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TECHNICAL SPECIFICATION FOR VACUUM SYSTEMS*

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INTRODUCTION

The vacuum systems at the Stanford Linear Accelerator Center (SLAC) consist of the following: Linac (excluding the BSY), PEP, SPEAR, and the Stanford Linear Collider (Final Focus, Arcs, Positron Source and Damping Rings). The systems are primarily of all-metal construction and operate at pressures from 10^{-5} Torr to 10^{-11} Torr. The primary gas loads during operation result from thermal desorption and beam-induced desorption from the vacuum chamber walls. These desorption rates can be extremely high in the case of hydrocarbons and other contaminants; therefore, these specifications place a major emphasis on eliminating contamination sources.

These specifications and procedures have been written to serve two primary purposes:

1. To insure the cleanliness and vacuum integrity of all SLAC vacuum systems.
2. To assist personnel involved with SLAC vacuum systems in choosing and designing components that are compatible with the existing systems and which, as determined through testing and evaluation, meet the quality and reliability of SLAC vacuum standards.

All vacuum components designs must be reviewed in detail and approved by an official representative of the SLAC Vacuum Group prior to installation. Requests for deviations from these specifications shall take the form of a written communication to SLAC's Klystron–Vacuum Group Leader detailing all modifications and/or alternatives. The request will be evaluated and a written approval or denial issued. Any modification or deviation that is incorporated into a vacuum assembly, but is not submitted for approval, is done at the user's risk and is subject to rejection of the entire assembly.

I. DESIGN

A. Document Control

Drawings must be produced for all components that will become part of or influence the vacuum system. Preferably, "off-the-shelf" items such as bellows, feedthroughs and flanges should also be drawn; but alternatively, they may be called out by the manufacturer's part number in the parts list. All drawings must indicate the operating parameters required and must include a complete materials list.* These drawings shall be submitted to the Vacuum Group for design review. Drawings must be approved by the Group Leader, the project engineer and the Design Coordinator of the Vacuum Group prior to any part fabrication or order.

B. Vacuum Loading Considerations

All components, assemblies and instruments must be designed to safely withstand the loading exerted by atmospheric pressure while under vacuum and must conform to the Mechanical Engineering Safety Inspection standards (Appendix VI). Modules utilizing bellows or geometries which result in differential loading while under vacuum must include restraints which prevent lateral and axial movements due to the differential pressure loading.

C. Thermal Requirements

Thermal requirements should be considered for all particle beam and synchrotron radiation absorbing surfaces in the vacuum system. This is necessary because the intense heat fluxes due to the radiation represent a potential catastropic hazard to the vacuum system. Absorbed heat causes temperature increases, outgassing and high local stresses. Therefore, no vacuum chamber, component or device should be added to the SLAC vacuum system without a thorough analysis of the effects of the radiation environment upon vacuum and structural integrity.

⋆ Material certification must be obtained for all fabrication materials. Refer to Section III.A concerning material certification.

The amount of heat absorbed by a surface depends on the following factors:

1. The surface material.
2. The field strength and configuration of the magnet producing the radiation.
3. The current and energy of the electron and/or positron beams.
4. The distance of the surface from the source of radiation.
5. The angle between the surface and the impinging radiation.

In general, conservative design criteria should be used. Some guidelines that should be observed when designing water-cooling passages are:

1. No welds, brazes or joints of any kind shall bridge water-cooled passages and vacuum spaces (see Appendix I, Figure 1).
2. Sufficient mass flow to hold the bulk temperature rise to less than 10°C.
3. Typical cooling water temperature is 40°C.
4. Maximum metal temperature on the vacuum side is 150°C.
5. Maximum metal temperature on the water side is 100°C.
6. Maximum water flow velocity is 6 meters/second.

Refer to SLAC–PUB–1245 by A. P. Sabersky entitled *The Geometry and Optics of Synchrotron Radiation,* SPEAR Notes 41 and 156, PEP Note 88, and PEP Engineering Note 76–5 by J. Jurow dated September 14, 1976 (Appendix IV) for additional information on cooling criteria and calculations.

D. Beam Stay Clear

All vacuum chambers must be designed to have a minimum inner diameter that shall not interfere with the officially published beam stay clear. Masks, bellows shields, collimators, beam stoppers and any other parts of the vacuum chamber must also conform to the minimum diameter.

II. PROCUREMENT

A. Material Types

Only metallic or ceramic materials may be used in the construction of any component or system which interfaces with the vacuum system. Elastomers or organic materials are not permitted unless they are specifically authorized.

Most pure metals, such as titanium and molybdenum, are acceptable for use in the vacuum; however, any materials other than those listed in the table below must be specifically approved.

Table 1. Approved Materials for Use in Vaccuum

Stainless Steel:[△] 304, 304L, 316, 316L, 321,[†] 347

Aluminum: 1100, 6061

Copper: OFE (ASTM F68)

Gold: Vacuum cast, 99.999%

Inconel (600, 718)

Ceramics

No attempt will be made to list the types of ceramics that are acceptable because a wide variety are used, especially for feedthrough purposes. However, as with all other materials, chemical analysis and fabrication techniques of ceramics to be used in the vacuum system must be provided by the vendor.[*]

Magnetic permeability is often important when stainless steel parts are near magnets or particle beams. Magnetic permeability requirements may differ but frequently 1.05 maximum permeability at 200 oersted is the acceptable limit.

[△] See Appendix VI for the Technical Specification *Guidelines for Purchasing Stainless Steel Material for Ultra High Vacuum Applications.*

[†] Note: Stainless steel type 321 is not suitable for applications requiring hydrogen firing.

[*] Material certification must be obtained for all fabrication materials. Refer to Section III.A concerning material certification.

Checking with the responsible physicist of a project may be necessary to determine what is required. Permeability can be measured using a Severin permeability indicator.

B. Flanges

In general, vacuum flanges are of the type commonly known as "ultra high vacuum" or "knife-edge" and must conform to the SLAC Technical Specification PS–202–631–04 entitled *Stainless Steel Flanges for Ultra High Vacuum Applications*. These flanges are all-metal and and are sealed by means of a flat, circular copper gasket. All-metal flanges are preferred in the majority of SLAC applications because they provide low outgassing rates, high reliability and resistance to high radiation environments.

Flange sizes are identified by their nominal O.D. in inches. Common sizes are 2–1/8, 2–3/4, 3–3/8, 4–1/2, 6, 8, 10, 13–1/4. Actual flange dimensions must conform to those shown in Appendix I, Figures 2, 3 and 4.

Skarpaas flanges, Klamp™ type flanges, Wheeler™ flanges and, in special cases, viton sealed flanges are acceptable.

Upon receipt from the vendor, all purchased flanges should be visually and mechanically inspected to insure that they conform to the dimensions and specifications required. The following steps should be taken in quality control of UHV, "knife-edge" type flanges:

1. Visual inspection for nicks, scratches, burrs and surface finish on:
   (a) Knife edge
   (b) Bolt circle face
   (c) Inner vacuum surfaces
   (d) Leak check groove
2. Measure knife edge dimensions as shown on appropriate flange drawing:
   (a) Counter bore

(b) I.D.

(c) Depth

3. Measure tubing counter bore dimension as shown on the drawing.

4. Visually inspect bolt holes with respect to knife edge for concentricity.

5. Test magnetic permeability. Permeability can be measured using a Severin permeability indicator (generally 1.05 maximum permeability at 200 oersted is the acceptable limit).

6. Spot check (1 out of every 20):

   (a) Bolt hole diameter

   (b) Bolt circle diameter

   (c) O.D. of flange

   (d) Small I.D.

   (e) Thickness of flange

7. Scribe each flange with an identifying number associated with a quality control record of measurements.

8. Cover knife edge side with a plastic flange cover and store.

C. Flange Bolts

Ultra high vacuum flange bolts have 12-point bolt heads and are fabricated from 300 series high tensile nonmagnetic stainless steel. Generally, they are fabricated in accordance with Specification IFI–115 from 305 stainless steel with a minimum tensile strength of 70 ksi.*

Bolts should be silver plated (.0002 to .0005 inch thick) to eliminate both the problem of galling and the contamination hazard caused by the high temperature

* Material certification must be obtained for all fabrication materials. Refer to Section III.A concering material certification.

thread lubricant normally used, which is readily picked up and transmitted by gloves, tissue, tools, clothing, and so on.

Bolt sizes and quantities are matched to flange sizes in the table below:

Table 2. Bolt Sizes for Specified Flanges

(All dimensions in inches.)

Flange Size (O.D.)	*Thread*	*Length*	*No. Required*
2–1/8	1/4–28	7/8	4
2–3/4	1/4–28	1–1/4	6
3–3/8	5/16–24	1–3/4	8
4–1/2	5/16–24	2	8
6	5/16–24	2	16
8	5/16–24	2–1/4	20
10	5/16–24	2–1/2	24
13–1/4	3/8–16	3	30

For convenience, bolts and appropriate nuts may be counted out according to the quantity required for each flange, bagged in plastic bags and labeled according to the bolt size.

D. Gaskets

D1. Gaskets for UHV Flanges

All gaskets for UHV "knife-edge" type flanges must be made from certified copper, UNS No. C10100 (OFE), ASTM B 152. The material must be free of blemishes, and the nominal thickness before the fabrication process must be .080 ± .0035 inches thick. The temper of the gaskets after fabication process must be 1/4 to 1/2 hard. Nicks and scratches may not exceed .003 inch width and .0005 inch depth. Burrs may not protrude more than .0005 inch. Lubricants used to fabricate gaskets must conform to SLAC Specification FP-202-631-14, Section 1. Gaskets may be shipped with a slight film of approved lubricant on them and must be packaged to prevent damage. Refer to SLAC Specification PS-202-061-42 for a complete gasket specification.

Gasket sizes are matched to flange sizes in the table below:

Table 3: Gasket Sizes for UHV Flanges

(All dimensions in inches.)

Flange Size (O.D.)	*Gasket O.D.*	*Gasket I.D.*
2-1/8	1.290 ± .002	1.010 ± .005
2-3/4	1.895 ± .002	1.451 ± .005
3-3/8	2.420 ± .002	2.007 ± .005
4-1/2	3.243 ± .002	2.506 ± .005
6	4.743 ± .002	4.006 ± .005
8	6.743 ± .002	6.007 ± .005
10	8.743 ± .002	8.007 ± .005

New gaskets should be visually and mechanically inspected upon receipt from the vendor. Gaskets should be handled with gloves at all times to prevent the copper from being etched by body oils. New gaskets must be chemically cleaned according to Section IV.C of these specifications before use. Cleaned gaskets should be handled with clean gloves according to Section V.B1 of these specifications.

D2. Special Gaskets

In areas where RF losses are a concern (such as in a storage ring), Specially Engineered RF Gaskets (SERF gaskets) are used. Material and fabrication methods must conform to those used for "knife-edge" flange gaskets described above.

Gaskets for Skarpaas flanges are made to SLAC Drawing Number

PF–761–181– (no suffix on drawing). These gaskets must adhere to all applicable sections of this specification with regard to materials, cleaning, fabrication, bakeout capability, and so on.

Klamp^{TM} type flanges use c-seals made of Inconel. These seals are sometimes plated. As with all other vacuum components, c-seals must adhere to all applicable sections of this specification with regard to materials, cleaning, fabrication, bakeout capability, and so on.

In cases where viton o-ring seals are to be incorporated into a vacuum system, the viton gaskets must initially be "conditioned" to remove excess chemicals and fillers left over from manufacture. The gaskets should be degreased with freon, then with alcohol in an ultrasonic bath. They are then baked out in a nitrogen bake for a minimum of 24 hours, followed by a vacuum bake at 140°C to 150°C for 72 hours. During subsequent bakeout of the chamber the temperature should not exceed 150°C.

E. Bellows

E1. Welded Diaphragm Bellows

Welded bellows are made of thin stainless steel diaphragms welded on the inside and outside diameters to form a series of convolutions. Hydrocarbon contamination of surfaces or particulate matter can be trapped in the crevices of these convolutions. Experience in ultra high vacuum has proven that postmanufacturing chemical cleaning is of negligible value in removing such contamination. Therefore, bellows made with improperly handled or poorly cleaned parts must not be used.

Welded bellows must be capable of maintaining continuous leak-free operation and withstand a minimum of 50 thermal cycles from room temperature to 200°C while under vacuum, in the stroke and offset positions specified. The duration of each thermal cycle is approximately 150 hours. Before being put into operation, each bellows will be tested by using a mass spectrometer helium leak detector. Any bellows which indicates leakage when tested with a minimum leak detector sensitivity of 2×10^{-10} standard cc/sec (He) per leak rate meter division is not acceptable.

Each step of manufacturing and testing of welded bellows must adhere to the specific procedures outlined in the SLAC Technical Specification PS-202-631-03 entitled *Stainless Steel Welded Bellows for Ultra High Vacuum Applications* to insure the integrity of the vacuum system. An exception to this is that "off-the-shelf" bellows may be used but they are not clean to the SLAC specifications. Therefore, before they may be installed in the vacuum system, bellows must be chemically degreased in Trichloroethane vapor and fired in a vacuum atmosphere at 600°C for eight hours at temperature and be allowed to cool for 24 hours following firing.

Bellows of the "welded-nested" type are preferred over other types (see Appendix I, Figure 5).

E2. Formed Bellows

Formed bellows without attached flanges or with internally welded flanges are recleanable and are permitted. Note, however, that they are limited in axial movement and lateral offset in comparison to welded bellows.

Forming must be hydroforming or mechanical forming. Roll forming is not acceptable. Welding must be by fusion butt weld. Lap welds are not permitted. These bellows must also adhere to all applicable sections of this specification with regard to materials, fabrication, cleaning, welding, leak tightness, bakeout capability, and so on.

F. Feedthroughs

F1. Electrical Feedthroughs

Feedthroughs used for electrical connections into the vacuum system shall be of the ceramic-to-metal type. No glass-to-metal feedthroughs are permitted. The preferred installation method is one in which the feedthroughs are mounted in a flange of the "knife-edge" type as detailed in Section II.B of this specification. The flange can then be bolted to a mating flange on a chamber or other component. Feedthroughs may also be welded directly to a chamber when a flange connection is not feasible. Weld joint design must conform to normal UHV practices as detailed in Section VI of this specification, and care must be exercised to prevent the weld from putting undue stresses on the ceramic. Voltages and currents carried by the feedthroughs must not exceed the manufacturer's ratings. Quality control of feedthroughs consists of visual and mechanical inspection of dimensions as shown by the appropriate drawing. Cleaning of feedthroughs shall conform to Section IV.E of these specifications. (See Appendix II for acceptable vendors.) Covers should be provided to protect the ceramics from damage after installation.

F2. Mechanical Feedthroughs

Bellows type mechanical feedthroughs may be used to impart a rotational or linear movement to components; O–ring sealed feedthroughs are not permitted. Feedthroughs must adhere to all applicable sections of this specification with regard to materials, fabrication, cleaning, welding, leak tightness, bake-out capability, and so on. Installation of these feedthroughs must be by means of a "knife-edge" type flange as detailed in Section II.B of this specification. Feedthroughs which have bearings exposed to vacuum must be evaluated regarding their UHV suitability. Feedthroughs containing parts that cannot be cleaned to the requirements in Section IV of these specifications will not be approved for use.

G. Gauges

G1. Nude Ion Gauge

Nude ion gauges must be mounted on flanges of the "knife-edge" type as detailed in Section II.B of this specification. The gauges must be bakeable to 450°C and must have replaceable filaments. The operating pressure range for these gauges is from 10^{-4} torr to 10^{-11} torr. (See Appendix II for acceptable vendors.)

Each gauge shall contain two independent filaments so that if one filament becomes inoperative, a change of an external connector would permit continuation of pressure measurement without vacuum interruption. Degassing must be by electron bombardment. Cable connections must be capable of withstanding repeated thermal bakeout cycles to 200°C.

All ion gauge controllers shall be modified at SLAC to comply with the pressure interlock system. The control unit should be rack mountable and have the following features:

1. Auto-ranging from 10^{-4} torr to 10^{-11} torr.
2. Degas power utilizing electron bombardment.
3. Dual trip set points, adjustable from the face of the controller.

Upon receipt from the vendor, ion gauges should be visually, mechanically and electronically inspected. Gauge components are fragile and must be handled with care. Clean gloves shall be worn and procedures for handling clean parts, as described in Section V.B1 of these specifications, should be used when handling components. Gauges should be inspected according to the following procedure:

1. Visual inspection:
   (a) Knife edge of flange (inspect for nicks, scratches, burrs)
   (b) Integrity of gauge elements
   (c) Foreign material in or around elements

2. Measure dimensions of the flange as per the SLAC drawing of the appropriate flange size.

3. Check continuity of filaments (two places) using a volt/ohm meter.

4. Check isolation of the following elements using a volt/ohm meter:

   (a) Filament to ground

   (b) Filament to grid

   (c) Filament to collector

   (d) Collector to ground

   (e) Collector to grid

   (f) Grid to ground

G2. Cold Cathode Gauge

Cold cathode gauges must function in the operating pressure range of 10^{-2} torr to 10^{-7} torr. These gauges shall be mounted on flanges of the "knife-edge" type as detailed in Section II.B of these specifications. Cold cathode gauge controllers must have dual trip set points. (See Appendix II for acceptable vendors.)

H. Pumps

The pumps used on any chamber or apparatus which interfaces with the vacuum system shall be of the sputter ion type of either diode or triode configuration.

Diode ion pumps consist of an anode and a set of Titanium cathode plates. The anode is at high positive potential with respect to the cathode plates. The pump body is at ground potential.

Triode ion pumps consist of an anode, a set of Titanium cathodes and two collectors. The cathode is at a high negative potential with respect to the anode and collectors. The pump body is at ground potential.

Pumps which require a filament for operation are not acceptable, nor are pumps which require water cooling, unless they are specifically authorized.

The pump body tubulations and attachments shall be made from type 304 or 304L stainless steel. The inlet flange shall be of the "knife-edge" type as detailed in Section II.B of these specifications. Standoff insulators for pump elements must incorporate a sputter shield to prevent the deposition of conductive coatings on the insulators during processing or operation of the pump.

The operating pressure range is 10^{-2} torr to 10^{-11} torr. Pumps must be capable of operating at a pressure of 1×10^{-6} torr for 25,000 hours without sputtering holes through the cathode plates and must be capable of operating for a minimum of 50,000 hours at 1×10^{-6} torr N_2 without failure due to any other characteristic which alters pump performance including insulator leakage, gas instabilities, reduction in pump speeds by more than 20% and vacuum envelope leaks.

Pumps must continuously operate for the warranty period at a temperature of 200°C and a relative humidity of up to 80% water vapor. In addition, they must be constructed to withstand ten bakeouts at a temperature of 450°C for up to 200 hours each with magnets removed. Pumps with magnet, connector and cable attached must withstand 50 bakeout cycles from ambient temperature to 250°C. The duration of each bakeout cycle is 100 hours.

Pumps shall be fitted with external ferrite type magnets which are painted to prevent corrosion. Magnets must be removable and secured to the pump by appropriate threaded fasteners. Magnets must maintain a pumping speed of 80% of the specified minimums or better. Prior to shipment the pump shall be baked out under vacuum at 400°C, pinched off and shipped under vacuum.

All pumps shall adhere to applicable sections of this specification with regard to materials, fabrication, cleaning, welding, leak tightness, bakeout capability, and so on. Refer to the SLAC Technical Specification PS-202-631-07 entitled *Sputter Ion Vacuum Pumps for UHV Applications* for detailed specifications on

110 l/s, 210 l/s and 400 l/s diode ion pumps.

I. Valves

I1. Appendage Valves

Manual valves used for pumpout and attachment of various appendages should be of the right angle type. The most commonly used size at SLAC is the 1–1/2 inch right angle valve. The entire valve must be capable of being repeatedly baked to 450°C in either the open or closed position without damaging the valve seat, drive mechanism or bellows. The valve design must allow operation in any orientation. To provide maximum conductance, the main seal disc must be fully retracted when the valve is in the fully open position. Valve flanges shall be of the "knife-edge" type as specified in Section II.B.

All manual valves, after receipt from vendor, shall be visually inspected, have the seat removed, cleaned and baked in conformance to the Bakeable Valve Cleaning Procedure in Appendix V.

I2. Isolation Valves

Pneumatic, remotely operable, beam line isolation valves shall be of the gate type. All internal parts, including the valve seal, shall be metal unless specifically authorized. The entire valve must be capable of being repeatedly baked to 200°C in either open or closed position without damaging the valve seat, drive mechanism or bellows. Refer to the SLAC Technical Specification PS–202–631–72 entitled *All Metal Isolation Valve* for details on valve specifications.

Valve flanges shall be of the "knife-edge" type as specified in Section II.B. Valve materials permitted to be exposed to the vacuum system are gold, OFE copper, 304, 304L, 316, 316L, 321, 347 stainless steel, Inconel 600 and 718.

J. Aluminum Extrusions

Extrusions shall be produced by the Direct Extrusion process. The aluminum alloy shall be Type 6061, heat treated to the T–4 condition by solution heat treatment or quench at the press. T-4 properties must meet the Aluminum Association Standards and Data for this type of product.

Aluminum extrusions will be evacuated to better than 10^{-10} torr by means of sputter ion UHV pumps. Extrusions must be capable of maintaining continuous leak-free operation and must be able to withstand a minimum of 50 thermal cycles to 200°C under vacuum. The duration of each thermal cycle is approximately 150 hours.

Refer to the SLAC Technical Specification PS-202-631-01 entitled *Extruded Aluminum Vacuum Chambers* for details on fabrication and testing of aluminum extrusions.

K. Roll Bonded Transition Material

Aluminum to stainless steel transition material is produced by a proprietary process known as "Roll Bonding." Parts fabricated from this stock are welded to aluminum extrusions or tubing on one side and to stainles steel flanges or tubing on the other. Refer to the SLAC Technical Specification PS-202-631-09 entitled *Roll Bonded Aluminum to Stainless Steel Transition Material* for details on production requirements for this material. (See Appendix II for acceptable vendors.)

The total thickness of the transition material currently in use at SLAC varies from .87 to .99 inches. In general, unfinished stock may be considered to have a reference dimension of .87 inches thick.

When designing a transition part, ideally, the distance from the bondline interface to the adjoining weld would be the maximum possible: 0.5 inches for aluminum and 0.37 inches for stainless steel. Since a reasonable intrusion of about 0.12 inches is necessary for locating and retaining adjacent parts, the recommended minimum z length from weld to interface is 0.25 inches on the stainless steel side, and 0.38 inches on the aluminum side.

Maximizing the bond line width is also desirable. Bond line width is best defined as the shortest distance between the vacuum and the atmosphere along the diameter of the part. Maximizing this dimension is important because it decreases the localized stress per unit area caused by differential thermal expansion during welding. A 0.5 inch bond line width is good insurance against bond failure; however, a minimum of 0.37 inches is acceptable.

III. FABRICATION

A. Material Certification

All metal or ceramic material used in the construction of any component that will become part of or influence the vacuum system (including "off-the-shelf" items) must be traceable to its original source certification, including physical and chemical test reports. When purchasing materials for UHV use, material certification and chemical test reports traceable to the mill heat lot number must be requested and should accompany shipment of the materials. When purchasing components, the vendor must be able to provide certifications of all materials used.

B. Surface Preparation

No operation which might result in contaminants becoming embedded in the material shall be used. Grinding with resin bonded wheels, using rouge, emergy cloth, crocus cloth or similar abrasives is prohibited.

C. Machining Lubrication

No lubricant may be used which might result in material contamination that cannot be removed by the cleaning methods described in Section IV of this specification. The use of cutting fluids or lubricants which contain sulphur or silicone compounds is prohibited. Acceptable lubricants are listed in the SLAC Process Specification FP–202–631–14 entitled *Fabrication of Ultra High Vacuum Components.*

IV. CHEMICAL CLEANING

The chemical cleaning procedures presently used at SLAC have been determined to yield the best results or UHV materials. All parts made from approved materials (listed in Section II.A) which will interface with the vacuum system shall be cleaned according to the following specifications. A proposed step-by-step cleaning process shall be submitted for approval when materials other than those listed are to be used.

No blind holes of small diameter (less than 1/8 inch) are permitted in parts to be chemically cleaned for UHV use because chemical solutions may be trapped in these holes. Small holes should be drilled through or vented (see Appendix I, Figure 11).

Cleaning procedures for unusual parts should be reviewed with the Chemical Cleaning Shop Coordinator prior to part fabrication.

A. 300 Series Stainless Steel (Types: 304, 304L, 316, 316L, 321, 347)

300 series stainless steel tubing and parts shall be chemically cleaned according to the steps in the following procedure.

1. Vapor degrease in hot (150°F) 1-1-1 TRICHLOROETHANE[2] vapor for five minutes.
2. Cold running tap water rinse for one minute.
3. Alkaline soak clean in ENBOND Q527 CLEANER[3] for five minutes at a temperature of 180°F.
4. Cold running tap water rinse for two minutes.
5. Immerse in a stainless steel pickle consisting of:

    One part NITRIC ACID 42° Baume

    One part HYDROFLUOURIC ACID 48%

    One part deionized[1] water

Solution shall be at room temperature. Immersion time shall be sufficient to clean surface of scale and oxide. Care should be taken to avoid over-etching. Part may be water-air blasted, scrubbed with Scotch Brite[12] or brushed with a stainless steel brush to facilitate oxide removal.

6. Cold running tap water rinse for two minutes.

7. Repeat Steps 3 and 4.

8. Immerse in MCDERMID No. 629 ACID DIP[4] for 30 seconds or 25–30% by volume of NITRIC ACID for two minutes. Both solutions are used at room temperature.

9. Cold running tap water rinse for two minutes.

10. Cold deionized[1] water rinse for two minutes.

11. Hot (150°F) deionized[1] water rinse for two minutes.

12. Analytical reagent grade ISOPROPYL ALCOHOL rinse at 115°F. (See attached specification in Appendix III.)

13. Oven dry at 150°F or blow dry with dry nitrogen gas preferably taken from an evaporated liquid source. (Dry, high purity (99.99%) water pumped nitrogen bottled gas may also be used. Oil pumped nitrogen is strictly prohibited.)

14. When dry, wrap in lint-free tissue and food grade aluminum oil.

B. Aluminum

B1. Aluminum—Caustic Etch Procedure

Aluminum tubing and parts shall be chemically cleaned according to the steps in the following procedure.

1. Vapor degrease in 1–1–1 TRICHLOROETHANE[2] for five minutes.

2. Cold running tap water rinse for one minute.

3. Soak in AMCHEM No. 53 NON–ETCH ALUMINUM CLEANER[5] for approximately five minutes.
4. Cold running tap water rinse for two minutes. If water breaks appear, repeat Steps 3 and 4.
5. Deoxidize in DIVERSEY–WYANDOTTE ALUTONE LIQUID DESMUTER AND DEOXIDIZER[7] at a concentration of 30% by volume until all mill scale is removed. (If preferred, Alutone may be substituted with Deoxidizer #6 from Amchem, Inc. This is a chromate type of solution and may be used for both Steps 5 and 9. *This solution cannot be dumped into the sanitary sewer.*)
6. Cold running tap water rinse for two minutes.
7. Cold deionized[1] water rinse for two minutes.
8. Hot (150°F) deionized[1] water rinse for two minutes.
9. Blow dry with nitrogen gas preferably taken from an evaporated liquid source. (Dry, high purity (99.99%) water pumped nitrogen bottled gas may also be used. Oil pumped nitrogen is strictly prohibited.)
10. When dry, wrap in lint-free tissue and food grade aluminum foil.

Aluminum—Procedure for Cleaning Large Extrusions

Large extrusion shall be processed in 24" wide × 48" deep × 52' long tanks using the following procedure.

1. Vapor degrease in 1–1–1 TRICHLOROETHANE[2] for five minutes.
2. Cold tap water rinse for one minute.
3. Soak in DIVERSEY–WYANDONTTE 17A NON–ETCH ALUMINUM CLEANER[8] at a concentration of 4 oz./gal. and at a temperature of 140°F for approximately five minutes.
4. Cold tap water rinse for two minutes. If water breaks appear, repeat Step 3.

5. Deoxidize in WYANDOTTE ALUTONE LIQUID DESMUTTER AND DEOXIDIZER[7] at a concentration of 20% by volume at a temperature of 70°F–72°F until all oxide is removed. Air agitate.
6. Cold tap water rinse for two minutes.
7. Etch in AMCHEM ETCHANT #33[6] at a concentration of four oz./gal. and a temperature of 140°F for one to ten minutes depending on depth of etch required.
8. Cold tap water rinse for two minutes.
9. De-smut until surface is clean. Repeat Step 5.
10. Cold tap water rinse for two minutes.
11. Cold deionized[1] water rinse for two minutes.
12. Hot (150°F) deionized[1] water rinse for two minutes.
13. Dry in air over at 150°F or with dry nitrogen blast. Nitrogen gas is preferably taken from an evaporated liquid source. (Dry, high purity (99.99%) water pumped nitrogen bottled gas may also be used. Oil pumped nitrogen is strictly prohibited.)
14. When dry, wrap openings in lint-free tissue and food grade aluminum foil.

All rinses should be running and, if possible, agitated with air from a low pressure blower. Do not use compressed air.

B3. Aluminum (#1312 Process)

The 1312 process for cleaning aluminum is used on objects that are too large for tank cleaning. The following procedure shall be used for such parts.

1. Solvent clean with 1–1–1 TRICHLOROETHANE.[2]
2. Cold running tap water rinse.
3. Steam clean with STEAM–DET[9] detergent inside and out for five minutes.

4. Cold running tap water rinse.

5. Cold running deionized[1] water rinse.

6. Flood with #1312 solution[10] until surface is covered or for one minute.

DO NOT EXCEED 1 MINUTE IMMERSION TIME
OR SMUTTING WILL OCCUR.

7. Tap water spray rinse using a hose and as much pressure and volume as possible.

8. Hot (150°F) deionized[1] water rinse for five minutes.

9. Blow dry with dry nitrogen gas preferably taken from a evaporated liquid source. (Dry, high purity (99.99%) water pumped nitrogen bottled gas may also be used. Oil pumped nitrogen is strictly prohibited.)

10. When dry, wrap openings in lint-free tissue and food grade aluminum foil.

C. OFE Copper

All OFE copper parts shall be chemically cleaned according to the steps in the following procedure.

1. Vapor degrease in 1–1–1 TRICHLOROETHANE[2] for five minutes.

2. Alkaline soak clean in ENBOND Q527 CLEANER[3] for five minutes at a temperature of 180°F.

3. Cold tap water rinse for two minutes.

4. Immerse in 50% HYDROCHLORIC ACID at room temperature for one minute.

5. Bright dip in one of the following solutions, depending on the surface finish required.

   (a) For 30 gallons at room temperature:
   SULFURIC ACID 66° Baume—13 gallons
   NITRIC ACID 42° Baume—7 gallons
   Water—10 gallons

HYDROCHLORIC ACID 20° Baume—15 fl. oz.

OR

(b) For 30 gallons at room temperature:
PHOSPHORIC ACID 75%—21 gallons
NITRIC ACID 42° baume—7 gallons
ACETIC ACID GLACIAL—2 gallons

6. Cold tap water rinse for two minutes.
7. Immerse in a solution of six avoirdupois ounces/gallon of POTASSIUM CYANIDE at room temperature for 15–20 seconds.
8. Cold tap water rinse for one minute.
9. Cold deionized[1] water rinse for one minute.
10. Hot (150°F) deionized[1] water rinse for 30 seconds.
11. Immerse in analytical reagent grade ISOPROPYL ALCOHOL at 115°F for 30 seconds. (See attached specification in Appendix III.)
12. Blow dry with dry nitrogen gas preferably taken from an evaporated liquid source. (Dry, high purity (99.99%) water pumped nitrogen bottled gas may also be used. Oil pumped nitrogen is strictly prohibited.)
13. Dry in air oven at 150°F.
14. When dry, wrap openings in lint-free tissue and food grade aluminum foil.

D. UHV Flanges

Experience at SLAC has determined that new vacuum flanges are not sufficiently clean, and additional chemical cleaning is necessary before they can be used in a UHV system. UHV flanges shall be chemically cleaned according to the steps in the following procedure.

1. Vapor degrease in 1–1–1 TRICHLOROETHANE[2] for five minutes.
2. Cold running tap water rinse for one minute.

3. Soak in ENBOND Q527 CLEANER[3] at a temperature of 180°F for five minutes. Brush with nylon bristle brush if necessary.

4. Cold running tap water rinse for two minutes.

5. Immerse in the following solutions:
   Nitric Acid 40° Baume .... 97% by volume
   Hydroflouric Acid 48% .... 3% by volume

   Solution shall be at room temperature. Immersion time 30–60 seconds.

6. Cold running tap water rinse for two minutes.

7. Cold deionized[1] water rinse for two minutes.

8. Hot (150°F) deionized[1] water rinse for two minutes.

9. Analytical reagent grade ISOPROPHYL ALOCHOL rinse at 115°F. (See attached specification in Appendix III.)

10. Oven dry at 150°F or blow dry with dry nitrogen gas preferably taken from an evaporated liquid source. (Dry, high purity (99.99%) water pumped nitrogen bottled gas may also be used. Oil pumped nitrogen is strictly prohibited.)

11. Wrap in lint-free tissue and food grade aluminum foil.

E. Ceramic–To–Metal Feedthroughs

Ceramic-to-metal feedthroughs present particular cleaning problems due to cracks and crevices inherent in their construction, which may trap acid cleaning solutions. Therefore, feedthroughs that have potential trapped areas shall NOT be acid cleaned. Feedthroughs shall be chemically cleaned according to the steps in the following procedure.

1. Vapor degrease in 1–1–1 TRICHLOROETHANE[2] for 15 minutes. Place feedthroughs on side in a stainless steel basket.

2. Ultrasonic in analytical reagent grade ISOPROPYL ALOCHOL for five minutes. (See attached specification in Appendix III.)

