CONCEPTUAL DESIGN STUDY FOR A VERY LOW-COST ALUMINUM ALLOY VACUUM CHAMBER IN A HIGH ENERGY LOW-FIELD COLLIDER

Hajime ISHIMARU
KEK National Laboratory for High Energy Physics,
1-1 Oho, Tsukuba, 305 Japan ishimaru@kekvax.kek.jp
(Jan. 12, 1996, and revised-1, April 9, 1996, revised-2, July 3, 1996)
Snowmass APS Workshop July 8, Monday 1996

1. INTRODUCTION

The purpose of this study is to propose an aluminum alloy vacuum chamber with superior performance and high reliability at extremely low cost for a 50 TeV low-field collider at Fermilab(1). Some initial parameters are:

1) 50 TeV proton-proton high energy collider: circumference about 500 Km compared to Superconducting Super Collider of 87 Km.
2) The single turn drive current magnet, in 1,000 m segments operating in liquid nitrogen or cold helium gas, resembles a high temperature superconducting power transmission line of 90 KA.
3) Extruded iron magnet yokes at ambient temperature.
4) Alternating gradient dipole magnets of 2 T without quadrupole magnets.
5) 250 m long extruded aluminum alloy beam chamber at ambient temperature.
6) A diameter of 1 m tunnel filled with nitrogen gas 100 m underground.
7) Assembly and adjustment of magnets and beam chambers by remote controlled robot systems.

Fig.1 shows the cross section of the superconducting transmission line, iron magnet yokes and two vacuum chambers installed in the tunnel.

2. COST EFFECTIVE BEAM CHAMBER REQUIREMENTS

1) Extremely low cost.
2) Extremely high reliability.
3) Reduce risk.
4) Remote handling robots to replace magnets and the beam chambers inside the tunnel.

3. BENEFITS OF ALUMINUM

Extrusion of elliptical or race tack shape chamber 250 m long is possible to build with pumping channel. Clean extruded aluminum alloy chamber has a very low specific outgassing rate(2). Key benefits for aluminum are:

1) An outgassing rate of approximately 10-13 Torr l/s cm2 can be achieve utilizing chemical process procedure(3) at 70°C several hours mild heating, 2) Aluminum has very high resistive to “melt-down” failure(4) than several tens of magnitude of stainless steel since aluminum is low energy loss and high thermal conductivity.

4. BACKGROUND OF VACUUM REQUIREMENTS

A. Synchrotron radiation(5, 6)

The power, photon number, and critical energy of synchrotron radiation of 50 TeV proton ring is 1.25 W/m, 4.6 x 1016 photons/s m, and 0.56 KeV respectively. These of the 50 GeV CERN LEP electron-positron collider are 50 W/m, 1.3 x 1016, and 89.5 KeV respectively. Power of synchrotron radiation is 40 times smaller than LEP. But the photon number is same level. Water cooling of vacuum chamber against synchrotron radiation will be not used. Dynamic outgassing due to synchrotron radiation is similar to LEP. Then, required linear pumping speed is similar to 50 GeV LEP.

B. Beam impedance

In electron storage rings short bunched beams produce a wide range spectrum of microwave (GHz) frequency components along the wall current. If the wall is not discontinuity occurs as a wake field loss.

Single bunch transverse impedance effect is proportional to ring radius and of beam chamber radius cubed of inverse. Impedance requirement is very serious problem for large ring with small aperture beam chamber.

C. Resistive wall instability

To avoid beam instability, low resistive wall beam chamber is required.

D. Eddy current

The eddy current effect refer to quenches as well as limits on the ramp rate, both of which extends us high resistivity to avoid deformation of the extruded beam chamber during quenching of superconducting magnet, a high resistive alloy is needed resulting in small eddy current effect.

5. VACUUM BEAM CHAMBER

A. Beam chamber

Circumference of the ring is about 500 km long. Extruded aluminum alloy beam chamber with elliptical or race track shape with pump channel are used in length about 250 m or more. The thickness of the beam chamber is 1.5 mm. Total number of 250 m long beam chamber is about 4,000 pieces along the entire rings. Synchrotron radiation irradiate the pump channel for one of the two beam chambers as shown in Fig.1. To avoid direct hitting of synchrotron radiation against the distributed pump, asymmetry pumping slot will be applied as Fig.2.

