CONSTRUCTION DETAILS
OF
ISOKINETIC SOURCE-SAMPLING EQUIPMENT

by

Robert M. Martin

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air Programs
Research Triangle Park, North Carolina
April 1971

The APTD (Air Pollution Technical Data) series of reports is issued by the Office of Air Programs, Environmental Protection Agency, to report technical data of interest to a limited number of readers. Copies of APTD reports are available free of charge to Federal employees, current contractors and grantees, and non-profit organizations - as supplies permit - from the Air Pollution Technical Information Center, Environmental Protection Agency, Research Triangle Park, North Carolina 27711 or may be obtained, for a nominal cost, from the National Technical Information Service, 5285 Port Royal Road, Springfield, Virginia 22151.

Publication No. APTD-0581

LIST OF FIGURES

LIST OF TABLES

CONTENTS

CONSTRUCTION DETAILS
OF
ISOKINETIC SOURCE-SAMPLING EQUIPMENT

INTRODUCTION

The following discussion was prepared in order that interested persons in local air pollution agencies might build their own source-sampling equipment. This equipment was designed and has been used since 1967 by employees of the U.S. Environmental Protection Agency's Air Pollution Control Office (APCO).* In a field test, the equipment was run for two 24-hour periods without encountering any malfunctions. APCO Publication No. APTD-0576, Maintenance, Calibration, and Operation of Isokinetic Source-Sampling Equipment, is recommended for use when the equipment becomes operational.

The ideas and experiences of numerous people, gained from many tests on a variety of sources, contributed to the design of this equipment. Although performance has been satisfactory in most instances, this equipment, like most, can still be improved.

A similar set of equipment is available commercially. It is being marketed for approximately $2,200 (1970 price). The commercial package includes the meter box, umbilical cord, sample box with glassware, and a probe.

---

*Formerly the National Air Pollution Control Administration.

METER BOX CONSTRUCTION

WOOD PARTS

Cut out the sides and top of the case from exterior grade 3/8-inch-thick plywood according to the specifications in Table 1 and Figure 1. Apply a good grade of casein or resorcinol glue, and nail these three parts together with 1-inch brads. Cut out and attach the back to this assembly. Cut the panel supports from pine, and glue and nail them to the inside of the case. Next, cut out the bottom (Figure 2) from 1/2-inch-thick exterior plywood, and make the 1/4-inch-wide groove for insertion of the panel.

Cut the bottom frame from 1- by 1-inch aluminum angle (Table 1), and weld the underside of each of the four corners. Drill and countersink 12 holes, 3 in each piece; and attach the frame to the underside of the bottom with 1/2-inch flathead screws. Figure 2 shows construction details for the meter box case bottom.

Cut out the panel from 1/4-inch-thick tempered Masonite,* and drill the holes according to the dimensions and pattern shown in Figure 3. Dimensions of some of the components and hole diameters may differ in size from those on the figure because of equipment changes. Check sizes before making the holes.

PLUMBING PARTS

Table 2 shows the parts that are necessary for the installation of the plumbing. Bolt the pump to the bottom with 1/4- by 1-inch bolts. Remove the oiler that comes with the pump and install a 1/4-inch-diameter plug in the oiler inlet hole. Attach a 1/4-inch male pipe to the 3/8-inch sweat adaptors in the top inlet and outlet ports of the pump.

Install the two valves and the 1/2-inch quick disconnect on the panel; they support the panel temporarily in place while the piping is being located. Cut and fit the pipe from the quick disconnect up to the valves and over to the vacuum gauge. Modify the oiler by drilling a 1/4-inch hole through the body and inserting a pipe cleaner for a wick. The wick should point in the direction of airflow to achieve the desired capillary action of oil. Attach this assembly to the tee between the valves,

---

*Mention of a specific company or product does not constitute endorsement by the U.S. Environmental Protection Agency.

and join it to the pump; continue installing the piping up to the meter. Tighten and solder all connections; use Teflon tape on all threaded joints.

The meter can be attached in a number of ways; the simplest is by the use of pipe adaptors. The fittings that hold the thermometers must be drilled out to 5/32-inch in order to hold the thermometer stems. The thermometer used on the inlet side of the meter must be bent slightly in order to clear the meter mechanism as it cycles. The thermometers are secured in the Swagelok fittings with Teflon ferrules. Fabricate and install the orifice as shown in Figure 4. The orifice can be enlarged after construction to achieve a better calibration. This procedure will be discussed further in the section on calibration. Shape a piece of Pentafoam so that it can be used as a shock-absorbing wedge between the meter and the pump. Keep the size of the foam to a minimum to avoid interference with the cooling airflow.

Attach the manometer to the panel with two 1/4- by 2-inch bolts. Mount the optional solenoid valves on a piece of 1/4-inch plywood, and attach this assembly to the back of the panel. Complete the attachment of the Tygon tubing from the orifice and of the pitot disconnects to the solenoid valves and manometer. This completes the piping. The fan is attached to the plumbing by means of clips soldered to the tubing.

ELECTRICAL HOOKUP

Refer to Table 3 for a list of the necessary electrical components. Remove the panel from the base, and mount lights, switches, timer, powerstat, and buzzer on it. Begin the electrical hookup with the power cord, and follow wiring instructions in Figure 5. Insert a piece of metal behind the powerstat, and ground it to the frame of the timer. Also ground the pump and timer to the power cord through the timer frame. Double-check the wiring to the Amphenol fittings for proper orientation. Then hook up the SPDT switch to the solenoid valves on the manometer zero assembly. Plug in and test all circuits for proper operation. Use an electric drill or voltmeter to check the operation of the powerstat through the Amphenol connector. Adjust the timer connection so that the buzzer and pilot light operate approximately for 15 seconds at the start of each 5-minute interval. Replace the panel, connect the pump and fan wires, and test.

FINISH DETAILS

Place the case over the assembly, and locate the thermometer and fan holes. Cut out the fan holes, and cover with a screen or grill of your choice. Cut out the thermometer windows, inlay the Plexiglas disks, and glue into place. Attach handles as desired. Cut away, with a bandsaw, any unnecessary portion of manometer, and mount the latter on the panel with 1/4- by 2-inch machine screws. Keep the right edge of the manometer even with the edge of the panel. Bore 1/4-inch-diameter holes for manometer lines through the panel, and connect the lines to pitot leads and the solenoid valve block. Install the leveling device as shown in Figure 6. Secure the panel to the panel supports with 3/4-inch wood screws through the aluminum frame. Mark the controls for quick identification to avoid errors in switching. Attach the aluminum angle to the front cover, as shown in Figure 1. The instrument is now ready for painting and calibration.

OPTIONAL SOLENOID VALVE ASSEMBLY

The purpose of this device is to allow the meter box operator to zero the manometer more conveniently while the test is running. The cost of the unit is around $50; it is not, however, essential to the operation of the sampler.

The solenoid valve assembly should be installed as shown in Figure 7. Three two-way solenoid valves are used in this assembly; two are usually open, and one is usually closed. One of the open solenoid valves, followed by a closed solenoid valve, is located on the upstream tap and an open solenoid valve on the downstream tap. When these valves are energized by closing the switch, the flow is blocked into the manometer and the usually closed solenoid valve opens to allow the pressure to equalize and bring the manometer to zero. If leveling must be done during the test, the Tygon tubing can be temporarily disconnected from the manometer taps to manually rezero the manometer.

Table 1. MATERIALS FOR METER BOX CONSTRUCTION

Component size, in.	Number of pieces	Dimensions, in.	Placement
1/2 plywood	1	12-1/4 by 12-1/2	Bottom
1/2 plywood	1	12-1/2 by 13	Top
3/8 plywood	2	12-1/2 by 23-1/2	Sides
1/4 plywood	1	12-1/2 by 23-3/8	Back
1/4 plywood	1	13-1/4 by 23-3/8	Front
1/4 Masonite	1	12-1/2 by 22-3/4	Panel
3/4 pine	2	3/4 by 22-1/2	Panel supports
3/4 pine	1	3/4 by 12-1/2	Panel support
1/8 Plexiglas	2	2-1/2 diameter	Thermometer windows
1 by 1 aluminum angle	2	13-1/2	Base frame, width
1 by 1 aluminum angle	2	13	Base frame, depth