3. Blow dry with dry nitrogen gas preferably taken from an evaporated liquid source. (Dry, high purity (99.99%) water pumped nitrogen bottled gas may also be used. Oil pumped nitrogen is strictly prohibited.)
4. Oven dry at 150°F for approximately two hours.
5. Wrap in lint-free tissue and food grade aluminum foil.

F. Welded Bellows Diaphragms

Welded bellows present cleaning problems because chemical solutions can be trapped in their convolutions. Therefore, all parts must be chemically cleaned PRIOR to welding and subsequent handling must be accomplished in a manner which does not contaminate the bellows. Bellows that are acceptable for the SLAC vacuum system without additional hydrogen firing must have the individual diaphragms chemically cleaned prior to welding according to the steps in the following procedure.

1. Individual diaphragms shall be suspended on a stainless steel holding fixture in such a way that they do not touch each other.
2. Vapor degrease in hot (150°F) 1–1–1 TRICHLOROETHANE[2] vapor for five minutes.
3. Cold running tap water rinse for one minute. Immersion rinse preferred over spray rinse.
4. Soak in ENBOND Q527 CLEANER[3] for five minutes at a temperature of 180°F.
5. Cold running tap water rinse for two minutes—NOT in tank used in Step 3 above.
6. Immerse in a stainless steel pickle consisting of:
   1 part 42° Baume Nitric acid
   1 part 48% Hydrofluoric acid
   1 part deionized[1] water

Solution shall be at room temperature. Immersion time shall be sufficient to clean surface of scale and oxide, approximately one minute. Care should be taken to avoid over-etching.

7. Cold running tap water rinse for two minutes—NOT in tank used in Step 3 or 5 above.

8. Immersion rinse in cold deionized[1] water for two minutes.

9. Analytical reagent grade ISOPROPYL ALOCHOL rinse. (See attached specification in Appendix III.)

10. Oven dry at 150°F or blow dry with dry nitrogen gas preferably taken from an evaporated liquid source. (Dry, high purity (99.99%) water pumped nitrogen bottled gas may also be used. Oil pumped nitrogen is strictly prohibited.)

11. When dry, remove from rack using clean white nylon gloves. Wrap individual diaphragm pieces in lint-free tissue and food grade aluminum foil.

G. Thin Stainless Steel Chambers or Formed Bellows

Thin (wall thickness less than .006 inches) stainless steel chambers, windows or formed bellows which contain no chemical traps shall be chemically cleaned according to the procedure for 300 series stainless steel. (See Section IV.A of these specifications.)

H. Ceramic

Ceramic parts used in the vacuum system as insulators, spacers, and so on shall be chemically cleaned according to the steps in the following procedure.

1. IGEPAL 710 CLEANING SOLUTION at room temperature:

   980 ml water

   20 ml AMMONIUM HYDROXIDE

   0.5 grams of IGEPAL 710[11]

   (a) Dissolve 0.5 grams of IGEPAL 710[11] in 500 ml of warm (120°F) water.

(b) Add 20 ml of AMMONIUM HYDROXIDE.

(c) Add water to make 1 liter.

2. Ultrasonic in IGEPAL 710 solution for five minutes.
3. Cold deionized[1] water rinse for one minute.
4. Rinse in 25% ACETIC ACID solution to neutralize ammonia.
5. Ultrasonic in cold deionized[1] water for three minutes.
6. Hot (150°F) deionized[1] water for one minute.
7. Ultrasonic in analytical reagent grade ISOPROPYL ALOCHOL for three minutes. (See attached specification in Appendix III.)
8. Oven dry.
9. Wrap in lint-free tissue and food grade aluminum foil.

Chemical Cleaning Notes

1. Minimum restivity for deionized water is 500,000 ohms
2. 1-1-1 TRICHLOROETHANE
   product of Dow Chemical Co.
3. ENBOND Q527
   product of Enthone, Inc., New Haven, Conn.
4. MCDERMID #629 ACID
   product of McDermid Co., Waterburry, Conn.
5. AMCHEM #53
   product of Amchem, Inc., Ambler, Penn.
6. AMCHEM ETCHANT #33
   product of Amchem, Inc., Ambler, Penn.
7. DIVERSEY-WYANDOTTE ALUTONE LIQUID DESMUTTER AND DEOXIDIZER
   product of Diversey-Wyandotte, Wyandotte, Mich.
8. DIVERSEY-WYANDOTTE 17A
   product of Diversey-Wyandotte, Wyandotte, Mich.
9. STEAM-DET detergent
   available from Bay Chemicals, San Jose, CA
10. #1312 solution
    product of ECO Chemical Products, Inc.,
    4250 Artesia Ave., Fullerton, CA 92633
11. IGEPAL 710
    product of GAF Corp., South San Francisco, CA
12. Scotch-Brite General Purpose Pad, Red, Part No. 7447,
    Aluminum oxide impregnated
    product of 3M Company

V. CLEAN ROOM PRACTICES

A. Clean Room Requirements

Assembly and welding must take place in a closed room specifically prepared for and designated as a CLEAN ROOM. A positive pressure, filtered air, ventilation system must be provided to prevent instrusion of airborne particles and/or fume contamination. Only those functions which are appropriate to a clean room area will be permitted within it.

Contamination can be particulate, liquid or gaseous. It can be introduced into the open vacuum chamber by exposure to contaminated air or direct contact with contaminated objects. Contamination can come from many sources. The single largest source is due to perspiration, body oils, hair, clothing, cosmetics, perfume, and so on, from people.

The following clean room procedures are presented as guidelines which must be followed and combined with good judgment and skill in order to produce clean ultra high vacuum systems.

1. No food, drink or smoking allowed in the clean room. A notice stating this should be posted at all clean room doors.

2. Limit clean room entry and exit, open doors briefly and only when necessary.

3. No hydrocarbons (that is, oil and grease) or dust-collecting materials, such as cardboard, are allowed in the clean room.

4. Equipment brought into the clean room must be clean. Carts, chambers, stands, tools and other equipment must not be oily or greasy and must be blown off with compressed air or wiped down with appropriate cleaning solutions immediately prior to entering the clean room. Note that wheels on carts must also be cleaned.

5. All wood must be completely covered with aluminum foil or painted and wiped down with alcohol.

6. Tools for clean room use should not leave the clean room.

7. Uncleaned tools should be used only for work on the exterior of chambers. Tools that will actually touch "clean" exposed vacuum surfaces should be degreased in the following solvents used in the order listed: acetone, freon, alcohol. Alcohol is the only solvent allowed in the clean room. After degreasing, the tools should be kept in clean trays in the clean room and be handled with clean gloves.

8. No cadmium plated tools or materials are permitted in the clean room.

9. No brass, lead or plastic tools or materials are permitted in the clean room.

10. Aluminum foil shall be of the type designated as DRY ANNEAL A, such as that sold for food service wrap. Each piece of aluminum foil is to be used only once and must be discarded after use. Foil must be free of any visible contamination.

11. Aluminum foil shall be stored in aluminum boxes. The lids on these boxes should be kept closed when the foil is not in use.

12. Lint-free tissue shall be stored in aluminum boxes. The lids on these boxes should be kept closed when not in use.

13. Use pens for writing in the clean room; do not use pencils. Do not bring unnecessary paper into the clean room.

14. Clean parts and vacuum chamber openings should be covered with clean aluminum foil at all times when work is not being performed on them. Clean tools should also be covered in a like manner when they are not in use.

15. Always wear clean protective clothing when working in the clean room. Clean room coats will be put on when clean room is entered and taken off upon exit. Authorized personnel may be allowed to enter the clean room without wearing clean room coats but may not stay longer than three minutes.

16. Clean room coats must not be removed from the clean room. They should be stored in a locker in the clean room or they may be hung on a coat hook in the clean room if a person is leaving the clean room temporarily and will be returning within a few minutes.

17. Clean parts shall only be handled by clean, white, nylon gloves.

18. Gloved hands which touch cleaned parts must touch nothing else. Gloves which touch uncleaned surfaces (face, clothing, tools, bench, chairs, and so on) shall be immediately replaced with a new pair.

19. Replace gloves with a new clean pair at the beginning of each shift and following period breaks.

20. Hands should be washed before wearing clean gloves. This must be done especially if any lotions or creams have been used.

B. Vacuum Assembly

B1. Handling Practices

The following handling procedures are presented as guidelines which must be followed and combined with good judgment and skill in order to produce clean ultra high vacuum systems. Assembly of clean parts should take place in a clean room whenever possible. When assembly must be performed in the field, adhere to clean procedures as closely as possible.

1. No food, drink, smoking or contaminants of any kind shall be near open vacuum chambers or clean parts.

2. Clean parts shall only be handled by clean, white, nylon gloves.

3. Gloved hands which touch cleaned parts must touch nothing else. Gloves which touch uncleaned surfaces (face, clothing, tools, bench, chairs, door knobs, and so on) shall be immediately replaced with a new pair.

4. Change clean gloves regularly and have a supply at hand.

5. Cover hair and arms if there is any possibility of them contacting a clean vacuum surface.
6. Handle UHV parts carefully.
7. Wrap clean parts in lint-free tissue and clean aluminum foil, label with the part number and date, and store in a clean tote. When in doubt about the cleanliness of a part, it should be recleaned.
8. Clean stainless steel trays or glass dishes should be used to hold small clean parts during assembly.
9. All tools that come in contact with clean surfaces should be degreased prior to use. See Item 7 in Section V.A entitled *Clean Room Requirements* for degreasing procedure.
10. Tools that come in contact with clean surfaces must be of noncontaminating material (no brass, lead, plastic or cadmium plated tools).
11. Vacuum chamber openings should be kept covered as much as possible with clean foil or blank flanges. Have clean foil ready when a chamber is opened. Do not leave a chamber uncovered.
12. Purge vacuum chamber with N_2 (from a liquid nitrogen source) if assembly is done outside the clean room or if necessary when inside the clean room.
13. Verify that assembly equipment and tools are not left inside a vacuum chamber before it is blanked off.
14. When welding clean parts, cables and strips must not contact clean surfaces.
15. When aligning chambers using optical alignment techniques, any tools used for measuring the internal clean parts of a chamber must conform to the description of clean tools as described above. Internal surfaces must be protected from contamination at all times.

B2. Flange Assembly

1. Examine knife edge to verify that there are no nicks or scratches before assembly.
2. Clean gasket clips or a clean stainless steel six-inch scale may be used as aids in aligning a gasket in a flange pair. Use caution to avoid damaging the knife edge.
3. Inspect bolts and nuts before tightening the flange pair.
4. Tighten "knife-edge" type flange pairs evenly using a "star" pattern or torqueing pattern until the flanges are snug. Then tighten bolts in a circular pattern around the flange pair until they are "metal-to-metal." (Do NOT tighten Curvac or Skarpaas flanges "metal-to-metal.")
5. In the "metal-to-metal" condition, there is no visible gap between two flanges in a flange pair. After tightening a flange pair, use a flashlight to visually inspect it for the "metal-to-metal" condition.

C. Clean Room Maintenance

In order to maintain the effectiveness of the clean room environment, the clean room should be cleaned daily according to the following procedure.

C1. Clean Room

1. Prior to clean room cleanup, all vacuum chamber openings should be blanked or double wrapped in clean foil and taped with plater's tape. All subassemblies should be double wrapped in foil and appropriately stored.
2. All tools should be returned to their proper storage locations in the clean room. (Tools are usually hung on a tool board.)
3. Sweep clean room floor.
4. Mop clean room floor with water only.
5. Use alcohol and lint-free tissue to wipe down all surfaces, including cabinets,

shelves, tables, door knobs, phones, window sills, tool boards and door exit signs.

C2. Gloves and Coats

1. Pick up all dirty gloves and place them in a tote.
2. Turn all dirty gloves right side out.
3. Wash gloves in washing machine using warm wash normal cycle.
4. Use 1/4 cup or 60 ml of AMWAY SA–8 PLUS or equivalent detergent per load.
5. Rewash without detergent.
6. Wear clean gloves when removing washed gloves from the washer.
7. Dry gloves in dryer on normal temperature until dry.
8. Prepare a clean tote. Use alcohol and lint-free paper to wipe down inside and outside of tote. Line inside with clean, dry, lint-free paper. Label tote "Clean gloves, not bagged."
9. Wear clean gloves when removing dry gloves from the dryer. Place clean, dry gloves into prepared clean tote.
10. Clean gloves should be bagged.
    (a) Wear clean gloves when handling clean gloves to be bagged.
    (b) Work on a table that has been cleared off and covered with clean aluminum foil and lint-free paper.
    (c) Bag clean gloves in pairs in plastic bags.
    (d) Place bagged gloves in an unlined tote labeled "Clean gloves, bagged."
11. Coats should be cleaned using the same washing and drying procedure used for gloves with the exception that clean gloves do not need to be worn when handling clean coats.

12. Clean coats should be hung in coat cabinets in the clean room.
13. The washer and dryer shall be used only to clean gloves and coats.
14. Occassionally wipe the internal surfaces of the washer and dryer (including the door) using alcohol and lint-free tissue.

D. Storage of Clean Chambers and Components

Storage of clean vacuum chambers and components shall be as follows:

1. Small components should be stored in covered glass dishes (Petri dish, typical) placed in desiccating cabinets in a clean room.
2. Parts and components should be wrapped in lint-free tissue and clean aluminum foil. Wrapped parts should be labeled and dated. They should then be placed in a labeled tote which should be stored in a clean room.
3. Chambers that are to be stored for a short term should be blanked off and stored in a clean room.
4. Chambers that are to be stored for a long term should be blanked off, backpurged with N_2 (from a liquid nitrogen source), wrapped in plastic sheeting, and stored in a covered area.

VI. WELDING AND BRAZING

A. Welding

All welding must take place in a clean room and welders must adhere to clean room practices as described in Section V of these specifications.

Thin (less than 0.010 inch thick) stainless steel or beryllium-copper parts (for example, RF shields) may be spotwelded using a resistance welding process. All other welding shall be by the tungsten inert gas fusion process, unless specifically approved. Welding electrodes shall be two percent thoriated tungsten.

Prior to welding, all parts must be cleaned according to Section IV of these specifications. Jigs, fixtures or chill rings which contact the clean parts must also be cleaned according to these specifications. Clean, white, nylon gloves must be worn when clean parts are handled during welding. If the gloves come in contact with anything other than clean surfaces, they must be replaced with new ones.

Only hand-held brushes with stainless steel bristles from .002 inches to .008 inches in diameter may be used for cleaning oxides off welds. Power-driven brushes, abrasive papers and abrasive wheel shall NOT be used. Hand scraper shall be high quality, high strength steel of triangular shape, heat treated to a minimum Rockwell hardness of 65. Brushes and scrapers shall be vapor degreased in TRICHLOROETHANE before use.

A1. Stainless Steel

Back purge stainless steel welds in all cases. Maintain gas flow until the metal cools to prevent oxidation. Use Argon or Nitrogen Commerical Grade 99.98 percent or mixture of these for cover and purge gas. Stainless steel parts should be welded within 48 hours after they are chemically cleaned.

A2. Aluminum

For welding thick parts, the suggested procedure is to use D.C. straight polarity with Atomic Grade Helium as the cover gas. This method does not require preheating of the parts. For parts of 1/8 inch thickness or less, use A.C. polarity with Argon cover gas. Aluminum parts should be welded within 24 hours after they are chemically cleaned.

A3. Joint Design

Figures 6 through 10 in Appendix I illustrate examples of joint designs recommended for ultra high vacuum systems. Inside welds should be made in every possible case. This becomes particularly important if the need arises to reclean the assembly at a later date. Assemblies which have internal crevices due to outside welds are considered nonrecleanable since these crevices act as traps for cleaning solutions.

A4. Filler Rod

Store filler metal in a manner such that it is protected from oil and other contaminants. The package seal must not be broken until just prior to welding. Rod from an opened package must be kept in a cabinet or other area within the clean welding area. Prior to welding, clean the filler rod using lint-free tissue and reagent grade acetone.

The following chart shows the filler rod that should be used with various alloys:

Table 4. Welding Filler Rod

Alloy		*Filler*	
Stainless Steel:	304	Stainless Steel:	308,308L
	304L		308L
	316		316, 316L
	316L		316L
	321		347
	347		347
Aluminum:	6061		4043 (Linde H.Q.)

B. Brazing

All braze joint designs should be reviewed with the Braze Shop Coordinator prior to fabrication. In most cases, brazing in a vacuum or a dry (dewpoint--80°F) hydrogen atmosphere is preferred. This prevents discoloration and "greening" of stainless steel.

Prior to brazing, the parts involved must be chemically cleaned according to Section IV of these specifications. These parts must then be handled according to the procedures for handling clean parts as described in Section V.B1 of these specifications.

All metal-to-metal and ceramic-to-metal brazes must have adequate filler metal to provide a smooth, uniform fillet throughout. Gaps, discontinuities or nonwet areas in the fillet are not acceptable. All filler metal shall be in the liquidus temperature range long enough to permit free flow throughout. In all possible cases the filler shall be placed in a manner which results in the joint side nearest the vacuum being uniformly filled.

There are a wide variety of commercially available brazing alloys which are acceptable; however, alloys containing zinc or cadmium are not permitted. The alloy used will depend to some extent upon the material being brazed, the joint design, stresses on the parts, and so on.

When brazing is performed by shops outside of SLAC, the vendor must be able to provide certifications of the brazing alloys used.

VII. HELIUM LEAK TEST

Following welding and inspection, vacuum assemblies shall be leak tested using a mass spectrometer helium leak detector fitted with a liquid nitrogen cold trap. (See Appendix II for acceptable leak detectors.)

A liquid nitrogen cold trap is used to protect the internal area of the vacuum component from leak detector roughing pump vapors. It must be installed between the vacuum component's connecting flange or test plate, and the leak detector inlet. On some leak detectors this requirement precludes the use of the built-in test port. In these cases, a side port inlet to the leak detector with an external valve and liquid nitrogen cold trap fitted to it must be used. The trap must be kept full of liquid nitrogen throughout the time testing is taking place.

A valve isolating the vacuum component from the test system should be installed between the component or test plate and the cold trap.

The vacuum component being tested shall be handled cleanly, as described in Section V.B1 of these specifications. Leak testing must be performed in an area remote from other operations so as not to pose a threat of airborne contamination. Food, drink and smoking shall be prohibited within proximity to the leak testing area. All tables used must be covered with clean aluminum foil.

Leak detector sensitivity for helium shall be calibrated to a minimum sensitivity of 2×10^{-10} standard cc/sec per leak meter division on the most sensitive range. Reject any vacuum component or assembly that, when probed with helium or is surrounded for at least one minute by a vessel containing 100 percent helium, results in a two percent deflection on the most sensitive range of the leak rate meter. Calibration of the leak detector sensitivity shall be performed just prior to leak testing.

O-rings or rubber flat stock used as a temporary seal for the purpose of testing vacuum components that do not have flanged ends shall be new rubber, clean and dry. No lubricants or grease of any kind are permitted without prior approval. Experience at SLAC has shown that low durometer O-rings or pure gum rubber sheet works satisfactorily if the seal loading is adequate. Solvents accelerate the deterioration of rubber; therefore, the recommended procedure for cleaning rubber stock is hand washing with soap and water followed by a thorough rinsing in water. Immediately following leak testing, those areas which have come in contact with the rubber seal must be wiped off using new lint-free and trichloroethane or freon TF.

Use of the leak detector, including periodic maintenance, must conform to the manufacturer's recommendations.

VIII. RGA TEST

Vacuum assemblies suspected of contamination may be tested with a quadrupole-type residual gas analyzer (RGA). The RGA used must be sensitive to a partial pressure of 10^{-14} torr and be capable of scanning in the 1 to 300 AMU range. Refer to the SLAC Technical Publication PS–202–631–06 entitled *A Quadrupole Residual Gas Analyzer* for details on RGA specifications. (See Appendix II for an acceptable RGA vendor.)

The RGA probe shall demonstrate a measured background, before exposure to the test system, of not more than 5×10^{-12} torr for the sum of all partial pressures above atomic mass 44. Both the RGA probe and the test chamber shall be maintained at the same temperature, which shall be in the range of 100°C to 150°C. In the test system, the sum of all partial pressures between atomic mass 44 and 100 shall not exceed the measured background of the RGA probe by more than 1×10^{-11} torr.

IX. BAKEOUT

All vacuum assemblies and components that will be installed as an integral part of the SLAC vacuum system shall be baked under vacuum. Assemblies that may produce high outgassing loads may be nitrogen baked initially, then vacuum baked. In a nitrogen bake, dry nitrogen gas from an evaporated liquid source is purged through the assembly while it is heated.

The bakeout temperature required for each assembly is dependent on the material from which the component is constructed. Typically, stainless steel vacuum chambers are baked at 200°C (maximum temperature 300°C), and aluminum vacuum chambers are baked at 180°C (maximum temperature 200°C). Chambers consisting of other materials should be evaluated individually to determine the maximum temperature required. The duration of the bakeout is dependent on the rate at which the chamber's base pressure reaches a steady state.

Assemblies or components which will be inaccessible after installation due to shielding, magnets, and so on shall be wrapped for bakeout, insulated and instrumented prior to installation in a manner such that repeated bakeouts can be accomplished simply by connecting a power source and thermocouple leads *in situ*.

X. VENTING AND PUMPDOWN

When venting a system from vacuum to atmospheric pressure, dry nitrogen shall be used as the venting gas. Preferably, the dry nitrogen gas is taken from an evaporated liquid source. (Dry, high purity (9.99%) water pumped nitrogen bottled gas may also be used. Oil pumped nitrogen is strictly prohibited.) Tubing used to connect the gas source to the vacuum system shall be clean, dry copper or stainless steel tubing and shall be connected to the system by means of a "knife-edge" flange, desribed in Section II.B of these specifications. A pressure relief valve is required in the venting line to prevent accidental overpressurization and rupture of the vacuum system.

Pumpdown from atmospheric pressure shall take place using cryosorption pumps or a mechanical pump fitted with a liquid nitrogen trap. A liquid nitrogen trap is used to prevent pump oil vapors from backstreaming and contaminating the vacuum system. When using a mechanical pump, the trap must be filled with liquid nitrogen prior to opening the pumpout valve to the vacuum system. The mechanical pump may be used down to pressures of approximately 10 Torr, at which point it should be valved off to protect against oil vapor backstreaming. Pumpdown from this pressure may proceed using cryosorption pumps until a pressure between 1 to 10 microns is reached. From this point on, pumping should continue using ion pumps.

Prior to breaking any flange connections for venting or pumpdown, the area to be disconnected should be wiped clean with lint-free tissue using the following solvents in the order listed: acetone, freon, alcohol. Once the flanged connections are broken, the openings to the vacuum system shall IMMEDIATELY be covered with clean new aluminum foil. Reassembly of the flange pairs shall be accomplished following the procedure described in Section V.B2 of these specifications.

APPENDIX I

ILLUSTRATIONS

Fig. 1

EXAMPLE OF WATER COOLED MODULE DESIGNED USING NO WATER TO VACUUM WELDS.

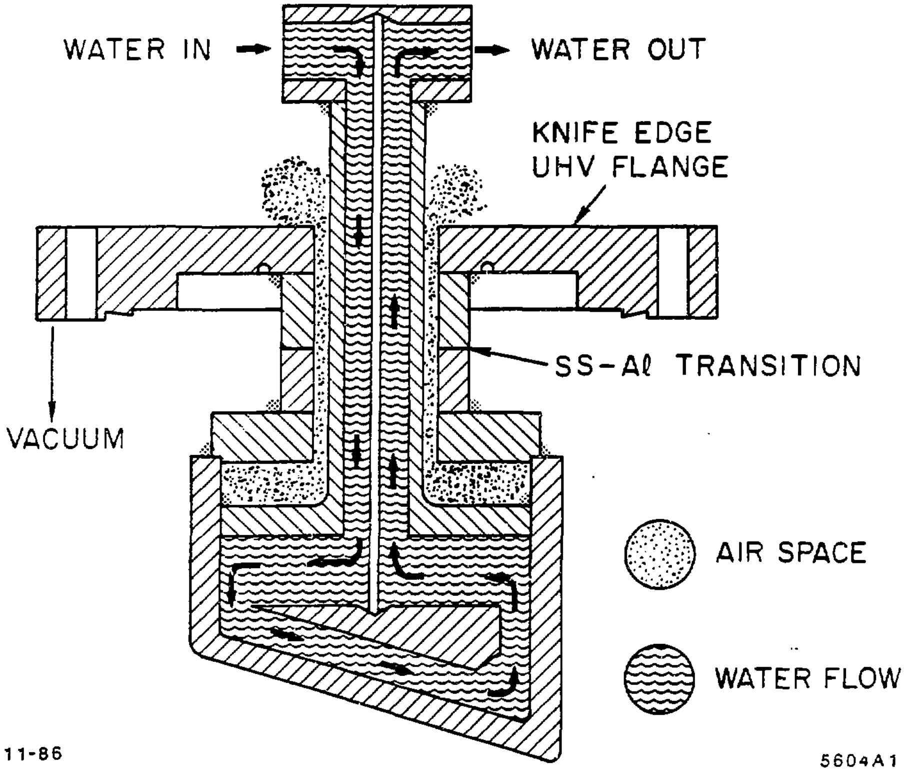

Figure 2. Nonrotatable Flange Dimensions

Flange	A	B	C	Max. Tube O.D.
2 1/8	2.125 ± .015	1.300 ± .002	1.090 ± .002	1
2 3/4	2.73 ± .015	1.902 ± .002	1.650 ± .002	1 1/2
3 3/8	3.37 ± .015	2.430 ± .002	2.200 ± .002	2
4 1/2	4.47 ± .015	3.250 ± .002	3.040 ± .002	2 1/2
6	5.[illegible] ± .015	4.750 ± .002	4.540 ± .002	4
8	7.97 ± .015	6.750 ± .002	6.540 ± .002	6
10	9.97 ± .015	8.750 ± .002	8.540 ± .002	8
13 1/4	13.25 ± .015	$11.595^{+.005}_{-.000}$	$11.350^{+.005}_{-.000}$	10 1/2

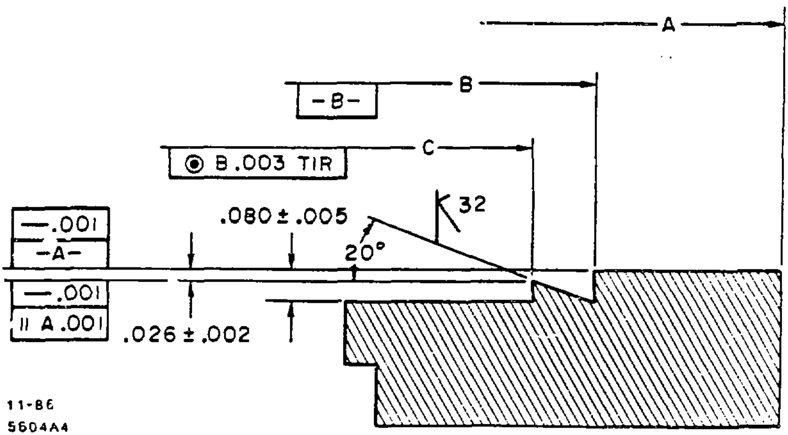

Figure 3. Rotatable Flange Insert Dimensions

Flange	A	B	C	Max. Tube O.D.
2 1/8	1.290 ± .002	1.090 ± .002	.210 ± .002	1
2 3/4	1.893 ± .002	1.650 ± .002	1.650 ± .002	1 1/2
3 3/8	2.424 ± .002	2.200 ± .002	.351 ± .002	2
4 1/2	3.241 ± .002	3.040 ± .002	.474 ± .002	2 1/2
6	4.741 ± .002	4.540 ± .002	.537 ± .002	4
8	6.741 ± .002	6.540 ± .002	.598 ± .002	6
10	8.741 ± .002	8.540 ± .002	.649 ± .002	8
13 1/4	$11.590^{+.000}_{-.005}$	$11.350^{+.005}_{-.000}$	.654 ± .002	10 1/2

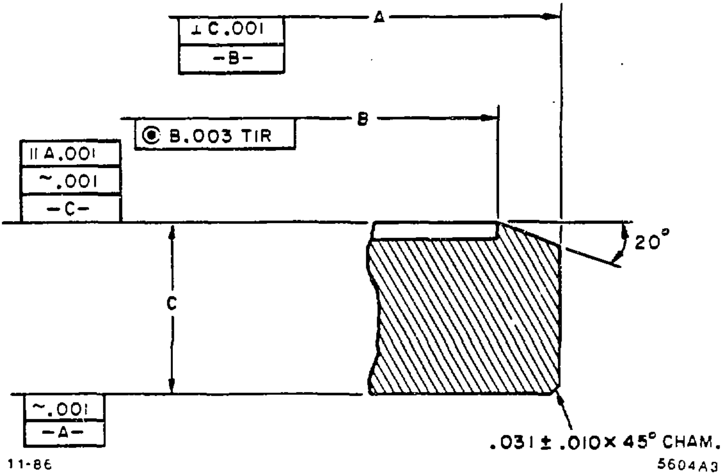

Figure 4. Rotatable Flange Receiver Dimensions

Flange	A	B	C	D	E
2 1/8	2.12 ± .015	1.075 ± .015	.470 ± .015	1.300 ± .002	.236 ± .001
2 3/4	2.73 ± .015	1.560 ± .015	.50 ± .015	1.902 ± .002	.301 ± .002
3 3/8	3.37 ± .015	2.030 ± .015	.68 ± .015	2.430 ± .002	.381 ± .001
4 1/2	4.47 ± .015	2.625 ± .015	.75 ± .015	3.250 ± .002	.500 ± .002
6	5.97 ± .015	4.125 ± .015	.84 ± .015	4.750 ± .002	.563 ± .002
8	7.97 ± .015	6.125 ± .015	.94 ± .015	6.750 ± .002	.624 ± .002
10	9.97 ± .015	8.125 ± .015	.97 ± .015	8.750 ± .002	.675 ± .002
13 1/4	13.25 ± .015	10.875 ± .015	1.18 ± .015	$11.595^{+.005}_{-.000}$	.680 ± .002

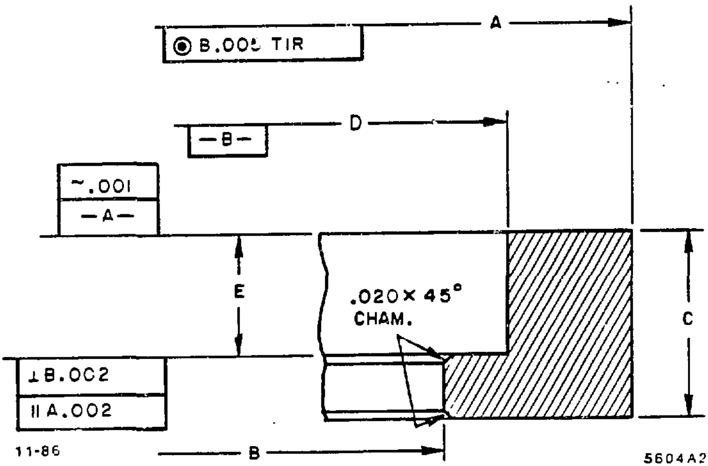

Fig. 5

DIAPHRAGM CONTOURS
FOR A WELDED-NESTED BELLOWS

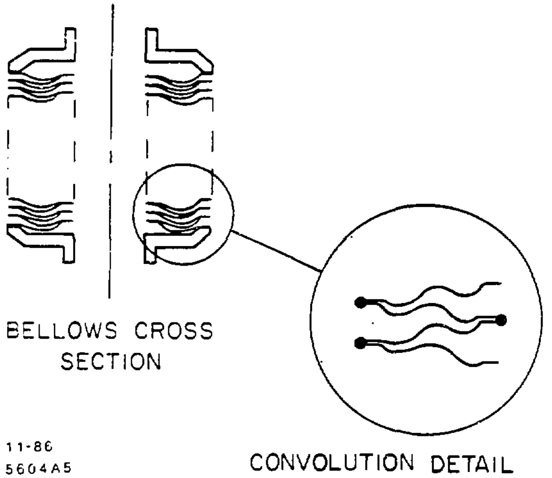

Fig. 6

PREFERRED JOINT DESIGN FOR WELDING
VACUUM FLANGES

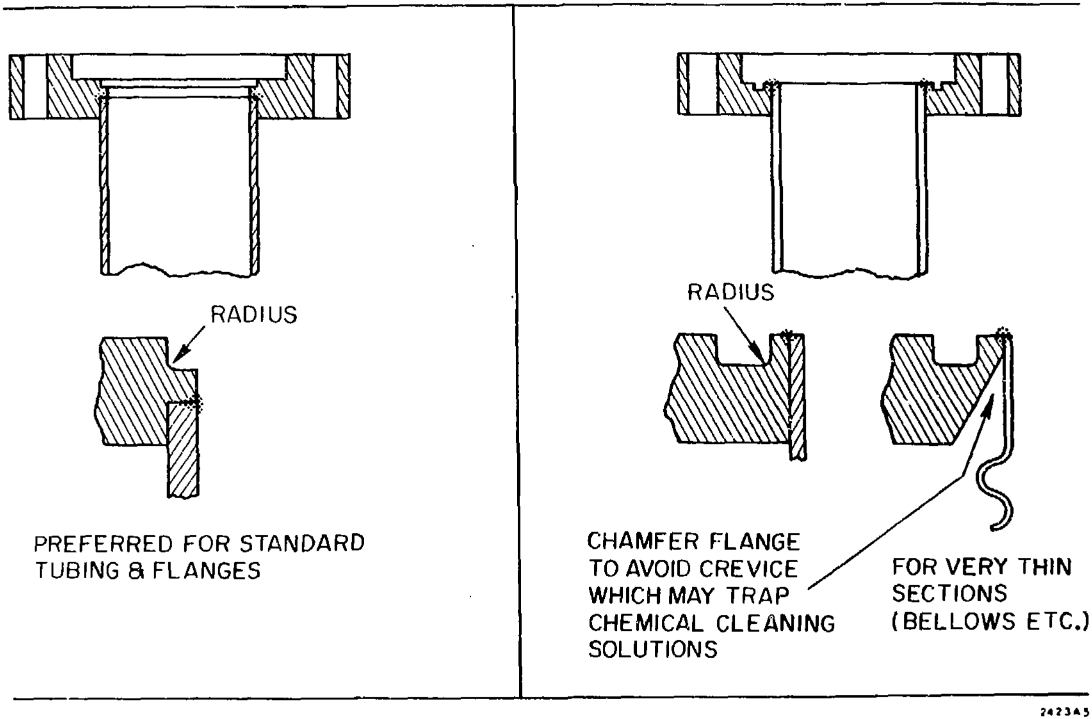

Fig. 7

PREFERRED JOINT DESIGN FOR WELDING
WELDED BELLOWS

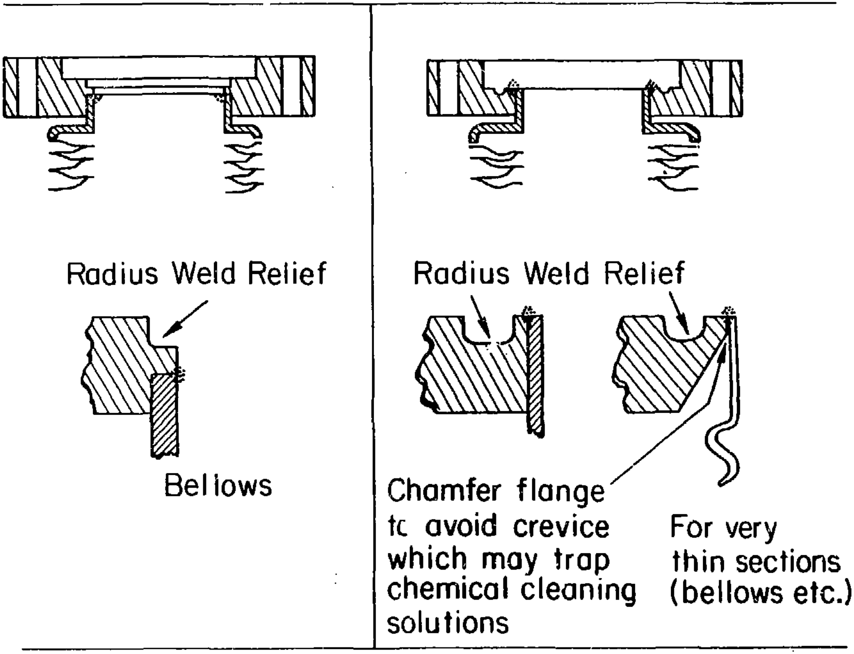

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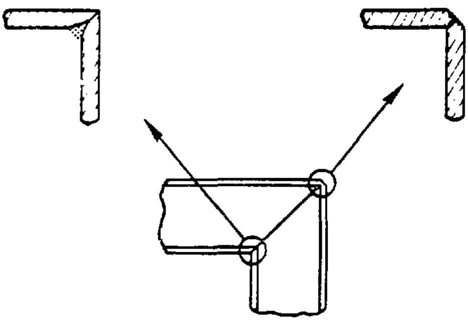
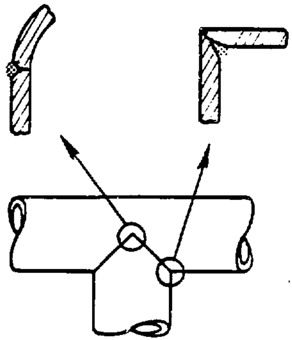
Fig. 8

