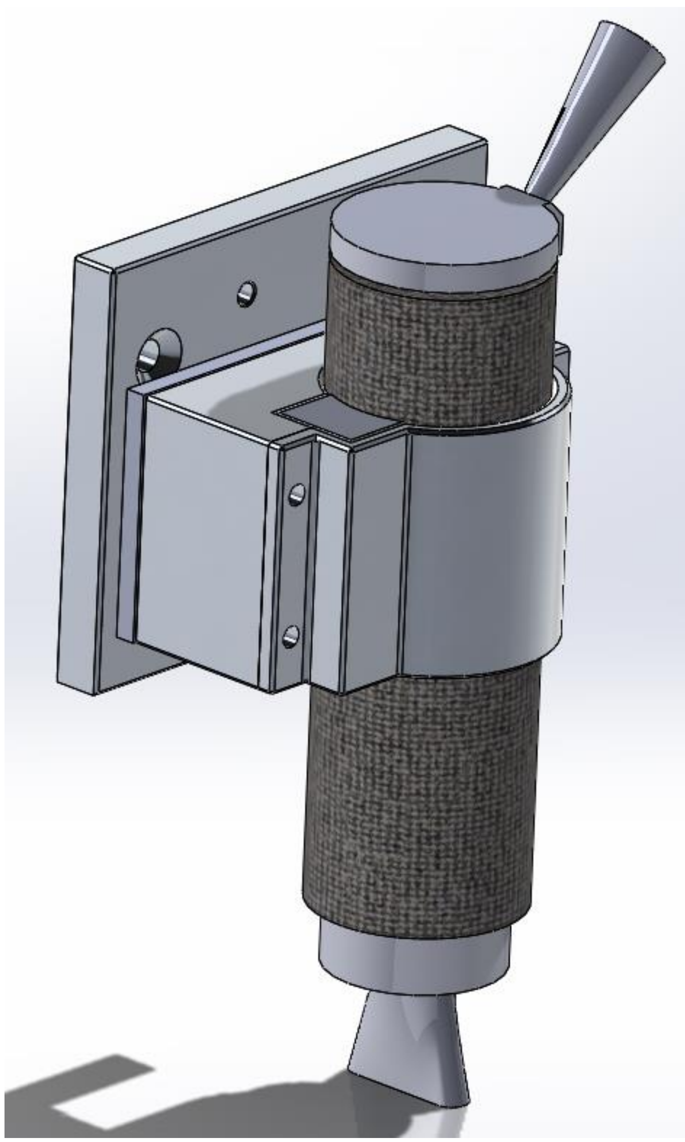


Figure 23. Glue gun mounting assembly with added thermal features and representation of HB500EHT glue gun.

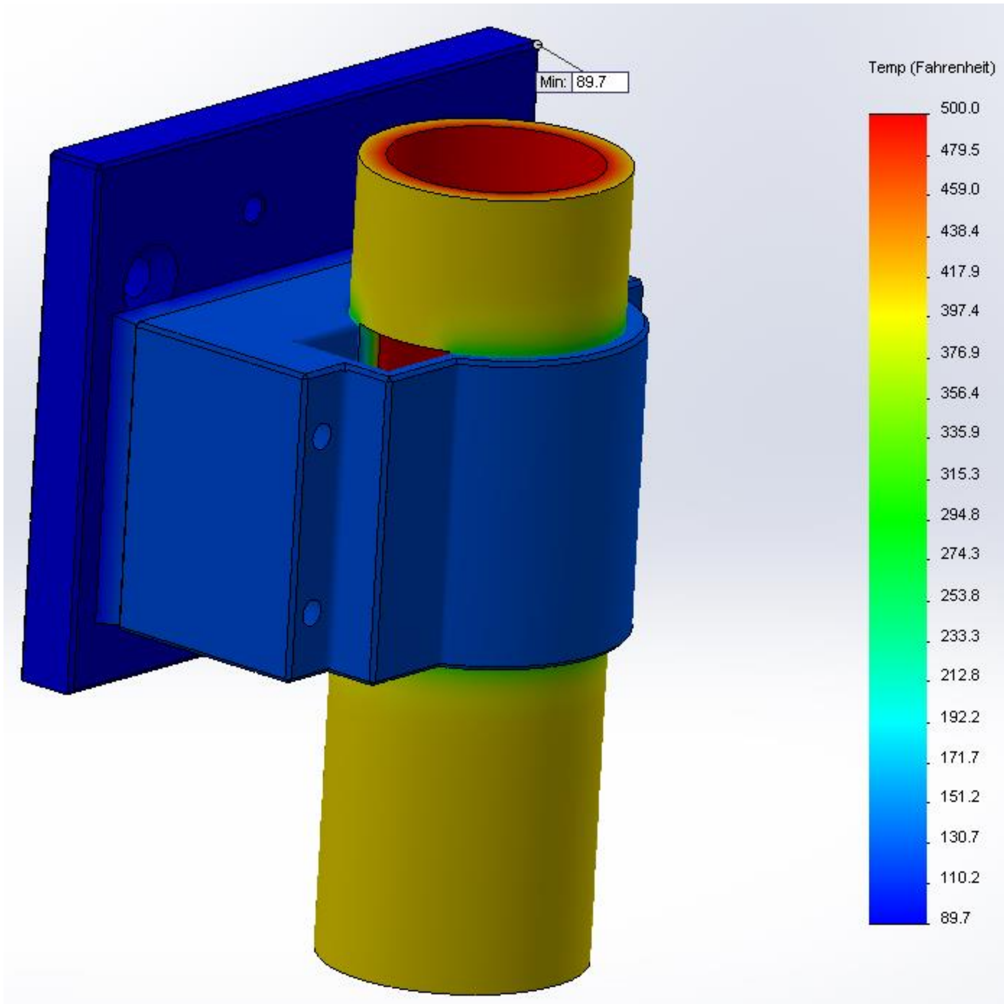


Figure 24. Temperature gradient across glue gun mounting assembly from heat transfer analysis.

The glue gun mounting bracket and plate will machined from 6061-T6 aluminum. All hardware used within the glue gun mounting assembly with be 316 stainless-steel. An exploded assembly view can be seen in Figure 25. Note that the figure does not depict the nylon sleeves and fiber washers.

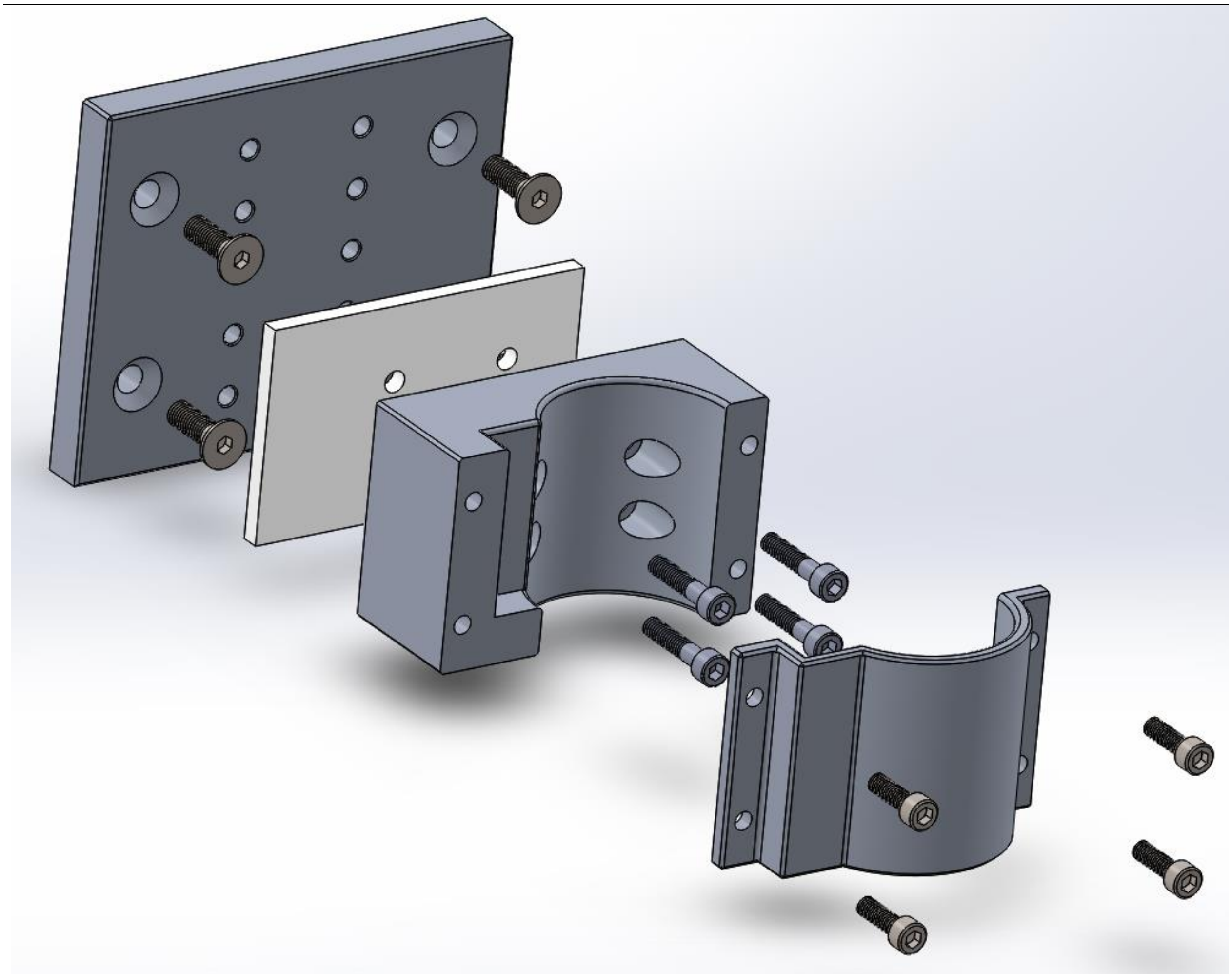


Figure 25. Exploded view of the assembly for the glue gun mounting bracket and plate.

The outer temperature of the glue gun, even with the thermal wrap, and the mounting bracket will be hot during operation, as can be seen in Figure 24. In order to satisfy the safety design requirements, a protective shield will cover around the glue gun and glue gun mounting assembly. This shield will be constructed from steel sheet metal and also lined with insulation. This insulation used with protect from convective and radiative heat transfer to ensure that the outer temperature of the shield will not burn the operator. The shield will also be clearly marked on all sides with "hot" warning labels for added safety. The proposed design of the shielding can be seen in Figure 26.

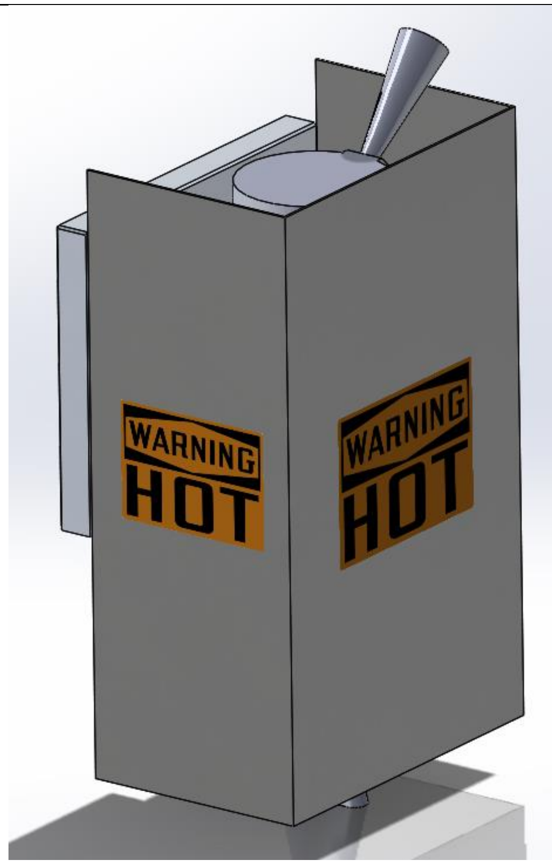


Figure 26. Glue gun mounting assembly with protective shielding.

Sensor/Chain Bracket

The sensor/chain bracket is a small bracket made of 1/8 sheet AISI 1018 steel. Figure 27 is a graphical representation of the sensor/bracket chain. The purpose of the bracket is to provide a mounting point for the visual sensor as well as provide an attachment point for the cable chain. The sensor/chain bracket will be affixed to the glue gun mounting bracket assembly as shown in figure 28.

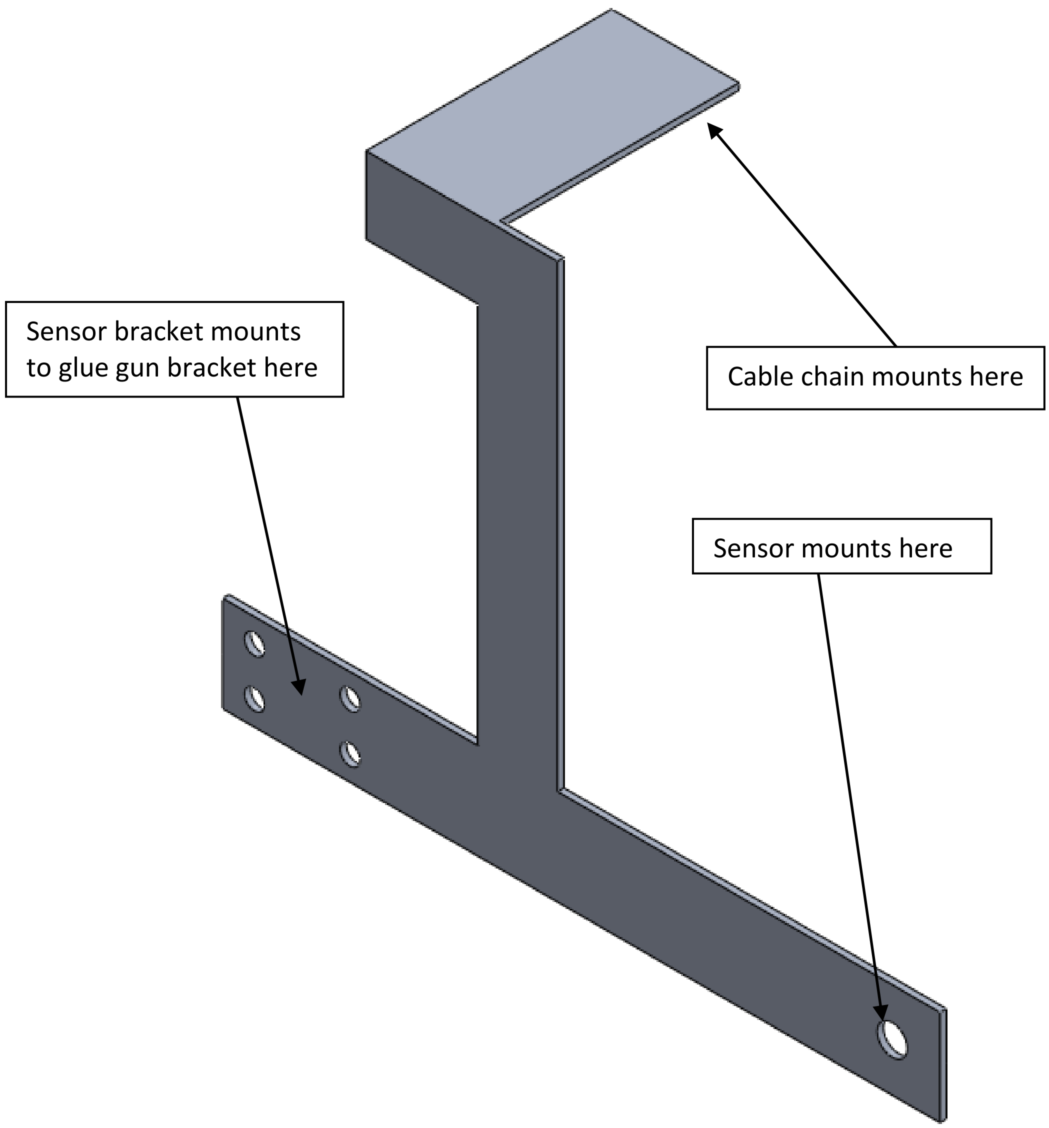


Figure 27. Sensor/Chain bracket.

The visual sensor will be mounted in front of the glue gun by a distance of $6\frac{1}{2}$ inches. This will allow the sensor to sense the presence of the glass mat and allow enough time for the glue gun to react to the input of the sensor. This concept and the complete operation of the sensor are described in detail in the sensor operation section.

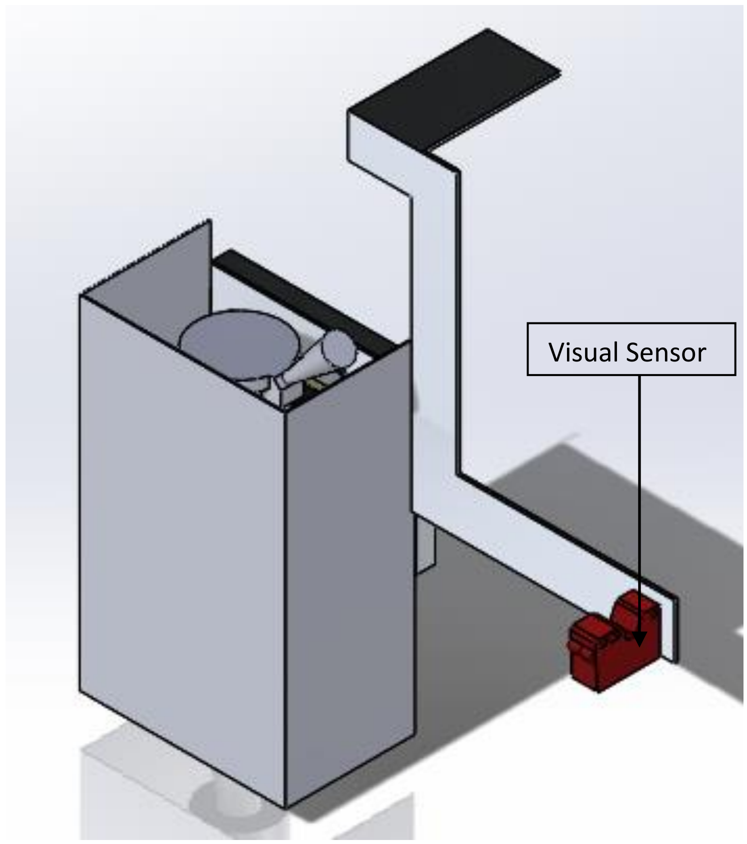


Figure 28. Sensor/Chain bracket shown attached to glue gun mounting bracket assembly.

Sensor Operation

While the complete automation of the system is not within the scope of this project, the team felt that it was necessary to detail the basic method by which the system could be automated.

The key component in the automation of this system would be a visual sensor. This sensor would be able to detect the transition from a dark medium to a light medium and vice versa. For example, if the sensor were to be slowly moved across figure 29, the sensor would produce a signal at points A and B. This signal would then be received by a controller which would have control over an electrically actuated valve in the glue gun. This valve would control the supply or air to the glue gun. Therefore, when the controller received a signal from the sensor, the controller would activate the glue gun air valve and the glue gun would begin to deposit glue. When the controller received the signal from point B, the air valve would be closed and the glue gun would cease depositing glue. Figure 30 is a basic block diagram representation of this

process. Figure 31 is a picture of a glass mat on the splice table. Note that in its current configuration, the splice table is not painted black and would have to be should this design be implemented.

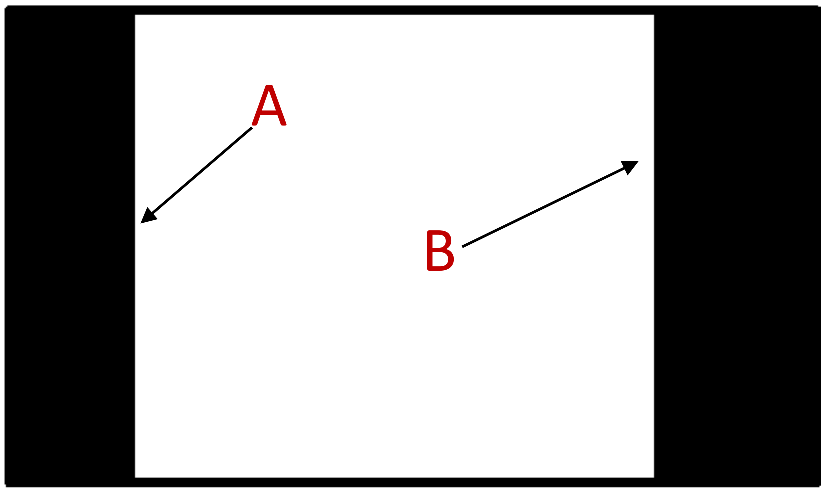


Figure 29. Sample glass mat on black splice table.

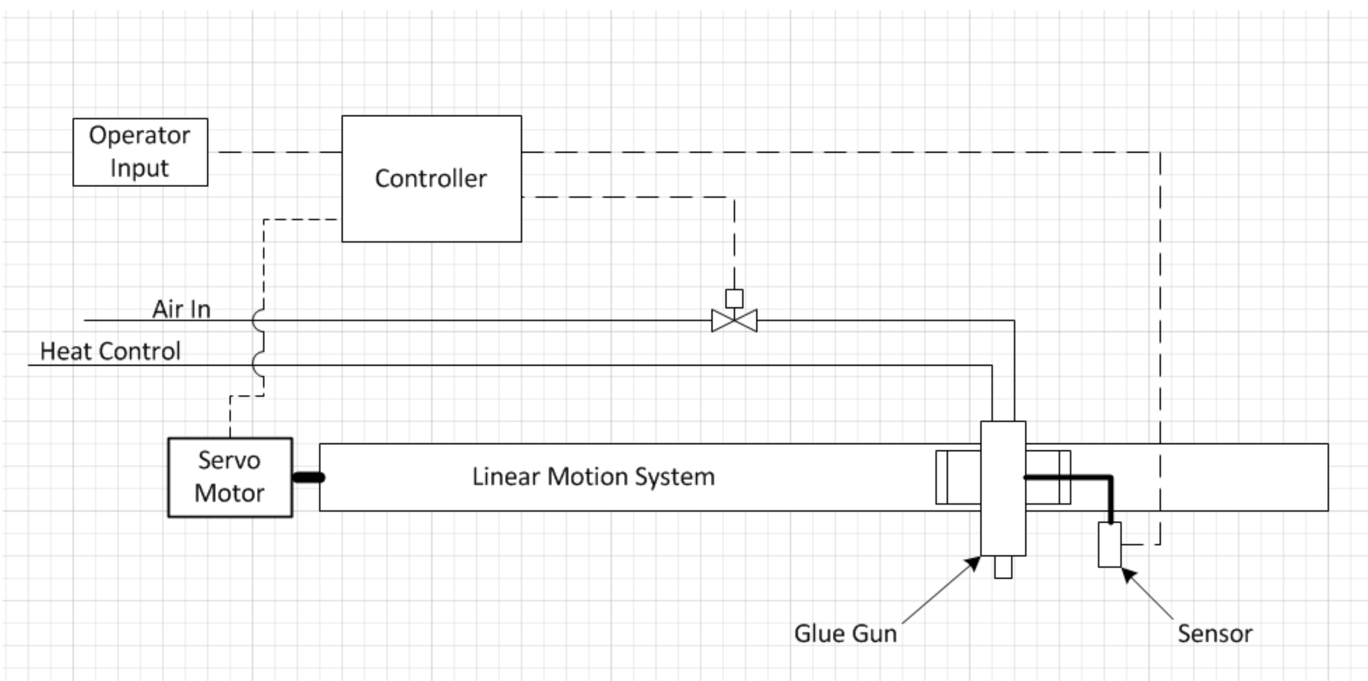


Figure 30. Basic block diagram representation of automated system.

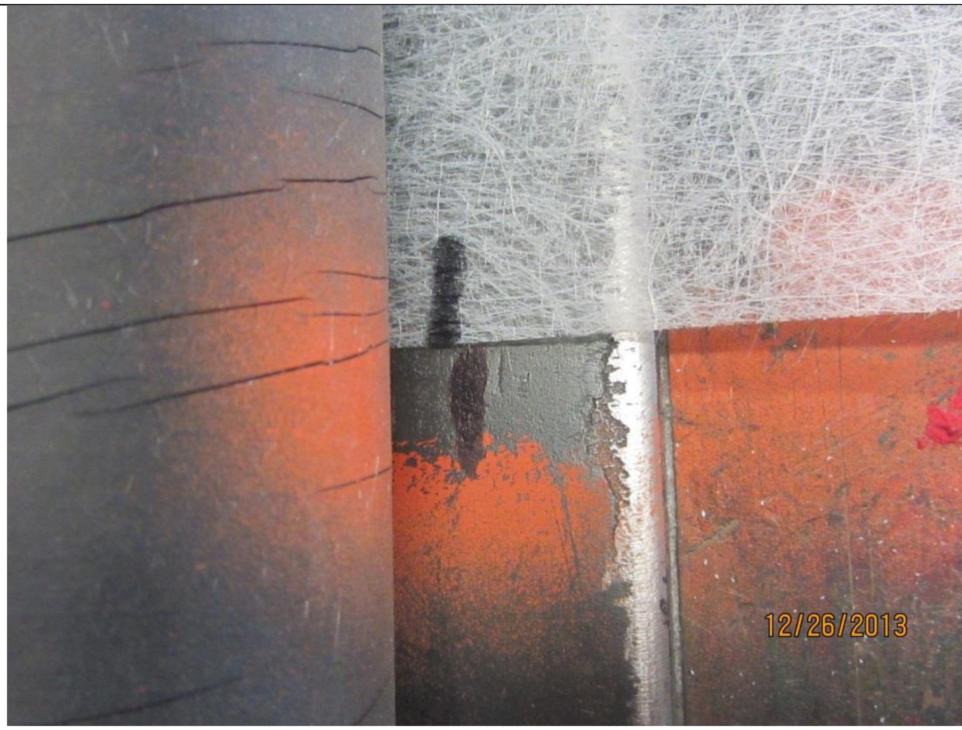


Figure 31. Glass mat on current splice table.

As noted in the discussion regarding the design of the sensor/chain bracket, the sensor is mounted $6\frac{1}{2}$ inches in front of the glue gun. This ensures that the glue gun has enough time to react to the initial sensor signal to begin gluing. Furthermore, this design also means that the air valve will shut off $6\frac{1}{2}$ inches from the end of the glass mat. This will ensure that any dribble that may still persist from the glue gun will be deposited on the glass mat and not the splice table.

Analysis Results

Retrofit Bracket

Steel

The following analysis is conducted assuming the bracket is made of AISI 1018 steel.

For detailed hand calculations of the following analysis, see Appendix J.

The following mass values were measured:

- Carriage = 6.9 kg
- Linear Track = 32.12 kg
- Retrofit Bracket = 13.1 kg
- Motor ≈ 4 kg

- This value was estimated based upon an arbitrary motor size and assuming the motor was made of solid steel.

These Values were then used to generate the following forces using a gravitational constant of $g = 9.81\ \frac{m}{s^2}$ and the equation $Force = Mass * Acceleration$.

- Moving Force = F_M = 67.7 N
- Linear Track Weight = F_T = 315.1 N
- Motor Weight = F_{mot} = 37.46 N
- Retrofit Bracket Weight = F_B = 128.5 N

A free body diagram was then created and used to find the maximum force (F_s) exerted upon any one of the square tubing supports utilized in the retrofit bracket.

$$F_s = 137.18\ N$$

Using the same free body diagram, the maximum moment (M) about the square tubing support was determined.

M = 53.97 lbs*in

Assuming that the material to be used is AISI 1018 steel the maximum normal stress (σ_{max}) was determined to be 30457.917 psi (See Appendix J)

Assuming a factor of safety of 4, equation 1 was used to determine the allowable normal stress (σ_{all}).

$$\sigma_{all} = \frac{\sigma_{max}}{FOS} \qquad \text{(Equation 1)}$$

$$\sigma_{all} = 7614.47925\ psi$$

The design needed to fulfill the criterion, $\sigma_{calc} < \sigma_{all}$ were σ_{calc} is the calculated normal stress in the square tubing.

$$\sigma_{calc} = \frac{M*c}{I} \qquad \text{(Equation 2)}$$

$$I = \frac{b*h^3}{12} \qquad \text{(Equation 3)}$$

$$I_{total} = I_B - I_b \ \text{(Equation 4)}$$

Equations 2, 3, and 4 were used to generate Table 4.

Table 4. Normal stress experienced by steel square tubing in retrofit bracket relative to size.

Wall Thickness (in)	Tubing Size (in)		σ_{calc} (psi)
	B	**b**	
.125	1.75	1.5	131.29
.1875	1.75	1.375	97.63
.25	1.75	1.25	81.68

As can be seen in table 4, all of the sizing options meet the design requirements. Given the availability of 1.75 X 1.75 square tubing with a wall thickness of 0.125 in, this size will be used in the design.

Aluminum

The following analysis is conducted assuming the bracket is made of 6061-T6 aluminum.

For detailed hand calculations of the following analysis, see Appendix J.

The following mass values were measured:

- Carriage = 6.9 kg
- Linear Track = 32.12 kg
- Retrofit Bracket = 4.5 kg
- Motor ≈ 4 kg
    - This value was estimated based upon an arbitrary motor size and assuming the motor was made of solid steel.

These Values were then used to generate the following forces using a gravitational constant of $g = 9.81\ \frac{m}{s^2}$ and the equation $Force = Mass * Acceleration$.

- Moving Force = F_M = 67.7 N
- Linear Track Weight = F_T = 315.1 N
- Motor Weight = F_{mot} = 37.46 N
- Retrofit Bracket Weight = F_B = 44.1 N

A free body diagram was then created and used to find the maximum force (F_s) exerted upon any one of the square tubing supports utilized in the retrofit bracket.

$$F_s = 116.1\ N$$

Using the same free body diagram, the maximum moment (M) about the square tubing support was determined.

$$M = 45.67 \text{ lbs*in}$$

Assuming that the material to be used is 6061-T6 aluminum the maximum normal stress (σ_{max}) was determined to be 40000 psi (See Appendix J)

Assuming a factor of safety of 4, equation 1 was used to determine the allowable normal stress (σ_{all}).

$$\sigma_{all} = \frac{\sigma_{max}}{FOS} \qquad \text{(Equation 1)}$$

$$\sigma_{all} = 10000 \text{ psi}$$

The design needed to fulfill the criterion, $\sigma_{calc} < \sigma_{all}$ were σ_{calc} is the calculated normal stress in the square tubing.

$$\sigma_{calc} = \frac{M*c}{I} \qquad \text{(Equation 2)}$$

$$I = \frac{b*h^3}{12} \qquad \text{(Equation 3)}$$

$$I_{total} = I_B - I_b \text{ (Equation 4)}$$

Equations 2, 3, and 4 were used to generate Table 5.

Table 5. Normal stress experienced by aluminum square tubing in retrofit bracket relative to size.

Wall Thickness (in)	Tubing Size (in)		σ_{calc} (psi)
	B	**b**	
.125	1.75	1.5	111.1
.1875	1.75	1.375	82.61
.25	1.75	1.25	69.12

As can be seen in table 5, all of the sizing options meet the design requirements. Given the availability of 1.75 X 1.75 square tubing with a wall thickness of 0.125 in, this size will be used in the design. Furthermore, the retrofit bracket will be made out of 6061-T6 aluminum in order to minimize weight.

Motor Sizing

The method used for sizing the motor was taken from the Thomson engineering selection tool found in the Thomson Lead Screws, Ball Screws, and Ball Splines catalogue which can be found in Appendix K.

Detailed hand calculations of this analysis can be found in Appendix L.

The first step of sizing the motor was determining the rotational speed required to achieve the target traverse time of 5 seconds. Using this target, the travel rate was determined to be $24000\frac{mm}{min}$.

$$n(rpm) = \frac{Travel\ Rate\ (\frac{mm}{min})}{Lead\ (mm)} \qquad \text{(Equation 5)}$$

Table 6 was generated using equation 5 and the available leads of 5mm, 7mm, 12mm, and 20mm.

Table 6. Linear traverse screw lead size and corresponding rotational speed.

Lead (mm)	5	7	12	20
n (rpm)	4800	3428.571	2000	1200

As can be seen from the above table, a lead screw of 20 mm would be optimum as a motor capable of only 1200 rpm would be necessary.

The next step in the motor sizing process was to determine the torque required by the motor.

$$\mathrm{T_d} = \text{Driving Torque}$$
$$\mathrm{T_b} = \text{Backdrive Torque}$$
$$\mathrm{F_{eq}} = \text{Operating Load}$$
$$\mathrm{P} = \text{Lead}$$
$$\mathrm{e} = \text{Efficiency (90\%)}$$

$$\mathrm{T_d} = \frac{\mathrm{F_{eq}(P)}}{2\pi\mathrm{e}} \qquad \text{(Equation 6)}$$

$$\mathrm{T_b} = \frac{\mathrm{F_{eq}(P)(e)}}{2\pi} \qquad \text{(Equation 7)}$$

Equations 6 and 7 were used to generate Table 7.

Table 7. Torque values and corresponding leads.

Lead (mm)	5	7	12	20
Driving Torque (Nm)	0.059	0.083	0.142	0.237
Back drive Torque (Nm)	0.048	0.067	0.115	0.192

The final step in the motor sizing process was to determine the necessary power of the motor.

$$P_d = Power$$

$$P_d = \frac{F_{eq}(P)(n)}{5.398*10^4} \text{(Equation 8)}$$

Table 8. Required power for corresponding lead sizes.

Power (Watts)	29.81	29.81	29.81	29.81
Lead (mm)	5	7	12	20
n (rpm)	4800	3428.6	2000	1200

Final Motor Specifications

Based upon tables 6, 7, and 8, the following motor specifications are provided.

Power > 30 Watts (0.04 hp)
Torque > 0.237 Nm (0.18 ft-lbs)
Speed > 1200 rpm

Cost Analysis

For a complete list of materials, costs, and suppliers, see Appendix M.

Design Verification Plan

Testing

In addition to the detailed test procedures outlined below, Appendix O also contains a detailed verification plan and corresponding results of the various tests. The DVP&R in Appendix O also gives the acceptable criteria for the results of each test.

Glue Gun Speed Calibration

The speed at which the glue gun traverses the linear slide system will be tested in conjunction with the height that the glue gun is from the glass mat in order to ensure the glue gun distributes an even bead of glue across the glass mat. The variables in this test will be linear traverse speed and glue gun height from the mat. The test will be run by first setting the glue gun height to some constant value and then varying the linear traverse speed. This process will be repeated for 3 or 4 glue gun heights. Using this data, an optimum glue gun height and linear traverse speed combination will be determined.

Glue Gun Automation Calibration

The glue gun system will be tested in order to determine the optimum time between when the sensor senses the beginning of the mat and when the glue gun begins distributing glue as well as when the sensor senses the end of the mat and when the glue gun shuts off. The target result of this test is to ensure that the glue gun system can distribute an even amount of glue across the mat without any overspray onto the splice table.

Glue Gun Bracket Heat Test

Before attaching the glue gun and bracket assembly to the linear motion carriage, the glue gun will be filled with glue and turned on. The glue gun bracket assembly will be allowed to reach a steady operating point. When this point is reached, temperature measurements will be taken at various points on the glue gun bracket in order to ensure that the temperature at the mounting plate does not exceed 160°F.

Splice Strength Test

The strength of the splices created by the new system will be measured in comparison to the strength of the current splices. The current splices will be subjected to a series of yield tests in order to find an average maximum tensile force each splice is capable of withstanding. The same procedure will be repeated with splices made using the new system. These two average maximum tensile force values will then be compared in order to determine how well the new system is able meet or exceed the current splice strength.

Design FMEA

In addition to the planned testing, Appendix Q contains a potential failure mode and effect analysis (FMEA) which lists potential predicted failures with the design. The FMEA also gives potential solutions to address the predicted failures should they arise.

Project Management Plan

Gantt Chart

Appendix N contains the Gantt chart created by the team detailing the schedule and progress of the project as a whole.

Overall Management Plan

Table 9 lists upcoming deadlines and deliverables for the project. These dates are taken directly from the team Gantt chart and are reproduced here as a quick reference.

Table 9. Upcoming deadlines and deliverables.

Task	Completion Date
Order Parts and Materials	5/23/14
Complete Construction of System	10/6/14
Demonstration for Sponsor	10/24/14
Complete Testing of System	11/13/14
Final Project Report	12/5/14

Appendix R contains the team contract. This contract defines the specific responsibilities of each team member in regards to completing the project. Additionally, Table 10 contains a quick reference of the specific tasks of the project and the team member responsible for ensuring the tasks completion.

Table 10. Roles and responsibilities of GAFSET.

Task/Role	Responsibility
Main Point of Contact	Justin Bracci
Treasurer	Chad Linafelter
Secretary/Recorder	Harry Zhao
Design Analysis/Review	All Team Members
Prototype Development	All Team Members
Prototype Construction	All Team Members/GAF Support
Prototype Testing	All Team Members/GAF Support
Results Analysis	All Team Members
Final Project Report	All Team Members

Prototype Manufacturing Plan

The team plans to manufacture all parts that are not being purchased from outside suppliers. These components include the retrofit bracket, glue gun mounting bracket, and sensor chain bracket. These components will be manufactured at Cal Poly by the team using both the hanger machine shop and the Mustang '60 machine shop. The raw materials needed to manufacture these components will be supplied by GAF and are included in the cost analysis presented in Appendix M. Table 11 gives an estimated production time for the components to be manufactured. The assembly time for the entire system is estimated to take approximately 3 weeks. As stated in the Gantt chart and Table 9, the prototype will be completed on or before October 6, 2014.

Table 11. Estimated component manufacturing time.

