LB-972

UNUSUAL ASSEMBLY METHODS USED IN DEVELOPING A NEW THYRATRON

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Approved

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Introduction

This bulletin describes several new techniques used in the development of a new high-current thyratron. The new assembly methods include the use of a Graham stud welder in the assembly of mount supports and the low-temperature oxidation of chromium-iron alloys for use in glass-to-metal seals.

Graham Stud Welder

The structure of the developmental thyratron is shown in Fig. 1. The siderods are two-piece assemblies consisting of an upper section having a diameter of 1/8 inch and a lower section having a diameter of 1/4 inch. The two sections are brazed together, as shown in Fig. 2, so that the lower section provides a shoulder on which the mount is supported. The tip at the bottom of the assembly is used for connection to the filament-terminal cup.

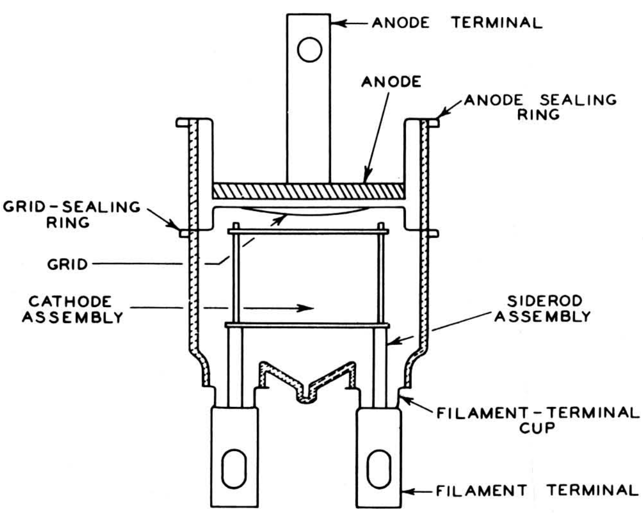

Fig. 1 - Structure of developmental high-current thyratron.

The stud-welding technique has been used successfully in many applications in the automotive line and in the welding of pins to name plates on such items as refrigerators, washers, and the like. The Graham stud-welding unit used for the assembly of the siderods to the filament terminal cup operates on a capacitance-discharge principle. A bank of eight 17000 microfarad capacitors is charged by a built-in motor generator in approximately 1 to 2 seconds.

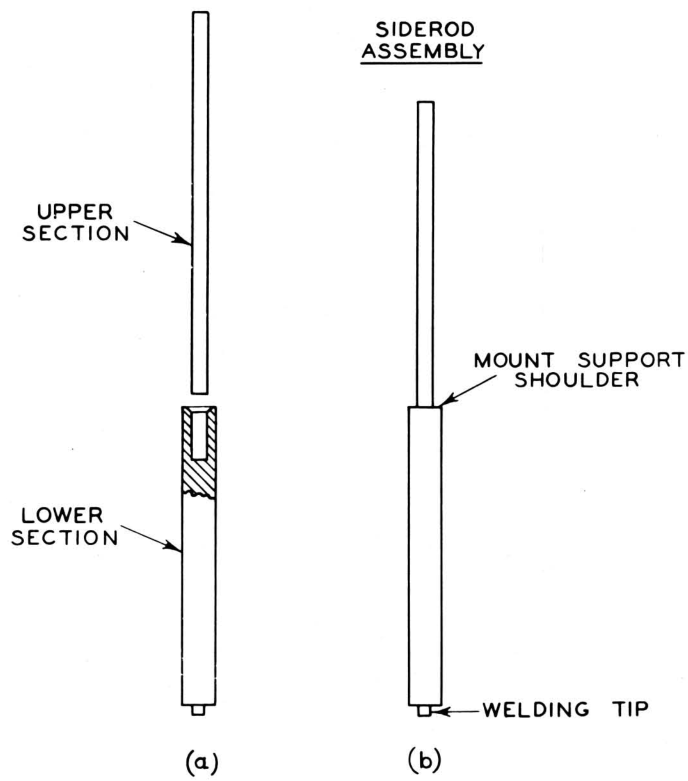

Fig. 2 - Siderod assembly showing upper and lower sections and welding tip.

An important factor in the stud-welding process is the small cylindrical tip, mentioned previously, on the joining face of the stud. The diameter and length of this tip vary according to the diameter of the stud to be welded and the materials involved. The studs, or siderods, are fed through a welding gun, shown in Fig. 3, which has a piston and piston rod extending downward and an appropriately sized collet attached to the end of the rod. The gun is actuated by air pressure, the piston rod moving the stud through the collet to the workpiece, which is held firmly on the table of the welding machine. The speed at which the stud travels toward the work may be varied by changing pressure on the rod end of the piston (the so-called "restore" pressure).

