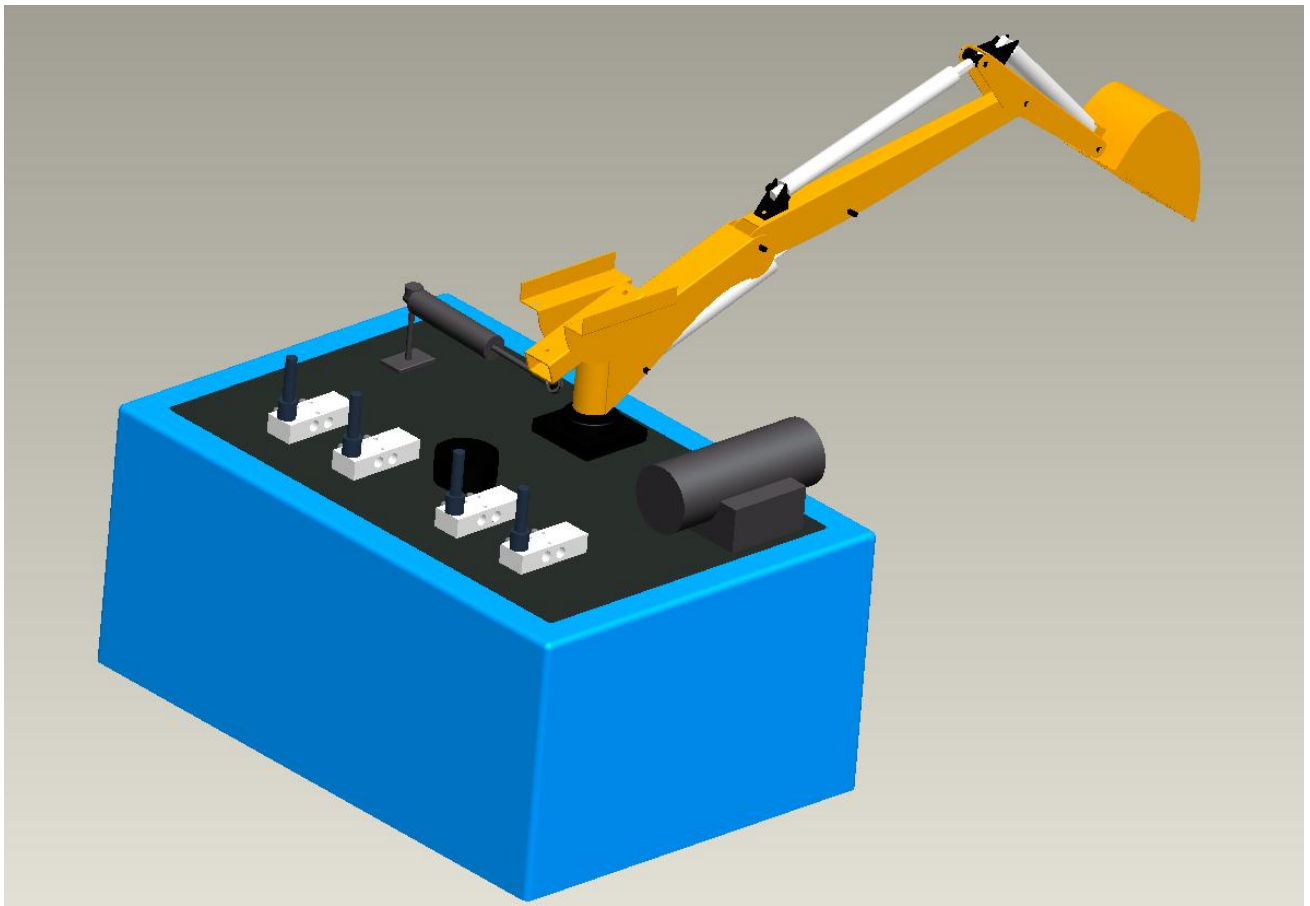


# **Assembly Instructions for the Portable Fluid Power Demonstrator (PFPD)**

**(Kit Version: Excavator Arm Trainer)**



## Table of Contents

Safety Instructions .....	3
Parts List.....	4
Assembly Instructions .....	6
Step 1 – Water Pump Assembly.....	6
Step 2- Board Fabrication .....	6
Step 3- Bracket Fabrication.....	9
Step 4 - Excavator Arm Fabrication.....	10
Step 5- Cylinder Assembly.....	14
Step 6- Excavator Arm Assembly .....	15
Step 7- Valve Preparation .....	17
Step 8- Final Assembly .....	19
APPENDIX I: BILL OF MATERIALS.....	24
APPENDIX II: VALVE CONFIGURATION TEMPLATE.....	27

## Safety Instructions

- A teacher or adult must always be present when students are operating the Portable Fluid Power Demonstrator.
- Proper clothing and closed-toed shoes should always be worn when handling the tools used in the construction of the Portable Fluid Power Demonstrator.
- Use caution when dealing with electrical components. Do not contact electrical components with water or electric shock could occur.
- The Portable Fluid Power Demonstrator can be operated using standard tap water as the working fluid and it is possible that surrounding surfaces will get wet, so care should be taken to avoid any wet surfaces where slipping can occur.
- Do not attempt to move the Portable Fluid Power Demonstrator without assistance once it is filled with water.
- Make sure all hoses are securely attached to both the cylinders and the valves before connecting the Portable Fluid Power Demonstrator to a power supply.
- The Portable Fluid Power Demonstrator with the excavator arm has a large swinging area which should be clear of any obstacles.
- Students should not get in the way of the arm in order to avoid any potential injury.
- Do not operate the Portable Fluid Power Demonstrator with higher pressure than specified in this manual; use the recommended pump or an air supply with less than 100 psi.
- The Portable Fluid Power Demonstrator arm has several potential “pinch points” where two surfaces meet. Do not put any objects in this space and do not operate the demonstrator if people are standing near or working on the arm.

## Parts List

The following parts will be needed to complete the assembly of the excavator arm trainer version of the Portable Fluid Power Demonstrator. A full Bill of Materials can be found in Appendix I.

Item No.	Name	Description	Qty
1	1/4" Blue Tubing	1/4" OD	15 ft
2	1/4" Red Tubing	1/4" OD	15 ft
3	3/8" Inlet Tubing	3/8" OD	2 ft
4	Excavator Arm	CAT Track-Type Digger	1
5	Plastic Storage Box	27 gal, J Terence Thompson Inc.	1
6	Wood Base	3/4" plywood, 2'X4', grade B or higher	1
7	Power Cord	3 prong cord	1
8	Teflon Tape	1/2" Wide	1
9	Shim Bushing	Polyeth, 3/4" OD, 1/4" ID, 6" L	1
10	Rectangular Steel Tubing	1-1/2"X3/4"X12" metal tubing	1
11	Boom & Stick Cylinder	1-1/16" Bore, 4" Stoke, Pivot Mount	2
12	Bucket Cylinder	3/4" Bore, 2" Stoke, Pivot Mount	1
13	Swing Cylinder	1-1/2" Bore, 4" Stroke, Pivot Mount	1
14	Flow Controller Elbow	1/4" Tube Size, 1/8"Thread	8
<b>Pump</b>			
15	Water Pump	100psi, 115VAC, 2.1 gpm, model:D3635E7011A	1
16	Water Pump Rubber Feet	1/4" ID (included with pump)	4
17	P-to-C Elbow - Pump Inlet	3/8" Tube Size, 3/8" NPT	1
18	P-to-C Elbow - Pump Outlet	1/4" Tube Size, 3/8" NPT	1
<b>Pressure Gauge</b>			
19	Pressure Gauge	100psi, 2.5" face, 1/4" NPT	1
20	Pressure Gauge Coupler	1/4" NPT to 1/4" NPT Brass Coupler	1
21	Pressure Gauge Bracket	1/2" EMT	1
22	Pressure Gauge Bracket Screws	5/8" L, 1/8" OD	2
23	Manifold P-to-C Triple Branch Union	5 Outlet, 1/4" Tube Size	1
24	Manifold P-to-C Male Run Tee	3 port, 1/4" Tube Size, 1/4" NPT Male	1
25	P-to-C Fixed Manifold Screws	1-1/4" L, 1/8" OD	4
<b>Levers</b>			
26	Lever Valve	4 Way, 5 Port, 3 Pos, 1/4"NPT	4
27	Lever Valve Screws	1-1/2" wood screw, 1/8" OD	12
28	Elbow Barb Tube Fitting	1/4" Tube Size, 1/8"NPT, 10 pcs/pk, semiclear white	8
29	P-to-C Elbow Fitting	1/4" Tube Size, 1/4"NPT Male	12
<b>Flange Bearing</b>			
30	Flange Bearing	4 Bolt, 1/2" Bore	2
31	Flange Bearing Bolts	2-1/2" L, 3/8"-16	4
<b>Swing Cylinder</b>			
32	Swing Cylinder Rod End	Ball Joint, 7/16"-20, Female 90deg to Male	1

