90 liter Reactor Build Manual

Overview

This is the construction manual for the 90 liter size biodiesel reactor. The design concept of this system was to produce a small scale farm type biodiesel reactor which by nature of its design and construction affords the ability to get consistently reliable quality results when used in conjunction with proper procedures and good quality chemicals to convert bio-oil feed stocks of reasonable quality into methyl ester fuel suitable for use in diesel internal combustion engines and oil burner type heating equipment.

Scope

This document covers the detailed description of the process of building the reactor. The instructions in this document therefore give specific guidance on how to assemble the sub components of the reactor system from the materials available as called out in the BOM (Bill Of Materials) included as an excel spreadsheet.

A section on parts substitution is included to advise on the important considerations for these components is given so that an appropriate choice of alternative materials and components can be made to ensure the final outcome will be a unit with equal functionality and safety to the original design concept. Some treatment of the subject of scalability of this design is included with the same consideration to appropriately informed choice as to the selection of components as well. It should be understood that the information regarding scalability is offered as a general guideline and that several factors that come into play in the course of up-scaling reactor size may result in performance that needs to be optimized through repeated experimentation until the exact configuration and process is realized.

Final assembly of sub components follows the description and instructional sections for the sub components. Some guidelines as to consideration of the location and use of the equipment is included in the final section of this manual, however, instructions for the use of the reactor are beyond the scope of this document and are the subject of another course and associated documents.

Purpose

The purpose of this manual is to provide guidance and step by step instruction for the construction and assembly of the 90 liter size biodiesel reactor. No warranty as to its use is expressed or implied in this document and no liability for its use or any possible outcome of its use is assumed by the author, Non Profit Fuel, or any of its members. Every effort is made in the design of this system to address safety, reliability and consistency concerns. Product of high quality can be produced by this system but the responsibility for safe use, and verification of the product quality is the responsibility of the user. This manual may have errors and is subject to changes as the need arises so always obtain the most recent version at www.nonprofitfuel.ca. Obsolete versions are not supported although considerable support may be obtained from the biofuels community in any case with regard to the evolution and best setup of biodiesel reactors in general. This project should be regarded as a work in progress. The design is expected to evolve as needs arise and as new ideas and processes become available. This is part of the reason why a biofuel experimenter must accept full responsibility for making sure everything is done correctly and in accordance with established knowledge of the biofuel community at the time any experiment or routine process is undertaken. Everything written in this document should be regarded as for information purposes only and what you do with that information is your own responsibility.

Another important consideration from an environmental perspective is the fact that this reactor design calls for many parts in the BOM which are produced within the framework of a fundamentally flawed global economic model which is unsustainable. There is a questionable aspect to this project in this regard since many of the part sources originate in offshore production sites. Undoubtedly those who are resourceful can find local and therefore environmentally responsible alternatives to the parts selection in

building this reactor. One of the constraints for this project was to offer something that would be universally achievable with readily available parts. This led to unfortunate choices having to be made in specifying a source that would be available to people in a large area rather than just my local community. I fully encourage the builder to look for local alternative sources of parts for this project as long as no compromises to the performance of the reactor result. Those who value time and money most, will likely build a system closely matching the one described here, but those with more important objectives will no doubt take a more sustainable approach to the execution and maintenance of the project.

A central theme of this project is that it is open sourced. Therefore if you have been charged for any copy of this document then a fraud has been committed and please let me know so I can pursue it.. All of the information contained in this and supporting documents is offered under the Creative Commons public license and is therefore free to distribute under the terms of the license.

Tools Required

Hand tools:

- Carpet knife
- Adjustable crescent wrench or spanner set.
- Pipe wrench.
- Rat tail file
- Half round file.
- Flat machinist's file
- Hacksaw
- Screwdriver set.
- Ratchet set.
- Tap and die set
- Hammer and center punch
- Bench vise
- Propane torch and pipe solder kit
- Wire cutter
- Wire stripper
- Multimeter
- Hole punch set

Power tools:

- Hand drill and the following bits;
- 50 mm (2") hole saw
- Stepped bit or combination bits up to ¾" (20mm)
- Wire feed welder and or TIG welder. Gloves and helmet.
- Chop saw
- Angle grinder.
- Bench grinder.

Work Practices

Since this reactor is a vacuum system one item of great importance is the treatment of sealing surfaces. All connections on the reactor tank and vacuum plumbing must be very well sealed to ensure

proper vacuum operation, therefore always heed the following precautions when working with pipe thread connections.

A. Avoid nicked or damaged threads on any component.
B. Use proper application of Teflon tape and pipe dope appropriate to the materials without exception.
C. Do not over torque compression fittings.
D. Avoid scratching the outer surface of the 3/8" and ½" tubing which will ruin the seal at the recirculation line attachment points for vacuum service.
E. Once components are installed such as the recirculation pump, or the coaxial drier. Use caution to avoid applying forces to these components which would over stress the connections and perhaps damage vacuum integrity of the system.
F. Use proper soldering techniques for soldered connections.

When working with tools, always use appropriate safety equipment and measures to avoid injury such as safety glasses, gloves, safety shoes, and proper attitude which means if you are not sure about what you are doing, do not proceed. Ask for clarification and make sure you have a clear understanding of what you have to do and what is required before proceeding.

Safety

Personal safety gear: Safety glasses, safety boots or shoes, work gloves.
Additional safety considerations: Always use proper techniques when working with power tools, lifting anything heavy, working with chemicals, electrical connections, or welding equipment.

Parts list

Parts list is generated in an excel spreadsheet as a bill of materials (BOM) This sheet is printed and included at the back of this manual.

Parts substitution

If you are attempting to build the system from scratch you may be able to save some money using locally souceable parts for substitution. Substituting parts can be fine as long as the system design constraints are not violated. The system must be able to achieve an ultimate vacuum of 28" Hg or better. The recirculation pump rate should not be degraded from that achievable with the materials and parts called out in the BOM. A higher pumping rate is not a problem but a lower recirculation rate should not be accepted. Therefore no reduction in pump capacity or plumbing size can be tolerated. Some latitude is available in the choice of vacuum pump as long as ultimate vacuum is met. Various arrangements can be made for mixing methoxide in terms of mixing motor, shaft and agitator, and some ancillary components such as the temperature gauge, vacuum gauge, and exhaust shroud type and size have considerable flexibility. The reactor vessel size, heating element voltage and power, should not be changed.

Main sections of this manual

1. Liquid trap.
2. Coaxial gas drier.
3. Methoxide mixer.

4. Support frame.
5. Reactor vessel.
6. System assembly.
7. Exhaust stack.
8. Electrical hookup.
9. Copyleft

1. Liquid trap

1. Trap vessel: A one gallon cider jug was chosen as a liquid vessel for this application because it is an appropriate size for a reactor in the 30 to 100 liter range. The cider jug is able to withstand the pressure created by the vacuum used in this system so long as it is in perfect shape with no chips, cracks or scratches anywhere on its surface. A bottle with any chips or scratches will likely implode under vacuum and MUST NOT BE USED. The purpose of the trap is to collect and prevent any liquid removed from the air pumped out of the reactor from reaching the vacuum pump and provides a convenient way of collecting this liquid.
2. Containment vessel: The trap vessel is housed in a containment vessel which serves three important purposes. The first purpose relates to safety and it is to prevent flying glass from being a hazard if the trap vessel was ever to implode. The second and related reason for the containment is that in the case that an implosion occurred when the trap contained methanol the exhausted containment vessel prevents methanol from escaping into the work area and contains the resulting methanol vapors to the area which is actively exhausted to the outdoors. This is an important safety feature of the design and must not be omitted. The final purpose relates to protection of the vacuum pump. The liquid removed from the air by the coaxial drier comes out at cold temperature and thus has a low vapor pressure. It is important to use insulation around the liquid trap to maintain this cold temperature so that liquid does not warm up and add to the vapour load on the vacuum pump. The containment vessel conveniently serves this purpose when fitted with insulating material as outlined below. The containment vessel is fabricated from a commonly available 5 gallon pail with simple modification to the lid as follows:
    A) Using a 50mm (2”) hole saw cut a hole in the center of the pail lid for the connection to the mouth of the trap vessel. This is where the rubber bung on the end of the coaxial drier will connect to the mouth of the trap vessel.
    B) A second 50mm (2”) hole will need to be cut for the exhaust port for the containment vessel. The exact position of this hole is not critical except that it must line up with the exhaust connection at the time of final assembly. The exhaust hole will be cut at that time to mate with the location of the lower exhaust stack.
    C) Using a carpet knife place a series of equally spaced cuts around the rim of the pail lid approximately 50 mm (2”) apart to ease removal and installation of the pail lid during use. **Photo #1** shows these details.

Photo #1. Top of Liquid trap containment vessel.

D) The pail is insulated with a roll of aluminized bubble wrap type insulation. Due to variations in dimensions of pails and cider jugs, rather than list dimensions here it makes more sense to give instructions as to the desired result needed and you can measure the dimensions of the materials you have on hand and cut them appropriately. Install the pail lid, and with a measuring tape, note the depth from the lid to the bottom of the pail. Cut the roll of insulation to this width and place the material into the pail so that it forms an insulating jacket roughly 50 mm (2") thick around the inside surface of the pail. The cider jug needs to sit so that the mouth of the jug is just at the height of the pail lid when the lid is installed, so measure the height of the bottle and subtract it from the depth of the pail you noted previously. This figure is the height of the spacer you need to install in the bottom of the pail to support the trap vessel. The spacer should offer insulation and be made of non absorbent type material. Depending on the dimensions you have to work with, you may be able to use the remaining strip of aluminized bubble wrap cut from the width of the roll when making the jacket as the spacer by trimming it to the correct dimension and rolling it up to form the spacer at the bottom of the pail. A galvanized duct cap for a 200 mm (8") round duct serves nicely as a support to rest on the insulated spacer for the cider jug to sit on. It distributes the weight of the bottle and also serves to keep the insulation jacket spread open against the sides of the pail. Use anything you have on hand which is suitable for this purpose. See **Photo #2** for details.

Photo #2. Insulated trap vessel.

