Construction Manual
for
High Altitude Test Chamber

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Table of Contents

Illustrations

Introduction

Since the 1930's the National Weather Service has flown radiosondes into the stratosphere via modest-sized latex sounding balloons. Over the last quarter century, various individuals have used similar balloons to carry radios and scientific experiments into the stratosphere. Most flights are designed to be exempt from regulation by the Federal Aviation Agency. The last fifteen years have seen programs develop through NASA Space Grant Consortia and on various college campuses. With the development of the Global Positioning System, the Automatic Packet Reporting System, and reliable high frequency modems, it is possible for high altitude balloons to be tracked and in most cases recovered. Since these flights typically last between two and five hours and only travel 10 to 200 kilometers, students can design, build, and fly their own experiments into the portion of the atmosphere known as "near space".

It would be desirable to conduct ground testing on the suitability of the student-built apparatus prior to flight to assure that the systems will work in the environments encountered in a typical high altitude balloon flight. The primary concerns are the cold temperatures and low atmospheric pressures.

Initial contacts with commercial vendors by the principal investigator yielded units with quoted prices ranging from $50,000 to $84,000. The simplest commercial unit that the investigator was able to secure cost $7,800! It was anticipated that a system could be constructed for less than $1,000. Efforts were made to use ordinary materials that could withstand the vacuum and thermal stresses. The system that is built following these instructions has reached temperatures of -35 ^{o}C (238 K) and pressures of 40 Pa (equivalent to 55 km altitude) in initial tests at DePauw.

This manual is intended to provide the information necessary for the construction of high altitude test chamber. The goal was to have an interior volume in the vacuum chamber of at least 0.027m^3 (1 cubic foot). The final dimensions of the vacuum chamber were limited by the interior space in the 5.1 cubic foot chest freezer that was already in use by the investigator (15.5 inches by 15.5 inches by 26 inches).

Parts List

Parts required to build this system (with actual costs or prices for items already on hand)

2 foot long 14 inch OD Schedule 40 PVC rigid plastic pipe (FlexPVC.com)	$181.49
1 sheet ½ inch thick 2 foot by 2 foot LEXAN sheet (freckleface.com)	$76.15
Robinair Two Way Brass Charging Manifold (Amazon.com)	$40.00
Charging Hoses 4 @ $18 each (Amazon.com)	$72.00
Omega DVG-64 Digital Vacuum gauge (Omega.com)	$175.00
Robinair 15800 8 CFM Dual Stage Vacuum pump (Amazon.com)	$221.41
Kenmore 5.1 Cubic Foot Chest Freezer (Sears)	$169.99
9 foot 2 ½ inch Rubber Garage Door Seal (DoIt Best Hardware)	$4.99
¼” NPT male to ¼” flare fitting - 3 required (DoIt Best Hardware)	$5.97
¼” flare to ¼” flare union (DoIt Best Hardware)	$1.99
¼” NPT male galvanized pipe nipple 1.5” long (DoIt Best Hardware)	$1.53
¼” NPT female galvanized pipe Tee (DoIt Best Hardware)	$3.92
3- 3 foot 3/8” x 16 threads per inch all thread rod (DoIt Best Hardware)	$10.50
12 3/8” x 16 hex head nuts (DoIt Best Hardware)	$2.40
TOTAL	$967.34

Tools and Expendable Supplies List

Superglue

2 Ton Epoxy

Teflon Pipe Tape

Caulk

9 inch by 12 inch sheets of 240 grit sandpaper

Band Saw or Hack Saw

Electric Drill

¼ inch, 3/8-inch, and 7/16 inch drill bits

¼ NPT pipe tap and tap handle

Razor blade knife

Permanent Marker

Preparing the Chamber

The well casing was pre-cut by the supplier to the requested 24-inch length. However, the ends of the casing were not perfectly even. The errors were within specifications, and would not be a problem in conventional use. To be a good mating surface for the gasket and lid, each end of the casing was sanded to until the ends were flat. A five-step procedure was followed.