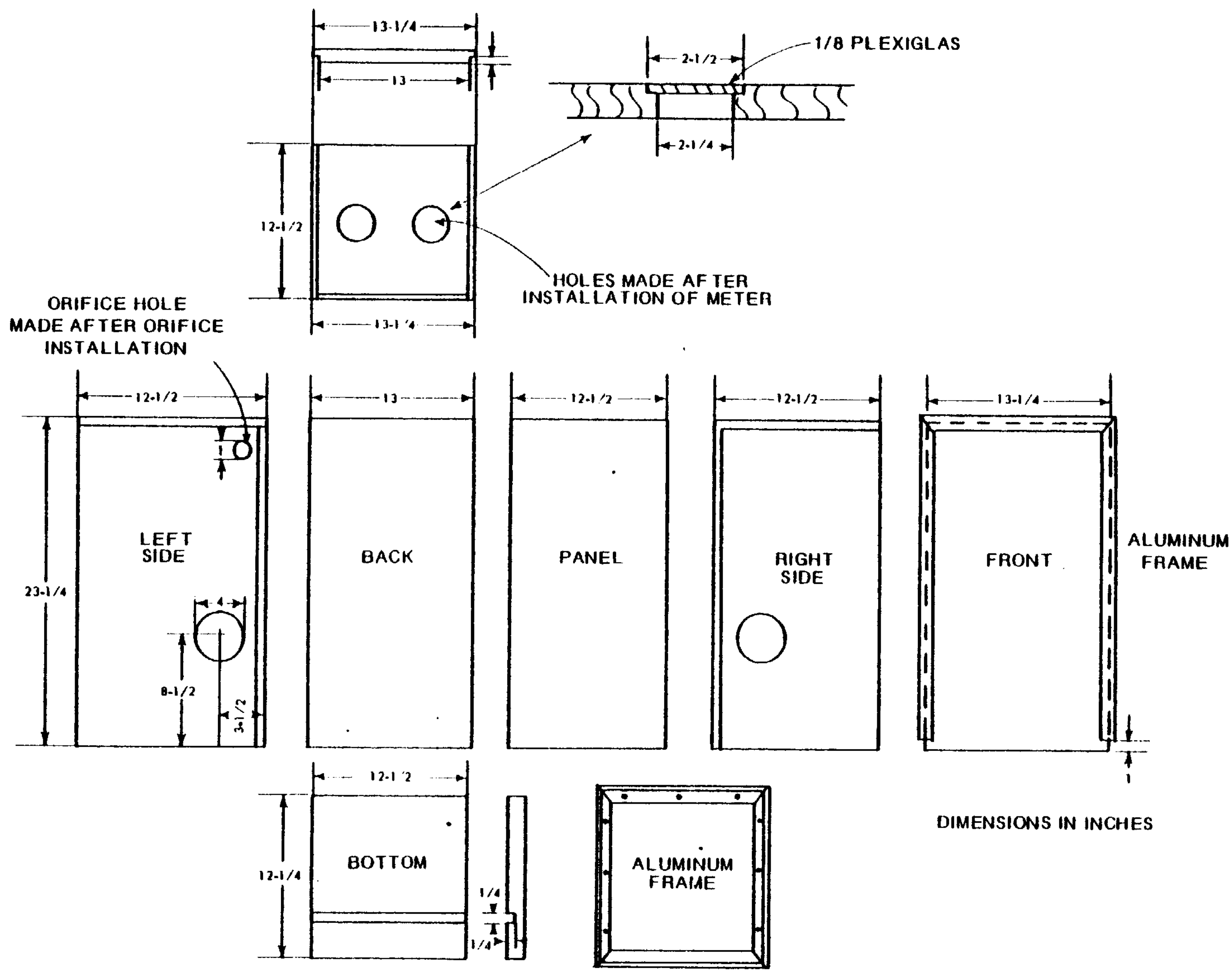


Figure 1. Meter box case construction diagram.

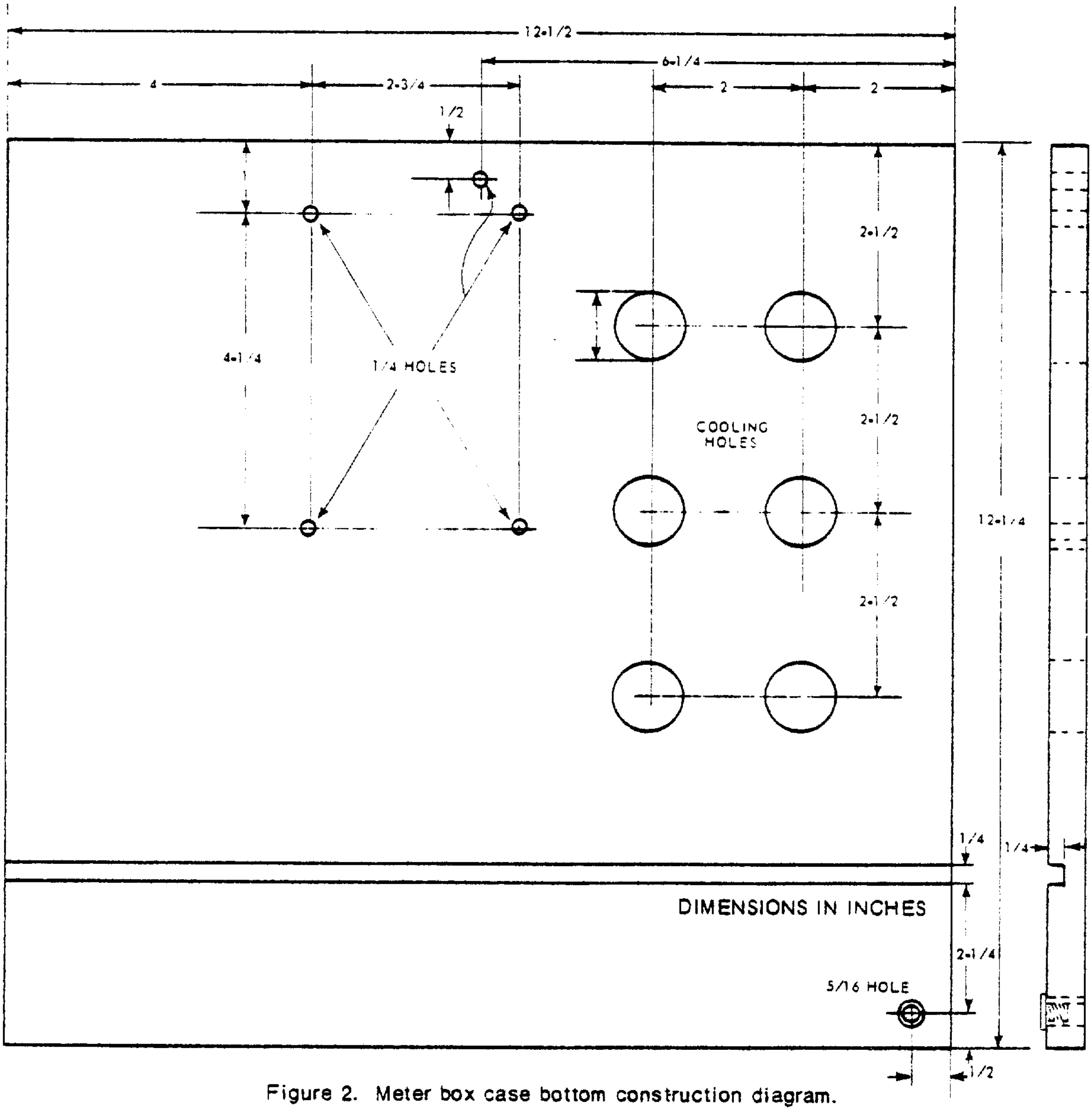


Figure 2. Meter box case bottom construction diagram.