Proposed is 99.99% high purity aluminum to suppress resistive wall instability. The aluminum alloy 7N01-T5 has high resistivity (three times copper), high strength (30 kg/mm2) with extrudability and weldability. During the design phase of SSC project, 7N01-T5 aluminum alloy pipe was tested in superconducting magnet as quench test with negligible deformation(7). To avoid eddy current effect during the quench for magnets, a high resistive 7N01 alloy co-extruded beam chamber is required. For uniform transmission of high frequency wall current, the skin depth thickness of less than 0.1 mm 99.99% high purity aluminum for the inner layer of the clad beam chamber(8) is proposed.

B. Clean extrusion

The EX extrusion process places a 250 m long section pipe inside of the beam chamber filled with dry oxygen and nitrogen mixture to produce a clean native oxide inner surface wall. After extrusion the pipe will be coiled in a 4 m in diameter for storage and transport filled with oxygen and nitrogen in closing both ends. Prior to assembly, coiled pipe will be stretched out check straightness without deformation of beam chamber using dry oxygen and nitrogen mixture fill to keep clean surface.

C. Surface treatment

To eliminate additional carbon contamination, ozone treatment(9, 10) was applied on the 250 m long beam chambers in-situ inside the tunnel. The surface of aluminum alloy beam chamber without any liquid treatment were exposed to ozone using dry nitrogen.

D. Unit chamber

Unit chamber houses a beam position monitor and two pressure gauges. The unit chamber is one piece housing as shown in Fig.3. The unit chamber of 0.2 m long is installed between the 250 m long beam chambers.

An clean machining of EXP process(11) is used for unit chamber. The EXP machining is processed in dry oxygen and argon mixture environment with Corona discharge, thus producing ozone. The ozone is extremely active with strong oxidizing and cleaning effects to remove organic contamination.

E. Lumped ion pump and pump manifold

The beam chamber has high-conductance side chamber. Lumped ion pump and roughing pump manifold must be installed in the end of the side chamber to maintain high conductance. Pumping speed of the lumped ion pump is 30 l/s. The pumping manifold haused separation valve to reduce the flanges. The high current feedthrough for NEG strip is also housed in the pumping manifold. Lumped ion pump, separation valve and high current feedthough are housed in the pumping manifold. This pumping manifold will be made one piece housing with minimum weld seams. Fig.4 shows pumping nanifold housed lumped ion pump, separation valve and high current feedthrough.

6. NO-BELLOWS DESIGN

To increase reliability and reduce risk, a simplified beam chamber is proposed. Cost savings come a reduction in number of components and less labor cost.

Vacuum leakage of an ordinary beam chambers is normally caused by flanges and bellows which also decrease the reliability of the system. To eliminate leakage and reduce cost, it is proposed that a simple extruded aluminum alloy beam chamber of 250 m long be constructed without flanges and bellows.

The aluminum alloy beam chamber of the TRISTAN electron-positron collider(12) had been joined using automatic welding without flanges which virtually eliminated any leakage. In Japan, super-express train, “Shinkansen” is all welded without gaps between rails. The rail has been designed to accommodate inner expansion and compression stress during temperature raise and fall. This situation closely represent the condition of this collider.

Thermal expansion of the beam of 250 m long is about 0.25 m for temperature rise of 50°C. Unit tensile stress σ against extruded aluminum alloy chamber with supported and fixed in-steel magnet yokes in ambient temperature is

$$\sigma = \eta E \; (t\text{-}t0)$$

where $\eta$is thermal expansion coefficient, E is modules of elasticity, and (t-t0) is temperature difference. For example, aluminum alloy thermal expansion coefficient: η: 2 x 10-5 /°C, E: 7,000 kg/mm2, and (t-t0): 50C. Then, σ = 7 kg/mm2. The unit tensile stress includes allowable stress for any aluminum alloy material. There appear to be safety margins for inner compression stress. The compressed force for 250 m long beam chamber is about 1,300 kg. The beam chamber is supported and fixed to iron magnets. Assembly of the beam chamber is supported and fixed in iron magnet yokes as shown in Fig.5.