33	Swing Cylinder Rod End nut	7/16"-20	1
34	Swing Cylinder Mounting Bolt	2-1/2" L, 3/8"-16	1
35	Swing Cylinder Mounting Plate	3/8"-16	1
36	Swing Cylinder Mounting Plate Bolts	1-1/2" L, 1/4"-20, Flat Head	2
<b>Other Cylinders</b>			
37	Stick & Bucket Mounting Bracket Bolt	5/8" L, 3/16"-20	4
38	Stick & Bucket Mounting Bolt	1" L, 1/4"-20	2
39	Boom Cylinder Mounting Bolt	2" L, 1/4"-20	1
40	Bucket Cylinder Clevis Bolt	3/4" L, 1/4"-20	1
41	Stick and Bucket Connecting Bolt	1-1/2" L, 1/4"-20	3
42	Boom, Base, Stick Connecting Bolt	1-1/2"L, 3/8"-16	2
43	Bucket Cylinder Rod Clevis	For 3/4" Bore	1
44	Stick & Boom Cylinder Rod Clevis	For 1-1/16" Bore	2
45	Boom Cylinder Rear Mount Nut	Coupling nut, 5/8"-18, 2-1/8"L	1
<b>Nuts &amp; washers</b>			
46	3/16 Lock Nut	3/16"-20, Lock-Nut	
47	1/4 Lock Nut	1/4"-20, Lock-Nut	
48	1/4 Washers	1/4" ID	
49	3/8 Nuts	3/8"-16	
50	3/8 Washers	3/8" ID	
51	Zip Ties	4" L, 0.1" W, 100 pcs/pk	
<b>Option 2</b>			
52	Linkage Bar	8mm bore, 100mm L	4
53	Control Lever Coupling Nut	1/4"-28, 7/8" L	1
54	Control Lever Base Pivot	Ball Joint, 1/4"-28, male-male	2
55	Control Lever Knob	plastic, 1/4"-28	2
56	Control Lever Threaded Rod	12"L, 1/4"-28	2
57	Control Rod & Base Nut	1/4"-28	
<b>Air Test</b>			
58	Air Regulator	200psi, 3/8"NPT Female-Female	1
59	Air Supply Quick Connect	3/8" Male, 3/8" NPT Female	1

**Note** – Throughout the assembly manual there will be numbers surrounded by parentheses. These numbers are referring to the item number in the table above and in the Bill of Materials in Appendix I.

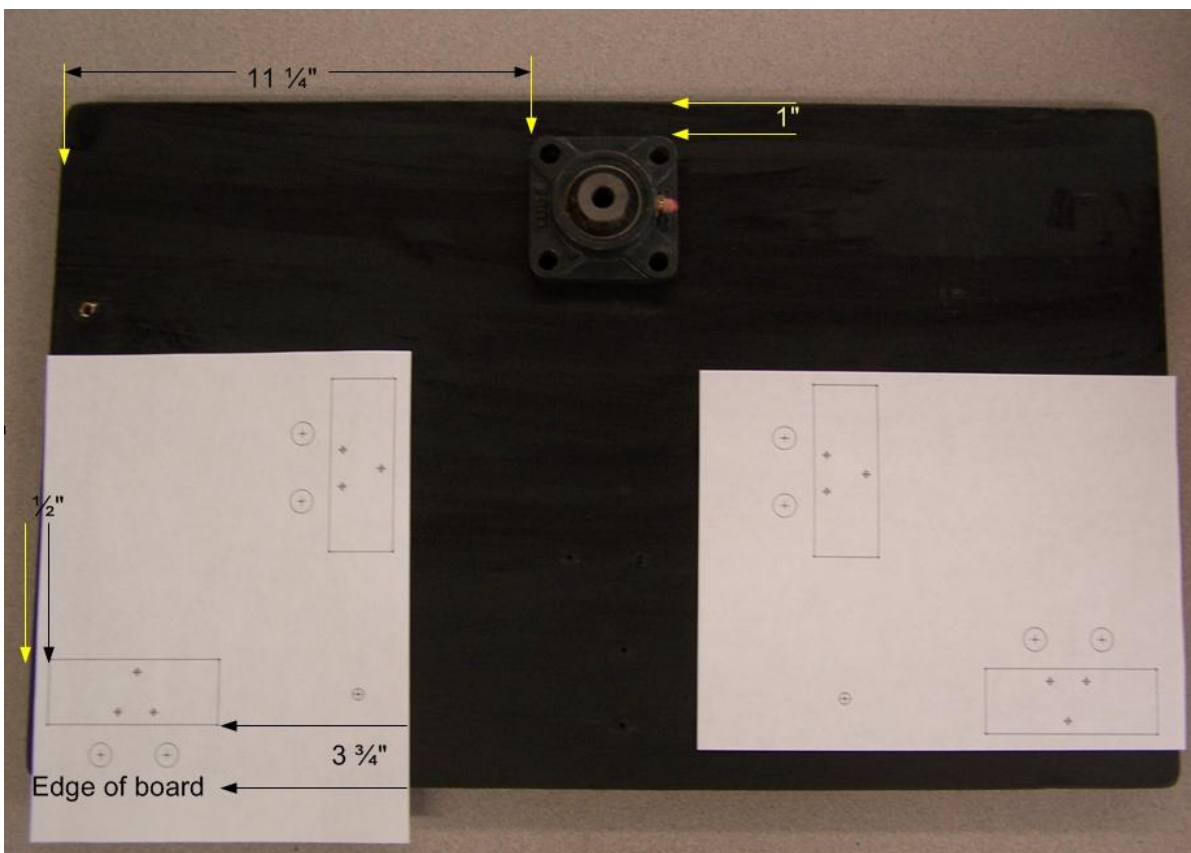
## Assembly Instructions

### Step 1 - Water Pump Assembly

Attached pump inlet elbow (17) and pump outlet elbow (18) to water pump (15). Add pipe tape if needed (8). To attach the power cord (7), solder the power cord to the water pump, black is “neutral”, white is “common”, and green is “ground”. Cut the pickup inlet line tubing (3) to 16” long. Also attach four rubber grommets (16) to the base of the pump.

### Step 2- Board Fabrication

Take the 3/4” plywood board (6) and cut it to the dimensions 23 3/4” by 14 3/4”. Note: These dimensions may vary depending on the size of the storage box lid (5) so adjust accordingly. The corners of the board will need to be rounded to properly fit into the lid. While this is not a critical dimension, one might want to start a 1/4” from the corner to start the round. Be sure the board will now fit in the storage box lid. At this point in time the flange bearings (30) may be mounted on the board. Their location is displayed in Figure 1, and must be this same distance (11 1/4”) in order to fit properly once all cylinders are in place. Two bearings are used, one on top and one on the bottom of the base board. After positioning the bearings, drill five 1/2” holes using the bearing as a template.



In Appendix III there is a template for mounting the valves. The template has the location of where the holes for the exhaust need to be drilled. These holes should be 1/2" holes. One might also want to drill pilot holes for the screws that mount the valves, which are 1/8" holes. The location and orientation of the templates for Option 2 can be seen in Figure 1. The template can also be arranged so the valves are in a straight row (Option 1), which allows each valve to be controlled individually. This arrangement can be seen later in Figure 25 on page 19.

The swing cylinder mounting plate (35) holes can also be drilled using the bracket as a template. The holes for the plate need to be drilled using a 1/4" bit. The location can be seen in Figure 2 and again must be the same distance.

