AFRL-DE-TR-2002-1033

AFRL-DE-TR-
2002-1033

H2 RECONSTITUTION

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February 2002

Final Report

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AFRL-DE-TR-2002-1033

This report has been approved for publication.

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*: February 2002	**2. REPORT TYPE**: Final Report
3. DATES COVERED *(From - To)*	Dec 2000 – Jan 2002
4. TITLE AND SUBTITLE	H2 RECONSTITUTION
5a. CONTRACT NUMBER	F29601-00-D-0074, DO 0008
5b. GRANT NUMBER	
5c. PROGRAM ELEMENT NUMBER	62605F
6. AUTHOR(S)	Mike Skipper, Mike Abdala Howard H. N. LaValley*
5d. PROJECT NUMBER	4867
5e. TASK NUMBER	HJ
5f. WORK UNIT NUMBER	03
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)	ASR Corporation 7817 Bursera NW Albuquerque, NM 87120
8. PERFORMING ORGANIZATION REPORT NUMBER	DC-TR-0328.008-1
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)	Air Force Research Laboratory/DE 3550 Aberdeen Avenue SE KIRTLAND AFB NM 87117-5776
10. SPONSOR/MONITOR'S ACRONYM(S)	AFRL
11. SPONSOR/MONITOR'S REPORT NUMBER(S)	AFRL-DE-TR-2002-1033

12. DISTRIBUTION / AVAILABILITY STATEMENT

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED.

13. SUPPLEMENTARY NOTES

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14. ABSTRACT: The high power microwave program at the Air Force Research Laboratory (AFRL) includes high power source development in narrow band and wideband technologies. The H2 source is an existing wideband source that was developed at the AFRL. A recent AFRL requirement for a wideband impulse generator to use in materials tests has provided the need to update the H2 source for the current test requirements. The H2 source is composed of a dual resonant transformer that charges a short length of coaxial transmission line. The transmission line is then discharged into an output coaxial transmission line with a self-break hydrogen switch. The dual resonant transformer is driven by a low inductance primary capacitor bank operating through a self-break gas switch. The upgrade of the coaxial hydrogen output switch is the focus of this report.

The hydrogen output switch was developed through extensive electrical and mechanical simulations. The switch insulator is made of Ultem 2300 and is designed to operate with a mechanical factor of safety equal to 4.0 at 1,000 psi. The design criteria, design data and operational data will be presented.

15. SUBJECT TERMS

pulsed power, high power microwave, dual resonant transformers

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. No. OF PAGES	19a. NAME OF RESPONSIBLE PERSON
					Robert J. Torres
a. REPORT	**b. ABSTRACT**	**c. THIS PAGE**			**19b. TELEPHONE NUMBER** *(include area code)*
UNCLASS	UNCLASS	UNCLASS	Unlimited	50	(505) 846-0296

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. 239.18

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1.0 OVERVIEW

This report documents the H2 reconstitution effort (Task Order 008, Ultrawideband Sources and Antennas, F29601-00-D-0074). The goal of the effort was to return the H2 system to a reliable and safe operational state while minimizing changes to the existing physical design. To insure the safety of personnel operating the system, it was necessary to perform a thorough mechanical evaluation of the system. Evaluation of system reliability required that an electrostatic analysis be performed to verify adequate field management and the development of a circuit model for the system to allow approximate predictions of system performance. The system was operated into the dummy load to verify system performance parameters.

The guidelines for modification of the existing components were as follows:

- New insulator parts were to be fabricated if necessary.
- The aluminum structural components were to be maintained with minimal modification (removing material from existing parts) if necessary to improve the electrical and mechanical performance

To date, a complete evaluation of the H2 system inventory has been performed. A complete mechanical and electrostatic analysis of the original system has been completed and the performance of the upgraded H3 transformer has been estimated through modeling techniques. The original design of the system has been modified to improve both the mechanical strength and the electrical reliability.

2.0 INVENTORY EVALUATION

The original H2 system is shown in Figure 1. The system had been previously disassembled and stored in several different locations requiring that the system components be located, identified and evaluated for usability before any mechanical or electrical analyses could be performed. A complete H2 transformer in satisfactory working order was not found and therefore after discussions with the original system designer (Richard Copeland, ITT Industries), it was decided that the H3 transformer would be the best choice for a replacement unit. The H3 and H2 transformer mounting flanges were designed to allow transformer compatibility. The transformer was disassembled and inspected for electrical and mechanical damage. Electrical damage was found, indicating the need for a redesign of the primary winding to eliminate field enhancement points. The pulse forming section and the hydrogen switch insulators were located and identified as the correct components. The transformer-end switch insulator exhibited a complete electrical breakdown through the bulk of the material with strong indications that a complete mechanical failure was imminent. An output-side switch insulator made of acrylic was not found although a nylon insulator was found. A nylon insulator is not suitable for both electrical and mechanical concerns. A complete set of suitable aluminum containment vessel components was located and the output dummy load was found to be in reasonable condition with some contact corrosion.

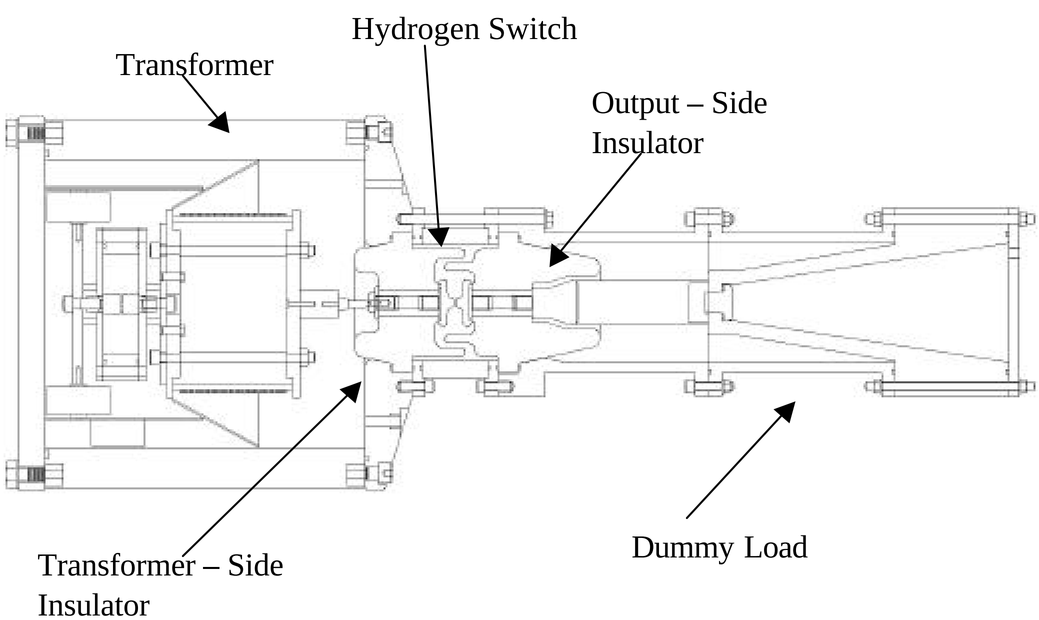

Figure 1. Original H2 System

3.0 TRANSFORMER MODIFICATION

The H3 transformer consists of a single primary winding and a 32–turn secondary winding with an as-designed coupling coefficient of 0.6 to allow dual resonant operation. The transformer was disassembled and inspected for electrical damage. Significant arc/corona damage was clearly evident near the primary winding feed point and a complete electrical failure was identified between the two ends of the primary winding. Also, some partial discharge activity was observed in the Mylar insulation between the primary and secondary windings of the transformer. The secondary winding was found to be adequate with no damage.

A new primary winding was fabricated to alleviate the formation of corona activity in the vicinity of the primary winding feedpoint. During fabrication of the winding, special care was taken to insure no sharp edges and the winding band edges were terminated with a ¼" diameter tube. A new nylon insulator was fabricated to isolate the opposite ends of the primary winding. The length of the Mylar insulation between the primary and secondary windings was increased to alleviate the partial discharge activity.   A picture of the revised primary/secondary winding assembly is shown in Figure 2.

The resonant frequency of the secondary winding with and without the primary winding shorted was measured to allow calculation of the coupling coefficient. The primary and secondary inductance of the secondary winding was measured using an LCR meter. The measured parameters are given in Table 1. To estimate the maximum output voltage of the transformer, a Pspice™ model of the transformer was formulated. The expected output charge voltage (hydrogen switch remains open) is shown in Figure 3.

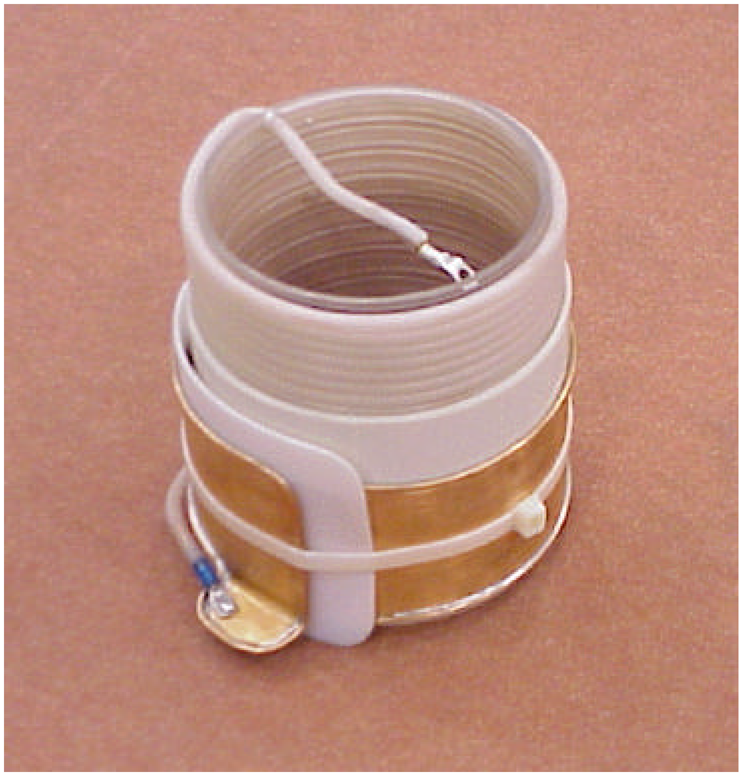

Figure 2. Revised H3 Transformer Assembly

TABLE 1. Revised H3/H2 transformer specifications.

Open Circuit Resonance	1.13 MHz
Short Circuit Resonance	1.62 MHz
Coupling Coefficient	0.72
Primary Inductance	74.4 nH
Secondary Inductance	74.3 μH
Primary Turns	1
Secondary Turns	32

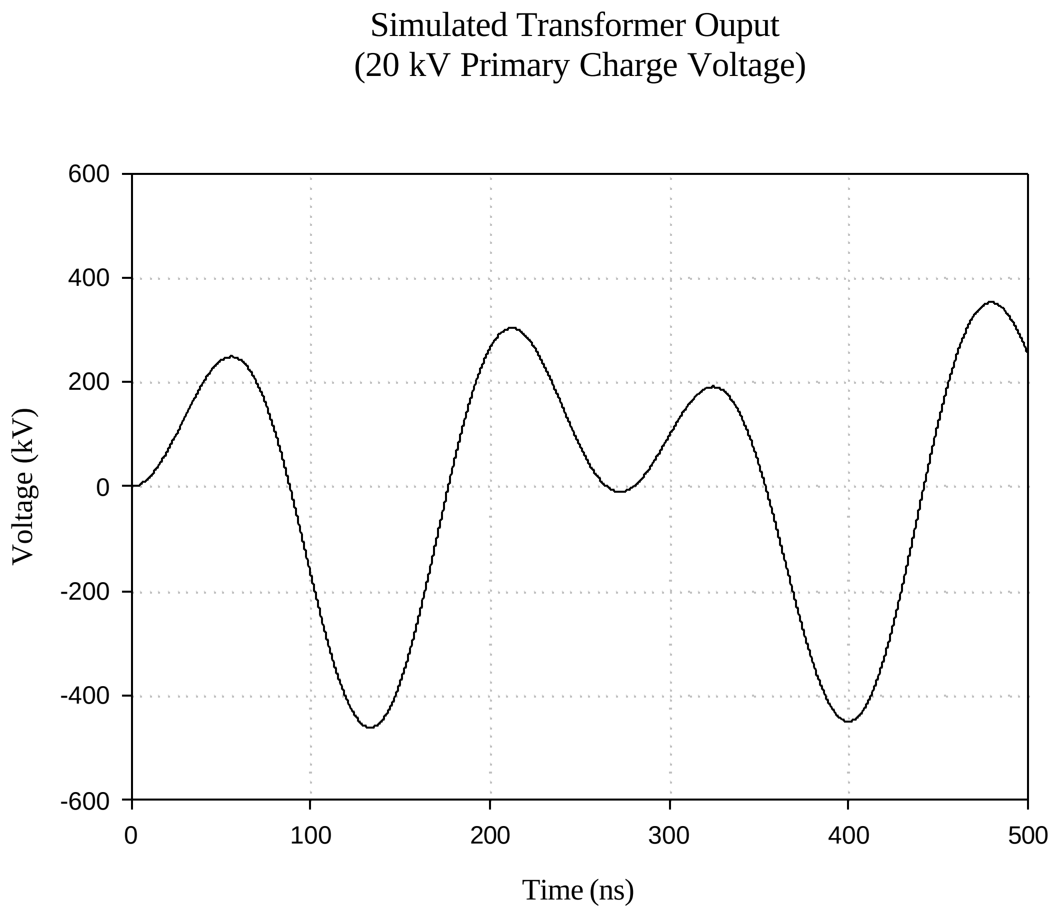

Figure 3. Simulated revised transformer output (hydrogen output switch remains open).

4.0 MECHANICAL ANALYSIS

The output switch in the H2 source is a self-break hydrogen design and is typically operated at a pressure of approximately 1,000 psig (see Figure 4). The source had experienced mechanical failures in the past. In the original H2 design, the dielectric gas containment components are fabricated from Acrylic and the entire switch is mechanically retained with all-thread stock. All outer conductor components are fabricated from aluminum and the switch electrode support shafts are fabricated from brass. The switch electrodes are tungsten.