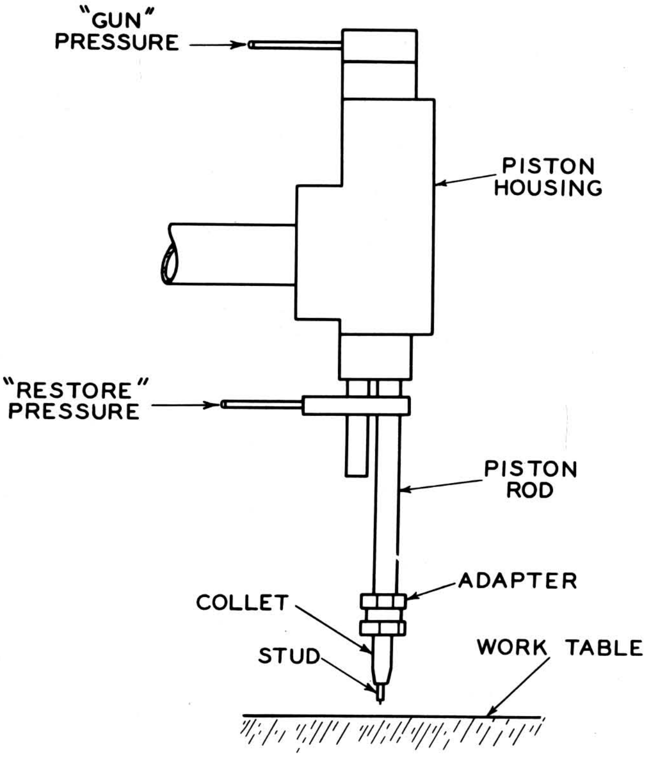

Fig. 3 - Welding gun used in assembly of developmental thyratron.

The principle of the welding action may be explained by tracing electrons through a cycle. After the capacitors are charged to their rated voltage, the charge is conducted to the welding gun, the collet, and the stud, all of which are traveling toward the work-piece at a rate of about 30 feet per second. The positive side of the capacitors is connected to the work table and then through ground clamps to the work-piece.

As the stud travels downward, the tip approaches and contacts the work-piece first. Initially, therefore, the discharge is concentrated at the small tip on the stud. Because the high current flow at this point causes overheating, the tip melts almost instantaneously. As the air surrounding the tip becomes ionized, electrons begin to flow from the stud to the work-piece, and an arc occurs. During the arcing process, the face of the stud and a corresponding area on the work-piece become molten. Simultaneously, a hammer blow resulting from the inertia of the moving piston-and-collet assembly forces together the two parts to be welded. The time consumed for this entire process is only 0.001 second.

The use of the Graham stud welder affords several advantages. No complex furnace or brazing fixtures are required. In view of the short duration of the arc, the rods are welded with little or no fillet, no distortion of the work, and a minimum amount of heat. Little cleaning is needed because the ionization caused by the discharge cleans both surfaces. For the same reason, there is no oxidation to impair the weld. In almost one hundred tubes made by the method, no failures occurred due to poor welds.

Glass-to-Metal Seals

The anode-grid assembly used in the developmental thyratron, shown in Fig. 4, consists of two metal cups connected by one cylinder of glass, and a second cylinder of glass below the lower cup. Three glass-to-metal seals must be made, one below the anode flange, and one each above and below the grid flange.

Because the developmental thyratron utilizes a "soft-glass" envelope, and because of the size of the seals, the choice of sealing metals was limited to a relatively small number of alloys. Two alloys were used in the developmental work, a chromium-iron alloy, 17Cr-83Fe, and a chromium-nickel-iron alloy, 6Cr-42Ni-52Fe. Before either of these alloys can be sealed to glass, the sealing surface of the metal must be oxidized. The formation of chromium oxide aids in making glass-to-metal seals because it adheres very strongly to the metal while at the same time dissolving in the glass. Because copper is used in both the anode and the grid, it is impossible to oxidize the assembly at the proper temperature without melting either the copper or the brazing alloy. Brazing to a preoxidized surface, however, is impractical.

Two possible solutions to this sealing problem were considered: (1) use of some means to remove the oxide in the brazing area, or to prevent its formation, so that the assembly can be oxidized prior to brazing; (2) the development of low-temperature oxidizing techniques.