A finite element analysis against inner compression stress was made for the long beam chamber with fixing of both ends as shown in Fig.6. And thermal cycle test from 20°C to 80°C was performed using 8.5 m long aluminum alloy beam chamber with anchored periodically to iron support and fixed ends. Many strain gauges installed in the beam chamber. Fig. 7

shows stress vs. temperature during thermal cycle test. Finite element analysis and thermal cycle test were shown this system will work.

7. PUMPS

A. Main pump

Given the criterion of the average pressure is 10-10 Torr range with beam. Dynamic gas road due to synchrotron radiation is same level of 50 GeV LEP. Required linear pumping speed of 100 l/s m will be same level. The beam chamber is installed in the magnet with 2 T magnetic field. The primary candidates of the main pump is distributed non-evaporable getter (NEG) strip. NEG strip is not able to pump rare gas such an argon and helium, and produces methane, a lumped ion pump of 30 l/s in combination with NEG strip is required.

B. Roughing pump

Required function for the roughing pump is first, pumping from atmospheric pressure to activation pressure, and second, roughing pump system are transportable cart station inside the tunnel. The roughing pump consists of 300 l/s turbomolecular pump with magnetic bearings and dry pump combination. The turbomolecular pump is wide range type. The dry pump consists of drag pump and diaphragm pump combination as an oil-free system. The roughing pump system will be operating from atmospheric pressure to 10-5 Torr range. The diaphragm pump will be operating from atmospheric pressure to about 1 Torr range together with dry pump. The turbomolecular pump will be starting 10-1 Torr range together with dry pump. Distance of the roughing pump is 250 m long. The seal for attaching and detaching the portable roughing station is elastomar O-ring. NEG strip of activating pressure must be keep of 10-4 Torr range. Required total desorbed gas from the 250 m long NEG strip during activation period will be order of 200 Torr l. After starting lumped ion pump of operating pressure of 10-5 Torr, the roughing pump station will be separated from the metal seal valve.

Vacuum gauge for control from atmospheric pressure to 10-5 Torr range will be used Convectron gauge and cold cathode gauge combination inside roughing pump station.

8. PRESSURE GAUGES

The pressure monitor system along the rings is very important for huge ultrahigh vacuum system installed in small size tunnel without human access. Two types of pressure monitors are proposed with successful operation at low cost. A current readout monitor for discharge of ion pumps can work as pressure monitor. But discharge of the ion pump is not stable in long time use.

A. Cold cathode gauges

Cold cathode gauge without filament is recommended for measurement in the from 10-4 Torr to 10-10 Torr range. Miniature size nude invert magnetron type within permanent magnet inside vacuum(13) as shown in Fig. 7 is recommended.

B. Ionization monitor

It has proposed that ionization monitor(14) as a pressure gauge be placed along the ring. The residual gas is ionized by high energy proton beams. Provided that the efficiency and the volume for ion collection are constant, the signal is proportional to pressure, beam current, and ionization cross section. Thus, measured distribution of signal along the ring can readily be converted to the relative pressure distribution.

Ionized ion will be corrected by the biased ion corrector electrode. Electrode consists of an ion corrector with the signal tied to an amplifier by triax vacuum feedthrough.

This ionization monitor acts as ion clearing electrodes along the rings.

C. Residual gas analyzer

The design concept is very low cost with high reliability. Then residual gas analyzer will not use along the ring. But point of view for vacuum science, some residual gas analyzer will be installed in the ring.

9. COMPONENTS

A. Beam position monitor

Beam position monitors are required every 250 m for x-y directions. Primary candidate of beam position monitor is four strip line electrodes type. This type can measure x-y directions simultaneously. The strip line electrode consists of alumina ceramics and titanium metallization with elliptical or race track aperture. This electrode is non-magnetic feature. The electrode is installed in the unit chamber. Four output signals are fed using non-magnetic SMA feedthroughs and mineral insulated coaxial cables. Non-magnetic feedthroughs consist of aluminum alloy and alumina ceramics using vacuum brazing(15). Center conductor is titanium. The feedthrough is welded to unit chamber made of aluminum alloy using electron beam welding.