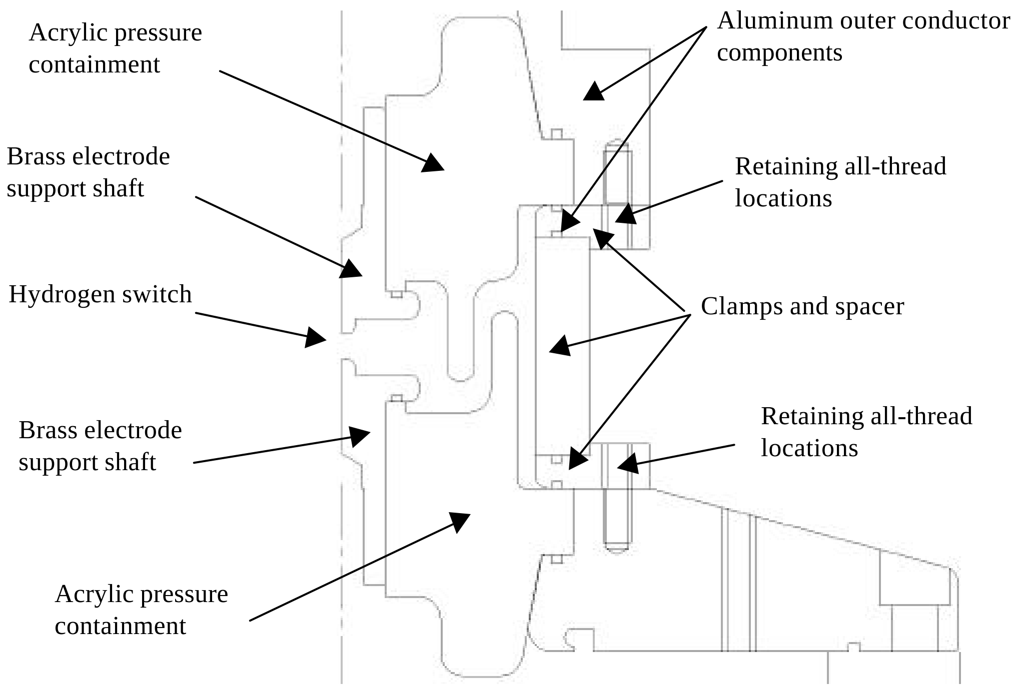

Figure 4. Original H2 output switch design.

The American Society of Mechanical Engineers (ASME) code[1] has been modified several times since the initial code was introduced in 1925. For pressure vessels a safety factor (or Factor of Safety, SF) of 4 is required unless finite element methods are used in which case the required safety factor is 3.5. Finite element analysis and a safety factor of 4 were used resulting in a conservative design. The switch components were mechanically analyzed to determine mechanical stress and deflection using Design Space™; a 3-dimensional finite element analysis (FEA) software package. Mechanical modifications to the original design were made in order to accomplish each of the following design goals:

[1] ASME Boiler Pressure Vessel Code, Section VIII

- Ensure a FS of at least 4.0 for the system,
- Accommodate electric field requirements,
- Use as many existing parts as possible, and
- Assure sealing at 1,000 psig.

In the original H2 design, the high-pressure output switch section is mechanically retained with approximately 8 lengths of 5/16” diameter all-thread. The H2 drawings specify “high tensile steel” all-thread, however, the highest strength all-thread available is approximately equivalent to grade 5. Calculations indicate that the number and size of all-thread retaining fasteners would have a FS of approximately 1.0. In the revised mechanical design, the switch output section is retained using 1/2" high strength bolts. Final FS determination for the retaining bolts is 5.4.

In the original H2 switch, the pressure containment dielectric components are fabricated from Acrylic. As a structural material, Acrylic must be used carefully. The initial tensile yield strength is approximately 8,000 psi. However, when Acrylic is left under tension for several hours continuously, the tensile yield strength declines to approximately 4,500 psi. As shown in Figures 5a and 5b, FEA analysis indicates mechanical stresses of approximately 6,000 psi in the Acrylic with a deflection between the electrodes of approximately 0.013”. As a result, the FS in the Acrylic components is approximately 1.0. The highest mechanical stresses in the original design are located in the corner as shown in Figure 5. A visual inspection of a failed H2 Acrylic insulator shows material cracking in this location as shown in Figure 6. In the revised design, the Acrylic is replaced with Ultem 2300. Ultem 2300 is manufactured by several companies using the Ultem epoxy resin manufactured by General Electric. The material used for the insulators was manufactured by Boedeker. The specification sheet is given in Appendix B Mechanically, Ultem 2300 has a measured tensile yield strength of approximately 19,000 psi and does not change significantly over time. Additionally, Ultem 2300 has been used successfully in both the JOLT transfer switch[2] and the Aimpoint /IRA output switch[3].

Although Ultem 2300 is substantially stronger than Acrylic, additional mechanical modifications were made to achieve a FS of 4.0. The geometry associated with the high mechanical stresses in Figure 5 was revised to distribute the mechanical stresses over a smoother surface as shown in Figure 7. The resulting mechanical stresses in the Ultem 2300 are reduced to approximately 5,000 psi, most of which is compressive. The rated compressive strength of Ultem 2300 is approximately 22,000 psi. As a result, the FS in the Ultem of the revised mechanical design is approximately 4.0. The deflection between the electrodes with the revised Ultem 2300 design is approximately 0.009”.

[2] “Jolt Transformer and Transfer Switch Design and Modifications Report,” ASR Corporation, 8 January 2001.
[3] The Ultem version of the AIMPOINT/IRA switch has been tested to more than 1-million shots with no apparent damage or degradation in performance.

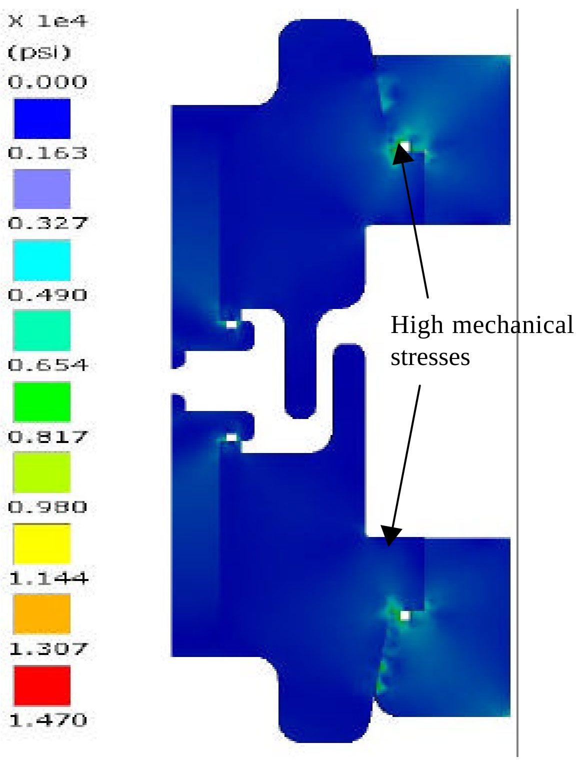

Figure 5a. Mechanical stresses in original H2 design.

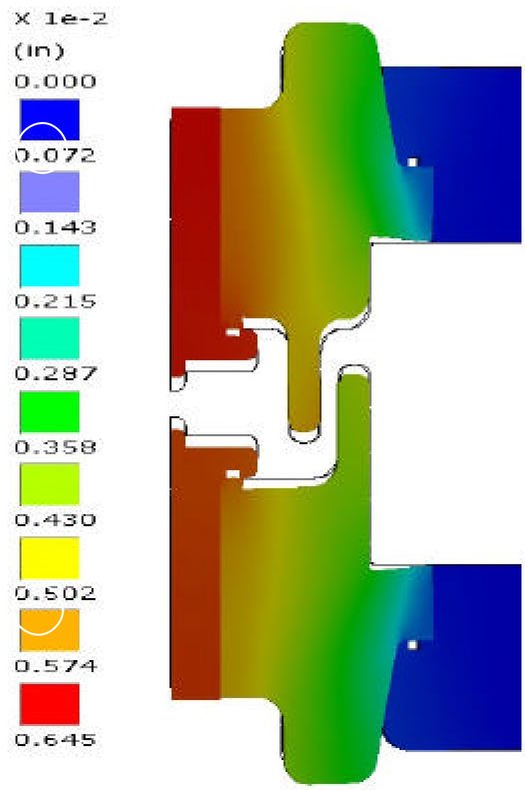

Figure 5b. Mechanical deflection in original H2 design.

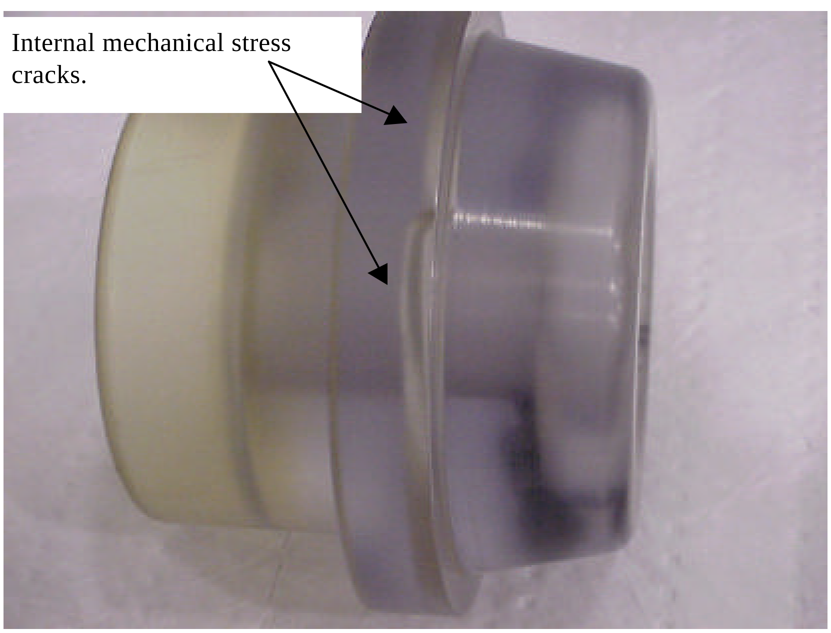

Figure 6. Image of failed Acrylic pressure containment component from the original H2 design. Dark regions are result of electrical failure.

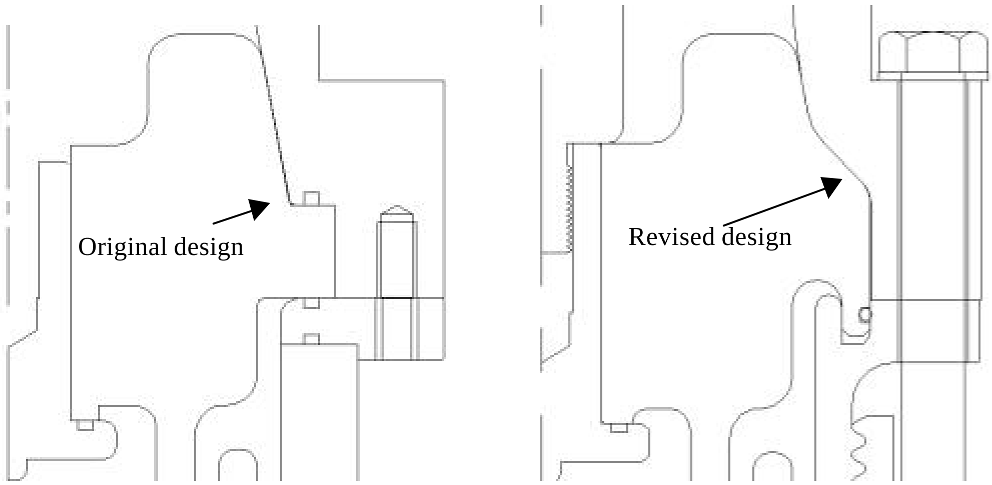

Figure 7. Original and revised mechanical load surfaces in output design.

Experience with previous high-pressure switches has indicated that it is preferable to place o-rings on surfaces that are not forced apart when high pressure is applied. Several o-rings in the original H2 design were placed in surfaces that were forced apart as shown in Figure 8. In the original design, as the switch is pressurized, the outer conductor components have a tendency to pull away from each other. If a large enough gap is established, the o-ring will be extruded out from between the components allowing the Hydrogen to escape. Such a pressure release could be violent. In the revised design, the o-ring is placed such that as the components move under the force of switch pressure, the o-ring stays in place and continues to seal.

The revised o-ring sealing concept necessitated a complete redesign of the clamp/spacer section of the original design as shown in Figure 9. The revised design is a two-piece screw-together unit that is stronger than the previous design. The highest mechanical stress in the aluminum outer conductor components is approximately 7,000 psi resulting in a FS of approximately 10.0. Both the original and revised mechanical designs are shown in Figure 10. All the design goals were met. The mechanical stress and deflection analyses of the revised design are shown in Figures 11a and 11b.

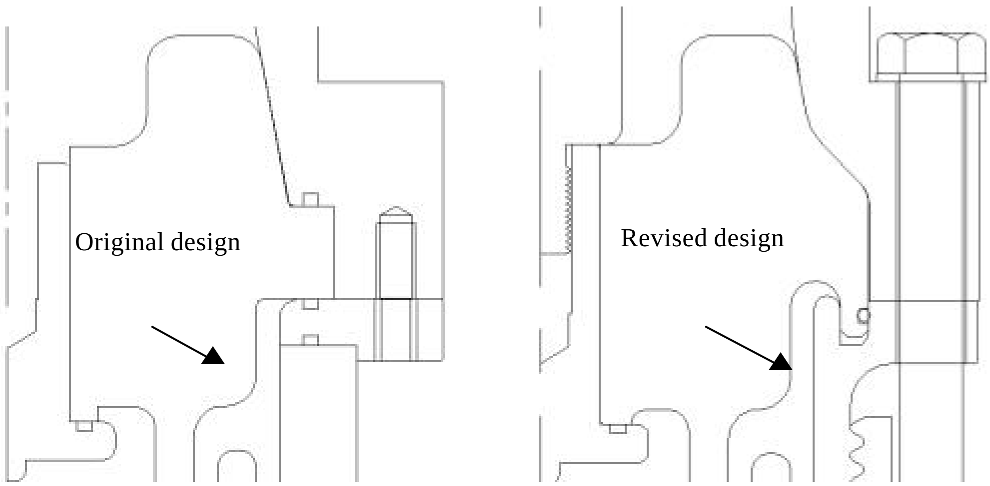

Figure 8. Original and revised o-ring locations.

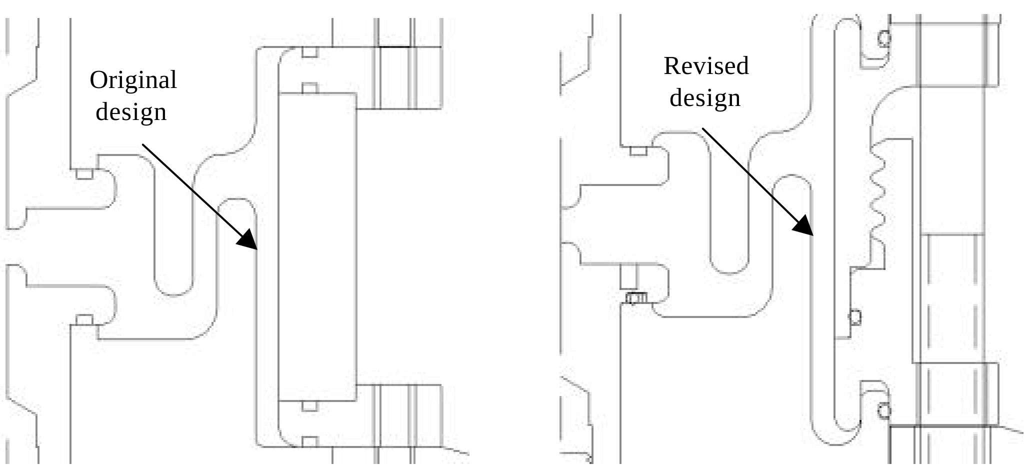

Figure 9. Original and revised clamps and spacer design.

