DESIGN, CONSTRUCTION, AND EVALUATION OF A
FLAME CULTIVATOR ATTACHMENT

by

Aaron Evans

BioResource and Agricultural Engineering
BioResource and Agricultural Engineering Department
California Polytechnic State University
San Luis Obispo
2013
TITLE: Design, Construction, And Evaluation of a Flame Cultivator Attachment

AUTHOR: Aaron Evans

DATE SUBMITTED: June 13, 2013

________________________________________  __________________________
Senior Project Advisor                      Signature

________________________________________  __________________________
Date

________________________________________  __________________________
Department Head                            Signature

________________________________________  __________________________
Date
ACKNOWLEDGMENTS

I would like to thank Dr. Andrew Holtz, my advisor on this project, for giving me valuable advice on the design of this project.

I would like to thank Mr. Virgil Threlkel for teaching me how to use many of the tools in shops 6 and 7.

I would like to thank Mr. Jerry Rutiz for giving me the opportunity to do this project.

I would like to thank my parents, who have paid for my education at Cal Poly and have supported me and loved me.

I would like to thank my fiancé Karlee for her love and support.

I would like to thank God for his love and mercy to me.
ABSTRACT

This senior project discusses the design, construction, and testing of a flame cultivator attachment. The project used existing torches, a tractor, and a cultivation sled to increase the usability of the farmer’s torches. This project includes two torch clamps, two propane tank brackets, and a removable valve panel.

Testing showed that the new system increases the safety and efficiency of the torches.
DISCLAIMER STATEMENT

The university makes it clear that the information forwarded herewith is a project resulting from a class assignment and has been graded and accepted only as a fulfillment of a course requirement. Acceptance by the university does not imply technical accuracy or reliability. Any use of the information in this report is made by the user(s) at his/her own risk, which may include catastrophic failure of the device or infringement of patent or copyright laws.

Therefore, the recipient and/or user of the information contained in this report agrees to indemnify, defend and save harmless the State its officers, agents and employees from any and all claims and losses accruing or resulting to any person, firm, or corporation who may be injured or damaged as a result of the use of this report.
TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACKNOWLEDGMENTS</td>
<td>III</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>IV</td>
</tr>
<tr>
<td>DISCLAIMER STATEMENT</td>
<td>V</td>
</tr>
<tr>
<td>TABLE OF CONTENTS</td>
<td>VI</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>VII</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>IX</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>LITERATURE REVIEW</td>
<td>3</td>
</tr>
<tr>
<td>History</td>
<td>3</td>
</tr>
<tr>
<td>Weed Response to Flame Cultivation</td>
<td>4</td>
</tr>
<tr>
<td>Torches</td>
<td>6</td>
</tr>
<tr>
<td>Propane Tank Securements</td>
<td>7</td>
</tr>
<tr>
<td>PROCEDURES AND METHODS</td>
<td>8</td>
</tr>
<tr>
<td>Design Procedure</td>
<td>8</td>
</tr>
<tr>
<td>Construction Procedure</td>
<td>17</td>
</tr>
<tr>
<td>Testing Procedure</td>
<td>31</td>
</tr>
<tr>
<td>RESULTS</td>
<td>33</td>
</tr>
<tr>
<td>DISCUSSION</td>
<td>34</td>
</tr>
<tr>
<td>RECOMMENDATIONS</td>
<td>35</td>
</tr>
<tr>
<td>REFERENCES</td>
<td>36</td>
</tr>
<tr>
<td>APPENDICES</td>
<td>36</td>
</tr>
</tbody>
</table>
LIST OF FIGURES

1. Cultivation Sled ........................................................................................................... 1
2. Existing mounting methods for tanks and torches...................................................... 1
3. Available panel space ................................................................................................... 2
4. An early flame cultivator in North Carolina .............................................................. 3
5. Pre-emergent flaming of vegetable beds ..................................................................... 4
6. Weeds before and after flame treatment .................................................................... 5
7. Staggered cross-flaming .............................................................................................. 6
8. A flat nozzle and a tubular nozzle ............................................................................... 7
9. Tool bar with diamond clamps attached ................................................................... 8
10. Clamp jaw design ..................................................................................................... 9
11. Second torch clamp design ...................................................................................... 9
12. Propane tank bracket design ................................................................................... 10
13. Propane tank bracket bottom support ..................................................................... 11
14. Propane tank bracket strap assembly ...................................................................... 11
15. Available valve panel strap assembly viewed from above and below ..................... 12
16. Valve panel plumbing design ................................................................................... 12
17. Flow of propane when control valve is open .......................................................... 13
18. AutoCAD overlay drawing of valve plumbing assembly .......................................... 13
19. Valve panel design ................................................................................................... 14
20. Valve panel design viewed from driver’s side ......................................................... 15
21. Brass fitting bracket ................................................................................................. 15
22. Placement of shims, brass fitting brackets, and valve tabs ..................................... 16
23. Valve panel with fender support ................................................................................ 17
24. Clamp jaw piece with holes drilled ......................................................................... 17
25. Location of cut in clamp jaw piece .......................................................................... 18
26. Clamp jaw pair .......................................................................................................... 18
27. Clamp jaw arm pieces .............................................................................................. 19
28. Clamp jaw arms ........................................................................................................ 19
29. Completed torch clamps ........................................................................................... 19
30. Top brackets arms welded to shanks, viewed from both sides ............................... 20
LIST OF TABLES
INTRODUCTION

Jerald Rutiz is a farmer from Arroyo Grande, CA who owns and operates a 28-acre pesticide-free farm. Because Mr. Rutiz does not use herbicides to control weeds on his farm, he must control them using other methods. One of the ways he controls weeds is by burning them. Currently, he does this using a tractor-pulled cultivation sled which has two propane-fueled hand torches mounted onto it. The cultivation sled is shown in figure 1.

![Figure 1. Cultivation Sled](image1.png)

The torches Mr. Rutiz uses are VT 3-30C Vapor Torches made by Flame Engineering. When this system is used, Mr. Rutiz clamps the rods of the torches onto the sled using C-clamps. This system works for controlling weeds, but several improvements could be made. Clamping the torches onto the sled using C-clamps provides no easy way to adjust the angle and height of the torches nor does it hold the torches very securely to the sled. The propane tanks are simply set on the sled, which does not hold them upright or keep them from rolling off of the sled. Mr. Rutiz’s existing methods of attaching the torches and propane tanks are shown in figure 2.

![Figure 2. Existing mounting methods for tanks (left) and torches (right).](image2.png)
A problem with this system is that when the tractor driver gets to the end of the row he is torching, he must raise the implement, get off the tractor, and manually turn down the torch flames to a pilot level. The driver must then turn around to start a new row, get off the tractor, turn up the torch flames to a higher level, and then get back on the tractor. The flame output of the torches is controlled only by small knobs on each torch, which provides no good way to know that the flame level is at the level same as with the previous row. A removable panel is needed which can vary the flow of propane from a pilot level to a high flow level, and which can completely shut off the flow of propane to the torches. This panel must easily attach and detach from the tractor. Available space for this panel is shown in the figure below.

Figure 3. Available panel space

The workers at Mr. Rutiz’s farm hesitate to use the torch system as it is, because it is not user-friendly nor is it necessarily safe. Mr. Rutiz has put forth the task to design and construct a torch system that will mount onto an existing cultivation sled. This system must utilize some of his existing torch components, which consist of his two propane tanks and two torch assemblies. This system must be user-friendly, adjustable, and safe.