Parts Manufactured By Team		
Part	**Method**	**Time Estimate**
Retrofit Bracket	**Cut, Bend, Weld, Drill**	**1 week**
Glue Gun Mount Brackets	**CNC**	**1 week**
Glue Gun Mount Plate	**CNC**	**2 days**
Cable Carrier Bracket	**Cut, Bend, Weld, Drill**	**1 day**
Protective Shield	**Cut, Bend, Weld, Drill**	**1 day**

Product Realization

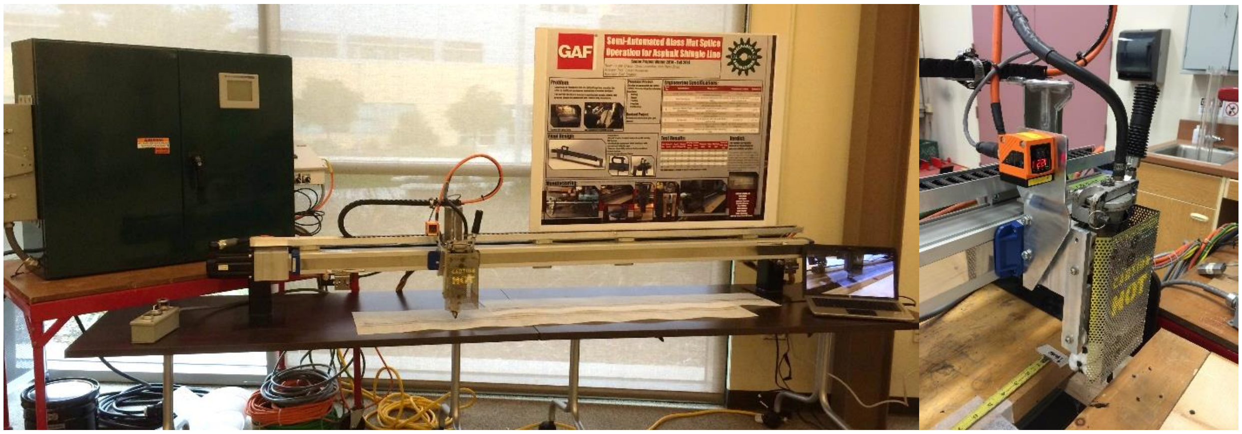


Figure 32. Completed prototype and detail of glue gun assembly.

Manufacturing Methods

All of the mechanical components of the system were manufactured by the team at Cal Poly with the exception of the servo motor coupling flange. The manufacturing of the components utilized a wide range of manufacturing techniques and tools including welding, machining, bending, and drilling to name a few. The primary tools utilized to manufacture the components were the mill, aluminum and steel TIG welder, and plasma cutter.

Test Stand

The test stand was made out of AISI 1018 steel using the horizontal band saw and the MIG welder. The construction of the test stand was fairly straight forward; the various pieces were cut to length and then welded together. The mounting holes for the retrofit bracket were drilled using the drill press after the test stand was welded together.

Retrofit Bracket

After receiving the ordered materials and reviewing the design of the retrofit bracket, the team determined that the bracket could be made using less material. The main influence on this decision was the arrival of the Thomson Linear mounting plates which were supplied with the linear system. The team was unaware of the inclusion of these parts with the linear system. After reviewing the old retrofit bracket design, the team determined that the Thomson Linear mounting plates were strong enough to compensate for the removal of the front plate from the old retrofit bracket design. A new retrofit bracket was designed the detailed drawings of which are included in the drawing package in Appendix S. The drawings for the old retrofit bracket can also be found in Appendix S.

The retrofit bracket was made in multiple steps out of 6061-T6 aluminum. The first step was to construct the 5 base plate M2 pieces. This was done using the plasma cutter to make rough cuts before using the mill to mill the plates to size and drill the holes. The backing plates were also made in this

manner. The square tubing M2 pieces were similarly made by first cutting them to length on the horizontal band saw before using the mill to face both ends. Using the aluminum TIG welder and 4043 aluminum filler rod, the backing plates, square tubing, and base plates were welded together into 5 separate sub-assemblies. These 5 sub-assemblies were then mounted to the test stand and the linear system was clamped to the sub-assemblies in order to check for alignment (see Figure 33). Once the alignment was verified, the guide channel was fitted onto the 5 subassemblies and welded in place. This completed construction of the retrofit bracket.

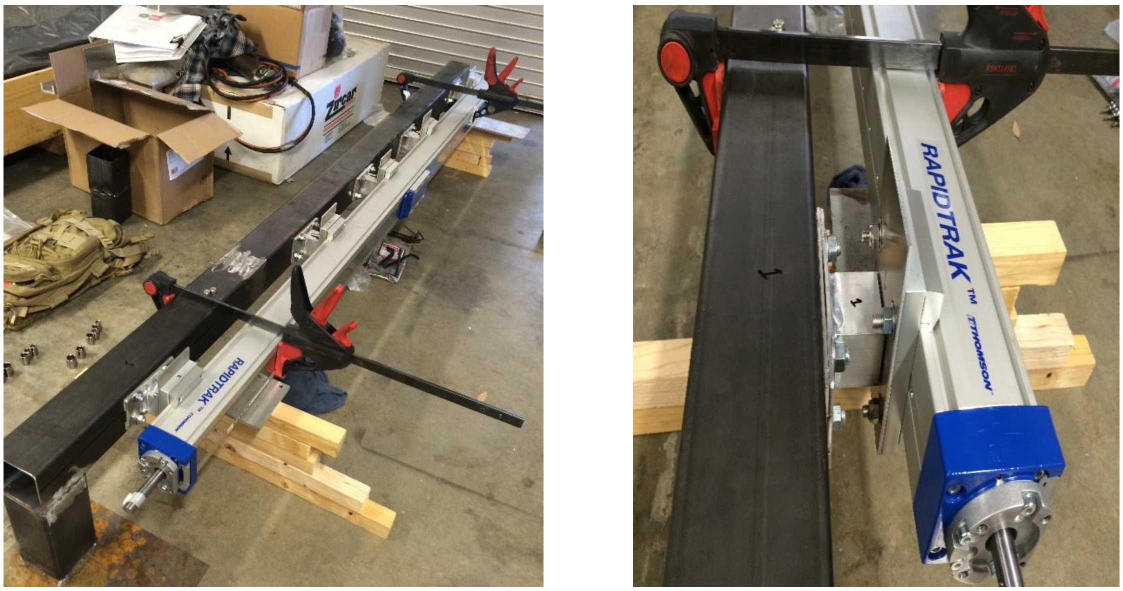


Figure 33. Retrofit bracket mock up and alignment.

Glue Gun Mount

After many meetings and discussion with the sponsors about our final proposed design for the glue gun mounting components (seen in Figure 25), the team decided to redesign the components once again for a couple reasons. First, there was speculation about the long-term integrity and rigidness of the glue gun mount when fibrous insulation was utilized between the gun and the mount due to pack-out. Instead, the team wanted to utilize the existing ceramic mounting blocks on the glue gun so that rigidity would be maintained indefinitely. Second, the original proposed design included complex features that would require CNC machining in order to produce a quality part. During the time of manufacturing, availability of CNC was delayed and would not allow enough time to test the part if time was spent waiting for CNC availability. The new components were designed to ensure that they could be completed by hand on a mill.

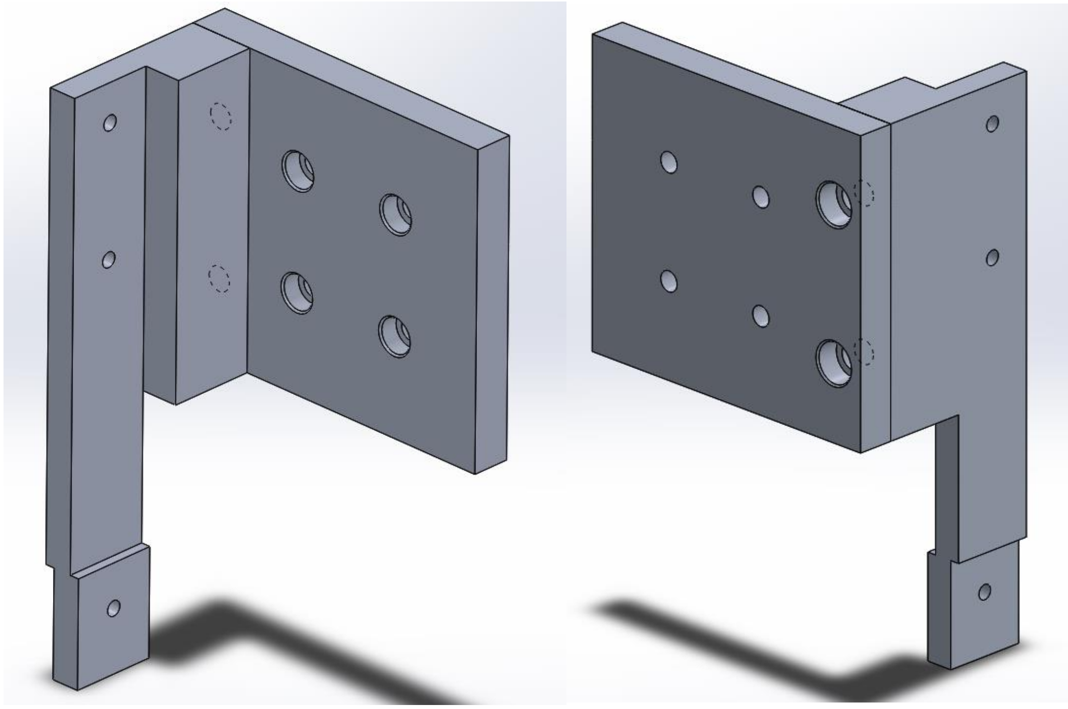


Figure 34. Revised design of glue gun mounting components.

The two parts of the design bolt together, as shown in Figure 34 above, and were still machined from 6061-T6 aluminum. It also still interfaces with the mounting plate original design with rigid insulation board in between. Due to time constraints, the team decided that the heat analysis completed for the previous design was for a worse case with maximum contact to the glue gun and that the new design had much less contact, so no new analysis was completed and real-time heat tests were conducted instead. As seen in Figure 35, the heat tests were conducted with the assembly off the linear system in case of a failure. Thermocouples were placed in various locations and the glue gun was run at operating temperature for 120 minutes while temperatures were recorded every 5 minutes. The design passed all heat requirements with large margins.

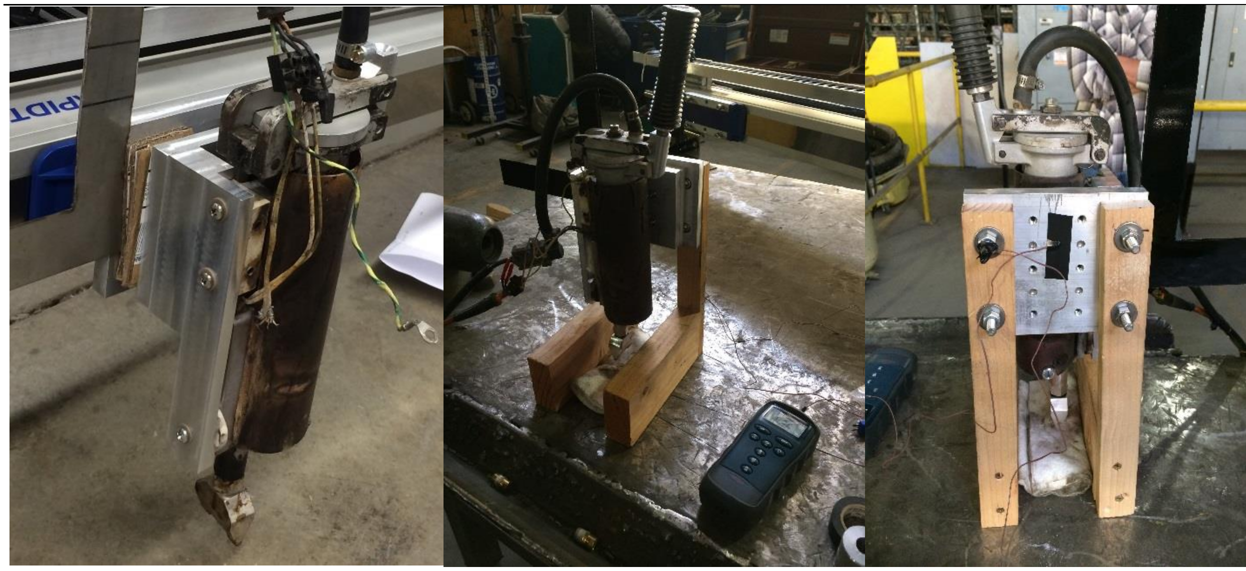


Figure 35. Glue gun mount mock-up and heat testing.

Mount Plate

The mounting plate design was manufactured to the original proposed design specifications with the addition of some tapped holes for the re-designed cable carrier bracket, laser sensor bracket, and for mounting the heat shield. The part was rough cut from stock 6061-T6 aluminum and milled down to exact dimensions. All holes were then drilled and necessary hole were through tapped.

Cable Chain Carrier Bracket

The initial design of the cable carrier bracket proved to be too flimsy and unsuitable for requirements of the system. After realizing this issue, the team set about designing a new, more rigid cable carrier bracket. During this process, a new sensor mount plate was also designed. The new bracket was manufactured using the plasma cutter, aluminum TIG welder, and mill. Figure 36 shows the old design of the cable chain carrier bracket and Figure 37 shows the new design.

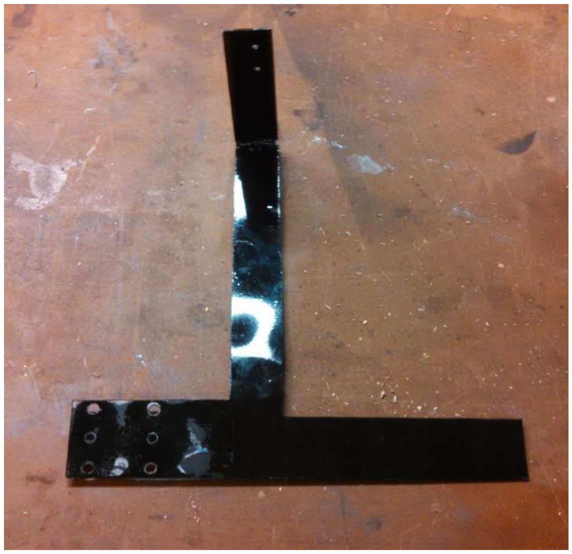


Figure 36. Old cable chain bracket.

Figure 37. New cable chain bracket.

Laser Sensor Bracket

Originally, the mounting point for use of a sensor that moved with the glue gun was part of the cable chain carrier bracket. When it was determined that the cable chain carrier bracket was not rigid enough, the decision was made to fabricate a separate bracket for the sensor to eliminate the possibly of sensor movement caused by forces from the cable chain when moving back and forth. This new bracket mounts

to the left-side edge of the mount plate and provides a mounting surface for the optical laser sensor as shown in Figure 38. The bracket was cut from 6061-T6 aluminum 1/8" stock using a plasma cutter, bent to the correct dimensions, and the edges were rounded and deburred.

Figure 38. Laser sensor bracket fitted to assembly.

Motor Mount Flange

This component was the only part that was not manufactured by the team. The reason for this was that the sponsor agreed on a servo motor for the prototype late in the manufacturing stage so the motor flange was designed by the team and sent out to a machine shop in southern California due to limited time constraints and high precision machining. This component couples the servo motor to the linear system. Figure 39 shows the motor mount flange incorporated into the prototype.

Figure 39. Motor mount flange on the prototype system.

Heat Shield

The heat shield was made out of expanded AISI 1018 steel. The shield is a safety feature that prevents direct contact with the glue gun. The shield was made using a metal shear to cut out the initial, rectangular shape. A sheet metal bender was then made to make the 90 degree and 45 degree bends. A drill press was used to make the two holes to attach the heat shield to the mount plate. After construction, the heat shield was found to be too flimsy. In order to overcome this deficiency, two reinforcing strips of AISI 1018 expanded steel were welded along the inside of the 90 degree bend. This step ensured that the shield would remain rigid and in place while the glue gun moved along the linear system. Figure 40 shows the manufactured heat shield.

Figure 40. Heat shield.

Recommendations for Future Manufacturing

If the above components were to be re-manufactured, there are multiple changes that can be made in order to simplify the manufacturing process. The first and foremost change would be to use a plasma cutter with a photoelectric eye in order to cut out the various brackets. This would ensure much more precise cuts as well as save time and material. The team was unable to utilize this piece of equipment during the manufacturing process due to maintenance issues. The team also found it use full to break up the various manufacturing steps into stages. For example, when manufacturing the retrofit bracket, one team member would cut out and size the base plates using the plasma cutter and mill. Another team member would position and drill the holes into the base plate and the last team member would weld the various components together. This production like method of manufacturing and assembly not only sped up the process but increased the quality of each individual part as each team member was able to become proficient with their particular task.

Another major change to the process that can be made is the inclusion of more time. While the team had more than enough time to design and produce a working prototype, more time could have been taken in order to produce a cleaner, more precise product. This improvement also coincides with the trial and error associated with testing a prototype. This topic will be addressed directly in the following conclusions section.

Design Verification Testing

The team first ran the completed prototype at the GAF plant in Shafter, CA when GAF sponsors completed the necessary controls equipment to run the prototype. This was to ensure that the system was ready to be tested by the team at Cal Poly. At this stage, many of the upgrades had been realized but not yet manufactured and would be incorporated onto the prototype when it was setup at Cal Poly.

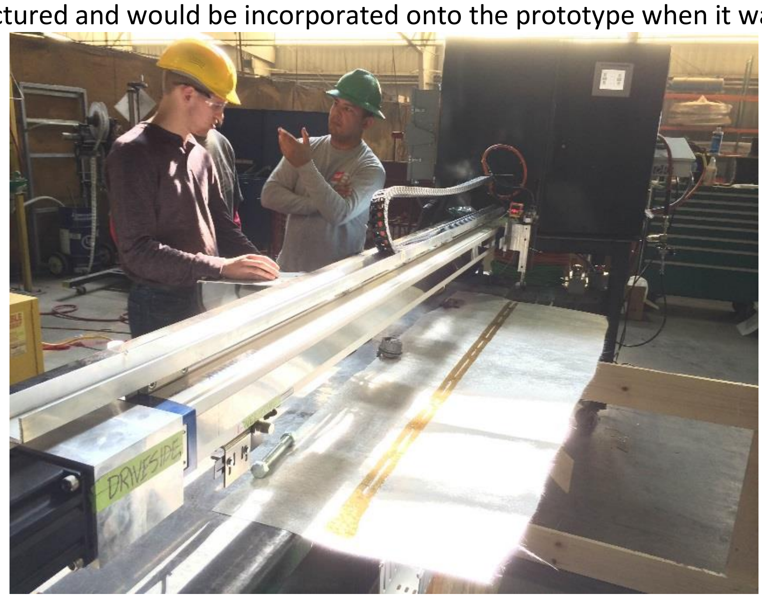


Figure 41. Initial setup and testing at GAF Shafter Plant.

Once the prototype was transported back to Cal Poly and the necessary design modifications were completed and incorporated onto the prototype, the system went through small preliminary heat checks once again to ensure that no components of the system were going to be in danger of damage by heat. Thermocouples were placed in various suspect locations, as shown in Figure 42, and monitored for 120 minutes at normal operating temperatures and conditions. All locations passed with very large margins and it was determined that nothing would be in danger of damage.

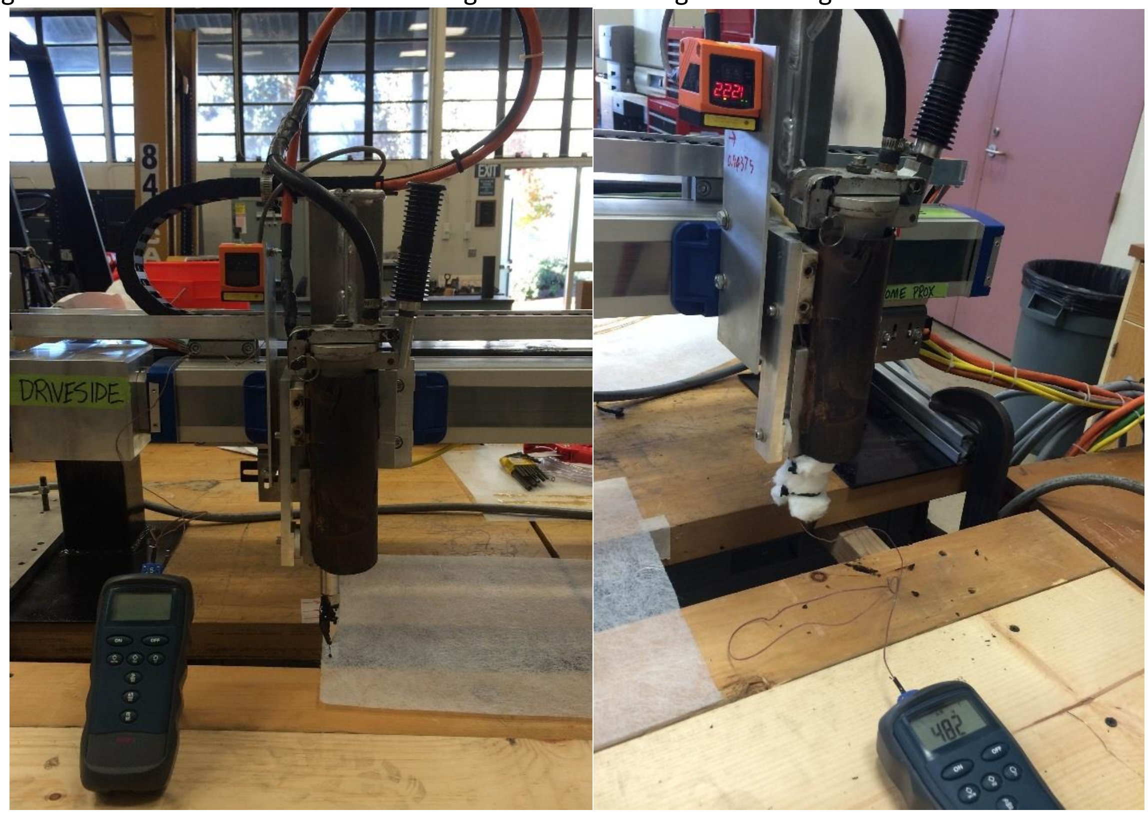


Figure 42. Preliminary heat testing before running the prototype.

Positions were then marked and measured on the testing table of various positions of glue gun, glue gun travel, mat positioning and laser positioning. These values were recorded during each run for repeatability purposes. All adjustable parameters were recorded for each run; these include: velocity, operator and drive side accelerations, operator and drive side glue start and stop delays, glue gun air pressure, total travel setting in HMI, fiberglass mat width, and home position to far edge of mat distance. All runs were made with the glue gun temperature set at 510°F at the control box and minimum glue pot time of 20 minutes. The testing setup can be seen in Figures 43 and 44 below. Runs were repeated with varying parameters in order to satisfy the design requirements. The most important requirements were bead size and distance of glue bead from the ends of the mat. Each runs sample, such those shown in Figure 45, were numbered and correlate to the table of results shown in Table 12. The setup, running, and shut down procedures that were followed can be found in the Gluing Testing Process Procedure document in Appendix T.

Figure 43. Prototype testing setup.

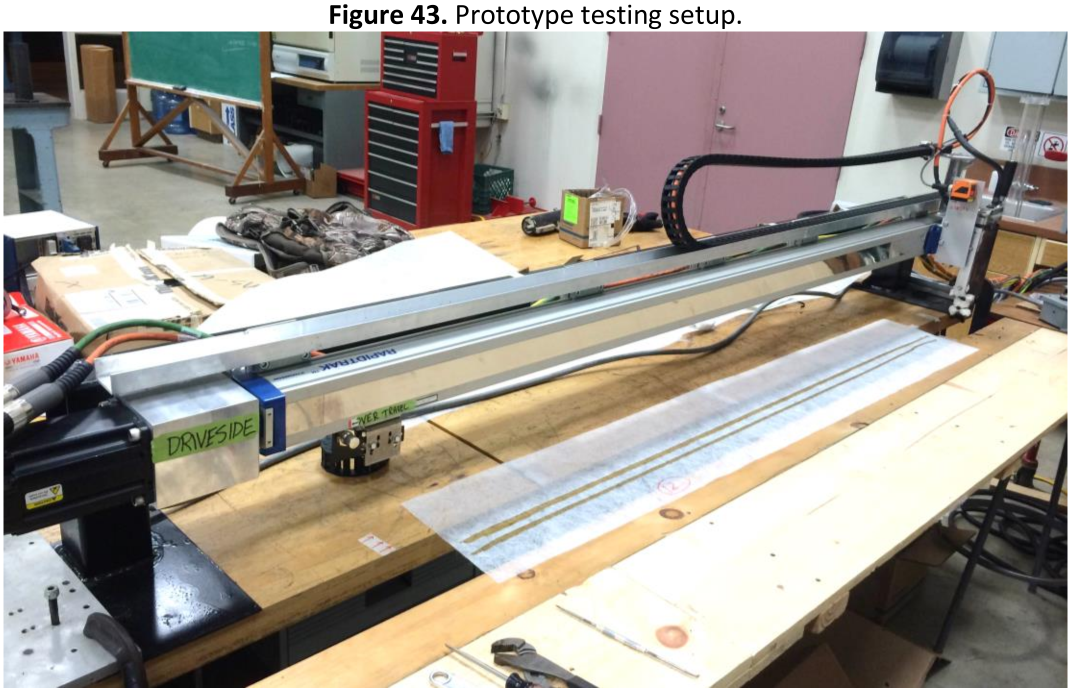


Figure 44. Prototype testing completed run.

Figure 45. Two samples from completed prototype testing runs.

Table 12. Prototype testing verification data.

	Velocity	Accel	Deccel	Operator Side Delay	Drive Side Delay	Pressure	Travel	Mat Size	Home to Mat Far Edge
Test No.	in/s	in/s²	in/s²	ms	ms	psi	inches	inches	inches
1	17	75	45	70	50	20	62	56	60
2	17	30	80	70	50	70	61	56	60
3	17	17	80	50	50	50	60	56	60
4	17	17	80	50	50	50	58	56	60
5	17	17	43	50	50	40	59.5	56	60
6	17	17	14	50	50	30	59.5	56	60
7	17	17	17	50	50	40	59.5	56	60
8	19	17	17	50	50	25	59.7	56	60
9	19	15	17	50	50	25	59.8	56	60
10	18	14	17	50	50	25	59.8	56	60
11	18	14	17	50	50	25	70	65	70
12	18	14	17	180	50	25	70	65	70
13	18	14	17	150	50	30	70	65	70
14	18	14	17	150	50	25	70	65	70
15	18	14	17	135	50	25	70	65	70
16	18	14	17	135	50	25	56	51	56
17	18	14	17	135	50	25	56	51	56
18	18	14	17	130	50	25	70	65	70
19	18	14	17	135	50	25	70	65	70
20	18	14	17	130	50	25	70	65	70

*All runs were made with glue gun temperature setting at 510°F on control box.

Design Verification Conclusions

Upon testing the prototype, the team discovered that the mat size adjustment within the HMI control panel limits the total travel from home of the glue gun system. This means that this value needs to be set by adding the mat width and the home-to-mat edge length (which was determined by the team to

be about 5 inches). A more accurate measurement will need to be made once the prototype is installed on the splice table. These bias values can be seen above in Table 12 between the total travel and actual mat size parameters. The team suggests that this bias of +5 inches (or measured value once installed) be programmed in so that the operator can input the size of the mat only to avoid confusion.

The team has found that with the parameter settings found below in Table 13, the prototype will correctly glue any size mat with the sole adjustment of travel length (also shown as mat width). Runs 15 through 20 above in Table 12 show these results, although many more runs were made following with these parameters to ensure repeatability.

Table 13. Suggested HMI parameter settings for gluing profile.

Velocity	Accel	Deccel	Operator Side Delay	Drive Side Delay	Pressure
in/s	in/s²	in/s²	ms	ms	psi
18	14	17	130-135*	50	20-25*
*Dependent on glue pot time and temperature.					

One important effect on these parameters that the team found during testing that should be noted was the pot time of the glue. Pot time of the glue refers to the amount of time the glue has spent inside the gun at operating temperature from the moment it is loaded into the gun. The dispensing characteristics change the longer the glue spends in the gun after completely melted. The team allowed a minimum pot time of 20 minutes before each run. Runs were also made with longer pot times averaging about 40 minutes. With the longer pot times, it was found that mainly the glue gun pressure needed to be reduced to about 20 psi in order to maintain correct bead size. It is suggested that this should be monitored during plant use and varied.

Furthermore, appendix O shows that the team was able to meet all of the test criteria laid out in the initial DVP and R.

Conclusions and Recommendations

In addition to the conclusions and recommendations stated in the previous section, the team would recommend that GAF pursue another senior project in order to further develop not only the automation of the gluing process, but the entire splice procedure. One of the major limitations while working on this project was the team's inexperience with automation, coding, and electrical. Being an all mechanical engineering team, the team had little to no experience in these fields and due to the time constraints of the project relied heavily on GAF to supply all of the automation and electrical work. If GAF were to sponsor another senior project, the team recommends that GAF look into sponsoring a multi-disciplinary team. This would ensure that the senior project team would be able to address all aspects of the automation process.

Prior to implementing the automatic gluing system into the plant, the team also recommends that GAF perform testing while the system is mounted to the current splice table. Due to the nature of the project, the senior project team was unable to carry out these tests. These tests will be crucial in analyzing how the automatic gluing system interacts, and even interferes with the other processes of the splice procedure such as cutting, pressing, and feeding. The automatic glug gun system should not be implemented into the current splice procedure before these tests are carried out.

The automatic gluing process is a worthwhile investment, one that in the long run will be able to save GAF both time and money. It has been our great pleasure and privilege to work with GAF and the GAF student engineering team would like to express our gratitude in being given this opportunity

Special Thanks

We would like to give special thanks to the following individuals for all of their help and support:

Jeff Munoz
Reuben Cavazos
Charlie Winans
Ron K'Miller
Rick Eckberg
Tony Ramos
Nigel Abraham
Eric Pulse

Appendices

GAF Student Engineering Team
Justin Bracci
Chad Linafelter
Harry Zhao
December 5, 2014

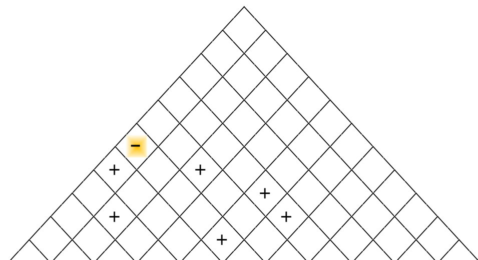
Appendix A. QFD

QFD: House of Quality
Project: GAF's Automated Splice Table
Revision: 1
Date: Tuesday, February 4 2014

Correlations	
Positive	+
Negative	−
No Correlation	

Relationships	
Strong	●
Moderate	○
Weak	▽

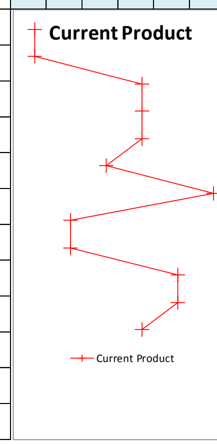
Direction of Improvement	
Maximize	▲
Target	◇
Minimize	▼



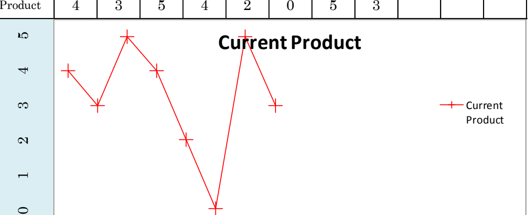
Row #	Weight Chart	Relative Weight	GAF	Maximum Relationship	WHAT: Customer Requirements (explicit & implicit) / HOW: Engineering Specifications	1 Sufficient Traverse Speed	2 Adequate Safety Shielding	3 Retrofit Design	4 Sensative Components Protected	5 Uniform Process	6 Auto-Alignment Capable	7 Utilizes Existing Glue Gun	8 One Man Adjustability	14 Control over system	15	16	Current Splicing Table Process	Row #
					Direction of Improvement	▲	▲	▲	▲	◇	▲	◇	◇					
1		16%	9	9	One Man Operation		○						●				0	1
2		5%	3	9	Compatible with Current Design			●				●					0	2
3		14%	8	9	Consistency	●			○	●	○			○			3	3
4		9%	5	9	Quick Process	●			○	○	▽		○				3	4
5		11%	6	9	Safety	▽	●		○								3	5
6		7%	4	9	Reliable	○	▽	○	●	●		○					2	6
7		5%	3	9	Compatable with Multiple Mat Sizes	○		○			●						5	7
8		4%	2	9	Splice Break Reduction	○				●							1	8
9		9%	5	9	Capable of Automation				○	○	●			○			1	9
10		5%	3	9	Shock Resistant		○	○	●				○				4	10
11		11%	6	9	No Overspray									●			4	11
12		5%	3	3	Easy maintanance		○		○			○					3	12
					HOW MUCH: Target	79 fpm	No direct contact with glue gun	Mounts to Press Plate Assembly	Operating Temperature < 160°F	20% reduction from current splice breaks	Verified through Testing	Yes or No Criteria	Total Weight < 200lb					
					Max Relationship	9	9	9	9	9	9	9	9	9				
					Technical Importance Rating	263.16	180.7	100	252.63	273.68	177.19	84.211	184.21					
					Relative Weight	17%	12%	7%	17%	18%	12%	6%	12%					
					Weight Chart													
					Our Product	4	3	5	4	2	0	5	3					

WHO: Customers

NOW: Current Product Assesment - Customer Requirements (0 1 2 3 4 5)



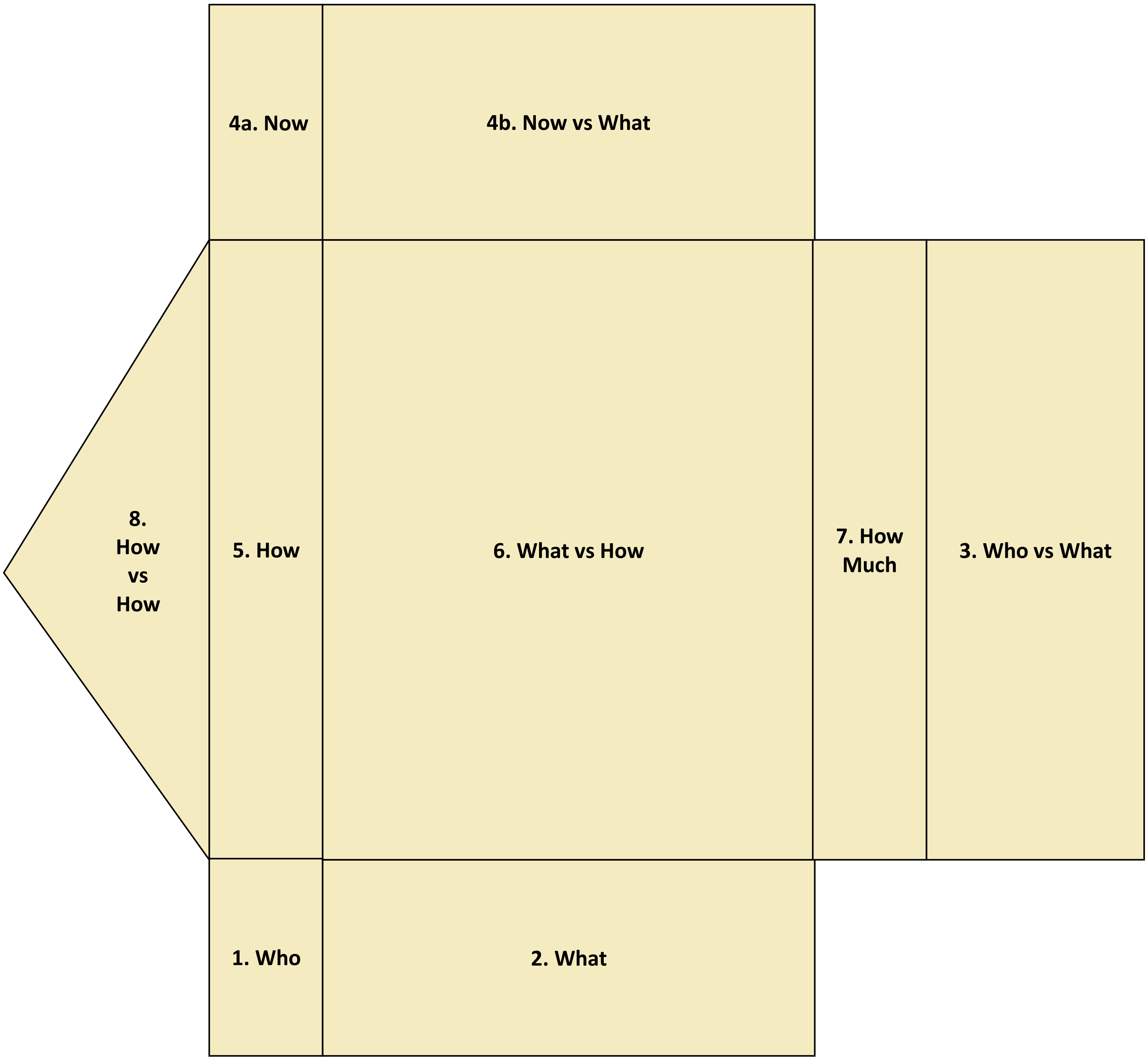
Current Product Assesment - Engineering Specifications



Column # | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 14 | 15 | 16

Template Revision: 0.9 Date: 4/23/2010
Christopher Battles

Appendix B. House of Quality Template (QFD)



Appendix C. TF Technical Data

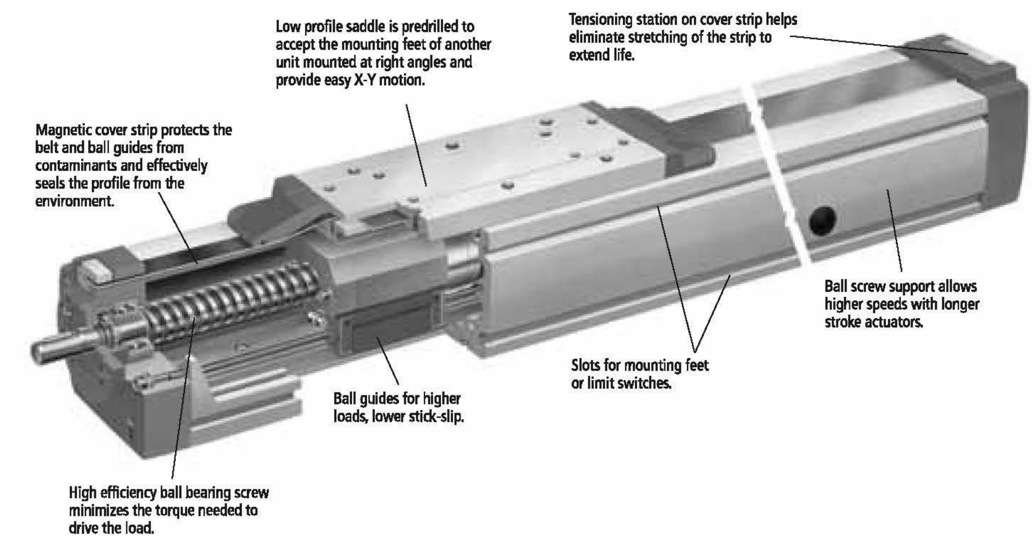
Phone: 1-800-554-8466
Website: www.linearactuators.com

Rapidtrak* Rodless Actuators

The ball bearing screw drive provides precise positioning and high load carrying capability. It can provide saddle speeds up to 49 inches per second and drive axial loads up to 1100 lbs. High stiffness and repeatability characterize the ball screw versions. Stroke lengths to 22 feet are standard.

