Document Prepared for:

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FINAL DESIGN REPORT

RAMMED EARTH TIRE PACKING PROCESS DESIGN

TEAM 15

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CLIENT APPROVAL FORM

I, Dr. Eric Bibeau, approve on behalf of University of Manitoba that the enclosed document may be distributed freely in order to satisfy, in part, the requirements of the University of Manitoba's *MECH 4860: Engineering Design* course.

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CLARIFICATION OF PROJECT CONTENT

For clarity in this report, below is a labelled diagram of a tire cross section and its primary constituents.

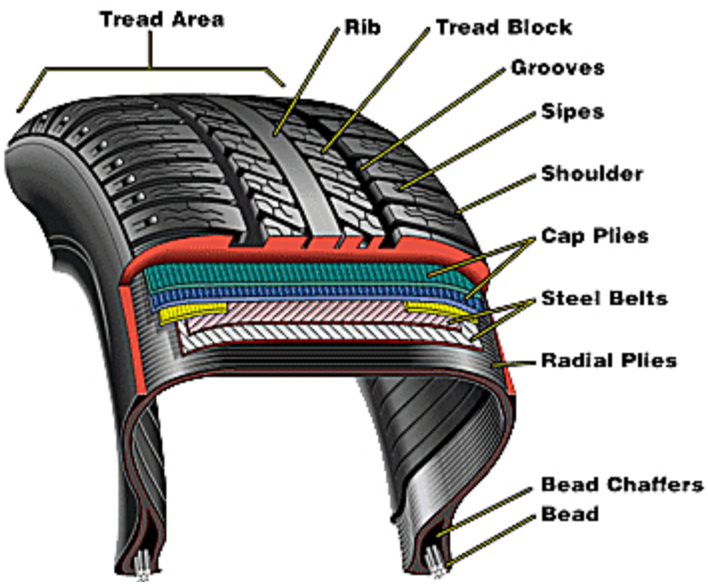

Figure 1 - Cross Section of Generic Automobile Tire [1].

Rammed Tire Structures utilize automobile tires that are densely packed with soil. These tires are stacked such that they act as the load bearing walls in the structure (Figure 2).

Figure 2 - Rammed Tire Structure during construction [13].

ABSTRACT

This report outlines a process designed for compacting soil into automobile tires. The current state of this process consists of manually filling and packing the soil with a sledge hammer. A mechanized process is needed to reduce time and labor necessary to pack tires with soil. This improved process will facilitate construction of rammed earth tire structures. The process outlined in this report consists of using a pneumatic backfill tamper and hydraulic cylinder press in conjunction with a lever mechanism to pack a tire with soil. This system consists of lightweight machinery that can be easily manipulated while working on the top of a tire wall. Due to elimination of sledgehammer, the recommended method greatly increases safety and decreases operator fatigue. In conclusion, the process designed by the project team is a low cost method that greatly improves upon the current method in terms of manual input, operator fatigue, safety, and time savings. The project team recommends implementation of this designed process for further testing and performance verification.

1 INTRODUCTION

Rammed Tire Structures are a type of alternative building that utilizes recycled materials for construction in order to maximize over all sustainability. The primary load bearing components of these structures are used automobile tires that are rammed tightly with soil, and assembled in wall configuration. Used tires are employed as the primary building block in these structures because of their strength, durability, and availability.

1.1 CUSTOMER NEEDS

Rammed Tire Structures are built primarily out of recycled tires that are filled with soil that is found on site. The tires are required to be packed densely enough so as to be very stable when stacked in wall configuration. Rammed Tire structures are still a relatively new concept, and as such, the techniques used for building them are fairly limited. Dr. Eric Bibeau has requested that a mechanized apparatus be devised to expedite the process of packing soil into tires for these structures.

Foremost, this apparatus must be capable of reducing the labor time, and labor intensity of packing a tire with respect to the current conventional method. It must be able to accommodate use with 15” and 16” tires of various profiles. The components for constructing the apparatus must be as economic as possible while still maintaining high quality of end product. To keep it as economical as possible, the major components should be available at local vendors. Ease of assembly is also important, and the ability to fabricate all components using commercially available methods.

1.2 PROJECT OBJECTIVES

The objective of this project is to design a portable, lightweight and effective system to facilitate packing of tires with soil. Our design will offer builders of Rammed Tire Structures a solution that will eliminate the dependence of the tire packing process on intensive manual labor. The project team will reduce the time necessary to pack each individual tire while providing a consistent density of the soil inside of the tire. All of these objectives will be met while maintaining a reasonable manufacturing cost. The intended users of the system are independent builders and contractors.

Methods currently used to assemble rammed tires into a wall configuration will not be altered. The scope of this project is limited to providing a method to pack individual automobile tires with soil for use in a wall. The viability and overall construction details of rammed earth tire structures will not be covered by this report.

1.3 TARGET SPECIFICATIONS

The goal of this project was to improve the process for preparing tires for use in Rammed Tire Structures. We analyzed the process of packing tires for use in Rammed Tire Structures, and noted all problems present in the current method. In designing a new process, the following criteria will be met:

- The system will consistently produce a completely filled and packed automobile tire.
- The density of soil inside a completely filled and packed tire will be comparable to that achievable by the current state process
- The system will be designed to work optimally with two operators present, but must be compatible for use by one operator, including setup.
- The design goal is a steady state cycle time of less than 14 minutes with two operators.
- The system must conform to all Manitoba Health and Safety regulations pertaining to the operation of the system.

1.4 TIME CONSTRAINTS

The project is on schedule and to be presented to the client on December 7, at 6:30 PM. A project schedule can be found in appendix B.

1.5 CODES AND STANDARDS

In order to fully integrate safety and code compliance in the final design, it is important to understand constraints and limitations imposed by codes, standards, and common safety practices. A search was completed by team members in order to find any such documents pertaining to the project. Findings are outlined in this section.

1.5.1 RAMMED EARTH TIRE STANDARDS

There are currently no standards pertaining to any aspect of the process of producing rammed earth tires. Since the current state of production uses manual labor extensively, the process is subject to extremely high variability in how full and packed each tire is before the operator deems it to be completed. This scenario leaves the project team with the job of quantifying and verifying a baseline standard requirement for what may be considered to be a fully filled and packed automobile tire.

1.5.2 MANITOBA WORKPLACE HEALTH AND SAFETY

The designed process will conform to all Manitoba Workplace Safety & Health regulations, which will lead to improvements made to the tire packing system to make it more ergonomic and will eliminate unnecessary strain on the worker during the process. A guideline published by Manitoba Workplace Safety and Health Division was utilized to analyze the designed systems with respect to excessive heavy or awkward lifting. An excerpt of the guideline may be reviewed in Appendix G. Furthermore, all materials and tools utilized in the system must be safe and conform to the Safety & Health regulations pertaining to construction power tool usage in Manitoba. A report outlining power tool safety considerations from Manitoba Workplace Health and Safety was used to analyze the tooling used, an excerpt of which may be found in Appendix G.

2 COMPETITOR'S PRODUCTS AND SPECIFICATIONS

The only competitor found was a small startup company that is suspected to be linked to the Canadian patent mentioned in the Appendix E. The description of the device provided by this company is found in the concept design descriptions. Below is a picture of this design, (Figure 3):

Figure 3 - Competitor's design [2].

This design provided by Tirewall Corp. shows their design consisting of two machines. The yellow "Tire Spreader" fills in the outer edges of the tire by spinning an impellor below a hopper containing soil. The red "Tire Tamper" fills in the center portion of the tire and packs it using a square tamping plate. The tire tamper has a hopper as well and feeds soil into the tire while tamping.

This machinery is heavy and requires the use of a gantry system to transport both machines along the top of the tire wall [2]. Characteristics of this design will not be incorporated into the delivered concept. This is due to the fact that this system consists of two very heavy machines to complete the packing process. The only aspect that could have been incorporated is the tamping plate; however, there are commercially available tampers that are much more portable than this design.

3 TESTING RESULTS

Testing was a very important part of this project due to a lack of quantitative data resources. Although there are many instructional resources on the internet and a few books on the subject of rammed earth tire structure construction, these are limited to the proven sledgehammer technique. In order to fully understand the problem, testing needed to be done to get a feel for the challenges involved in compacting soil into a tire cavity. The problem may seem like a simple one, but a lightweight mechanized solution is not simple. This section describes the team's findings while testing concepts. Not all of the original concepts were tested. A record of the original design concepts can be found in appendix A.

3.1 TESTING DAY ONE

In order to fully understand the problem the team performed a baseline tire packing trial. A number of old tires were filled with soil and placed in a small wall-like configuration. For the acquisition of baseline data, a five pound sledge hammer was used. One person filled the tire while another operated the sledge.

Figure 4 – Two fully packed tires.

The average time taken to pack soil into the tire was 14 minutes. The process was quite rigorous, requiring intense amounts of energy. Team members were nearly exhausted after one tire. It was discovered that varying soil types would make it difficult to quantify the completion of a packed tire. The only true way to tell that a tire is completely packed is that the tire simply does not accept any more soil. At this point, the sidewalls are bulged out and the tire does not deform in any measureable way when a person applies their full weight to the outer edges of the tire. The team also noted that a packed tire could be rolled without any soil falling out of the openings. Lifting the tire was strenuous, even with two people, highlighting the need to pack the soil into the tire directly in its final resting place.

3.2 TESTING DAY TWO

The second testing day was focussed on validating the concept of removing all or part of the upward facing sidewall. The belief held by the team was that removing the top sidewall would greatly simplify the problem of packing soil within the sidewall region, and that special techniques would no longer be required. Packing or tamping could be approached from a strictly vertical direction. There was also speculation as to whether removal of the side wall would adversely affect the structure of the overall wall.

Figure 5 - Removal of side wall.

As shown in the photograph above, a reciprocating saw was used to cut directly through the tire sidewall. The process was timed at 30 seconds. Thus, if used, this additional step would not greatly increase the overall time taken to pack the tire. Once the tire wall was removed, the filling and packing of the tire took approximately 4 minutes which was a great improvement over the baseline method.

A few tires were packed using this method; however, the results were not as expected. The removal of any length of the side wall eliminated the steel band found in the bead of the tire. The outward pressure from packing the tire simply stretched the remaining part of the side wall into a vertical orientation and the soil seemed to squish upward out of the tire limiting the amount that the soil could be compacted. The combination of reduction in packed soil density and the lack of structure on the top of the tire resulted in a comparatively weak tire wall. A small force on the side of the tire could now deform a tire where this is not the case when the side wall is not intact. The deformed wall of the tire is indicated by the arrow in the photograph below.

Figure 6 - Packed Tire Without Side Wall.

As a result of the findings from these tests, removal of the sidewall was deemed unsatisfactory as it did not meet the client's requirements of producing an element for a stable tire wall structure.

3.3 TESTING DAY THREE

At this point in the design process the team had narrowed the possible design concepts down to three main designs; namely, a gravity driven cone shaped ram, a tamper tool with an adapted head, and an auger type design. Due to the lack of quantifiable data with respect to the designs, a method of comparison was needed in order to rate them in terms of effectiveness and speed.

A simple scaled representative test was devised in order to compare the designs. The auger design was not included in this test as the team was unable to acquire an auger or any representative device. A cinderblock was used to simulate a gravity powered Ram by dropping it from a two foot height. A tamping tool was simulated using an air chisel with a steel plate attached. These were compared to the conventional method of swinging a sledge hammer.

In order to standardize the volume of soil packed, the bottom of a 5 gallon bucket was used and a packed depth of 5.5 inches was used as the complete condition. The final weight was measured after packing was complete for each method.

Table 1 - Concept Testing Results

	Sledge Hammer	Cinderblock	Air Chisel
Time to pack	3 Minutes, 5 seconds	5 minutes	3 Minutes, 20 seconds
Final Average Weight	27 lbs	26	25
Volume	0.25 cubic feet	0.25 cubic feet	0.25 cubic feet
Density	108 lbs/cuft	104 lbs/cuft	100 lbs/cuft
Relative Manual Input	High	Very High	Low

Each method gives similar results. The air chisel and cinderblock were comparable with respect to speed and effectiveness, however when manual labour input is taken into account, the air chisel is far superior.

Upon finding that the air chisel was in fact an effective way to pack the soil even with a relatively small tamping plate (6.5x3"), the team decided that this was the method of choice for the final design. Although a Wacker Neusen Jumping Jack had initially been selected, a more lightweight and manoeuvrable tool was needed.

3.4 TESTING SUMMARY AND CONCLUSIONS

As a result of testing the following concepts were ruled out:

- Gravity powered ram
- Removal of side wall

A vibratory tamper was validated and it was found that a lightweight tamping tool should be utilized. It was also found that lifting the side wall during tamping would be a definite asset to the entire process. After testing the team made a decision that a lateral forcing tool such as a hydraulic cylinder with plates may help the process as well.

Additional research results can be found in appendix E. An auger was not pursued due to limited testing resources.

4 TAMPER WITH LIFTED SIDE WALL DESIGN

4.1 MECHANICAL TAMPER: JUMPING JACK VS. PNEUMATIC TAMPER

Originally, the mechanical tamper researched was the Wacker tamper, as illustrated below in Figure 8. These tampers are widely used for small scaled tamping in paving and landscaping applications.

Figure 7 - Ingersoll Rand pneumatic tamper [4].

Figure 8 - Wacker tamper used for soil compaction [3].

Upon further investigation into commercial compaction, and specifically rammed earth projects, the pneumatic backfill tamper was discovered, as shown above in Figure 7. These tampers are designed for tamping backfill in trenches, foundations, and posts.

Some key characteristics of common models of the two types of tampers were collected and summarized in Table 2.

Table 2 – Comparison of Jumping Jack to pneumatic tamper [5], [6]

	Sullair MTB -6	Wacker Neuson Wacker BS50-2i
Description:	Pneumatic backfill tamper	Jumping jack vibratory packer
Power Input:	Compressed Air - 32 CFM @ 90 psi	2-stroke internal combustion engine
Operating Weight:	40.5 lbs.	131 lbs.
Approximate Cost:	$600 - 800	$2500 - 3000

It is projected that the jumping jack vibratory tamper will have a higher capacity for packing soil, but the pneumatic tamper has considerable advantages with respect to maneuverability, power input type, and overall unit cost. Team members decided unanimously that any mechanical vibratory tire packing technique would utilize a pneumatic backfill tamper.

4.1.1 SULLAIR MTB-6 PRODUCT FEATURES

The pneumatic tamper chosen for the application of rammed earth tire packing is the Sullair MTB-6, Figure 9. This is a common and commercially available model of tamper that features comparable size and maneuverability of other pneumatic backfill tampers, but at a reduced cost. Some of the main features of the Sullair MTB-6 are summarized in Table 3 below.

Figure 9 - Picture showing Sullair MTB-6 Tamper [14]

Table 3 - Sullair MTB-6 Product Features [14]

Net. Weight :	40.5 lbs.
Length:	48.75 inches
Bore and Stroke:	1.5 inches x 5.5 inches
Blows per minute:	500
Air Consumption:	32 cubic feet per minute
Air Inlet:	3/8 inch NPT

4.1.2 PNEUMATIC TAMPER COST SUMMARY

Below is a cost summary for the components required to implement a pneumatic backfill tamper for the operation of the rammed earth tire packing system.

Table 4 - Cost Summary of MTB-6 Backfill Tamper

Component Description:	Quantity:	Cost (CAD):
Sullair MBT-6 [15]	1	$719.00
Shipping and Handling		$100.00
25 ft x 3/8" Industrial PVC Air Hose [16]	1	$22.99
	Taxes @ 12%:	$101.04
	Total:	$943.03

4.2 RAISED SIDEWALL FIXTURE

The idea of changing the tire geometry in order to aid the dirt packing process was conceived as a result of the first test day. During the initial packing tests, team members filled and packed tires using the manual (sledge hammer) method. It was observed that the geometry of an un-lifted sidewall acted as a barrier to filling and packing the tire sidewall region. This is illustrated in Figure 10.

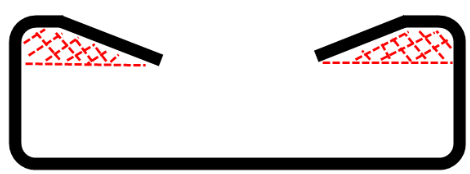

Figure 10 - Concept sketch of automobile tire showing void at upper sidewall region, as indicated by red dashed lines.

The concept of changing tire geometry was realized through two initial design concepts: Lifted Sidewall Bottle Jack (Figure 11), and the Lifted Sidewall Hinged Lever Arm (Figure 12). Further testing of these concepts showed that a simple lever mechanism provided enough force to sufficiently lift the sidewall.

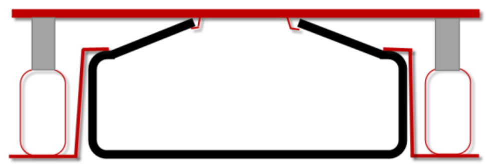

Figure 11 - Lifted Sidewall Bottle Jack concept sketch.

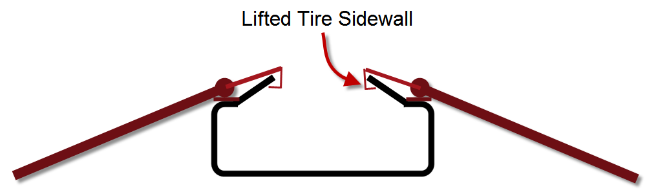

Figure 12 - Lifted sidewall Hinged Lever Arm.

Further investigation of the lifted sidewall concept led to the conclusion that utilizing a hinged lever arm would provide significant advantages over the bottle jack concept. The advantages include mobility and setup time, with the assumption that the lifting effectiveness of the two concepts is comparable. Details regarding testing of a hinged lifting mechanism can be found in appendix G.

The Lifted Sidewall concept resulted in the design of a frame that attaches to the tire bead using a flat hook. A lever arm with an over center latch is anchored to the lower portion of the tread surface. The lever arm is pulled by hand to lift the sidewall. The over center action of the hinge locks the mechanism in place. Figure 13 shows an evolved concept sketch of the lifted sidewall design that utilizes the lever arm. This provided the basic design for the raised sidewall final assembly.

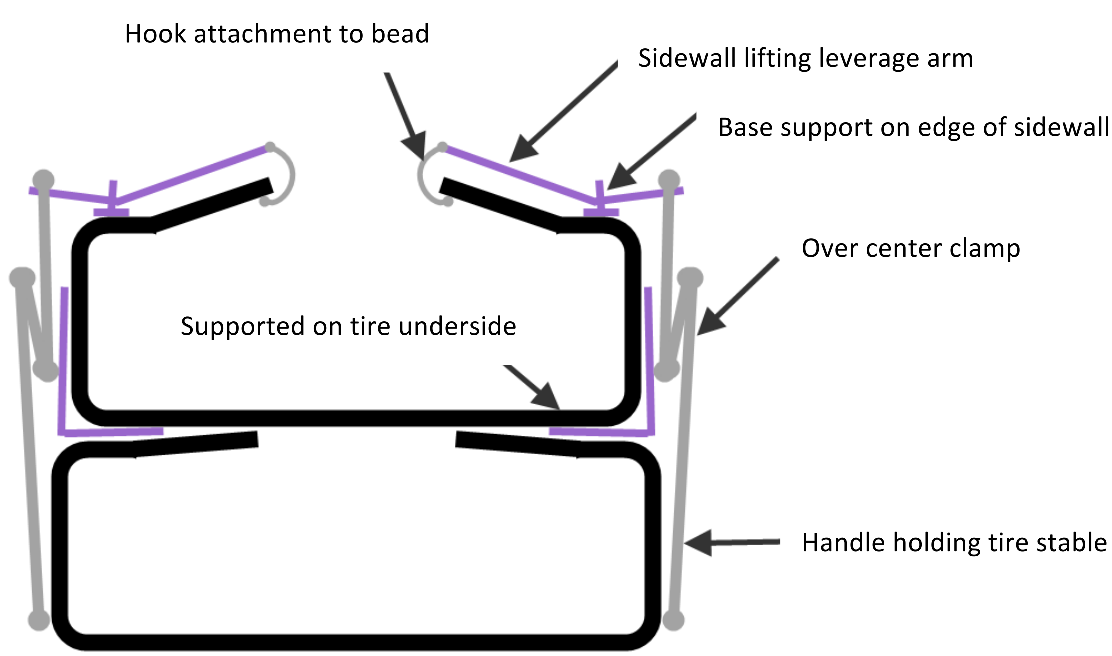

Figure 13 - Evolved concept sketch of sidewall lifting mechanism.

The following sections explain the components that assemble to form the Raised Sidewall Fixture. Detailed preliminary Engineering drawings of these components may be found in Appendix I.

4.2.1 EXTENDABLE LEVERAGE MEMBER ASSEMBLY

The lever arm design relies on the application of a linear force on the tire bead in the vertical direction in order to raise the sidewall of the tire upwards. The Leverage Member assembly shown in Figure 14 has a hook which will attach to the underside of the tire bead. When the hinged end of the member receives downward pull from the over center bar, the member will rotate about the Upper Plate. The Upper Plate acts as a fulcrum, pulling the hooked end and the tire sidewall in an upward direction. The leverage member has been design to lift the sidewall approximately 3” upward.

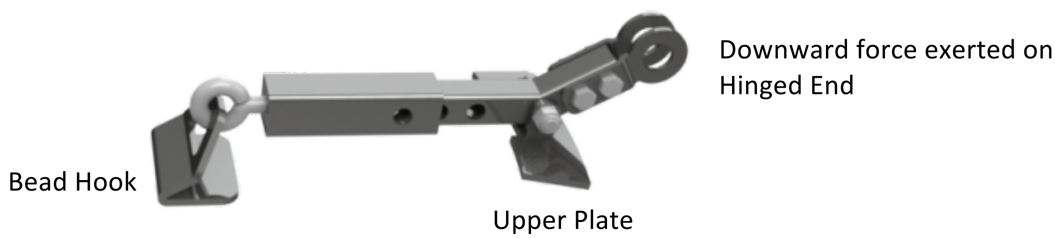

Figure 14 – Extendable Leverage Member Assembly.

4.2.2 OVER CENTRE CLAMP ASSEMBLY

The downward force applied to the Leverage Member is supplied by the Protex 43-4000 Heavy Duty Over Centre Clamp. This clamp (Figure 15) fits the geometry of the tire, has an adequate range of motion, and provides sufficient force for the application. The design would require the modification of the handle by welding on a section of 1inch square tubing to accommodate a handle on the packing fixture (Figure 16).

Figure 15 - Protex 43-4000 heavy duty over center clamp [7].

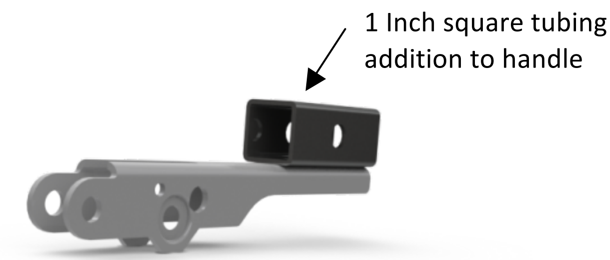

Figure 16 - Modification to clamp handle.

4.2.3 TIRE CATCH PLATE ASSEMBLY

The fixture is anchored to the tire using an adjustable Tire Catch Plate (Figure 17). This plate mounts to the underside of the Over Center Clamp and to the lower sidewall of the tire. The length adjustment in this assembly will accommodate tires between 195 and 265 mm in width. Adjustment may be made by loosening two Wing Nuts, sliding the Lower Catch Plate to the desired position, then re-torquing the nuts.

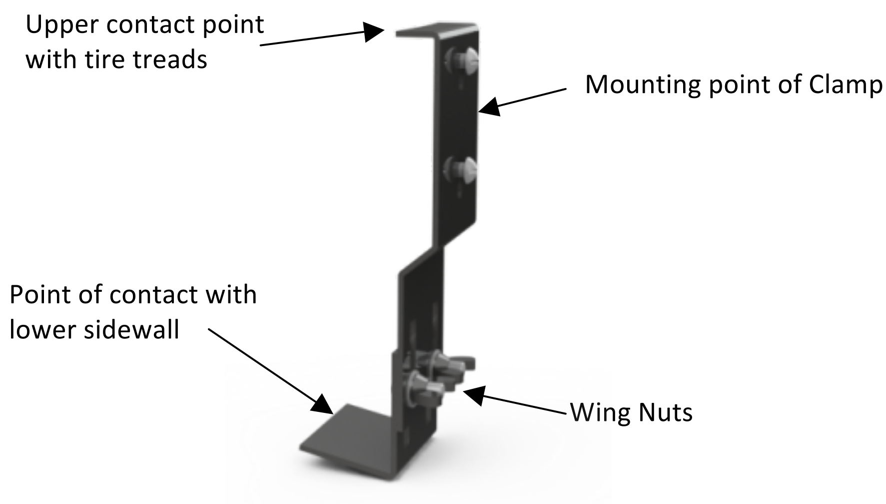

Figure 17 - Components in Tire Catch Plate Assembly.

4.2.4 DOUBLE WIRE SNAPPER PIN

All pin connections in the Raised Sidewall Fixture will utilize a ¼ inch diameter 1 and ¾ inch long Snapper Pin (Figure 18). These will be secured to the frame of the fixture via stainless steel bead chain. These pins offer quick operation and will not be easily lost on the job site, as they will be affixed to the frame.

Figure 18 - Double Wire Snapper Pin [18].

4.2.5 CLAMP HANDLE EXTENSION

The handle for the clamp serves a twofold purpose in this design. The primary purpose of the handle is to serve as a stability aid, with the handle also reducing the force required to close the clamp. The stability feature is useful only when the tire wall is at three layers or higher. When the clamp is closed, the handle aligns the tire on the wall by resting vertically against the tire two levels below, (Figure 19). The handle inserts into the square tubing on the clamp and is secured with a pin. Figure 20 shows the Handle Extension used in the ground level configuration and Figure 19 shows the Handle Extension as a stability aid.

Figure 19 - Clamp Handle Extension in stability configuration.

Figure 20 - Clamp Handle Extension in ground level configuration.

4.3 METHOD OF OPERATION OF RAISED SIDEWALL FIXTURE

Figure 21 shows the major assembly components as referred to in this section.