Second candidate for the beam position monitor is the electrostatic pickup split type. Fig. 8 shows a photograph of the model for beam position monitor made of ceramics and titanium metallization. Horizontal and vertical type are needed for x-y directions separately

B. Gate valve

The beam chamber is isolated by metal seal gate valve. Requirement for gate valve is extremely high reliability. The gate valve seals are designed for differential pumping by utilizing leak free dual mirror finished surfaces(16). The seal consists of silver membrane of 0.1 mm in thickness housed in indium to maintain uniform contact with the opposite side of the mirror surface. Even silver membrane will be brake, leak could not come. The gate valve has RF shield to maintain smooth wall current with elliptical or race track aperture. This gate valve seals are not sensitive microdust. This gate valve has locked mechanism. The vacuum system separated by 500 gate valves along the ring. The distance between gate valve is about 1 km long. Ends of each gate valve will be automatically welded to the beam chamber without flanges and bellows.

C. Separation valve for roughing pumping station

The separation valve will be housed in the roughing pump manifold. The roughing pump station is portable type. After activating NEG pump and lumped ion pump starting, the separation valve will be closed. The metal seal will be used Helicoflex O-ring(17). The sealing surface is mirror finished with concave to maintain uniform sealing pressure. The mirror surface is TiC coating to avoid scratching and sticking.

10. PROTOTYPE BEAM CHAMBER FOR EVALUATION

The prototype beam chamber 250 m long with elliptical or racetrack shape and pumping channel is installed in iron magnet yokes. Assembly of the beam chamber will be made together with superconducting magnets of 250 m long section. The beam chamber of 250 m long will be joined to the unit chamber of 0.4 m long housed in the beam position monitor, ion pump, pressure gauges and isolation valve as roughing pumping manifold using automatic welding equipment. The joining beam chambers are welded to unit chamber without any flange and bellows. The beam chamber is anchored to iron yoke periodically to control thermal effect.

Automatic welding equipment fitting for the elliptical or race track aperture will be developed for small size, light weight and easy to handle as remote controlled robot to ensures uniform penetration.

Pumping time of atmospheric pressure to NEG strip activating pressure will be several tens hours for roughing pump station. During NEG strip activation the roughing pump must be pumped large quantity of outgassing from the NEG strip with maintaining 10-4 Torr. Pumping conductance for 250 m long beam chamber is small, high conductance side chamber is necessary to maintain 10-4 Torr.

We will evaluate for NEG strip as main pump. During NEG activation the chemical process using dicloro-propane will be made at 70°C with mild heatup. The lumped ion pump operation is started by a single switch ON using new type controlled power supply(18) with D-shaped I-V characteristic (fold-back over current protection) is being used. This power supply is about one-tenth the size of a standard unit. To reduce cost, it is recommended that controlled power supply be used.

To recover ultrahigh vacuum range after exposure to atmospheric pressure of nitrogen environment in the tunnel, fast-pump down process(19) will be tested using super-dry nitrogen gas.

The predicted ultimate pressure on the NEG pump is 10-11 Torr range without beam.

11. DISCUSSION

A. Why aluminum alloy ?

The complex cross section of 250 m long with low cost may excludes the use of stainless steel. The aluminum alloy ultrahigh vacuum system has many benefits such as: 1)low outgassing at low temperature heating of 70°C using chemical process of dicloro-propane, 2)high resistive to melt-down failure with about two orders of magnitude compared to stainless steel since aluminum is low energy loss and high thermal conductivity, 3)low thermal emissivity, 4)low residual radioactivity due to fast decay characteristics, 5)complete non-magnetic nature, and 6)light weight.

B. Synchrotron radiation

Synchrotron radiation of critical energy is X ray range. Photon number is same level for 50 GeV LEP. Dynamic gas desorption due to synchrotron radiation is main gas road. Required linear pumping speed is 100 l/s as similar to 50 GeV LEP. Ozone gas treatment in-situ is effective to reduce dynamic outgassing due to synchrotron radiation(20).

