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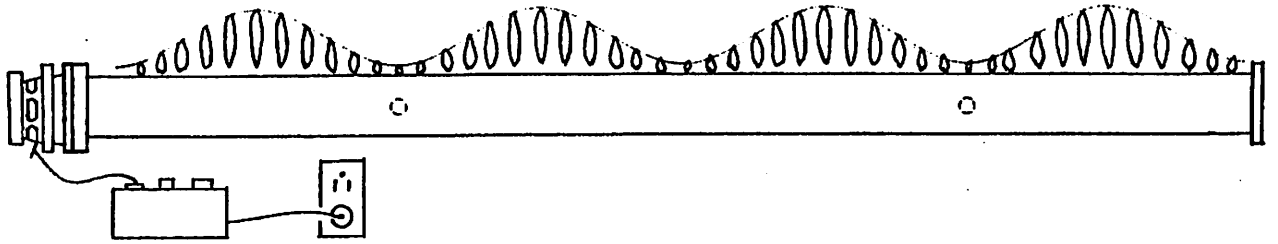
The ultimate single speaker flame tube - It uses about 65 flames to display the standing wavelengths of different frequencies in a sine wave pattern; the sounds are heard, as well. Change the frequency and the wavelength changes. "Beats" are seen and heard, also. An audio oscillator, a keyboard, a CD player, a computer, etc. can be connected to it. It can be made to use methane or propane.

Diagram:



The single speaker flame tube is one of the most dramatic and educational pieces of physics demonstration apparatus ever developed. It is safe if used properly. It is relatively easy to build, inexpensive, and easy to operate.

The tube's simple design is a combination of ideas from V.M.I., Union College, and J. B. Johnston. Johnston has eliminated the need for any soldering and changed it to a dual-purpose tube that can use either methane or propane, depending on the situation. Where no gas is available or the pressure is too low, a 20 lb. (or less) propane tank supply has been used successfully.

Warning: For safety, be sure that a licensed propane distributor makes up the necessary connector apparatus between the tank (pressure regulator, shutoff valve, etc.) and the tube; no gas leaks!

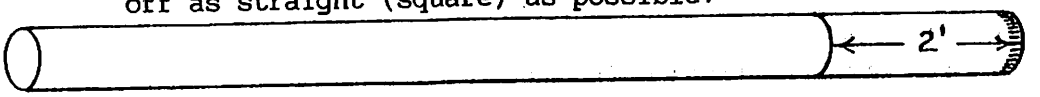
To produce "beats" will require a second audio oscillator but not a second speaker, strange but true!

Because lighter than air methane and heavier than air propane have different densities, the wavelengths of each at the same frequency will be different, thus indicating different speeds of sound. (Faster in methane!) To show the two different speeds (wavelengths) at the same time, however, requires a second tube. Worth the extra effort? You decide.

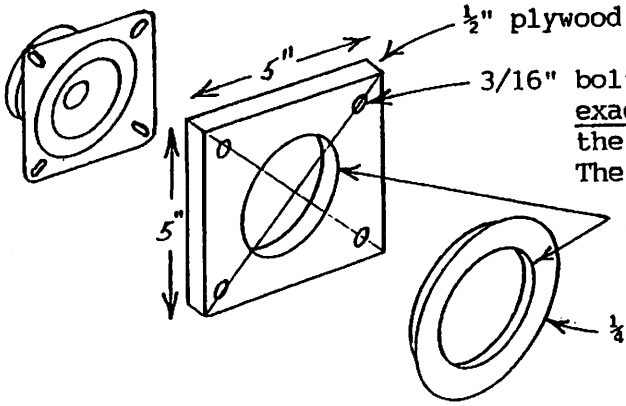
For easy display anywhere, especially on small tables, a pair of simple stands is recommended. Their design and construction are included in these instructions.

A personal note. Of course, you are free to make changes in the tube's design and construction; these instructions are only suggestions that worked for me. I have made fifteen of these tubes in my woodshop. I have retained one dual-purpose tube and one for propane only so I can perform the ultimate demonstration showing relative speeds of sound in different gases. I built my first tube in 1978 and have never regretted it. It still serves me well and thrills most observers. I keep a 20 lb. propane tank on hand for travel.
Good luck!

