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Vacuum Chamber for Shearography Nondestructive Evaluation

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TECHNICAL MEMORANDUM

VACUUM CHAMBER FOR SHEAROGRAPHY NONDESTRUCTIVE EVALUATION

I. INTRODUCTION

Electronic holographic and shearographic nondestructive evaluation (NDE) are optical inspection methods that can detect subsurface flaws such as unbonds and delaminations in bonded, laminated, composite, or coated structures. The two methods detect flaws by displaying, in real time on a video monitor, the surface deformation (strain) that results from the structure being stressed by either a steady-state load (pressure, vacuum, or mechanical) or a dynamic load (temperature or acoustic vibration). Since the structure or coating is locally weak where a subsurface flaw exists, holographic or shearographic NDE will detect an area of high surface deformation (strain) when a load is applied.

Figure 1 is a shearography image of debond in the Kevlar™ fiber urethane insulation on a test cylinder due to vacuum excitation of the component. This inspection was performed with a Pratt & Whitney electronic holography/shearography inspection system (EH/SIS). This system uses a ND:YAG laser with a frequency doubler to produce a constant-wave 532-nm green light source for illumination of the test object. Light is reflected from the object and acquired by a standard CCD video camera, equipped with special optics, for imaging processing. Images may be acquired through an optically clear nondistorting medium.

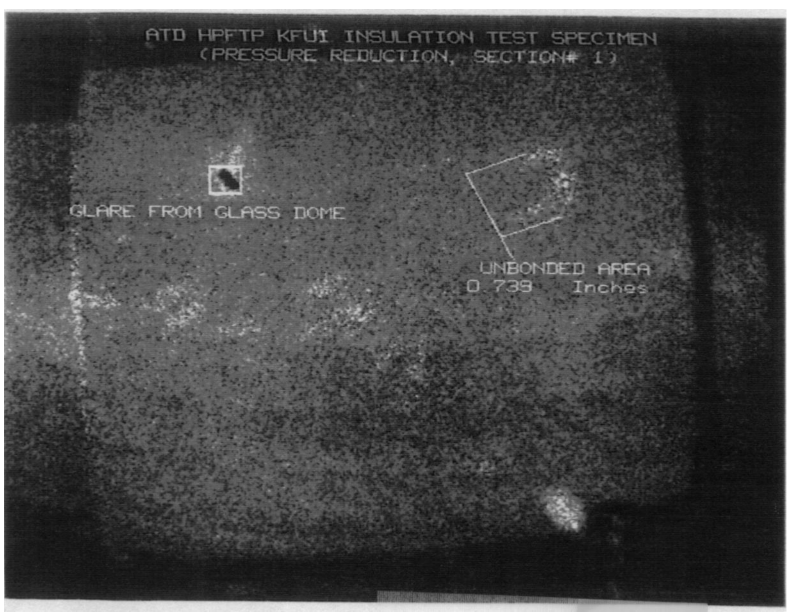


Figure 1. Shearography detected debond in Kevlar™ insulated urethane insulation.

II. CONCEPTUAL DESIGN

The bell jar is the most commonly recognized device for a controlled vacuum environment in scientific experiments. A cylindrical glass vessel would be the ideal choice as a vacuum chamber because the test object could be viewed from any direction without opening the chamber to rotate the piece. Due to the limitations of the available bell jar sizes and the optical distortion caused by the curvature of the vessel walls, another design was required.

III. PROTOTYPE DEVELOPMENT AND OPERATION

The design chosen was a hexagon-shaped vacuum chamber made of six flat acrylic panels. The flat optically clear panels would provide distortion-free viewing from all sides. The vacuum excitation chamber consists of three major components: a lid, chamber body, and base plate (fig. 2). The chamber accommodates a specimen of 1 m in diameter (maximum). The chamber body was constructed of 56- by 122- by 2.54-cm acrylic panels solvent welded to form a continuous hexagon tube, open at both ends. The top and bottom edges are fitted with molded continuous neoprene rubber channel gaskets to insure a vacuum seal. The removable lid consisted of a flat hexagon of 3.81-cm acrylic material. The oversized lid rests on the channel gasket that covers the top of the vacuum chamber, closing the open end. The channel gasket that covers the bottom of the chamber rests upon a reinforced 122- by 122- by 3.81-cm aluminum base plate. The chamber has four handles so that it may be easily moved from the isolation table to its storage cart. Care should be taken not to roll the channel gasket off the bottom edge of the chamber during movement. The chamber should be lifted clear of the base plate and not dragged when moved.

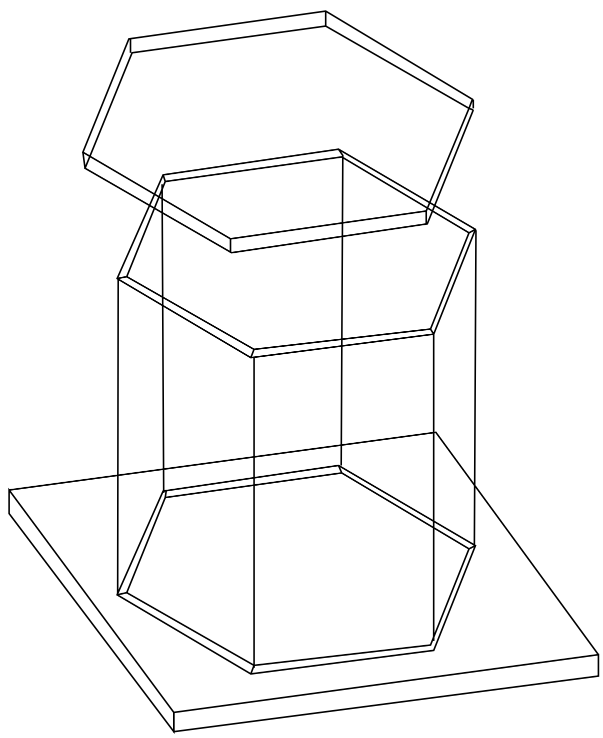


Figure 2. Chamber with lid and base plate.