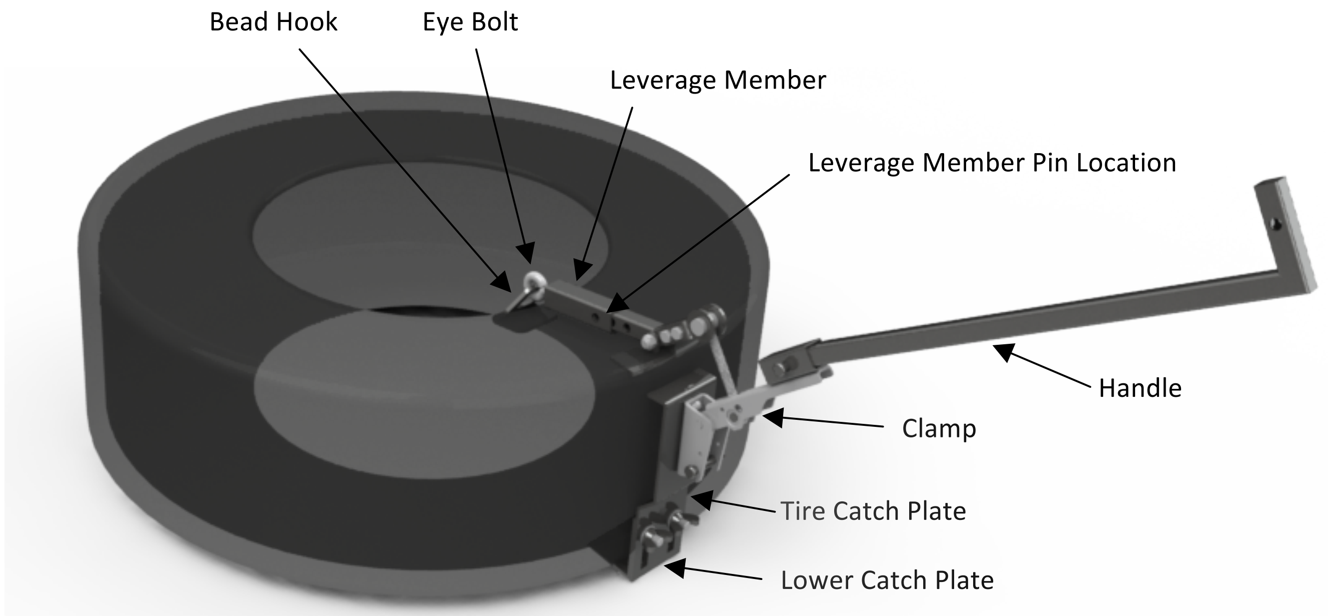

Figure 21 - Raised Sidewall Fixture Assembly.

The following steps will be utilized to prepare a tire for packing:

A. The fixture is placed against the tire with the Lower Catch Plate contacting the lower sidewall. If the top of the Tire Catch Plate is not aligned with the edge of the tire, the two wing nuts can be loosened to adjust the length of the Lower Catch Plate and accommodate the tire width.

B. The pin is removed from the Leverage Member and the Bead Hook is placed under the bead of the tire. The Leverage Member is then retracted until the Eye Bolt is approximately vertical with respect to the tire bead. The pin is then aligned and inserted back through the Leverage Member.

C. If the handle is not already inserted into the clamp then it may be inserted and secured with the pin. The Clamp may then be engaged. The before and after states of the Raised Sidewall Fixture are shown in Figures 22 and 23:

Figure 22 – Sidewall Fixture un-deployed

Figure 23 - Sidewall Fixture deployed

4.4 COST ANALYSIS - RAISED SIDEWALL FIXTURE

Table 5 - Cost of Raised Sidewall Fixture.

Component Description:	Quantity:	Cost:
3/8" Eye bolt - Zinc Plate [17]	1	$2.07
3/8" Square Nut - Finish [17]	1	$0.10
1/4" x 1.25" Hex Head Bolt [17]	2	$0.21
1/4" Hex Head Nut [17]	2	$0.06
3/8" x 1.25" Hex Head Bolt [17]	1	$0.21
3/8" Hex Head Lock Nut [17]	1	$0.06
3/8" x 1" Carriage Bolt [17]	2	$0.04
3/8" Wing Nut [17]	2	$0.33
5/16" x 1" Stove Bolt w/ Nut [17]	2	$0.26
Protex 43- 4000 [7]	1	$30.83
1/4" x 1-3/4" Zinc Round Double Wire Snapper Pin [18]	3	$12.90
Stainless Steel Bead Chain [17]	3	$2.16
	Taxes @ 12%:	$5.65
	Total:	$54.86

Table 5 includes a cost breakdown of primary components in the Raised Sidewall Fixture. The cost of the steel building materials, fabrication, and labor were not included in this cost analysis. They were not included in the breakdown because the scale of production could not be projected. The overall cost of the Raised Sidewall fixture is sufficiently low to warrant prototype construction.

5 HYDRAULIC CYLINDER DESIGN

After exploring many options regarding packing mechanisms, it was determined that a hydraulic cylinder could pack a tire effectively. The primary impediment to an effectively packed tire is packing the soil in the area underneath the tire wall. To pack underneath the side wall, there needs to be some form of lateral force imposed upon the soil within the sidewall region. A simple hydraulic cylinder will complete this task. It is lightweight, portable, has a short setup time, and can pack soil with great force.

Assortments of cylinders from the hydraulic department at Princess Auto were considered prior to final selection. To determine which cylinder would best fit this application several aspects needed to be considered. These aspects included, total retracted length, cylinder bore, stroke length, hydraulic force, and the ability to modify the cylinder by adding a tool head or any other components. Since the objective is to design for packing 15 and 16 inch tires, it is most important to select a cylinder that has a total retracted length under 15 inches. Following this other selection aspects may be considered. The cylinders found that were nearest size to the 15 inch constraint offered by Princess Auto is 12 and 14 inches in total retracted length. The 12 inch cylinder has a maximum piston stroke of 4 inches, and the 14 inch cylinder has a maximum stroke of 6 inches. All other cylinder options would be ineffective for this application based upon geometry and stroke.

5.1 HYDRAULIC CYLINDER SELECTION

The 12inch cylinder was deemed unsuitable as it would not extend far enough into the sidewall. The 4 inch stroke of the piston is equivalent to 2 inches of motion on opposite sides of the tire. It is believed that this will not be sufficient stroke. If there was a desire to pack tires of a smaller diameter, a 12 inch cylinder may become a viable option. This left the final selection to the 14inch cylinder, in which a determination of appropriate bore sized needed to be made. Bore size is directly related to the hydraulic force on the piston; by comparing the force available from the various cylinder options listed on specification sheets, the ideal cylinder was selected.

The 2" Bore x 6" stroke utility cylinder made by Shur-Lift, as seen in Figure 24, was selected for this application. It is 14inches in length as measured from center of each pinhole fitting on opposing ends of the cylinder. This cylinder is readily available at Princess Auto locations and is made out of plain carbon steel. This will make for ease of weld and cutting so that modification can be made without much trouble. All other needed specifications may be resourced from Table 6. The pinhole fixtures provide an excellent support for securing an appropriate tool head.

The cylinder has easy access bolt ports for hydraulic hose attachment. The 9424 lbs of pushing force delivered by the cylinder is more than adequate for densely packing soil and leaves the magnitude of packing density up to the operator.

Figure 24 - 14 inch Hydraulic Cylinder (9424 lb. force) [8]

Below, Table 6 summarizes some of the key features of the selected hydraulic cylinder.

Table 6 - Specifications of selected hydraulic cylinder [8]

3,000 PSI max. continuous pressure
Features cross tube mounting ends
2" bore
#6 ORB ports
1" dia. pinholes
Base pineye width: 2-3/4"
Rod pineye width: 2-1/4"
9,424 lbs. push @ 3,000 PSI
Stroke: 6"
Retracted length: 14"
Rod dia.: 1-1/4"
NOTE: Retracted length is measured center of pinhole to center of pinhole.

5.2 HYDRAULIC CYLINDER ASSEMBLY - COMPONENTS

The hydraulic cylinder (Figure 24) requires the use of some fabricated steel components in order to packed a rammed earth tire. These parts and accessories include a 1/4" plate fixed at both ends of the cylinder which act as the primary load distributing surface. It also includes a pin to secure the plate assembly to the pin eye located at the top of the piston. A fixed handle is attached to allow for easy movement and operation of the cylinder. Finally, a four-way hydraulic control valve is to be attached to the handle assembly to control the movement of the piston.

For further details of all fabricated components in the Hydraulic Cylinder Assembly, consult Appendix J.

5.2.1 PACKING PLATE

Two identical steel plates are to be fabricated in order to act as the load distributing surfaces for the hydraulic cylinder. The shape of the plate is as displayed in Figure 25. These packing plates are to be made out of ¼ inch mild steel, rolled to a radius of curvature of 7.5 inches to be congruent with the diametrical shape of 15 inch tires. This will be sufficient for use in 16 inch tires as well. The overall width is to be approximately 8 inches along the curve, and the height is to be 6 inches. The two packing plates are to be fixed to the hydraulic cylinder in different ways.

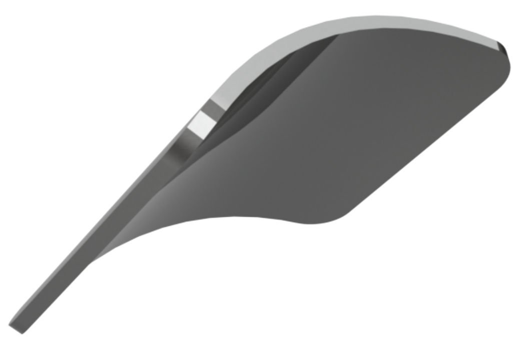

Figure 25 - ¼ inch Steel Packing Plate.

5.2.2 TOP PACKING PLATE

The plate fixed directly to the piston will be referred to as the top packing plate. The pin eye that is located on the piston head is to be used for securing this top plate to the piston. In order to secure it, mounting tabs as seen attached to the top plate in Figure 26, must be welded 2 and 3/8 inches apart. In addition, 1inch holes need to be drilled such that they align concentrically with the 2 ¼ inch long pin eye once the tabs are welded to the top plate. This is so that the pin featured in Figure 28 can be fitted through the drilled holes and pin eye to complete the securement of the plate. Since a pin joint is being used, there will be some range of motion, but the joint will be stable and self-balance.

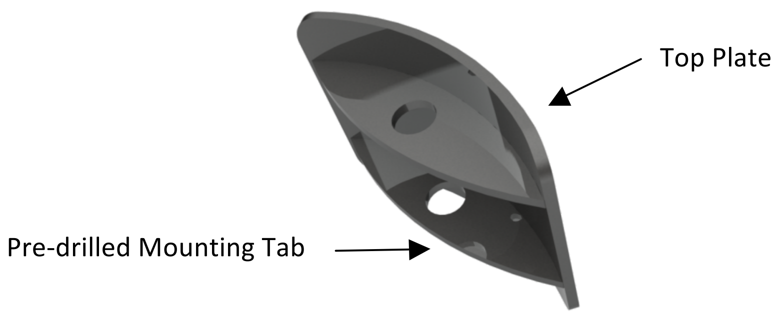

Figure 26 - Top Packing Plate.

5.2.3 BOTTOM PACKING PLATE

The plate fixed to the base of the hydraulic cylinder will be referred to as the bottom packing plate. Unlike the top packing plate, it is to be fixed without any range of motion. Rather it is fixed by a butt weld directly to the cylinder base. In order to prepare a good welding surface, the base pin eye must be cut in half. Then the plate is butted to the semi-circular piece, and welded to it. To assist in maintaining strength, four ¼ inch thick mounting tabs are to be cut out of mild steel. As seen in Figure 27, these tabs are secured to the cylinder and bottom plate. This will be accomplished utilizing welded joints.

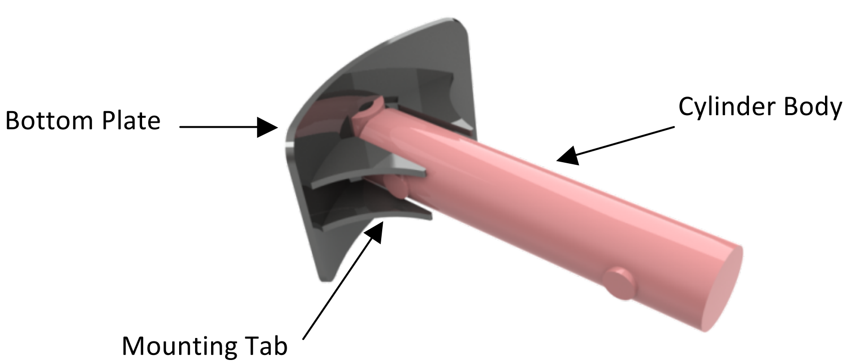

Figure 27 - Bottom Packing Plate

5.2.4 ONE INCH DIAMETER PIN

As displayed in Figure 28, a 1x 6-1/4 inch hitch pin was selected to be used in this design. It is available at Princess Auto locations at a cost of $8.99. It will be used for attachment of the top ¼ inch plate. This pin will slide through the drilled holes on the fabricated top packing plate assembly of Figure 26, and through the pin eye. The pin will effectively secure the plate to the piston head. Its length will need to be trimmed to approximately 3 inches in order to avoid interference with piston operation. It is expected to be able to withstand the maximum loading conditions of the piston.

Figure 28 - Pin for tool head securement.

5.2.5 HANDLE

As represented in Figure 29, a handle has been designed to assist mobility of the hydraulic cylinder. It is to be made out of 1 inch square tubing, with 16 gauge wall thickness. The handle is comprised of three pieces that are miter cut, such that two smaller pieces may be butted perpendicular to the longest piece. The butt joints must be welded to the long piece which is approximately 3 feet in length. Once assembled, the handle must then be welded to the hydraulic cylinder body. The overall alignment is represented in Figure 31. The handle will allow the user to move the entire assembly around at will, and eliminate the need to bend down to move the unit. A hydraulic control valve will be mounted to the handle.

Figure 29 - Handle

5.2.6 4-WAY SELECTOR VALVE

Since the hydraulic cylinder being used is known as a double acting cylinder, a 4 way hydraulic valve such as the BM20 is necessary for correct operation of the cylinder. The BM20 control valve, as seen in Figure 30, was selected for use on the hydraulic cylinder. It is available at Princess Auto locations, and is reasonably priced at $109.99. It's single spool design is ideal for this application since one hand can be used to control the retraction of the piston. It can be mounted to the handle as seen in Figure 31 in order to eliminate the need to find placement for the valve when not in use. Its operational pressure of 3600 PSI (Table 7) is adequate for the 3000 PSI maximum demand of the hydraulic cylinder that is being used. A high rate of flow is not necessary for this application; therefore this 4.5 GPM flow rate will also suffice.

Figure 30 - BM20 single spool directional hydraulic control valve [10].

Below, Table 7 supplies the four way selector valve product features:

Table 7 - Specifications of selected BM20 hydraulic control valve [10].

Features: Standard 3-position, 4-way/spring return to neutral unless otherwise stated
Max. Return line pressure: 1,100 PSI
Relief valve pre-set @ 2,100 PSI, adjustable from 1,500 PSI to 3,750 PSI
Control handles can be mounted in vertical or horizontal position
Max. Continuous pressure: 3,600 PSI
Max. continuous flow: 4.5 GPM
Peak flow: 6.6 GPM
Top inlet/outlet and work ports: #6 ORB
Side inlet/outlet ports: #8 ORB
Single spool

5.3 HYDRAULIC CYLINDER FINAL ASSEMBLY

Figure 31 is a complete assembly of all components. The hydraulic control valve has been attached to the handle such that is readily accessible to one of the operator's hands while using the other hand to grasp the handle for stability and control of the device. The top and bottom packing plates, and the handle is mounted such that appropriate room has been given to the hydraulic hose ports on the side of the cylinder body. From a standing position, the operator will have full control of the assembly.

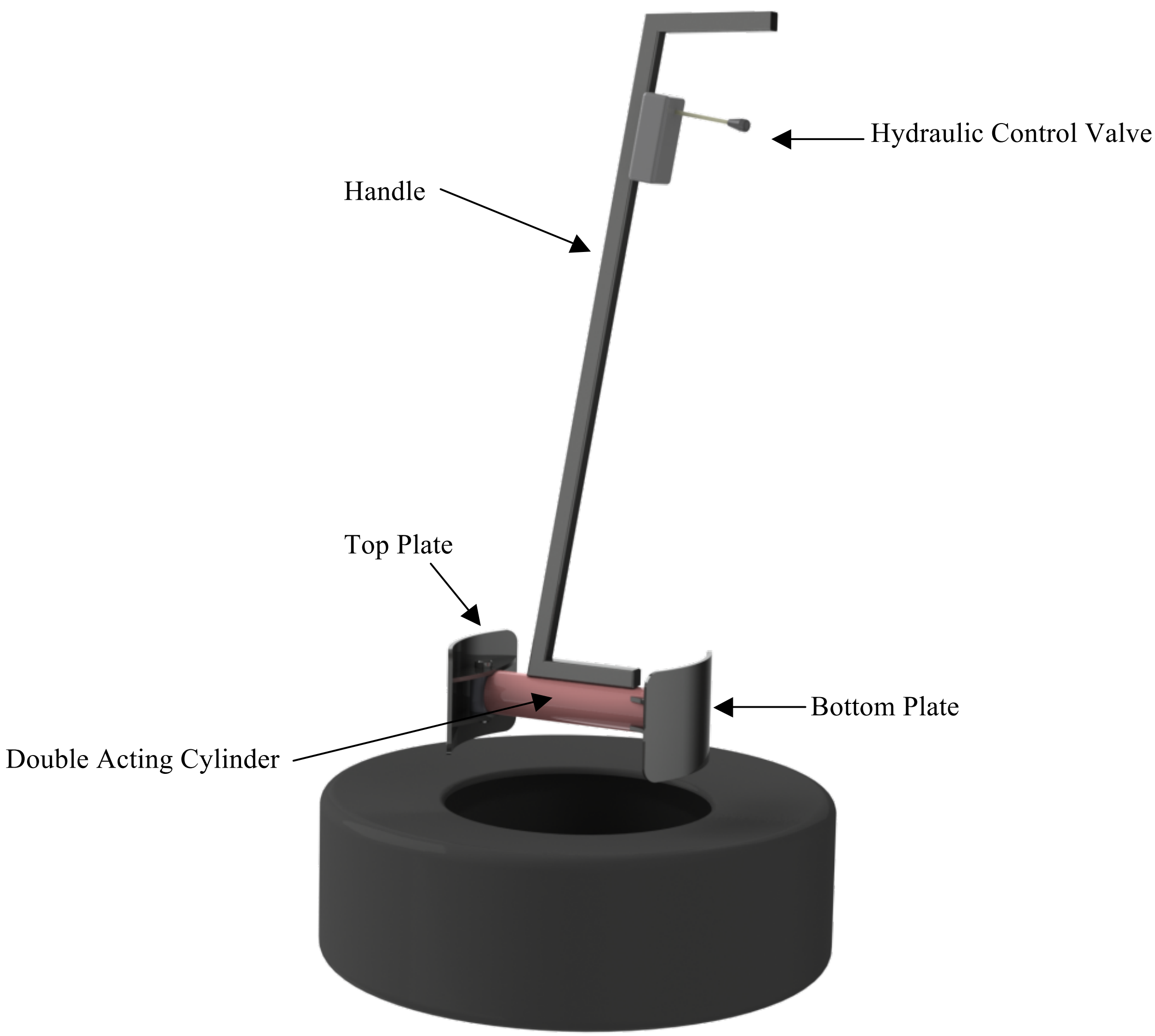

Figure 31 - Final Hydraulic Cylinder Assembly.

5.4 METHOD OF OPERATION

The hydraulic cylinder assembly is to be used in the following process:

A. Soil is to be shoveled into the tire side wall.
B. Using the handle, the hydraulic cylinder assembly is placed into the center tire region.
C. The control valve is actuated such that the piston extends.
D. The control valve is held open until the operator feels the soil has been packed adequately.
E. The control valve is then actuated such that the piston retracts.
F. Once the piston is retracted fully, the assembly is rotated 45 degrees.
G. The process is then repeated until the soil has been packed to the operator's satisfaction.
H. More soil can now be placed in the sidewall area and packed in the aforementioned order until the entire sidewall region of the tire is filled and packed.

5.5 COST OF HYDRAULIC CYLINDER ASSEMBLY

A cost breakdown for the primary components of the Hydraulic Cylinder Assembly is shown in Table 8. Cost of raw materials such as steel plating and square tubing has not been included, as overall production quantity is unknown. The overall cost of the Hydraulic Cylinder Assembly is sufficiently low to warrant prototype construction.

Table 8 – Cost Analysis of Hydraulic Cylinder Assembly.

Component Description	Quantity:	Cost (CAD)
14 inch Double Acting Hydraulic Cylinder [8]	1	$134.99
BM20 Single Spool Directional Hydraulic Control Valve [10]	1	$109.99
1 inch Hitch Pin [9]	1	$8.99
3/8 inch 2-Wire High Flex Hydraulic Hose (60 ft. of hose) [12]	1	$107.40
#6 ORB M-F hydraulic fitting [12]	4	$31.96
#8 ORB M-F hydraulic fitting [12]	2	$15.98
#6 ORB Male x 3/8" NPT Female Swivel 90° [12]	4	$27.96
3/8 inch JICM 37° x 8 ORBM 90° Adapter [12]	2	$9.78
3/8 inch NPT Hydraulic Quick Coupler Tip [12]	2	$11.98
	Taxes @ 12%:	$55.08
	Total:	$514.11

6 RECOMMENDED FILL AND PACK PROCESS

The air tamper and hydraulic cylinder devices can be used independently to achieve the resultant packed tire. The most effective direction of packing for the pneumatic backfill tamper is in the vertical direction, whereas the cylinder packs solely in the horizontal plane. The primary deficiency of the air tamper resides in its inability to pack effectively underneath the sidewall. This is because the sidewall blocks tamping strictly in the vertical plane. However, there is some angular mobility in the use of the air tamper that allows access to the soil located underneath the sidewall; therefore it is possible to use the tamper independently. The primary deficiency of the hydraulic cylinder is that it has no ability to pack in the vertical plane whatsoever. If one were to try to use the hydraulic cylinder independently, then soil would have to be packed manually into the void left in the tire's center region. When both devices are combined in a packing process, the sum of their effective packing regions will yield a well packed tire both under the sidewall and within the inner diameter of the tire.

Operationally, there is an order to how the devices should be used, although some discretion will left to the operator pending further testing and verification. First, a Raised Sidewall Fixture is deployed on both sides of the tire to raise the sidewall for better access to the interior. The Hydraulic Cylinder Assembly is then used to pack soil into the sidewall area in the process outlined in section 6.4. Once the lateral packing completely fills the sidewall region at a density that is satisfactory for the operator, the Hydraulic Cylinder Assembly may then be removed from the tire and placed aside. Following this, the only region left to be filled and packed with soil is the center region. At this point, the air tamper will then pack soil in the center until the tire is completely filled with packed soil.

7 PROJECT SUMMARY

7.1 COST SUMMARY

The itemized cost analysis for the Sullair MTB-6 Backfill Tamper, Raised Sidewall Fixture, and the Hydraulic Cylinder Assembly has been documented in Sections 5.1.2, 5.4, and 6.4, respectively. Overall the cost of implementing the recommended rammed earth tire packing system is summarized in Table 9.

Table 9 – Cost summary of recommend rammed earth tire packing process.

Sub-System Description	Quantity:	Cost (CAD)
Sullair MTB-6 Pneumatic Backfill Tamper w/ accessories	1	$943.03
Lifted Sidewall Fixture	2	$54.86
Hydraulic Cylinder Assembly	1	$514.11
	Total:	$1,566.86

The overall cost of the recommended process falls well below the client's recommendation of a $5000 system implementation spending limit. Based on cost, the project team has concluded the system to be viable for prototyping and further testing.

7.2 SATISFACTION OF PROJECT REQUIREMENTS

The goal of the tire packing designs presented by the project team is to improve the process for preparing tires for use in Rammed Tire Structures. The concepts presented used the current manual tire packing method as a baseline for the packing effectiveness requirement. In the recommended process, utilizing the hydraulic lateral packing and the raised sidewall with the pneumatic backfill tamper, the client's requirements of a packing system have been satisfied. By utilizing both systems the tire packing will far exceed the current manual method with respect to process consistency, on the grounds that the proposed systems utilize mechanical power input, resulting constant operator performance. The client requires that the proposed system pack the soil to a density that is comparable to the current manual state. The two proposed systems packing effectiveness must be proven in further testing. The current manual state requires only one operator to be present. The proposed system requires only one worker to be present to setup and operate the system; however, the proposed tire packing system will perform optimally with two or three operators present. The goal of the client was to reduce the manual labor required to fill and pack a rammed earth tire.

The proposed system that includes use of the Raised Sidewall Fixture, Hydraulic Cylinder Assembly, and the Sullair pneumatic tamper will drastically reduce the manual input during the tire filling and packing process. The project objective to reduce the time required to fill and pack a tire will be reduced by this system; however, with limited success, due to the setup time required by the system. The time required by the proposed system will be a more consistent value, since the operation of the system is much less dependent on operator fatigue levels. The project objective to require power input that was available by a small scale contractor was achieved with limited modification to the client requirements. The pneumatic capacity required by the air tamper will require a large industrial air compressor, and the hydraulic cylinder assembly will need a hydraulic power source. The justification for the hydraulic power requirements was that a rammed earth tire structure would require the movement of a large amount of soil. The implement that would already be on site to dig the hole for the structure, and supply loose soil for tire packing, could easily be utilized as a hydraulic power source. As required by all systems, operation must not cause undue danger or stress to the operators. The proposed system does not require heavy lifts, feature awkward movements or present large operational hazard, resulting in the recommended process being completely viable for further testing and verification.

7.3 RECOMMENDATIONS

In closing, the packing system presented by the project team has been successful in reducing the required labor input to fill and pack a rammed earth tire. The system will include packing of the sidewall region of the tire by the Hydraulic Cylinder Assembly, with the center region packed by the Sullair MTB-6 pneumatic backfill tamper, with the Raised Sidewall Fixture utilized throughout the process to reduce filling time and to steady the tire position on the wall. The limitations of this system are that the overall projected cycle time will not be drastically reduced over the current manual method. The advantages of the proposed system are a reduced labour input, more consistent packing effectiveness, and more consistent tire throughput. The final recommendation of the project team is fabricate a prototype Hydraulic Cylinder Assembly and Raised Sidewall Fixture, and to purchase or rent a pneumatic backfill tamper, in order to test the system performance in order to verify the projections made in this report.

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APPENDIX A - TECHNICAL CONCEPT DESCRIPTIONS AND SELECTION

A.1 DESIGN

This section contains a description of each concept that was considered as a possible solution to meet the project objectives. Although many more ideas were discussed among the team, the following section contains selected concepts that were deemed suitable for further consideration. These concepts will be referred to later by name according to their given titles in this section. Concepts are listed in no particular order of importance.

A.2 CURRENT STATE

The current state of rammed earth tire packing, represented in Figure 33, includes as few as a single worker equipped with a shovel, a manual tamping plate, and an 8lb sledge hammer.

The tire is initially leveled and placed where it will lie in the tire wall. A small piece of cardboard is inserted into the tire to prevent dirt from falling out the lower tire bead hole. The tire is then filled from a loose mound of soil aggregate. The tamping plate may then be used to pack the first dirt in the tire through vertical impact. The sledge hammer may also be used to pack the bottom portion on the tire by pounding down wards and outwards, so that the dirt is packed and distributed into the lower parts of the sidewall portion of the tire. Once the dirt has been packed completely, more dirt is added to the tire and packing with the sledge hammer continues with downward and outward blows. The upper portion of the tire sidewall area will be packed by shoveling dirt into the center or the tire, then hammering in an outward motion in a direction almost parallel to the ground plane. This is continued until the packed earth pushes up the tire sidewall, making it firm and suitable for supporting another packed tire on top of it.

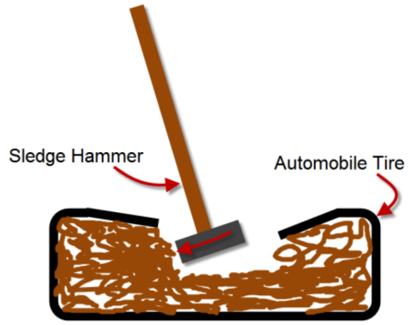


Figure 32 - Current State

The current state of rammed earth tire packing is the cheapest option with respect to capital investment during start up. The hand tools required are trivial and many contractors would already have them. The cost associated with the current state of the tire packing process comes with labor input and the time required to complete any project, which can make rammed earth tire structures unviable.