C. Cooling for beam chamber

Linear power density of about 1 W/m from synchrotron radiation, water cooling will be not use.

NEG strip st707 is used for main pump, water cooling is not necessary during 450°C activation. Temperature rise due to 450°C heating will be approximately 70°C due to low emissivity characteristics of aluminum alloy(21).

D. Heating source for chemical process

The chemical process required about 70°C heating. The NEG activation procedure is 450°C heating process. During activation, aluminum alloy beam chamber is heated upto about 70°C. Then, additional heater is not necessary. If DIP is chosen as main pump, additional heater is necessary.

E. Why no bellows ?

To reduce cost and to increase reliability drastically, bellows must be eliminated. Thermal effect can solve within acceptable inner compression stress. After that, minimum impedance feature is obtained fortunately.

F. Main pump selection

Main pump selection will be evaluated for installation, engineering structure, assembly, reliability, cost, and operations for long time use.

First candidate of the main pump is NEG strip. Dynamic desorption is similar to 50 GeV LEP, ordinary NEG strip with standard size will be needed. Required heating power will be about 200 W/m for NEG strip st707 in 450°C activation. Terminal voltage is about 400 V and current feed is about 80 A at 25 mm wide, 250 m long and 0.8 mm in thickness constantan base. Engineering design for NEG strip for electrical insulation and thermal expansion feature housed in pump channel is needed. Required pressure for NEG activation is minimum 10-4 Torr. To maintain 10-4 Torr pressure during NEG activation, ramp rate of the heating must be controlled.

DIP must be utilize magnetic field of superconducting magnet. If DIP will be installed in small pump housing inside magnet yoke, pumping speed is small. Additional DIP will be installed in outside of the magnet. Pumping speed is proportional to number of Penning discharge cell and height of the discharge cell. Discharge cell diameter depends on magnetic field strength. Magnetic field is 2 T, cell diameter of high field type will be about 3 mm(22). Stray magnetic field is gradually 0.2 T, then cell diameter will be about 15 mm. Function of lumped ion pumps are different for combination of NEG strip or DIP. Required pressure for DIP starting even use of new pump controller is 10-5 Torr. The pumping time of roughing pump station for DIP is much longer of several 100 hours.

G. High conductance side chamber

Large quantity of outgassing from the NEG strip during activation must be pumped. Pumping conductance for 250 m long beam chamber is small, high conductance side chamber is necessary to maintain 10-4 Torr for NEG activation period.

H. Beam impedance and resistive wall

Bellowsless and flangeless beam chamber has very smooth inner wall with minimum impedance effect(23). Pumping slot with continuous along the 250 long chamber has small impedance compared with many small holes periodically.

The beam chamber has clad structure with 99.99% high purity aluminum inside. If requirement of more low wall resistivity, 99.999% or 99.9999% high purity aluminum is possible. Generally, high purity aluminum has large crystal grain size. Single crystal layer inside the beam chamber is much better to reduce high frequency wall resistance.

I. Melt-down failure due to accidental beam hitting

Proton beam stored energy of 50 TeV is 50 GJ. This is one of the primary concern(6). Accidental beam loss become hitting beam chamber. For high energy beam has very large penetration length. Energy loss balance must be considered. Low energy loss materials are key factor to avoid a catastrophe. Energy loss proportional to material density ρ and atomic number squared z2. Aluminum has low energy loss and high thermal conductivity materials. Aluminum is melted-down for localized high heat flux of 220 W/mm2 of high energy beams.

J. Microparticle trapping

In electron storage rings microparticles are charged positive due to photoelectron emitting by the synchrotron radiation and are trapping inside the beams(24). For positron storage rings microparticle trapping phenomena was not occurred. Then, proton ring will not occurred. For anti-proton ring microparticle trapping will be concern due to synchrotron radiation.

K. Multipactoring and ion desorption stability

For high current of several 10 amperes proton storage ring such as CERN-ISR had dynamic gas description effect for the pressure bump instability on stainless steel and multipactoring effect on the aluminum alloy chambers(25). This multipactoring effect on aluminum alloy chamber is of primary concern. W.Turner suggested that beam induced multipactoring effect and ion desorption will be large safety margins(5).