Ball bearing screw drive units provide high load capability and high precision.

- Speeds up to 49 inches per second.
- Thrust loads up to 1100 lbs.
- Suitable for mounting in any position – horizontal, vertical, upside down or on an incline.
- Low torque required to drive the load due to high efficiency ball bearing drive.
- Linear bearings provide low stick slip for precise positioning and ease of moving load.



Trouble free, reliable motion control

The new M-family of Rapidtrak rodless actuators provides several solutions for long trouble-free operation.

- Belt Drive units for operation up to 200 inches per second.
- Ball Screw Drive units for pushing up to 1100 lb and precision positioning.
- Ball Guide units for applications needing low stick-slip or saddle loads to 1650 lb.
- Prism Guide units for high shock, vibration or applications needing adjustable preload.

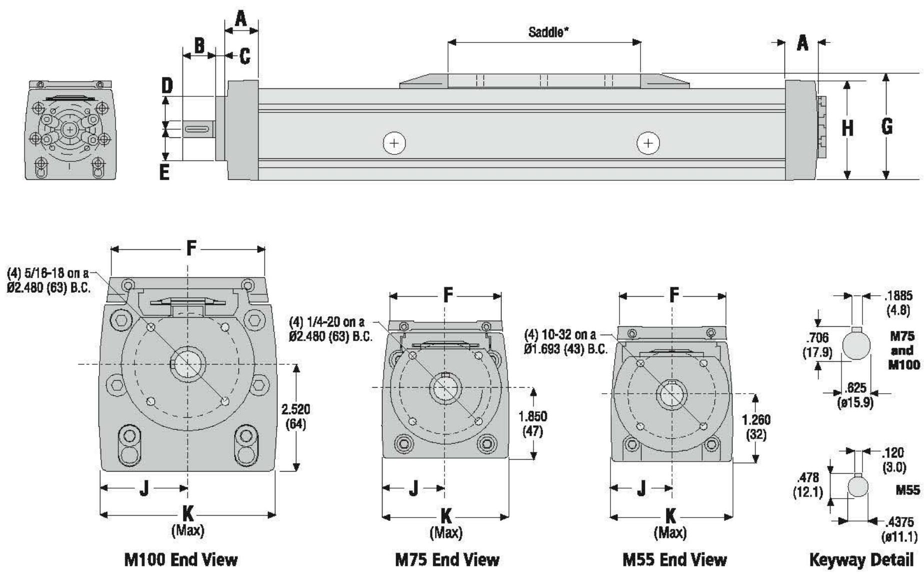
Common features of all actuator models

- Ball Guides provide high load capability and low friction for precise positioning.
- Saddles have a new low profile design with the bolt pattern set up for mounting another Rapidtrak in the perpendicular axis.
- New modified slots for easier mounting. Allows material to be blown or washed out.
- Mounting Feet are modular for ease of installation.
- Limit Switch Brackets mount to the new modified slots for easy installation and adjustment.
- Cover Band protects the ball screw and ball guide from contaminants and keeps lubrication inside.
- Cover Band Stretcher extends the life of the cover band and eliminates the need to tension it as it wears.
- Magnetic Strips hold the cover band in place during operation to protect the ball screw and ball guide.
- Drive Flanges are available for servo, step, AC and DC motors.
- Stroke Lengths are available up to 22 feet.
- Rodless design allows the load to be mounted directly to the saddle, eliminates the need for support bearings and reduces the overall length of the unit.
- Custom Systems are available with the motor and control mounted and tested at the factory. Contact your local Thomson Linear Products salesperson or distributor.

THOMSON

Dimensions - Ball Screw Drive

Phone: 1-800-554-8466
Website: www.linearactuators.com



Dimensions in inches (mm)

Profile Size	Load Support	Dimensions									
		A	B	C	D	E	F	G	H	J	K
M55	Prism	1.14 (29)	1.18 (30)	0.35 (9)	0.91 (23)	1.10 (28)	1.93 (49)	2.72 (69)	2.46 (62.5)	1.14 (29)	2.28 (58)
M55	Ball Guide	1.14 (29)	1.18 (30)	0.35 (9)	0.91 (23)	1.26 (32)	1.93 (49)	2.72 (69)	2.46 (62.5)	1.14 (29)	2.28 (58)
M75	Prism	1.26 (32)	2.70 (68.5)	0.43 (11)	1.07 (27.3)	1.85 (47)	2.99 (76)	3.64 (92.5)	3.33 (84.5)	1.69 (43)	3.39 (86)
M75	Ball Guide	1.26 (32)	2.70 (68.5)	0.43 (11)	1.07 (27.3)	1.85 (47)	2.99 (76)	3.64 (92.5)	3.33 (84.5)	1.69 (43)	3.39 (86)
M100	Prism	1.46 (37)	2.50 (63.5)	0.39 (10)	1.10 (28)	2.52 (64)	3.66 (93)	4.67 (118.5)	4.31 (109.5)	2.12 (53.8)	4.23 (107.5)
M100	Ball Guide	1.46 (37)	2.50 (63.5)	0.39 (10)	1.10 (28)	2.52 (64)	3.66 (93)	4.67 (118.5)	4.31 (109.5)	2.12 (53.8)	4.23 (107.5)

*See page C-19 for saddle dimensions.

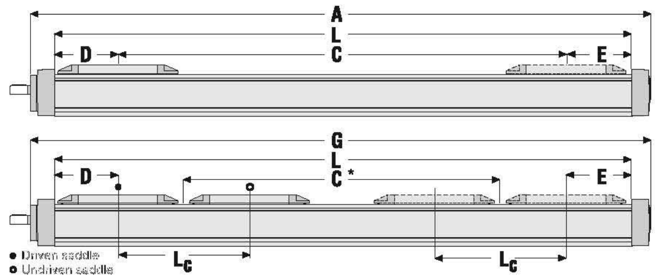
Size	Support	Weight Calculation	
		A Saddle	C Saddle
M55	Prism	4.85 lb + L (cm)* 0.97 lb	7.5 lb + L (cm) *0.97 lb
M55	Ball Guide	4.85 lb + L (cm)* 0.9 lb	14.55 lb + L (cm) *0.9 lb
M75	Prism	9.26 lb + L (cm)* 1.81 lb	13.01 lb + L (cm) *1.81 lb
M75	Ball Guide	9.92 lb + L (cm)* 2.32 lb	20.94 lb + L (cm) *2.32 lb
M100	Prism	18.74 lb + L (cm)* 3.13 lb	26.46 lb + L (cm) *3.13 lb
M100	Ball Guide	19.84 lb + L (cm)* 3.79 lb	37.48 lb + L (cm) *3.79 lb

*See page C-19 for saddle dimensions.

Saddles/Stroke Lengths

A Saddle

C Saddle



Ball Screw Drive		Screw Supports	A	C	D	E	Minimum L_C	G	L*	Saddle Length
M100	Ball Guide (TF10K)	0	"C"+19.528	Stroke length	8.031	8.031	13.780	"A"+"L_C"	"C"+16.063	12.047
		1	"C"+21.575	Stroke length	9.055	9.055	13.780	"A"+"L_C"	"C"+18.110	12.047
		2	"C"+25.512	Stroke length	11.024	11.024	13.780	"A"+"L_C"	"C"+22.047	12.047
	Prism Guide (TG10K)	0	"C"+19.134	Stroke length	8.031	8.031	13.780	"A"+"L_C"	"C"+16.063	12.047
		1	"C"+20.394	Stroke length	8.662	8.662	13.780	"A"+"L_C"	"C"+17.323	12.047
		2	"C"+24.331	Stroke length	10.630	10.630	13.780	"A"+"L_C"	"C"+21.260	12.047
M75	Ball Guide (TF07K)	0	"C"+15.984	Stroke length	6.457	6.457	9.840	"A"+"L_C"	"C"+12.913	8.583
		1	"C"+19.449	Stroke length	8.189	8.189	9.840	"A"+"L_C"	"C"+16.378	8.583
		2	"C"+23.386	Stroke length	10.157	10.157	9.840	"A"+"L_C"	"C"+20.315	8.583
	Prism Guide (TG07K)	0	"C"+15.984	Stroke length	6.457	6.457	9.840	"A"+"L_C"	"C"+12.913	8.583
		1	"C"+20.000	Stroke length	8.465	8.465	9.840	"A"+"L_C"	"C"+16.929	8.583
		2	"C"+24.016	Stroke length	10.472	10.472	9.840	"A"+"L_C"	"C"+20.945	8.583
M55	Ball Guide (TF06K)	0	"C"+14.390	Stroke length	5.827	5.827	7.870	"A"+"L_C"	"C"+11.654	7.244
	Prism Guide (TG06K)	0	"C"+14.390	Stroke length	5.827	5.827	7.870	"A"+"L_C"	"C"+11.654	7.244

*For C Saddle (dual) configuration, L = L (A Saddle) + L_C

Maximum allowable distance between supports

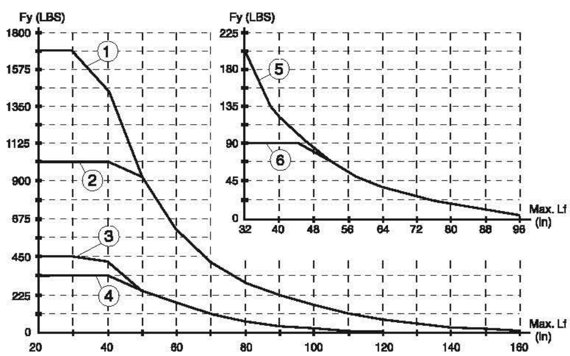
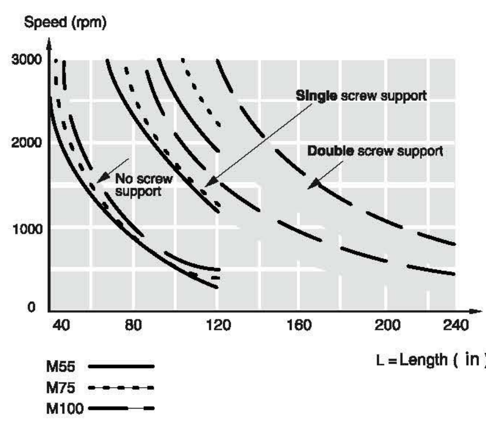


Figure 1: General installation instructions

The curves show max. allowed distance (Lf) between every mounting point for different loads (Fy) for different units.

① TF10K
② TG10K
③ TF07K
④ TG07K
⑤ TF06K
⑥ TG06K

Critical speed



Appendix D. MF Technical Data

THOMSON
Linear Motion. Optimized.

M75

Ball Screw Drive, Ball Guide

» Ordering key - see page 194
» Accessories - see page 135
» Additional data - see page 182

General Specifications

Parameter	M75
Profile size (w × h) [mm]	86 × 75
Type of screw	ball screw with single nut
Carriage sealing system	self-adjusting steel cover band
Screw supports	number of screw supports to be specified by customer at order
Lubrication	lubrication of ball screw
Included accessories	none

Performance Specifications

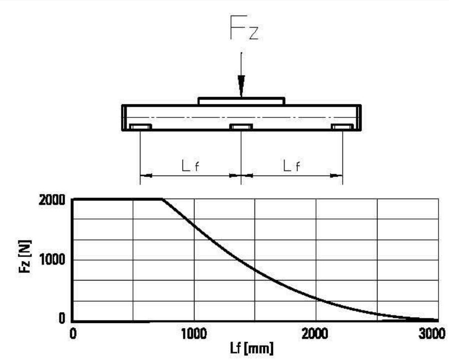
Parameter		M75
Stroke length (Smax), maximum	[mm]	4000
Linear speed, maximum	[m/s]	1,0
Acceleration, maximum	[m/s^2]	8
Repeatability	[± mm]	0,05
Input speed, maximum	[rpm]	3000
Operation temperature limits	[°C]	-20 – 70
Dynamic load (Fx), maximum	[N]	2500
Dynamic load (Fy), maximum	[N]	2000
Dynamic load (Fz), maximum	[N]	2000
Dynamic load torque (Mx), maximum	[Nm]	18
Dynamic load torque (My), maximum	[Nm]	130
Dynamic load torque (Mz), maximum	[Nm]	130
Drive shaft force (Frd), maximum	[N]	600
Drive shaft torque (Mta), maximum	[Nm]	30
Screw diameter (d0)	[mm]	20
Screw lead (p)	[mm]	5, 12,7, 20
Weight of unit with zero stroke of every 100 mm of stroke of carriage of option single screw support of option double screw supports	[kg]	 6,90 1,05 2,50 1,70 3,58

Carriage Idle Torque (M idle) [Nm]

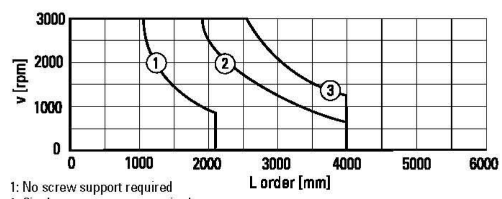
Input speed [rpm]	Screw lead [mm]		
	p = 5	p = 12,7	p = 20
500 - no screw supports	0,04	0,1	0,16
500 - with screw supports	0,06	0,12	0,2

M idle = the input torque needed to move the carriage with no load on it.

Deflection of the Profile

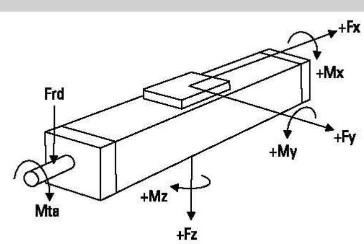


Critical Speed



1: No screw support required
2: Single screw support required
3: Double screw supports required

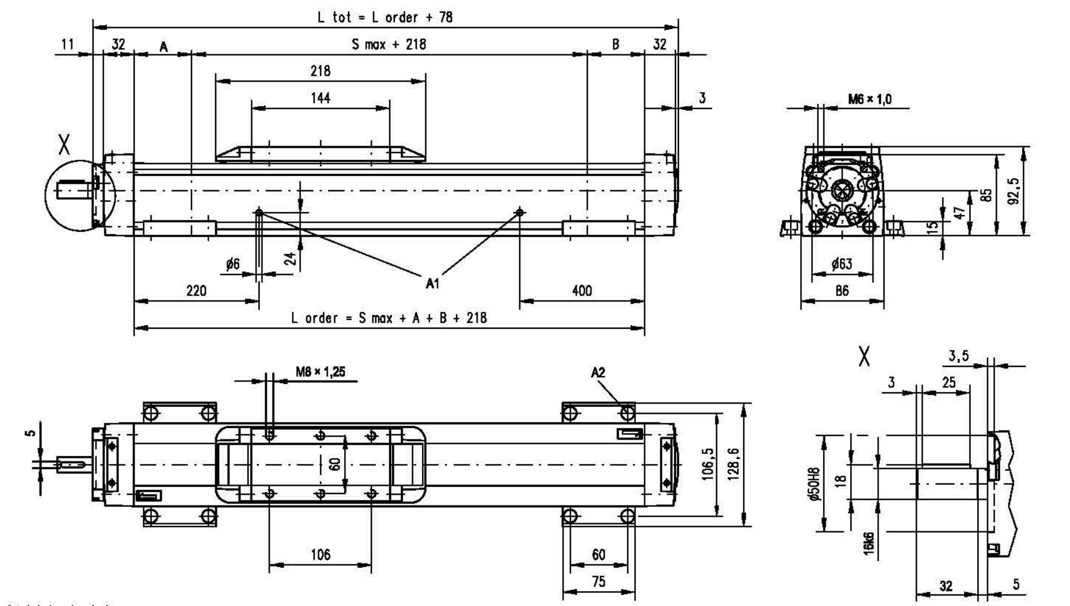
Definition of Forces



Dimensions	Projection
METRIC	

M75

Ball Screw Drive, Ball Guide

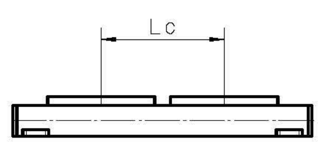


A1: lubrication holes
A2: ø13,5/ø8,5 for socket head cap screw M8

Screw support configuration	A [mm]	B [mm]	Ordering length (L order) [mm]	Total length (L tot) [mm]
No screw support	5	5	L order = Smax + A + B + 218	L tot = L order + 78
Single screw support	60	60	L order = Smax + A + B + 218	L tot = L order + 78
Double screw supports	126	126	L order = Smax + A + B + 218	L tot = L order + 78

Double Carriages

Parameter		M75
Minimum distance between carriages (Lc)	[mm]	250
Dynamic load (Fy), maximum	[N]	3000
Dynamic load (Fz), maximum	[N]	3000
Dynamic load torque (My), maximum	[Nm]	Lc[1] × 1,5
Dynamic load torque (Mz), maximum	[Nm]	Lc[1] × 1,5
Force required to move second carriage	[N]	2
Weight of unit with zero stroke of carriages	[kg]	 12,2 5,0



Screw support configuration	A [mm]	B [mm]	Ordering length (L order) [mm]	Total length (L tot) [mm]
No screw support	5	5	L order = Smax + A + B + Lc + 218	L tot = L order + 78
Single screw support	60	60	L order = Smax + A + B + Lc + 218	L tot = L order + 78
Double screw supports	126	126	L order = Smax + A + B + Lc + 218	L tot = L order + 78

[1] Value in mm

GAF Student Engineering Team
Justin Bracci
Chad Linafelter
Harry Zhao
December 5, 2014

Appendix E. WM Technical Data

THOMSON
Linear Motion. Optimized.

WM60S

Ball Screw Drive, Ball Guide, Single Ball Nut, Short Carriage

» Ordering key - see page 191
» Accessories - see page 135
» Additional data - see page 182

General Specifications

Parameter	WM60S
Profile size (w × h) [mm]	60 × 60
Type of screw	ball screw with single nut
Carriage sealing system	self-adjusting plastic cover band
Screw supports	included in all units that require screw supports
Lubrication	central lubrication of all parts that require lubrication
Included accessories	4 × mounting clamps

Performance Specifications

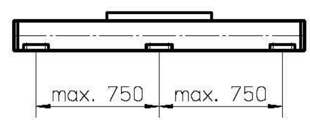
Parameter		WM60S
Stroke length (Smax), maximum	[mm]	5000
Linear speed, maximum	[m/s]	2,5
Acceleration, maximum	[m/s²]	10
Repeatability	[± mm]	0,02
Input speed, maximum	[rpm]	3000
Operation temperature limits	[°C]	0 – 80
Dynamic load (Fx), maximum	[N]	2800
Dynamic load (Fy), maximum	[N]	1400
Dynamic load (Fz), maximum	[N]	1400
Dynamic load torque (Mx), maximum	[Nm]	50
Dynamic load torque (My), maximum	[Nm]	100
Dynamic load torque (Mz), maximum	[Nm]	100
Drive shaft force (Frd), maximum	[N]	500
Drive shaft torque (Mta), maximum	[Nm]	35
Ball screw diameter (d_0)	[mm]	20
Ball screw lead (p)	[mm]	5, 20, 50
Weight of unit with zero stroke of every 100 mm of stroke of each carriage	[kg]	 3,80 0,65 1,00

Carriage Idle Torque (M idle) [Nm]

Input speed [rpm]	Screw lead [mm]		
	p = 5	p = 20	p = 50
150	0,7	1,0	1,4
1500	1,1	1,6	2,0
3000	1,5	1,8	2,2

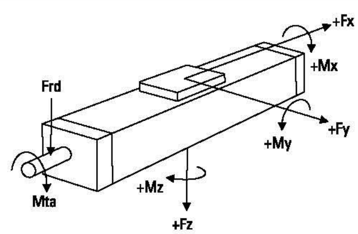
M idle = the input torque needed to move the carriage with no load on it.

Deflection of the Profile



A mounting clamp must be installed at least every 750 mm to be able to operate atmaximum load. Less clamps may be required if less load is being operated, see the additional technical data for more information.

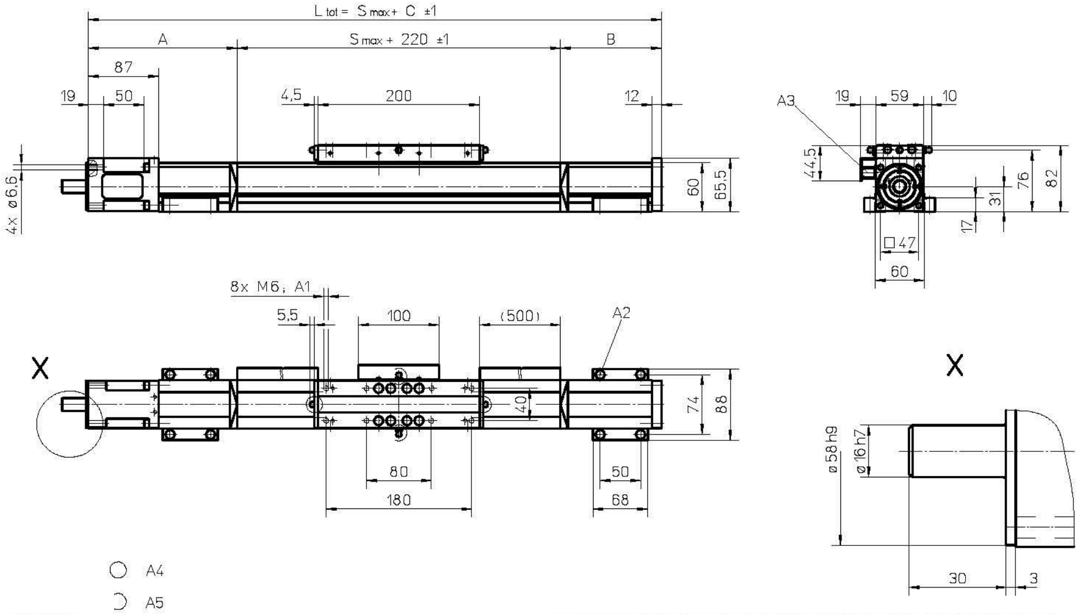
Definition of Forces



Dimensions	Projection
METRIC	

WM60S

Ball Screw Drive, Ball Guide, Single Ball Nut, Short Carriage



A1: depth 11
A2: socket cap screw ISO4762-M6×20 8.8
A3: ENF inductive sensor rail kit (optional - see page 172)

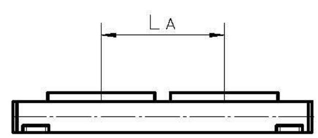
A4: tapered lubricating nipple to DIN71412 AM6 on fixed-bearing side as standard feature
A5: can be changed over to one of the three alternative lubricating points by the customer

Stroke length (Smax) [mm]	A [mm]	B [mm]	C [mm]
0 - 580	95	20	335
581 - 1140	110	60	390
1141 - 1805	130	80	430
1806 - 2460	155	105	480
2461 - 3125	175	125	520
3126 - 3780	200	150	570
3781 - 4445	220	170	610
4446 - 5000	240	190	650

Double Short Carriages

Parameter		WM60S
Minimum distance between carriages (L_A)	[mm]	255
Dynamic load (Fy), maximum	[N]	2800
Dynamic load (Fz), maximum	[N]	2800
Dynamic load torque (My), maximum	[Nm]	L_A[1] × 1,4
Dynamic load torque (Mz), maximum	[Nm]	L_A[1] × 1,4
Force required to move second carriage	[N]	18
Total length (L tot)	[mm]	Smax + C + L_A

[1] Value in mm



Appendix F. DryLin Technical Data and Cost

DryLin® ZLW - Technical data

Technical data ZLW-1040

Marking	Unit	Basic 02	Standard 02
Weight without stroke	kg	0,9	1,0
Weight / 100 mm stroke	kg	0,14	0,14
Max. stroke length*	mm	2.000	2.000
Linear travel per revolution	mm/U	66	70
Gear teeth		RPP 3M	AT 5
Toothed belt material		Neoprene with GF	PU with steel
Toothed belt width	mm	15	16
Belt tension	N	150	200
Max. radial load	N	200	300
Deflection		Grooved ball bearing	Grooved ball bearing
Max. speed dependent on 60% on-time	m/s	3	5
Max. position variation of the carriage, load dependent.**	mm	± 0,35	± 0,2

*We'd be glad to offer larger stroke lengths on request after technical consultation and review.
**Effectively measured values at max. permitted load in horizontal installation position

Technical data ZLW-0630

Marking	Unit	Basic 02	Standard 02
Weight without stroke	kg	0,38	0,4
Weight / 100 mm stroke	kg	0,08	0,08
Max. stroke length*	mm	1.000	1.000
Linear travel per revolution	mm/U	54	54
Gear teeth		HDT 3M	MTD 3
Toothed belt material		Neoprene with GF	PU with steel
Toothed belt width	mm	9	9
Belt tension	N	75	100
Max. radial load	N	100	100
Deflection		Grooved ball bearing	Grooved ball bearing
Max. speed dependent on 60% on-time	m/s	2	2
Max. position variation of the carriage, load dependent.**	mm	± 0,2	± 0,2

*We'd be glad to offer larger stroke lengths on request after technical consultation and review.
**Effectively measured values at max. permitted load in horizontal installation position

Figure E1. DryLin® ZLW-Technical Data.

Quote: D568431REV0

Thank you for the opportunity to quote the following:

Pos	Part	Quantity	UOM	Price $	$ Total
1	DRYE-568431-1	1.00	$/Pc	$1,253.44	$1,253.44

Slide Table - ZLW-1040-02-S-100-L/R-2000 Standard Version
Stroke - 2000mm
Motor Kit - MK-0109
Includes:
Motor - MOT-AN-S-060-035-060-L-A-AAAA
Stepper - NEMA23SXL/litz wires
Assembly - MONT0030000
Motor Flange - MF-1040-NEMA23-S
Coupling - COU-AR-K-080-100-32-32-B-AAAA
Current Lead Time: 4-6 Weeks

Figure E2. Price Quote for original Concept Design that uses Igus linear motion part.

GAF Student Engineering Team
Justin Bracci
Chad Linafelter
Harry Zhao
December 5, 2014

Appendix G. Weighted Decision Matrix

		Concepts					
		Rolls Royce		Toyota		Chevy	
Design Criteria	**Weighting Factor**	**Non-weighted Satisfaction**	**Weighted Satisfaction**	**Non-weighted Satisfaction**	**Weighted Satisfaction**	**Non-weighted Satisfaction**	**Weighted Satisfaction**
One man operation	0.25	100	25	100	25	100	25
Hands-off operation of glue gun	0.20	100	20	100	20	100	20
Safety of system	0.15	90	13.5	90	13.5	65	9.75
Protection from high particulate environment	0.05	95	4.75	90	4.5	50	2.5
Ease of maintenance	0.05	80	4	80	4	85	4.25
Ease of glue gun replacement	0.20	85	17	85	17	80	16
Ruggedness of system	0.05	95	4.75	85	4.25	60	3
Simplicity of system components	0.01	75	0.75	75	0.75	75	0.75
System precision	0.04	95	3.8	95	3.8	65	2.6
Overall Satisfaction	**1.00**		**93.55**		**92.8**		**83.85**

GAF Student Engineering Team
Justin Bracci
Chad Linafelter
Harry Zhao
December 5, 2014

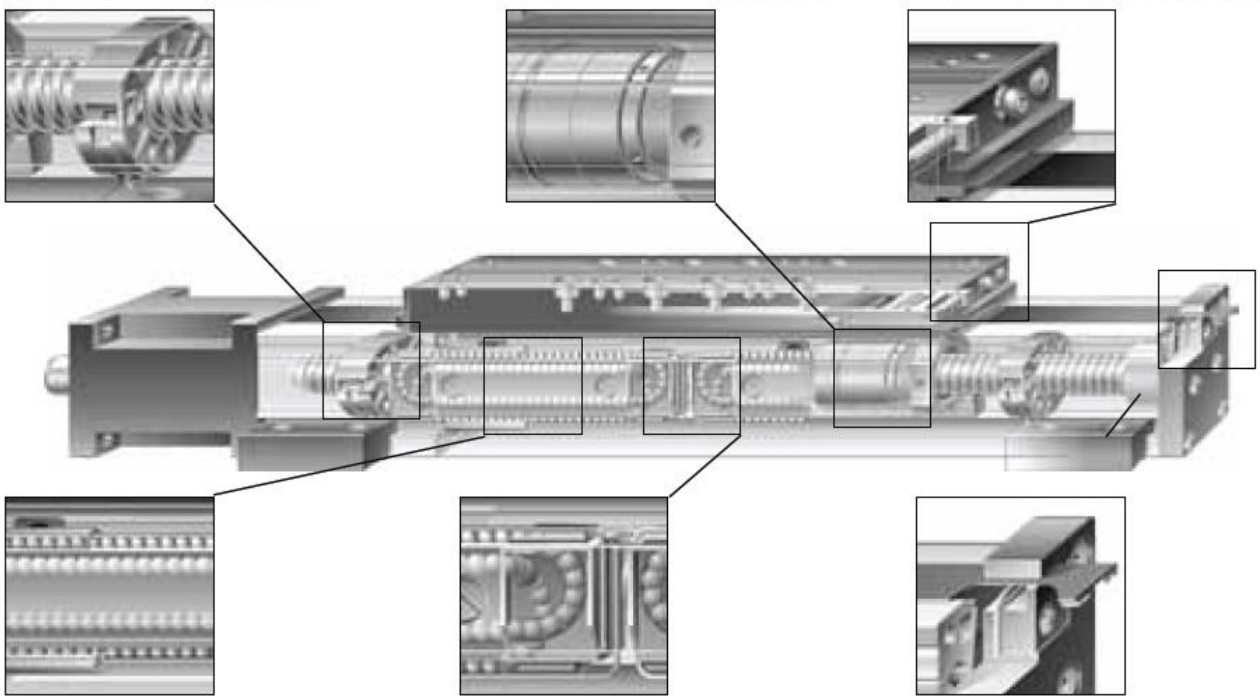
Appendix H: Thomson Linear Technical Presentation

WM-Series Technical Presentation

Screw support
Patented screw support system permits high speeds at long stroke lengths while reducing the available stroke with a minimum.

Double ball nuts
Double pre-tensioned ball nuts improve the accuracy and allow re-tensioning, increasing the lifetime of the unit.

Central lubrication
One central lubrication point on the carriage services the entire unit resulting in a minimum maintenace requirement.



Ball guides
Integrated patented ball guides with hard-ened steel tracks for optimum performance.

Ball cages
The balls in the ball guides are protected by a ball cage which ensures a long life.

Cover band
The patented self-adjusting cover band protect the unit from the penetration of dirt, dust and liquids.

10 www.thomsonlinear.com

Appendix I: Linear System Mounting Bracket Data

THOMSON
Linear Motion. Optimized.

Accessories

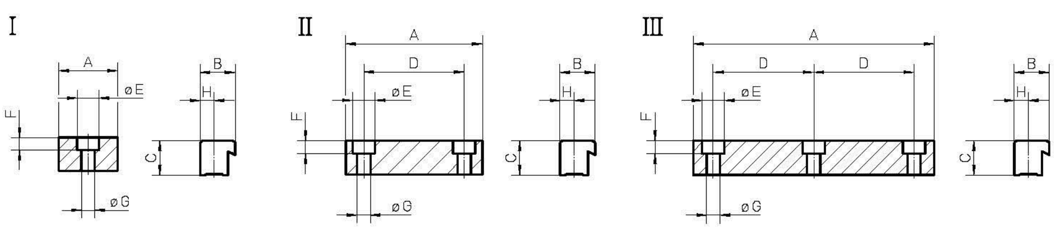
Mounting Kits

Mounting Clamps (single clamp)

Unit type	I	II	III	A	B	C	D	øE	F	øG	H	Screws	Ms [Nm]
WH40	–	890 885 0001	–	54	16	9,5	40	10	5,7	5,5	7	ISO4762-8.8	5,4
WH50	–	890 885 0001	–	54	16	9,5	40	10	5,7	5,5	7	ISO4762-8.8	5,4
WH80 / WB60	–	890 190 02	–	68	17,5	17	50	11	6,5	6,6	7	ISO4762-8.8	9
WH120	–	890 192 13	–	80	25	18	50	15	8,5	9	10	ISO4762-8.8	20
WM40 / WB40	–	890 885 001	–	54	16	9,5	40	10	5,7	5,5	7	ISO4762-8.8	5,4
WM60 / WV60 / WZ60	–	890 190 02	–	68	17,5	17	50	11	6,5	6,6	7	ISO4762-8.8	9
WM80 / WV80 / WZ80	–	890 190 02	–	68	17,5	17	50	11	6,5	6,6	7	ISO4762-8.8	9
WM60Z / WM80Z	–	890 190 02	–	68	17,5	17	50	11	6,5	6,6	7	ISO4762-8.8	9
WM120 / WV120	–	890 192 13	–	80	25	18	50	15	8,5	9	10	ISO4762-8.8	20
MLS60	–	890 190 02	890 192 26	68/120	17,5	17	50	11	6,5	6,6	7	ISO4762-8.8	9
MLS80	–	890 192 13	890 192 31	80/200	25	18	50	15	8,5	9	10	ISO4762-8.8	20
M50 [1]	D312 248	–	–	25	30	20	–	–	–	6,5	14	ISO4762-8.8	9,4
M55 [1]	D313 403	D313 402	–	25/56	25,5	10,7	41	9,5	5,3	5,5	10,2	ISO4762-8.8	5,5
M75 [1]	D312 747	D312 748	–	30/75	28,5	15	60	14	8,5	8,5	11	ISO4762-8.8	23
M100 [1]	D312 339	D312 334	–	45/92	46,5	22	60	17	10,5	10,5	20	ISO4762-8.8	45

[1] no screws included in the shipment of these clamps

Ms = tightening torque of screws



Appendix J: Retrofit Bracket Hand Calculations Analysis

Steel

Mass Values:

Glue Gun = 2.72 kg

Carriage = 2.50 kg

Cable bracket = 0.13 kg

Glue Gun Bracket = 1.55 kg

Single Screw = 1.70 kg

Linear Guide = $\frac{1.05 kg}{100mm} \cdot \frac{1mm}{0.0393701 in} = \frac{0.2667 kg}{in}$

Linear Guide Base = 6.90 kg

Motor ≈ 3.81865 kg

Retro Fit Bracket = $(1664.24\ cm^3)\left(\frac{7.87 g}{cm^3}\right)$

Retro Fit Bracket = 13097.5688 g = 13.0975688 kg

Carriage Total = 2.72 + 2.50 + 0.13 + 1.55

Carriage Total = 6.9 kg

Linear Track Total = $1.70 + \left(\frac{0.2667 kg}{in}\right)(88.19 in) + 6.90$

Linear Track Total = 32.1203 kg

Force Values:

Moving Force; $F_M = (6.9\ kg)(9.81\ m/s^2)$

$F_M = 67.689\ N$

Linear Track Force; $F_T = (32.1203\ kg)(9.81\ m/s^2)$

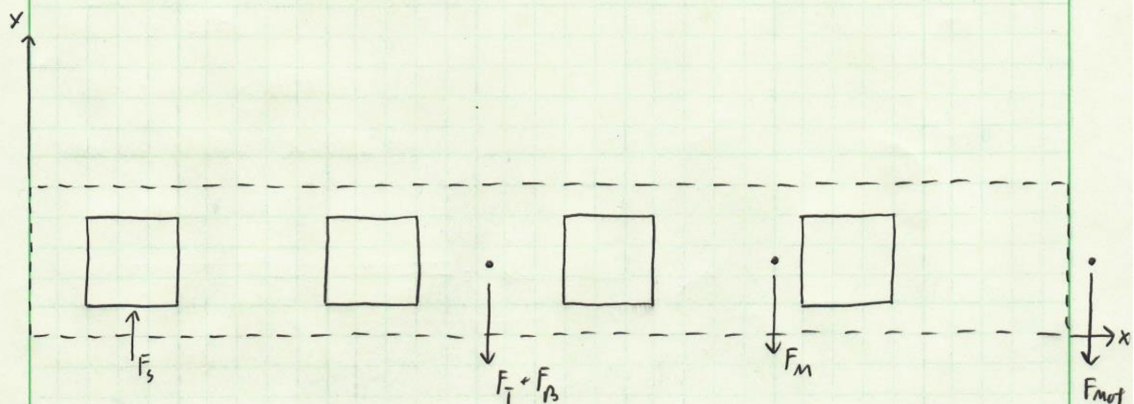
$F_T = 315.0998\ N$

Motor Force; $F_{Mot} = (3.81865\ kg)(9.81\ m/s^2)$

$F_{Mot} = 37.4609699\ N$

Bracket Force; $F_B = (13.0975688\,kg)(9.81\,m/s^2)$

$F_B = 128.002\,N$



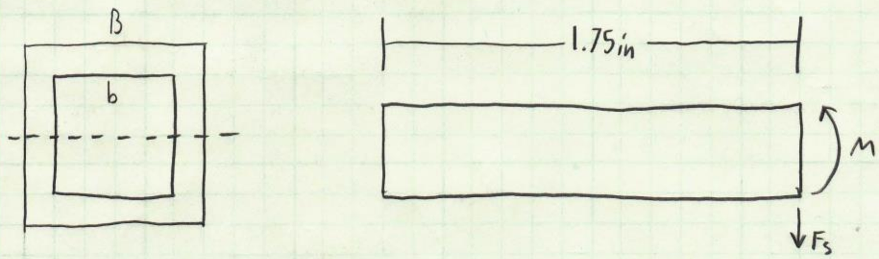
$\Sigma F_y = 0$

$0 = 4F_s - F_T - F_B - F_M - F_{Mot}$

$0 = 4F_s - 315.0998 - 128.002 - 67.689 - 37.4609699$

$4F_s = 548.2517699$

$F_s = 137.0629425\,N = 30.81298\,lbs$



$M = F_s(1.75in)$

$M = (30.81298\,lbs)(1.75in)$

$M = 53.92270665\,lbs \cdot in$

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

$I = \frac{bh^3}{12}$

$I = I_B - I_b$

$I_B = \frac{B^4}{12}$ $\quad I_b = \frac{b^4}{12}$

$I = \frac{1}{12}(B^4 - b^4)$

$c = \frac{1}{2}B$

Assume Material is AISI 1018 steel

$\sigma_{max} = 30457.917$ psi

Assume a FOS of 4

$\sigma_{all} = \frac{\sigma_{max}}{4}$

$= \frac{30457.917 \text{ psi}}{4}$

$\sigma_{all} = 7614.47925$ psi

$\sigma \le \sigma_{all}$

$\frac{Mc}{I} \le 7614.48$ psi

$$\frac{(53.92270665 \text{ lbs}\cdot\text{in})(\frac{1}{2})B}{\frac{1}{12}(B^4 - b^4)} \le 7614.48 \text{ psi}$$

See Table

Appendix K: Thomson Linear Motor Sizing Tools

Ball Screws — Metric Series Engineering

Need a quote or have a question about an application? Contact us in North America at

Phone: 540-633-3549
Fax: 540-639-4162
Email: thomson@thomsonlinear.com

Engineering

Engineering Guidelines for Metric Series Ball Screws

Selecting a Ball Screw Assembly for Your Application — Metric Series

A ball screw assembly is a mechanical device for translating rotational motion to linear motion. As well as being able to apply or withstand high thrust loads, they can do so with minimum internal friction. They are made to close tolerances and are therefore suitable for use in situations in which high precision is necessary. The selection of the correct ball screw assembly for a specific application is an iterative process to determine the smallest envelope and most cost-effective solution. Below is a list of the most common (but not complete) design considerations used to select a ball screw assembly.

