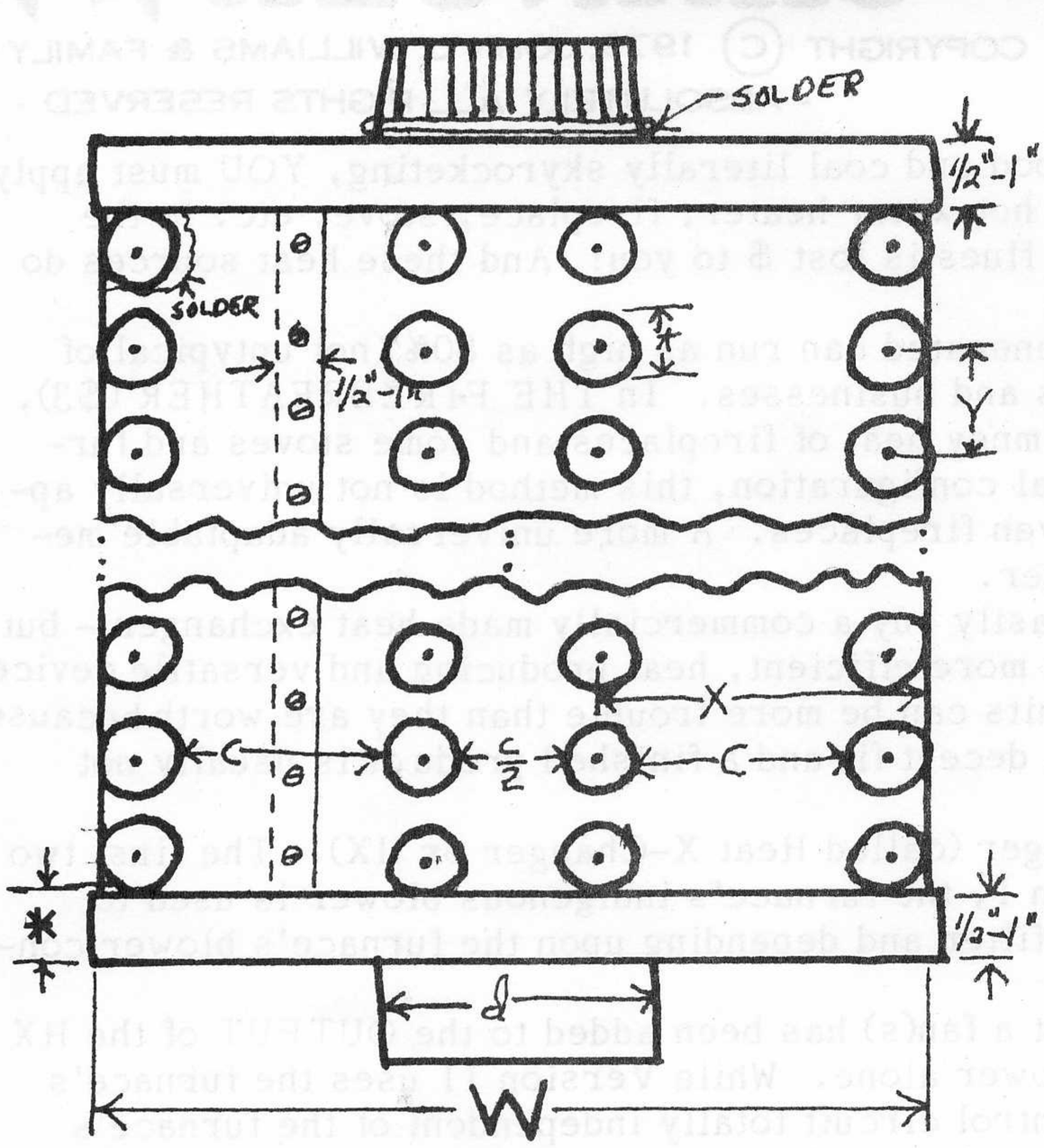