A.3 PATENTED DESIGN – PATENT NUMBER CA 2543766

The following excerpt is the abstract of Canadian patent number 2543766. It is important to consider this design as an option and to clarify that any other designs mentioned in this

> "A vibratory plate compactor with aggregate feed system includes a frame, a soil compacting plate and a drive mechanism, such as a hydraulic motor, is mounted on the frame and has a rotatable drive shaft which uses a V-belt to drive a vibratory actuator on the tamping plate. The frame also carries a hopper that uses a screw conveyor to force the stored aggregate into a vertical conduit. A tamping piston forces aggregate out of the vertical conduit, through apertures in the compactor plate and compacts the loose soil with a multitude of blows, the vibratory plate is then actuated to further compact the aggregate. The process is repeated until the cavity is filled and compacted to the required density. The vibratory plate compactor with aggregate feed system is ideally suited to filling and compacting aggregate in used automobile tires that are used in the formation of a tire wall."

A.3 "LIFTED SIDEWALL BOTTLE JACK"

The Lifted sidewall bottle jack method, as seen in Figure 34, includes a small fixture as well as a powered tamping tool. This method will work optimally with two workers present, in order to speed setup and to pack and add soil simultaneously.

The lifted sidewall method will work on the basis of changing the tire geometry in order to fill and pack the portion of the tire under the sidewall. In the case of the bottle jack method, two small hydraulic rams are attached at the top to the bead of the tire, with the base of the rams supported by the outer most radius of the tire sidewall. The rams are then extended, pulling the tire bead upward, and allowing more access to the upper sidewall region of the tire.

Once the fixture has been setup and deployed, the packing stage would begin. This would be completed most effectively by a vibratory compactor, as shown in Figure 39, fitted with a bit that would fit easily inside the tire. Packing would be completed with one operator running the compactor, and another simultaneously adding soil to the tire. The tire would be completely filled and packed by this method.

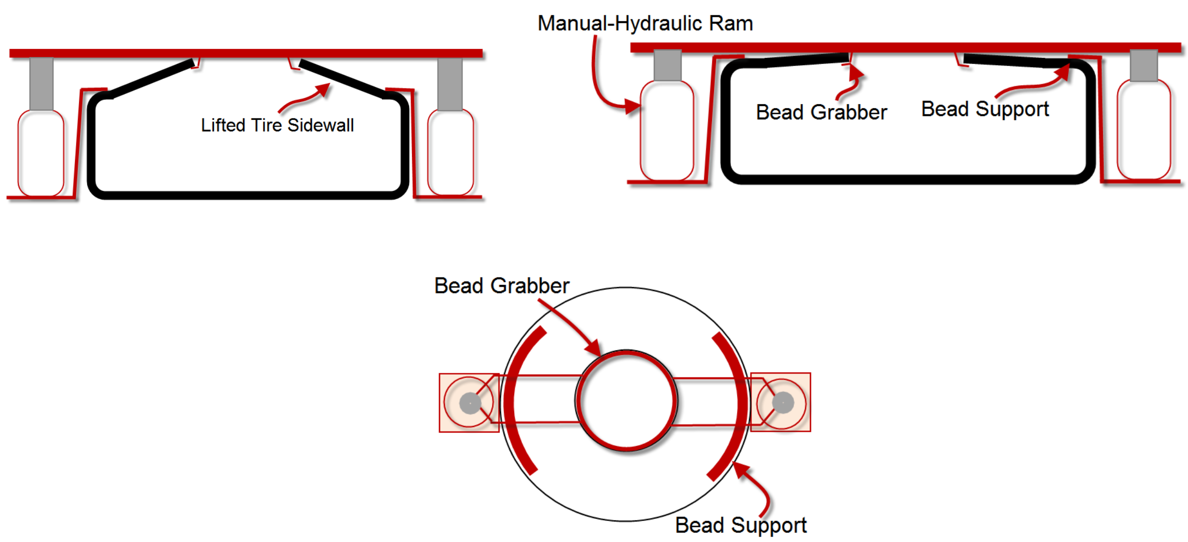


Figure 33 - Lifted Sidewall Bottle Jack (Top and Side Views)

The lifted sidewall method would have a reasonable small initial capital cost, since only a small mechanical fixture need be fabricated, and the vibratory compactor is commercially available. Savings would be found in faster throughput of filled and packed tires, as well as a large reduction in manual labor required compared to the current state.

A.4 "WASHING MACHINE"

The washing machine design seen in Figure 35 is a rig consisting of a turntable with a horizontally oriented circular plate and constraints around the periphery of plate. The tire sits inside of the constraints. An electric motor with a belt drive spins the turntable at high speed while a soil and water slurry is added to the center. Centrifugal force pulls the dirt into the cavity of the tire and water from the slurry exits from pre drilled holes in the outer diameter of the tire. Once the cavity of the tire is filled and sufficiently packed the turntable is stopped and the tire unloaded. The center of the tire must be packed manually, however the amount of labor needed for this portion alone is significantly less than packing the full tire manually.

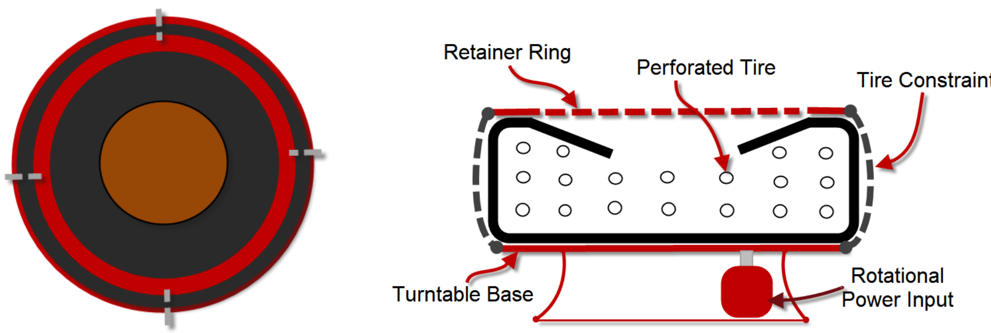


Figure 34 - Washing Machine

This method will require moderate capital investment including a frame, hub and drive motor. Due to the anticipated weight of this machine, it will not be able to be set up on top of the wall and thus the filled tires will have to be lifted onto the wall. Mixing of the soil with water will also pose additional labor to the process.

A.5 "SLIDE HAMMER"

In the case of the slide hammer design represented in Figure 36, a guide pole is placed vertically in the center of the tire. The pole must be supported at the top using guy wires or other supporting method. A massive cone shaped slider is placed over the guide pole. The cone is lifted using a winch or other mechanism to the top of the pole. Soil is added to the tire and the cone is released, dropping to compress the soil downward and outward. This process is repeated until the tire is fully packed. No further processing is required. The cone shaped rammer geometry may be optimized to ensure most efficient packing.

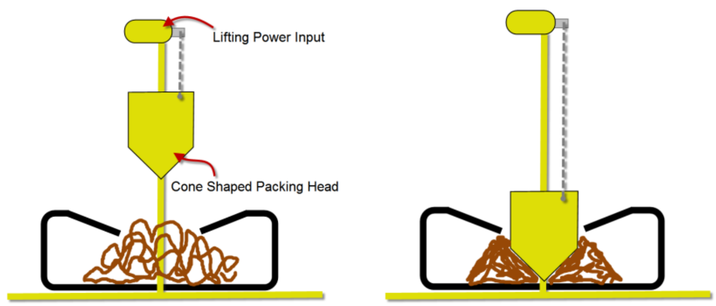


Figure 35 - Slide Hammer

Cost of this method is considerably low. It can be done in place on the tire wall. One laborer can fill soil each time the weight is being lifted providing added efficiency.

A.6 "AIR POWERED SLIDE HAMMER"

A frame is clamped to the tire. This frame includes a pressure vessel with a piston cylinder. The piston is attached to a cone shaped tamper. The pressure vessel charges by means of an air supply while the tire is being filled with soil manually. When the tire is filled with unpacked soil, a quick release opens a high volume valve pushing the cone downward with immense force and velocity. The process is repeated until the tire is fully packed with soil.

Manufacturing this setup is slightly more costly than the weight driven slide hammer described above. However because a pressure vessel is used in place of a long pole, awkwardness of setup on the tire wall can be avoided. Added cost is justified for this reason.

A.7 "REMOVAL OF SIDE WALL"

Transmission of forces from vertical to horizontal poses the largest challenge in the tire packing process. Commercially available tampers pack strictly in a vertical fashion. Any such tools could be used if one side wall was simply cut away, such as the tire represented in Figure 37. The tire would then be filled with soil and packed using an appropriate power tool. Material being removed from the tire would not produce additional waste because it would be incorporated into the soil mixture.

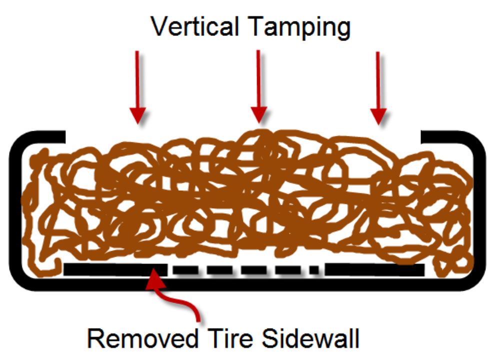


Figure 36 – Removal of Side Wall

The cost to implement this solution would be very low and would consist of a reciprocating saw to cut the rubber. It must be determined if the absence of the top wall of the tire will compromise the structure of the wall. If not, this option will effectively keep cost the same while decreasing potential flow time.

A.9 "AUGER"

In the case of the auger design, as seen in Figure 38, the tire is sealed in on the bottom half with a piece of cardboard. An auger placed vertically is strapped to the tire using chains. The weight of the auger ensures that dirt will not escape from the bottom. The auger is turned on and dirt is added through the top. When the motor is loaded sufficiently, a breaker will trip. The pitch of the auger blade is critical to ensure forceful packing.

Auger equipment can be found where farm supplies are sold. Startup cost would be relatively high due to the need to purchase a motor and design a drive system.

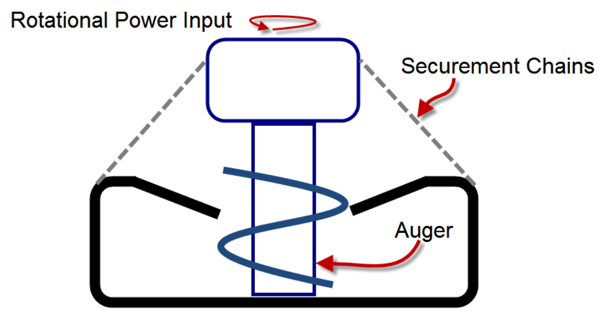


Figure 37 – Auger

A.10 "HORIZONTAL CAM HAMMER"

A vertical shaft with stacked cams runs through the center of stacked, mirrored half-moon shaped spring tensioned hammers. Soil is added around the shaft in the center of the tire. A plate/lid is placed over the tire and the shaft is rotated. The lid is lifted and more soil is added.

This Method could potentially be configured in a variety of ways.

Cost of designing this mechanism would be high. Dynamic analysis would be required. Capital cost would be large.

A.11 "PANCAKE TAMPER"

The Pancake tamper method, as seen in Figure 39, features a low-profile tip mounted onto a vibratory tamping tool. This method will work optimally with two operators present.

Setup for the Pancake Tamper method would simply involve setting up the tire, inserting the cardboard retainer, and placing the Pancake Tamper into the tire.

The Pancake Tamper would both mechanically tamp the soil as well as distribute soil to the inside of the tire mechanically through the use of a small feed auger. One operator would use the Tamper, moving it around the inside of the tire to ensure even distribution of soil. The second operator would be responsible for shoveling soil into a small hopper which the auger would feed from. The Pancake Tamper would pack the tire until it was almost fully, with the low profile tamping plate reaching under the sidewall to ensure full even compaction across the tire diameter. The very top of the upper sidewall would be finished packing using a sledge in a similar fashion to the current manual method.

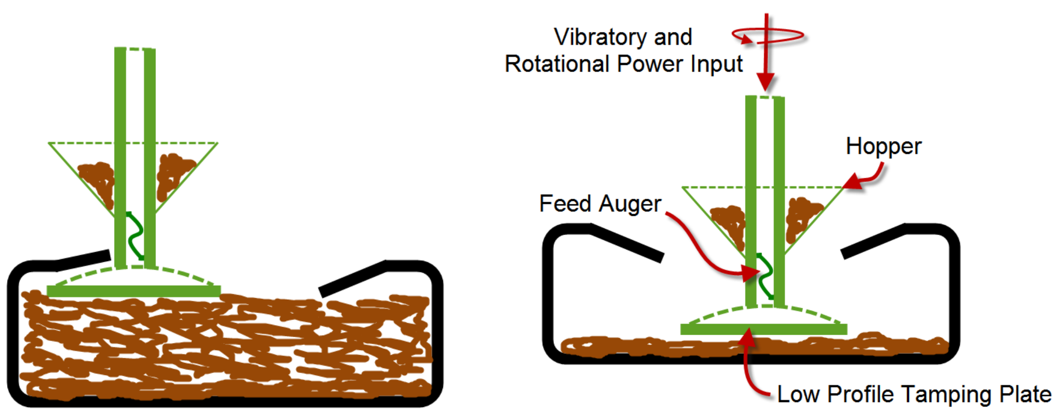


Figure 38 - Pancake Tamper

The Pancake Tamper would feature a moderate amount of initial capital cost due to the auger feed drive system and vibratory compactor. However, compactors are commercially available and a simple auger drive and tamping plate may be fabricated while easily staying within the financial constraints of the client.

A.12 "LIFTED SIDEWALL HINGED LEVER ARM"

The lifted sidewall hinged lever arm method, as seen in Figure 40, includes a small fixture as well as a powered tamping tool. This method will work optimally with two workers present, in order to speed setup and to pack and add soil simultaneously.

The lifted sidewall method will work on the basis of changing the tire geometry in order to fill and pack the portion of the tire under the sidewall. In the case of the hinged lever arm method, two hinged lever arms are positioned on either side of the tire. A component of the lever arm grasps the bead of the tire's sidewall in such a way that when the lever arms are actuated, the tire bead will be lifted upwards. The setup also includes a frame that holds the lever arm setup securely to the tire.

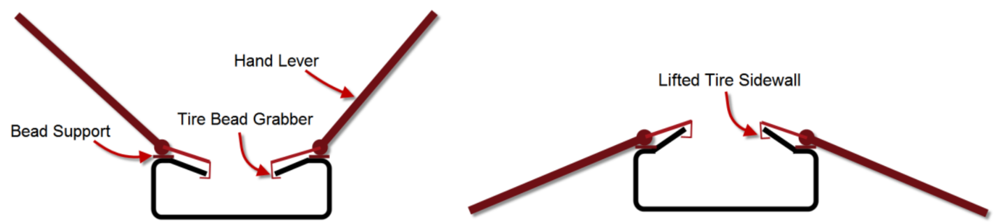


Figure 39 - Lifted Sidewall Hinged Lever Arm

Once the fixture has been setup and deployed, the packing stage would begin. This would be completed most effectively by a vibratory compactor, as shown in Figure 39, fitted with a bit that would fit easily inside the tire. Packing would be completed with one operator running the compactor, and another simultaneously adding soil to the tire. The tire would be completely filled and packed by this method.

The lifted sidewall method would have a reasonable small initial capital cost, since only a small mechanical fixture need be fabricated, and the vibratory compactor is commercially available. Savings would be found in faster throughput of filled and packed tires, as well as a large reduction in manual labor required compared to the current state.

A.13 "TWO-STAGE MANUAL LATERAL PACKING"

The Two-Stage Manual Lateral Packing method, as seen in Figure 41, includes a small fixture, as well as a powered tamping device. This method will work optimally with two workers present, in order to speed setup and to pack and add soil simultaneously.

This method will work without any change to the geometry of the tire. It will employ a hinged lever arm system, that when acted on will complete the lateral component of packing. It is difficult to pack soil into the sidewall once a tire is nearly full; this method will be able to mimic the lateral motion of the current state process, with use of manual leverage. This setup includes a frame that can secure the manual lever arm device to the tire.

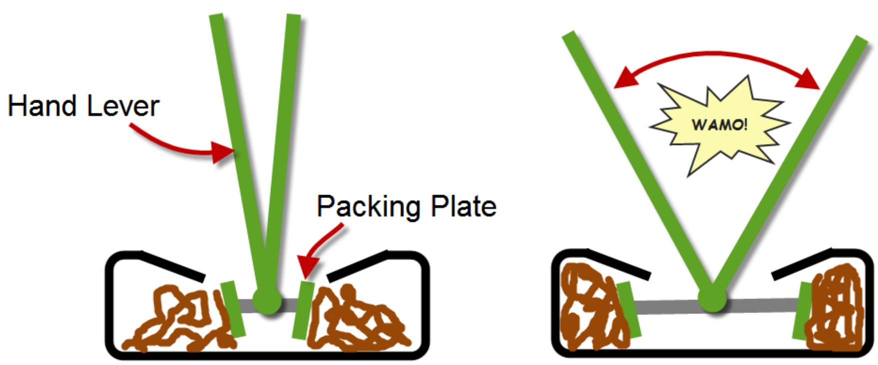


Figure 40 - Two Stage Manual Lateral Packing

It is a two-stage process in that the lateral packing must be done separately from the downward packing. The downward component will be completed by a vertical vibration tamping device. Following the downward packing, the hinged setup will be used to pack laterally.

This method would be very inexpensive to prototype and produce, since a small hinged fixed need be fabricated, and the tamping device is commercially available. This device would be more economical than current state through better cycle time, and reduction of labor.

A.14 "SCREW TYPE CONE HEAD"

The screw type cone head method, as seen in Figure 42, is a one stage process, which includes a power tamping tool and a special tool head fitted to it.

This method works on the principles of shear and torque. The tamping device, complete with a conical tool head, is used to not only pack downward and outward, but also to compress the dirt through rotational motion. Similar to an impact drill, some of the vibration of the tamper will be converted into angular motion of the tool head. By designing the tool head with screw like properties, the downward vibration combined with rotational motion can be used to effectively pack soil into the tire.

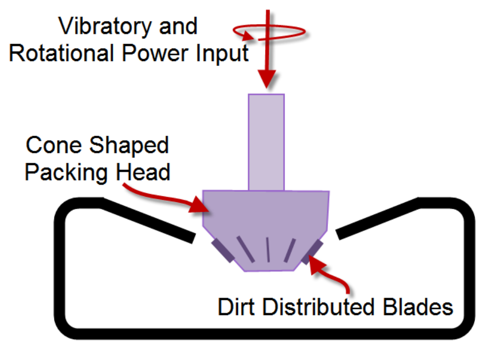


Figure 41 - Screw Type Cone Head

This method would have a notable initial capital cost because of the complicated tool head. Its intricate design would require skilled fabrication and assembly to ensure proper function of the tool itself. The vibratory compactor is commercially available. Savings would be found in faster cycle time of filled and packed tires, and significant reduction of labor with respect to current state. This method also eliminates the need for a two stage process of packing, which will effectively expedite the packing process.

A.15 SCREENING MATRIX AND SCORING MATRIX

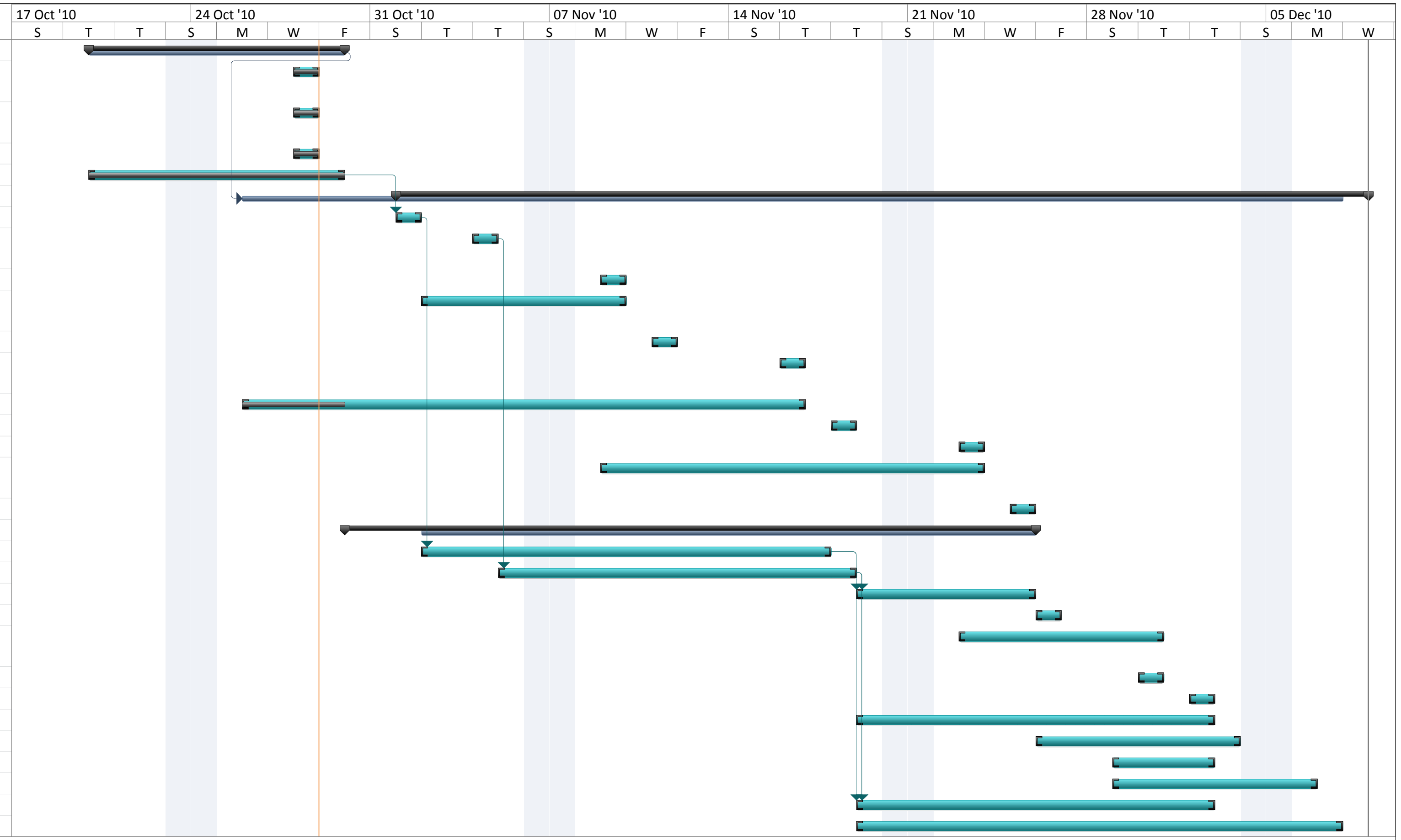
As seen in Figure 43, a decision matrix has been created to aid in the selection of the 13 different designs. The design specifications are based upon several parameters defined by our client and inferred by the team. All scores are assigned a scale of one to ten. Weighting is also based on a one to ten scale in which the parameters were rated. This matrix was very helpful in giving us a qualitative analysis of the designs. The team has no quantitative data to be able to make a detailed comparative analysis, therefore rating characteristics of these designs based on intuition was critical.

Design Specifications	Portable	Lightweight	120 V	Design Difficulty	Packing Effectively	Manufacturability	Low Cost	Can it Attach to the Wal	Speed	Manual Input	Variability	Soil Versatility	Marketability	Safety	Ergonomics	Total
Weighting	6	6	4	4	10	8	7	5	7	8	5	5	6	7	5	
Screw Type Hammer Cone	9	8	10	9	8	3	5	8	10	6	7	9	9	8	7	700
Manual Lateral Pack	6	8	10	8	7	8	9	5	6	3	7	8	7	9	4	644
Washing Machine	0	0	10	6	7	5	4	0	4	4	8	6	3	1	3	372
Slide Hammer	3	6	10	9	10	6	9	8	7	10	8	9	10	3	7	711
Slide Hammer with Pressure Vessel	2	4	10	6	9	5	4	8	7	10	8	9	10	2	8	626
Current State	9	9	10	10	10	10	10	9	2	0	4	8	0	8	2	623
Youtube	0	0	0	3	9	2	3	0	5	5	6	6	3	1	9	344
Pancake Tamper	9	9	10	10	6	10	10	8	8	6	7	9	8	6	7	747
Tamping w/ lifted sidewall (hinge)	7	8	10	7	9	6	7	8	7	6	7	9	8	6	7	687
Tamping w/ lifted sidewall (bottle jack)	6	8	10	7	9	6	6	7	6	6	7	9	8	6	7	662
Laterallly Stacked Cam hammer	8	8	10	0	7	3	3	5	7	6	7	7	7	6	7	562
Auger	8	7	10	3	7	9	6	8	9	6	8	6	8	4	6	653
Cut Out One Side Wall	10	10	10	10	10	10	10	10	10	10	4	10	6	8	9	857

Figure 42 - Decision Matrix for Design Selection

APPENDIX B – PROJECT SCHEDULE

ID	Indicators	Task Mode	Task Name	Duration	Start	Finish
1	✓		**Phase II - Concept Design**	**8 days**	**Wed 20/10/10**	**Fri 29/10/10**
2	✓		Submint Report draft to Tarek Elmekawwy and TA for feedback	1 day	Thu 28/10/10	Thu 28/10/10
3	✓		Meet with Dr. Bibeau to approve report and discuss progress	1 day	Thu 28/10/10	Thu 28/10/10
4	✓		Make Final Report Revisions	1 day	Thu 28/10/10	Thu 28/10/10
5	✓		**Concept Design Report, & E-copy to advisor (50%)**	**8 days**	Wed 20/10/10	Fri 29/10/10
6			**Phase III - Final Design**	**28 days**	**Mon 01/11/10**	**Wed 08/12/10**
7			Team Meeting (Scheduling and Planning)	1 day	Mon 01/11/10	Mon 01/11/10
8			Team Meeting (Concept Design Analysis Definition) & Meet With Dr. Bibeau	1 day	Thu 04/11/10	Thu 04/11/10
9			Team Meeting (Possible field day for testing)	1 day	Tue 09/11/10	Tue 09/11/10
10			**Submit Log Book, Gantt Chart, Meeting Minutes/Advisor**	**6 days**	Tue 02/11/10	Tue 09/11/10
11			Team Meeting (Dividing up workload for Report	1 day	Thu 11/11/10	Thu 11/11/10
12			Team Meeting (Dividing up workload for Oral Presentation)	1 day	Tue 16/11/10	Tue 16/11/10
13			Make Simulations and Models	16 days	Tue 26/10/10	Tue 16/11/10
14			Team Meeting (Report Compilation)	1 day	Thu 18/11/10	Thu 18/11/10
15			Team Meeting (Report Revision)	1 day	Tue 23/11/10	Tue 23/11/10
16			**Submit Log Book, Gantt Chart, Meeting Minutes/Advisor**	**11 days**	Tue 09/11/10	Tue 23/11/10
17			Team Meeting (Fine Tuning of Report)	1 day	Thu 25/11/10	Thu 25/11/10
18			***Internal Draft Report Complete***	***20 days***	***Sat 30/10/10***	**Thu 25/11/10**
19			Goal Definition	12 days	Tue 02/11/10	Wed 17/11/10
20			Design Analysis	10 days	Fri 05/11/10	Thu 18/11/10
21			Report Compilation	5 days	Fri 19/11/10	Thu 25/11/10
22			*Revision of other team's report complete*	*1 day*	*Fri 26/11/10*	Fri 26/11/10
23			***Submit Log Book- Advisor , Gantt Chart, Meeting Mins--TA***	***6 days***	*Tue 23/11/10*	Tue 30/11/10
24			Team Meeting (Presentation Planning and Refining)	1 day	Tue 30/11/10	Tue 30/11/10
25			Team Meeting (Presentation Practice)	1 day	Thu 02/12/10	Thu 02/12/10
26			**Draft Reports, To be redistributed to another team**	**10 days**	Fri 19/11/10	Thu 02/12/10
27			**Draft Report Evaluations due and returned to team**	**6 days**	Fri 26/11/10	Fri 03/12/10
28			*Revisions of Report Complete*	*4 days*	*Mon 29/11/10*	Thu 02/12/10
29			**Final Project Report, Peer Evaluation-3**	**6 days**	Mon 29/11/10	Mon 06/12/10
30			*Poster and Presentation Complete*	*10 days*	*Fri 19/11/10*	Thu 02/12/10
31			**Poster and Oral Defense**	**13 days**	Fri 19/11/10	Tue 07/12/10