1. The ends of the well casing were colored by a permanent marker.

2. Four sheets of 240 grit - 9 x 12 inch sandpaper were attached side-by-side (forming an 18 x24 inch rectangle) to a smooth hard top table with the abrasive side facing up.

3. The end of the casing was placed on top of the sandpaper and rotated about its vertical axis with a slight downward pressure. The direction of the rotation was reversed periodically and the casing was moved across different regions of the sandpaper.

4. After one or two minutes, the sanding was stopped and the casing inverted to see if the permanent marker had been removed.

5. If some of the permanent marker was still visible, portions of the end were still too low. Steps 3 and 4 were repeated until the marker was removed and the end was flat. See Figure 1.

Figure 1 - End of Casing after smoothing

There must be a connection to the vacuum system from the chamber. The simplest location for the connection is on the wall of the casing. The exact position along the wall is not critical. The Schedule 40 plastic casing has ½-inch thick walls that can accommodate sufficient threads from the fitting to insure a solid connection to the ¼-inch male NPT to ¼ -inch male flare fitting. Here are the steps for mounting the fitting to the casing.

1. Drill a ¼" pilot hole through the side of the casing about eight inches from one end of the casing.

2. Enlarge the hole to 7/16" with the larger drill bit.

3. A ¼" NPT pipe cuts the threads through the side of the casing following the technique of rotating the tap one-half turn clockwise then one-quarter turn counterclockwise, until threads were through the entire side of the casing. NOTE: Initially you may need to turn the tap clockwise for several turns until the tap begins to cut into the wall of the hole.

4. The pipe thread end of the fitting was wrapped in Teflon pipe tape and screwed into the hole.

5. As added insurance for a good vacuum seal, 2 ton epoxy was applied to the inside and outside of the casing next to the fitting. See Figure 2.

Figure 2 - Exterior View of Flare Fitting attached to Casing Wall

Cutting the Lids

The lids were fabricated from a single square piece of ½ inch thick Lexan that measured 24 inches along each edge. To insure stability of the chamber, extra material is needed to allow for three all-thread rods to hold the lids against the door gaskets and pipe as the chamber is placed in the freezer. The simplest configuration, with minimal waste of material is an octagon circumscribed on a 14-inch diameter circle. There is just enough material in the single sheet of Lexan to make the two lids. (See Figure 3)