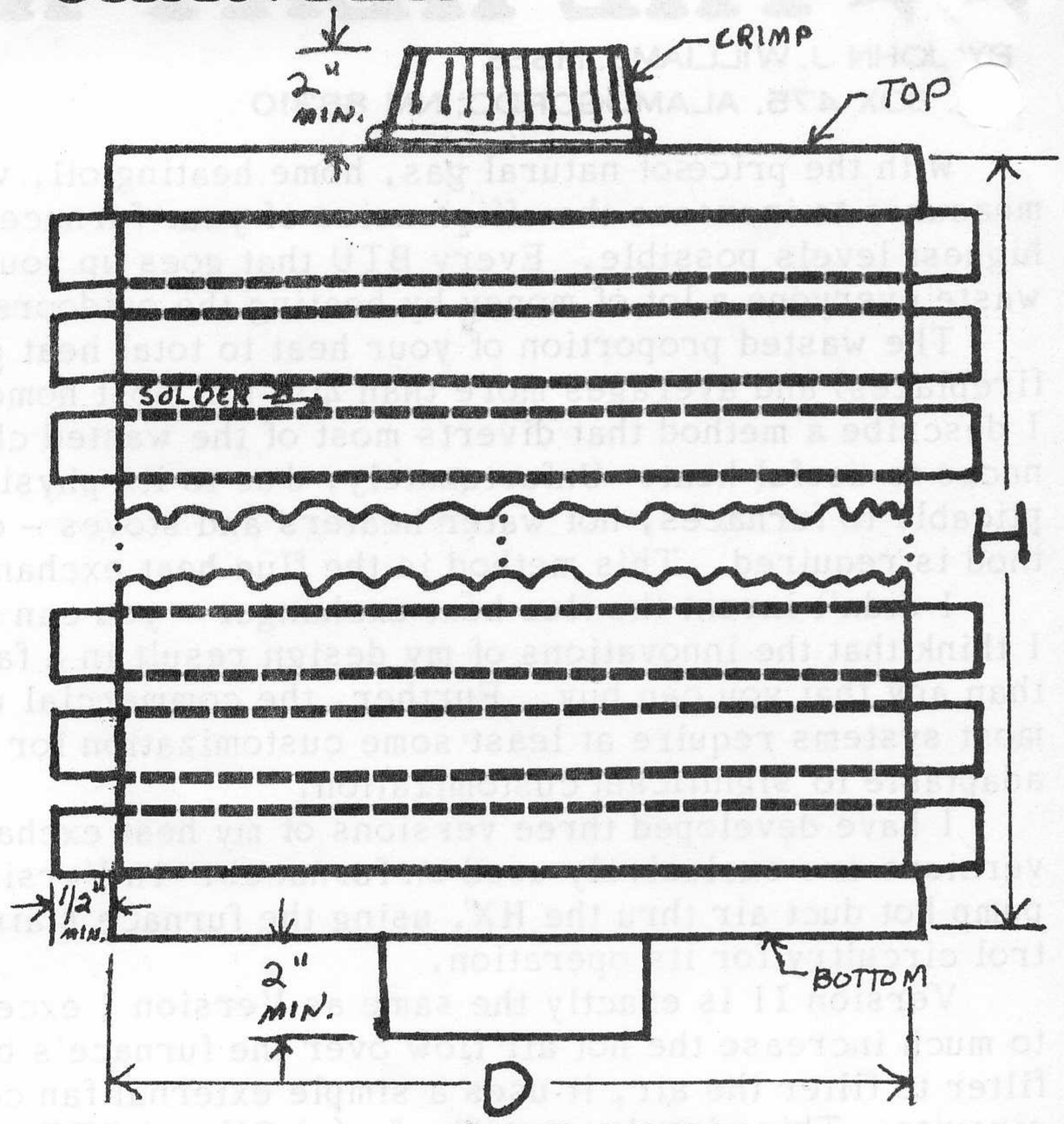
THE HEAT X - CHANGER