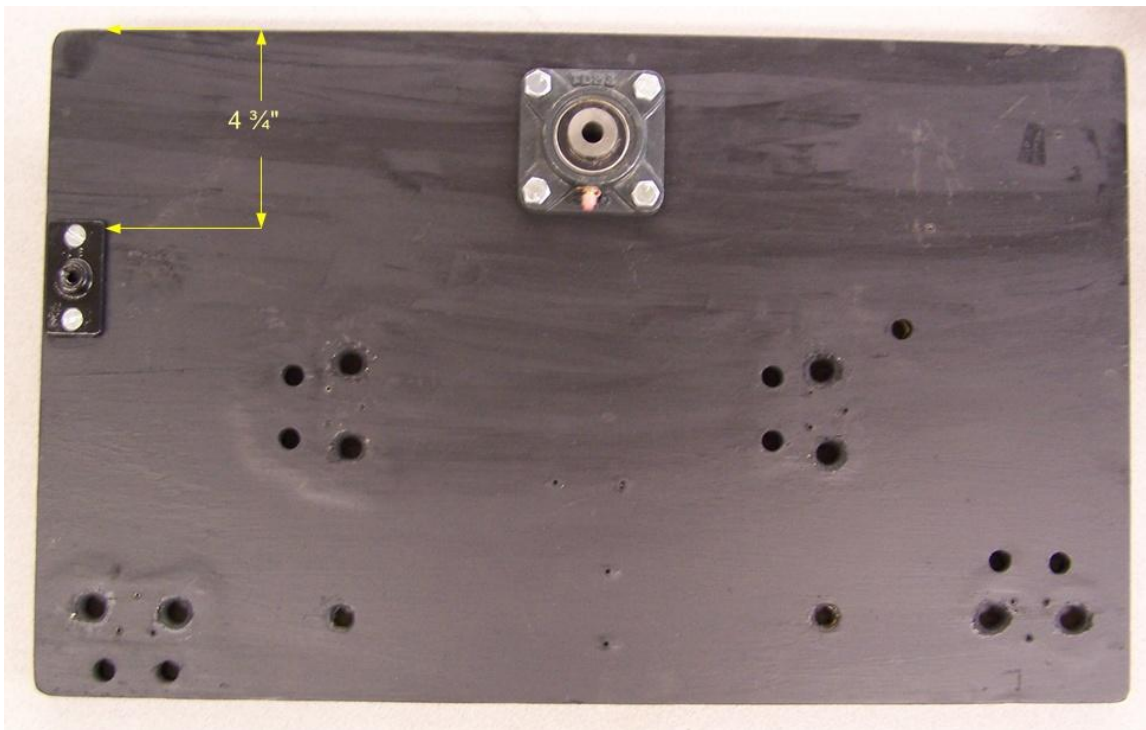


Figure 2: Swing Cylinder Mounting Plate Location

The final hole that needs to be drilled is a 1/2" hole for the water pump inlet hose. The best way to find the location of this hole is set the pump on the board in the approximate location as Figure 3 shows. Then using line of sight, approximate where the hole will need to be drilled for the hose to come through the board. Figure 3 has arrows showing approximately where this needs to be done.

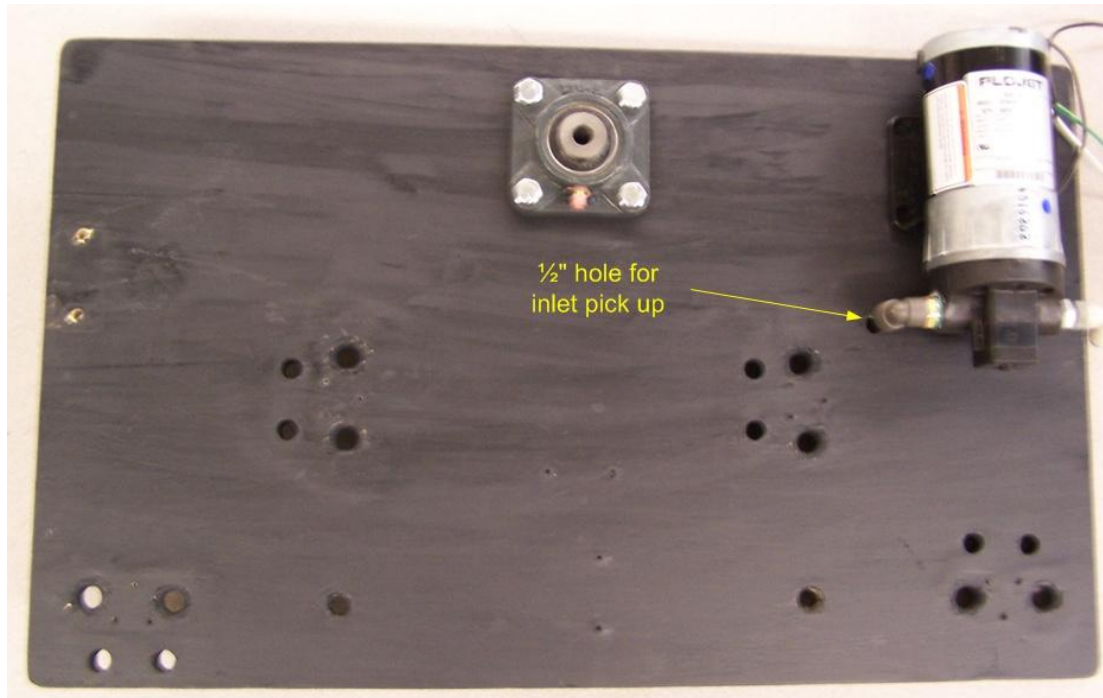


Figure 3: Water Pump Inlet Hole Location

After all of the holes are drilled in the board, the same holes will need to be drilled in the plastic top of the carrying case. This can easily be done by just placing the board on the top and running the drill bit through the holes drilled through the board. A square hole will need to be cut out of the plastic top of the carrying case for the bearing that is on the bottom of the board. This can be done using a utility knife or hand saw.

At this point the two bearings can be mounted using bolts (31), washers (50), and nuts (49). The swing cylinder mounting plate can be attached using bolts (36), lock nuts (47), and washers (48). Refer to Figure 2 above.



### Step 3- Bracket Fabrication

Two brackets will need to be made for the rear mount of two cylinders. When fabricating the brackets, use steel tubing (10). The bracket dimensions are shown in Figure 4. The easiest way to make these brackets is to first cut the steel tubing to 1.3" long. Then cut diagonally in half as seen in Figure 4. Two 3/16" holes and one 1/4" hole will need to be drilled as shown in Figure 4. After the holes have been drilled, round off any sharp edges.

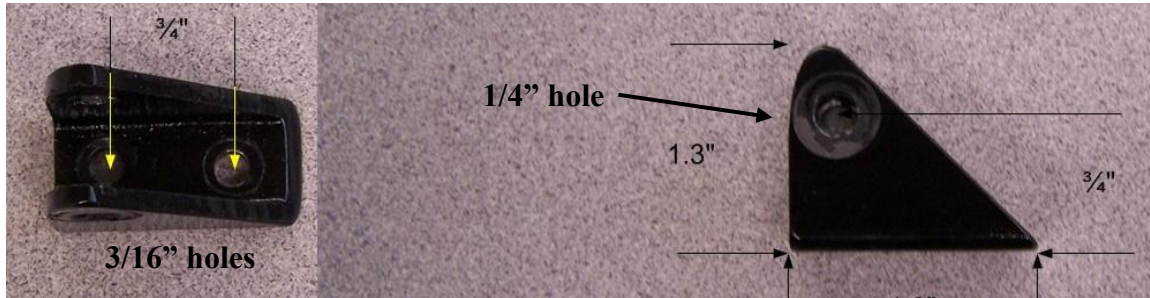


Figure 4: Cylinder Rear Mount Brackets

boom cylinder needs to be made. Take the boom cylinder rear mount nut (45) and first drill 1/4" hole in the position that Figure 5 shows. After that, cut the piece to 1.75 inches as shown in Figure 5.

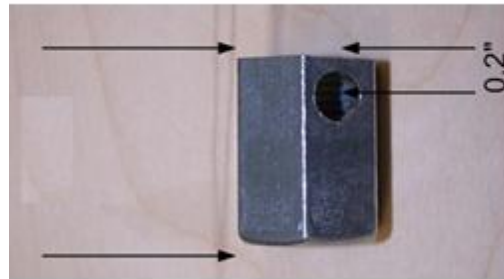


Figure 5: Boom Cylinder Mount

The swing cylinder front mount needs to be made. This should be done using the same steel tubing (10) as used for the stick and bucket cylinder brackets. The two 1/4" holes in the left of Figure 6 should be drilled so that the bracket will mount to the base of the excavator arm (Figure 14). The hole on the right of the mount is 7/16".

