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ULTRA HIGH VACUUM COMPONENTS FOR THE PROPOSED STANFORD TWO MILE LINEAR ELECTRON ACCELERATOR

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ABSTRACT

A number of all metal components have been developed at Stanford University for the proposed Two Mile Linear Electron Accelerator. These include a vacuum seal for waveguide, a one inch bakeable ultra high vacuum valve and an all metal bakeable waveguide valve, suitable for high-power S-band (10 cm) radiofrequency transmission. All components have a leak rate less than 10^{-10} standard cc/sec. of Helium.

SCOPE OF VACUUM SYSTEM

The vacuum system for the proposed two mile accelerator at Stanford evacuate the main accelerator structure, the input waveguide which carries the rf power from the klystrons to the accelerator, and the output waveguide which carries the unused power to a high power load. In addition, the system provides for detecting leaks, monitoring pressure, and protecting system components. The vacuum system design will provide a means of replacing klystrons without interfering with accelerator operation.

There are two reasons for requiring a vacuum in a linear electron accelerator: to prevent electron scattering, and to prevent electrical breakdown. These requirements are discussed below.

The pressure in the accelerator structure must be low enough to prevent the electrons from being scattered excessively by the remanent gas molecules. Using the multiple-scattering theory of Rossi and Greisen[1], an approximate expression for the root-mean-square scattering displacement of the electrons has been found to be[2]

$$(\langle y^2 \rangle_{av})^{\frac{1}{2}} = \frac{V_s}{K} \left(\frac{T}{2}\right)^{\frac{1}{2}} \text{ cm}$$

where V_s is a constant = 21 Mev, K is the average electron energy gradient along the accelerator in Mev/cm , and T is

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1. B. Rossi and K. Greisen, Rev.of Modern Physics, 13 ,268 (1941)
2. R.B. Neal, M.L. Report 185, p. 77 (Feb.1953)

the length of the accelerator in radiation lengths. The radiation length at a pressure of p mm of Hg is $(2.51 \times 10^7/p)$ cm. If we wish to limit the rms scattering displacement to 0.1 cm in the accelerator length, we obtain for $K = 0.033$ Mev/cm (i.e., $V_T = 10$ Bev)

$$p \leq 4 \times 10^{-6} \text{ mm Hg}$$

A very high vacuum in the accelerator and the adjacent input and output high power waveguides will reduce the possibility of electrical breakdown. Replacement of individual klystrons can be accomplished by a separately pumped short section of waveguide between the klystron and the accelerator. This section must have either a separate vacuum system and a vacuum tight window, or a waveguide valve.

The conditions required for satisfactory accelerator operation include the following:

1. Pressure of the order of 10^{-7} mm Hg.
2. An all metal system.
3. Adequate cleaning and elimination of contaminants by chemical techniques, baking and rf processing.
4. Location of controls and components in radiation shielded areas.

COMPONENTS

Some of the components developed and tested to meet the above system requirements are described below.

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Demountable Waveguide Joining

The requirement for an electrically continuous inner surface is met by using a copper gasket seal. The gasket consists of a ring of copper of rectangular cross section with a raised ridge opposing ridge on each side. Electrical contact is made at the inner edge of the ring. The ring may be either circular for cylindrical waveguide or rectangular for rectangular waveguide. The vacuum seal is made at the raised ridge. To effect a seal the raised ridge is pressed into the copper ring by two opposing lapped hard surfaces.

Figure 1 shows both rectangular and circular gaskets in sizes ranging from 1 in. to 6 in. ID. Figure 2 shows the cross section of a typical gasket, before compression and after compression. The dimensions of the ridge are shown on the figure. Rectangular seals have been tested in an rf recirculator up to 18 megawatts peak power and 18 kw average power at S-band (10 cm) without arcing or excessive heating. The measured VSWR is unity over the bandwidth of the waveguide.

The copper waveguide is brazed into a stainless steel flange which then provides a mating surface for the copper gasket. Figure 3 shows a quick disconnect flange system where copper waveguide is brazed into the stainless steel flanges. Two bolts are used to draw the tapered clamping bars together, as shown in Figure 4.

The measured leak rate on a mass spectrometer leak detector was less than 10^{-13} standard liters/sec. for the assembly shown. Sealed off klystrons using these seals have not shown an increase in pressure over a period of several months. The sealed off pressure was in the 10^{-9} mm Hg. region.

High Temperature Testing

Over 300 gaskets have survived many bake cycles ranging from 8 hours to 56 hours at 600° C. In a most severe test, a rectangular gasket assembly was vacuum tight after being cooled from 720° C to -187° C by quenching in liquid nitrogen. Gaskets can be made of OFHC copper either by blanking and coining or machining from tubing or sheet stock. After the forming operation the gaskets are degreased, chemically cleaned and fully annealed in a hydrogen atmosphere.