The objectives for this project are to design and construct the following:

- 2 clamps for holding the torch rods on the cultivation sled
- 2 brackets for holding a standard barbeque propane tank on the cultivation sled
- A series of valves and hoses that will allow the flow of propane to be controlled from the tractor
- A removable panel that will hold the valves on the tractor next to the driver
LITERATURE REVIEW

A search was initiated to find information on the design of tractor-drawn flame cultivators, safety regulations regarding the use of propane, and existing flame cultivator units. Flame cultivators can be referred to as 'weed burners', 'agricultural flamers', 'flame cultivators' and various combinations of those terms. For the purposes of this document they will be referred to as 'flame cultivators'.

History

The invention of the flame cultivator has existed since the mid-1800s; and according to Cohen (2006), the first flame cultivator was patented in 1852. The first recorded use of a tractor-drawn flame cultivator was in 1938 by Price McLemore in Alabama. (possible picture from Alabama Archives here) Mr. McLemore's invention used one large kerosene tank which fed a total of four burners; the device covered two rows, providing two burners for each row. The tanks were pressured by a bicycle pump that Mr. McLemore would pump while operating his device (Flame Engineering, 2013).

The general use of flame cultivators began in the late 1930s and increased throughout the 1940s. Their use continued to increase until the mid-1960s. By this time the main fuel used with flame cultivators was propane. Throughout this time flame cultivation proved to be useful for weed control in cotton, potatoes, strawberries, soybeans, corn, sugarcane, and various other crops (Ascand, 1995). Flame cultivation also proved useful during this time for controlling plant disease and certain pests. The figure below shows an early flame cultivator used in the 1940s in Wisconsin.

Figure 4. An early flame cultivator in North Carolina (ECU Digital Collections, 2013).
It is estimated that by 1946 the number of flame cultivators in the Mississippi Delta had reached at least 1,000 (Flame Engineering, 2013). By 1965 there were approximately 25,000 flame cultivators being used commercially throughout the United States (Cohen, 2006). From the late 1960s until the 1980s the use of flame cultivators decreased, due to increasing availability of herbicides and the rising oil prices during that time. In the 1980s, as the demand for organic and pesticide-free farming grew, flame cultivation came back into use as an efficient method to combat weeds, pests, and plant disease (Diver, 2002).

**Weed Response to Flame Cultivation**

Although flame cultivation by definition uses flame to kill weeds, in most cases the weeds are not killed by burning up as a piece of paper would burn. The heat of a propane flame can reach a temperature of 3500 °F, although the temperature a weed experiences is closer to 2000 °F (Flame Engineering, 2013). This intense heat causes the sap in the plant leaves to rapidly expand. This rapid expansion causes the cells of the plant leaves to explode; the plant leaves instantly wilt and die shortly after. The plant then, having no leaves to support growth, dies (Cohen, 2006).

There are two main types of flame cultivation: ‘pre-emergent flaming’ and ‘post-emergent flaming’ (Diver, 2002). The design of this project is for a flame cultivator that will be used primarily for pre-emergent flaming.

**Pre-emergent Flaming.** Pre-emergent flaming takes place before a crop emerges from the soil. There are two main methods of pre-emergent flaming; one method uses flaming before the crop is planted and the other method uses flaming after the crop is planted, just before the crop emerges from the soil. The figure below shows an example of pre-emergent flaming.

![Figure 5. Pre-emergent flaming of vegetable beds (photo from Flame Engineering)](image)

When pre-emergent flaming is used before a crop is planted it is known as either the ‘stale-seedbed' technique or as ‘seedbed sterilization’ (Diver, 2002). In the stale-seedbed technique, a vegetable bed is formed first; and whenever soil is disturbed to form a bed,
weeds almost inevitably appear soon afterward. The farmer waits till new weeds appear or irrigates the bed to encourage a flush of weeds. Once a sufficient amount of weeds have sprouted, the farmer will flame the weeds, thus leaving a stale seedbed to plant a crop in. This process of irrigating and planting may be repeated several times to eliminate as much of the weed seed bank in a bed as needed (Rutiz, 2011). The two images below demonstrate the effects of the stale-seedbed technique before and after a bed was flamed.

![Image](image_url)

**Figure 6.** Weeds before (left) and after (right) flame treatment (*Growing Grounds of Santa Maria, CA.*, 2012)

When pre-emergent flaming is used after a crop is planted it is called the 'peak-emergence' technique. In this method of pre-emergent flaming a farmer will plant his crop into a formed bed, and then he will irrigate as necessary for the crop to germinate. A few days before the crop emerges from the soil, the farmer will flame the weeds that have emerged up until that point. Because the crop is below the soil when the weeds are flamed, the crop remains unharmed. Pre-emergent flaming has proved useful for crops such as carrots, beets, turnips, spinach, cilantro and other slow-germinating crops that cannot be flamed post-emergence (Diver, 2002).

Timing is crucial when using the peak-emergence flaming method, because if a crop has begun to emerge from the soil, a flame treatment could partially or completely destroy the crop along with the weeds (Bond and Grundy, 2001). Although the emergence time for a crop can be predicted according to the crop’s germination time and time of year, it is preferable to test a planted bed periodically to determine how far away a crop’s emergence actually is. Jerald Rutiz (2011) found that he could check a crop's nearness to emergence by scraping under the soil surface with a pocket knife to check the depth of crop seedlings. Another method a farmer can use to determine the date of a crop's emergence is by laying a sheet of plastic or glass over a small section of a planted bed. When the crop seeds beneath the plastic or glass emerge, it is time to flame cultivate. The theory behind this is that, because of the heat produced by the glass or plastic lying in the sun, the crop seeds beneath the glass or plastic will emerge a few days before the rest of the seeds in the uncovered bed (Diver, 2002).

**Post-emergent Flaming.** Post-emergent flaming takes place after a crop has emerged from the soil and is usually not used until a crop is mature enough to survive a flame treatment. Post-emergent flaming can also be known as 'selective flaming' (Diver, 2002).
With this method of flame cultivation, the flames are directed either in between the plants or at the base of the plants. The only instance when flames are aimed directly at the plant foliage is when the elimination of crop foliage is desired, as can be the case with potatoes, cotton, and other crops (Flame Engineering, 2013). When directed at the base or just below of the plants, the flame is directed at the stem and not the foliage of the plant. The figure below, taken from Flame Engineering’s (2013) Agricultural Flaming Guide, diagrams the staggered cross flaming method of post-emergent flaming.

Figure 7. Staggered cross flaming (Flame Engineering, 2012)

If flames directed at the same plant are not staggered as shown above, the colliding flames will sweep upward, causing damage to the plant foliage (Diver, 2002).