The pipe (VMI design): Start with a 4" dia. galv. smoke pipe, 10 ft long, with the seam on the bottom. Buy it at a wholesale plumbing and/or heating supply. Cut off 2 ft with a hacksaw or a metal cutting band saw. Cut it off as straight (square) as possible!



The speaker plate (Johnston design):



3/16" bolts holes (4) must match those on the speaker end plate exactly (perfectly)! So drill these after you have made the speaker end plate, and matched it up with this plate. The bolts (and their holes) must miss touching the ring.

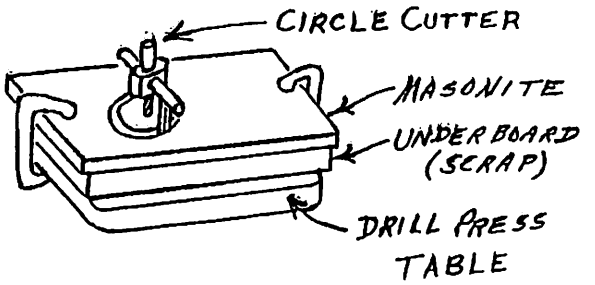
3 5/8" I.D. of both plywood and tempered masonite ring (flange). Use a sanding drum to smooth up after gluing, if possible (but not critical).

¼" thick tempered masonite ring (flange) pressure glued (Elmer's) to plywood. "Pressure glued" means tightly clamped. This ring holds the Saran Wrap.

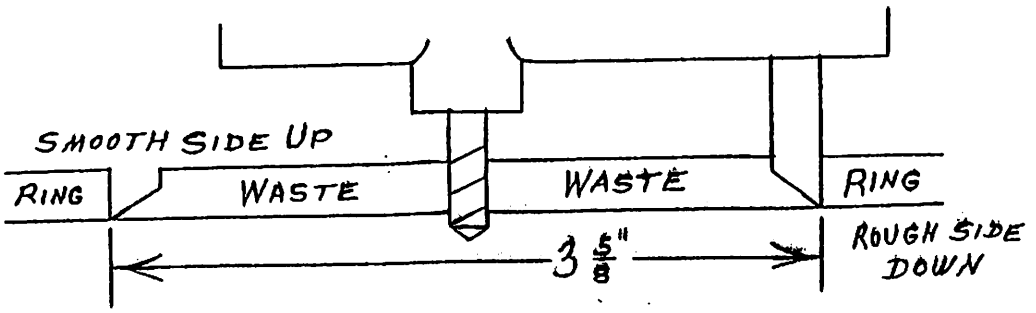
Note: With a circle cutter on a drill press, cut the 3 5/8" I.D. hole in the ½" plywood. Then go to the first step in cutting out the ring (flange). Use an underboard for both.

Steps in making the tempered masonite ring (flange):

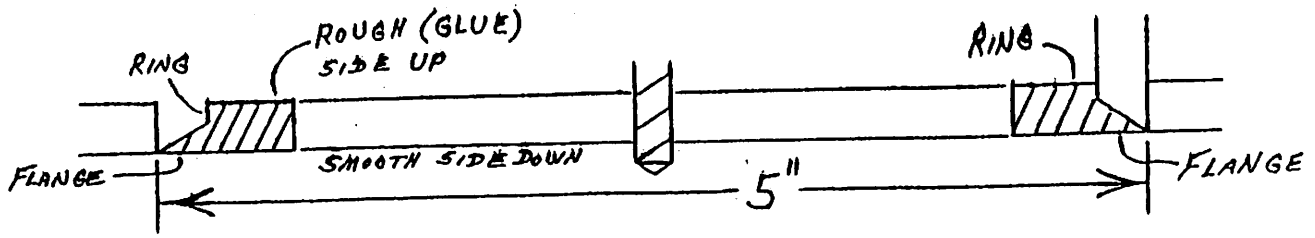
(a) Select a large piece of ¼" thick tempered masonite and clamp it, smooth side up, flat on an underboard on the drill press.