PREFERRED JOINT DESIGN FOR FULL PENETRATION OUTSIDE WELDS ON TEES AND ELBOWS

MITRED ELBOW



MITRED TEE



BRANCH TEE

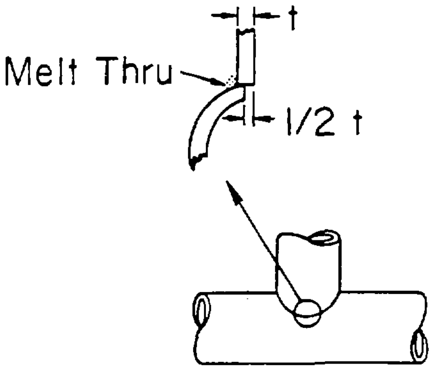


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Fig. 9

PREFERRED JOINT DESIGN
FOR WELDING VACUUM COMPONENTS

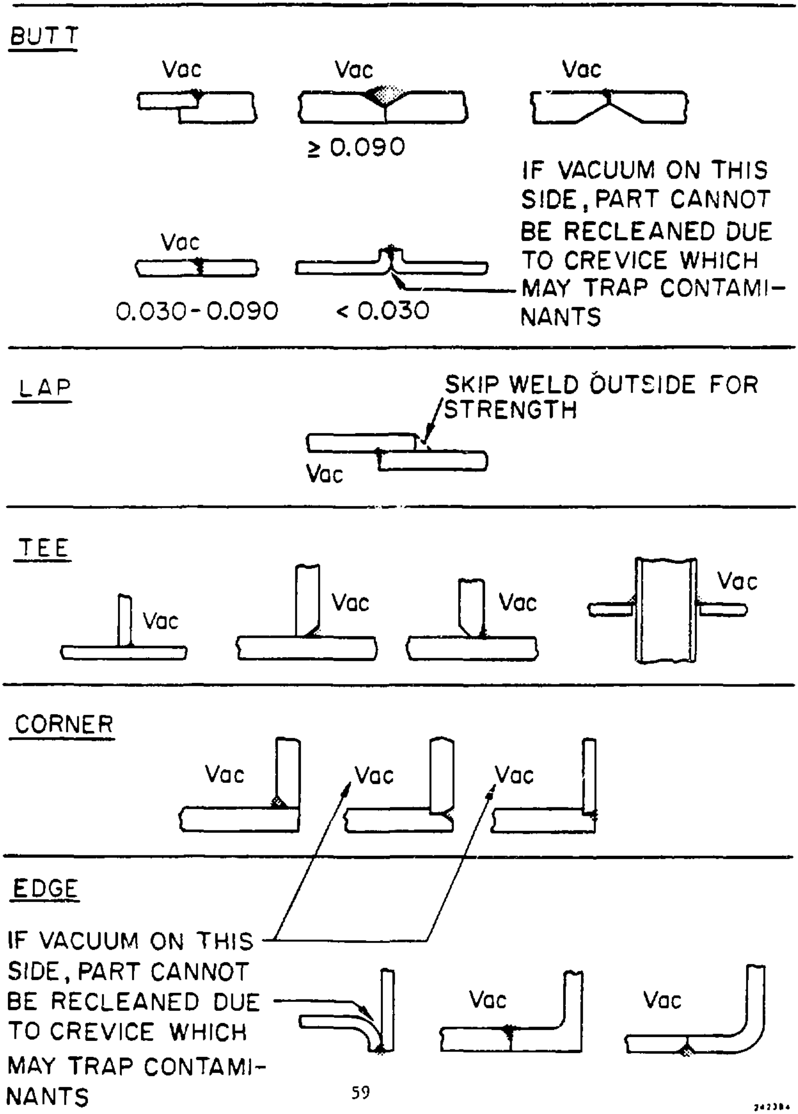
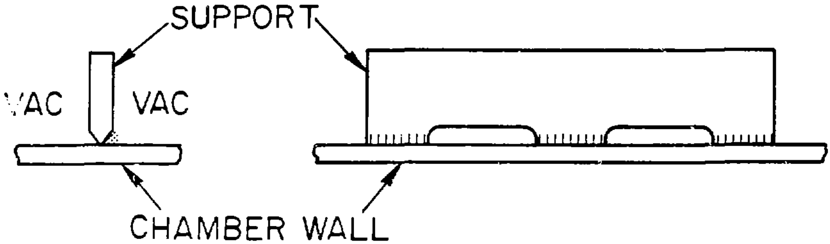
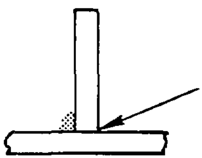


Fig. 10

PREFERRED JOINT DESIGN FOR WELDING INTERNAL SUPPORTS



SUPPORT SHOULD BE CHAMFERED ON BOTH SIDES WHERE IT CONTACTS CHAMBER WALL TO AVIOD CREVICES.

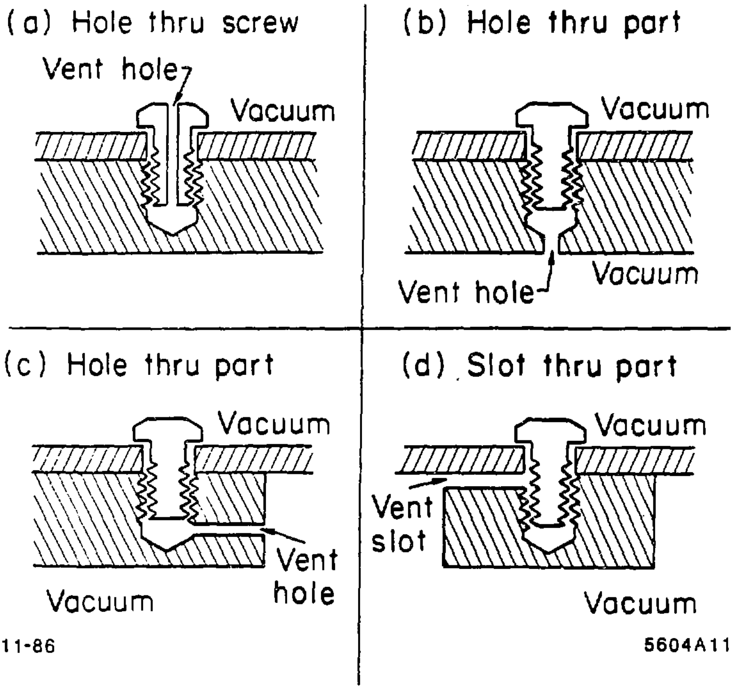


AVOID JOINTS SUCH AS THIS WHICH ARE TRAPS FOR CLEANING SOLUTIONS. COMPONENTS HAVING SIMILAR TYPE JOINTS AS PART OF THE INTERNAL (VACUUM) STRUCTURE WILL BE CONSIDERED NOT RECLEANABLE FOLLOWING FINAL ASSEMBLY.

242347

Fig. 11

EXAMPLES OF VENTED SCREWS



APPENDIX II

VENDOR LIST

Acceptable Vendors for Vacuum Components and Equipment

1. *Flanges:*

   Varian, MDC and Perkin-Elmer.

2. *Ion Pumps:*

   Varian and Perkin-Elmer.

3. *Right Angle Valves:*

   Varian and MDC.

4. *Welded Bellow:*

   Standard Bellows Co.

5. *Electrical Feedthroughs:*

   Insulator Seal Corp. and Ceramaseal Corp.

6. *Nude Ion Gauges:*

   Type UHV–24, Varian p/n 971–5008 or equivalent.

7. *Cold Cathode Gauges:*

   Varian p/n 0524–F2818–301 or equivalent.

   Gauge Controller: Varian p/n 860–L5797–301 or equivalent.

8. *Roll Bonded Transition Material:*

   Sole source from Spur Industries, E. 17404 Euclid Ave., Spokane, WA 99216.

9. *Leak Detectors:*

   The following leak detectors or approved equivalents are acceptable:

   Varian (NRC) Model 925 or 936

   Veeco MS–9, MS–90, MS–18

   DuPont (CEC) Model 24–120B.

10. *Residual Gas Analyzer:*

    U.T.I. Model 100C or equivalent.

APPENDIX III

ISOPROPYL ALCOHOL SPECIFICATION

Isopropyl Alcohol Specification Limits*

$CH_3CHOHCH_3$	(6.58 lbs.)	M.W. 60.10

Assay (by weight)	>99.80%
Spec. Grav. at 20/20°C	0.786 to 0.787
Distillation Range	1.0°C
Acidity (as acetic acid)	0.002%
Residue after Evaporation	<0.001%
Heavy Metals (as Pb)	<0.0001%
Distillation, 760 mm	Shall entirely distill within a 0.5°C range, which shall include 82.3± 0.1°C.
Isopropanol	99.8% by weight, minimum
Permanganate time test	20 minutes, minimum
Dilution test	Clear
Color	10 platinum-cobalt, maximum
Odor	Nonresidual
Suspended matter	Substantially free
Boiling point	82.3°C
Spectrographic Analyses	Parts/Billion
Iron	10–50
Copper	1–5
Nickel	1–5
Aluminum	10–5
Manganese	1–5
Neutrality	Passes A.C.S. Test
Solubility in Water	Passes A.C.S. Test

*Specifications from the Baron–Blakeslee Company.

APPENDIX IV

NOTES ON SYNCHROTRON RADIATION

A. The Geometry and Optics of Synchrotron Radiation

B. Criteria for Synchrotron Radiation–Absorbing Surfaces (SPEAR–41)

C. Critical Synchrotron Radiation–Absorbing Surfaces (SPEAR–156)

D. Synchrotron Radiation–Absorbing Surfaces (PEP–88)

E. Vacuum Chamber Cooling Water Requirements (PEP 76–5)

SLAC-PUB-1245
(A)
May 1973

THE GEOMETRY AND OPTICS OF SYNCHROTRON RADIATION*

A. P. Sabersky
Stanford Linear Accelerator Center
Stanford University, Stanford, California 94305

ABSTRACT

The geometrical-optical properties of synchrotron radiation coming from a curving, relativistic electron beam do not fit into any usual category of light or radiation source. The center of the apparent source of radiation depends on the position of the observer with respect to the orbit, and the source has an axial extent which is a function of the sizes of the beam and the observation aperture. The beam image formed by focusing the synchrotron light is subject to distortions and depth of field errors. These errors are calculated, and, in some cases, methods of correction are given. The limits put on resolution by geometrical effects are given. Beam orbit changes cause errors in the angular acceptance of observation systems: these effects can also be corrected. The dimensions of the diffuse shadows cast by rays from the finite-sized source impinging on edges are calculated.

(Submitted to Particle Accelerators.)

* Work supported by the U. S. Atomic Energy Commission.

INTRODUCTION

In high energy electron accelerators and storage rings, synchrotron radiation gives the machine designer many problems, and solves a few. This paper gives derivations of the properties of synchrotron light interesting to those who use synchrotron light to study electron beams in extent and intensity, and those who use the synchrotron light itself as a tool.

Geometric Properties

We concern ourselves with the problem of an observer at a point struck by synchrotron radiation. What point on the electron orbit illuminates the observation point, and how is the location of the emission point to be defined?

We first represent the electron beam as a single line and the emitted radiation as rays tangent to a curved orbit. We deal only with orbits in uniform magnetic fields and field-free spaces throughout. The observation point is in a field-free region adjacent to a sharply bounded bending field, in the plane of the bend. The geometry of the problem is shown in Fig. 1. In Appendix A, we derive equations for the emission distance ℓ and the angle with respect to the local straight trajectory, 2δ.

$$\delta = \tan^{-1}\left[\frac{-\ell_0-(\ell_0^2+d(2R+d))^{1/2}}{2R+d}\right] \approx \frac{-\ell_0-\left[\ell_0^2+2dR\right]^{1/2}}{2R} \qquad \text{for small } \delta \text{ and } R \gg d$$

$$\ell = \frac{d}{\sin 2\delta} + R\tan\delta \approx \frac{d}{2\delta} + R\delta$$

where the independent variables are

R = the radius of bend

ℓ_0 = the distance from the end of the curved orbit to a perpendicular from the observation point

d = the perpendicular distance from the observation point to the straight trajectory.

If one is using these equations in the design of synchrotron radiation shields or other systems it is very convenient to plot sets of solutions on a graph for reference.

When the orbit of the electron beam moves radially, the emission point moves also. We look at the case in which the orbit moves perpendicular to itself at the original emission point. For $\cos 2\delta \approx 1$, the changes in orbit position can be expressed as changes in d.

The change in emission distance, ℓ, with d is given by

$$\frac{\partial \ell}{\partial d} = \frac{R\left(\ell_0 + k^{1/2} - d \cdot R \cdot k^{-1/2}\right)}{\left(\ell_0 + k^{1/2}\right)^2} - R \cdot k^{-1/2} \qquad k = \ell_0^2 + 2dR$$

This quantity defines the slope of a line of emission points with respect to the original observation axis (Fig. 2). If $\partial^2 \ell / \partial d^2 \ll \partial \ell / \partial d$ in the region of interest, $\partial \ell / \partial d$ can be considered a constant. $\partial \delta / \partial d$ can be treated similarly. For the full emission angle, $\gamma = 2\delta$

$$\frac{\partial \gamma}{\partial d} = (\ell_0^2 + 2dR)^{-1/2} \qquad \tan 2\delta \cong \gamma$$

Since ℓ changes with d, the horizontal angular acceptance of an aperture at the observation point also changes with orbit displacements. The fractional change in aperture angle, $\alpha = s/\ell$ (Fig. 12), for a displacement Δd is:

$$\frac{\Delta\alpha}{\alpha} = -\frac{\Delta d}{\ell}\frac{\partial \ell}{\partial d} \qquad\qquad \Delta d\,\frac{\partial \ell}{\partial d} \ll \ell$$

This effect may be troublesome in photometric work. A method of correction is given in Appendix B.

Beam Image: Horizontal Component

A curved particle beam emitting a collimated cone of light tangent to its curvature is an unusual object for optical observation. We use the phase-space techniques commonly applied to charged particle optics[1] for analysis. We assume that defining apertures are rectangular, so that the ray optics can be treated separately in the horizontal and vertical planes.

Following the geometrical analysis of the previous section, we first treat a line beam emitting a single ray tangent to its curvature. We leave out the dependence of angle on time and assume that our observation system looks at all rays for all time. The optical axis is the ray passing through the center of the observation aperture (Fig. 3). The tangent point, T, is the point $x = 0$, $z = 0$, and angles are referred to the z axis, as shown. For example, we look at two points on opposite sides of T, T1 and T2 at an angle δ (Fig. 4). The tangent at T1 is projected forward to the $z = 0$ line, and the tangent at T2 is projected backwards. All tangents are similarly projected to $z = 0$. For small θ, the trace of the tangents on the $x - \theta$ plane at $z = 0$ is expressed by (see Fig. 5):

$$x = \frac{1}{2} R\theta^2$$

It is desirable to work at $z = 0$ because a linear transformation of this trace to another z results in a very complex function.

When a beam of electrons with a finite size, $\pm x_0$, and zero divergence is centered on the line beam of the previous section, the rays it emits fill an area whose boundaries are parallel to the original central ray line (Fig. 6). This area will be referred to as the source area.

Visible synchrotron light has a divergence angle in the horizontal plane, typically milliradians for ultrarelativistic electrons. The particle beam also has a finite divergence.* The total light divergence angle, θ_{tot}, is usually given as the quadratic sum of these two divergences. The total divergence has no effect on the intensity distribution in the source area if

$$\tfrac{1}{2}R\theta_{tot}^2 \ll x_0 \ .$$

We treat only this case.

A restricting aperture forms a pair of lines parallel to θ axis in phase space. The aperture edges can be transformed backwards or forwards along the optical axis to any other point, where they will also appear as a pair of parallel straight lines. We define an aperture $\pm a$ wide, symmetrical about the optical axis. The equations of the edges are, for the $+a$ and $-a$ edges, respectively,

$$x - a = 0$$

$$x + a = 0.$$

Transformed backwards a distance ℓ along the Z axis, the equations of the edges are

$$\theta + (x-a)/\ell = 0$$

$$\theta + (a-x)/\ell = 0$$

The two edges of the observation aperture, transformed back to the emission point, are superimposed on the source area (Fig. 7). In this case, the aperture

---

* We assume that the beam divergence is small enough so that its size is constant in the region of interest.

size (±a), is smaller than the beam size (±x).

We can now define exactly the boundaries of the source area seen through the aperture, and we need to know how accurately this source represents the horizontal beam cross-section. A typical optical observation device, such as a television camera or photographic film, looks at the intensity distribution in one plane perpendicular to the optical axis. All information about angular distribution or x, θ correlation is lost in this process. What we see is the projection of the distribution in (x, θ) onto the x axis.

If the beam were an ordinary self-luminous object, the boundaries of the light source area would be straight, parallel to the θ axis and symmetrical about $x = 0$.

However, looking at Fig. 7 as an example, we can see errors due to curvature and asymmetry of the source area boundaries. The magnitude of the error is approximately equal to the difference between x_0 and the projections of the four intersection points onto the x axis. An approximation to the total error, Δx_0, is given by

$$\Delta x_0 = R\left(\frac{x_0 + a}{\ell}\right)^2$$

If $\Delta x_0 \ll x_0$, we may forget about the distortions. Note that as the quantity a becomes very small, Δx_0 does not go to zero.

If the distortions are a problem, they can be partially compensated with second-order optics (Appendix C) or improved by increasing ℓ.

The treatment so far has been geometrical, and one must include diffraction effects when dealing with small horizontal apertures.

Shadow Effects

If the observation point is an edge, such as a protection collimator, the synchrotron radiation casts a shadow whose edge is tangential to the beam orbit (Fig. 8). The distribution of electrons in a real beam causes a penumbra to extend beyond the straight shadow edge cast by a line beam. The angular power distribution in the penumbra is related to the radial power distribution in the beam, exactly as the shadow angle is related to radial orbit displacements. The power distribution in a penumbra radially outward from an edge is determined by the beam power distribution radially inside the beam center line. For a radial beam current distribution P(r) the angular penumbral power distribution is

$$P(\text{angular}) = P(r) \frac{\partial \gamma}{\partial d}$$

For a Gaussian beam current distribution with standard deviation width x, the total power in the penumbra is

$$P(\text{penumbra}) = 1.25 \, P_\theta \frac{\partial \gamma}{\partial d}$$

where P_θ is the power per radian in the synchrotron radiation.

Beam Image -- Vertical

In this section we derive the vertical resolution of an ideal optical system used to observe the electron beam by its emitted light. Since the emission properties of the beam determine the ultimate resolution limit, rather than the properties of the optical system, we shall always refer to the resolution in object space.

An electron beam emitting synchrotron radiation is a self collimated luminous object. The angular divergence of the light in the vertical plane is a function of the bending radius and the energy of the electron beam. A useful, precise tabulation of synchrotron light properties can be found in Reference 2. The ultimate vertical resolution in the image is determined by the vertical angular divergence of the light, ϕ

$$\delta y_1 \approx \frac{\lambda}{\varphi}$$

neglecting polarization effects.

δy = resolution

λ = light wavelength

ϕ = angular width.

The electron beam has a finite divergence, and this should be properly added to the light divergence angle, for resolution and depth of field calculations; however, the beam divergence is usually small compared to the light divergence angle, and will be ignored.

For a beam with horizontal size x_0, each edge of the horizontal aperture defines a line which is a boundary of the horizontal emission area (Fig. 9). The other two edges have the curvature of the orbit. The angle subtended by an aperture of size a is

$$\theta = a \frac{\partial \theta}{\partial d}$$

Thus, the length of arc forming the curved boundary is

$$C = R \cdot a \cdot \frac{\partial \theta}{\partial d}$$

Treating the emission area as a parallelogram, the effective z extent of the horizontal emission area can be expressed, for small θ, as

$$\delta z = x_0 \frac{\partial \ell}{\partial d} + R \cdot a \cdot \frac{\partial \theta}{\partial d}$$

The depth field of error is

$$\delta y_2 = \delta z \cdot \phi$$

If all distributions of angle and intensity are Gaussian, the vertical resolution is given by

$$\delta y = \left[(\delta y_1)^2 + (\delta y_2)^2\right]^{1/2} \quad .$$

For a more exact formulation of the depth-of-field problem, one must consider the effect of the sharp edges of the emission area due to the aperture edges differently from the "soft" edges due to the beam-intensity distribution.

It is interesting that the vertical resolution depends on horizontal beam size and horizontal aperture.

It is possible to reduce the effect due to the beam horizontal size by placing a horizontal image stop in the image plane of the optical instrument (Fig. 10). The restricted image can be re-focused or the stop may be put slightly upstream of the image plane.

If the image is to be scanned with a slit, the slit may be tilted with respect to the optical axis so that it is parallel to the image of the line of emission points.

Acknowledgements

I wish to thank F. Bulos and H. Wiedemann for reading the manuscript.

APPENDIX A
SYNCHROTRON LIGHT GEOMETRY

Referring to Figure 11,

$$\ell_0 = \overline{AB}$$

$$\ell = \overline{EC}$$

$$d = \overline{CB}$$

$$m = \overline{EF} = \overline{FA}$$

$$m = R \tan \delta$$

$$\overline{FB} = \ell_0 - m$$

$$d = \overline{FB} \tan 2\delta$$

$$d = (\ell_0 + R \tan \delta) \tan 2\delta$$

let $x = \tan \delta$

$$\tan 2x = \frac{2x}{1 - x^2}$$

$$\frac{2x}{1 - x^2} (\ell_0 + Rx) = d$$

finally

$$\tan \delta = \frac{-\ell_0 - \left[\ell_0^2 + d(2R + d)\right]^{1/2}}{2R + d}$$

$$\ell_1 = \frac{d}{\sin 2\delta} + R \tan \delta$$

APPENDIX B

ACCEPTANCE ANGLE CORRECTION

The acceptance angle is $\alpha = s/\ell$ (refer to Fig. 12). The fractional change in acceptance is

$$\Delta\alpha/\alpha = \frac{\Delta d}{\ell} \cdot \frac{\partial \ell}{\partial d}$$

for

$$\Delta\ell = \Delta d(\partial \ell/\partial d) \ll \ell \; .$$

We shall use the proportionality between $\Delta\ell$ and $\Delta\gamma$ to correct the acceptance change. An optical system for correction is shown schematically in Fig. 13. The filter at the focal plane of the lens has a transmission profile for light

$$T(x) = \text{power (transmitted)/power(total)} \qquad 0 < T \leq 1$$

For an orbit distortion, d, the power at the aperture is

$$P_{(d)} = P \frac{s}{\ell - d\,(\partial\ell/\partial d)}$$

P = power radiated into 1 radian

The ray passes through the lens and reaches the filter at

$$x = -f\gamma = -f \cdot d \cdot (\partial\gamma/\partial d)$$

thus

$$d = -\frac{x}{f} \cdot \frac{\partial d}{\partial\gamma}$$

and P(d) expressed as power variation at the focal plane, P(x), is

$$P(x) = P \frac{s}{\ell - \frac{x}{f} \frac{\partial\ell}{\partial\gamma}}$$

where x is the ray deviation at the focal plane (Fig. 13). Now, we posit a constant power passed through the system, independent of d

$$P_0 = P(x) \cdot T(x) \; .$$

P_0 is the power transmitted when $\gamma = 0$, and

$$P_0 = P \cdot T_0 \cdot \frac{s}{\ell}$$

$$T_0 = T(x) \text{ at } x = 0.$$

T_0 is arbitrary, and can be chosen for convenience. Then,

$$T(x) = \frac{P_0}{P_x} = T_0 + \frac{T_0 x}{f \cdot \ell} \frac{\partial \ell}{\partial \gamma} .$$

APPENDIX C

CORRECTION OF THE PHASE-SPACE CURVATURE

We wish to straighten the boundaries of the source area by introducing corrections into the horizontal imaging system, assuming that the horizontal and vertical optical systems are separable. At the source, the distortion in each ray is an error in x, proprotional to θ^2. We need to transform the distribution of rays such that we have errors in θ, proportional x^2, then they can be corrected by a focussing device.

We use the optical system illustrated in Fig. 14. The lens f has focal length f.

The first order transformation matrix for this system, up to f', is

$$T = \begin{pmatrix} 0 & f \\ -1/f & 1-\ell/f \end{pmatrix}$$

We work with a single ray from the central trajectory, (X_0, θ_0), $x_0 = \frac{1}{2}R\theta_0^2$.

In front of f' we have the ray coordinates

$$x = f\theta_0$$

$$\theta = \beta\theta_0 - \frac{x_0}{f} = \beta\theta_0 - \frac{1}{2}\,\frac{R\theta_0^2}{f} \qquad \beta = 1 - \ell/f$$

If we were imaging a conventional point source instead of the curved central trajectory, $x\equiv 0$, and the second term would be zero. Since the second term is second order in θ_0, we need a second-order lens, which is described by the simplified second-order lens matrix

$$\begin{pmatrix} 1 & 0 \\ -\frac{1}{k} & 1 \end{pmatrix} \cdot \begin{pmatrix} x_i^2 \\ \theta_i \end{pmatrix} = \begin{pmatrix} x_f \\ \theta_f \end{pmatrix}$$

where $1/k$ is the strength of the second-order element.

At the exit of the second-order lens we have

$$x = f\theta_0$$

$$\theta = \beta\theta_0 - \frac{1}{2} \frac{R\theta_0^2}{f} - \frac{f^2\theta_0^2}{k}$$

In order to eliminate all second-order terms,

$$\frac{1}{2} \frac{R\theta_0^2}{f} + \frac{f^2\theta_0^2}{k} = 0$$

thus

$$k = -2f^3/R$$

A conventional (first order) thin lens transforms rays such that

$$\theta = -\frac{x_0}{f}$$

A thin second-order lens has the characteristic

$$\theta = -\frac{x_0^2}{k}$$

This lens may be realized by grinding a reflecting or refracting surface to a third-order curve $Z \propto x^3$ (Fig. 15).

We look at the image in its normal position (Fig. 14).

REFERENCES

1. For example, A. P. Banford, The Transport of Charged Particle Beams (E. & F. N. Spon, Ltd., London, 1966).
2. R. A. Mack, "Spectral and angular distributions of synchrotron radiation," Report No. CEAL-1027, Cambridge Electron Accelerator Laboratory (1966).

FIGURE CAPTIONS

1. Basic geometry of synchrotron radiation emission and observation.
2. Definition of the optical axis and line of emission points.
3. Coordinates for phase space representation of the light source.
4. Projection of tangent rays to the source plane.
5. Phase-space representation of the light source at $z = 0$.
6. Light source area.
7. A distant aperture transformed backwards onto the source area.
8. Shadow effects due to finite beam size.
9. Horizontal emission area of a beam observed through an aperture.
10. A system which limits depth-of-field error due to horizontal beam size.
11. Detailed geometry of synchrotron radiation emission and observation.
12. The change in acceptance angle due to horizontal orbit distortions.
13. An optical system which corrects errors in the angular acceptance of a photometric system due to horizontal orbit distortions.
14. An imaging optical system which corrects errors in the horizontal plane due to source curvature.
15. A second-order focusing element.