FRONT OR BACK VIEW



SIDE VIEW

$C = (2W - 8\pi)/5$
$X = 3\pi/2 + C$

$(H-K1)/\pi \geq r \geq (H-K1)/1.5$
$Y = (H-K1-\pi)/(r-1)$ WHERE
K1=2, BOTTOM FLUE STUB.
K1=4, NO BOTTOM FLUE STUB.

$W = (K2d^2 + 4d\pi)/D$
K2 = 0.8, NATURAL GAS
K2 = 1.0, OIL, COAL, WOOD, ETC.

Figure 1: Various views of the HX used in all three versions. The separation of the bottom row of tubes from the bottom of the HX (See *) is 1" if you use a bottom flue stub. However, if you mount the HX directly on top of the heat source, allow 3" here for adequate distribution of flue gases. The number of rows (r) must be an integer value. Choose such an r, then evenly space the rows. r should be at least 4 to make the project worthwhile. The middle two columns are spaced closer together (c/2) to provide a better distribution of flue gas heat to the tubes. Note that the width (W) above results in a greater total cross-sectional area for flue gas passage than the cross-sectional area of the flue itself, particularly in the case of dirty fuels. This is because the tubes collect lamp black and ash with years of use and this extra space minimizes clogging and frequency of brushing out of these deposits.

4. You must have very good skills as a general handy-man and mechanic, including torch soldering. 5. Versions II and III require the skills of a good electronic/electrical technician.

Cost will run you at least $50 for Version I and $90 for Versions II and III for materials alone. Special tools are required, including a right angle drill drive, nibbler, chassis punches (including a large one), large tube cutter, sheet metal and welding clamps, propane torch, etc. In addition, many other special tools will save you considerable time and effort. Very good tools of all kinds, reasonably priced, can be obtained from U.S. General Supply, 100 General Pl., Jericho, NY 11753. If you don't have and can't borrow the required tools and don't expect to use them enough to justify their purchase for one project, you will probably be better off NOT building your HX, even if all other factors look good.

I spent three solid days of very hard work building our HX (Version II). Special interfacing was required. I started from scratch. Hours of planning, measuring, chasing down parts, cutting, bending, filing, soldering (over two pounds of solder!), screwing (over 100 sheet metal screws!) left me utterly exhausted. Schedule your time accordingly - it is a pretty big job.

Also, unless you can rest your HX on the surface of the heat source, you will have to build some metal support structure (stand, ceiling wires, etc.) as your finished HX will weigh at least 30 pounds and be too heavy to be supported by the flue structure alone.

After all the time, hard work, risk and expense that went into our HX, I am very happy with it. Measurements indicate that we are saving about 23% of our natural gas due to this improvement alone. With the cost of natural gas very high, we will have recovered material expenses within two short years. Further, I believe that the HX costs are deductible as an energy conservation project from federal taxes.

Since the fan and control circuits are really the only things to worry about, the HX should be trouble-free for its foreseeable lifetime. If you can stand up to building one, it is certainly worth it in the end.

Space here does not permit a detailed "solder blue wire to pin A" type of construction description as everyone's needs are different. Each system has to be custom-fitted to meet your heat source and its flue and your physical, environmental, financial and time constraints, and your attributes and capabilities. Only YOU can decide the best design to suit all of these important variables.

The main purpose of this publication is to provide you the general design pattern and design and construction insights learned thru my experience and education to permit you to build the most effective, easiest, simplest, trouble-free and inexpensive HX possible and to avoid the wasted time, trouble and money that results from a design from scratch.

VERSION I - FURNACES ONLY

Furnaces have both a flue and hot air duct that generally run parallel to each other at least for a few feet. The objective is to push a fraction of the warm air of the hot air duct thru the very hot HX to pick up additional heat resulting in about a 25° F increase in the duct air temperature.

This version is the simplest, least expensive and easiest and quickest to build. It is also virtually 100% maintenance free (except when wood, coal or home heating oil is used because they leave deposits of carbon black inside the HX that need to be brushed out periodically as needed). It requires no additional fan(s), filter(s) or control circuit. It uses air pressure developed by the furnace's blower to force the air thru the HX (this air has been cleaned by the furnace's filter).

But this method suffers in that the ultimate efficiency (described above) can be practically met only under rare circumstances. Further, the circuit that controls the furnace's blower turns the blower ON and OFF according to the temperature of the furnace's heat exchanger which is located some distance from the flue and has little relationship to flue temperature changes. Thus, much heat is lost up the flue before the blower even turns ON and the blower turns OFF before the flue has cooled.

Commercial heat exchangers usually use a simple ON-OFF toggle switch to control the fan - which is even less efficient than depending upon the furnace's control circuit. Commercial heat exchangers also use galvanized steel tubes which are not as conductive and as heat storing as copper tubes. You gain a substantial increase in recaptured energy by building your HX with the more expensive copper tubes.