- Compression or Tension Load
- Linear Velocity
- Positional Accuracy and Repeatability
- Required Life Expectancy
- Mounting Configuration
- Dimensional Constraints
- Input Power Requirements
- Environmental Condition

At a minimum, the design load, linear velocity, and positional accuracy should be the known inputs and are used to calculate the diameter, lead, and load capacity of the ball screw assembly. Individual ball screw components are then selected based on life, dimensional constraints, mounting configuration, and environmental conditions.

The following procedure will take you through the most common application-based selection of a ball screw assembly. As no two applications are the same, so the determination process is never the same.

1. Determine the required positional accuracy and repeatability that your application requires (page 198). Backlash is the linear independent motion between the ball screw and the ball nut and can be controlled by preloading the ball nut (page 199). The manufacturing process, rolled screws versus ground screws, dictates the accuracy (page 199).
2. Determine how you plan to mount the ball screw assembly into your machine (see page 187). The configuration of the end supports and the travel distance (Max L) will dictate the load and speed limitations of the ball screw.
3. A ball nut in tension can handle loads up to the rated capacity of the nut. For a ball nut in compression, calculate the Permissible Compression Loading (page 197) or use the Compression Loading Chart (page 202) to select a ball screw diameter that meets or exceeds your design load.
4. Calculate the lead of the ball screw that will produce the speed requirement (page 196).
5. The ball nut life can then be calculated using the Dynamic Load Rating (C_{am}) provided in the catalog detail pages. Since multiple ball nuts may be available for a given diameter and lead, use the chart on page 105 to select available styles.
6. Every ball screw has a rotation speed limit, which is the point of excessive vibration/harmonics in the screw. The critical speed is dependent on the end support configuration. Calculate the Critical Screw Speed of the chosen ball screw (page 197) or use the Acceptable Speed Chart (page 201) to determine the critical speed.
7. If the load, life and speed calculations confirm that the selected ball screw assembly meets or exceeds the design requirements, then proceed to the next step. If not… Larger diameter screws will increase the load capacity and increase the speed rating. Smaller lead screws will decrease the linear speed (assuming constant input motor speed), increase the motor speed (assuming constant linear speed), and decrease the input torque required. Higher lead screws will increase the linear speed (assuming constant input motor speed), decrease the input motor speed (assuming constant linear speed), and increase the input torque required. Repeat steps 3 thru 5 until the correct solution is obtained.
8. Determine how the ball nut will interface into your application. A ball nut flange is the typical method of attaching the ball nut to the load. Threaded ball nuts and cylindrical ball nuts are alternative ways to provide the interface.
9. Additional design considerations and features are also available. Preloaded ball nuts are available to reduce system backlash and increase positional accuracy. Wiper kits to protect the assembly from contaminants and to contain lubrication are standard on some units and optional on most others. Bearing supports and end machining are also available as options for all ball screws.
10. The final considerations are system mounting and lubrication. The ball nut should be loaded axially only as any radial loading significantly reduces the performance of the assembly (page 200). The assembly should also be properly aligned with the drive system, bearing supports, and load to achieve optimal performance (page 200). The ball screw assembly should never be run without proper lubrication. Many lubricants are available depending on the application and environment (page 200).

Note: Application and customer service support is available to assist in the selection of your ball screw assembly. Please contact your local Thomson representative or the customer support center (1-540-633-3549 — TCS) for any additional assistance.

Engineering Guidelines for Metric Series Ball Screws

Ball Screw Assembly Selection Example:
Inputs:

Load: 133,440 N Compression Maximum
44,480 N dynamic
Linear Speed: 5.08 meter/min.
Input Speed: 400 rpm
Travel: 2159 mm
Life: 2.5×10^4 meters

1. **Accuracy (pages 198 and 199)**
   No Preload and Standard Rolled (±50 μm per 300mm)

2. **End Supports (page 187)**
   Fixed/Supported

3. **Determine Screw Diameter**
   From Chart (page 202): Ø50mm

   From Equation (page 197): $133{,}440 / .8 = \dfrac{1.47 \times 9.687 \times 10^4 \times d_r^4}{(2159)^2}$

   therefore, $d_r = 44.8$mm

4. **Determine Lead (pages 196 and 105)**

   $\text{Lead} = \dfrac{5.08 \text{ meter/min.}}{400 \text{ rpm}}$ therefore, Lead = 12.7mm, Use 10mm

5. **Determine Life**
   From Catalog (page 118): Dynamic Load = 66,400 N

   $\text{Life (revolutions)} = \left[\dfrac{66{,}400}{44{,}480}\right]^3 \times 10^6$

   therefore, Life = 3.3×10^6 revs (3.3×10^4 meters)

6. **Determine Critical Speed**
   From Catalog (page 118): Screw Root Diameter is 43.0mm

   From Equation (page 197): $.8 \times 1.47 \times 1.2 \times 10^6 \times \dfrac{d_r}{l^2}$

   therefore, Speed = 1,301.8 rpm

   Verified via Chart (page 201)

7. **Design Verification**
   OK per load, speed and life.

8. **Load Interface**
   Flanged connection preferred.

9. **Additional Requirements**
   - Wipers required
   - Bearing Supports required
   - End Machining needed
   - Right Hand Thread
   - Carbon Steel

10. **Mounting and Lubrication**
    System will require motor interface and linear rails for alignment.
    TriGel 450R

Product Selection (page 118):

Ball Nut: P/N 7832818
Ball Screw: P/N 7832817-P5

Engineering

Engineering Guidelines for Metric Series Ball Screws

Design Formulas

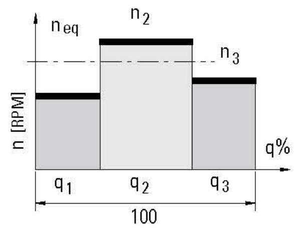
These formulas allow you to calculate a number of important factors which govern the application of Thomson ball screws.

1. Ball Screw Life (L)

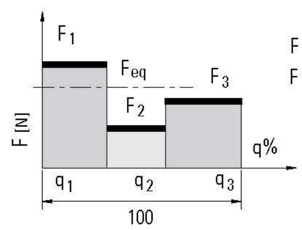
The ball screw assembly's useful life will vary according to load and speed. Life is typically rated at 90% confidence, L10 (which represents time at which 90% of assemblies still perform).

Functional life should be determined by approximating equivalent rotational speed and loading force over typical performance cycles.

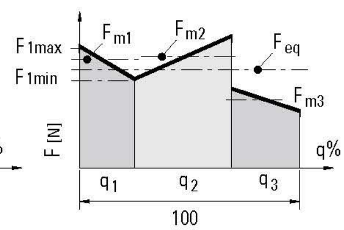
Simple rotational speed profile



Simple loading profile (1)



Simple loading profile (2)



$$n_{eq}\left[min^{-1}\right] = \sum_{i=1}^{n} n_i \times \frac{q_i}{100}$$

$$F_{eq}\left[N\right] = \left(\sum_{i=1}^{n} F_i^{\,3} \times \frac{n_i}{n_{eq}} \times \frac{q_i}{100}\right)^{1/3}$$

$$F_{eq}\left[N\right] = \left(\sum_{i=1}^{n} F_{mi}^{\,3} \times \frac{n_i}{n_{eq}} \times \frac{q_i}{100}\right)^{1/3}$$

Modified Life

$$L_{10}\left[\text{revolutions}\right] = \left[\frac{C_{am}}{F_{eq}}\right]^3 \times 10^6$$

$$L_{h10}\left[\text{hours}\right] = \frac{L_{10}}{n_{eq} \times 60}$$

Parameters:

- n_{eq} = equivalent operating rotational speed [rpm]
- F_{eq} = equivalent operating load [N]
- C_{am} = dynamic load rating [N] (see specification tables) (Based on 1.0 million revolutions)

2. Rotational Speed Required for a Specific Linear Velocity

$$n = \frac{\text{Travel Rate (mm x min.}^{-1})}{\text{Lead (mm)}}$$

n = rpm

3. Machine Service Life

After ball screw life (L) is calculated, apply it to the following formula to determine machine service life.

$$\text{Machine Service Life (in years)} = \frac{L_{h10}\ [\text{hours}]}{(\text{machine operating hours}) \cdot (\text{days/year}) \cdot \left(\frac{\text{ball screw operating hours}}{\text{machine operating hours}}\right)}$$

Engineering Guidelines for Metric Series Ball Screws

4. Torque

a. Driving torque: $T_d \text{ (N•m)} = \dfrac{F_{eq} \times P}{2\pi e} = 1.77 \times 10^{-4} \times F_{eq} \times P$

b. Backdrive torque: $T_b \text{ (N•m)} = \dfrac{F_{eq} \times P \times e}{2\pi} = 1.43 \times 10^{-4} \times F_{eq} \times P$

(conversion of linear to rotational motion)

F_{eq} = Equivalent Operating Load (N)
P = Lead (mm)
e = Efficiency = 0.90
T_d = Driving Torque (N•m)
T_b = Backdrive Torque (N•m)
1 lb-in. = 0.113 N•m

5. Power

$$P_d \text{ (W)} = \frac{F_{eq} \times P}{(2\pi)\, e} \times \frac{n}{9.546 \times 10^3} = \frac{F_{eq} \times P \times n}{5.398 \times 10^4}$$

P_d = Power (W)
n = rpm
1 hp = 746 W

6. Permissible Rotational Speed

The permissible rotational speed depends on two factors: critical screw speed and critical nut speed.

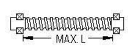
6a. Critical Screw Speed

The critical screw speed is related to the natural frequency of the screw shaft. Exceeding this value may result in excessive vibration. The critical screw speed may be found using the following equations or the chart on page 201.

$$n_c = C_s \times 1.2 \times 10^8 \times \frac{d_r}{l^2}$$

$$n_s = n_c \times S$$

n_c = Critical Speed (rpm)
n_s = Safe Drive Speed
d_r = Root Diameter (mm)
l = Length between Bearing Supports (mm)
S = Safety Factor (0.8 maximum)
C_s = End Fixity Factor

End Fixity Factor - Critical Screw Speed			
	End Supports		C_S
A		One end fixed, one end free	0.36
B		Both ends supported	1.00
C		One end fixed, one end supported	1.47
D		Both ends fixed	2.23

6b. Critical Nut Speed

The critical nut speed is related to the velocity of the ball bearings rotating around the screw shaft. Exceeding this value may result in permanent damage to the ball recirculation components. Thomson recommends a maximum DN value of 140,000 for standard internal transfer designs, which encompass the majority of the Metric products. Higher values may be accommodated by special design (consult with applications engineering).

$DN = d_0 n$

where
d_0 = nominal shaft diameter (mm)
n = rotational speed of shaft (rpm)

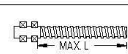
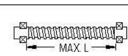
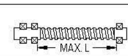
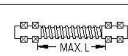
7. Permissible Compression Loading

Exceeding the recommended maximum compression force may result in buckling of the screw shaft.

$$F_c = \frac{C_s \times 9.687 \times 10^4 \times d_r^4}{l^2}$$

$$F_s = F_c \times S$$

F_c = Critical Buckling Force (N)
F_s = Safe Compression Force (N)
d_r = Root Diameter (mm)
l = Max Unsupported Length (mm)
S = Safety Factor (0.8 maximum)
C_s = End Fixity Factor

End Fixity Factor - Permissible Compression Loading			
	End Supports		C_S
A		One end fixed, one end free	0.25
B		Both ends supported	1.00
C		One end fixed, one end supported	2.00
D		Both ends fixed	4.00

Engineering

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Engineering Guidelines for Metric Series Ball Screws

Accuracy Classes

Accuracy is a measure of how closely a motion system will approach a command position. Perfect accuracy, for example, means that advancing a ball nut a precise amount from a given point on the screw always requires exactly the theoretically predicted number of revolutions.

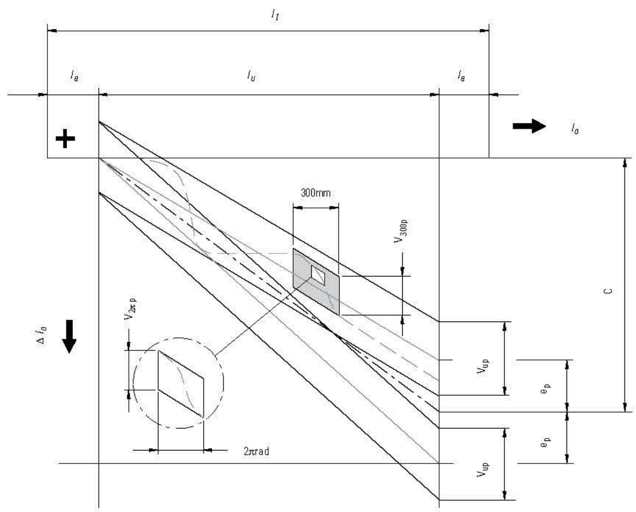
Metric ball screws are produced in two main tolerance classes: T (transport) and P (positioning). Transport grade ball screws are used in applications requiring only coarse movement or those utilizing linear feedback for position location. As such, most transport grade screws are provided with nuts having backlash (T7 grade screws cannot be supplied with preloaded nuts). Precision grade ball screws are used where repeatable positioning within microns is critical, without the use of a linear feedback device.

Differences between P & T grades are highlighted in the graph. T grade transport screws allow greater cumulative variation over the useful length of the screw. P grade positioning screws contain accumulation of lead error to provide precise positioning over the screw's entire useful length.

- l_o = nominal travel
- l_1 = thread length
- l_o = travel deviation
- l_u = useful travel
- l_e = excess travel
- C = travel compensation for useful travel (std. = 0)
- e_p = tolerance for actual mean travel deviation (the difference between the maximum and minimum values of the permissible actual mean travel)
- V_{up} = permissible travel variation within useful travel, l_u
- V_{300p} = permissible travel deviation within 300mm travel
- $V_{2\pi p}$ = permissible travel deviation within 1 revolution

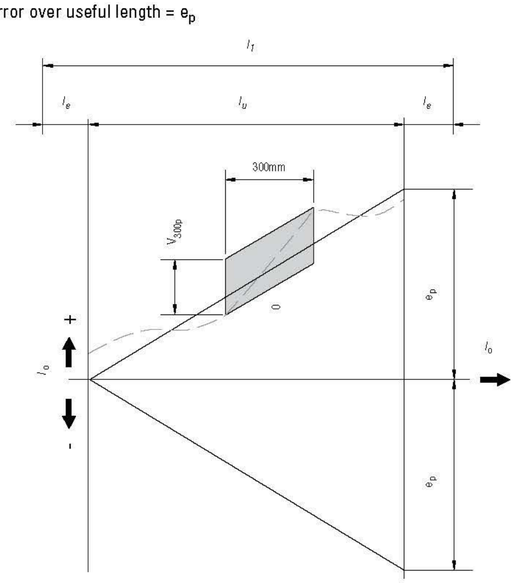
P — Positioning Class Ball Screws

Maximum error over useful length = $e_p + 1/2V_{up} + C$



T — Transport Class Ball Screws

Maximum error over useful length = e_p



GAF Student Engineering Team
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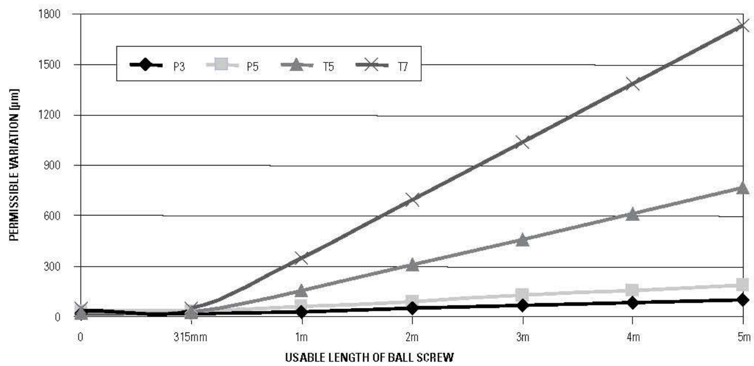
December 5, 2014

Engineering Guidelines for Metric Series Ball Screws

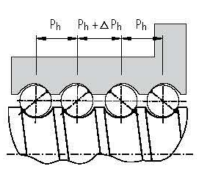
Permissible Travel Variation Over Usable Length



Tolerance Class	Lead Accuracy V_{300p}	Permissible Travel Deviation V_{up} (µm) Over Screw Length l_u (mm)															
		l_u	>		315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000
		(mm)	?	315	400	500	630	800	1000	1250	1600	2000	2500	3150	4000	5000	6300
P3	±12 µm/300mm	e_p (µm)		12	13	15	16	18	21	24	29	35	41	50	62	76	—
		V_{up} (µm)		12	12	13	14	16	17	19	22	25	29	34	41	49	—
P5	±23 µm/300mm	e_p (µm)		23	25	27	30	35	40	46	54	65	77	93	115	140	170
		V_{up} (µm)		23	25	26	29	31	35	39	44	51	59	69	82	99	119
T5	±23 µm/300mm	V_{up} (µm)		23	$=2 \times l_u/300 \times V_{300p}$												
T7	±52 µm/300mm	V_{up} (µm)		52	$=2 \times l_u/300 \times V_{300p}$												

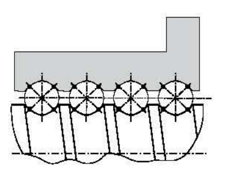
Preload Types

Precise Preload (Type Z0)
(Available with FL nut only)



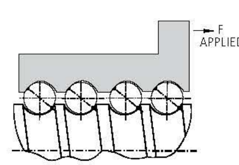
- The lead is offset within the ball nut to provide a precise preload.
- The preload is approximately 10% of dynamic load capacity, but can range from 2% to 13% as specified by customers.
- Typically used where both repeatability and high stiffness are required.

Preload (Type Z1)



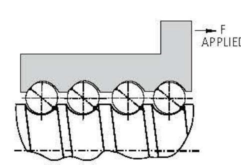
- Oversized balls slightly larger than the ball groove space are used to provide zero backlash between the screw and nut.
- The preload is approximately 1% to 2% of dynamic load capacity.
- Typically used for positioning applications where higher-level repeatability is desired.

No Preload (Type Z2)
(Standard lash)



- Axial play is present between screw and nut.
- Typically used for transport or vertical applications.

No Preload (Type Z3)
(Minimum lash)



- Axial play is present between screw and nut (held to .05mm maximum).
- Typically used for transport or vertical applications.

Engineering

Engineering Guidelines for Metric Series Ball Screws

Lubrication Guidelines

Ball screws must be lubricated to operate properly and achieve the rated life. We recommend using TriGEL-450R or TriGEL-1800RC for lubricating ball screws. Other oils and greases may be applicable but have not been evaluated.

The TriGEL grease can be applied directly to the screw threads near the root of the ball track. Some ball nut sizes are available with threaded lube holes for mounting lubrication fittings. For these ball nuts, the TriGEL grease can be pumped directly into the nut. Please refer to the catalog detail views to verify which ball nuts have the threaded lube holes. It is recommended to use these nuts in conjunction with a wiper kit to contain the lubricant in the body of the nut.

Ball screws may require lubrication frequently frequently depending on both environmental and operating conditions. If the lubricant appears to be dispersed before this point or has become dry or crusted, the maintenance interval should be reduced. Before adding additional grease, wipe the screw clean, removing the old grease and any particulate contamination seen on the screw. If oil is being used, the best results may be obtained by utilizing a continuous-drip type applicator.

Nut Loading

Axial loading (on nut or screw) is optimal for performance and life. For applications requiring radial loads, please contact us.

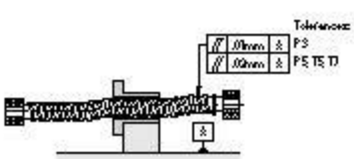
Axial Loading: optimal

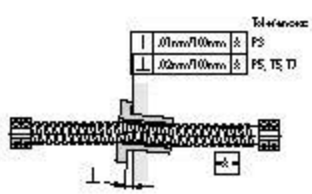
Radial Loading: detrimental*

* Minimize radial loading to less than 5% of the axial load.

Nut Mounting

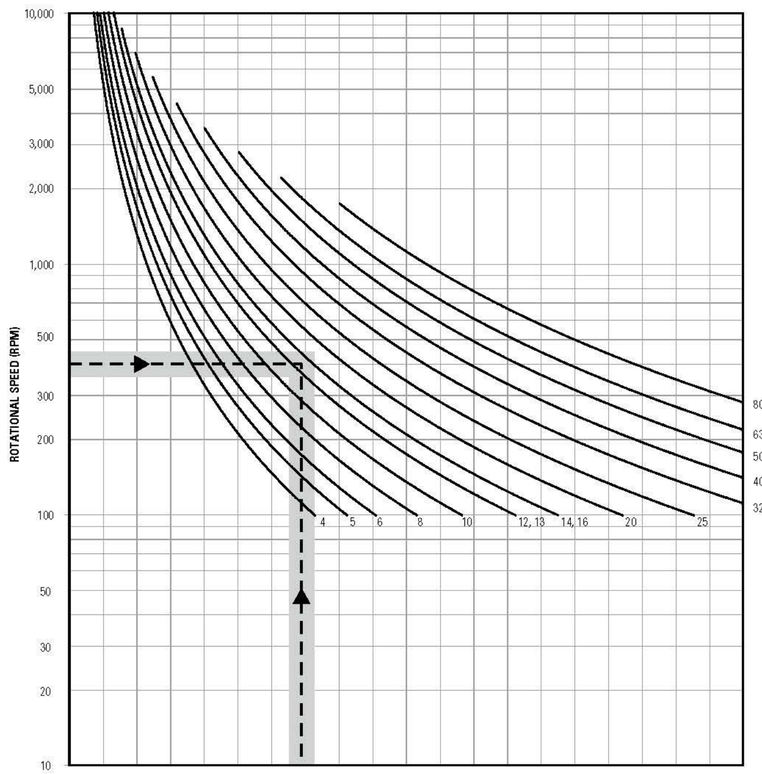
Use the following guidelines to achieve optimal performance. (All units are mm)





Engineering Guidelines for Metric Series Ball Screws

Acceptable Speed† vs. Length for Screws



END SUPPORT TYPE

Type	End support	Unit																				
A	One end fixed, other end free (MAX. L)	Inches	6	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102	108	114	120
		mm	152	304	457	609	762	914	1056	1219	1371	1524	1676	1828	1981	2133	2286	2438	2590	2743	2895	3048
B	Both ends supported (MAX. L)	Inches	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170	180	190	200
		mm	254	508	762	1016	1270	1524	1778	2032	2286	2540	2794	3048	3302	3556	3810	4064	4318	4572	4826	5080
C	One end fixed, other end supported (MAX. L)	Inches	12	24	36	48	61	73	85	97	109	121	133	145	158	170	182	194	206	218	230	242
		mm	304	609	914	1219	1549	1854	2159	2463	2768	3073	3378	3683	4013	4318	4622	4927	5232	5537	5842	6146
D	Both ends fixed (MAX. L)	Inches	15	30	45	60	75	90	105	119	134	149	164	179	194	209	224	239	254	269	284	298
		mm	381	762	1143	1524	1905	2286	2667	3022	3403	3784	4165	4546	4927	5308	5689	6070	6451	6832	7213	7569

Example: Travel rate of 400 rpm.
Unsupported length of 85 in. (2159mm).
End fixity of one end fixed, other end supported.

All screws with curves which pass through or above and to the right of the plotted point are suitable for the example. The acceptable velocities shown by this graph apply to the screw shaft selected and are not indicative of the velocities attainable of all of the associated ball nut assemblies. Consult Thomson engineering for high speed applications.

†80% of critical speed

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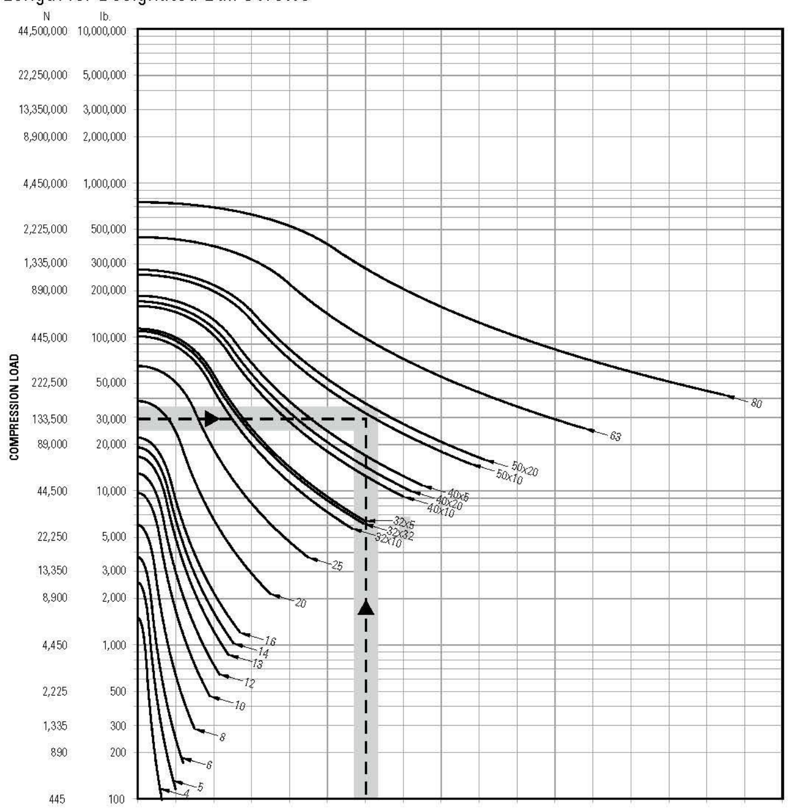
Engineering Guidelines for Metric Series Ball Screws

Compression Load vs. Length for Designated Ball Screws



END SUPPORT TYPE

Type	End support	Units																	
A	One end fixed, other end free (MAX. L, LOAD)	Inches	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85
		mm	127	254	381	508	635	762	889	1016	1143	1270	1397	1524	1651	1778	1905	2032	2159
B	Both ends supported (MAX. L, LOAD)	Inches	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160	170
		mm	254	508	762	1016	1270	1524	1778	2032	2286	2540	2794	3048	3302	3556	3810	4064	4318
C	One end fixed, other end supported (MAX. L, LOAD)	Inches	14	28	42	57	71	85	99	113	127	141	156	170	184	198	212	226	240
		mm	356	711	1067	1448	1803	2159	2515	2870	3226	3581	3962	4318	4674	5029	5385	5740	6096
D	Both ends fixed (MAX. L, LOAD)	Inches	20	40	60	80	100	120	140	160	180	200	220	240	260	280	300	320	340
		mm	508	1016	1524	2032	2540	3048	3556	4064	4572	5080	5588	6096	6604	7112	7620	8128	8636

Example: Maximum system load is 30,000 lb. (133,500 N).
Length of 85 in. (2159mm).
End fixity of one end fixed, other end supported.

All screws with curves which pass through or above and to the right of the plotted point are suitable for the example.

The suitable compression loads shown in this graph are not to exceed the maximum static load capacity as given in the rating table for the individual ball nut assembly.

202 www.thomsonlinear.com

Appendix L: Motor Sizing Hand Calculations Analysis

ME 429 4/30/14 Motor Sizing

<u>Rotational Speed Required for a Specific Linear Velocity</u>

$n = rpm$

$$n = \frac{\text{Travel Rate } (mm/min)}{\text{Lead } (mm)}$$

$$\text{Travel Rate} = \frac{2000\,mm}{\frac{1}{12}\,min} = 24000\ mm/min$$

Lead Choices: 5 mm, 7mm, 12mm, and 20mm

See Table

<u>Torque</u>

Driving Torque = T_d Backdrive Torque = T_b

Operating Load = F_{eq}

Lead = P

Efficiency = e

$$T_d = \frac{F_{eq}(P)}{2\pi e}$$

$F_{eq} = 67.05322587\,N$

$e = 0.9$

$$T_d = \frac{(67.05322587\,N)(P)}{2\pi(0.9)}$$

$T_d = (11.85761372)(P)\ Nm$

See Table

$$T_b = \frac{F_{eq}(P)(e)}{2\pi} = \text{Backdrive Torque}$$

$$T_b = \frac{(67.05322587\ N)(0.9)\ P}{2\pi}$$

$$T_b = (9.604667113)(P)\ Nm$$

See Table

<u>Power</u>

P_d = Power

n = rpm

$$P_d = \frac{(F_{eq})(P)(n)}{5.398 \cdot 10^4}$$

$$P_d = \frac{(67.05322587\ N)(P)(n)}{5.398 \cdot 10^4}$$

$$P_d = 0.0012421865\ Pn$$

Appendix M: Detailed Cost Analysis

*Items Highlighted in yellow are to be ordered by sponsor.
**Items not highlighted are to be obtained by student engineering team to be reimbursed later by sponsor.

COST ANALYSIS							
Part	Manufacturer	Part #	Notes	Material	Qty	Price per	Total Price
Motor Coupling	Thomson Linear	Custom Order	Supply motor make and model	Custom Order	1	$600.00	$600.00
Linear Motion System	Thomson Linear	TF07K729A00S224	2 weeks lead time. Nearest distributor Applied Inudstrial loacated in Santa Maria, CA. (805) 928-1863	-	1	$3,964.00	$3,964.00
Mounting Clamps	Thomson Linear	D312748	Verify with distributor that mounting kit matches linear motion system	-	6	Estimate	$90.00
Mounting Bracket Insulator	Morgan Thermal Ceramics	BTU-BLOCK Board Panel		-	-	Estimate	$300.00
Mounting Plate	McMaster Carr	69445T515		6061 T6 Al	1	$82.89	$82.89
Mounting Bracket 1 and 2	McMaster Carr	8975K264	1 ft length	6061 T6 Al	1	$44.38	$44.38
Protective Shield	McMaster Carr	8983K155 (12x18x0.060)	12x18x0.060	305 SS	2	$31.29	$62.58
Glue Gun and Protective Shield Insulation Material	Unifrax	29KLITE146#	Fiberfrax Durablanket S Superthin	-	1	$70.00	$70.00
Cable Chain	McMaster Carr	55835K93	Price per foot	Glass Filled Nylon	8	$12.43	$99.44
Square Tube 1.75in x 1.75in	McMaster Carr	6546K6	2 ft length	6061 T6 Al	1	$20.93	$20.93
100"x5"x0.125" Aluminum Plate	Online Metals.com	Custom Order		6061 T6 Al	1	$70.00	$70.00

U-Channel, 2" Base x 1" Legs	McMaster Carr	1630T29	5 ft length	6061 T6 Al	1	$18.65	$18.65
U-Channel, 2" Base x 1" Legs	McMaster Carr	1630T29	3 ft Length	6061 T6 Al	1	$13.05	$13.05
Test Mount Bottom Plate	McMaster Carr	9517K372		AISI 1018	2	$38.51	$77.02
Test Mount Top Bar 1	McMaster Carr	6527K434	6 ft length	AISI 1018	1	$69.19	$69.19
Test Mount Top Bar 2	McMaster Carr	6527K434	3 ft length	AISI 1018	1	$41.51	$41.51
Test Mount Verticle Bar	McMaster Carr	6527K434	1 ft length	AISI 1018	1	$22.83	$22.83
Protective Shield Raw Material	McMaster Carr	9255T57	24"X 24" 20 guage with 1/8" holes	steel	1	$22.41	$22.41
5/16 x 18 x 1.00 Flat Head Socket Cap	McMaster Carr	92185A583	box of 10	316 SS	1	$6.81	$6.81
1/4 x 20 x 0.75 Socket Head Cap	McMaster Carr	92185A540	box of 10	316 SS	1	$3.41	$3.41
1/4 x 20 x 1.25 Socket Head Cap	McMaster Carr	92185A544	box of 10	316 SS	1	$4.26	$4.26
M8x1.25x30 Socket Head Cap	McMaster Carr	92290A434	box of 10	316 SS	1	$11.01	$11.01
1/2 x 13 x 5 Socket Head Cap	McMaster Carr	91257A732	box of 5	Grade 8 Steel	4	$11.34	$45.36
1/2 x 13 x 5 Hex Nut	McMaster Carr	93827A245	box of 25	Grade 8 Steel	1	$8.05	$8.05
Fiberglass Insulating Washers	McMaster Carr	93493A235	box of 10	Fiberglass	1	$3.68	$3.68
Insulating Sleeves	McMaster Carr	94639A146	box of 100	Nylon 6/6	1	$9.98	$9.98
						SUB TOTAL	$5,761.44
						TAX @ 8%	$460.92
						TOTAL	$6,222.36
						*Shipping not included	

Optional Products							
Part	Manufacturer	Part #	Notes	Material	Qty	Price per	Total Price
Glue Gun Body Insulation-Rigid	Zircar Ceramics	Type ALC & ALC-AA - Custom Order Size	Offer circular pieces down to 1/2" thick walls, 1"-12" ID	Alumina Fiber	1	Call	Call
Rigid Insulation Board	Zircar Ceramics	A10009	ZAL-15, 18in.W x 24in.L x 0.50in.T	Alumina Fiber	1	$409.00	$409.00

Resources:

http://www.zircarceramics.com/pages/rigidmaterials/specs/alc.htm

http://www.zircarceramics.com/pages/rigidmaterials/specs/zal15.htm

GAF Student Engineering Team
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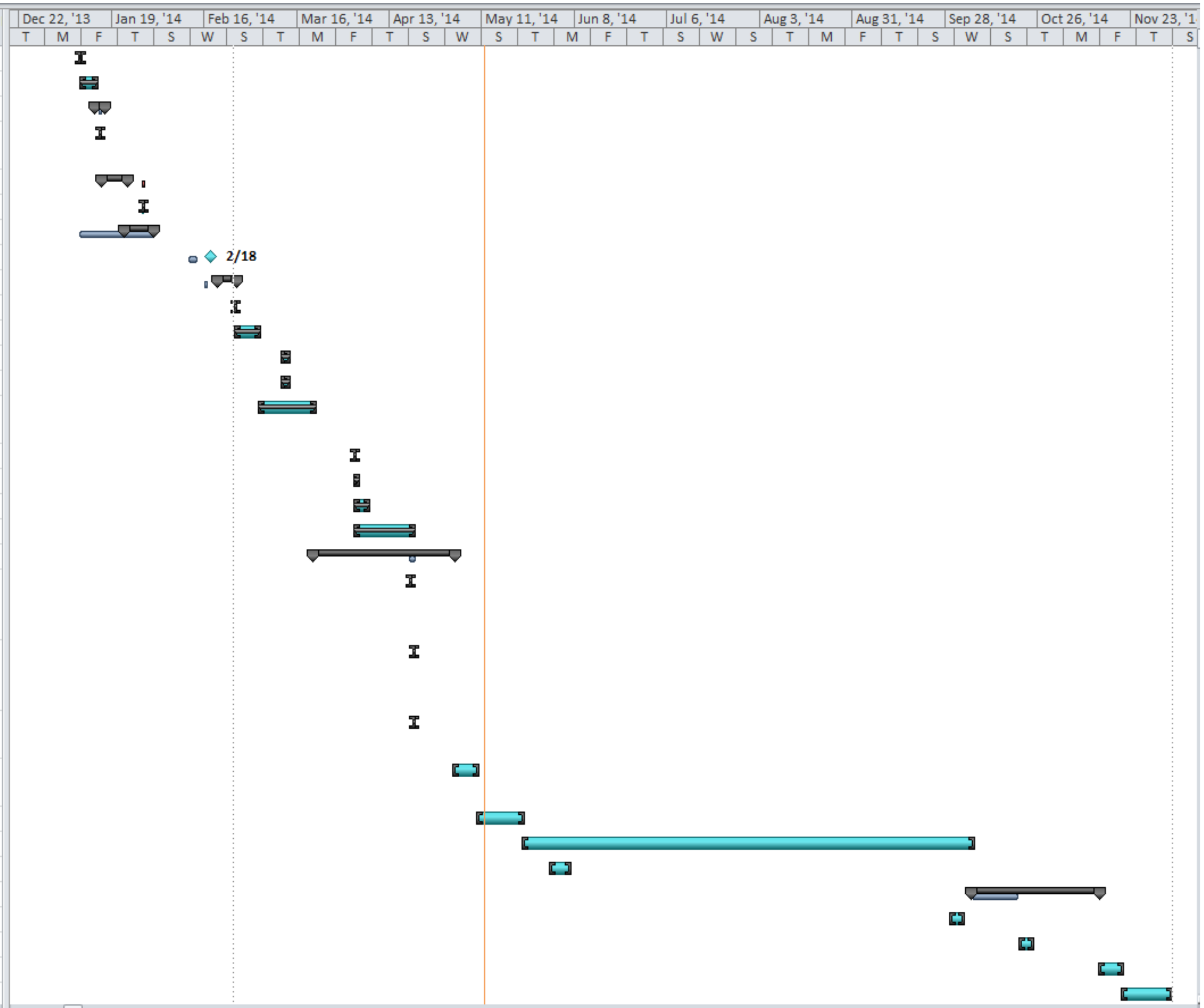
December 5, 2014