2. Coaxial gas drier

The coaxial gas drier is fabricated from two lengths of copper water pipe, three reducing tee fittings and a ½" solder x 3/4" MPT adapter. The drier gets its name from the fact that the length of ½" copper pipe runs coaxially through the center of the outer ¾" copper pipe which forms the water cooling jacket around it. At either end of this jacket a reducing tee is fitted in order to accomplish this but the reducing tees must be slightly modified to allow this as follows.

A) The reducing tee which has a ¾" port on one connection and a ½" port on each of the remaining sides has a slight internal swelling or shoulder on the inside diameter which is intended to prevent over insertion of the pipe into the fitting. On the ½" port opposite the ¾" port we need to remove this shoulder so that the ½" pipe can slide all the way through the fitting to run inside the ¾" pipe. This is done with a rattail file as shown in **photo# 3**.

Photo #3. Removing the end stop shoulder.

Work carefully and remove only enough material to allow the fitting to slide down the ½" pipe. Removing too much will only weaken the fitting and possibly result in a leak. Modify both of the tee fittings in this way.

B) Using a pipe cutter cut a 91 cm (36")length of ¾" pipe, a 15 cm (6") length of both ¾" and ½" pipe, and a 114 cm (45")length of ½" pipe as well as two 32 mm (1.25")lengths of ½" pipe.

C) Before soldering it is important that the surface of the copper be clean and free of oxide. Use sandpaper to ensure a bright exposed copper surface to the inside of the fittings and outside surface of the pipe at the area to be soldered. Take care from this point to avoid letting any grease or dirt including from fingerprints from contaminating these surfaces as you work. The upper tee fittings on the ¾" jacket serve to seal against water but the pipe thread adapter solder joint and the lower tee are vacuum connections which have to be extremely leak tight, so save those connections for last if you are inexperienced in this type of soldering. Position the ½" pipe inside the ¾" pipe. Apply a fine film of flux paste to the ends of the ¾" pipe and fully insert it into the tee fittings at either end. Adjust the position of the ½" pipe to allow you to get some flux paste into the area where the solder connection will be by alternately sliding the pipe up a bit and applying the paste before sliding back the other way to bring the paste into the joint area. You want to leave about 62mm (1.5") protruding from the tee on the one end where the thread adapter goes and have both of the tees aligned in the same direction. **Photo# 4** shows the top end of the coaxial drier partly assembled.

Photo #4. Top end of coaxial drier showing water jacket connection in exploded view.

D) In order to make a good solder joint both pieces of metal to be joined have to be clean and hot enough to melt the solder. Support the assembly so as to maintain alignment and allow freedom to work around the fittings with a propane torch without getting the flame near anything flammable. Apply the flame to one side of the fitting so that it is heating both the fitting and the pipe. Allow time for the assemble to heat. Depending on the ambient temperature this may take half a minute or more. DO NOT put the solder into the flame. Apply the solder at the junction of the pipe and fitting on the opposite side to where the flame is applied and when the metal is hot enough the solder will flow. You should see the solder run completely around the joint at this point and that is sufficient. More solder than this just makes a mess and does not make a better joint. Take care to avoid dripping hot solder on yourself or anyone assisting. Do the ½" connection first and then the second ½" and you will find that the latent heat from the first connection makes the second one go much faster. Do the ¾" connection last. Do not disturb the position of anything while it is hot. Wait for the connection to cool until the solder solidifies before moving anything. Repeat for the tee at the opposite end.

E) Clean and apply flux to the two short sections of ½" pipe and insert them into the remaining ½" ports on the tee fittings. Install two boiler drain valves to the ends of these sections and remove the valve stems by loosening the nut beneath the valve handle before soldering in place.

F) The vacuum port is fabricated out of another reducing tee and a short section of ¾" tubing. Use the same techniques outlined above. The branch of the tee is connected to the vacuum valve with a short 150 mm (6") section of ½" tubing terminated in a sweat to ¼" FPT transition. At this point a simple test of this component is advised to check the integrity of solder connections. The pump can be connected to the manifold and the upper (1/2" end) can be blanked with a rubber stopper. The other end is fitted with the #6 stopper and inserted into the liquid trap. Use the implosion guard for safety with this test. Compare the sound of the pump with the vacuum valve open and closed and it should be the same. A change in pump noise indicates a leak. Pressure testing with soap bubbles is the best way to find it if there is one. See photo # 4a

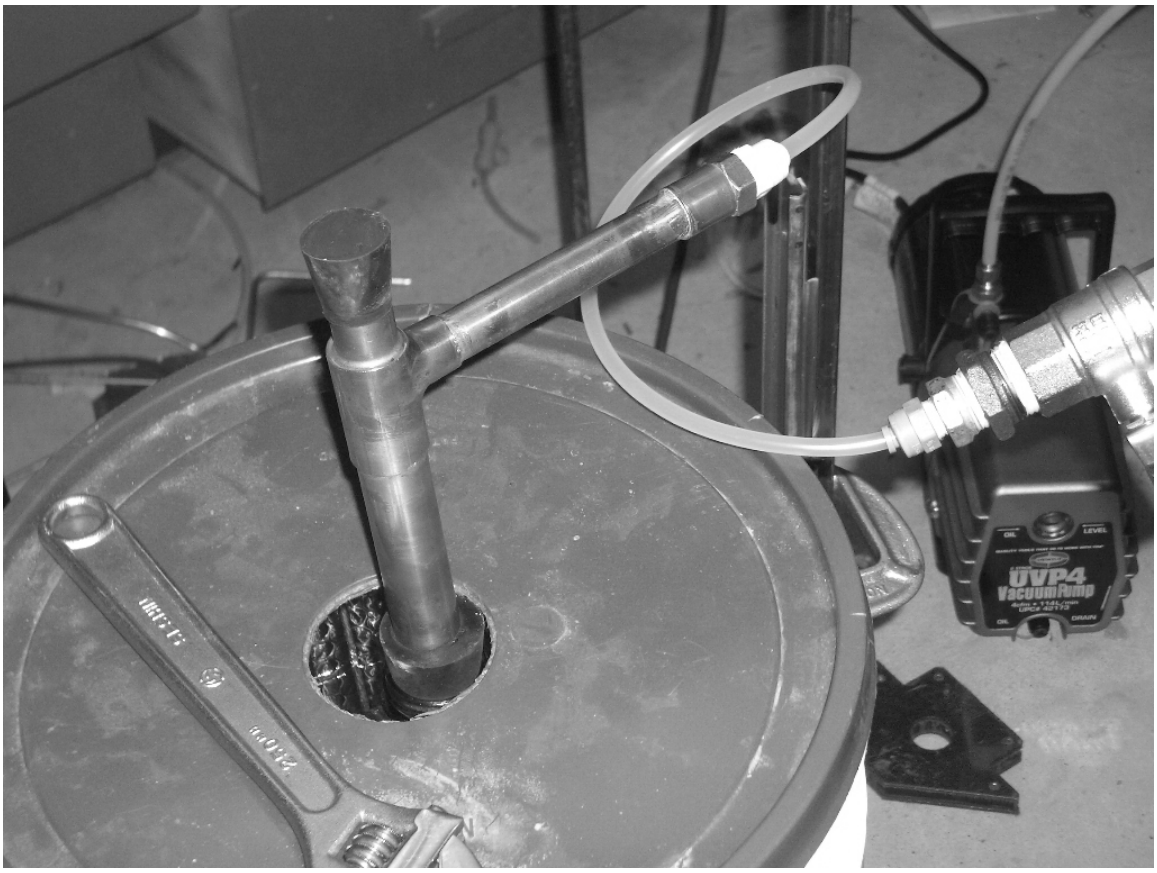


Photo #4a. Testing vacuum integrity of vacuum manifold solder joints.

G) **See Photo #5** but before soldering rotate the tee so that the vacuum port points in the opposite direction to the direction of the hose connections on the boiler valves.

H) Install the vacuum valve at this port and a 14/"MPT x 3/8" quick connect on the opposite side of the valve.

Photo #5. Detail of lower end of coaxial drier.

I) Carefully clean and flux the top end of the ½" coaxial pipe and the ¾" pipe thread adapter fitting and prepare to solder it on the end of the pipe. Arrange the assembly vertically with this connection at the bottom and support the fitting so that it won't fall off the end of the pipe during the soldering process. Be sure to use plenty of heat and make sure you see the solder run quickly around the entire circumference of the joint before removing the heat. Let the completed assembly cool in place without disturbance. Protect the adapter threads and set the drier aside for later.

J) A number 6 rubber stopper is used as a bung for the liquid trap. A ¾" hole needs to be made in the stopper, for the end of the coaxial drier. If you do not have a ¾" hole punch then cut the hole by sharpening the end of a short section of 3/4" copper pipe and using it as a hole cutter. Position the sharpened tube end at the desired location on the small end of the stopper and lubricate it with some soap or glycerin and then use a vise to force the cutter through the stopper.

K) Insert the 3/4" vacuum tube through the stopper from the larger diameter end. Use soap or glycerin as a lubricant to ease this process.

3. Methoxide Mixer

The methoxide mixer assembly is made from a stainless steel stock pot and surrounded by a plastic shroud made from a 5 gallon pail. The shroud is connected to the exhaust so that no vapours from within can escape into the room during the mixing process even when the trap door is opened. You may have to look around until you find a combination of pail and pot that fit together. Basically all you need is to be able to put the stock pot into the bucket so that it sits at the bottom and use a bucket that is deep enough to allow room for a funnel to be placed through a hole in the pot lid and still be able to put the lid on the bucket.

Exhaust shroud.

A. A second 5 gallon pail is used similar to the liquid trap exhaust shroud. This lid will have a trap door which can be opened and closed for adding chemicals. Fashion the door by cutting a wedge shape from the edge toward the center. The width of the wedge should be about 6" (150mm) at the outer rim of the lid. Tin snips work well for this. Use a small hinge to secure the trap door near the center of the bucket lid. See **Photo #6**

Photo #6 Methoxide mixer lid.

B. Cut the lid with slits around the perimeter in a similar fashion as was done for the liquid trap.
C. Roughly 3" (75mm) from the side of the lid opposite the trap door drill a xxx" (xxmm) hole for the mixer motor mount, insert the mount as shown in the photo and set the lid aside.
D. On the bottom of the pail drill a ¾" (20mm) hole at the center.