Design your HX to be as tall as possible to permit the maximum transfer of flue heat to the tubes. It should have as many rows of copper tubes (r=number of rows of tubes) that can possibly fit into its height to increase heat transfer. The spaces between the copper tubes should be as narrow as possible to permit maximum surface area contact with the hot flue gases. This means that the width of the HX should be as small as possible, and, because the total cross-sectional area of the spaces between the tubes should at least equal the cross-sectional area of the flue, the HX depth should be as large as possible. However practical limitations restrict the depth of the HX to about three times the flue diameter (3d) when the top and bottom flue stubs are directly in line. When they are displaced along the depth dimension, HX depth should not exceed 3d+s (s=separation of flue center lines along the depth dimension).

I have found that four columns of copper tubes is about the optimum number (except for very large flues). The copper tubes should be between 3/4" and 2" diameter with 1" about optimum; they should be rigid and thick-walled ("L" type).

DESIGN STEPS

STEP 1: Carefully examine the physical, environmental, financial and time constraints that you will be working under. It is very important that you spend enough time in the planning of this project - don't let yourself get rushed into the construction phase. Take careful measurements of your heat source, flue and hot air duct and sketch the three orthoganal views of their relationships. Determine the HX height, depth and copper tube size you desire. The HX must not interfere with the flue cut-off, if it has one.

STEP 2: The remaining HX dimensions can be calculated from Figure 1.

STEP 3: You should now be ready to buy the copper tube (rigid, "L" type) and sheet metal (24 guage, min.) Total length, in inches, of the copper tube is equal to the total number of tubes for your HX (4r) times the length of each tube (D+1, min.). Carefully draw out all views of your HX and then the sheet metal layout before cutting, bending and fitting. Allow $\frac{1}{2}$" to 1" overlap for attaching the two ends together. See Figure 2. For ease of construction and assembly, the top and bottom pieces should be separate pieces of sheet metal. Allow $\frac{1}{2}$" to 1" overlaps all around the top and bottom pieces to be bent at right angles for fit and attachment around the HX body. Make all cuts of tubing and sheet metal yourself to lessen expense

STEP 4: Cut out the pieces for the body of the HX and its top and bottom. Scribe out all bends and corner cutouts. Be sure that the HX body overlap occurs between columns of tubes to minimize heartburn. I prefer self-tapping sheet metal screws to join sheet metal but spot welding, soldering and machine screws are OK too. Bends can be made in an ordinary vise whose widths are extended with pieces of angle iron, by a wide mouth vise or by a sheet metal brake. Use a hard mallet to make all bends very sharp.

STEP 5: Layout the tube hole center points on the front and back of the HX and drill or punch out pilot holes. Using a chassis punch just large enough to allow passage of the copper tubes, punch out all (8r) tube holes. Cut the copper tubes to the desired lengths. Remove burrs and sharp edges. Polish the ends of

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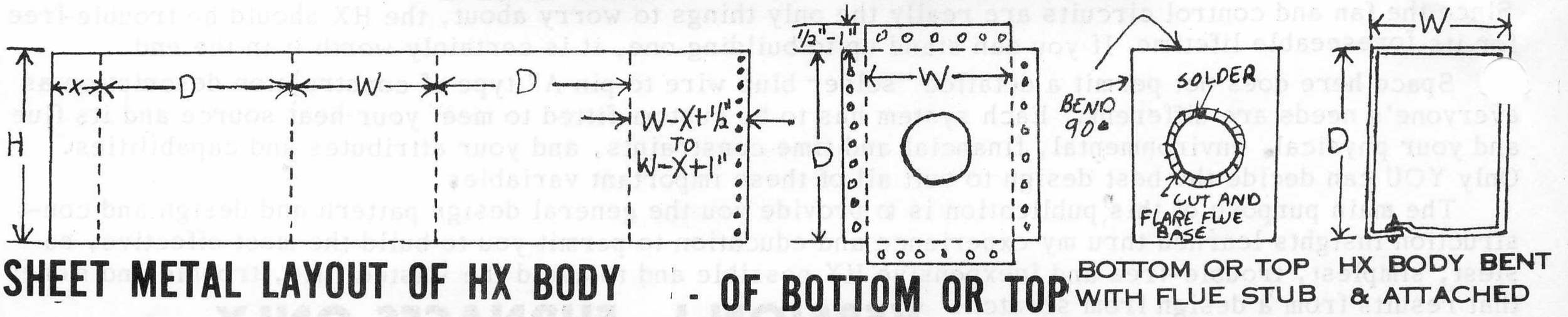

Figure 2: Sheet metal layouts for the body and top and bottoms of the HX.

all tubes and a strip along the length of the half of the tubes that will be soldered to the inside sides of the HX. Starting with the side columns, place in one tube at a time and (acid core) solder into place against the HX side. Be very liberal with your solder to increase the heat capacity of the HX and the conductivity of the HX wall heat to the tubes. After all the tubes have been soldered into place, place into position all the tubes of the center columns. Then solder all 4r tubes in the front and back of the HX. Be careful, you must not allow flue gas leaks around the tube holes. As in all soldering jobs, thoroughly wash out with water after soldering. Allow to dry. Paint the insides heavily with a flat black auto engine or other high temperature spray paint.