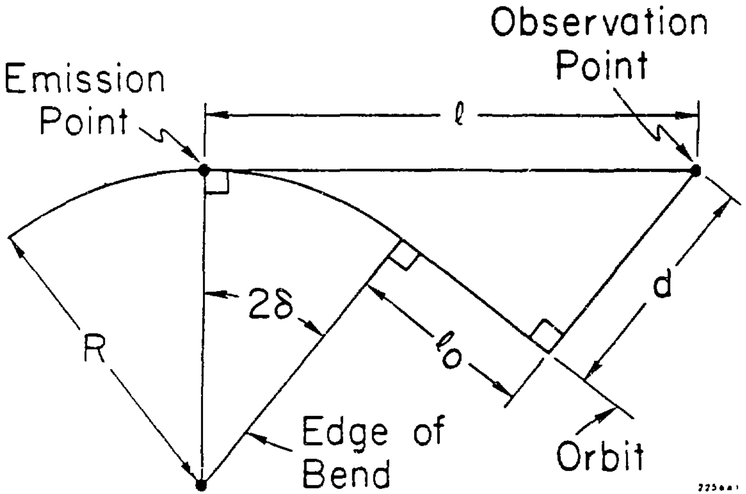

Observation
Point
Emission
Point
ℓ
2δ
R
d
ℓo
Edge of
Bend
Orbit

Fig. 1

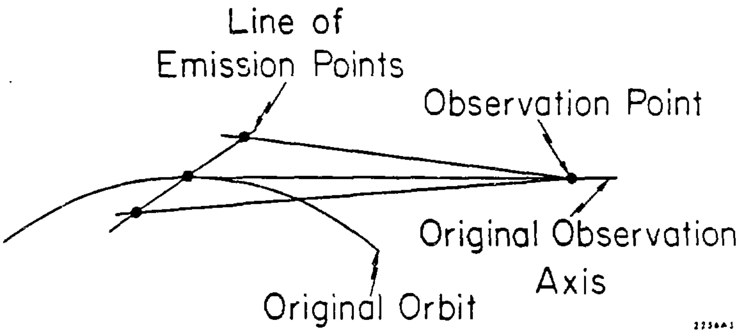

Line of
Emission Points
Observation Point
Original Observation
Axis
Original Orbit

Fig. 2

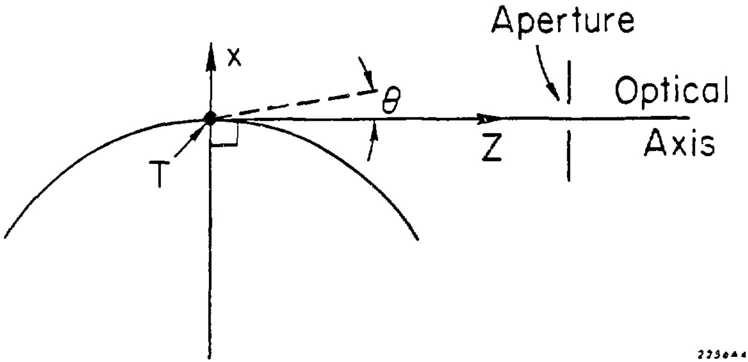


Fig. 3

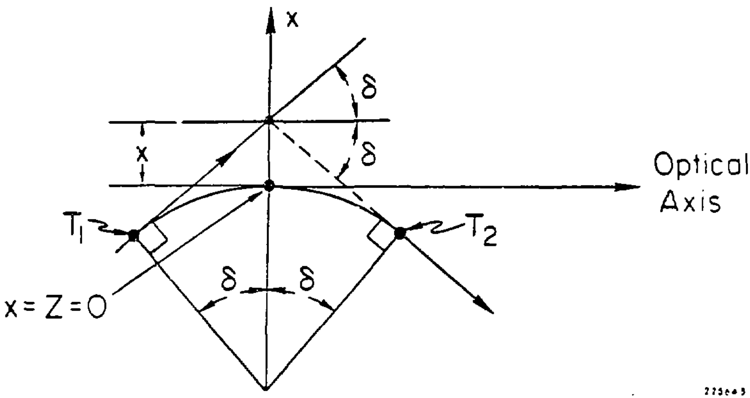


Fig. 4

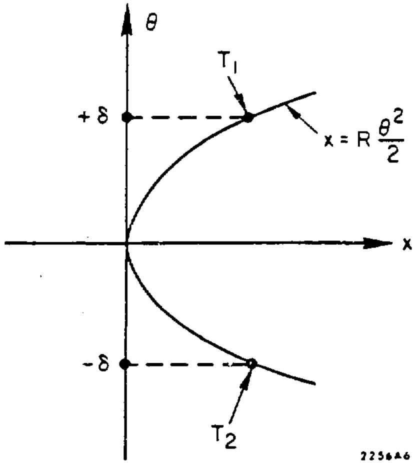


Fig. 5

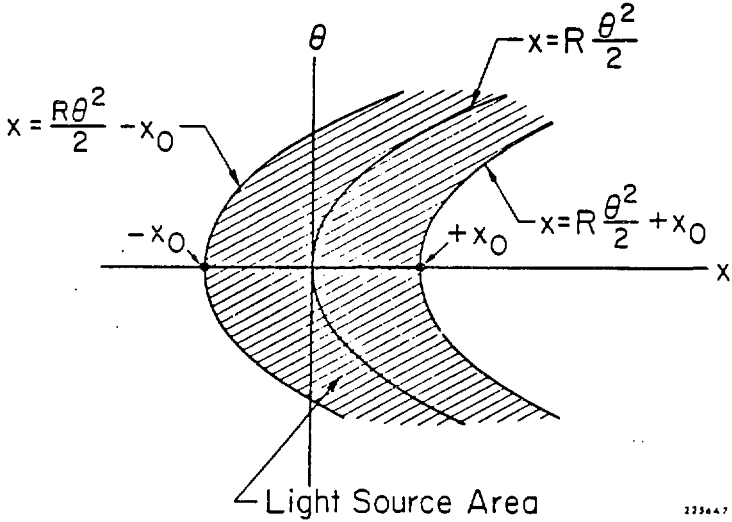


Fig. 6

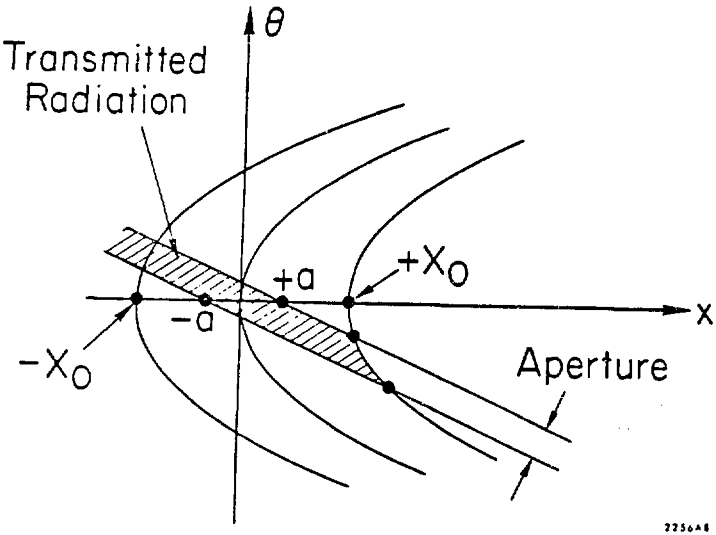


Fig. 7

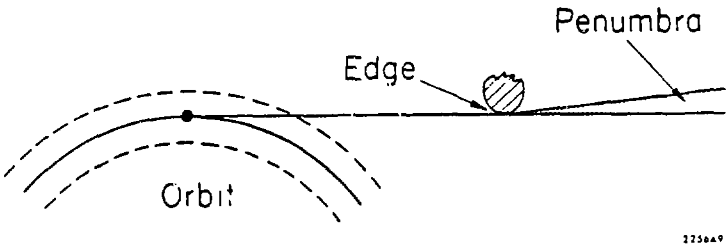


Fig. 8

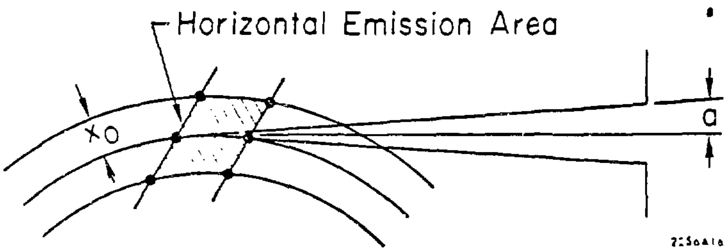


Fig. 9

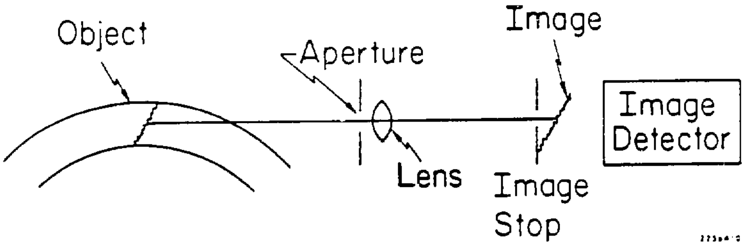


Fig. 10

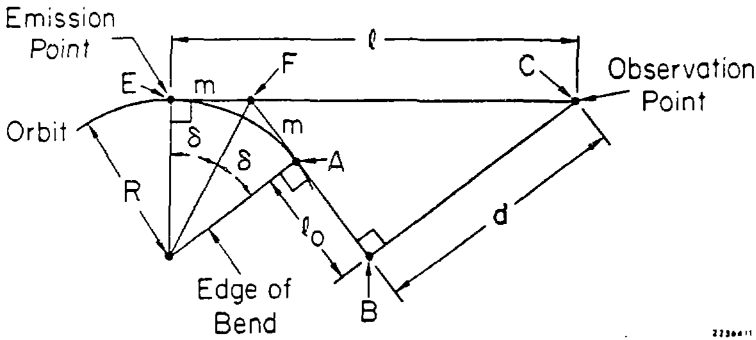
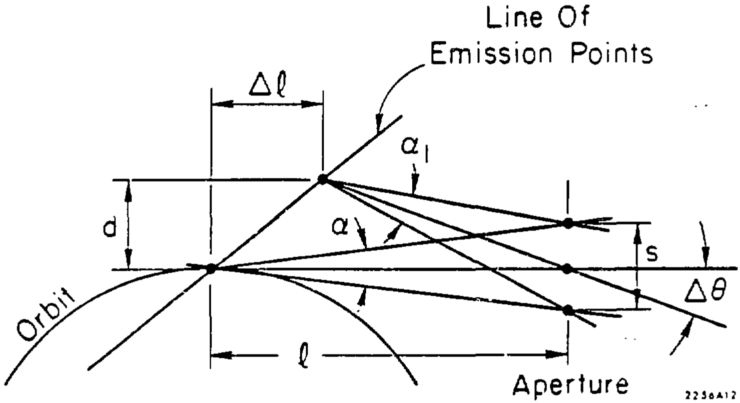

Emission
Point
E
m
F
ℓ
C
Observation
Point
Orbit
δ
m
δ
A
R
ℓo
d
Edge of
Bend
B
2236A11

Fig. 11



Line Of
Emission Points
Δℓ
α₁
d
α
s
Δθ
Orbit
ℓ
Aperture
2256A12

Fig. 12

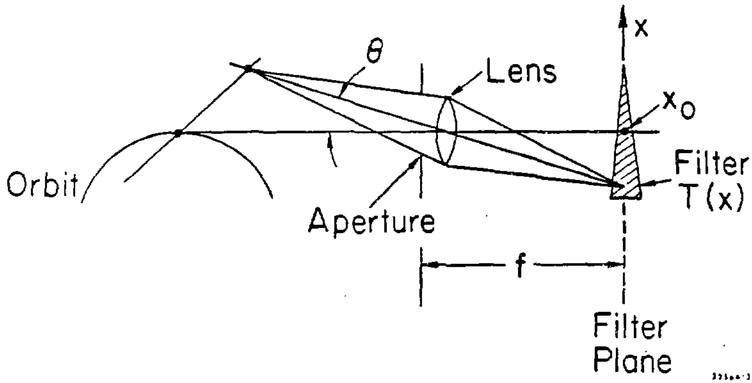


Fig. 13

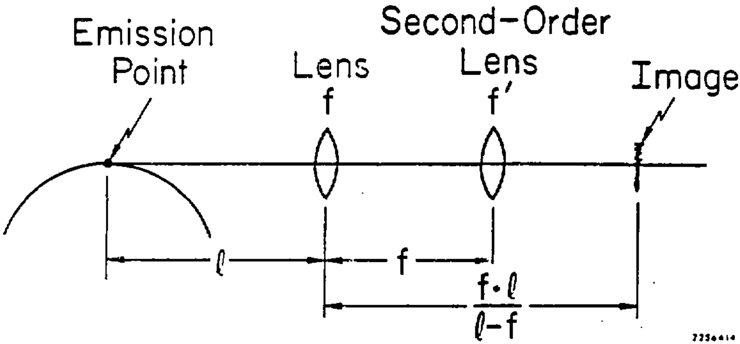


Fig. 14

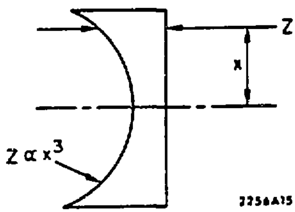


Fig. 15

SPEAR-41
J. Jurow
11-17-70

Criteria for Synchrotron Radiation-Absorbing Surfaces

All surfaces which can tangentially "see" the electron beam orbit are subject to synchrotron radiation. The heat flux which must be dissipated by such surfaces may be quite intense and represents a potentially catastrophic hazard to the operation of the storage ring. In almost all cases, the radiation-absorbing surfaces must be water-cooled and conservative design criteria are necessary to minimize the danger of opening a water leak into the vacuum chamber. In addition, intense radiation fluxes may represent high local gas loads due to both thermal outgassing and electron desorption.

The rate of energy lost per turn by a circulating electron is given by Schwinger:[1]

$$\delta E = 88.5 E^4 / R \quad ,$$

where

δE = energy lost per turn in keV

E = beam energy in GeV

R = magnetic radius in meters

Hence, for a single 2-GeV, 0.5-A, beam at SPEAR, the total power radiated will be:

$$P = 88.5 \times 2^4 \times 0.5/12.72 = 55.7 \text{ kW} \quad .$$

With an average geometric radius of approximately 31.5 meters, the average linear power flux to be absorbed is:

$$\acute{P}_{av} = \frac{55.7 \times 10^3}{2\pi \times 31.5 \times 10^2} = 2.8 \text{ watts/cm} \quad .$$

However, the local linear power flux depends on the angle at which the radiation strikes the absorbing wall. If the wall were normal to the radiation, the linear flux would be as high at 70 watts/cm.

For the water-cooled walls of the vacuum chamber modules, the maximum linear flux has been calculated to be 6.9 watts/cm for one beam and 9.3 watts/cm for both beams. For a straight section parallel to the beam line, the maximum linear flux would be 5.5 watts/cm for both beams.

In order to calculate the actual heat flux to be dissipated at the absorber surface, it is necessary to know the "height" of the synchrotron radiation strip at the surface. This height is a function of the beam height and the synchrotron radiation.

Schwinger[1] gives the angular extent of the beam as approximately

$$\chi = \frac{m_0 c^2}{E}$$

where

χ =angle with the orbital plane

E in MeV at 2.0 GeV

$$\chi = \frac{0.51}{2 \times 10^3} = 0.25 \times 10^{-3} \text{ rad} \quad .$$

Tables for calculating the angular distributions are given by Mack.[2] Two calculations from these tables show tht 92% of the 2770-eV photons lie within 0.18×10^{-3} rad and 90% of the 275-eV photons lie within 0.44×10^{-3} rad. We should use the equation given by Schwinger as a design basis.

The height of the heated stip may be estimated as:

$$h = 2(y + \chi d)$$

where

y = half beam height

χ = angular dispersion in radians

d = tangential distance from the beam centerline to the absorbing surface

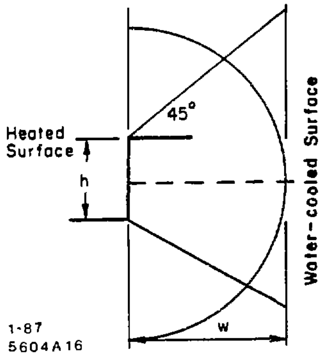
For the curved chamber wall, $d \approx 125$ cm, and $y \to 0$ for the natural beam height:

$$h = 2 \times 0.25 \times 10^{-3} \times 125 = 0.625 \text{ mm} \quad ,$$

$$Q = \frac{\acute{P}}{h} = \frac{9.3}{0.0625} = 150 \text{ watt/cm}^2$$

and 1120 watts/cm^2 for a surface perpendicular to the synchrotron radiation at the chamber wall.

Having established the heat flux to be dissipated, we may now calculated, or rather estimate, the temperature difference between the cooling water and the inner surface of the absorber. In lieu of attempting to solve the heat equation, we may estimate that all heat is transferred within the region bounded by the 45° lines shown in Fig. 1. In this case, the temperature difference across the metal wall is given by:



$$\Delta T = \frac{q}{2k} \int_0^w \frac{dx}{h + 2x} = \frac{q}{2k} \ell n \left(\frac{h + 2w}{h} \right) \quad .$$

For a 0.635-cm thick aluminum wall and a 0.1-cm wide heated strip:

$$k = 2.2 \text{ watts/cm}^\circ\text{C}$$

$$w = 0.635 \text{ cm}$$

$$h = 0.0625$$

$$q = 10.0 \text{ watts/cm}$$

$$\Delta T_m = \frac{10}{2 \times 2.2} \ell n(21.3) = 7.0^\circ\text{C}$$

Some justification for this approximation is given in previous heat transfer calculations,[3] where it was shown that the solution of the heat equation could be approximated by assuming that all the heat is transferred in the region bounded by the half-cylinder shown in Fig. 1. In this case, the temperature difference is given by:

$$\Delta T_m = \frac{q}{\pi k} \ell n \left(\frac{2w}{h} \right)$$

and for h considerably smaller than $2w$, this approximation gives a temperature difference 30% smaller than the value calculated above.

The temperature difference between the water and the absorber wall is given by:

$$\Delta T_f = \frac{q}{h_f A} \quad .$$

A reasonable value for the coefficient of heat transfer, h_f, is 0.8 watts/cm^2 °C for water flowing at 6.5 ft/sec.

$$A = 2w + h = 1.33\ \text{cm}^2$$

$$\Delta T_f = \frac{10}{.8 \times 1.33} = 9.6°\text{C} \quad .$$

The total temperature difference between the water and the inner wall of the absorber is, then, $\Delta T = 17°\text{C}$.

These calculations show that the design for the radiation absorbers within the extruded aluminum vacuum chambers is quite conservative. Even if the RF power is doubled, and adding a factor of 20% which is usual in heat transfer calculations, the temperature difference would still be less than 36°C.

It should be noted that the heat flux at the inside surface of the absorbing surface is 150 watts/cm^2. Based on extensive tests,[4,5] the maximum local heat flux used in the design of beam dumps, scrapers, and collimators for the accelerator was 1.0 kW/cm^2.

The criteria established above should also be used for radiation masks and absorber walls of different materials. For instance, a surface which sees a linear flux of 70 watts/cm at a distance of 1.25 meters from the beam orbit would have local heat flux of 1120 watts/cm^2 and a temperature difference of 96°C.

In summary, the following criteria are proposed for all radiation-absorbing surfaces:

1. No aluminum welds between water-cooled passes and vacuum chambers.

2. The linear power flux:

$$\acute{P} = \frac{88.5 \times 10^3 E^4 I \sin\alpha}{2\pi R d}$$

where

$\acute{P}$ = power in watts/cm

E = beam energy in GeV

I = beam current in amps

d = tangential distance between absorber and beam orbit in cm

α = angle between the surface and the synchrotron radiation

R = magnetic radius in meters

3. The height of the heated area:

$$h = 2(y + \chi d)$$

where

h = height

y = half beam height = 0 cm

χ = radiation dispersion from centerline

= $m_0c^2/E = 0.25$ milliradians at 2 GeV

d = tangential distance between absorber beam centerline

4. A safety factor of 50%.

5. A factor of 2 allowance for increase in RF power.

6. Maximum heat flux related to the heat surface (to be used only for very carefully controlled situations with proper allowance for erosion, buildup of deposits, thermal stress, and so on).

$$\emptyset_{\max} = 1.0\,\mathrm{kW/cm^2}\quad .$$

Postscript: at 3 GeV and 150 kW/beam:

$$\delta E = \frac{88.5 \times 81}{12.72} = 567\ \text{keV}$$

$$I = \frac{150\ \text{kW}}{567\ \text{keV}} = 0.265\ \text{amps}$$

$$\chi = \frac{0.51}{3 \times 10^3} = 0.17 \times 10^{-3}\ \text{rad}$$

$$h = 2 \times 0.17 \times 10^{-3} \times 125 = 0.425\ \text{mm}$$

$$\acute{P}_{max} = 26\ \text{watts/cm}$$

$$Q = \frac{26}{0.0425} = 610\ \text{watts/cm}^2$$

$$\Delta T_m = \frac{26}{2 \times 2.2} \ell n \left(\frac{1.313}{0.0425} \right) = 18^\circ\text{C}$$

$$\Delta T_f = \frac{26}{.8 \times 1.31} = 25^\circ\text{C}$$

$$\Delta T = 43^\circ\text{C}$$

The margins are getting tight.

References

1. J. Schwinger, *On Classical Radiation of Accelerated Electrons,* Phys. Rev. **75**, 1912 (1949).

2. R. Mack, *Spectral and Angular Distributions of Synchrotron Radiation,* CEAL-1027 (1966).

3. E. Garwin and J. Jurow, *Preliminary Heat Transfer Design of a Beam Scraper,* SLAC-TN-63-68 (1963).

4. J. Jurow, *Some Corrosion Effects on Aluminum at High Heat Transfer Rates,* SLAC-TN-64-71 (1964).

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SPEAR–156
J. Jurow
7 February 1973

Critical Synchrotron Radiation-Absorbing Surfaces

One of the ultimate limits for upgrading the SPEAR beam parameters is the cooling capacity of the vacuum-chamber wall and the various beam scrapers. The design criteria for cooling the chamber walls were derived in SPEAR–41.[1] In this note we calculate and compare the heat flux and temperature rise on the chamber walls, the synchrotron-light-beam port scraper, and the septum scraper. Table 1 gives the results for a 4.2–GeV beam with a total of 200 kW radiated by each beam.

Table 1.

	Wall	Synch. Port	Septum
Linear flux (watts/cm)	33	53	66
Flux (watts/cm^2)	1100	725	1300
Metal temperature rise (°C)	28	107	85
Water temperature rise (°C)	33	30	41
Total temperature rise °C)	61	137	126
Temperature (°C)	101	177	166

Linear Power Density (see Fig. 1)

The synchrotron-light power emanating from the arc "s" on the beam orbit is equal to $S \times P_T/2\pi R$, where P_T is the total power radiated around the ring, R is the magnetic radius, and s is the arc length.

Since $\delta/d = s/R$ and α is the angle between the absorbing surface and the synchrotron ray, we have

$$\acute{P} = \frac{P_T \sin \alpha}{2\pi d} \quad ,$$

where $\acute{P}$ is the linear power density and d is the distance to the absorbing surface.

Flux

The angular dispersion of the synchrotron light is[2]

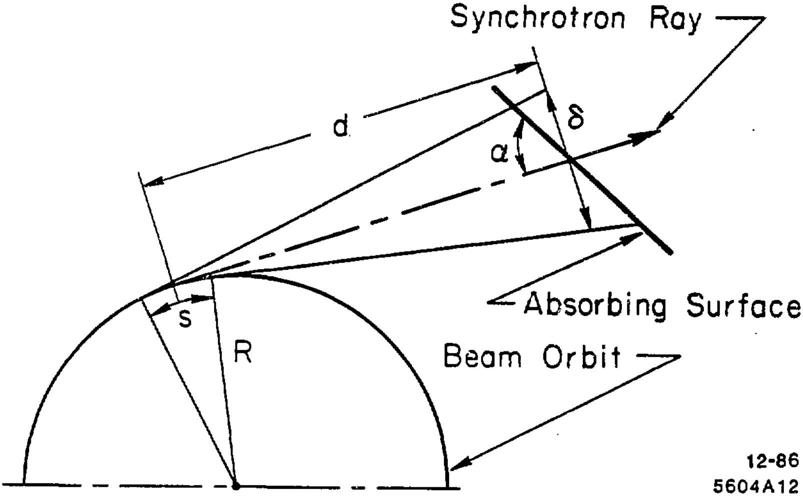
$$\chi = \frac{mc^2}{E} = \frac{.051 \times 10^{-3}}{E} \quad ,$$

where χ is the angle with the orbital plane in radians and E is the beam energy in GeV.

The width of the heated strip is $h = 2\chi D$.

The heat flux is $\emptyset = \acute{P}/h$.

FIGURE 1


Synchrotron Ray
d
δ
α
Absorbing Surface
s
R
Beam Orbit
12-86
5604A12

Water Temperature

The temperature rise between the water and the wall is

$$\Delta t_f = \frac{\acute{P}}{h_f A} \quad ,$$

where h_f is the coefficient of heat transfer, 0.8 watt/cm^2 - °C for a flow of 6.5 ft/sec, and A is the cooling area, cm^2.

The temperature of the cooling water is 40°C.

Synchrotron Port

The distance to the mask d is 300 cm and the mask angle α is 30 degrees. Hence, the linear power density is

$$\acute{P} = \frac{200 \times .05 \times 10^{-3}}{2\pi \times 300} = 53 \text{ watts/cm} \quad .$$

The angular dispersion is

$$\chi = \frac{0.51 \times 10^{-3}}{4.2} = 0.121 \text{ mrad} \quad .$$

The strip width at the mask is then

$$h = 2 \times 0.121 \times 10^{-3} \times 300 = 0.073 \text{ cm} \quad .$$

The heat flux is therefore

$$\emptyset = \frac{53}{0.073} = 725 \text{ watts/cm}^2 \quad .$$

A view of the synchrotron-light port scraper is given in Fig. 2a. The cross section in Fig. 2b defines the heat-transfer problem. The heat is deposited along line "B" and is conducted to the water passage "W." The temperature rise in the region $\Delta \acute{t}_m$ is given by

$$\Delta \acute{t}_m = \frac{q}{mk} \ln(b/a) \quad ,$$[1]

where q = linear heat flux, 26.5 watts/cm, k = thermal conductivity, 2.2 watts/cm–°C, a = 0.3 cm, L = 1.0 cm, b = 1.1 cm, m = (b - a)/L = 0.8.

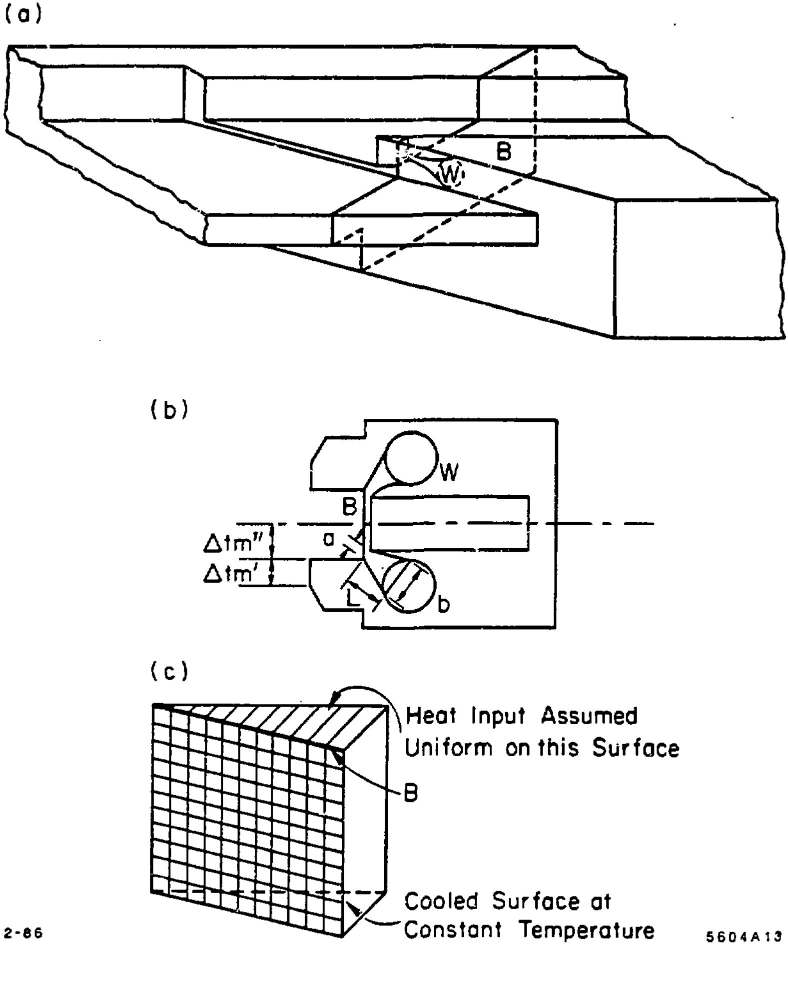
Hence,

$$\Delta \acute{t}_m = \frac{26.5}{0.8 \times 2.2} \ln \frac{1.1}{0.3} = 19.5°\text{C} \quad .$$

The heat transfer in the region $\Delta\ \tilde{t}_m$ is somewhat more complicated, since it involves a wedge-shaped section as shown in Fig. 2c. The temperature rise in this region was calculated by dividing the region into 121 squares and writing the simultaneous equations for the heat balance at each square. The results of the computer calculation show that the temperature rise will be 87°C. The temperature rise between the water and the metal is

$$\Delta t_f = \frac{26.5}{0.8 \times 1.1} = 30°\text{C} \quad .$$

FIGURE 2


(a)
B
W
(b)
W
B
$\Delta tm''$
$\Delta tm'$
a
L
b
(c)
Heat Input Assumed
Uniform on this Surface
B
Cooled Surface at
Constant Temperature
12-86
5604A13

Vacuum-Chamber Wall

The linear power density for a 56-kW beam is 9.3 watts/cm.[1] Therefore, the power density at 200 kW will be

$$\acute{P} = 9.3 \times \frac{200}{55.7} = 33.4 \text{ watts/cm} \quad .$$

The wall is 125 cm from the origin of radiation and the strip width is

$$h = 2 \times 0.121 \times 10^{-3} \times 125 = 0.0302 \text{ cm} \quad .$$

The heat flux is

$$\emptyset = \frac{33.4}{0.0302} = 1100 \text{ watts/cm}^2 \quad .$$

The temperature rise in the metal is

$$\Delta t_m = \frac{33.4}{2 \times 2.2} \ln\left(\frac{2 \times 0.0635}{0.0302}\right) = 28.4°\text{C} \quad .$$

The temperature rise in the water is

$$\Delta t_f = \frac{33.4}{0.8 \times 2 \times 0.635} = 33°\text{C} \quad .$$

Septum Mask

The mask is 204 cm from the origin of the radiation and is at an angle of 25° from the ray. The linear power density is

$$\acute{P} = \frac{200 \times 10^3 \sin 25}{2\pi \times 204} = 66 \text{ watts/cm} \quad .$$

The strip width is

$$h = 2 \times 0.121 \times 10^{-3} \times 204 = 0.0495 \text{ cm} \quad .$$

The heat flux is

$$\emptyset = \frac{66}{0.0495} = 1330 \text{ watts/cm}^2 \quad .$$

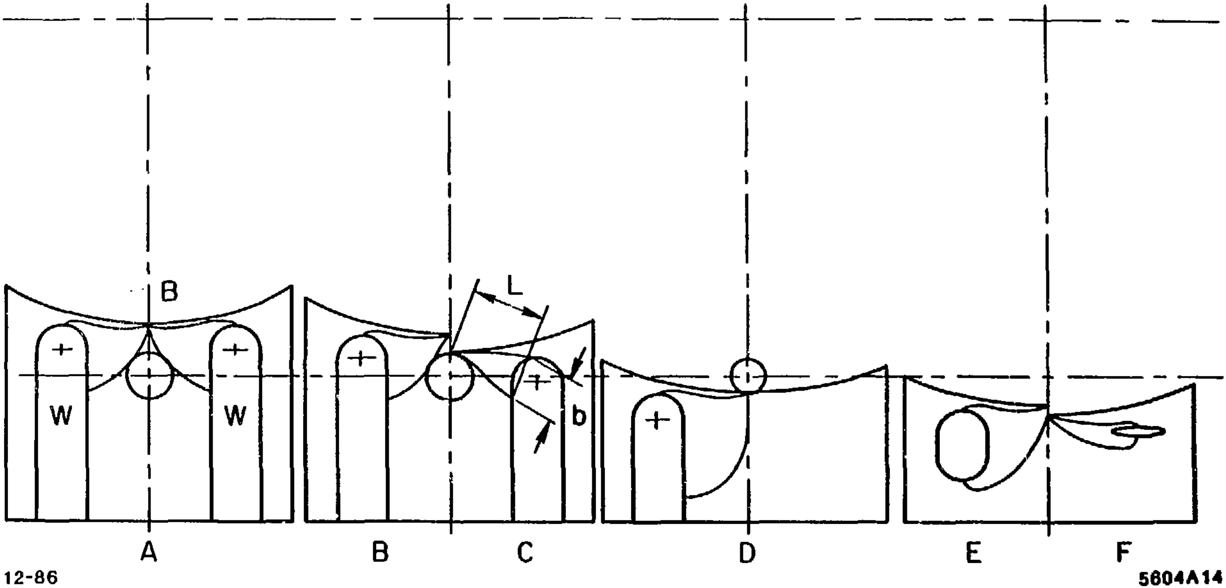
Cross sections through the septum mask are shown on Fig. 3. The critical cross section is 3c, where a = h/2 = 0.0248 cm, L = 1.5 cm, b = 1.0 cm, q = 66/2 = 33 watts/cm, m = (1.0 - 0.03/1.5) = 0.65, Δt_m = 33/(0.65 × 2.2) ln 1.0/0.0248 = 85°C.

The temperature rise in the water is

$$\Delta t_f = \frac{33}{0.8 \times 1.0} = 41.3°\text{C} \quad .$$

If the heat transfer were strictly two-dimensional, the condition shown in Fig. 3f would be even more severe. No attempt has been made to solve the three-dimensional problem represented by Figs. 3e and 3f.

FIGURE 3



References

1. J. Jurow, *Criteria for Synchrotron Radiation-Absorbing Surfaces,* SPEAR-41 (1970).

2. J. Schwinger, *On Classical Radiation of Accelerated Electrons,* Phys. Rev. **75**, 1912 (1949).

PEP–88
J. Jurow
N. Dean
July 1974

Synchrotron Radiation–Absorbing Surfaces

The design criteria, formulas and parameters for heat transfer at the surfaces which must absorb the power of the synchrotron radiation are summarized in this note. The formulas have been derived in Refs. 1 and 2.

The linear power flux is given by

$$\acute{P} = \frac{P_T \sin\alpha}{2\pi d} \quad ,$$

where

$\acute{P}$ is the linear power flux;

P_T is the total power radiated;

α is the angle between between the radiation and the absorbing surface;

d is the distance from the origin of radiation to the absorbing surface.

The width of the heated strip is

$$H = d \times 10^{-3}/E \quad ,$$

where

H is the width of the heated strip;

E is the beam energy in GeV.

The temperature rise across the metal wall is

$$\Delta T_m = \frac{\acute{P}}{2k} \ell n \left(\frac{H + 2w}{H} \right) \quad ,$$

where

ΔT_m is the temperature rise in °C across the metal wall;

k is the conductivity in watts/cm–°C;

w is the thickness of the wall in cm.

The temperature rise at the cooling water film is

$$\Delta T_f = \frac{\acute{P}}{2\mathrm{h\ w}} \quad ,$$

where

ΔT_f is the temperature rise in °C of the cooling water film;

h is the coefficient of heat transfer in watts/cm²–°C.

The heat flux on the water side of the wall is

$$\emptyset_c = \frac{\acute{P}}{2\mathrm{w}} \quad .$$

The values of the parameters used are

k 2.2 watts/cm–°C for aluminum;

h 0.8 watts/cm²–°C for water flowing at about 2 meters/sec.

Implicit in these formulas are the following assumptions

1. The particle beam is a line source of synchrotron radiation and the height of the heated strip is due solely to the natural beam divergence.
2. The heat path through the metal diverges at 45°.

3. At no time will the water temperature be high enough to result in local boiling.

Calculated results are shown in Table 1. Column A is for the extruded chamber wall with two-beam operation at 2.6 MW/beam. Column B is for the extruded chamber wall with one beam at 5.2 MW. Columns C and D are for typical masks with two beams at 2.6 MW/beam. Column E is for the mask with one beam at 5.2 MW. Column F is an example of a severe application on SPEAR II.

The results show an adequate margin of safety in the thermal design of the extruded vacuum chamber walls. The maximum metal temperature on the vacuum side of the wall will be 148°C. The maximum water temperature at the metal surface will be 83°C. The cooling surface heat flux will be 30 w/cm^2, which is less than 1/3 of normal boiling fluxes.

Due to the fact that the angle of incidence of the synchrotron radiation at the masks is much greater than for the extruded chamber, design conditions for the masks are much more severe. Column C shows that with a 1-cm-thick wall, the water temperature at the metal surface would be 173°C; that is, 23°C below boiling at 14 atm. Due to the possibility of local pressure fluctuations and other transient conditions, we consider this margin to be inadequate.