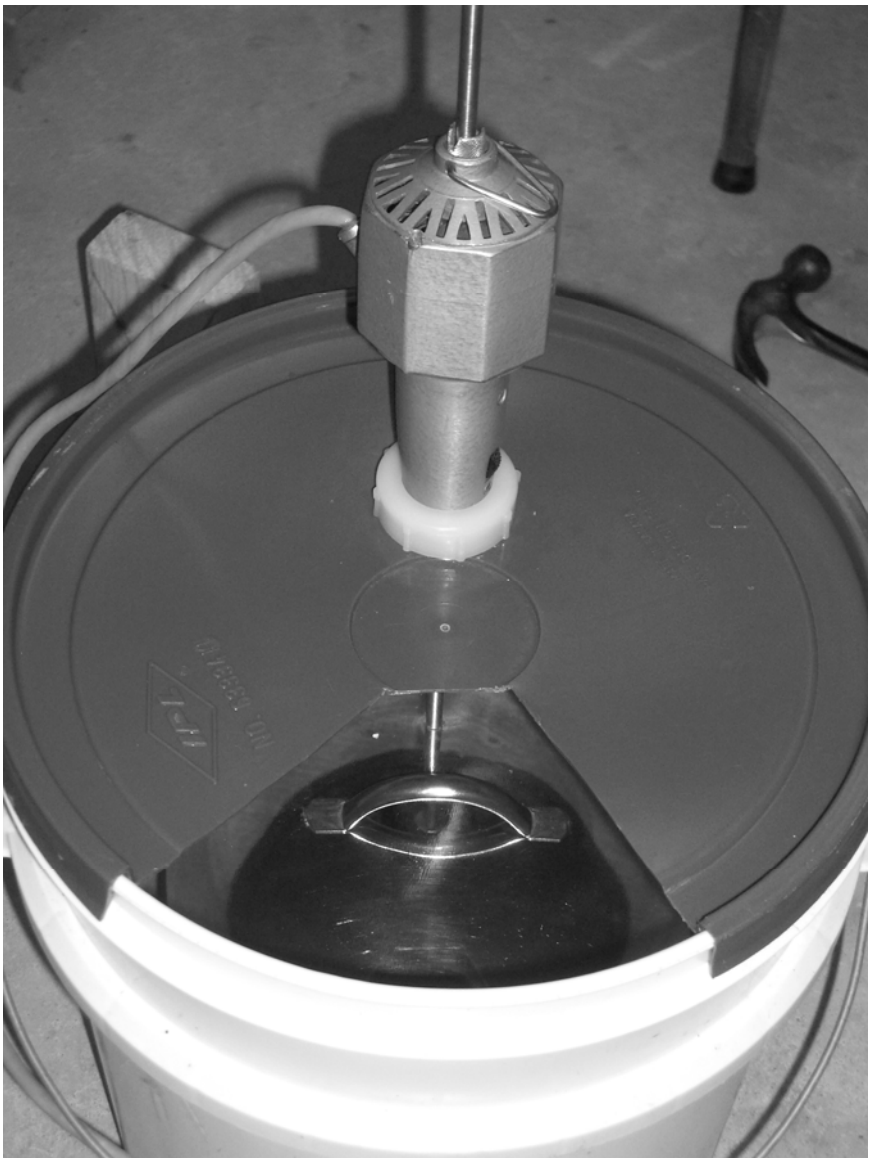
Modification of stainless stock pot.

A. The bottom of the pot needs to be deformed to a convex shape so that all the Methoxide drains to the fitting which will be welded to the center bottom of the pot. This can be done with a press or by supporting the pot around its edge and using weights to deform the bottom outwards.
B. Drill a ¼" (6mm) hole in the center of the pot at the point of maximum depression.
C. Using a hacksaw squarely cut the threaded portion of the stainless methoxide fitting off and de-burr the hole. Be careful not to damage the flared end of the fitting.
D. Use a TIG welder to weld the fitting to the bottom of the pot at the hole location. Put the ferrules for the fitting aside in a safe place and put the compression nut on the fitting to protect it. If the sealing surfaces are damaged after this point it will be a real problem so keep them protected until it is time to install the methoxide delivery line.

Photo #7 Stock pot detail

E. Place the stock pot into the pail so the methoxide fitting protrudes from the hole in the bottom of the pail. You may need to bend or remove handles if any on the sides of the pot to make it fit in the bucket. My pot had the handles riveted on with aluminum rivets. I drilled these out and used plastic 1/4-20 bolts to fill the holes. I cut the length of the bolts so that they just extend to the sides of the bucket and hold the pot from moving around inside the bucket. The methoxide level doesn't go as high as those holes but I didn't want to leave them open.
F. Place the lid on the pot.
G. Place the lid on the pail and open the trap door.
H. The mixer shaft needs a hole drilled in the end and tapped with 6-32 threads. Check the shaft for straightness by rolling on a flat surface.

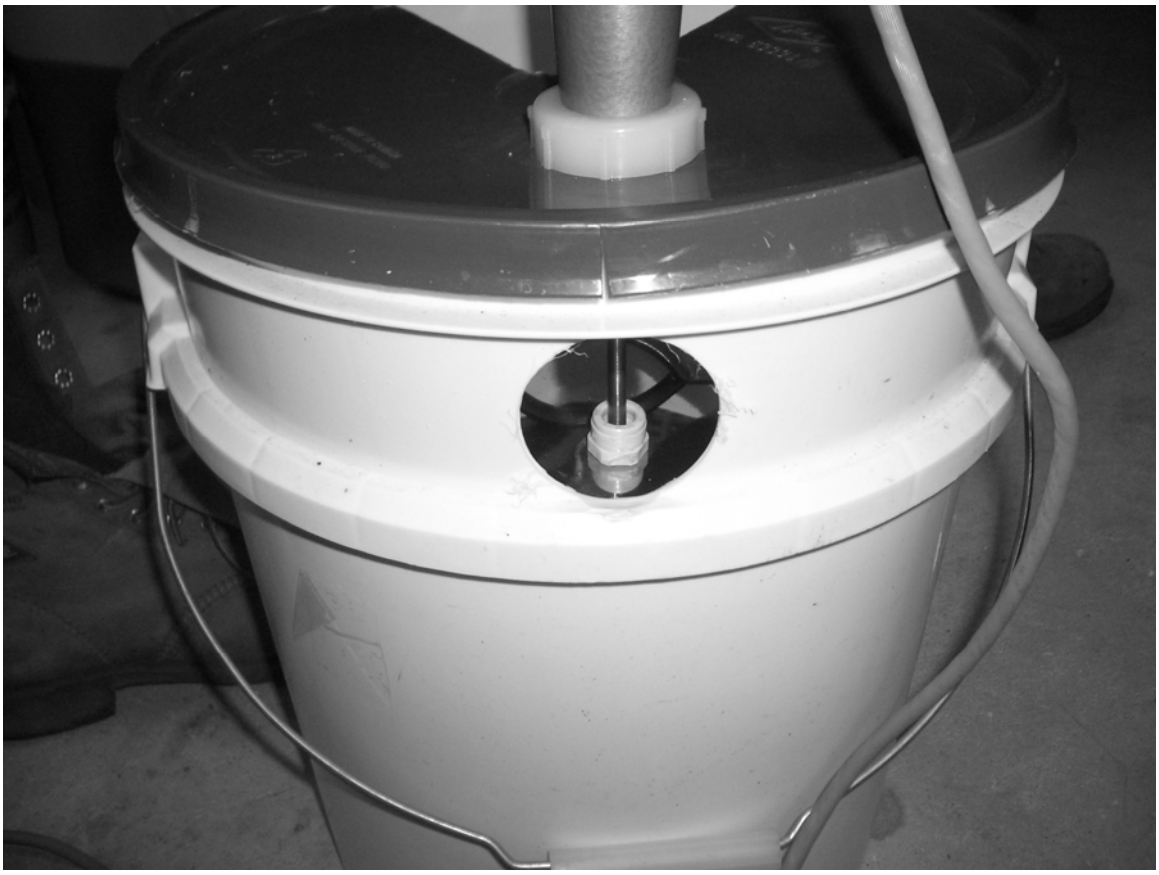
I. Loosen the locking ring on the methoxide mixer motor and temporarily place the methoxide mixer motor into the motor mount as it appears in the photo. Temporarily screw in a small piece of 6-32 threaded stock or a 6-32 machine screw with the head removed into the end of the mixer shaft. Slide the stainless mixer shaft through the motor till the threaded insert contacts the lid of the stock pot. Mark this location accurately on the lid of the pot. If you grind the threaded piece to a point you will be able to mark the spot by just raising the shaft a little and letting it fall.



J. Take your funnel and lower it through the trap door till it rests on the lid of the stock pot. Mark the location on the lid of the stock pot where the center of the bottom of the funnel rests.
K. Remove the lid of the stock pot and drill a 7/16" (11mm) hole for the mixer shaft.
L. Remove the ferrule and o ring from the ¼" MPT x ½" hose quick connect fitting to be used as the mixer shaft bushing.
M. Thread the fitting into the hole in the pot lid.
N. Place the pot temporarily in the pail and check the Using the stepped bit saw, drill a ½" hole so that your funnel sits on the lid of the stock pot with the end of the funnel protruding through this hole. Use tin snips to enlarge the funnel hole to the correct diameter to fit the funnel. I have used

a recycled plastic PET juice bottle as a funnel in one case and it required a 50mm (2") hole. PET may not last well with two stage process chemicals but it is easily replaced.

O. Finally measure the distance from the lid of the stock pot to the top of the bucket and mark a spot on the bucket 2" (50mm) above this point for the exhaust port.
P. Using a 2" (50mm) hole saw, cut a hole through the side of the bucket at the point you just marked.