Appendix N: Gantt Chart

		Task Mode	Task Name	Duration	Start	Finish
1	✓		Receive Project	1 day	Thu 1/9/14	Thu 1/9/14
2	✓		Intro letter to Sponsor	4 days	Thu 1/9/14	Tue 1/14/14
3	✓		**Team Contract**	**3 days**	**Tue 1/14/14**	**Thu 1/16/14**
4	✓		Discuss Team Expectations	1 day	Wed 1/15/14	Wed 1/15/14
5	✓		**Problem Statement**	**6 days**	**Thu 1/16/14**	**Thu 1/23/14**
6	✓		Shafter Plant Visit	1 day	Tue 1/28/14	Tue 1/28/14
7	✓		**Project Proposal**	**7 days**	**Thu 1/23/14**	**Fri 1/31/14**
14	✓		**Present Concept Models**	**0 days**	**Tue 2/18/14**	**Tue 2/18/14**
16	✓		**Decision Matrix**	**4 days**	**Thu 2/20/14**	**Tue 2/25/14**
20	✓		Project Gantt Chart	1 day	Tue 2/25/14	Tue 2/25/14
21	✓		Concept Design Report	6 days	Tue 2/25/14	Tue 3/4/14
22	✓		Design FMEA & DVP	3 days	Tue 3/11/14	Thu 3/13/14
23	✓		Design Analysis Plan	3 days	Tue 3/11/14	Thu 3/13/14
24	✓		Schedule CDR with Sponsor	14 days	Tue 3/4/14	Fri 3/21/14
25	✓		Brainstorm for Glue Gun	1 day	Wed 4/2/14	Wed 4/2/14
26	✓		Morph Chart	2 days	Wed 4/2/14	Thu 4/3/14
27	✓		PUGH Matrix	4 days	Wed 4/2/14	Sun 4/6/14
28	✓		New Concept Design Rep	14 days	Wed 4/2/14	Sun 4/20/14
29	✓		**Final Design Report**	**31 days**	**Fri 3/21/14**	**Fri 5/2/14**
30	✓		Analysis, stress, and deflection calculations for press	1 day	Sat 4/19/14	Sat 4/19/14
31	✓		Analysis, stress, and deflection calculations for	1 day	Sun 4/20/14	Sun 4/20/14
32	✓		Cost analysis for components needed	1 day	Sun 4/20/14	Sun 4/20/14
33			Obtain Sponsor Approval	6 days	Fri 5/2/14	Fri 5/9/14
34			Order Parts & Materials	11 days	Fri 5/9/14	Fri 5/23/14
35			Begin Construction of Sy:	97 days	Fri 5/23/14	Mon 10/6/14
36			End of Quarter Report	6 days	Sat 5/31/14	Fri 6/6/14
37			**Begin Testing of System**	**29 days**	**Mon 10/6/14**	**Thu 11/13/14**
41			Project Update Memo	5 days	Mon 9/29/14	Fri 10/3/14
42			Hardware Demo	5 days	Mon 10/20/14	Fri 10/24/14
43			Senior Design Expo	6 days	Thu 11/13/14	Thu 11/20/14
44			Final Project Report	12 days	Thu 11/20/14	Fri 12/5/14



Appendix O: DVP&R

GAFSET DVP&R

Report Date	5/13/2014	Sponsor	GAF					Component	REPORTING ENGINEER:			
TEST PLAN									**TEST REPORT**			
Item No	Specification or Clause Reference	Test Description	Acceptance Criteria	Test Responsibility	Test Stage	SAMPLES		TIMING		TEST RESULTS		NOTES
						Quantity	Type	Start date	Finish date	Test Result	Quantity Pass	Quantity Fail	
1	Calibrate Correct Traverse Profile	Determine optimum traverse speed to maintain consistancy	Fullfills item No. 3 Criteria	Chad	PV	20	C	5/15/2014	10/20/2014	PASS	13	7	Initial failures due to calibration process
2	Glue Overspray	Glue cannot be distributed onto splice table	no glue 0.25 inches from end of glass mat	Harry	DV	20	B	5/15/2014	10/20/2014	PASS	16	4	Initial failures due to calibration process
3	Glue distribution	Consistent and controlled amount of distributed glue on mat	bead size plus/minus 20%	Justin	DV	20	C	4/1/2014	10/27/2014	PASS	18	2	Failures due to glue gun overheating
4	Glue Gun Mount Plate Temperature	Mount plate must not exceed design temperature	< 160°F	Entire Team	DV	10	B	5/15/2014	6/13/2014	PASS	10	0	Temperature did not exceed 100°F
5	Semi-Automated Procedure	One man must be able to perform entire operation	1 person	Entire Team	PV	20	B	4/1/2014	11/10/2014	PASS	N/A	N/A	
6	Splice Area	Ensure glue gun can traverse entire splice area	5" by 67.5"	Harry	PV	10	C	4/1/2014	10/13/2014	PASS	N/A	N/A	
7	Calibrate Glue Gun H	Determine optimum glue gun height from table	Fullfills item No. 3 Criteria	Chad	DV	20	C	5/30/2014	6/2/2014	PASS	N/A	N/A	

Appendix P: Glue Gun Mount Heat Transfer Analysis

Simulation of GlueGunMountingAssem

Date: Friday, May 09, 2014
Designer: GAFSET Team
Study name: Study 1
Analysis type: Thermal(Steady state)

Table of Contents

Description

No Data

Assumptions

Original Model

Model Analyzed

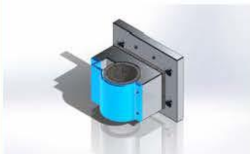
Model Information

Model name: GlueGunMountingAssem
Current Configuration: Default

Solid Bodies			
Document Name and Reference	**Treated As**	**Volumetric Properties**	**Document Path/Date Modified**
Cut-Extrude1 	Solid Body	**Mass:0.0113995 kg Volume:7.12513e-005 m^3 Density:159.99 kg/m^3 Weight:0.111715 N**	**C:\Users\melab\Downloads\Mounting Bracket Thermal Study Model\Mounting Bracket Thermal Study Model\GunInsulationBlanket.SLDPRT** May 09 17:06:41 2014
Chamfer1 	Solid Body	**Mass:0.610398 kg Volume:0.000226073 m^3 Density:2700 kg/m^3 Weight:5.9819 N**	**C:\Users\melab\Downloads\Mounting Bracket Thermal Study Model\Mounting Bracket Thermal Study Model\MountBracket_1of2.SLDPRT** May 09 16:13:45 2014

GAF Student Engineering Team
Justin Bracci
Chad Linafelter
Harry Zhao
December 5, 2014

GAFSET Team
5/9/2014

Fillet2 	Solid Body	Mass:0.144879 kg Volume:5.3659e-005 m^3 Density:2700 kg/m^3 Weight:1.41982 N	C:\Users\melab\Downloads\Mounting Bracket Thermal Study Model\Mounting Bracket Thermal Study Model\MountBracket_2of2.SLDPRT May 09 16:13:45 2014
LPattern1 	Solid Body	Mass:0.00728297 kg Volume:4.55214e-005 m^3 Density:159.99 kg/m^3 Weight:0.0713731 N	C:\Users\melab\Downloads\Mounting Bracket Thermal Study Model\Mounting Bracket Thermal Study Model\MountInsulator.SLDPRT May 09 16:13:45 2014
Chamfer3 	Solid Body	Mass:0.673104 kg Volume:0.000249298 m^3 Density:2700 kg/m^3 Weight:6.59642 N	C:\Users\melab\Downloads\Mounting Bracket Thermal Study Model\Mounting Bracket Thermal Study Model\MountPlate.SLDPRT May 09 16:13:44 2014
Boss-Extrude1 	Solid Body	Mass:0.209952 kg Volume:7.776e-005 m^3 Density:2700 kg/m^3 Weight:2.05753 N	C:\Users\melab\Downloads\Mounting Bracket Thermal Study Model\Mounting Bracket Thermal Study Model\ProtectiveShield.SLDPRT May 09 16:13:44 2014
Boss-Extrude1 	Solid Body	Mass:0.00701203 kg Volume:8.76504e-007 m^3 Density:8000 kg/m^3 Weight:0.0687179 N	C:\Users\melab\Downloads\Mounting Bracket Thermal Study Model\Mounting Bracket Thermal Study Model\m6x31 bolt reps.SLDPRT May 09 16:13:45 2014
Boss-Extrude1 	Solid Body	Mass:0.00701203 kg Volume:8.76504e-007 m^3 Density:8000 kg/m^3 Weight:0.0687179 N	C:\Users\melab\Downloads\Mounting Bracket Thermal Study Model\Mounting Bracket Thermal Study Model\m6x31 bolt reps.SLDPRT May 09 16:13:45 2014

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Boss-Extrude1 	Solid Body	**Mass:0.00701203 kg** **Volume:8.76504e-007 m^3** **Density:8000 kg/m^3** **Weight:0.0687179 N**	**C:\Users\melab\Downloads\Mounting Bracket Thermal Study Model\Mounting Bracket Thermal Study Model\m6x31 bolt reps.SLDPRT** May 09 16:13:45 2014
Boss-Extrude1 	Solid Body	**Mass:0.00701203 kg** **Volume:8.76504e-007 m^3** **Density:8000 kg/m^3** **Weight:0.0687179 N**	**C:\Users\melab\Downloads\Mounting Bracket Thermal Study Model\Mounting Bracket Thermal Study Model\m6x31 bolt reps.SLDPRT** May 09 16:13:45 2014

Study Properties

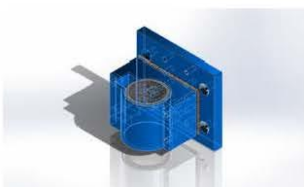
Study name	Study 1
Analysis type	Thermal(Steady state)
Mesh type	Solid Mesh
Solver type	FFEPlus
Solution type	Steady state
Contact resistance defined?	No
Result folder	SolidWorks document (C:\Users\melab\Downloads\Mounting Bracket Thermal Study Model\Mounting Bracket Thermal Study Model)

Units

Unit system:	SI (MKS)
Length/Displacement	mm
Temperature	Kelvin
Angular velocity	Rad/sec
Pressure/Stress	N/m^2

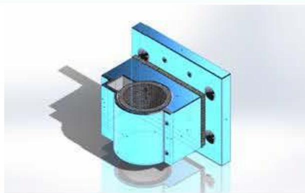
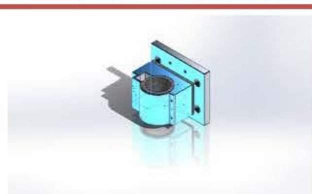
GAFSET Team
5/9/2014

Material Properties

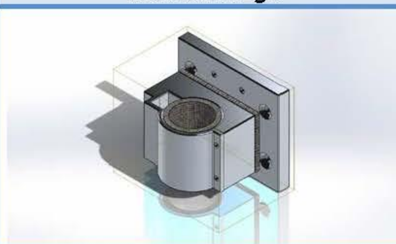
Model Reference	Properties	Components
	**Name:** Fiberous Insulation Blanket **Model type:** Linear Elastic Isotropic **Default failure criterion:** Unknown **Thermal conductivity:** 0.1 W/(m.K) **Mass density:** 159.99 kg/m^3	SolidBody 1(Cut-Extrude1)(GunInsulationBlanket-1)
Curve Data:N/A		
	**Name:** 6061 Alloy **Model type:** Linear Elastic Isotropic **Default failure criterion:** Unknown **Thermal conductivity:** 170 W/(m.K) **Specific heat:** 1300 J/(kg.K) **Mass density:** 2700 kg/m^3	SolidBody 1(Chamfer1)(MountBracket_1of2-1), SolidBody 1(Fillet2)(MountBracket_2of2-1), SolidBody 1(Chamfer3)(MountPlate-1), SolidBody 1(Boss-Extrude1)(ProtectiveShield-1)
Curve Data:N/A		
	**Name:** BTU-BLOCK Board **Model type:** Linear Elastic Isotropic **Default failure criterion:** Unknown **Thermal conductivity:** 0.0231 W/(m.K) **Mass density:** 159.99 kg/m^3	SolidBody 1(LPattern1)(MountInsulator-1)
Curve Data:N/A		
	**Name:** AISI 316 Annealed Stainless Steel Bar (SS) **Model type:** Linear Elastic Isotropic **Default failure criterion:** Unknown **Thermal conductivity:** 16.3 W/(m.K) **Specific heat:** 500 J/(kg.K) **Mass density:** 8000 kg/m^3	SolidBody 1(Boss-Extrude1)(m6x31 bolt reps-1), SolidBody 1(Boss-Extrude1)(m6x31 bolt reps-2), SolidBody 1(Boss-Extrude1)(m6x31 bolt reps-3), SolidBody 1(Boss-Extrude1)(m6x31 bolt reps-4)

Curve Data:N/A

Thermal Loads

Load name	Load Image	Load Details
Convection-1		**Entities:** 17 face(s) **Convection Coefficient:** 15 W/(m^2.K) **Time variation:** Off **Temperature variation:** Off **Bulk Ambient Temperature:** 290 Kelvin **Time variation:** Off
Temperature-3		**Entities:** 1 face(s) **Temperature:** 500 Fahrenheit
Radiation-1		**Entities:** 15 face(s) **Radiation Type:** Surface to surface **Open system:** Off **Emissivity:** 0.1

Contact Information

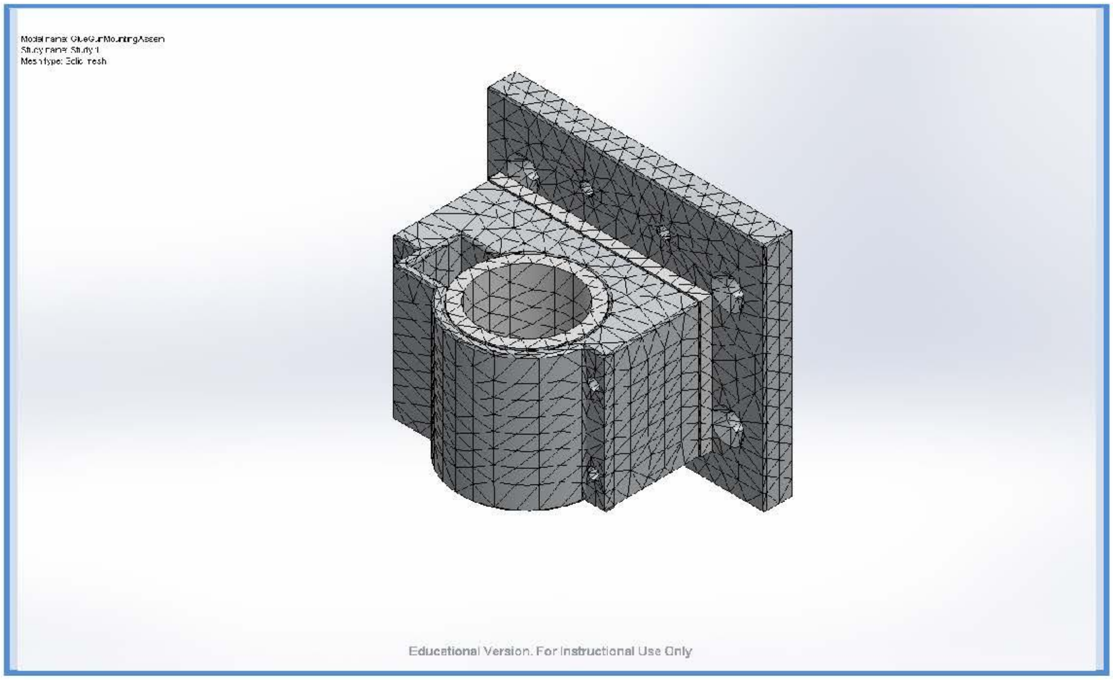
Contact	Contact Image	Contact Properties
Global Contact		**Type:** Bonded **Components:** 1 component(s) **Options:** Compatible mesh

Mesh Information

Mesh type	Solid Mesh
Mesher Used:	Curvature based mesh
Jacobian points	4 Points
Maximum element size	8.33221 mm
Minimum element size	0.41661 mm
Mesh Quality	High
Remesh failed parts with incompatible mesh	Off

Mesh Information - Details

Total Nodes	47614
Total Elements	28106
Maximum Aspect Ratio	42.018
% of elements with Aspect Ratio < 3	59.8
% of elements with Aspect Ratio > 10	0.452
% of distorted elements(Jacobian)	0
Time to complete mesh(hh;mm;ss):	00:00:03
Computer name:	ME-13-107-08

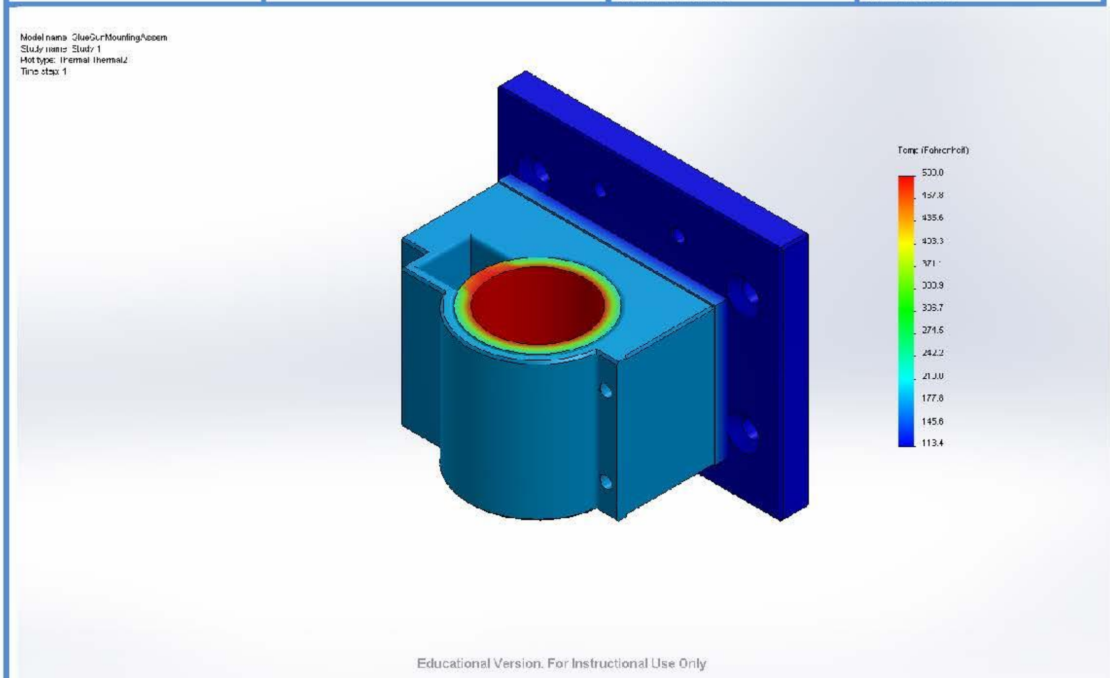


Sensor Details

No Data

Study Results

Name	Type	Min	Max
Thermal2	TEMP: Temperature	113.357 Fahrenheit Node: 19763	500 Fahrenheit Node: 223



GlueGunMountingAssem-Study 1-Thermal-Thermal2

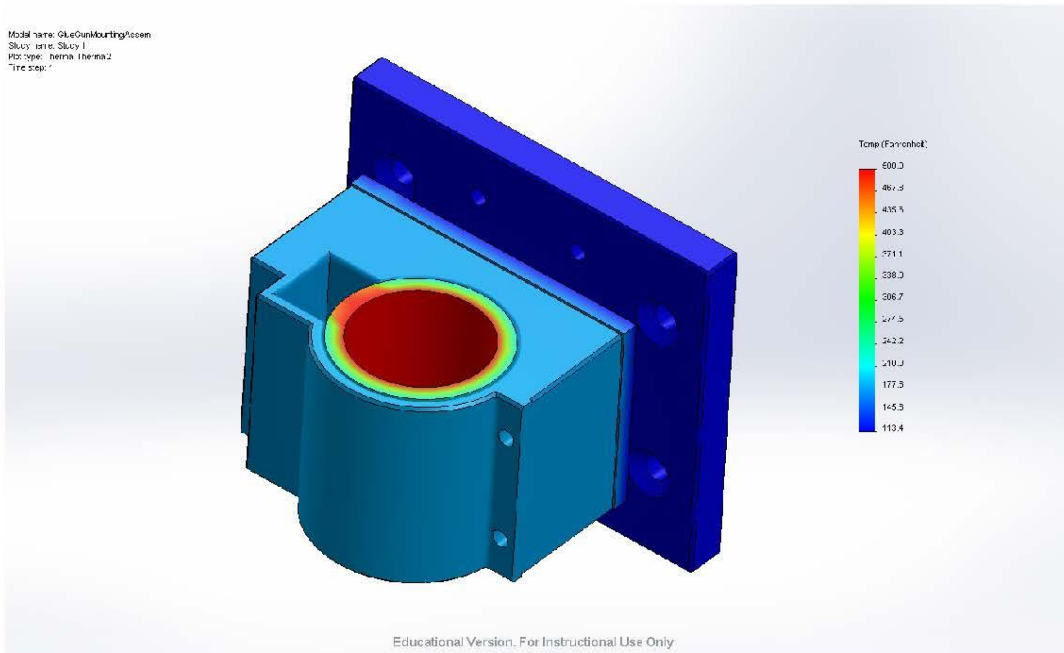


Image-1

Conclusion

GAF Student Engineering Team
Justin Bracci
Chad Linafelter
Harry Zhao
December 5, 2014

Appendix Q: FMEA

Potential
Failure Mode and Effect Analysis
(Design FMEA)

___ System | **FMEA Number:**
___ Subsystem
___ Component | **Design Responsibility:** | **Page 1 of 1**
Model Year(s)/Vehicle(s): | **Key Date:** | **Prepared By:**
Core Team: | **FMEA Date (Orig.)** **(Rev.**

Item / Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Potential Cause(s) / Mechanism(s) of Failure	Occur	Crit	Recommended Action(s)	Responsibility & Target Completion Date	Action Results: Actions Taken	Sev	Occur	Crit
Glue Gun	Too much/ little glue on mat	Improper splice	7	Automatic feeding too slow or fast	2	14	Testing to determine optimum constant glue gun speed	Justin, Harry, and Chad 9/11/14				
	Glue dispensed too early/ late	Uneven distribution of glue	7	Wrong timing from the sensor	2	14	Calibrate the inconsistent placement of the glass mat	Justin, Harry, and Chad 9/11/14				
	Insufficient heat to melt glue	Glue is too hot and burns	6	Glue gun insulation is too efficient/traps too much heat	3	18	remove insulation/use insulation with higher thermal conductivity	Justin and Chad				
		Glue is too cold	7	Glue gun insulation is not efficient/too much heat escapes	2	14	Use insulation with lower thermal conductivity	Justin and Chad				
	Glue dries too quickly	Splice not strong enough	7	Automatic feeding too slow or low room temperature	2	14	Determine optimum glue gun speed or install thermal wires in table	Justin, Harry, and Chad 9/11/14				
	Glue runs off of mat	Creates a mess	4	Glue gun discharges glue at wrong time	2	8	Testing to determine when glue gun needs to distribute glue	Justin, Harry, and Chad 9/11/14				
		Glue interferes further down production line, improper splice	7		2	14						
		Injury to operator	8		2	16						
Motor	Motor is unable to supply the needed amount of power to move the glue gun	Unable to dispense glue across mat	7	Broken part in motor	2	14	Weekly test on motor	Justin, Harry, and Chad 9/11/14				
Supply cables	Cables get in the way of glue gun movement	Glue gun is unable to traverse linear track	7	Cables getting tangled up with the linear track system	2	14	Have cables retract or extend from the carrier	Justin, Harry, and Chad 9/11/14				
Glue Gun Mount Bracket	Mounting Bracket Becomes too hot	damage to linear motion system	9	Glue gun insulation is not efficient/too much heat escapes	2	18	Add heat sinks or insulation with lower thermal conductivity	Justin, Harry, and Chad 9/11/14				
Retrofit Mount	Shock of handling press bracket causes retrofit bracket to come loose	Halt in production	9	insufficient mounting strength to press bracket	1	9	Tighten bolts/increase number of mounting points	Justin, Harry, and Chad 9/11/14				

Appendix R. Team Contract

GAFSET Team Contract

Mission:

The mission of the GAF Student Engineering Team (GAFSET) is to successfully work together to fulfill the needs of GAF. The GAF Design Team will research and analyze the given problem and work towards developing an effective solution.

Section 1—Name

A. This organization shall be known as the GAF Student Engineering Team (GAFSET).

Section 2—Membership

A. Members of the team include: Justin Bracci, Harry Zhao, and Chad Linafelter.
B. No member shall purport to represent the team unless so authorized by the team.
C. Each member shall be provided a copy of the team contract.
D. Officers of the team shall include those listed below with their designated responsibilities.
  1. Communications Officer: Justin Bracci
    a. Be main point of communication with sponsor
    b. Facilitate meetings with Sponsor
    c. Team time management
  2. Team Treasurer: Chad Linafelter
    a. Maintain team's travel budget
    b. Maintain team's materials budget (in 2nd quarter)
    c. Obtain necessary materials from sponsor (co-ordinate with Communications Officer)
  3. Secretary/Recorder: Harry Zhao
    a. Maintain information repository for team (e.g. team binder, google docs site, etc..)
    b. Ensure proper documentation of all team meetings.
  Note: Items subject to change at any time.

Any items not listed above will be the communal responsibility of all members on the team.

Section 3—Decision Making

A. By Consensus
B. Voting methods (oral, written, etc.)
C. Voting outcomes (majority)

Section 4—Team Interactions

A. All affairs of the team shall be governed by Robert's Rules of Order, unless otherwise specified.
B. Meetings shall be held during scheduled times as agreed upon by team members and scheduled by communications officer.
C. Unless otherwise noticed, all meetings will be held in person in Building 192 room 132.
D. Special meetings of the team may be called by any member of the team or sponsor via all means of communication.
E. Attendance is mandatory unless an approved excuse.
F. Meeting discussions will be conducted in a conversational format with special regard for a dialogue that is respectful and considerate of all members in attendance.
G. A meeting agenda, distributed 2 days in advance, will guide meeting topics and timing.
H. The length of meetings shall be stated 2 days in advance.
I. All team members are expected to be punctual.

1

J. Violation of any team meeting will be publicized to members using: phone calls, team websites, e-mail, and texting.
J. Notices shall be distributed not less than 2 days before the meeting date.
K. Violation of team rules will result in a trial conducted by the non-violating team members in order to determine the violator's punishment.

Section 5—Quality of Work

A. Each team member is expected to perform satisfactory work subject to the discretion of the other team members.
B. Any team member may be asked to re-evaluate any aspect of their work by a majority vote from the rest of the team.

Section 6—Conflict Resolution

A. All conflicts will be made open to the team and discussed.
B. Team members will work to achieve a compromise and end the conflict in the interest of the success of the team.
C. If a compromise is not achieved, the entire team will bring the conflict to the faculty advisor who will then mediate a discussion and solution.
D. All team members will maintain a professional attitude throughout the conflict resolution process.

Section 7—Amendments

A. A majority vote amongst team members is necessary in order to amend this document.
B. A written notice to a vote being taken must be provided to each team member 3 days in advance to the vote being taken. Furthermore, after the document is amended, a copy of the new document must be furnished to each team member.

Section 8—Effective Date (Required)

A. This contract of the GAFSET team shall become effective on 1/14/14.
B. Dates of amendment must be recorded in minutes of meetings at which amendments were approved, together with a revised set of bylaws.

Section —Signatures

X___ Justin Bracci ______________ Date:____ 1/14/14____
Justin Bracci

X_____ Harry Zhao ______________ Date:_____1/14/14_____
Harry Zhao

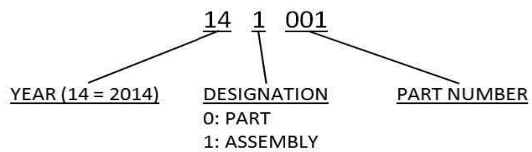
X______ Chad Linafelter__________ Date:______1/14/14___
Chad Linafelter

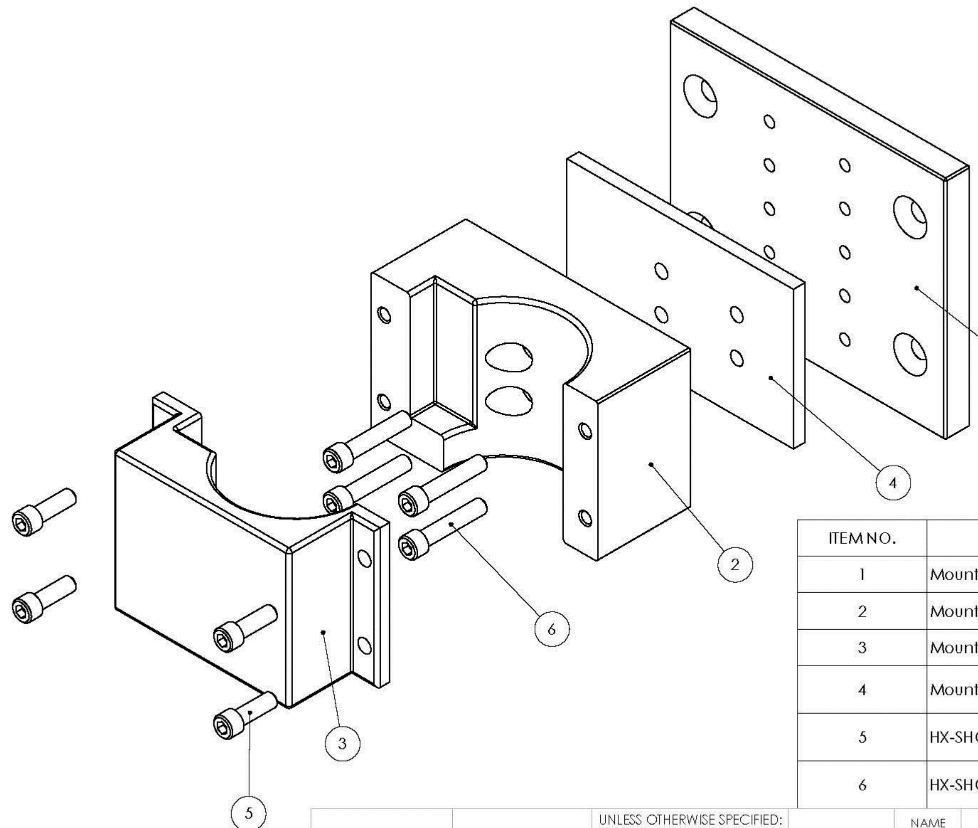
Appendix S: Drawing Package

GAFSET ENGINEERING DOCUMENT CONTROL

ASSEMBLY	PART NUMBER	DESCRIPTION	CURRENT REV	RELEASE DATE
141001		GLUE GUN MOUNTING ASSEMBLY	-	6/9/2014
	140001	MOUNTING BRACKET 1 OF 2	-	6/9/2014
	140002	MOUNTING BRACKET 2 OF 2	-	6/9/2014
	140003	MOUNT PLATE	A	6/9/2014
	140004	BTU BLOCK BOARD INSULATION 1 OF 2	-	6/9/2014
	140005	CABLE CHAIN BRACKET	-	6/9/2014
141002		RETROFIT MOUNTING BRACKET	-	6/9/2014
	140006	FRONT PLATE	-	6/9/2014
	140007	BASE PLATE	-	6/9/2014
	140008	SQUARE TUBING	-	6/9/2014
	140009	GUIDE CHANNEL	-	6/9/2014
141003		TEST FIXTURE	-	6/9/2014
	140010	UPRIGHT	-	6/9/2014
	140011	BASE	-	6/9/2014
	140012	HORIZONTAL L	-	6/9/2014
	140013	HORIZONTAL S	-	6/9/2014
141004		RETROFIT MOUNTING BRACKET M2	-	10/3/2014
	140014	BASE PLATE M2	-	10/4/2014
	140015	SQUARE TUBING M2	-	10/5/2014
	140016	GUIDE CHANNEL M2	-	10/6/2014
	140017	BACKING PLATE	-	10/7/2014
141005		GLUE GUN MOUNTING ASSEMBLY L	-	10/6/2014
	140018	GLUE GUN MOUNT A	-	10/6/2014
	140019	GLUE GUN MOUNT B	-	10/6/2014
141006		CABLE CHAIN BRACKET B	-	11/12/2014
	140020	CABLE CHAIN BRACKET 2A	-	11/12/2014
	140021	CABLE CHAIN BRACKET 2B	-	11/12/2014
	140022	CABLE CHAIN BRACKET 2C	-	11/12/2014
	140023	CABLE CHAIN BRACKET 2D	-	11/12/2014
	140024	SUPPORT BLOCK	-	11/12/2014
	140025	MOTOR FLANGE	B	10/21/2014
	140026	HEAT SHIELD	-	11/13/2014

GAFSET ENGINEERING DOCUMENT NUMBERING:





ITEM NO.	PART NUMBER	MATERIAL	QTY.
1	MountPlate	AL 6061-T6	1
2	MountBracket_1of2	AL 6061-T6	1
3	MountBracket_2of2	AL 6061-T6	1
4	MountInsulator	BTU BLOCK BOARD	1
5	HX-SHCS 0.25-20x0.75x0.75-N	316 SS	4
6	HX-SHCS 0.25-20x1.25x1.25-N	316 SS	4

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ANGULAR: MACH± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
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MFG APPR.		
Q.A.		