STEP 6: Construct the top and bottom pieces. The flue stubs can be cut from the section of flue that the HX is replacing or from a small piece of straight flue (plumbing store). Acid core solder the stubs to the top and bottom. Wash out, dry and apply paint.

STEP 7: Assemble the top and bottom to the body after bending the overlaps. Seal all holes and cracks with muffler cement (auto stores). Attach with screws (do not solder or spot weld).

STEP 8: Install the HX. See Figure 3. Turn ON furnace. Make sure that the flue gases pass thru the HX unimpeded (no back up) and that no flue gas escapes from the HX to the local environment. Correct all defects. Carefully determine the position of the HX to the hot air duct. If the hot air duct is connected to the air conditioning ducts, a duct cut-off will usually lie just above or inside the furnace. The hole you make in the duct must be totally above or totally below this duct cut-off when it is closed (summer) or air conditioning air will pass into the furnace thru the HX-to-duct interface conduit. Design and construct your HX-to-duct interface. Cut the hole in your air duct and install the interface to both the HX and duct. The duct hole need not be larger in area than the total passageway area of the copper tubes (at least $3.2i^2r$; i=inside tube diameter).

STEP 9: Your furnace may be located in a room with a door on it. You must then design, construct and install a vent to the door and an HX-to-door interface conduit as in Figure 3. Remove the door and mark the door frame corresponding to the top, bottom and sides of the HX. This can be done by holding a flat ruler against the top, bottom and sides of the HX and then rotating the ruler until it touches the door frame above and below it for the sides and left and right for the top and bottom. Mark the door frame where contacted (8 marks total). Reinstall the door and then draw light lines on the door connecting respective frame marks; this leaves the outline of the HX's position and size on the door. Find a metal vent that best suits your pattern. Center this vent on the HX outline of the door vertically and on the sides of the door horizontally. Mark off the vent hole. Remove the door and cut out the vent hole. Reinstall the door and carefully measure the distance from the inside of the closed door (thru the vent hole) to the main body of the HX. Install the vent. The HX-to-door interface must fit air tight against the door when it has strips of molding on its door-side flange and the door is completely closed. Design and construct this interface accordingly. As with the HX-to-duct interface, I have found that if the interface is of complicated design, it is easier to design and build it in four pieces (two with overlapping flanges for attachment to the other two). If you wish to vent your HX to another room, thru a wall, you must design and construct an HX-to-wall interface, which, of course, will be frimly attached to both the HX and the wall.

VERSION II — VERSION I WITH FAN(S)

The HX is constructed exactly as in Version I. After the Version I construction has been completed shut OFF all other vents to the room to be heated and observe the heating effect of your HX. If it is inadequate, a fan(s) should be installed as in Figure 4 to increase the air flow. Compact, efficient, quiet and high-output boxer fans are available in electronic parts stores. You will need one (or more) suitable for hot air that will fit inside the HX-to-door or HX-to-wall interface. Buy also the electronics parts that you will need to build the control circuit as a simple ON-OFF control is totally inadequate.

This simple circuit is described in Figure 5. It is essentially a level detector (Schmitt Trigger) with a thermistor controlled input level. It can be easily built in a 3"X4"X2" minibox on electronic perforated board. All resistors are 1/4 watt, 5%, unless otherwise specified. Choose any thermistor with a decent linearity and a 25° C resistance of 2K ohm to 50K ohm. Place the thermistor on a very warm