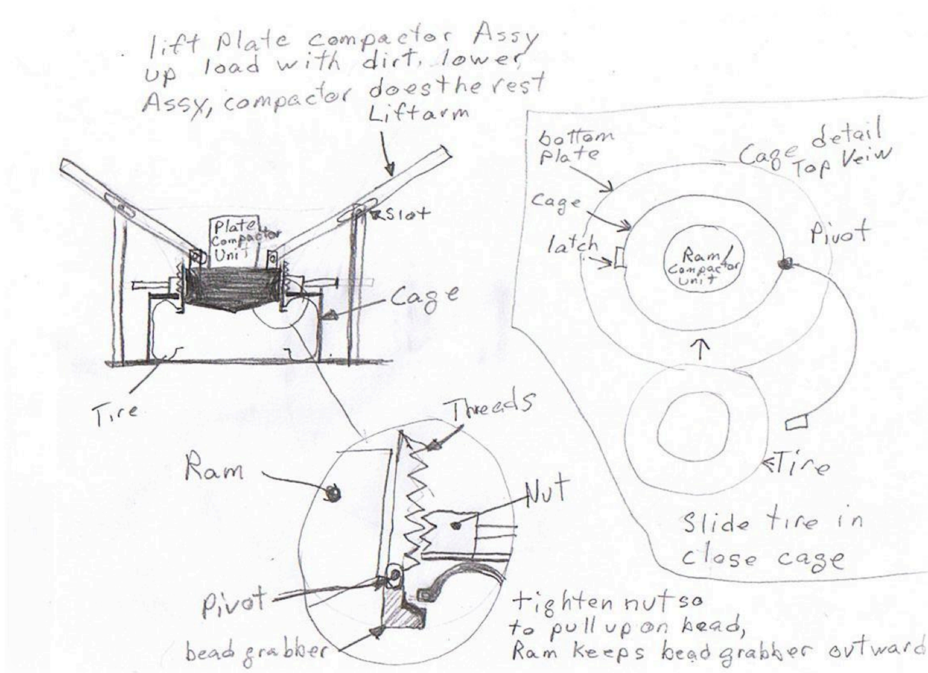


Project: Rammed Tire Project Sch
Date: Fri 29/10/10

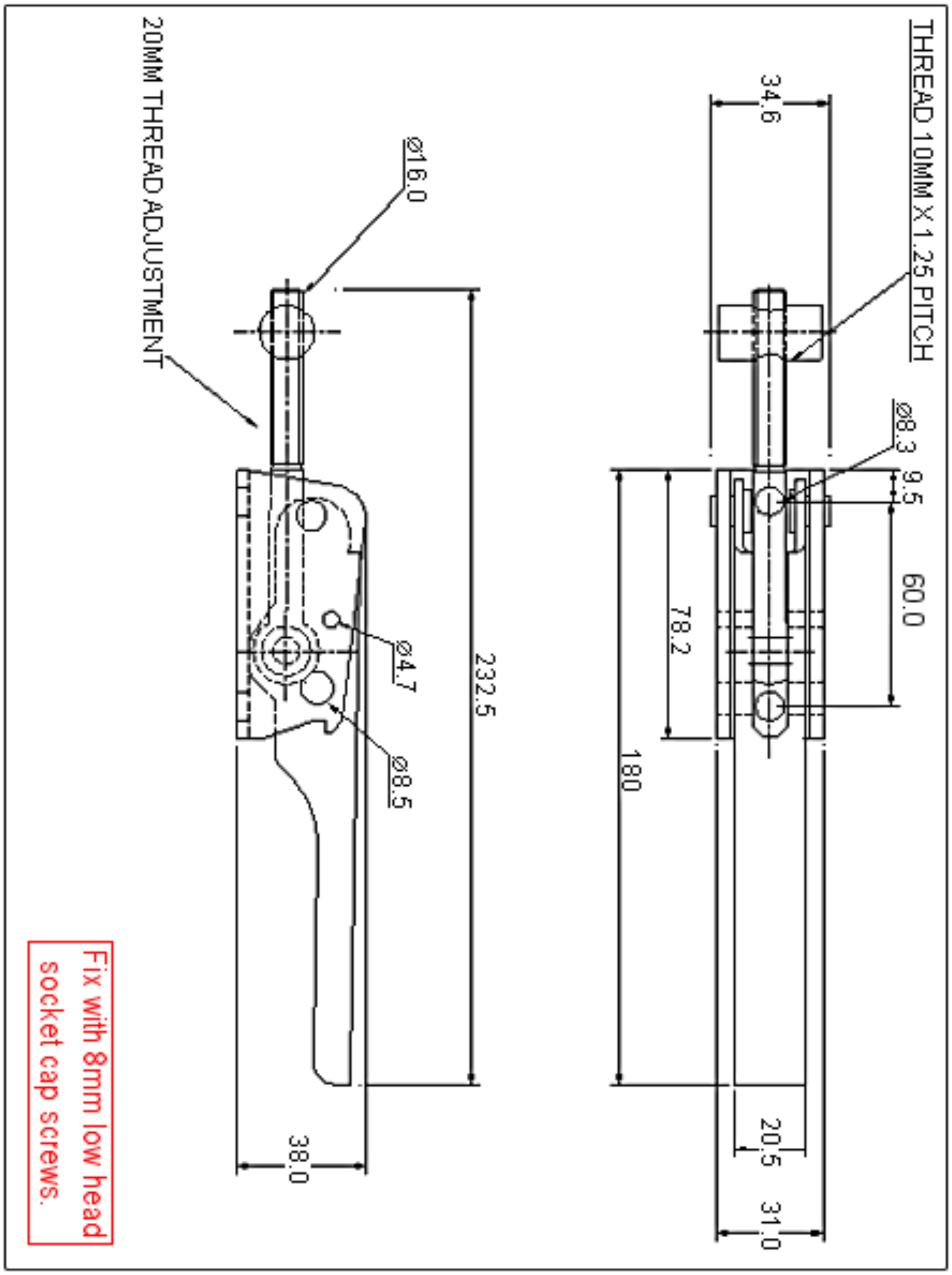
Task	Summary	External Milestone	Inactive Summary	Manual Summary Rollup	Finish-only
Split	Project Summary	Inactive Task	Manual Task	Manual Summary	Deadline
Milestone	External Tasks	Inactive Milestone	Duration-only	Start-only	Progress

APPENDIX C - SKETCH OBTAINED FROM MR. MANETA

This Sketch was obtained from Mr. Maneta as mentioned in appendix E. Although this design was not used, it gave the team some insight with regards to problems associated with packing tires.



APPENDIX D - SCHEMATIC OF 43-4000: HEAVY DUTY ADJUSTABLE FASTENER



http://www.protex.com/product/show/name/43-4000

APPENDIX E – RESEARCH RESULTS

E.1 DISCUSSIONS WITH EXPERTS

As a team, we have met with our client to discuss the current manufacturing process and to gather critical information regarding design concepts. One team member has been in contact with Greg Maneta, who works in collaboration with Dr. Bibeau on alternative building projects. He specializes in design, and prototyping, and based on his experience was able to provide input on ideas for an effective tire packing apparatus. Mr. Maneta was also able to provide some preliminary design sketches which may be found in Appendix C.

E.2 TEAM BRAINSTORMING

The Team has relied mainly on brainstorming and previous experience to produce concepts for this process. The largest source for idea generation on the Rammed Earth Tire system solutions have been group members' past experience with construction and engineering projects. During the team brainstorming sessions, certain concepts were suggested, followed by all team members providing input as to what a system implementing that idea would entail. Full system concepts were also presented by individual team members at meetings, to which the team as a whole would provide feedback and suggest improvements.

E.3 PATENT AND LITERATURE SEARCH RESULTS

E.3.1 LITERATURE SEARCH RESULTS

The unconventional nature of sustainable building construction as well as the simple nature of the tire packing process has seemingly resulted in no published articles detailing Rammed Earth Tire packing. The team searched a number of online engineering report databases, but has found no published works directly detailing processes for packing tires. Some relevant information has been found in articles concerning the construction of the tire walls, which provide some background details about the building requirements. The most useful resource providing information on the current manual packing method has been a number of internet videos and websites detailing how the Rammed Earth tires are packed during the building construction.

E.3.2 PATENT SEARCH RESULTS

Rammed earth tire packing is not a new activity and has been going on for more than three decades. This prompted the team to search for existing patented designs encompassing tools or purpose machinery for packing automobile tires with soil. Both the Canadian and US patent databases were searched using the advanced database searching tools for Boolean combinations of key words pertaining to the project. After exhaustive searching, two patents were found that are may prove useful to choosing a final design.

- United States Patent No. 6457912 B1 – Foundation Construction Using Recycled Tire Walls
- Canadian Patent No. 2543766 – Vibratory Plate Compactor with Aggregate Feed System

In terms of our project, we are including the design found in Canadian Patent No. 2543766 among possible concept designs. It was evaluated alongside original designs but the team takes no credit for its inception.

APPENDIX F – AUGER DESIGN FOR FURTHER TESTING CONSIDERATION

Visiting a local peat moss processing plant revealed some new ideas about how to fill the tire. Here, soil is mixed with fertilizers, bagged, and pressed into bales. The bales are then stacked onto pallets and restrained for shipping. Most of the processing and packaging of the soil is automated, making use of chain conveyors, screw conveyors, augers, hoppers and mixers. Describing the challenge of packing soil into tires to the resident maintenance mechanic revealed an interesting design concept. The mechanic told us that there is a specific screw conveyor that feeds a hopper. Sometimes when the hopper is clogged, the screw conveyor continues running and results in compaction of the soil in the hopper to a very dense state. This concept could be used to solve the tire packing problem.

Particulate solids such as soil mixtures are often treated as a fluid for processing. An auger is a very common tool used in various applications requiring elevation and lateral movement of such particulate solids. An auger could be used to compact soil in a cavity that is larger in diameter than the auger casing. In principle this would be analogous to mechanical advantage provided by common hydraulic systems where the force applied in a relatively small diameter conduit is amplified in a receiving chamber of larger diameter.

The auger casing needs to be attached temporarily to the tire in so that the flighting can effectively move the soil into the tire. The feed configuration must also be such that soil enters the auger laterally and cannot move upward in the cylinder. The flighting needs to have a specific pitch in order to create a certain volumetric displacement of soil per revolution.

A very helpful paper regarding design considerations and performance evaluation of screw conveyors was interrogated for information in order to design an auger to force feed soil into a tire. This document could potentially be used to select design parameters for a tire packing auger [19].

Initially, a design in which the flighting of the auger nearest the tire is larger in diameter than the tire opening itself was chosen. It is thought that this configuration would be an efficient means of displacing soil into the outermost regions of the tire cavity. Wider flighting could be tested, however, the disadvantage would be additional effort required to twist the tire on and off. Although conceptually a good idea, due to practical considerations this concept was not used in our design.

The challenge remains as to how the soil will be moved into the outside of the tire cavity. If the flighting of the auger were perpendicular to the shaft (moving radially outward from the center of the shaft) then the force of the auger on the soil would be directly downward. As a result, the soil would be packed only downward and the auger would be pushed upward before the cavity could be filled. I order to avoid this it is proposed that the flighting be angled upward 30-40 degrees from the previously described perpendicular condition. The contrast between these two designs is illustrated in the Figure 44.

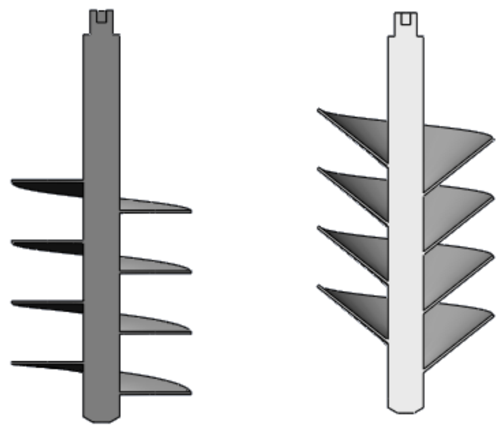


Figure 43 - Perpendicular vs. Angled Flighting

The angled flighting would provide a resultant force on the soil that would push the soil downward and outward and force it to fill the tire cavity. As the cavity fills, the auger will move up and stretch the sidewall up with it.

Process Breakdown:

A. The tire is placed on the structure in its exact resting location
B. The Auger is to be lifted onto the wall
C. The Auger is placed into the tire opening
D. Clamps are closed fastening the auger housing onto the tire
E. Auger is switched on
F. Dirt is filled into the hopper using a shovel
G. Dirt is filled into the auger until sidewalls angle upward at ~30 degrees
H. The auger is switched off
I. Clamps are opened and the auger is lifted from the tire
J. The auger can be lifted to the next tire

A concept exploded assembly view of an auger concept can be seen below, (Figure 45):

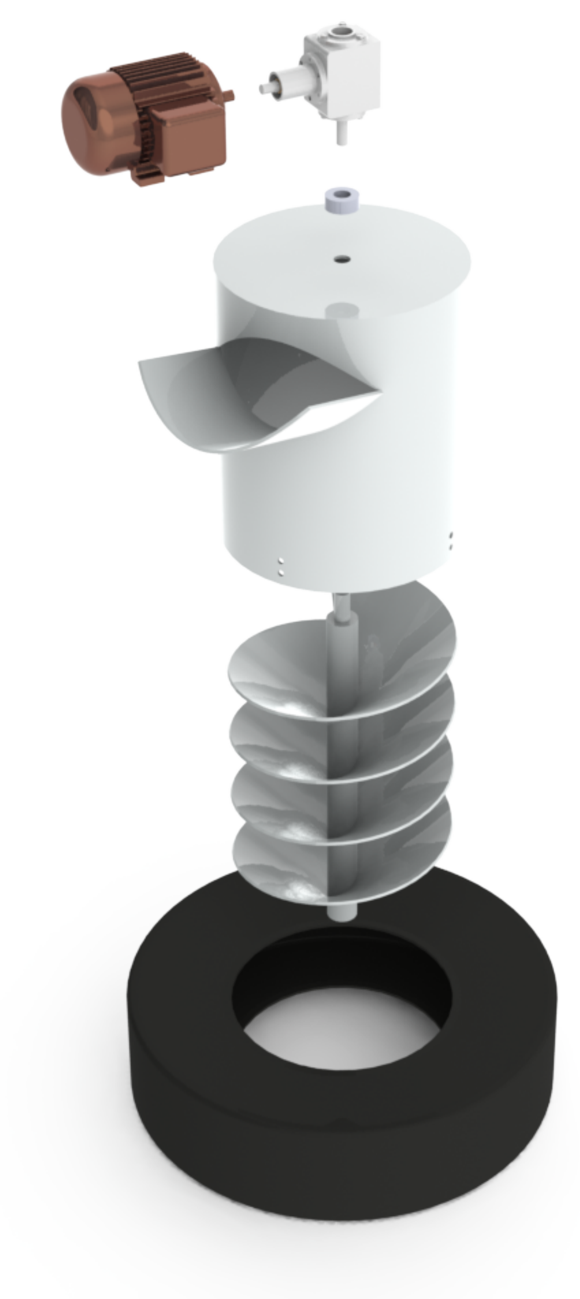


Figure 44 - Exploded Assembly View of Auger Concept

APPENDIX G – TESTING OF LIFTED SIDEWALL MECHANISM

In order to prove that raising the sidewall of a tire in the manner that the Raised Sidewall Fixture does is possible, the project team embarked on a simple proof of concept test. A piece of round tubing was clamped to the bead of a P205/75 R15 automobile tire laying on its side, as shown in Figure 46. Applying a downward load onto the round tubing to simulate the behavior of the leverage arm was able to successfully lift the sidewall of the tire 3 inches above the 'relaxed' state of the tire.

Figure 45 – Sidewall lifting test

The force required to lift the tire sidewall 3 inches at the bead was measured used a digital spring scale. The load measured translated on the end of pipe indicated that the force required to displace the tire bead 3 inches was 300 N. The results of this test showed project team members that the raised sidewall concept can work, and it gave a baseline of operational performance of the device.

APPENDIX H – HEALTH AND SAFETY DOCUMENTATION

Guideline

for Safeguarding Machinery and Equipment

Workplace Safety & Health Division
200 - 401 York Aveue
Winnipeg, Manitoba
R3C 0P8

WORK SAFE BC

Manitoba

June 2008

Machinery and equipment hazards

Hazards created by machinery and equipment can be classified as **mechanical** and **non-mechanical.**

Mechanical hazards

Recognizing mechanical hazards

A good way to recognize mechanical hazards is to observe how the moving parts of a machine operate and how parts of a worker's body are likely to come into harmful contact with them.

Some moving machinery and equipment parts can endanger a worker in more than one way. For example, an abrasive wheel can explode and cause serious impact injuries. Or, minor abrasion can result when a worker's hand accidentally rubs against the wheel.

Machine parts generally move in one of three ways: they rotate, they slide, or they can rupture, fragment, and/or eject.

- Single rotating parts, such as shafts or couplings, present a risk of snagging or entanglement. Two or more parts rotating together, such as feed rolls and V-belt and pulley drives, create nip points (see Figures 1.1 and 1.2).
- Parts that slide or reciprocate, such as dies in punch presses, create shearing or crushing hazards.
- Parts that can rupture or fragment, such as an abrasive wheel, may cause impact injuries.

Figures 1.1 to 1.5 illustrate common mechanical hazards where hands, limbs, hair, clothing, and sometimes the entire body can be injured from harmful contact with unguarded moving machine parts. The illustrations show typical cases, not all possibilities.

Principal mechanical components of machinery

Most machines have three principal components:

- A power source (often an electrical motor)
- A power train that transfers moving energy
- Tooling

Hazards from these components generally involve the following:

- Power transmission parts. These are the moving parts of the power train. They usually consist of belts, pulleys, chains, sprockets, gears, shafts, and couplings. Many of the moving parts illustrated in Figures 1.1 and 1.2 are power transmission parts.
- Point of operation. This is where the tooling of the machine is contained and the machine's work is performed. The term "feed point" is sometimes used to describe the working area of the machine.

The types of machine components and drives shown in Figures 1.1 to 1.5 are very common in most industrial operations. They account for a large number of serious injuries in the workplace.

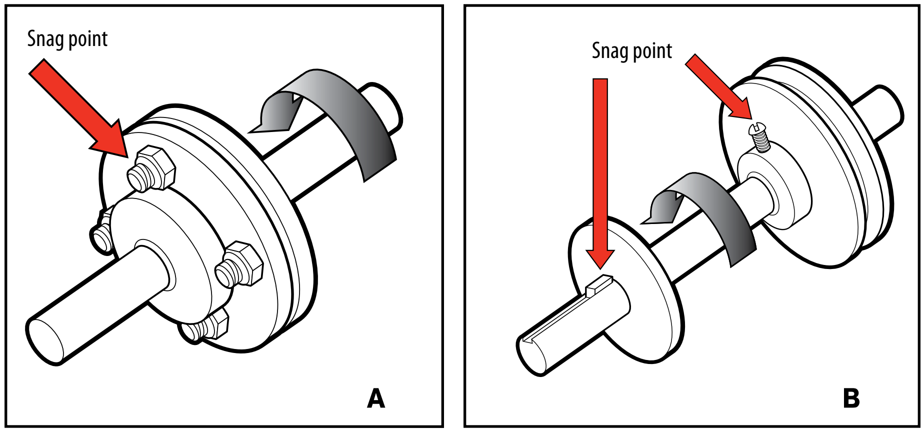


Figure 1.1. Single rotating parts presenting a snagging/entanglement hazard.
(A) Snagging hazard from projecting flange bolts on rotating coupling.
(B) Snagging hazard from projecting keyway and set screw on rotating shaft.

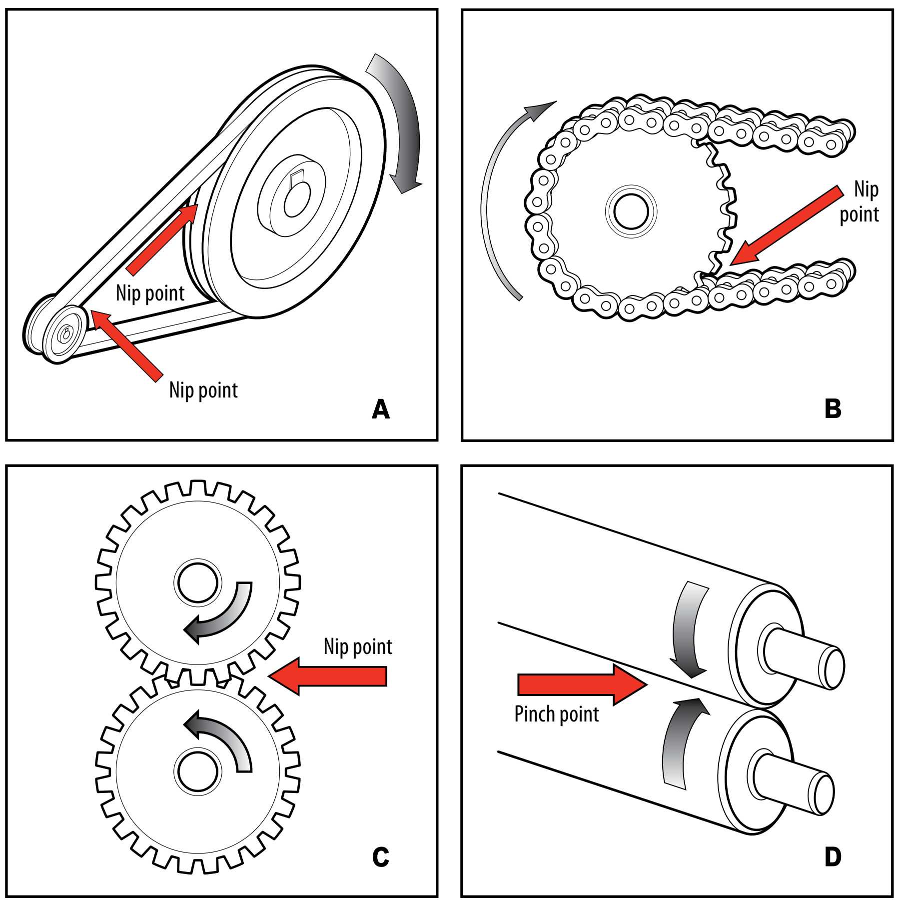


Figure 1.2. Multiple rotating parts presenting an in-running nip point hazard. (A) V-belt and pulley drive: a common source of in-running nip points on powered industrial machinery. (B) Typical chain-sprocket drive. (C) Typical exposed gears. (D) Typical feed rolls.

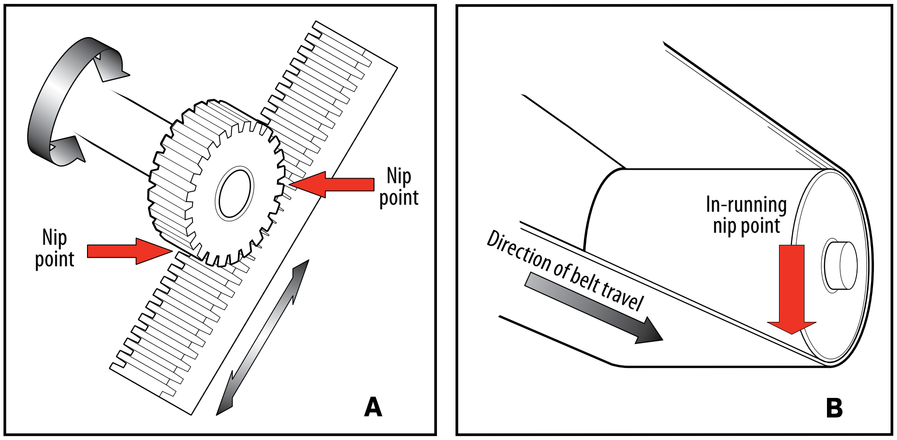


Figure 1.3. Combination of rotating and sliding parts and reversing parts, creating two in-running nip point hazards. (A) Rack and pinion gears. (B) Conveyor belt spool.

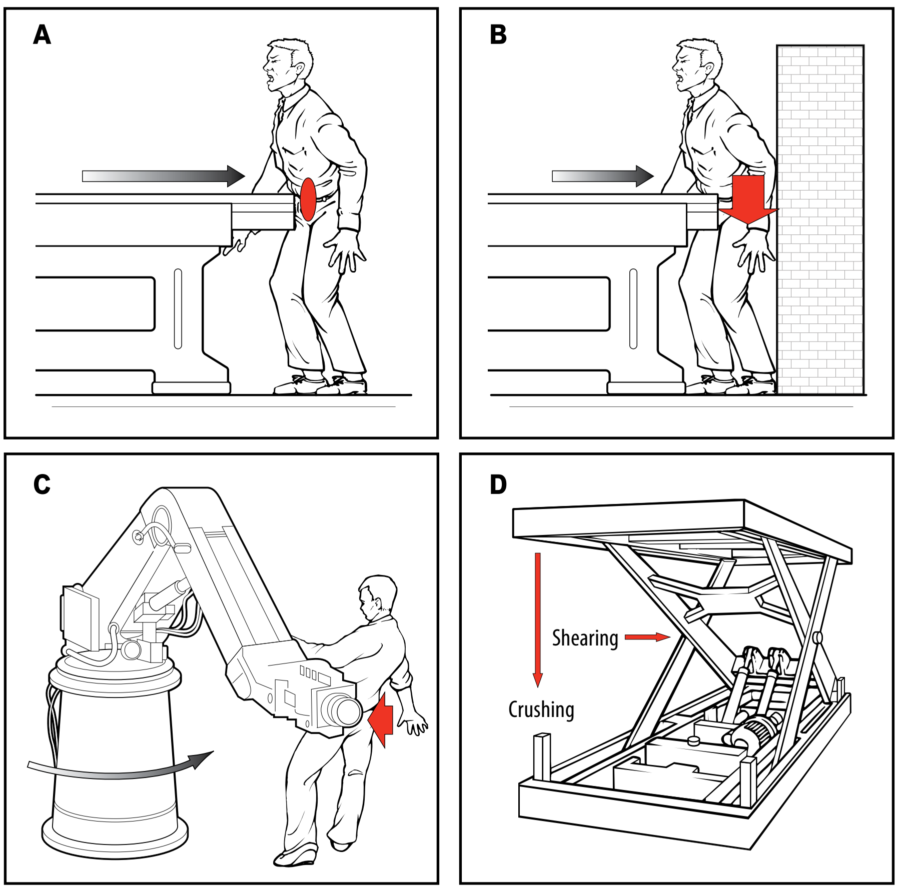


Figure 1.4. Sliding/pivoting movement creating struck by/crushing hazards.
(A) Sliding milling table striking worker in abdomen.
(B) Sliding milling table crushing worker against adjacent wall. (C) Worker struck by robot arm.
(D) Scissor lift creating crushing/shearing hazards.