Given the conductivity of the metal and the coefficient of heat transfer of the water, we may calculate the wall thickness which minimizes the metal temperature to be 2.75 cm. The results are shown in Column D. It should be noted that the metal temperature is significantly higher than will be experienced at SPEAR II.

For comparative purposes, Column F shows the calculated hottest spot for SPEAR II located at the mask for the Stanford Synchrotron Radiation Project light port and shows the calculated metal temperature to be 148°C.

References

1. J. Jurow, *Criteria for Synchrotron Radiation-Absorbing Surfaces*, SPEAR-41 (1970).

2. J. Jurow, *Critical Synchrotron Radiation-Absorbing Surfaces*, SPEAR-156 (1973).

Table 1.

	A PEP Wall	B PEP Wall	C PEP Mask	D PEP Mask	E PEP Mask	F SPEAR II SSRP
Energy (GeV)	15	15	15	15	15	4.2
Power/beam (MW)	2.6	5.2	2.6	2.6	5.2	0.15
No. of beams	2	1	1	1	1	1
Angle	30 mr	30 mr	15 deg	15 deg	15 deg	30 deg
Distance (cm)	438	530	500	500	500	300
Linear Flux (w/cm)	46	70	213	213	426	40
Strip Height (mm)	.29	.35	.33	.33	.33	.73
Wall Thickness (cm)	1	1	1	2.75	2.75	1
Flux (w/cm^2)	23	30	53	53	106	18
Metal Temp. Rise (°C)	45	65	198	247	494	80
Water Temp. Rise (°C)	26	43	133	48	96	23
Supply Temp. (°C)	30	30	30	30	30	40
Bulk Temp. Rise (°C)	10	10	10	10	10	5
Water Temp. (°C)	66	83	173	88	136	68
Metal Temp. (°C)	111	148	371	335	630	148

Boiling fluxes vary from 150 to 900 w/cm^2.

Boiling temperature at 14 atm = 196°C.

Stanford Linear Accelerator Center — Stanford University

ENGINEERING NOTE

STATUS	SUBJECT CODE	FILE NO
	PEP/VAC	76-5

AUTHOR
Jurow, J.

DATE: Sept. 14, 1976 — PAGE 1 OF 2

PROJECT—JOB
PEP Vacuum Note

TITLE
Vacuum Chamber Cooling Water Requirements

Reevaluation of vacuum system cooling water requirements for 55 MA/Beam ring current (1.5 MW/Beam).

It is assumed that all the snychrotron radiation power is absorbed by the cooling water system.

Criteria for establishing cooling water flow:

1. Sufficient velocity to insure good heat transfer.

2. Sufficient mass flow to hold the bulk temperature rise to less than 10°C.

3. Large enough flow passages and piping to insure that the pressure drop is reasonable.

The extrusion flow passage area is 1cm x 3cm.

The calculated coefficient of heat transfer is 0.8 w/cm^{2}°C for a velocity of 1.5 m/sec. Since 0.8 w/cm^{2}°C is the design value for calculating the thermal conditions of the absorbing chamber wall, the minimum velocity should be 1.5 m/sec.

A velocity of 1.5 m/sec through a 3.0 cm^2 flow passage yields a ring flow of 43.2 1/sec. The temperature rise for this flow and 3 mw of synchrotron power is 16.6°C which is too high.

A temperature rise of 10°c plus a 10% margin gives a flow of 78.9 1/sec for the ring or 13.2 1/sec per sextant. Scaling the flow required for the wiggler (or symmetry section) requires an additional 4.2 1/sec per sextant. The insertions will require 4 x 1.5 1/sec. The total flow for the ring would then be 140.4 1/sec. We round this up to 150 1/sec.

The velocity through the extruded passage will be 2.74 m/sec and the calculated pressure drop through each extrusion will be 1.85 Atm. (This compares reasonably with the scaled pressure drop through the SPEAR extrusions). The pressure drop through 5/8" tubing, 1/2" piping, valves and fittings between the headers and the chambers will be 2.71 Atm. The total calculated pressure drop is 4.5 Atm. We add 20% margin to give a design pressure drop of 5.5 Atm which is a reasonable value.

The present Conventional Facilities Specifications show 6" distribution headers in the tunnel and 8" riser up to the utility pads. For the flows given above, the velocity in the 6" pipes would be 4.2 fps, the pressure drop would be less

FILE NO.

than 1 psi/100 ft. If the pipe size were reduced to 4", the velocity would be 9.5 fps and the pressure drop would be 6.6 psi/100 ft. or 24.8 psi for the header. This velocity is excessive and the pressure drop is probably costly. It is recommended that the header sizes remain at 6".

Reducing the riser size to 6" from 8" would increase the velocity from 4.8 fps to 8.4 fps and the pressure drop from 0.83 psi/100 ft. to 1.31 psi/100 ft. The velocity is marginally high and consideration could be given to reducing the size.

It should be noted that the SPEAR water system was originally designed for a nominal 10 gpm per girder or 180 gpm for the ring. Due to changes in straight section configuration, additional demands such as SSRP and variations in modified piping, the latest flow measured was 266 gpm, an increase of 48%.

APPENDIX V

BAKEABLE VALVE CLEANING PROCEDURE

PROJECT—JOB PEP VACUUM NOTE (Revised 12-5-86)

TITLE 1 1/2" BAKEABLE VALVE CLEANING PROCEDURE (for Varian part #951-5027)

I. GASKET REMOVAL

1. Remove valve from box or container. Wear clean gloves. (Note 1)
2. Inspect valve;
   a) Check for scratches and nicks, especially on knife edge.
   b) Check for any obvious damage or contamination.
3. Place clean aluminum foil on flange "B".
4. Clamp valve securely in vise. (Note 2)
5. Open valve. (use torque wrench at first)
6. Remove valve gasket with clean gasket removal tool.
7. Place aluminum foil on flange "A".
8. Back drive socket out until last thread is even with valve body. Remove any excess thread lubricant that is on drive socket using clean acetone.
9. Crank drive socket to a half way in position. (Note 3)

II. RINSING

1. Rinse using clean acetone. (Note 4)
2. Hold aluminum foil tightly on flange "A" so that solvent will not leak out.
3. Pour approximately 50cc's of solvent into valve through flange "B".
4. Cover flange "B" tightly with aluminum foil. Swirl and agitate solvent in valve.
5. Pour solvent out of valve through flange "A".
6. Place new aluminum foil on flanges.
7. Repeat steps II 2 - II 6 using clean freon.
8. Repeat steps II 2 - II 6 using clean alcohol.
9. Be sure that new aluminum foil has been placed on flanges after final rinse.

TITLE 1 1/2" BAKEABLE VALVE CLEANING PROCEDURE

III. BAKING

1. Remove foil from flange "A" and attach to baking manifold with a clean gasket. (Note 1) (Bolts should only be tightened enough to insure that knife edges are uniformly in contact with the gasket.)
2. Make sure that the aluminum foil is loosely wrapped on flange "B".
3. Put entire assembly in oven and attach clean copper line to manifold.
4. Set up heavy dry nitrogen purge through manifold.
5. Bake entire manifold at 150°C for 3 to 4 hours.
6. After baking let valves cool for 3 hours.
7. Stop nitrogen purge.
8. Remove from manifold and place aluminum foil on flange "A". Store in clean room. (Note 1)

IV. GASKET INSTALLATION

1. Clamp valve securely in vise. (Note 2)
2. Remove foil from flange "A". Using tweezers "Cleaned for Vacuum" place a new "Cleaned for Vacuum" valve gasket into piston.
3. Make sure that gasket is straight in piston.
4. Close valve and torque to 50 ft. - lbs. to seat copper valve gasket. (Make sure there are absolutely no contaminants on seat or gasket.)
5. Open valve. Check that seat is securely seated then retorque to 35 ft. - lbs.

V. LEAK CHECK

1. Assemble processed valve on leak check manifold with flange "A to manifold. (The valve should still be closed and torqued to 35 ft. - lbs.)
2. Flange "B" should be open to the atmosphere.
3. Leak check entire assembly. (Note 5) (Note 6)
4. Place "Blank Flange" on flange "B".
5. Untorque and open valve to half way open position.
6. Leak check remaining portion of valve. (Note 5) (Note 6)
7. Remove valve from manifold and blank flange from valve. (Note 1)
8. Place new aluminum foil on flanges after leak checking.

TITLE
1 1/2" BAKEABLE VALVE CLEANING PROCEDURE

VI. PACKAGE AND STORAGE

1. Inscribe serial number on leak tight valve with electric pencil.
2. Record serial number in log book.
3. Attach "Cleaned for Ultra High Vacuum" tag. Tag should indicate the following:
   a) Serial number.
   b) Date and technician who leak checked valve.
   c) Valve torqued to 35 ft. - lbs.
4. Place valve in plastic bag.
5. Store completed valve in desiccating cabinets.

Note 1: At no time should any objects other than "Cleaned for Vacuum" items touch inside of valve. (i.e. no fingerprints, dirt, dust, oil, etc.)
Note 2: Hold valve at main body. Take care not to damage body.
Note 3: Drive socket should remain in this position for duration of the rinse and bake steps.
Note 4: Rinse valve in a well ventilated area, wear solvent proof gloves at all times and keep solvent off of clothing and skin.
Note 5: Use a Mass Spectrometer Leak Detector with a minimum sensitivity of 2.0×10^{-10} STD cc/SEC/DIV. Valve must show N.I.L. to be considered leak tight.
Note 6: Separate valves with any indicated leaks from leak tight valves.

1 1/2" BAKEABLE VALVE CLEANING PROCEDURE

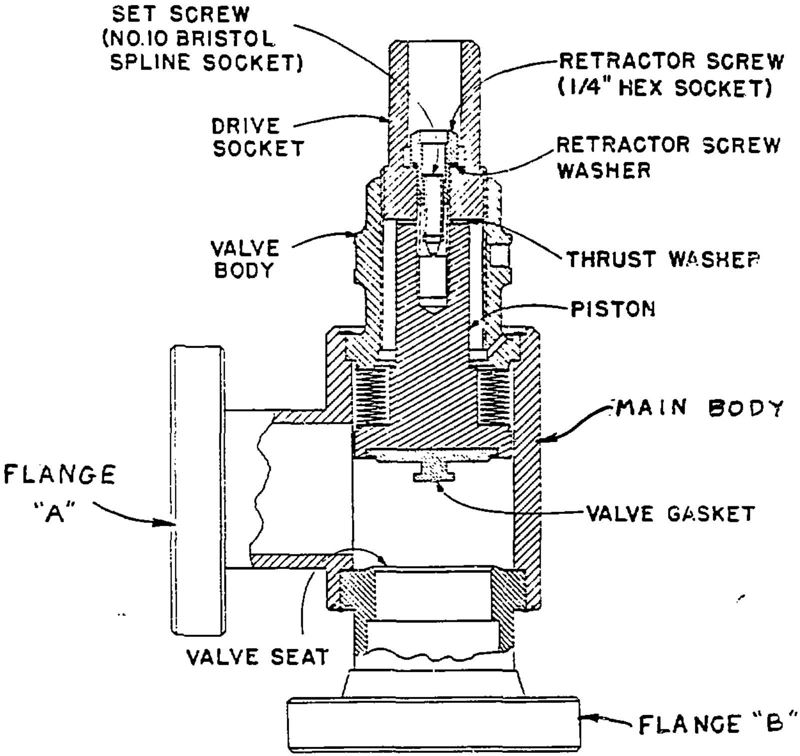


FIGURE 1. 1½ – INCH BAKEABLE VALVE

APPENDIX VI

MECHANICAL ENGINEERING SAFETY INSPECTION (MESI)

Mechanical Engineering Safety Inspection (MESI)*

Mechanical Engineering Safety Inspection (MESI) is administrated by the Environmental Safety Office (SLAC ext. 2345) under authority from the Mechanical Engineering Department. Their purpose is to provide written approvals of design, fabrication, pressure test, and operation stages of pressure or vacuum vessels (that is, any vessel or container with a product of volume and differential pressure exceeding [one cubic foot] $\times$ [one atmosphere]). While the primary responsibility for safety remains with the cognizant user group, no work may proceed from one to another sequential stage in design to operation of a vessel without prior written approval of MESI.

In carrying out its function, MESI will:

1. Approve or disapprove design, fabrication, pressure test and operating procedures for pressure or vacuum vessels meeting the definition.
2. Review re-use of any vessel, including surplus units, after the original purpose has been met.
3. Excuse from its jurisdiction:
   - (a) Dispersed energy storage. Where the energy content is low and no chance of overpressure exists, MESI may grant exemption from inspection. For example, a long vacuum pipe of small diameter.
   - (b) Inspection by alternate authority. MESI will not inspect nor record a vessel bearing an ASME Code stamp that is subject to periodic inspection by State or insurance safety inspectors.
   - (c) A vessel procured bearing an ASME Code stamp that will not be subject to a periodic inspection must be inspected by MESI.

*Excerpts from memo by W. K. H. Panofsky entitled *Terms of Reference—Mechanical Engineering Safety Inspection (MESI)*, revised July 22, 1977.

(d) Vessels used in physics experiments that cannot be designed, fabricated or operated entirely within MESI rules will be transferred to the jurisdiction of the Hazardous Experimental Equipment Committee at the time such incompatibility is determined.

4. Issue written approvals of design, fabrication, pressure test and operation stages of a vessel under MESI jurisdiction.

5. Document approvals for design, fabrication, pressure test and operational procedures; and maintain these records for the life of the vessel.

6. Establish standards and practices for pressure or vacuum vessels.

7. Mark any vessel under its jurisdiction with a MESI serial number.

MESI has the authority to stop procedures they deem unsafe for vessels under their jurisdiction. The experimenter or Group Leader affected by MESI's decisions may appeal to the Hazardous Experimental Equipment Committee (HEEC).

APPENDIX VII

TECHNICAL SPECIFICATIONS

Number	*Title*
PS–202–061–42	UHV Flange Gasket Specification
PS–202–631–01	Extruded Aluminum Vacuum Chambers
PS–202–631–03	Stainless Steel Welded Bellows
PS–202–631–04	Stainless Steel Flanges
PS–202–631–06	Quadrupole Residual Gas Analyzer
PS–202–631–07	Sputter Ion Vacuum Pumps
PS–202–631–09	Roll Bonded AL/SST Transition Material
PS–202–631–10	Differential Ion Pumps
PS–202–631–12	Contouring OFHC Copper Tubing
PS–202–631–13	OFHC Copper Tubing
FP–202–631–14	Fabrication of UHV Components
PS–202–631–70	Chemical Cleaning Tanks
PS–202–631–71	Piping and Duckboards
PS–202–631–72	All–Metal Isolation Valves
PS–202–631–73	Guidelines for Purchasing SST
PS–236–105–07	Aluminum Tubing

REV	DESCRIPTION	DRN	CHK	APP	DATE
1	Added Note 2.2	SLC 10/77	RTM 11/77	[illegible]	11/10/77
2	Updated Copper Specification Revised Approved Machining Coolants Retyped	RW	[illegible]	[illegible]	12-5-84

1.1 Gaskets must be made from certified copper, UNS No. C10100 (OFE), ASTM B 152-77. Material must be free of blemishes and nominal thickness before fabrication process must be .080" ± .0035. Temper of gaskets after fabrication process must be 1/4 to 1/2 hard. (45 to 82 Rockwell 'F' scale.) Fabricated dimensions will be held to the following tolerances; outside diameters within ± .002", inside diameters within ± .003". Nicks and scratches must be within the physical limits of not deeper than .0005", nor wider than .003". Burrs cannot protrude more than .0005". Lubricants used to fabricate gaskets must be University approved per SLAC specification FP-202-631-14, section 1. Gaskets may be shipped with slight film of approved lubricant on them and must be packaged to prevent damage.

2.2 PF-202-061-34 2-1/2 OD Gaskets

Fabricated dimensions will be held to the following tolerances; outside diameters within ± .001", inside diameters within ± .003.

THIRD ANGLE PROJECTION

ALL DIMENSIONS ARE IN MILLIMETERS UNLESS OTHERWISE SPECIFIED

DO NOT SCALE DRAWING	SCALE NONE	NEXT ASSEMBLY
LAWRENCE BERKELEY LABORATORY, University of California, Berkeley, Calif. PEP STANFORD LINEAR ACCELERATOR CENTER, Stanford University, Stanford, Calif.	UNLESS OTHERWISE SPECIFIED TOLERANCES SURFACE FINISH (MICROINCHES) ENGR D. Bostic DFTS Y.K. CHKD RTM 6/77 APPROVALS [illegible]	POSITRON-ELECTRON PROJECT U.H.V. FLANGE SPECIFICATION GASKET PS - 202 - 061 - 42 - R 3 A

M/F

TECHNICAL SPECIFICATION

FOR

EXTRUDED ALUMINUM VACUUM CHAMBERS

PS-202-631-01-R4

Submitted by ______________________ Vacuum Group
Urban K. Cummings

Approved by ______________________ Deputy Group Leader
Daniel M. Wright

Approved by ______________________ Group Leader
Norman R. Dean

Stanford Linear Accelerator Center
Stanford University
Stanford, CA 94305
May 14, 1976
Revised September 20, 1984
Revised May 24, 1985

1.0 INTRODUCTION

1.1 The aluminum extrusions made to this specification will become the primary beam chamber of a high energy physics experiment. These extrusions will be evacuated to 10E-10 torr by means of sputter ion ultra high vacuum pumps. Extrusions must be capable of maintaining continuous leak free operation and withstand a minimum of 50 thermal cycles to 200 degrees centigrade under vacuum. The duration of each thermal cycle is approximately 150 hours.

Before being put into operation, each extrusion will be tested by the University, using a mass spectrometer helium detector. Any extrusions which indicates leakage when tested with a minimum sensitivity of 2x10E-10 standard cc/sec per division, is not usable for this requirement.

2.0 SCOPE

2.1 This document specifies the minimum requirements for producing aluminum extrusions of the type described in the Introduction, Paragraph 1.1. This specification also includes the requirements for providing an extrusion die, for testing the extrusions, including the test tooling and for preparation and delivery of the extrusions.

3.0 APPLICABLE DOCUMENTS

3.1 The applicable provisions of the following documents of issue in effect on date of Invitation to Bid shall become a part of this specification, to the extent specified herein.

1. "Aluminum Association Standard and Data"; The Aluminum Association, 818 Connecticut Ave., N.W., Washington, DC 20006.

4.0 REQUIREMENTS

4.1 The University does not require the vendor to be responsible for assurance that the extrusions delivered will meet the leak test requirement described in the Introduction, Paragraph 1.1. However, the vendor <u>is</u> required to use every possible means to maintain the highest level of manufacturing standards and quality control throughout every step of production to preclude failure of an extrusions during these leak testing procedures.

4.2 Extrusions made to this specification shall be produced by the Direct Extrusion process. The aluminum alloy shall be Type 6061, heat treated to the T-4 condition by quench at the press. Solution heat treatment is <u>not</u> recommended. T-4 properties must meet the Aluminum Association Standards and Data for this type of product.

4.3 The extrusion die shall become the property of the University. Vendor shall retain possession of the extrusion die and any other backup tooling required to produce these pieces. The retention period shall extend five years from the date of the University's most recent use of the die. After the five year period, destruction or disposal of said tooling shall take place only upon written permission of the University. If the University elects to reorder additional extrusions during the 5 year period and the die has been disposed of, without written permission of the University, vendor is responsible for producing the necessary tooling at no cost to the University.

4.4 Required Drawings

Prior to construction of the die, vendor shall submit to the University, for written approval, the production drawing of the extrusion cross section. Drawing shall show all dimensions and a tolerance on each dimension. In addition, the drawing must show the location of all bond lines where extruded metal rejoins after passing through the die.

4.5 Source Inspection

A representative of the University shall be permitted to witness the extruding, straightening, cutting and testing sequences required in this specification. Die trials may be included in the above. Vendor shall schedule arrangements so as to give the University at least 5 working days notice prior to production. Extrusions made for delivery to the University shall not be produced prior to the arrival of the University representative.

4.6 Extrusion Parameters

a. Filtered Metal

In the molten state, prior to casting, all billet metal for these extrusions shall be degassed using nitrogen, argon, or other combinations of gasses. The maximum level of residual hydrogen resulting from said degassing shall be .22 ml of H per 100 gm of aluminum. Molten billet metal shall be filtered by means of rigid meida, spinning nozzle or other process. Filtering must reduce the impurity and contamination level in the billet to meet Class A ultrasonic discontinuity limits when tested per MIL I-8950 B. Certification of conformance to both of the above requirements shall be furnished to the University accompanying other reports called in this specification.

b. Billets

Each drop from the above melt shall have a sample cast, faced off and a quantometer or other spectrochemical analysis taken. A certified report of each piece tested shall be furnished in written form to the University representative at the time the extrusions are produced. The first billet through the press shall be a starter billet, either half or full size. No finished extrusions may be taken from this starter.

c. Burp Cycle

If a bridge type die is used, the extrusion press must be given a "burp cycle" by breaking the seal between the container and the die. This will serve to release entrapped air in the die hollows and prevent blisters in the extruded piece.

d. Lubricant

No grease or other lubricant shall be used on the billets or dummy block, except as specifically approved by the University representative.

e. Minimum Butt

The minimum weight of the billet butt, whether sheared or stripped, shall be 10% of the original billet weight. The length of the butt shall be no less than 4 inches.

f. Quench

The quench at the press must be carefully controlled so as to produce essentially identical mechanical properties throughout the extrusion cross section. The University prefers quench at the press rather than oven re-heat. Serious vacuum outgassing problems can occur from the intrusion of algicides and other water treatment chemicals into the two vacuum passages.

g. Stretch

All stretching shall be for the purpose of straightening. The amount of stretch shall be measured as each piece is pulled and the result recorded as a percentage of original condition. Under no circumstances shall the stretch exceed 2.0%.

h. Rough Cutting

The location of the rough cut, with respect to the quench box, shall be chosen so as to minimize the intrusion of water into the ends of the extrusion.

i. Numbering

All extrusions shall be sequentially numbered at the press with an indelible marker. If more than one finished length is to he taken from a billet, each shall be numbered in sequence as they come off the press. The extrusion shall be marked at both ends with the sequence number, followed with the letter F or B, to indicate front or back. After cutting to finished length, the identity number shall be engraved using a vibrator tool, on the inside of both ends of the extrusion.

j. Length

Past experience with flare testing has indicated that the total run-out of each billet should be a minimum of 25% greater than the total finished length(s). The amount of front and back crop shall be at the discretion of the vendor. Again, past experience has shown that approximately 95% front crop has been necessary in order to meet the flare tests required in section 5.1.

4.7 Inspection

a. Requirements

Extrusions which have been straightened and cut to finished length shall be sent out for inspection by the University representative. Inspection shall take place inside the building, in an area which permits easy access to both ends and the full length of each extrusion. Provision for a flat surface on which to inspect for twist and straightness would be appreciated.

b. Tolerances

Unless otherwise agreed to on the approved drawings, dimensional tolerance on cross section measurements, length, straightness, twist, etc., shall be as prescribed in the applicable Aluminum Association Standards.

c. Flatness

The tolerance on flatness of the specified extrusion surfaces shall be as follows: The maximum allowable deviation from a flat surface is .004" per inch width (of flat surface). This deviation shall be only in the outward (convex) curvature, when viewing the extrusion in cross section.

d. Twist

The maximum allowable twist in the finished length shall be per the Aluminum Association Standards: 1/4° per foot, 3° maximum.

e. Finish

The finish required on the inside surfaces of the extrusion is more critical than the outside surface. The test for acceptance of both internal and external finish is that it be equal to, or better than that of a Surface Finish Sample provided by either the University or the vendor and agreed to by both. The Surface Finish Sample is used as a standard for comparison purposes. The finish of the "as-extruded" pieces must meet this test. Marks or blemishes on the external surfaces, due to subsequent handling, need only meet the finish requirements of the Aluminum Association Standards for this product.

4.8 Test Samples

From the front and back crops, described in Section 4.6 above, test samples shall be taken immediately adjacent to the finished length cuts. Four such samples shall be taken: two from the front and two from the back. One back sample shall be used for the mechanical properties tests described in Section 5.4. One front sample is to be shipped to the University for the purpose of vacuum testing. The remaining two are to be used for the flare tests described in Section 5.1. The length of the samples shall be approximately 1/3 greater than the long dimension of the extrusion cross section. All samples shall be identified with an indelible marker to indicate the extrusion number and the letter which indicates the location from which the sample was taken. Indelible marking means the use of a pen containing an ink which is not soluble in the fluid used as a lubricant/coolant on the cut off saw. If only one finished length is taken from each push, the front and back and adjacent samples shall be marked (for push 4) 4F and 4B respectively. For multiple lengths, from each push, the first piece off the front (after the crop) and the adjacent samples shall be all marked 4-1. NOTE: always mark the end of the finished length with the same identity as the adjacent samples. The next cut from the push will be two more test samples marked 4-2 followed by the finished length marked 4-2 adjacent to the end from which the samples were cut. Repeat with 4-3, 4-4, and so on. The last length cut from the back of the push shall be marked as follows: the <u>front</u> end shall be marked as before: four, dash, followed by the next number in sequence. The <u>back</u> end of the last cut and the two adjacent samples shall all be marked the same as the front end and the letter B added. Example: 4-4B.

4.9 Final Acceptance

Notwithstanding the inspection requirements at the vendor's plant, as described herein, the final acceptance of the extrusions shall take place following delivery to the University at the Stanford Linear Accelerator Center, 2575 Sand Hill Road, Menlo Park, CA 94025.

5.0 TEST PROVISIONS

5.1 Flare Testing

Each flare sample taken shall be tested as follows: first, three flare testing tools shall be made by the vendor, each made to test on of the three hollows in the extrusion. All tools are tapered wedges, circular in cross section and sized appropriately for the passage it tests. On each test sample, the flaring tool shall be forced into its respective hollow by means of a hydraulic or air actuated ram type press. The purpose of the flare test is to stretch the metal in all four walls of the hollow to determine the integrity of the welds. We are especially interested in the wall(s) which contain a weld zone. The test is performed by flaring each hollow, continuing to expand the length and width dimensions of the hollow until a separation takes place. If the separation takes place <u>at</u> a weld location and the separation is due to an inadequate weld bond, the length from which the sample was taken is then rejected. An unacceptable weld bond is one on which both parted faces show evidence of longitudinal stream line and not the random, grainy surface which is characteristic of sound metal. In all cases the length and width dimensions of the hollow being tested must expand at least 15% before separation in order for the length to be accepted.

5.2 Re-Testing

A rejected length does not mean that the full length of the extrusion is rejected. Past experience with flare test failures has shown that the required length of nose crop was often underestimated and successful welding was achieved further back in the extrusion. Any finished length of an extrusion can be accepted providing that the flare tests are successful from both ends of the length.

5.3 Retention of Flare Sample

All flare samples from acceptable lengths shall be retained by the vendor until permission for disposal has been received from the University.

5.4 Mechanical Property Tests

From each push of extrusions that are shipped to the University, the Mechanical Properties Test Sample, required in Section 4.8, shall be tested and a written report of the results shall be furnished to the University representative. The report shall include the results of testing the ultimate tensile strength, yield strength, elongation and hardness of each sample. The "minimums" prescribed in the Aluminum Association Standards for this alloy, temper designation and class of product must be met before the extrusions are prepared for shipment.

5.5 Test Records

Records of all results of spectrochemical analysis, Mechanical Properties Tests, dimensional checks and quality control provisions shall be retained for a period of 1 year. Inspection of these records and copies of the same shall be made available to the University representative upon request.

6.0 PREPARATION FOR DELIVERY

6.1 Preservation and Packaging

Extrusions which have been accepted for delivery, to the University, shall be in bundles of no more than twelve pieces, each as follows:

1. Both ends of each extrusion shall be enclosed with a double layer of heavy weight Kraft paper which his circumferentially wrapped and attached to the extrusion using 3M #471 vinyl plastic tape (or

University approved equal). The extrusion/length number shall be written on the paper cover at both ends of each length.

2. Extrusions shall be prepared for shipment using a totally enclosed wooden box, the design and construction details of which are mutually agreed upon by both the University and the vendor at the time the order is placed.

6.2 Shipment

Extrusion bundles which must be lifted by machinery shall use a strongback, or slings not less than 8 feet apart. A single pickup in the center of long extrusions is prohibited. This requirement will be strictly enforced in order to prevent high bending stresses in the extrusions. Extrusions awaiting shipment shall not be stored outside of the building. Date of shipment, way-bill number, carrier name and other pertinent transit information must be conveyed to the University at the time of delivery.

TECHNICAL SPECIFICATION

FOR

STAINLESS STEEL WELDED BELLOWS
FOR ULTRA HIGH VACUUM APPLICATIONS

PS-202-631-03 R2

Submitted by ________ Mechanical Engineering Department
Urban K. Cummings

Approved by ________ Group Leader
Norman R. Dean

Approved by ________ Department Head
Robert A. Bell

PEP PROJECT
Standard Linear Accelerator Center
Stanford University
Stanford, California
November 5, 1976
March, 1978 - Revised - R1
May, 1978 - Revised - R2

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 The stainless steel bellows made to this specification will become part of primary Beam Chamber of the Positron-Electron-Project (PEP) Storage Ring, a joint project of the University of California Lawrence Berkeley Laboratory and Stanford University, hereinafter referred to as "The University".

These bellows will be evacuated to a pressure of 10^{-10} Torr by means of sputter - ion type U.H.V. pumps. In order to attain this low pressure, great care must be taken during fabrication and testing to maintain the high cleanliness levels required. Welded stainless steel bellows deserve special attention to cleanliness because of their unusual construction. Experience in ultra high vacuum has proven that post-manufacturing chemical cleaning is of negligible value in removing hydrocarbon contamination of surfaces or particulate matter trapped in the crevices of welded bellows convolutions. Bellows made with improperly handled or poorly cleaned parts are rendered useless for our purpose.

Bellows must be capable of maintaining continuous leak free operation and withstand a minimum of 50 thermal cycles from room temperature to 200°C while under vacuum, in the stroke and offset positions specified. The duration of each thermal cycle is approximately 150 hours.

Before being put into operation, each bellows will be tested by the University using a mass spectrometer helium leak detector. Any bellows which indicates leakage when tested with a minimum leak detector sensitivity of 3×10^{-10} standard cc/sec (He) per leak rate meter division, is not usable for this requirement.

2.0 SCOPE

2.1 This document specifies the minimum requirements for producing welded stainless steel bellows of the type described in the introduction Section 1.1 This specification also includes the requirements for clean handling and welding and chemical cleaning of the bellows diaphragms and for Quality Control and testing of the finished bellows. Also included are requirements for preparation for delivery of the bellows.

3.0 APPLICABLE DOCUMENTS

3.1 The applicable provisions of the following documents of issue in effect on the effective date of award shall become part of this specification, to the extent specified herein.

1. AMS 5512E, steel sheet, strip, and plate, corrosion and heat resistant (SAE 30347).
2. AMS 5513B, steel sheet, strip, and plate, corrosion resistant (SAE 30304).
3. AMS 5639C, steel bars, forgings, tubing and rings, corrosion resistant (SAE 30304).
4. AMS 5566F, Steel tubing seamless or welded, corrosion resistant (SAE 30304).

4.0 REQUIREMENTS

4.1 General

The type of bellows required under this specification is made up of a series of thin stainless steel diaphragms welded on the inside and outside diameters to form a series of convolutions.
The diaphragms shall be formed to a shape commonly referred to as "Nesting Ripple" and are made in left and right configurations alternately so as to fit snugly when welded together.
Each step of manufacturing and testing must adhere to the specific procedures outlined herein to insure that the finished bellows meet The University's requirements. No deviation from this specification or those stipulated herein will be permitted without prior written permission of the University.

4.2 SERVICE REQUIREMENTS

The internal environment of the bellows is Ultra High Vacuum, 10^{-10} torr or lower. The external environment is atmospheric pressure and $200^{o}C$ temperature imposed during the periodic bake out described below. The pressure differential is 1×10^{-5} Pascals ($15 lbs/in^2$) Bellows must remain leak tight after exposure to 50 thermal cycles of 150 hours duration each at a temperature of $200^{o}C$, whilst under vacuum.

During the period of each bakeout cycle, the bellows will undergo the specified axial stroke and offset requirements called for on the University drawing accompanying this specification. In addition to the above, bellows must remain leak tight for the number of stroke cycles at ambient temperature as called for on the drawing.

4.3 MATERIALS

Diaphragms shall be made from AISI type 347 stainless steel sheet or strip conforming to AMS-5512E except finish must be No. 2 B-N or No. 2 bright annealed. End plates, tubulations, guides or other fittings shall be made from VACUUM MELTED AISI type 304 or 304L stainless steel conforming to AMS-5513B or AMS-5639C. Certifications required in Paragraph 5.3 must state "VACUUM MELTED". Stainless steel tubing used in conjunction with end fittings must conform to AMS-5566F.

If vendor prefers to use materials conforming to Specifications other than above, written permission to do so must first be obtained from the University.

4.4 END FITTINGS AND ATTACHMENTS

All attachments to the bellows convolutions such as guides, end plates tubulations or other fittings must be made from wrought materials such as plate or bar stock. Cast material is not acceptable. Welded tubing may be used but must conform to the appropriate specification in section 4.3. Fittings made by rolling flat stock into a ring and welding the ends together are not permitted. Forged parts may be used only with prior approval of the University. The surface finish of all fittings and attachments must be 64 micro inches or better as specified on the drawing(s). All stock surfaces must be machined to remove scale or roughness caused by pickling or rolling.

After machining, each piece shall be inspected on all surfaces. Any part which is not 100% sound metal, i.e., free of inclusions, cracks, seams, slivers, sponginess, segregation, or any other surface imperfection, including file marks, burrs or sharp edges, shall be rejected. Disposal of such rejects shall be accomplished in such a way as to prevent any possibility of future use for University parts.