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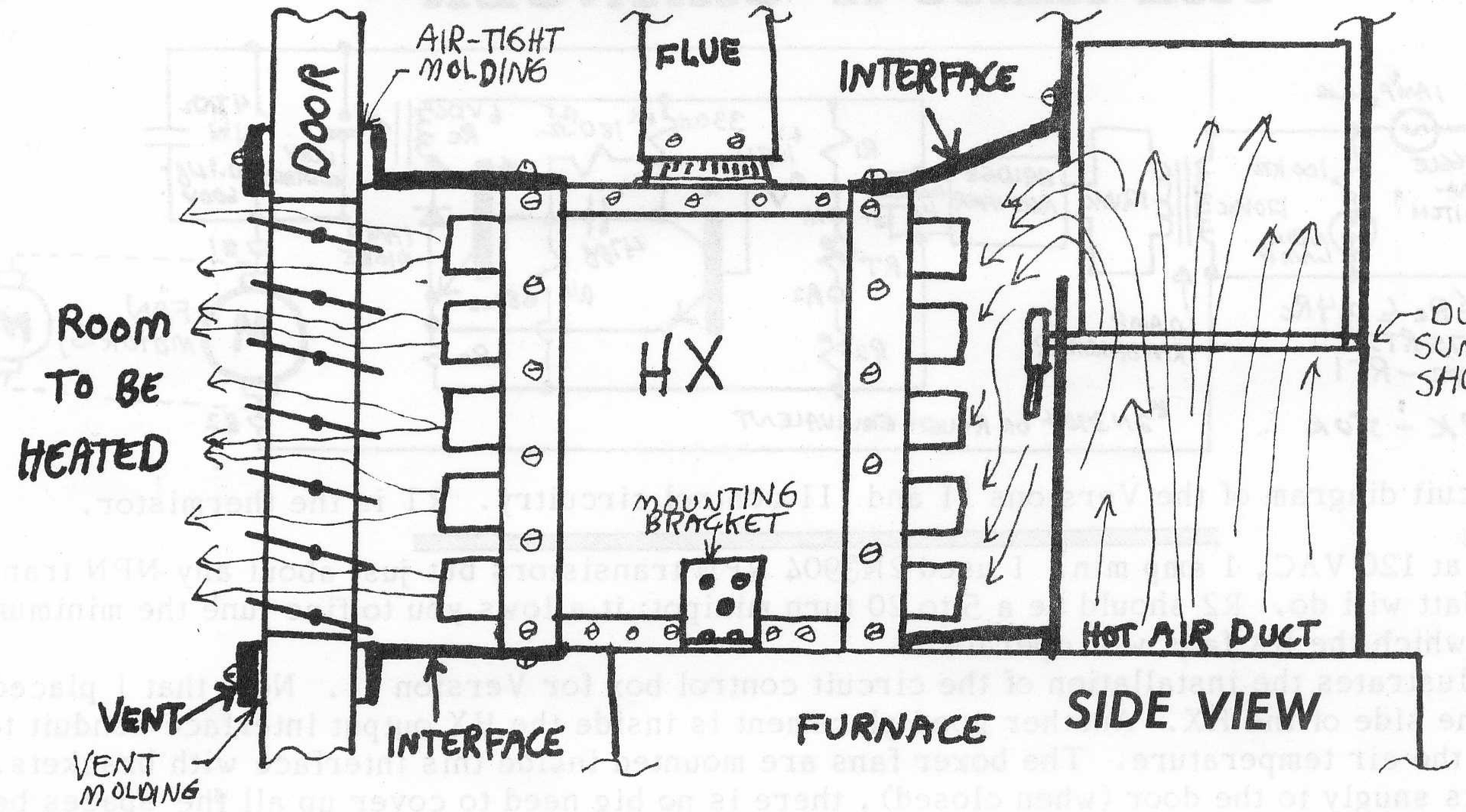