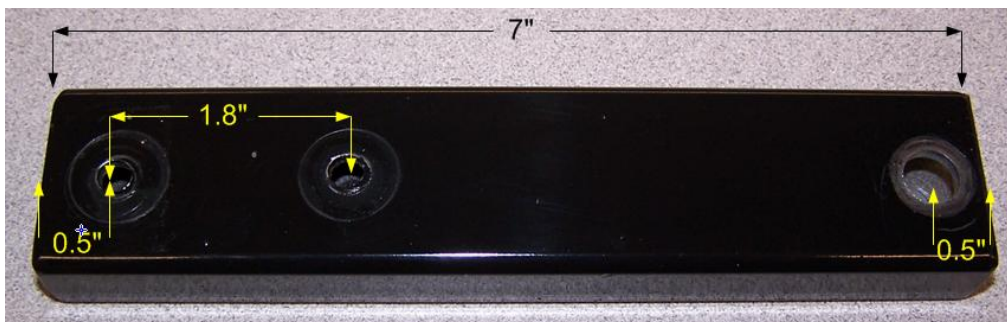


Figure 6: Swing Cylinder Front Mount

A mounting point for the rear of the boom cylinder needs to be made. Take the boom cylinder rear mount nut (45) and first drill 1/4" hole in the position that Figure 5 shows. After that, cut the piece to 1.75 inches as shown in Figure 5.

#### **Step 4 - Excavator Arm Fabrication**

Step 4 involves fabricating and assembling the excavator arm (4). Care should be taken to not mar the paint, unless the user is planning on refinishing the arm after assembly. The arm will come in four main parts. The base, boom, and stick will need to be modified. To start with, the handles will need to be removed. This can be done by cutting the button cap on an arm as shown in Figure 7 and removing the handle which was held on by this cap. This can also be done by firmly clamping the button cap and wiggle arm loose. Once the handles are removed, the black plastic stoppers can easily be pushed out.



Figure 7: Button Cap to Remove

The second handle can be removed by using a small wheel grinder or file to cut the welds which are shown in Figure 8.

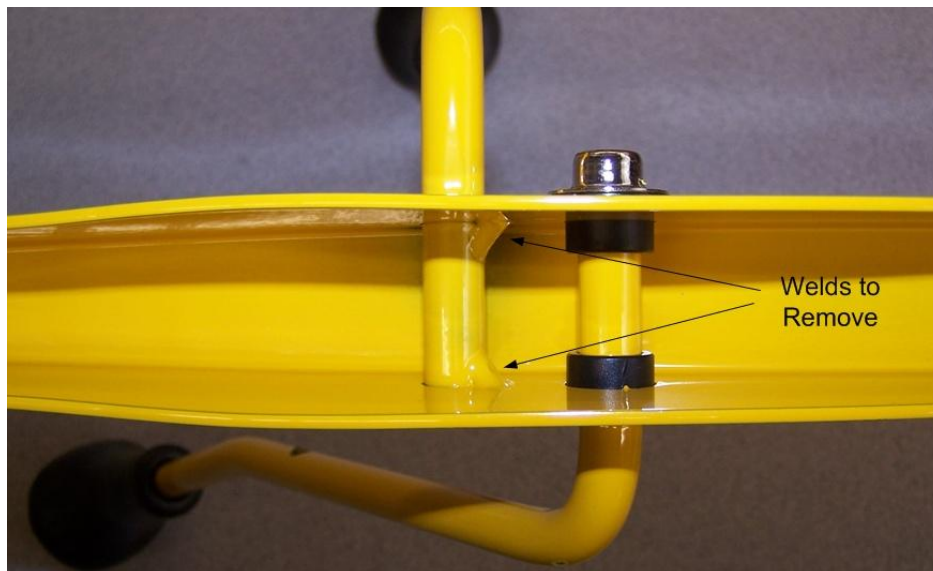


Figure 8: Welds to Remove

A 1/4" hole will need to be drilled for the boom cylinder connection to the base arm. The location of this hole can be seen in Figure 9.

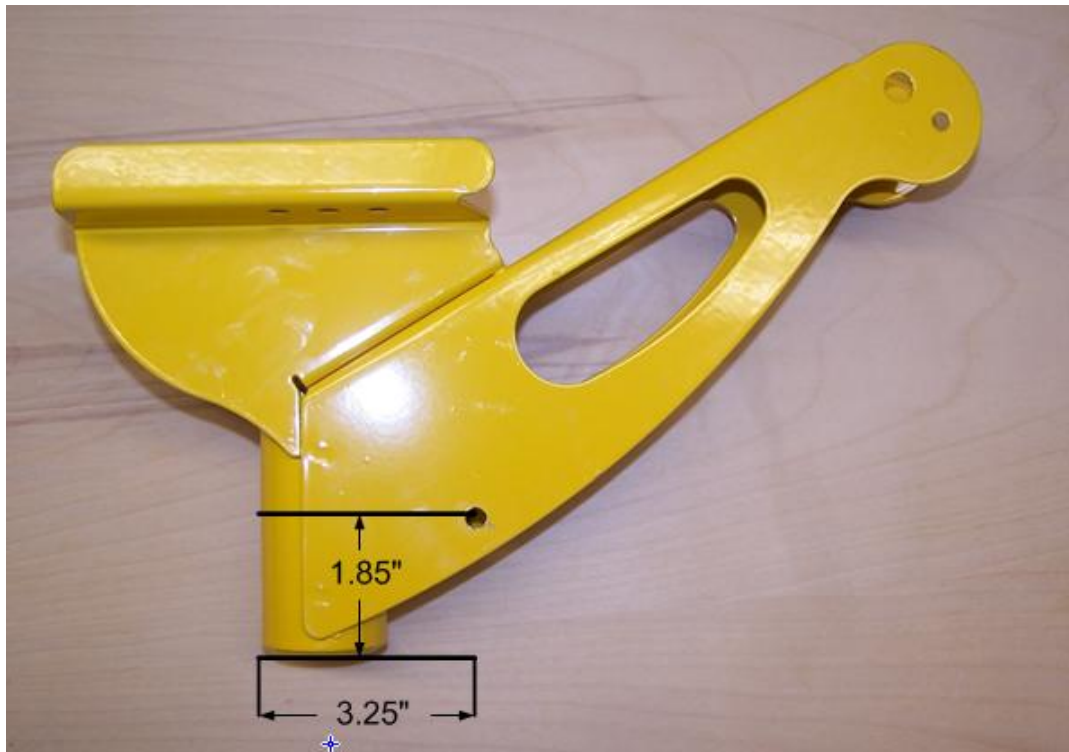


Figure 9: Boom Cylinder Mounting Hole

The back of the base arm will need to be filed down flush with the slope of the arm as seen in Figure 10. This will allow for the swing cylinder front mount (Figure 6) to mount flush to the base later in the assembly.

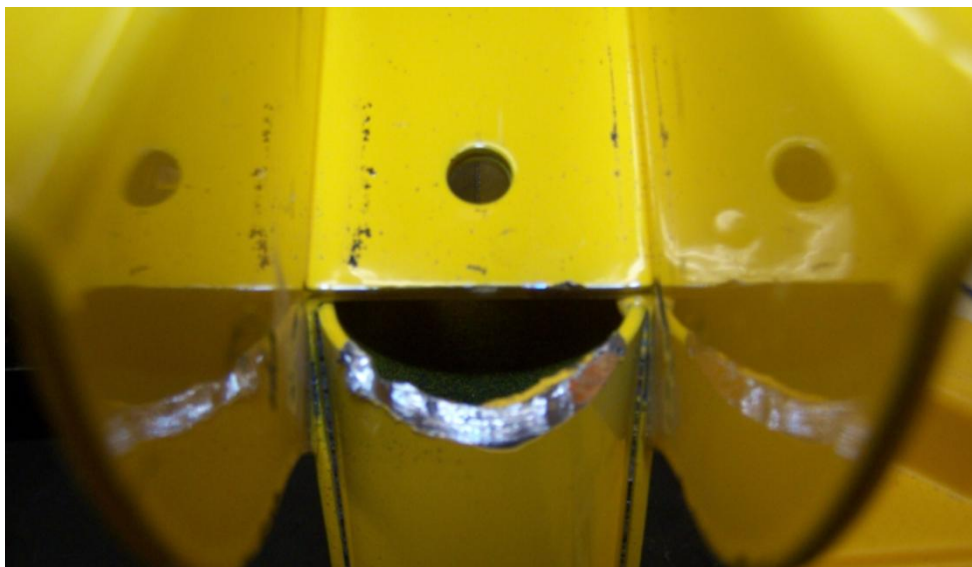


Figure 10: Base Arm Filing Location

Another 1/4" hole will need to be drilled in the boom for the boom cylinder. The location of this hole can be seen in Figure 11.