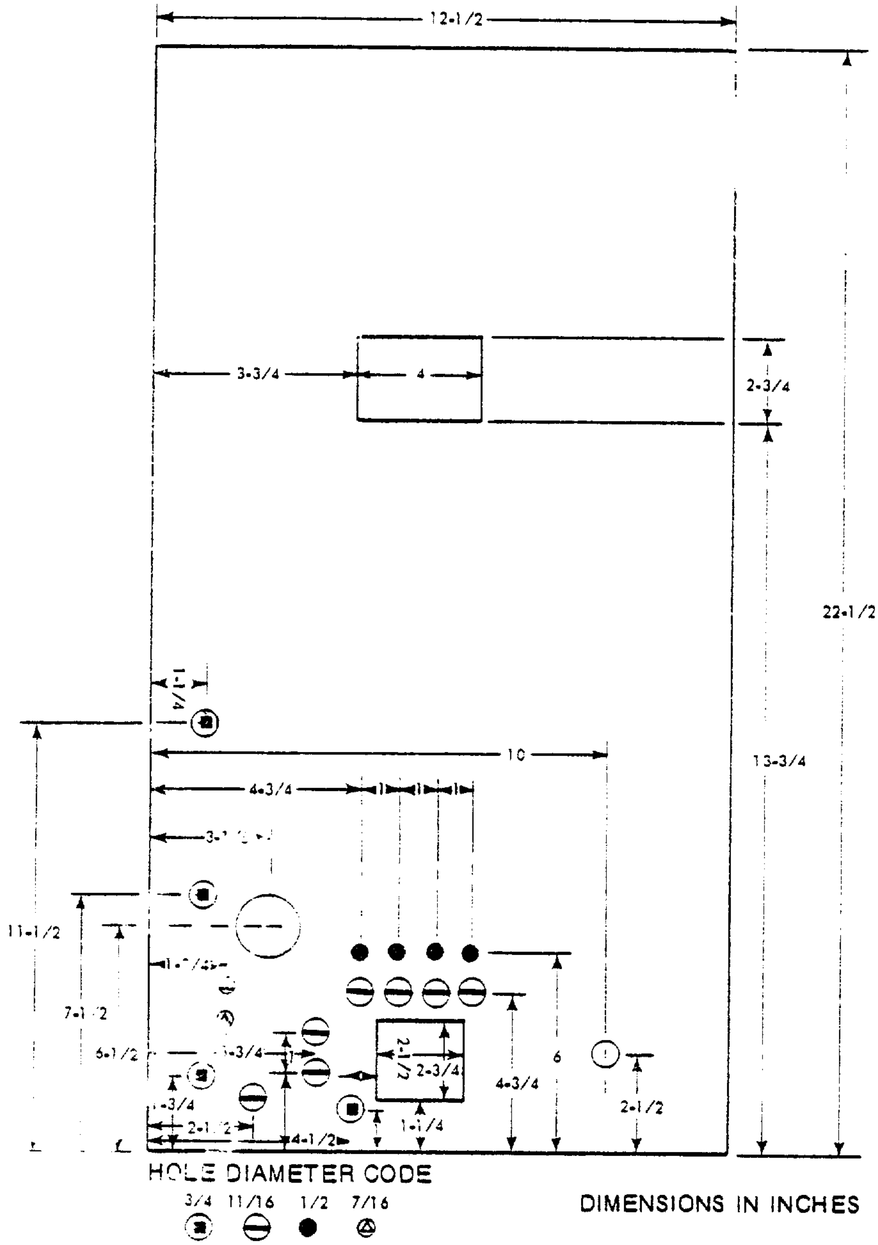


Figure 3. Meter box panel hole pattern diagram.

Table 2. PLUMBING PARTS LIST FOR METER BOX

Part	Description and/or catalog number
1 pump	Gast 522-V3
1 oiler	Gast, modified wick oiler
1 muffler	Gast glass jar, modified
1 vacuum gauge	Gast, 0-30 in.
1 gas meter	Rockwell N-68 S 175S 175CFH direct readout, $1 \times 10^{-2} ft^3$
1 manometer	Dwyer No. 422010, inclined vertical manometer
1 valve, needle	Whitey 1 RF 4-A
1 valve, ball	Hoke 30201-5
1 quick disconnect	Swagelok 810-1/2 in. QC-6100, bulkhead
2 quick disconnects	Swagelok 400-1/2 in. QC-6100, bulkhead
3 male elbows	Swagelok 600-2-4
1 male connector	Swagelok 400-1-2
3 adaptors	1/4-in. male pipe to 3/8-in. sweat, copper
1 adaptor	1/4-in. male pipe to 1/4-in. sweat, copper
1 adaptor	1/4-in. female pipe to 3/8-in. sweat, copper
4 ells	3/8-in. sweat, copper
2 tees	3/8-in. sweat, copper
1 tee	1/4-in. pipe, copper
3 nipples	1/4-in. pipe, close, copper
1 adaptor	1/4-in. male pipe to 1/8-in. male pipe, copper
1 union	3/8-in. sweat, copper
3-ft tubing	3/8-in. hard copper
3-ft tubing	1/4-in. soft copper
1 ell	1/4-in. sweat, copper
2 connectors	1/8-in. tubing to 1/16-in. butt-weld Swagelok 200-1-2W
4 inserts	1/4-in.-OD tubing; 1/8-in.-ID Swagelok 405-2
1 roll tape	"Strip Teeze" Swagelok, Teflon
2 ferrules	Swagelok 203-1, Teflon
2 ferrules	Swagelok 204-1, Teflon
6-ft tubing	1/4-in.-OD by 1/8-in.-ID Tygon
2 thermometers	Weston Model 2261 - 40° to 160° F

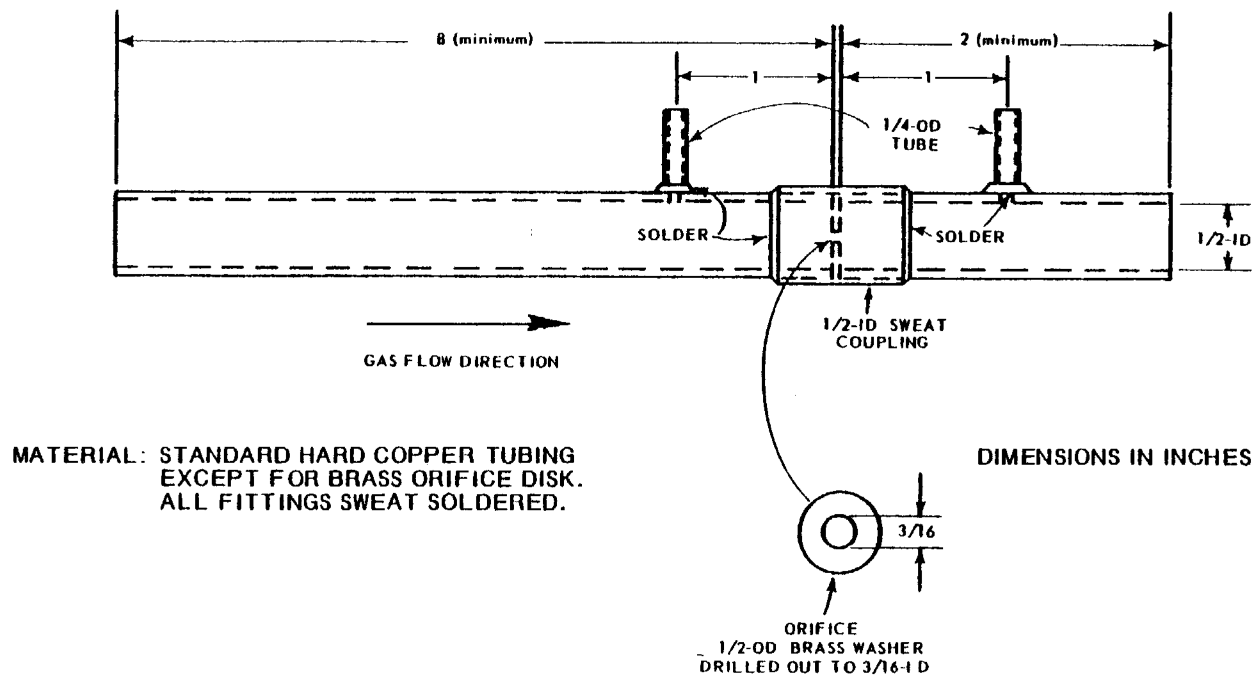


Figure 4. Orifice construction diagram.

Table 3. ELECTRICAL PARTS LIST FOR METER BOX[a]

Part	Part number and/or manufacturer	Cost, $
1 male plug	Eagle parallel ground-rubber-handle cap, 15 A @ 125 V Allied 26A3717	$ 0.45
4 SPDT toggle switches	Standard duty 115-V, 15-amp solder terminals Allied 56A4534	0.57
1 SPDT toggle switch	Standard duty 115-V, 15-amp solder terminals Allied 56A4536	0.66
6 pilot lights	Snaplite neon lights (pilot), series 32 Allied 60A7922	0.75
1 Amphenol connector	Series 3106A, 145-25	1.26
1 Amphenol cable clamp	3057-[illegible]	0.57
1 variable transformer	Powerstat, No. 10B Allied 54E2536	8.50
1 relay	Potter and Blumfield BU-120 AC	1.85
1 interval timer	Industrial timer CM-5 foundation unit Allied	18.75
1 gear rack assembly	Industrial timer A-30 Allied 58E8518	1.75
1 cooling fan	Rotron 100-cfm muffin fan venturi model Allied 60E8597	14.50
3 solenoid valves	Skinner Precision Industries, New Brittain, Connecticut B 2 DA9052 115/60 VN7-308	10.00 (approximately)
30-ft, 16-gauge stranded hookup wire		

[a]Allied Radio Catalog Numbers are provided for reference, not as suggestion for purchase.