Because vacuum deformation of the base plate would cause significant movement of the test specimen, a false bottom was constructed of 1.27-cm plate aluminum to fit inside the test chamber. This hexagon-shaped “table” fits easily inside the chamber with support legs at the perimeter. The flat plate of the table was drilled and tapped with $^1/_4$-inch-20 SAE holes to allow for the installation of support members and fixtures for specimens under inspection. Any deflection that occurs during extreme vacuum conditions is most significant in the middle of the base plate and less evident in the chamber walls. Because the table is supported along the perimeter of the chamber walls, the “free floating” table dampens any movement due to vacuum deformation.

With the lid removed, the chamber could be tilted on its edge for easy insertion and removal of the specimen table under the raised chamber edge. Easy access could also be gained for any small test objects that required inspection (fig. 3).

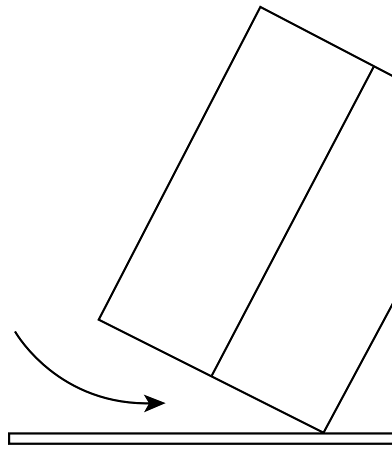


Figure 3. Tilt to insert part.

An industrial wet/dry vacuum head installed on a 55-gal drum was used to provide a vacuum source to quickly reduce the pressure in the chamber. The vacuum's 3.81-cm hose pipe is attached to the vacuum out-gas ball cock by a quick release connector. The 3.5-hp two-stage bypass motor moves 110 CFM of air at the static pressure rate of 26.2 Kpa (3.8 lb/in^2 gauge). This volume enabled the chamber pressure to be reduced and held at 26.2 Kpa (3.8 lb/in^2 gauge) in 18 s. A conventional vacuum pump requires at least 10 times longer to achieve the same vacuum. Rapid changes in the internal pressures of the test specimen with respect to the chamber environment provides more possibility of movement in unbonded materials. Slower vacuum rates allow for the equalization of the internal pressure differentials that cause detectable movement (fig. 4).

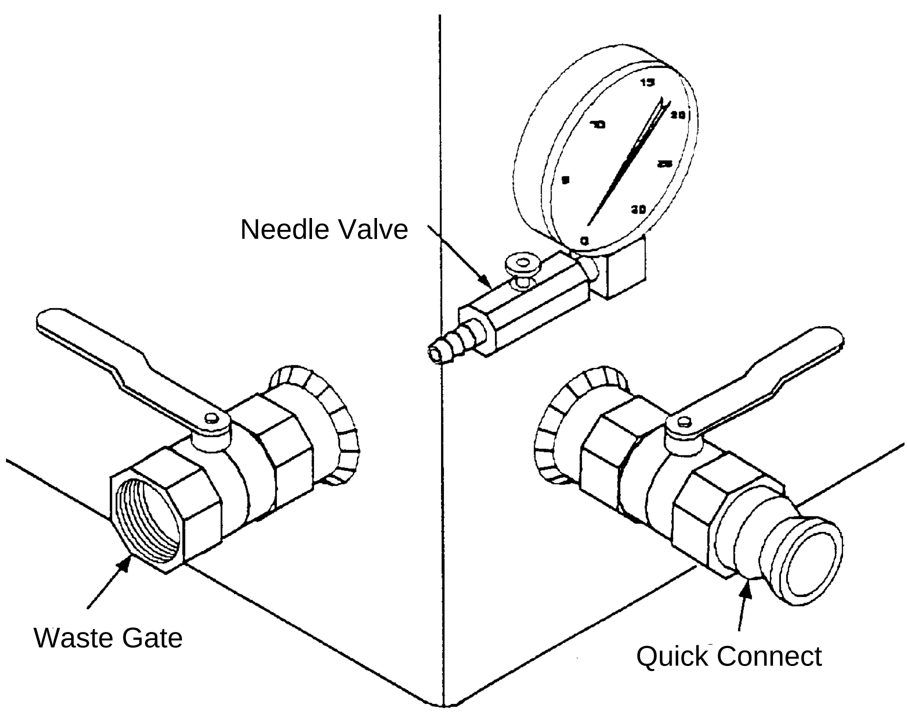


Figure 4. Pressure control valves.

Once the desired pressure had been reached, the vacuum out gas ball cock is closed to maintain the desired pressure in the test chamber. A second gas ball cock is installed as a “waste gate.” The waste gate is adjusted until the air flow entering the chamber equaled the air flow exiting the chamber. This “fine tuning” of the waste gate aids in establishing an equilibrium between atmosphere and the vacuum source when constant vacuum levels are required. The waste gate also allows pulsing of the vacuum level in the chamber. A needle valve is provided for precision control of air flows entering the chamber. In cases where heavier steady-state loads are needed to stress a part, a 0.635-cm hose barb connector attached to the needle valve allows any conventional vacuum pump to be attached and further reduce the pressure in the chamber.

As a safety precaution, a vacuum breaker has been installed on the chamber. The vacuum breaker has been set at 44.13 Kpa (6.4 lb/in^2 gauge). Once the vacuum inside the chamber reaches the preset level, the breaker opens to the outside atmosphere and stabilizes the pressure in the chamber (fig. 5).

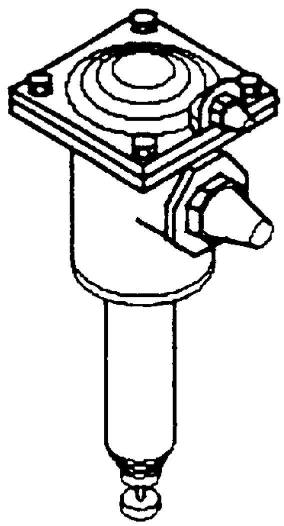


Figure 5. Vacuum breaker.

IV. CONCLUSIONS AND RECOMMENDATIONS

The vacuum excitation chamber has proven to be an excellent method for stressing aerospace components. The results achieved so far indicate that shearographic/holographic optical NDE is a viable method for detecting surface deformations resulting from subsurface flaws. Further evaluation would appear to be in order to validate this method as an acceptable means of NDE inspection.