**Torch Nozzle Style.** The two main styles of torch nozzles are known as ‘tubular’ and ‘flat’. Lague et al (1997) found through their experiments that flat, fan-shaped nozzles can produce maximum temperatures of around 2400 °F. They also found through their experiments that tubular nozzles can produce slightly higher maximum temperatures of around 2550 °F. A flat nozzle (left) and a tubular nozzle (right) are shown in the figure below.
Lague et al (1997) concluded that flat vapor burners were better suited for non-selective flaming where broad coverage is required, and they concluded that tubular vapor burners were better suited for selective flaming where narrow coverage is required. Ascard (1995) cited research by Holmoy and Storeheier (1995) stating that “flat burners producing a broad, thin and short flame are preferable for selective flaming with open inclined burners, whereas tubular burners producing long narrow flames are better suited for non-selective flaming with covered flamers.” These seeming disparities of opinion can be accounted for, because both flat and tubular nozzles are used in non-selective flaming and selective flaming. Non-selective flaming is more commonly used for pre-emergent flaming, because weeds are the only plant above the soil. Selective flaming is better suited to post-emergence flaming, because flaming of crop foliage is generally not desired. The above conclusions by Lague et al (1997) do not actually contradict the citation by Ascard (1995), because the longer side of a flat torch nozzle can be oriented parallel or perpendicular to the direction of the crop rows.

### Propane Tank Securements

Information was found on the website of the Occupational Health and Safety Administration on how propane tanks must be secured to a moving object. According to OSHA standards, the structure holding a removable propane tank must be able to withstand a static load equal to twice the weight of a full propane tank including its attached parts using a factor of safety of four (OSHA).
PROCEDURES AND METHODS

Design Procedure

Unless specified otherwise, all members of this design shall be constructed of mild steel. Any hot rolled steel with an ultimate strength of at least 50,000 psi shall be acceptable for this design.

Torch Clamps. The torch clamps had to be designed to hold the rods of the torches securely to the cultivation sled, while also allowing at least 2 degree of freedom of movement for the torches. It was decided that the best place for these clamps to attach to the sled would be the rearmost tool bar, shown in figure 9 below.

Figure 9. Tool bar with diamond clamps attached.

Since another cultivation sled was to be used exclusively for the torches, it was determined that the diamond clamps could be used as attachment points for the torch clamps. The best place for the torch clamps to attach to the diamond clamps was the 5/8” bolt that holds the cultivation shank in place; and since the cultivation shanks would not be used at the same time as the torches this would be a useful attachment point. The torch clamps were designed after clamps commonly used for microphone stands and camera stands. These types of clamps typically have two pieces of material that sandwich a rod. When a clamp of this type is loose, the rod can slide back and forth through the clamp and can be rotated about the axis of the clamp’s bolt. The torch clamps needed to hold a rod that was 45/64” in diameter. Figure 10 shows the initial design for the torch clamps.
The 5/8” bolts from the diamond clamps would fit in the horizontal holes of the torch clamps and secure them to the diamond clamps. The vertical holes of the above torch clamp jaws would hold the torch rods. This design would allow the torch height to be adjustable, and it would allow the torches to rotate about the axis of the 5/8” diamond clamp bolt. Both adjustments could be accomplished with the loosening and tightening of the 5/8” bolt.

It was later determined that another design was needed that would give the torches one more degree of freedom. A second torch clamp design was created that would allow the torches to rotate and move in any direction. This second design would use the initial torch clamp jaws, and would have a ¼” x 2” thick arm that the initial clamp jaws would attach to. The second torch clamp design is shown in figure 11 below.

The 5/8” bolt holding the clamp jaws to the clamp arm would now loosen and tighten the clamp jaws, and would allow them to rotate almost a complete 360 degrees. Having the clamping pieces offset to the side would allow the torches to rotate with minimal interference from the cultivation sled’s diamond clamps.

**Propane Tank Brackets.** Propane tank brackets were needed that would securely hold the tanks to the cultivation sled and yet would also allow the tanks to be taken off the sled easily for refilling. The diamond clamps were again considered as a mounting point for
the brackets to the cultivation sled, and it was determined that the diamond clamps would be the best place to secure the brackets to. Attaching the tank brackets to the diamond clamps would allow the brackets to be removed easily if the need arose. With this in mind, the tank brackets were designed with a 2” x ½” shank that would fit in the diamond clamps of the cultivation sled.

Regulations regarding the securement of propane containers to moving objects were found on the Occupation Health and Safety Administration website. The regulation that most governed the design for the propane tank brackets was OSHA Standard 1910.110(e)(4)(iii), which states: “Permanent and removable fuel containers shall be securely mounted to prevent jarring loose, slipping, or rotating, and the fastenings shall be designed and constructed to withstand static loading in any direction equal to twice the weight of the tank and attachments when filled with fuel using a safety factor of not less than four based on the ultimate strength of the material to be used. Field welding, when necessary, shall be made only on saddle plates, lugs or brackets, originally attached to the container by the tank manufacturer.” Calculations in appendix B show that this design satisfies the OSHA requirement. The propane tank bracket design is shown in figure 12.

Figure 12. Propane tank bracket design.

With the aforementioned regulation in mind, the brackets were designed to have a 2” x ½” joist along the bottom of the tanks. The propane tank bottom support is shown in figure 13.
The 2” x ½” joist will provide the vertical support for the weight of the propane tanks, which will be the most significant load experienced by the tank brackets. Perpendicular to the 2” x ½” joist there will be two 2” x ¼” bottom tank bracket arms attached where the center of the tanks will sit on the ½” x 2” joist. At the end of each of these bottom tank brackets arms and at the end of the 2” x 1/2” joist will be ¼” thick ¾” tall tabs. These tabs will keep the bottom of the tanks in place. The main tank straps holding the tanks to the vertical shank of the brackets were designed to be 1/8” x 2”. The propane tank bracket strap assembly is shown in figure 14.

These straps would hold the tank at the center of the bracket, preventing it from shifting in all directions. As shown in figure 14, the straps would be tightened and loosened by a carriage bolt and a wingnut. The top bracket arms which are directly connected to the top of the 2” x ½” shank are designed to be ¼” x 2”. These provide the strength required to withstand the forces the propane tank scavenge when the tractor is rapidly started and stopped.

**Valve Panel.** The valve panel was designed to fit in an area on the tractor’s fender approximately 5” x 9”. This requirement was followed loosely, but the final design was not much larger than this. The available panel space is shown in figure 15 below.
To design the valve panel, it was first necessary to design the system of valves and fittings that the valve panel would hold and protect. An existing problem with Mr. Rutiz’s system was that the tractor operator was required to turn down the torch flame levels manually at the end of each row. This required getting off of the tractor at the end of a row, turning down each torch to a pilot level, turning the tractor around to drive down the next row, turning the torches back up to a high level, and then getting back on the tractor and driving down the row. Because of the above reasons, the valve panel needed to include a way to switch back and forth from a pilot flame level to a high flame level. The valve panel also needed to include a master shutoff valve that would control all propane going to the torches, allowing the torches to be completely shut off in an emergency or when the operator is finished flaming. The final design for this valve panel plumbing assembly included two ball valves and one needle valve. The valve panel plumbing assembly design is shown in figure 16 below.

The short-handled ball valve is the master shutoff valve. The needle valve, which is oriented upside down in figure 16, is the pilot control valve. The long-handled ball valve is the flow control valve. For this design the propane would flow from the tanks into the master shutoff valve. From there it would flow through either the pilot valve or through the flow control valve. If the flow control valve were closed the propane would flow through the needle valve, allowing only a pilot flame if the torches were lit. If the flow control valve were open any amount, most of the propane would flow through it, since it is the path of least resistance for the propane to expand. After passing through the pilot
valve and/or the flow control valve, the propane would flow to the torches. Figure 17 visually shows how propane should flow if the flow control valve were to be open.