L. Corrosion due to synchrotron radiation

Radiation damage (26) for long time use is small against low critical energy of 0.5 KeV. Synchrotron radiation acts to atmosphere and organic such as plastics. NOx and SOx are produced from air. NOx and SOx react with humidity, HNO3 and H2SO4 are produced. Organic materials such a vinyl-chloride and Teflon are desolved to Cl and F. After that, HCl and HF are produced. Tunnel environment will be filled with nitrogen. To suppress the radiation corrosion, water must be eliminated. Organic material made from Cl, F and S components must be eliminated.

M. Risk free against leaks

Proposed design is basically without use of flanges and bellows between the beam chambers. The risk of leak are only welded vacuum sections, vacuum feedthroughs and bellows of gate valves. The risk of the weld part is proportional to the number of welds. In the basic design, the welded parts are joining the ends at the unit chamber between the beam chamber. The number of the weld seam per every 250 m long beam chamber is only two seams. NEG strip use high current feedthroughs and DIP use high voltage feedthroughs. The unit chamber of 0.4 m long with one piece housing has four coaxial vacuum feedthroughs of beam position monitor, one high voltage feedthrough for ion pump, one triax feedthrough of cold cathode gauge, and one triax feedthrough for ionization monitor, and one isolation valve.

Brazed vacuum feedthrough has some risks against vacuum leak. It is proposed that double seals using brazing between metal and ceramics, and organic Vacseal be used to reduce leakage to a minimum. Brazed seal has low outgassing with some risk. Organic seal of Vacseal has less risk against vacuum leakage.

Gate valve consists of dual inner seals, valve housing and bellows as actuation. The valve housing will be designed with minimum weld seams without any metal seal and coated on weld seams by Vacseal. Generally, under dynamic operation bellows has a risk for leakage for long time use. To avoid leakage from bellows actuation. Vacseal must be coated on the bellows. Vacseal acts as anti-corrosion treatment and release small defect effect from the metal surfaces such a boundary of crystal grain. Therefor, there is less risk for leakage from atmosphere.

Isolation metal seal valve with remote control is necessary between the pumping manifold and the roughing pump. Sealing performance of the metal seal valve is sensitive to fine dusts. The superior performance of the dual seal minimizes the risk against any leakage. The dual seal is a metal seal and elastomar seal combination as the elastomar seal has less risk against the leak.

Organic materials such as the Vacseal and the elastomar O-ring be affected radiation damage for long time use.

N. Non-helium leak testing inside the tunnel

Since the conductance of the 250 m long chamber with small aperture is very small, the time response for helium leak testing is very slow. In TRISTAN beam chamber for arc section were all-welded. No flanges were used. There were no leaks for welding parts during the 10 years of beam operation. Beryllium windows for electron beam injection and extraction were used in TRISTAN and the beryllium windows were corrosed by synchrotron radiation. To avoid corrosion, the beryllium windows were coated initially Vacseal sealant. This protection is very efficient for several years even under a severe radiation environment. Leaks occurred for electron-positron collider with complicated beam chamber inside the large detector. To eliminate the leak, Vacseal spraying was made as remote handler with success.

It is proposed that non-helium leak testing for weld parts be initially coated with Vacseal sealant for any weld seams inside the tunnel.

O. Replacement of beam chamber

If the superconducting magnets with vacuum beam chamber is replaced using remote handling robot, the gate valve will be closed. A pull top opener such as beer or corned-beef cans as robot handler are adopted at weld seams in parallel.

P. Argon gas sources elimination

Expected pumping action against the ion pump are small for rare gases such a helium and argon. After power outage of long time for closed aluminum alloy ultrahigh vacuum system, main component pressure rise up to 10-7 Torr range is primary argon. The pumping system is NEG cartridges and ion pumps. But ion pumps were not operated during power outage. Gas source of argon for aluminum alloy ultrahigh vacuum system is estimated as gas bubbling flushing process to produce less hydrogen inside aluminum alloy, clean extrusion of EX process, and TIG welding.