APPENDIX A

VACUUM CHAMBER DESIGN DRAWINGS

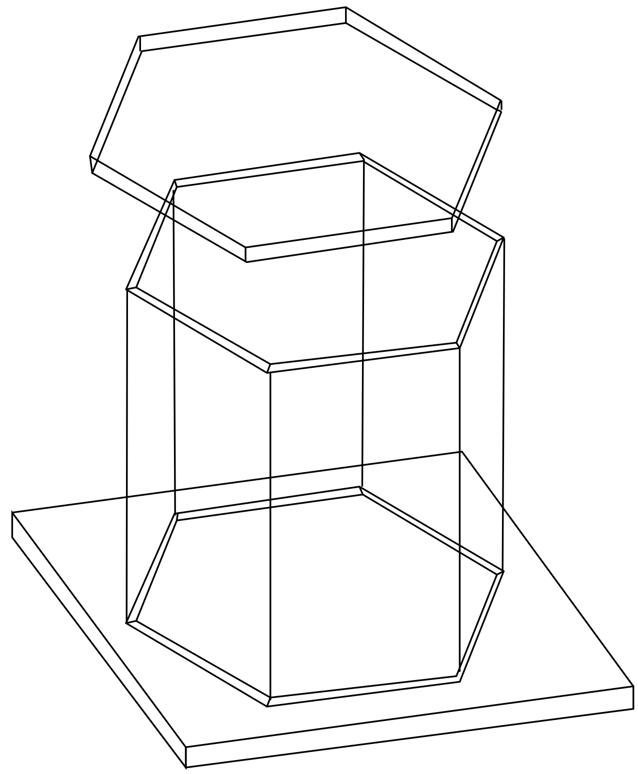


Figure A-1. Vacuum excitation chamber lid, chamber body, and base plate.

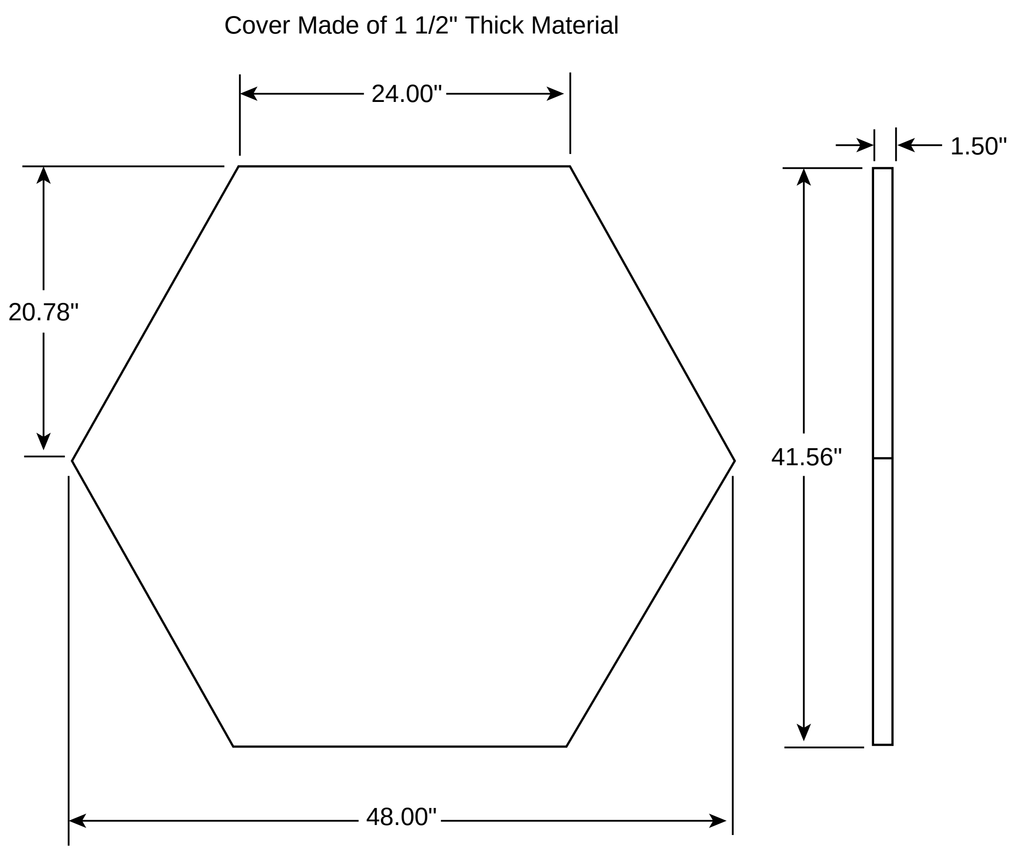


Figure A-2. Vacuum excitation chamber lid.