Vacuum Pipe Joining

Several flange systems have been devised. One of these is shown in Figure 5, in which the solid flange and seal flange are brazed to their respective pipes. A second seal system not requiring brazing of the pipe to the flange is shown in Figure 6. A groove is cut in the pipe near each end, in which a split ring is contained by the outer flange. The sealing surface on each pipe may then be lapped before use. As can be seen in the Figure 6, the split ring will align the gasket and the pipes. Since the flanges are free to rotate, bolt orientation is not important. The inside dimension of the gasket and pipe are the same, thus a smooth inner surface is obtained. Adequate exposed area on the outside provides easy leak detection.

Vacuum Pipe Union

A union designed for vacuum use provides a seal with a thin copper gasket of the general configuration described above. The gasket is originally flat, but is deformed to a conical shape by the union. As can be seen in Figure 7, brazing is unnecessary with the split ring described above.

All Metal Valve

A bellows sealed all-metal valve has been constructed and tested. The seal is provided by a raised ridge on a copper seal gasket similar to the type described above. A stainless steel disk which has been copper plated and lapped is pressed against the seal gasket. The ridge is not completely flattened during a valve cycle. Some of the design features of this valve are shown in Figure 8.

The valve disk may be lapped in the event of damage either during baking or some other cause. No specific disk alignment is required. The seat and vacuum seal are one piece and may be joined directly to the system without additional plumbing, providing high open conductance. The orientation of the valve is unimportant.

The leak rate as measured by a mass spectrometer was less than 10^{-13} standard liters/sec. after 250 closures. The sealing torque remained at 30 ft. lbs. throughout the test for the one inch size. No deterioration resulted from cycling the valve to 400° C in the closed position. The valve has been constructed in sizes from ½ in. shown in Figure 9 for up to an air valve and as large as 2 in. ID. A photograph of the 1 in. valve is shown in Figure 10 .

Waveguide Valve

To permit the replacement of klystrons without affecting the accelerator vacuum, an all-metal bellows-sealed valve has been developed in a waveguide configuration. The valve is designed

- 5 -

to carry 30 megawatts peak rf power at S-band. The valve body forms a transition from rectangular to circular and back to rectangular guide in a right angle bend. In Figure 11 the sealing cone as shown in position 1 provides a continuous rf surface when the cone is flattened; in position 2 the cone provides a vacuum tight closure between the klystron and the accelerator. The cone and the inner walls of the transition are plated with .005 in. of OFHC copper to provide a high conductivity surface. A matching section and iris are included to provide for fine tuning.

Principle of Sealing Cone Operation

In Figure 12 the principle of the sealing cone is shown. In A the cone is shown in the relaxed position, while in B the cone is flattened to meet the wall. The cone is made of a hard spring material while the cylinder is made of stainless steel. The sealing torque depends on the valve size.

A complete valve assembly is hsown in Figure 13. The sealing cone is located either in the rf seal position or the vacuum seal area by rotating the plunger actuator. The position collar gives a reference for future seals. The inner shaft provides the force to flatten the cone and make a seal. Vacuum closures may be repeated in the same position or as close as .007 in. apart. The seal area is $1\frac{1}{2}$ in. long, thus giving many positions for closure. A photograph of a test valve is shown in Figure 14.

~~The valve has been tested~~

The valve has been tested both at low and high rf power. In the open position the VSWR is 1.05 over a 10 Mc/sec bandwidth at S-band (10 cm) . The high-power characteristics have been tested to 16 megawatts peak and 16 kilowatts average power in an rf recirculator without arcing or excessive heating.

Sealing Properties

The waveguide valve has provided a vacuum tight closure with a leak rate of less than 10^{-13} standard liter/sec as measured by a mass spectrometer leak detector. The seals have been obtained both with and without internal copper plating. More than 50 cycles are possible at~~a~~ any one seal position. Seal positions have been located as close as .010 inches. The sealing torque is dependent on the clearance between the sealing cone and the wall, for our configuration a torque of 50 ft. lbs. was required on a 3/4 inch bolth with 13 threads per inch.

Other Configurations

The valve has been adapted to provide a large conductance opening in sizes from 2½ in. ID to 6 in. ID. The 2½ in. model is shown in Figure 15.

CONCLUSIONS

Thec components described have indicated the feasibility of providing an all metal system for vacuum systems for linear electron accelerators. The components developed include flanges, seals, and a variety of all-metal valves.

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COMPONENTS FOR THE PROPOSED STANFORD TWO MILE LINEAR ELECTRON ACCELERATOR

List of Figures