All brass fittings in this design, except for the needle valve, are from McMaster-Carr. All fittings are specified to be ¼” NPT thread, keeping with the threads of the existing torches.

Although the exact sizes of the fitting and valves were known before they were assembled, the exact overall size and location of each fitting relative to the others was unknown. This was unknown, because the exact male and female pipe thread sizes can differ from piece to piece. Once all the fittings had been adequately tightened with pipe thread sealant in place, the exact distances between fittings were measured. The measurements were then entered into Solid Works, and a drawing was made of a top view of the assembly. This drawing was then opened in AutoCAD, and was used to create the design for the valve panel shell. The drawing as it was in AutoCAD is shown in figure 18. The green in this drawing, except for the dimensioning, is where cuts were to be made on the CNC plasma.
The circles around the valves were specified to be 1-¼” in diameter, giving enough room for any difference in dimensions of the plumbing assembly if it were to be taken apart and reassembled. The size of the rectangular space around the union fitting serves this same purpose. The spacing around the edges of the plumbing assembly, as shown in figure 18, was specified to be 1/8”. This space would give enough room for any small changes in dimension of the plumbing assembly. This space also allows for spot welds that would be made on the inside of the valve panel shell.

The dimensions from the AutoCAD drawing were then used to design to the valve panel shell. The valve panel shell was specified to be constructed of 10 gauge steel. The valve panel top was designed using the same dimensions of the AutoCAD drawing. The side, front, and rear pieces were designed to be 2 inches tall, and each had the same respective lengths and widths as the valve panel top. The valve panel design is shown in figure 19.

![Valve panel design](image)

**Figure 19.** Valve panel design.

On the rear valve panel piece is a 1” x 3.5” opening to allow for the propane hoses that would go to the torches. A ¾” diameter hole is shown on this piece to allow for the propane hose from the tanks to connect to the master shutoff valve. On the driver’s seat side of the valve panel shell, the valve panel shell was designed to have a 4” x 2” opening. This opening, shown in figure 20 below, would allow the operator to adjust the pilot valve without having to take the valve panel off of the tractor.
To keep the plumbing assembly square with itself and the valve panel shell, shims were designed that the plumbing assembly would rest against. These shims would keep the plumbing assembly from contacting the valve panel shell on curved surfaces, like the rounded edges on the ball valves. The final design for the valve panel shims specified them to be 0.125” thick. The placement of the shims is shown in figure 22. Once the valve panel shell had been designed to the dimensions of the valve panel plumbing assembly, a design was needed that would hold the plumbing assembly to the valve panel shell. Brackets were designed that would hold the plumbing assembly to the valve panel in two places. The individual brackets are shown in figure 21.

Each bracket would consist of two ½” steel cubes which are welded to the valve panel shell, each drilled and tapped to receive a ¼”-20 bolt. The valve panel plumbing assembly would be held to the panel by two of the above brackets. The bent bracket strap would be constructed of 1/16” sheet metal and would be held to the panel by two ¼” bolts. Each bolt would have a flat washer and a lock washer between the bracket strap and the bolt. Figure 22 shows how these brackets were configured relative to the plumbing assembly and the valve panel shell.
Figure 22. Placement of shims (red), brass fitting brackets (blue), and valve tabs (orange).

Tabs were needed to keep the plumbing assembly in place and to keep the valves from rolling over relative to the valve panel shell. The valve tabs, boxed in orange in figure 22, are designed to be ¾” squares constructed of 10 gauge steel. As with the valve panel plumbing assembly, the exact locations of the brass fitting brackets, shims, and valve tabs can vary depending on how much the plumbing assembly is tightened. That is why room for movement of the plumbing assembly was allowed for the brackets.

The last part of the valve panel that needed to be designed was the system for mounting the valve panel to the tractor’s fender. The tractor’s fender was constructed of approximately 1/16” steel, and it had a larger support underneath it constructed of approximately 10 gauge steel. The tractor’s fender is shown in figure 15. It was determined that a sufficient way to hold the valve panel to the tractor’s fender would be by using two 3/8” bolts. A fender support piece, constructed of 10 gauge steel, would be kept on the tractor at all times. This would be held on the fender by flat washers and locknuts. This fender support piece would provide strength to the fender, keeping the 3/8” bolts from shearing the fender material. The valve panel would have tabs at each end having holes that would fit over the 3/8” bolts. The valve panel would be held against the locknuts by wingnuts. The complete valve panel with its fender support piece is shown in figure 23.
Construction Procedure

All welding done for this project was accomplished using a MIG welder.

Torch Clamps. Each pair of clamp jaws was cut from pieces of 1” thick steel plate. Two pieces, each 1” x 2” x 1 ½”, were cut from the 1” plate. Each piece was cut out with a band saw, and the sharp edges were sanded with a belt sander. Figure 24 shows the plate that one pair of clamp jaws was cut from. Each hole was center punched, center drilled, and then drilled with a 3/8” bit. Each piece then had one 21/32” hole drilled in it and one 11/16” hole drilled in it. The 11/16” holes were later re-drilled to be 45/64” to better fit the torch rods. All holes for the torch clamps were drilled using the large drill press in shop 7. The dimensions and locations of the holes are shown in Appendix C. Figure 24 shows one clamp jaw piece after the holes had been drilled in it.
Each clamp jaw piece was then cut in half through the middle of the 11/16” hole. This cut was done with a band saw having a 1/16” kerf. This cut required marking the piece down the center, and then lining the mark up with the center of the band saw blade. Figure 25 shows where these cuts were done.

![Figure 25. Location of cut in clamp jaw piece.](image)

After each clamp piece was cut in half, all four clamp jaws were deburred and marked to show which jaw belonged to which. Figure 26 shows one clamp jaw pair after being cut in half.

![Figure 26. Clamp jaw pair.](image)
The torch clamp arms were constructed of $\frac{3}{4}$" x 1 ½" barstock. Each piece of the torch clamp arms was cut to length using the bandsaw. The edges were then deburred, and the holes were drilled using the large drill press. The sharp edges of the holes were also deburred. The dimensions and locations of the holes are shown in Appendix C. Figure 27 shows how the pieces appeared after being cut and drilled.

![Figure 27. Torch clamp arm pieces.](image1)

While being held perpendicular to each other, each piece was spot welded together. The connections were then completely welded, according to the construction drawings in Appendix C. Figure 28 shows the appearance of the torch clamp arms after being welded together.

![Figure 28. Torch clamp arms.](image2)

The torch clamps were then assembled as shown in figure 29.

![Figure 29. Completed torch clamps.](image3)
Propane Tank Brackets. The 1/2” x 2” shanks for the propane tank brackets were cut from ½” steel plate using the bandsaw. Each shank was cut to be 19” long. The 10 ½” long joists and the 2” gussets were also cut from the same ½” plate. The sharp edges were deburred from all these pieces using the belt sander. The top tank bracket arms were cut to length on the bandsaw, using 2” x ¼” barstock. The 19” shanks were stood upright on a welding table using welding magnets. The top tank bracket arms were also held upright by welding magnets, with the long sides of the brackets parallel to the welding table. With each bracket arm held at 27 degrees to its corresponding 19” shank, spot welds were placed along each seam between the pieces. After the angle of the top tank brackets arms was sure to be 27 degrees, the seams were completely filled in with weld. The weld bead on the inside of the bracket was ground down, using a grinding wheel followed by a sanding disc, to make the inner connection between the bracket arms and the shank smooth. Figure 30 shows the appearance of the shanks with the top tank bracket arms welded to them.