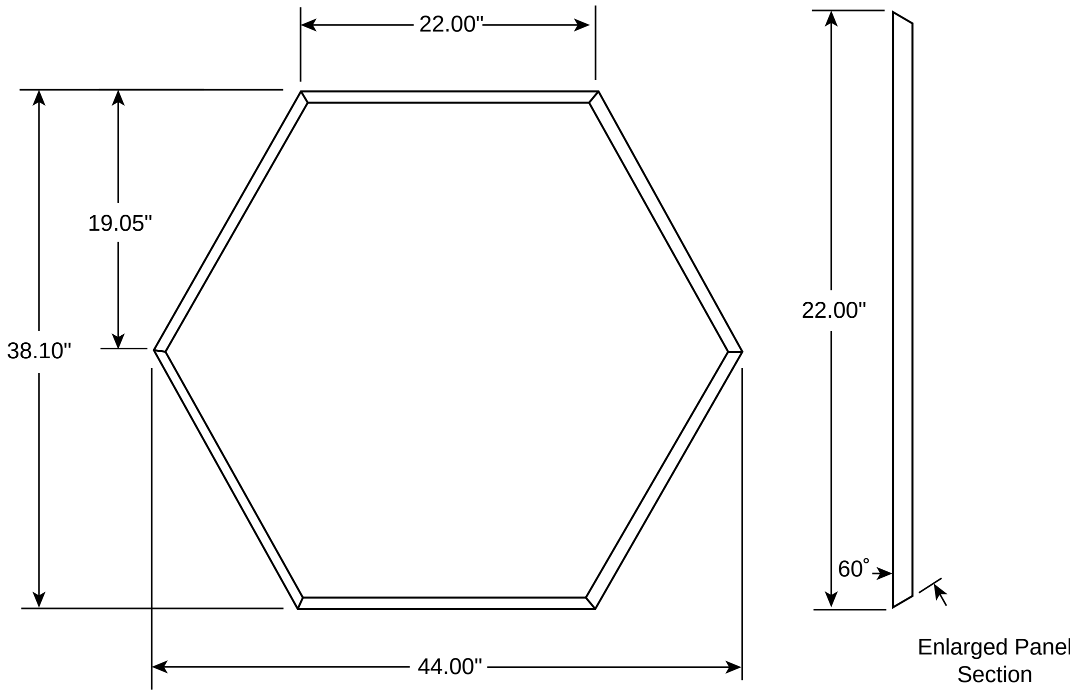


Figure A-3. Vacuum excitation chamber footprint (top view).

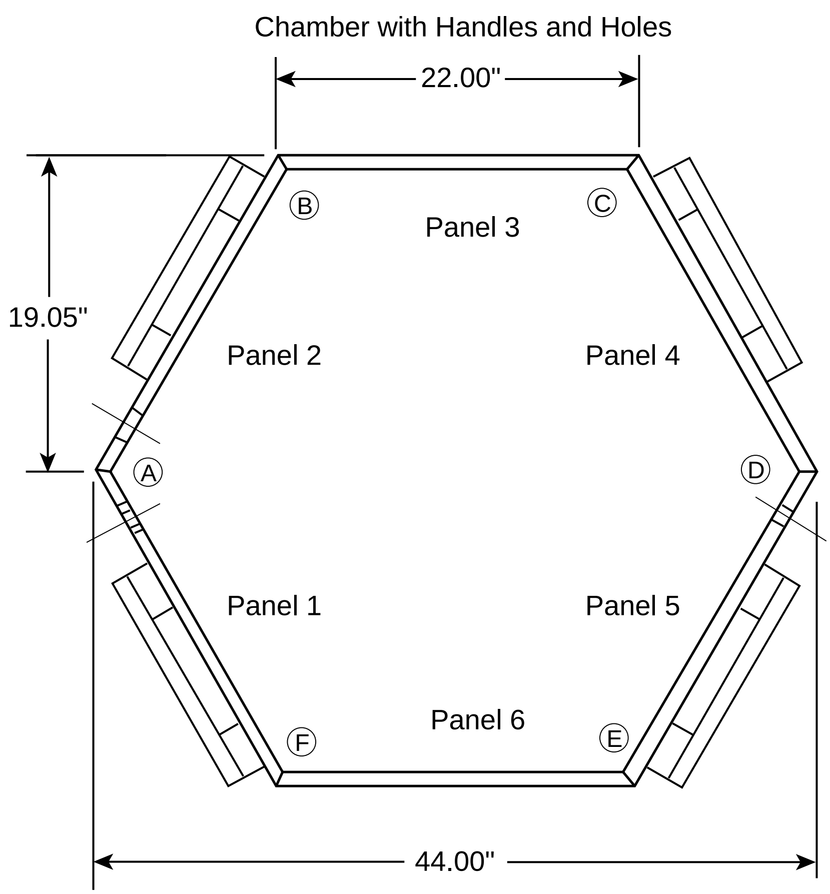
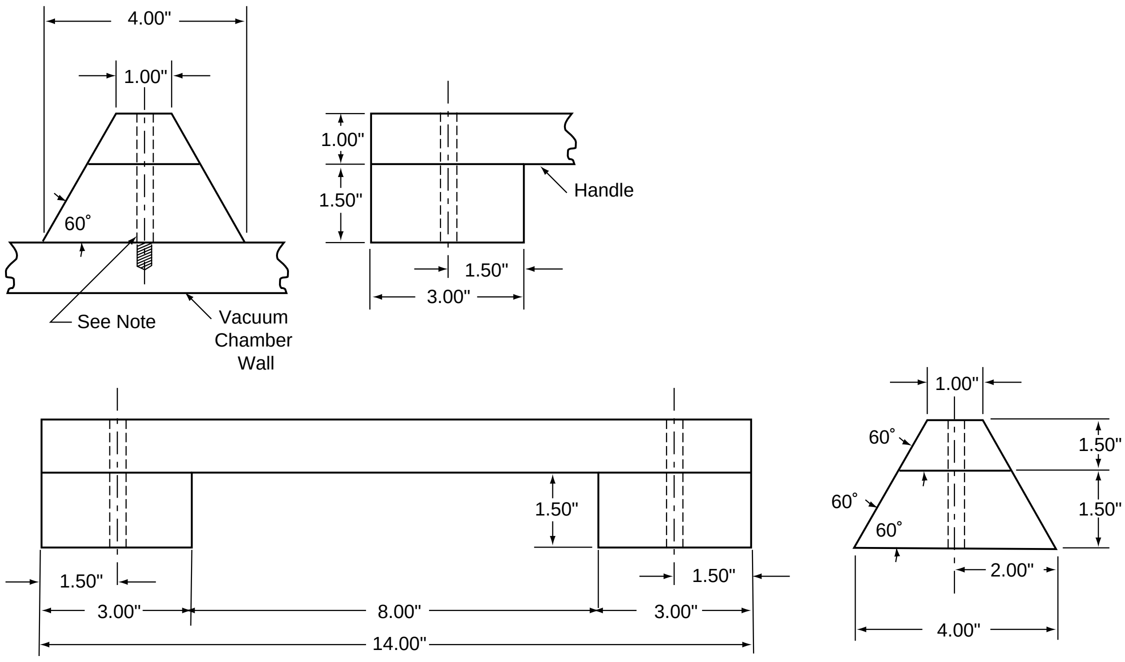
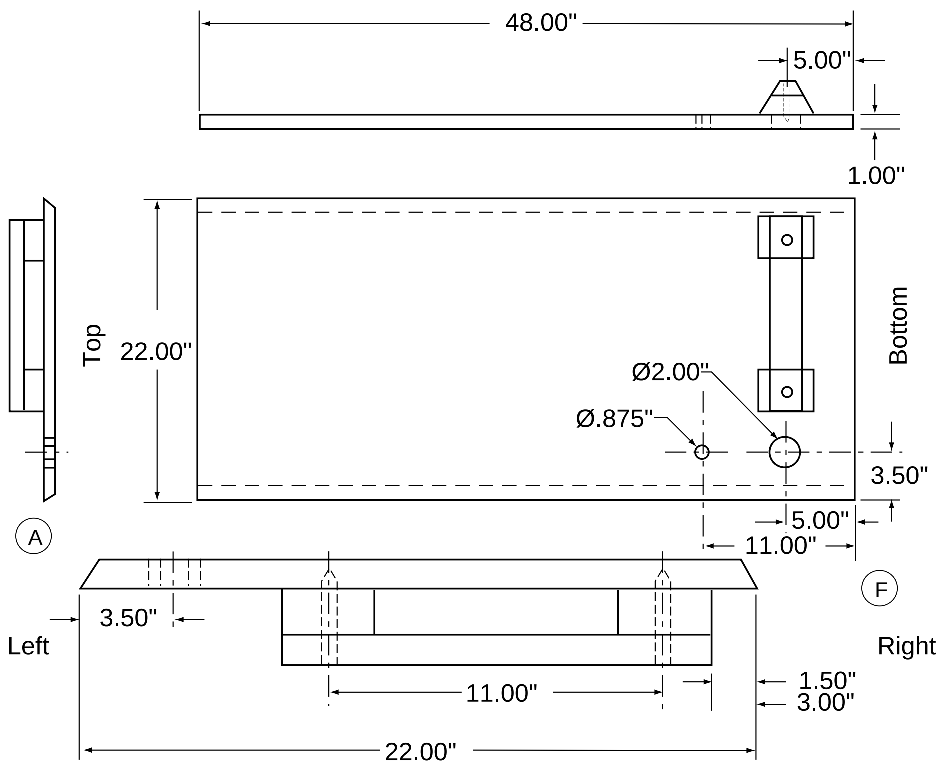