(b) First, cut out the center hole (3 5/8" dia.).

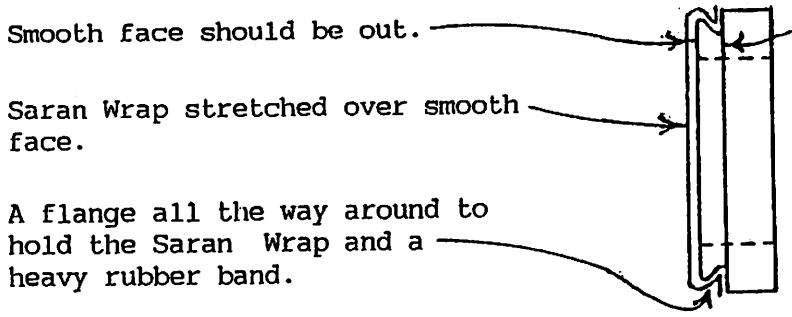


(c) Second, turn the remaining masonite over, rough side up, and reclamp after recentering the opening with the circle cutter; then cut through, leaving the special ring.



Note: If you do not have a circle cutter, you may use a scroll (jig) saw for cutting out the ring and the holes in the plates. A sanding drum would help smooth the holes but is not critical.

Profile of ring attached to plywood:

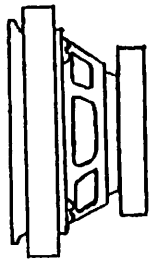


By hand, sand down and smooth up the edge of the flange so the Saran Wrap won't tear.

Note: The Saran Wrap should be carefully stretched under the rubber band until all wrinkles are removed, and it appears as a smooth, taut drumhead. Beware! Saran Wrap "ages". If several years old, discard it, and start fresh.

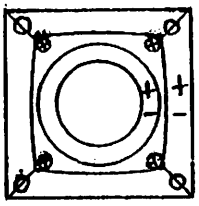
The rest of the speaker unit:

profile:



Center the 4" dia. acoustic suspension speaker (8 ohms), #40-1197 (before 2002) at Radio Shack and attach with four 3/8" X 8 panhead screws. (new cat. no. for speaker after 2002)

As you look at the back, have the + and - terminals on the right side.

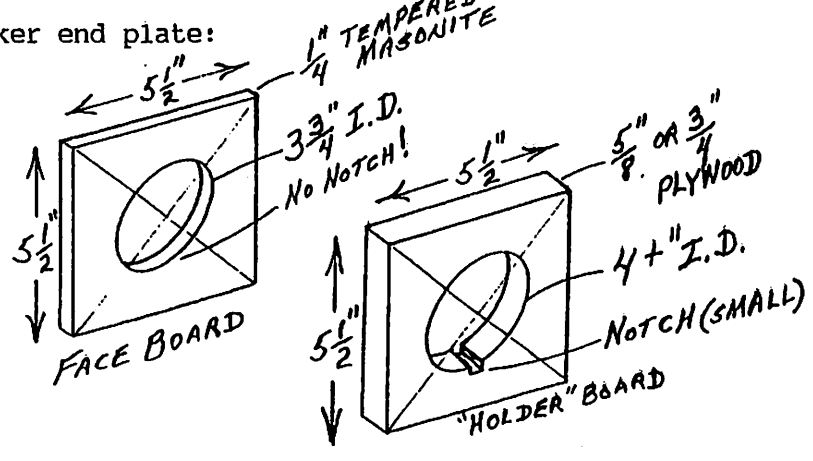


Extra needs: 4 - 3/16" bolts, washers, and wing nuts - length depends on the thickness of the plywood used