![Figure 30. Top brackets arms welded to shanks, viewed from both sides.](image)

The bottom tank bracket arms were cut to 3-1/4” from ¼” x 2” barstock. The next pieces welded together were the 10 ½” joists and the bottom tank bracket arms. Each joist was clamped to a welding table with its corresponding bottom bracket arms held at 3-½” from the end of the joist. They were spot welded together on the bottom seam, and the bottom edges were fillet welded. The top edges were butt welded, and then sanded using a sanding disc to give them a smooth appearance. See Appendix C for welding details and further dimensioning.

The 10-1/2” joists were placed perpendicular to the 19” shanks and were held in place by welding magnets. With the joists held at the 8-1/4” from the top of the shanks, the pieces were spot welded on each side. The 2” gussets were centered along the bottom connection of the joists and the shanks. While being held in place by clamps, the gussets were spot welded to the shanks and the joists. After it was certain that the joists were
perpendicular to the shanks, the pieces were completely welded together. Figure 31 shows the appearance of one of the shanks with its bottom support piece welded to it.

![Image of a bottom support welded to a shank.](image)

**Figure 31. Bottom support welded to shank.**

When the joists were initially welded to the shanks, the weld bead along the top of the joists had insufficient penetration. The bad weld beads were ground down, and the seams were welded again with the welder at a hotter setting.

The tank bracket end tabs were then welded to the ends of the 10-1/2” joists, and the tank bracket side tabs were welded to the ends of the bottom tank bracket arms. See Appendix C for welding details.

Next, the pieces of steel were cut out for the main tank straps, the 7.125” tanks straps, and the 8.625” tank straps. The main tank straps were constructed of 1/8” x 2” flatstock, and both of the 8.625” tank straps were constructed of 10 gauge steel. One of the 7.125” tank straps was constructed of 1/8” x 2” flatstock, and the other was constructed of 10 gauge steel. Before any of the tank strap pieces were bent, their respective holes and slots were machined. The 25/64” slots were machined on main tank straps using an end mill bit on the milling machine in lab 7. They were then bent with a roller until they achieved a 6-1/4” radius. The 6-1/4” radius bend in the 7.125” and 8.625” tank straps were done using a small piece of pipe and a vice. All other bends were accomplished using the finger break in lab 6. Figures 32, 33, and 34 detail the bends placed in the tank straps. See Appendix C for orientation of individual bends.
Figure 32. Bend details for main tank straps.
Figure 33. Bend details for 8.625” tank straps.
Figure 34. Bend details for 7.125” tank straps.
After all of the tank straps were machined and bent, the 7.125” and 8.125” tank straps were fitted onto the top tank bracket arms. Minor adjustments were made to some of the bends so that the straps would not hug the tanks too tightly. These adjustments were done using a deadblow hammer and a vice. Once all the edges were lined up, according to the specifications in Appendix C, the 7.125” and 8.125” tanks straps were spot welded to the top tank bracket arms. The edges were then fully welded together, and the welds were made smooth with a sanding disc. Figure 35 shows the propane tank brackets thus far in the construction.

Next, the 2” weldable hinges were welded to the main tank straps. The welds were made smooth using a sanding disc. The unwelded ends of the 2” weldable hinges were held to the 7.125” tank straps by vice grips. The ends of the main tank straps having the bends and slot were held to the 8.625” tank straps by the 3/8” carriage bolts and wingnuts. In this way it was certain that the hinges would be square and that the slots in the main tank straps would line up the holes in the 8.625” tank straps. The unwelded ends of the weldable hinges were welded to the 7.125” tank straps, and the welds were made smooth using a disc sander. Figure 36 shows one completed propane tank bracket.
Valve Panel. The valve panel shell was designed and constructed after the valve plumbing assembly was assembled. With pipe thread sealant placed on the male threads of each fitting, the valve plumbing assembly was assembled. Each fitting was tightened unit it was snug with the fitting it was connected to. To allow the valve plumbing assembly to be assemble and taken apart, the 5” hose assembly was connected to the needle valve by a ¼” FNPT union fitting. This fitting was the last fitting in the assembly to be tightened.

The measurements of the valve plumbing assembly were then used to create the DXF file that would be used to cut the valve panel shell pieces out on the CNC plasma. The exact dimensions of the valve panel shell pieces are shown in Appendix C. A sheet of 10 gauge steel was placed on the CNC plasma, and the valve panel pieces were cut out. Figure 37 shows the valve panel pieces being cut out on the CNC plasma in shop 6.

Figure 36. Completed propane tank bracket.

Figure 37. Valve panel being cut out on CNC plasma.

Figure 38 shows the individual valve panel pieces before they were welded together.
The valve panel shell pieces were then held together using welding magnets. Each edge was spot welded on the inside and outside edges, and then the outside edges were completely welded together. The outside welds were smoothed and rounded using a fine grit disc sander. Figure 39 shows the valve panel shell after being welded together.

It was noticed that no hole was present for the propane hose which would connect to the master shutoff valve. To fix this, a \( \frac{3}{4}'' \) hole was cut on the back valve panel piece using a hole saw. The edges of the hole were rounded off a smoothed using a die grinder. This is hole is shown in the figure 40. Next, the valve plumbing assembly was fit inside the valve panel shell. Figure 40 shows the valve plumbing assembly being fit in the valve panel shell.
The 2” x 2.5” shim and the 2.25” x 3.25” shim were cut from 3/16” plate, and were spot welded to the valve panel shell. These shims were found to be too thick, so they were machined down to 0.125” using the milling machine. The ¾” valve panel tabs were held in place against their respective ball valves, and their position was marked. They were then spot welded to the valve panel shell.

The ⅝” cube blocks for the brass fitting brackets were cut out of ½” plate using the bandsaw. Their rough edges were filed down and they were drilled and tapped at their centers using a ¼”-20 tap. The brass fitting brackets were cut from 1/16” sheet, and were cut to be ½” x 2-1/4”. 9/32” holes were drilled in each end of the bracket, ½” in from the end and ½” from the sides. The brackets were then bent using a custom made set of die. These die are shown in figure 41.

The dies were used on the large hydraulic press in shop 7. Each brass fitting bracket was centered on the die and was bent. The bends in the bracket near the back of the panel were approximately 45 degrees. The bends in the bracket near the front of the panel were approximately 60 degrees. The second bends were made steeper using 18 gauge sleeves inside the die. The steeper bends were needed there, because of the smaller available
space for the brass fitting brackets. The brass fitting brackets were then assembled as shown in Appendix A. Their position on the valve panel shell was measured using digital calipers. This was done while the valve plumbing assembly was sitting in the valve panel shell. The plumbing assembly was taken out of the valve panel shell, and the brass fitting brackets were welded in place. The placement of the brass fitting brackets and the placement of the ¾” valve panel tabs were measured to fit the position of the valve plumbing assembly. The dimensions of the brass fitting brackets can be found in Appendix A.

The valve panel tabs were cut from 10 gauge steel; and they were drilled with 13/32” holes, according to the dimensions shown in Appendix A. The valve panel tabs were then welded to the valve panel shell. The valve panel fender support was also cut out from 10 gauge steel and its holes were drilled to match the dimensions of the valve panel tabs.