Figure A-4. Vacuum excitation chamber panel locations (top view).



Note: Handles will be glued and bolted.
1/4" – 20 X 3" bolt or fabricator's choice.
Tapped hole must not break through to inside of chamber wall.

Figure A-5. Vacuum excitation chamber handle construction.



Enlarged Top View

Figure A-6. Vacuum excitation chamber panel 1.

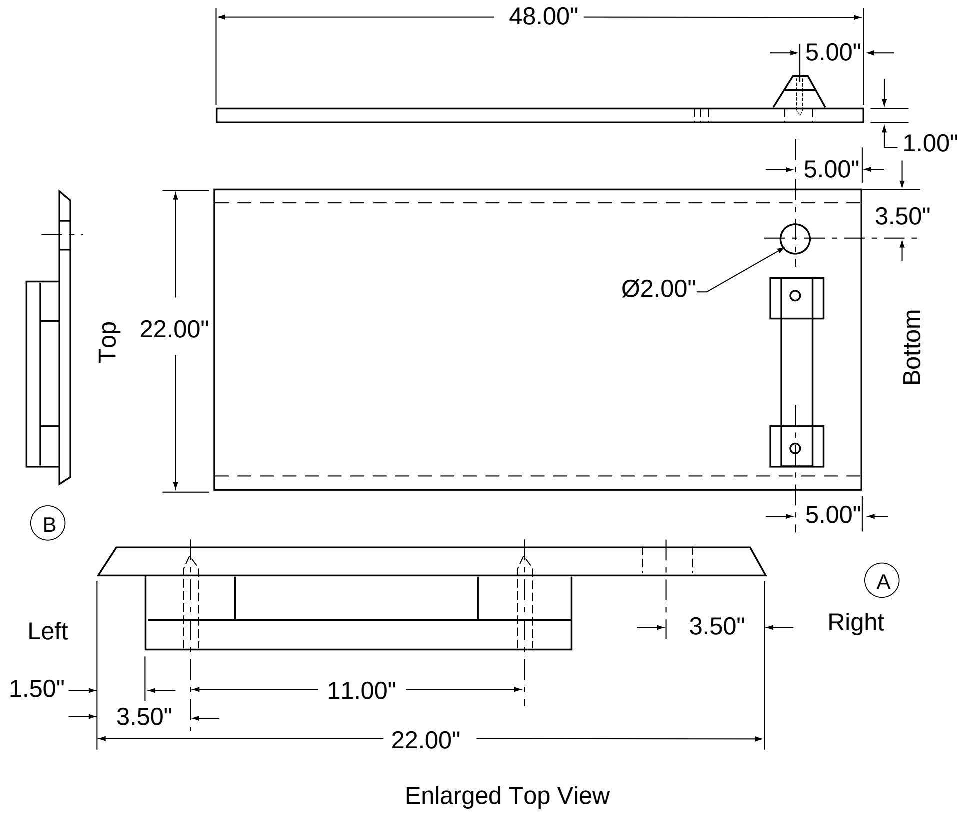


Figure A-7. Vacuum excitation chamber panel 2.

