Hydraulic Hand Press

Final Project Report

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Sponsored by the Estrella Warbirds Museum

DISCLAIMER

Statement of Disclaimer

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Abstract:

This report provides a thorough description of the design of a hydraulic hand-operated press by mechanical engineering students at California Polytechnic State University, San Luis Obispo, California, for the Estrella Warbirds Museum in Paso Robles, California. It begins with research into hydraulic operations, a brief study of fluid power and incompressible fluids, and a look into existing products. Specified customer requirements stipulate the loading and general size constraints. As part of the project, a schedule is laid out following industry techniques. Brainstorming and decision matrices are utilized as well, conveying our design process. A basic structure is developed using strength of materials, beam bending theory, applied/allowable stress analysis, and material deflection. Additional features are developed based on a more specific investigation of customer requirements. This report not only covers the press design, but also documents its construction and testing of the structure. Cost analysis and material choices are relayed along with a complete set of engineering drawings for the manufacture of the press. Testing and failure modes are analyzed with an overall goal of customer safety in mind.

Introduction:

Bramah Hydraulics, as part of a senior project for the Mechanical Engineering Department at California Polytechnic State University, San Luis Obispo, California, was responsible for the design, construction, and testing of a hand-operated hydraulic press to be used in the fabrication of custom aircraft parts. The sponsor of this project, the Estrella Warbirds Museum, will be using our press in their extensive efforts of restoring historic military aircraft for display. Our press will allow them to easily accomplish many operations, such as molding compound curves out of aluminum, straightening heavy structural members, pressing bearings, and bending brackets. The goals of this project include satisfying the specific requirements provided by our sponsor for the hydraulic press and successfully executing the multiple phases of the project on time, while establishing a positive relationship with the Warbirds Museum. The museum plays a significant role in maintaining our national history and preserving the past. The quality of their work is as impressive as it is important, and we hope that our efforts on this project will pay tribute to theirs.

Background:

The use of fluids as a source of power has been studied since the ancient Greek era. Pumps, turbines, dams, and other devices all use unique fluid properties to gain engineering advantage. Our specific case, the hydraulic press, uses a simple relationship given by Pascal's principle, which says that the pressure at all points of a closed system will be constant. Therefore, the force applied to one piston in a hydraulic cylinder will be related to the force obtained by another piston in a connected cylinder by the ratio of the piston areas. Joseph Bramah, our company's namesake, used this relationship when inventing and patenting the hydraulic press in 1795. Today, hydraulic presses are the most commonly used and efficient form of modern press.

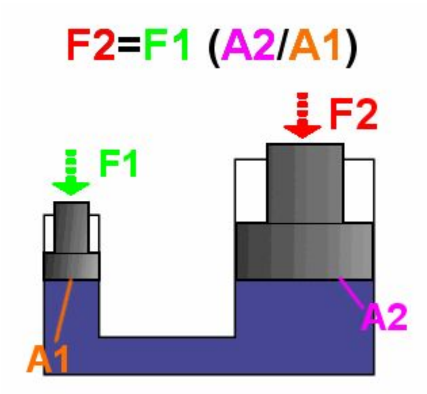

Figure 1: Pascal's Principle and Hydraulic Force Multiplication

The Estrella Warbirds Museum has made it their legacy to restore historic military airplanes for the public to admire. They operate out of a prime location that sits just off a taxi way at the Paso Robles Airport in California. This gives them a unique opportunity to accept a wide variety of airplanes that can be flown in that would otherwise need to be dissembled and trucked in, and then reassembled.

Their commitment to historic aircraft is great. They have flown all over the world to investigate, repair, and return with new military aircraft. Many members often take time from their work on a restoration project to be able to share their excitement with the visitors that are allowed to wander among the aircraft. The combined knowledge of the members is extremely impressive, with many being veteran pilots of conflicts, including the Korean, Vietnam, and Gulf wars.

Objectives and Design Specifications:

Bramah Hydraulics was responsible for the design, fabrication, and testing of a hand-operated hydraulic press and its components. Bramah Hydraulics kept in contact with the Warbirds Museum throughout each step of the project until it concluded on December 3rd , 2009.

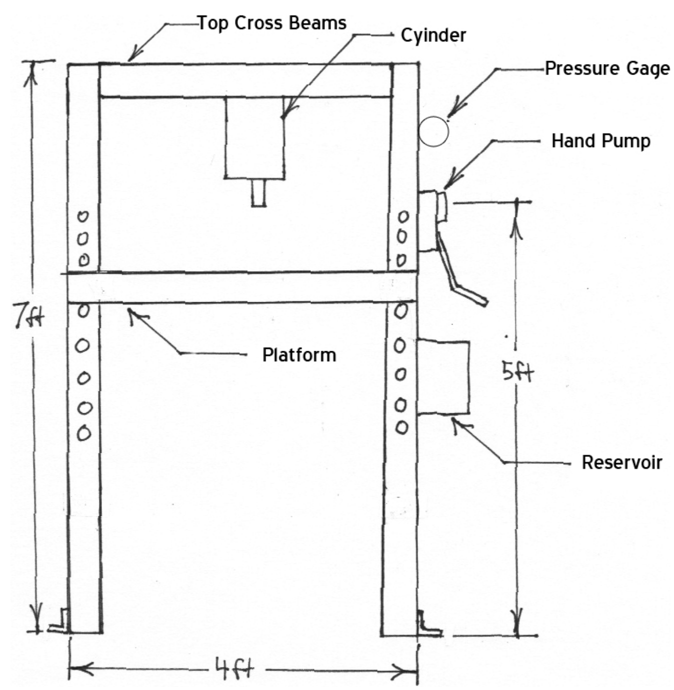

Figure 2: Sketch of Press as specified in the Project Proposal

Our design began with the project description written by the Estrella Warbirds Museum, including all size, material, and usability requirements stated within the project specifications documentation that can be seen in **Appendix A** and are summarized as follows: Human power is to be used to operate a hydraulic press. The hand pump should be located at a height of around five (5) feet and positioned on the right side of the press to allow for an average-sized person to easily operate the press. The four-way, three-position hydraulic valve will be mounted to the frame within one (1) foot of the hand pump. The frame will be constructed of U-channel steel of appropriate size to withstand ten tons compression and tension. The overall dimensions will be seven (7) feet tall and four (4) feet wide with an appropriate depth to maintain stable operation. The frame cross pieces will be doubled up to provide a wide, stable platform as well as to hold the hydraulic cylinder in place. The pressure gauge should be mounted in plain view at a height of between five to six (5-6) feet. A one-gallon hydraulic reservoir will be mounted securely to the frame out of the way of the press operation. The entire press frame and hydraulic components will be connected with bolts to allow for disassembly. All hoses and connections will use type AN aircraft connections and the pump will use red aircraft 5606 fluid. All applicable OSHA standards will be followed for safe operation. The final design was presented March 7th, 2009.

Fabrication and assembly of the hydraulic press was done both at the Estrella Warbirds Museum shop facilities on Saturdays as well as at the Cal Poly Aero Hanger, and Bonderson Project Center, multi-purpose machine shops located on the Cal Poly

campus. Fabrication of the press began April 13th, 2009 and was completed for testing November 30th, 2009.

Management Plan:

The Bramah Hydraulic team consists of two members: Nathan Brown and Matt Knorr. They were responsible for all aspects of this hydraulic press project. Work was evenly split between the two, catering specific tasks to individual talents.

Appendix C displays our current Gantt chart, a visual aid used for project scheduling. Tasks, goals, and deliverable due dates are listed on this chart as bars representing their start/end dates and necessary completion time. The museum was informed as updates occurred. The chart encompasses a combined total of 467 work hours. This includes everything from museum visits, time spent writing various reports, weekly meetings with our project advisor, construction/fabrication, assembly, and testing.

Meetings with our faculty advisor, Professor Owen, occurred every week on Thursday at 10:00 am, for two quarter (6 months). We begin with an agenda created in advance and go over what we have accomplished during the previous week and our plans for the upcoming week. Professor Owen guided our efforts with suggestions of design ideas and comments on general progress. After each meeting one member writes up minutes documenting what was discussed. Meeting agendas and minutes will be made available for sponsor review if desired. During the third quarter, we were advised by Professor Lee McFarland. He provided crucial knowledge on fabrication techniques and gave us advice when it came to modification and necessary redesigns.

Design Development:

Our research for this project encompassed not only an extensive look into the theory and operation of hydraulic presses but also a search of similar products on the market. Many commercial, hand-operated hydraulic presses are currently available. However, in deciding on a design we used a quality function deployment chart to evaluate the specific customer needs and give these needs a numerical value with which to compare designs and test their acceptability to the Museum. Seen in **Appendix B**, our quality function deployment chart, or “House of Quality”, takes vague customer requirements and translates them into engineering design specifications. At the same time, it was used to compare existing options that are already commercially available. Our case in which we were given many specific design details to begin with made the house of quality is somewhat unnecessary. From this chart we concluded that the precise nature of our customer requirements would eliminate the benchmarks as viable options.

Another aspect of our research involved the investigation of standards and code requirements related to the construction of our press. The U.S. Department of Labor’s Occupation Safety and Health Administration (OSHA) website revealed a few considerations. General machine guards (barrier guards, two-hand tripping devices, electronic safety devices, etc.) must be provided to protect the operator and other employees in the machine area from hazards created by the point of operation, nip points, etc. Many other regulations related specifically to electrically powered hydraulic presses exist, which do not apply to our hand powered design. The fact that our press is hand-operated and not driven by a motor makes it inherently much safer. We have obtained

the Material Safety Data Sheet for the aircraft 5606 hydraulic fluid specified in the project description, and have looked over potential hazards that come with its use.

We used our research described above by applying the tried and tested layouts of comparable hydraulic hand press designs as a platform to design our initial concept. We also conducted brainstorming sessions to come up with more efficient, ergonomic, useful, and time-saving ideas for press designs to improve upon the standard commercially available models. The best of these innovations was presented to the Warbirds Museum for approval before proceeding with the final design. The final design incorporated all the project objectives and was also presented for approval. Each of these stages requiring approval was subject to adjustment until the museum was satisfied with the plan. The building process could not begin until this occurred. Following the construction phase, the press was tested to see if it accomplished the project goals. When problems with the design were encountered, it was modified or rebuilt until the objectives were met. Also during the testing phase, improvement of specific parameters sometimes warranted modification of the finalized press. Once the press operation met the project objectives and was presented at the senior design expo, the press was ready for delivery to the Estrella Warbirds Museum to be put into service.

Progress was made in the design phase that included initial stress calculations for the structural members of the press frame. **Appendix D** shows those calculations in full, including a basic layout of the press frame. It was concluded using the max pressing capacity of 10 tons that the horizontal U-channel steel members must be greater than 4 inches wide. We decided to use a 6-inch-wide dimension for the horizontal cross beams

and use 7-inch-wide vertical members to allow for more room for attaching components and allow for a significant safety factor.

The hydraulic aspect of this project has been started as well. We have looked into the specifics of hydraulic schematics and the associated symbols. **Appendix E** shows an initial diagram for our system. Notice the included four-way, three-position valve, and the double-acting cylinder.

Brainstorming plays a pivotal role in our design process. One area where we came up with ideas was the method used to safely raise and lower the press work platform. We used an evaluation tool known as a decision matrix to compare potential designs to one another in order to choose the best one. In the matrix, a series of design categories, such as the design cost, ease of use, and safety, are written next to a list of competing designs. In these tables, each design is compared to an idea that is set as the standard for all the other designs, therefore called the datum. The designs are rated for each category using either a plus, indicating a design better than the datum, a minus indicating an idea worse than the datum, or an 'S' indicating the two are equivalent. **Appendix F** shows three of these tables, using a different datum each time.

With the "By Hand" idea, the platform changes position by lifting it to a new position, removing the pins that it was previously sitting on, placing them at their new location, then setting the platform back on the pins. It is heavy, hard to operate with one person, and unsafe when loaded. However, it is cheap (set as cost reference cost all ideas) and easy to manufacture.

Scissor hydraulics would use a scissor lift underneath the platform and utilize a hand pump. This will need to be built since there is no complete, off-the-shelf scissor lift

available, but the design is basic. All the parts are easily available on sites like McMaster-Carr and Grainger. This lift should be a very safe design due to the rigidity of the triangular frame, but also depends on where the pump handle is placed. The limited range is the current problem since it is the range that is causing the need to build our own scissor lift as opposed to a complete device. The cost of this idea would be in the range of $300 to $600 for the cylinder, unless we could find one for free, and $100 to $250 for the necessary steel.

Telescoping hydraulics would utilize a hydraulic cylinder that would be sandwiched between the platform on top and a rigid cross member underneath. A rigid hydraulic cylinder of 4 ft. stroke is expensive. A telescoping cylinder would be very expensive. However, the benefit would be that all the parts to get it connected are already available, or relatively cheap. Cost for this idea would be about $620 (http://www.grainger.com/Grainger/items/5PP02)

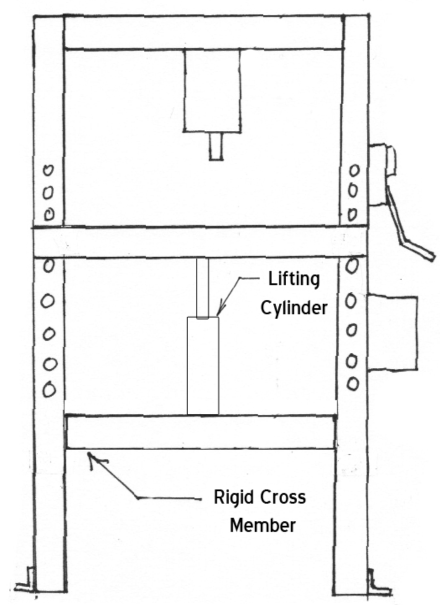

Figure 3: Telescoping Cylinder to lift Platform

The rack-and-pinion option consists of a series of gears and pinions attached to the platform that would be hand cranked and would follow racks that are vertically attached to the upright beams. This option would cost around $330 including a rack and pinion, a handle, a ratchet, and a pawl (http://www.mcmaster.com/#rack-and-pinion-gears/=klc9u).

For the hand winch/pulley idea, a hand winch is attached to the outside of one upright beam. A wire rope fixed at the winch is run over a pulley at the top cross beams, back down and attached to the platform. The cost of this option is outlined below:

Cost: Hand Winch - $70 (http://www.mcmaster.com/#hand-winches/=kkoek)
Steel Cable - $25 (http://www.mcmaster.com/#aircraft-wire-rope/=kljl4)
Pulley - $43.55 (http://www.grainger.com/Grainger/wwg/productIndex.shtml)
Total – $138.55

The figures in **Appendix G** show concept sketches of our two top concepts. We decided on the pulley/winch and a modification of the scissor hydraulics, substituting a hand crank for the cylinder. These choices were made based on the results of our decision matrices and the preliminary cost analysis. They also prove to be the least complex ideas in terms of construction.

Further analysis was done to decide what size the rods were needed to hold the platform during loading. The calculations can be seen in **Appendix H.** The pins size came out to be .69" using a yield stress safety factor of 2 and was rounded up to the standard size of 1" for a total safety factor of 4.2. The trolley system that would support the cylinder needed to be sized as well. **Appendix I** shows the calculations used to design the trolley.

Appendix L shows the layout drawings for the overall press design and the proposed mechanism to move the cylinder from side to side. **Appendix M** takes the design into greater detail with drawings showing each part that will have to be fabricated. All the features are dimensioned and materials are called out.