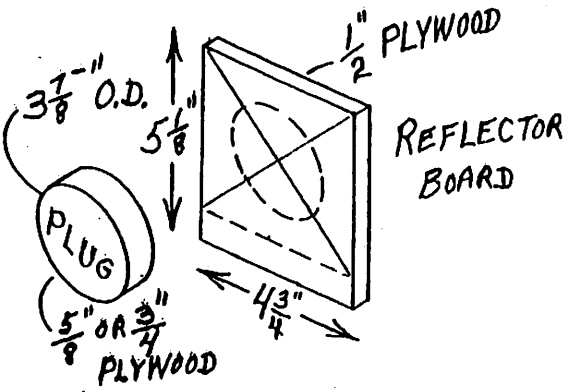
The end (pipe) plates (Johnston design): made from wood and tempered masonite

This gets tricky if you want a reasonably tight fit on each end. Remember, however, that the gasket seal can easily cover up slight gaps. I am giving you ID's and OD's that are close. For the speaker end plate, if you have a sanding drum, you can easily increase a slightly small ID up to a correct fit. If the ID is too large (pipe inside is too loose), clean the end of the pipe with white gas and try some electrician's tape or masking tape around the outside of the pipe to increase its OD. You may not need to go all the way around the pipe with the tape. You can always pull back and cut off too much tape from the pipe. It's time for "trial and error"! Also, a little notch in the"holder" board is required to allow for the seam on the bottom of the pipe. The opening on the masonite face board is smaller and without a notch, as it serves as a "stop" for the end of the pipe and a smooth face (junction and seal) for the Saran Wrap of the speaker plate flange when bolted together. It's the Saran Wrap that "seals" that end of the tube to prevent a gas leak; the bolts make it a "pressure seal". For the reflector (board) end plate, the "plug" is glued and nailed to the board as shown. If the plug OD is too great, sand it down; if too small, wrap some tape around the plug to increase its OD. More "trial and error"!

speaker end plate:

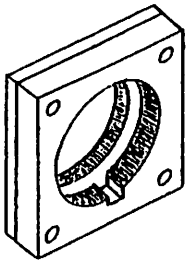


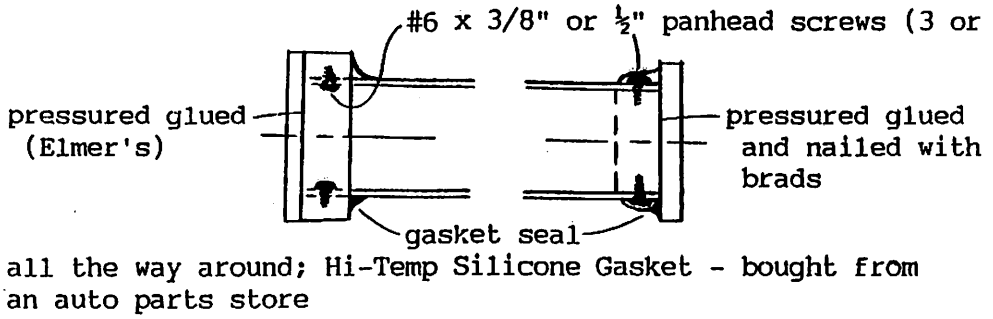
reflector end plate:

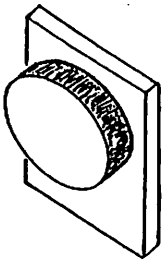


Note: Make the face board as shown. When you have cut out the hole and notch on the "holder" board, you must try it on the end of the pipe for size and make any further adjustments for a reasonably tight fit. Only after you are satisfied with the fit, do you pressure glue the face and holder boards together to complete the speaker end plate. Now match up the speaker plate (without the speaker attached) with the speaker end plate to drill the four 3/16" bolt holes.
Make the reflector board as shown. When you have cut out the "plug", you must try it in the end of the pipe for size and make any further adjustments for a reasonably tight fit. Only after you are satisfied with the fit do you pressure glue the plug and reflector board together to complete the reflector end plate. The plug bottom should be up about 13/16" from the bottom of the reflector board.