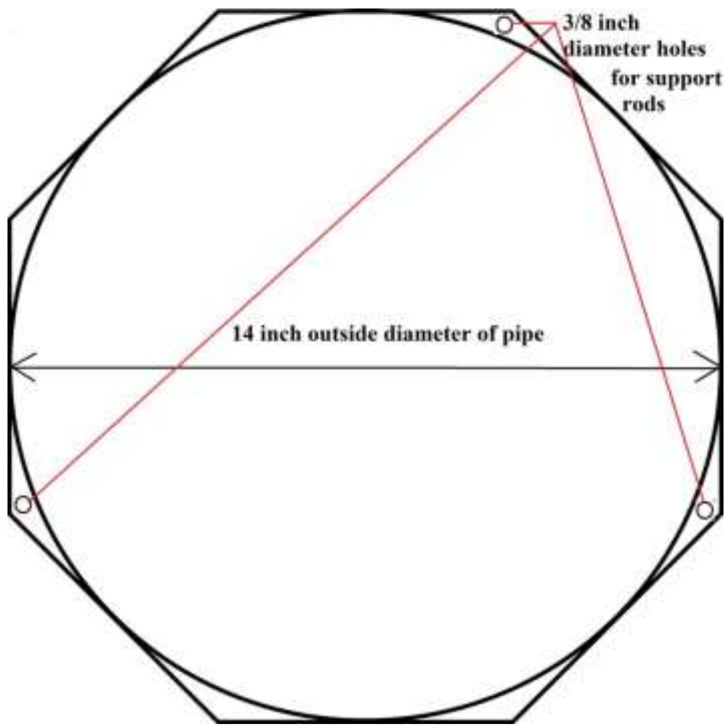

Figure 3 – Hexagon Lid with location of support rod holes

BEFORE making any cuts draw two 14-inch diameter circles on the Lexan. The circles can be drawn by sitting the casing on top of the sheet. The casing must be located with two points of the casing just touching the edge of the sheet. Please see the orange circles on Figure 4. The following sequence of cuts were made to the Lexan sheet using a band saw. The cuts could be made with a hand held jigsaw (also called a saber saw).

1. Cut along the diagonal of the 24-inch square Lexan sheet to create two right triangles with 24-inch long sides. Each of the remaining two pieces will be used to make one of the lids. (See the green line on Figure 4). You will have two right triangle shaped pieces with 24-inch long sides. Each piece will need to have the following cuts.

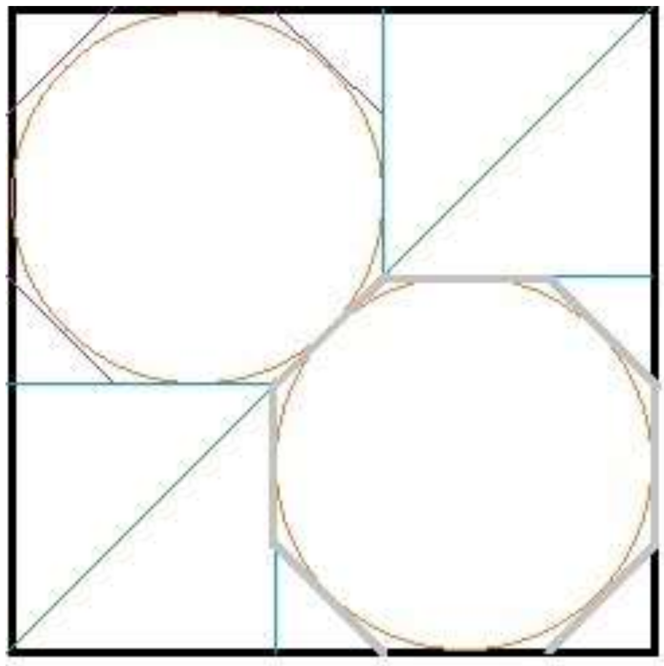

Figure 4 – Lexan Sheet with cuttings marked

2. Remove the triangular corners of each piece by making cuts parallel to the side 14 inches from the corner. (See the blue lines in Figure 4). There are four cuts to make in this step.

3. Remove the remaing small triangular corners by cutting along a line connecting points that are 4 inches from the corner. (See the purple lines in Figure 4). There are six cuts to make in this step.

You should have two octagon shaped pieces of Lexan that will cover the ends of the casing and leave a little extra material for the support rod holes, as was seen in Figure 3.

The final step in constructing the lids is to drill the holes for the support rods. As seen in Figure 3, these holes should not be in adjacent vertices of the octagon.

To insure proper alignment of the support rod holes, it is recommended that you set one lid on top of the other and drill through both sheets at the same time. Please be careful to clamp the two pieces together and clamp the assembly to the drill press or support table if using a hand drill. The holes must be 3/8-inch in diameter.

Fabricating the Gaskets

Gaskets must be formed to fit between the Lexan and the casing. Two gaskets are required. The following procedure creates one gasket.

1. Using a razor blade knife cut a 45 inch long piece from the 9-foot long rubber garage door seal. The door seal has an L-shaped cross section.

2. Wrap the piece of the garage door seal around one end of the casing with the short leg of the seal on top of the end of the casing and the long leg covering the side of the casing. The material will overlap since 45 inches is longer than the circumference of the casing.

3. Using the razor blade knife, cut through the two layers of overlapping gasket to make a single piece with ends that match.

4. Apply a small bead of Superglue to the ends of the gasket and hold them together for one minute to insure a good bond.