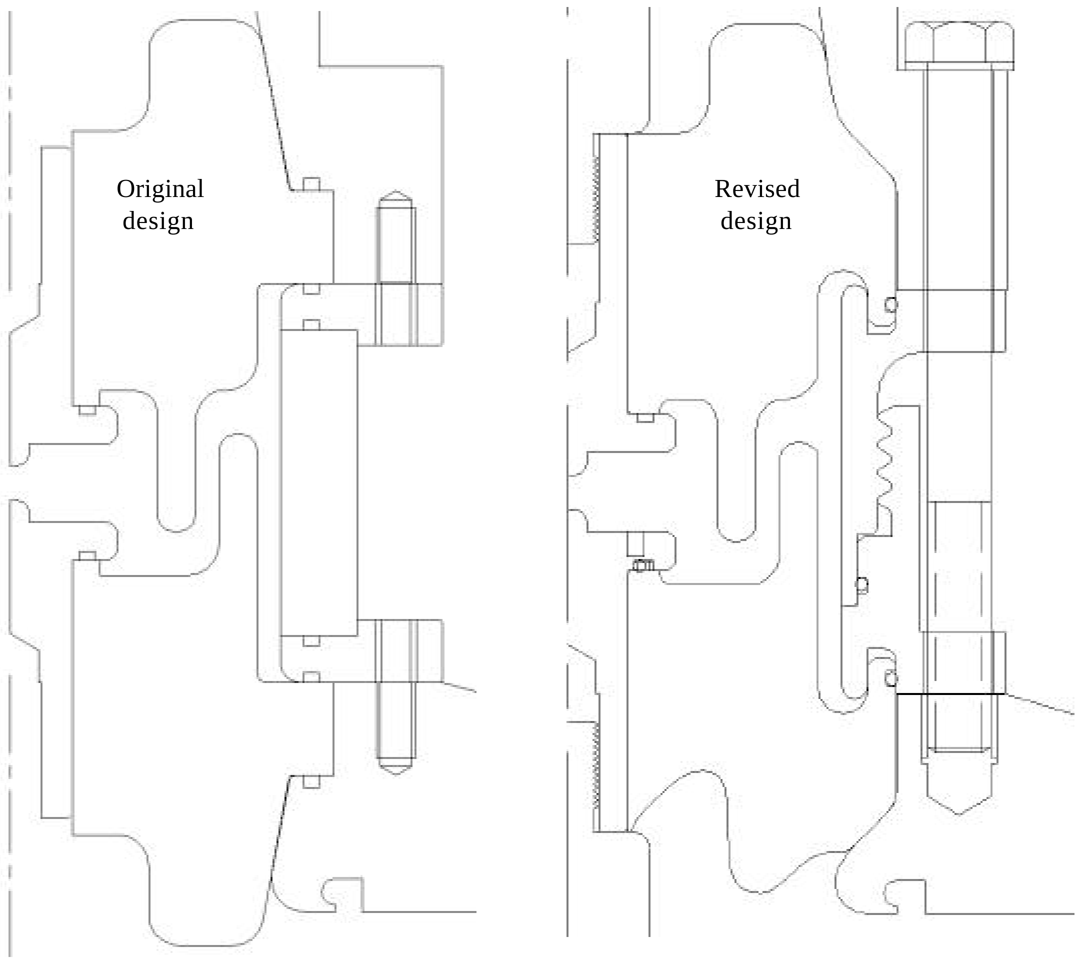

Figure 10. Original and revised H2 output switch designs.

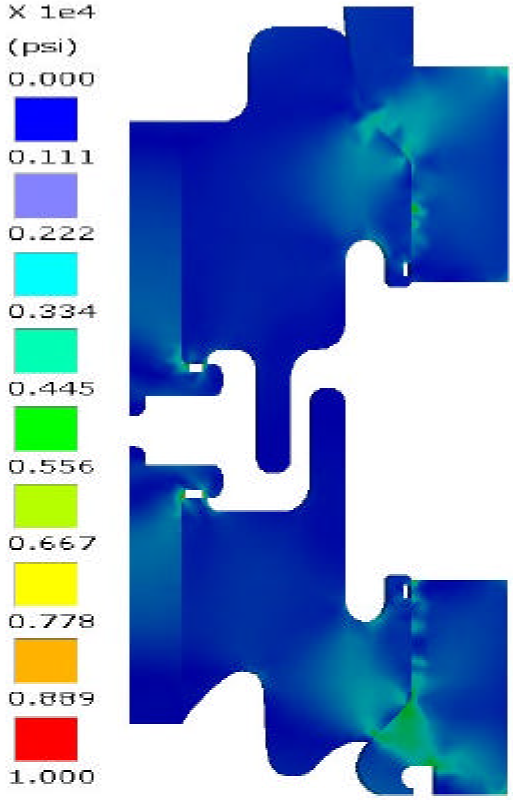

Figure 11a. Mechanical stresses in revised H2 design.

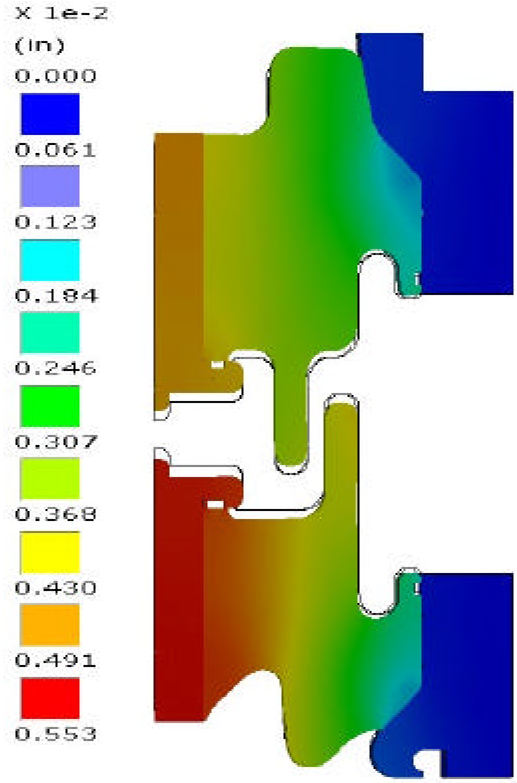

Figure 11b. Mechanical deflection in revised H2 design.

5.0 ELECTRIC FIELD ANALYSIS

The H2 switch components were electrically analyzed to determine the maximum field levels using Electro™; a two-dimensional boundary element method software package. Based on empirical data obtained during the JOLT experiments, the following criteria was used:

- Field levels at metal/Ultem 2300 interfaces should be limited to less than 100 kV/cm
- Field levels at metal/oil interfaces should be limited to less than 350 kV/cm
- Tangential field levels along insulator surfaces that bridge a gap between two oppositely charged conductors should be limited to 160 kV/cm when in oil
- Tangential field levels along insulator surfaces that bridge a gap between two oppositely charged conductors should be limited to 130 kV/cm when in oil

During operation of the H2 source, the transformer side of the hydrogen switch is charged slowly in approximately 300-400 ns while the output side remains isolated and at ground potential. When the hydrogen switch closes, the output side of the source is charged to a lower peak voltage (approximately half the transformer-side voltage) and the effective stress time is less than 10 ns. Therefore, the primary electrical concern was associated with the switch insulator on the transformer side of the source while the output switch is open.

The unmodified design for the transformer-side insulator used for the electrostatic analysis is shown in Figure 12. The lower end is the source transmission line that is charged by the transformer. A voltage contour plot of the original design is shown in Figure 14 and an E-Field magnitude plot is shown in Figure 16. The high-field areas are clearly evident in Figure 16 with some areas exceeding 250 kV/cm. The four specific areas of concern are the three triple points (#1, #2, #3) and the aluminum/ Ultem 2300 interface at the center conductor. Shielding techniques were used to move the high field areas into the hydrogen or oil insulated region where higher fields can be sustained without permanent damage to insulation.

The field levels at triple point #1 are actually very low (see Figure 18), however, the field levels in the very near vicinity are in excess of 250 kV/cm (see Figure 16). The field levels at triple point #2 (see Figures 22 and 24) are also in excess of 250 kV/cm. The observed electrical failure of this insulator was initiated and terminated at these two triple points. The aluminum was recessed as is shown in Figure 15 to shield the triple point (#2) and move the high field areas into the oil dielectric. This results in higher fields in the oil region while greatly reducing the field levels at the Ultem/aluminum/oil interface. As is shown in Figure 23 and Figure 25, the field level at triple point #2 is reduced to less than 120 kV/cm. The peak field levels in the oil are increased to almost 180 kV/cm. Note that the o-ring groove in the vicinity of triple point #2 has been eliminated.

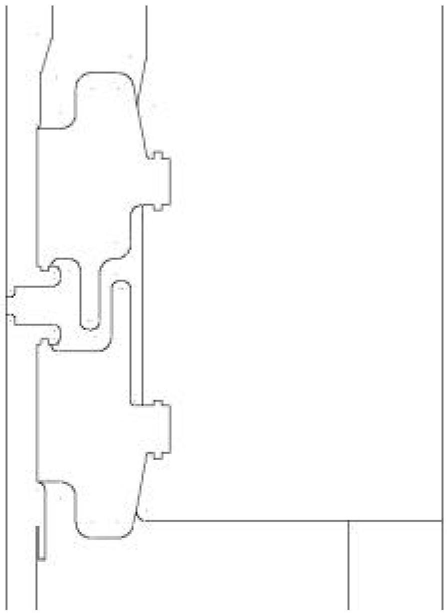

Figure 12. Original H2 design.

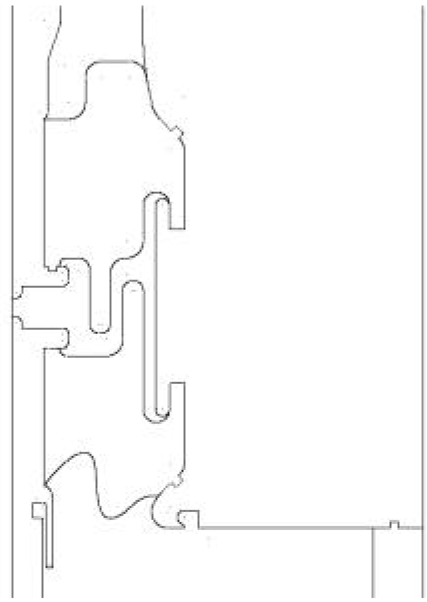

Figure 13. Revised H2 design.

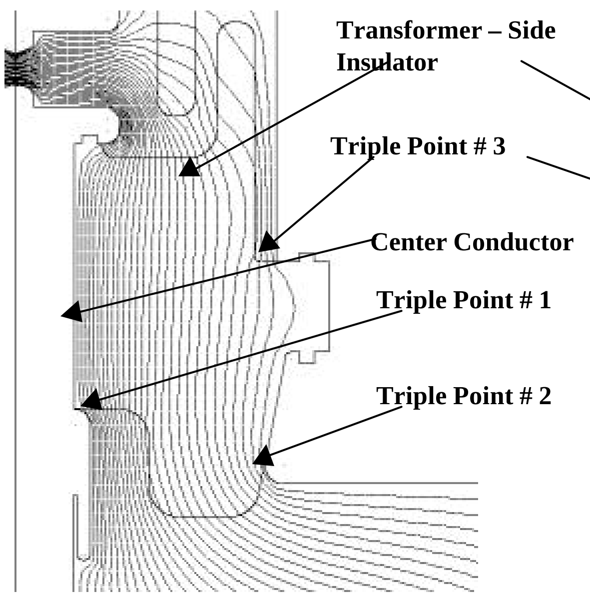

Figure 14. Voltage contour plot for original H2 design.

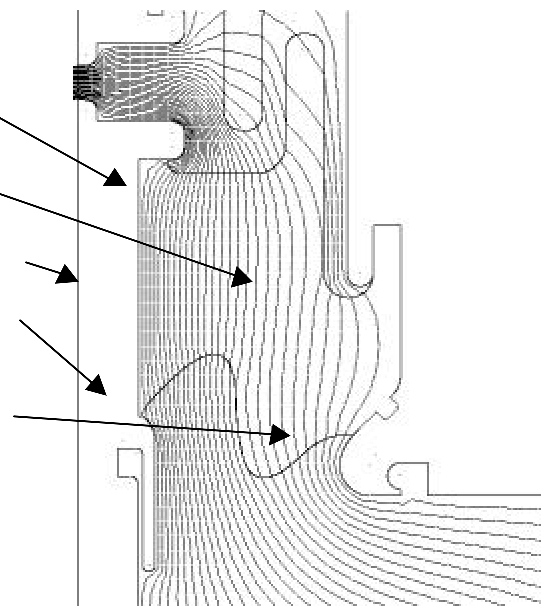

Figure 15. Voltage contour plot for the revised H2 design.

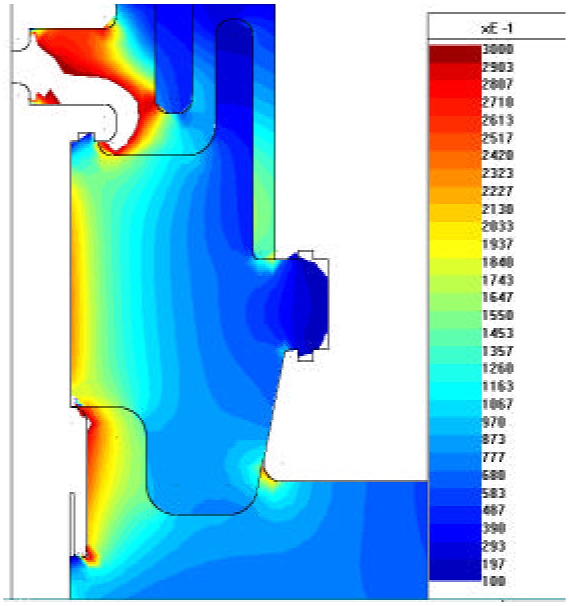

Figure 16. E-Field magnitude plot for H2 original design (kV/cm).

