

Mini-F: A Small Plasma Focus Device

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I. INTRODUCTION

Those who have followed this publication know of my fondness for coaxial plasma guns. I constructed my first gun sometime around 1972 and reported on it in Vol. 2, No. 1 and Vol. 3, No. 3. For reference, Figure 1 shows the configuration. This gun one was in use until recently when I began an entire rebuild of my main vacuum bench.

While a number of interesting effects could be observed with the gun (I had some great pictures of multiple beams proceeding from an analyzing magnet placed at the muzzle of the gun but put them in some safe place and can't find a single one), the physical and electrical arrangement was inadequate to produce a true dense focus and, hence, beam energy was low.

A few years ago I purchased a low inductance single-terminal capacitor with specs. adequate for a real dense plasma focus coaxial gun: 59 μF (measured) at 10 kV (2950 Joules) and an inductance of under 0.035 μH .

As my model, I used the 3.3 kJ UNU/ICTP (United Nations University Training Program on Plasmas and Laser Technology) device which was developed at the University of Malaya in Kuala Lumpur, Malaysia, and a smaller 2 kJ device that was also developed at the same university [1]. The bigger device was designed for fusion studies using deuterium as the fill gas. The smaller device was for x-ray studies with argon.

I simplified the configuration somewhat with the one capacitor in place of several and by placing the gun and spark gap directly over the capacitor, eliminating the need to couple with multiple parallel coaxial cables.

My main interest is not so much with fusion and x-ray generation but rather with the properties of the beam. The other article in this issue goes into some great detail on materials modification with coaxial guns. Those readers that are interested in the general operation of these guns and for their use in fusion studies should refer to the above cited articles and to Vol. 1, No. 2 and Vol. 6 No. 3/4.

II. CONSTRUCTION

Figure 2 shows the gun in cross section. The drawing is to scale and dimensions can be assessed based on the data given below. The device is assembled on a 6-inch square piece of 1/4-inch thick brass plate. To provide some thickness I soldered a 3-inch diameter by 1/2-inch

thick brass disk in the center of the brass plate. To provide a passageway for the pumpout port I cut a 3/4-inch diameter hole at the perimeter of the disk prior to soldering. (Please note that a thicker piece of brass or aluminum would save the effort of doing all of this. Some construction choices were made on the basis of materials on hand.) The hole for the pumpout is drilled and tapped for 1/4-inch pipe thread.

The feedthrough/insulator assembly is the tricky part. I ended up using a 25mm Ace Glass Co. (800-692-3333) Ace-Thred that was cut from one end of a chromatographic column (e.g. Ace #5820-34). An Ace nylon bushing and O-ring is also required (#7506-10). The Ace fittings have a bore of 25mm. Since I wanted to use standard 3/4-inch copper water tube (0.875-inch diameter) for the center (anode) conductor, I pressed a piece of 1-inch od, 1/16-inch wall stainless steel seamless tubing over the copper tube where the electrode will be within the glass insulator. The vacuum-side end of the stainless tube was soldered to the copper tube. The insulator should extend about 30-35 mm above the base.