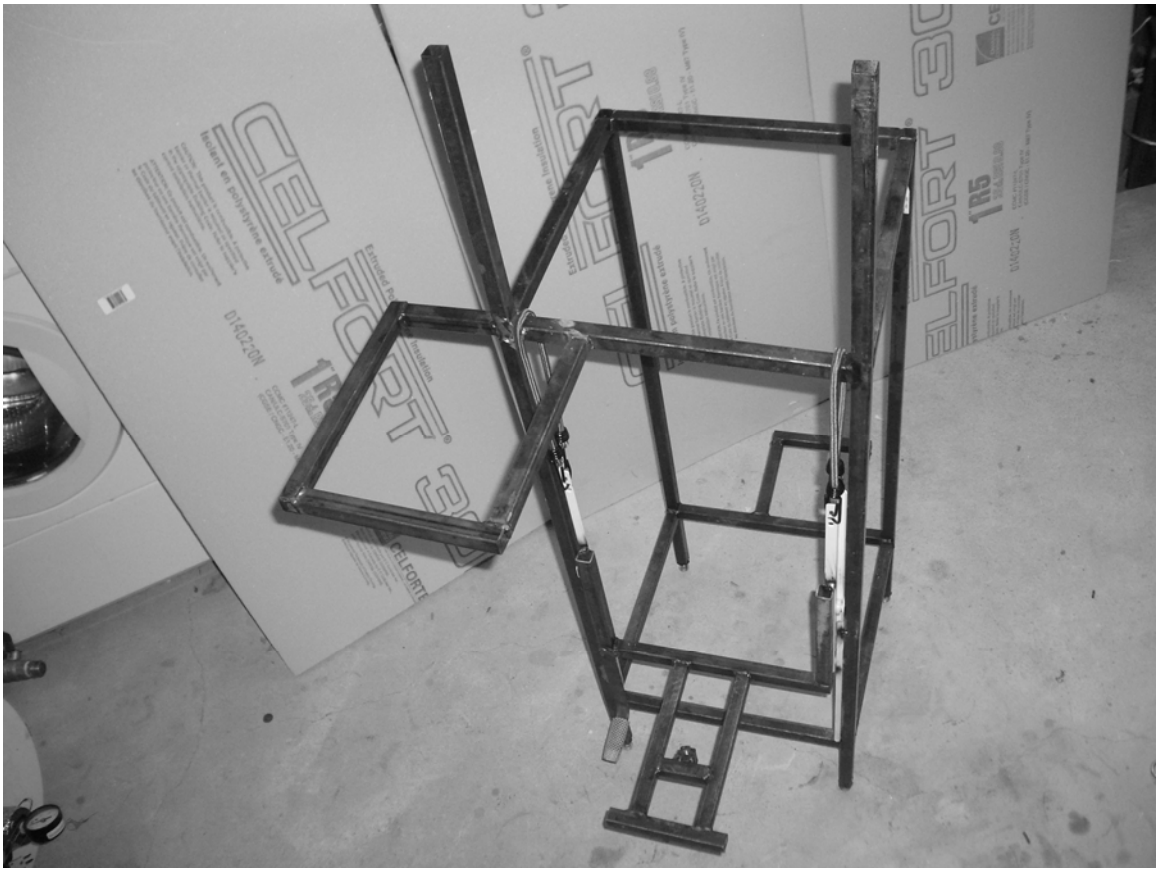


4. Support Frame

The frame is constructed from 19mm (3/4") square tubular structural steel tubing using welded construction. A small wire feed welder suitable for material up to 3mm (1/8") thickness will suffice for this job. The tubing must be cut accurately using a hacksaw or chop saw if available. A chop saw is preferred since the square cut it provides greatly eases the ability to maintain squareness during the welding of the assembly. An angle grinder is handy at times for grinding down welds and rounding corners quickly but a hand file could be used to accomplish this where necessary as well. Be sure to avoid fire hazards while welding and grinding work is taking place.

A) Start by cutting the 3/4" tubing to various lengths as shown in the bill of materials.
B) The frame as shown in **photo #8** has a left and right side. Start by fabricating the left side then the right side which is taller and has the sliding bracket for the liquid trap. Once the two frame halves are constructed they will be joined together by upper and lower joiner tubes in the front and back. After the two frame halves are joined, the

remaining sections will be added to the frame with it standing in place. These sections consist of the methoxide mixer support and the liquid trap bracket.



Photo#8 Completed frame as example. (Actually a frame from a 30 litre system).

C) Left hand side (LHS) construction begins by clamping the longer front and rear tubes in position with a joiner tube between them flush with one end and a second joiner tube positioned a distance of 125 mm (5”) from the opposite ends of the tubes. Clamp everything square and tack weld the joiners in position. Welder’s corner magnets are very handy for this part. Check squareness again before completely welding the joiners in place.

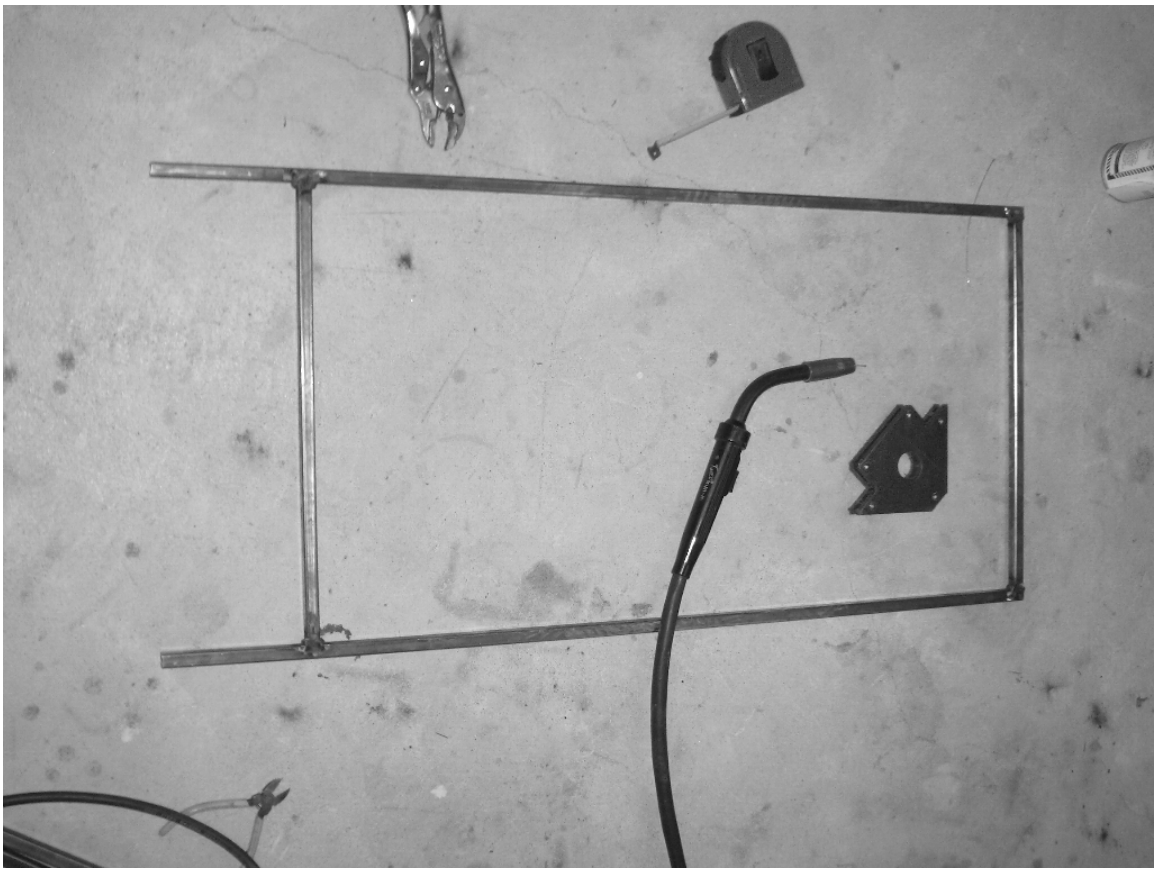


Photo #9 LHS frame detail.

D) Similarly the right side (RHS) frame members are clamped and welded, but in this case the joiners are positioned 300 mm (12”) away from one end and 125 mm (5”) from the opposite end. To avoid later problems compare the length of the upper and lower joiner tubes and make sure they are exactly the same length. **Failure to do this** will result in problems with the sliders on the liquid trap support bracket later on.