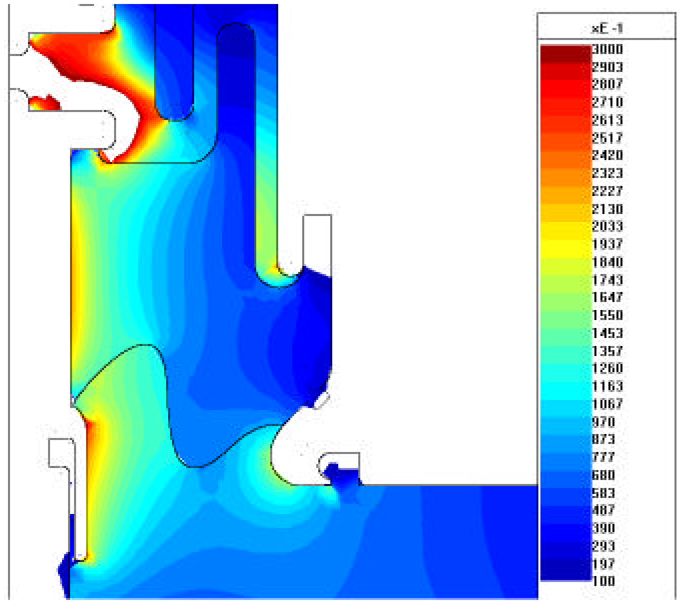

Figure 17. E-Field magnitude plot for the revised H2 design (kV/cm).

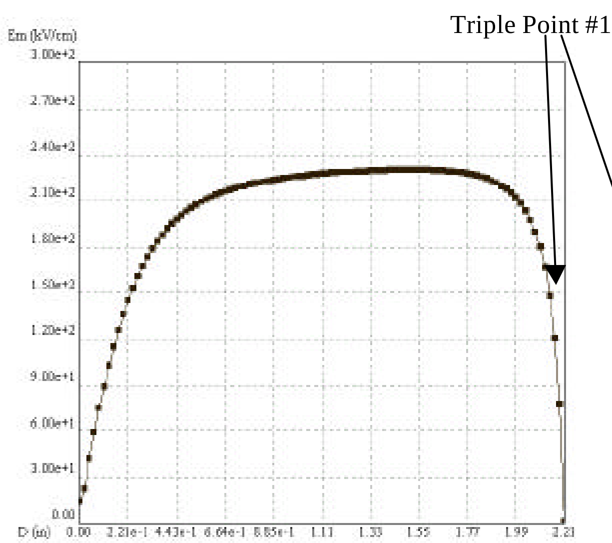

Figure 18. E-field magnitude along conductor/Ultem interface for the original H2 design (see figure 20).

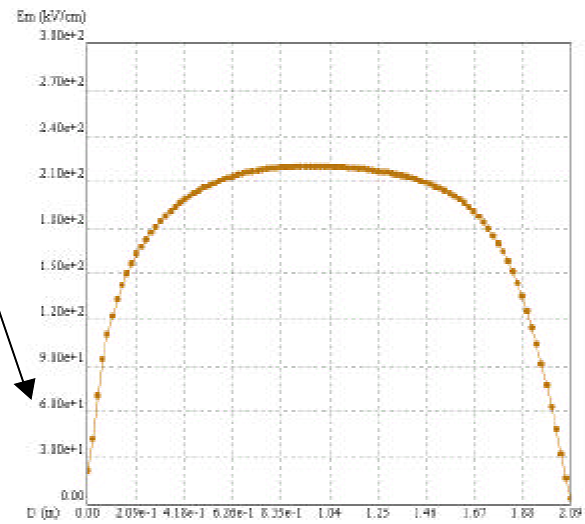

Figure 19. E-field magnitude along conductor/Ultem interface for the revised H2 design (see figure 21).

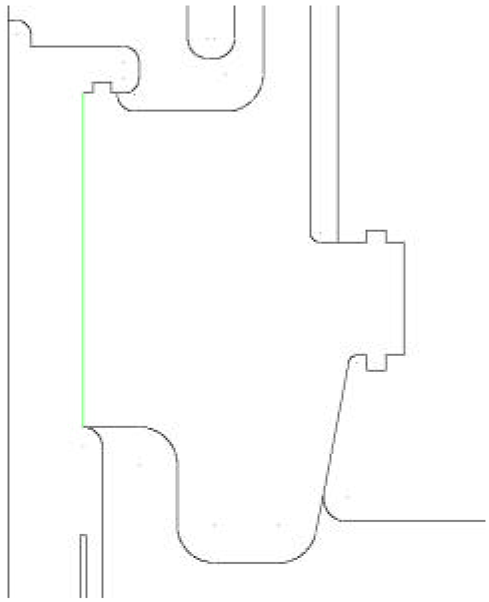

Figure 20. Plot region for Figure 18 (green line).

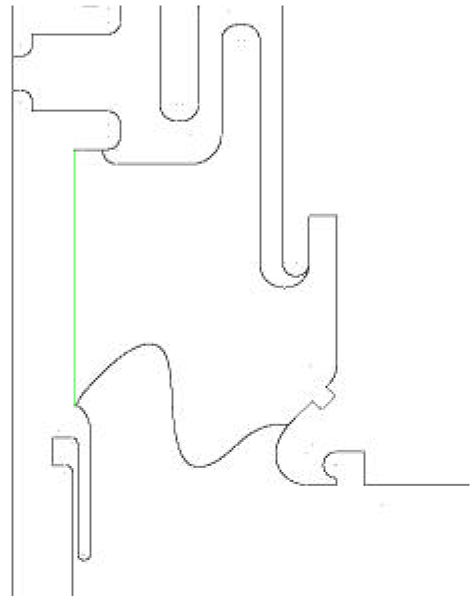

Figure 21. Plot region for Figure 19 (green line).

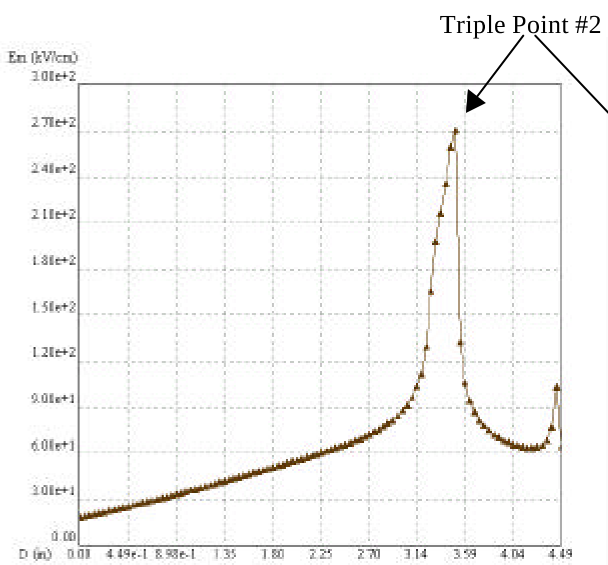

Figure 22. Electric field magnitude at the Ultem/aluminum/oil triple point for the original H2 design (see Figure 24).

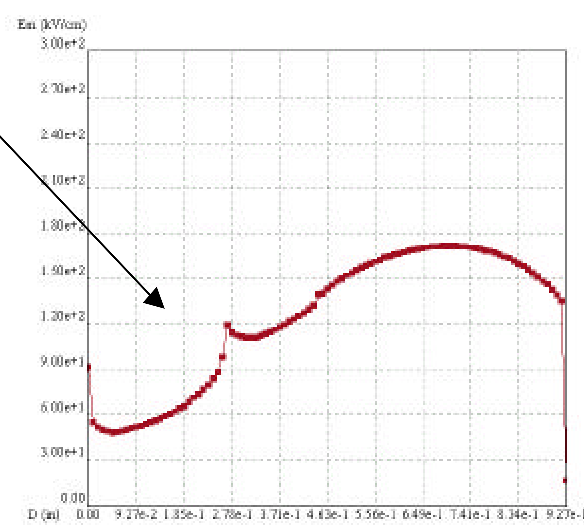

Figure 23. Electric field magnitude at the Ultem/aluminum/oil triple point for the revised H2 design (see Figure 25).

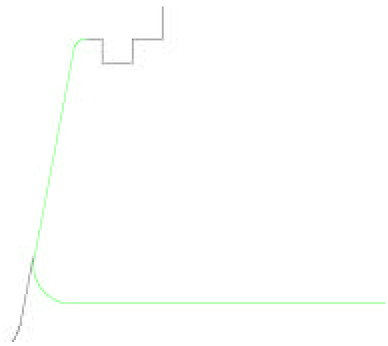

Figure 24. Plot region for Figure 22 (green line).

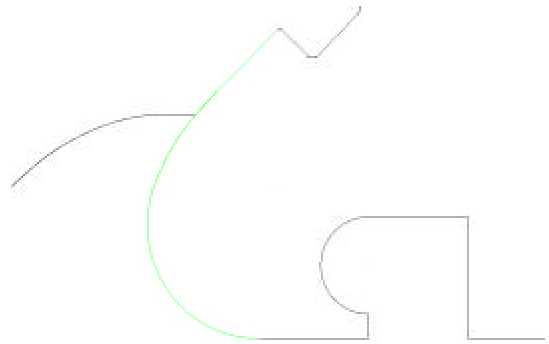

Figure 25. Plot region for Figure 23 (green line).

Increasing the oil gap between the Ultem 2300 and the metal and changing the angle of incidence for the Ultem 2300 to less than 90 degrees (approximately 45 degrees) decreased the field levels at and in the vicinity of triple point #1. The higher dielectric constant of the Ultem 2300 insulator results in the high field region being “pushed” into the oil region. This effect is shown very clearly in the voltage contour plots (see Figure 15).

Using a similar technique, the field levels at triple point #3 were reduced to acceptable levels by moving the triple point “behind” the aluminum. Again, this places the high field area into the higher strength hydrogen insulated area. The o-ring is placed in a very low field area.

As is shown in Figure 18 and Figure 19, the field levels at the aluminum/ Ultem interface along the center transmission line conductor are above the acceptable limits for both the original and the revised design. The field levels for the revised design have been reduced slightly by the changes made at the three triple points. The field levels in this area can only be reduced further by changing the ratio of the inner/outer conductor radius, or by increasing the outer conductor significantly while maintaining the same inner conductor radius. A change in either radius will alter the source line impedance and will result in a change in the output pulse characteristics. This would also require a redesign and manufacture of the aluminum components. To reduce the field levels to acceptable levels, the source charge voltage will have to be reduced to 60 % of the expected transformer output of 460 kV (i.e., 280 kV).

The electric field levels tangential to a dielectric surface bridging two conductors are important to minimize the risk of electrical flashover across the surface. As shown in Figure 26, the tangential field level exceeds 160 kV/cm for the original design. The revised design limits the tangential field level to less than 130 kV/cm (see Figure 27).

The field levels associated with the system after the hydrogen switch closes are much less critical since the stress time is much shorter and the peak voltage is lower. The field levels are shown in Figures 30, 31, and 32. The levels are well within the guidelines discussed above.

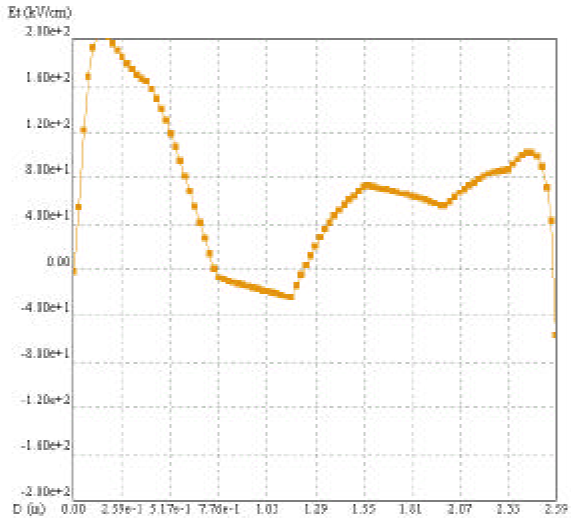

Figure 26. Tangential electric field levels along Ultem bridge for the original H2 design (see Figure 28).

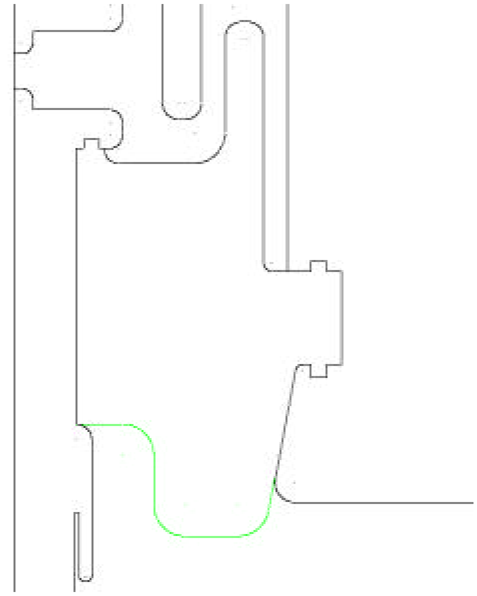

Figure 28. Plot region for Figure 26 (green line).

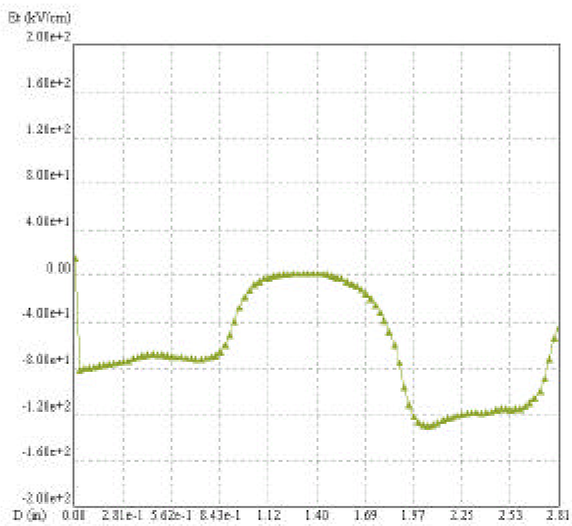

Figure 27. Tangential electric field levels along Ultem bridge for revised H2 design (see Figure 29).

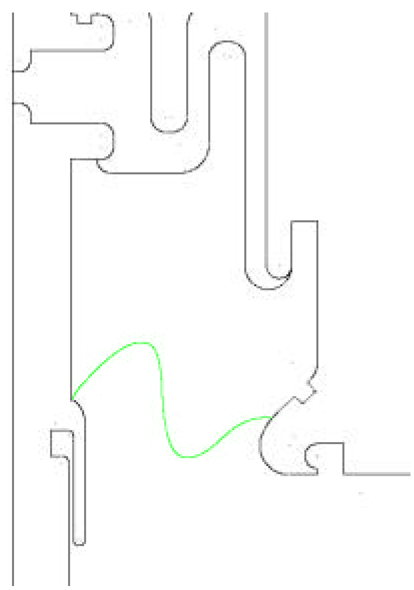

Figure 29. Plot region for Figure 27 (green line).