Repeat this procedure for the second gasket.

Fabricating the Support Rods

The three support rods are cut from the all-thread rod. The rods were cut to a length of 26 inches (longer than the 25.25 inch tall casing with two lids and gaskets) and less than the interior height of the freezer). When cutting all-thread rod, you should have two nuts screwed onto the rod on each side of the cut. The nuts will be removed after the cut and will smooth out any burrs in the threads. The rods were cut on the band saw, but the cuts can be made with a handheld hacksaw.

Modifying the Chest Freezer Lid

A 7/16-inch diameter hole was drilled through the lid of the chest freezer to hold a ¼-inch flared fitting union to connect the vacuum hoses to the chamber and permit the lid of the freezer to be completely closed. The exact location of this hole is not critical, but should not be directly above the chamber since the top of the chamber is too close to the lid when it is closed.

Modifying the Charging Manifold

The charging manifold is designed to connect the gauges to the low-pressure and high-pressure sides of a refrigerant system with the refrigerant cylinder connected to the common center fitting. The valves open the appropriate side to allow the refrigerant to enter the system. For the high altitude vacuum chamber, the flare fitting intended to connect to the refrigerant cylinder is removed from the manifold and replaced with the ¼-inch NPT pipe nipple. The open end of the nipple is connected to a 1/4-inch NPT tee.

Each of the open ends of the tee is fitted with ¼-inch NPT to ¼-inch flare fittings. One end of the tee is connected by a hose to the vacuum chamber and the other end is connected to the Omega digital vacuum gauge. A picture of the modified manifold is seen in Figure 5.

Figure 5 - Modified Manifold

Connecting the system

All parts have been fabricated for your high altitude vacuum chamber. Figure 6 is a schematic representation of the connections. The Robinair vacuum pump is connected to the valve with the blue handle (the low-pressure end of the manifold). Operational instructions are provided in a separate document: OPERATING THE HIGH ALTITUDE VACUUM CHAMBER.

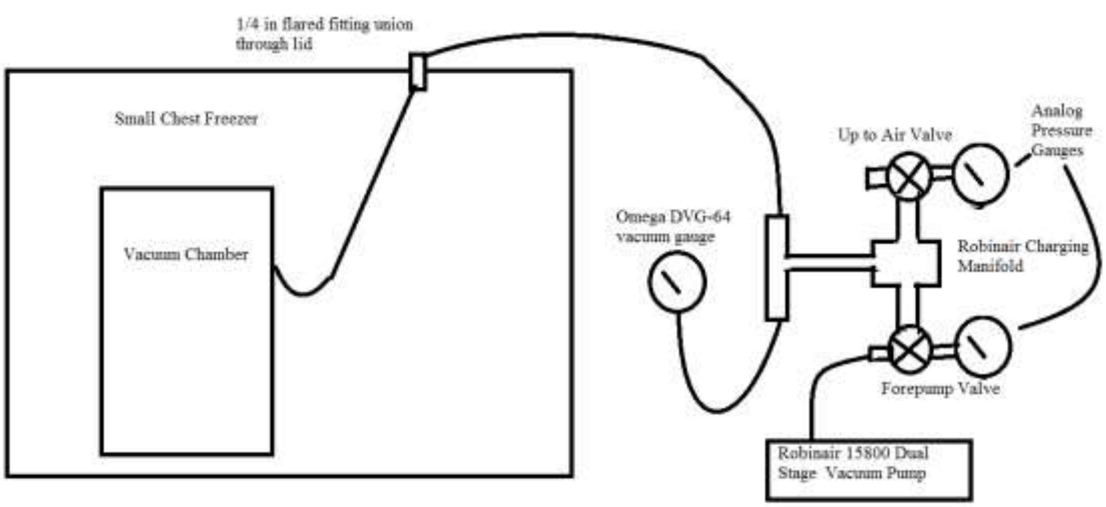

Figure 6 - Schematic of connected system