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CONSTRUCTION OF A HIGH-POWER RF WINDOW

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ABSTRACT

This report describes the construction of a reheatable high-power ceramic window used with a traveling-wave linear accelerator between the accelerator waveguide and the source of rf power. This window consists of a high-purity alumina disk mounted in the common wall between two offset sections of rectangular waveguide. This location removes the ceramic disk from direct electron bombardment, in case this is a problem. O. F. H. C. copper is vacuum-cast around the edge of the disk, which is metalized with titanium hydride. A molybdenum washer is cast in the copper centered on the edge of the disk, which reduces the strain on the copper-ceramic joint during subsequent reheats by restricting the expansion of the copper.

After being cast, the metalized disk is machined, then vacuum-checked, heated to 500° in hydrogen, cooled and rechecked for vacuum tightness. If still vacuumtight, it is hydrogen-furnace-brazed with a silver-copper eutectic into the waveguide assembly.

Windows of this type typically have a voltage-standing-wave ratio (V. S. W. R.) in the range 1.01 to 1.03. One window gave a V. S. W. R. of 1.01 at 2855 megacycles with a V. S. W. R. less than 1.02 for 200 megacycles centered around 2850 megacycles. This type of window has been used successfully on four linacs.

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INTRODUCTION

In the construction of traveling-wave linear accelerators, an rf window is normally needed between the accelerator waveguide and the source of rf power. The Berkeley Mark I accelerator used a Polyethylene disk clamped between two flanges. A V-ring turned in one of the flanges was pressed into the Polyethylene disk to form the vacuum seal when the two flanges were clamped together. A choke flange reduced the current at the clamped joint. This window ran at several megawatts of power and had periodic failures.

With the construction of the second linear accelerator, it was desired to fabricate some form of ceramic window of high reliability. In addition, the klystrons being supplied were to be pulsed for 10-microsecond pulses instead of the designed 2- μ sec pulses, so the manufacturer was uncertain about his output window working at this level. Therefore, the development of a reheatable high-power ceramic window was undertaken.

The final windows had a voltage-standing-wave ratio (V. S. W. R.) in the range of 1.01 to 1.03. The specifications on one of the windows gave a V. S. W. R. of 1.01 at 2855 megacycles with a V. S. W. R. less than 1.02 for 200 megacycles centered around 2850 megacycles. To date these windows have been used on four linacs and have operated quite satisfactorily. The only ones that have been lost were punctured at about 4 megawatts power when a magnetron drifted off frequency and produced a large V. S. W. R. with a high voltage at the window.

Design

The simplest geometry for metal-to-ceramic fabrication is the round disk. It was decided therefore that the disk would be mounted in a section of cylindrical waveguide brazed between two sections of rectangular waveguide. By measuring the V. S. W. R. and attenuation, it was soon found that the optimum length for the cylindrical section is zero, or a simple hole between the two sections of rectangular waveguide. A series of tests was made to determine the optimum hole size in the common wall between two 10.5-cm waveguides. Quarter-wave shorting plugs were used to obtain the lowest V. S. W. R. and attenuation. Improvement of these factors was noted as the hole diameter increased; however, for apertures between 2 and 2.5 inches the position of the choke short partially covered the hole. Because of this, slope shorts of approximately 30 degrees were used for these apertures. A V. S. W. R. of less than 1.1 was obtained. There was some

leakage of power at these shorts and the attenuation was on the order of 3 or 4 decibels.

Tests were then made using various ceramic windows brazed in stainless steel rings (as shown in Fig. 1) clamped between waveguide sections with apertures the same size as those in the rings. Results followed the trend of the previous tests. The window with a 2.25-in. aperture required the choke short to partially obscure the window. The sloping short improved the V. S. W. R. and attenuation. However when similar shorts were soft-soldered in the waveguides, the V. S. W. R. was higher and the attenuation lower.