The propane tank brackets and the valve panel shell were bead-blasted. All steel parts were then primed using several coats of ACE Rust Stop Primer. Once the primer had dried, the steel parts were painted using black gloss ACE Rust Stop Enamel. The handle of the master shutoff valve was painted using red enamel paint to differentiate it from the yellow handle of the flow control valve.

After the paint had dried, the flame cultivator attachment was completely assembled. To attach the valve panel and the valve panel fender support to the tractor’s fender, two 13/32” holes were drilled in the fender at the same hole spacing as the hole spacing of the fender support piece. The complete valve panel was then attached to the tractor. Figure 42 shows the valve panel mounted on the tractor.

![Figure 42. Valve panel mounted on tractor from front (left) and side (right).](image)

The propane tank brackets were attached to the diamond clamps on the tool bar closest to the driver. Figure 43 shows the propane tanks brackets attached to the cultivation sled.
The pressure regulator, pressure gauge, 72” hose assembly, and 36” hose assembly can be seen in figure 43. These parts were not part of the construction, but were part of the final flame cultivator attachment assembly.

The torch clamps were attached to the 5/8” bolts of the diamond clamps on the rearmost tool bar of the cultivation sled. Figure 44 shows the torch clamps attached to the sled and holding the torches.

The plumbing schematic showing the position of assembly for each piece is shown in Appendix C.
**Testing procedure**

**Torch Clamps.** The torch clamps were attached to the diamond clamps. The torch clamps were tightened without flattening the lock washers. At this level of tightness the torches were held in place. They could be adjusted, and would stay in their position after adjustment. Figure 44 shows the torch clamps during testing.

**Propane Tank Brackets.** The propane tank brackets securely held the propane tanks to the cultivation sled. No movement of the brackets or tanks other than slight vibration, neither turning nor sliding, was observed when the tractor started and stopped. Figure 43 shows the propane tank brackets during testing.

**Valve Panel.** The valve panel was connected to the torch hose assemblies and to the 72” hose assembly. The pressure regulator and the pressure valve were plumbed according to the plumbing schematic in Appendix C. As with the valve panel plumbing assembly, all fittings and hoses were assembled with pipe thread sealant added to the male pipe threads of each hose or fitting.

The valve panel was first tested for leaks. The existing needle valves on the torches were closed, and the propane tanks were turned completely off. The master shutoff valve was in the off position, and the flow control valve was in the off (low flow) position. Both tanks were turned on. The master shutoff valve was turned on, and the flow control valve was left in the closed position. The pilot valve was opened a half-turn. The needle valve on each torch was opened, and both torches were lit. The pilot valve was adjusted until it allowed only a small pilot flame. The flow control valve was opened, and then it was again turned down to the low flow position. Figure 45 shows testing of the torches, at pilot and full flame levels.

The flame cultivator attachment was tested on 7 carrot rows at Rutiz Family Farms. About 10% of the carrots had emerged by this time, but Mr. Rutiz decided that the rows should still be torched to optimize yield. The flow control valve was turned to “low flow” before each row was started, and the cultivation sled was lifted. Once the operator began driving down each row, the cultivation sled was lowered and the flow control valve was turned to “full flow”. When the operator arrived at the end of each row, the cultivation sled was lifted and the flow control valve was turned to “low flow”. The operator then turned the tractor around to drive down the next row. This process was repeated for each row. The tractor’s speed was about 2-3 miles/hour while traveling down the rows.
Figure 45. Torches at pilot flame (left) and full flame (right).

Instructions for the flame cultivator attachment are located in Appendix E.
RESULTS

When the propane tanks were turned on, the pressure gauge needle immediately turned up and stabilized at about 55 psi. A faint hissing sound was heard near the tee fitting which attaches to the regulator and the 36” hose assembly. The area was squirted with soapy water, and bubbles formed at two places on the tee fitting. The fittings and hose connected to the tee fitting were tightened, and the leak was stopped. Another leak was found inside the valve panel plumbing assembly. The leak was between the flow control valve and the 5.5” brass nipple. The brass nipple was tightened, and the leak was stopped. After all leaks were fixed, the propane tanks were re-opened.

After the torches were lit and the flow control valve was turned to “full flow”, the torches immediately responded with high flame levels. When the flow control valve was turned down to “low flow”, the flames decreased to a pilot level again. There was about a 2 second delay from when the flow control valve was turned down to when the torches were back at a pilot level.

At the end of the testing for the flame cultivator attachment, the propane tanks had a thin layer of ice on them. The pressure valve read about 30 psi when the testing was done.

The propane tank brackets securely held the propane tanks to the cultivation sled while the tractor was driven, and they did not allow the tanks to move or twist when the cultivation sled was lowered and lifted.

The angle and height of the torches were easily adjusted with the torch clamps. The torch clamps did not allow the angle or the height of the torches to change due to the movement of the cultivation sled.
DISCUSSION

Bending stress calculations, found in Appendix B, show that the propane tank bracket design satisfies the requirement of the OSHA regulation.

When the torches were first lit during testing, the pressure regulator was set at about 55 psi. The normal operating pressure given by Flame Engineering for their VT 3-30C torches is 30 psi (Flame Engineering, 2013). Testing the torches at 55 psi for an extended period of time could account for the ice on the outside of the propane tanks. The higher pressure would cause a higher flow rate of propane from the tanks, causing the tanks to cool more rapidly. The ice may have also affected the pressure regulator by partially blocking up opening within the regulator.

One of the propane tanks had a slightly larger bottom flange than the propane tanks that were measured for this project. This caused one edge of the tank to sit outside of one of the tank bracket side tabs.
RECOMMENDATIONS

After the flame cultivator attachment was completely assembled, it was obvious that the 72” hose assembly was too long for its purpose. This hose assembly could have been no longer than 60”. The excess of hose length is shown in figure 46.

Figure 46. Side view of the flame cultivator attachment.

Another thing that could be changed is the length of the brass nipple that connects the pressure regulator and the FNPT Tee fitting. The length of the brass nipple is 5.5”, and the weight of the regulator and hose on this length could cause unneeded stress on the FNPT Tee fitting.

The bottom support of the propane tank brackets could be made slightly wider and longer, so that the bottom flange of any standard 40 lb propane tank would fit within the bracket’s side and end tabs. The tabs were designed to give the tank ¼” of slack on every side of the tank’s bottom flange, but this amount of slack was not enough for one of the propane tanks that was used during testing.
REFERENCES


APPENDIX A

HOW PROJECT MEETS REQUIREMENTS FOR THE BRAE MAJOR
HOW PROJECT MEETS REQUIREMENTS FOR THE BRAE MAJOR

Major Design Experience

The BRAE senior project must incorporate a major design experience. Design is the process of devising a system, component, or process to meet specific needs. The design process typically includes the following fundamental elements as outlined below. The project addresses these issues as follows.

Establishment of Objectives and Criteria. Project objectives and criteria are established to meet the needs and expectations of Mr. Jerry Rutiz. See Design Parameters and Constraints section below for specific objectives and criteria for the project.

Synthesis and Analysis. The project will incorporate normal stress calculations and gas flow and pressure calculations.

Construction, Testing and Evaluation. The flame cultivator attachment will be designed, constructed, tested, and evaluated.