The insulator tube has an outside diameter of 1-1/4

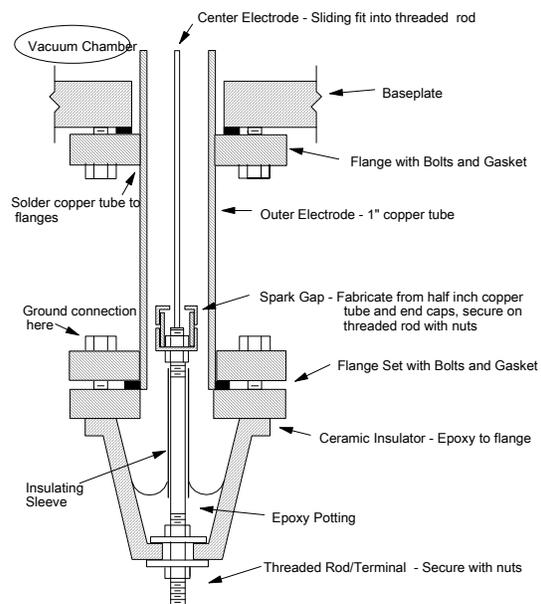


Figure 1 - Coaxial Plasma Gun

Figure 1 - The Author's 1972 Coaxial Gun

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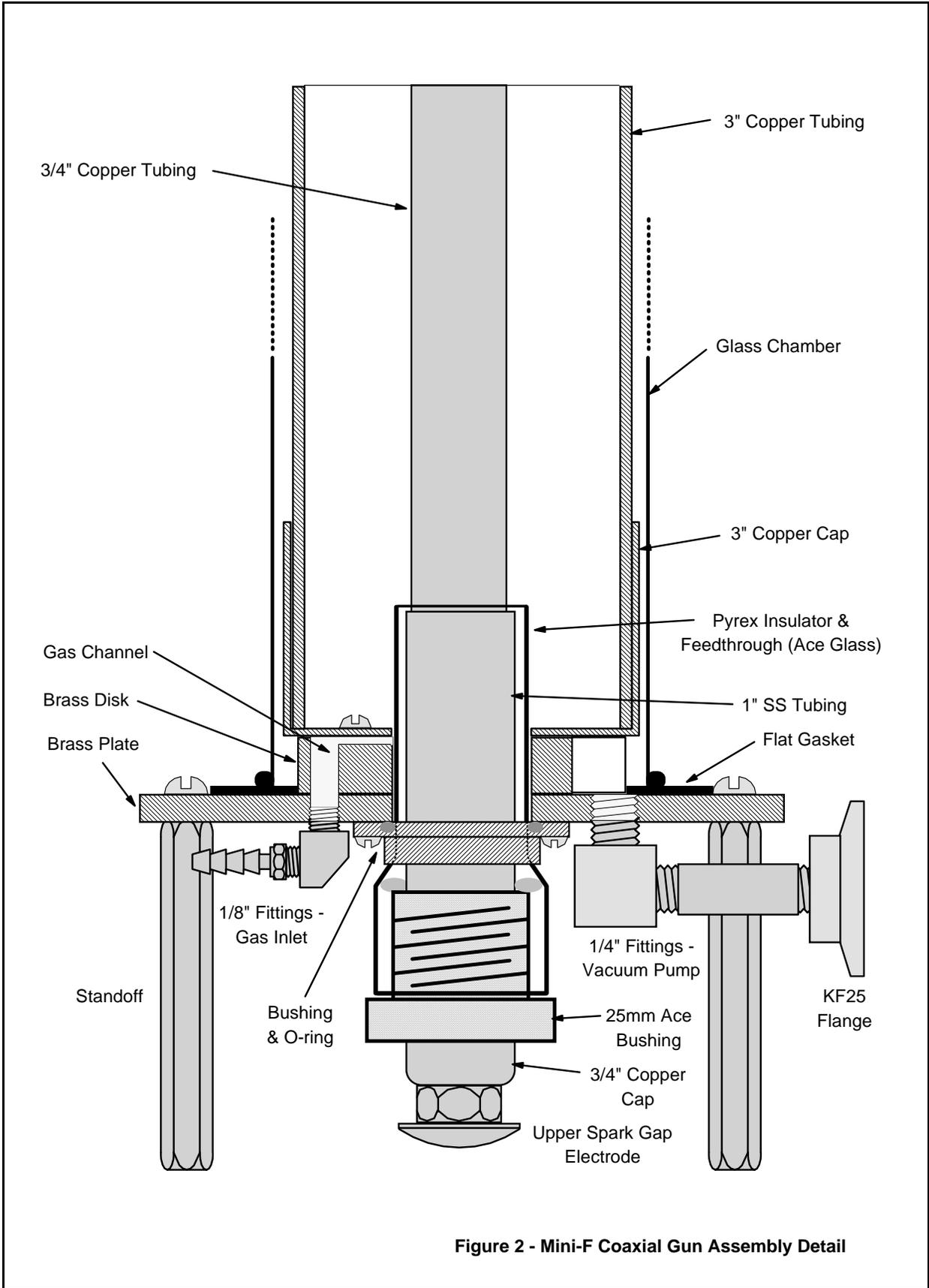
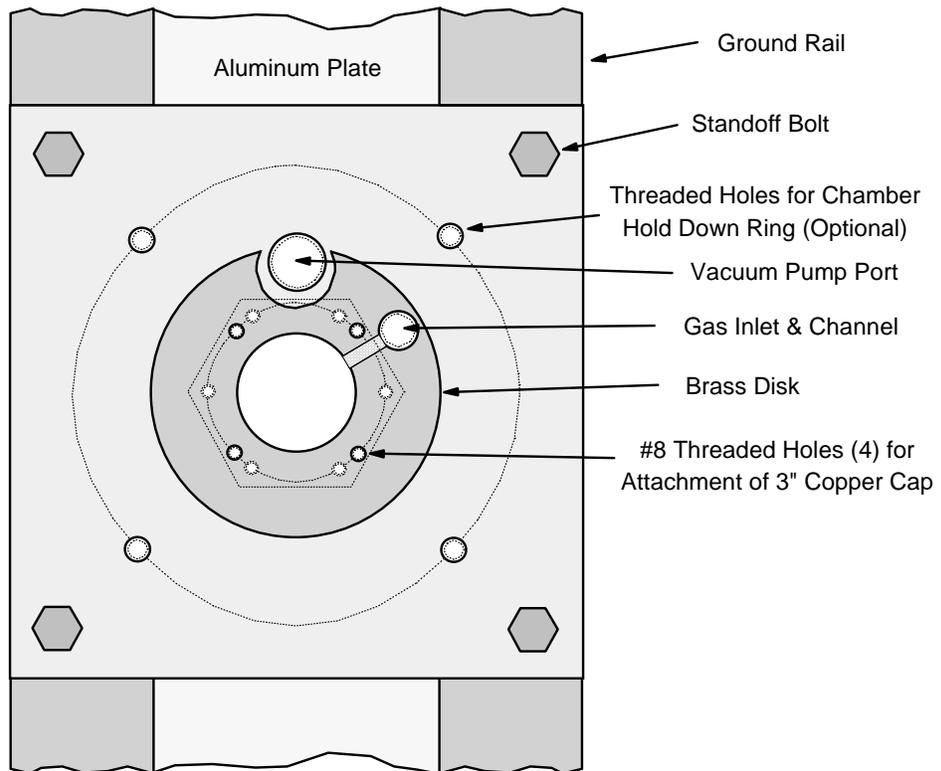