4.5 LUBRICANTS AND FINISHING MATERIALS

All lubricants, cutting fluids, etc., used in manufacturing must be "sulphur-free". Upon request, vendor must provide the University representative with all information needed to identify the source and constituents of all fluids and lubricants used.

The use of abrasive cloth or paper, buffing or polishing compounds, or resin bonded grinding wheels is prohibited in finishing any part of the bellows. Material removal must be accomplished with the use of metal tools.

4.6 TOOLING

All-metal tooling is strongly recommended for cutting and forming the diaphragms. The use of urethane or other plastic materials is not recommended. The possibility of minute particles of plastic adhering to the diaphragms presents a serious contamination hazard.

If plastic materials are used in conjunction with the cutting and forming operations, an ultrasonic cleaning operation must be performed on the diaphragms in addition to required chemical cleaning. See Section 4.11.

4.7 RETENTION OF TOOLING

In order that the University be able to re-order additional bellows without incurring further tooling or service charges, the vendor is required to retain possession of all tooling required to produce these bellows. The retention period shall extend four years from the date of the University's most recent order. After the four year period, destruction or disposal of said tooling shall take place only upon written permission of the University. If the University elects to reorder additional bellows within the four year period, and the tooling is not available, vendor is responsible for providing replacement tooling at no cost to the University.

4.8 GLOVES AND CLEANING CRITERIA

Briefly, the criteria for making bellows which meet the University's cleanliness requirements is:

1. Cut and form the diaphragms without increasing the contamination level of the stock as supplied by the mill.
2. Machine or form the fittings without adding non-cleanable contamination to the parts.
3. Chemically clean all components to obtain an ultra high vacuum surface.
4. Assemble, weld, leak test and package the bellows without re-contaminating them in any way.

The University will provide the vendor with an adequate supply of clean, white nylon gloves to be used exclusively for the specific operations stated herein.

4.9 CUTTING AND FORMING

In order to eliminate finger marks and contamination hazards accompanying them, University provided gloves must be worn by persons handling the stainless steel sheet during cutting, forming and packaging the diaphragms. Gloves which are no longer usable in the clean room operations should be used for this purpose. Discard gloves when noticeable soiled. After cutting and forming, each diaphragm shall be visually inspected on both sides. Any indentation, dimple or other surface imperfection including rough edges sha[illegible] be cause for rejection of that diaphragm. Following inspection, diaphragms shall be wrapped in aluminum foil and stored in a closed container marked "Parts Not Cleaned".

4.10 ALUMINUM FOIL

Aluminum foil must be of the type designated as Dry Anneal A, such as that sold for Food Service wrap. Aluminum foil is to be used only once. After use for any part of this specification foil must be discarded. Foil used must be free of any visible contamination.

4.11 CHEMICAL CLEANING

Prior to welding, all diaphragms and fittings shall be chemically cleaned per Appendix A attached. The spacer wires used to separate convolutions during O.D. welding shall also be cleaned per the above spec. After oven drying, a visual inspection shall be made on both sides of every diaphragm using a 2 or 3 power Inspection Glass. Reclean any piece which shows any sign of water marks, stains or chemical residue. Following this inspection all parts shall be wrapped in approved aluminum foil and stored in closed containers identified as "Parts Cleaned to U.H.V. Spec". Good practice for U.H.V. dictates that parts be welded within 24 hours of chemical cleaning. This rule shall be adhered to in so far as possible.

The above specification also stipulates:

A. The location and set-up of the cleaning facility be approved by the University prior to use.

B. That a University representative be present to witness the first pieces being cleaned in each bellows order.

C. Eating, drinking and smoking are prohibited in the chemical cleaning room.

4.12 CLEAN ROOM

Assembly and welding must take place in a closed room specifically prepared for and designated as a Clean Room. A positive pressure, filtered air, ventilation system must be provided to prevent intrusion of airborne particles and/or fume contamination. Only those functions which are appropriate to a clean room area will be permitted within it. Vendor must obtain approval of the clean room location, arrangement and set-up from the University prior to use. Vendor shall also provide and obtain approval for a clean room maintenance list and schedule. Other manufacturing operations which take place within the room which are not connected with the University's work must be compatible with the ultra high vacuum nature of the clean room and not pose a threat of contamination.

All eating, drinking or use of tobacco is prohibited within the clean room. A notice so stating shall be posted on the entry door(s).

4.13 ASSEMBLY, WELDING AND USE OF GLOVES

When unwrapping cleaned diaphragms in preparation for welding, they shall only be handled by clean, University provided gloves. Gloved hands which touch cleaned parts must touch nothing else!

When wearing gloves, welder must be alert at all times not to touch his face, clothing, tools, bench, chairs, etc. Actuation of switches, adjustment of welding torch, etc., must be performed with the glove removed. Gloves which touch un-cleaned surfaces shall be immediately replaced with a new pair. New gloves shall also be used at the beginning of each shift and following period breaks. Any device or apparatus which is covered with University approved aluminum foil at the beginning of each shift may be touched by gloved hands.

It is recommended that all work surfaces such as the tops of I.D. welders assembly benches, etc., be covered with approved aluminum foil.

All those parts of the welding machines which come in contact with, or even close proximity to the diaphragms being welded must be thoroughly cleaned and wiped down with Trichloroethane or Freon TF and lint free tissue at the beginning of each shift. This will be followed by wiping down with another tissue using electronic grade methanol or electronic grade isopropyl alcohol. Welded convolutionsshall be covered with aluminum foil immediately following welding and inspection.

The handling criteria for assembly of the convolutions, for inserting the spacer rings and welding the core; etc., shall be the same as for welding the diaphragms: use new gloves at the same intervals; gloved hands which touch cleaned parts touch nothing else, and machinery which comes in contact with or close proximity to the bellows shall be wiped down with the same solvent procedures as before. Unless otherwise approved, all welding shall be by Tungsten Inert Gas (GTA) fusion process without the use of filler rod.

It is important to state that leak tightness alone is not the only criteria for the acceptability of weld quality. The appearance and workmanship of the welding is equally important. All weld beads shall be continuous and uniform in height and width, and have a cross-section profile which indicates proper fusion of the adjoining diaphragms. Discontinuities or changes in the weld bead which are 1/3 larger or smaller than the normal bead width or height shall be cause for rejection of the entire bellows. Rewelds or repairs to such welds are not permitted. When each weld is completed, taper off the current to avoid pin holes or cracks caused by too rapid a weld shut-off. Under no circumstances shall any weld bead be touched with the use of files, rotary burrs, etc.

4.14 FINAL ACCEPTANCE

Not withstanding the inspection requirements at the vendor's plant as described herein, final acceptance of the bellows shall take place following delivery to, and leak testing by the University.

5.0 INSPECTION, QUALITY CONTROL AND TEST PROVISIONS

5.1 SOURCE INSPECTION

A designated University representative shall be permitted to witness all manufacturing and testing operations herein required. Upon request, representative shall be provided with records and dates on materials and tests and inspections which were performed in the representative's absence. When so requested, vendor shall notify the University five working days prior to the performance of any test or operation requested to be witnessed.

5.2 RESPONSIBILITY FOR TESTS

Unless otherwise stated, all tests required herein shall be performed by the vendor without additional cost to the University. Equipment and test apparatus used by the vendor shall be properly maintained and operated according to the manufacturers instructions. The use of faulty test equipment will void any tests performed. It is the vendors responsibility to provide experienced and qualified personnel to operate the equipment and perform the tests.

5.3 MATERIAL CERTIFICATION

Vendor shall furnish original source test certifications of all materials which are a part of the final assembly. Material for which no certifications are available shall not be used in any part of the bellows assembly.

Certifications must be copies of the original physical and chemical test reports from the mill source of the ingot or billet. "Certs" retyped on suppliers forms are not acceptable.

5.4 PROTOTYPE ACCEPTANCE TESTS

If so required by the University's purchase order, the following prototype acceptance tests must be performed on bellows made by the vendor for this purpose. Prior to production, three bellows shall be manufactured as specified on the University's drawings which accompany the order. Unless otherwise noted, all requirements of this specification must be adhered to in manufacturing. A jig or fixture shall be constructed by the vendor to test the bellows according to the number of cycles, the offset and the stroke length requirements called for on the drawing. A proposed test program, including a sketch of the test fixture, must be submitted to and approved by the University prior to beginning the tests. The vacuum and elevated temperature service environment of the bellows must be a part of the test procedure. Any leak tightness, mechanical or other failure of a bellows prior to completion of the test will be cause for rejection of the bellows design offered, as well as cancellation of the University's order for same. If all three bellows test satisfactorily, a report of the test results must be provided and production shall commence upon receiving approval from the University.

5.5 HELIUM LEAK TEST

Leak testing may only be performed on the finished bellows complete with end flanges welded on. No testing is permitted on sub-assemblies or capsules prior to final assembly. The only exception to the above is machined parts and fittings which may be leak tested prior to chemical cleaning. Following welding and inspection completed bellows shall be leak tested using a mass spectrometer helium leak detector fitted with the side trap called for in Section 5.6. Unwrapping, handling and rewrapping of the bellows during leak testing shall also follow the previous glove restrictions; periodic glove changes, no contamination transfer, etc. Leak detector may be any one of the following or university approved equal:

Varian (NRC) Model 925 or 936.
Veeco MS-9, MS-90, MS-18.
DuPont (CEC) Model 24-120B.

Use of the leak detector including periodic maintenance must conform to the manufacturer's recommendations. During leak testing, the helium nozzle shall be directed at the gap between the spacer wires (chill rings) inserted between each convolution. In that way, helium gas will enter the void between the convolutions and reach the ID weld. Leak detector sensitivity for helium shall be a minimum of 2×10^{-10} standard cc/sec per leak meter division on the most sensitive range. Reject any bellows that, when probed with helium or surrounded by a vessel containing 100% helium for one minute , results in a 2% deflection on the most sensitive range of the leak rate meter. Calibration of the leak detector sensitivity shall be performed just prior to leak testing the bellows. In the event that the leak detector fails to meet the minimum sensitivity set herein, and the vendor chooses to test the bellows with less sensitivity the responsibility that the bellows so tested meet the minimum requirements rests with the vendor. Bellows tested by the University which fail the minimum requirements will be rejected. Leak testing must be performed in an area sufficiently remote from other operations so as not to pose a threat of airborne contamination. Food, drink and smoking shall be prohibited within proximity to the leak testing area. Tables used must be covered with aluminum foil.

O-rings or rubber flat stock used as a temporary seal on the ends of the bellows for the purpose of leak testing shall be new rubber, clean and dry. No lubricants or grease of any kind are permitted. Experience at SLAC shows that low durometer O-rings or pure gum rubber sheet works satisfactorily if the seal loading is adequate. The most satisfactory cleaning procedure for rubber stock, is hand washing with soap and water followed by a thorough rinsing. Solvents accelerate the deterioration of rubber. Immediately following leak test. Those areas which have been in contact with the rubber seal must be wiped off using new lint free tissue and trichlorethane or freon TF. Each bellows shall be wrapped in approved aluminum foil and a label attached to outside stating that the unit has been leak tested satisfactorily. The University Part No. (Drawing No.) shall also be marked on the leak test label.

5.6 LEAK DETECTOR SIDE TRAP

In order to protect the internal area of the bellows from leak detector roughing pump vapors, a liquid nitrogen trap and valve must be installed between the bellows test plate and the leak detector inlet. On some leak detectors this requirement precludes the use of the built-in test port. In these cases a side port inlet to the leak detector must be used and an external test plate, valve, and LN_2 side trap fitted to it. Valve must be situated between the test plate and the trap. Most leak detectors have such accessories available. Refer to the manufacturer for assistance. The side trap set-up must be approved by the University prior to use. When testing the first bellows of a series, trap shall be filled with LN_2 when pumpdown pressure reaches 30 milli-torr.

Trap must be kept full of LN_2 all the time testing is taking place. After testing the last bellows of any series, the thimble portion of the trap shall be removed while still full of LN_2. After emptying the contaned LN_2, the thimble shall be allowed to warm up to room temperature. Keep the container portion of the trap covered with aluminum foil. After the thimble reaches room temperature, thoroughly rinse all external parts with trichloroethane or Freon TF. Follow immediately with Methanol or Isopropanol rinse. Re-assemble trap but do not pump down until the next leak test series.

6.0 PREPARATION FOR DELIVERY

6.1 PACKAGING

Each bellows which is accepted shall be completely wrapped with new aluminum foil immediately following leak testing. It will then be placed in a new polyethlene bag and the open end heat sealed. This package will then be placed in its own corrugated paper wrap. Shipment of individually wrapped bellows shall be made in a corrugated carboard carton. Do not exceed ten bellows per carton. It is the vendor's responsibility that the cartons selected be able to withstand the abuse received by common carrier shipment. The "Packing Slip" accompanying shipment must be affixed to the outside of the container.

6.2 IDENTIFICATION

The outside of the shipping carton shall have a SLAC "Do Not Open----" label affixed. These labels will be supplied by the University.

6.3 MARKING FOR SHIPMENT

All exterior shipping containers shall be adequately and properly marked for identification. All packages shall include the following minimum marking:

a. Addressee
b. Shipper
c. University purchase order number and/or subcontract number.

d. Special markings, warnings or tags in accordance with ICC regulations.

7.0 DRAWINGS

Vendor shall provide the University with two copies of the bellows assembly drawing used in manufacturing. Drawings must be sent first class mail, separate from the shipment.

8.0 APPENDIX A

CHEMICAL CLEANING PROCEDURES AND SOLUTIONS

1. Welded Bellows Diaphragms, End Fittings and Attachments

Welded bellows present special cleaning problems in that the convolutions represent areas that trap chemical solutions. Therefore all diaphragms, end fittings, etc., must be chemically cleaned <u>prior to</u> welding. Subsequent handling must be done in a manner which does not contaminate the bellows. Any bellows assembly which is contaminated following final welding is not recleanable and will be rejected.

The cleaning procedure for stainless steel parts is as follows:

1. Pieces shall be suspended on a stainless steel holding fixture in such a way that diaphragms or parts do not touch each other.
2. Degrease in trichlorethane vapor for 5 minutes.
3. Cold running tap water rinse for 1 minute. Immersion rinse preferred over spray rinse. Dip in and out numerous times.
4. Alkaline* soak clean for 5 minutes at a temperature of 190°F.
5. Cold running tap water rinse for 2 minutes. <u>Not</u> in tank 3 above.
6. Immerse in a stainless steel pickle solution consisting of:

   1 part 42° Baume Nitric Acid
   1 part 48% Hydrofluoric acid
   1 part distilled water

   Solution shall be at room temperature. Immersion time is approximately 1 minute. Do not over-etch.
7. Cold running tap water rinse for 2 minutes. <u>Not</u> in tank 3 or 5 above.
8. Immersion rinse in cold de-ionized or distilled water for 2 minutes. (minimum resistivity of 500,000 ohms)
9. Immersion rinse in hot (150°F.) de-ionized or distilled water for 2 minutes. (minimum resistivity 500,000 ohms)
10. Immersion rinse in electronic grade methanol or isopropanol.

* Enthone Brass Cleaner, Mfg.: Enthone Inc., New Haven, Conn.

11. Oven dry at 150°F. or blow with dry nitrogen gas preferably taken from an evaporated liquid nitrogen source. Dry, high purity (99.99%), water-pumped nitrogen bottled gas may also be used.

12. When dry, remove from rack using clean, white nylon gloves. Wrap individual pieces in lint-free tissue or new aluminum foil.

2. Aluminum Spacer Rings

The following shall be used for cleaning of all aluminum parts:

1. Vapor degrease in Trichlorethane for 5 minutes.
2. Cold running tap water rinse for 1 minute.
3. Soak in Amchem No. 53 Non-Etch Aluminum Cleaner** for approximately 5 minutes.
4. Cold running tap water rinse for 2 minutes. If water breaks appear, repeat steps 3 and 4.
5. Deoxidize in Wyandotte Alutone Liquid Desmutter and Deoxidizer*** at a concentration of 20 percent by volume until all mill scale is removed.
6. Cold running tap water rinse for 2 minutes.
7. Etch in Amchem Etchant #33** from 1-10 minutes depending on depth of etch required.
8. Cold running tap water rinse for 2 minutes.
9. Desmutt until surface is clean. Use same solution as step #5.
10. Cold running tap water rinse for 2 minutes.
11. Cold distilled water rinse for 2 minutes (minimum resistivity 500,000 ohms).
12. Hot (150°F.) distilled water rinse for 2 minutes (minimum resistivity 500,000 ohms).

** Wyandotte Alutone is a product of Wyandotte Chemical Inc., Wyandotte Mich. It is biodegradeable and may be dumped to sanitary sewers. If preferred, Deoxidizer #6 from Amchem, Inc. may be substituted. Deoxidizer #6 is a chromate type of solution and may be used for both steps #5 and #9. This solution cannot be dumped into the sanitary sewer.

*** Amchem #53 and Etchant #33 are products of Amchem, Inc., Ambler, Pa.

13. Blow with dry nitrogen gas preferably taken from an evaporated liquid source. Dry, high purity (99.99 percent) water pumped nitrogen bottled gas may also be used.

14. When dry wrap in lint free tissue or new aluminum foil.

3. Copper Spacer Rings

All copper parts shall be cleaned according to the following procedure:

1. Vapor degrease in trichlorethane for 5 minutes.
2. Cold running tap water rinse for 1 minute.
3. Soak in Enthone Brass Cleaner at a temperature of 190° F.
4. Cold running tap water rinse for 2 minutes.
5. Dip in 50 percent Hydrochloric acid at room temperature for 1 minute.
6. Cold running tap water rinse for 1 minute.
7. Bright dip in a solution consisting of:

   Sulfuric Acid 66° Baume . . . . .60 percent
   Nitric Acid 42° Baume . . . . .40 percent
   Hydrochloric Acid 20° Baume . . . . .1/5 fluid oz. per gallon
   Distilled Water . . . . .add 8 fluid oz. per 5 gallons of solution
   Solution at room temperature.

   For a slower, more controlled dip use the following solution:

   Phosphoric Acid, 75 percent . . . . .3 parts by volume
   Nitric Acid, 42° Baume. . . . . .1 part by volume
   Solution at room temperature.

8. Cold running tap water rinse for 2 minutes.
9. Cyanide dip in a solution consisting of:

   Potassium cyanide . . . . .8 avoir. oz.
   Potassium hydroxide . . . . .2 avoir. oz.
   Add distilled water to make 1 gallon.
   Solution shall be at room temperature.
   Immersion time: approximately 30 seconds.

10. Cold running tap water rinse for 2 minutes.
11. Cold distilled water rinse for 2 minutes. (minimum resistivity of 500,000 ohms)
12. Hot (150° F.) distilled water rinse for 2 minutes. (minimum resistivity of 500,000 ohms)
13. Electronic grade methano or isopropanol rinse.
14. Oven dry at 150° F. or by blowing with dry nitrogen gas, preferably taken from an evaporated liquid source. Dry, high purity (99.99 percent) water pumped nitrogen bottled gas may also be used.
15. When dry, wrap in lint free tissue or new aluminum foil.

Electronic Grade Methanol or Isopropanol Specification

Purity, percent W, min.	99.85
Specific Gravity, 20/20° C. (in air), max.	0.7927
Color (Pt-Co standards), max.	5
Acidity, (as HAc), percent W, max.	0.003
Alkalinity, (as NH_3), percent W, max.	0.003
Acetone Content, percent W, max.	0.003
Distillation Range	1.0° C. incl. 64.5° C.
Nonvolatile Matter, g/100 ml, max.	0.001
Permanganate Time, min.	30 minutes
Carbonizable Substances (Pt-Co Standard), max.	50
Odor	Characteristic and free of foreign odors.

TECHNICAL SPECIFICATION

STAINLESS STEEL FLANGES

FOR ULTRA HIGH VACUUM APPLICATIONS

PS-202-631-04-R1

Submitted by ______________________ SLAC Vacuum Group
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February 1, 1977
Revised: February 6, 1985

1.0 INTRODUCTION

1.1 The flanges made to this specification will become a part of various ultra high vacuum systems used for research in high energy physics experiments at the Stanford Linear Accelerator Center, a part of Stanford University, hereinafter referred to as the University.

The beam chamber and other components and systems to which these flanges will be welded, all operate at 10^{-10} Torr and all are thermally cycled to 200^{0} C.

Flange design shall be of the type commonly known as "knife edge" which require a flat, circular copper gasket as the sealing medium. All flanges must be capable of maintaining continuous leak-free operation as defined below and withstand a minimum of 50 thermal cycles while under a moderate amount of tensile shear stress. The duration of each thermal cycle is approximately 150 hours.

Each flange made to this specification will be subjected to a mass spectrometer helium leak test by the University. Leak-free operation is defined as: no indication more than a 2% deflection on the most sensitive range of a leak detector which has been calibrated to a sensitivity for helium of 2×10^{-10} standard cc/sec on the most sensitive range.

These requirements all call for great care in the selection of raw material, in the preparation of forged blanks and in finish machining of the flanges.

2.0 SCOPE

2.1 This document specifies the minimum requirements for producing stainless steel flanges of the type described in the introduction, Sec. 1.1.

This specification also includes the requirements for Quality Assurance and Inspection of Raw Materials, Forged Blanks and Finished Flanges and for reporting same.

3.0 APPLICABLE DOCUMENTS

3.1 SPECIFICATIONS

The applicable provisions of the following documents of issue in effect on the effective date award shall become part of this specification, to the extent specified herein.

1. AVS 3.2-1965 "Flanges Bakeable to 500^{0}C", American Vacuum Society, 335 E. 45 St., New York, NY 10017

2. AVS 3.3-1958 "Method for Testing Flange Seals to 500^{0}C", American Vacuum Society.

3. ASTM A-182 "Forged - - - Parts for Hi Temperature Service".

4. Federal Specification QQ-S-763d "Steel Bars, Shapes and Forgings, Corrosion Resisting".

5. MIL-S-862B "Steel - - - Billets, Corrosion Resisting: Reforging Application".

6. ASTM E-112 "Estimating the Average Grain Size of Metals".

7. ASTM E45-1976 "Determining the Inclusion Content of Steel".

8. MIL Standard 105D "Sampling Procedures and Tables for Inspection by Attributes".

4.0 UNIVERSITY DRAWINGS

The drawings provided by the University and subsequent revisions of such drawings, which are stipulated in the University purchase order for flanges made to this specification, all become a part of this specification.

4.1 REQUIREMENTS

The proposed vendor must be able to substantiate his technical capabilities which qualify him to produce UHV flanges to this specification. One important factor is recent experience in successful production of quantities of UHV flanges. Other factors to be considered are Quality Assurance and Inspection operations and machine tool capabilities for producing the flanges needed to meet the University delivery schedule.

Not withstanding the requirements herein for the raw materials, the manufacturing procedures and test requirements, the University will, upon vendor's request, consider alternative methods of material preparation for example, the use of electro-slag remelted (ESR) stainless steel which represents an enhancement of the raw materials from which the flanges are made. Such requests by the vendor, for University consideration of specific alternatives, must include an explanation of the reasons for the change proposed and how they represent an improvement in the finished product.

4.2 SEAL DESIGN

All flanges made to this specification shall be of the knife edge type which uses a flat circular copper gasket to effect a leak tight, bakeable seal. Flanges are to be manufactured according to the University drawings which accompany this specification. The copper gaskets are not a part of this specification or order.

4.3 RAW MATERIALS

Procurement of raw material shall be as follows:

A. All flanges and flange parts are to be made from certified AISI type 304 stainless steel.

B. Those flanges whose outside diameter is 2.75" or less may be made from bar stock provided it is purchased as and certified to the requirements of Sec. 4.5 and meets the inspection and test procedures called out in Sec. 5.

C. All flanges whose outside diameter is larger than 2.75" shall be made from forgings according to the process specified in Sec. 4.4. The 'plugs' (blanks) for these forgings shall be cut from billets certified to ASTM A-182 chemistry and federal specification AA-2-763d. If such material is not readily available, vendor may use, upon approval of the University, billets certified to MIL-S-862B Class 1 (304) for reforming purposes. Past experience has proven that these rather stringent specifications are a necessity in order to obtain billets made from ingots which have had sufficient discard to insure a homogenous structure free from injurious piping, non-metallic inclusions and undue segregation. This has proven to be the most effective method in obtaining flanges which are absolutely leak free.

D. Certifications for all materials, which are used in manufacturing flanges shall, upon request, be furnished to the University in the form of Mill test certificates. "Certs" copied onto supplies or intermediaries forms will not be accepted. As a minimum, each certificate shall state:

1. The heat number of the melt.

2. The purchaser's name, order number and date.

3. A description of the material including the specification to which it is made.

4. The results of chemical analysis reporting all elements listed in the specification for that alloy.

5. The result of physical tests of mechanical properties for hardness, ultimate tensile strength, yield strength and percent elongation.

4.4 FORGINGS

A. Flanges and flange parts which are required to be made from forgings must be formed by a process referred to as "Cross Forging". This process is performed by hammer forging each piece triaxially at a "hot-cold work" temperature, approximately 1800°F.

Billets from which forging blanks are cut have predominantly longitudinal metal flow due to drawing out to length in forging or rolling. In order to obtain finished flanges free from these potential leak paths the metal must receive 100% work and complete recrystallization to obtain the necessary fine grain structure.

Beginning with a 'plug' cut from a billet sized according to the diameter(s) and weight of the finished blank, the piece must first receive a reduction of between 50% to 400% (depending on size) to obtain a predominant change in direction of metal flow, typically a 90% change for smaller flanges. This means a 3" or 4" RCS (round corner square) billet for smaller flanges and a 5" or 6" billet for larger flanges. This is followed by drawing out; first from corner to corner, then edge to edge, rotating approximately 45° each time to obtain a round. This "extrudes" the metal in directions opposite to the previous flow thus blocking off potential leak paths. The additional work in the metal also provides the necessary grain refinement required for UHV flanges.

The final operation for solid flanges and inserts is to hammer the plug into a *Pocket Die* (of larger diameter) causing the metal to re-flow outward and fill the die. For rings to be used as retainers for rotatable inserts, the final operation is hammering into a ring die which produces the proper I.D. and O.D. and a center punch out blank which is discarded unless withheld for testing purposes. These final steps in the cross forging process are a "blocking in" operation which adds to the fine grain structure while closing the ends of flow lines to prevent leakage in both longitudinal and transverse directions. The finished forging should have at least a No. 2 grain size in the smaller flanges and no more than a No. 6 in larger sizes. Refer to ASTM E-112 for explanatory information.

B. HEAT TREATMENT

Forged blanks shall be stress relief annealed at approximately 1975°F prior to roughing machining. Time at temperature and method of cooling depend on section thickness and shall be choosen to achieve optimum properties. Certification of heat treatment including time, temperature and quench shall be provided upon request of the University.

C. ROUGH MACHINING

Following forging and heat treatment, each piece shall be rough machined using only "sulphur free" cutting fluids. Upon request, vendor shall provide the University with all information needed to identify the source and constituents of all working fluids used.

D. HARDNESS

A hardness test shall be performed by the vendor on rough machined forgings in the annealed condition. All flanges must be certified to be a minimum hardness of Rockwell B-79 throughout. Typically, flanges should all be in the range of Rockwell B-85 to 90 which is the most desirable.

The maximum hardness allowable is Rockwell B-95. Vendor may choose his own sampling rate for test purposes but must certify that all flanges meet the minimum requirement. The University will make hardness tests on finished flanges received from the vendor. Any flange which fails to meet the hardness requirement within 1/2" on either side of the knife edge will be rejected.

E. PERMEABILITY

In the annealed condition the magnetic permeability of each forging shall not exceed 1.05 at 200 Oersted, (air equal to 1.00). Magnetic permeability of austenitic stainless steel is a function of the mount of free ferrite present in the alloy. The maximum ferrite allowed shall be 0.5%. This can be measured by means of the Severin Standard Ferrite Indicator. Any flange exceeding 0.5% shall be rejected.

F. METALLURGICAL TEST SAMPLES

Vendor must provide, upon request, sample pieces from each lot of heat treated forgings to rough machining. Samples will be used for the purpose of metallurgical testing by the University. These samples are to be provided at no cost to the University and will not be returned due to the destructive nature of the tests. For this purpose, a lot shall consist of all pieces in a specific type and size which are forged at one time. For a lot of less than 100 pieces a minimum of one sample shall be provided. For lots of over 100 pieces the minimum number of samples shall be one piece per 100 produced.

The University shall select the sample(s) at random from the lots of rough forging produced. Sample(s) may be either flange blanks or in case of rings, the "punch out" which is normally discarded. All lots which have samples taken shall be withheld from further processing until the University's tests are completed, the vendor notified of the results and the material approved for further processing.

The University will test the samples in two ways. First, a section will be taken from the sample, faced off, polished and microscopically examined for grain size and structure and for porosity and inclusions following the guide lines of ASTM E45-75. The criteria for acceptance shall be that of MIL-S862b, para. 3.8: "Material shall be uniform in quality and condition free from pipes, seams, cracks, porosity, segregation or any other defects which, due to the nature, degree or extent, detrimentally affect its suitability for the service intended", in this case UHV flanges. In cases where the vendor and the University are unable to agree on the suitability of material tested, the services of an independent laboratory and registered metallurgical engineer shall be used to make a determination. Costs incurred will be borne by the University. Second, another sample about 2" in diameter will be taken, machined down to approxiamtely .007" thickness, chemically cleaned, baked at 250°C to remove non-metallic impurities and tested for leakage on a mass spectrometer helium leak detector calibrated with a minimum sensitivity for helium of 2 x 10^{-10} std cc/sec on the most sensitive range of the leak detector. Any sample which indicates leakage of more than a 2% deflection on the leak rate meter set to the most sensitive scale of the leak detector shall be reported. If the test sample should fail either of the above two requirements, 4 additional samples shall be taken from the lot and tested. *If any one of these fails the entire lot shall be rejected.*

G. FLANGE MACHINING

Flanges are to be machined per the drawings furnished by the University. The use of automatic lathes for machining is strongly recommended. Cutting fluids used for machining must be "sulphur free". Upon request, vendor shall provide the University with a list of the names of all lubricants and cutting fluids to be used in manufacturing. The use of abrasive paper, buffing compounds or grinding wheels is prohibited in any finished operation. All seal details are to be cut with form tools made specifically for that diameter flange. All dimensions and angles on form tools are to be inspected on an optical comparator before use when new and after reforming.

Form tools are to be changed when seal detail dimensions and/or surface finish approach their tolerance limits. Three critical dimensions: gasket restraining diameter, knife edge height and knife edge diameter, are to be checked on <u>each</u> flange by the machine operator using gauges designed specifically for each measurment on each size flange. The first flange machined after each change in tooling is to be 100% inspected by the vendors Quality Assurance group before the run is continued. This inspection is to be done using test instruments that are separate from the production tests equipment. The output of all machined flanges is to be sampled continously by the Quality Assurance inspector per MIL-STD-105D (refer to Sec. 5.4). The inspector will check all flange dimensions with instruments that are separate from those used by the machine operator.

H. CLEANING AND HANDLING

Prior to final inspection, each flange shall be chemically cleaned by vapor degreasing in trichloroethane followed by an alkaline soak cleaner, a thorough tap water rinse and drying with warm, oil-free air or dry nitrogen. Movement of finished flanges from machining to cleaning and inspection shall be within protective handling containers made specifically for this purpose.

4.5 BAR STOCK

The bar stock from which flanges 2 3/4" and smaller are made shall be procured and tested <u>by the vendor</u> according to the following procedures:

A. Alloy designated shall be AISI type 304. Bars shall be purchased as and certified as, conforming to federal specification QQ-S-763d indicating the condition desired either A or B.

B. The magnetic permeability of bar stock shall be the same as for forgings, refer to Sec 4.4E.

C. The hardness of the bar stock shall be the same as for forgings (Sec. 4.4D) except that measurements shall be taken on the face of the bar at a diameter equal to one half the radius and outward. Finished flanges must meet the minimum hardness requirements in the area of the knife edge seal.

D. Coupon samples shall be taken from both ends of each bar for analysis and testing. Each bar shall be marked with the Heat number as taken from the certifications accompanying shipment. Each bar shall also be marked with a BAR NUMBER using a consecutive numbering sequence for all bars submitted from a given Heat. Each coupon shall bear the same markings as the bar from which it is taken. Markings shall be easily read and not removable by chemical etch. A copy of the original certification from each heat from which bars are submitted shall accompany the coupon samples.

E. Coupon samples shall be the same diameter as the bar from which they are taken, shall be 3/8" thick +/- 1/8" and be taken perpendicular to the longitudinal axis of the bar.

F. All samples shall be machined to .062" thickness and have a surface finish suitable for the macroscopic examination specified below. Identify each coupon as required above.

G. Test the sample for hardness and record the result.

H. Prepare samples for macroscopic examination as follows: samples shall first be heated in water to the same temperature as the following acid solution. Samples shall be immersed in a solution consisting of equal parts, by volume, of concentrated hydrochloric acid and water at approximately 160°F for a period of time sufficient to develop fully the macro structure.

Fresh acid shall be used for each lot of samples. After etching, the samples shall be washed in running tap water and any deposit removed by scrubbing. The sample shall then be dipped in cold concentrated nitric acid, washed in cold tap water and dried. After etching, the grain structure shall be examined with a 30 power microscope. Results are to be interpreted by a metallurgist. There should be no evidence of pipes, bursts, segregations, porosity, looseness, seams, pinholes, cracks, non-metallic inclusions, or any other defects which detrimentally affect its suitability for the service intended.

I. A microscopic examination shall also be performed on coupon samples according to the sampling procedures and acceptance-rejection criteria in MIL-STD-105D. Refer to Sec. 5.4. Results of this microscopic examination shall be interpreted by a metallurgist and shall follow the requirements of ASTM E-45-75 for "Microscopical Methods".

Should this tests reveal defects which are judged to be injurious or even questionable in terms of its use for UHV flanges, the bar shall be rejected.

J. Following the macroscopic examination (and a microscopic, if done), each coupon that is accepted thus far will be helium leak tested as follows:

1. Chemically clean each piece first by vapor degreasing in trichloroethane followed by 15 minutes ultrasonic cleaning in freon TF.