To reduce gas load against lumped ion pumps, argon gas must be eliminated in any process. During ingot process of aluminum alloy, gas bubble flushing uses halogen and argon mixture to remove hydrogen gas inside melted aluminum alloy. Therefore, ingot process must be changed from argon to nitrogen gas. Filling mixed gas inside the extruded pipe for clean extrusion process will be replace from oxygen and argon to oxygen and nitrogen mixture. TIG welding source is classified as AC, DC with straight polarity and DC with reverse polarity. DC with straight polarity is electron hitting mode without argon ion bombardment. In this case, back-seal gas inside the tube will be use from argon to nitrogen to prevent argon outgassing from the welding bead.

12. KEY RECOMMENDATIONS

Key recommendations for conceptual design are:

1) Construct co-extruded 99.99% high purity aluminum and high resistive aluminum alloy 7N01 beam chambers with clad structure together with high-conductance side chamber for NEG strip as main pump of 250 m long.

2) Unit chamber of 0.2 m long houses the beam position monitor and two pressure gauges.

3) Lumped ion pump, roughing pump manifold with separation valve and high current feedthrough are housed in pump manifold.
4) Using automatic welding, beam chambers and unit chamber can be joined without flanges and bellows.
5) Periodically anchored to iron yokes controlled thermal effect.
6) Chemical process using dicloro-propane will be made at 70°C with mild heating.
7) Risk free against leakage using Vacseal sealant for weld seam, vacuum feedthroughs, and bellows.
8) Non-helium leak testing against assemblies inside the tunnel.

Proposed design will be satisfied with very low cost, very reliability, high performance with minimum impedance, reduce risk against leakage, and remote handling robots operation.

To realize the proposed aluminum alloy vacuum system, systematic and continuous R & D is needed.

ACKNOWLEDGMENTS

The author wishes to thank for their encouragement’s and valuable technical discussions.

Weiren Chow	Fermilab
Gerald Dugan	Cornell University
David Finley	Fermilab
William Foster	Fermilab
Steve Holms	Fermilab
Gerry Jackson	Fermilab
Hans Jostlein	Fermilab
Frank Koide	SMC
Karl Koepke	Fermilab
Peter Limon	Fermilab
Ernest Malamud	Fermilab
Masa Mishina	Fermilab
John People	Fermilab
Joseph Rogers	Cornell University
Wolfgang Stoeffl	Lawrence Livermore Laboratory
William Turner	Lawrence Barkley Laboratory
Achim Weiderman	University of Tennessee

Finally, the author acknowledges ALVALAB for support.

Figure Captions

Fig.1. Double-C type magnet with superconducting transmission line and two vacuum beam chambers.
Fig.2. A cross section of extruded aluminum alloy beam chamber.
Fig.3. The Unit chamber housed in beam position monitor, lumped ion pump, pressure gauges, separation valve for roughing pump manifold.
Fig.4. The beam chamber is periodically anchored to the iron yokes to control thermal effects without bellows.
Fig.5. Fig shows finite element analysis with fixed ends.
Fig.6. Fig. shows strain vs. temperature during thermal cycles from 20°C to 80°C for 8.5 m long beam chamber with fixed ends.
Fig.7. Miniature size nude type inverted magnetron gauge with permanent magnet inside vacuum.
Fig.8. Photograph shows model beam position monitor electrode made from ceramics and titanium metallization.