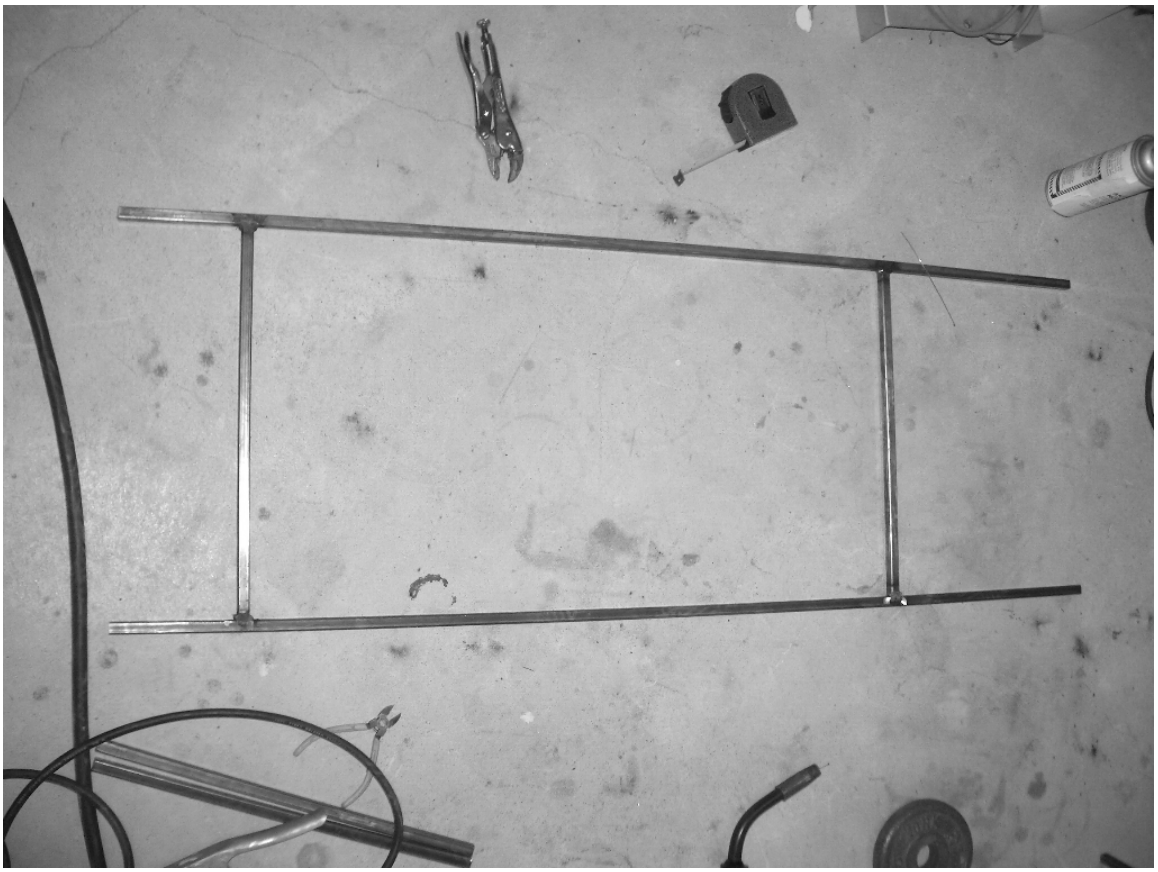


Photo #10 RHS Frame detail

E) Lay two joiner tubes on a flat work surface suitable for welding such as metal or concrete and position the LHS and RHS frame sides so that the upper and lower joiner tubes on each side match up with the two joiner tubes laying on the work surface. The frame is laying on it's back in this orientation. Using bar clamps, clamp the frame sides in position and maintain square alignment. Similarly clamp the front upper and lower joiner tubes in place maintaining alignment with the upper and lower joiner tubes on the LHS and RHS. Check squareness in at all corners and adjust if necessary to get best alignment. Tack all joiners and check alignment again before completing the joiner tube welds.

Photo #11 Frame fit up.

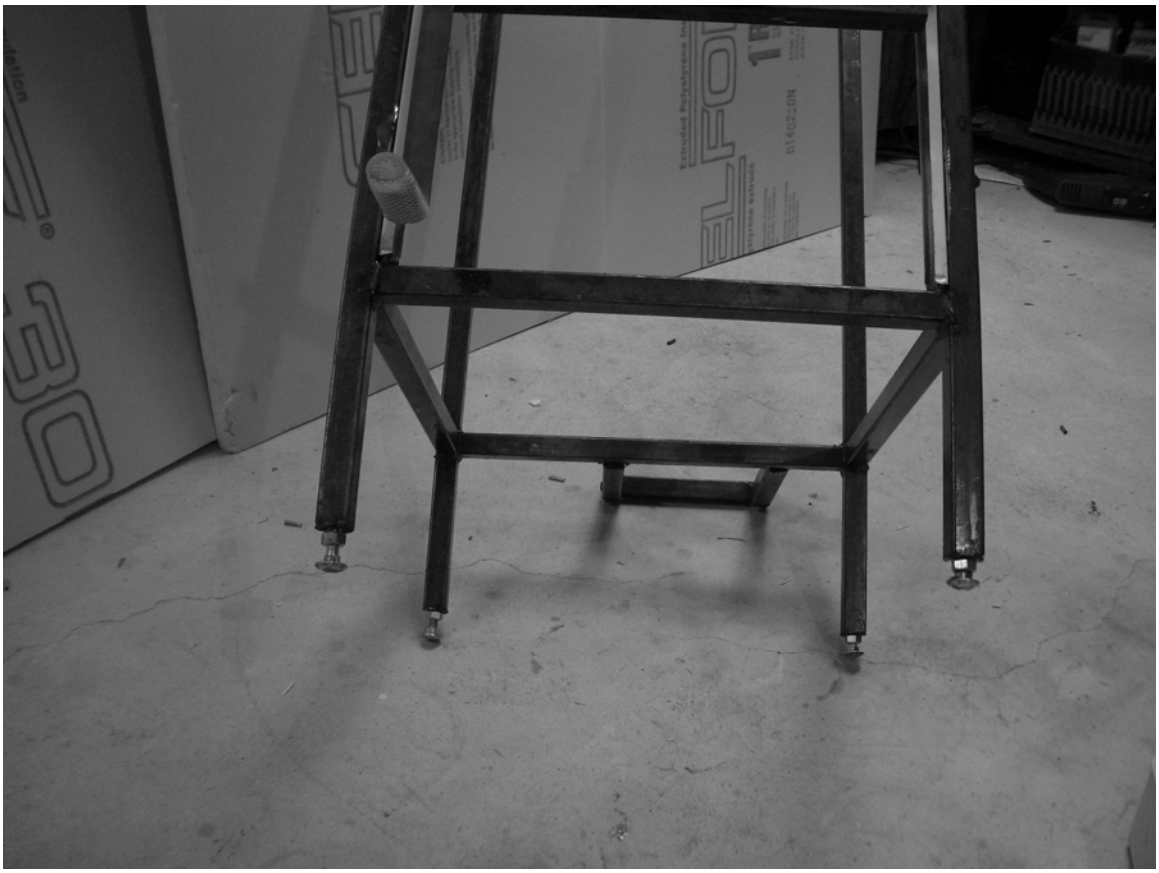


Photo #12 Lower frame detail.

F) Position a tee nut with the threaded part inside the end of each side tube at the bottom end and tack weld in position as shown in **Photo #12.**
G) Thread a ¼" nut onto each of four ¼" stove bolts and thread these into the tee nuts. These are the leveling feet for the frame.
H) Stand the frame on its feet and adjust the levelers so that the frame rests solidly without teetering on it's legs.
I) Cut a piece of plywood to fit on the lower joiner tubes and create a platform for the vacuum pump. Vacuum pumps often leak a little oil so it is a good idea to place the pump in a shallow pan or cookie sheet on this platform.
J) Remove paint from the ends of the drawer slides opposite where the roller is and a section on each side 50mm (2") from the roller end so that the drawer slides can be tack welded in position on the inside surfaces of the RHS frame sides as in Photo #11
K) Cut the front, rear and bottom piece of the liquid trap bracket and position them as shown in photo #8
L) Cut the front, rear and side pieces of the pail support for the liquid trap bracket and position them as shown in photo #8 centered along the lower slider joiner tube to form the pail support and weld squarely in place. Alignment is not critical.
M) Insert the matching halves of the drawer slides and measure the exact distance between the sliders. Insert thin cardstock between the rollers and guides to allow free movement after welding and temporarily tape slides in position. Measure distance between slides top and bottom. If the distance is not the same you will experience difficulty which will be difficult to correct. Tack the bucket support bracket tubes to

the sliders with the smallest tack possible and check for free operation. Adjust as necessary before welding permanently.

N) Cut a 225mm (9") length of 12mm x 3mm (½" x 1/8") flat bar stock and bend it 90 degrees 50mm (2") from the end to form a foot pedal and weld it to the front end of the liquid trap bracket as in **photo #8 and #12**.
O) Weld methoxide support left side piece on to front of frame as an extension of the RHS joiner tube.
P) Tack methoxide support front piece to the end of the piece attached in previous step.
Q) Tack methoxide support right piece to the end of the latest piece.
R) Finally add the rear piece for the methoxide support. Check for squareness and weld up remaining joints. Check **photo #8** for details.

5. Reactor vessel

Removal of Anode rod.

A. On the top cover of the hot water tank there is a large plastic cap that needst to be removed and the insulation beneath it will have to be cut away.
B. Using a 1-1/16" socket unscrew the anode rod which is located on top of the tank close to one side.

Removal of hot and cold water ports.

A. Using a pipe wrench remove the pipe nipples at these ports.
B. One of these nipples will be reused at the inlet port so take care to protect the threads.

Vacuum port hole preparation.

A. On the top center of the tank there is a blank fitting which needs to be modified with a hole to open it to the tank interior. The threads must not be damaged while doing this. If you can arrange to do this while drilling in an upward direction it will prevent metal bits from falling into the tank which will have to be removed otherwise. Mark the center with a center punch and drill a ¼" (6mm) pilot hole and then successively larger holes up to 1/2" (12mm). This is easily done using a stepped drill bit.

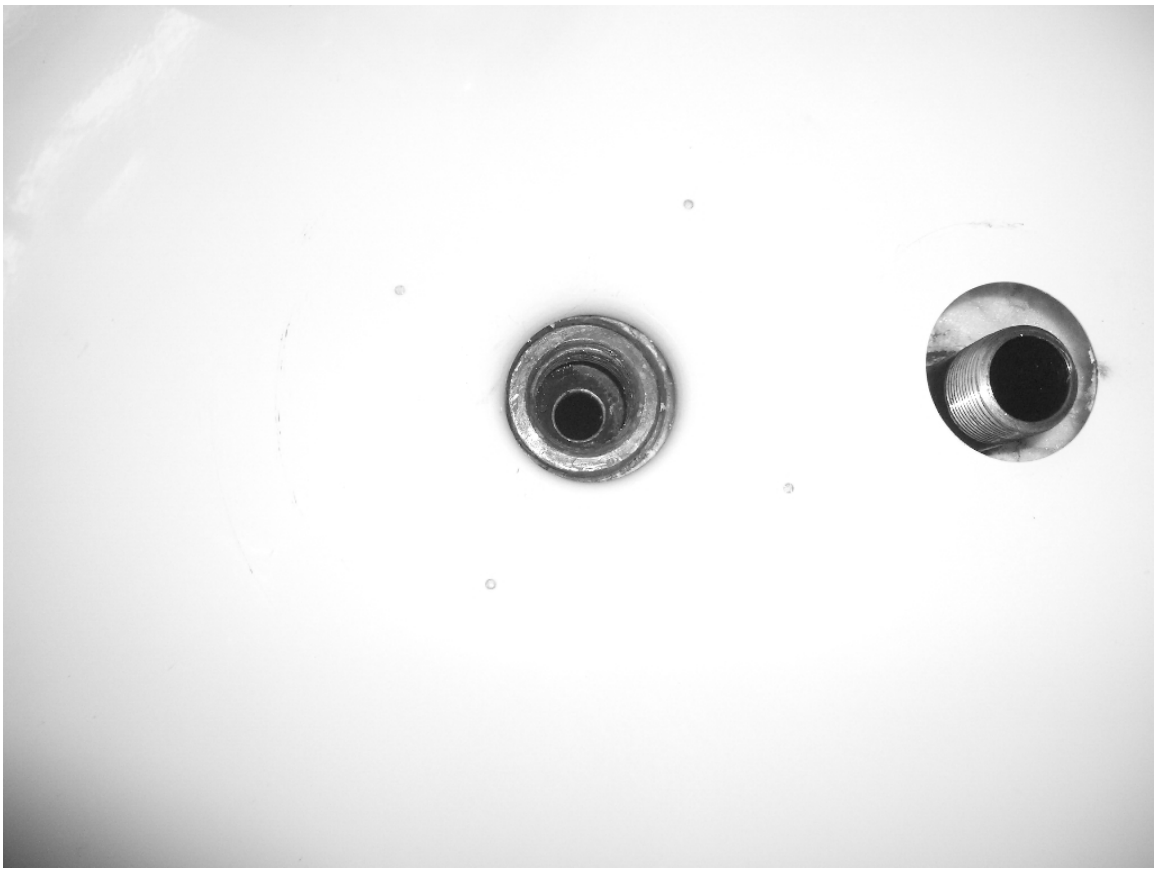


Photo #13 Preparing top of tank.

