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CONSTRUCTION OF VACUUM SYSTEM FOR TRISTAN ACCUMULATION RING

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Introduction

An all aluminum-alloy vacuum system for TRISTAN accumulation ring (2.5–8 GeV) is now under construction. Aluminum and aluminum alloys are preferred materials for ultrahigh vacuum systems of large electron storage rings because of their good thermal conductivity, extremely low outgassing rate and low residual radioactivity.

The bakeout temperature of an aluminum alloy system is generally limited to approximately 150°C by the decrease in mechanical strength with temperature. If ordinary stainless steel components are mixed in an otherwise aluminum alloy system, effective bakeout of the stainless steel is often impossible because of the temperature limitations due to aluminum. Then, the ultimate pressure is often limited by outgassing of the stainless steel components. Ordinary stainless steel components and stainless steel-aluminum transitions have been eliminated as much as possible from the TRISTAN design.[1] Suitable aluminum alloy vacuum chambers, elliptical bellows, fittings, flange/gasket/bolt, nut and washer combinations, feedthroughs, gauges, optical windows, sputter ion pumps, turbomolecular pumps, valves and related aluminum alloy vacuum components have been developed.

Beam Chamber

Vacuum beam chambers for the dipole and quadrupole magnets are extruded using porthole dies. The aluminum alloy (6063-T6), used here, provides superior performance in extrusion. For ultrahigh vacuum performance, a special extrusion technique is applied, to prevent the usual growth of a porous aluminum oxide film, with trapped contaminates that later causes desorption of gases. An oxygen and argon atmosphere is maintained in the extrusion process. As a result, the inner surfaces of the extrusion are covered by a fine non-porous, dense oxide film, with a thickness of about 30 Å. The outgassing performance can be described as follows. Typical outgassing rates 24 hours after initial evacuation are about 2×10^{-11} torr l/s cm^2. The outgassing rate after then baking 24 hours at 150°C is less than 10^{-13} torr l/s cm^2, by as measured the through put method. Next, the chamber is vented to atmospheric pressure, from an initial pressure in the order of 10^{-10} torr, using an oxygen and argon mixture. The chamber can now be exposed to atmosphere for several hours. This chamber will still have an extremely short pump-down time to ultrahigh vacuum, without baking. Typical outgassing rates after exposure to atmosphere, without baking, are 10^{-12} torr l/s cm^2 after 24 hours. An aluminum vacuum chamber made by ordinary extrusion techniques does not have such an extremely low outgassing rate.

Bellows

Aluminum alloy (3004) seamless elliptical bellows are inserted between the dipole and quadrupole magnet chambers. Such bellows are produced by hydraulic forming of a seamless tube. Using an aluminum alloy bellows, if it is made thin enough to obtain good elastic performance, welding of the bellows to the flange or chamber becomes difficult, especially if the wall thickness is below 1 mm. However, if it is made thicker for the purpose of easy welding to the flange, the elastic performance of the bellows is degraded. In our bellows, the thickness of the corrugated part is reduced to 0.3 mm while a thickness of the welding edge parts is 2–4 mm. This contributes to both getting sound welds and retaining good elastic performance. The seamless bellows and the beam chambers are joined by fully automatic welding.

Ceramic Chambers

The ceramic chambers for the kicker magnets, fast bump magnets and the slow beam intensity monitor are inserted in the aluminum alloy beam chambers. The ceramic chamber (98% alumina) and special aluminum alloy (3003) elliptical bellows are brazed with brazing sheet (4003-3003-4003) in a vacuum furnace. First, MoMn paste is painted on the ceramic surfaces and heated in a hydrogen furnace. Second, the metallized surfaces are electro-plated with Ni and sintered again in a hydrogen furnace. The ceramic chamber with aluminum bellows is joined to the aluminum alloy beam chamber using fully automatic welding. The inner surface of the ceramic chamber is coated with a TiMo alloy by vacuum evaporation, to permit a smooth flow of the RF wall current.

Cooling

Average radiated power along the beam chamber is about 1 kW/m for 8 GeV, 30 mA × 30 mA beams. The dipole magnet chamber has two cooling channels and the quadrupole magnet chamber has one cooling channel. The diameter of the cooling channel is 10 mm. To absorb the radiated power that otherwise would fall on the bellows ond the ceramic chamber, small cylinders are inserted on the inner surface of the chambers.