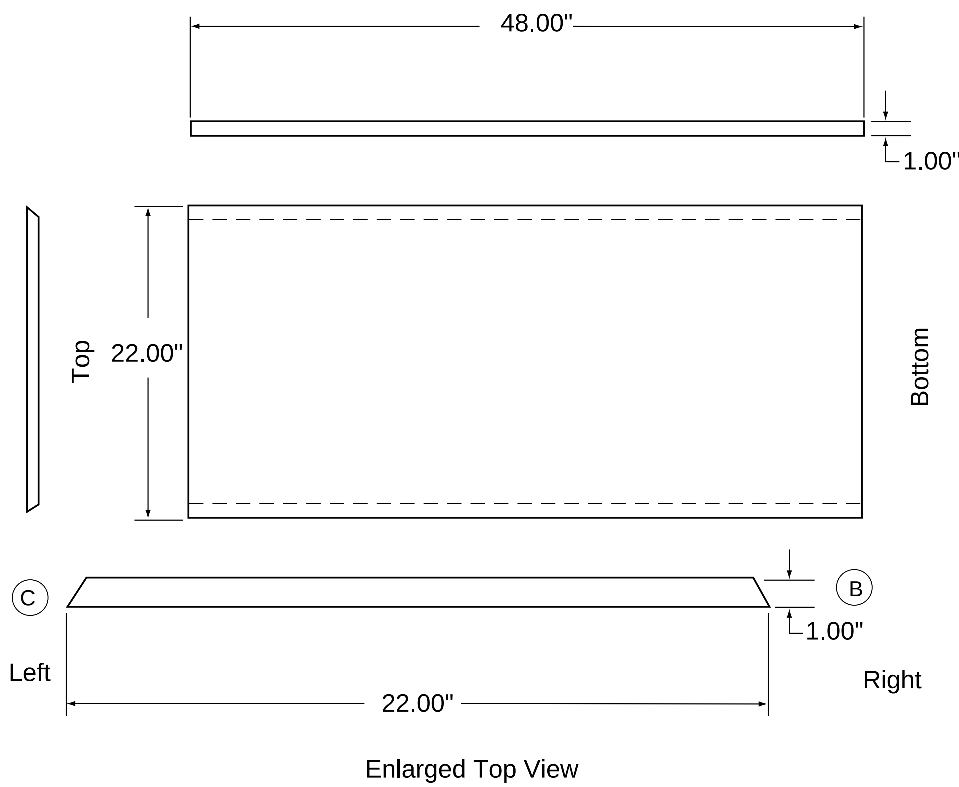


Figure A-8. Vacuum excitation chamber panel 3.

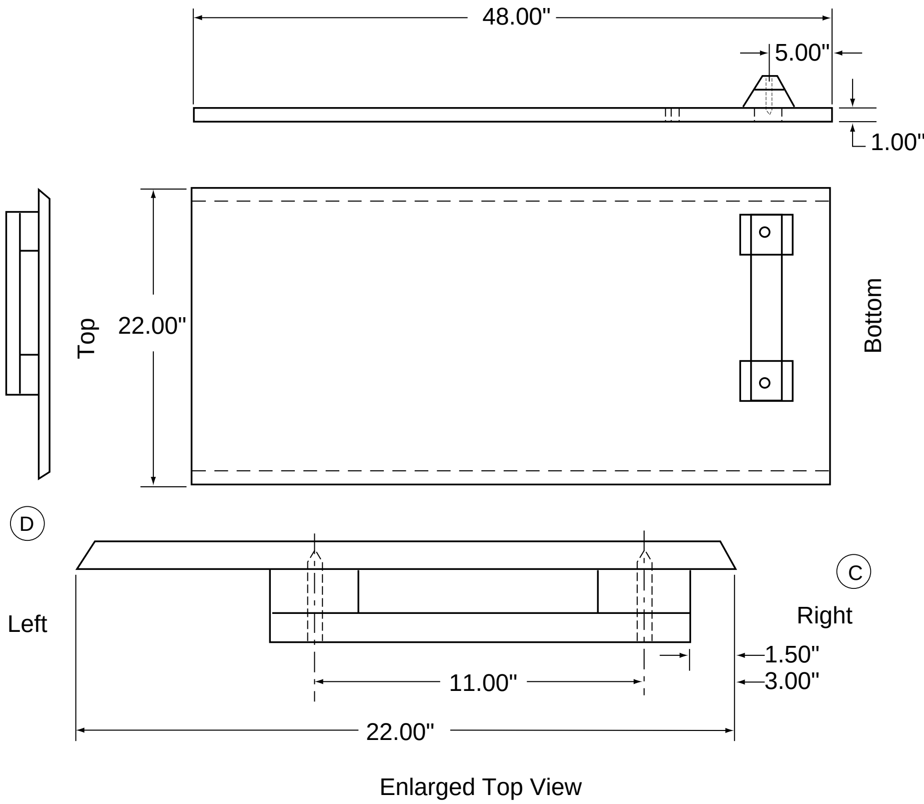


Figure A-9. Vacuum excitation chamber panel 4.

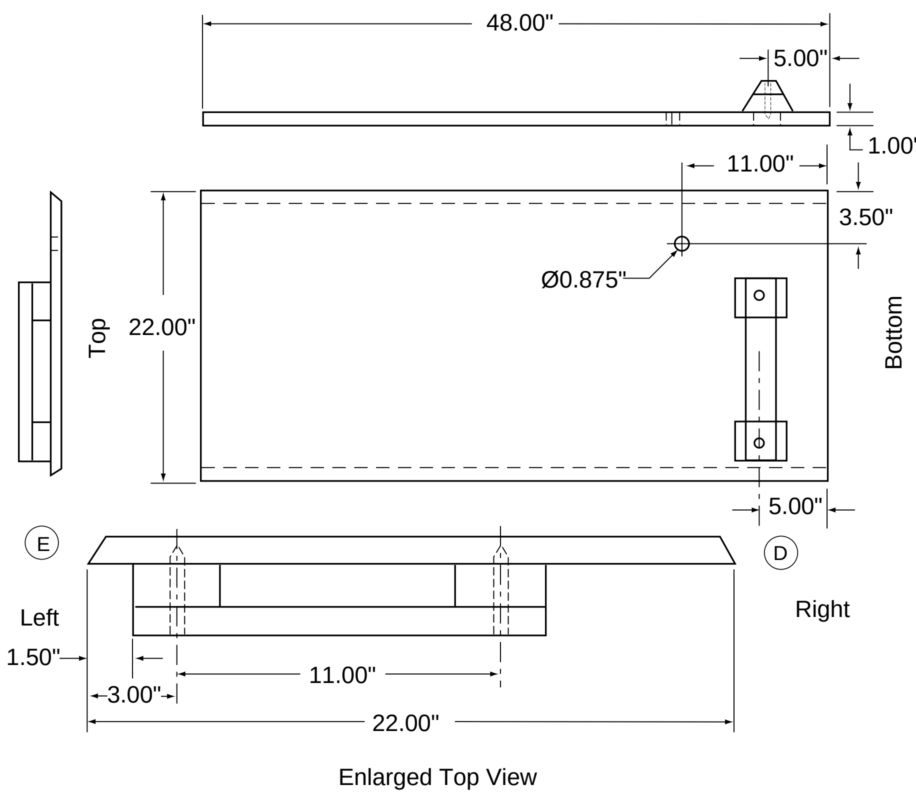


Figure A-10. Vacuum excitation chamber panel 5.