2. Bake Coupon(s) at 450^{O}C for 4 hours in air or inert atmosphere.

3. Leak test on mass spectrometer helium leak detector calibrated to a minimum sensitivity for helium 2×10^{-10} std cc/sec per leak rate meter division on the most sensitive scale. Reject any coupon which, when probed with helium for at least one minute, results in a 2% or more deflection on the most sensitive range of the leak detector.

4. If the coupon from either end of a bar fails any of the above tests, the entire bar from which the sample was taken will be rejected. If 20% of the coupons from the bars of a given melt fail the test, the entire melt is rejected.

5. All coupons must be retained by the vendor until such time as bars have been used for production of flanges. Records of traceability of all accepted bars by Purchase Order number, bar number, date and heat number shall be kept by the vendor.

4.6 FINISHING BAR STOCK FLANGES

Final machining, cleaning and handling of flanges made from bar stock shall follow the same requirements as for forged flanges. Refer to Sec. 4.4.

4.7 IDENTIFICATION MARKING

Vendor must mark each flange retaining ring and flange with an identity mark made by impression stamp, engraving, or similar method. Identity mark shall be the manufacturers name, trade name or trade mark. Use of identity marks other than the above must be submitted to the University for written approval prior to use. The identity mark shall be located on the outside periphery of non-rotatable flanges and in the same location on the retainer rings for rotatable flanges.

4.8 DISPOSAL OF DEFECTIVE MATERIAL

Vendor shall establish specific procedures for disposal of all flanges, parts or materials found unacceptable for this specification. Such procedures must be essentially error proof to eliminate defective material from re-entering production.

4.9 FINAL ACCEPTANCE

Final acceptance of all flanges shall take place following delivery to and inspection by, the University.

4.10 REPLACEMENT OF DEFECTIVE FLANGES

Flanges which fail to meet any of the requirement of this specificationn, as determined by the tests and inspection performed by the University, including flanges which may be incorporated into a system and found to be defective, shall be replaced at no additional cost to the University, within 90 days of notification by the University.

4.11 PRE-AWARD INSPECTION

The University may send representatives to prospective vendor's plant prior to award for the purpose of inspecting manufacturing facilities and reviewing the quality assurance organization. Vendor shall be prepared to respond to inquiries regarding information provided in Sec. 4.1 and such other sections of the specification pertinent to determining the qualifications of the prospective vendor.

Discussions of these related topics shall include the person(s) responsible for inspection, quality assurance, production and purchasing of flange materials,.

5.0 TEST PROVISIONS, QUALITY ASSURANCE AND INSPECTION

5.1 RESPONSIBILITY FOR TESTS

Except as noted, all tests and inspections required herein shall be performed by the vendor without additional cost to the University. Equipment and test apparatus used by the vendor shall be properly maintained and operated according to the manufacturer's instructions. The use of faulty test equipment will void any tests performed. It is the vendor's responsibility to provide personnel qualified to operate the equipment and perform the tests.

5.2 SOURCE INSPECTION

A designated University representative shall be permitted to witness any or all of the test and inspection provisions herein required. When so requested, the vendor shall notify the University 48 hours prior to the performance of a given test or inspection. In addition, the University reserves the right to inspect any other process of procurement or manufacturing pertaining to these flanges including forging which may be made by a sub-contractor.

5.3 QUALITY ASSURANCE

Vendor must have a Quality Assurance organization that is independent of the manufacturing group and reports directly to management. Quality

Assurance must include a functioning quality system that is responsible for material control in the following areas:

A. Process control, to the extent that changes in material, dimensions or testing do not occur without adequate coordination.

B. Procurement control, such that material suppliers are qualified and are audited to appropriate standards.

C. Identification and control of raw materials to assure that pertinent sections of the specification are strictly adhered to and that accepted and rejected materials are not intermixed.

D. Inspection and test procedures that are uniform and consistent, that proper records are maintained and calibration of appartus is documented as required.

E. Handling, storage and shipping flanges such that final product is not damaged and that defective parts are not accidently intermixed with accepted parts.

5.4 ACCEPTABLE QUALITY LEVEL (AQL)

MIL-STD-105D shall be used as the basis for acceptance or rejection of lots being inspected. This applies to the microscopic examination required in Sec. 4.6I and output of all machined flanges per 4.6G.

The procedure to be followed is: General inspection level II, single sampling, normal inspection, to an AQL of 2.5, with reduced inspection not permitted but tightened inspection required per paragraph 8.3.1.

Lots which are rejected on the above basis may be 100% inspected by the vendor. All flanges that are found acceptable on this basis may be further processed for shipment.

The maximum lot size for inspection purposes shall be: A) 500 pieces for flange sizes 2.75" and under; B) 200 pieces for flange sizes larger than 2.75" outside diameter.

5.5 FLANGE INSPECTION

In addition to the requirements of other sections, all flanges, after being chemically cleaned, shall be 100% visually inspected for defects in surface finish and damage to the seal surface.

5.6 RETENTION OF RECORDS

A record shall be made of all tests and data required herein including those of raw materials. All such records shall be available to the University upon request and for a minimum of 2 years from the date the data is taken.

5.7 UNIVERSITY INSPECTION

Upon receipt of flanges from the vendor, the University will inspect all flanges to verify conformance to the dimensional and surface finish requirements of this specification. Flanges which fail to meet the requirements for this section shall be rejected.

6.0 PREPARATION FOR DELIVERY

6.1 PACKAGING

Flanges shall be shipped either in extra heavy duty corrugated board or wood boxes which have separating partitions between each flange or "skin-packed" with foam between flanges. Wood boxes shall have a skid type base for forklift handling.

6.2 MARKING FOR SHIPMENT

The outside of each shipping box shall show:

A. The addressee.

B. Vendors name and address.

C. University purchase order number.

D. Any special markings in accordance with ICC regulations.

TECHNICAL SPECIFICATION

FOR

A QUADRUPOLE RESIDUAL GAS ANALYZER

PS-202-631-06

Submitted by ______ Terrence W. Martin ______ Engineering Physicist

Approved by ______ Norman R. Dean ______ Group Leader

Approved by ______ Robert A. Bell ______ Group Leader

PEP Project
Stanford Linear Accelerator Center
Stanford University
Stanford, California
October 15, 1976

1.0 GENERAL

1.1 Specifications for a precision mass analyzer system consisting of an electronics console (including a separate RF generator) and analyzer probe.

2.0 SPECIFICATIONS FOR ANALYZER PROBE

2.1 The probe shall employ a quadrupole type mass filter.

2.2 Both a Faraday cap and a Channeltron® multiplier will be employed as ion detectors. The output current of the multiplier shall be linear to 10 micro-amps.

2.3 The Analyzer Probe shall be bakeable to a temperature 400°C. The maximum operating temperature shall be greater than 150° C.

2.4 Xenon gas will be used for factory calibration procedures so that no residual gas peaks are observed at 10^{-9} Torr pressure levels.

2.5 The Probe shall be mounted on a 4-1/2" Stainless Steel Conflat* Flange shipped under vacuum.

2.6 The probe shall be free of any hydrocarbon contamination within detectable limits at ultra high vacuum operation.

3.0 SPECIFICATIONS FOR ELECTRONICS CONSOLE

3.1 The electronics console must be directly compatible with a U.T.I. 5180-38 analyzer probe.

3.2 The analyzer system shall be operable in a range 1 to 300 AMU range.

3.3 Range scanning requirements

a. Adjustable mass width with digital readout in AMU units.
b. Variable mass center adjustment with digital readout in AMU units.
c. At least three pre-programmed width/center functions.
d. Requires a range re-start control and variable sweep from at least 100 msec to 10 minutes.

* Varian Associates™

3.4 The unit shall be sensitive to a partial pressure of 10^{-14} Torr or 0.1 ppm whichever is greater.

3.5 STABILITY

a. Peak Location shall be $\pm$ .05 AMU/8 hrs.

b. Peak Height Stability shall be $\pm$ 1%/8 hrs.

3.6 Maximum operating pressure of the analyzer system shall be 10^{-3} Torr.

3.7 OUTPUT

a. Pre-scan digital readout of scan width and center scan in AMU units.

During the scan the unit shall provide a digital readout of the mass (in AMU units) and ion current during the scan.

b. BCD digital computer output.

c. Analog output for chart or xy recorder with a range of 0 to 10 volts. A ramp generator output shall be provided such that output is 0 volt during reset function and 10 volts at a maximum width function. The ion current shall be available in analog output from 0 to 10 volts.

3.8 The unit shall include appropriate technical or operations manuals and all necessary cables.

4.0 PRIOR APPROVAL

4.1 The vendor is required to provide a University representative with detailed manufacturing procedures used in the construction of the analyzer probe. Approval for the same must be received prior to manufacture.

4.2 General specifications of the electronics console shall be supplied to the University representative for approval.

4.3 Packaging and shipping details shall be supplied to the University representative for prior approval.

5.0 SPARE PARTS

5.1 Spare parts shall be available for a period of five (5) years.

TECHNICAL SPECIFICATION

SPUTTER ION VACUUM PUMPS

FOR ULTRA HIGH VACUUM APPLICATIONS

PS-202-631-07-R2

Submitted by ______________ Mechanical Engineering Department
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Approved by ______________ Group Leader
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Approved by ______________ Department Head
Robert A. Bell

PEP PROJECT
Stanford Linear Accelerator Center
Stanford University
Stanford, California
May 9, 1977

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Revised June 21, 1977

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1.0 INTRODUCTION

1.1 The Ultra High Vacuum Pumps made to this specification will be used to evacuate the primary Beam Chamber of the Positron-Electron-Project (PEP) Storage Ring, a joint project of the University of California Lawrence Berkeley Laboratory and Stanford University, hereinafter referred to as "The University".

The beam chamber, pumps and other vacuum system components will all be operated at 10^{-10} Torr. To achieve and maintain this pressure all vacuum system components will be thermally cycled from ambient to $200^{\circ}C$. The entire system must withstand a minimum of 50 thermal cycles of 150 hours duration each and retain leak tightness of minimum 2×10^{-10} standard cc/sec helium.

This specification calls for three sizes of pumps to be used at various locations in the Storage Ring. In selecting the most satisfactory pump for each use, the University will require the vendor to demonstrate, by the tests specified herein, all the pertinent operating characteristics judged essential to our application. These requirements call for high reliability in the design of the pump, for great care in the selection of materials and for special handling in machining, welding, chemical cleaning, assembly and bakeout.

2.0 SCOPE

2.1 This document specifies the minimum requirements for producing three sizes of sputter ion pumps of the type described in the introduction, Paragraph 1.1. This specification also includes the requirements for evaluation testing of several parameters of each size pump for quality assurance in manufacturing and for preparation for shipment. Also included is the requirement for a high voltage connector (and cable) to fit the high vacuum feedthrough on the pump.

3.0 APPLICABLE DOCUMENTS

3.1 The applicable provisions of the following documents of issue in effect on the effective date of award shall become part of this specification, to the extent specified herein.

a. ASTM A-240-75a "Heat-resisting Chromium and Chromium Nickel Stainless Steel Plate, Sheet and Strip for Fusion Welded Unfired Pressure Vessels".

b. AMS 5513b"Steel Sheet, Strip and Plate, Corrosion Resistant (304)".

c. AMS 5511c"Steel Sheet, Strip and Plate Corrosion Resistant" (304L)".

d. ASTM A-269-76 "Seamless and Welded Austenitic Stainless Steel Tubing for General Service".

e. AMS 5566f"Steel Tubing, Seamless or Welded, Corrosion Resistant (304).

f. SLAC/PEP Specification PS-202-631-04 RO "Stainless Steel Flanges for U.H.V. Applications."

g. AMS 2645g"Flourescent Penetrant Inspection".

h. SLAC Specification QC-034-100-01 R3,- "Quality Control Workmanship Standards"

i. AMS 7472h"Bolts and Screws, Steel, Corrosion Resistant (Roll Threaded).

4.0 REQUIREMENTS

4.1 GENERAL

The University requires that the vendor be responsible for assurance that the Ion Pumps and any other parts supplied with the pumps meet all the requirements of this specification. Inspection of procedures and records by the University does not alter that responsibility in any way. No deviation from this specification or those stipulated herein will be permitted without prior written permission of the University, including alternatives specified as "University Approved Equal".

4.2 PUMP DESCRIPTION

All pumps shall be of the two element type more commonly referred to as Diode type pumps. Pumps shall be fitted with external magnets. Pumps which require a filament for operation are excluded, as are pumps which require water cooling.

Pumps shall be furnished completely assembled, with all parts and fittings necessary in order for the pump to function as an operable unit. The power unit necessary to activate the pump is not included in this requirement.

4.3 ENVIRONMENTAL CONDITIONS

All pumps and attachments thereto (including high vacuum connector and cable) must be designed for and warranted to continuously operate (for the period of the warranty) at a temperature of 200°C and a relative humidity up to 80% water vapor.

Particular attention must be directed to the design and manufacturing methods used in the high voltage feedthrough and mating connector. Past experience with ion pumps used on high energy particle accelerators has shown that these components are particularly susceptible to failure in humid environments.

In addition to the requirements of the pump magnets, in Section 4.9, all pumps must be constructed to withstand ten bakeouts at a temperature of 450°C for up to 200 hours each with magnets removed. Pumps with magnets, connector and cable attached must withstand 50 bakeout cycles from ambient temperature to 250°C for up to 100 hours each cycle. No part of the pump or operating characteristic shall be affected by such bakeouts. Seismic requirements are stipulated in Section 4.7.

4.4 VACUUM PERFORMANCE

The following minimum operating requirements shall be met or exceeded by pumps made to this specification.

a. Operating Pressure Range:
1×10^{-2} Torr to less than 1.5×10^{-10} Torr.

b. Pumping speeds for the following gasses:

Species	Pump A	Pump B	Pump C
N_2	110 l/s	210 l/s	400 l/s
Ar	30	55	100
CO	105	200	380
H_2	200	380	720
He	35	65	120

Note: Spread in test data of $\pm$ 5% permitted except for H_2 which $\pm$ 10% is permitted.
Speed values taken at 5×10^{-7} Torr. Measurements made with 7.2 kV high voltage. Test procedures outlined in Section 5.0.

c. Operating life
Vendor is required to provide evidence of or demonstrate to the University's satisfaction that pumps are capable of operating at a pressure of 1×10^{-6} Torr for 25,000 hours without sputtering holes through the cathode plates. Pumps must be capable of operating for a minimum of 50,000 hours at 1×10^{-6} Torr N_2 without failure due to any other characteristic which alters pump performance including: insulator leakage, gas instabilities, reduction in pump speeds by more than 20% and vacuum envelope leaks.

d. Maximum time for blanked off pump to reach 1×10^{-4} Torr when started at 10 millitorr:
15 minutes with uncooled pump valved off at flange and after pump interior has been opened to air at 27^0C temperature and 50% relative humidity for 30 minutes.

e. Air stability:
After pumping on air for 24 hours at 1×10^{-5} Torr, pressure fluctuations shall not exceed a factor of 5 at any pressure between 1×10^{-8} and 1×10^{-6} Torr for 4 hours thereafter.

f. Argon Stability
After pumping argon at a pressure of 1×10^{-6} Torr for 1,000 hours there shall be no periodic, cyclic or impulsive type pressure instabilities. Any instability which does occur and which cannot be demonstrated to be caused by changes in test leak-in rate, will be defined as an instability.

4.5 PUMP SIZE LIMITATIONS

The University requires three different capacity pumps made to this specification:

Pump	Pumping Speed (N_2)
A (Form 1 or 2)	110 l/sec
B	210 l/sec
C	400 l/sec

There are two alternatives for pump A. Form 1 is a conventional configuration, Form 2 is a more compact geometry with the inlet flange location best suited to the installation space limitations. Form 2 also includes an auxiliary port connection.

The maximum dimensions for all pumps are shown in Figures 1 through 4 attached.

4.6 MAXIMUM WEIGHT

The weight of each pump with magnets in place shall not exceed the following maximums:

Pump	Weight
A	140 lbs.
B	200 lbs.
C	350 lbs.

4.7 SEISMIC REQUIREMENTS

All pumps (with magnets affixed) must be designed for, and be capable of withstanding an accelerating force of .75 G. The tests to be performed in meeting this requirement are given in Section 5.2.3.

4.8 MATERIALS AND PARTS

All parts and materials for pumps and connectors shall be new and compatible with the design and performance requirements of this specification. All individual components of the pumps and connectors must be functionally and dimensionally interchangeable.

Pump body tubulations and attachments shall be made from Type 304 or 304L stainless steel. Pump body wall thickness shall be minimum of .109 inches conforming to ASTM A-240, AMS-5513 or AMS-5511. Tubing shall conform to ASTM A-269 or AMS-5566. Other components shall be as specified in subsequent sections. All metals which become part of the pump must be purchased to a specific specification, either ASTM, AMS, or other. Metals which are not traceable to a certification shall not be used.

Materials and parts which are finished by painting, plating or other surface preparation must meet the requirements of SLAC Specification No. QC-034-100-01.

The use of cutting fluids or lubricants which contain sulphur or silicone compounds is prohibited. Certifications of materials shall be furnished per Section 5.7.

4.9 PUMP MAGNETS

Pumps shall be fitted with ferrite type magnets which are external to the pump body. Magnets must be removable and secured to the pump by appropriate threaded fasteners. Magnets must be capable of meeting the bakeout requirements of Section 4.3 and maintaining pump speed not less than 80% of the specified minimums. Magnets shall be painted to prevent corrosion and withstand the bakeout required. The stray magnetic field shall not exceed those values stated in Figure 5 attached.

4.10 PUMP ELEMENTS

All internal pump elements must be removable through the flange inlet. The exception to this is the compact 110 l/sec pump, Form 2. The design of all internal elements shall permit easy disassembly, removal and replacement of the high voltage interconnecting harness and anode/cathode assembly. Such replacement shall not require grinding or welding.

Active pump element materials will be vacuum fired at $800^{\circ} \pm 20^{\circ}C$ for a minimum of 12 hours prior to assembly in the pumps to afford the lowest hydrogen base pressure of delivered units.

Standoff insulators for pump elements must incorporate a sputter shield to prevent the deposition of conductive coatings on the insulators during processing or operation of pump.

4.11 OPERATING VOLTAGE AND POLARITY

The operating voltage of the pump shall be 7.2 kV.
Internal connections to the active elements of the pump shall be:
Positive anode connection shall be made to the high voltage feedthrough and Negative Cathode connection shall be made to the ground on the pump body.

4.12 SUPPORT/BRACKETS MOUNTING

The only pump which requires support brackets for mounting is the Type C pump. These pumps shall have brackets welded to each side of the pump body. Brackets shall have threaded holes for fastening purposes. Brackets will support pump during seismic tests in Section 4.7. Bracket details shall be included in vendor drawings required in Section 7.1.

4.13 WELDING

All welding of the pump body shall be by the gas tungsten arc (GTA) process by fusion welding. Filler metal for a specific weld will only be permitted if the vendor indicates such requirement on the drawings submitted and receives approval of same.

All welds shall be made on the vacuum side if the pump design permits. otherwise they shall be welded with 100% penetration from the atmosphere side. Interior surfaces of full penetration welds shall be smooth and free of drop through.

4.14 CHEMICAL CLEANING

Following welding and leak testing, pump body internal surfaces will be thoroughly chemically cleaned. One step of the chemical cleaning process shall be acid etch solution to remove surface oxides and expose the base metal. Subsequent rinses must be thorough and leave no residues. Chemical cleaning of the pump bodies may be inspected by the University representative.

4.15 LEAK INTEGRITY

Wherever stated in this specification, the criteria for vacuum tightness is as follows:

Test with a mass spectrometer helium leak detector calibrated to a minimum sensitivity for helium of 2×10^{-10} std. cc/sec per leak rate meter division on the most sensitive range. Reject any part which, when blanketed with helium for at least one minute, results in a 2% deflection on the most sensitive range of the leak detector.

4.16 AUXILARY PORT CONNECTION

The 110 l/sec Form 1 pump shall have included an auxiliary port connection open to the pump body. The desired location is shown in Fig. 1. Flange shall be 2-3/4" O.D. non-rotatable. Pump will be supplied with this connection sealed with a non-rotatable blank flange. Both flanges must meet the requirements of SLAC/PEP specification PS-202-631-04, or Varian manufactured ConFlat[R] Flanges.

4.17 INLET FLANGE

The inlet flange to the pump shall be non-rotatable and 8 inches outside diameter. Inlet flanges must be welded on in such a way that a plane passing through the center of the flange and equidistant from adjacent bolt holes, shall be parallel to the main planes of symmetry of the pump. Leak check groove shall be oriented to be in the same plane as the long axis of the pump. Bolt holes and leak check groove shall be shown on drawings.

ConFlat[R] Flange is a Registered Trademark of Varian Associates

All flanges, including the high voltage feedthrough and auxiliary port inlets shall conform to SLAC/PEP specification PS-202-631-04 or be Varian manufactured ConFlat[R] Flanges.

4.18 BLANK-OFF FLANGE

All pumps shall be furnished with a non-rotatable blank-off flange attached to the inlet flange. Inlet blank-off flange must also meet the requirements of SLAC/PEP Spec. PS-202-631-04 or be a Varian manufactured ConFlat[R] Flange. These blank-off flanges will not be returned to the vendor. Blank-off flange will have an OFHC copper tube attached. After pinch-off, which follows processing of the pump, the end of the copper tube shall have a protective cover adequate to prevent damage to the exposed edge.

4.19 FLANGE FASTENERS

All bolts used on pump flanges shall be 12 point head austenitic stainless steel conforming to AMS-7472 with Flourescent Penetrant Inspection per AMS 2645. Hex nuts for bolting shall also be wrought austenitic stainless steel, type 302, 304 or 305, of a quality level commensurate with the above bolts.

4.20 HIGH VOLTAGE FEEDTHROUGH

High voltage feedthrough assembly must be identical for all sizes of pumps. Feedthrough must be attached to the pump by means of a removable flanged connection. Flange shall meet the requirements of Section 4.17 Ceramic part must be a minimum of 94% pure Al_2O_3 and have the outer surface glazed.

The ceramic-to-metal assembly must be brazed in dry hydrogen using pure copper as the braze alloy and be prepared by the Moly-Manganese metallizing process. All Kovar parts shall be nickel electro-plated using a copper strike first. Following plating, surfaces shall be: 1) neutralized such as with dilute ammonia, 2) multiple rinses finishing with distilled water, 3) ultrasonic agitation in isopropyl alcohol, 4) thorough drying. The only other material allowed as part of the feedthrough is type 304 stainless steel. High voltage feedthrough must meet the environmental conditions of Section 4.3 and detailed drawings shall be submitted per Section 7.1.

4.21 HIGH VOLTAGE CONNECTOR AND CABLE

Each unit shall be supplied with a high voltage connector to make connection with the pump high voltage feedthrough and provide protection for the electrical hazards involved. The high voltage connector shall be identical and interchangeable on all sizes of pumps. Connector shall include a 12 ft. long high voltage cable with the end opposite the connector prepared as a pigtail. Insulation to the center conductor shall not be removed.

The outer cover of the connecting cable shall be spiral wrapped .008 in. wall 302 or 304 stainless steel (such as Anaconda #451564-0400, 3/8 inch outside diameter) or University approved equal. Within the sheath there shall be a teflon insulated inner conductor rated at 20 kV minimum and a tinned copper braid ground wire of a size equivalent to the current carrying capacity of a No. 14 AWG wire. Braid shall be connected to the ground connection on the connector outer sleeve.

Connector and cable must be rated for the maximum operating voltage of the pump. Connector and cable must meet the environmental and bakeout requirements of Section 4.3.

The connector internal insulator shall be glazed aluminum oxide (AL_2O_3) free of any scratches or other defects. The center conductor and outer ground return high voltage connections must be maintained by a positive action force such as spring tension or other University approved method. Center conductor connector must be stainless steel throughout. Electroplated spring material alloys are not permitted. The outer sleeve of the connector may be carbon steel, at the vendors option, but must be nickel plated to prevent corrosion.

Outer sleeve of the connector must have a red "Danger - High Voltage" warning label permanently affixed.

Detailed drawings and specifications for materials of the connector and cable shall be submitted for approval as part of the requirements of section 7.1.

4.22 PUMP CONOITIONING, FINAL PREPARATION, AND LEAKAGE CURRENT TEST

Following final assembly each pump will be "conditioned" by baking at $425^{o} \pm 50^{o}C$ for at least 12 hours, while being evacuated by an external ion pump. Rough pumping shall be by cryosorption pumps only or University approved equal. Upon cooling, pump must achieve a final pressure of 1×10^{-9} Torr or less in order for conditioning to be completed. Following conditioning, pump shall be pinched off under vacuum and the leakage current shall be measured. Leakage current must not exceed 1 micro amp using a 6.8 to 7.2 kV power supply. The pump shall have all external surfaces conditioned by glass bead b asting (or University approved equal) to remove oxides from bakeout.

Each pump shall then be fitted with magnets and have a final test of internal pressure with the pump operating. Pump current shall be equal to or less than a pressure equivalent of 1.5×10^{-10} Torr.

4.23 SERIAL NUMBERS

Each pump shall have a Serial No. assigned to it. Serial Number shall be permanently engraved on the pump body in the general location indicated on the pump outline drawings attached. Any sequential numbering system is acceptable so long as numbers are not duplicated on different sized pumps. Marking shall be a minimum of 1/4" high numerals and be by means of vibrator engraver or University approved equal.

4.24 FINAL ACCEPTANCE

Notwithstanding the inspection requirements at the vendors plant as described herein, final acceptance of all pumps shall take place following delivery to and testing by the University.

The University reserves the right to perform any or all tests which would be required to verify that the pumps delivered conform to the requirements of this specification. Units which fail any of the tests performed will be deemed unacceptable and returned to the vendor for replacement at no cost to the University. Shipping costs of return and replacement shall also be borne by the vendor.

4.25 SPARE PARTS

The vendor is required to provide a list of all spare parts which may be required for repairing or rebuilding pumps. Spare parts list shall include: complete electrode systems, single parts of the electrode system such as sputter elements and ceramic insulators, high voltage feedthroughs, permanent magnets, and all other parts which may be required for replacement.

4.26 INSTRUCTION MANUALS

At the time of delivery of the pumps vendor shall supply five copies of an instruction manual for each size pump. Manual shall contain a detailed technical description of the pump, a parts list and information necessary to operate, disassemble and rebuild the pump. A complete set of drawings of the pump with all its components shall accompany each instruction manual.

4.27 WARRANTY OF PUMP AND PARTS

Vendor must warrant the following:

a. Field strength of the pump magnets shall not be reduced by more than 10% of the original value within four years after acceptance of the pump.

b. All parts of the pump will be warranted for three years against material and manufacturing faults. The warranty period begins at the time of acceptance of the pumps by the University.

   If a single component fails, vendor must replace it.

   If the pump as a whole is found not to satisfy the specified performance requirements before the end of three years after acceptance, vendor is free either to repair the pump at no cost to the University or to provide a replacement.

c. Spare parts per Section 4.25 shall be available for a period of 6 years from the date of acceptance of the final pump provided under this procurement.

5.0 INSPECTION, TEST PROVISIONS AND QUALITY CONTROL

5.1 SOURCE INSPECTION

A University Representative shall be permitted access to witness any phase of manufacturing, testing and conditioning of these pumps. Upon request, vendor shall make available to the University all records and data on materials and procurement on tests, and manufacturing and other operations which pertain to these pumps.

Upon request, vendor shall notify the University no less than 24 hours in advance of any function or operation chosen to be witnessed or inspected by the University representative.

5.2 PERFORMANCE TESTS

Pumps furnished under this specification shall be subject to the following tests:

Ultimate Pressure
Pumping Speed
Seismic Load

The above tests shall be performed by the vendor on pumps which have been manufactured and processed identically to production units.

The quantity and size of pumps to be tested shall be as specified in the procurement documents.

Notwithstanding satisfactory completion of tests on selected units, all pumps must meet the requirements of these performance tests.

5.2.1 ULTIMATE PRESSURE TESTS

A. Ultimate pressure tests shall be performed using a test apparatus as shown in Fig. 6 attached. The nude Bayard-Alpert type ionization gauge and controller for same shall be furnished by the University. The gauge will be operated at an emission current of 4 mA. The gauge does not require calibration prior to installation.

B. The test dome shall be constructed with welding on the vacuum side wherever possible, otherwise shall be 100% penetration from the atmosphere side. Test dome shall be chemically cleaned to U.H.V. standards prior to welding. It is to the vendors advantage to perform the welding and assembly in a clean room to U.H.V. cleanliness standards. Test dome shall be assembled with new, clean, copper gaskets. System must be vacuum tight to the requirements of Sec. 4.15. The test dome and associated parts shall withstand bakeout to 400°C and remain leak tight to the same requirement.

C. Pump Condition and preparation:

1. The pump to be tested will have been pinched off under vacuum following all manufacturing procedures per this specification.
2. No gasses will be introduced from an external source and pumped by this pump prior to, during or subsequent to the manufacturing bakeout or prior to or during these ultimate pressure tests.
3. The pump will be vented to high purity dry nitrogen gas via the pinch-off tube. The seal off flange will be removed and the test dome installed.
4. The pump and test dome will be roughed with a cryosorption pump system only. An auxiliary sputter ion pump may be installed on the roughing valve to assist during the initial bakeout of the dome and pump to be tested.
5. The dome system and ion pump to be tested will be baked at a temperature of 350° to 400° for at least 48 hours. The test pump may be energized with high voltage during this bakeout procedure.

D. Ultimate pressure measurement:

Following the above bakeout, the pump will be allowed to cool and remain at ambient temperature (20 $\pm$ 5^{o}C) for the duration of the test. The ultimate pressure of the pump is defined as that pressure indicated by the ionization gauge 24 hours subsequent to the pump reaching room temperature following bakeout. The pumps tested must demonstrate ultimate pressure equal to or less than 1 x 10^{-10} Torr.

5.2.2 PUMPING SPEED MEASUREMENTS

The pumping speed of a vacuum pump depends on three variables: the pumping pressure, the nature of the gas pumped and the method by which the pumping speed is measured. In addition, the speed of a sputter-ion pump depends considerably on the history of the pump before the measurement. Hence, the mention of a pumping speed is relevant only if one specifies the pressure, the gas, the measuring method and the state of the pump.

At present, there is no international standard for pumping speed measurements on sputter-ion pumps at low pressures. The University therefore, specifies its own method for pumping speed measurements and defines as pumping speed the speed as measured by this method. The vendor must accept this method for the qualifying test, for acceptance tests by the University and for the settlement of possible warranty claims.

A. A pumping speed test dome shall be constructed as shown in Fig. 7 attached. The nude Bayard-Alpert type ionization gauge and controller for same shall be furnished by the University. The gauge will be operated at an emission current of 4 mA. The gauge does not require calibration prior to installation.

B. Test dome shall be constructed with welds on the Vacuum side wherever possible otherwise shall be 100% penetration from the atmosphere side. Test dome shall be chemically cleaned to U.H.V. standards prior to weld. It is to the vendors advantage to perform the welding and assembly in a clean room to U.H.V. cleanliness standards. Test dome shall be assembled with all new clean copper gaskets. System must be vacuum tight to the requirements of Sec 4.15. Test dome and associated parts shall withstand repeated bakeouts to 400°C and remain leak tight to the same requirement.

C. The foil apertures indicated in Fig. 7 are required for measurement of pump speeds for each of the following gasses:

Pump	Aperture diameter (mm)				
	Ar	N_2	H_2	CO	He
A	19	35	24	34	12
B	27	48	33	47	16
C	37	66	46	65	22

D. Sequence of test gas in speed measurements shall be Nitrogen first, then Argon followed by Carbon Monoxide, Hydrogen and Helium last. Tests made in any sequence other than the above will be void. After the speed measurement for each gas, aperture shall be changed and system baked out prior to next speed measurement.

E. Measurement of pumping speed will be made at 5×10^{-8} Torr, 5×10^{-7} Torr and 5×10^{-6} Torr. The designated pump speed for a specific gas shall be that measured at a pressure 5×10^{-7} Torr under steady state conditions.

F. Steady state conditions are defined as that speed where a linear regression of data, taken over a period of not less than one hour, and having a sample size not less than six datum points, has a slope equal to or less than 2% of the nominal speed, and where one standard deviation of these data does not exceed $\pm$ 5%.

G. Pumpdown and bakeout prior to speed measurements should follow the same guidelines as for ultimate pressure tests, Section 5.3.

H. The pumping speed is calculated from:

$$S_p = C_A \left(\frac{P_2 - P_1}{P_1}\right)$$

where S_p = Pumping Speed $\frac{\text{liters}}{\text{sec}}$

C_A = Conductance of the aperture $\frac{\text{liters}}{\text{sec}}$

P_2 = Pressure in the inlet gas chamber above the aperture Torr

P_1 = Pressure in the pump entry chamber below the aperture Torr

The above calculation is intended as a relative measure of pumping speed for various conditions. No correction is made for some variables which could introduce minor differences in the measured pumping speed.

I. Calculation of the conductance of the aperture is from:

$$C_A = 3.64\, A \left(\frac{T}{M}\right)^{1/2}$$

where C_A = Conductance of aperture, $\frac{\text{liter}}{\text{sec}}$

A = Area of aperture, cm^2

T = Temperature of Gas, ^oK

M = Molecular weight of of the Gas, $\frac{\text{grams}}{\text{Mole}}$

5.2.3 SEISMIC TESTS

Vendor is required to demonstrate, by actual test with magnets attached, the capability of withstanding 5 "Drops" (with an accelerometer attached) of .75G. For the purpose of these tests, pumps A and B shall be supported by the inlet flange only. Pump C shall be supported by the mounting brackets on one side only.

Tests shall be performed in three planes normal to each other, one being axial to the pump inlet. Following the tests, each pump must remain vacuum tight to the requirements of Section 4.15 and not suffer any internal damage which affects operation or function of the pump.