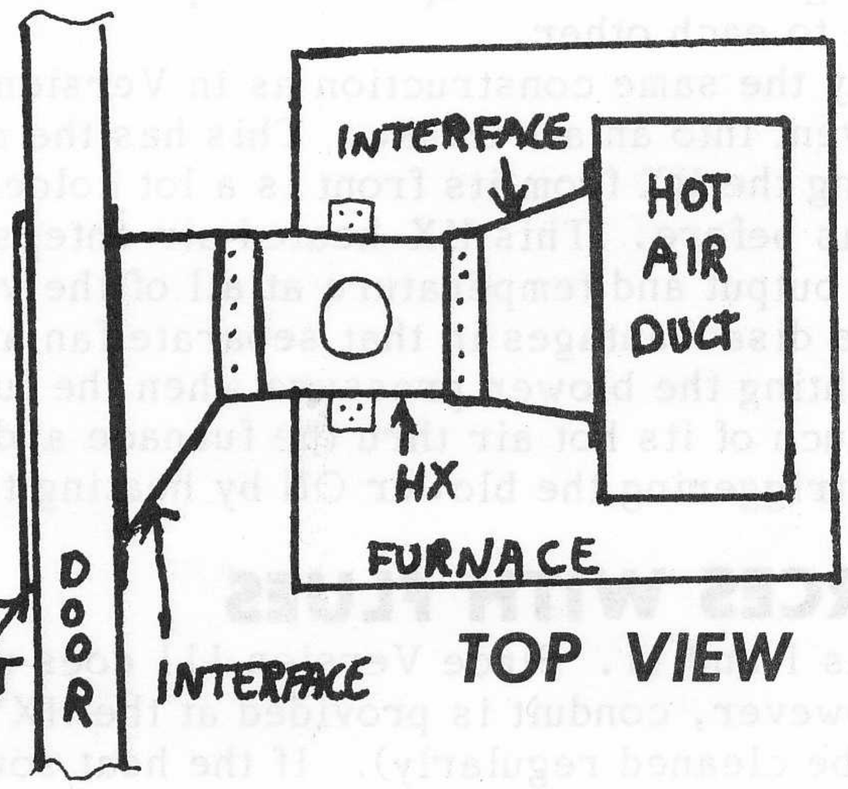
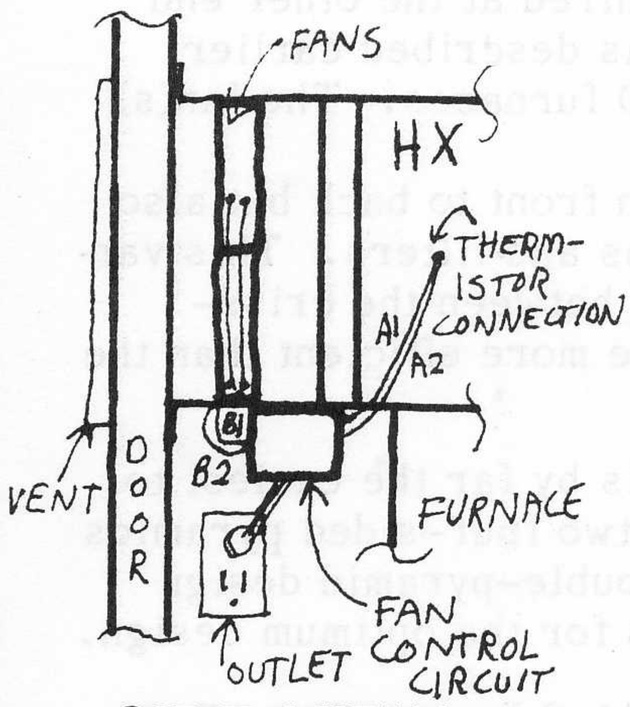
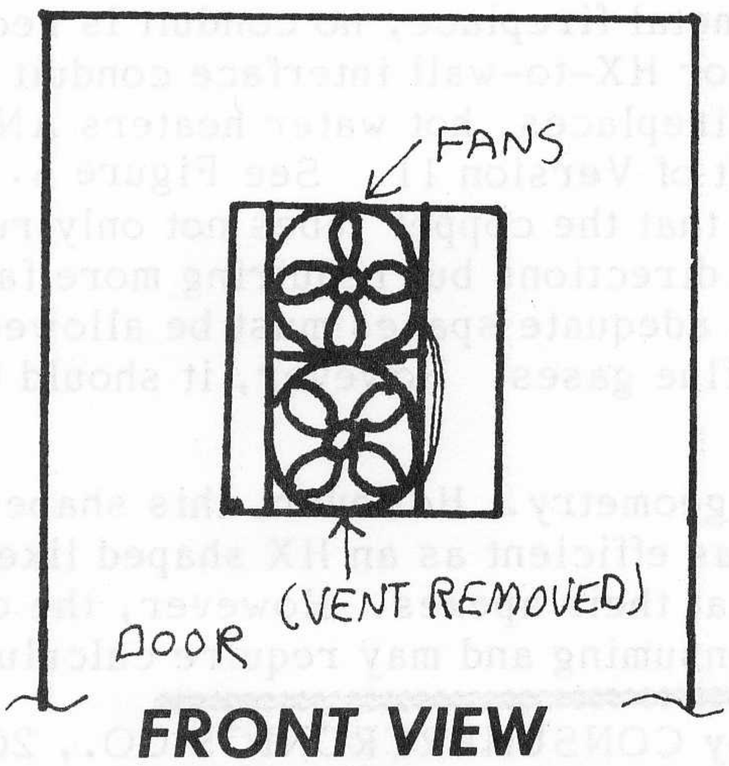