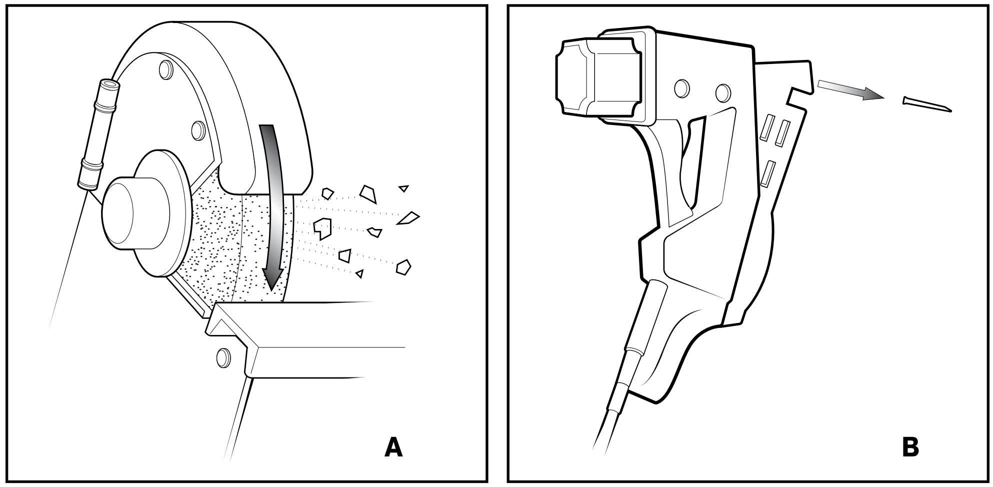


Figure 1.5. Hazards from fragments and projectiles.
(A) Fragments from exploding abrasive wheel. (B) Projectile from pneumatic nail gun.

Health hazards

Workers operating and maintaining machinery can suffer adverse effects other than physical injury caused by moving parts. They can be exposed to hazards through inhalation, ingestion, skin contact, or absorption through skin. For example, without adequate safeguards, control measures, and personal protective equipment, a worker may be at risk of occupational disease resulting from exposure to:

- Toxic or corrosive chemicals that can irritate, burn, or pass through the skin
- Harmful airborne substances that can be inhaled, such as oil mist, metal fumes, solvents, and dust
- Heat, noise, and vibration
- Ionizing radiation such as X-rays and gamma rays
- Non-ionizing radiation such as ultraviolet light (UV), radio frequency (RF) energy, and lasers
- Biological contamination and waste
- Soft tissue injuries (for example, to the hands, arms, shoulders, back, or neck) resulting from repetitive motion, awkward posture, extended lifting, and pressure grip

Other hazards

Some hazards are associated with things other than moving parts:

- Slips and falls from and around machinery during maintenance
- Unstable equipment that is not secured against falling over
- Fire or explosion
- Pressure injection injuries from the release of fluids and gases under high pressure
- Electrocution from faulty or ungrounded electrical components

Machines must be safeguarded to protect workers from these non-mechanical hazards as well as the more obvious mechanical hazards.

Sometimes a safeguard used to eliminate or minimize a mechanical hazard can be modified to also minimize a non-mechanical hazard. For example:

- A guard designed to prevent access to moving parts may also absorb noise.
- Welding curtains designed to shield against arc flash can also protect against spatter and burns.
- Guards surrounding abrasive wheels can also be used as a shroud for local exhaust ventilation.

Hierarchy of safeguarding controls

When selecting a safeguard or a combination of safeguards, always start at the top of the hierarchy shown below. Choose a less effective safeguard only when the more effective solution is impracticable.

For example, you may be able to eliminate the need to hand-feed a machine by installing an automated feeder. Installing a fixed barrier guard across a feed point may be practicable if the feed stock is a flat sheet metal blank; for larger material, you may have to allow access to the point of operation using two-hand controls or a light curtain (a presence-sensing device) instead.

Hierarchy of Safeguarding Controls			
Most effective	1. Elimination or substitution	• Eliminate human interaction in the process • Eliminate pinch points • Automate material handling	
↓	2. Engineering controls (safeguarding technology)	• Mechanical hard stops • Barrier guards • Interlocked guards	• Presence-sensing devices • Two-hand controls
↓	3. Awareness	• Lights, beacons, strobes • Computer warnings (PLC-generated) • Restricted space painted on floor	• Beepers • Horns and sirens • Warning signs and labels
↓	4. Training and procedures (administrative controls)	• Safe work procedures • Safety equipment inspections	• Training • Lockout
Least effective	5. Personal protective equipment	• Safety eyewear • Face shields • Hearing protection	• Gloves • Respirators

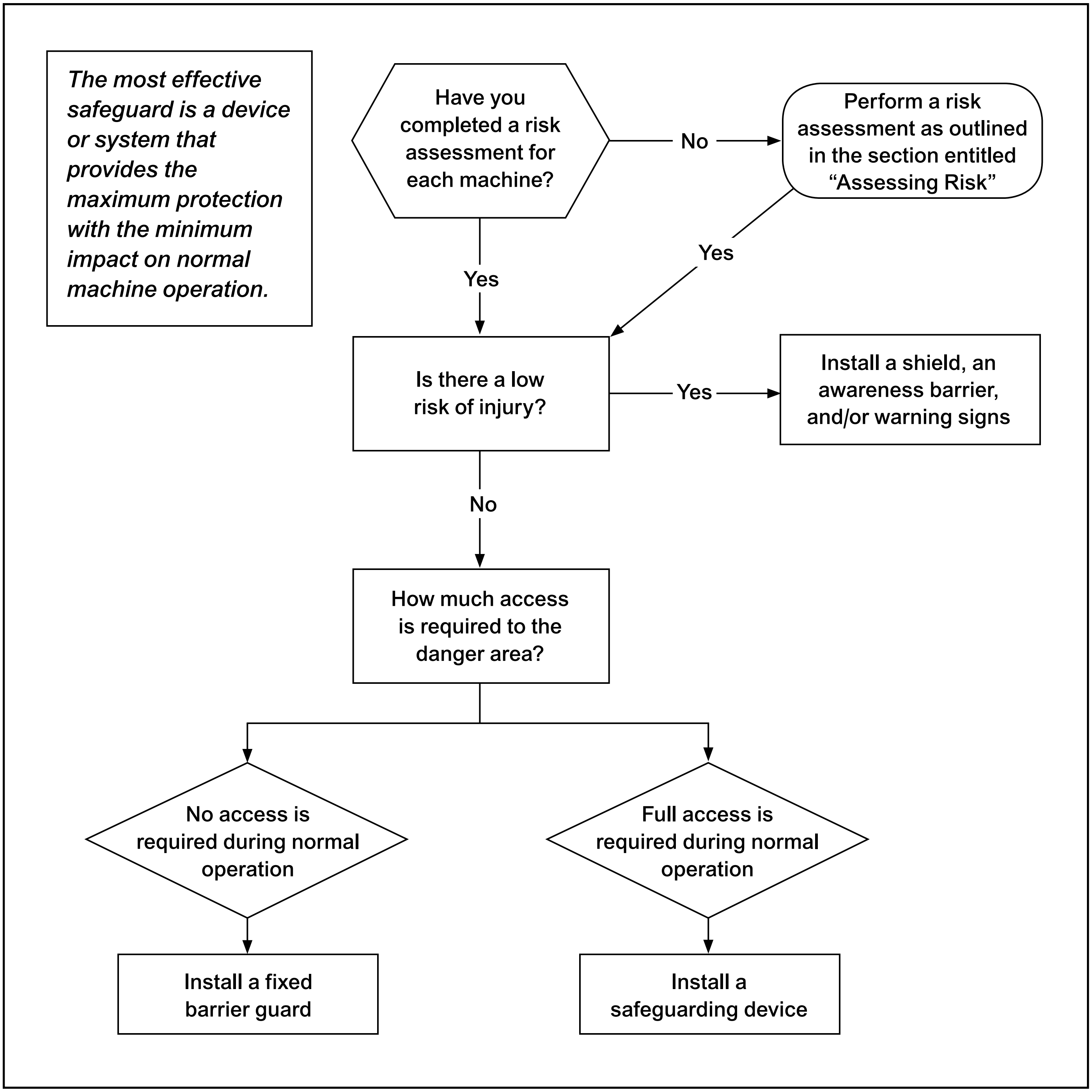


Figure 3.17. Selecting the right safeguard.

Table 3.3. Guide to selecting the right safeguard.

Type of Safeguard	Typical Applications	Action of Safeguard	Advantages	Limitations
Physical guards				
Fixed power transmission barrier guard	• V-belt drives • Chain sprocket drives • Motor couplings and power take-offs (PTOs) • Flywheels	• Completely prevents hands or body parts from entering the danger area	• Provides complete protection if kept in place • Easy to install	• May interfere with lubrication unless modified
Fixed point-of-operation barrier guard	• Bread slicers • Meat grinders • Sheet metal shears • In-running nip points of rubber, paper, and textile rolls • Power presses	• A complete enclosure that admits feed stock or removal of finished product but will not allow hands into danger zone	• Provides complete protection if kept in place • May leave both hands free • Suitable for any type of machine clutch (part/full revolution)	• Generally limited to flat feed stock • May require special tools to remove jammed stock • May interfere with visibility
Barrier guard (hinged or sliding) with simple interlocking	• Most power presses • Balers/compactors • Foundry presses • Robotic systems	• Opening the guard will stop the machine • Machine will not start with guard open	• Leaves both hands free for feeding • Opening and closing of guard can be automatic	• Location of controls must comply with safety distance requirements • Depends on control reliability for safe functioning
Barrier guard (hinged or sliding) with powered interlocking (guard locking)	• Foundry tumblers • Laundry extractors, dryers, and tumblers • Centrifuges • Paint mixers • Some dough and pastry mixers	• Machine will not start with guard open • Guard cannot be opened until machine movement is at complete rest	• Provides complete and positive enclosure until machine is at rest • Does not inhibit production	• Requires careful adjustment and maintenance • May not function in the event of electrical or mechanical failure
Automatic or semi-automatic feed with point of operation enclosed	• Power press blanking operations • Coining and stamping machines • Drop chute chippers • Pastry machines	• Stock fed by chutes, hoppers, conveyors, rolls, movable dies, etc. • Enclosure will not admit any part of the body	• Increase in production • Worker cannot place hand in danger zone	• High installation cost for short runs • May require skilled maintenance
Limited feed opening or slide travel	• Foot-powered shears • Some punch and brake presses	• Feed opening or machine travel is limited to 6 mm (¼ inch) or less • Fingers cannot enter danger area	• Provides positive protection • No maintenance or adjustment needed	• Small opening limits size of stock • Requires effective supervision/training

Type of Safeguard	Typical Applications	Action of Safeguard	Advantages	Limitations
Other safeguards				
Two-hand controls	• Hand-fed power press operations • Hydraulic presses • Re-bar formers • Tube benders • Paper guillotine shears	• Simultaneous activation of both controls initiates a machine cycle • Releasing either control during cycle causes machine to stop	• Forces both hands out of danger zone • No interference with hand feeding • No adjustments required • Easy to install • Allows feeding and removal of complex parts not possible with a barrier guard	• Location of controls must comply with safety distance requirements • Depends on control reliability for safe functioning • Hands not free to support feed stock • Hazards to workers other than the operator must be safeguarded
Presence-sensing device: • Light curtains • Radio frequency antennae • Pressure-sensitive mats	• Brake presses • Part revolution (air clutch) presses only • Robotic systems	• When sensing field is interrupted, a stop signal is sent to quickly stop the machine	• Does not interfere with normal feeding or production • No obstruction on the machine or around the operator	• Expensive to install • Location of device must comply with safety distance requirements • Depends on control system reliability for safe functioning • Hazards to workers other than the operator must be safeguarded • May require frequent adjustment/calibration
Limited machine movement devices (“jog,” “inch,” and “setup” modes)	• Printing presses • Power presses (during setup and maintenance)	• Provides operator or maintenance with a means to “inch” or “jog” machine movement during setup	• Gives operator and maintenance safe control over hazardous machine movement	• Can be dangerous if used during production mode on power presses (the CSA Standard notes that these must not be used for production purposes)
Self-adjusting feed guard	• Band saws • Table saws • Mitre saws • Circular hand saws • Jointers • Wood shapers • Large-capacity steel plate shears	• Barrier or enclosure will admit operator’s hands but warn him before danger zone is reached	• Makes hard-to-guard machines safer • Generally does not interfere with production • Easy to install • Admits varying sizes of stock	• Protection not complete at all times – hands may enter danger zone. • Guard may be easily defeated • Choice of last resort

Type of Safeguard	Typical Applications	Action of Safeguard	Advantages	Limitations
Emergency body contact devices: • Crash bar • Panic bar • Trip wire • Belly bar	• Trim saws • Flat roll ironers • Calenders • Rubber mills • Platen presses • Conveyors • Wood chippers	• Without intentional movement, worker contacts the emergency stop device, which sends a stop signal to the machine	• Makes hard-to-guard machines safer • Does not interfere with production	• Requires proper installation and maintenance • Depends on control system reliability for safe functioning • May require installation of a machine braking system
Passive worker restraint devices ("hold-backs")	• Horizontal-fed sawmill chippers • Soil auger feed points • Power press operations	• Worker is tethered by means of a safety belt and lanyard, or by hand wristlets and fixed cables, and cannot access the danger area	• Easy to install • Inexpensive • Permits maximum hand feeding	• Can be difficult to supervise • Worker resistance (changing old habits) • Must be adjusted to individual operator
Active worker restraints ("pull-backs")	• Mechanical clutch power presses • Brake presses • Embossing presses	• A cable-operated attachment connected to the operator's hands pulls them back if they remain in the danger zone	• Acts even in the event of accidental mechanical repeat • Easy to install • Adaptable to frequent die changes	• Requires effective supervision • Worker resistance (changing old habits) • Must be adjusted to individual operator and operation
Awareness barriers: • Protective shield • Splash guard	• Lathe chucks • Milling machines • Drill presses • Machine tools	• Partial barriers that contain liquids and flying chips or turnings	• Easy to install • Does not impede operation	• Provides limited protection against harmful contact with moving parts

Guideline

for the Prevention of

Musculoskeletal Injuries

Workplace Safety & Health
Division
200 – 401 York Avenue
Winnipeg, Manitoba
R3C 0P8

December, 2006

Manitoba

INTRODUCTION

Introduction

Musculoskeletal injuries (MSI) account for a significant number of work injuries in Manitoba. Musculoskeletal injury means an injury or disorder of the muscles, tendons, ligaments, joints, nerves, blood vessels or related soft tissue including a sprain, strain or inflammation.

Since work-related MSI tends to occur when the physical demands of the action, task, movement or job exceeds the ability of the body, changes must be considered for the workstation, equipment, tools, work practices, work rate, body movements and employee training to reduce the risk of injury.

Examples of MSI

- muscle strain
- tendon and/or ligament sprain
- hernatiatied intervertebral disk (slipped disc)
- osteo arthritis
- adaptive changes to muscle length
- ligament disorders
- circulatory disorders (ex: varicose veins)

Workplace Safety and Health Regulation Requirements

Part 8 of Manitoba Workplace Safety and Health Regulation, M.R. 217/2006 requires employers to do a risk assessment, in consultation with the safety and health committee, or representative. If there is no committee or representative the employer must do a risk management in consultation with employees where a risk of MSI:

- is known to be present
- is reasonably obvious
- has been identified

- If the assessment identifies a risk to employees, measures must be taken to implement: engineering controls (design, position of equipment)
- administrative controls (safe work procedures)
- appropriate work schedules, or personal protective equipment

Employers must ensure employees who may be at risk of MSI are informed of the risk as well as signs and symptoms of MSI. Employers must also ensure employees are trained in control measures to eliminate or reduce the risk of MSI.

ASSESSING THE RISK

Introduction

When employers are aware or have been told that a work activity creates a risk of musculoskeletal injury, they must ensure the risk is assessed. This assessment must identify:

- risk factors acting on the worker (ex: forceful exertion)
- areas of the body at risk of MSI (ex: lower back)
- source of the risks (ex: lifting boxes)

Based on the assessment, employers must implement controls to eliminate or reduce, as much as reasonably practical, the risk of musculoskeletal injury.

Risk factors

Following is a list of MSI risk factors. To properly reduce or control the risk, it is important to recognize why these factors create a risk of injury. Any combination of the listed physical demands will increase the risk of injury.

<u>Awkward or sustained postures</u>: These occur when employees must adopt non-neutral postures to perform their duties. Neutral posture is a relaxed body standing upright with the arms hanging comfortably at the side. Non-neutral postures (ex: slouching, bending forward at the waist, twisting through the trunk, working with the elbows away from the body, prolonged standing on a hard surface, etc.) increase the load on the musculoskeletal system. Non-neutral postures reduce blood flow to working muscles and increase leverage (ex: the longer the crowbar, the greater the force). Consider reducing non-neutral postures by making the work environment more adjustable and bring the work closer to the centerline of the employees' body to increase the employees' control over body movement and reduce the risk of injury.

<u>Forceful exertions</u>: These occur when employees must adopt perform actions that have the potential to overload the musculoskeletal system. There is a physical limit to the amount of stress the musculoskeletal system can endure before a structural failure occurs. It is much like a metal chain lifting more than its rated capacity and one of the links fails as a result. Depending on the posture during the forceful exertion, the link which fails may be the wrist, elbow, shoulder, lower back, or any other part of the musculoskeletal system. Forceful exertions may cause failure on the gross scale (ex: a herniated or slipped disc), or the micro scale (ex: microscopic tears in the muscles, tendons, or ligaments) which may develop into a MSI. To reduce the risk of injury, consider decreasing the physical effort required to perform work.

Repetitive motions: These occur when employees are required to perform the same sequence of actions for extended periods with little or no variation in the muscles used. Repeated movements, without significant change in work activity, may cause the musculoskeletal system of the body to suffer small injuries. With repeated exposure, these injuries may develop into a MSI. Consider rest breaks and job rotation throughout the day to reduce the risk of injury.

Vibration: This is the direct transfer of repeating movements of a machine, or tool, to the body. It is an action (ex: when a hand tool or heavy machine shakes repeatedly) causing the muscles to tighten and circulation to decrease. Consider using tools with less vibration; wrapping tools with anti-vibration wrap; using anti-vibration gloves; and ensuring machinery is maintained to reduce vibration.

Mechanical compression: This occurs when there is external pressure on the soft tissues, either at high forces and/or for prolonged periods of time (ex: leaning on a barrier, resting hands on a desk while typing, using tools that dig into the hand). When there is external pressure on the soft tissues, the blood flow and nerve function may be affected. Consider removing or modifying barriers, using tools with improved design and putting padding on hard edges or surfaces.

Assessment methods

When an assessment is performed, the risk factor(s) which may cause an injury must be identified. Consider using one or more of the following tools to identify the risks for MSI associated with the job.

Job Hazard Analysis

What: This process describes the steps required for job completion, and identifies the risks which may cause injury. Typically this analysis includes all risks which may cause any injury, including MSI.

Why: Analyzing a task step-by-step allows easier identification of risks, which may be difficult to see, or describe, when the task is observed as a whole. A job hazard analysis is standard in workplace safety and health risk analysis.

When: Use this tool before developing safe work procedures, or standard operating procedures for a job, especially one that has not been assessed for risks.

See Appendix A –job hazard analysis for further information.

Physical Demands Description

What: This is a clear and complete list of the movements and other physical requirements needed to perform a job. This list describes the weights, forces, frequencies and postures employees will be exposed to during their work.

Why: Effective communication of the physical demands of a task with those who may require this information is important to help identify risks. Examples may include: current employees, new employees, supervisors, human resource people, or health care professionals. Uncontrolled risks for injury may exist if the identified demands and the actual processes are different. Employees can help ensure any differences between these demands and processes are brought to the attention of the appropriate person.

When: Use this tool when a complete list of the physical demands of a job, or task, is required. Start with the physical demands description of the modified or light duty jobs to better accommodate the physical capabilities of employees returning to work following an injury. This tool may also help injured employees give an effective description of their jobs to their health care provider, who in turn, may then offer effective treatment.

See Appendix B – physical demands description for further information.

Ergonomic Risk Factor Checklist

What: A checklist designed to identify specific risks for musculoskeletal injury with the effect of increased exposure on the risk of injury. This checklist assigns scores to each risk factor, which are added together for an overall job score. This information is useful for prioritizing and identifying jobs, tasks and movements with increased risk of MSI.

Why: This checklist can identify risks for MSI present in a specific aspect of a job, or the job as a whole. It allows employees to assign a score to each movement which can be used to identify hazardous aspects of jobs (or whole jobs) which require control measures. These scores can also serve as a benchmark for any further modifications.

When: Use this tool during the assessment of jobs suspected of containing risks for musculoskeletal injury. When any changes are made to the physical demands of the work, use this checklist to see if the changes are effective.

CONTROL MEASURES

Introduction

“Control measures,“ when applied to musculoskeletal injuries, refer to deliberate changes to a job to reduce the employees’ risk of suffering MSI.

These changes must be designed to reduce the physical demands of work to a level at, or below, the physical capabilities of the employee. Changes may be made to:

- the physical design of the work and workspace
- the procedures and body movements used to perform the work
- the pace at which the work is performed
- to personal protective equipment

It is preferable to use a combination of these controls when considering the best method to reduce the risk of employee injury.

Engineering Controls

Since MSI occurs when the physical capabilities of the employee are exceeded, making physical changes to the work is the most effective way to reduce the risk of injury. Risk for MSI increases when the physical demands increase so, consider ways to reduce those demands. Keep in mind that the weight of body parts (ex: arms or torso) can increase the risk of injury when employees use awkward postures. Engineering controls should focus on reducing force and exposure to awkward postures.

It is important to note the following:

- weight of materials, tools, and equipment handled
- force required for holding, grasping, turning, flipping any materials, tools, equipment
- distances employees are required to reach, bend, lift
- Postures used during work (ex: stoop-lift, squat-lift, non-neutral shoulder and wrist joint angles)

All of these forces, weights, angles, postures and distances may increase the risk of MSI through an increase in the physical demands on employees’ bodies. Successful engineering controls reduce these risks by reducing the physical demands. Increasing adjustability will allow employees to adjust the work to a comfortable position and avoid awkward or sustained postures.

APPENDIX A

Job Hazard Analysis

Conducting a Job Hazard Analysis (JHA)

There are three steps to conducting a job hazard analysis (JHA):

1. Break the job down into its basic steps.
2. Identify the hazards present in each step.
3. Develop controls for all hazards you have identified.

Step 1 – Breaking the Job into Steps

Every task can be broken down into steps. These steps should become the basis of the safe work procedure.

Identifying every step of the task is essential. Write down ***everything***. After each step is identified, go back and combine things or eliminate unnecessary detail.

To give a clear understanding of the task, the steps must include every key step required to do the task correctly, but don't include excess detail that will over burden the process.

Limit the number of steps you actually record. If there are too many steps in the job, break it down into two jobs. Generally there should be no more than 15 steps in a job.

Five steps involved in analysis by observation and discussion:

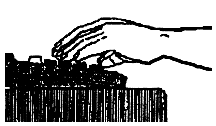
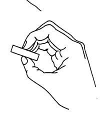
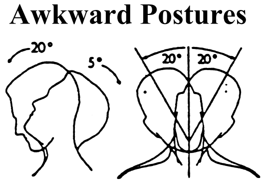
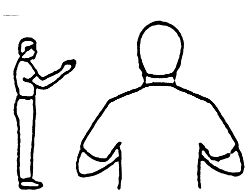
1. Select several employees willing to share their knowledge and experience.
2. Be clear about what is being done and ensure the employees understand it is the work – not the employee -- being evaluated.
3. Watch the employees do the jobs and record the initial breakdown.
4. Discuss the breakdown with the employees for accuracy, and encourage them to share their knowledge and experience.
5. Repeat steps 2, 3 and 4 with other employees, if appropriate and record the basic steps again.