Finished end plates and their attachment to the pipe:





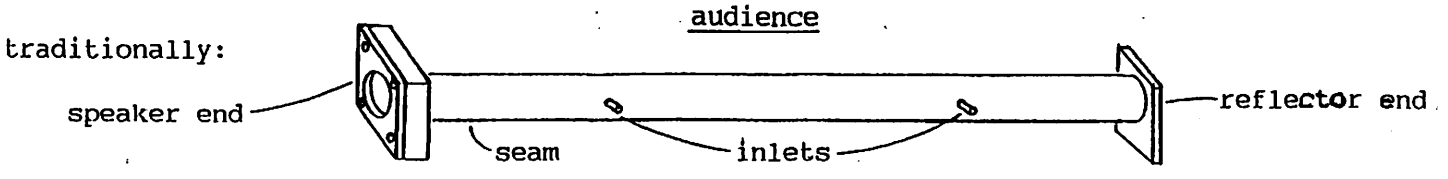


all the way around; Hi-Temp Silicone Gasket - bought from an auto parts store

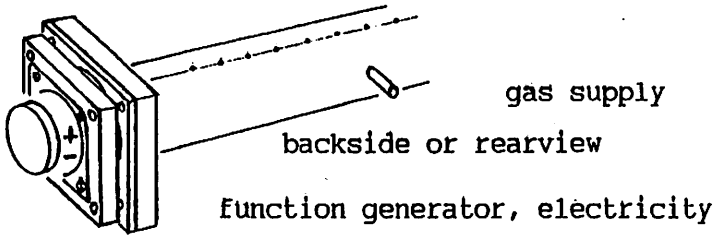
Notes: To fasten the speaker end plate, Philips head screws should be driven inside the tube. Predrill the metal tube from the outside, then press on the speaker end plate. With an angle driver (Eazypower #80943, ¼" Hex) and a 3/32" hex drill bit, drill the pilot holes for the #6 x 3/8" or ½" Philips panhead screws. Drive the screws inside with a right angle hand driver ( ). To shorten the drill bit (which is too long), cut the butt of the hex shank off and grind flat. To make the shank fit tight in the angle driver's socket, add a little masking tape to the side(s) of the shank until it fits snug in the socket so it won't fall out while being used.

Clean all metal areas with white gas (Coleman's) where gasket seal and epoxy putty ~~(is)~~ are to be applied. The pipe generally comes with an oily film to retard rusting.

Decision time. With the pipe's seam on the bottom and the future gas inlets on the back side, consider which end you want the speaker on as you operate it and the audience sees it. Decide the positions of all gas inlets and end plates before attaching anything permanently.



On my tube, I have the speaker + and − terminals facing the back.



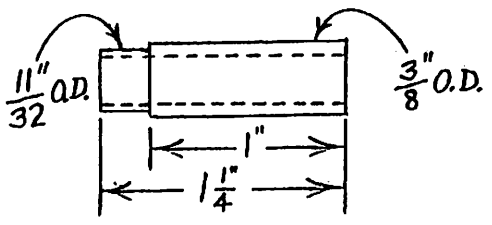
Notes: When attaching the end plates, attach the speaker plate first so the pipe's seam is on the bottom; drill the pilot holes with the angle driver and twist in the screws. Don't over-twist the screws and tear out the wood's "treads" - plywood is "soft"! The difficult part is finding a long, even place on a tabletop or floor (wall?), so the reflector (plug) end plate can be properly aligned with the speaker plate (won't wobble too much when used).

(cont.)

Insert the "plug" in the remaining end (with predrilled screws holes in the tube) and twist the plate until it is aligned with the speaker plate. Drill the final screwholes in the "plug" and screw things together. The proper alignment is one of craftsmanship; it is not critical to the tube's operation.