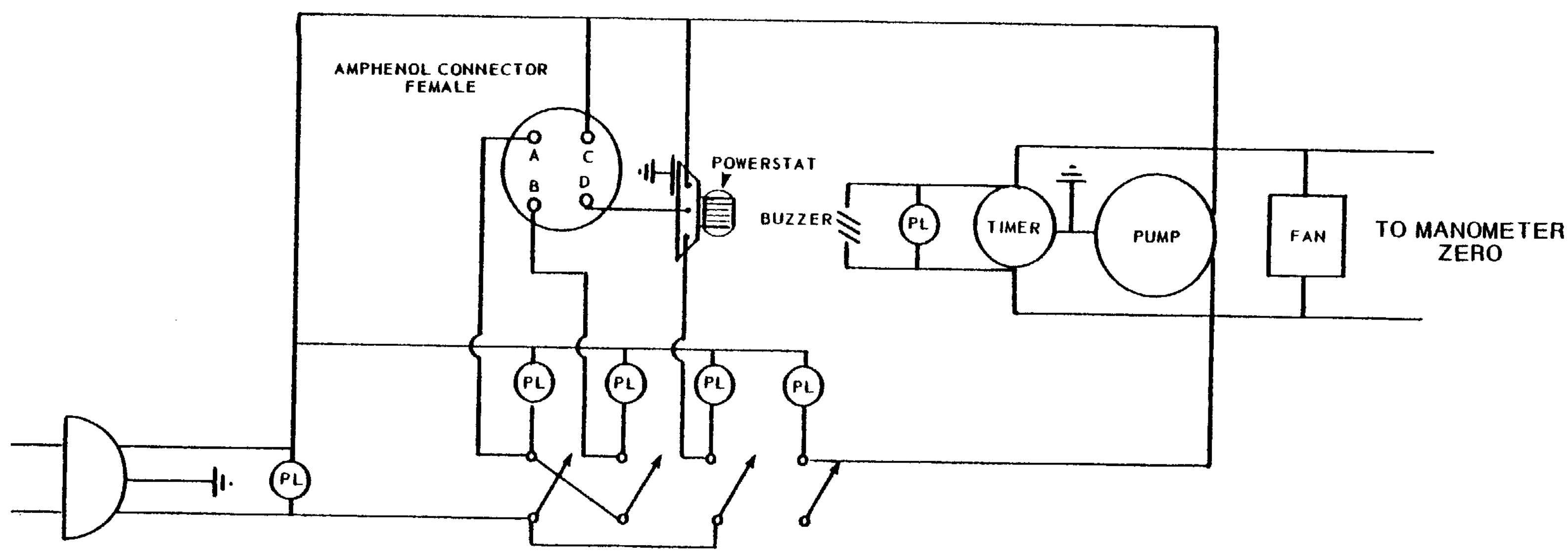


Figure 5. Meter box wiring diagram.

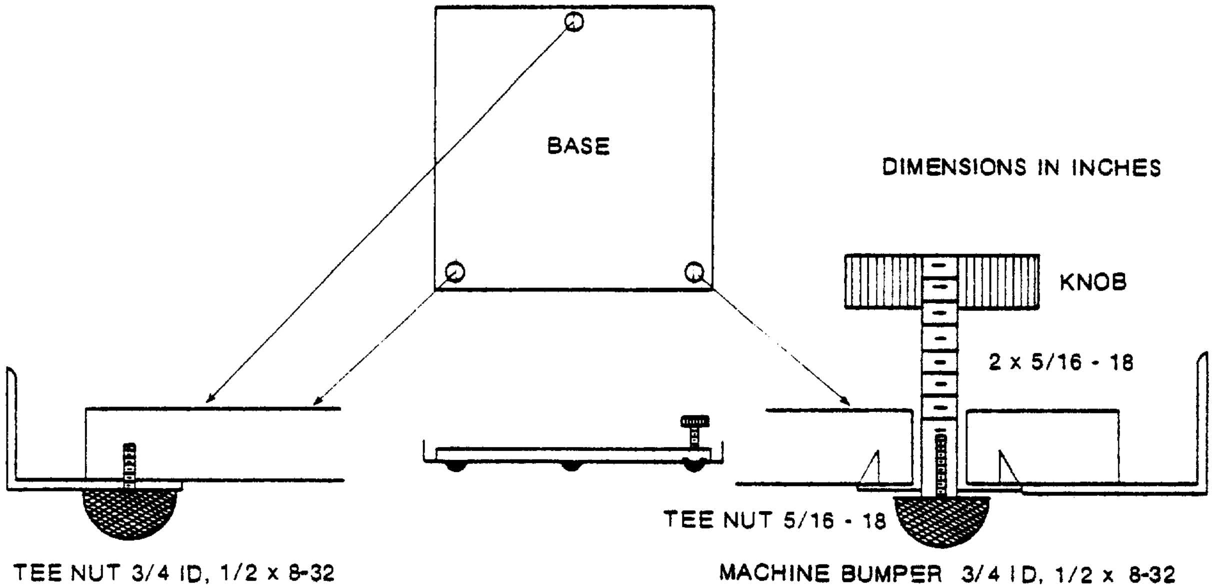


Figure 6. Leveling device construction diagram.

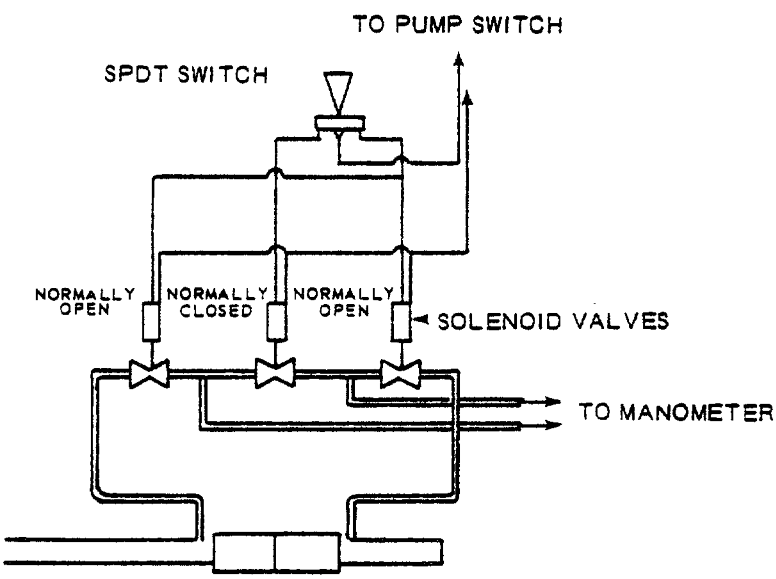
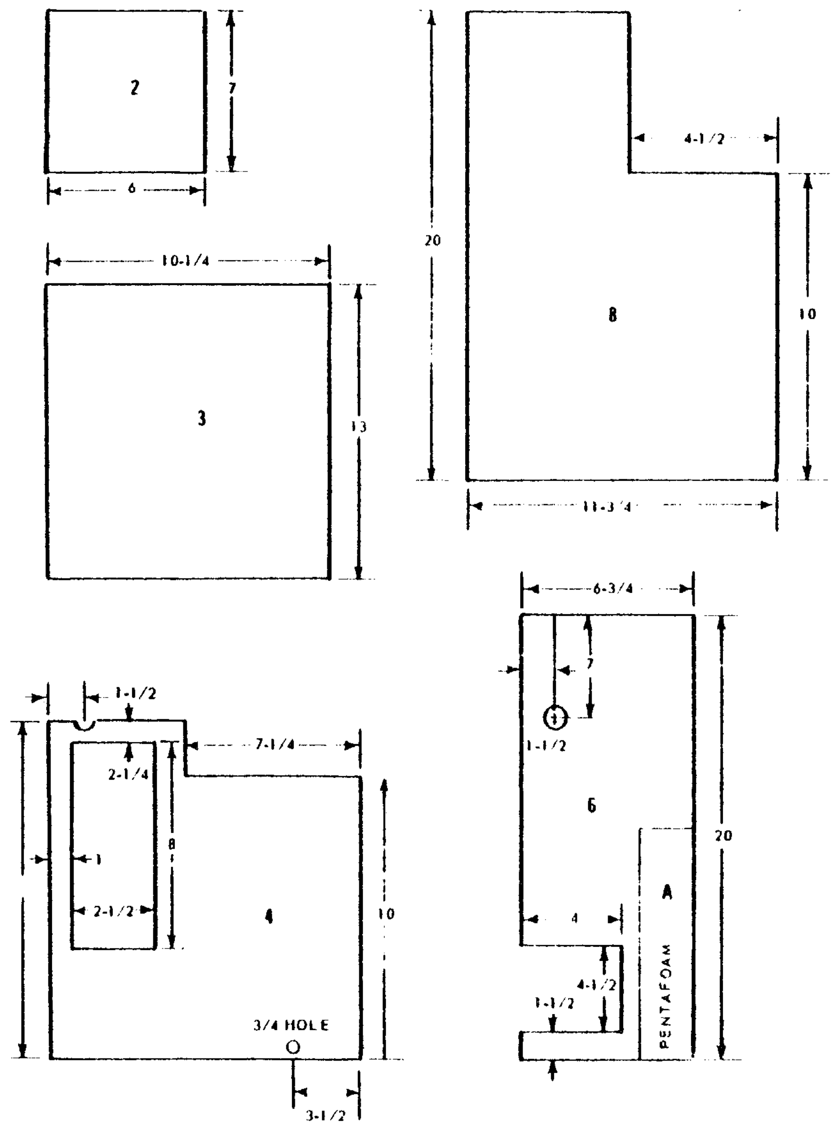


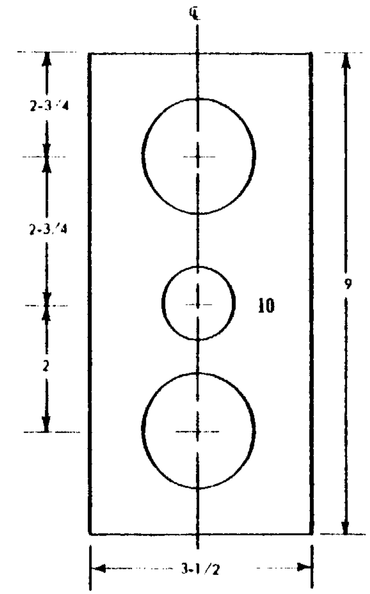
Figure 7. Optional solenoid assembly diagram.