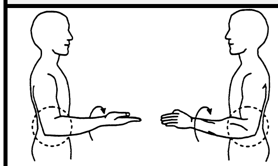
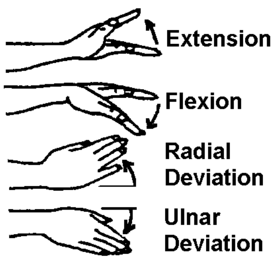
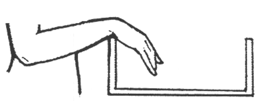
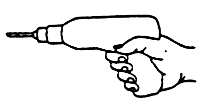
APPENDIX B

ERGONOMIC RISK FACTOR CHECKLIST

UPPER EXTREMITY RISK FACTOR CHECKLIST

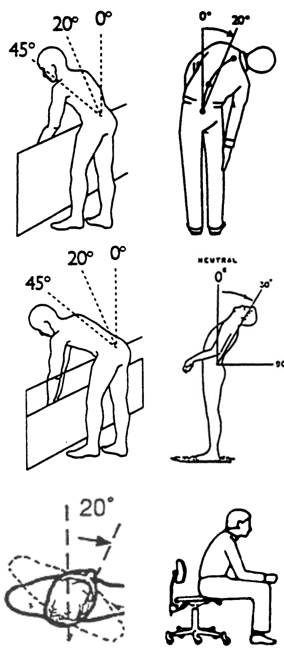
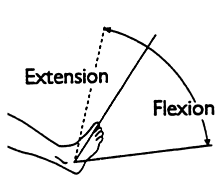
Date: ________ Analyst: ____________ Job: ________________ Location:

RISK FACTOR CATEGORY	RISK FACTORS	EXPOSURE Is the risk factor present within the job or task?	TIME				SCORE
			0% to 25% of total time	25% to 50% of time	50% to 100% of time	If total time for job is >8 hrs, add 0.5 per hour	
Upper Limb Movements	**1.** Moderate: steady motion with regular pauses	☐ Yes ☐ No	0	1	2		
	2. Intensive: rapid steady motion without regular pauses	☐ Yes ☐ No	1	2	3		
Keyboard Use 	**3.** Intermittent keying	☐ Yes ☐ No	0	0	1		
	4. Intensive keying	☐ Yes ☐ No	0	1	3		
Hand Force (Repetitive or Static) 	**5.** Squeezing hard with the hand in a power grip	☐ Yes ☐ No	0	1	3		
	**6.** Pinch more than 2 pounds	☐ Yes ☐ No	1	2	3		
Awkward Postures 	**7.** Neck: twist/bend (twisting neck >20°, bending neck forward >20° or back < 5°)	☐ Yes ☐ No	0	1	2		
	**8.** Shoulder: unsupported arm or elbow above mid-torso height	☐ Yes ☐ No	1	2	3		

RISK FACTOR CATEGORY	RISK FACTORS	EXPOSURE Is the risk factor present within the job or task?	TIME 0% to 25% of job time	25% to 50% of time	50% to 100% of time	If job time is >8 hrs, add 0.5 per hour	SCORE
	**9.** Rapid forearm rotation	☐ Yes ☐ No	0	1	2		
	**10.** Wrist: bend or deviate	☐ Yes ☐ No	1	2	3		
Contact Stress 	**11.** Hard/sharp objects press into skin	☐ Yes ☐ No	0	1	2		
	12. Using the palm of the hand or wrist as a Hammer	☐ Yes ☐ No	1	2	3		
Vibration 	**13.** Localized vibration (without dampening)	☐ Yes ☐ No	0	1	2		
	**14.** Whole-body vibration (without dampening)	☐ Yes ☐ No	0	1	2		
Environment	**15.** Lighting (poor illumination or glare)	☐ Yes ☐ No	0	0	1		
	16. Adverse temperatures	☐ Yes ☐ No	0	0	1		
Control Over Work Pace	**17.** One control factor present = 1 Two or more control factors present = 2	☐ Yes ☐ No					
		TOTAL UPPER EXTREMITY SCORE					

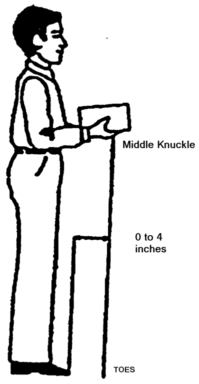
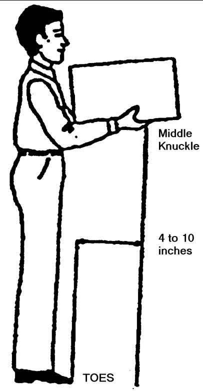
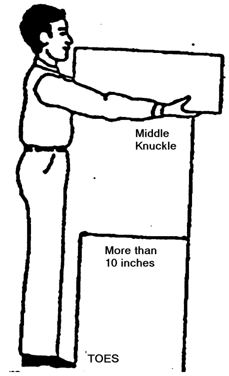
BACK AND LOWER EXTREMITY RISK FACTOR CHECKLIST

Date: __________ Analyst: ____________ Job: __________________ Location: _______________________

RISK FACTOR CATEGORY	RISK FACTORS	EXPOSURE Is the risk factor present within the job or task?	TIME				SCORE
			0% to 25% of time	25% to 50% of time	50% to 100% of time	If job time is >8 hrs, add 0.5 per hour	
Awkward Postures 	**18.** Mild forward or side bending of torso more than 20°; less than 45°	☐ Yes ☐ No	0	1	2		
	19. Severe forward bending of torso more than 45°	☐ Yes ☐ No	1	2	3		
	20. Backward bending of torso	☐ Yes ☐ No	0	1	2		
	21. Twisting of torso	☐ Yes ☐ No	1	2	3		
	22. Prolonged sitting without adequate back support	☐ Yes ☐ No	0	1	2		
	23. Standing stationary or inadequate foot support while seated	☐ Yes ☐ No	0	0	1		
	24. Foot action (pedal), standing stationary with inadequate foot support, balancing	☐ Yes ☐ No	0	1	2		
	25. Kneeling/ squatting	☐ Yes ☐ No	1	2	3		
	**26.** Hip abduction (repetitive/ prolonged)	☐ Yes ☐ No	0	1	2		
	27. Repetitive ankle extension/ flexion	☐ Yes ☐ No	0	1	2		

RISK FACTOR CATEGORY	RISK FACTORS	EXPOSURE Is the risk factor present within the job or task?	TIME				SCORE
			0% to 25% of time	25% to 50% of time	50% to 100% of time	If job time is >8 hrs, add 0.5 per hour	
Contact Stress	**28.** Hard/Sharp objects press into skin	☐ Yes ☐ No	0	1	2		
	29. Using the knee as a hammer or kicker	☐ Yes ☐ No	1	2	3		
Vibration 	**30.** Whole-body vibration (without dampening)	☐ Yes ☐ No	0	1	2		
Push/Pull	**31.** Moderate load	☐ Yes ☐ No	0	1	2		
	32. Heavy load	☐ Yes ☐ No	1	2	3		
Control Over Work Pace	**33.** One control factor present = 1 Two or more control factors present = 2	☐ Yes ☐ No					
Manual Handling Checklist Score (Add scores 2 & 3 from page 3 and insert total here)							
Total Back and Lower Extremity Score							

MANUAL HANDLING CHECKLIST

34(a). STEP I:	**NEAR LIFT**	**MIDDLE LIFT**	**FAR LIFT**
Determine if the lift is near, middle, or far (body to hands) - Use an average horizontal distance if a lift is made every 10 minutes or less. - Use the largest horizontal distance if more than 10 minutes pass between lifts.			

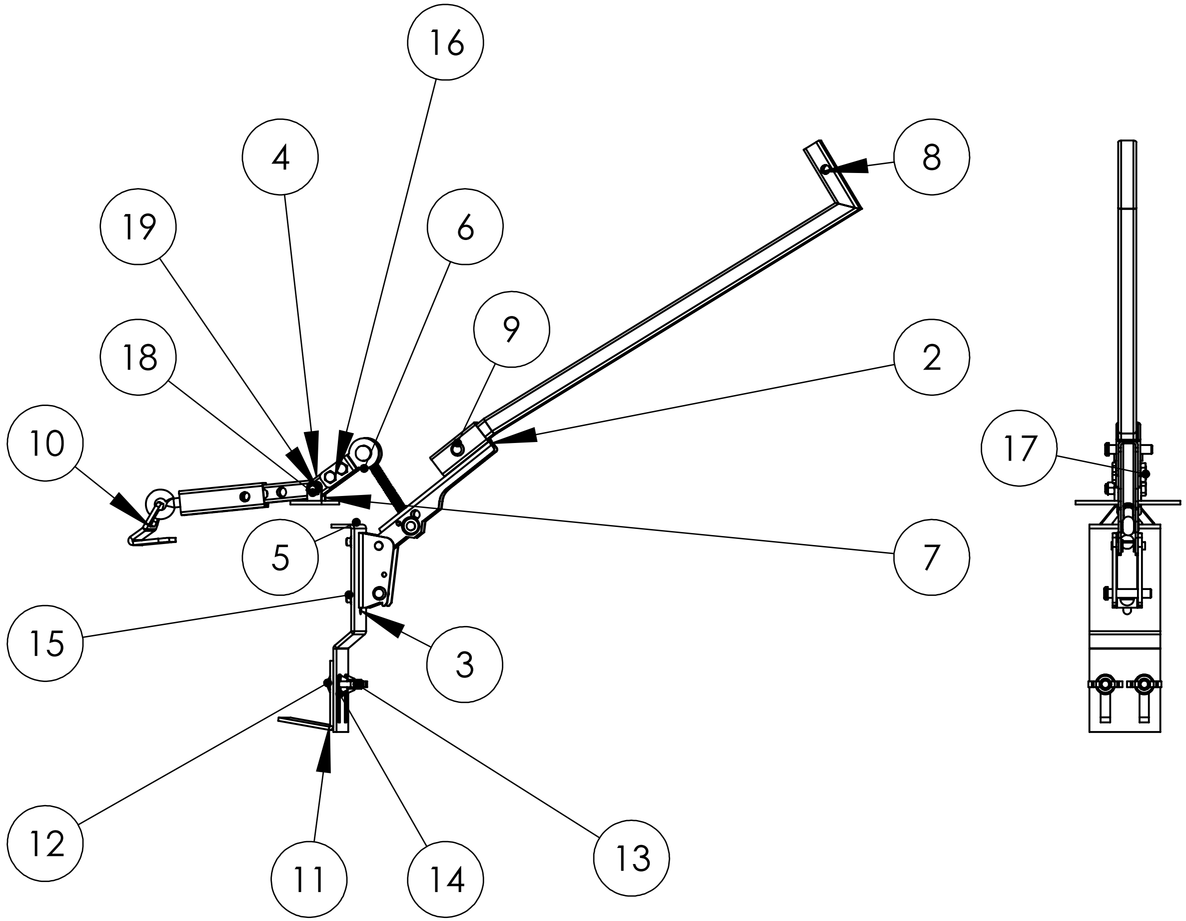
34(b). STEP II:	**NEAR LIFT**		**MIDDLE LIFT**		**FAR LIFT**	
Estimate the weight lifted in kg (pounds) - Use an average weight if a lift is made every 10 minutes or less. - Use the heaviest weight if more than 10 minutes pass between lifts. - Enter 0 in the total score if the weight is 4.54 kg (10 lb.) or less.	**DANGER ZONE**	More than 51 lb. 23.13 kg 5* points	**DANGER ZONE**	More than 15.88 kg (35 lb.) 6 points	**DANGER ZONE**	More than 12.7 kg (28 lb.) 6 points
	CAUTION ZONE	7.71 to 23.13 kg (17 to 51 lb.) 3 points	**CAUTION ZONE**	5.44 to 15.88 kg (12 to 35 lb.) 3 points	**CAUTION ZONE**	4.54 to 12.7 kg (10 to 28 lb.) 3 points
	SAFE ZONE	Less than 7.71 kg (17 lb.) 0 points	**SAFE ZONE**	Less than 5.44 kg (12 lb.) 0 points	**SAFE ZONE**	Less than 4.54 kg (10 lb.) 0 points

*If lifts are performed more than 15 times per shift, use 6 points. **Step II Score:**

STEP III:	**Factor**	**Occasional lifts (<1 hr/shift)**	**Frequent lifts (>1 hr/shift)**	
Determine the points for other risk factors - Use occasional lifts if more than 10 minutes pass between lifts - Use the more than 1 hour points if the risk factor occurs with most lifts and lifting is performed for more than 1 hour	**35.** Twist torso during lift	1	1	
	36. Lift one-handed	1	2	
	37. Lift unexpected loads	1	2	
	38. Lift 1-5 times/minute	1	1	
	39. Lift > 5 times/minute	2	3	
	40. Lift above the shoulder	1	2	
	41. Lift below the knuckle	1	2	
	42. Carry objects 3.05 to 9.14m (10 to 30 feet)	1	2	
	43. Carry objects > 9.14 m (30 feet)	2	3	
	44. Lift while seated or kneeling	1	2	
		Step III Score:		

APPENDIX I – RAISED SIDEWALL FIXTURE COMPONENT DRAWINGS

ITEM NO.	PART NUMBER	QTY.
1	P235 75 R15	1
2	43-4000	1
3	Lower Tire Catch Panel	1
4	Leverage Member	1
5	B18.22M - Plain washer, 8 mm, regular	2
6	Connecter Tab	2
7	Upper Plate	1
8	Handle	1
9	Pin	2
10	Leverage Member Extension	1
11	Lower Tire Catch Adjustment	1
12	.375 x .75 inch wing nut	2
13	.375 inch wing nut	2
14	.375 inch flat washer	2
15	stove bolt nut .375 in .75 long	2
16	.25 in hex bolt 1.25 lng	2
17	.25 hex head nut	2
18	.375 in hex head bolt 1.5 lng	1
19	.375 in top lock nut	1



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN **INCHES**
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:

FINISH:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN	RG		11/28/10
CHK'D			
APPV'D			
MFG			
Q.A			

MATERIAL: Mild Steel

WEIGHT:

TITLE: Raised Sidewall Fixture - Final Assy

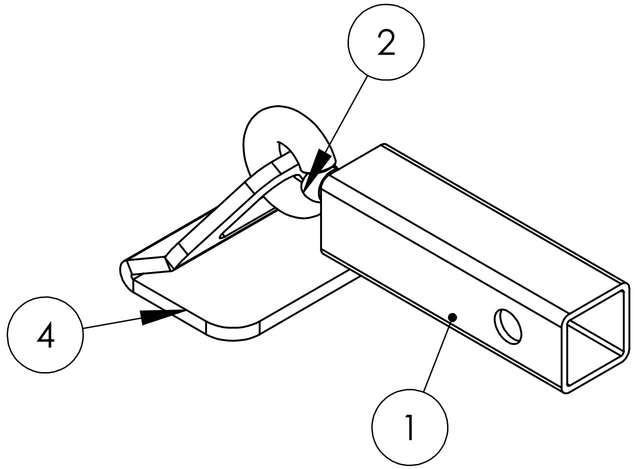
DWG NO.

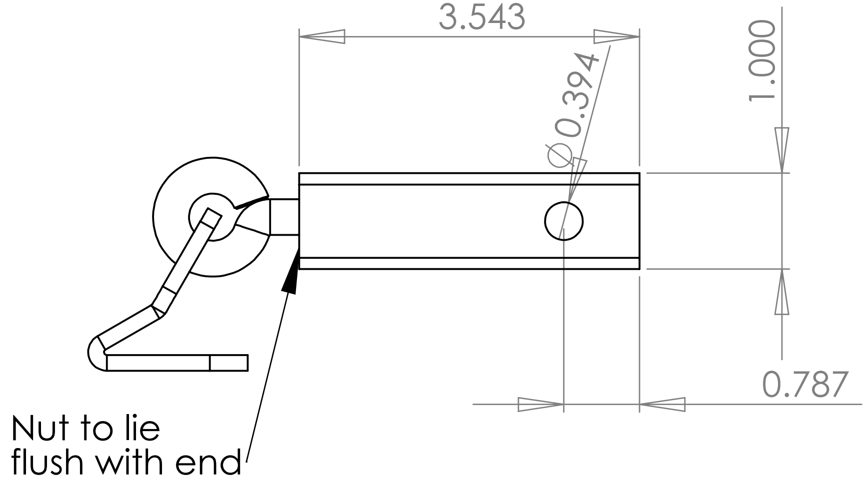
A4

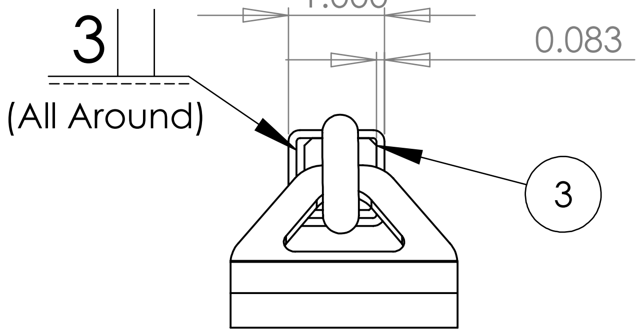
SCALE:1:20

SHEET 1 OF 1

ITEM NO.	PART NUMBER	QTY.
1	Leverage Member Extension	1
2	eyebolt	1
3	Square Nut	1
4	Bead Hook	1







UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN **INCHES**
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:

FINISH:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN	RG		11/28/10
CHK'D			
APPV'D			
MFG			
Q.A			

MATERIAL: Mild Steel

WEIGHT:

TITLE: Leverage Member Extension -Weldt

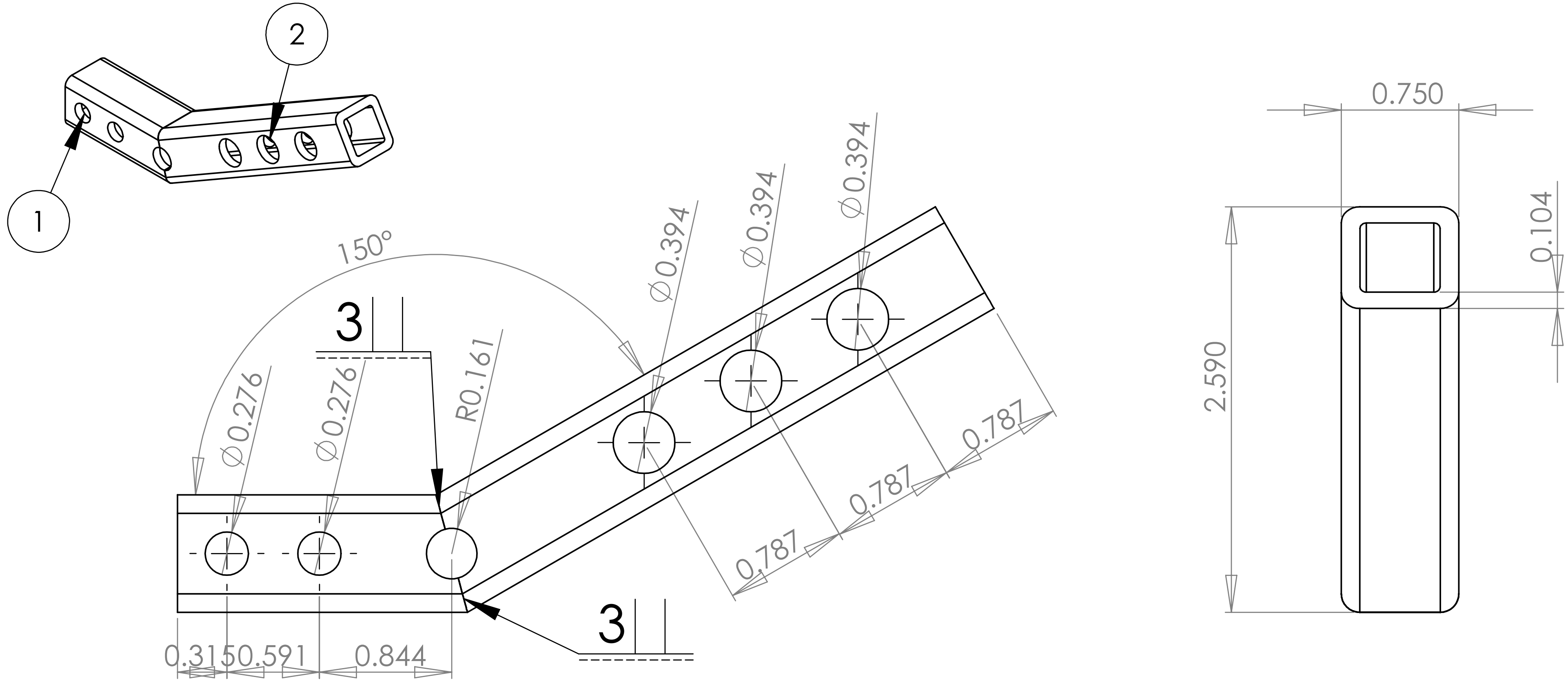
DWG NO.

A4

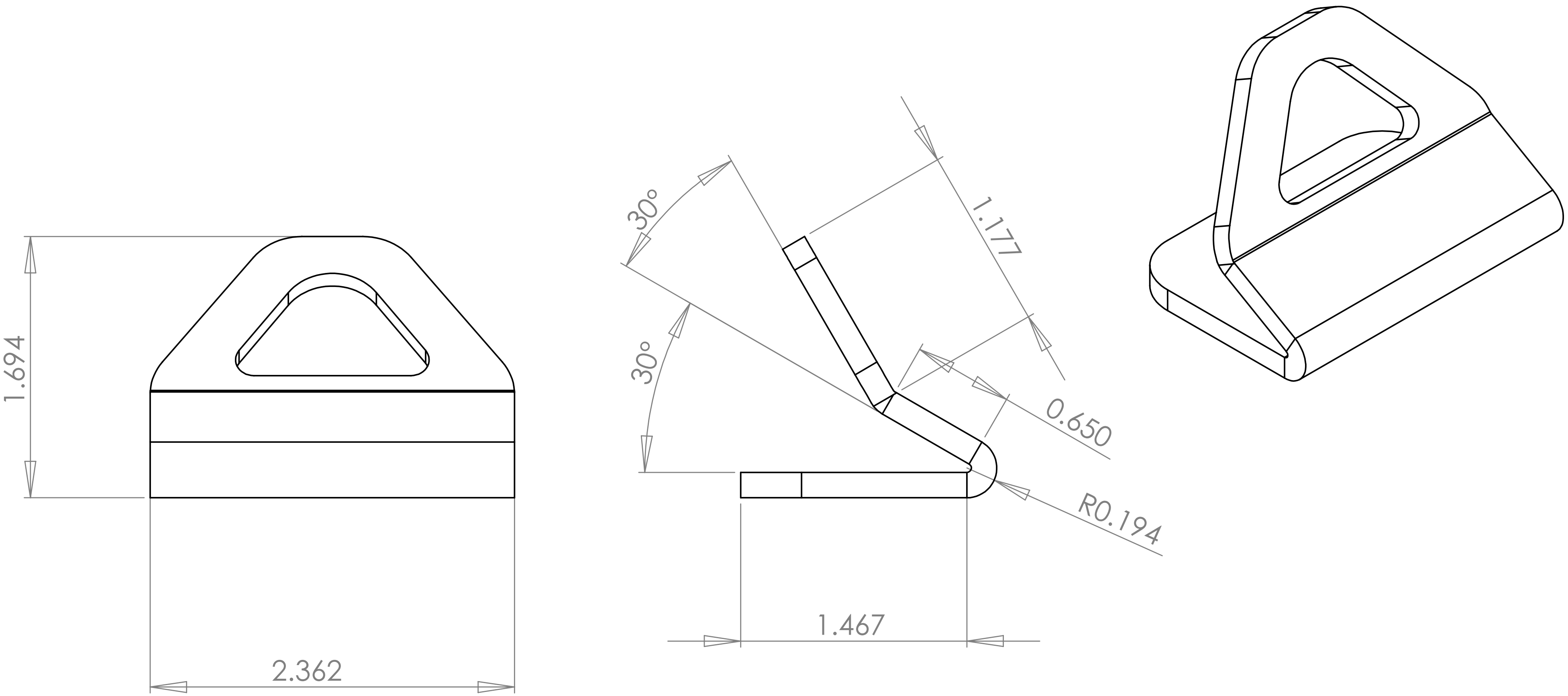
SCALE:1:2

SHEET 1 OF 1

ITEM NO.	QTY.	LENGTH	ANGLE1	ANGLE2	UNIT_OF_MEASURE	MATERIAL
1	1	47	-	0.00	LENGTH	Plain Carbon Steel
2	1	98.55	0.00	-	LENGTH	Plain Carbon Steel



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN **INCHES** SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:	FINISH:	DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME / SIGNATURE / DATE		TITLE:	
DRAWN	RG / / 11/28/10		Leverage Member - Weldt	
CHK'D				
APPV'D				
MFG				
Q.A		MATERIAL: Mild Steel	DWG NO.	A4
		WEIGHT:	SCALE:1:1	SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN **INCHES** SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:	FINISH:	DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION

	NAME	SIGNATURE	DATE
DRAWN	RG		11/28/10
CHK'D			
APPV'D			
MFG			
Q.A			

MATERIAL: Mild Steel

WEIGHT:

TITLE:

Bead Hook

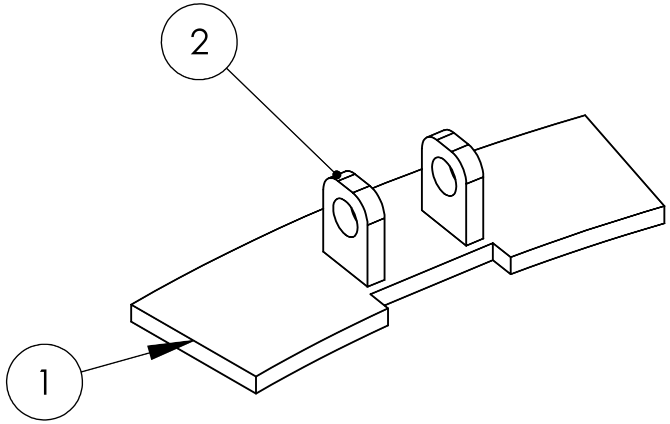
DWG NO.

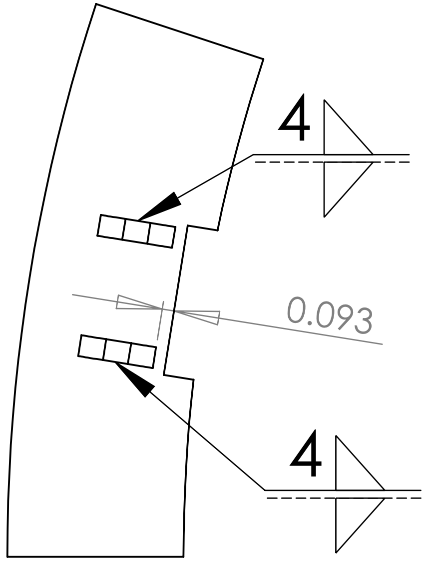
A4

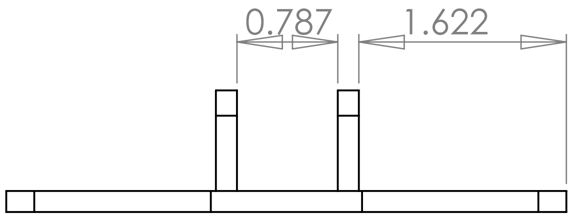
SCALE:1:1

SHEET 1 OF 1

ITEM NO.	PART NUMBER	QTY.
1	Upper Catch Plate	1
2	Upper Catch Tab	2







UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN **INCHES**
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:

FINISH:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN	RG		11/28/10
CHK'D			
APPV'D			
MFG			
Q.A			

MATERIAL: Mild Steel

WEIGHT:

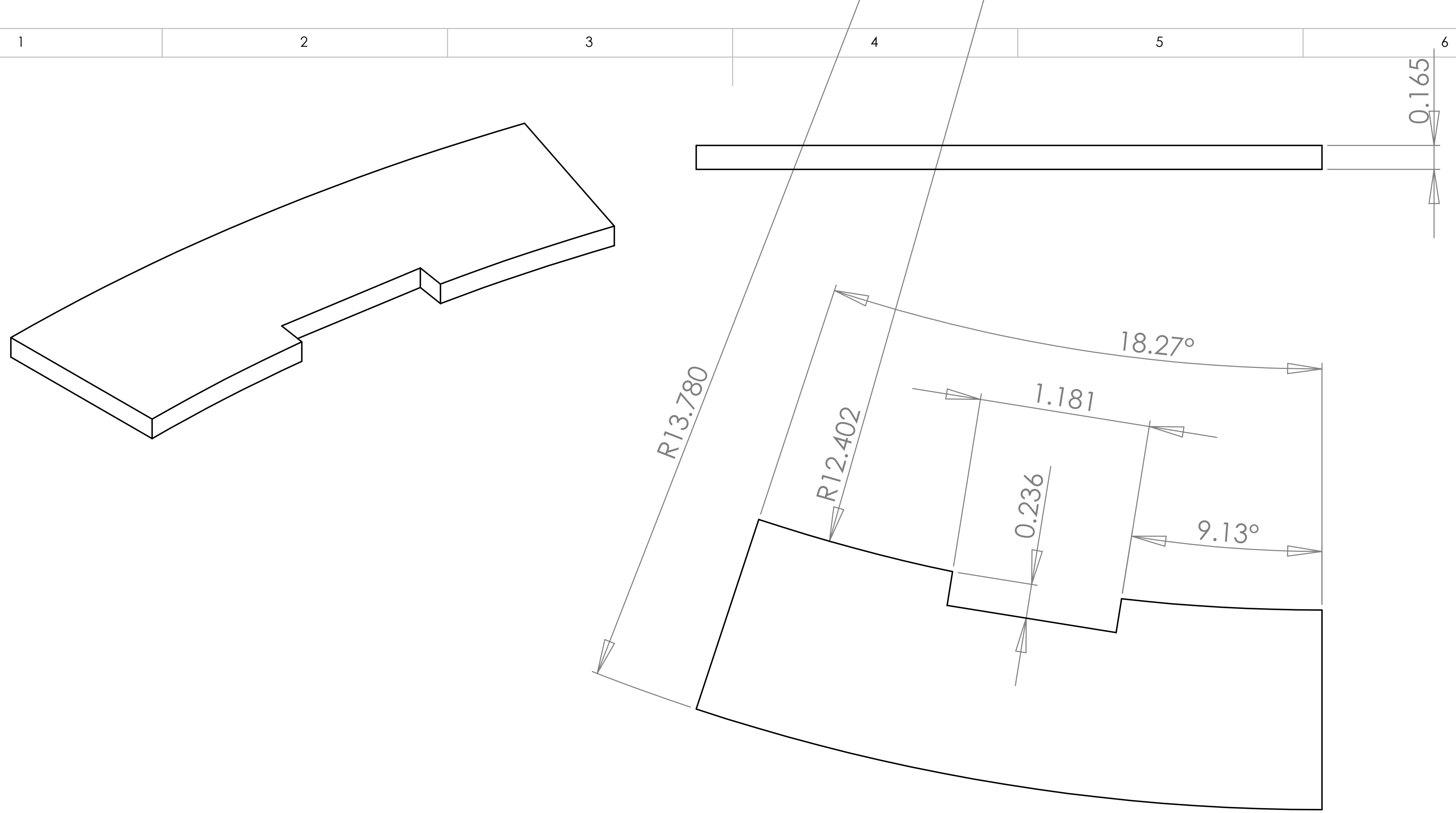
TITLE: Upper Plate - Weldt

DWG NO.