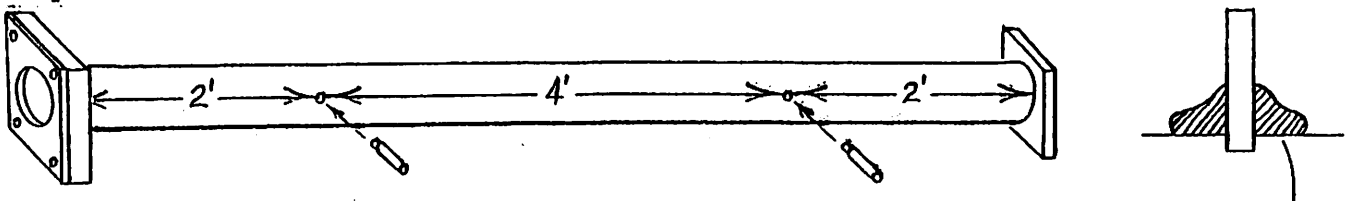
With both end plates fastened securely, apply a generous portion of gasket seal to cover the seam between the wood plates and the metal tube. Also, cover the screwheads on the reflector plate. The seals on both ends of the tube must be perfect (no leaks), or you will have a fire when you start up the tube for the first time. If this happens, turn off the gas immediately. Inspect the leak and add more gasket seal. Remember, it takes about 24 hrs. for the seal to "dry" (cure?). Gasket seal is like most caulks that come in a tube; it has a separate nozzle that must be cut off at an angle. Use a fairly large opening; the job requires a generous amount, and it makes it easier to push out of the tube. One tube of gasket seal is plenty! Push the nozzle back and forth while applying, to push the seal into the seam and make a "fillet". When done, remove the nozzle and seal the tube of caulk with its original cap. Let the caulk in the nozzle "cure" (dry) and poke it out later so the "clear" nozzle can be used again.

The gas inlets (VMI - Union C. design):



Use 3/8" O.D. copper tubing; bend it as straight as possible before cutting off the coil; put in a metal lathe; and carefully turn down one end slightly (to 11/32" O.D.) for a little shoulder for a stronger junction with the smoke pipe. 5/16" I.D. red rubber hose works fine to attach 3/8" O.D. copper tubing (gas inlets) to gas jets (supplies).

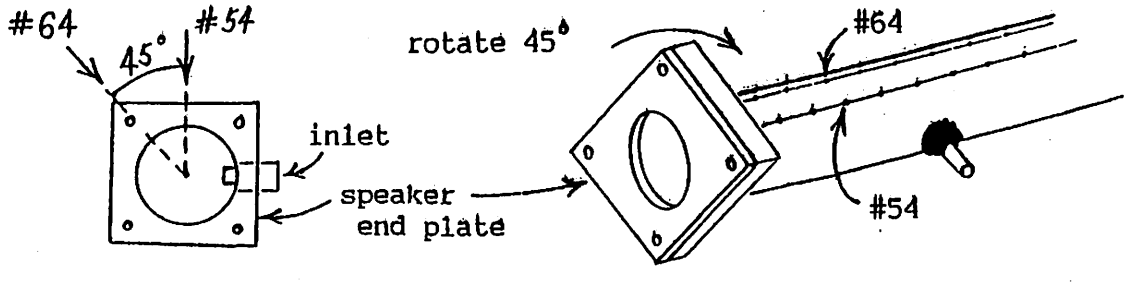
With the smoke pipe seam on the bottom, drill two clean gas inlet holes in the back side (approximately 90° from the bottom seam) of the pipe with an 11/32" bit. Remember which is the speaker end thus, the "back" side of the tube. Remember, also, to clean, with white gas, the area around the holes in the pipe and "shine up" the copper's surface before using the epoxy putty. The inlets should "putty" in beautifully.



Note: If you do not have a metal lathe, try to find someone who does, living near you (a gunsmith?) who could perform this task for you. If not, drill a 3/8" dia. hole(s) in the pipe, insert the copper gas inlet(s) about 3/16" and "putty" the inlet(s) in place. Use a "fillet" around the inlet to strengthen the junction.