Figure 2 - Mini-F Coaxial Gun Assembly Detail

Top



Bottom

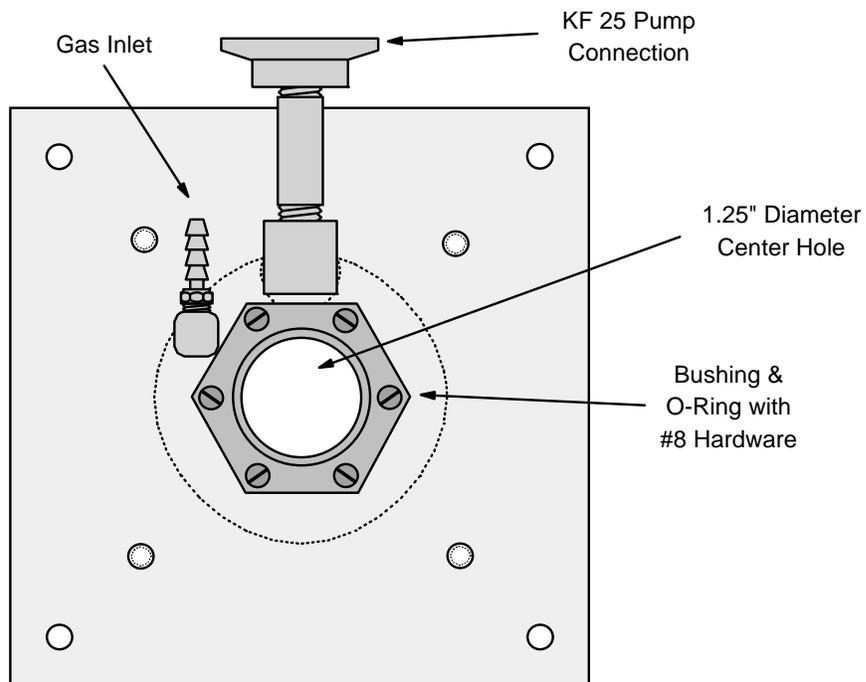


Figure 3 - Mini-F Coaxial Gun Base Plate

nches. I sealed the tube to the base plate with a compression fitting that I fashioned from a brass slip-joint sink drain fitting. A large brass or aluminum washer would serve just as well. The compression fitting simply squeezes an o-ring between the fitting, the base plate and the insulator tube. The fitting is secured with six #8 machine screws that are drilled (not through the plate!) on a 1.95-inch bolt circle. The bottom of the center electrode is capped with a 3/4-inch copper cap.

The outer electrode is made from 3-inch copper water tube about six inches in length. (The ends of the inner and outer electrodes should be coplanar.) The base of the outer electrode is captured in a 3-inch copper cap which, in turn, is affixed to the brass disk with four #8 machine screws.

It is not essential to have the outer electrode be a solid cylinder. As shown in Figure 4, I cut a wide slot in the electrode to permit visual access to the inner electrode/insulator area. I also drilled a hole in the inner electrode should I want to conduct any experiments with the electron beam that propagates downward through the electrode from the pinch region. Several 1/4-inch diameter rods (6 or 8) can also be used in place of the cylindrical outer electrode.

A gas inlet has to be provided for the working gas. The gun may be operated in either of two modes. The first is with the gas pressure at a fixed value, usually in the range of a few Torr. Here the working gas is fed at some rate through either a capillary leak or a needle valve. (A static fill is recommended for the more precious gases.) Since the gap between the inner and outer electrodes will break down at less than the full rated voltage of the capacitor, a spark gap switch is provided to initiate the discharge at the proper time. The spark gap is rather crude and just consists of opposing carriage bolt heads. I have not shown the trigger electrode.

In the case of the second mode, the gun is pumped to a pressure below which the interelectrode gap will fire. This is generally below about 10 to 20 milliTorr. To fire the gun a puff of gas is injected via a fast acting solenoid valve.

In either case, a gas inlet is required and it should introduce the gas at the base of the insulator. In this design, the gas is directed through a port drilled for 1/8-inch pipe thread fittings. I milled a 1/4-inch wide slot from the inlet hole to the center hole to deliver the gas.

Figure 3 shows the base plate in top and bottom views. Shown in the top view are the ground rails on which the base plate is mounted via four 4-1/4 inch long standoffs. The ground rails are the same length as the capacitor (about 16 inches for the cap that I have) and are drilled at each end with the holes coinciding with the capacitor's four mounting holes. In my arrangement, the capacitor is below a wooden cabinet top, the bolts

holding the capacitor against the worksurface and also acting as the ground connections to the capacitor. There is also a 1/8-inch thick aluminum plate with a 2.5-inch hole for the center (hot) terminal. This plate is sandwiched between the ground rails and the cabinet top. Figure 4 shows the mounting arrangement in cross-sectional detail.

Figure 4 shows the complete assembly, less the chamber. Not shown are the brass bellows valve and pressure gauge that are attached to the KF25 pumpout port. I also have not shown the chamber. The one now in use is along the lines of the chamber shown in the drawing of the coaxial gun of Vol. 6, No. 3/4, an Ace Glass 1.5 liter "funnel" (#5822-15).

CITED REFERENCES

- [1] S. Lee and P.H. Sakanaka, Eds., *Small Plasma Physics Experiments*, World Scientific, Singapore, 1988.