Joining

The beam chambers of the dipole and quadrupole magnets, the gate valves, the ceramic chambers, and the bellows are directly joined by a fully automatic welding machine without flanges. This welding machine was designed to move the welding torch around the elliptical cross section of the vacuum chamber and uses a specially-shaped guide rail to obtain the proper welding speed. It employs straight polarity with a special dual-frequency, modulated time structure. The separation between adjacent dipole and quadrupole magnets is kept to a minumum.

For demountable joints a new Conflat style seal,[2] which consists of Cr_2N coated aluminum alloy (2219-T87) flanges, aluminum gaskets (1050-H18), aluminum alloy bolts (2024-T4), nuts (6061-T6) and washers (2017-T3) is used. The knife edge is a superfinished surface processed by a flat diamond tool. This is needed for reliable sealing characteristics. A chromium-nitride film is deposited on the surface of the flange by the ion plating method. The thickness of the Cr_2N is about 3 μm and its micro-Vickers (10 gr) hardness is very high, about 1300. The Cr_2N treatment on the flange gave nearly perfect protection against sticking between the knife edge and the gasket. The Helicoflex[3] is preferable over the usual solid gaskets for the combination system of an aluminum alloy Conflat and an ordinary stainless steel Conflat flanges. Using the Helicoflex avoids leaks caused by the different thermal expansion coefficients of aluminum alloy and stainless steel during baking cycles.

Beam Monitors

Four button-type pickup electrodes to detect the

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beam position are to be installed in each quadrupole magnet chamber. The Al-SMA feedthroughs[4] are welded to the mount by electron beam welding. The mount with electrodes is welded to the beam chamber using TIG welding. The Al-SMA feedthrough consists of ceramic and aluminum alloy, sealed by vacuum brazing.

Optical Window

The window consists of an aluminum alloy (3003) sleeve and a sapphire disk. The sleeve and the metallized sapphire are brazed with aluminum alloy solder in a vacuum furnace. The diameter and the thickness of the sapphire disks are 30 mm and 3 mm, respectively. The sapphire window assembly is welded directly to the Al-Conflat flange using electron beam welding.

All Metal Gate Valve and Angle Valves

Installation of gate valves in the beam ducts is desirable to protect the large ultrahigh vacuum system from venting to air. By relying on differential pumping for the seal, dual flat-face-seals[5-6] are used without gaskets or knife edges. The sealing surfaces of the isolating plate are polished to a smooth mirror-like finish by a flat diamond tool and coated with Cr_2N for surface hardening. The valve seats, which are 0.1 mm thick aluminum, are pressed against the sealing surfaces by compressed air ($2 \sim 5$ kg/cm^2). A close-contacting metal surface seal is obtained. The maximum conductance is 10^{-5} l/s for each seal. The total leak rate with a differential pumping speed of 10 l/s is less than 10^{-10} torr l/s. The intermediate pressure in the valve body is about 10^{-4} torr. The aperture of the gate valve is of the same elliptical shape as the vacuum beam chamber. When the valve is open, a bellows assembly is inserted to continue the original aperture of the beam duct and to maintain a smooth path for the RF wall current.

We have designed all aluminum alloy angle valves using the sealing principle of the Helicoflex against a smooth, mirror-finished surface. If the surfaces of a flange and of the Helicoflex are sufficiently smooth and accurate (0.1 S), repeated sealing is possible with the same tightening force. For the aluminum alloy flange (2219-T87), a smooth mirror finish is easily and economically obtained using a flat diamond tool in spite of the hardness of the material. The finished surface can be hardened further by a Cr_2N treatment. A valve using these principles was tested on a helium leak detector and found to have a leak rate of less than 10^{-10} torr l/s during 100 opening and closing cycles, with a constant torque of about 150 kg cm for an ICF-114 type.