This essentially fixed the desired electrical design of the window. The next task was to fabricate such an assembly. The ceramic disk in stainless steel rings was vacuumtight and reproducible; however, on reheating (which was necessary in order to braze the window into the waveguide section) the ceramic fractured. The stainless steel rings were replaced by copper rings. The solder being used dissolved the copper and left voids in the ring. About this time the possibility was considered of placing a copper ring around the ceramic disk without any of the overlap (as in the two-ring case) by vacuum-casting the copper. Test castings were made and the excess copper machined off as shown in Fig. 2. This showed some pull-away of the copper from the ceramic on reheat. To prevent this a 0.015-in. thick molybdenum washer was cast in the copper positioned as shown in Fig. 3. The window constructed in this way successfully withstood reheating. It was then brazed into a section of 1/8-in. thick copper and was found to be vacuumtight. This assembly was reheated several times and still remained vacuumtight.

The first windows were made with the ceramic disk soldered in one section of waveguide and the second section clamped to it. This sparked at the clamp joint near the window. The design was then modified slightly and the disk was soldered between two sections of waveguide. This eliminated the major sparking problem.

Fabrication

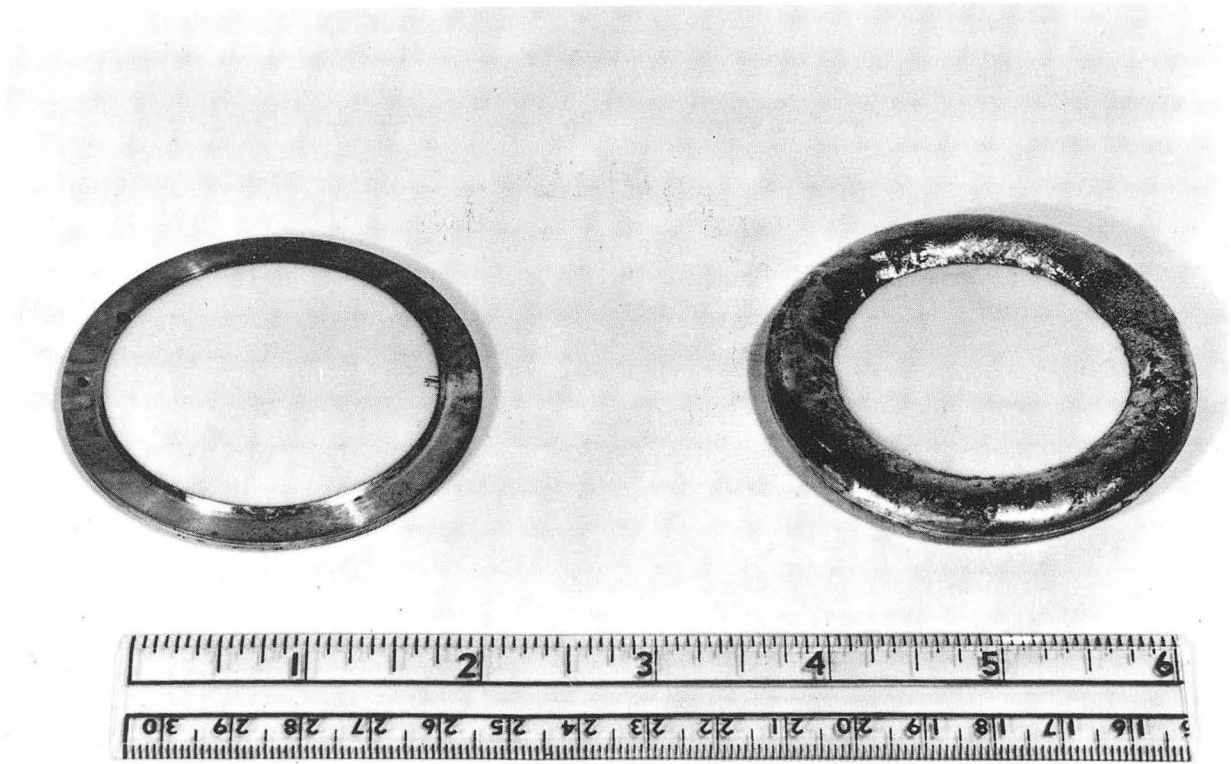
The ceramic disks used were high-purity alumina ground to finished dimensions, 2.00 in. in diameter and 0.115 in. thick.