Pricing analysis was done on our design to figure out both what this press will cost and what it would have cost without the access to materials and donations that we

have been provided. Bills of materials with approximate pricing can be found on the layout drawings in **Appendix L**. The total cost for the purchased items for the press was \$422.62. Our initial budget estimation was \$552.86, with the museum initially providing \$300 in funds in addition to the steel they made available. Both our initial cost estimate and the final cost have been tabulated and can be found in **Appendix J.**

Product Realization:

Construction of the hydraulic press began with acquiring all the necessary steel U-channel beams for the frame structure. These beams were transported from the museum to Cal Poly's campus shops to be cut to size. A horizontal metal band saw was as seen in Figure 4 was used for this purpose. All bolt connection holes were then machined, primarily using drill presses (Figure 5). The required 32 x 1'' diameter support pin holes were drilled by stepping up bit sizes in ¼'' increments. All burred and sharp edges were smoothed out using pneumatic rotary tools and files. The beams were then either sandblasted or treated with Naval Jelly to remove all rust deposits and prepare them for paint. The sandblasting setup we used

Figure 4: Horizontal metal band saw cutting crossbeam to length

can be seen in Figure 6. Coats of rust preventative primer were sprayed on to all frame beams, followed by finish coats.

The trolley assembly required to support the cylinder was fabricated from 1'' thick steel flanges welded onto a ¼'' steel plate. Figure 7 shows our welding equipment.

Figure 5: Drill press drilling 1/2'' bolt holes

Our purchased I-beam trolley was then attached using bolts. The cylinder is supported by a 1 ¼'' shaft running through its clevis hole. 2'' angle iron pieces were then welded and bolted to the ¼'' plate to prevent the cylinder from swinging out of plane. Our original design called for cylinder support beams to prevent this. The original cylinder provided was perfectly sized to fit inside of these support beams. This cylinder, however, turned out to be unusable due to extreme corrosion of the internal bore and piston. We acquired a smaller used cylinder that would not contact the planned support beams. Therefore altered the design and came up with a new method of stabilizing the cylinder. The change in cylinders also altered our design pressure. Since the press would now need to operate at around 2000 psi, the relief valve we purchased would be ineffectual since it had a range of 500-1500 psi. The following design verification section covers this issue in more detail.

Figure 7: Sandblasting set-up

Figure 6: Welding apparatus

The winch, pulleys, pump handle, pressure gauge, selector valve, and hydraulic reservoir were all bolted and/or strapped to the frame at ideal locations for operation. Lengths of AN aircraft hydraulic hose were acquired from the museum and attached, with the proper fittings and Teflon wrapping, to all the mounted components. These hoses were then bundled and strapped to the frame for better aesthetics and to make sure nothing would get tangled. Figure 8 shows the finalized press as presented at the senior project expo.

Figure 8: Finalized press

Design Verification:

Testing of this hydraulic press included the analysis of the center of gravity of the press and its susceptibility to tipping, as well as the determining the moving platform's susceptibility to jamming and pinch points. The safety of all personnel either running the press or those working in the vicinity was the top concern when testing. **Appendix K** contains a detailed failure mode effects analysis which breaks down the individual tests we performed. A wooden mock up of the frame and winch-operated platform-lifting assembly was created to initially test proof-of-concept of our solution. Figure 9 shows this model constructed of 2x4s, with the winch and all the pulleys attached. We also used

this mock up for placement height estimates for the pump handle and other components. Winch speeds were measured on both the model and the final press to ensure the platform could be raised and lowered in a reasonable amount of time. When raised from the ground level to the top holes it took 1 minute and 10 seconds. Adjustment from one pin hole to the subsequent hole took on average 38 seconds, accounting for the time it took to remove and replace the support pins. Due to deadlines and scheduling conflicts, on site testing of the hydraulic system was not finished by the finalization of this report. As of the expo, all fittings were connected and all components were in place. The system simply needs to be charged with hydraulic fluid at the museum site. The load will be tested to ensure the supply of 10 tons of pressing force from the hydraulic press without bending, breaking, or significant movement of the frame. Any leaks in the system will be addressed and taken care of. Since the safety relief valve purchased is not sufficient to prevent the overloading of the frame, we will notify the museum of the needed replacement poppet for the valve and ensure the press is not operated above its limits.

Figure 9: Wooden press mock up with winch and pulley system attached

Conclusions and Recommendations:

The Bramah Hydraulics team has spent much time and effort designing and building this hydraulic press. Careful study of existing products have led us to conclude that specifications like the use of C-channel steel beams and an all bolted construction, although not ideal, are more than satisfactory for the required purpose. Our estimations show that the hydraulic cylinder could be used for a much higher capacity press, but the constraints mentioned limit the strength of the frame. The construction process led to many unforeseen problems. These problems were addressed on the fly during the fabrication of the press using scrap materials and a limited budget. This led to many solutions that may not have been the most elegant or optimized, but it should be noted that this prototype meets and exceeds all specified requirements. Our design may not be optimized for weight or minimization of parts, but we believe it represents a positive and powerful concept for an environmentally conscious consumer. Reusing or repurposing materials can be a significant way to improve the natural condition. A simple recommendation to buy a more refined catalog press would ignore this advantage while denying us as students such a beneficial learning experience.

Appendix A: Project Specifications Documents

At the beginning of this project we were supplied documents by Estrella Warbirds sponsor, Mr. Al Schade, specifying details of the hydraulic press. The two documents are seen below.

HYDRAULIC HAND PRESS DESCRIPTION

The hydraulic hand press frame shall be constructed of industrail steel U channel of sufficient size and strength to withstand 10 tons of compression on the cross beams and 10 tons of tension on the outside vertical beams.

The press shall be seven feet in height, four feet in width and shall free stand on the shop floor. The cross beams shall be double and adjustable in height over a four foot range starting from six inches below the end of the ram shaft. The hydraulic ram shall be suspended from two cross beams positioned across the top of the vertical frame members. The hand pump shall be mounted solidly to the right side of the vertical frame five feet above the base.

The pressure gauge shall be mounted within good view when operating the hand pump. An hydraulic reservoir of one gallon capacity shall be affixed to the press frame in a place that does not interfere with the operation of the press.

All frame connections and attaching parts shall utilize bolts rather than welding. The selector valve shall be placed near the hand pump for ease of operation. All hoses (AN type) shall be flexible and with aircraft connections.

The hydraulic fluid shall be aircraft 5606, red in color. The hydraulic ram shall be stabilized at the rod end to prevent any lateral movement.

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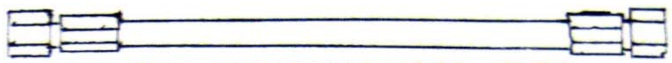
HYDRAULIC HAND PRESS

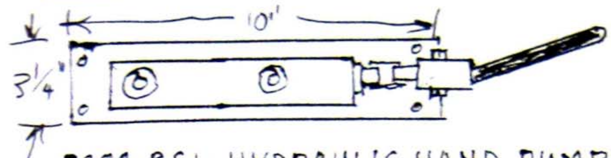
PARTS LIST

1



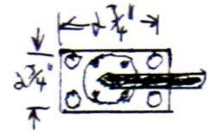
3000 P.S.I. HYDRAULIC HOSE (TYP.)

2



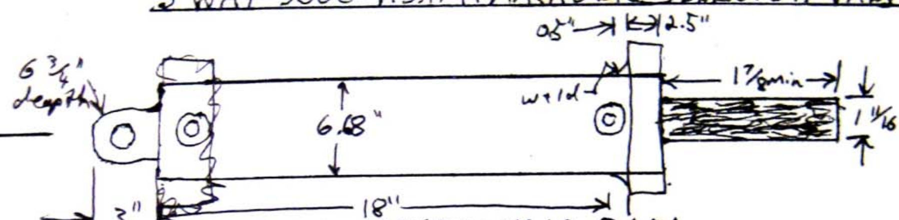
3000 P.S.I. HYDRAULIC HAND PUMP DOUBLE ACTION

3



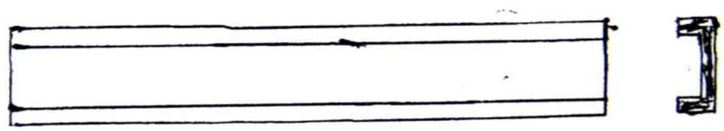
3 WAY 3000 P.S.I. HYDRAULIC SELECTOR VALVE

4



3000 P.S.I. HYDRAULIC RAM

5



INDUSTRIAL STEEL U CHANNEL (TYP.)

6

3000 P.S.I. HYDRAULIC PRESSURE GAUGE

Appendix B: Quality Function Deployment (QFD) Chart

This chart shows the steps in defining the project to meet the customer's requirements as well as give a numerical value to these requirements. These customer requirements are listed in the first column with the comparably defined engineering requirements listed in the first row. In the second and third columns the customer requirements were rated on importance then normalized to add up to 100 across the entire list. The engineering requirements are compared to the customer requirements through a correlation scheme of using a 1, 3, or 9 with 9 being a strong correlation and 1 being a week correlation. The far right column shows the correlation between currently available hydraulic presses and the customer requirements. The last row shows the final target values derived from the engineering/customer correlations and how the available products compare to it. This shows that what is currently available is unsatisfactory as well as guide the design in creating a hydraulic hand press to satisfy the Museums need.

Hydraulic Hand Press Estrella Warbirds Museum

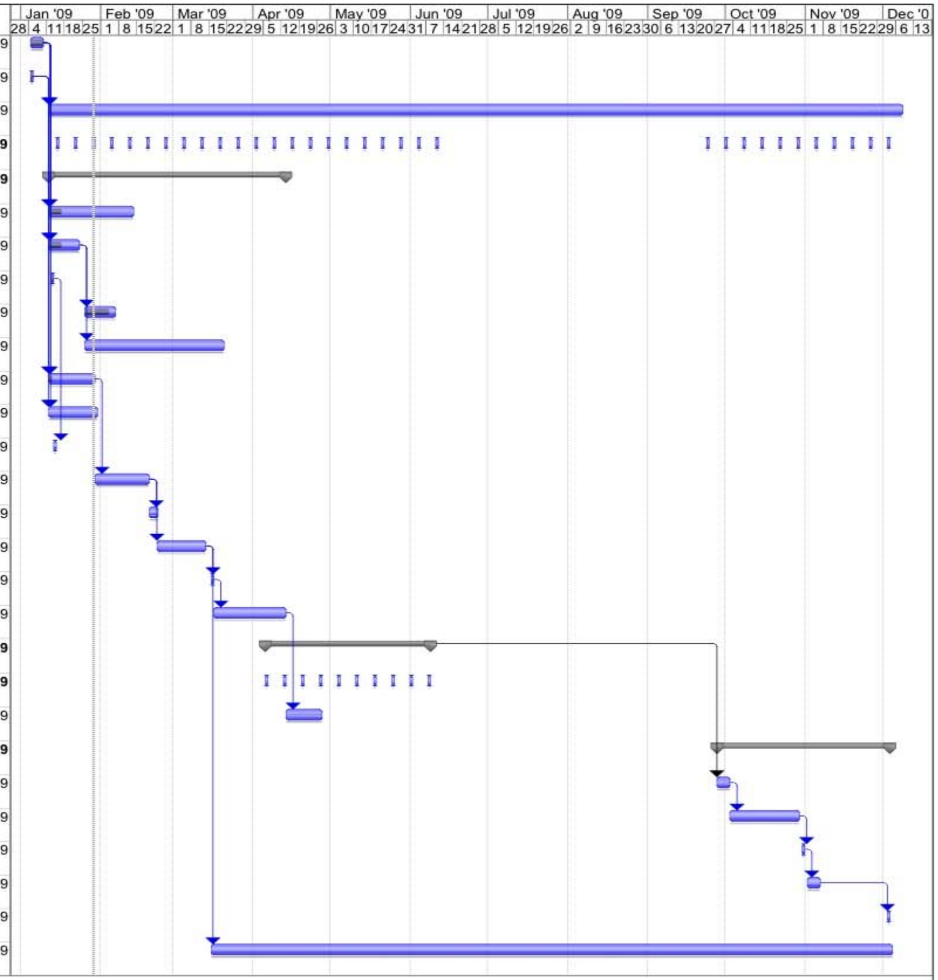
Customer Requirements	Weighting	Normalized Weight (Total 100)	Max. Width	Max. height	Minimum Reservoir Volume	Flexible hoses with aircraft connection	Uses aircraft 5606 hydraulic fluid	U-channel steel beams	Max. range of hand pump above base	Fastener Type	Double-wide crossbeams	Westward 12-ton	McMaster-Carr 12-ton	McMaster-Carr 25-ton Heavy Duty
			Engineering Requirements									Benchmarks		
Safe material loading	25	16						9				4	5	5
Stable hydraulic ram	15	10						3				4	5	5
Free Standing	13	8						9				5	5	5
Adjustable platform height	13	8						3			1	4	2	3
Easy access to hand pump	13	8	3	1					9			4	3	3
No leaks in connections	12	8				9						5	5	5
Able to be disassembled	10	7								9		5	5	5
Visible pressure gauge	10	7							1			1	1	3
Stable work piece platform	8	5									9	3	3	4
Sufficiently sized hydraulic reservoir	8	5			9							5	5	5
Selector valve close to hand pump	8	5							3			1	1	5
Uses convenient materials for fluid and hoses	8	5				9	9					1	1	1
Can't be too tall/short	5	3		9								3	5	4
Can't be too wide/thin	5	3	9									2	2	4
Totals	153	100												
Units			ft.	ft.	gal.				ft.					
Targets			4	7	1	yes	yes	yes	5	bolted	yes			
Benchmark #1 Westward 12-ton			2	5	N/A	no	no	yes	bad	bolted	yes			
Benchmark #2 McMaster-Carr 12-ton			2	2	N/A	no	no	yes	bad	bolted	yes			
Benchmark #3 McMaster-Carr 25-ton Heavy Duty			3.5	2.25	N/A	no	no	yes	bad	bolted	yes			

● = 9 Strong Correlation
○ = 3 Medium Correlation
Δ = 1 Small Correlation
Blank No Correlation

Appendix C: Project Schedule (Gantt chart)

The Gantt chart that follows shows the proposed time table for the design, fabrication, and testing of a Hydraulic Hand Press for the Estrella Warbirds Museum by Bramah Hydraulics. The hours listed in the chart were updated as progress was made on the project.