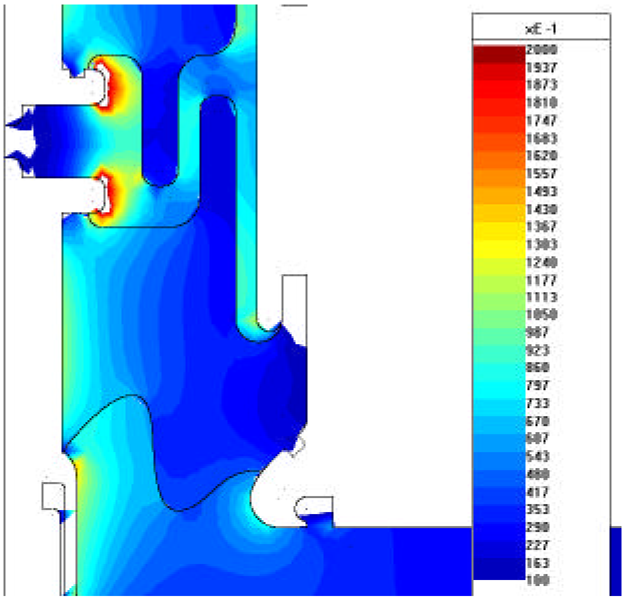

Figure 30. Closed switch E-Field magnitude plot of transformer-side insulator for the revised design (kV/cm).

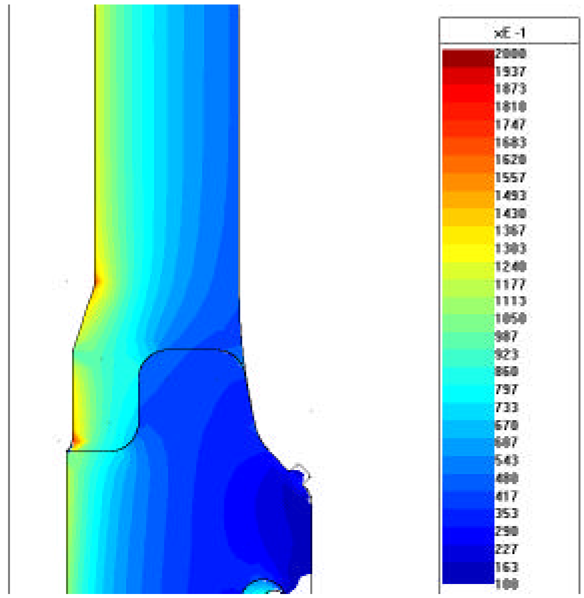

Figure 32. Closed switch E-Field magnitude plot of the output section for the revised design (kV/cm).

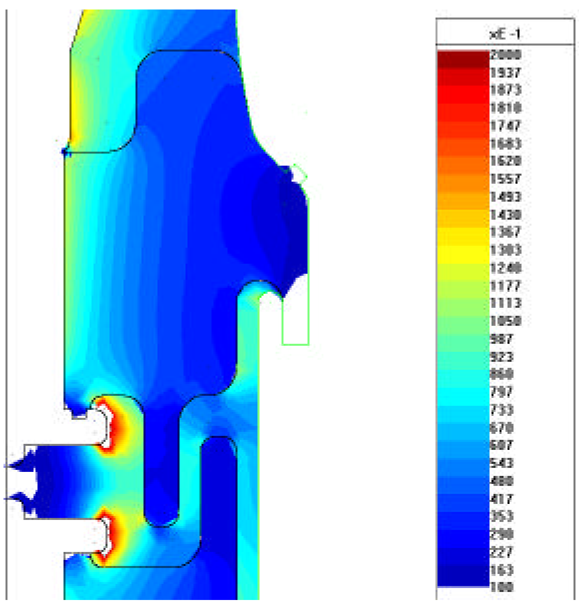

Figure 31. Closed switch E-Field magnitude plot of the output-side insulator for the revised design (kV/cm).

6.0. EXPERIMENTAL DATA

Before the complete H2 system was assembled, the high pressure hydrogen switch was hydrostatically tested for 24 hours at 1000 psi as required by ASME code for pressure vessels operated with personnel in the vicinity. The test was successful and no leaks were detected. The switch was then disassembled and the Ultem components were baked at 100 degrees Celsius to remove surface moisture remaining from the hydrostatic test. The parts were then immediately placed inside a vacuum chamber for 6 hours. The dual-resonant transformer was filled with transformer oil (Shell Diala AX) and placed under a vacuum of less than 25 inches Hg for two days to insure that a minimum of trapped air would be present to maximize reliability of the transformer. The dummy load was prepared by filling the assembly with a solution composed of de-ionized water with Sodium Thiosulfate. The concentration of Sodium Thiosulfate was adjusted to achieve a 50-Ohm load resistance. The resistance was measured using a 400-volt pulse generator.

The capacitive sensor located on the output section of the source was calibrated using a time domain reflectometry (TDR) measurement to determine the normalized frequency dependent transfer function and a slow high voltage pulse (10 kV peak) was applied to the output conductor to obtain the sensor division ratio. The transfer function was determined to be:

$$\frac{V_o}{V_i}(w) = \frac{215 \cdot 10^{-6}}{1 - j\dfrac{174 \cdot 10^{6}}{w}}$$

To insure that the hydrogen switch is closing on the second peak of the transformer output, a Pearson current probe (0.05 V/A) was used to measure the transformer secondary current in the transformer ground strap. The current is then integrated to obtain a representation of the secondary voltage. The magnitude of the secondary voltage cannot be determined using this method since the secondary capacitance is not known nor can it be measured easily.

The source was fully assembled and placed inside a Universal Shielding Corporation shielded enclosure for testing. A Maxwell CCDS power supply controlled by a Stanford DG-535 pulse generator was used charge the primary capacitance to 30 kV. A block diagram of the setup is shown in Figure 33.

The primary switch was charged to 12 psi with air and the main switch was set to 450 psi for the experiments. The normalized integrated secondary current (secondary voltage) for a typical shot is shown in Figure 34 and the source output voltage is shown in Figure 35. The hydrogen switch fires at the peak of the second peak of the secondary voltage to maximize the output voltage for a given input voltage. The peak output voltage of approximately 100 kV indicates that the transformer is charging the source capacitance to 200 kV. The maximum repetition rate achieved was 10 Hz for a burst of less than 10 shots. The repetition rate is limited by the low pressure primary switch.

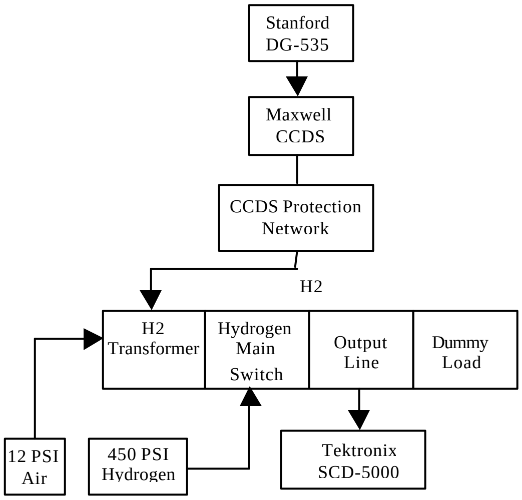

Figure 33. Block diagram.

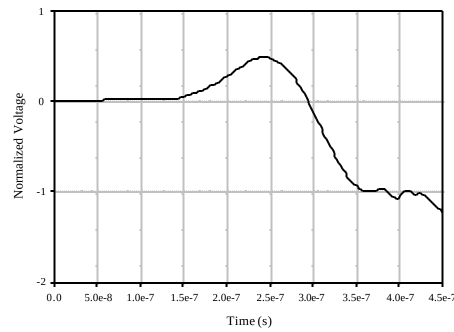

Figure 34. Normalized secondary voltage derived from the secondary current.

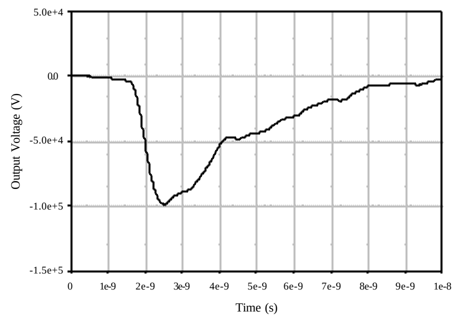

Figure 35. Processed H2 output sensor voltage.

7.0 OPERATING PROCEDURES

The operating procedure is as follows:

1. Inspect the dual-resonant transformer for obvious air bubbles. If bubbles are present in the high voltage areas of the transformer, the unit should be evacuated before operation.

2. A shielded Stanford DG-535 or a Hewlett Packard 8112 should be set to provide a 1.0 ms pulse. The output of the pulse generator should be connected to the enable input of the Maxwell CCDS power supply. **Caution:** Typical supplies require a low (0 volt) signal to enable and a high (5 volt) signal to disable. For a normal supply, the pulse generator should be set for an inverted output.

3. Set the CCDS set voltage to 30 kV. **Caution:** Do not exceed

4. The primary switch should be charged to 12 psi with air.

5. The main output switch should be charged to 450 psi with ultra-pure hydrogen.

6. Qualified personnel should be present and all high voltage safety procedures should be followed. Turn on the CCDS and trigger the pulse generator (Stanford or Hewlett Packard) and monitor the output pulse.

8.0 CONCLUSIONS

The H2 system has been evaluated both mechanically and electrically and design changes have been made to improve the safety and reliability of the system. The mechanical safety factor was improved from 1.0 to 4.0 for long-term operation and the electrical field levels at the critical triple-point areas have been reduced to acceptable levels. It is recommended that the system be operated at a peak transformer output voltage of 280 kV (e.g. 30 kV CCDS charge voltage), or less. The field levels along the center conductor/Ultem interface remain at unacceptable levels for reliable, long term, high rep rate operation (i.e. kHz) at CCDS charge voltages in excess of 30 kV.

If replacement insulators were available, system testing at elevated voltages (maximum of 460 kV output from the transformer) would allow a full evaluation of the Ultem insulator. This would greatly improve the available data base for the Ultem material and would be very helpful for future design efforts.

A complete set of the fabrication drawings for the revised design can be found in Appendix B.

The H2 pulse repetition rate is limited by the primary circuit's air charged switch. A significant improvement to the system would be realized by replacing the primary switch with a high pressure hydrogen trigatron (ASR/AFRL hermetically sealed trigatron). This could be accomplished without modifications to the system. The primary cost would be the cost for the trigatron.

Appendix A
Specification Sheet for Ultem 2300

Ultem® PolyEtherImide Specifications

Rt. 2 · Box 5 · 904 West 6th St., Shiner, Texas 77984
Phone: 1-361-594-2941 Fax: 1-361-594-2349 E-Mail: http://www.boedeker.com/contact.htm
1-800-444-3485

GENERAL PROPERTIES

Ultem® PolyEtherImide (PEI) is an amber transparent high performance polymer which combines high strength and rigidity at elevated temperatures with long term heat resistance. Ultem® offers excellent dimensional stability combined with broad chemical resistance.

Ultem® is also inherently flame resistant and low smoke generating. It excels in medical reusable applications requiring repeated sterilization and is available in FDA compliant colors.

ULTEM® GRADES

Ultem® 1000 - unfilled
Unfilled Ultem® excels in hot air and water environments. It's hydrolitically stable -- it retains 85% of tensile strength after 10,000 hour boiling water immersion and 100% of tensile strength after 2,000 steam autoclave cycles at 270°F. It is also UV and gamma radiation resistant.

Ultem® 2100 - 10% glass filled, **Ultem® 2200 - 20% glass filled**,
Ultem® 2300 - 30% glass filled
Glass reinforced Ultem® provides even greater rigidity and dimensional stability while maintaining many of the useful characteristics of basic Ultem®. The glass reinforcement yields a product with an exceptional strength-to-weight ratio and increased tensile strength.

(see also Semitron ESd 410 or or Tempalux CN Static-Dissipative Ultem Specifications)

TYPICAL PROPERTIES of ULTEM®

ASTM or UL test	Property	Ultem® 1000 unfilled	Ultem® 2300 30% glass
	PHYSICAL		
D792	Density (lb/in³) (g/cm³)	0.046 1.28	0.055 1.51
D570	Water Absorption, 24 hrs (%)	0.25	0.18
	MECHANICAL		
D638	Tensile Strength (psi)	16,500	17,000
D638	Tensile Modulus (psi)	475,000	800,000
D638	Tensile Elongation at Break (%)	80	3.0
D790	Flexural Strength (psi)	20,000	30,000
D790	Flexural Modulus (psi)	500,000	900,000
D695	Compressive Strength (psi)	22,000	32,000
D695	Compressive Modulus (psi)	480,000	620,000
D785	Hardness, Rockwell	M112 / R125	M114 / R127
D256	IZOD Notched Impact (ft-lb/in)	0.5	1.0
	THERMAL		
D696	Coefficient of Linear Thermal Expansion (x 10^{5} in./in./°F)	3.1	1.1
D648	Heat Deflection Temp (°F / °C) at 264 psi	392 / 200	410 / 210
D3418	Glass Transition Temp (°F / °C)	419 / 215	419 / 215
-	Max Operating Temp (°F / °C)	340 / 171	340 / 171
C177	Thermal Conductivity (BTU-in/ft²-hr-°F) (x 10^{4} cal/cm-sec-°C)	0.90 3.10	0.90 3.10
UL94	Flammability Rating	V-O	V-O
	ELECTRICAL		
D149	Dielectric Strength (V/mil) short time, 1/8" thick	830	770
D150	Dielectric Constant at 1 MHz	3.15	3.70
D150	Dissipation Factor at 1 MHz	0.0013	0.0015
D257	Volume Resistivity (ohm-cm)at 50% RH	6.7 x 10^{17}	3.0 x 10^{16}

NOTE: The information contained herein are typical values intended for reference and comparison purposes only. They should NOT be used as a basis for design specifications or quality control. Contact us for manufacturers' complete material property datasheets.
All values at 73°F (23°C) unless otherwise noted.
ULTEM is a registered trademark of General Electric Company

Boedeker Plastics, Inc.
Rt. 2 · Box 5 · 904 West 6th St., Shiner, Texas 77984
TOLLFREE : 1-800-444-3485
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Appendix B
H2 Drawings