COMMENTS:

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NEXT ASSY | USED ON
APPLICATION

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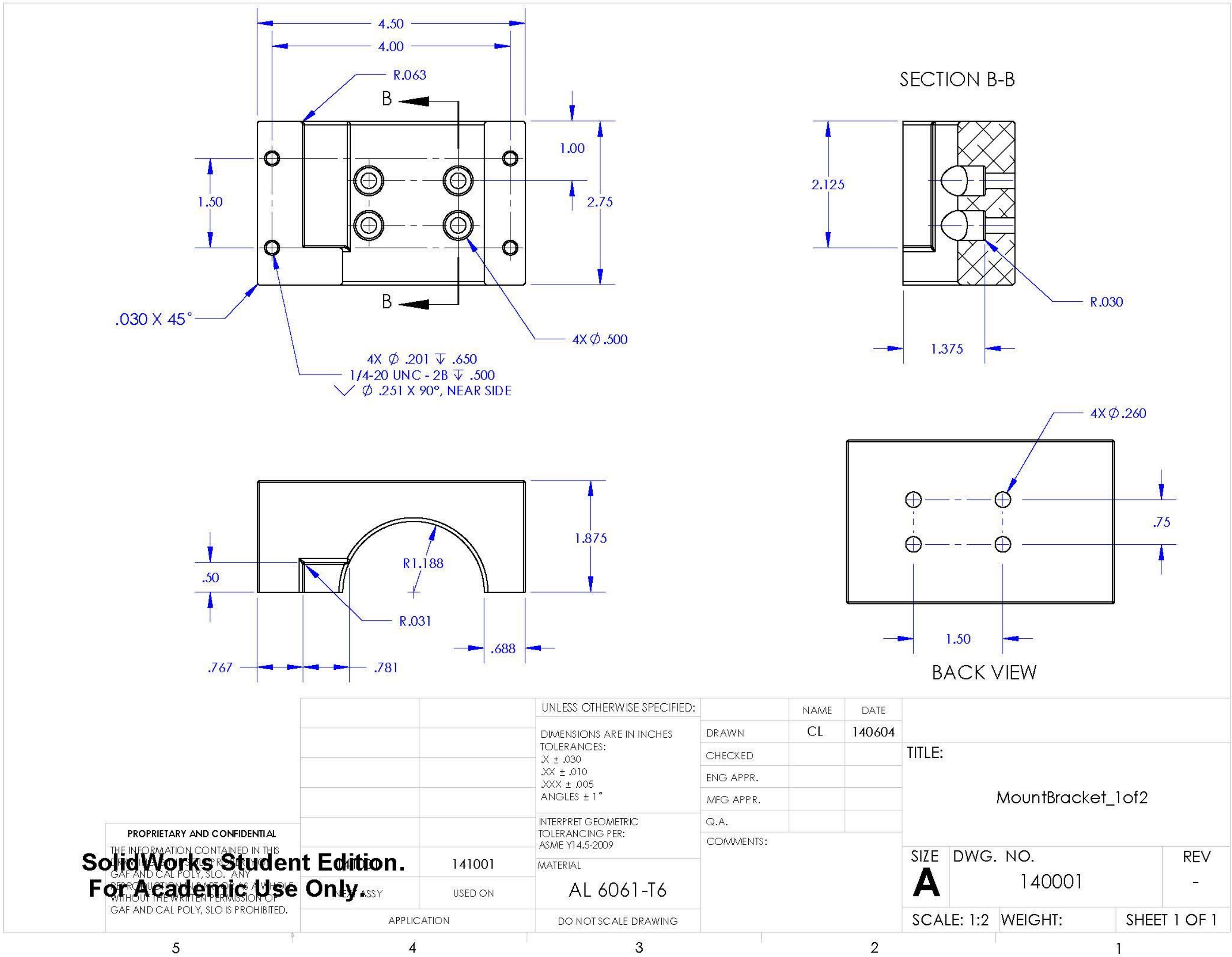
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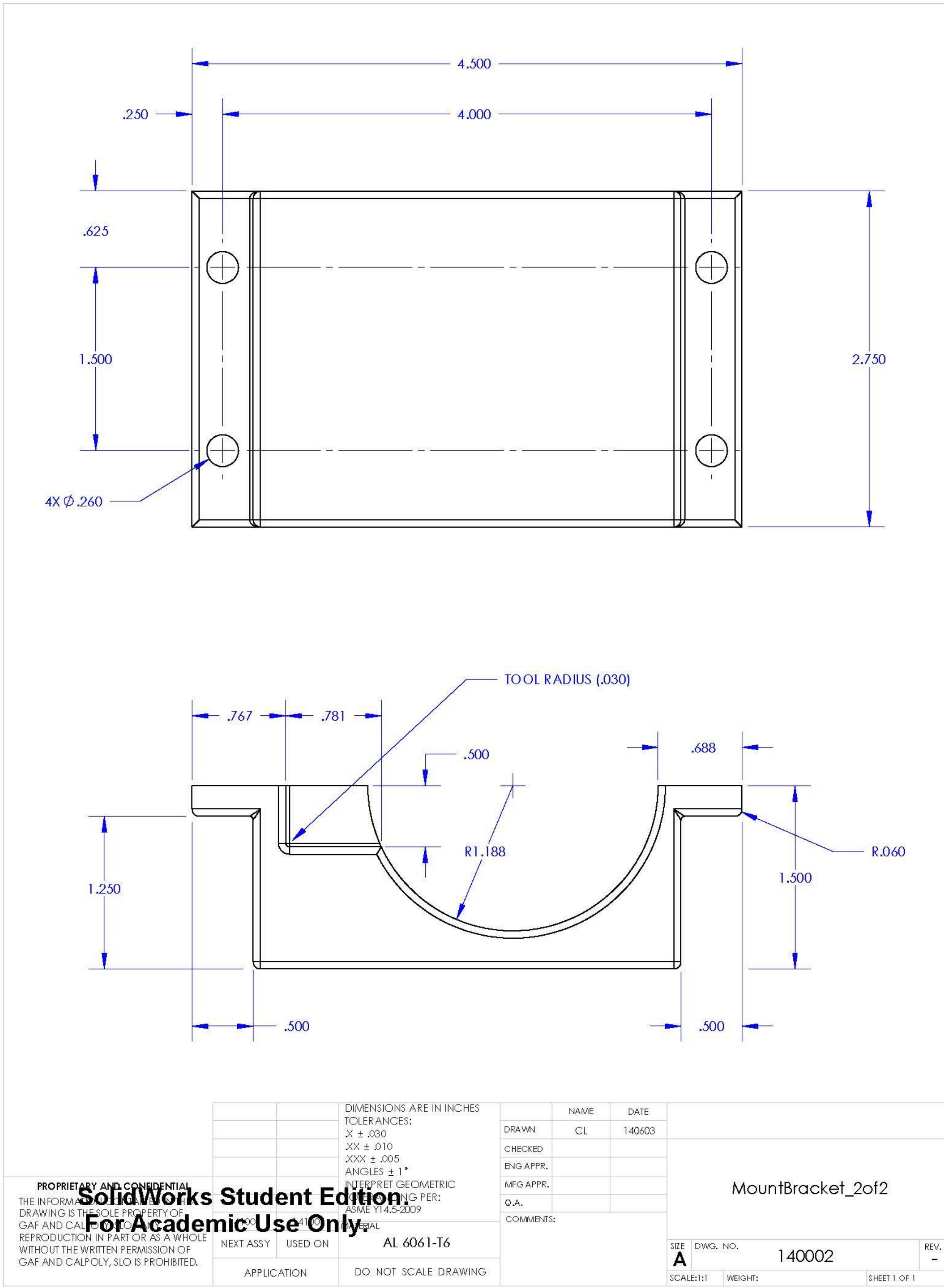

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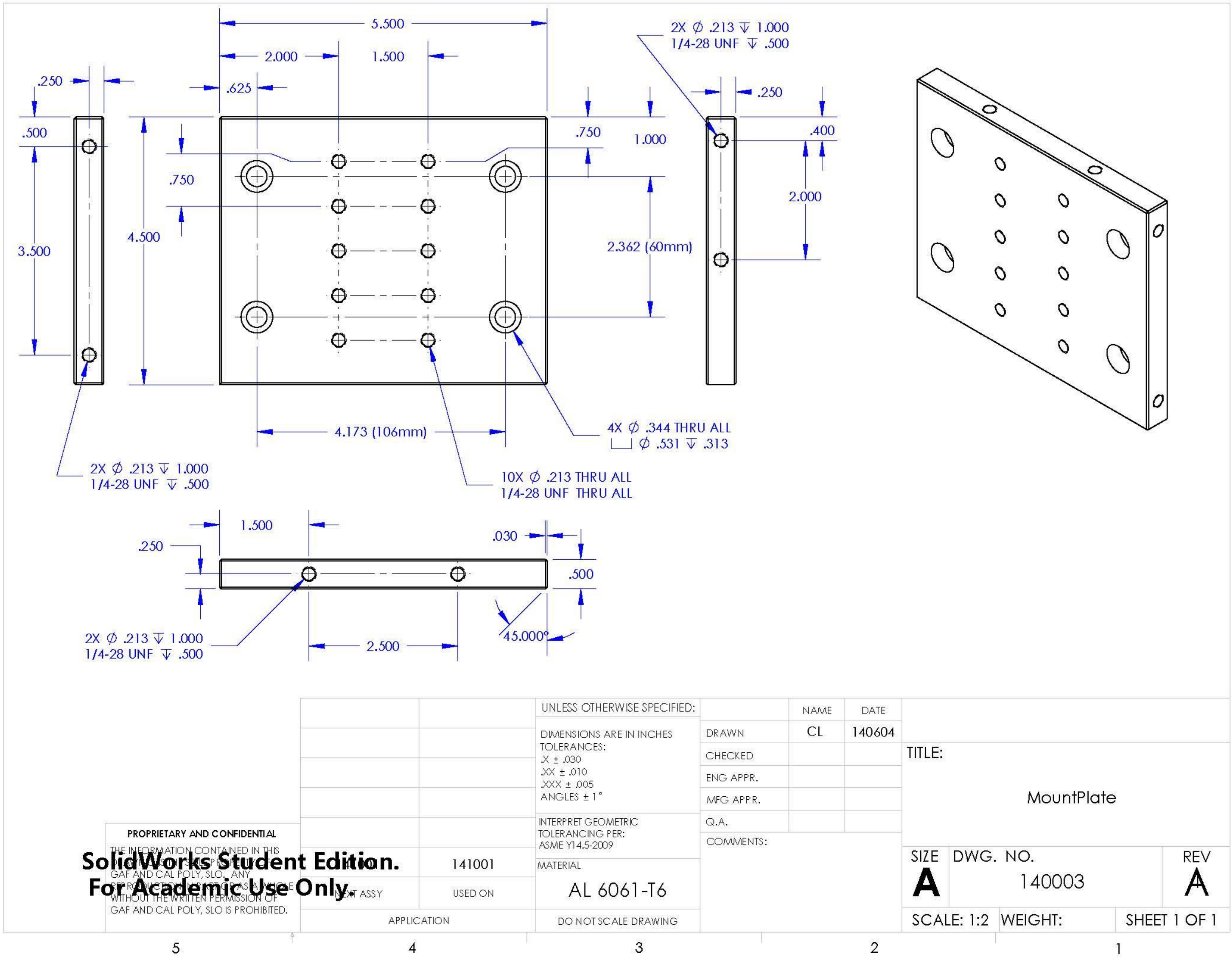
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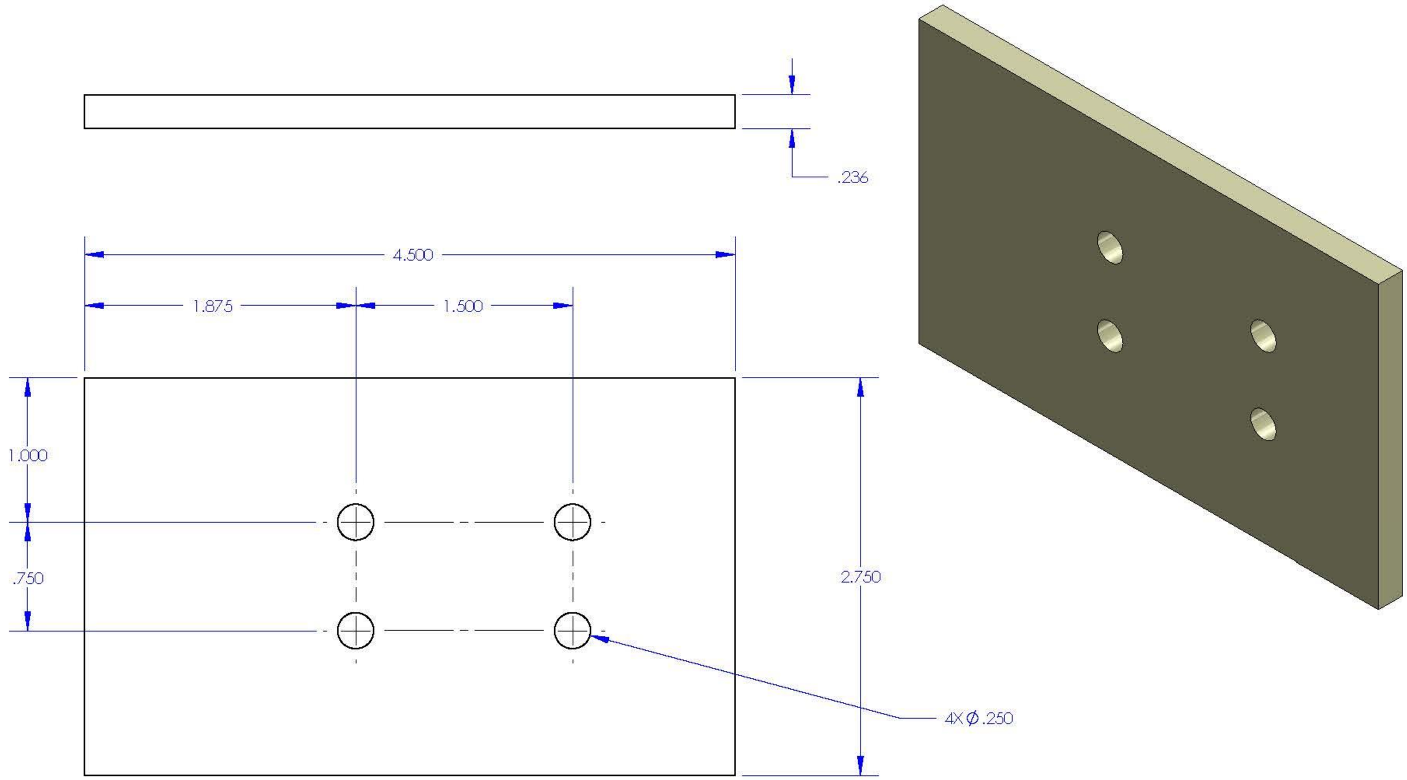

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APPLICATION	DO NOT SCALE DRAWING

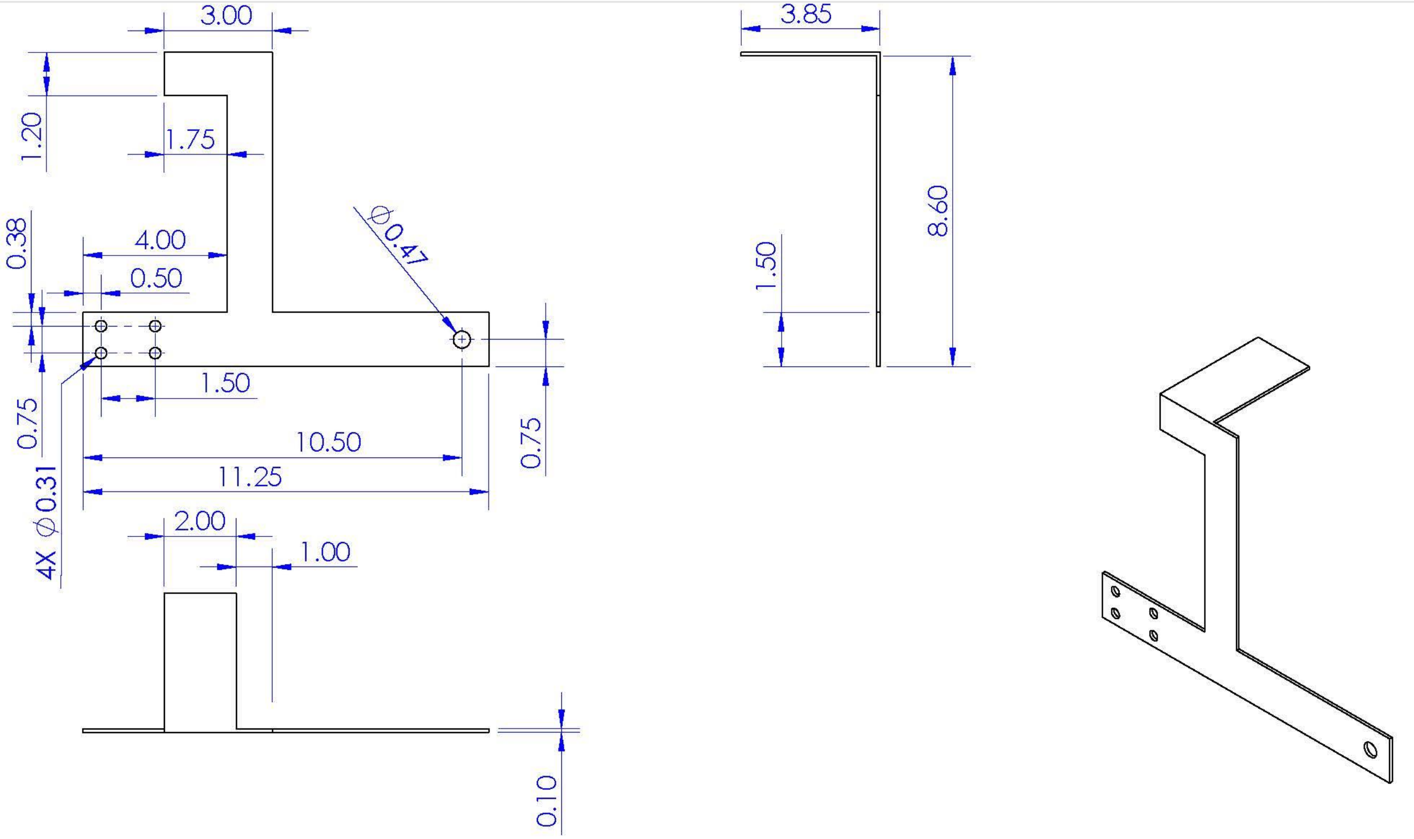
	NAME	DATE
DRAWN	CL	140604
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

TITLE: MountInsulator

SIZE	DWG. NO.	REV
A	140004	-

SCALE: 1:1 WEIGHT: SHEET 1 OF 1

5 4 3 2 1



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
.X ± .030
.XX ± .010
.XXX ± .005
ANGLES ± 1°
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5-2009
MATERIAL: AL 6061-T6
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	JB	140604
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

TITLE: CABLE CHAIN BRACKET

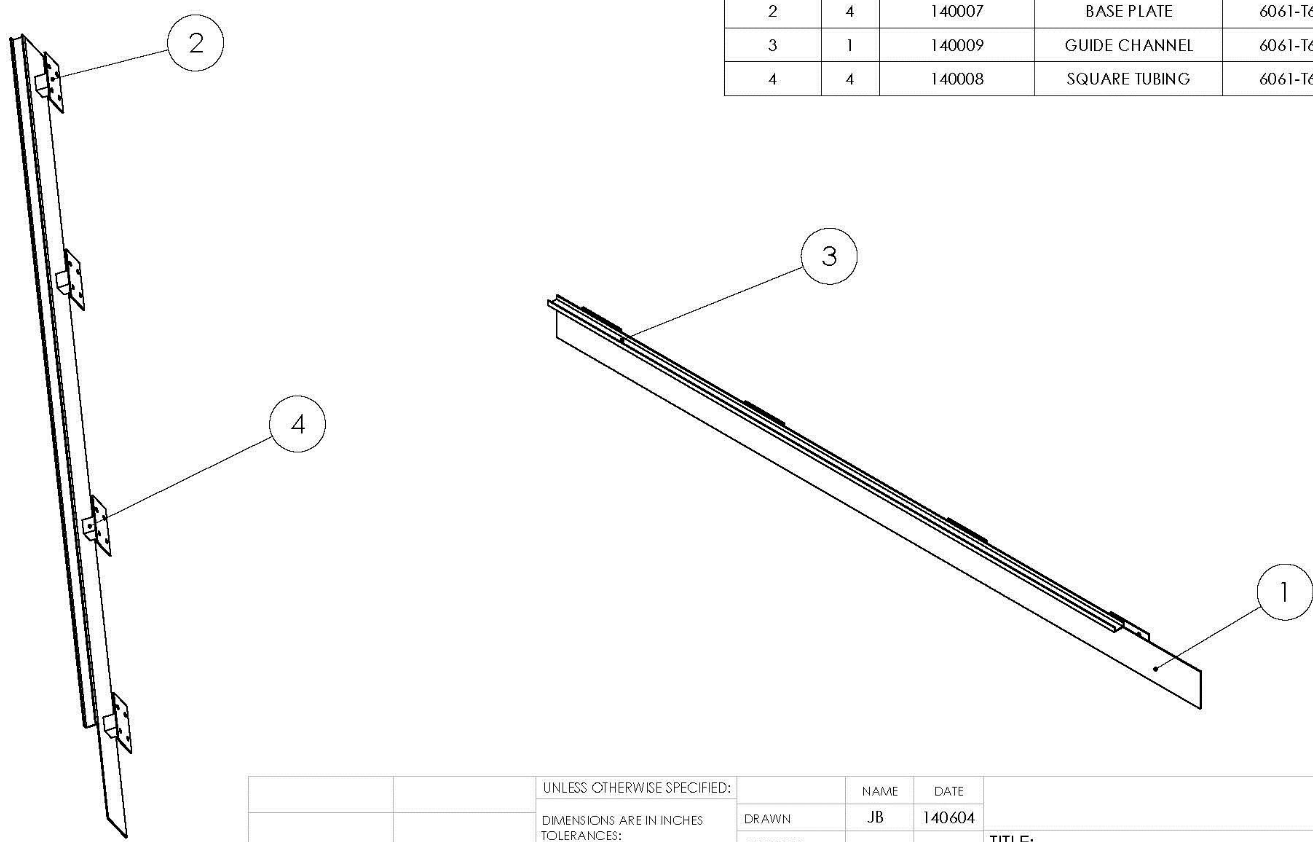
SIZE A | DWG. NO. 140005 | REV -
SCALE: 1:4 | SHEET 1 OF 1

141001 NEXT ASSY | 141001 USED ON
APPLICATION

5 4 3 2 1

GAF Student Engineering Team
Justin Bracci
Chad Linafelter
Harry Zhao
December 5, 2014

ITEM NO.	QTY.	PART NUMBER	DESCRIPTION	Material
1	1	140006	FRONT PLATE	6061-T6 (SS)
2	4	140007	BASE PLATE	6061-T6 (SS)
3	1	140009	GUIDE CHANNEL	6061-T6 (SS)
4	4	140008	SQUARE TUBING	6061-T6 (SS)



UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: .X ± .030 .XX ± .010 .XXX ± .005 ANGLES ± 1°	DRAWN	JB	140604
	CHECKED		
	ENG APPR.		
	MFG APPR.		
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5-2009	Q.A.		
MATERIAL AL 6061-T6	COMMENTS:		
DO NOT SCALE DRAWING			

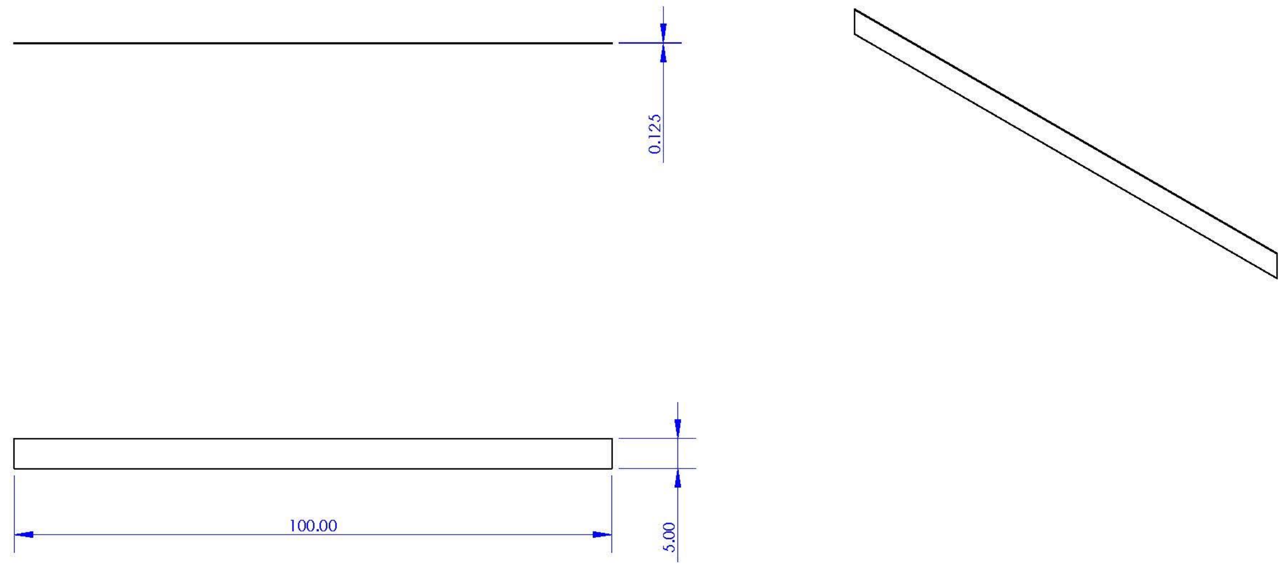
NEXT ASSY | USED ON
APPLICATION

TITLE:
RETROFIT BRACKET

SIZE	DWG. NO.	REV
A	141002	-

SCALE: 1:16 SHEET 1 OF 1

5 4 3 2 1



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DIMENSIONS ARE IN INCHES
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.XX ± .010
.XXX ± .005
ANGLES ± 1°
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5-2009
MATERIAL
AL 6061-T6
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	JB	140604
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

TITLE:
FRONT PLATE

SIZE A | DWG. NO. 140006 | REV -
SCALE: 1:24 | SHEET 1 OF 1

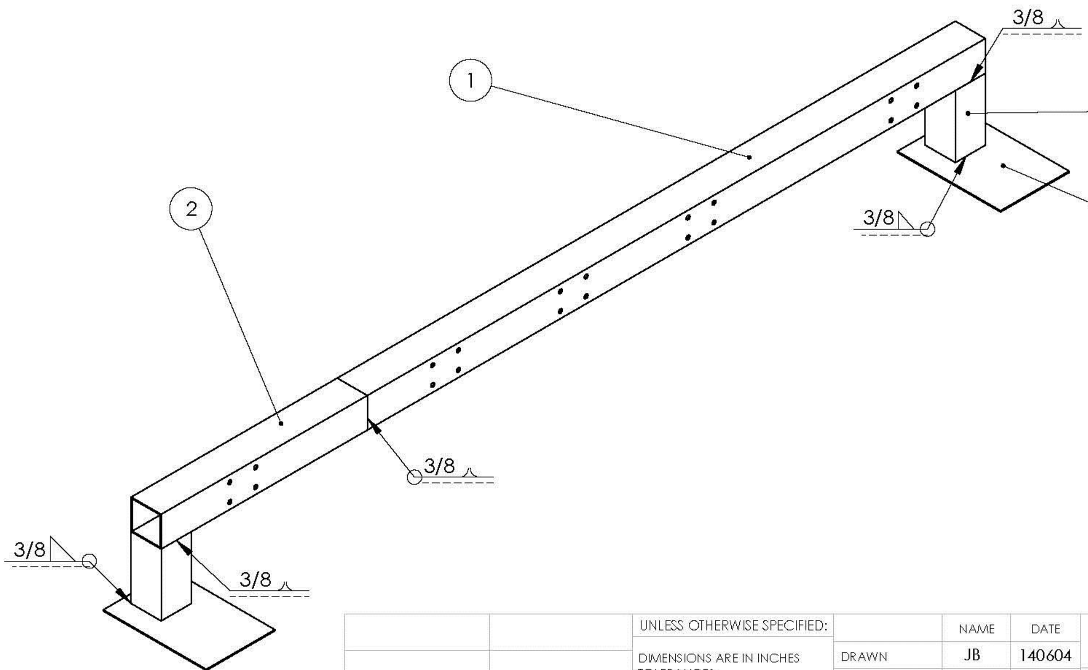
NEXT ASSY	USED ON
141002	141002

APPLICATION

5 4 3 2 1

GAF Student Engineering Team
Justin Bracci
Chad Linafelter
Harry Zhao
December 5, 2014

ITEM NO.	QTY.	PART NUMBER	DESCRIPTION	Material
1	1	140012	Rectangular Tubing 72	Plain Carbon Steel
2	1	140013	Rectangular Tube 24	Plain Carbon Steel
3	2	140010	Rectangular Tub 8.25	Plain Carbon Steel
4	2	140011	Base Plate	Plain Carbon Steel



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
.X ± .030
.XX ± .010
.XXX ± .005
ANGLES ± 1°

INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5-2009

MATERIAL: AISI 1018

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	JB	140604
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE: TEST MOUNT

SIZE: A | DWG. NO.: 141003 | REV: -

SCALE: 1:12 | SHEET 1 OF 1

NEXT ASSY | USED ON

APPLICATION

5 4 3 2 1

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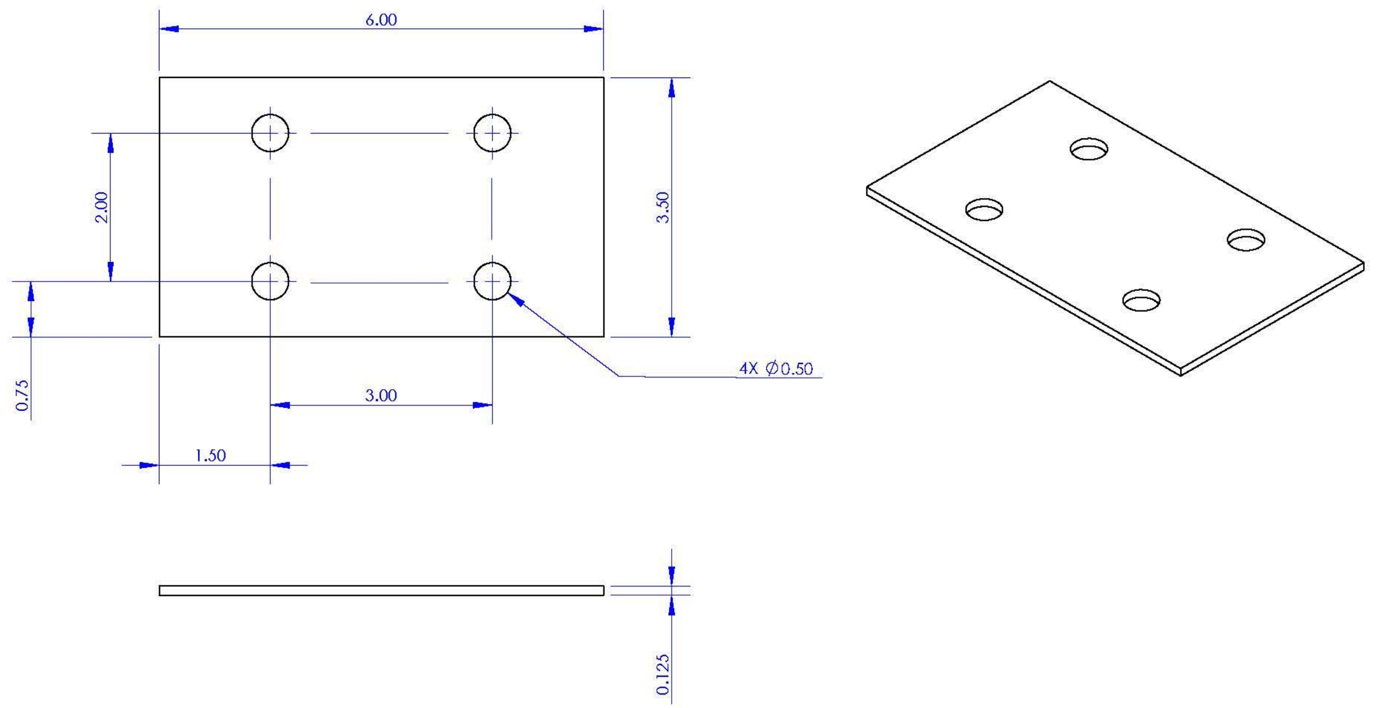

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
.X ± .030
.XX ± .010
.XXX ± .005
ANGLES ± 1°

INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5-2009

MATERIAL: AL 6061-T6

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	JB	140604
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

TITLE: BASE PLATE

SIZE: A
DWG. NO. 140007
REV: -
SCALE: 1:2
SHEET 1 OF 1

NEXT ASSY	USED ON
141002	
APPLICATION	

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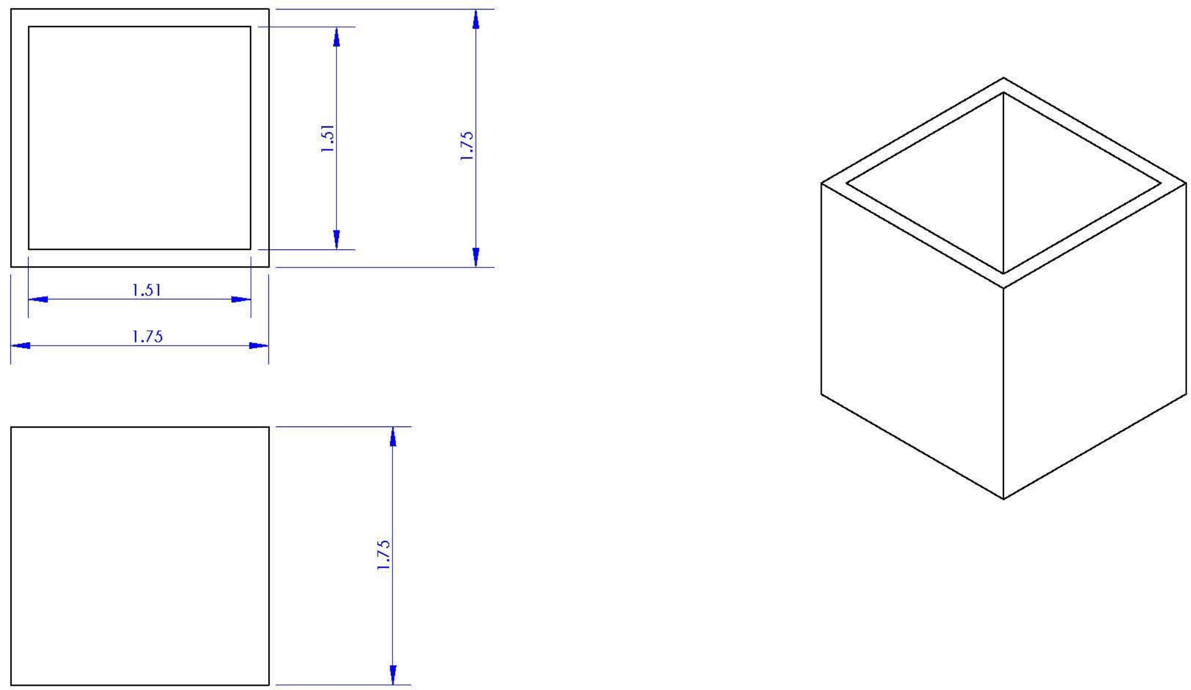
5 4 3 2 1



		UNLESS OTHERWISE SPECIFIED:		NAME	DATE	
		DIMENSIONS ARE IN INCHES TOLERANCES: .X ± .030 .XX ± .010 .XXX ± .005 ANGLES ± 1°	DRAWN	JB	140604	
			CHECKED			TITLE:
			ENG APPR.			SQUARE TUBING
			MFG APPR.			
		INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5-2009	Q.A.			
			COMMENTS:			
[illegible]	141002	MATERIAL				SIZE A / DWG. NO. 140008 / REV -
NEXT ASSY	USED ON	AL 6061-T6				
APPLICATION		DO NOT SCALE DRAWING				SCALE: 1:1 / SHEET 1 OF 1

5 4 3 2 1

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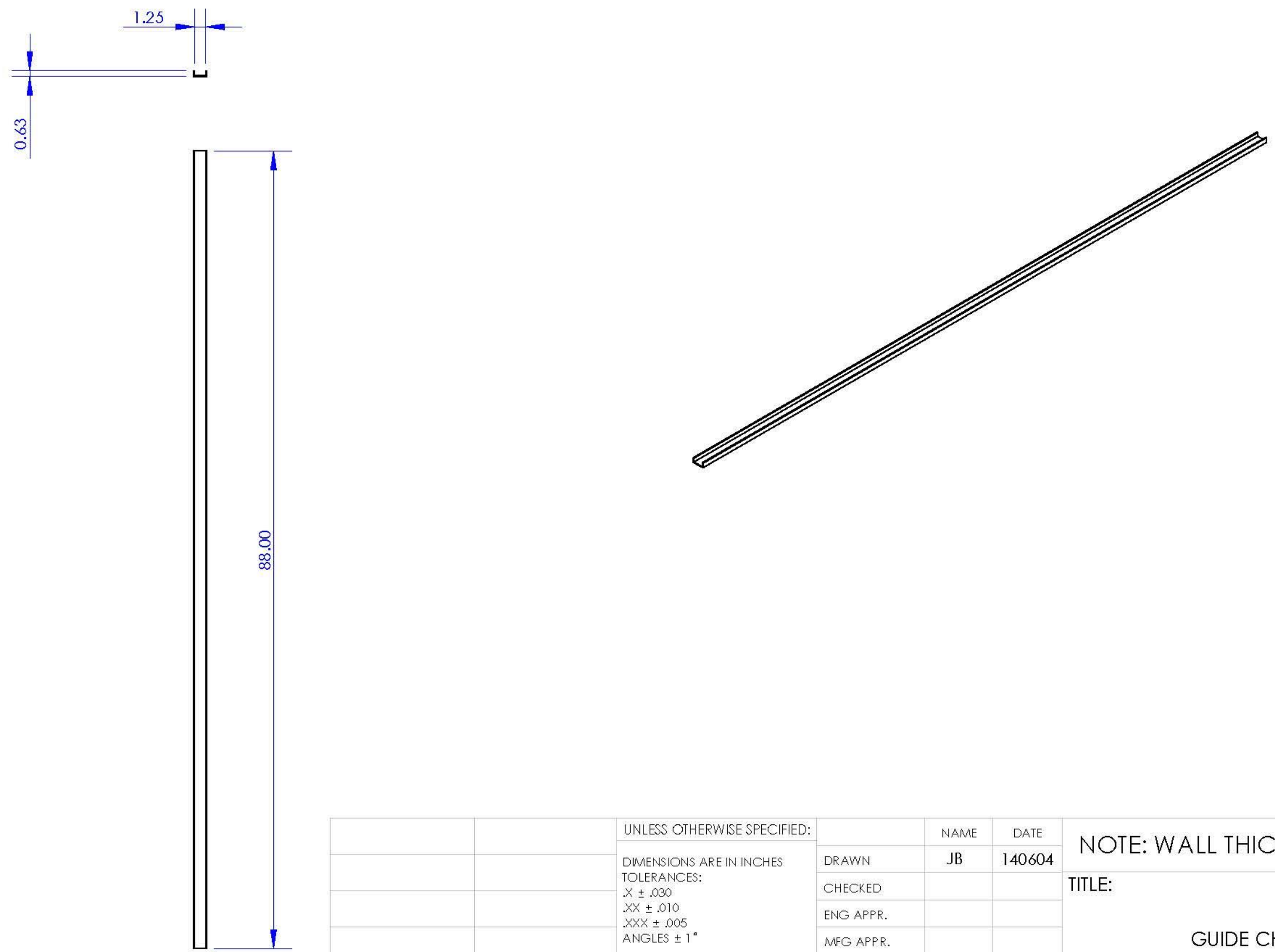
December 5, 2014



UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: .X ± .030 .XX ± .010 .XXX ± .005 ANGLES ± 1°	DRAWN	JB	140604
	CHECKED		
	ENG APPR.		
	MFG APPR.		
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5-2009	Q.A.		
MATERIAL AL 6061-T6	COMMENTS:		
DO NOT SCALE DRAWING			

NOTE: WALL THICKNESS .125

TITLE:

GUIDE CHANNEL

SIZE	DWG. NO.	REV
A	140009	-

SCALE: 1:24 SHEET 1 OF 1

NEXT ASSY 141002	USED ON
APPLICATION	

5 4 3 2 1

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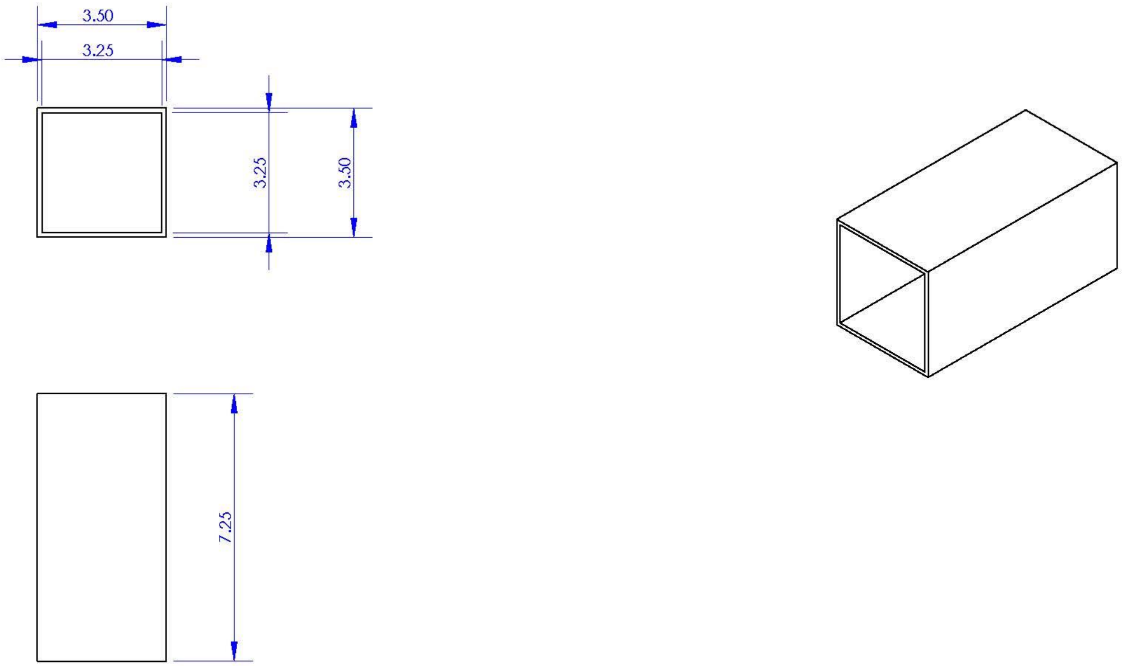
December 5, 2014



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INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5-2009		
MATERIAL	AISI 1018	
DO NOT SCALE DRAWING		

	NAME	DATE
DRAWN	JB	140604
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

TITLE: UPRIGHT

SIZE	DWG. NO.	REV
A	140010	-
SCALE: 1:4		SHEET 1 OF 1

141003	
NEXT ASSY	USED ON
APPLICATION	

5 4 3 2 1

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Harry Zhao
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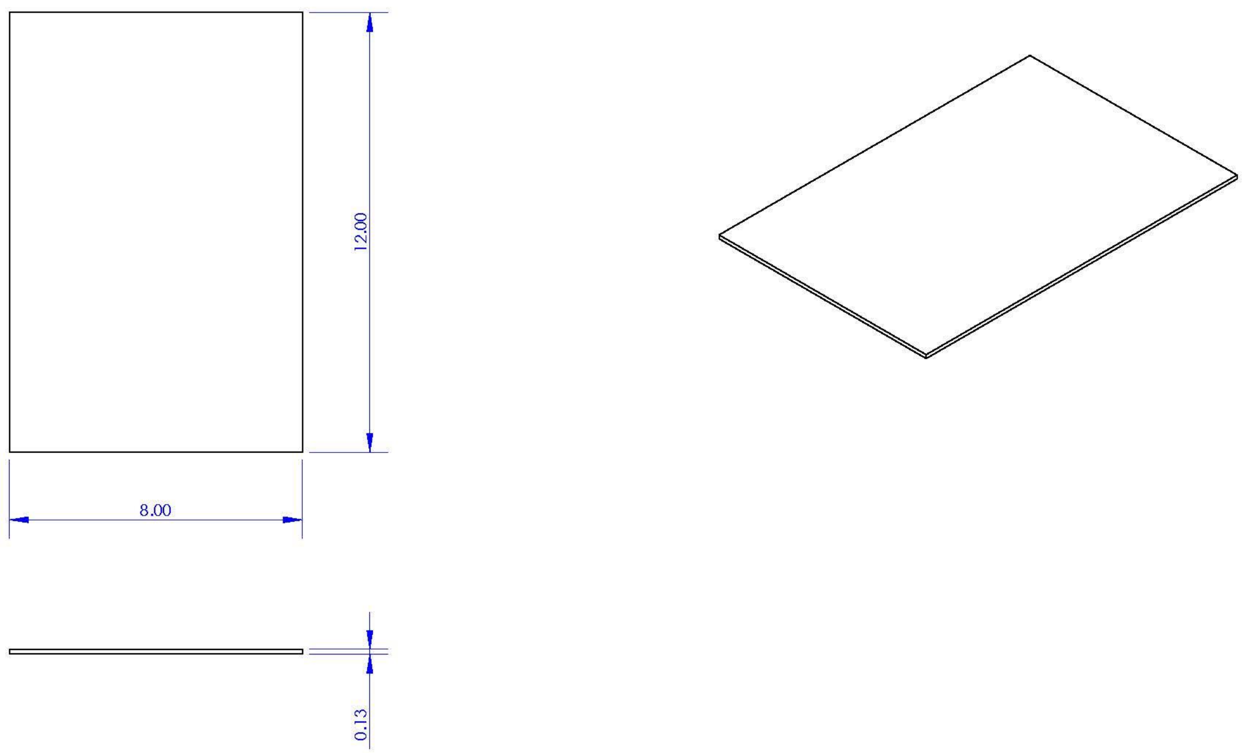

UNLESS OTHERWISE SPECIFIED:	NAME / DATE	
DIMENSIONS ARE IN INCHES TOLERANCES: .X ± .030 .XX ± .010 .XXX ± .005 ANGLES ± 1°	DRAWN JB 140604 CHECKED ENG APPR. MFG APPR. Q.A.	TITLE: BASE
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5-2009	COMMENTS:	SIZE A DWG. NO. 140011 REV -
MATERIAL AISI 1018		SCALE: 1:4 SHEET 1 OF 1
DO NOT SCALE DRAWING		

	141003
NEXT ASSY	USED ON
APPLICATION	

5 4 3 2 1

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Harry Zhao
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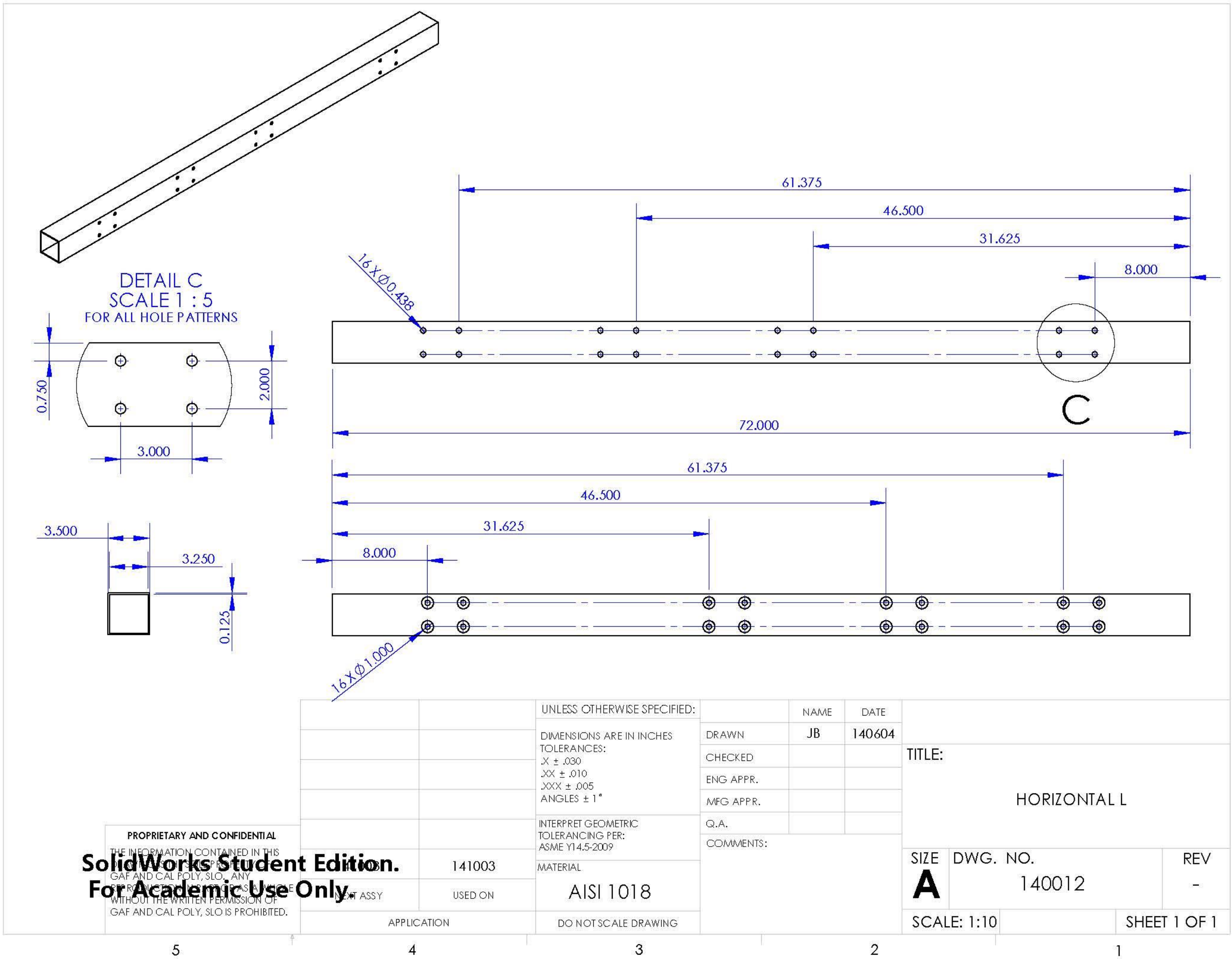

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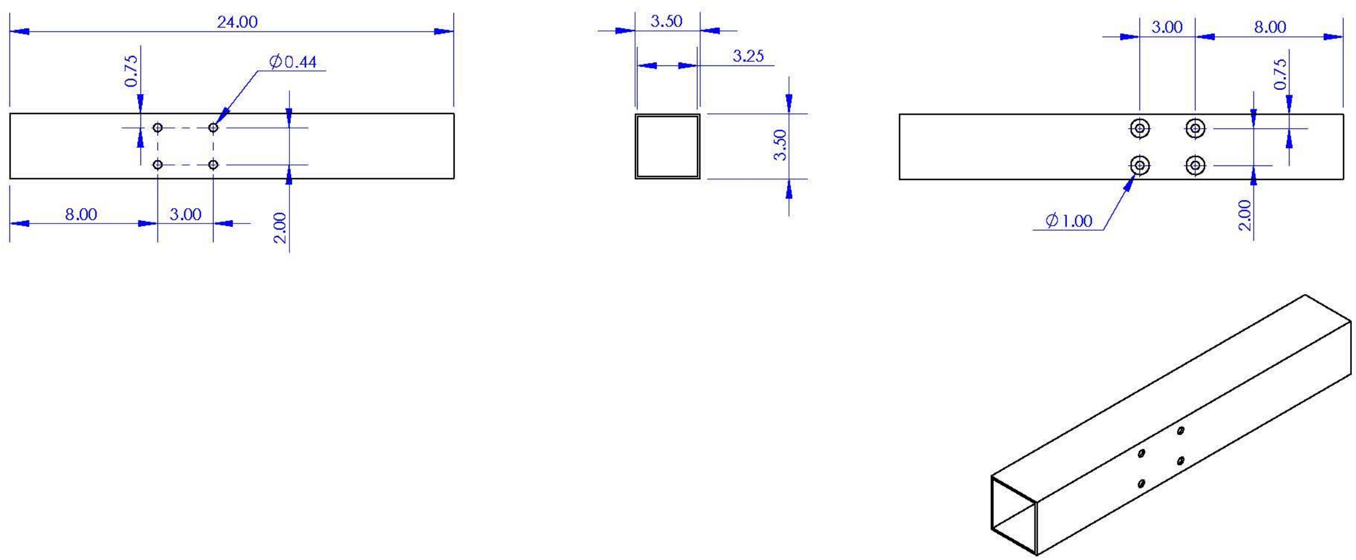
Harry Zhao
December 5, 2014



UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
.X ± .030
.XX ± .010
.XXX ± .005
ANGLES ± 1°

INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5-2009

MATERIAL: AISI 1018

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	JB	140604
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

TITLE: HORIZONTAL S

SIZE	DWG. NO.	REV
A	140013	-

SCALE: 1:8 SHEET 1 OF 1

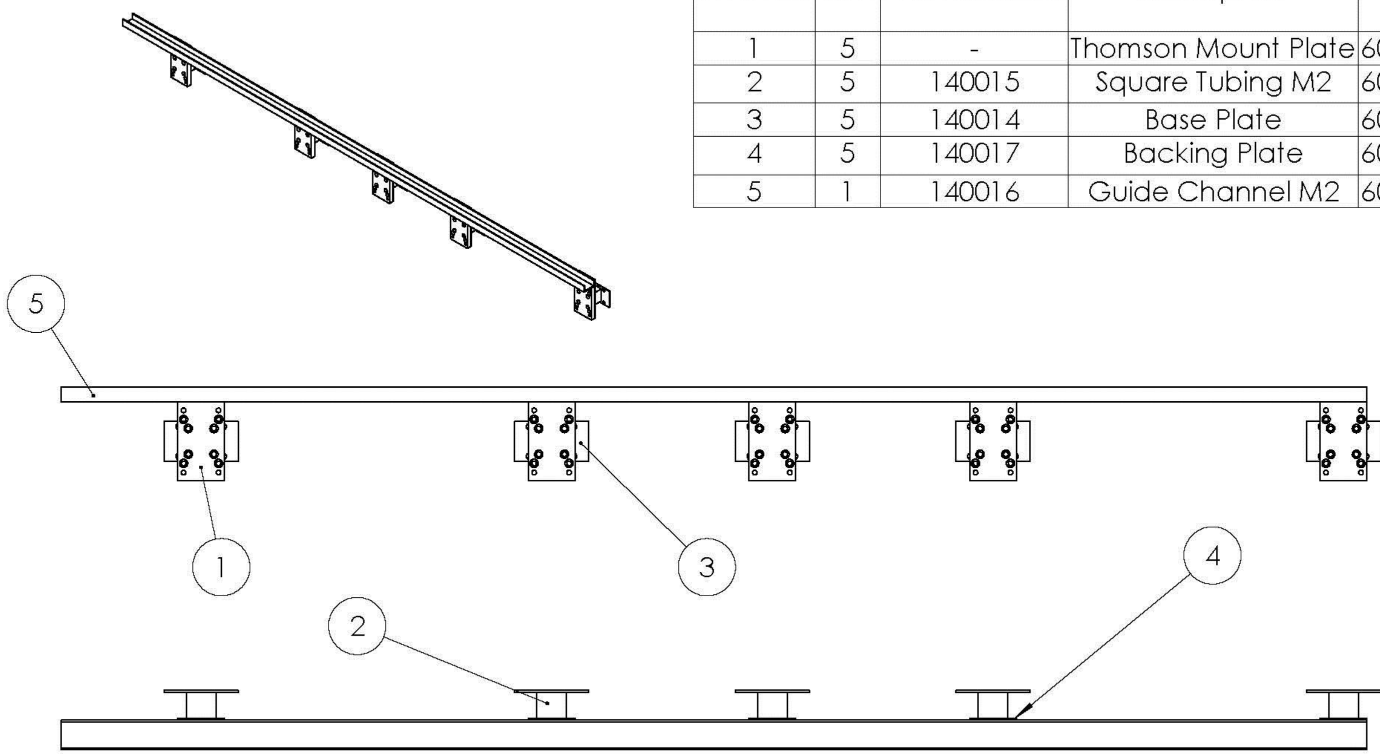
141003
NEXT ASSY | USED ON
APPLICATION

5 4 3 2 1

Mechanical Engineering CAL POLY

GAF Student Engineering Team
Justin Bracci
Chad Linafelter
Harry Zhao
December 5, 2014

ITEM NO.	QTY.	PART NUMBER	Description	Material
1	5	-	Thomson Mount Plate	6061-T6 (SS)
2	5	140015	Square Tubing M2	6061-T6 (SS)
3	5	140014	Base Plate	6061-T6 (SS)
4	5	140017	Backing Plate	6061-T6 (SS)
5	1	140016	Guide Channel M2	6061-T6 (SS)



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
.X ± .030
.XX ± .010
.XXX ± .005
ANGLES ± 1°
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5-2009
MATERIAL: AL 6061-T6
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	JB	141003
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

NEXT ASSY	USED ON
141005	-

APPLICATION

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TITLE: RETROFIT BRACKET M2

SIZE: A | DWG. NO.: 141004 | REV: -

SCALE: 1:10 | WEIGHT: | SHEET 1 OF 1

5 4 3 2 1

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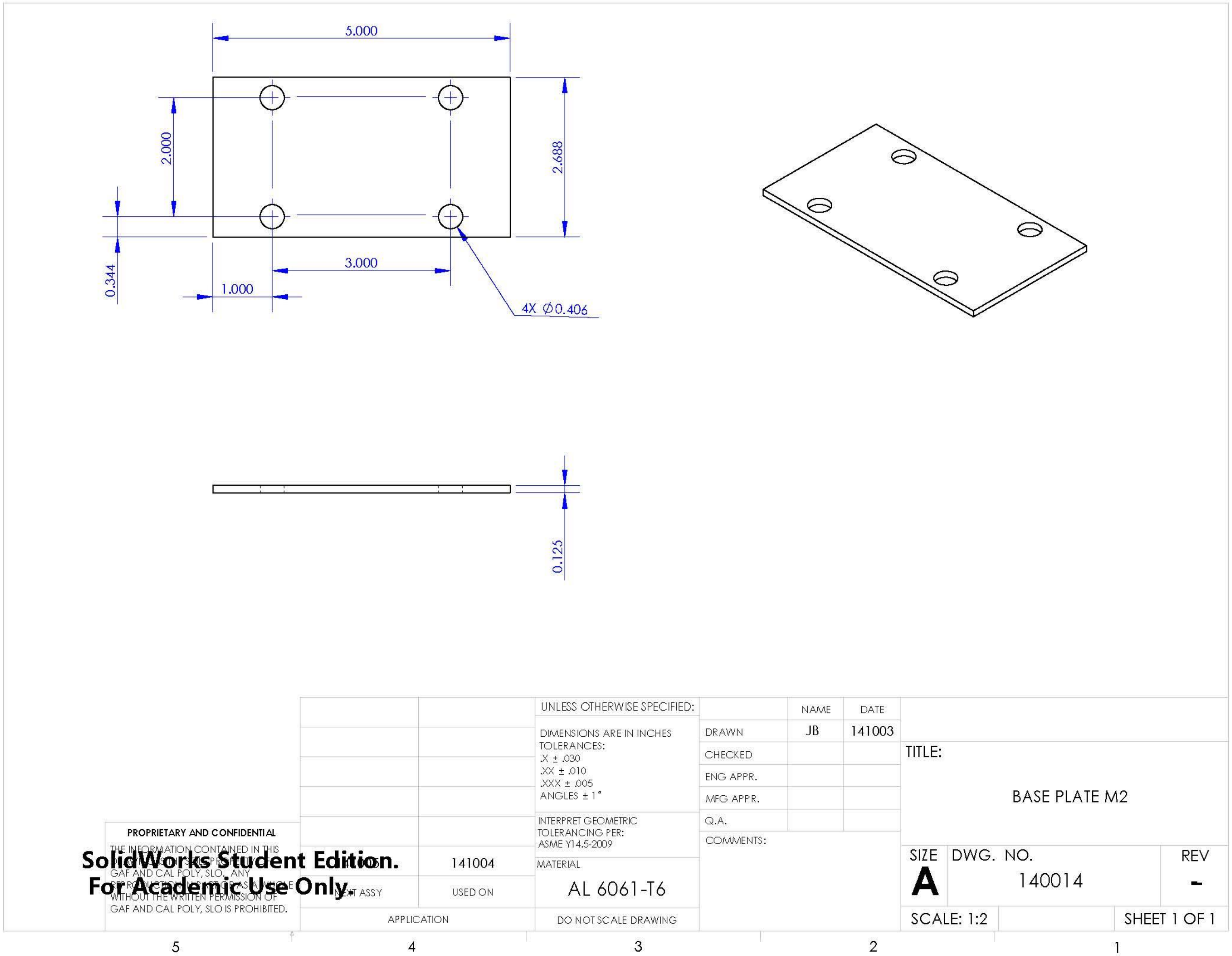
Harry Zhao
December 5, 2014



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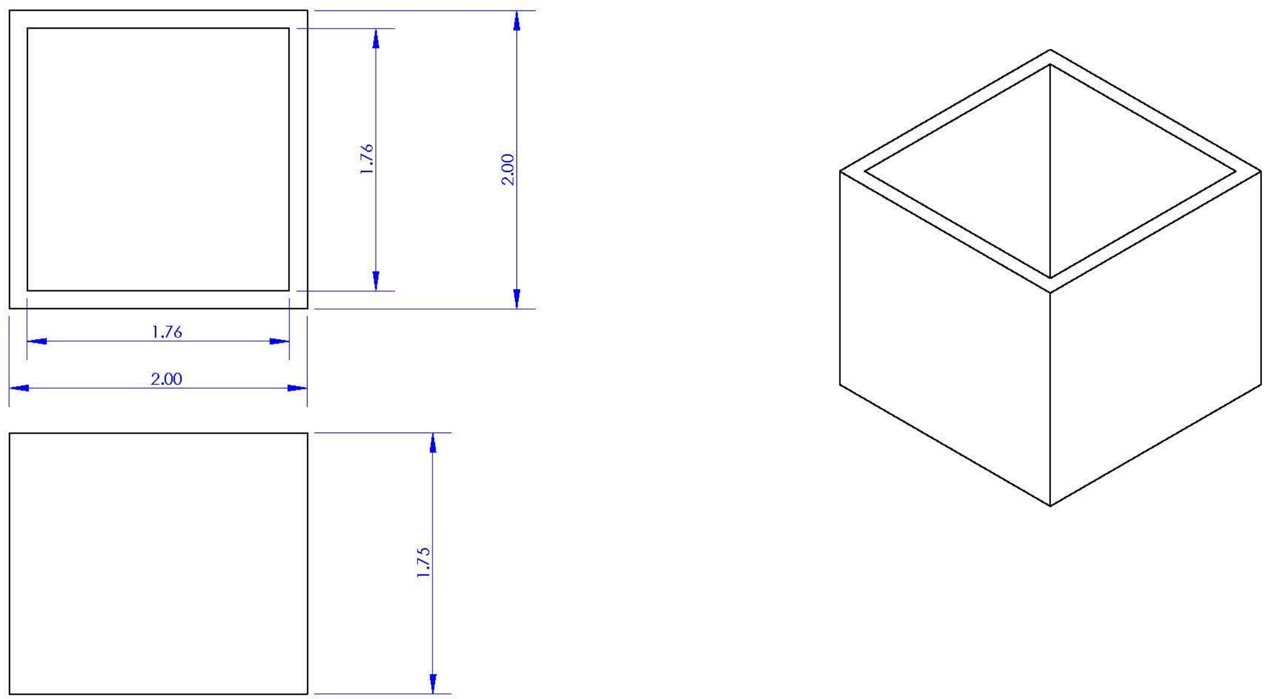
Harry Zhao
December 5, 2014



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
.X ± .030
.XX ± .010
.XXX ± .005
ANGLES ± 1°
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5-2009

	NAME	DATE
DRAWN	JB	141003
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

TITLE: SQUARE TUBING M2

SIZE	DWG. NO.	REV
A	140015	-

SCALE: 1:1 SHEET 1 OF 1

MATERIAL: AL 6061-T6

DO NOT SCALE DRAWING

NEXT ASSY	USED ON
141004	

APPLICATION

5 4 3 2 1

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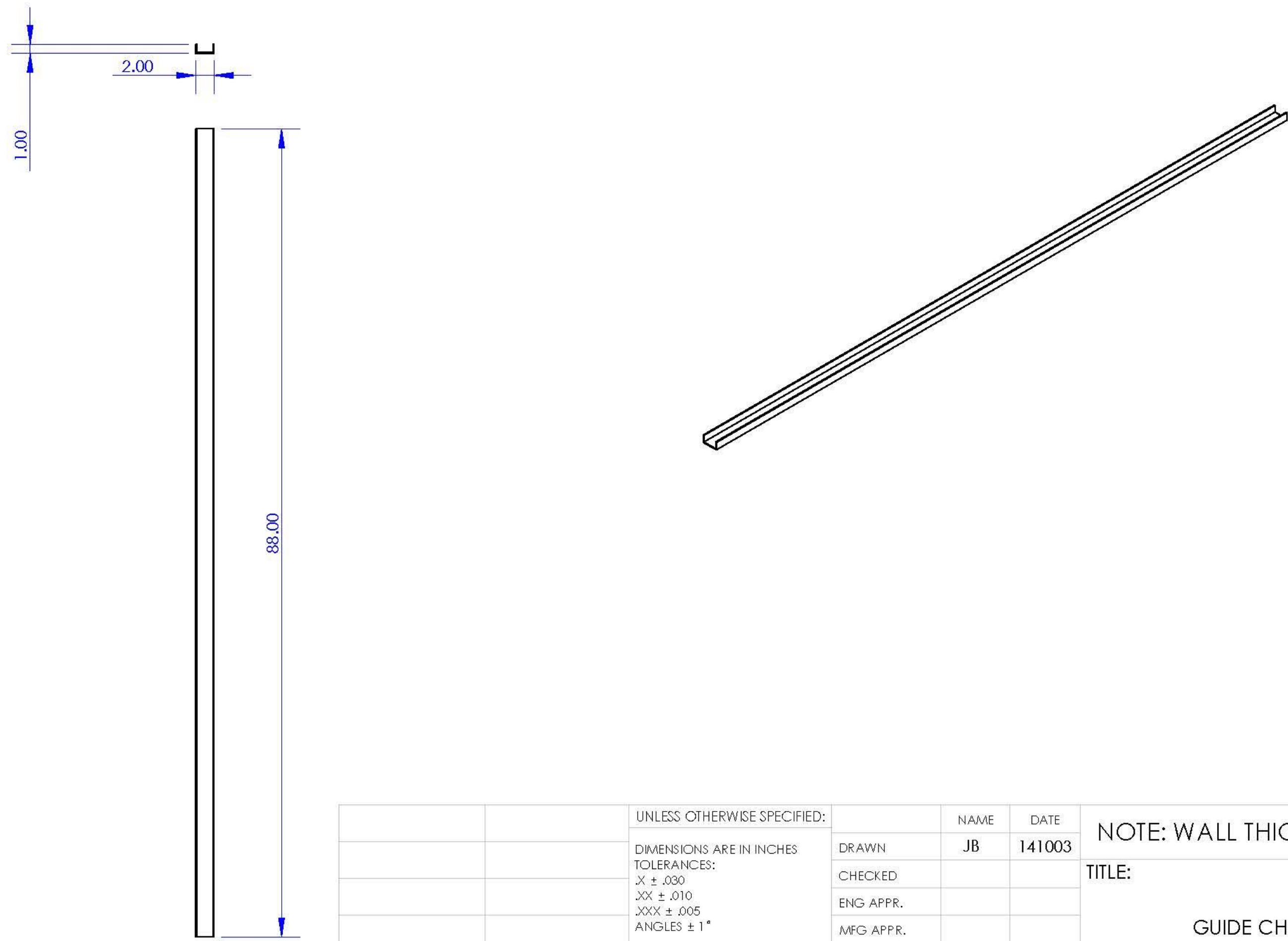

UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: .X ± .030 .XX ± .010 .XXX ± .005 ANGLES ± 1°	DRAWN	JB	141003
	CHECKED		
	ENG APPR.		
	MFG APPR.		
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5-2009	Q.A.		
MATERIAL: AL 6061-T6	COMMENTS:		
DO NOT SCALE DRAWING			

141004	USED ON
NEXT ASSY	
APPLICATION	

NOTE: WALL THICKNESS .125

TITLE: GUIDE CHANNEL M2

SIZE	DWG. NO.	REV
A	140016	-
SCALE: 1:16		SHEET 1 OF 1

5 4 3 2 1

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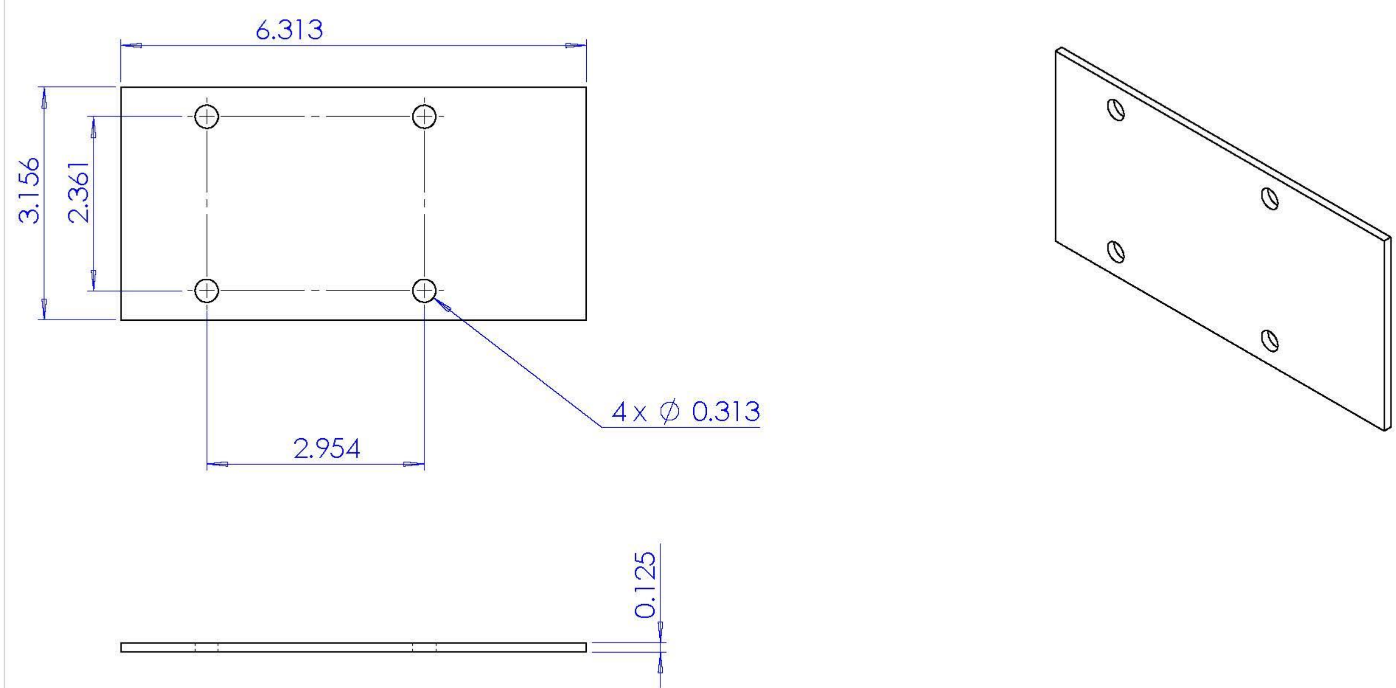
December 5, 2014



NEXT ASSY	USED ON
141005	141004

APPLICATION

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
.X ± .030
.XX ± .010
.XXX ± .005
ANGLES ± 1°

INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5-2009

MATERIAL
AL 6061-T6

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	JB	141003
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

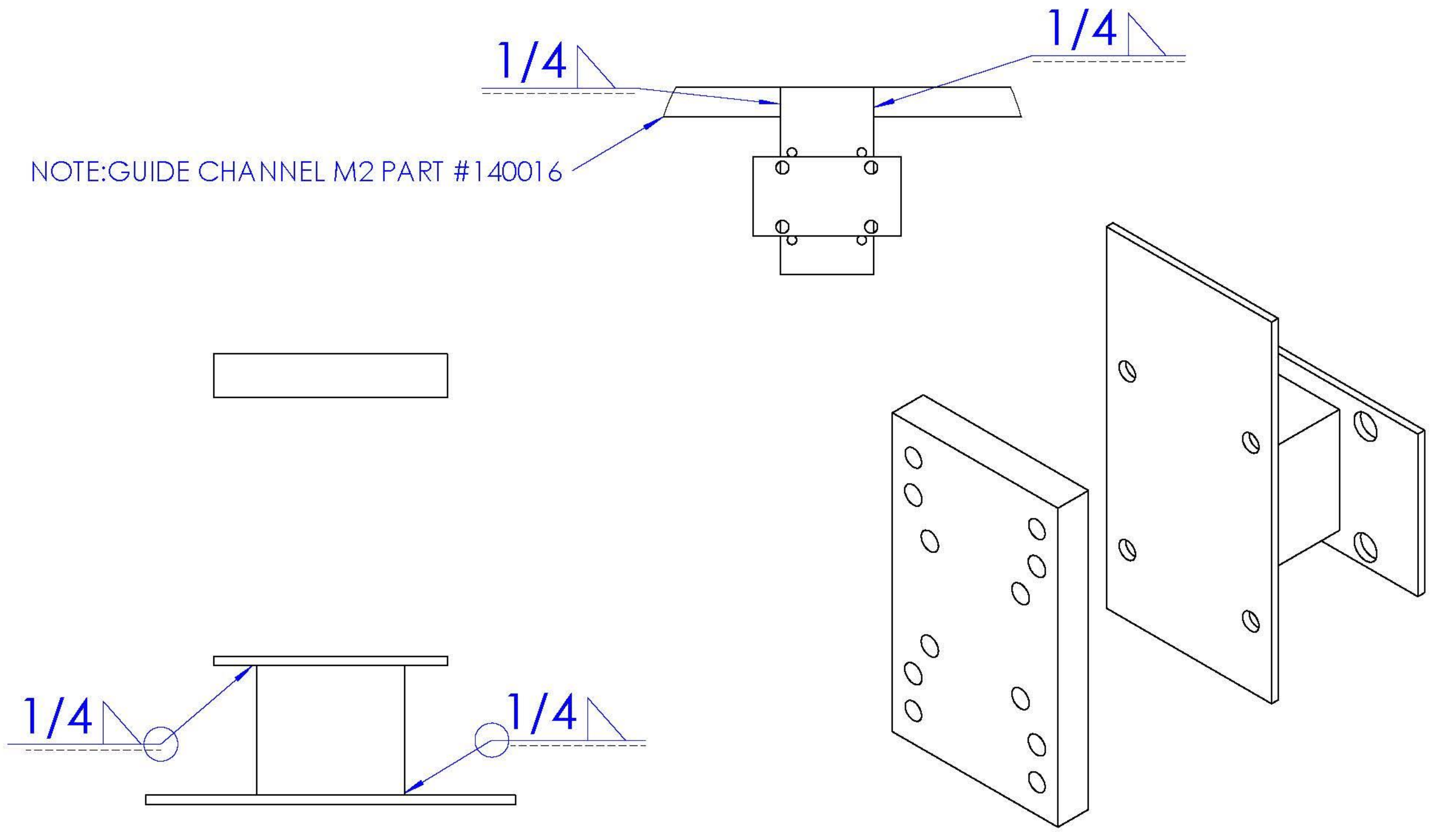
COMMENTS:

TITLE:
BACKING PLATE

SIZE A | DWG. NO. 140017 | REV -

SCALE: 1:2 | WEIGHT: | SHEET 1 OF 1

5 4 3 2 1



UNLESS OTHERWISE SPECIFIED:	NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: .X ± .030 .XX ± .010 .XXX ± .005 ANGLES ± 1°	DRAWN JB	141003
	CHECKED	
	ENG APPR.	
	MFG APPR.	
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5-2009	Q.A.	
MATERIAL AL 6061-T6	COMMENTS:	
DO NOT SCALE DRAWING		

TITLE: EXPLODED VIEW

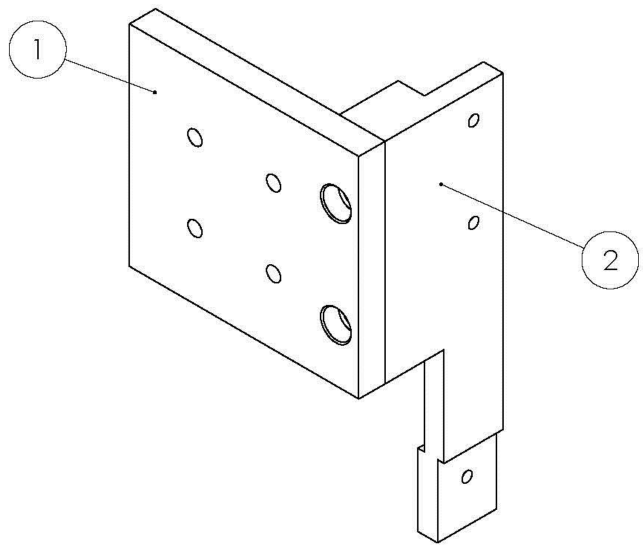
SIZE A | DWG. NO. - | REV -

SCALE: 1:5 | WEIGHT: | SHEET 1 OF 1

NEXT ASSY	USED ON
-	-
APPLICATION	

5 4 3 2 1

ITEM NO.	QTY.	PART NUMBER	DESCRIPTION	Material
1	1	140019	Glue Gun Mount B	6061-T6 (SS)
2	1	140018	Glue Gun Mount A	6061-T6 (SS)



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
.X ± .030
.XX ± .010
.XXX ± .005
ANGLES ± 1°
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5-2009
MATERIAL: AL 6061-T6
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	JB	141006
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