ID	Indicators	Task Name	Duration	Work	Start
1	✓	Project Presentations	1 wk	12 hrs	Mon 1/5/09
2	✓	Project Preference Form	1 day	4 hrs	Mon 1/5/09
3		Writing In Logbook	239 days?	60 hrs	Mon 1/12/09
4		**Meetings with Professor Owen**	**233 days**	**33 hrs**	**Thu 1/15/09**
38		**Hydraulic Press Design Phase**	**66 days?**	**196 hrs**	**Mon 1/12/09**
39		Hydraulic Background Research	5 wks	14 hrs	Mon 1/12/09
40		Develop Press Specs	2 wks	14 hrs	Mon 1/12/09
41	✓	Project Introduction Letter to Al Schade	1 day	4 hrs	Tue 1/13/09
42		QFD - House of Quality	2 wks	16 hrs	Mon 1/26/09
43		Solidworks Model	2 mons	20 hrs	Mon 1/26/09
44		Project Proposal	14 days	20 hrs	Mon 1/12/09
45		Conceptualization	3 wks	20 hrs	Mon 1/12/09
46		Initial Museum Visit	1 day	8 hrs	Wed 1/14/09
47		Interim Design Report	3 wks	30 hrs	Fri 1/30/09
48		Evaluate Estrella Warbirds Museum Feedback	0.25 wks	4 hrs	Fri 2/20/09
49		Final Design Report	3 wks	36 hrs	Mon 2/23/09
50		Critical Design Review	1 day	8 hrs	Mon 3/16/09
51		Procurement of Needed Steel U-beams	1 mon?	2 hrs	Tue 3/17/09
52		**Building Phase**	**46 days**	**90 hrs**	**Mon 4/6/09**
53		**Museum Visits for Assembly**	**46 days**	**80 hrs**	**Mon 4/6/09**
64		Machining Steel Beams	2 wks	10 hrs	Tue 4/14/09
65		**Testing Phase**	**51 days?**	**52 hrs**	**Mon 9/28/09**
66		Manufacturing and Test Review	1 wk	10 hrs	Mon 9/28/09
67		Press Operation Refinements	4 wks	20 hrs	Sat 10/3/09
68		Test on Aircraft Form	1 day	4 hrs	Sat 10/31/09
69		Design Alterations	1 wk?	10 hrs	Mon 11/2/09
70		Senior Design EXPO	1 day	8 hrs	Thu 12/3/09
71		Final Project Report	9.6 mons	40 hrs	Mon 3/16/09



Project: Bramah Hydraulics Gantt Chart NMB
Date: Thu 1/29/09

Nathan Brown

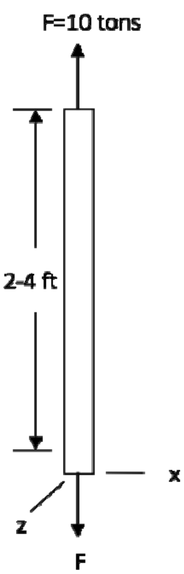
Page 1

Appendix D: Beam Sizing Analysis

This section shows the analysis used in selecting beam sizes for the Hydraulic Hand Press. The analysis began with sizing the double wide u-channel cross beams in tension at 10 tons.

<u>Vertical Beam Analysis</u>

Material properties of plain carbon steel:



$\sigma_{sy} = 36\ kpsi$ **Yield Stress**

$\sigma_U = 58 - 80\ kpsi$ **Ultimate Stress**

$E = 30\ Mpsi$ **Elastic Modulus**

$$\sigma_y = \frac{F}{A}$$

$$\sigma_y = \sigma_{sy} = \frac{F(S.F.)}{A}$$

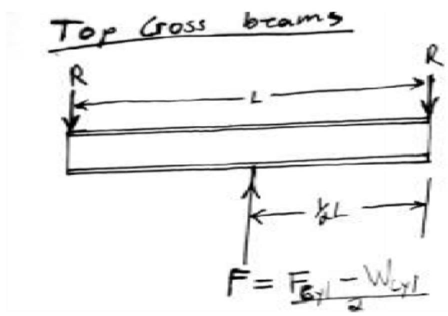
$$A = \frac{F(S.F.)}{\sigma_{sy}}$$

$$A = \frac{(20{,}000\ lbs)(2.5)}{(36{,}000\ {}^{lbs}/_{in^2})}$$

$$A \geq 1.39\ in^2$$

Any channel greater than C4. Chose 7" so the cylinder would fit between the cross beams.

Buckling analysis was done to see if it would show the need of an area greater than $1.39in^2$.



$$F_{cyl} = PA$$

$$F_{cyl} = 3000\ psi\ \left(\frac{\pi(6\ in}{4}\right)^2$$

$$F_{cyl} = 84{,}823\ lb_f$$

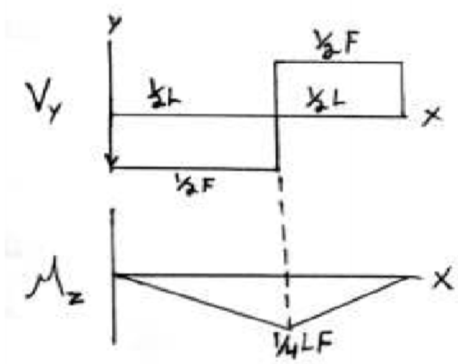
$$\sigma_{a,b} = \frac{M * y}{I}$$

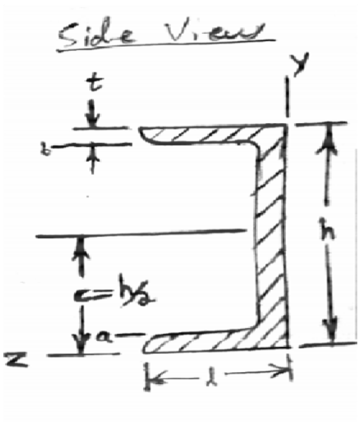
$h = 4\ in \qquad L = 4\ ft$

$\Sigma F_y = 0$

$F = 2R$

$\underline{R = \frac{1}{2}F}$





$$Q_a = \bar{y}' A'$$

$$Q_a = \left(1.227 + \frac{.273}{2}\right) l \cdot t$$

$$Q_b = \left(h - \frac{t}{2}\right) l \cdot t$$

$$W_{cyl} = 100\ lb$$

$$I_c = 3.85\ in^2$$

$$F = \left(\frac{20{,}000 - 100}{2}\right) lb$$

$$F = 9950\ lbs$$

$$\sigma_a = \frac{\left(\frac{h}{2} - t\right)(F)}{I_c}$$

$$\sigma_a = \frac{\left(\frac{4in}{2} - .296\ in\right)(9950\ lb)}{3.85\ in^4}$$

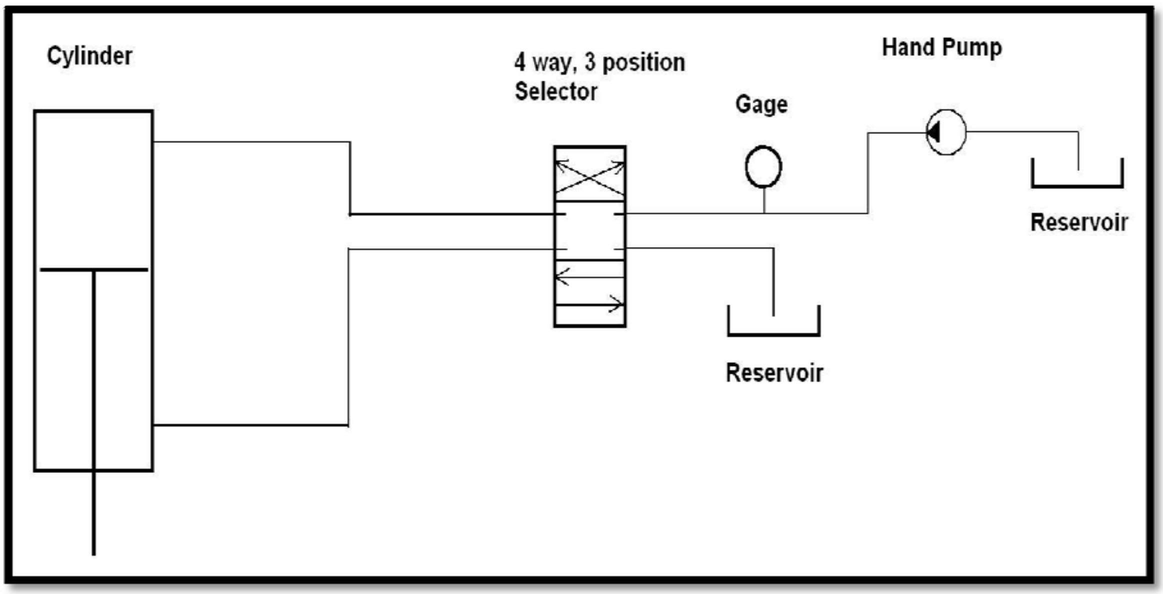
$$\sigma_a = 52846\ psi$$

This calculation shows that a 4 in channel is too small. 6 in was chosen from the following graph of various beam sizes and their stress levels.

Channel Size (min weight/ length)	Moment of Inertia I_{zz} (in^4)	Flange Thickness t (in)	Flange Length l (in)	Stress at mid section $\sigma = Mc/I_{zz}$	Stress at a $\sigma_a = My_a/I_{zz}$	First Moment of Inertia $Q_a = t^2 l/2$	Shear Stress $\tau = FQ/I_{zz} l$	Von Mises Stress $\sigma_{1a} = -\sigma_a/2 + \sqrt{(\sigma_a^2 + \tau^2)}$	Von Mises Stress $\sigma_{1a} = -\sigma_a/2 - \sqrt{(\sigma_a^2 + \tau^2)}$
8	32.6	0.390	2.260	1221	13222	3.35	453	6619	-19841
7	21.3	0.366	2.090	1635	17568	2.54	567	8793	-26361
6	13.1	0.343	1.920	2279	24217	1.86	737	12120	-36337
5	7.49	0.320	1.750	3321	34752	1.31	995	17390	-52142
4	3.85	0.296	1.584	5169	52846	0.87	1417	26442	-79288
3	1.66	0.273	1.410	8991	88255	0.52	2231	44156	-132411

Appendix E: Hydraulic Schematic

This shows the hydraulic system that will be used in the Hydraulic Hand Press project. The reservoir is a 1 gallon drum that holds excess hydraulic fluid. Everything but the reservoir has already been provided by the museum. The selector switch allows the fluid to push the cylinder bore in or out. The gauge was placed right after the hand pump to ensure the largest pressure reading in the system at all times. A fixed 700 psi release valve will be utilized to ensure the frame is not loaded to failure and remains inside its designed 10-ton range.



Appendix F: Decision Matrices for Platform Lifting Ideas

These decision matrices were used to compare potential designs to one another in order to choose the best one. In the matrix, a series of design categories, such as the design cost, ease of operation, and safety, were written next to a list of competing designs. In these tables, each design is compared to an idea that is set as the standard for all the other designs, this is known as the datum. The designs are rated for each category using either a plus indicating whether a design is better than the datum design, a minus indicating the idea is worse, or an 'S' indicating the two are the same. The pluses, minuses, and "sames" were added up and the designs with the highest numbers became the most likely methods to choose.

Concepts		**By Hand (Datum)**	Scissor Hydraulics	Telescoping Hydraulics	Hand Winch and Pulleys	Rack and Pinion
Criteria	Wgt					
Cost	5	**S**	-	-	-	-
Ease of Operation	3	**S**	+	+	+	-
# of Parts	1	**S**	-	-	-	-
Manufacturability	3	**S**	-	-	-	-
Safe Operation	5	**S**	+	+	+	+
Part Availability	3	**S**	-	-	-	-
Range	5	**S**	-	-	S	S
Load Capacity	3	**S**	+	+	+	+
Interference	4	**S**	S	S	-	-
	#+	**0**	4	4	4	3
	#-	**0**	5	5	6	7
	#S	**8**	1	1	0	0
Weighted total		**0**	-4	-4	-8	-14

Concepts		By Hand	Scissor Hydraulics	Telescoping Hydraulics	**Hand Winch and Pulleys (Datum)**	Rack and Pinion
Criteria	Wgt					
Cost	5	+	-	-	**S**	-
Ease of Operation	3	-	S	S	**S**	S
# of Parts	1	+	S	S	**S**	-
Manufacturability	3	+	-	+	**S**	-
Safe Operation	5	-	S	S	**S**	S
Part Availability	3	+	-	S	**S**	S
Range	5	S	-	-	**S**	S
Load Capacity	3	-	S	S	**S**	S
Interference	4	+	+	+	**S**	+
	#+	5	1	2	**0**	1
	#-	3	4	1	**0**	3
	#S	0	4	5	**8**	4
Weighted total		8	-10	5	**0**	-8

Concepts		By Hand	**Scissor Hydraulics (Datum)**	Telescoping Hydraulics	Hand Winch and Pulleys	Rack and Pinion
Criteria	Wgt					
Cost	5	+	**S**	-	+	+
Ease of Operation	3	-	**S**	S	S	S
# of Parts	1	+	**S**	S	S	-
Manufacturability	3	+	**S**	+	S	-
Safe Operation	5	-	**S**	S	S	S
Part Availability	3	+	**S**	-	+	+
Range	5	+	**S**	S	+	+
Load Capacity	3	-	**S**	S	S	S
Interference	4	S	**S**	S	-	-
	#+	4	**0**	1	2	2
	#-	3	**0**	3	1	3
	#S	1	**8**	5	5	3
Weighted total		4	**0**	-2	4	-3

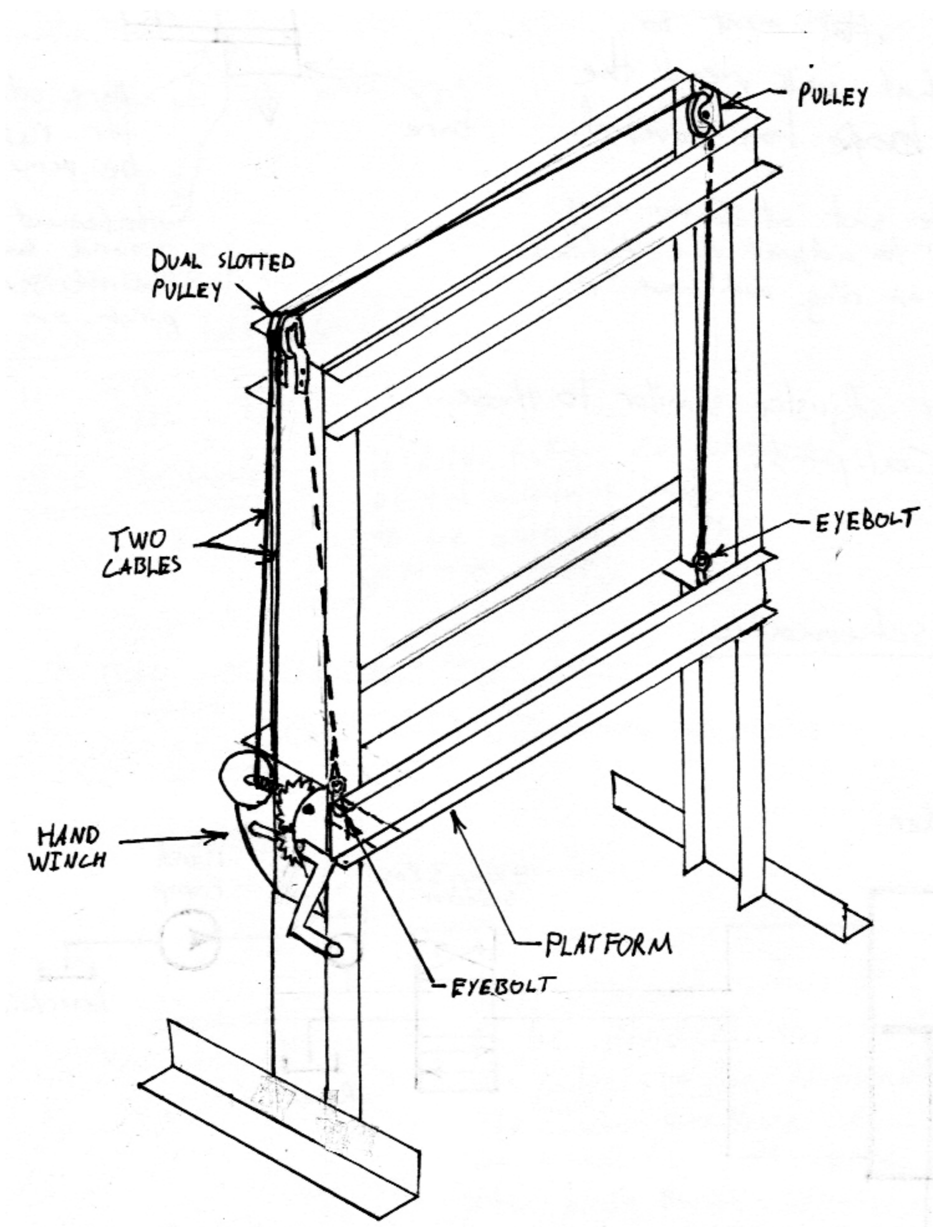
The first matrix shows nothing being close to the by hand method due to everything being more expensive or requiring more parts.