The disk is first cleaned to prepare it for metalizing. This is done by scrubbing the disk with a good cleanser of the household type. In rinsing they should be scrubbed with fresh water to remove all of the cleanser. From this point on the disks should be handled with tongs or gloves only. A final rinse in 190-proof alcohol and drying complete the clean-up procedure. The molybdenum washer is sandblasted with a dental type industrial sandblaster to improve the bond of the copper to the molybdenum. It is then cleaned in the same way as the ceramic disk. The copper is a strip of 1/8-in. thick O. F. H. C. copper rolled into a ring. The amount of the copper is determined by the mold. There should be the same amount of copper above the molybdenum washer as below after the melt. If there is an unequal distribution of copper on one side of the ceramic, there is a good chance of fracturing the ceramic by flexing during the cooling of the casting.



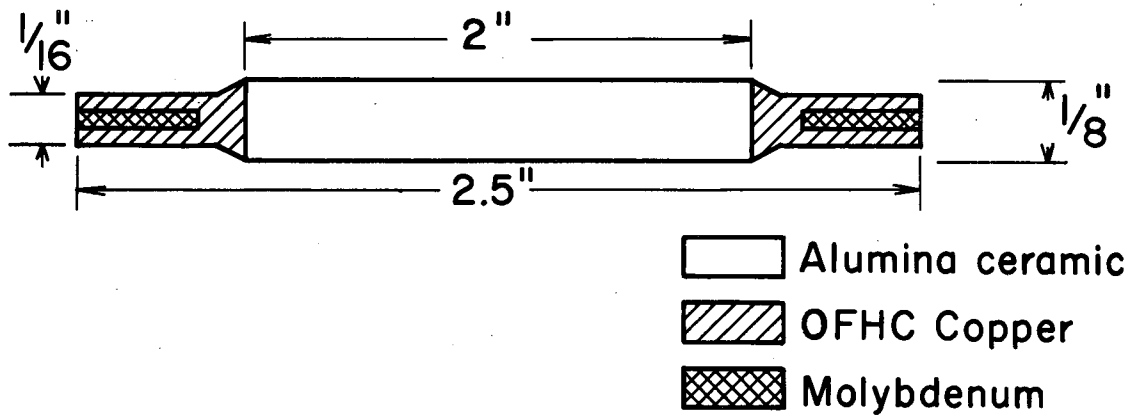
ZN-2233

Fig. 1. Test window of ceramic brazed in stainless steel rings.



ZN-2235

Fig. 2. Copper cast ring before and after machining.



MU - 18228

Fig. 3. Cross section of copper-ceramic joint showing molybdenum washer.

A thin coating of metalizing mix is then painted on the edge and a 1/16-in. ring on both faces at the edge. The coating on the faces is later ground off but it is put on as an aid in getting a good wetting on the edge right up to the faces of the disk.

After the ceramic metalizing mix has dried the parts are assembled in a graphite mold (Fig. 4). The mold is placed in a vacuum furnace and the mold lid placed in position. If the mold lid is not used there is a possibility of fracturing the ceramic owing to too rapid a heating of the exposed top of the disk compared to the shielded bottom of the disk. A thermocouple is placed on top of the disk in the center so as to provide pressure on the center of the disk. This serves two functions: to measure the disk temperature and to prevent the disk from floating when the copper melts. After a vacuum of approximately 1×10^{-5} mm Hg is obtained, the power can be brought on. The temperature increase should be held down to about 20 to 30° C per minute. There will be a large pressure burst at about 450° C when the hydride breaks down and hydrogen is evolved. As the melting point is approached, the temperature increase should be slowed down to let the temperature equalize in all parts of the mold. At the time of the melt the pressure should be less than 4×10^{-5} mm Hg if consistent results are to be attained. The temperature is allowed to rise about 30° C above the point of the melt before reducing power. The power is lowered slowly to reduce the temperature by about 30° C a minute until 850° C is reached. The power is turned off and the furnace is allowed to cool to room temperature.