NEXT ASSY	USED ON
-	-

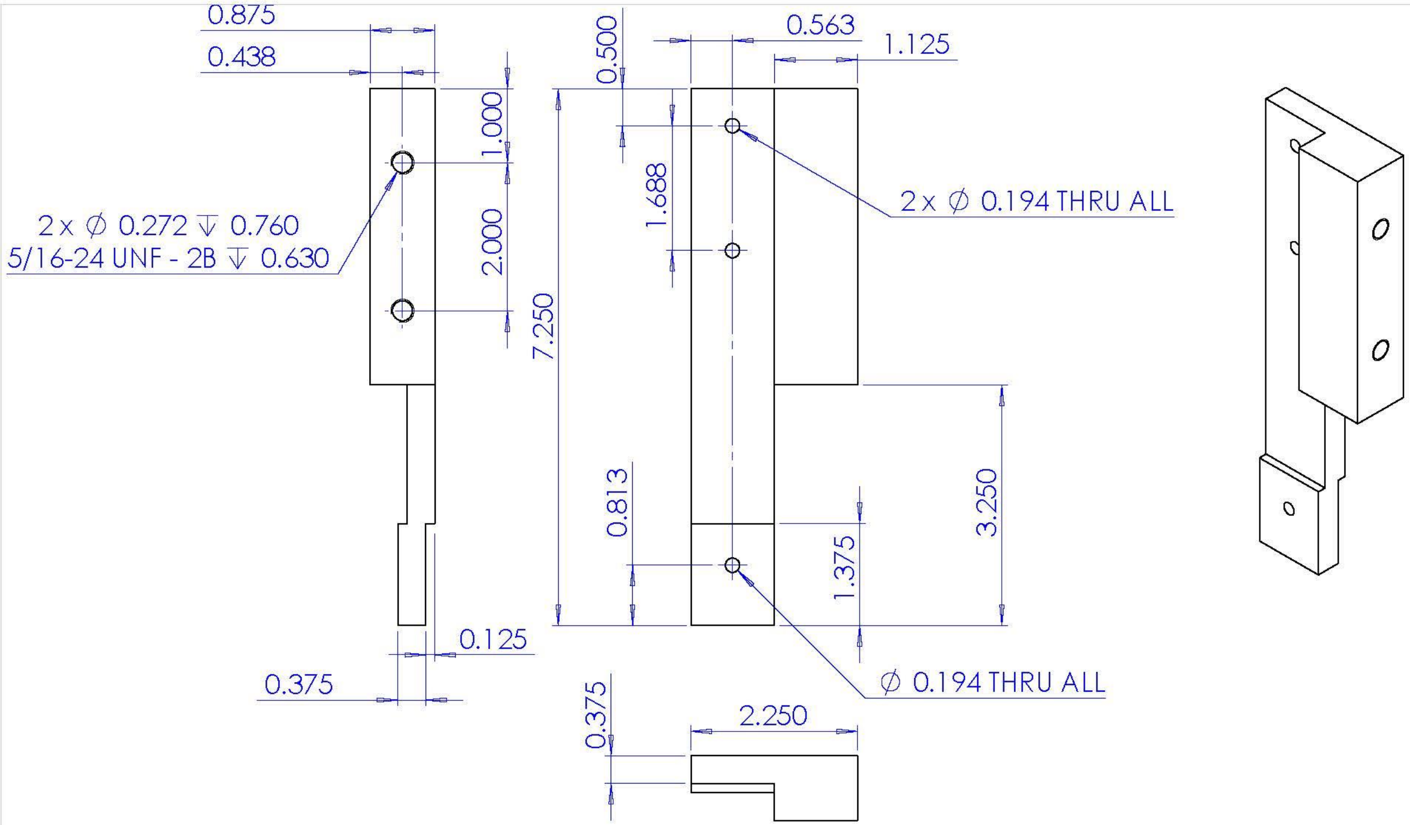
APPLICATION

TITLE: GLUE GUN MOUNT ASSEMBLY L

SIZE A | DWG. NO. 141005 | REV -

SCALE: 1:2 | WEIGHT: | SHEET 1 OF 1

5 4 3 2 1



		UNLESS OTHERWISE SPECIFIED:	
		DIMENSIONS ARE IN INCHES TOLERANCES: .X ± .030 .XX ± .010 .XXX ± .005 ANGLES ± 1°	
		INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5-2009	
-	141005	MATERIAL 6061-T6 (SS)	
NEXT ASSY	USED ON	AL 6061-T6	
APPLICATION		DO NOT SCALE DRAWING	

	NAME	DATE
DRAWN	JB	141006
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

TITLE:

GLUE GUN MOUNT A

SIZE	DWG. NO.	REV
A	140018	-
SCALE: 1:2	WEIGHT:	SHEET 1 OF 1

5 4 3 2 1

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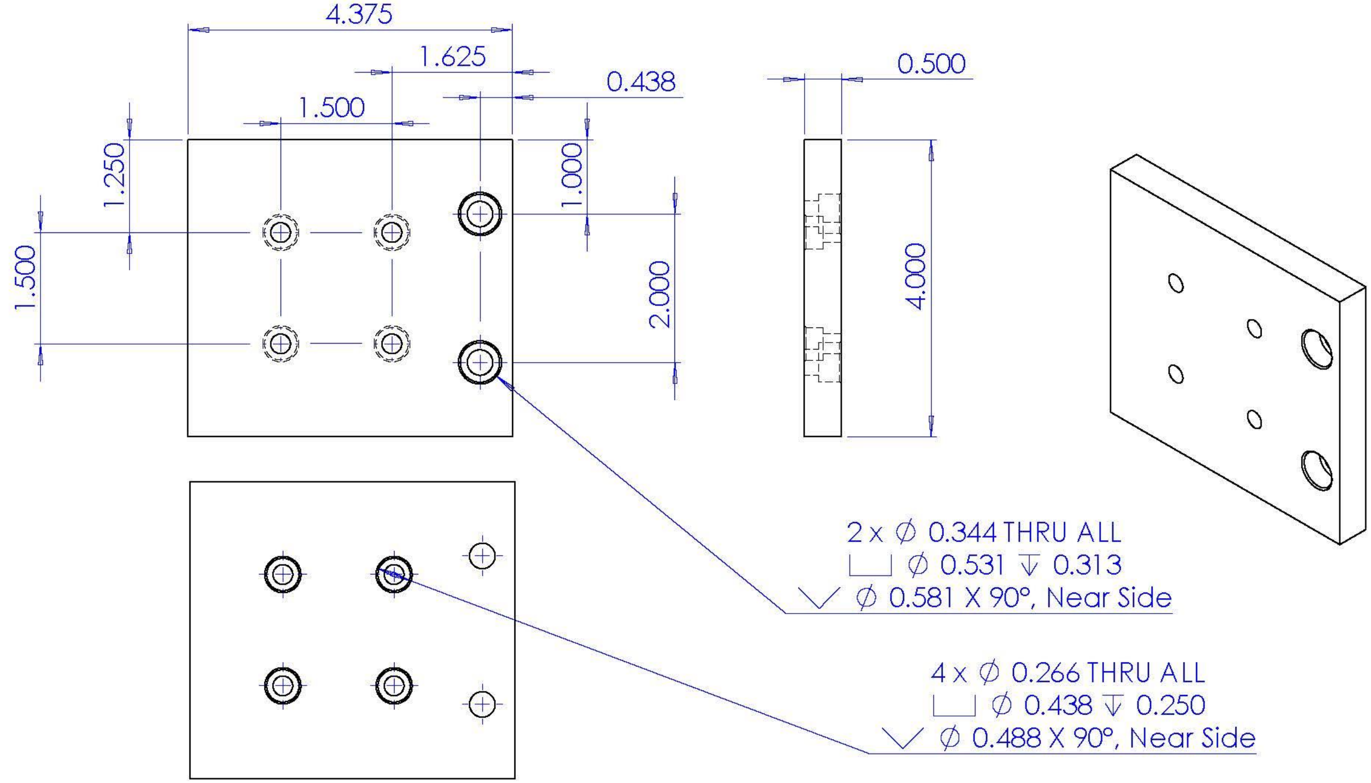
December 5, 2014



	NAME	DATE
DRAWN	JB	141006
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
.X ± .030
.XX ± .010
.XXX ± .005
ANGLES ± 1°
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5-2009
MATERIAL 6061-T6 (SS)
AL 6061-T6
DO NOT SCALE DRAWING

NEXT ASSY	USED ON
-	141005

APPLICATION

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TITLE:
GLUE GUN MOUNT B

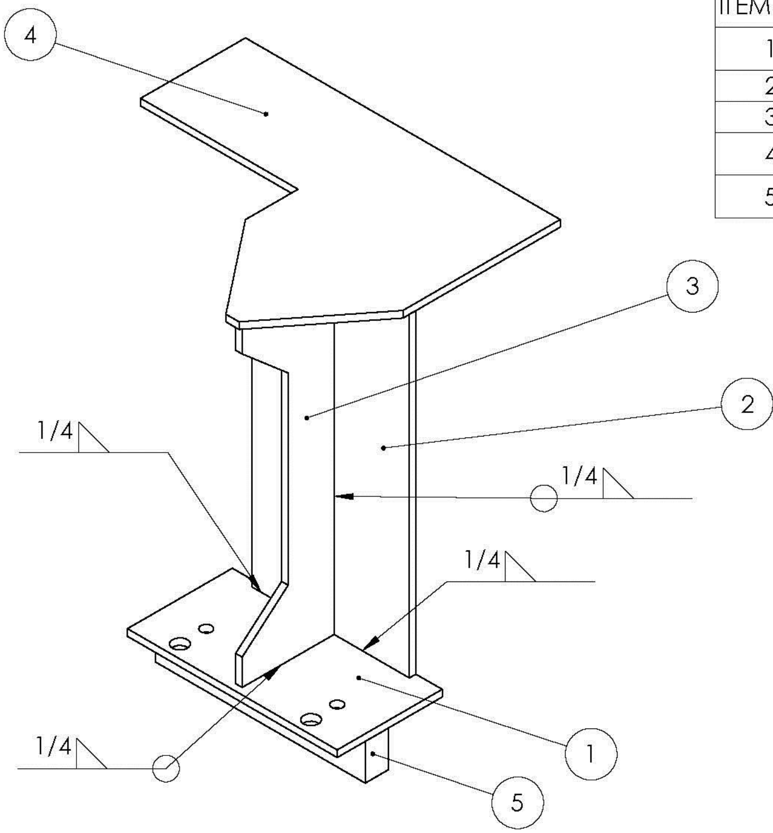
SIZE	DWG. NO.	REV
A	140019	-

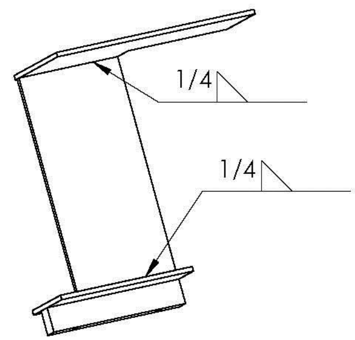
SCALE: 1:2 WEIGHT: SHEET 1 OF 1

5 4 3 2 1

GAF Student Engineering Team
Justin Bracci
Chad Linafelter
Harry Zhao
December 5, 2014

ITEM NO.	QTY.	PART NUMBER	DESCRIPTION	Material
1	1	140020	BRACKET 2A	6061-T6 (SS)
2	1	140021	BRACKET 2B	6061-T6 (SS)
3	1	140022	BRACKET 2C	6061-T6 (SS)
4	1	140023	BRACKET 2D	6061-T6 (SS)
5	1	140024	SUPPORT BLOCK	6061-T6 (SS)





UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
.X ± .030
.XX ± .010
.XXX ± .005
ANGLES ± 1°
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5-2009
MATERIAL
AL 6061-T6
DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	JB	141112
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

TITLE:
CABLE_CHAIN_BRACKET_REVB

SIZE A | DWG. NO. 141006 | REV -
SCALE: 1:2 | WEIGHT: | SHEET 1 OF 1

NEXT ASSY | USED ON | -
APPLICATION

5 4 3 2 1

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Harry Zhao
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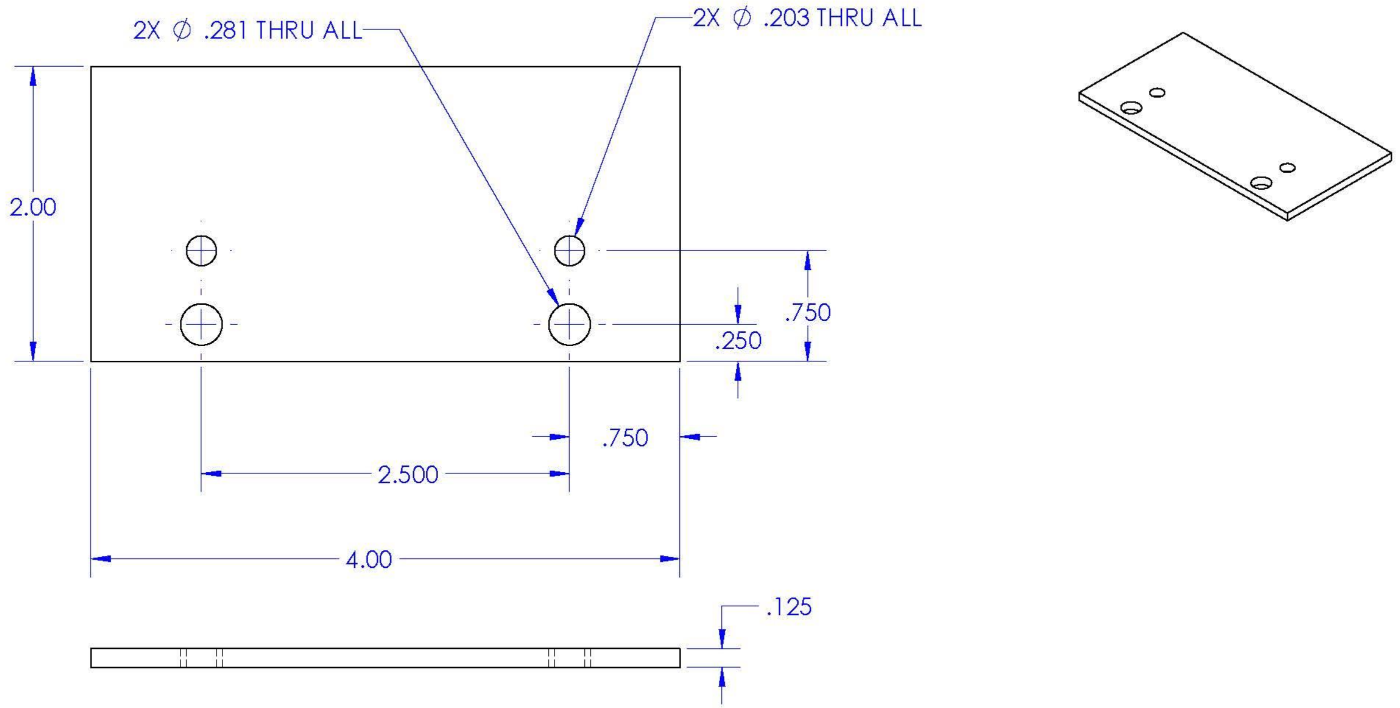

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
.X ± .030
.XX ± .010
.XXX ± .005
ANGLES ± 1°

INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5-2009

MATERIAL: AL 6061-T6

DO NOT SCALE DRAWING

	NAME	DATE
DRAWN	JB	141112
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

TITLE: CABLE_CHAIN_BRACKET_2A

SIZE	DWG. NO.	REV
A	140020	-

SCALE: 1 WEIGHT: SHEET 1 OF 1

NEXT ASSY	USED ON
	141006

APPLICATION

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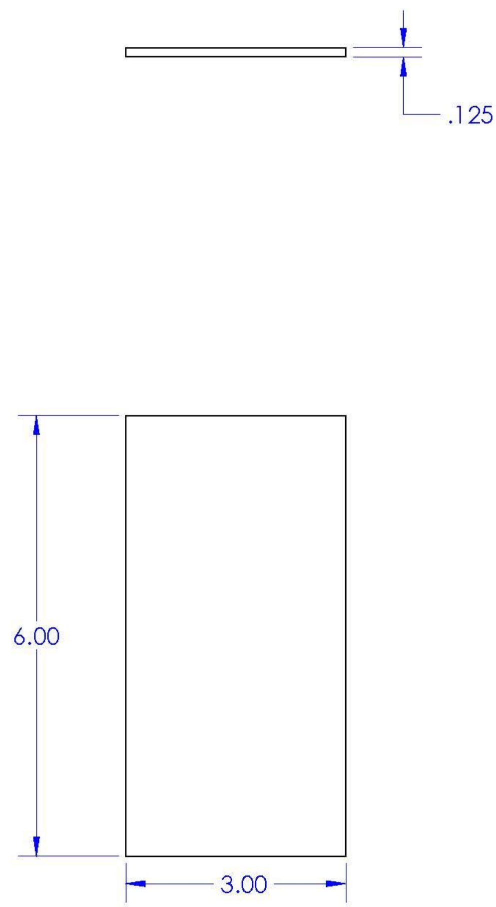

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MFG APPR.			
Q.A.			CABLE_CHAIN_BRACKET_2B
COMMENTS:			

DIMENSIONS ARE IN INCHES
TOLERANCES:
.X ± .030
.XX ± .010
.XXX ± .005
ANGLES ± 1°
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5-2009
6061-T6 (SS)
MATERIAL
AL 6061-T6
DO NOT SCALE DRAWING

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APPLICATION	

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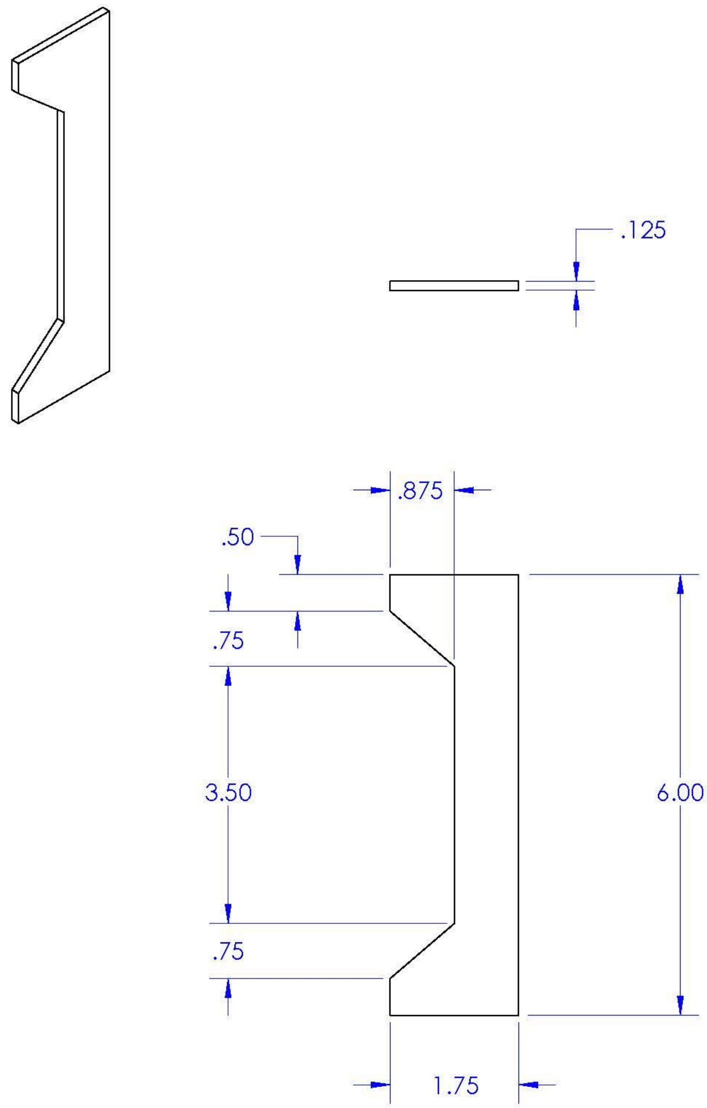

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MATERIAL AL 6061-T6
DO NOT SCALE DRAWING

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ENG APPR.		
MFG APPR.		
Q.A.		
COMMENTS:		

CABLE_CHAIN_BRACKET_2C

SIZE A | DWG. NO. 140022 | REV. -
SCALE:1:2 | WEIGHT: | SHEET 1 OF 1

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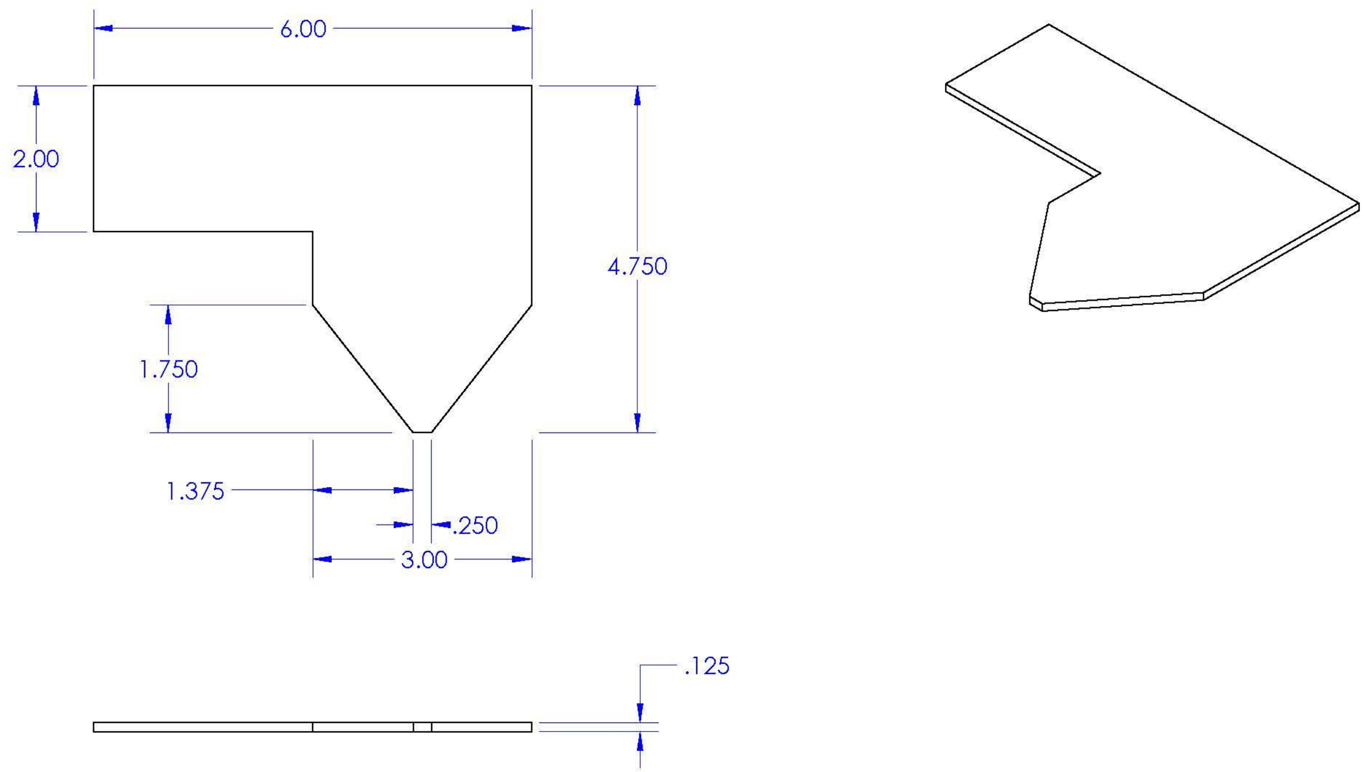

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MATERIAL AL 6061-T6	COMMENTS:		
DO NOT SCALE DRAWING			

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NEXT ASSY	USED ON
APPLICATION	

TITLE:

CABLE_CHAIN_BRACKET_2D

SIZE	DWG. NO.	REV
A	140023	-
SCALE: 1:2	WEIGHT:	SHEET 1 OF 1

5 4 3 2 1

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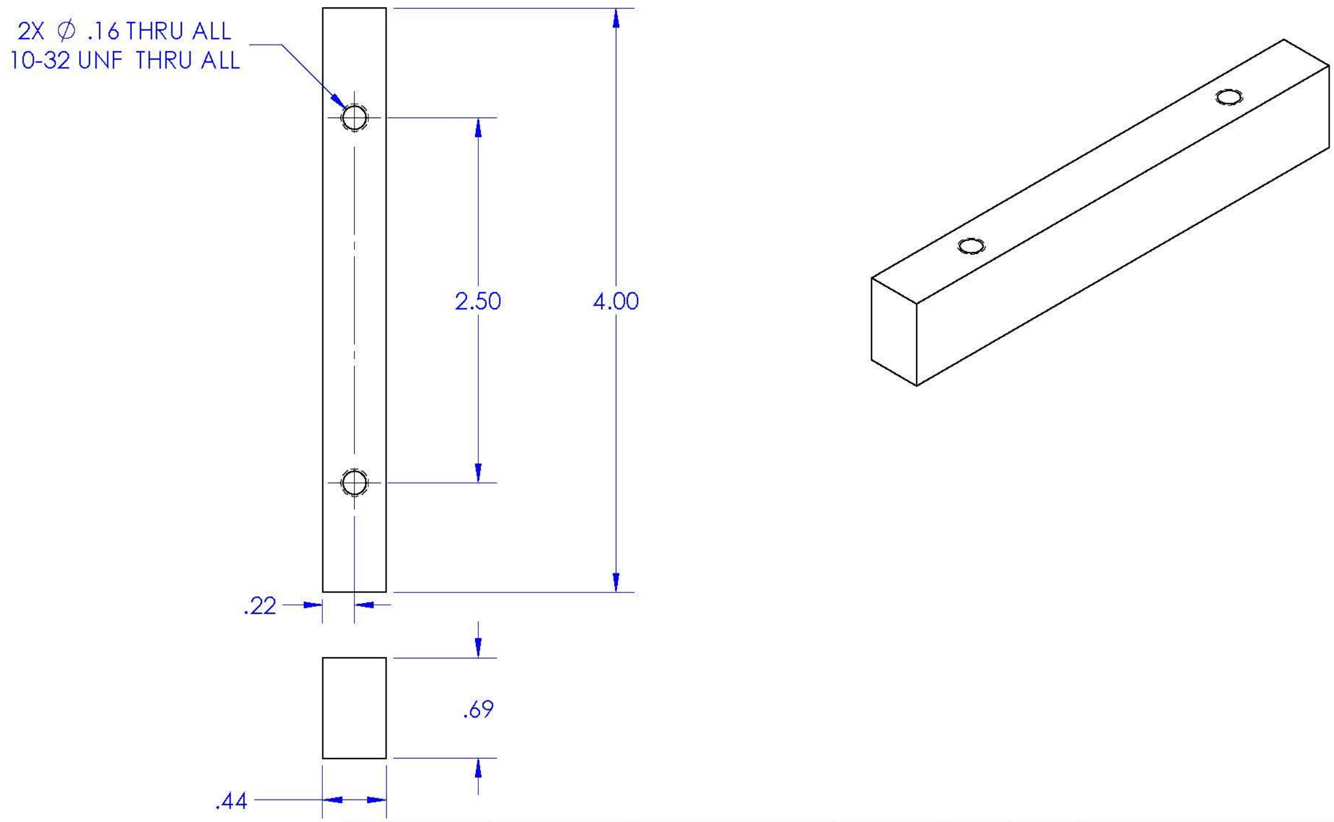

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DO NOT SCALE DRAWING			

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APPLICATION	

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TITLE: SUPPORT_BLOCK

SIZE	DWG. NO.	REV
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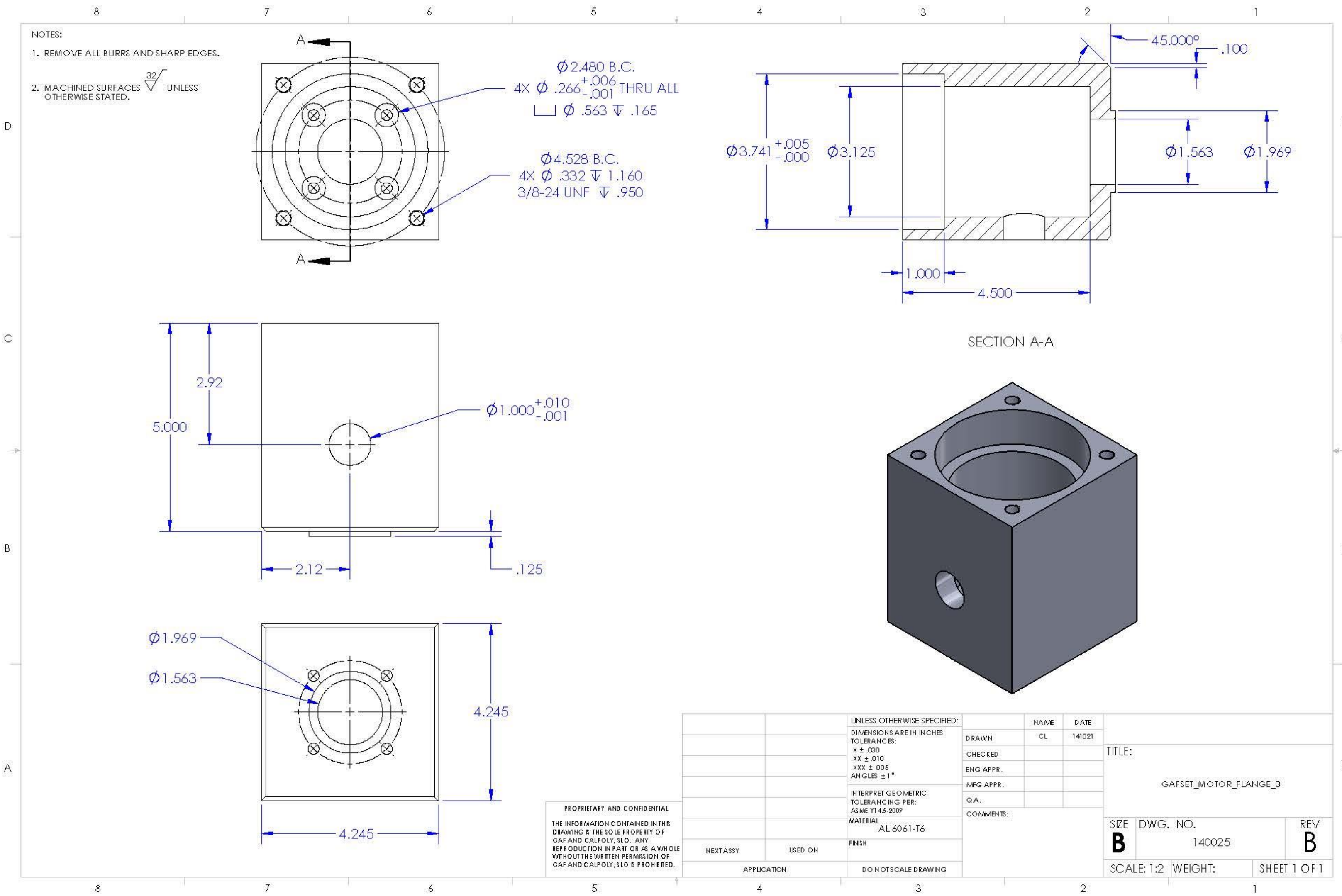
SCALE: 1:1 WEIGHT: SHEET 1 OF 1

5 4 3 2 1



NOTES:
1. REMOVE ALL BURRS AND SHARP EDGES.
2. MACHINED SURFACES 32 UNLESS OTHERWISE STATED.
A
A
Ø2.480 B.C.
4X Ø .266 +.006 -.001 THRU ALL
Ø .563 ↧ .165
Ø4.528 B.C.
4X Ø .332 ↧ 1.160
3/8-24 UNF ↧ .950
45.000°
.100
Ø3.741 +.005 -.000
Ø3.125
Ø1.563
Ø1.969
1.000
4.500
SECTION A-A
2.92
5.000
Ø1.000 +.010 -.001
2.12
.125
Ø1.969
Ø1.563
4.245
4.245
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NEXT ASSY
USED ON
APPLICATION
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN INCHES
TOLERANCES:
.X ± .030
.XX ± .010
.XXX ± .005
ANGLES ±1°
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5-2009
MATERIAL
AL 6061-T6
FINISH
DO NOT SCALE DRAWING
NAME
DATE
DRAWN
CL
141021
CHECKED
ENG APPR.
MFG APPR.
Q.A.
COMMENTS:
TITLE:
GAFSET_MOTOR_FLANGE_3
SIZE
B
DWG. NO.
140025
REV
B
SCALE: 1:2
WEIGHT:
SHEET 1 OF 1

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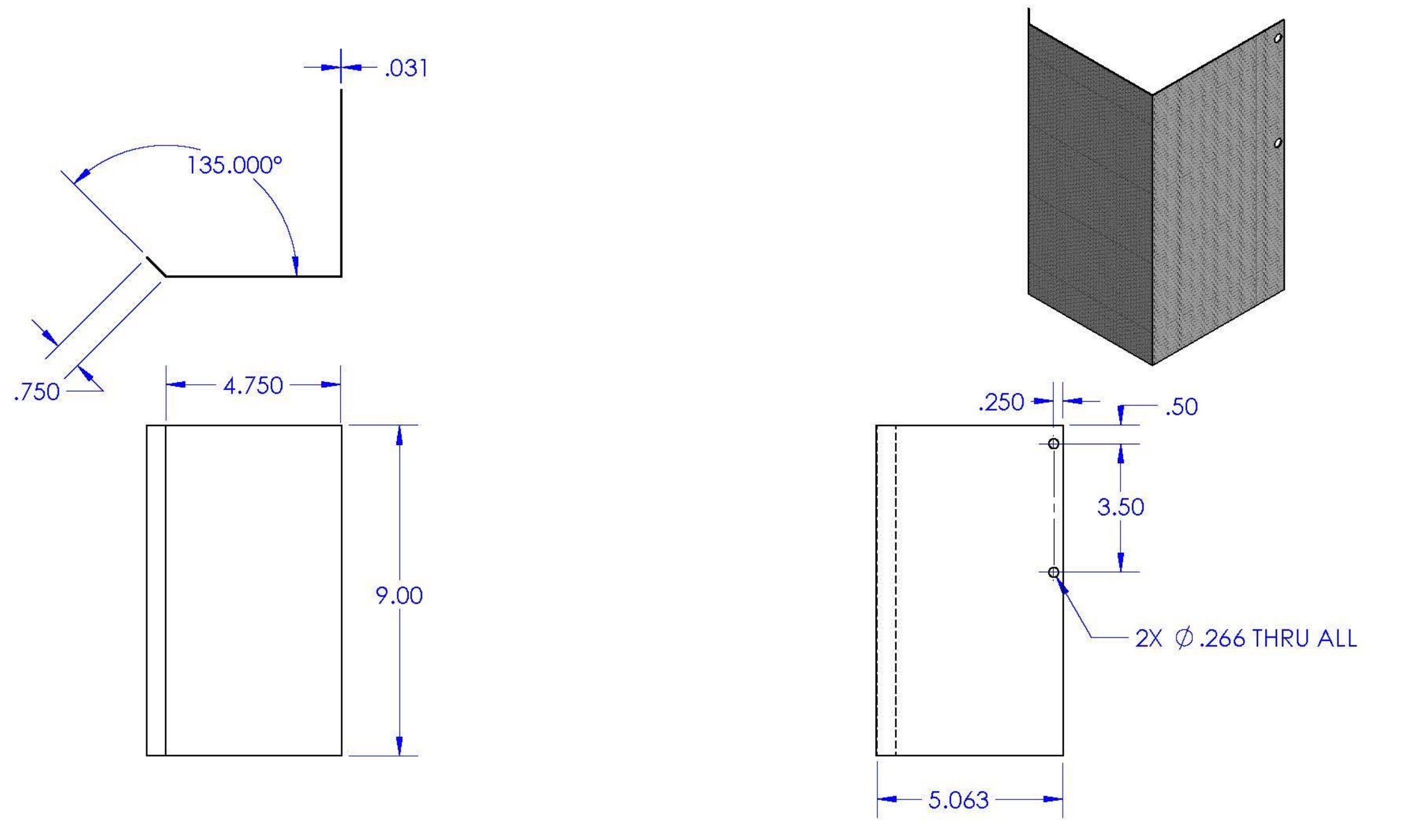

UNLESS OTHERWISE SPECIFIED:		NAME	DATE			
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	CHECKED			HEAT SHIELD REV		
	ENG APPR.					
	MFG APPR.					
INTERPRET GEOMETRIC TOLERANCING PER: ASME Y14.5-2009	Q.A.					
MATERIAL AISI 1018	COMMENTS:			SIZE A	DWG. NO. 140026	REV -
DO NOT SCALE DRAWING				SCALE: 1:4	WEIGHT:	SHEET 1 OF 1

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APPLICATION	

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Appendix T: Gluing Process Testing Procedure Document

GAFSET Automated Gluing Process Testing Procedure

General Safety Notes:

1. Eye protection is required at all times during testing.
2. Safety gloves are required when handling the glue gun and fiberglass mat.
3. Long sleeves, pants and closed toe shoes are required at all times.
4. Special caution should be taken when working around 480 volt components.

Testing Procedure:

1. Ensure power supplies (480v and 120v) are securely plugged into correct receptacles.
2. Check that all insulated wires are in working condition.
3. Ensure that the electrical control cabinet is closed before running any tests.
4. Ensure that there is an emergency stop button at each end of the linear gluing system.
5. Ensure that all objects are 2 feet clear from linear system and glue gun.
6. Turn on all breakers and power switches for linear gluing system.
7. Position fiberglass mat centered beneath glue gun movement profile.
8. Open glue gun and fill with glue beads to required height on gun and ensure gun is securely closed.
9. Wait 15 minutes or when glue gun temperature indicator reads 500°F.
10. Ensure operator(s) are clear of glue gun by at least 2 feet.
11. Press start button to run glue gun movement profile.
12. Wait until glue gun completes movement profile and has returned to home before performing any tasks on system.
13. Let dispensed glue on mat sit for 5 minutes minimum before handling.
14. Repeat tasks 3 through 13 as necessary for required testing of system.

Shut-Down Procedure:

1. Purge all remaining glue from gun into catch can and turn off glue gun control.
2. Turn off main breaker for 480 volt power supply and lock out with provided lock-out locks.
3. Un-plug 480 volt power cord from wall receptacle.
4. Un-plug all 120 volt power cords from wall receptacles.
5. Allow glue gun to cool for 45 minutes before leaving the system unattended.
6. Turn off all remaining breakers inside control cabinet and lock cabinet.