B. Ensure that the tank is clean and free of metal fragments. Remove the heater element and use a magnet if necessary to accomplish this. Turn the tank right side up and mount it on the stand and secure it with a strap against the side of the frame extension legs on the right hand side. So that the heater element access hatch is adjacent to the frame RHS so that it is free to be removed

Installation of fill port.

A. Prepare and install a ¾" x 3" pipe nipple at the port where the anode rod was removed. The cold nipple removed from the tank earlier can be reused for this purpose. Prepare the other end and install a ¾" ball valve. Tighten and check clearance of the motion of the valve handle.
B. Prepare and install a ¾" garden hose adapter to the end of the fill valve.

Level Interlock

A. A port must be added above the level of the heating element for the interlock switch. This is done by adapting the upper heater element port with a 1" x ½" reducing bushing. The switch is marked with NO and NC on opposite faces of the hex flats to indicate normally open or normally closed operation. Prepare and install the interlock switch in the bushing and do not over tighten the plastic switch but complete the tightening process with the NO facing upwards.

6. System assembly.

Recirculation system.

A. Prepare and install the ¾" MPT x ¾" socket fitting at the lower cold water inlet port. Do not over tighten this plastic fitting.
B. Cut a 62 mm (2.5") piece of ¾" PVC pipe and glue it into the fitting just installed.
C. Glue the ¾" PVC cross on the end of the piece just installed and orient it so the branches of the cross are vertical.
D. Cut a 62 mm (2.5") piece of ¾" PVC pipe and glue it into the outer end of the cross just installed.
E. Glue the 1" x ¾" reducing bushing into one end of the PVC 1" 90 degree elbow, and then glue the elbow on the stub of ¾" pipe extending from the cross so that the 1" elbow points upward.

Photo #14 Building inlet manifold.

F. Cut a 150mm (6") length of clear 1" PVC pipe and glue it in the end of the elbow just installed.
G. Prepare and install the 1" MPT x 1" socket PVC fitting to the recirculation pump inlet.
H. Using a Phillips screwdriver remove the bolts which go through the pump end plate which secure the pump to the bell on the pump motor. Holding the pump housing together remove it from the end of the motor. Carefully open the pump housing and set the impeller assembly safely aside. Remember that it has a large and powerful magnet inside.
I. Prepare the threads on the pump outlet and install the 90 degree PVC fitting on the pump outlet so that the fitting angles in the opposite direction of the pump inlet.

J. Observe the hole pattern on the pump end plate and note that there is one hole missing from the pattern. This hole corresponds to the pump outlet port. Rotate the pump end plate for proper hole pattern alignment with the opposite half of the pump housing and temporarily insert two of the bolts to maintain this alignment of the two pump halves.
K. Temporarily dry fit the pump loosely on the upper end of the 1" clear pipe stub protruding from the cross. Do not apply force to the cross.
L. Cut a 300mm (12") length of ½" clear PVC pipe and temporarily dry fit it to the pump outlet fitting to aid in alignment in the next step.

Photo #15 Building Recirculation loop.

M. Rotate the pump so that the pump outlet angles toward the tank and aligns directly with the upper hot water tank fitting. Mark this alignment at the junction of the pump inlet and the 1" inlet tube and then glue the inlet fitting to the 1" pipe stub.
N. Prepare and install the 3/4" MPT x ½" socket fitting at the tank hot water port. Take care not to over tighten.

O. Measure from the fitting just installed to the tube extending from the pump outlet and cut a section of ½" pipe to the correct length so that when the ½" 90 degree elbow is fitted to the section it will align properly to accept the pipe from the pump outlet.
P. Glue this pipe section and a 90 degree elbow on the end of it oriented downward.
Q. Cut a 50mm (2") section of ½" pipe and glue it into the elbow at the pump outlet and glue the half of the ½" pipe union which does not have the nut, to the end of it.
R. Carefully measure the distance from the pipe union to the upper elbow at the tank hot water connection and cut a length of ½" clear PVC pipe to fit.
S. Remove the bolts that were temporarily used for pump alignment in step (J) which allows the pump housing to rotate to the side.
T. Glue the ½" pipe section into the upper elbow.
U. Slide the union nut onto the section just glued and secure it out of the way with a piece of tape to hold it up.
V. The next step requires care to make sure the union halves mate properly. The procedure will be to insert the half union on to the pipe and then rotate the pump housing so that the union halves line up before the glue sets. Dry fit the fitting first to practice this as there is only one chance to get it right. Have someone assist you if necessary as the glue will set quickly so it is essential to rotate the pump housing in to position to get the union halves mated while the glue still allows adjustment.
W. A 62mm (2.5") length of ¾" pipe and a ¾" MPT to socket transition can be glued in the branch of the cross pointing downward.
X. Prepare the threads on the previous fitting to accept a ¾" ball valve for the tank drain and set it aside until the glue dries for 1/2 hour.
Y. In the mean time prepare and thread the 1/8" stainless pipe nipple into the ¾" x 1/8" PVC reducing bushing.
Z. Install the stainless 90 degree elbow to the other end of the nipple and install the male 1/8" MPT fitting of the methoxide metering valve to the elbow so that the female port on the valve ends up pointing in the opposite direction of the PVC reducer and install the 1/8 MPT x ¼ quick connect white PP fitting to the female port.
AA. Glue the assembly in vial the reducer into the top of the cross manifold so that the handle of the methoxide valve points at a convenient angle toward the front of the system.
BB. Install the ¾" drain valve at the bottom of the cross manifold using two wrenches to avoid putting stress on the plastic manifold and ensuring clear motion of the valve handle.
CC. The pump impeller can now be returned to the pump housing and the motor reinstalled with it angled so the mounting plate is to the left and at right angles to the side of the tank.
DD. Hold the mounting brackets up to the pump and bend them as necessary so that the pump motor can be securely attached to the tank. Drill the brackets as necessary and bend them to facilitate the motor mounting so that they are securely mounted to the tank and bolted to the motor plate by ¼-20 hardware.

Photo #16 Recirc pump and Methoxide valve mounted. System ready for leak testing.

EE. With all valves closed the reactor should now be vacuum tight. In order to test this, the coaxial drier and liquid trap need to be installed.

FF. Once the system can be pumped down, check to see that a vacuum of 28" Hg can be achieved. Seal any leaks if this is not the case.

Coaxial drier.

A. Prepare and thread the pipe nipple removed from the water connections to the port on top of the tank where the anode rod was removed as in Photo #13.
B. Install a ¾" tee on the end of this nipple and tighten till the branch of the tee points to the RHS.
C. Install the ¾" x ¼" bushing on the top of the tee and install the vacuum gauge into this bushing.
D. Prepare and install a 355 mm (14") long ¾" nipple into the branch of the tee and install a 90 degree elbow on the end tightening until it points downward.
E. Prepare the pipe adapter on the end of the coaxial drier and install the unit into the elbow in the previous step, tightening until the boiler valves point to the RHS rear and the vacuum pump port points toward the front of the system.
F. Attach bungee cords to the flame slide and place a 1 gallon cider jug inside the liquid trap bucket and carefully mate the rubber stopper with the mouth of the bottle. BE CAREFULL NOT TO KNOCK THE BOTTLE AGAINST THE END OF THE DRIER AND NEVER USE A CHIPPED OR CRACKED BOTTLE.
G. The cole parmer pump comes with a flare type fitting which must be adapted to a 3/8" OD polyethylene tube for pumping down the system. Other pumps may use different type connections. Ensure proper connections at this point to preserve vacuum integrity. This can be checked by observing the pump sound when pumping on a blocked off port. Connect the 3/8" pumping line and close the vacuum valve. Turn on the pump and observe that it produces the same sound as it did in a blanked off condition. This is a good indication that the connections between the pump and vacuum valve of the system are leak tight.
H. Pump the system down and observe the ultimate vacuum. It should reach at least 28" Hg. Close the port and turn the pump off. The system pressure should not rise more than 1" Hg in a 12 hr period. Record the time and vacuum rise for future reference as it will be invaluable for troubleshooting the system should it be required one day.