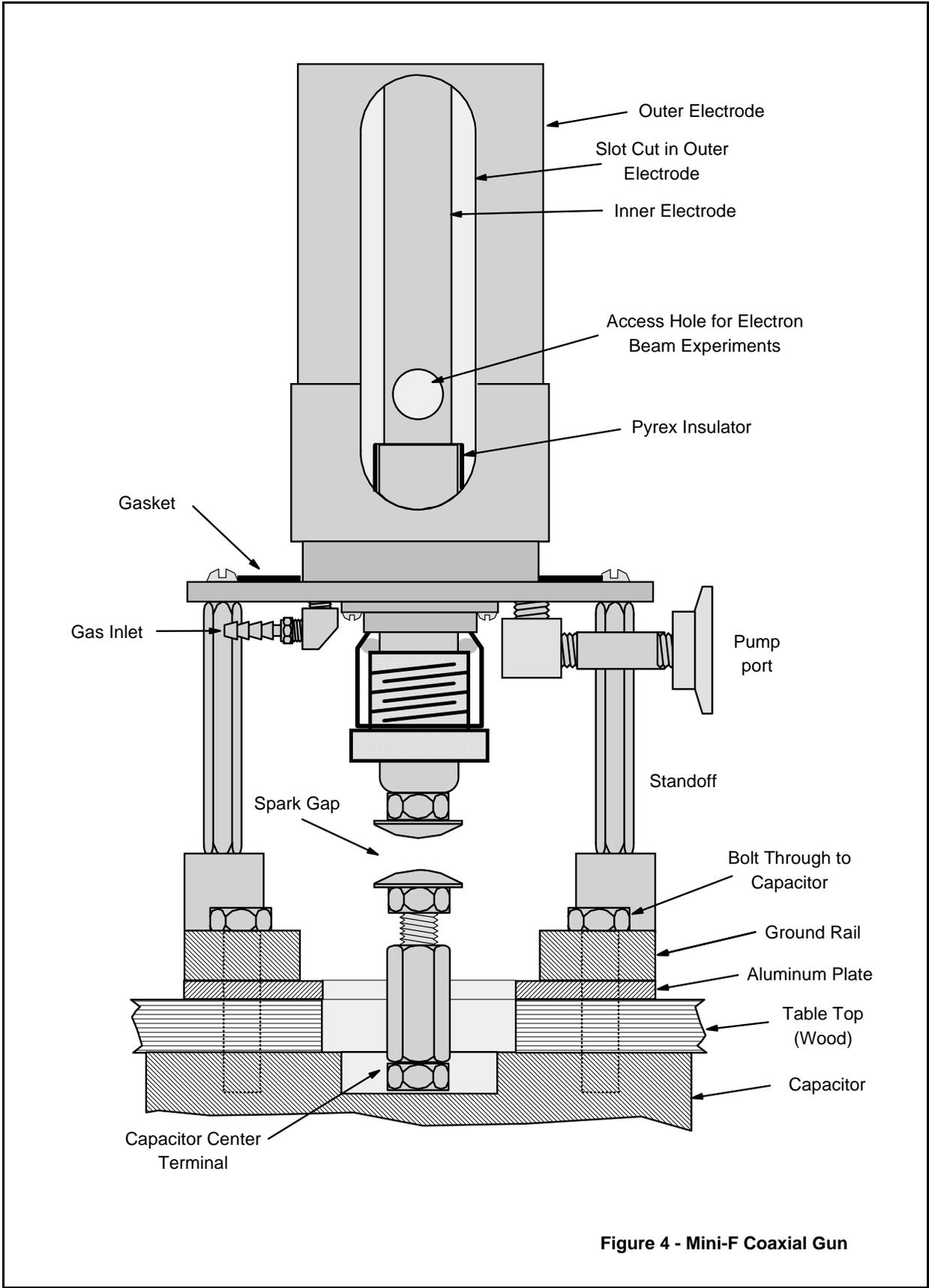


Figure 4 - Mini-F Coaxial Gun