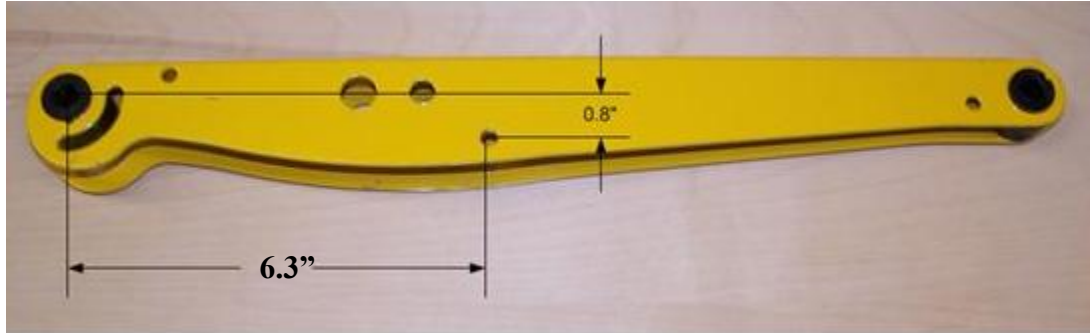


Figure 11: Boom Cylinder Mounting Hole

Using the brackets from Step 3 as templates, two 3/16" holes will need to be drilled in both the boom and the stick. The location of those can be seen in Figures 12 and 13 below. After the holes are drilled, the brackets can be attached using the bolts (37) and lock nuts (46).



Figure 12: Stick Bracket Attachment



Figure 13: Boom Bracket Attachment

The swing cylinder front mount can now be attached to the base as shown in Figure 14 using bolts (41), nuts (47), and washers (48).



Figure 14: Swing Cylinder Front Mount Assembly

The arms may now be assembled using the connecting bolts (41, 42), nuts (47, 49), and washers (48, 50). The boom and stick connecting bolt (42) will need to be cut to 1.75" long and the base and boom connecting bolt (42) will need to be cut to 2.25" to fit properly. Shim bushing (9) will need to be cut and used as a spacer for each bolt connection. The orientation of the parts and the bolts can be seen in Figure 15. Note: The handles that were removed in the above steps are still connected in this image.



Figure 15: Assembled Excavator Arms

### ***Step 5- Cylinder Assembly***

All of the cylinders need to be prepared. First the flow control elbows (14) will need pipe tape applied if they do not already have it. They will then need to be threaded into the two ports on the cylinders. All four cylinders use the same elbows. Use caution when tighten the elbows as they are somewhat delicate. An example of a cylinder can be seen in Figure 16. Rod ends will also need to be attached to the cylinder rods. The Boom cylinder (11) and Stick cylinder (11) get a rod clevis (44). The Bucket cylinder (12) gets rod clevis (43). Swing cylinder (13) gets rod end (32).



Figure 16: Cylinder Preparation

### ***Step 6- Excavator Arm Assembly***

The cylinders can now be mounted on the excavator arm. From the shim bushing (9), cut four 0.25" spacers for the stick and bucket cylinder rod clevis mount and two 0.35" spacers for the boom cylinder rear mount. See Figures 17, 18 and 19 for spacer placement.

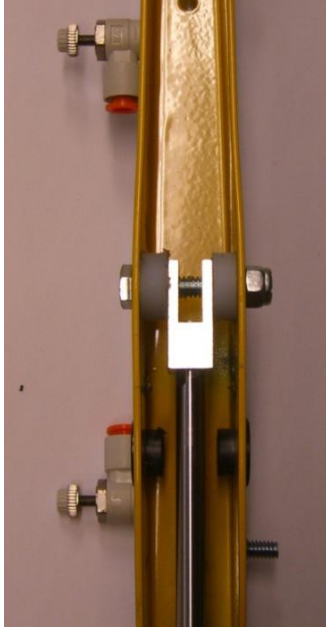


Figure 17: Boom Rod Clevis Mount



Figure 18: Stick Rod Clevis Mount

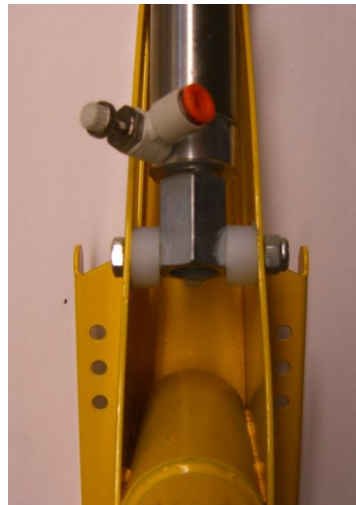


Figure 19: Boom Cylinder Rear mount

Use the mounting bolts (38, 39, 40, & 41) to attach the cylinders to the excavator arm Figure 20 shows the location of the cylinders and bolts and corresponding part numbers.

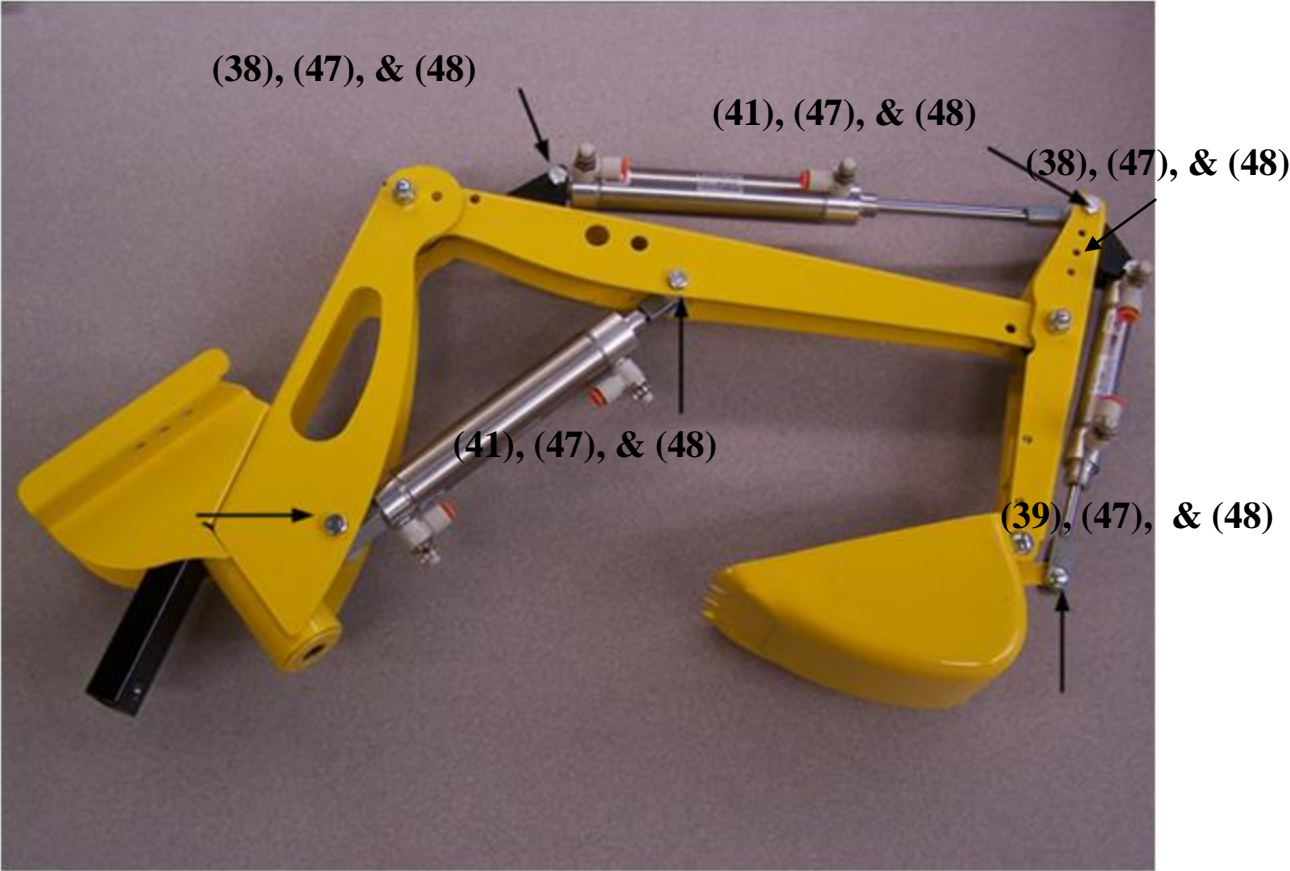


Figure 20: Main Arm Assembly



### ***Step 7- Valve Preparation***

The four valves (26) will now need to be prepared. Two different fittings will need to be used. The exhaust port elbow (28) and the in and out push to connect elbow (29) are needed. First attach one exhaust port elbow, then attach all three push to connect elbows. Finally you may want to cut off the tip of the remaining exhaust port elbow to allow for easier assembly. An example of how all four of these valves should be assembled can be seen in Figure 21.



Figure 21: Valve Assembly

### **Option 1 - Four Mechanical Controls**

Each lever valve will be controlled individually, so the valves will simply need to be placed on the mounting board as seen in Figure 25.