Incorporation of Applicable Engineering Standards. The project will utilize OSHA standards for liquid petroleum, and AISC standards for allowable normal stresses.

Capstone Design Experience

The engineering design project must be based on the knowledge and skills acquired in earlier coursework (Major, Support and/or GE courses). This project incorporates knowledge/skills from these key courses.
- 129 Lab Skills/Safety
- 234 Mechanical Systems
- 421/422 Equipment Engineering
- CE 204 Strength of Materials
- ENGL 149 Technical Writing
- CM 115 Fundamentals of Construction Management

Design Parameters and Constraints

The project should address a significant number of the categories of constraints listed below.

Physical. The angle and height of the torches must be adjustable. The propane flow must be able to be controlled from the tractor. The propane tanks must be securely mounted to the cultivation sled.

Economic. The cost of materials for the project should not exceed $200.
**Environmental.** The project is assisting in the abatement of weeds without the use of herbicides.

**Sustainability.** The project is assisting the continuation of a pesticide-free farm that is farmed using sustainable practices such as green-manuring and good crop rotation.

**Manufacturability.** The project could be repeated for other famers.

**Health and Safety.** The torch attachment must satisfy all OSHA regulations regarding the use of liquid petroleum.

**Ethical.** N/A

**Social.** N/A

**Political.** N/A

**Aesthetic.** The torch clamps and tank brackets will be symmetric.
APPENDIX B

DESIGN CALCULATIONS
Each propane tank bracket must withstand a force equal to 2 times the static weight of a standard 40 lb propane tank in any direction using a factor of safety of 4. (OSHA)

Design force of tank on propane tank brackets = 2 x (F.O.S. of 4) x 40lb = 320 lb

Assuming 1020 HR steel plate is used for shank and joist of propane tank brackets,

\[ \sigma_{\text{ult}} = 64 \text{ ksi} \]

\( \sigma_{\text{design}} \) must be less than \( \sigma_{\text{ult}} \)

\[ \sigma_{\text{max}} = \frac{M_{c}}{I} \quad \text{(Shigley’s Mechanical Engineering Design)} \]

where,

\[ M = \text{(force)} \times \text{(lever arm)} = (320 \text{ lb})(6.455”) = 2065.6 \text{ lb} \]

\[ c = 0.250” \]

\[ I = bh^{3}/12 = (2.000”)(0.500”)^{3}/12 = 0.02083 \text{ in}^{4} \]

\[ \sigma_{\text{design}} = \frac{(2065.6 \text{ lb})(0.250”)}{(0.02083 \text{ in}^{4})} = 24791.2 \text{ psi} = 24.8 \text{ ksi} \]

\( \sigma_{\text{design}} \ll \sigma_{\text{ult}} \) therefore, design is adequate.
APPENDIX C

CONSTRUCTION DRAWINGS
<table>
<thead>
<tr>
<th>TITLE:</th>
<th>2&quot; Clamp Leg</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMMENTS:</td>
<td></td>
</tr>
<tr>
<td>QUANTITY:</td>
<td>2</td>
</tr>
<tr>
<td>SHEET NO.:</td>
<td>A-2</td>
</tr>
<tr>
<td>DRAWING BY:</td>
<td>AARON EVANS</td>
</tr>
<tr>
<td>MATERIAL:</td>
<td>MILD STEEL</td>
</tr>
<tr>
<td>DO NOT SCALE</td>
<td></td>
</tr>
<tr>
<td>SHEET 2 OF 31</td>
<td></td>
</tr>
</tbody>
</table>

**ALL DIMENSIONS IN INCHES**

- Width: 2.00
- Height: 0.75
- Hole Diameter: 21/32"
3" Clamp Leg

ALL DIMENSIONS IN INCHES

TITLE: 3" Clamp Leg

COMMENTS: 3" Clamp Leg

QUANTITY: 2

SHEET NO. A-3

DRAWING BY: AARON EVANS

MATERIAL: MILD STEEL

DO NOT SCALE

SHEET 3 OF 31
Torch Clamp Jaw

All dimensions in inches

Material: Mild Steel

Drawing by: Aaron Evans

Quantity: 4

Sheet No.: A-4

Comments:

- Torch Clamp Jaw
- 45/64"
- 21/32"
Torch Clamp Arm

3" Clamp Leg

2" Clamp Leg

90°

0.25

COMMENTS:

MATERIAL: MILD STEEL

QUANTITY: 2

SHEET NO.: A-5
Main Tank Strap
2" Weldable Hinge
3/8" Tank Strap Bolt
3/8" Wingnut
Top Tank Bracket Arm
2" Gusset
Bottom Tank Bracket Arm

7.25" Tank Strap
Tank Bracket End Tab
Tank Bracket Side Tab
10.5" Joist
19" Shank

COMMENTS:

TITLE: Propane Tank Bracket

ALL DIMENSIONS IN INCHES

QUANTITY: 2

MATERIAL: MILD STEEL

DRAWING BY: AARON EVANS

SHEET NO.: B-1

DO NOT SCALE

SHEET 6 OF 31
10.5" Joist

All Dimensions in Inches

Title: 10.5" Joist
Comments: 
Quantity: 2
Sheet No.: B-3
Drawing By: Aaron Evans
Material: Mild Steel
Do Not Scale
Top Tank Bracket Arm

ALL DIMENSIONS IN INCHES

TITLE: Top Tank Bracket Arm

COMMENTS: 

QUANTITY: 4

SHEET NO. B-4

DRAWING BY: AARON EVANS

MATERIAL: MILD STEEL

DO NOT SCALE

SHEET 9 OF 31
Main Tank Strap

COMMENTS: Refer to report for instructions on construction of this part.

ALL DIMENSIONS IN INCHES

TITLE: Main Tank Strap

QUANTITY: 2

MATERIAL: MILD STEEL

DRAWING BY: AARON EVANS

DO NOT SCALE

SHEET NO. B-6

SHEET 11 OF 31
7.125" Tank Strap

Comments: Refer to report for instructions on construction of this part.

All dimensions in inches

Material: Mild Steel

Drawing by: Aaron Evans

Sheet No.: B-7

Sheet 12 of 31
8.625" Tank Strap

COMMENTS: Refer to report for instructions on construction of this part.

MATERIAL: MILD STEEL

DRAWING BY: AARON EVANS

ALL DIMENSIONS IN INCHES

TITLE: 8.625" Tank Strap

QUANTITY: 2

SHEET NO. B-8

DO NOT SCALE

Sheet 13 of 31
Title: Tank Bracket End Tab

All Dimensions in Inches

Drawn by: Aaron Evans
Material: Mild Steel

Quantity: 2

Comment: Tank Bracket End Tab

Sheet: B-9

Do Not Scale

Sheet 14 of 31
2" Gusset

ALL DIMENSIONS IN INCHES

COMMENTS:

TITLE: 2" Gusset

QUANTITY: 2

SHEET NO. B-11

DRAWING BY: AARON EVANS  MATERIAL: MILD STEEL  DO NOT SCALE

SHEET 16 OF 31
Valve Panel Shell

ALL DIMENSIONS IN INCHES

TITLE:

QUANTITY: 1

SHEET NO. C-3

COMMENTS:

DRAWING BY: AARON EVANS

MATERIAL: MILD STEEL

DO NOT SCALE

SHEET 20 OF 31
Complete Valve Panel

3/8" Locknut
3/8" Wingnut
3/8" Washer
3/8" Bolt
Fender Space
Valve Panel Fender Support