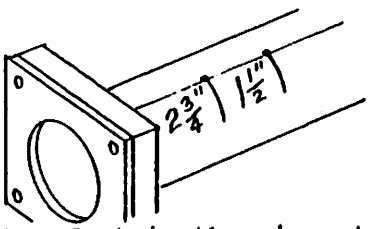
The flame holes (VMI - Union C. - Johnston design):

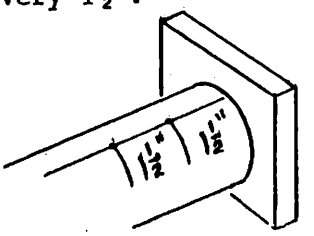
Decision time. Do you want a tube that uses only methane or only propane or uses both? If you are sure of using only one gas, you need only drill one set of holes on top of the pipe for that gas (#54 for methane and #64 for propane). If you decide on the multi-purpose tube, you must drill two different sets of holes for each gas. I use methane at home, and wherever I can find it on the road. I convert to propane only when methane is not available or the pressure is too low. I drilled my two sets of holes 45° apart as described in the diagram.



Note: The set of holes I'm not using is covered with fresh plastic electrical tape (one with a dull finish, not the shiny 3M kind). I leave the tape on the tube for only a couple of months while using it. If I store it for a longer time, I remove and discard the tape. Never apply a slimy, gummy old tape that will clog up the holes, or leave the tape on too long allowing this condition to develop. A roll of tape stored in a cool, slightly humid place (a cellar?) will last many years.

The drilling operation. Lay out a straight center line from end to end on top of the pipe. Starting on the solid reflector end, mark the center line every 1½".

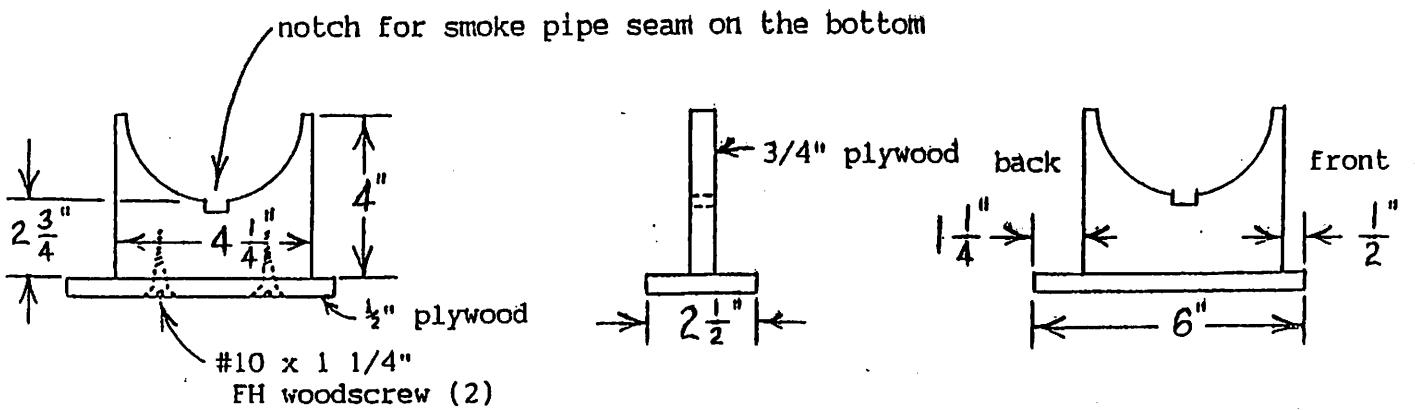




Simply make a little dent in the pipe at each mark; there are sping-loaded metal center punches for this operation, but a simple metal center punch and hammer will do. The dent centers the drill and holds a little "cutting" fluid (3 in 1 oil will do). With this procedure, I have never broken a drill; I do recommend, however, that you keep a spare(s) on hand. I used a hand-held electric drill straight down with light pressure. A new, sharp bit will do the work. Use a drill bit in your fingers or a "pin vise" to ream out any metal flakes and oil that do not leave the hole clean and clear. If the hole becomes slightly larger because of tearing the flake off, it won't matter - not critical. You should have around 65 holes or so when you are finished. I did not drill the last hole near the speaker end plate; thus, I left a space of about 2 3/4" to lessen any heat build-up on the plate, Saran Wrap, etc.