The second matrix using the hand winch as the datum showed that the hand winch and the telescoping methods were the most promising.

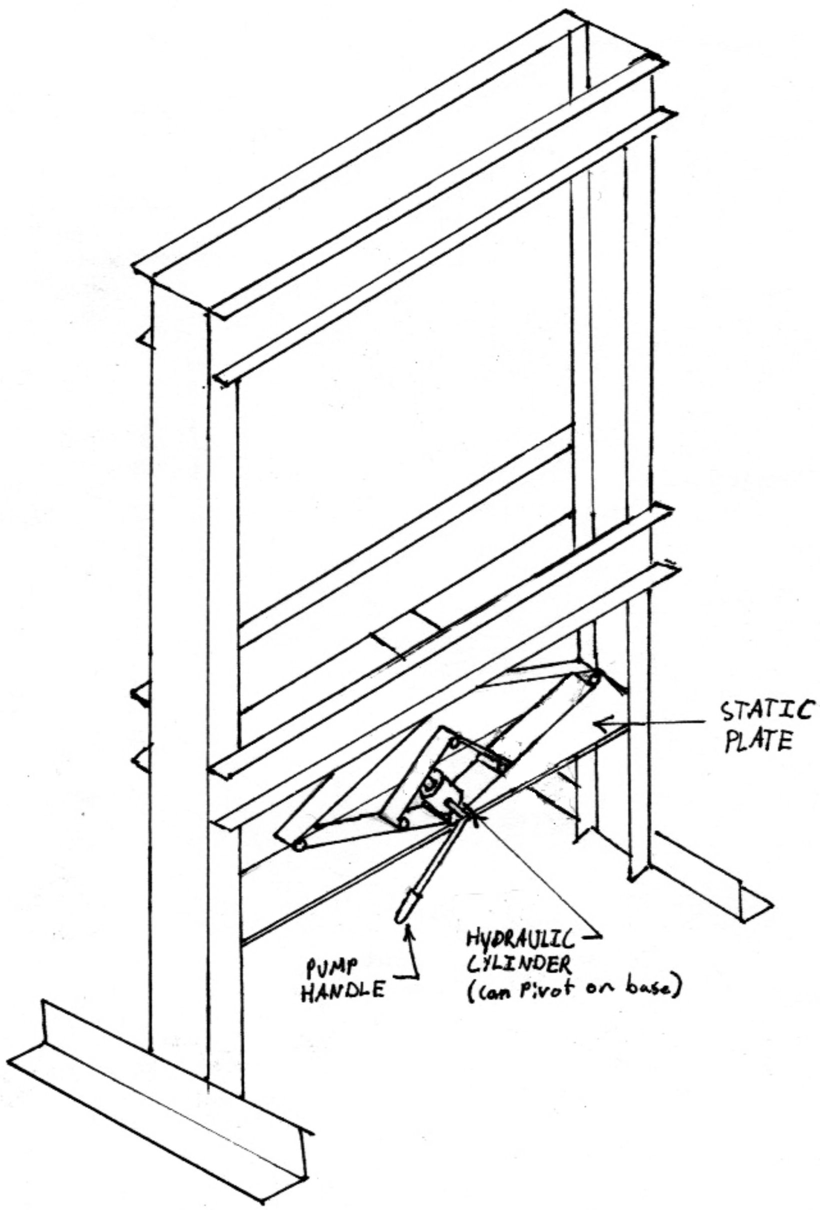
The third matrix used the scissor hydraulics as the datum and came up with the hand winch as the best choice. We selected the hand winch design because of is consecutive high ratings in the matrices.

Appendix G: Lift Concept Sketches

Winch/Pulley:



Scissor Crank:



APPENDIX H: Platform Support Pin Calculation

Calculations for sizing the adjustable platform support pins can be seen below. The maximum pressing force was combined with a load estimation of 200 lbs. and an approximation of the weight of the platform. This combined force was then distributed to the two support pins. By relating a shear stress equation to the material yield stress, a pin diameter was found, with a total safety factor of 4.2. Two 1'' nominal diameter ASTM-A36 steel rods will be used to support the press platform. Deflection of the loaded pins was also calculated to rule out such a failure mode. The analysis showed less than 0.075 in. deflections in a worst-case over-hanging beam bending situation. A simple force over area calculation was done on the support pinhole projected area in the vertical members. The applied contact stress allowed for an adequate safety factor of 2.6.

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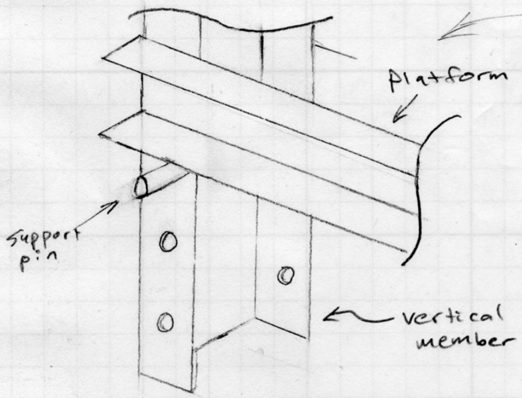
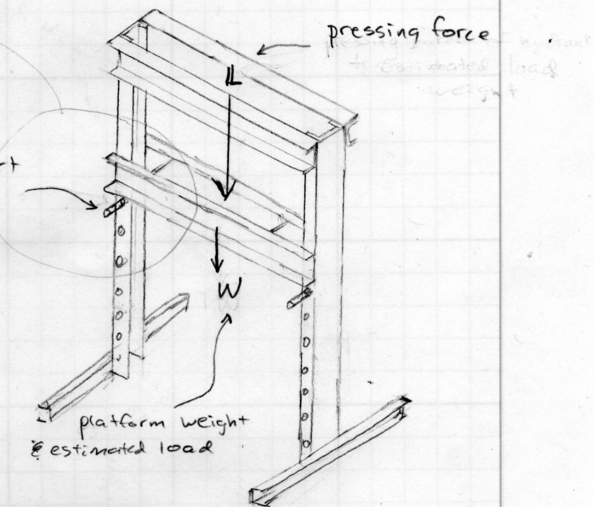
Support Pin Analysis:





$L = 2(10{,}000\ \text{lb}) = 20{,}000\ \text{lb}$

$W = \underbrace{25\ \text{lb/ft}\,(4\text{ft})(2)}_{\text{platform}} + \underbrace{200\ \text{lb}}_{\text{load}} = 400\ \text{lb}$ $\qquad F = W + L = 20{,}400\ \text{lb.}$

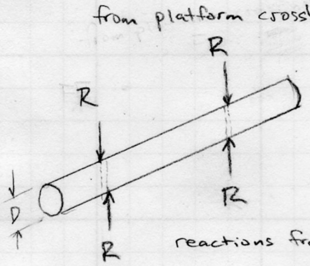
[A-36 steel 4' X 10" channel]

oversized (using 6" crossbeams)

Support Pin Shearing

$R = \dfrac{F}{4} = 5100\ \text{lb.}$

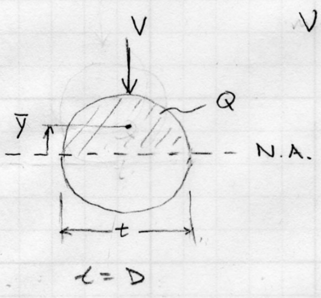
from platform crossbeams



Assume pin material A-36 steel

$E = 29\ \text{Msi} \quad \sigma_y = 36\ \text{ksi} \quad \sigma_{ut} = 58\ \text{ksi}$

reactions from vertical member flanges at center of pin holes.



$V = \text{max shear} = R = 5100\ \text{lb.}$

$$Q = A_{shaded} \cdot \bar{y} = \frac{\pi D^2}{8}\left(\frac{2D}{3\pi}\right) = \frac{D^3}{12}$$

$$I_{circle} = \frac{\pi D^4}{64}$$

shear stress $\quad \sigma_s = \dfrac{VQ}{It} = \dfrac{(5100\ \text{lb})\left(\frac{D^3}{12}\right)}{\frac{\pi D^4}{64}\,(D)} = \dfrac{27{,}200}{\pi D^2}$

w/ matr. S.F = 2 $\Rightarrow \quad \dfrac{27{,}200}{\pi D^2} = \dfrac{\sigma_y}{2} = 18\ \text{ksi}$

$D = 0.694\ \text{in} \Longrightarrow$ use $\boxed{1\ \text{in.}}$ nominal for S.F. = 4.2 total

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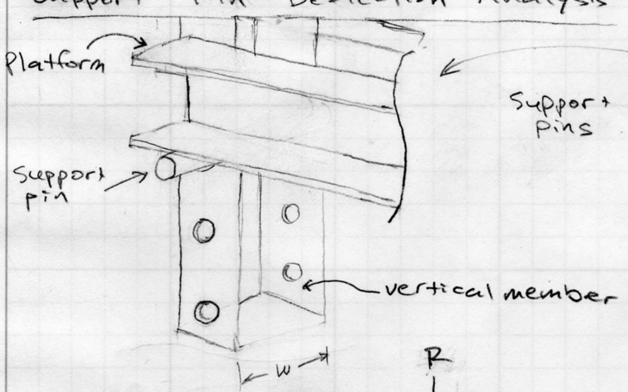
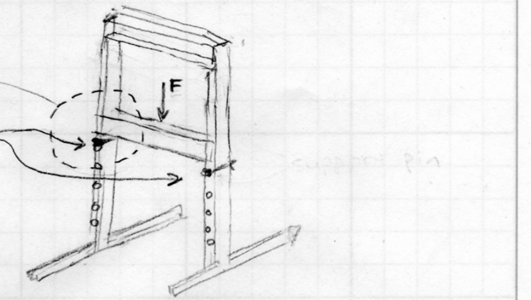
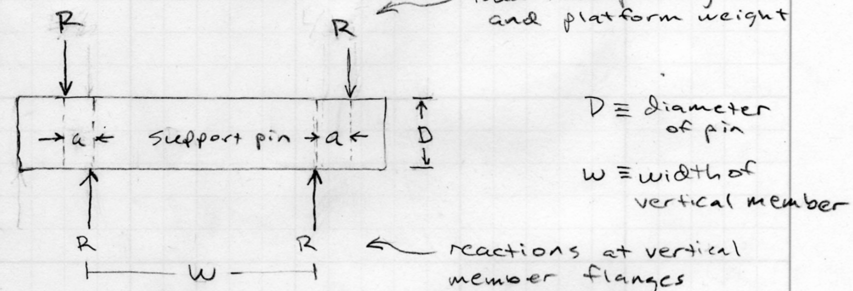
Support Pin Deflection Analysis







$D \equiv$ diameter of pin

$w \equiv$ width of vertical member

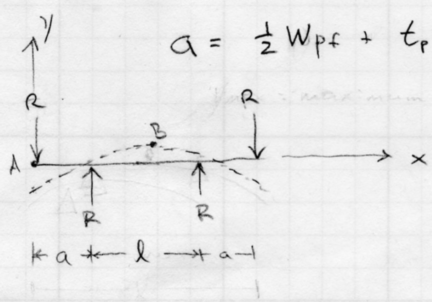
For deflection analysis, modeled as a simply supported beam.

Assumed 1/2 loads act through midpoint of the platform flange width, with R acting through the midpoint of the vertical flange thickness, symmetrically.

Distance a is estimated as follows:

$$a = \frac{1}{2} W_{pf} + t_p + \frac{1}{2} t_{vf}$$

(W_{pf} : platform flange width
t_p : platform web thickness
t_{vf} : vertical member flange thickness)



A. Deflection at F application : $y = \frac{Ra^2}{6EI}(2a + 3l)$

B. Deflection at center of beam : $y = -\frac{Ral^2}{8EI}$

Support Pin Analysis CONT.

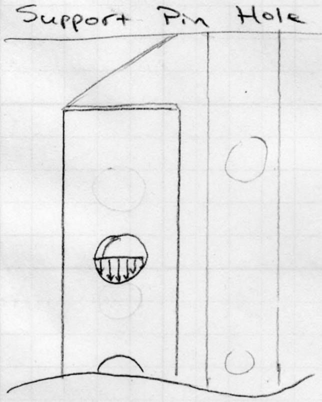
W/ $a = \frac{1}{2}(1.920") + 0.343" + \frac{1}{2}(0.366") = 2.169"$

$E = 29$ Msi, $I_c = \frac{\pi (1 in)^4}{64} = 0.04909\ in^4$, $l = 7 in$, $R = 5100$ lb.

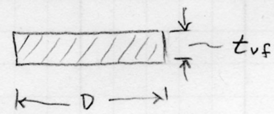
deflection at A = 0.071 in. (downward)

deflection at B = 0.048 in. (upward)

Support Pin Hole Contact Stress



Projected area of support pin hole



$A_p = (1 in)(0.366 in) = 0.366\ in^2$

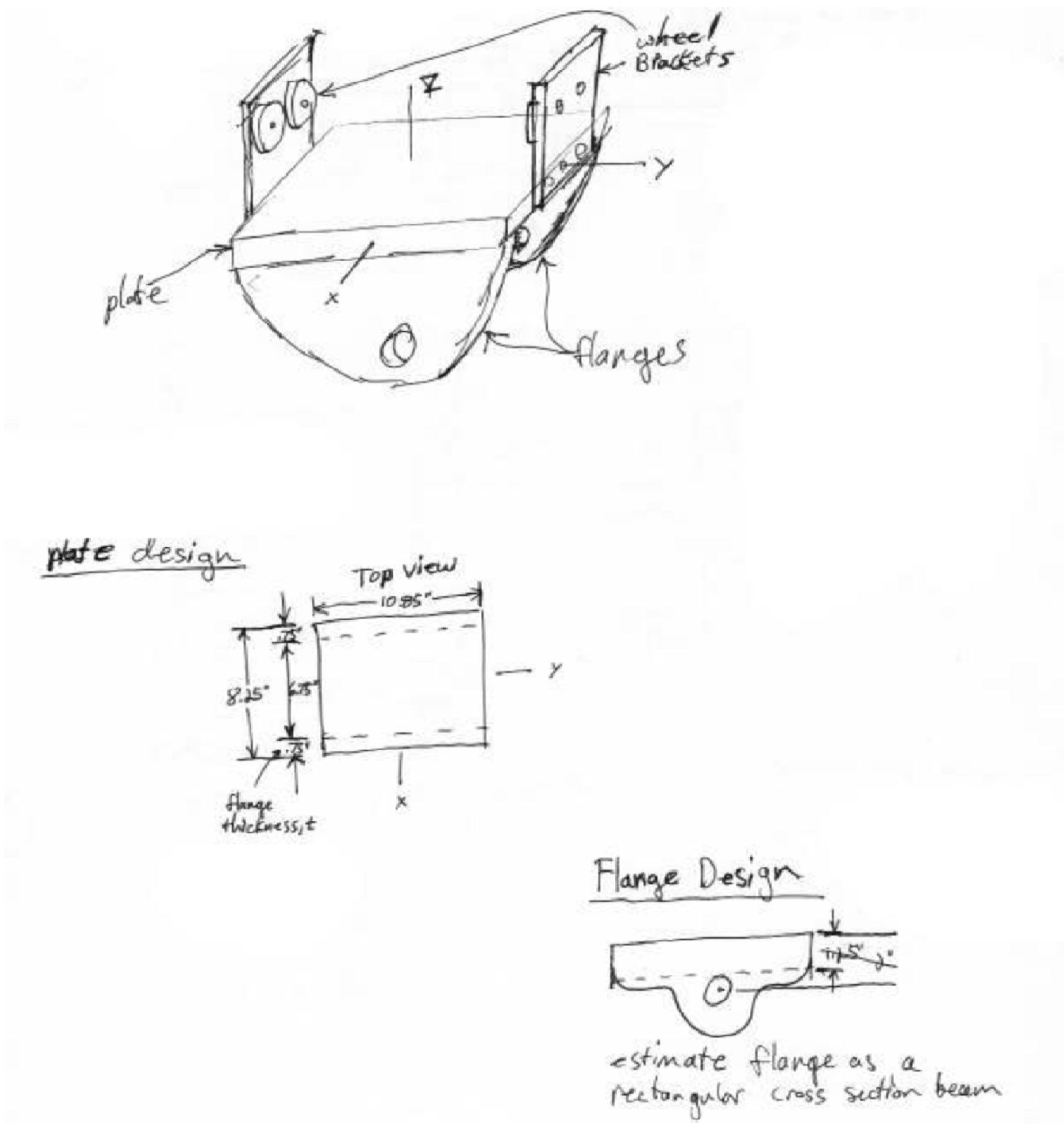
compressive stress $\sigma_c = \frac{F}{A} = \frac{R}{A_p} = \frac{5100 lb}{0.366\ in^2} = 13,900$ psi

gives S.F. of 2.6 for A-36 yield strength

APPENDIX I: Trolley Sizing Calculation

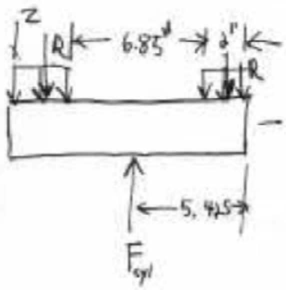
Here, the trolley base plate and flanges are sized based on stress. Applied stresses are compared to allowable stresses to give nomial dimensions such as length, width, and material thickness. To keep it simple, we designed the trolley out of plain carbon steel A-36. Better material may be available which will allow for less bulk.