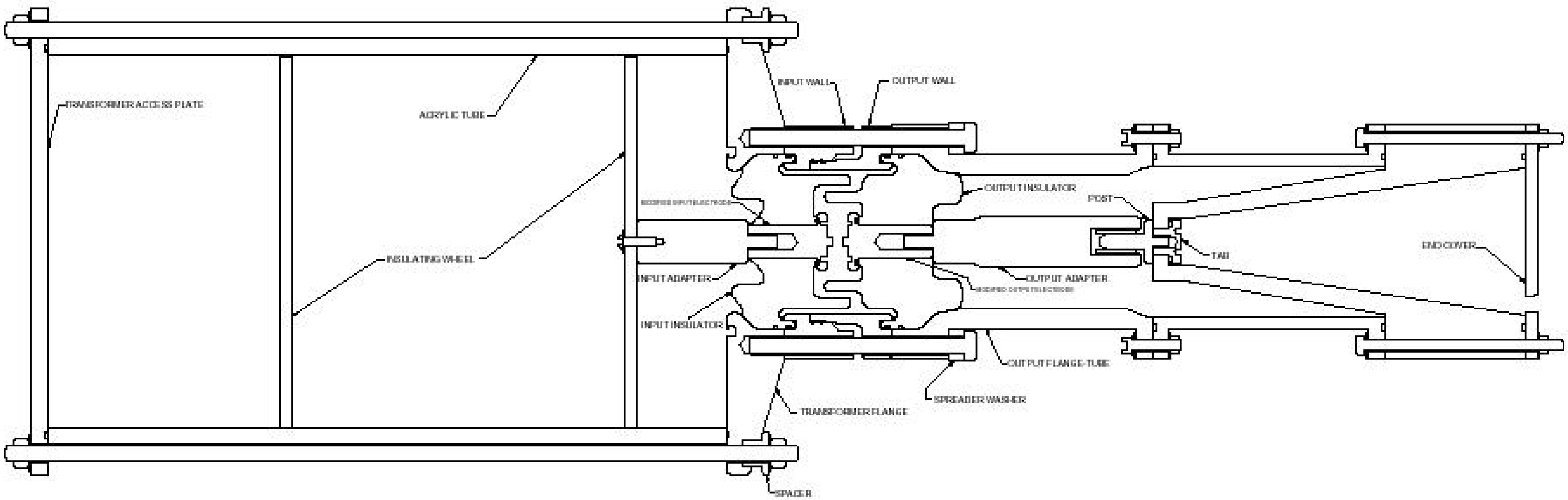

Figure B-1. H2 Assembly

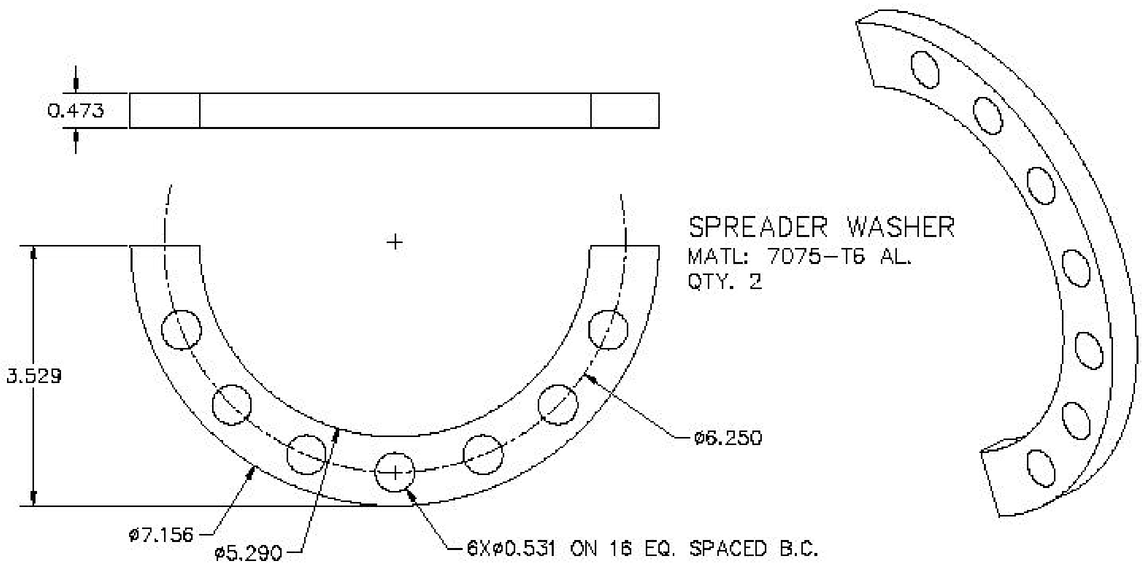

Figure B-2. Spreader Washer

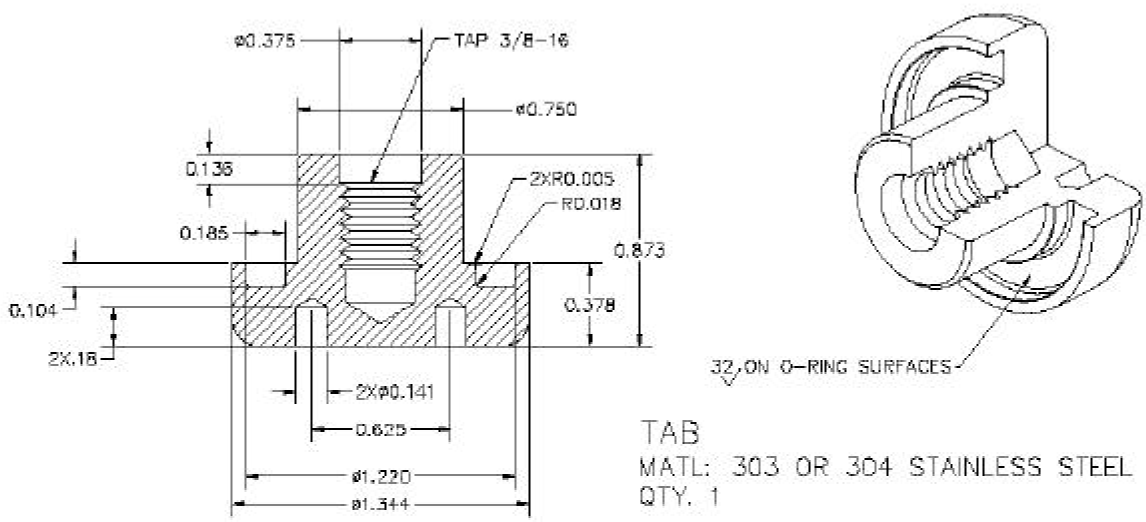

Figure B-3. TAB

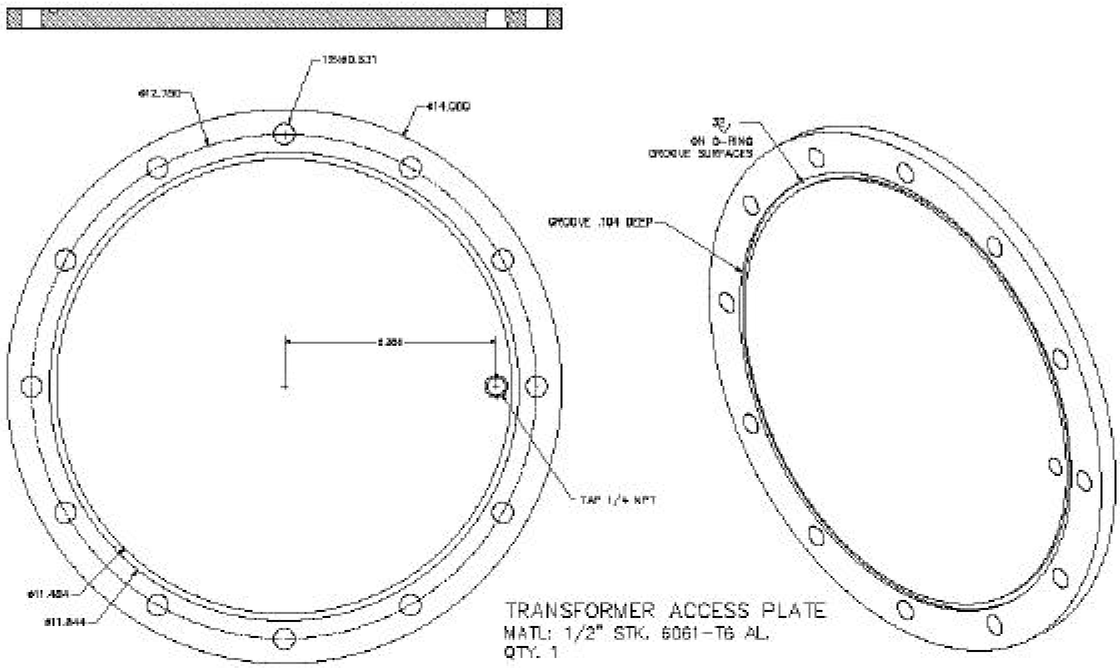

Figure B-4. Transformer Access Plate

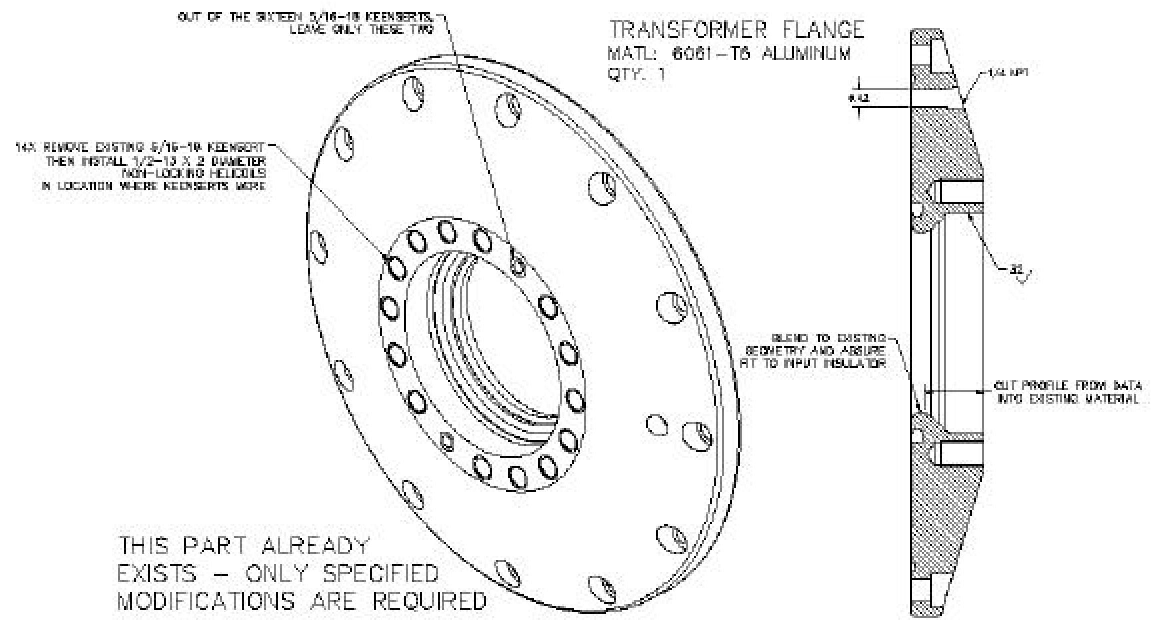

Figure B-5. Transformer Flange

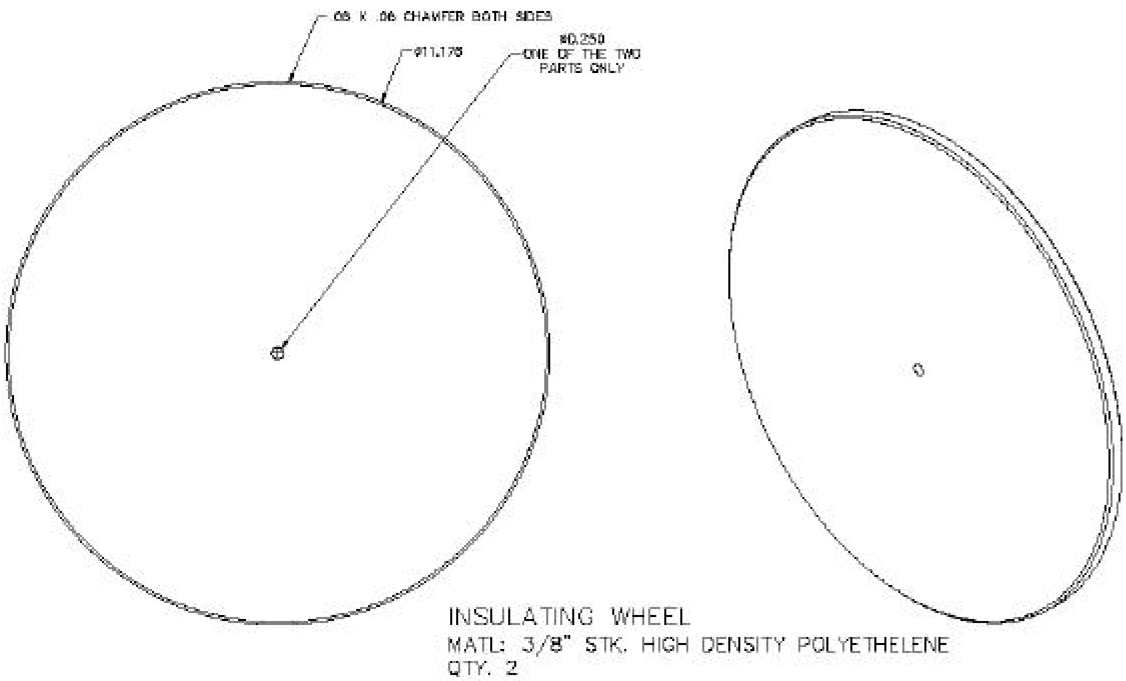

Figure B-6. Insulating Wheel

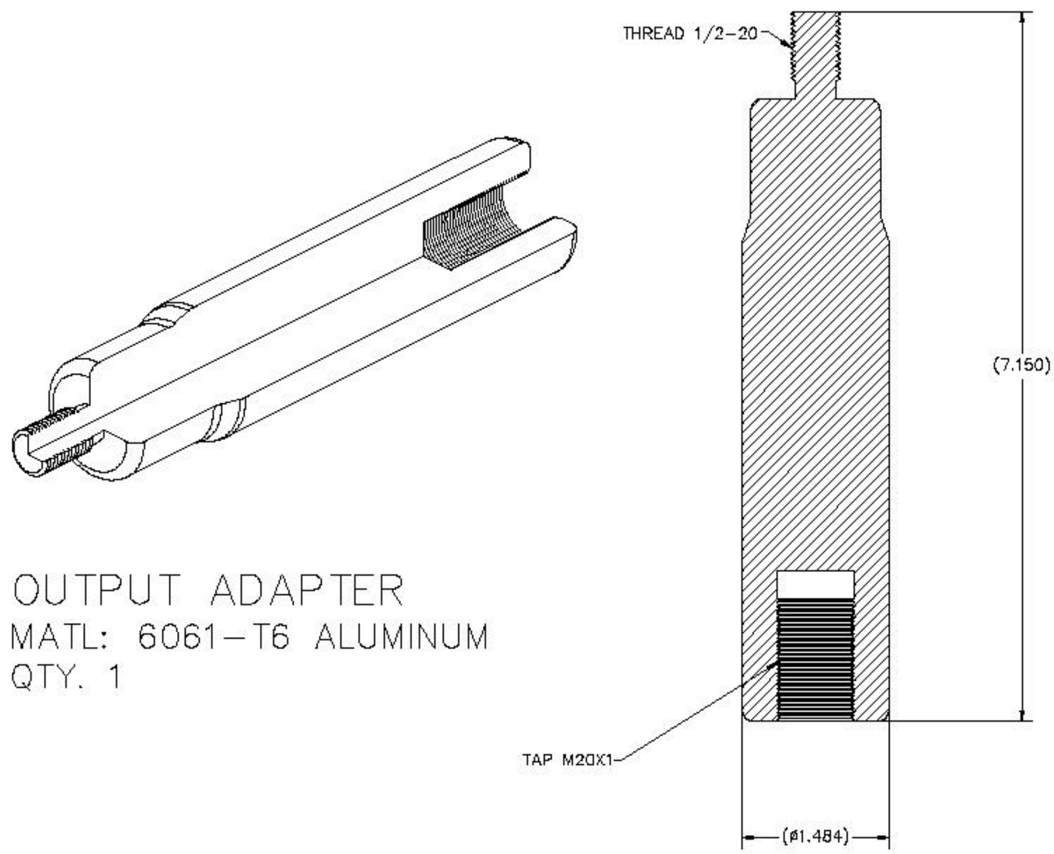