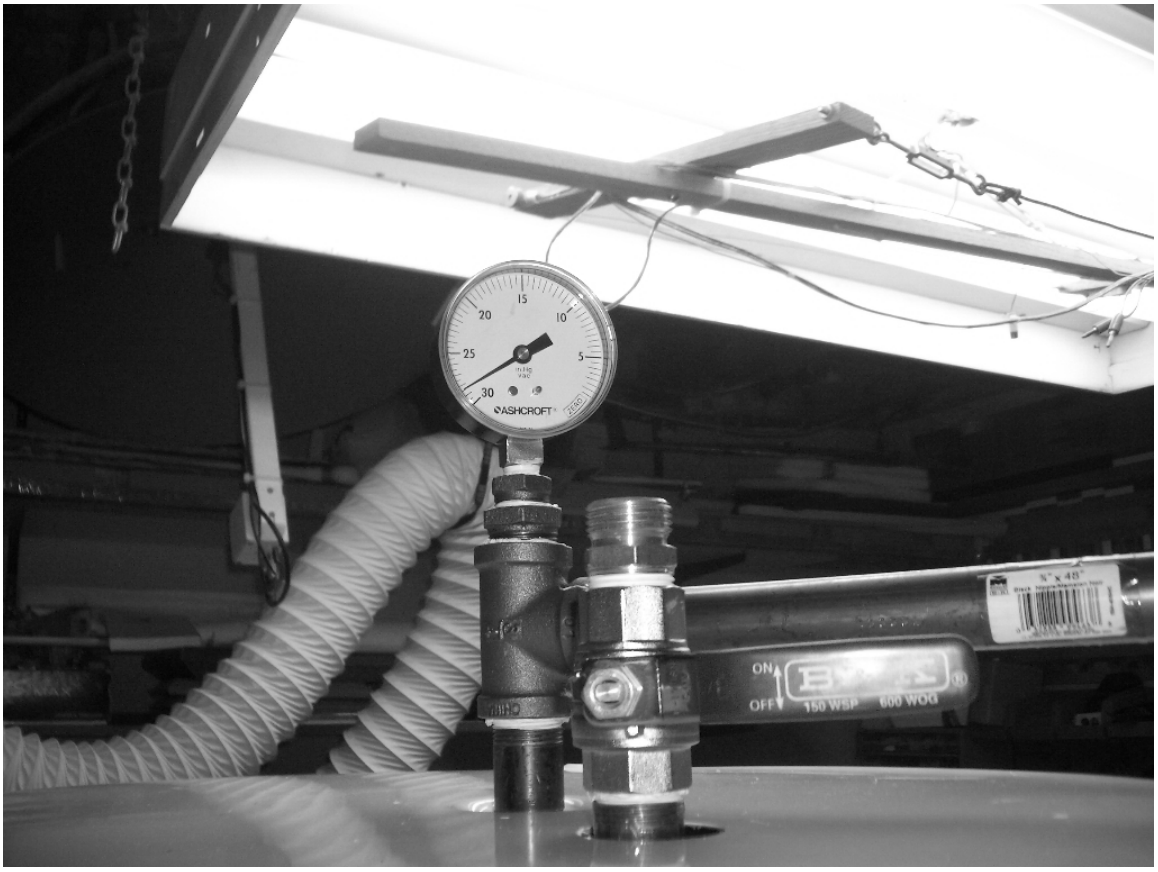


Photo #17 Checking system ultimate vacuum.

7. Exhaust stack.

The exhaust stack consists of three connections for the liquid trap, vacuum pump and methoxide mixer. The main stack length is 75mm (3") ABS pipe. A 75mm (3") to 38mm (1-1/2") 45 degree tee and a 75mm (3") to 38mm (1-1/2") reducer serve to adapt to the 38mm (1-1/2") exhaust lines which connect to the liquid trap and the methoxide mixer. The branch which runs to the liquid trap also has a tee which contains a bushing to connect to the exhaust hose from the vacuum pump.

A. Using a hacksaw cut a 200mm (8") length of the 75mm (3") ABS pipe. Apply ABS solvent cement according to the directions and install the reducer on one end of this piece.
B. Glue the 45 degree tee on the other end so that the tee branch is angled toward the end with the reducer.
C. Using two hose clamps, secure this section to the rear riser in the RHS frame top. Do not tighten the hose clamps so that final alignment can be done later.
D. Glue a 45 degree street elbow into the branch of the 45 degree tee so that it is oriented with the end horizontal.
E. Cut a 38 mm (1-1/2"") length of 38 mm (1-1/2") ABS pipe and glue it into the end of the 45 degree elbow from the previous step.
F. Glue a 38mm (1-1/2") 90 degree elbow on the piece installed in the previous step so that it is oriented straight toward the front of the system.
G. Cut a 254 mm (10") length of 38 mm (1-1/2") ABS pipe and glue it into the elbow installed in the last step.
H. Temporarily mount the methoxide exhaust shroud on its stand and then adjust the height of the exhaust stack so that the exhaust pipe installed in the previous step lines up with the exhaust port in the side of the pail.
I. Tighten the hose clamps on the exhaust stack to maintain this alignment. **Photo #18**.

Photo #18 Adjusting exhaust manifold height.

J. Install but DO NOT GLUE a 38mm (1-1/2”) 45 degree street elbow on the piece installed in the previous step so that it is oriented toward the end of the coaxial drier.
K. Cut a 38 mm (1-1/2”) length of 38 mm (1-1/2”) ABS pipe and glue it into the elbow installed in the last step.
L. Glue the 38 mm (1-1/2”) tee onto the piece installed in the last step with the branch of the tee oriented downward.
M. Glue the 38mm (1-1/2”) X 13mm (1/2”) FPT bushing into the 38mm (1-1/2”) tee.
N. Cut a 38 mm (1-1/2”) length of 38 mm (1-1/2”) ABS pipe and insert BUT DO NOT GLUE it into the remaining port of the tee.
O. Fit but DO NOT YET GLUE a 45 degree elbow to the length of pipe just installed and orient it downward.
P. Measure the vertical distance from the bottom of the rubber stopper on the end of the coaxial drier to the elbow installed in the previous step and cut a section of 38 mm (1-1/2”) ABS pipe to that length and dry fit it to the elbow.
Q. Check the orientation of these pieces to ensure that the lower exhaust duct ends beside the end of the coaxial drier and at the same height as the rubber stopper. Adjust the length if necessary.
R. Glue the remaining connections in this orientation.
S. Take the lid from the liquid trap containment vessel and hold it so that the rubber stopper on the coaxial drier lines up with the hole in the center of the lid. Mark the location where the exhaust stack meets the surface of the lid and cut a hole for it using a 50 mm (2”) hole saw.

8. Electrical hookup.

The hot water tank has a 220 volt element but it will be powered with 110 volt AC so that it will only produce ¼ of the rated power. The system requires six switched electrical outlets for the following:

1. Exhaust fan.
2. Vacuum pump.
3. Heater.
4. Cooling pump (if used -recommended)
5. Mixing pump.
6. Methoxide mixer.

These can be made by combining switched outlets in dual duplex boxes. Ensure sufficient amperage and circuit protection on the circuit feeding the switch bank by adding up the current requirements for each of the components in the system. Assume a value of 3.5 amps for a 220 volt heater of 1500 watt capacity running on 110 volts. The boxes may be mounted wherever convenient such as welding to the frame or may be wall mounted beside the system as is the preference of the builder. They should be in reach of the system. One solution is to mount them on the top of the tank as shown in **PHOTO #19**

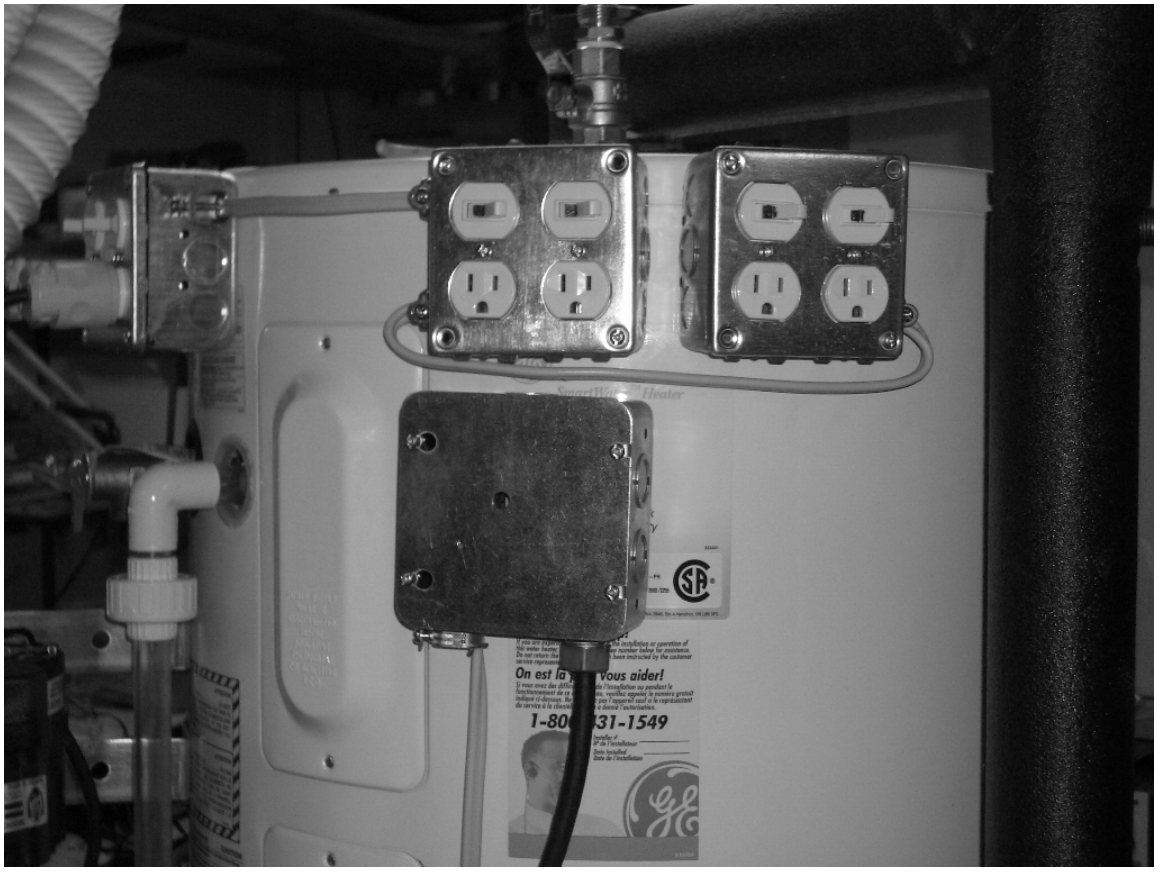


Photo #19 Electrical controls mounted.

The heater element must also be interlocked with a level switch so that it can never be energized without being immersed. Dry powering the heater will result in heater burnout and could result in an explosion if there were explosive vapours in the reactor at the time. Never defeat this interlock or omit it from a system

when building one. The level interlock is not rated for the power of the heater so therefore a solid state relay is wired in series with the heater for this purpose. The relay is energized by the level switch. Mount the relay box on the side of the tank, Beside the access port for the upper element where the interlock switch is located. The electrical power inlet to this box comes from a switched outlet. If you are not qualified to do this wiring then have it done by someone who is. Always ensure there is no power connected when working with electrical wiring.