## Option 2 - Two Mechanical Controls

The control joysticks will now be assembled. First, the coupling nut (53) needs to be cut in half. Next, the cut coupling nut can be screwed onto the control lever base pivot (54) as seen in Figure 22. Make two of these pivot assemblies.



Figure 22: Base Pivot

Attach the threaded rod (56) to the base pivot assembly, slide two linkage bars (52) onto the threaded rod, put a nut (57) on the threaded rod, and attach the control lever knob (55) to the bar. The configuration can be seen in Figure 23. Make two of these control joystick assemblies.

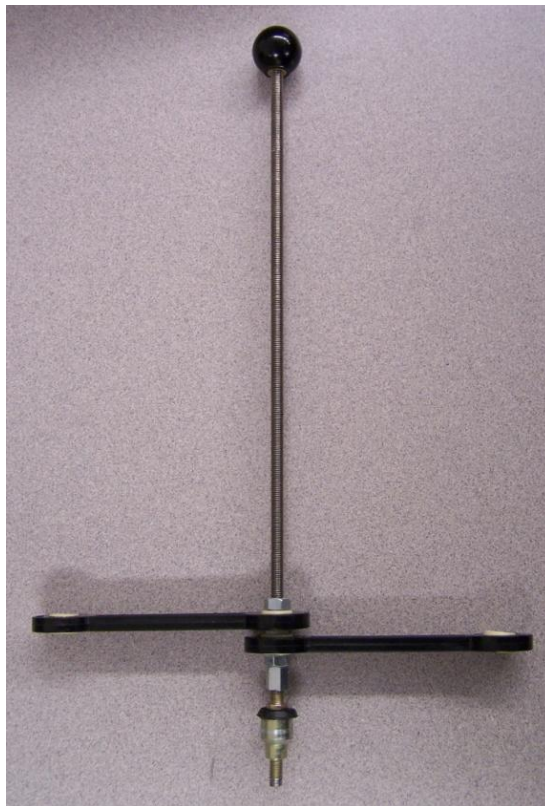
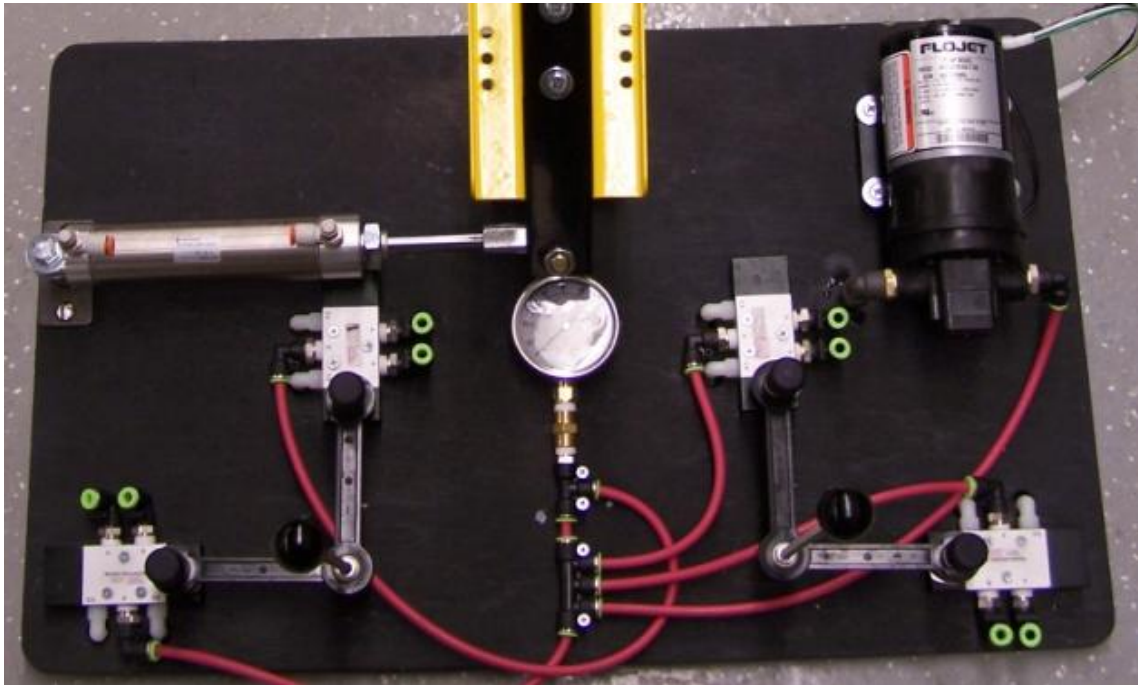


Figure 23: Joystick Assembly

### ***Step 8- Final Assembly***

The valves can now be attached to the board using screws (27). For Option 2, the joystick can also be attached using the nut (57) and washer (48). The orientation of Option 2 can be seen in Figure 24 and Option 1 can be seen in Figure 25.



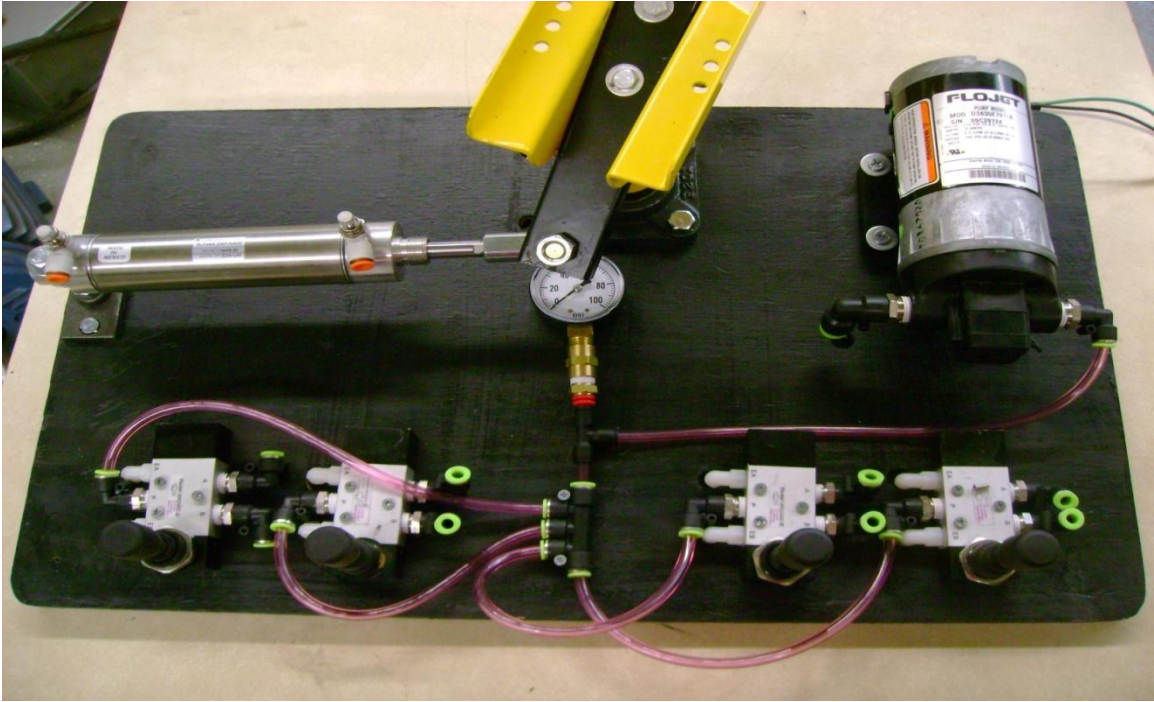


Figure 24: Final Board Assembly for Option 2

The excavator arm can now be attached to the board using the 110 mm bolt which comes with

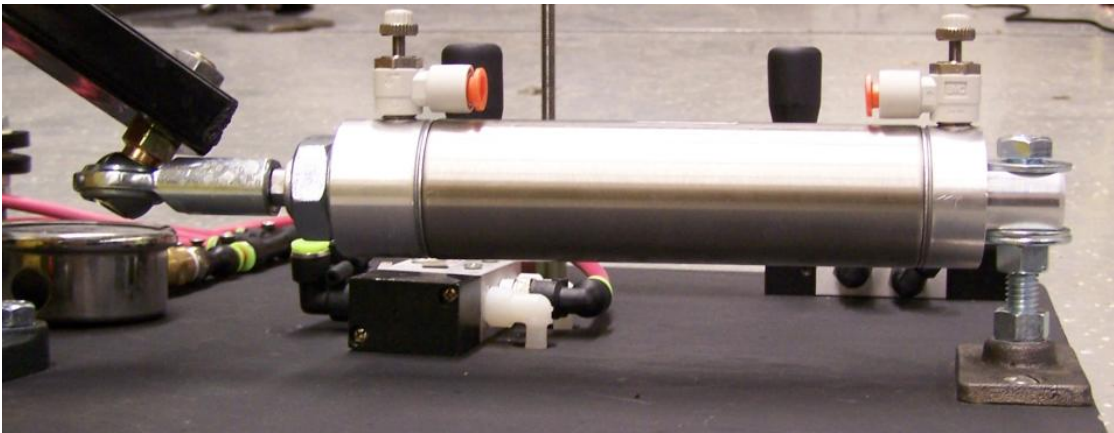


Figure 26: Swing Cylinder Attachment

Figure 25: Final Board Assembly for Option 1

the excavator arm. The swing cylinder can also now be mounted to the board using the bolt (34), two nuts (49), and three washers (50) for the rear mount and nut (33) for the attachment to the arm. The orientation of this can be seen in Figures 26.