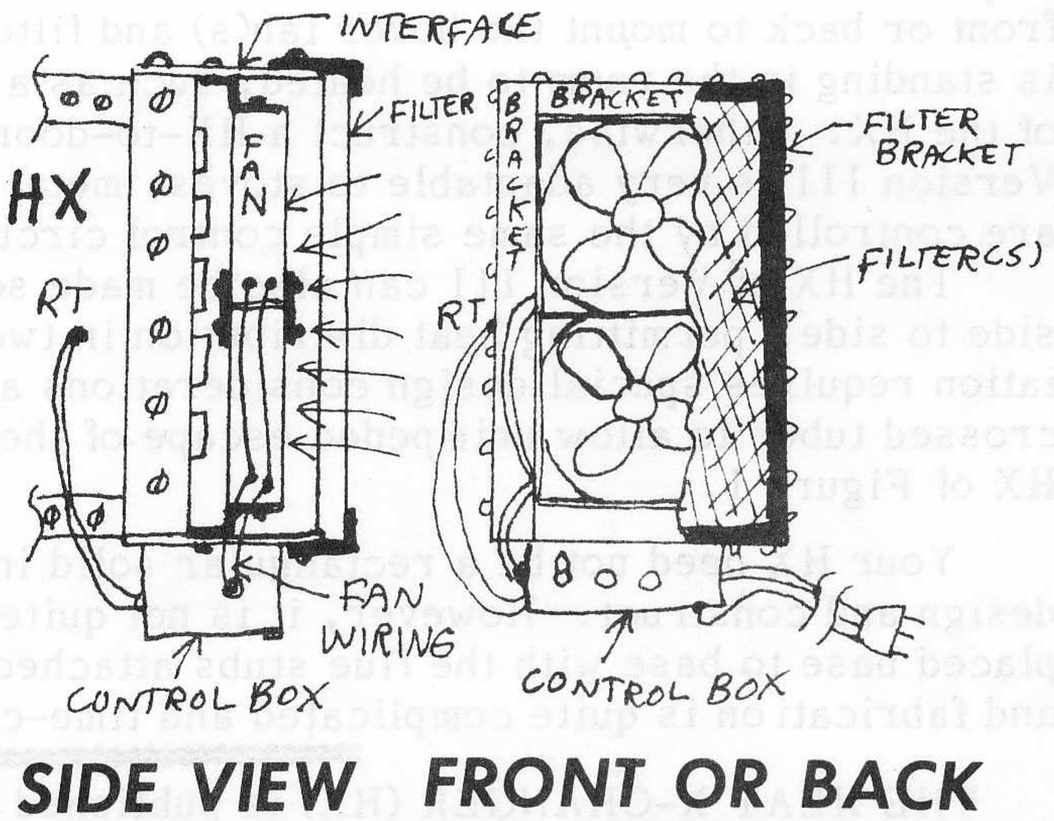
Figure 3: Various views of the Version I HX with cut aways of vent, interfaces and duct provided. HX is installed on top of the furnace, which is located in a furnace closet with a door. Note how the HX-to-door interface molding provides an air-tight seal when the door is closed, and how the duct hole lies completely above and does not interfere with the duct shut-off. This HX-to-duct interface was somewhat difficult to install. I took the HX off the furnace, installed the interface, replaced the HX back onto the furnace and installed the interface to the duct. The mounting brackets on both sides of the HX assure its security.

VERSION I





VERSION II



VERSION III

Figure 4: Various views of the Versions II and III installations showing fans. I have found that the best method for attaching the thermistor to the body of the HX is to install a sheet metal screw slightly lower than midway up and epoxing the thermistor to the head of this screw.

(but not hot) surface. Measure its resistance (RT1). Place on a very cool (but not cold) surface. Again measure the resistance (RT2, larger than RT1). Rc, of course, is the DC resistance of the fan motor control relay coil. Anything from 100 to 1000 ohms is OK as long as it operates on 6 VDC and the con-