When cool, the disks are removed from the mold and machined to the dimensions shown in Fig. 3. The excess metal on the two faces can be removed by hand-lapping with No. -80 wet or dry carbonundum paper and kerosene. It can be finished with a finer paper or preferably ground off with a diamond wheel.


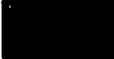

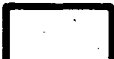
The finished window is then vacuum-checked. If it is vacuumtight it is sandwiched between two copper plates and reheated to 500° C in a hydrogen atmosphere. If the window is still vacuumtight it is ready to be brazed into a waveguide assembly. It should be noted that no window that remained vacuumtight on reheating has ever been lost in the brazing operation.

The waveguide section is fabricated as shown in Fig. 5. Two sections of waveguide, two sloping shorts, both flanges, and the window are all brazed together in one operation using silver-copper eutectic solder in a hydrogen atmosphere. The hydrogen prevents the silver from depositing on the ceramic (as it might in vacuum), and it also allows the use of stainless steel for clamping without the danger of brazing the clamps to the work.

The copper waveguide is special-order 1/8-in. -wall O. F. H. C. copper. The sloping shorts and flanges are also made from O. F. H. C. copper.

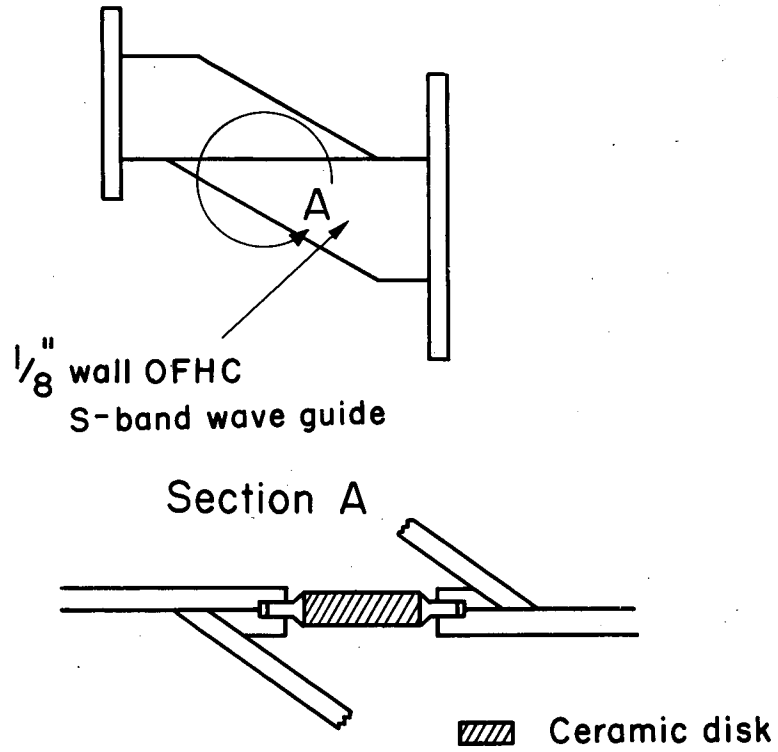
Occasionally, some of the window assemblies have come out of the hydrogen furnace with small leaks on sections of the waveguide. These can usually be patched with soft solder using a torch. Because of the high temperature, silver solders are not recommended for this type of repair.



-  Ceramic
-  Molybdenum washer
-  OFHC copper
-  Graphite mold

MU - 18256

Fig. 4. Cross section showing disk in graphite mold ready for casting. Mold cover is not shown. Small ceramic spacers hold disk off bottom of mold. (Not to scale.)