Cylinder Trolley Design Analysis



assumptions:

small shear s

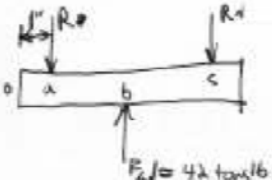


(4+ tons)

$$\Sigma M_a = 0$$

$$-8.85\,\text{in}\,R + F_{cyl}\left(\frac{6.85}{2} + 1\,\text{in}\right) = 0$$

$$R = 21 \text{ tons}$$

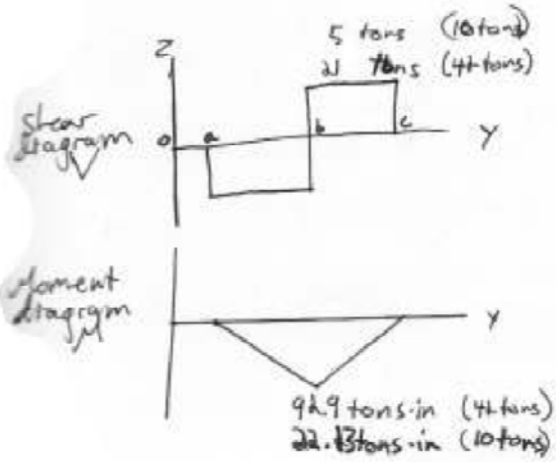


(10 tons)

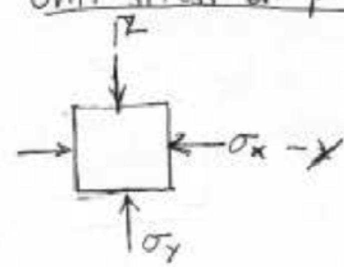
$$\Sigma M_a = 0$$

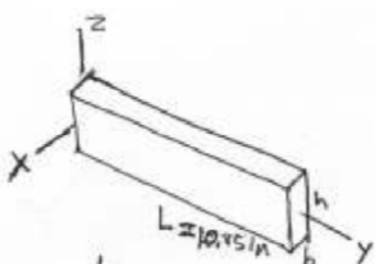
$$-(8.85\,\text{in}\,R + F_{cyl}\left(\frac{6.85}{2} + 1\,\text{in}\right)) = 0$$

$$R = 5 \text{ tons}$$



Unit stress at point b





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

$$\sigma_x = \frac{Mc}{I} = \frac{Mc}{\left(\frac{b h^3}{12}\right)}$$

$$\sigma_x = \frac{12Mc}{b h^3}$$

$$\sigma_y = \frac{F}{A}$$

$$\sigma_y = \frac{F_{cyl}}{bh}$$

Von Mises Failure Criteria

$$\sigma' = (\sigma_x^2 - \sigma_x\sigma_y + \sigma_y^2 + \cancel{3\tau_{xy}^2}^{\,0})^{1/2}$$

mises stress

$$= \left(\frac{144M^2c^2}{b^2h^6} - \frac{12MF_{cyl}c}{b^2h^4} + \frac{F_{cyl}^2}{b^2h^2}\right)^{1/2}$$

Von Mises stress cont.

$$\sigma' = \left(\frac{36 M^2}{b^2 h^4} - \frac{6 M F_{cyl}}{b^2 h^3} + \frac{F_{cyl}^2}{b^2 h^2} \right)^{1/2} = \frac{\sigma_{sy}}{2}$$

Flange thickness, b

using force over area of direct shear.

A = projected Area of Pin.

See figure on page 41, where $t = b$

$$\frac{\sigma_{sy}}{2} = \frac{F_{cyl}/2}{A}$$

$$b = \frac{2 F_{cyl}/2}{d\, \sigma_{sy}}$$

$$= \frac{(84{,}000\,lb)}{(1.5\,in)(36{,}000\,psi)}$$

$$\underline{\underline{b = 1.5\,in}}$$

for 10 ton press load

$$\Rightarrow \quad b = \frac{20{,}000\,lb}{(1.5\,in)(36{,}000\,psi)}$$

$$b = .37'' \approx .5\,in$$

$$\frac{\sigma_{sy}}{2} = \left[\frac{1.3809 \times 10^5\,ton^2}{h^4} - \frac{1.0405 \times 10^4\,ton^2/in}{h^3} + \frac{784\,tons^2}{h^2} \right]^{1/2}$$

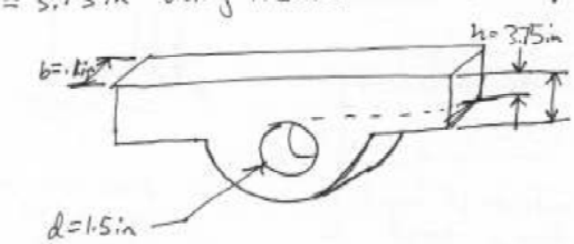
Von Mises stress using 10 tons not 42 tons Press load.

$$\frac{\sigma_{sy}}{2} = \left[\frac{36\,(22.13\,ton\,in)^2}{(.5\,in^2)^2 h^4} - \frac{6\,(22.13\,ton\,in)(10\,ton)}{(.5\,in)^2 h^3} + \frac{(10\,ton)^2}{(.5\,in)^2 h^2} \right]^{1/2}$$

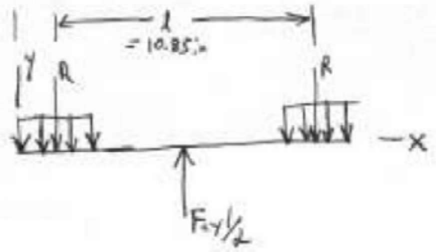
$$9\,\frac{tons}{in^2} = 18{,}000\,psi = \left[\frac{70522.1\,ton^2}{h^4} - \frac{5311.2\,ton^2/in}{h^3} + \frac{400\,ton^2/in^2}{h^2} \right]^{1/2}$$

$$\boxed{\cancel{h \approx 3.5\,in}}$$

@ b = 1, h = 3.75 in using iterations on excell spreadsheet "TrolleyFlange Study.xl



Trolley Flange deflection



Free body diagram of Trolley flange as analysed on pg. 45-47 with added plate thickness of 1" on top

deflection equation from Sigley's 8th ed ~~pg~~ Table A-9-5:

$$y_{max} = -\frac{F_{cyl}\, l^3}{24 E I}$$

$$I = \frac{b h^3}{12}$$

$$= \frac{-F_{cyl}\, l^3}{2 E \cancel{b} h^3}$$

$$= \frac{-(20{,}000\,lb)(10.85\,in)}{2(30\,Mlb/in^2)(1\,in)(4.75\,in)^3}$$

$$\boxed{y_{max} = -3.37\times10^{-5}\,in}$$

Seeing deflection of hight based on trolley flange only:

$$= \frac{-(20{,}000\,lb)(10.85\,in)}{2(30\,Mlb/in^2)(1\,in)(3.75\,in)^3}$$

$$\boxed{y_{max} = -6.86\times10^{-5}\,in}$$

Side view of Trolley Flange and plate beam

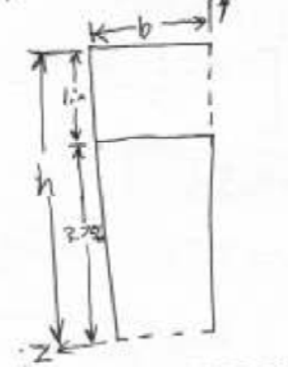


plate continued in-y direction

b = 1in
h = 4.75in

flange hole centerline

plate thickness (viewed as part of h above) chosen as conservative thickness since the Trolley flange is capable of carrying all the load. The thickness was then chosen to be made from same ~~material~~ size metal as the trolley flange.

APPENDIX J: Cost Analysis

The table below shows a pricing breakdown for required materials and parts. Many of these items we have priced for a projected total cost, aware that many materials will be donated. Our final pricing outline is seen on the next page. All receipts, packing orders, and invoices refered to here were kept and are available.

Initial Cost Analysis

Fasteners	Manufacturer Name	Product Number	Qty	Price Ea.	Price Total
Eye Bolts	McMaster-Carr	3014T45	2	$2.92	$5.84
Bolts (Beam connections)	McMaster-Carr	92865A835	25	$0.90	$22.50
Nuts	McMaster-Carr	90490A436	25	$0.20	$5.00
Single Mounted Pulley	McMaster-Carr	3099T34	2	$6.39	$12.78
Double Mounted Pulley	McMaster-Carr	3099T44	1	$10.74	$10.74
Block Pulley	McMaster-Carr	3099T13	1	$10.83	$10.83
Wire (3/16")	McMaster-Carr	3450T31	25	$0.46	$11.50
Paint					
4" steel Channel	Metals Depot	C2454	6	$28.08	$168.48
7" Steel Channel	Metals Depot	C2798	2	$117.60	$235.20
2" Angle Steel	Metals Depot	A1211218	2	$10.00	$20.00
700 PSI Safety Valve	Northern Tool	RD-1850-H	1	49.99	$49.99
				Total	$552.86

Cost Analysis cont.

Bramah Hydraulics Final Cost Breakdown for Estrella Warbirds Hydraulic Hand Press
December 2nd, 2009

Retailer/Order No.	Item	Price	Tax+S/H	Subtotal
McMaster-Carr	1500 lb. worm gear winch (3/16'')	$ 63.75		
0508NBROWN	zinc-plated double pulley (3/16'')	$ 10.74		
	zinc-plated double pulley swivel eye	$ 13.97		
	2 x zinc-plated single pulley (3/16'')	$ 12.78		
			$15.60	$ 116.84
Grizzly on Amazon	1-ton Heavy Duty I beam trolley	$ 59.95		
104-8373649-1065006			$11.76	$ 71.65
McMaster-Carr	Grade 5 zinc-plated 3/4''-10 hex cap	$ 9.99		
1003NBROWN	Grade 5 zinc-plated 3/4'' nyloc nuts	$ 6.19		
	3/4'' yellow zinc steel flat washers	$ 7.81		
			$ 7.22	$ 31.21
Dynamtic, Inc.	Cross Hydraulic Relief Valve	$ 65.00		
86P58766FU171564U			$10.00	$ 75.00
Fastenal	4 x 1/2''-13 gr. 5 hex nuts	$ 0.91		
WQ9Y8PK43119	4 x 1/2'' flat washers	$ 0.37		
	2 x 3/4''-10 gr. 5 hex cap screws	$ 2.52		
	4 x 1/2''-13 gr. 5 hex cap screws	$ 2.07		
	2 x 3/4''-10 gr. 8 nyloc nuts	$ 1.68		
	2 x 3/4 SAE flat washers	$ 0.54		
			$ 8.32	$ 16.41
McMaster-Carr	2 x 1'' Nitride coated steel shaft (12'')	$ 28.60		
1019NBROWN			$ 7.61	$ 36.21
McMaster-Carr	1-1/4'' Nitride coated steel shaft (12'')	$ 21.70		
1125NBROWN	2 pk. Gr. 5 3/4''-10 zinc hex screws	$ 14.86		
			$ 8.77	$ 45.33
Home Depot	Rustoleum Paint and Primer	$ 29.97		$ 29.97
(In store)				
			TOTAL	$ 422.62

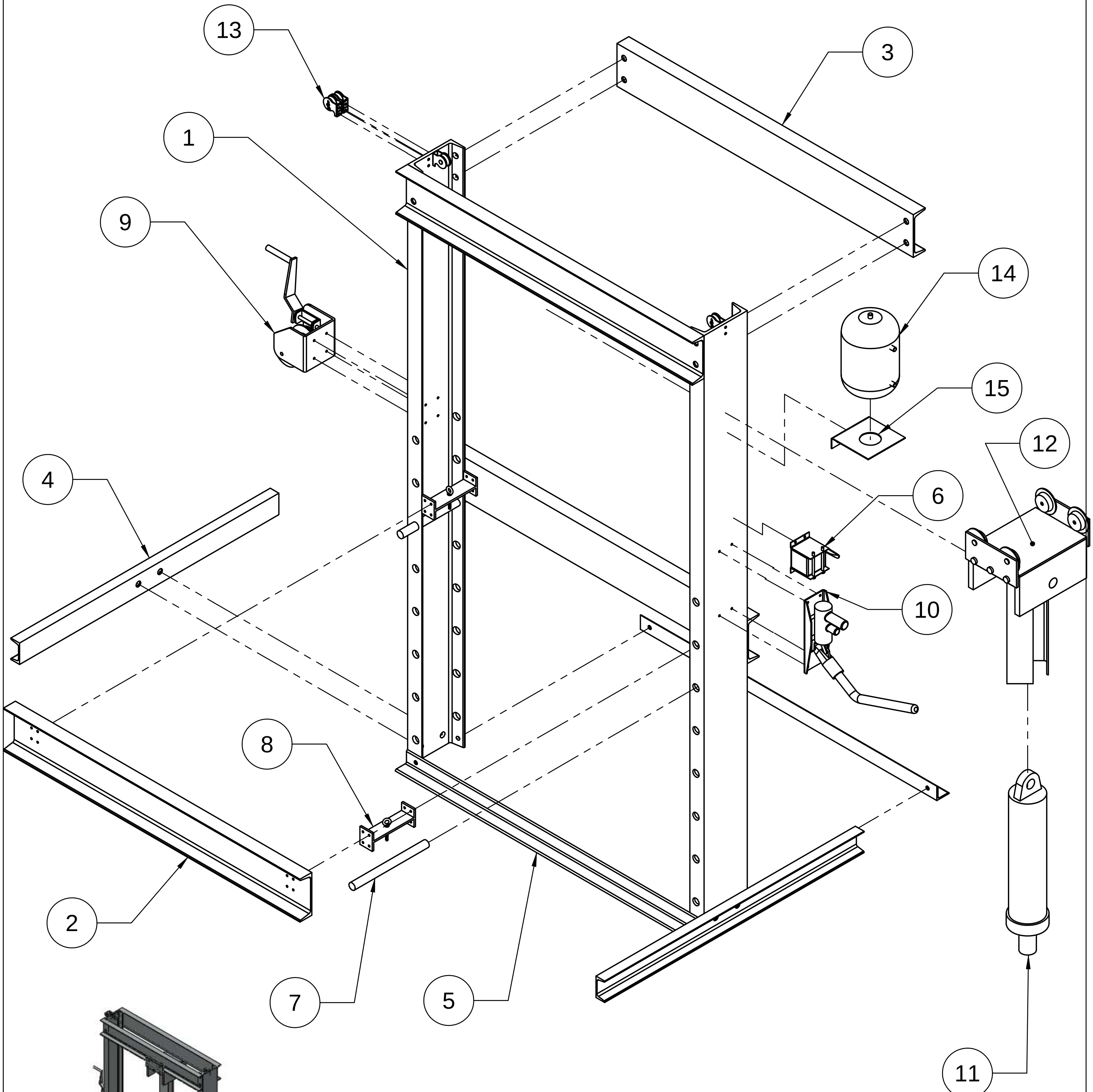
APPENDIX K: Failure mode effects analysis (FMEA)

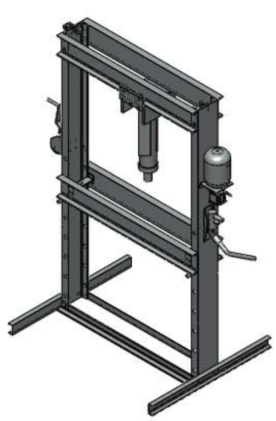
The table here displays our plan for identifying and testing the various failure modes and effects associated with the operation of this press.