All Aluminum Alloy Ion Pumps

We have developed a new structure for the built-in distributed sputter ion pump.[5-6] Its anode consists of five layers of perforated aluminum (1050) plate. The cathode is a titanium rod 2.6 mm in diameter, and is insulated from the vacuum chamber. The insulated cathode makes it possible to measure the Penning discharge current at a pressure as low as 10^{-9} torr, and may open up the possibility of using the built-in pump as an ultrahigh vaccum gauge. This pump has about 100 l/s m pumping speed for nitrogen at 10^{-7} torr. The pump has an extremely short pump down time to ultrahigh vacuum, to the order of 10^{-9} torr after only 24 hours initial operation and to the order of 10^{-10} torr after 150°C, 24 hour, initial bakeout procedure.

We have also developed a new self contained sputter-ion pump. The pump shell, ICF type flanges, Al-SHV feedthrough, and the pump element, except for the titanium cathode, are made of aluminum alloy. The anode material and structure are the same as in the distributed pump. Pumping characteristics of this pump are nearly the same as in the distributed ion pump.

Turbomolecular Pump

A 50 l/s turbomolecular pump has been made of aluminum alloys. The flange is Al-Conflat flange and the body is aluminum alloy. This turbomolecular pump also has an extremely short pump-down time to ultrahigh vacuum of 10^{-9} torr after a 100°C, 24 hour initial bakeout procedure.

Bulk Getter Pumps

The cartridge of a bulk getter pump (type 101/CT/AM/30D) has been mounted on an Al-Conflat flange equiped with the Al-BNC feedthrough. A second type of the pump, using a linear getter pump element, 1 m long, is installed in the insertion quadrupole magnet chamber, near the e^+e^- colliding points. The current feed is from an aluminum-ceramic sealed, 125 A feedthrough.

Roughing System

Initial pump-down is accomplished by a combination of 50 l/s turbomolecular pumps and 240 l/min mechanical pumps. A semi-automatic isolation angle valve is installed between the beam chamber and the roughing pump. For semi-automatic operation, a simple flywheel winding tape with a weight on its shaft is adopted with a manual angle valve as an actuator. This flywheel type actuator is useful as a safety valve in the case of unexpected power failure. To start up the distributed ion pump and the ion pump at the pressure of 10^{-6} torr the roughing pump system was used from atmospheric pressure to 10^{-7} torr range.

Fittings

A seamless cross-piece, a T-piece and a 90° elbow are made from aluminum alloy (6063-T6) using a bulging method. Aluminum alloy Conflat flanges are welded to these pieces. They are useful by themselves as ultrahigh vacuum components. The T-piece is also used in the construction of the angle valve body. A small die-cast cross-piece, a T-piece and a 90° elbow with KF-flange are useful in the rough-pumping system.

Heater and Insulation

A straight sheath heater, which is made of an aluminum (1050) sheath, 77% Ni-20% Cr coil heater and zirconia insulation, is pressed into the groove of the vacuum chambers. The vacuum chambers are thermally insulated by laminated Kapton films (20 μm) which are aluminized and embossed.

Gauge

Bayart-Alpart gauge electrodes are mounted on an Al-Conflat flange with the Al-14P-BNC feedthrough. Also an inverted magnetron type, cold cathode gauge has been made of aluminum alloys.

Control

Control of the vacuum system is simplified by restricting the operation pressure range of the sputter ion pumps. The operating pressure range of these sputter ion pumps is between 10^{-6} torr and 10^{-10} torr. The discharge current near 10^{-6} torr is of the order of mA. We therefore use 5.5 kV, 5 mA and 5.5 kV, 20 mA DC-DC converter-type high voltage power supplies. They are very small in size and light in weight. Two of the 5 mA type power units or a single 20 mA type power unit can be housed in a 2 unit NIM-module. The power feeder between the control and the pump is a coaxial cable (RG-59U) with a SHV connector. Two cold cathode gauge controllers or four Convectron gauge can be housed, 2U-NIM-modules. These ion pump and various gauge controllers are interfaced to a mini-computer network.

Conclusion

Assembly of the beam transport line from the 2.5 GeV linac to the accumulation ring and the accumulation ring itself are now under way. First beam tests of the accumulation ring will start in November 1983. The present system satisfied conditions such as high performance, high reliability, impedance matching, simplicity, low wasted space between magnets, small size, low residual radioactivity and low cost.