SAMPLE BOX CONSTRUCTION

Refer to Figures 8 and 9 for part numbers. Figure 10 is a three-dimensional view of the assembled parts.

Begin construction by cutting out the parts. Attach part number 3 to parts 8, 6, and 4; attach with screws so that part 3 can be removed for servicing the fan and heater components. To this assembly, add bottom (part 9); attach with glue and screws except at the joint with part 3. Using glue and small brads, attach parts 7, 12, and 5, in that order. At this point, the impinger bath area (shaded section on Figure 11) should be lined with fiber glass cloth and resin to provide a water-tight compartment. Place tape on all joints and apply at least two coats of resin. While the fiber glass is curing, attach parts 1 and 2; add hinges for the attachment of part 3. Also install a catch and knob to part 1. An electrical parts list is given in Table 4, and Figure 12 shows a wiring diagram. Screw the thermostat housing, Amphenol fitting, and probe socket to part 10. Form an aluminum shield around the heating coil, and attach it to the blower. Remove part 3, and attach the blower and thermostat into place. Complete the wiring of the fan and thermostat, and replace part 3. Glue Pentafoam insulation onto parts 6 and 12, and insert impinger support (part 11). Paint the inside of the heater compartment with aluminum paint for heat reflection; also paint the exterior of the box.





MATERIALS:

3/8-EXTERIOR PLYWOOD
1 PC. 6 x 7 NO. 2
1 PC. 10-1/4 x 13 NO. 3
1 PC. 11-1/2 x 13 NO. 4
1 PC. 6-3/4 x 20 NO. 6
1 PC. 11-3/4 x 20 NO. 8
1 PC. 3-1/2 x 9 NO. 10

DIMENSIONS IN INCHES
(drawings not to scale)

Figure 8. Sample box construction dia im, plywood parts.

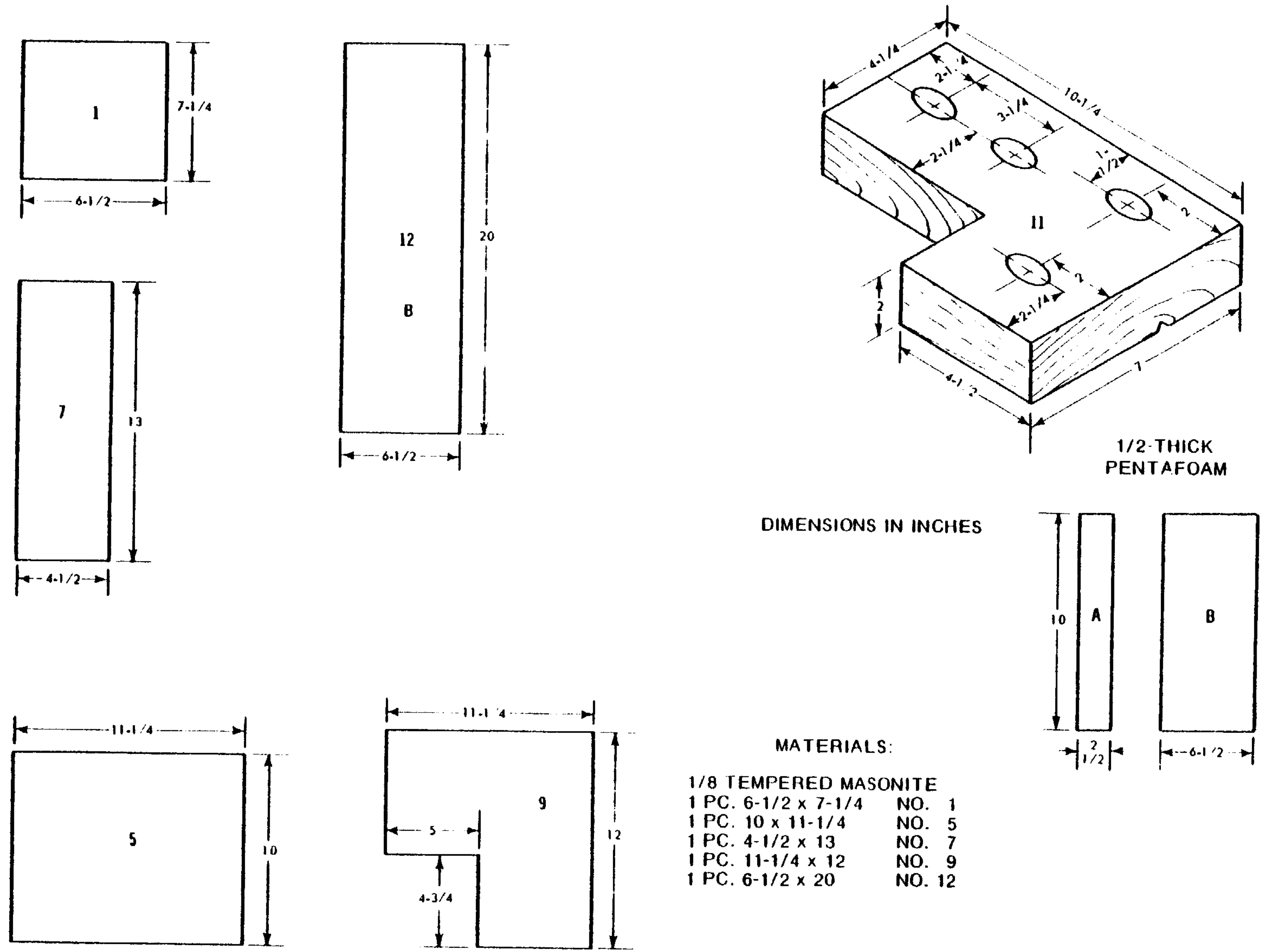


Figure 9. Sample box construction diagram, Masonite and Pentafoam parts.

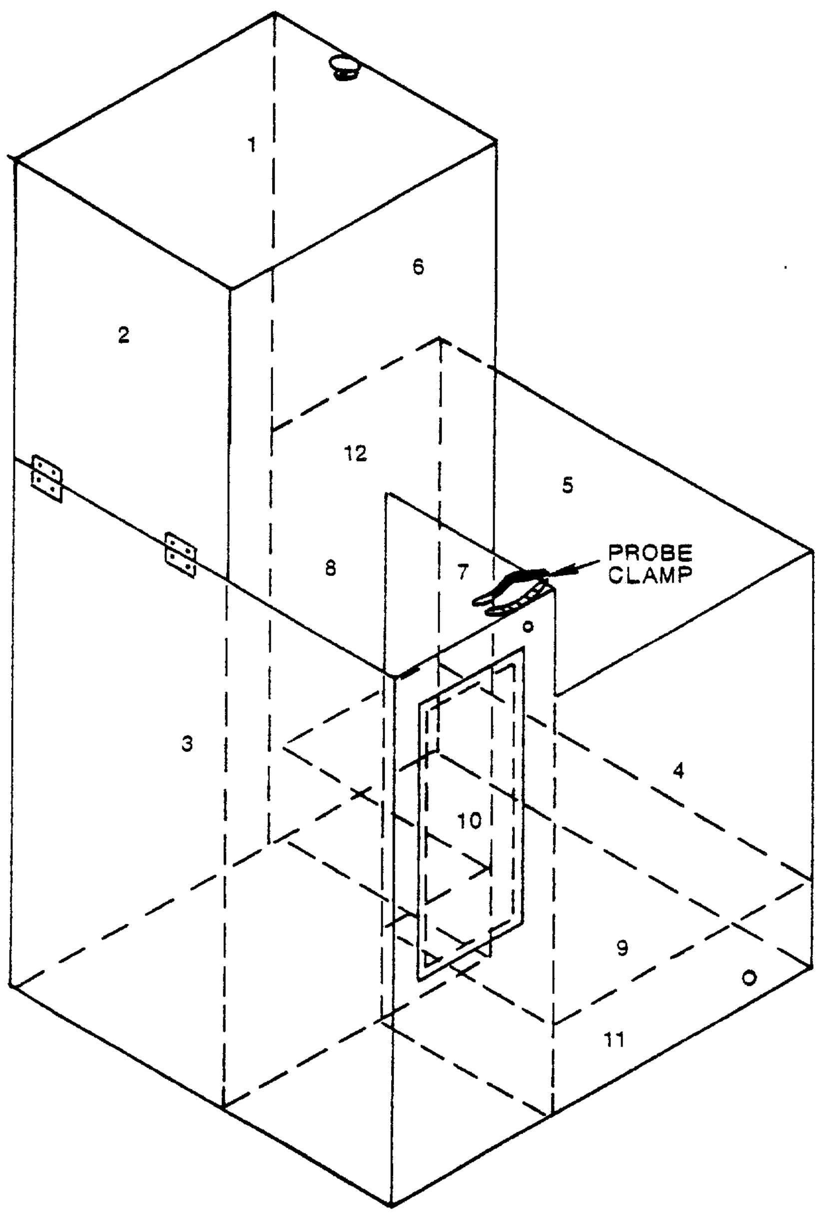


Figure 10. Three-dimensional view of sample box.