A4

SCALE:1:2

SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN **INCHES**
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:

FINISH:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN	RG		11/28/10
CHK'D			
APPV'D			
MFG			
Q.A			

MATERIAL: Mild Steel

WEIGHT:

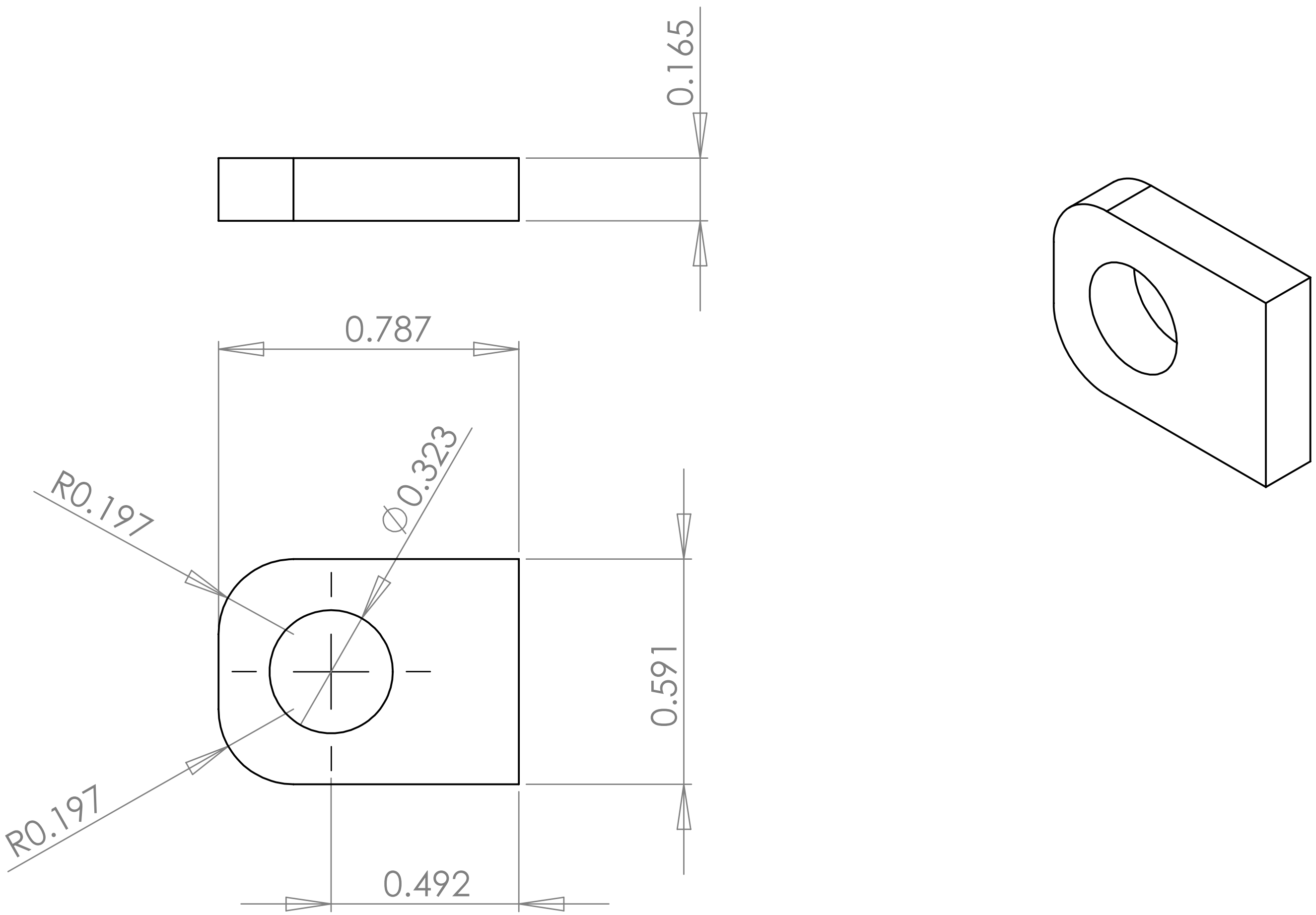
TITLE: Upper Catch Plate

DWG NO.

A4

SCALE:1:1

SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN **INCHES**
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:

FINISH:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN	RG		11/28/10
CHK'D			
APPV'D			
MFG			
Q.A			

MATERIAL: Mild Steel

WEIGHT:

TITLE:

Upper Catch Tab

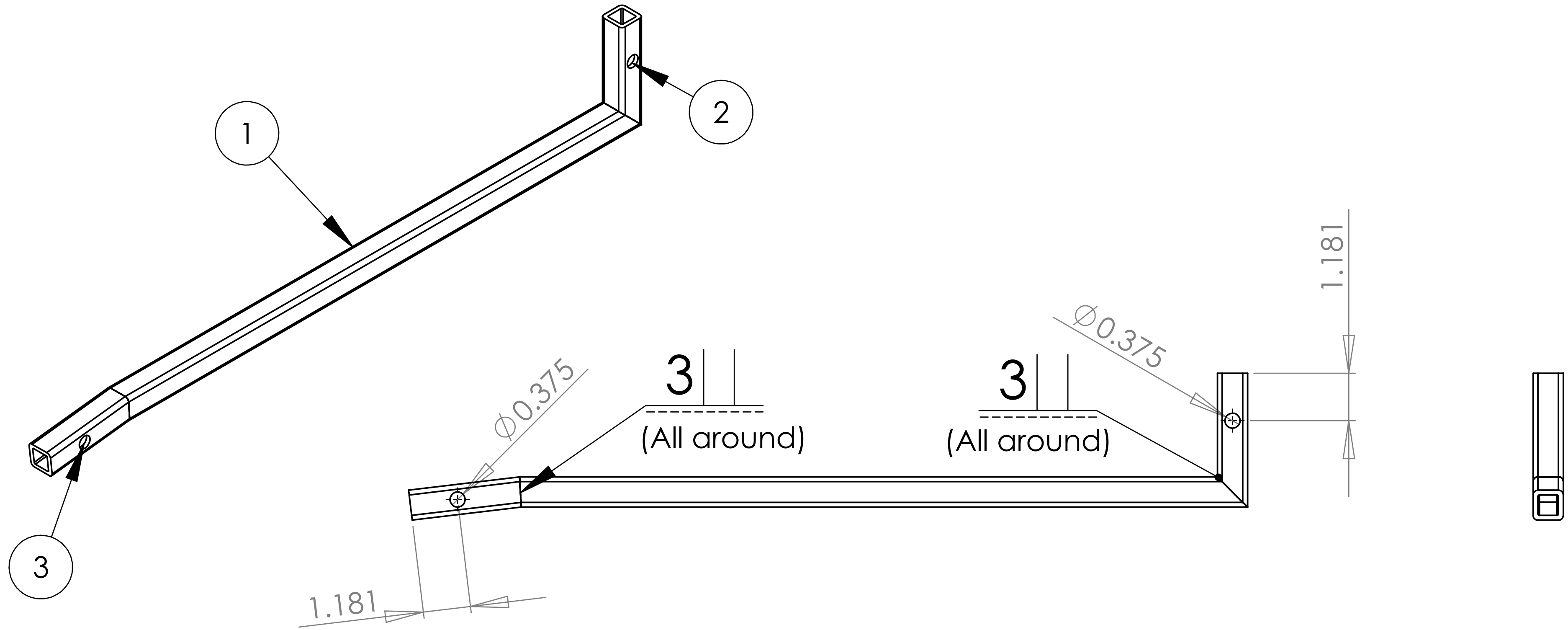
DWG NO.

A4

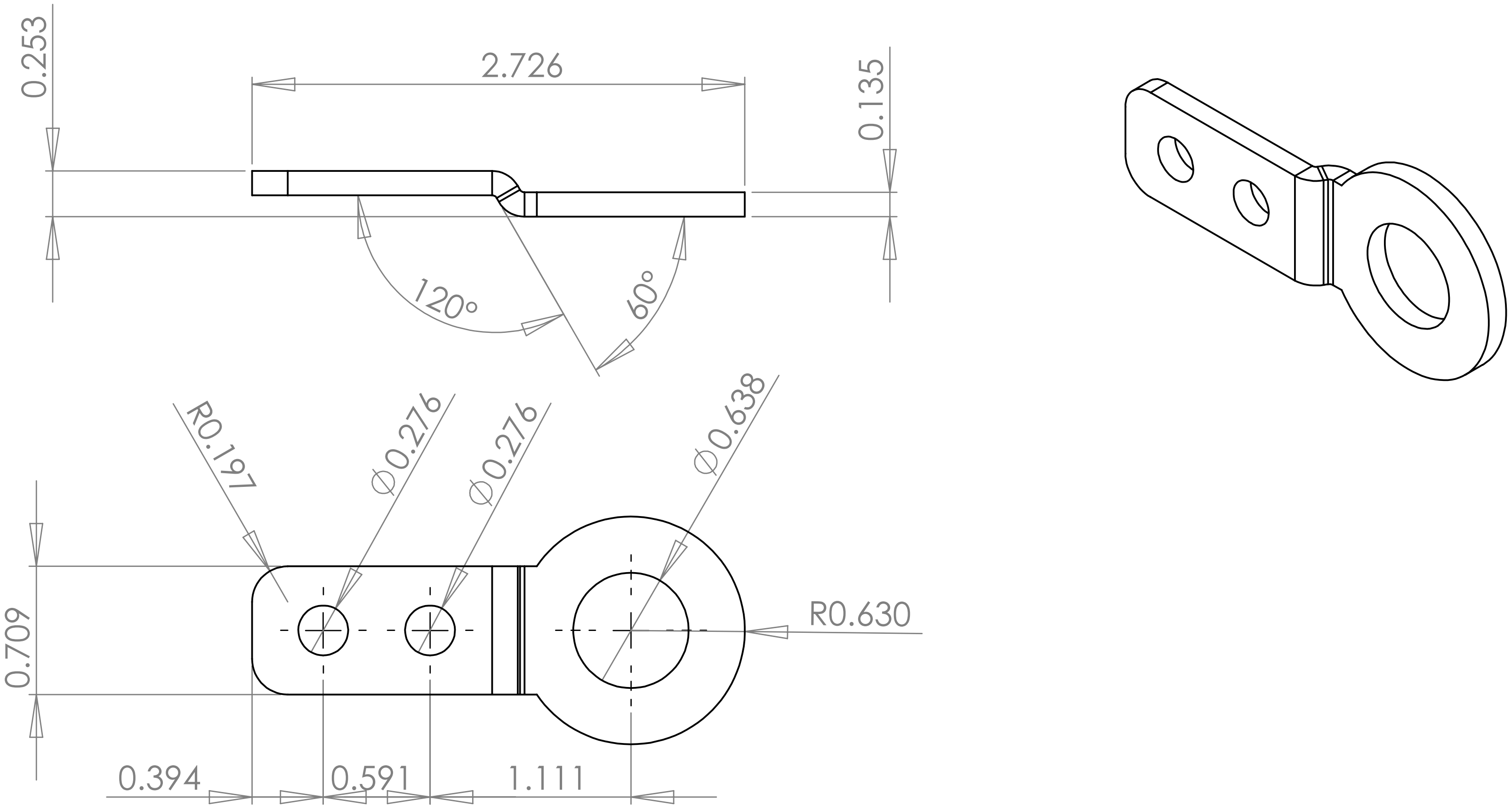
SCALE:2:1

SHEET 1 OF 1

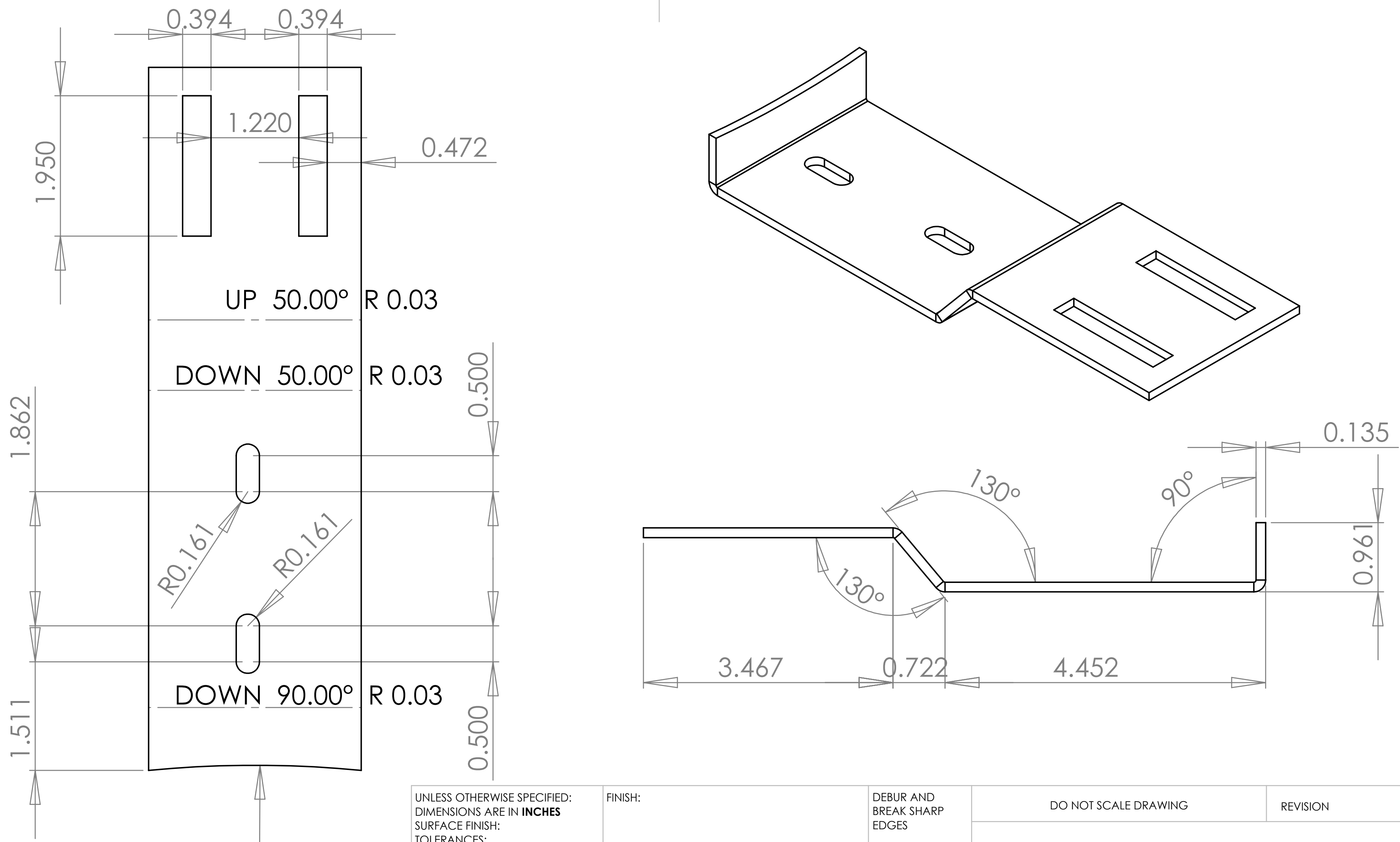
ITEM NO.	QTY.	LENGTH	ANGLE1	ANGLE2	UNIT_OF_MEASURE	MATERIAL
1	1	460.1	3.43	45.00	LENGTH	Plain Carbon Steel
2	1	84.53	45.00	0.00	LENGTH	Plain Carbon Steel
3	1	70.57	0.00	3.43	LENGTH	Plain Carbon Steel



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN **INCHES** SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:	FINISH:	DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE	TITLE:
DRAWN	RG		11/28/10	Handle - Weldt
CHK'D				
APPV'D				
MFG				
Q.A		MATERIAL: Mild Steel		DWG NO. A4
		WEIGHT:		SCALE:1:5 SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN **INCHES** SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:	FINISH:	DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME / SIGNATURE / DATE		TITLE:	
DRAWN	RG	11/28/10	Hinged Edge - Tab	
CHK'D				
APPV'D				
MFG				
Q.A		MATERIAL: Mild Steel	DWG NO.	A4
		WEIGHT:	SCALE:1:1	SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN **INCHES** SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:	FINISH:	DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION

	NAME	SIGNATURE	DATE
DRAWN	RG		11/28/10
CH'D			
APV'D			
MFG			
Q.A			

TITLE:

Lower Tire Panel

MATERIAL: Mild Steel

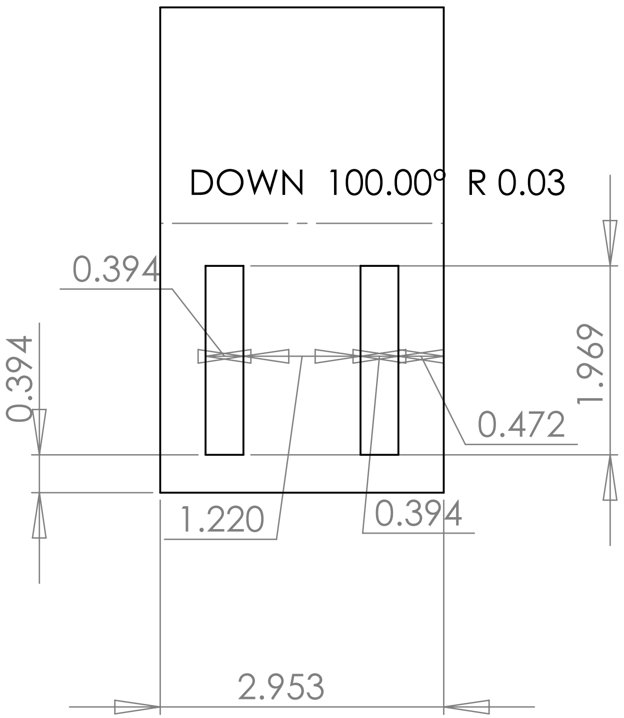
DWG NO.

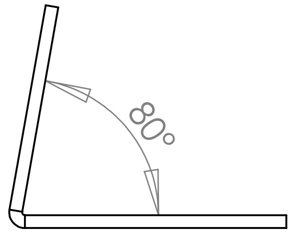
A4

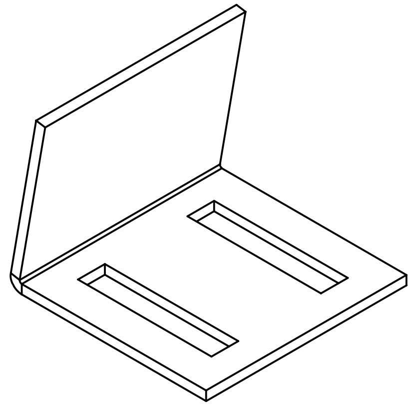
WEIGHT:

SCALE:1:2

SHEET 1 OF 1

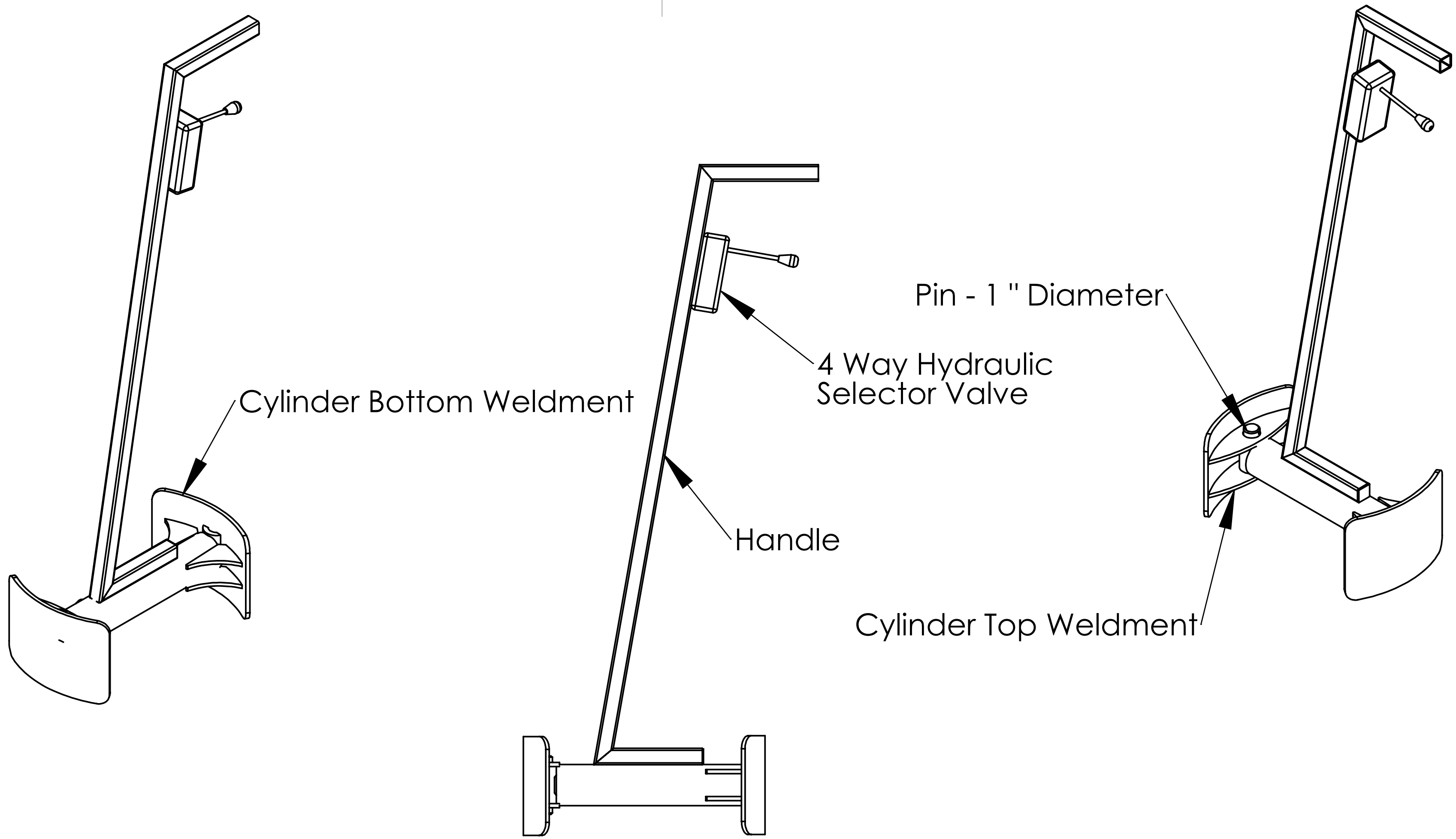






UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN **INCHES** SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:	FINISH:	DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION	
	NAME	SIGNATURE	DATE	TITLE: Lower Tire Catch	
DRAWN	RG		11/28/10		
CHK'D					
APPV'D					
MFG					
Q.A			MATERIAL: Mild Steel	DWG NO.	A4
			WEIGHT:	SCALE:1:2	SHEET 1 OF 1

APPENDIX J - HYDRAULIC CYLINDER ASSY COMPONENT DRAWINGS



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN **INCHES**
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:

FINISH:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN	RG		11/28/10
CHK'D			
APPV'D			
MFG			
Q.A			

MATERIAL: Mild Steel

WEIGHT:

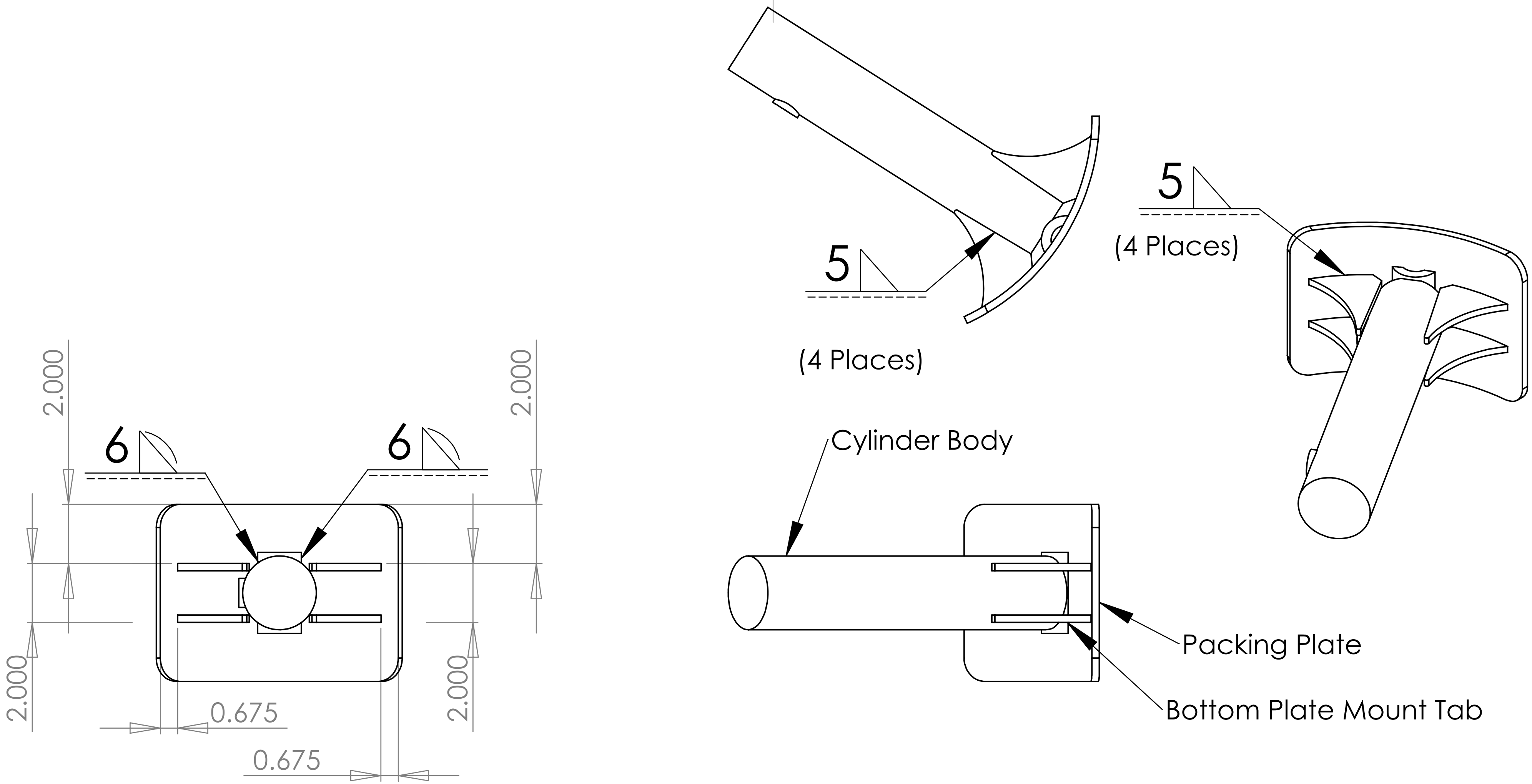
TITLE: Cylinder Side Pack - Final Assy

DWG NO.