Figure B-7. Output Adapter

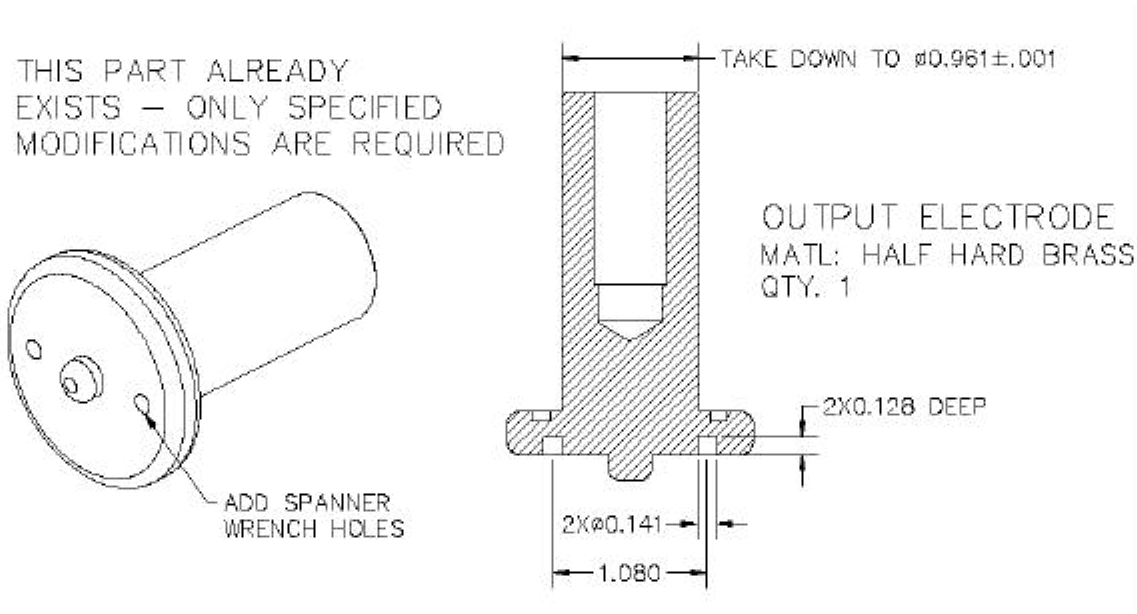

Figure B-8. Output Electrode

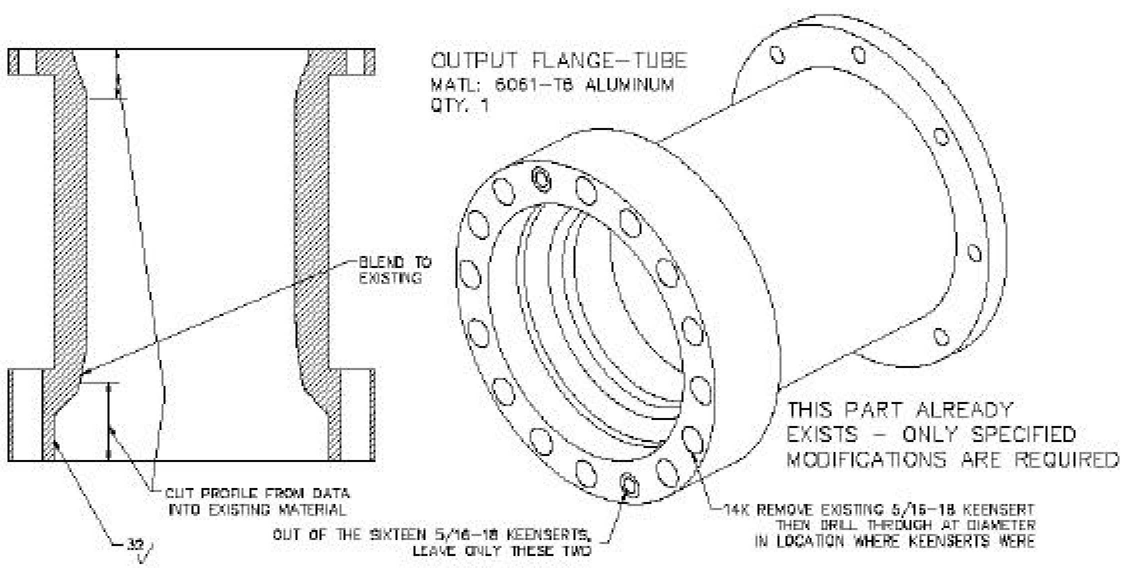

Figure B-9. Output Flange-Tube

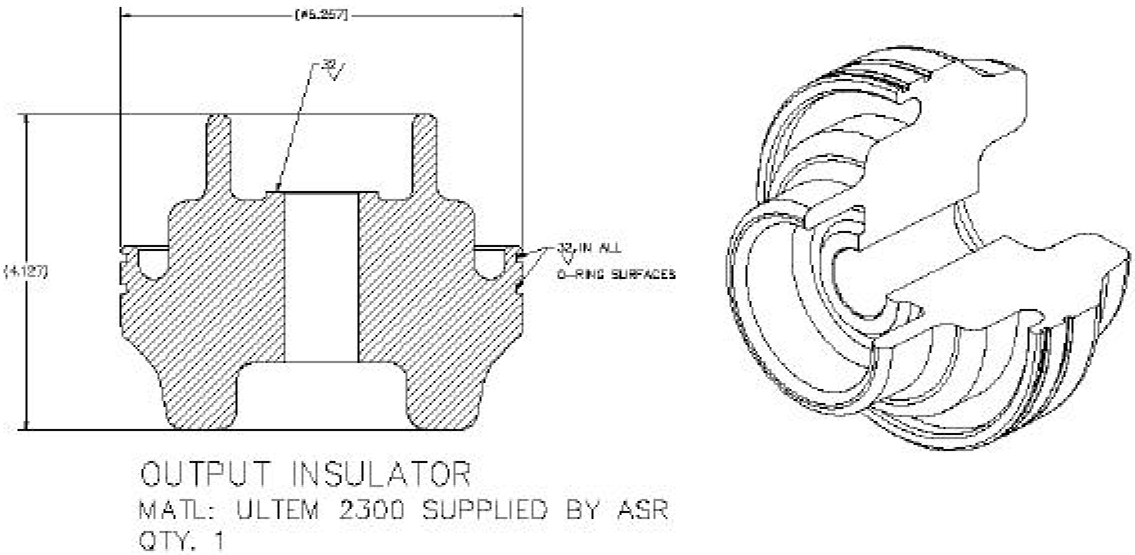

Figure B-10. Output Insulator

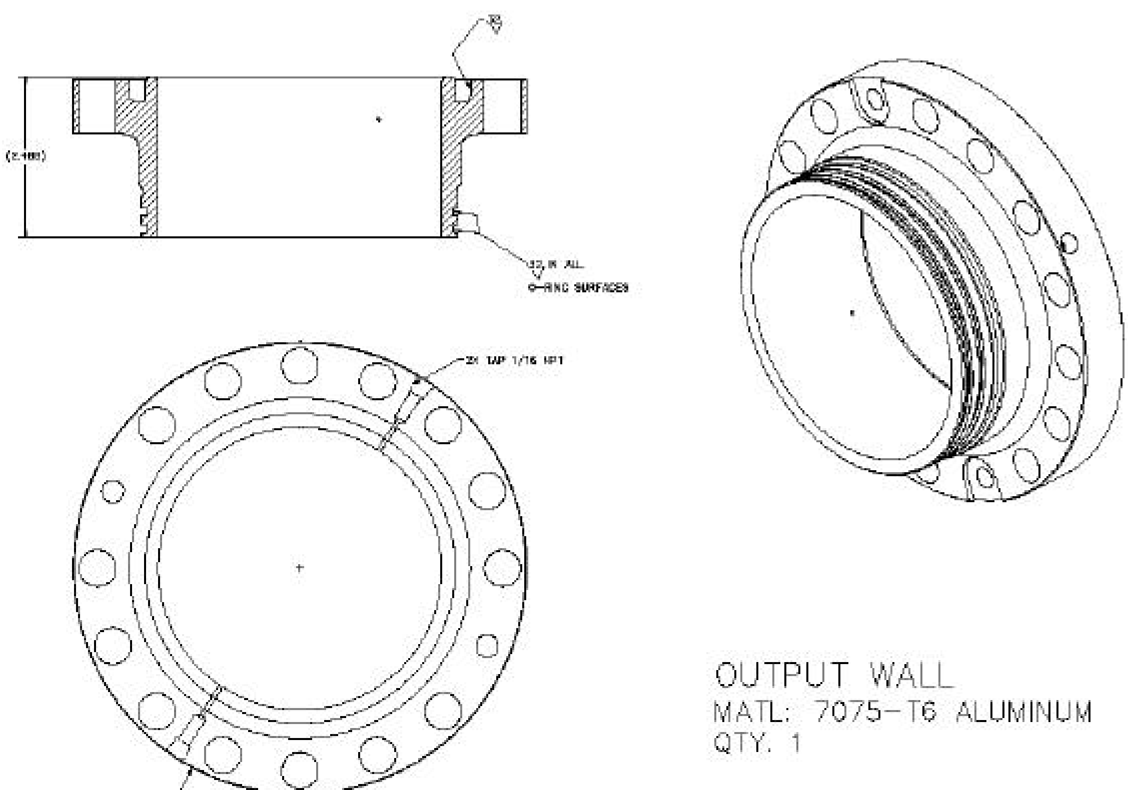

Figure B-11. Output Wall

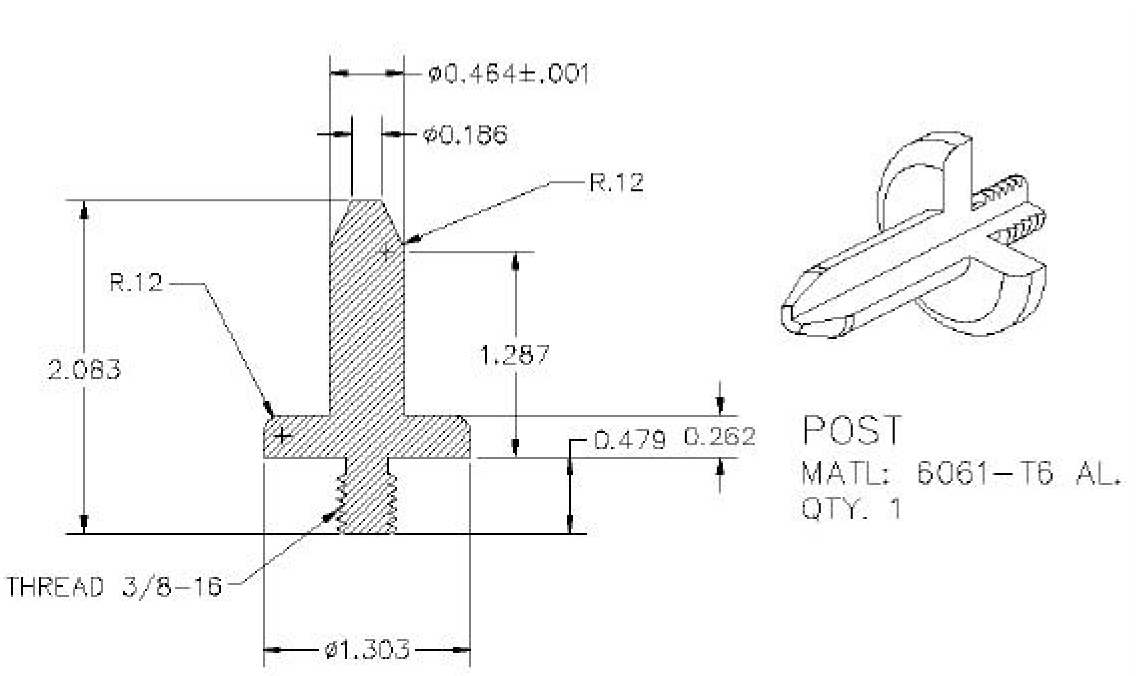

Figure B-12. Post

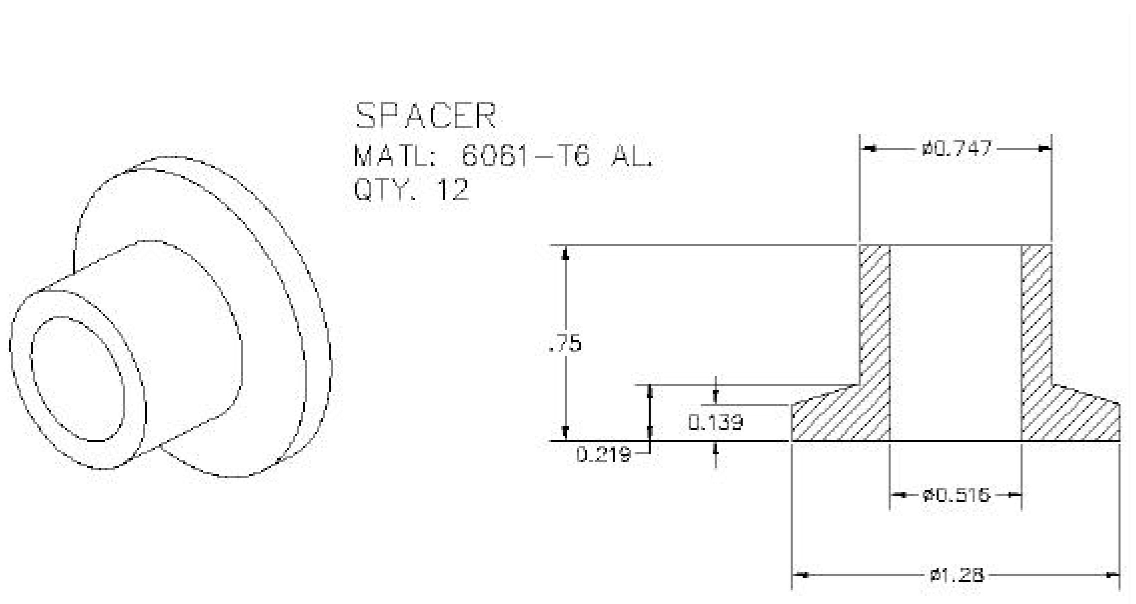

Figure B-13. Spacer