	Report Date: 2-24-09	**TEST PLAN**	Estrella Warbirds		
Item No	Specification or Clause Reference	Test Description	Acceptance Criteria	Test Responsibility	Test Stage
1	Stable Frame	Analysis using a horizontal force will be required to just lift one side of a leg using statics and the center of gravity, from a force applied at shoulder height by two average males.	The frame remains static on the ground for a force of 200 lbs	MK + NB	CV
		Two average men pushing the frames at shoulder height.	The frame remains static on the ground	MK + NB	PV
		Using analysis, the force of an truck hitting the frame will only make the frame slide and not tip over.	Simulating a truck moving at 5 mph with a bumper height of 3ft high, the frame wont tip.	MK + NB	CV
2	Aircraft cable breaking	The aircraft cable and hand winch to hold the platform with a weight for a specified amount of time.	Pass - Hold the platform and 100 lbs for 10 min without breaking.	MK + NB	PV
3		The aircraft cable and hand winch to hold the platform with a weight and move to a specified height.	Pass - Hold the platform and 100 lbs and move to the max height from 4ft below.	MK + NB	PV
4	Hydraulic Leak	Test the Hydraulic system for leaks during operation.	Pass - Seals and connections remain dry for 20 cycles of the piston from max to min extension.	MK + NB	PV
5	Pump Handle Breaks	Analyze the amount of force required to bend the handle when it is fully extended and at a static position.	Pass - Max deflection of .01 in.	MK + NB	CV
6	Insufficient Pressure Requirements	Measure the pressure at various points in the line	Pass - Test both inlet and outlet ports on cylinder while at bore extremes to be able to reach 3000 psi.	MK + NB	PV
7	Obstructions presenting possible impact	Avoidance of frame making contact with the operator or bystanders	Simulate operation of the system while standing in various positions around the press.	MK + NB	DV
8	Test Ergonomics (Single man operation of platform lifting)	Study fatigue of operator turning the Hand Winch and cycling the Hand Pump	Can Raise/Lower the Platform 2 feet without resting or switching hands and can achieve full cylinder bore extension of 18 inches.	MK + NB	PV
9	Max Pressure	Make sure safety release valve engages as rated and all hydraulic components hold max pressure.	Fully extend cylinder bore and increase pressure slowly until max pressure is reached or safety valve is engaged.	MK + NB	PV
10	Platform pins won't jam	Ensure the platform pins slide smoothly into and out of each position along the vertical beams	Insert the platform pins and load at 50% for each position. Repeat process once all positions have been tested	MK + NB	DV+ PV

Appendix L: Layout Drawings with Bills of Materials

Layout DWG. NO. 1 shows the exploded view of the proposed hydraulic hand press for the Estrella Warbirds Museum. The Bill of Materials (BOM) has a minimal cost analysis of necessary purchases. The availability of the rest of the items was checked with the museum so as to save as much as possible on materials. DWG. NO. 2 shows the exploded view of the cylinder's proposed horizontal motion trolley. Based on a I-beam trolley, the assembly was fabricated to hold the cylinder rigid during operation.





Note: Hardware not pictured

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	NAME	DATE
DRAWN	Nathan Brown	12/8/09
CHECKED	Matt Knorr	12/8/09
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

MATERIAL
Steel: Various

FINISH

NEXT ASSY	USED ON
APPLICATION	

DO NOT SCALE DRAWING

Hydraulic Hand Press Assembly

Bramah Hydraulics
Cal Poly San Luis Obispo
in conjunction with the
Estrella Warbirds Museum

SIZE A | DWG. NO. 1 | REV.

SCALE:1:16 | WEIGHT: 607 lb | SHEET 1 OF 3

ITEM NO.	PART	DESCRIPTION	QTY.	PRICE
1	Vertical Member	C7x14.75 A-36 Steel from Estrella/Donations/PRW	2	-
2	Platform Cross Member	C6x8.2 A-36 Steel from Estrella/Donations/PRW	2	-
3	Top Cross Member	C6x8.2 A-36 Steel from Estrella/Donations/PRW	2	-
4	Leg Member	C3x4.1 A-36 Steel from Estrella/Donations/PRW	2	-
5	Base Support Angle Iron	2" Angle Iron from Estrella/Donations/PRW	2	-
6	Selector Valve	Supplied by the Estrella Warbirds Museum	1	-
7	Platform Support Pin	Part 4437T121 from McMaster Carr	2	$21.66
8	Platform Center I-Bracket	Part 9517K215 from McMaster Carr	2	$32.43
9	Hand Winch	3205T15 w/ cable from McMaster Carr	1	$86.81
10	Hand Pump	Supplied by the Estrella Warbirds Museum	1	-
11	Hydraulic Cylinder	Supplied by the Estrella Warbirds Museum	1	-
12	Trolley Assembly	See DWG. NO. 2 for Trolly BOM	1	-
13	Lift Pulley	Part 3099T13 from McMaster Carr	4	$10.83
14	Hydraulic Reservoir	1 Gallon Tank as specified (dimension unknown)	1	-
15	Reservoir Platform	Salvaged stainless steel from Cal Poly scrap	1	-

Vendor Data:

Estrella Warbirds Museum - Sponsers of hydraulic press project. Supply yard and shop with available steel, tools, hardware, and cables.

www.ewarbirds.org
4251 Dry Creek Road
Paso Robles, CA 93446

PRW Steel - Paso Robles Welding Steel Supply. Founded by Keith Kirkland, with extensive experience in the manufacturing process, welding & retail steel sales, focusing on complete customer satisfaction.

www.prwsteel.com
2905 Union Road
Paso Robles, CA 93446

McMaster Carr - General online construction supplier. Fast delivery times and good support.

www.mcmaster.com
600 N County Line Rd.
Elmhurst, IL 60126-2081

NEXT ASSY | USED ON
APPLICATION

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
MATERIAL
FINISH
DO NOT SCALE DRAWING

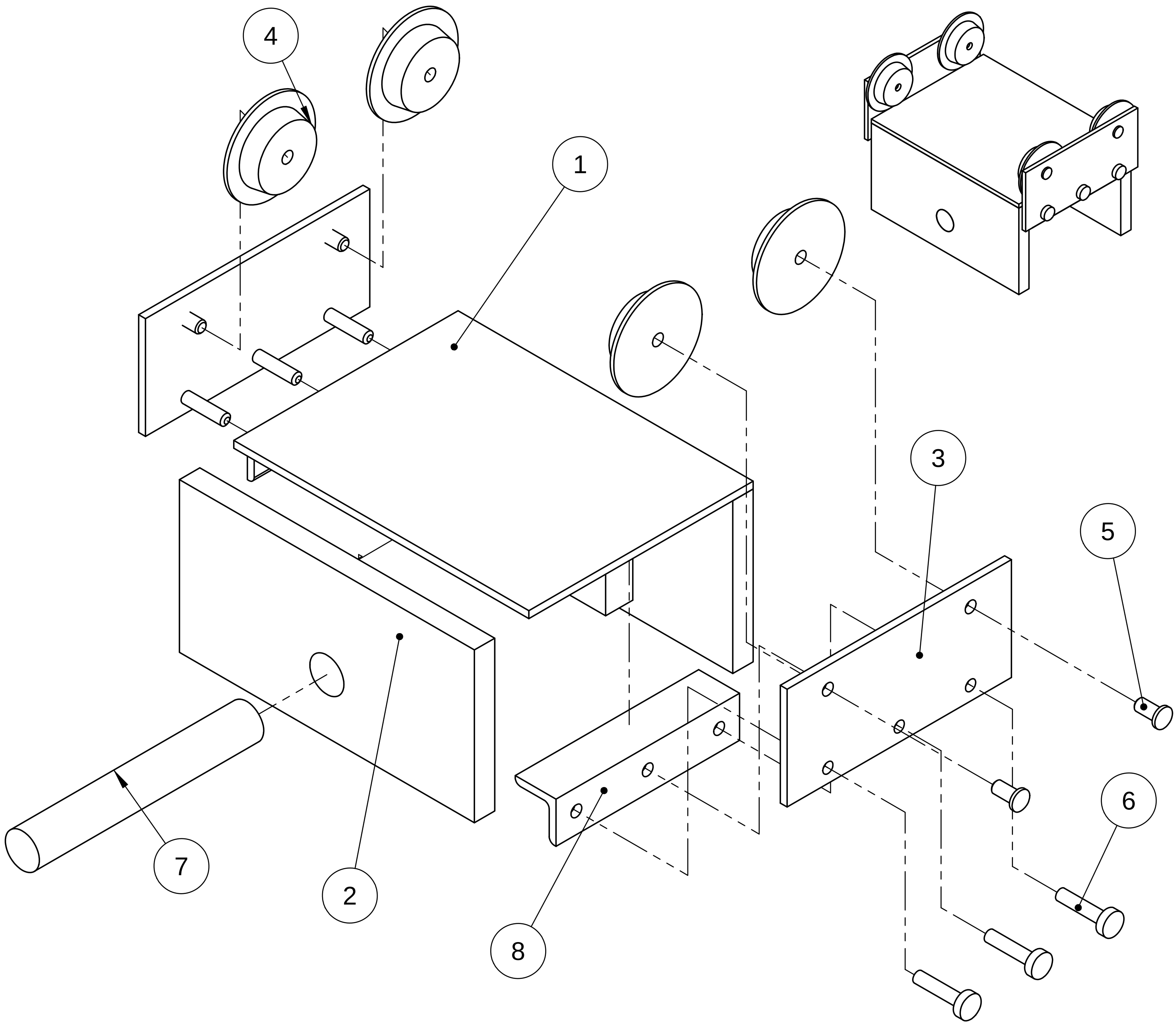
	NAME	DATE
DRAWN		
CHECKED		
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

Bill of Materials for DWG. 1

Bramah Hydraulics
Cal Poly San Luis Obispo
in conjunction with the
Estrella Warbirds Museum

SIZE A | DWG. NO. Bill of Materials2 | REV.
SCALE:1:32 | WEIGHT: | SHEET 2 OF 3



ITEM NO.	Part Description	Supplier	Part Number/Details	Price	QTY.
1	Trolley Base Plate	Estrella Warbirds	--	--	1
2	Trolley Clevis/Flange	Estrella Warbirds	--	--	2
3	Wheel Bracket	Estrella Warbirds	--	--	2
4	Steel Wheel (x4)	McMaster Carr	3267T61 (as part of off-the-shelf trolley)	$125.95	1
5	Wheel Axle	McMaster Carr	Supplied w/ Item 4	--	4
6	3/8"-24 UNC X 1.5"	McMaster Carr	92865A219	$.70ea	6
7	Clevis Rod	McMaster Carr	90075K361	$25.79	1
8	Trolley Angle Bracket	Estrella Warbirds	--	--	2

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	NAME	DATE
DRAWN	Matt Knorr	12/8/09
CHECKED	Nathan Brown	12/8/09
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

MATERIAL
Steel: Various

FINISH

PPLICATION

DO NOT SCALE DRAWING

Cylinder Trolley Assembly

Bramah Hydraulics
Cal Poly San Luis Obispo
in conjunction with the
Estrella Warbirds Museum

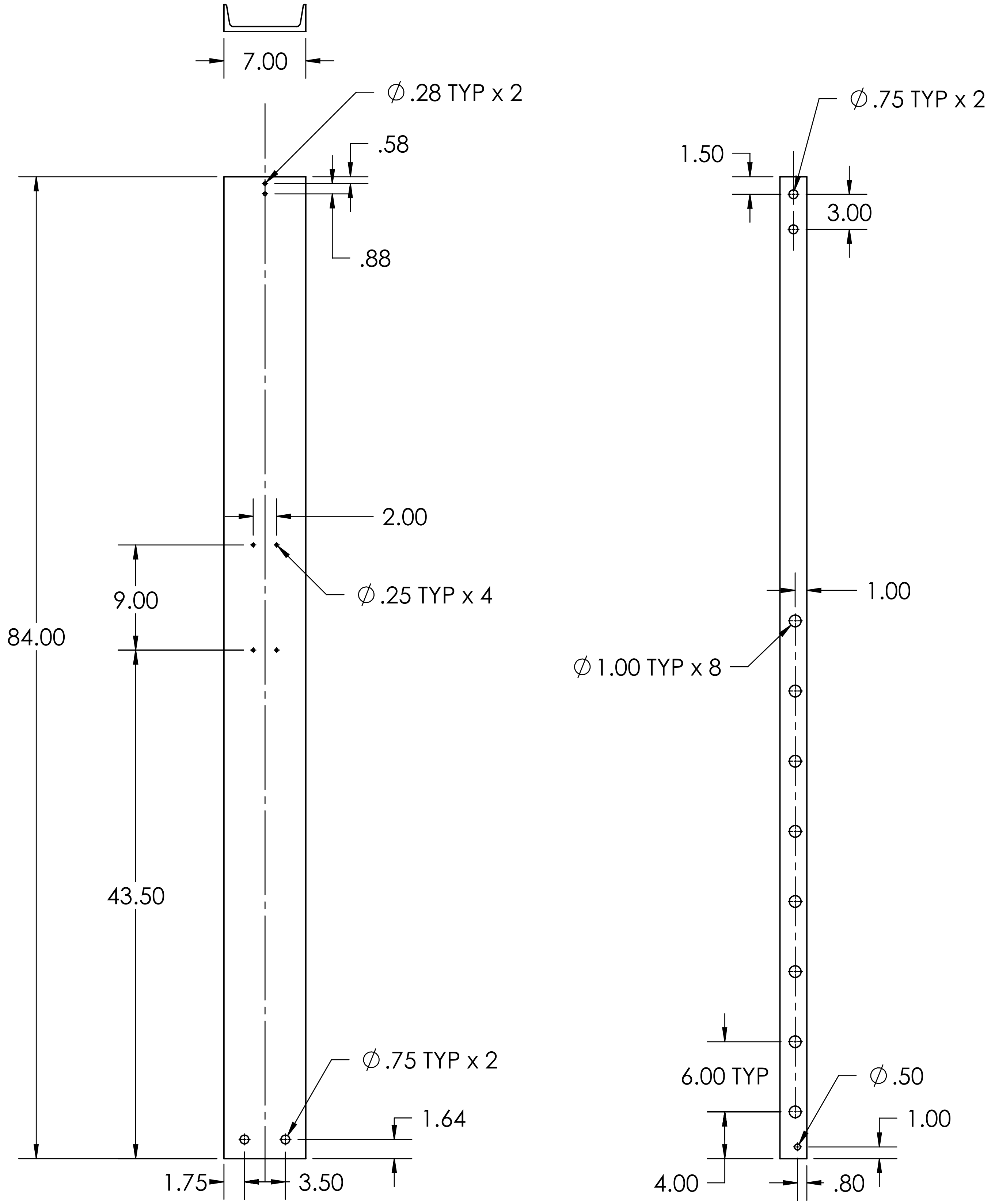
SIZE	DWG. NO.	REV.
A	2	

SCALE:1:4 | WEIGHT: | SHEET 1 OF 1

APPENDIX M: Detailed Part Drawings

The following drawings show the exact positioning of all desired features to be machined for the required custom parts. Overall sizing, cuts, and holes are all specified for fabrication, along with materials and detail notes.