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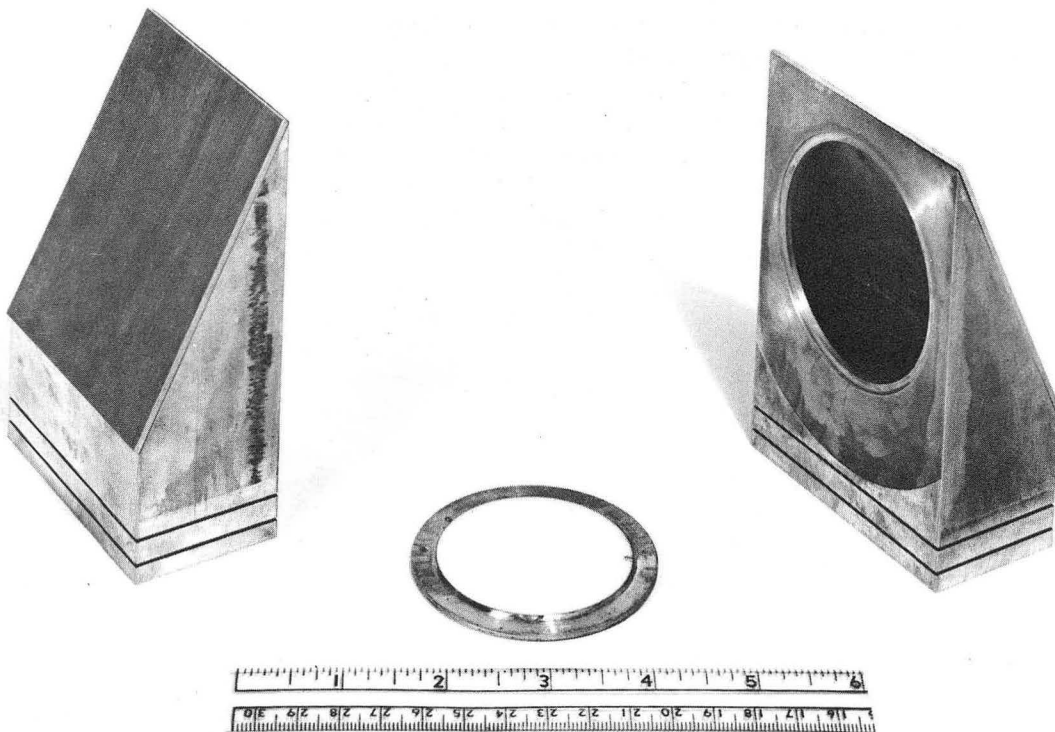
Fig. 5. Cross section of the waveguide. (Not to scale.)

Metalizing

The metalizing mix is a solution of titanium hydride, parlodion, and amyl acetate. The parlodion is dissolved in amyl acetate to form a solution about the consistency of thick cream. Then the titanium hydride is added (about 50% by volume). The mix must be kept agitated during use to keep the titanium hydride from settling out. The mix should be painted on in a thin layer. If there is too little parlodion, the dry mix will brush off the ceramic. If there is an excess of parlodion there will be a poor layer of titanium hydride when the parlodion is driven off. If an excess of titanium hydride is used, there will probably be a dendritic crystal growth in the copper with a resultant porous casting. This also occurred with several batches of ceramic where enough calcium leached out during the melt to form a dendritic crystal structure. This was overcome by preheating the ceramic to 1200°C in vacuum and then proceeding as before.

Zirconium hydride can be used in place of titanium hydride at a higher pressure. However the wetting of the ceramic is not as good.

The exact mix is best determined by using some test pieces of ceramic and checking the flow and smoothness of the copper or solder for various mixtures of the hydrides.



ZN-2234

Fig. 6. Waveguide parts and window ready for assembly.

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