ALL DIMENSIONS IN INCHES

TITLE: Complete Valve Panel
QUANTITY: 1
SHEET NO: C-7

COMMENTS:

MATERIAL: MILD STEEL
DRAWING BY: AARON EVANS
DO NOT SCALE

SHEET 24 OF 31
Valve Panel Fender Support

ALL DIMENSIONS IN INCHES

COMMENTS:

TITLE:

DRAWING BY: AARON EVANS
MATERIAL: MILD STEEL
DO NOT SCALE

QUANTITY: 1
SHEET NO.: C-8

SHEET 25 OF 31
Brass Fitting Bracket

All dimensions in inches

Title: Brass Fitting Bracket

Comments: Brass Fitting Bracket

Quantity: 2

Sheet No.: C-11

Drawing by: Aaron Evans

Material: Mild Steel

Do not scale

Sheet 28 of 31
Plumbing Assembly Clamp Block

1/4"-20 Threaded
2" x 2.25" Shim

ALL DIMENSIONS IN INCHES

TITLE: 2" x 2.25" Shim

COMMENTS: COMMENTS:

QUANTITY: 1

DRAWING BY: AARON EVANS

MATERIAL: MILD STEEL

DO NOT SCALE

SHEET NO. 1

SHEET 30 OF 31
2.25" x 3.25" Shim

ALL DIMENSIONS IN INCHES

TITLE: 2.25" x 3.25" Shim
COMMENTS: 
QUANTITY: 1
SHEET NO. C-14
DRAWING BY: AARON EVANS
MATERIAL: MILD STEEL
DO NOT SCALE

SHEET 31 OF 31

material: MILD STEEL

all dimensions in inches
ALL DIMENSIONS IN INCHES

VALVE PANEL SHELL
CNC PLASMA
DRAWING

MATERIAL: 10 GAUGE
AUTHOR: AARON EVANS
SHEET NO: C-15
APPENDIX D

HARDWARE LIST
<table>
<thead>
<tr>
<th>Quantity</th>
<th>Item</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1/4” NPT 90° Male-Female Elbow (street elbow)</td>
<td>McMasterCarr.com</td>
</tr>
<tr>
<td>2</td>
<td>1/4” NPT 90° Female-Male-Female Tee</td>
<td>McMasterCarr.com</td>
</tr>
<tr>
<td>1</td>
<td>1/4” NPT 90° Female-Female-Male Tee</td>
<td>McMasterCarr.com</td>
</tr>
<tr>
<td>1</td>
<td>1/4” NPT 90° Female-Female-Female Tee</td>
<td>McMasterCarr.com</td>
</tr>
<tr>
<td>1</td>
<td>1/4” MPT x MPT brass nipple 5.5” length</td>
<td>McMasterCarr.com</td>
</tr>
<tr>
<td>1</td>
<td>1/4” NPT Female x Female Ball Valve_lever handle</td>
<td>McMasterCarr.com</td>
</tr>
<tr>
<td>1</td>
<td>1/4” NPT Female x Female Ball Valve_T handle</td>
<td>McMasterCarr.com</td>
</tr>
<tr>
<td>2</td>
<td>1/4” MNPT Hex nipple</td>
<td>McMasterCarr.com</td>
</tr>
<tr>
<td>1</td>
<td>567 RD Medium Capacity - Adjustable Regulator 1/4” FPT Inlet x 1/4” FPT Outlet</td>
<td>FlameEngineering.com</td>
</tr>
<tr>
<td>1</td>
<td>G-23 0-100 P.S.I. Pressure Gauge 1/4” MPT Stem</td>
<td>FlameEngineering.com</td>
</tr>
<tr>
<td>4</td>
<td>1/4”-20 Hex bolts X 3/4” Length</td>
<td>Miner's Hardware</td>
</tr>
<tr>
<td>4</td>
<td>#12 Flat Washers</td>
<td>Miner's Hardware</td>
</tr>
<tr>
<td>4</td>
<td>1/4” Lock Washers</td>
<td>Miner's Hardware</td>
</tr>
<tr>
<td>2</td>
<td>3/8”-16 Carriage Bolts X 3.5” Length</td>
<td>Miner's Hardware</td>
</tr>
<tr>
<td>2</td>
<td>1-1/2” Long 3/8” Hex Bolts</td>
<td>Miner's Hardware</td>
</tr>
<tr>
<td>4</td>
<td>3/8” Flat Washers (large)</td>
<td>Miner's Hardware</td>
</tr>
<tr>
<td>4</td>
<td>3/8”-16 Wingnuts</td>
<td>Miner's Hardware</td>
</tr>
<tr>
<td>1</td>
<td>Standard-Wall Brass Threaded Pipe Nipple, 1/4 Pipe Size X 5” Length</td>
<td>Miner's Hardware</td>
</tr>
<tr>
<td>2</td>
<td>1/4” FPT Hex Coupler</td>
<td>Miner's Hardware</td>
</tr>
<tr>
<td>2</td>
<td>5/8”-11 Hex Bolts X 2” Length</td>
<td>Miner's Hardware</td>
</tr>
<tr>
<td>4</td>
<td>5/8” Lock Washers</td>
<td>Miner's Hardware</td>
</tr>
<tr>
<td>1</td>
<td>LP Pipe Thread Sealant</td>
<td>Miner's Hardware</td>
</tr>
<tr>
<td>2</td>
<td>5/8” Flat Washers (small)</td>
<td>Miner's Hardware</td>
</tr>
<tr>
<td>1</td>
<td>1/4” MNPT X 1/4” MNPT High Pressure Propane Hose Assembly, 72” Length</td>
<td>Contractor's Maintenance, San Luis Obispo, CA.</td>
</tr>
<tr>
<td>1</td>
<td>1/4” MNPT X 1/4” MNPT High Pressure Propane Hose Assembly, 36” Length</td>
<td>Contractor's Maintenance, San Luis Obispo, CA.</td>
</tr>
</tbody>
</table>
APPENDIX E

FLAME CULTIVATOR ATTACHMENT INSTRUCTIONS
The following instructions are modeled after the instructions that Flame Engineering provides for their flame cultivator units.

**Startup**

1. Make sure all valves are in the closed position.

2. Open propane tank valves.

3. Check for propane leaks by spraying a soapy solution along at every fitting junction. If hissing is heard, propane is smelled, or if bubbles form, turn off the propane tank valves immediately. Repair any leaks, and then repeat steps 1 - 3.

5. Turn on master shutoff valve.

6. Light each torch individually by opening the torch's needle valve and igniting the torch. After each torch is lit, torch needle valves may be completely opened. Adjust pilot valve to desired level if needed.

7. Operate flame cultivator attachment, always being aware of what is behind the torches.

WARNING: IF TORCHES BLOW OUT DURING OPERATION, IMMEDIATELY TURN OFF MASTER SHUTOFF VALVE AND REPEAT STEPS 5 AND 6. IF PROPANE IS SMELLED AT ANY TIME DURING OPERATION, TURN OFF MASTER SHUTOFF VALVE, TURN OFF TRACTOR, AND IMMEDIATELY GET AWAY FROM THE TORCHES. DO NOT GO NEAR TORCHES UNTIL FLAMES HAVE COMPLETELY BURNED OUT.