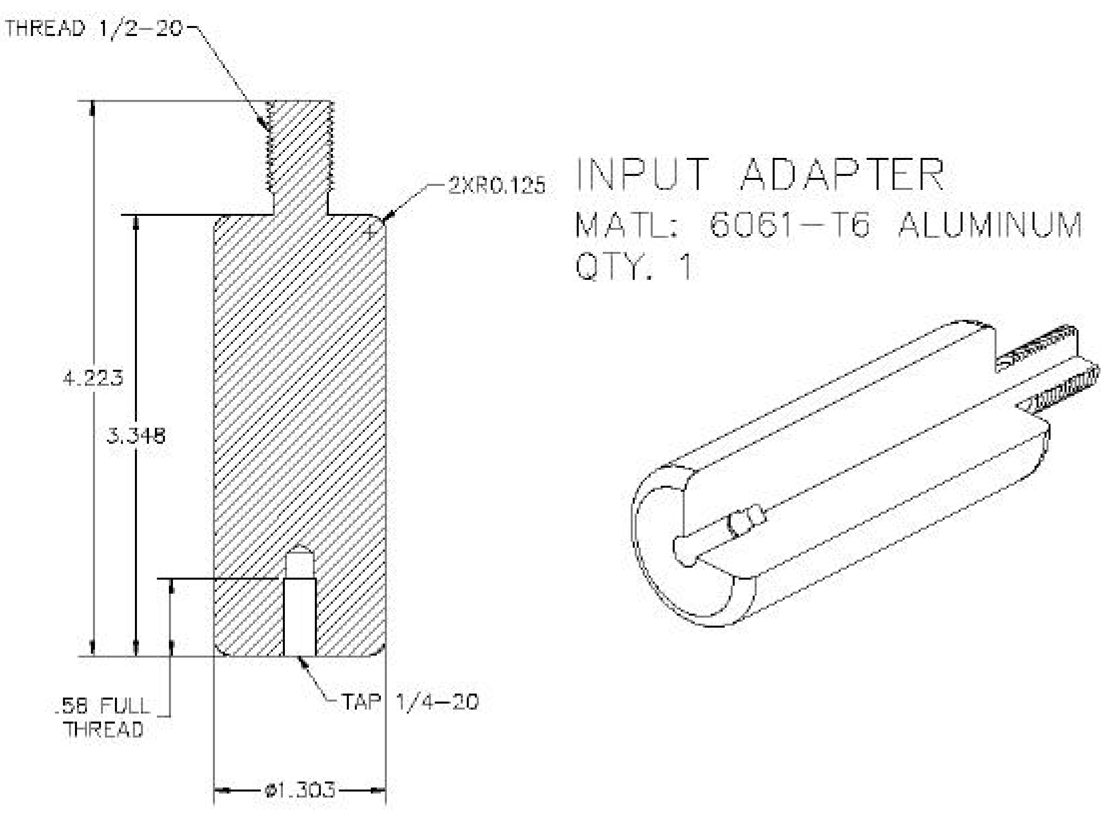

Figure B-14. Input Adapter

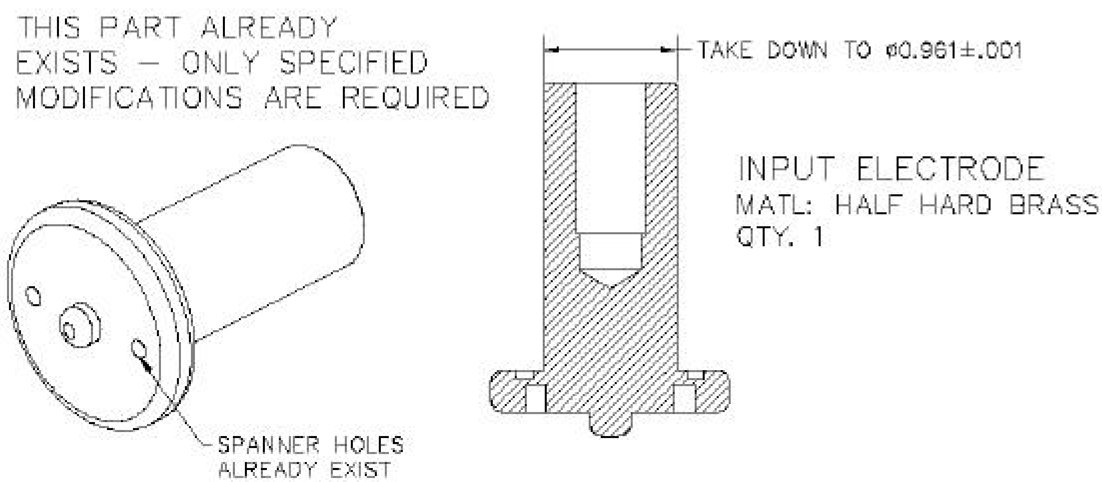

Figure B-15. Input Electrode

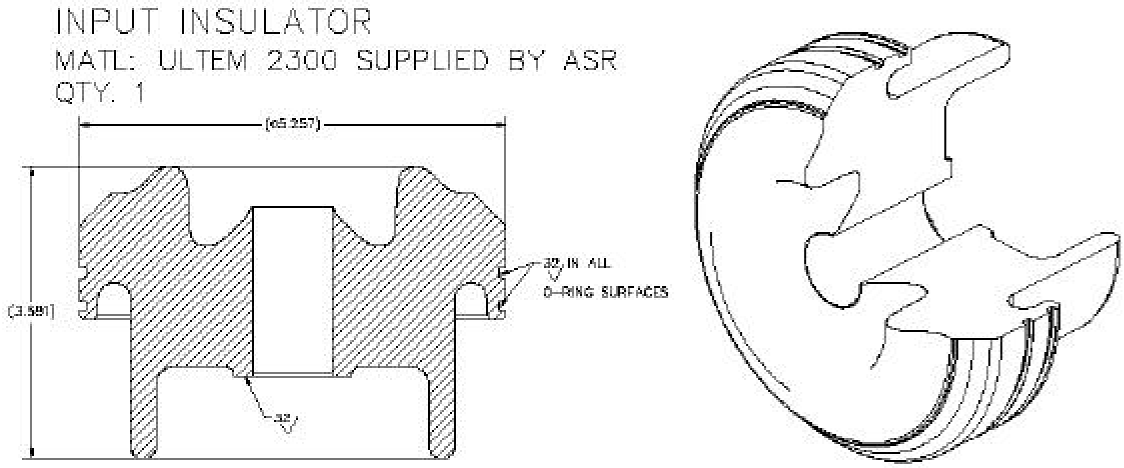

Figure B-16. Input Insulator

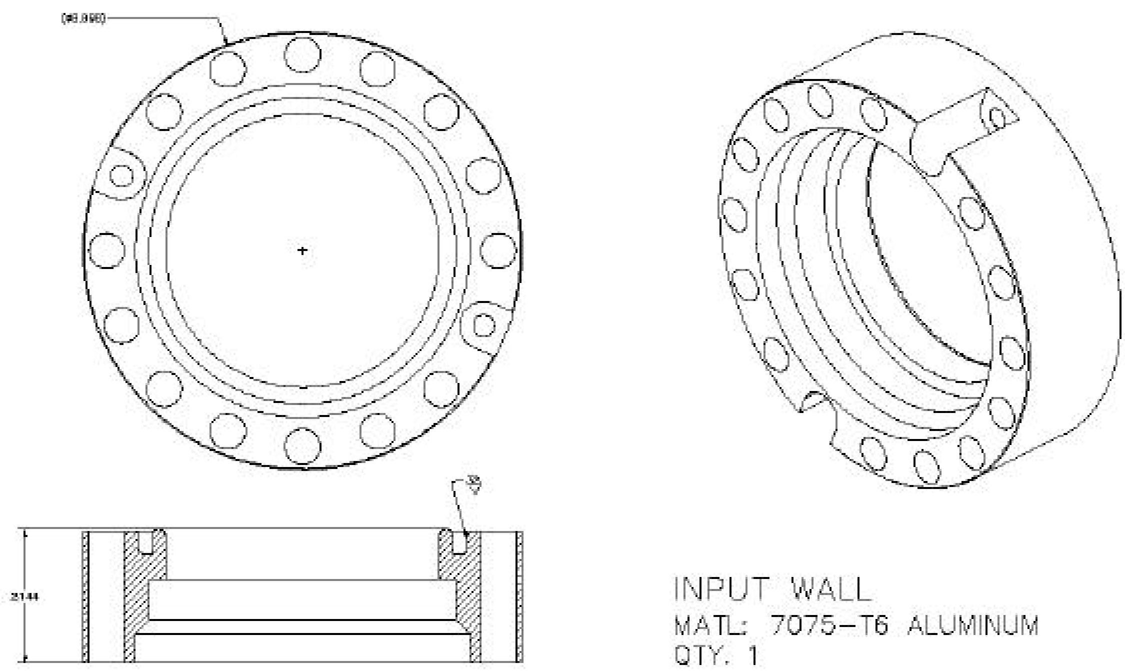

Figure B-17. Input Wall

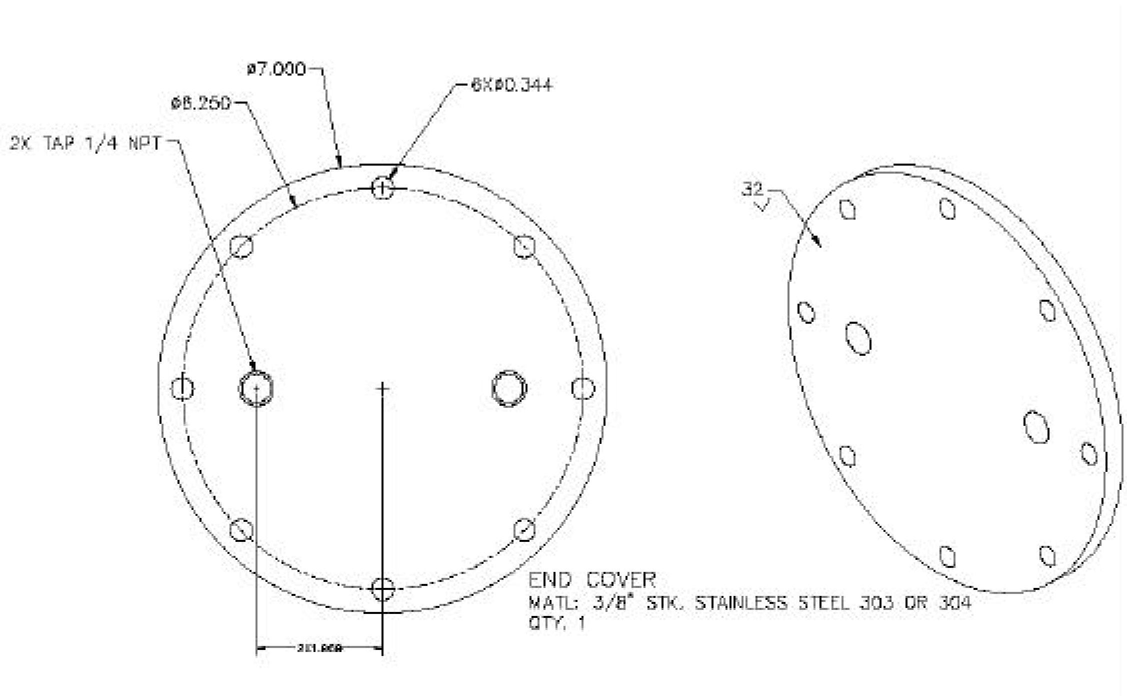

Figure B-18. End Cover

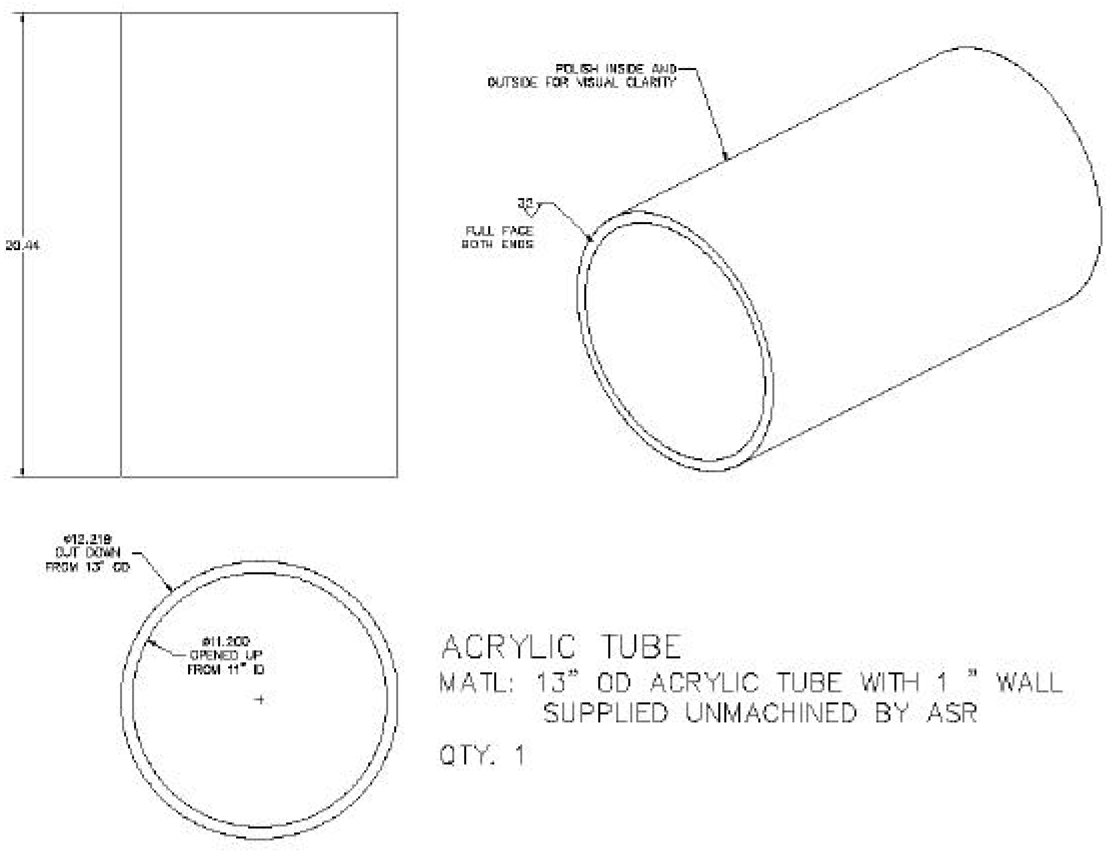

Figure B-19. Acrylic Tube

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