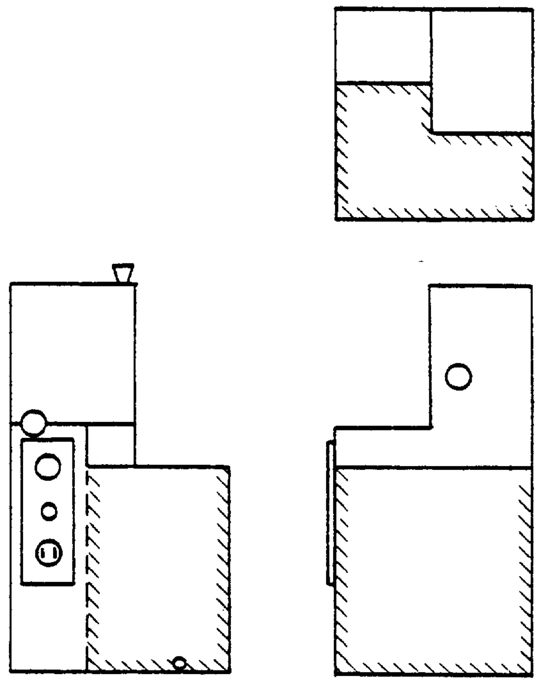


Figure 11. Impinger bath area. (Shaded area reinforced with fiber glass.)

Table 4. ELECTRICAL PARTS LIST FOR SAMPLE BOX

Part	Part number and/or manufacturer	Approximate cost, $
Amphenol connector	Series 310A, 145-2P	1.43
Amphenol cable clamp	3057-6	0.57
Thermostat	White Rodgers, St. Louis 23, Mo. 1002-6 Temperature Control	20.00
Blower	Dayton (1) 2C782 Dayton Electric Mfg. Company Chicago, Ill.	15.20
Heating element	Eagle Electric Mfg. Company Long Island City, N. Y.	1.50
Base, 2-piece porcelain	Eagle Electric Mfg. Company Long Island City, N. Y.	2.00
Socket	Amphenol 160-2 Allied No. 47E2524	0.93

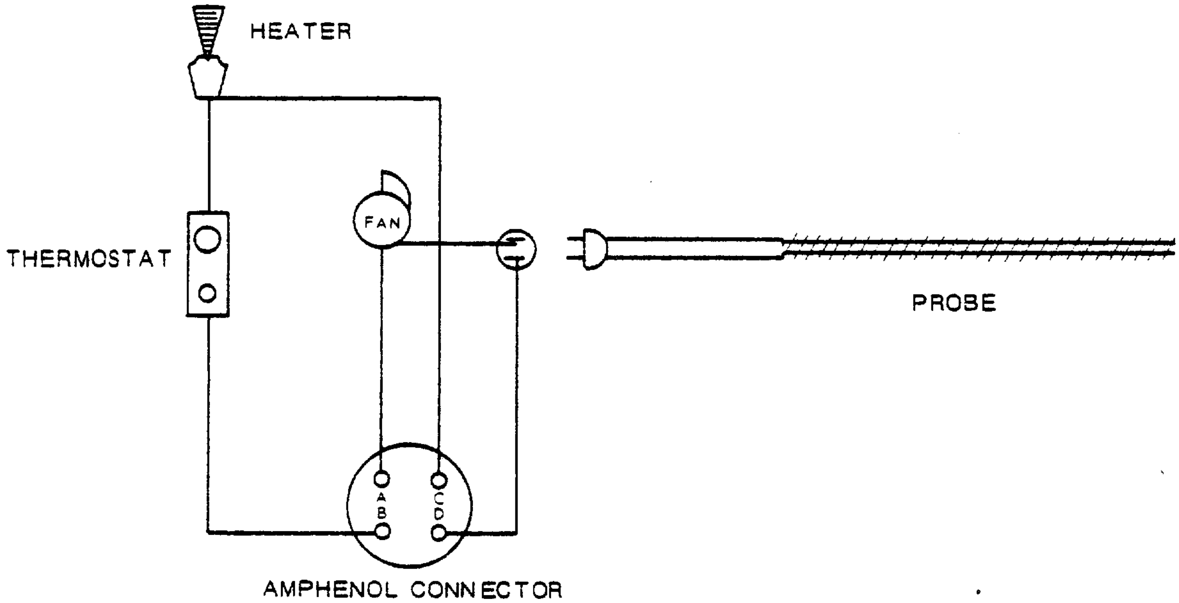


Figure 12. Sample box wiring diagram.

UMBILICAL CORD CONSTRUCTION

Table 5 is a parts list for umbilical cord construction. The umbilical cord may be made in any length up to 200 feet without encountering a prohibitive pressure drop; for convenience, however, it is preferable to make a number of cords, each 25 feet long. Figure 13 shows construction details for the umbilical cord. The cord is fabricated by cutting 25-foot lengths of the components—vacuum hose, electric wires, and pitot tubing—and laying them together in a clear working area. Starting 2 feet from one end, wrap the components together with a suitable tape such as "Mystic" cloth tape or plastic electrical tape. Wrap the cord up to 2 feet from the other end. Orient the ends of the cord by specifying one a meter end and the other a sample end; the meter end should be plugged into the meter box, and the sample end should be attached to the sample box.

At the meter end of the vacuum hose, attach a 1/2-inch male quick disconnect by screwing the thread of the 1/4-inch pipe into the hose. Attach the two male 1/4-inch quick disconnects to the pitot lines and solder the electric cords into the male Amphenol connector. On the sample end, attach the fittings in the same way, using a female Amphenol fitting and quick disconnects.

Table 5. PARTS LIST FOR 25-foot UMBILICAL CORD

Part	Description and/or catalog number
50-ft Tygon tubing	1/4-in.-OD by 1/8-in.-ID
25-ft pressure hose	3/8-in.-ID Neoprene air hose
50-ft electric cord	16-gauge zipcord
1 roll tape	Mystic or plastic electrical
2 quick disconnects	1/4 F 400 - 1/4 QC - 600
2 quick disconnects	1/4 M 400 - 1/4 QC - 200
1 quick disconnect	1/2 F 810-1/2 QC - 100 - 4
1 quick disconnect	1/2 M 810-1/2 QC - 200
1 Amphenol connection	Series 3106A - 145-25 (female)
1 Amphenol connection	Series 3101A - 145-25 (male)
2 Amphenol cable clamps	3057 - 6

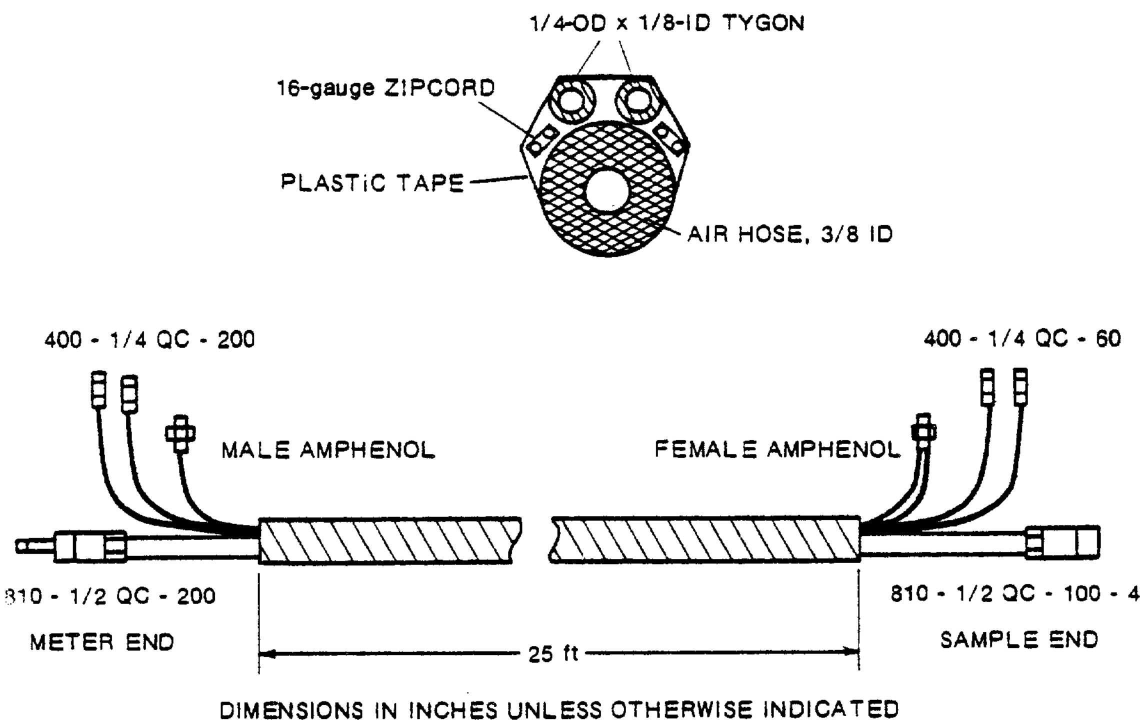


Figure 13. Umbilical cord construction diagram.