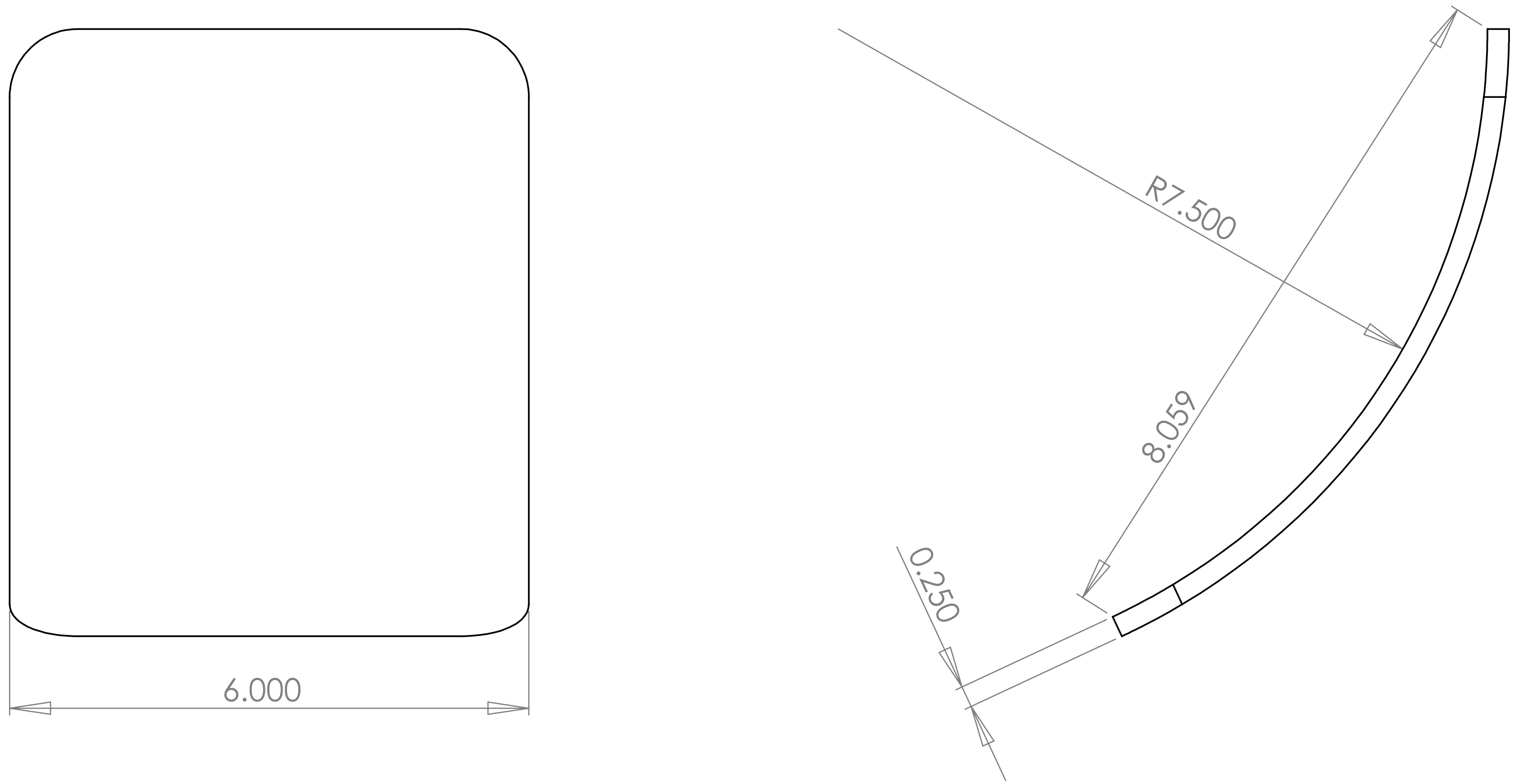
A4

SCALE:1:20

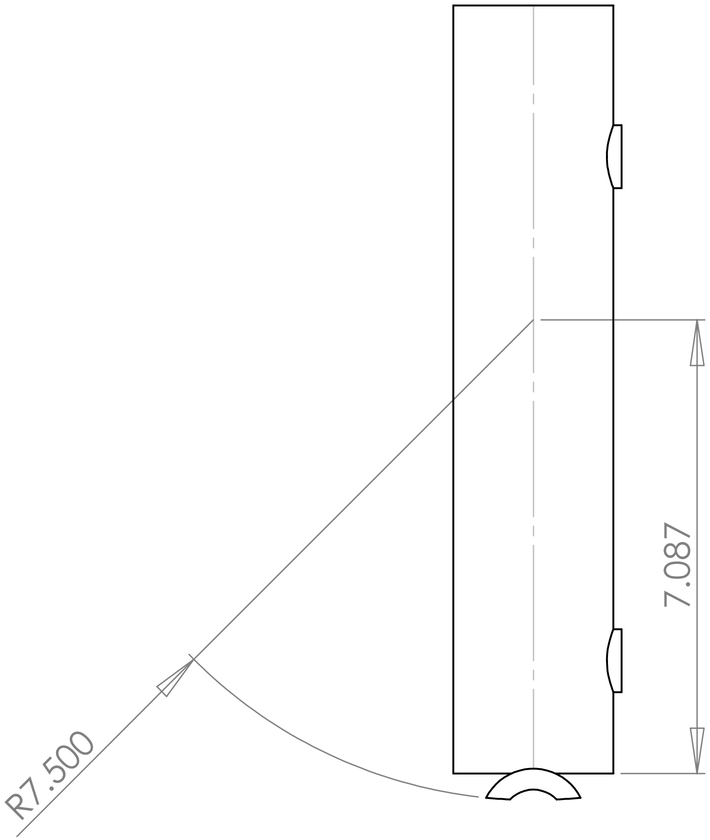
SHEET 1 OF 1

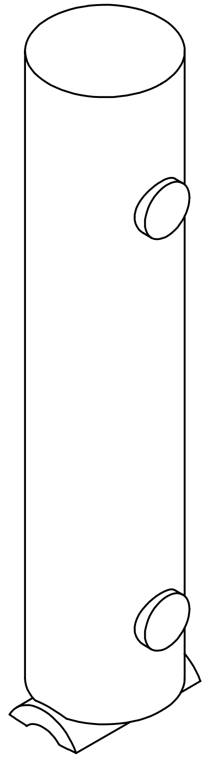


UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN **INCHES** SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:	FINISH:	DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME / SIGNATURE / DATE		TITLE:	
DRAWN	RG / 11/28/10		Cylinder Bottom - Wldt	
CHK'D				
APPV'D				
MFG				
Q.A		MATERIAL: Mild Steel	DWG NO.	A4
		WEIGHT:	SCALE:1:5	SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN **INCHES** SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:	FINISH:			DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE		TITLE:	
DRAWN	RG		11/28/10		Packing Plate	
CHK'D						
APPV'D						
MFG						
Q.A				MATERIAL: Mild Steel	DWG NO.	A4
				WEIGHT:	SCALE:1:5	SHEET 1 OF 1





UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN **INCHES**
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:

FINISH:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN	RG		11/28/10
CHK'D			
APPV'D			
MFG			
Q.A			

MATERIAL: Mild Steel

WEIGHT:

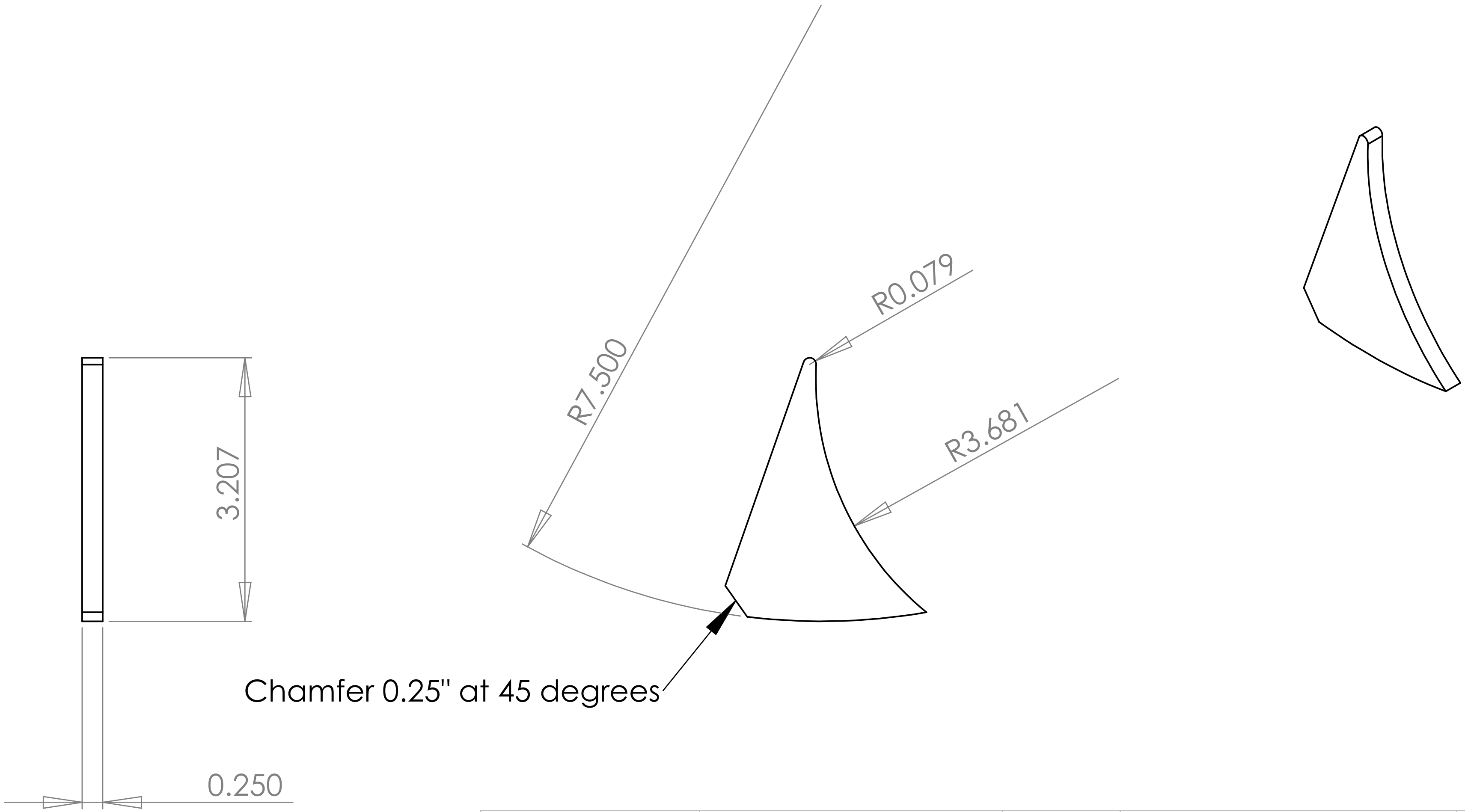
TITLE: Cylinder Base

DWG NO.

A4

SCALE:1:5

SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN **INCHES**
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:

FINISH:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN	RG		11/28/10
CHK'D			
APPV'D			
MFG			
Q.A			

MATERIAL: Mild Steel

WEIGHT:

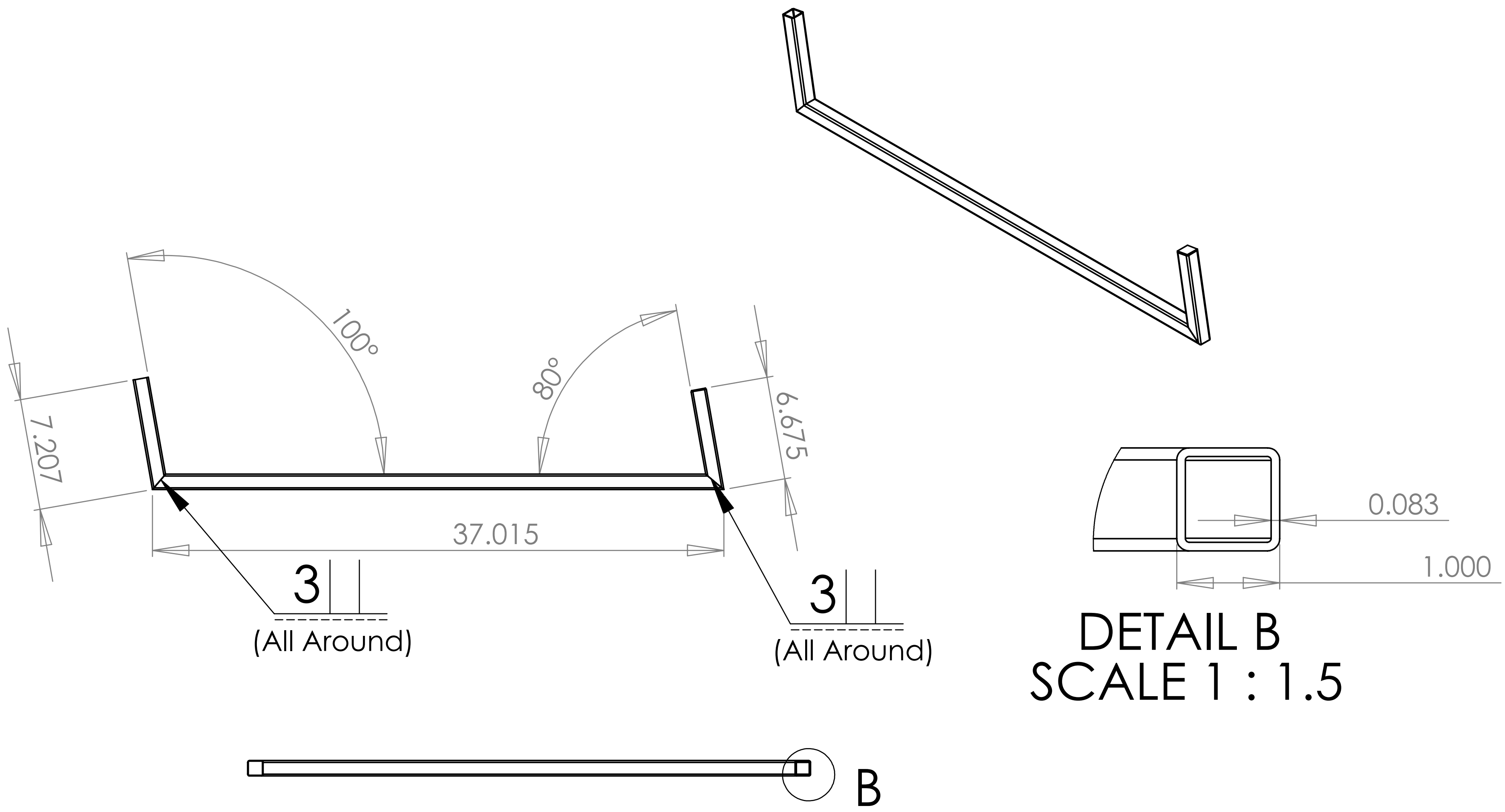
TITLE: Bottom Plate Mount Tab

DWG NO.

A4

SCALE:1:1

SHEET 1 OF 1



UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN **INCHES**
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:

FINISH:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN	RG		11/28/10
CHK'D			
APPV'D			
MFG			
Q.A			

MATERIAL: Mild Steel

WEIGHT:

TITLE:

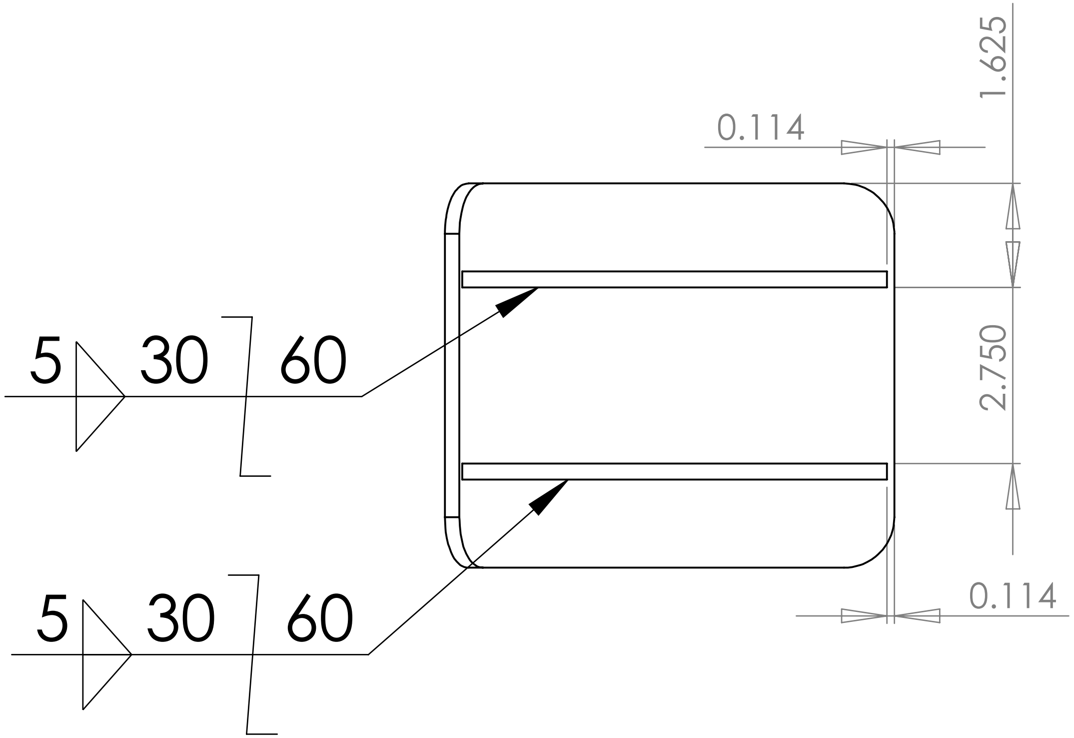
Cylinder Handle

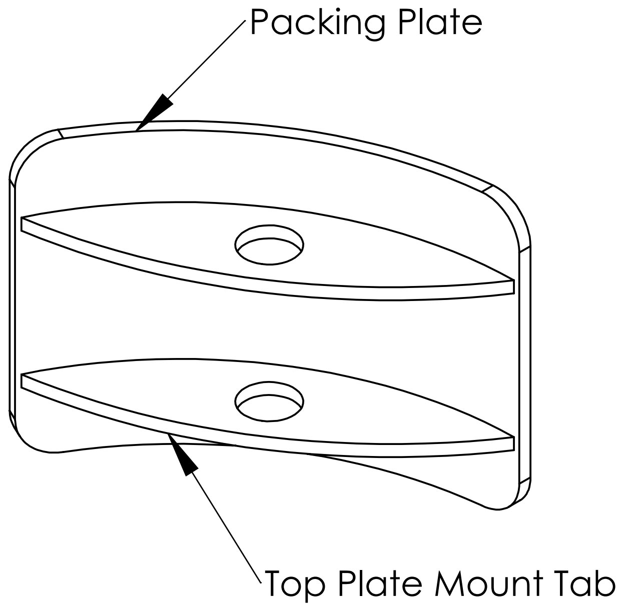
DWG NO.

A4

SCALE:1:10

SHEET 1 OF 1





UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN **INCHES** SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:	FINISH:	DEBUR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION

	NAME	SIGNATURE	DATE
DRAWN	RG		11/28/10
CHK'D			
APPV'D			
MFG			
Q.A			

TITLE:

Top Plate - Wldt

MATERIAL: Mild Steel

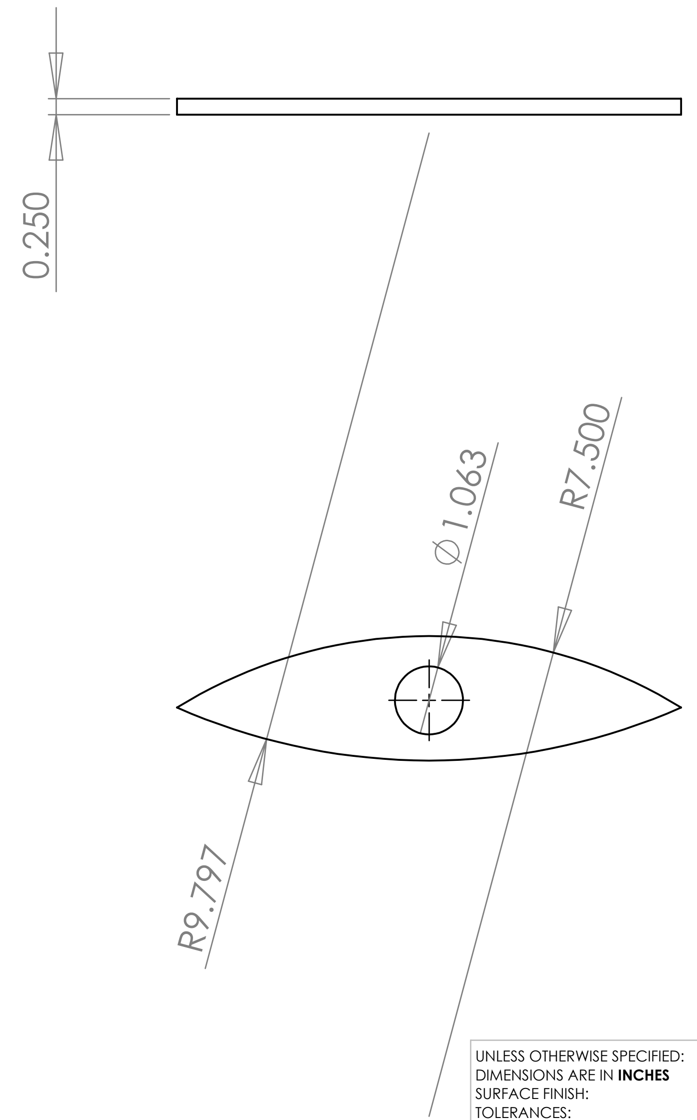
DWG NO.

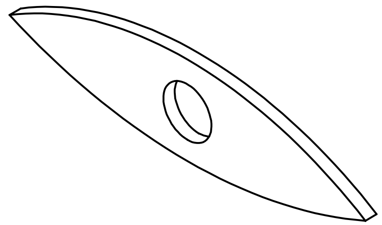
A4

WEIGHT:

SCALE:1:5

SHEET 1 OF 1





UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN **INCHES**
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:

FINISH:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN	RG		11/28/10
CH'D			
APPV'D			
MFG			
Q.A			

MATERIAL:
Mild Steel

WEIGHT:

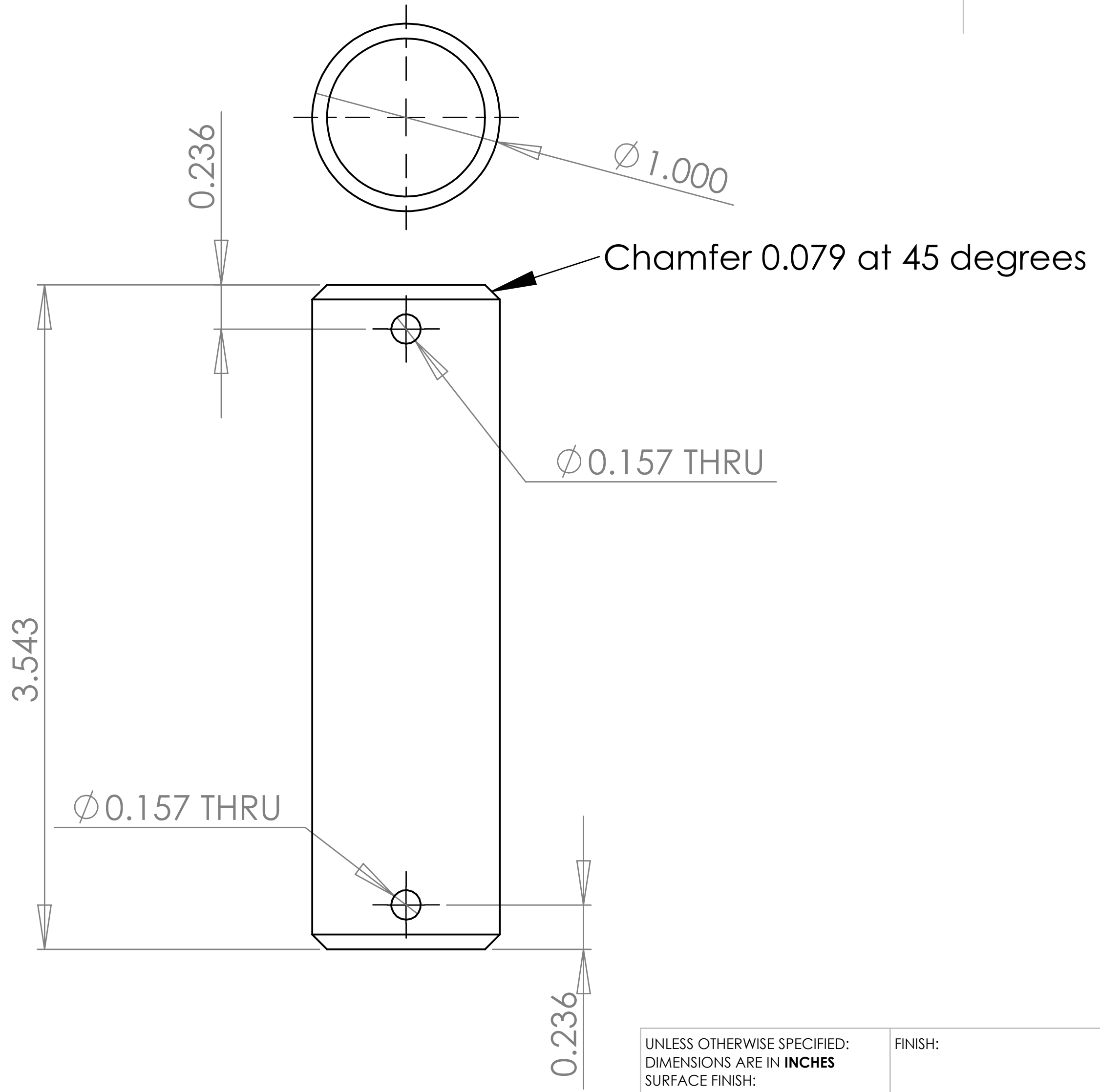
TITLE:
Top Plate Mount Tab

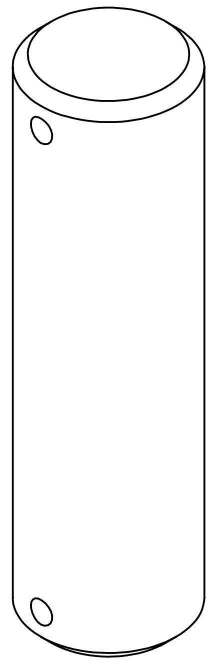
DWG NO.

A4

SCALE:1:2

SHEET 1 OF 1





UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN **INCHES**
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:

FINISH:

DEBUR AND BREAK SHARP EDGES

DO NOT SCALE DRAWING

REVISION

	NAME	SIGNATURE	DATE
DRAWN	RG		11/28/10
CHK'D			
APPV'D			
MFG			
Q.A			

MATERIAL: Mild Steel

WEIGHT:

TITLE:

Pin - 1" Diameter

DWG NO.

A4

SCALE:1:1

SHEET 1 OF 1