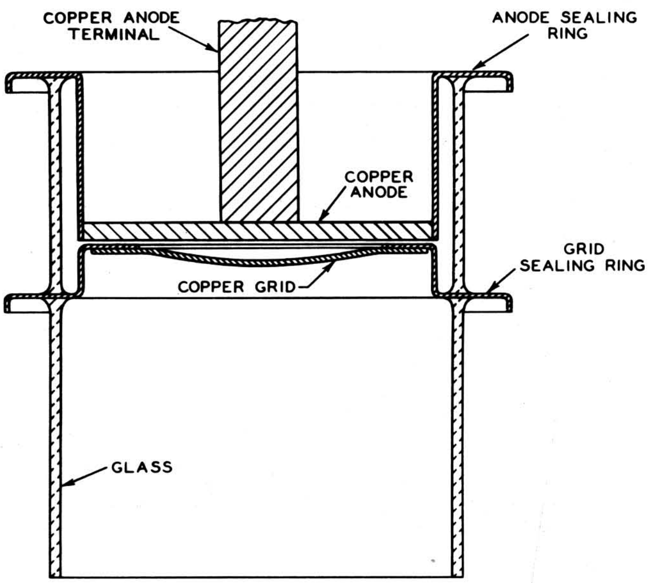

Fig. 4 - Anode-grid assembly used in developmental thyratron.

An attempt was made to prevent oxide formation in the brazing area by the use of nickel plating having a thickness of 0.001 to 0.002 inch. This method, however, was generally unsuccessful due to stripping or peeling. Removal of the oxide by mechanical means such as sandblasting, wire brushing, or other abrasive medium, was also unsuccessful.

Chemical removal of the oxide is very satisfactory. The assemblies are cleaned in a hot solution of potassium permanganate in sodium hydroxide, and are then washed in hydrochloric acid. The chief disadvantages of this method are the time required for the solution to react ($1\frac{1}{2}$ to 2 hours) and the need for masking the sealing surfaces to prevent their being attacked by fumes.

Because oxidizing prior to brazing was not too successful, oxidizing after brazing was tried. The first method of attack was to braze the assembly in dry hydrogen and then oxidize at as high a temperature as possible in wet hydrogen. Because the gold-copper brazing alloy 65Au-35Cu has a melting point of about 1000 degrees C, the highest oxidizing temperature which could be used safely was 975 degrees C. Seals made by this method were gassy, which indicated insufficient firing to drive out gas entrapped in the metal, and they had very poor seal color, which indicated insufficient chromium oxide. The gas problem was remedied by firing the glass sealing alloy in a reducing atmosphere of dry hydrogen at 1200 degrees C for 15 minutes prior to sealing, but seals made in this manner were still weak.

In an effort to improve the strength of the seal by an increase in the amount of chromium oxide, the metal surfaces were chromium-plated prior to sealing. The sealing alloy was carefully cleaned and was then plated with 0.0002 inch of chromium in the seal area. The plated metal was fired in dry hydrogen at 1200 degrees C for 10 to 15 minutes to out-gas the metal and partially alloy the chromium with the base metal. The assembly was then brazed and lightly sandblasted in the sealing area with alundum. After the sandblasting operation, the assembly was oxidized at 975 degrees C for one hour. The additional chromium in the critical sealing area produced a very good dark green chromium oxide. However, this procedure has one drawback--the time required to mask the part. For small parts, which can be entirely plated, this method is eminently suitable.

The second method used to improve the glass-to-metal seal embodied a technique borrowed from kinescope processing. The parts were prepared as in the first method, i.e., cleaned, brazed, sandblasted, and oxidized at 975 degrees C for two hours to provide the maximum oxide possible. The sealing areas were then sprayed to a depth of 0.004 to 0.007 inch with a porcelain enamel consisting of a mixture of soda, lime, silica, and boron oxide. It is not necessary to glaze the frit prior to sealing in a separate operation.

This method was very successful and is being used at present. Simple jigs are used to mask the sections which must be kept clean. Because the assembly is mounted on a rotating turntable and the spray gun is locked in position and adjusted for constant air pressure, it is simple to duplicate results every time.

Although not too much is known regarding the nature of the bond effected by the frit, it is evident that several mechanisms are involved. Mechanical adherence is improved by the sandblasting of the sealing surface. The increase in surface area and the fine particle size of the frit permit intimate contact between the two materials. When a seal is made directly to sandblasted metal, without frit, the surface tension of the liquid glass prevents close contact.

Because the sealing alloy contains chromium, nickel, and iron, the oxides formed are principally Cr_2O_3 and Fe_2O_3 with nickel oxides present in small quantities. Two separate and distinct chemical effects occur during frit sealing. As the seal is made and the temperature of the metal increases, the thickness of the oxide layer on the metal also increases. If this layer becomes too thick, the metal will not dissolve sufficiently in the glass. Although the oxide-metal interface and the oxide-glass interface have good adherence, the oxide layer has poor cohesive properties. This weakness of the oxide layer frequently causes stripping of seals. The glazing of the frit, which takes place at relatively low temperature, prevents the formation of excessive amounts of oxide on the metal.

A second bonding effect is the solubility of the metallic oxides in the frit. Although the frit does not form a regular crystalline structure when it is glazed, it is said to resolve into a disordered lattice. Because the metallic oxides are soluble in the enamel, metal atoms can be found within this lattice structure. This effect creates a very strong bond between oxide layer and glass layer.

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