The pressure gauge (19), brass coupler (20), three-port manifold (24) and five-port manifold (23) need to be assembled as seen in Figure 27. Pipe tape is required for all pipe threads if none already have pipe tape. Use manifold screws (25) to secure both manifolds. You may also want to secure the pressure gauge with a bracket (21) and screws (22), which should be placed around the brass coupler.

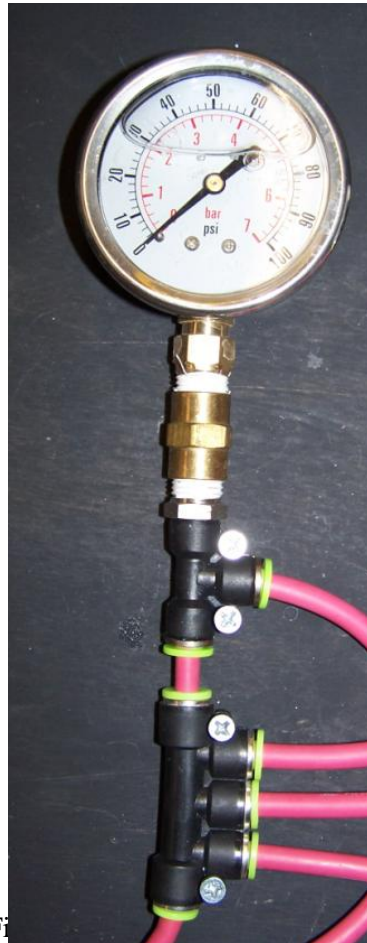


Figure 27: Pressure Gauge Assembly

With the excavator arm fully assembled the lines can now be ran and cut to length. First cut and place the system pressure lines, use red tubing (2). The system pressure lines can be seen in Figure 28.

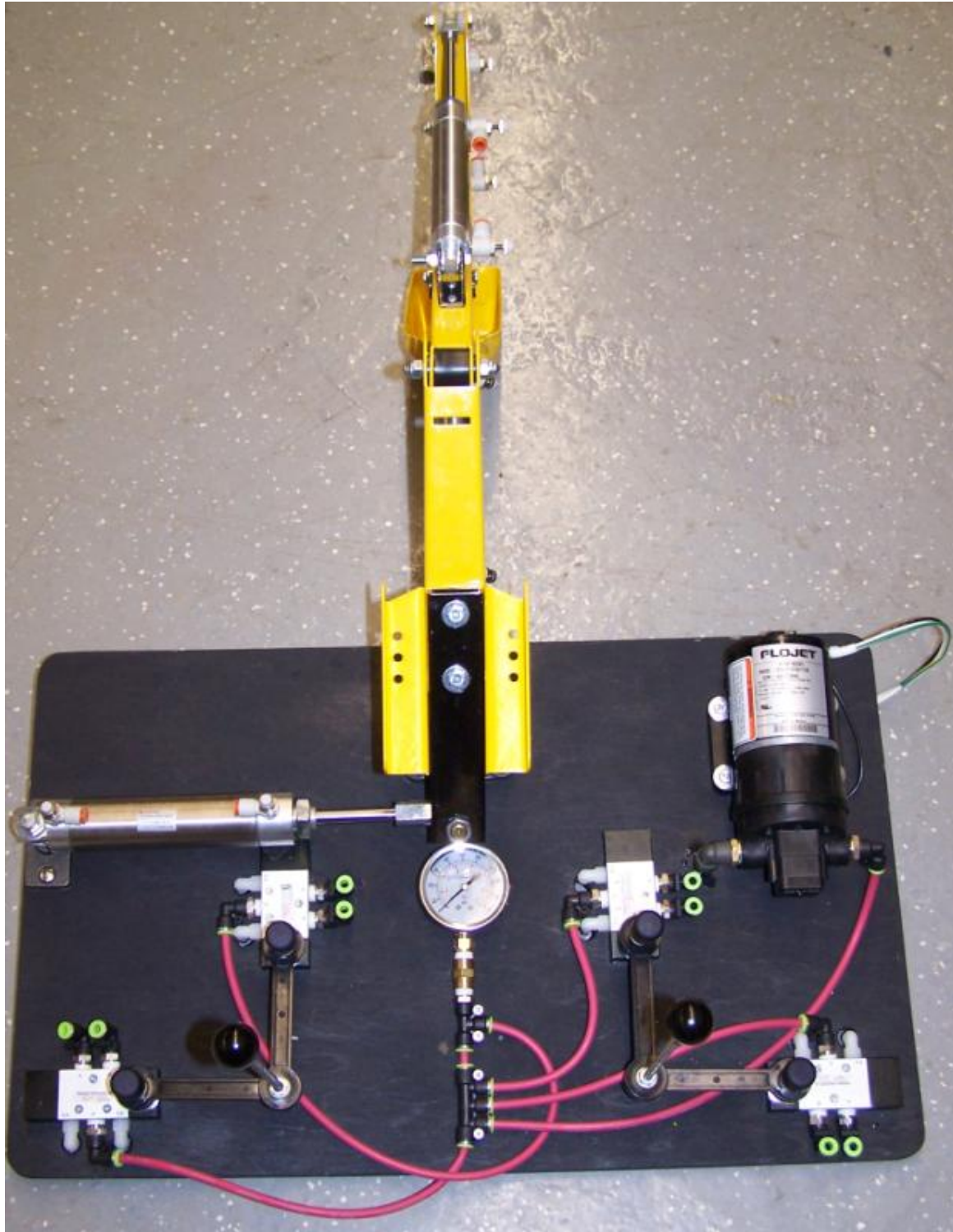


Figure 28: System Pressure Lines Configuration

Once the system lines are in place, the work port lines can be added, use blue tubing (1). Make sure to give plenty of length for each work port line, since the excavator arm will be going back and forth. You can group the tubing together with zip ties (51) to make the excavator look less crowded.

The excavator arm can now be tested. For testing with water, add enough water to the plastic case so that the end of the inlet tubing for the water pump is completely submerged. Connect the main line from the manifold to the water pump. Then be sure that all of the flow control elbows are completely screwed out. Plug in the water pump and move the levers. The excavator arm should move.

For testing with air, it is very important to make sure all the flow control elbows are screwed all of the way in. Then screw out one full turn and test the motion of the arm. Next connect the main inlet line from the manifold to an air supply (59). Use the air regulator (58) to control the pressure of the air. Move the levers. The flow control elbows will now need to be adjusted to achieve the desired speed and power for the arm.

### **Step 8- Completion of Excavator Arm**

Disassemble the excavator arm. The board and brackets will now need to be painted. The board can either be painted or stained. Be sure to clean the brackets and paint them as well. This will prevent the board and brackets from deteriorating from the water. After the paint has dried reassemble the excavator arm and enjoy!