PITOBE CONSTRUCTION

Refer to Table 6 for the parts necessary for pitobe construction. Pitobes of any length from 2 to 10 feet may be used without encountering problems during sampling. The first step is to cut the sheath to the desired length and weld a Swagelok 5/8-inch ferrule nut onto one end of the tube. The nut must be square with the end of the tube. The use of a pilot shaft as shown in Figure 14 will ensure that it is square. Welding may be done with silver solder if the probe will not be used in stacks where the temperature exceeds 1,000° F; if higher temperatures will be encountered, arc welding will be necessary. On the opposite end of the sheath, cut a notch to clear the electric wire for the probe heat as shown in the figure.

PITOT

The pitot is made by bending a 45-degree angle on the end of a 3/8-inch stainless steel tube and cutting as shown in Figure 14. After two of these have been cut, they are welded together with the cut ends facing in opposite directions and in as good alignment as possible. The welds should be about 1 foot apart along the length of the pitot. The pitot should be 2 inches shorter than the sheath, and the last weld should not be closer than 6 inches from the end, as shown in Figure 14. Bend out the two ends slightly to facilitate attachment of quick disconnects. When the above steps have been completed, weld the pitot to the sheath using short pieces of 1/4-inch stainless steel. The center of the pitot opening must be 3-1/2 inches from the front of the sheath nut so that the pitot and nozzle will be adjacent during sampling. To determine the length relationship of the various parts, let L = length of the probe sheath with the nut welded on; then the length of the pitot tube without the quick disconnects will be L minus 2 inches, and the length of the glass probe will be L plus 2 inches.

PROBE GLASS

The glass insert length must be determined before the ball joint is attached. The latter usually must be custom-made by a glassblower. After the ball joint is attached, a No. 7 rubber stopper, bored as shown in Figure 14, is slipped onto the glass tube. After the stopper is in place, a 25-foot Nichrome wire is logarithmically wound onto the glass and held in place with glass electrical tape. The wire is doubled, and the winding is begun about 2 inches from the end and continued along the length of the probe. As each few inches is wound, a piece of tape is put on to hold the wire as the winding is continued. After the entire probe has been wound with wire, it is then rewound with the glass tape. The remaining two ends of the Nichrome wire are soldered to the zipcord, which plugs into the sample box.

Table 6. PITOBE PARTS LIST

Part	Description
1 union	Swagelok 1010-6
25-ft wire	Nichrome 26 B & S Curtin 22870 F
2 male quick disconnects	Swagelok 400-1/4 QC-200
1 rubber stopper	No. 7
1 ball joint	Ground glass No. 28
2-ft electrical cord	16-gauge 2-conductor zipcord
1 plug	Male, 2-prong
1 roll tape	Scotch electrical No. 27 - 4EGT - G784T
2-ft pitot tubing[a]	3/8-in.-OD thin-wall stainless steel
1-ft glass tube[a]	5/8-in.-OD Pyrex
1-ft probe sheath[a]	1-in.-OD by 0.035 wall MIL-T-8504 Seamless Summeril AWTR 304

[a]Per foot of pitobe.

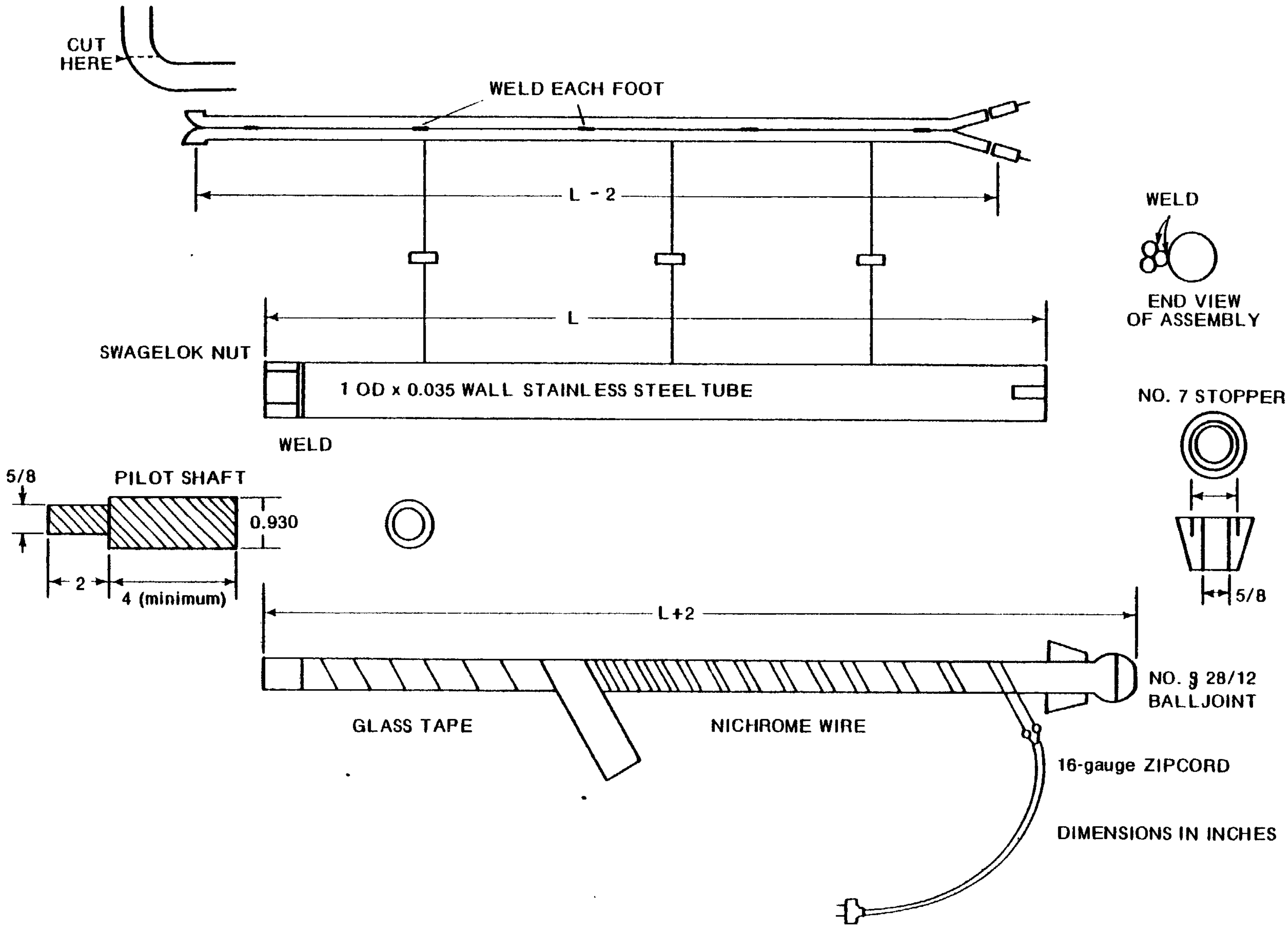


Figure 14. Pitobe construction diagram.

GLASSWARE

Refer to Table 7 for the glassware parts list. The probe is connected directly to a cyclone that has been modified by the addition of No. 28/15 ground-glass ball joints. The cyclone, built as shown in Figure 15, is attached to a modified filter holder (Figure 16) that has also been fitted with ball joints. The filter holder is held together with a clamp that is fabricated from 1/8-inch aluminum. This filter holder contains a glass frit and also has a silicone rubber gasket, which can be made by most gasket companies.

From the filter, a ball-joint-fitted connector leads into the first impinger. A set of three connectors then leads through the three remaining impingers. Refer to Table 8 for the impinger connector parts list. These impingers also have been modified by the addition of ball joints. The last impinger is attached to an umbilical cord connector that contains a check valve to prevent backpressure from pulling the impinger liquids into the filter. All of this glass modification should be done by a competent glassblower. If the sampling situation does not require the use of a cyclone, then a bypass fitting can be used.