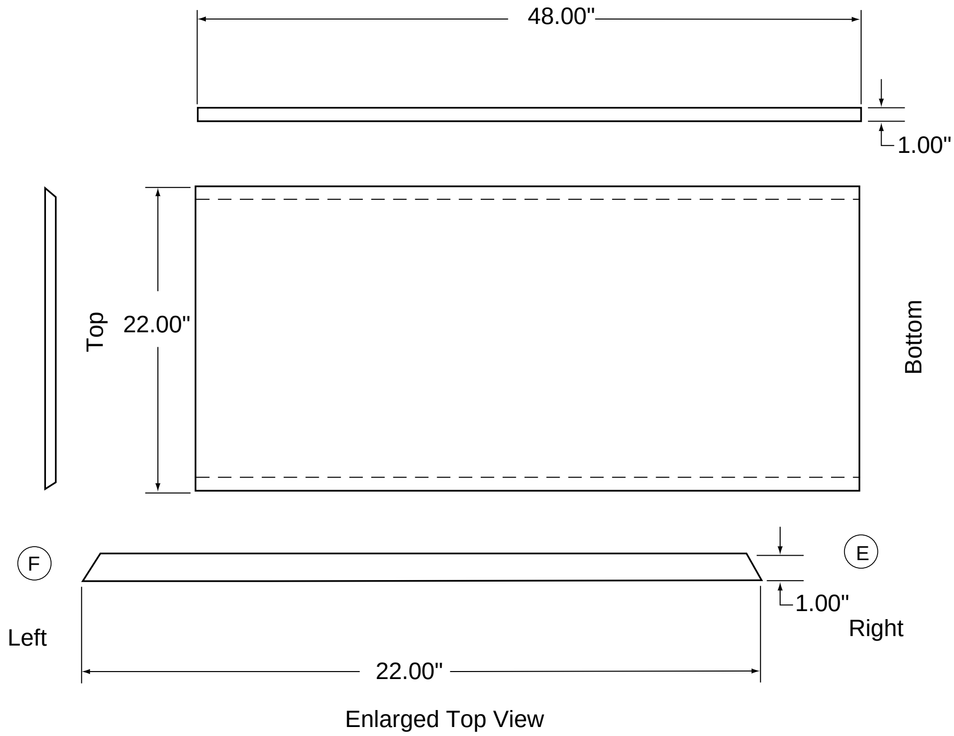


Figure A-11. Vacuum excitation chamber panel 6.

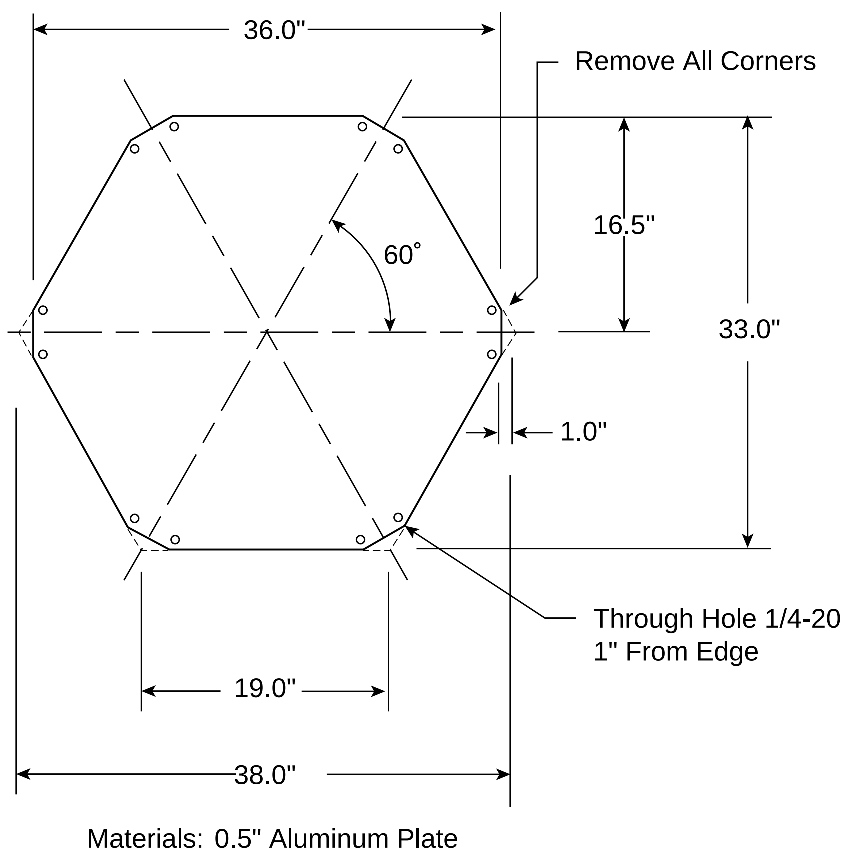


Figure A-12. Vacuum excitation chamber floating bottom.