## APPENDIX I: BILL OF MATERIALS

Item No.	Name	Description	Qty	Unit	Name2	Cat. No	Unit Price	Total
1	1/4" Blue Tubing	1/4" OD	15	ft	McMaster-Carr	5648K254	\$0.41	\$6.15
2	1/4" Red Tubing	1/4" OD	15	ft	McMaster-Carr	5648K252	\$0.41	\$6.15
3	3/8" Inlet Tubing	3/8" OD	2	ft	McMaster-Carr	5648K263	\$0.83	\$1.66
4	Excavator Arm	CAT Track-Type Digger	1	pcs	Kettler USA	see next page	\$89.78	\$89.78
5	Plastic Storage Box	27 gal, J Terence Thompson Inc.	1	pcs	Local*(Lowe's)	44066	\$14.97	\$14.97
6	Wood Base	3/4" plywood, 2'X4', grade B or higher	1	pcs	Local*		\$13.88	\$13.88
7	Power Cord	3 prong cord	1	pcs	Local* (Home Depot)	09412-89-01	\$2.49	\$2.49
8	Teflon Tape	1/2" Wide	1	pcs	Local*(Lowe's)	25010	\$0.97	\$0.97
9	Shim Bushing	Polyeth, 3/4" OD, 1/4" ID, 6" L	1	pcs	McMaster-Carr	1988T11	\$8.81	\$8.81
10	Rectangular Steel Tubing	1-1/2"X3/4"X12" metal tubing	1	pcs	McMaster-Carr	6566K313	\$17.90	\$17.90
11	Boom & Stick Cylinder	1-1/16" Bore, 4" Stoke, Pivot Mount	2	pcs	McMaster-Carr	6498K656	\$27.41	\$54.82
12	Bucket Cylinder	3/4" Bore, 2" Stoke, Pivot Mount	1	pcs	McMaster-Carr	6498K634	\$21.59	\$21.59
13	Swing Cylinder	1-1/2" Bore, 4" Stroke, Pivot Mount	1	pcs	McMaster-Carr	6498K676	\$45.52	\$45.52
14	Flow Controller Elbow	1/4" Tube Size, 1/8" Thread	8	pcs	Poweraire	NAS2201F-N01-07S	\$10.10	\$80.80
<b>Pump</b>								
15	Water Pump	100psi, 115VAC, 2.1 gpm, model:D3635E7011A	1	pcs	Kim Supply	2130-032	\$98.50	\$98.50
16	Water Pump Rubber Feet	1/4" ID (included with pump), 50/pk	1	pk	McMaster-Carr	9307K14	\$4.06	\$4.06
17	P-to-C Elbow - Pump Inlet	3/8" Tube Size, 3/8" NPT	1	pcs	Poweraire	E3/8-N03	\$1.29	\$1.29
18	P-to-C Elbow - Pump Outlet	1/4" Tube Size, 3/8" NPT	1	pcs	Poweraire	E1/4-N03	\$1.11	\$1.11
<b>Pressure Gauge</b>								
19	Pressure Gauge	100psi, 2.5" face, 1/4" NPT	1	pcs	Local* (Home Depot)	TC2104	\$9.46	\$9.46
20	Pressure Gauge Coupler	1/4" NPT to 1/4" NPT Brass Coupler, F-F	1	pcs	Local*(Lowe's)	34834	\$2.33	\$2.33
21	Pressure Gauge Bracket	1/2" EMT	1	pk	Local*(Lowe's)	301380	\$1.97	\$1.97
22	Pressure Gauge Bracket Screws	5/8" L, 1/8" OD (#6 size)	1	pk	Local*(Lowe's)	57226	\$0.98	\$0.98
23	Manifold P-to-C Triple Branch Union	5 Outlet, 1/4" Tube Size	1	pcs	Poweraire	TBU1/4	\$2.70	\$2.70
24	Manifold P-to-C Male Run Tee	3 port, 1/4" Tube Size, 1/4" NPT Male	1	pcs	Poweraire	PUUT1/4-N02	\$1.56	\$1.56
25	P-to-C Fixed Manifold Screws	1-1/4" L, 1/8" OD (#6 size)	1	pk	Local*(Lowe's)	57228	\$0.98	\$0.98
<b>Levers</b>								
26	Lever Valve	4 Way, 5 Port, 3 Pos, 1/4"NPT	4	pcs	Poweraire	4H230C-S	\$52.00	\$208.00
27	Lever Valve Screws	1-1/2" wood screw, 1/8" OD (#6 size)	2	pk	Local*(Lowe's)	57229	\$0.98	\$1.96



28	Elbow Barb Tube Fitting	1/4" Tube Size, 1/8"NPT, 10 pcs/pk, semiclear white	1	pk	McMaster-Carr	2974K155	\$5.97	\$5.97
29	P-to-C Elbow Fitting	1/4" Tube Size, 1/4"NPT Male	12	pcs	Poweraire	E1/4-N02	\$0.87	\$10.44
<b>Flange Bearing</b>								
30	Flange Bearing	4 Bolt, 1/2" Bore	2	pcs	Surplus Center	1-201-8-4-C	\$8.95	\$17.90
31	Flange Bearing Bolts	2-1/2" L , 3/8"-16	4	pcs	Local* (Home Depot)	55748	\$0.96	\$3.84
<b>Swing Cylinder</b>								
32	Swing Cylinder Rod End	Ball Joint, 7/16"-20, Female 90deg to Male	1	pcs	McMaster-Carr	60645K451	\$7.52	\$7.52
33	Swing Cylinder Rod End nut	7/16"-20	1	pk	Local*(Lowe's)	138292	\$0.68	\$0.68
34	Swing Cylinder Mounting Bolt	2-1/2" L, 3/8"-16	1	pcs	Local* (Home Depot)	55748	\$0.96	\$0.96
35	Swing Cylinder Mounting Plate	3/8"-16	1	pcs	McMaster-Carr	11445T1	\$1.69	\$1.69
36	Swing Cylinder Mounting Plate Bolts	1-1/2" L, 1/4"-20, Flat Head	2	pcs	Local* (Home Depot)	654337	\$0.16	\$0.32
<b>Other Cylinders</b>								
37	Stick & Bucket Mounting Bracket Bolt	5/8" L, 3/16"-20	4	pcs	Local*			\$0.00
38	Stick & Bucket Mounting Bolt	1" L, 1/4"-20	2	pcs	Local* (Home Depot)	203308	\$0.23	\$0.46
39	Boom Cylinder Mounting Bolt	2" L, 1/4"-20	1	pcs	Local* (Home Depot)	654345	\$0.18	\$0.18
40	Bucket Cylinder Clevis Bolt	3/4" L, 1/4"-20	1	pk	Local*(Lowe's)	135990	\$1.04	\$1.04
41	Stick and Bucket Connecting Bolt	1-1/2" L, 1/4"-20	3	pcs	Local* (Home Depot)	654337	\$0.16	\$0.48
42	Boom, Base, Stick Connecting Bolt	1-1/2" L, 3/8"-16	1	pk	Local*(Lowe's)	135829	\$1.04	\$1.04
43	Bucket Cylinder Rod Clevis	For 3/4" Bore	1	pcs	McMaster-Carr	6498K42	\$3.56	\$3.56
44	Stick & Boom Cylinder Rod Clevis	For 1-1/16" Bore	2	pcs	McMaster-Carr	6498K43	\$3.56	\$7.12
45	Boom Cylinder Rear Mount Nut	Coupling nut, 5/8"-18, 2-1/8"L	1	pcs	McMaster-Carr	902648235	\$2.04	\$2.04
<b>Nuts &amp; washers</b>								
46	3/16 Lock Nut	3/16"-20, Lock-Nut		pk	Local*			\$0.00
47	1/4 Lock Nut	1/4"-20, Lock-Nut	2	pk	Local*(Lowe's)	137475	\$0.68	\$1.36
48	1/4 Washers	1/4" ID	1	pk	Local*(Home Depot)	327915	\$2.25	\$2.25
49	3/8 Nuts	3/8"-16	2	pk	Local*(Lowe's)	135800	\$1.04	\$2.08
50	3/8 Washers	3/8" ID	1	pk	Local*(Lowe's)	43783	\$2.78	\$2.78
51	Zip Ties	4" L, 0.1" W, 100 pcs/pk	1	pk	McMaster-Carr	7130K52	\$2.33	\$2.33
<b>Option 2</b>								
52	Linkage Bar	8mm bore, 100mm L	4	pcs	igus	EGZM-08-100		
53	Control Lever Coupling Nut	1/4"-28, 7/8" L	1	pcs	McMaster-Carr	90264A440	\$0.69	\$0.69
54	Control Lever Base Pivot	Ball Joint, 1/4"-28, male-male	2	pcs	McMaster-Carr	8412K41	\$5.34	\$10.68

55	Control Lever Knob	plastic, 1/4"-28	2	pcs	McMaster-Carr	6046K32	\$1.44	\$2.88
56	Control Lever Threaded Rod	12"L, 1/4"-28	2	pcs	McMaster-Carr	91187A250	\$3.50	\$7.00
57	Control Rod & Base Nut	1/4"-28						
<b>Air Test</b>								
58	Air Regulator	200psi, 3/8"NPT Female-Female	1	pcs	Local*			\$0.00
59	Air Supply Quick Connect	3/8" Male, 3/8" NPT Female	1	pcs	Local*			\$0.00

## **APPENDIX II: VALVE CONFIGURATION TEMPLATE**

--please see attached pdf files