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Part name	Description	Qty	Source	UPC code	Manufacturer	Part number	Data	Price	Ext. Price
Recirc. Pump	68 lpm 110v	1	Cole Parmer		March	A-07023-06	Catalog page	$351.32	$351.32
Exhaust fan	110v furnace type	1	Surplus		Emerson	M-053		$25.00	$25.00
Water heater	100L 220V water heater	1	Home depot	020352497327	GE	GE30P06JAG		$269.00	$269.00
Heater interlock switch	Side mounted level switch	1	Omega			LVN-92	Catalog page	$22.00	$22.00
Heater interlock relay	Solid state zero crossing switch	1	Omega			SSRL240AC25	Catalog Page	$30.00	$30.00
Vacuum pump		1	Cole Parmer			RK-07164-50	Catalog page	$470.67	$470.67
Vacuum Gauge	0-30" Hg	1	Cole Parmer		Ashcroft	A-68004-00	Catalog page	$23.85	$23.85
Temperature Gauge	Digital meat thermometer	1	Cole Parmer			A-90025-05	Catalog page	$25.10	$25.10
Aluminized bubble wrap	24" x 10 ft roll.	1	Home depot	716511320000				$12.97	$12.97
Frame LHS front	0.75" X 0.75" X 36"square tubular steel	5	Home depot	771878671677				$6.95	$34.75
Frame LHS rear	0.75" X 0.75" X 36"square tubular steel	0	Home depot	771878671677					$0.00
Frame RHS front	0.75" X 0.75" X 48"square tubular steel	0	Home depot	771878671677					$0.00
Frame RHS rear	0.75" X 0.75" X 48"square tubular steel	0	Home depot	771878671677					$0.00
Frame joiner tubes	0.75" X 0.75" X 16"square tubular steel	0	Home depot	771878671677					$0.00
1/4" tee nuts	1/4"-20	4	Home depot	000000129432				$0.36	$1.44
1/4" Carriage bolts	1/4"-20 x 2"	4	Home depot	000000137338				$0.27	$1.08
1/4" nuts	1/4"-20	4	Home depot	000000131119				$0.10	$0.40
									$0.00
Methoxide mixer left support piece	0.75" X 0.75" X 5"square tubular steel	0	Home depot	771878671677					$0.00
Methoxide mixer front support piece	0.75" X 0.75" X 11.5"square tubular steel	0	Home depot	771878671677					$0.00
Methoxide mixer right support piece	0.75" X 0.75" X 9"square tubular steel	0	Home depot	771878671677					$0.00
Methoxide mixer rear support piece	0.75" X 0.75" X 10"square tubular steel	0	Home depot	771878671677					$0.00
									$0.00
Vacuum valve	Brass needle valve	1	Cole Parmer			A-68831-00	Catalog page	$16.32	$16.32
Liquid trap bracket side piece	0.75" X 0.75" X 8"square tubular steel	0	Home depot	771878671677					$0.00
Liquid trap bracket bottom piece	0.75" X 0.75" X 15"square tubular steel	0	Home depot	771878671677					$0.00
Liquid trap bucket support piece	0.75" X 0.75" X 9"square tubular steel	0	Home depot	771878671677					$0.00
Foot pedal	0.5" X 0.125" X 9" steel flat bar	0.33	Home depot	771878671035			3 ft length	$4.46	$1.47
Drawer slide	12" length.	1	Home depot	773199360018				$3.76	$3.76
Broom clips	clips to hold fill and wash hoses	2	Home depot	079325777287				$2.29	$4.58
									$0.00
Vacuum port horizontal piece	15"x 3/4" black pipe nipple	1	Home depot	32888???????				$1.36	$1.36
Vacuum Gauge port	3/4" tee black pipe	1	Home depot	032888406490				$0.99	$0.99
Gauge adapter	3/4" x 1/2" reducing bushing B.P.	1	Home depot	032888407053				$1.08	$1.08
Gauge adapter reducer	1/2" x 1/4" reducing bushing B.P.	1	Home depot	032888309647				$0.82	$0.82
Coaxial drier adapter	3/4" elbow black pipe	1	Home depot	032888406155				$0.89	$0.89
Coaxial vacuum port	1/2" sweat x 1/4" FPT	1	Home depot	685768203322				$2.22	$2.22
Coaxial vacuum port extension	1/2" x 4" copper water pipe	0.13	Home depot	400020054432					
Coaxial drier fitting	3/4" MPT x 1/2" sweat socket copper fitting	1	Home depot	????????????				$2.77	$2.77
Coaxial drier ends	3/4" x 1/2" copper reducing end tee	2	Home depot	685768204107				$2.78	$5.56
Coaxial drier valves	1/2" boiler valve	2	Home depot	032888020030				$3.98	$7.96
Coaxial drier jacket	3/4" x 24" copper water pipe	1	Home depot	400020054449			6 ft length	$8.99	$8.99
Coaxial drier tube	1/2" x 32" copper water pipe	1	Home depot	400020054432			6 ft length	$4.99	$4.99
Rubber stopper	#6 with 3/4" hole	1	Cole Parmer						$0.00
									$0.00
									$0.00
Drain valve adapter	3/4" soc x 3/4" MPT PVC fitting	1	JJ Downs			436-007W			$0.00
Drain valve	3/4" ball valve	1	Home depot	032888070042				$9.98	$9.98
Drain hose adapter	3/4" MPT to garden hose adapter	1	Home depot					$3.59	$3.59
									$0.00
									$0.00
Pump bracket	6" 90 degree angle bracket	1	Home depot	044315048005				$3.94	$3.94

Pump inlet adapter	1" MPT x 1" PVC solvent weld bushing	1	J.J.Downs			436-010W			$0.00
Injector body	3/4" PVC cross	1	J.J.Downs			420-007W			$0.00
Pump side cross adapter	1" x 3/4" socket reducing elbow	1	J.J.Downs			406-131W			$0.00
Tank side lower fitting	3/4"MPT x 3/4" socket PVC	1	J.J.Downs			436-007W			$0.00
Recirc line pump fitting	1/2 FPT x 1/2" socket 90 elbow	1	J.J.Downs			407-005W			$0.00
1/2" union	1/2" union w EPDM	1	J.J.Downs			497-005W			
Upper recirc. elbow	1/2" MPT x 1/2" socket elbow	1	J.J.Downs			409-005W			
Recirc tank fitting	3/4 MPT x 1/2 socket	1	J.J.Downs			436_101W			
Inlet pipe	3/4" PVC pipe sched 40	2	J.J.Downs				Qty by the foot		
Pump stand	1" x 6" clear PVC pipe sched 40	1	J.J.Downs				Qty by the foot		
Recirc pipe	1/2" CLEAR PVC pipe sched 40	4	J.J.Downs				Qty by the foot		$0.00
Methoxide inlet reducer bush	3/4" spig x 1/2" soc	1	J.J.Downs			437-101W			
Methoxide inlet reducer threaded bush	1/2" spig x 1/8" FPT	1	J.J.Downs			438-071W			
Solvent cement	for PVC pipe	1	J.J.Downs						$0.00
Methoxide valve	Stainless needle valve	1	Tubefit		Noshok	101 MFAS		$51.00	$51.00
									$0.00
									$0.00
Inlet hose adapter	3/4" MPT to garden hose adapter	1	Home Depot					$3.59	$3.59
Inlet valve	3/4" ball valve	1	Home Depot	032888070042				$9.98	$9.98
Inlet elbow	3/4" street elbow	1	Home Depot	032888406353				$1.46	$1.46
Inlet adapter	3/4" x 3" nipple	1	Home Depot						$0.00
Interlock adapter		1	Home Depot						$0.00
5 gallon Pail		2	Surplus						$0.00
									$0.00
									$0.00
Methoxide vessel	Stainless steel 8 quart stock pot	1	Canadian Tire	42-3625-6				$19.99	$19.99
Filling funnel	Funnel with screw cap	1	Canadian Tire	28-3336-0				$7.97	$7.97
Methoxide fitting	1/4" stainless compression fitting	1	Tubefit		SS-400-1-4				$0.00
Methoxide delivery line	1/4" x 0.04" wall PE tube x 5 foot length	1	J.J.Downs		Parker	E-43-005			$0.00
Mixer motor	Electric drafting eraser.	1	Surplus		Kohinoor			$9.99	$9.99
Mixer shaft	1/4" x 24" 316 stainless rod	1	Metal supermarket						$0.00
Mixer prop		1	Flitecraft						$0.00
Prop screw	6-32 stainless panhead machine screw	1	any						$0.00
1/4" wheel collet	Collet with setscrew								$0.00
Shaft bushing	1/4" OD x 1/4" MPT quick connect	1	Home depot						
Mixer motor mount	ABS trap adapter	1	Home depot	039923195180				$1.39	$1.39
									$0.00
Exhaust duct large	3" ABS drain pipe	1	Home depot	622454091146				$16.89	$16.89
Exhaust duct small	1-1/2" ABS drain pipe	1	Home depot	622454091178				$4.19	$4.19
Exhaust fan coupling	3" rubber with clamps	2	Home depot	018578000773				$5.88	$11.76
Exhaust 90	1-1/2" ABS 90 elbow	1	Home depot						
Exhaust 45	1-1/2" ABS 45 elbow	1	Home depot						
Exhaust street 45	1-1/2" ABS 45 street elbow	2	Home depot						
Exhaust Tee	1-1/2" ABS tee	1	Home depot						
Exhaust branch	3" x 3" x 1-1/2" 45 deg ABS tee	1	Home depot	039923280435				$3.98	$3.98
Exhaust reducer	3" x 1-1/2" ABS reducer	1	Home depot	039923201348				$2.98	$2.98
Vacuum pump bushing	1-1/2" glue in x 1/2" FPT ABS reducing bush	1	Home depot	062852601644				$1.96	$1.96
									$0.00
Electrical box	Power distribution box	4	Home depot	626463080876				$3.10	$12.40
Cover plate	Switch and outlet cover	3	Home depot	622538422729				$2.77	$8.31
Switched outlet	Power switch with 3 prong outlet	6	Home depot	068679161217				$8.48	$50.88
									$1,567.57