Table 7. GLASSWARE PARTS LIST

Part	Description
Cyclone	Specially fabricated as shown in Figure 15
Filter	Fabricated
Impinger	6800 - Corning
Connectors	Fabricated from ball joint and 1/2-in.-ID glass tubing
Ball joints	Corning No. 6762 ball 28/12
Socket	Corning No. 6764 socket 28/12
Clamps	Ball and socket joint clamp size No. 28

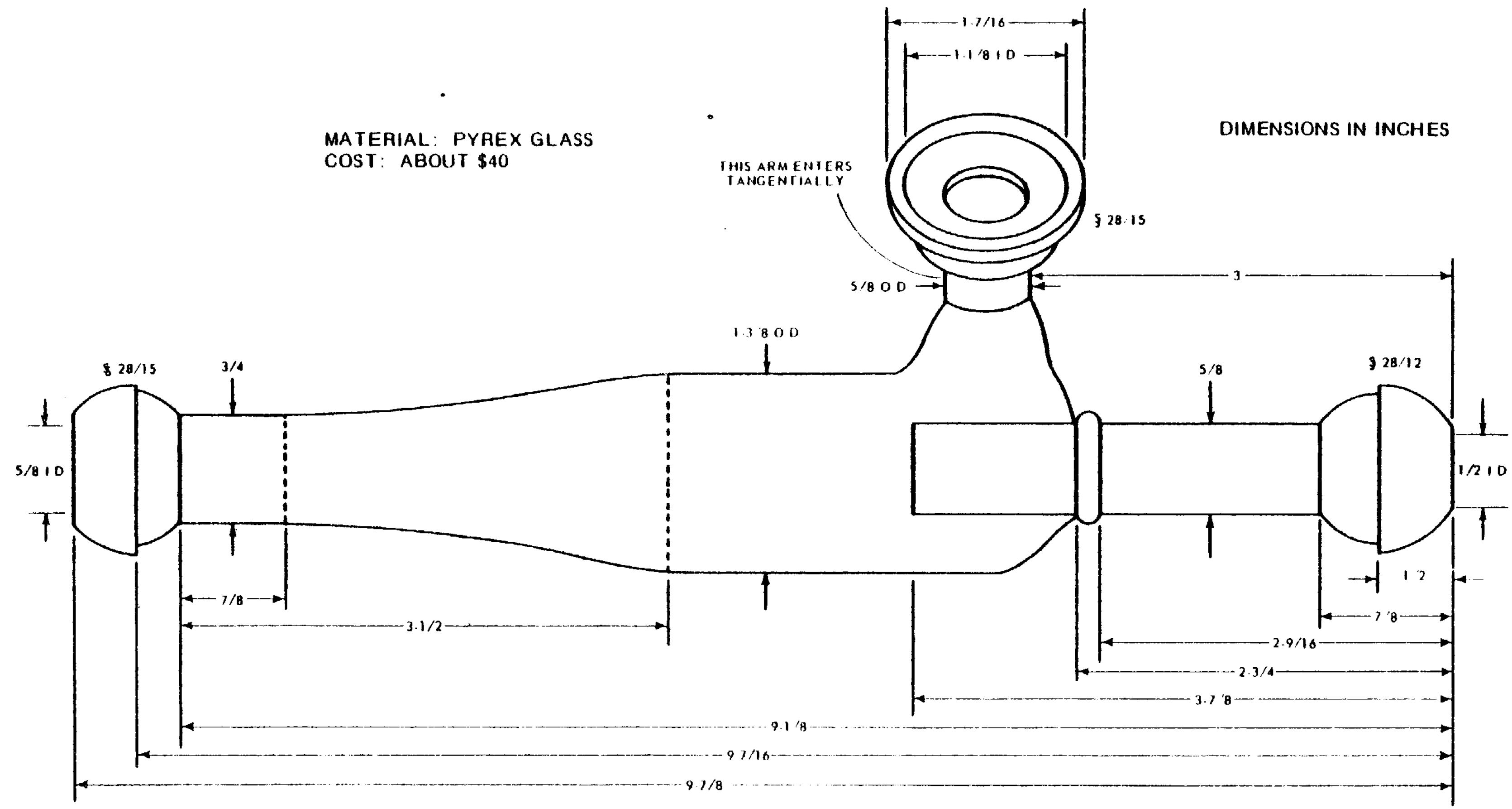


Figure 15. Source-sampling cyclone.

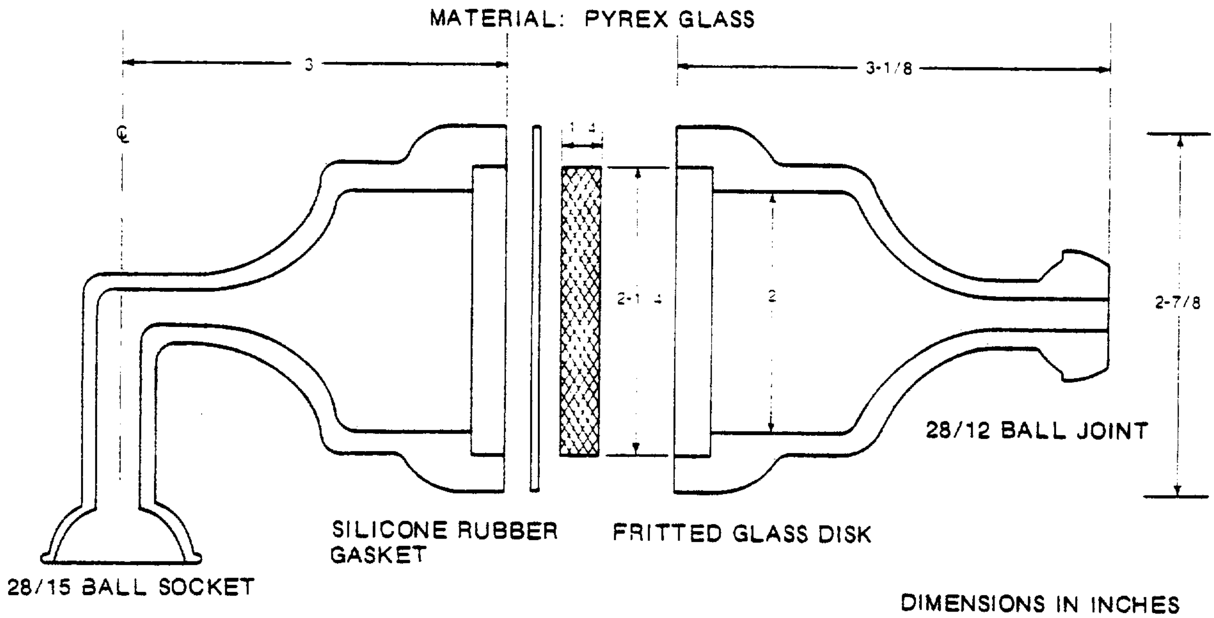


Figure 16. Sectional view of filter holder.

Table 8. PARTS LIST FOR IMPINGER CONNECTOR

Part	Description
Ball joint	Female, stainless steel
Check valve	NUPRO 8-C 1/2-in. tubing
Quick disconnect	Swagelok, 810-1/2-in. QC-600
Tube	3/8-in.-stainless steel, 3 in. long
Hose	3/8-in.-ID Neoprene air hose
Connector	Swagelok 200-1-2W, 1/8-in. tubing to butt weld
Thermometer	Weston dial Model 2292 25 - 125° F

CALIBRATION PROCEDURES FOR ORIFICE AND METER

A preliminary check should be made of the following parts for proper operation before trial test: pump, pump oil, quick disconnects, valves, manometers, dry test meter, thermometers, lights, buzzer, Amphenol, Variac, and vacuum gauge. Vacuum should be tested for leakage at 27 inches.

TERMINOLOGY

cfm	=	ft^3/min
$\Delta H_@$	=	Orifice pressure differential in inches of water that gives 0.75 cfm of air at 70° F and 29.92 in. Hg
Y	=	Dry meter differential, in. H_2O
P_b	=	Barometric pressure, in. Hg
CF_w	=	Wet test meter reading, ft^3
CF_d	=	Dry test meter reading, ft^3
T_w	=	Temperature, wet test meter, °F
IT_d	=	Input temperature, dry, °F
OT_d	=	Output temperature, dry, °F
T_d avg	=	$(IT_d + OT_d)/2$, °F
T	=	Time, minutes
WTM	=	Wet test meter

PROCEDURES

With the meter and pump enclosed and a wet test meter attached (1 cubic foot per revolution), allow the equipment to warm up and the dry parts of the WTM to become wetted (approximately 1/2 hour). Level the box by turning the adjusting screw in the lower right front corner. Then zero the manometer by placing the manometer switch in the up position; adjust the fluid level if necessary. After the warmup period, run a trial test at an orifice manometer setting of 2 inches H_2O and CF_w of 10 to obtain $\Delta H_@$ and Y.

Step 1

Calculate $\Delta H_@$ by using the formula

$$\Delta H_@ = \frac{0.0317 \text{ (manometer orifice)}}{P_b\ (OT_d + 460)} \left[\frac{(T_w + 460)t}{CF_w}\right]^2 \qquad (1)$$

If the value is not within 1.6 to 2.1 (1.84 desired), the orifice can be drilled in increments of 1/64 inch to lower the value; if the value is below 1.6, then the orifice should be replaced and the procedure repeated in calibration.

Step 2

Calculate Y by using the formula

$$Y = \frac{CF_w \cdot P_b \, (T_d \text{ avg} + 460)}{CF_d (P_b + 0.147) \, (T_w + 460)} \qquad (2)$$

Y is obtained during the trial run along with $\Delta H_@$. If the value is not within 0.99 and 1.01 (1.00 desired), adjustments have to be made to the meter. To adjust the meter, remove the four screws on the top of the meter, carefully remove the lid, and expose the lever mechanism to make sure that the adjusting nuts "A" and "B" are in position. To adjust the meter, "A" and "B" are turned clockwise to decrease the value of Y and counterclockwise to increase the value of Y. After making the adjustment, replace the lid and screws and run another trial test.

☆ U. S. GOVERNMENT PRINTING OFFICE: 1972 – 746-764 / 4120