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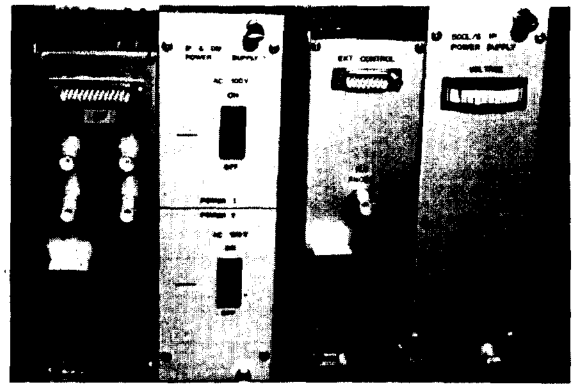
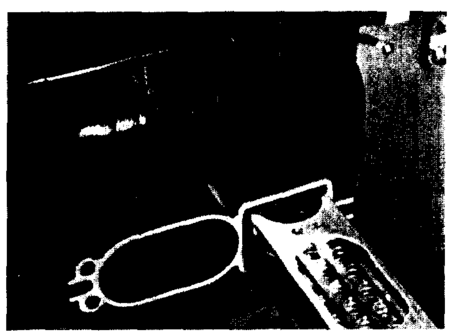


Fig.3 5.5 kV, 5 mA and 5.5 kV, 20 mA DC-DC converter-type high voltage power supply for ion pumps.



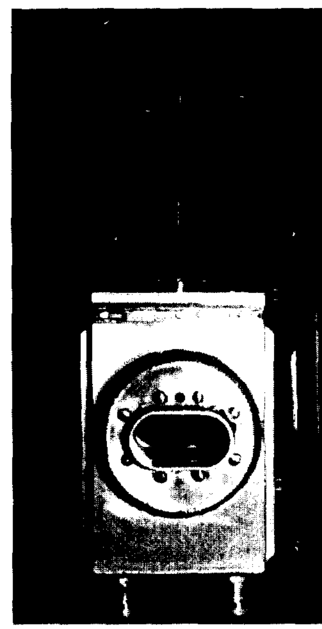


Fig.1 Aluminum alloy seamless elliptical bellows is inserted between the dipole and quadrupole magnet chambers by a fully automatic welding machine without flanges. Wasted space between magnet becomes minimum.
Fig.2 Aluminum alloy distributed sputter ion pump is installed in the dipole magnet chamber.

Fig.4 Dual-flat-face-seal-with-differential-pumping type aluminum alloy gate valve.

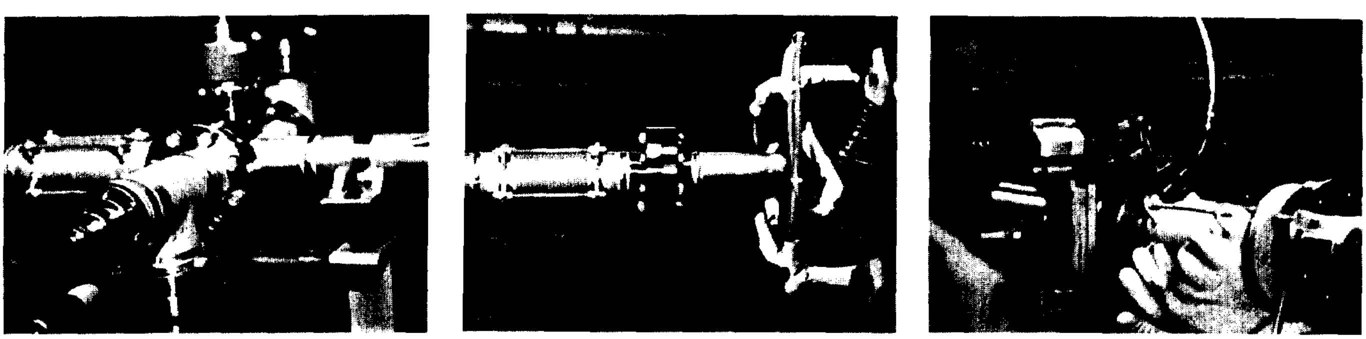


Fig.5 Assembly of the beam transport between the injector linac and the ring.
5.a Rughing pump station and 30 l/s ion pump. 5.b Vacuum chamber for the quadrupole magnet, Al-Conflat flanges and the Al-seamless bellows. 5.c The beam chamber of the quadrupole magnet and the bellows are directly joined by a fully automatic welding machine without flange.