The 1 pair of stands (Johnston design):

The stands are made of ½" and 3/4" plywood. They can be spaced any suitable distance apart allowing the tube to be set up almost anywhere. They raise the multi-purpose tube up so it can be rotated 45° (gas inlets downward) into the propane gas position.



Special acknowledgments.

My original inspiration came from the remarkably successful tube built and demonstrated by Professors D. Rae Carpenter, Jr. and Richard B. Minnix of the Physics Department at the Virginia Military Institute in Lexington, Virginia. Their "VMI design" is so fundamentally sound that little, if any, change was necessary.
While building the tube, I benefited greatly from the special construction techniques, now the added "Union C. design", developed by Mr. Jack Hogle, Chief machinist of the Physics Department at Union College in Schenectady, New York. We finally built three of these tubes together. The use of epoxy putty also came from Union C. many years later.
In conclusion, I could not have developed my special, successful design without the exceptional talents and expertise of these men. I will always be very grateful for their many lessons and patience with me.

Operating procedures:

(a) After installing the Saran Wrap, drumhead-tight, over the flange, bolt the speaker plate tightly to the speaker end plate (4 bolts).

(b) Tape over the unused set of holes, if necessary, and connect the tube's gas inlets with tight-fitting hoses to the gas supply (jets?).

(c) Having done everything to prevent a possible gas leak, turn the gas on part way, allowing the gas to fill up the tube. (I use wood matches.) When the tube seems filled with gas, light a match and move it steadily over the holes as fast as the flames form. If a flame goes out, relight it immediately. Be prepared to immediately turn down or turn off the gas if any flame is more than a couple of inches high. Your gas control is more important than a fire extinguisher! If the flames are too low, turn up the gas.

(d) Adjust the gas supply to get steady, well-shaped flames that "stand up". Too much gas (too much pressure) will blow the flames out. Too little and the flames will "drift" or "sag" with the slightest draft or breeze in the room.

(e) Turn on the sound system and play into the tube; adjust the speaker volume and the gas supply for a "best flame pattern".

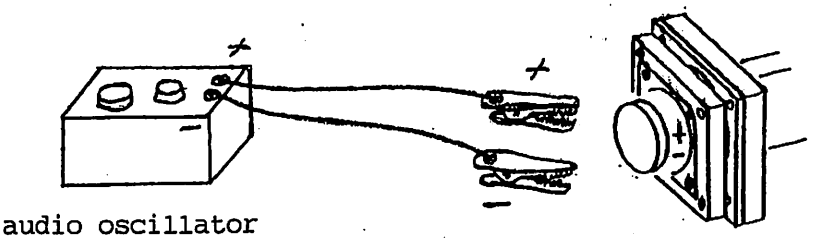
(f) You will quickly learn that a change in audio frequency will require a change in volume for a "best flame pattern" and that dropping from higher to lower frequencies produces smoother flame patterns than the reverse procedure. Practice is time and effort well-spent.

(g) Plan to do all of your demonstrations in as short a time as possible. A closed-up room (no doors or windows open) with fans and/or blowers turned off is best to operate in; you want to eliminate all possible drafts or breezes. This situation, of course, will quickly become stuffy and warm from the large amount of energy released by the burning gas. Again, practice will probably allow you to modify this situation somewhat (to provide for some ventilation) without affecting the flame pattern.

(h) When you are ready to turn off the gas, rapidly blow out the flames first. This will prevent any "suck-back" of the flames into the tube which might be dangerous. Then turn off the gas. Disconnect the hoses and unbolt the wood speaker plate to allow the gas to dissipate faster. Remember to remove the tape over the holes before any lengthy storage.

Electronic signals to the speaker plate (tube speaker):

(a) Simple wave (flame) patterns due to changes in amplitude (volume or gain) and frequency (function generator). (VMI-Johnston design)



audio oscillator

(b) "Beats" with a one-speaker flame tube. (VMI-Johnston design) Turn down the gas supply (keep flames low); may need to turn up the volume a little. Keep frequency low (long wavelength). Need two 100-ohm resistors (from Radio Shack?).