REFERENCES

1. G.W.Foster and E.Malamud: New low-cost approach to high energy hadron collider at Fermilab, (1993)
http:www-ap.fnal.gov./PIPE
2. H.Ishimaru: All-aluminum alloy ultrahigh vacuum system for large scale electron-positron collider, J. Vac. Sci. Technol, A2 (1984) 1170
3. K.Tatenuma, T.Momose, and H.Ishimaru, Quick acquisition of clean ultrahigh vacuum by chemical process technology, J. Vac. Sci. Technol, A11 (4), Jun/Aug (1993) 1719
4. H.Ishimaru: Development and applications for all-aluminum alloy vacuum systems, MRS Bulletin, Vol.XV, No.7 (1993) 23
5. W.Turner: Synchrotron radiation in a large, warm-bore collider, Mini-Symposium, APS Annual Meeting, Indianapolis, May 3 (1996)
6.W.Chou: A Quick survey of a Future Hadron Collider, Internal note, Jun 10 (1996)
7. H.Ishimaru and M.Niino: 99.99% aluminum/7N01 clad beam tube for SSC-HEB and related components, Vugraph presentations from the second proton collider vacuum technical meeting, SSCL, Dallas, TX, May 24-25 (1993)
8. H.Ishimaru, K.Narushima, K.Kanazawa, Y.Suetsugu, D.Bintinger, Hans Jostlein and D.Trobojvic: 99.99% al/6063 alloy coextruded cryogenic beam tube, J. Vac. Sci. Technol, A6, No.3 May/Jun (1988) 1293
9. T.Momose, Y.Maeda, K.Asano, and H.Ishimary: Surface analysis of carbon on ozone treated metals, J. Vac. Sci. Technol, A13, No.3. May/Jun (1995) 515
10. T.Momose, A.Asano, N.Ohta, Y.Kanda, and H.Ishimaru: Auger electron spectroscopy characterization of aluminum alloy wxposed to

synchrotron radiation, J. Vac. Sci. Technol. A13. No.2 Mar/Apr (1995) 488
11. H.Ishimaru: European Vacum Confernce (1994)
12.H.Ishimaru, T,Momose, K.Narushima, H.Mizuno, K.Kanazawa, H.watanabe and M.Shimamoto: All-aluminum alloy ultrahigh vacuum system for 30 GeV electron-positron collider, J. Vac. Sci. Technol. A4 (1986) 1762
13 Asamaki, Shinku (in-Japanese)
14. H.Ishimaru, S.Shibata, and M.Inokuti: Ionization cross section of gases for protons at kinetic energy between 20 MeV and 385 GeV, and applications to vacuum gauges in superconducting accelerators, Phy. Rev. A, Vol.51, No.6, Jun (1995) 4631
15.H.Ishimaru: Aluminum alloy-ceramic ultrahigh vacuum and cryogenic feedthrough useful from Dc to 6.5 Ghz, Vacuum, Vol.32 (1982) 753
16. H.Ishimaru, T.Kuroda, O.Kaneko, Y.Oka and K.Sakurai: All aluminum alloy, 800-mm inner diameter gate valve using dual flat-face seals together with differential pumping, J. Vac. Sci. Technol. A3 (1985) 1703
17.K.Itoh, K.Waragai, H.Komuro, T.Ishigaki and H.Ishimaru: Development of an aluminum alloy valve for extremely high vacuum system, J. Vac. Sci. Technol. A8 (1990) 2836
18. H.Hisamatsu, T.Momose, and H.Ishimaru: A D-shaped I-V characteristics (fold-back over-current protection) ion pump powersupply for the TRISTAN e+e- colliding ring, Vacuum Vol.43, No.12 (1992) 1181
19. M.Miki, K.Itoh, N.Enomoto and H.Ishimaru: Characteristics of extremely fast pump-down process in an aluminum ultrahigh vacuum system, J. Vac. Sci. Technol, A
20. Y.Maeda, to be presented AVS Meting (1996)
21. K.Itoh, T.Ishigaki, A.Kamikawana, and H.Ishimaru: High vacuum degassing furnace made from aluminum alloy and its thermal characteristics, J. Vac. Sci. Technol, A7 (1989) 2435
22.D.Blechschmidt : High field distributed ion pump (CERN) private communication.
23. H.Ishimaru: Low cost warm bore vacuum chamber options, Mini-Symposium, APS Annual Meeting, Indianapolis, May 3, (1996)
24. H.Saeki, T.Momose, and H.Ishimaru: Observations of dust trapping phenomena in the TRISTAN accumulation ring and study of dust removal in a beam chamber, Rev. Sci. Insturm. Vo.62, No.4 Apr. (1991) 874
25.O.Grobner and R.Calder: Beam induced gas desorption in CERN intersecting storage rings, IEEE Trans. Nucl. Sci. Vol.20, No.3 Jun (1973) 760
26. T.Momose and H.Ishimaru: Radiation damages in TRISTAN vacuum systems. J. Vac. Sci. Technol. A9, No.4 Jun/Aug 91991) 2149