NOTE: All holes are through-holes unless otherwise noted



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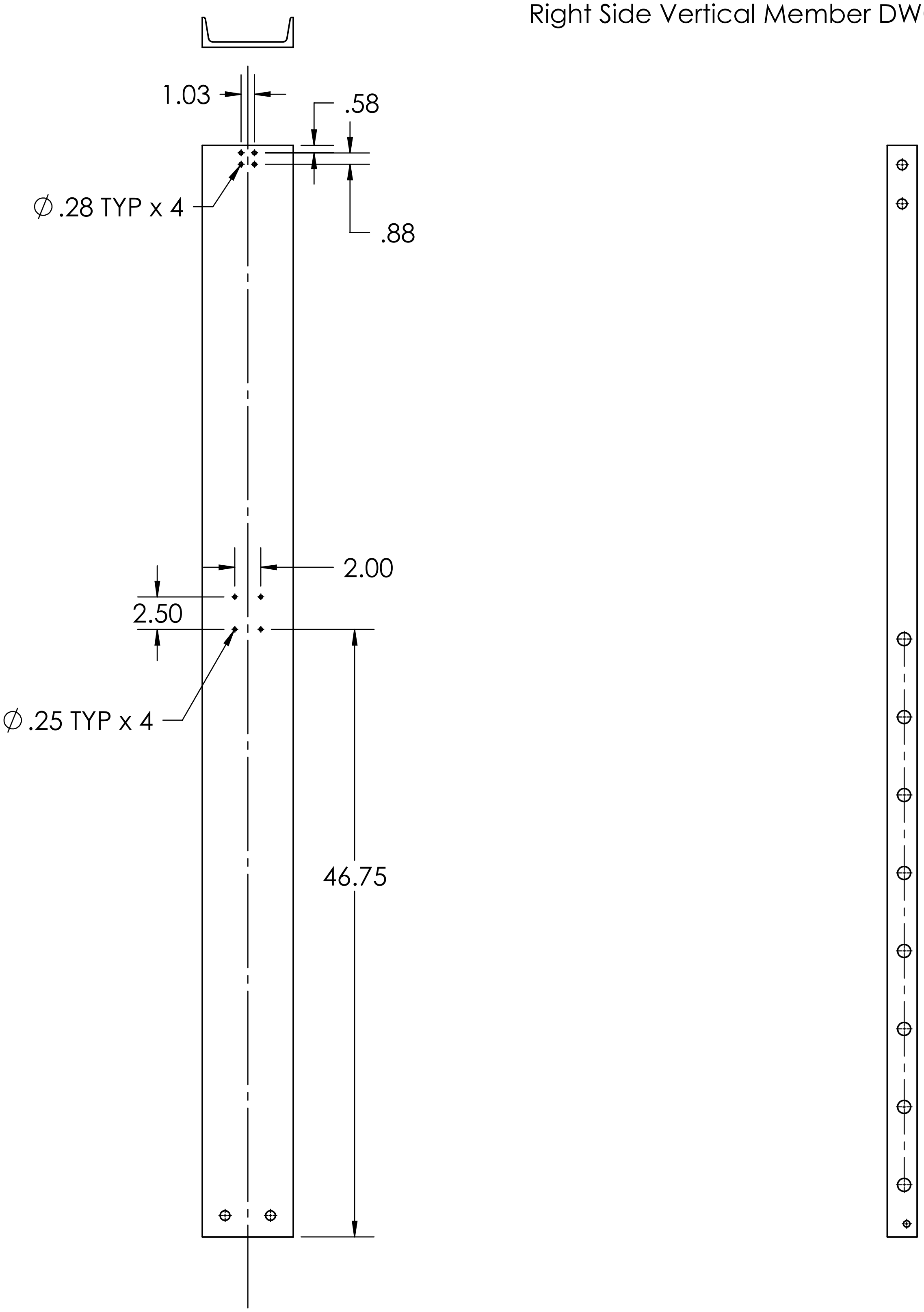
		NAME / DATE	Bramah Hydraulics **Cal Poly San Luis Obispo** in conjuction with the *Estrella Warbirds Museum*
		DRAWN: Nathan Brown, 3/13/09	
		CHECKED: Matt Knorr, 3/13/09	
	MATERIAL Plain Carbon Steel C7x14.75	ENG APPR. MFG APPR. Q.A. COMMENTS:	SIZE A · DWG. NO. 3 · SHEET 1 OF 11

Note: For all un-dimensioned features, refer to Right Side Vertical Member DWG. NO. 3



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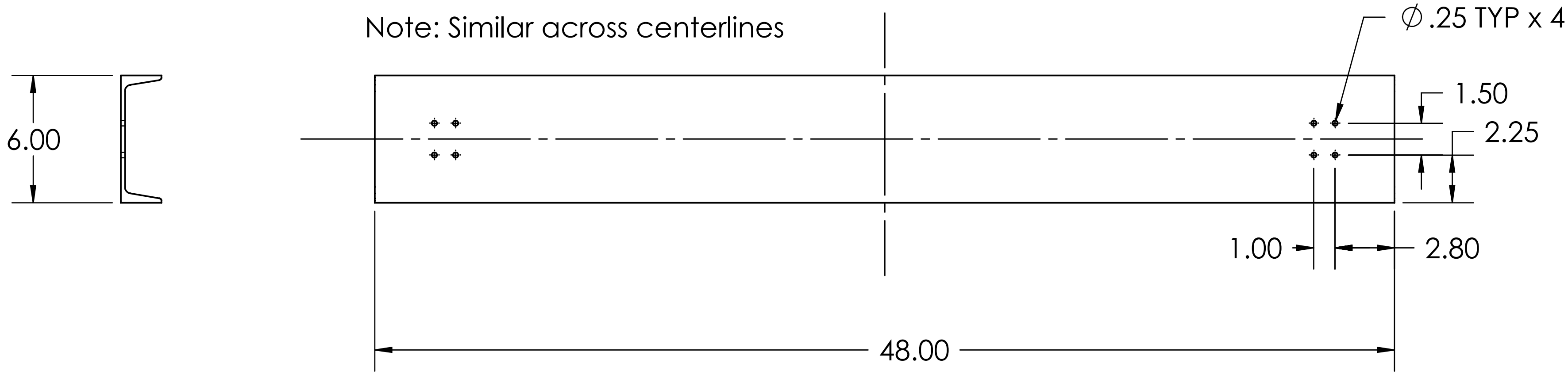
			NAME / DATE	Bramah Hydraulics **Cal Poly San Luis Obispo** in conjuction with the *Estrella Warbirds Museum*
		DRAWN	Nathan Brown 3/13/09	
		CHECKED	Matt Knorr 3/13/09	
	MATERIAL Plain Carbon Steel C7x14.75	ENG APPR. MFG APPR. Q.A. COMMENTS:		SIZE **A** · DWG. NO. 4 · SHEET 2 OF 11



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UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

Plain Carbon Steel
C6x8.2

	NAME	DATE
DRAWN	Nathan Brown	3/13/09
CHECKED	Matt Knorr	3/13/09
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

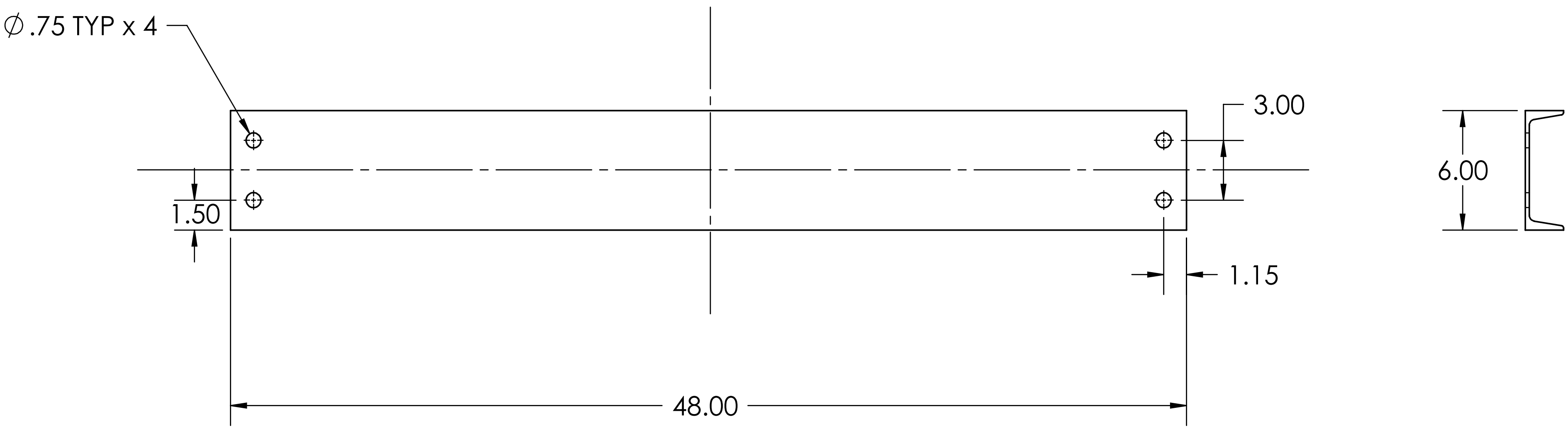
Platform Cross Member

Bramah Hydraulics
Cal Poly San Luis Obispo
in conjuction with the
Estrella Warbirds Museum

SIZE	DWG. NO.	REV
A	5	

SCALE: 1:8 WEIGHT: 32.5 lb SHEET 3 OF 11

5 4 3 2 1



NEXT ASSY | USED ON

APPLICATION

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

Plain Carbon Steel
C6x8.2

	NAME	DATE
DRAWN	Nathan Brown	3/13/09
CHECKED	Matt Knorr	3/13/09
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

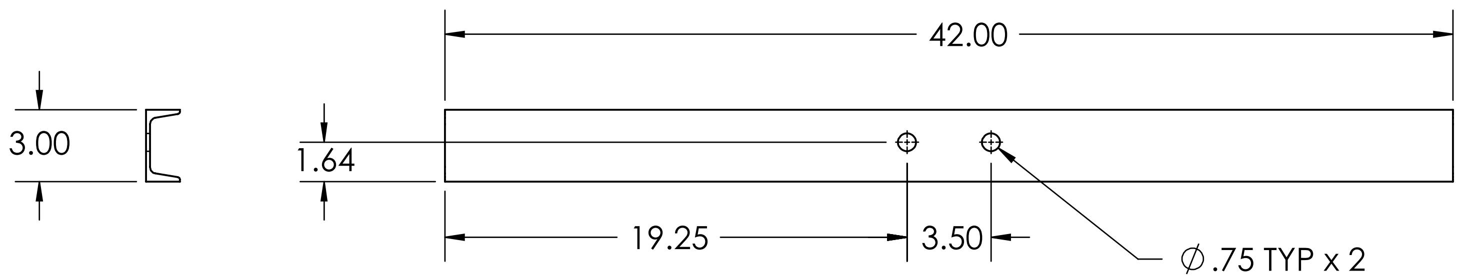
Top Cross Member

Bramah Hydraulics
Cal Poly San Luis Obispo
in conjuction with the
Estrella Warbirds Museum

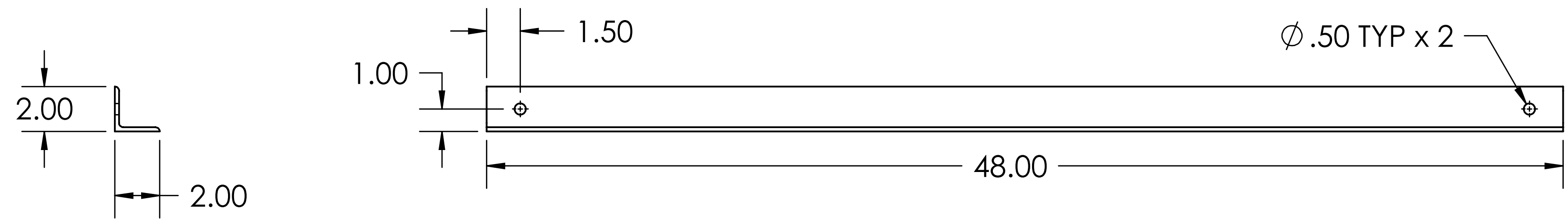
SIZE	DWG. NO.	REV
A	6	

SCALE: 1:8 | WEIGHT: 32.4 lb | SHEET 4 OF 11

5 4 3 2 1



	UNLESS OTHERWISE SPECIFIED:		NAME	DATE	Leg Support Member
	DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN	Nathan Brown	3/13/09	Bramah Hydraulics **Cal Poly San Luis Obispo** in conjuction with the *Estrella Warbirds Museum*
PROPRIETARY AND CONFIDENTIAL THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF BRAMAH HYDRAULICS. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF BRAMAH HYDRAULICS IS PROHIBITED.		CHECKED	Matt Knorr	3/13/09	
		ENG APPR.			
		MFG APPR.			
	INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.			
	MATERIAL Plain Carbon Steel C3x4.1	COMMENTS:			SIZE A — DWG. NO. 7 — REV
NEXT ASSY — USED ON APPLICATION					SCALE: 1:8 — WEIGHT: 14.2 lb — SHEET 5 OF 11



UNLESS OTHERWISE SPECIFIED:		NAME	DATE
DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN	Nathan Brown	3/13/09
	CHECKED	Matt Knorr	3/13/09
	ENG APPR.		
	MFG APPR.		
INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
MATERIAL Plain Carbon Steel	COMMENTS:		