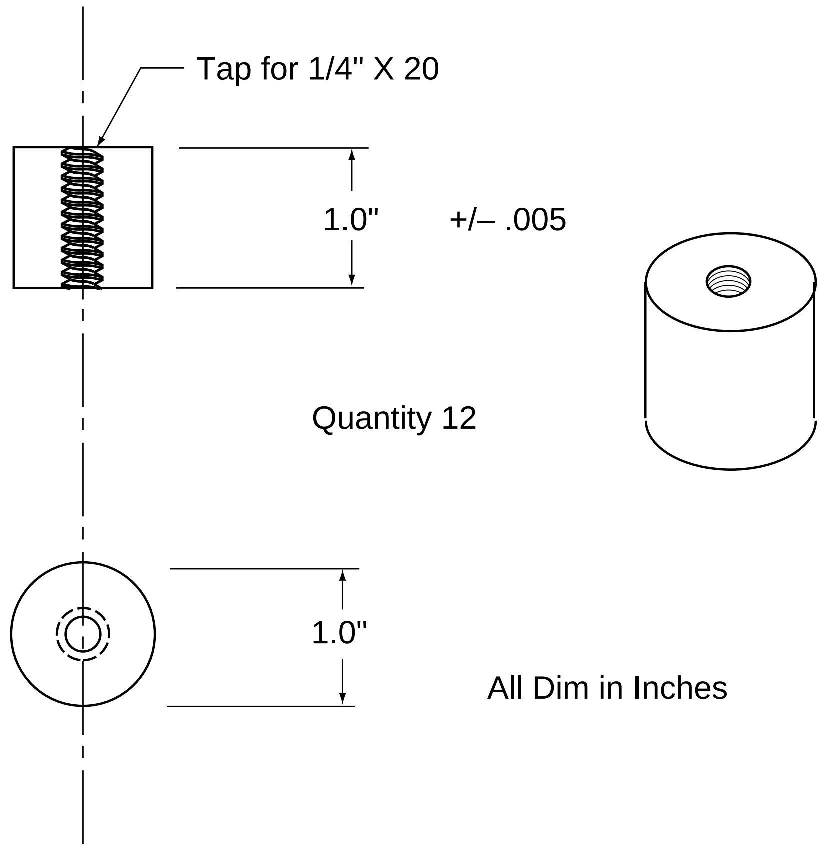


Figure A-13. Vacuum excitation chamber floating bottom legs.

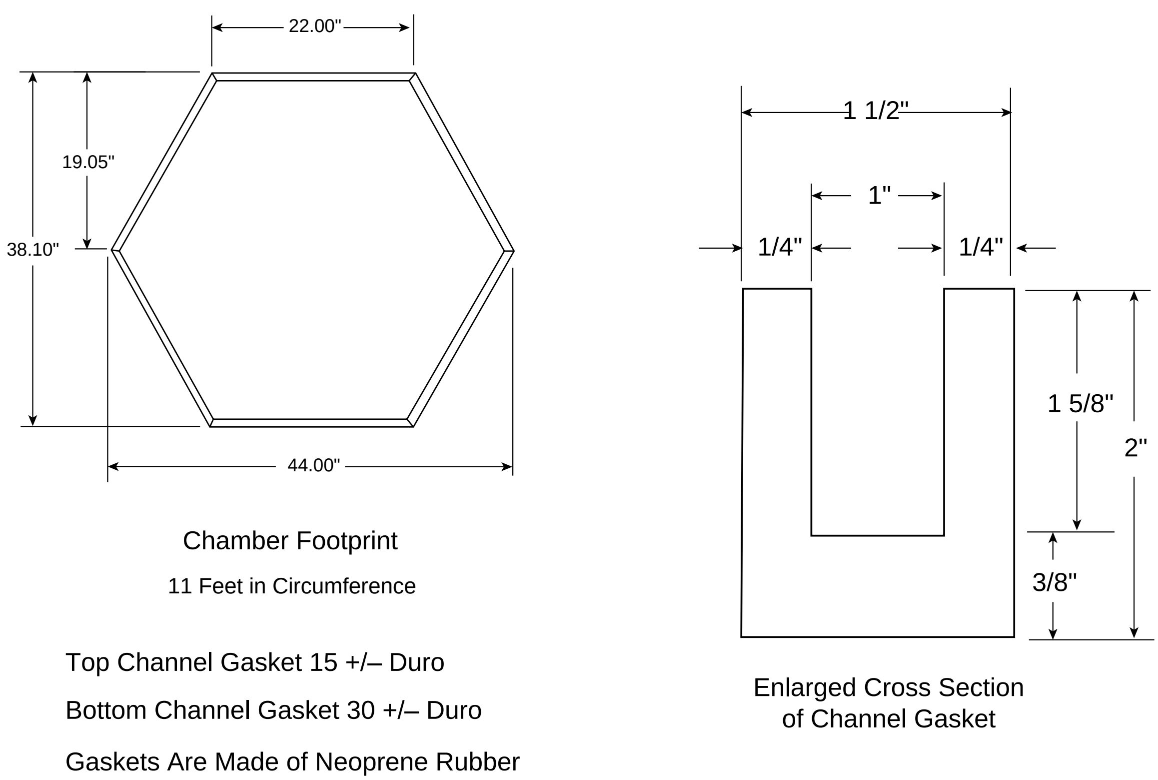


Figure A-14. Vacuum excitation chamber channel gaskets.

APPENDIX B

VACUUM CHAMBER PARTS LIST

PARTS LIST – VACUUM EXCITATION CHAMBER

1. Vacuum excitation chamber – 1-in acrylic plate (chamber weight – 250 lb)
2. Chamber lid – $1^1/_2$-in acrylic plate (lid weight – 90 lb)
3. Top edge gasket (neoprene rubber 15±5 duro)
4. Bottom edge gasket (neoprene rubber 30±5 duro)
5. Vacuum gauge, bourdon tube type, $4^1/_2$-in dial, $^1/_4$-in pipe size
6. Needle valve, $^1/_4$-in pipe size
7. $^1/_4$-in close nipple, brass
8. $^1/_4$- by $^1/_4$-in hose barb, brass
9. $^1/_2$-in to $^1/_4$-in reducer, brass
10. $^1/_4$-in 45˚ elbow, brass
11. $^1/_8$-in muffler/filter
12. $^1/_2$-in muffler/filter
13. $^1/_4$-in tee, brass
14. Vacuum breaker, adjustable, $^1/_2$-in pipe size
15. 2 each $1^1/_2$-in by $^1/_{16}$-in rubber washers
16. 2 each $^7/_8$-in by $^1/_{16}$-in rubber washers
17. 2 each $1^1/_2$-in PVC acid drains
18. 2 each $^1/_2$-in brass drains
19. 2 each $1^1/_2$-in gas ball cocks
20. Industrial wet/dry vacuum head assembly
21. 55-gal FRH drum
22. Drum dolly, 55-gal
23. $1^1/_2$-in quick connect coupled with hose clamps
24. Vacuum chamber storage cart
25. 48- by 48- by $1^1/_2$-in aluminum base plate (base plate weight – 345 lb)
26. Chamber false floor, $^1/_2$-in plate aluminum – hexagon shape