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NEXT ASSY USED ON

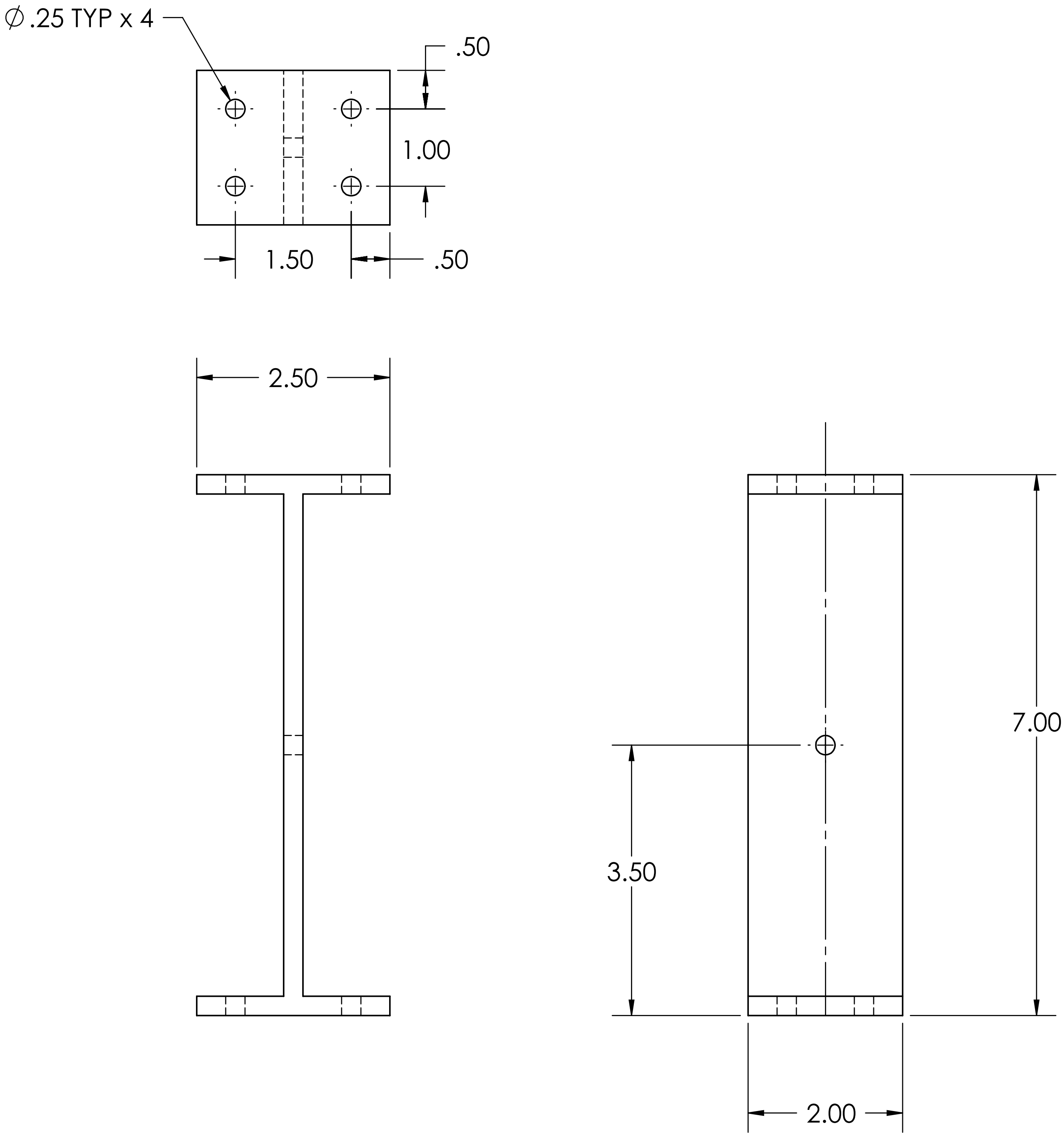
APPLICATION

Base Support Angle Iron

Bramah Hydraulics
Cal Poly San Luis Obispo
in conjuction with the
Estrella Warbirds Museum

SIZE	DWG. NO.	REV
A	8	

SCALE: 1:8 WEIGHT: 9.6 lb SHEET 6 OF 11



		SCALE: 1:2		Platform Center I-Bracket
	INTERPRET GEOMETRIC TOLERANCING PER:	NAME	DATE	Bramah Hydraulics **Cal Poly San Luis Obispo** in conjuction with the *Estrella Warbirds Museum*
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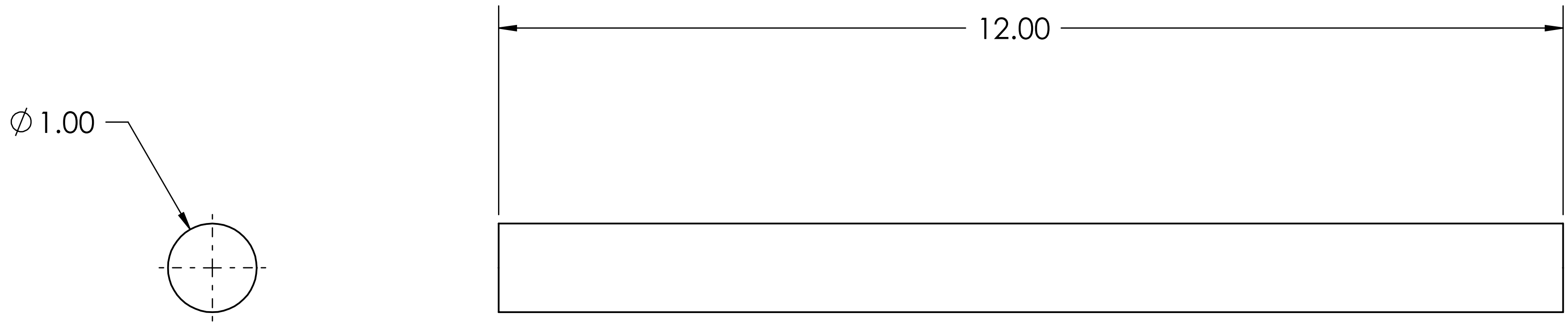
		CHECKED	Matt Knorr	3/13/09
	MATERIAL Plain Carbon Steel	ENG APPR.		
		MFG APPR.		SIZE **A**
		Q.A.		DWG. NO. 9
		COMMENTS:		SHEET 7 OF 11



	UNLESS OTHERWISE SPECIFIED:		NAME	DATE
	DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN	Nathan Brown	3/13/09
		CHECKED	Matt Knorr	3/13/09
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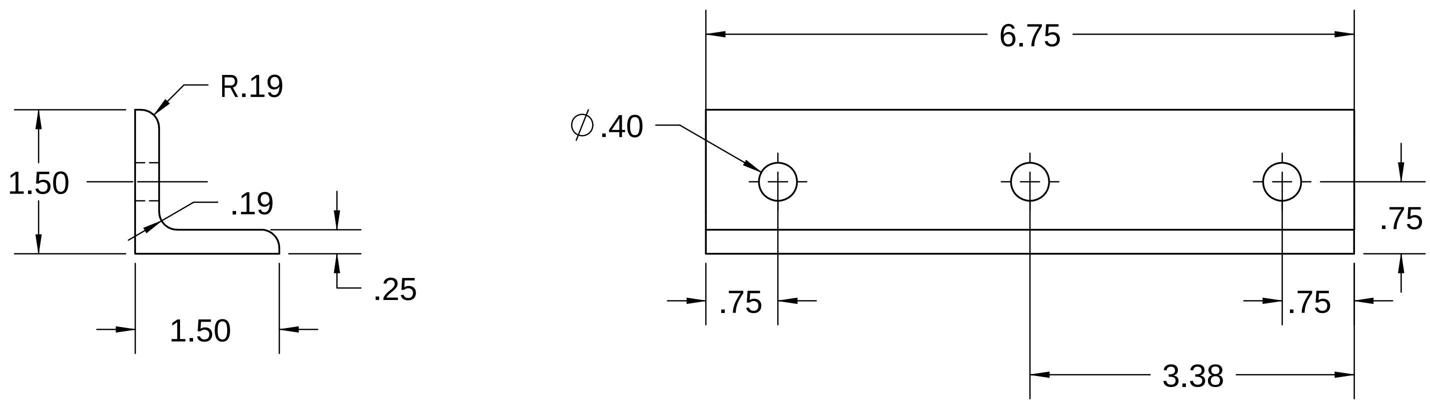
		MFG APPR.		
	INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
	MATERIAL Plain Carbon Steel	COMMENTS:		
NEXT ASSY USED ON APPLICATION				

Platform Support Pin

Bramah Hydraulics
Cal Poly San Luis Obispo
in conjuction with the
Estrella Warbirds Museum

SIZE	DWG. NO.	REV
A	10	

SCALE: 1:2 | WEIGHT: 2.7 lb | SHEET 8 OF 11



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NEXT ASSY USED ON

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UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR: MACH ± BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

MATERIAL

Plain Carbon Steel

	NAME	DATE
DRAWN	Nathan Brown	12/1/09
CHECKED	Matt Knorr	12/1/09
ENG APPR.		
MFG APPR.		
Q.A.		

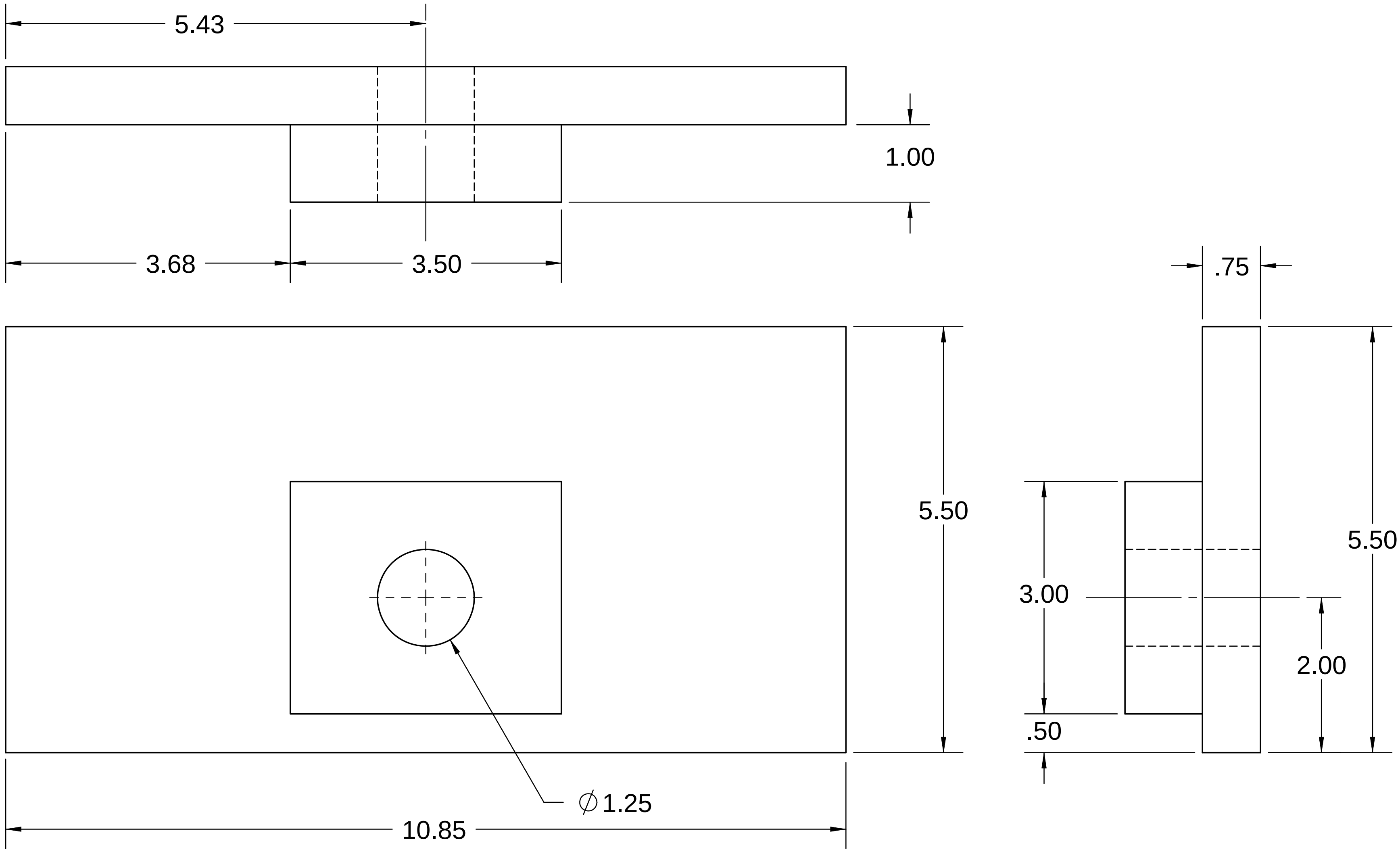
COMMENTS:

Trolley Angle Bracket

Bramah Hydraulics
Cal Poly San Luis Obispo
in conjuction with the
Estrella Warbirds Museum

SIZE	DWG. NO.	REV
A	11	

SCALE: 1:2 | WEIGHT: 8.9 lb | SHEET 10 OF 11



Trolley Clevis/Flange

Bramah Hydraulics
Cal Poly San Luis Obispo
in conjuction with the
Estrella Warbirds Museum

PROPRIETARY AND CONFIDENTIAL

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NEXT ASSY   USED ON

APPLICATION

UNLESS OTHERWISE SPECIFIED:

DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL±
ANGULAR: MACH±   BEND ±
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±

INTERPRET GEOMETRIC TOLERANCING PER:

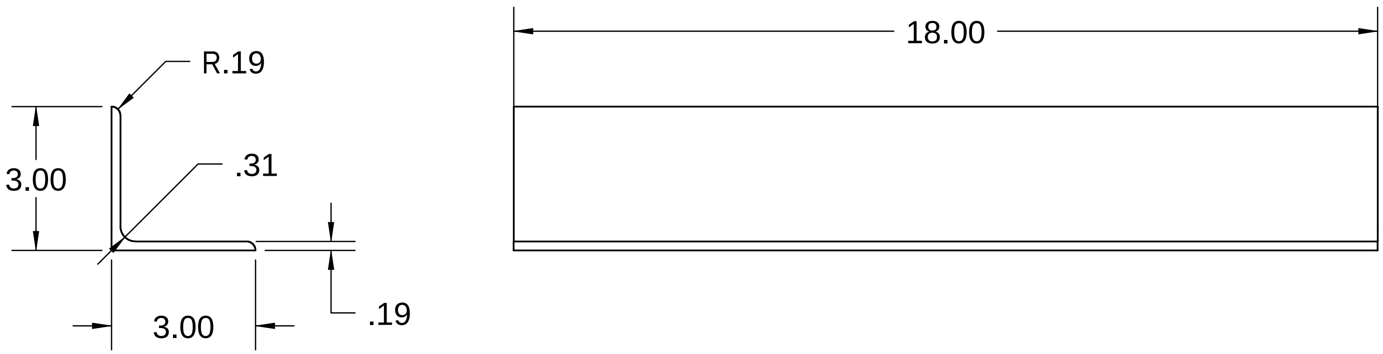
MATERIAL
Plain Carbon Steel

	NAME	DATE
DRAWN	Nathan Brown	12/1/09
CHECKED	Matt Knorr	12/1/09
ENG APPR.		
MFG APPR.		
Q.A.		

COMMENTS:

SIZE	DWG. NO.	REV
A	12	

SCALE: 1:2 | WEIGHT: 8.9 lb | SHEET 10 OF 11



	UNLESS OTHERWISE SPECIFIED:		NAME	DATE
	DIMENSIONS ARE IN INCHES TOLERANCES: FRACTIONAL ± ANGULAR: MACH ± BEND ± TWO PLACE DECIMAL ± THREE PLACE DECIMAL ±	DRAWN	Nathan Brown	12/1/09
		CHECKED	Matt Knorr	12/1/09
PROPRIETARY AND CONFIDENTIAL THE INFORMATION CONTAINED IN THIS DRAWING IS THE SOLE PROPERTY OF BRAMAH HYDRAULICS. ANY REPRODUCTION IN PART OR AS A WHOLE WITHOUT THE WRITTEN PERMISSION OF BRAMAH HYDRAULICS IS PROHIBITED.		ENG APPR.		
		MFG APPR.		
	INTERPRET GEOMETRIC TOLERANCING PER:	Q.A.		
NEXT ASSY / USED ON / APPLICATION	MATERIAL Plain Carbon Steel	COMMENTS:		

Trolley Cylinder Supports

Bramah Hydraulics
Cal Poly San Luis Obispo
in conjuction with the
Estrella Warbirds Museum

SIZE	DWG. NO.	REV
A	13	

SCALE: 1:2	WEIGHT: 8.9 lb	SHEET 10 OF 11