5.3 TEST MONITORING

A University representative will be present to witness all performance tests made by the vendor. Vendor must notify the University a minimum of 48 hours in advance of beginning the tests.

5.4 TEST RECORDS

A record shall be kept of all such pump tests performed. The record shall give date, name of person(s) performing tests, environmental conditions, duration of tests, equipment used, test procedures, diagrams for test setups, all test data and any irregularities observed during testing. All records of tests made at the request of the University shall be available for inspection by the University and copies provided if so requested. Records of calibration of test instruments used in conjunction with above tests shall be made available.

5.5 MATERIALS CERTIFICATION

Vendor is required to obtain and make available for inspection by the University, certifications of all materials used in construction of the pump, pump parts, connectors and cables. Certification shall be in the form of original source test reports of mechanical properties, chemical composition, or other requirements called out in the specifications.

6.0 PREPARATION FOR DELIVERY

6.1 PRESERVATION AND PACKAGING

Pumps shall be shipped under vacuum in a pinched-off condition as described in Section 4.22. When packaged, pumps shall be free of moisture, dirt, soils or any residues from surface preparation. All painted surfaces must be thoroughly dry. Pump shall be totally enclosed and sealed within a minimum .006 inch thick polyethelene bag.

Pumps shall be lashed down by metal strapping to a wooden pallet with skids of sufficient height to permit pickup by fork lift. A protective barrier shall be placed between metal straps and pump surfaces. No more than two pumps may be placed on a pallet. Vendor shall provide an example (at the vendors place of business) of the complete packaging method to be used for shipment of pumps. University approval of packaging is required prior to making the first shipment. Electrical connectors and instruction manuals shall be shipped separately from pumps, as will certifications or other records requested.

6.2 MARKING FOR SHIPMENT

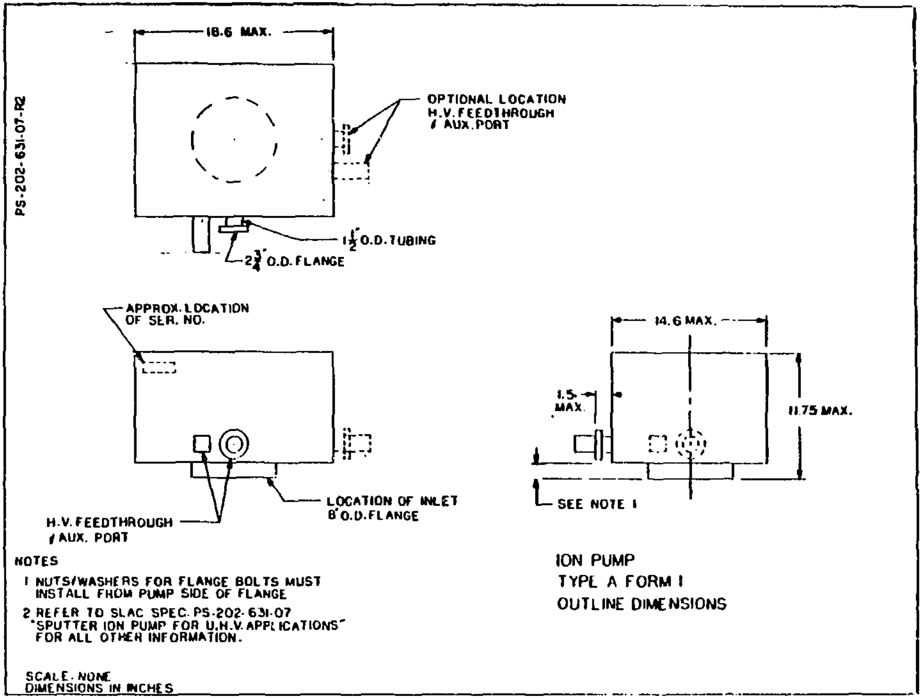
Exterior of shipping containers shall be adequately and properly marked for identification. All containers shall include the following minimum exterior marking:

a. Addressee
b. Shipper
c. SLAC subcontract or purchase order number
d. Special markings, warnings or tags in accordance with ICC regulations.

7.0 DRAWINGS, TECHNICAL DATA

7.1 REQUIRED DRAWINGS

Vendor must submit three complete sets of drawings for each pump showing all dimensions and details of all parts internal and external, which comprise the pump, feedthrough, connector, and cable. The orientation of the leak check groove must be shown on all flange details. If not shown on the drawings, all materials of manufacture shall be included in a specification which must accompany the drawings. Prior to beginning manufacturing, vendor must receive University approval of all drawings. University approval of the drawings in no way relieves the vendor from responsibility to meet all requirements of this specification.



PS-202-631-07-R2
18.6 MAX.
OPTIONAL LOCATION
H.V. FEEDTHROUGH
/ AUX. PORT
1½" O.D. TUBING
2¾" O.D. FLANGE
APPROX. LOCATION
OF SER. NO.
14.6 MAX.
1.5
MAX.
11.75 MAX.
SEE NOTE 1
LOCATION OF INLET
8" O.D. FLANGE
H.V. FEEDTHROUGH
/ AUX. PORT
NOTES
1 NUTS/WASHERS FOR FLANGE BOLTS MUST INSTALL FROM PUMP SIDE OF FLANGE
2 REFER TO SLAC SPEC. PS-202-631-07 "SPUTTER ION PUMP FOR U.H.V. APPLICATIONS" FOR ALL OTHER INFORMATION.
ION PUMP
TYPE A FORM I
OUTLINE DIMENSIONS
SCALE: NONE
DIMENSIONS IN INCHES

Fig. 1

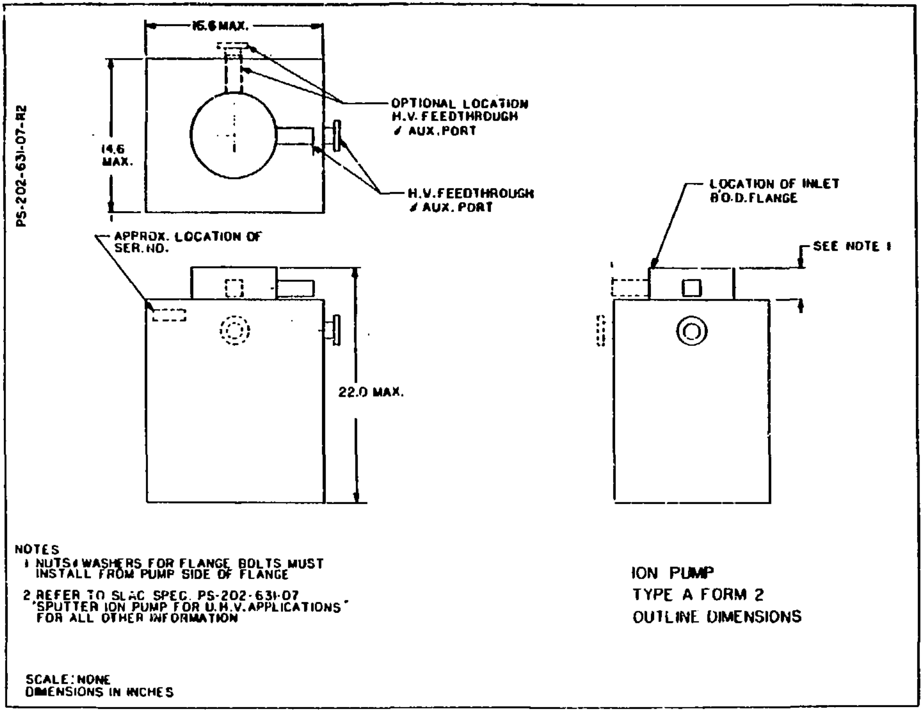
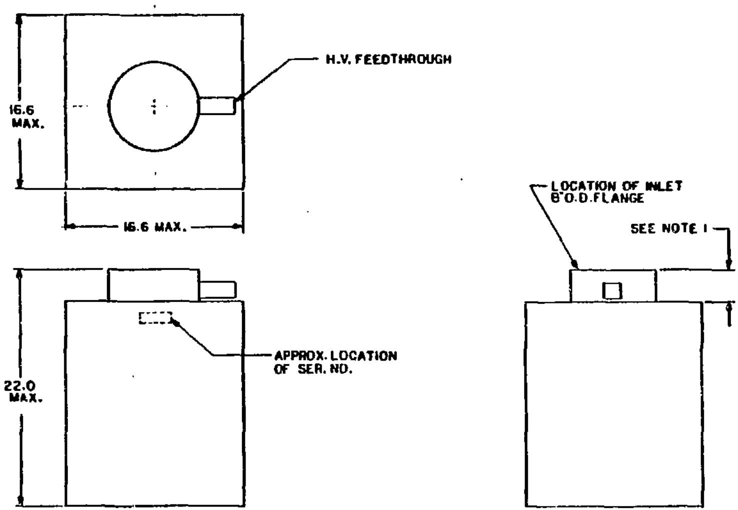

PS-202-631-07-R2
15.6 MAX.
14.6 MAX.
OPTIONAL LOCATION H.V. FEEDTHROUGH & AUX. PORT
H.V. FEEDTHROUGH & AUX. PORT
APPROX. LOCATION OF SER. NO.
22.0 MAX.
LOCATION OF INLET 8 O.D. FLANGE
SEE NOTE 1
NOTES
1 NUTS & WASHERS FOR FLANGE BOLTS MUST INSTALL FROM PUMP SIDE OF FLANGE
2 REFER TO SLAC SPEC. PS-202-631-07 'SPUTTER ION PUMP FOR U.H.V. APPLICATIONS' FOR ALL OTHER INFORMATION
SCALE: NONE
DIMENSIONS IN INCHES
ION PUMP
TYPE A FORM 2
OUTLINE DIMENSIONS

Fig. 2

PS-202-631-07-R2



NOTES

1 FLANGE BOLTS MUST INSTALL FROM PUMP SIDE OF FLANGE

2 REFER TO SLAC SPEC. PS-202-631-07 "SPUTTER ION PUMP FOR U.H.V. APPLICATIONS" FOR ALL OTHER INFORMATION

ION PUMP
TYPE B
OUTLINE DIMENSIONS

SCALE: NONE
DIMENSION IN INCHES

Fig. 3

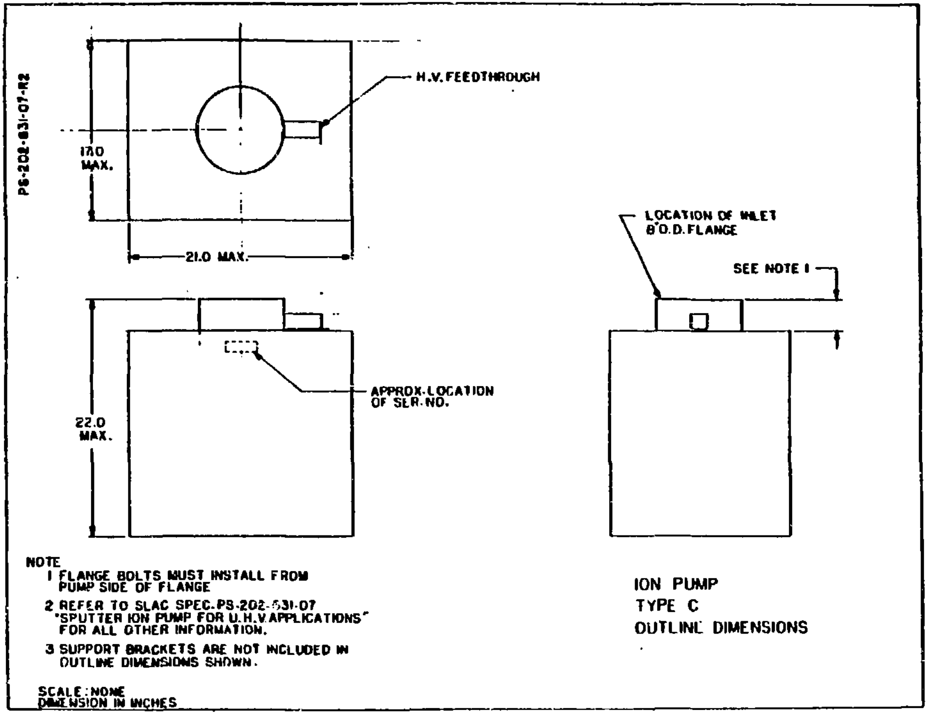

PS-202-631-07-R2
H.V. FEEDTHROUGH
17.0 MAX.
21.0 MAX.
22.0 MAX.
APPROX. LOCATION OF SER. NO.
LOCATION OF INLET 8" O.D. FLANGE
SEE NOTE 1
NOTE
1 FLANGE BOLTS MUST INSTALL FROM PUMP SIDE OF FLANGE
2 REFER TO SLAC SPEC. PS-202-531-07 "SPUTTER ION PUMP FOR U.H.V. APPLICATIONS" FOR ALL OTHER INFORMATION.
3 SUPPORT BRACKETS ARE NOT INCLUDED IN OUTLINE DIMENSIONS SHOWN.
SCALE: NONE
DIMENSION IN INCHES
ION PUMP
TYPE C
OUTLINE DIMENSIONS

Fig. 4

PS-202-631-07 R2

FIELD STRENGTH (GAUSS)

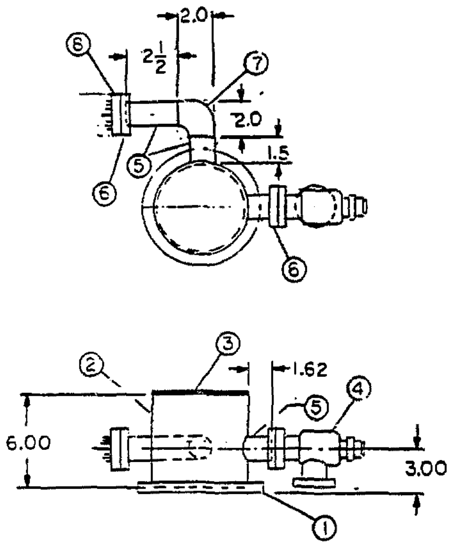
DISTANCE * (INCHES)	PUMP A	PUMP B	PUMP C
2	.5	3	.7
4	.4	2	.8
6	.35	1.5	.9
8	.3	1.0	.8
10	.25	.7	.7
12	.1	.2	.2
15	.03	.02	.04

* AWAY FROM FLANGE FACE, ALONG INLET TUBE ℄ PERP. TO FLANGE PLANE

STRAY MAGNETIC FIELD SURROUNDING PUMPS

FIG 5

PS-202-631-07 R2



ULTIMATE PRESSURE. TEST DOME

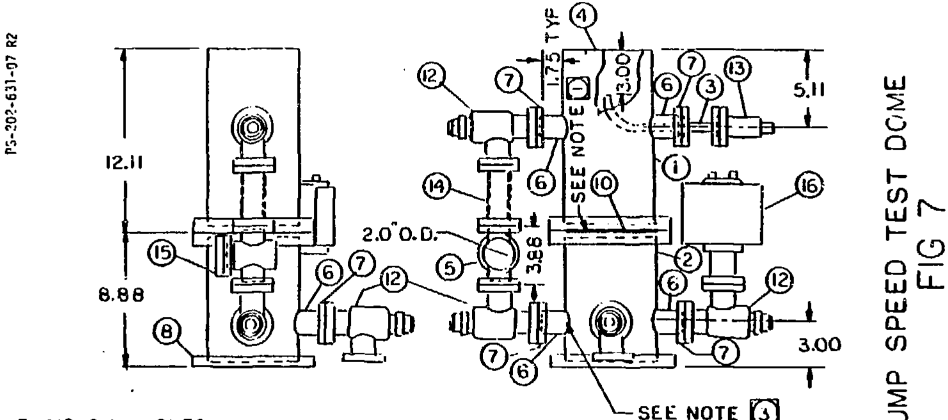
FIG 6

2 FOR ALL OTHER INFORMATION REFER TO SLAC SPEC. PS-202-631-07

1 ALL WELDS ON VACUUM SIDE OR 100% PENETRATION ON ATMOSPHERE SIDE

NOTES DIMENSIONS IN INCHES

ITEM	DESCRIPTION	QTY	ITEM	DESCRIPTION	QTY
5	TUBE 1.5O.D.X.062W 304 S.STL.	2			
4	BAKEABLE VALVE	1	8	NUDE ION GAUGE BAYARD-ALPERT TYPE	1
3	PLATE TOP .109 THK.304 S.STL.	1			
2	TUBE 6"O.D. X.083 W 304 S.STL.	1	7	90°ELBOW 1.5O.D.X.062W304 S.STL.	1
1	FLANGE 8"O.D.X 6"I.D.304 S.STL.	1	6	FLANGE 2.75 O.D.X 1.5I.D.304S.STL.	2



DIMENSIONS IN INCHES

NOTES

3. ENTRY HOLE FOR ITEM ⑥ INTO ② IS 400 DIA

2 ALL WELDS ON VACUUM SIDE OR 100% PENETRATION ON ATMOSPHERE SIDE

1 FOR APERATURE ASS'Y AND ALL OTHER INFORMATION REFER TO SLAC SPEC. PS-202-631-07

ITEM	DESCRIPTION	QTY	ITEM	DESCRIPTION	QTY
1	TUBE 6.00 O.D. X .083 WALL 304 S STL	1	16	HIGH THROUGHPUT ION PUMP W/MAGNET	1
2	TUBE 6.00 O.D. X .083 WALL 304 S.STL.	1	15	NUDE ION GAUGE BAYARD-ALPERT TYPE	1
3	DIFFUSER ASS'Y 304 S.STL.	1	14	1 1/2 FLEX COUPLING	1
4	PLATE TOP .109 THK. 304 S.STL.	1	13	VARIABLE LEAK VALVE	1
5	GAUGE ASS'Y 304 S.STL.	1	12	BAKEABLE VALVE	4
6	TUBE 1.62 LG. X 1.50 O.D. X .062 WALL 304 S.STL.	5	11	CURVAC FLANGE 8 O.D. ULTEC 261-6040	1
7	FLANGE 2.750 O.D. X 1.5 I.D. 304 S.STL.	5	10	APERATURE OF HC CO FOIL .008 THK. MAX.	1
8	FLANGE 8 O.D. X 6 I.D. 304 S.STL.	3	9		

Fig. 7

ORDER AS FOLLOWS:

Transition material produced by a proprietary process known as "ROLL BONDING".

TOTAL THICKNESS:

0.87" + .12" - 0". Consisting of approximately .5" aluminum alloy 3003 and .37" stainless steel alloy 304.

FLATNESS:

When placed on a flat surface, no part of the plate shall exceed .12" from flat per 12" in width or length dimension.

BOND INTEGRITY TEST:

Zero radius 90° bend test samples shall be taken along the full length of all four sides of each piece shipped. Criteria for acceptance: no visible separation. Samples shall be retained by vendor for a period of 30 days to permit inspection at our option.

SPECIFICATION:

Material shipped must meet the requirements of Kaiser Aluminum & Chemical Company specification #KA-09006A. Copies are available from Spur Industries.

CERTIFICATIONS:

Mill source test reports of chemical analysis by heat number shall be provided for both alloys of all plates shipped. Ordinary "certs" are not acceptable. A certification of bend tests is also required.

WEIGHT:

Approximately 22.4 lbs per ft^2.

PLATE SIZE:

Typically 16" by 18" is an optimum size for most vacuum system applications, taking into account such factors as: minimizing cutting waste, handling weight for one person, and maximum utilization of vendors usable plate width. If needed, larger or smaller sizes are also available. Consult with vendor for specifics.

SOLE SOURCE:

Spur Industries
E. 17404 Euclid Ave.
Spokane, WA 99216
509-924-2800 (ATTN: Lyle Jorgens)

STANFORD LINEAR ACCELERATOR CENTER U S ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION STANFORD UNIVERSITY STANFORD CALIFORNIA	Technical Specification: ROLL BONDED ALUMINUM TO STAINLESS STEEL TRANSITION MATERIAL	
ENGR U. Cummings / DES / CHK / APPROVAL UCC 3-6-86	PS-202-631-09-R1 Revised: 3/6/86	A

mFR1

TECHNICAL SPECIFICATION

DIFFERENTIAL ION PUMPS
FOR ULTRA HIGH VACUUM
PS-202-631-10-RO

Submitted by ______________________ Vacuum Group
Urban K. Cummings

Approved by ______________________ Deputy Group Leader
Daniel M. Wright

Approved by ______________________ Group Leader
Norman R. Dean

Stanford Linear Accelerator Center
Stanford University
Stanford, California 94305

November 1, 1985

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 The Vacuum Pumps made to this specification will become a part of various UHV systems used for research in high energy physics experiments at the Stanford Linear Accelerator Center, a part of Stanford University, hereinafter referred to as the University.

The beam chamber, pumps and other vacuum system components will all be operated at 10E-10 Torr. To achieve and maintain this pressure all vacuum system components will be thermally cycled from ambient to 200°C. The entire system must withstand a minimum of 50 thermal cycles of 150 hours duration each and retain leak tightness of minimum 2x10E-10 standard cc/sec helium.

This specification calls for three sizes of pumps to be used at various locations. In selecting the most satisfactory pump, the University may require the vendor to demonstrate the pertinent operating characteristics judged essential to our application. Our requirements call for high reliability in the design of the pump, for great care in the selection of materials and for special handling in machining, welding, chemical cleaning, assembly and bakeout.

2.0 SCOPE

2.1 This document specifies the minimum requirements for producing three sizes of sputter ion pumps of the type described in the introduction, Paragraph 1.1. This specification also describes evaluation testing of several parameters of each size pump for quality assurance in manufacturing and for preparation for shipment. Also included is the requirement for a high voltage connector and cable to connect the vacuum feedthrough on the pump to the required HV power supply.

3.0 APPLICABLE DOCUMENTS

3.1 The applicable provisions of the following documents of issue in effect on the effective date of award shall become part of this specification, to the extent specified herein.

a. ASTM A-240-75a "Heat-resisting Chromium and Chromium Nickel Stainless Steel Plate, Sheet and Strip for Fusion Welded Unfired Pressure Vessels".

b. AMS 5513b "Steel Sheet, Strip and Plate Corrosion Resistant" (304)".

c. AMS 5511c "Steel Sheet, Strip and Plate Corrosion Resistant (304L)".

d. ASTM A-269-76 "Seamless and Welded Austenitic Stainless Steel Tubing for General Service".

e. AMS 5566f "Steel Tubing, Seamless or Welded, Corrosion Resistant (304)".

f. SLAC/PEP Specification PS-202-631-04-R1 "Stainless Steel Flanges for U.H.V. Applications".

g. SLAC Specification QC-034-100-01 "Quality Control Workmanship Standards.

h. AVS Technical Standards 4.7 "Procedure for Measuring the Ultimate Pressure of Capture Pumps". Revision 1973.

i. AVS Technical Standards 4.8 "Procedure for Measuring Speed of Pumps without Working Fluids".

4.0 REQUIREMENTS

4.1 GENERAL

The University requires that the vendor be responsible for assurance that the Ion Pumps and any other parts supplied with the pumps meet all the requirements of this specification. Inspection of procedures and records by the University does not alter that responsibility in any way. No deviation from this specification or those stipulated herein will be permitted without prior written permission of the University, including alternatives specified as "University Approved Equal".

4.2 PUMP DESCRIPTION

All pumps shall be of the two element, diode type, more commonly referred to as differential ion or "D-I" pumps containing both titanium and tantalum cathode plates. Pumps shall be fitted with external magnets. Pumps which require a filament for operation are excluded, as are pumps which require water cooling.

Pumps shall be furnished completed assembled, with all parts and fittings necessary in order for the pump to function as an operable unit. The power supply necessary to activate the pump is not included in this requirement.

4.3 ENVIRONMENTAL CONDITIONS

All pumps and attachments thereto (including high voltage connector and cable) must be designed for and warranted to continuously operate (for the period of the warranty) at temperatures up to 200^{0}C and relative humidity up to 80% water vapor at 20^{0}C.

Particular attention must be directed to the design and manufacturing methods used in the high voltage feedthrough and mating connector. Past experience with ion pumps used on high energy particle accelerators has shown that these components are particularly susceptible to failure in humid environments.

In addition to the requirements of the pump magnets, in Section 4.9, all pumps must be constructed to withstand ten bakeouts at a temperature of 450°C for up to 200 hours each with magnets removed. Pumps with magnets, connector and cable attached must withstand 50 bakeout cycles from ambient temperature to 250°C for up to 100 hours each cycle. No part of the pump or operating characteristic shall be affected by such bakeouts. Seismic requirements are stipulated in Section 4.7.

4.4 VACUUM PERFORMANCE

The following minimum operating requirements shall be met or exceeded by pumps made to this specification. Measurements made on unused pumps.

a. Operating Pressure Range:

1x10E-3 Torr to less than 1.5x10E-10 Torr.

b. Pumping speeds for the following gasses:

Species	Pump A	Pump B*	Pump C
N2	20 l/s	270 l/s	400 l/s
Ar	4	54	80
CO	20	270	380
H2	32	430	640
He	6	81	120

*NOTE: Vendor may also propose a 220 l/s pump with proportionate pumping speeds for the species listed. Pump speed measurements made per AVS Technical Standard 4.8. Spread test data of +/- 5% permitted except for Hydrogen which +/- 10% is permitted.

Speed values taken at 5x10E-7 Torr. Measurements made at pump manufacturers recommended operating voltage.

c. Operating Life:

Vendor is required to provide evidence of or demonstrate to the University's satisfaction that pumps are capable of operating at a pressure of 1x10E-6 Torr for 25,000 hours without sputtering holes through the cathode plates. Pumps must be capable of operating for a minimum of 50,000 hours at 1x10E-6 Torr Nitrogen without failure due to any other characteristics which alters pump performance including: insulator leakage, gas instabilities, reduction in pump speeds by more than 20% and vacuum envelope leaks.

d. Maximum Time for Blanked Off Pump to Reach 1x10E-4 Torr When Started at 1 Millitorr:

15 minutes with uncooled pump valved off at flange and after pump interior has been opened to air at 27^{o}C temperature and 50% relative humidity for 30 minutes.

e. Air Stability:

After pumping on air for 24 hours at 1x10E-5 Torr, pressure fluctuations shall not exceed a factor of 5 at any pressure between 1x10E-8 and 1x10E-6 Torr for 4 hours thereafter.

f. Argon Stability:

After pumping argon at a pressure of 1x10E-6 Torr for 1,000 hours there shall be no periodic, cyclic or impulsive type pressure instabilities. Any instability which does occur and which cannot be demonstrated to be caused by changes in test leak-in rate, will be defined as an instability.

4.5 PUMP SIZES

The University requires three different capacity pumps made to this specification:

Pump	Pumping Speed (N2)	Maximum Dimensions (In.) L	W	H
A	20 l/sec	6	9	10
B	270 l/sec	16.5	16.5	22
C	400 l/sec	16.5	20	22

4.6 MAXIMUM WEIGHT

The weight of each pump with magnets in place shall not exceed the following maximums:

Pump	Weight (lbs.)
A	26
B	225
C	400

4.7 SEISMIC REQUIREMENTS

All pumps (with magnets affixed) must be capable of withstanding an accelerating force of .75 G. The tests to meet this requirement are given in Section 5.3.

4.8 MATERIALS AND PARTS

All parts and materials for pumps and connectors shall be new and compatible with the design and performance requirements of this specification. All individual components of the pumps and connectors must be functionally and dimensionally interchangeable with pumps of the same size.

Pump body tubulations and attachments shall be made from Type 304 or 304L stainless steel. Pump body wall thickness shall be minimum of .109 inches conforming to ASTM A-240, AMS-5513 or AMS-5511. Tubing shall conform to ASTM A-269 or AMS-5566. Other components shall be as specified in subsequent sections. All metals which become part of the pump must be purchased to a nationally recognized commercial specification, either ASTM, AMS or other. Metals which are not purchased to a specific specification shall not be used.

Materials and parts which are finished by painting, plating or other surface preparation must meet the requirements of SLAC Specification QC-034-100-01.

The use of cutting fluids or metal working lubricants which contain sulphur or silicone compounds is prohibited. The maximum permissible sulphur content is 0.05% (500 ppm). Certifications of materials shall be furnished if requested by the University.

4.9 PUMP MAGNETS

Pumps shall be fitted with ferrite type magnets which are external to the pump body. Magnets must be secured to the pump by appropriate threaded fasteners for the purpose of removability. Magnet must be capable of the bakeout requirements of Section 4.3 and maintaining pump speed not less than 80% of the specified minimums. Magnets or magnet covers shall be painted to prevent corrosion and withstand the bakeout required. The stray magnetic field shall not exceed those values stated below.

Distance* (Inches)	Field Strength (Gauss)		
	Pump A	Pump B	Pump C
2	1.0	3	.7
4	.5	2	.8
6	.2	2	.9
8	<.1	1.0	.8
10		.7	.7
12		.2	.2
15		.02	<.1

*Away from flange face, along inlet tube center line, perpendicular to flange plane.

4.10 PUMP ELEMENTS

All internal pump elements must be removable through the flange inlet except for pump A. The design of all removable elements shall permit easy disassembly, removal and replacement of the high voltage interconnecting harness and anode/cathode assembly. Such replacement shall not require grinding or welding.

Active pump element materials will be vacuum fired at 600 +/- 20°C prior to assembly in the pumps to afford the lowest hydrogen base pressure of delivered units.

Standoff insulators for pump elements must incorporate a sputter shield to prevent the deposition of conductive coatings on the insulators during processing or operation of pump.

4.11 OPERATING VOLTAGE AND POLARITY

The operating voltage of the pumps may be either 5.5 KV or 7.5 KV. Pumps from a given vendor shall all operate at the same one voltage for speed measurement and operation. Internal connections to the active elements of the pump shall be: the positive anode connection shall be made to the high voltage feedthrough and the negative cathode connection shall be made to the ground on the pump body.

4.12 SUPPORT BRACKETS OR MOUNTING BOSSES

Pumps B and C require either support brackets or threaded bosses for mounting. Threaded bosses and brackets shall be welded to the pump body. Brackets shall have holes for fastening purposes. Bracket details shall be included in vendor drawings required in Section 7.1. Vendor must specify how pump is to be supported in order to meet seismic requirements in 4.7.

4.13 WELDING

All welding of the pump body shall be by the gas tungsten arc (GTA) process by fusion welding. Filler metal for a specific weld will only be permitted if the vendor indicates such requirement on the drawings submitted and receives approval of same.

All welds shall be made on the vacuum side if the pump design permits, otherwise they shall be welded with 100% penetration from the atmosphere side. The interior surface of full penetration outside welds shall be smooth and free of drop through.

4.14 CHEMICAL CLEANING

Following welding and leak testing, pump body internal surfaces will be thoroughly cleaned. One step of the chemical cleaning process shall be acid etch solution to remove surface oxides and expose the base metal. Subsequent rinses must be thorough and leave no residues. Chemical cleaning of the pump bodies may be inspected by the University representative.

4.15 LEAK INTEGRITY

Wherever stated in this specification, the criteria for vacuum tightness is as follows:

Test with a mass spectrometer helium leak detector calibrated to a minimum sensitivity for helium of 2x10E-10 std cc/sec per leak rate meter division on the most sensitive range. Reject any part which, when blanketed with helium for at least one minute, results in a 2% deflection on the most sensitive range of the leak detector.

4.16 FLANGES

All flanges connected to the pump shall be of the "knife edge" type made per SLAC specification PS-202-631-04 or University approved equal. Flange details must be shown on drawings required in Section 7.1. Inlet flanges must be welded on in such a way that a plane passing through the center of the flange and equidistant from adjacent bolt holes, shall be parallel to the main planes of symmetry of the pump. Flange bolt holes and orientation of the leak check groove shall be shown on drawings.

4.17 BLANK-OFF FLANGE

All pumps shall be furnished with a non-rotatable blank-off flange attached to the inlet flange. Inlet blank-off flange must all meet the requirements of SLAC specification PS-202-631-04 or University approved equal. These blank-off flanges will not be returned to the vendor. Blank-off flange will have an OFHC copper tube attached. After pinch-off, which follows processing of the pump, the end of the copper tube shall have a protective cover adequate to prevent damage to the exposed edge.

4.18 FLANGE FASTENERS

Bolts used on pump inlet flange shall be rolled thread, 12 point head, high tensile strength Type 305 austenitic stainless steel. Hex nuts for bolting shall also be wrought austenitic stainless steel, Type 302, 304 or 305, of a quality level commensurate with the above bolts.

4.19 HIGH VOLTAGE FEEDTHROUGH

High voltage feedthrough assembly must be identical for all sizes of pumps. Except for pump A, feedthrough must be attached to the pump by means of a removable flanged connection. Flange shall meet the requirements of Section 3.1.f. Ceramic part must be a minimum of 94% pure Aluminum oxide and have the outer surface glazed.

The ceramic-to-metal assembly must be brazed in dry hydrogen using a copper-gold braze alloy and be prepared by the Moly-Manganese metallizing process. All Kovar parts should be nickel electro-plated using a copper strike first. Following plating, surfaces shall be: 1) neutralized such as with dilute ammonia, 2) ultrasonic agitation in isopropyl alcohol, 4) thorough drying. The only other material allowed as part of the feedthrough is Type 304 stainless steel. High voltage feedthrough must meet the environmental conditions of Section 4.3 and detailed drawings shall be submitted per Section 7.1.

4.20 HIGH VOLTAGE CONNECTOR AND CABLE

Each unit shall be supplied with a minimum 12 foot long high voltage cable and connectors to make connection with a high voltage power supply and provide protection for the electrical hazards involved. The high voltage connection to the pump shall be interchangeable on all sizes of pumps. The H.V. connector to the power supply shall be an SHV type.

Connector and cable must be rated for the maximum operating voltage of the pump. Connector and cable must meet the environmental and bakeout requirements of Section 4.3.

The connector internal insulator shall be glazed aluminum oxide free of any scratches or other defects. The center conductor and outer ground return high voltage connections must be maintained by a positive action force such as spring tension or other University approved method. Center conductor connector must be stainless steel throughout. Electroplated spring material alloys are not permitted. The outer sleeve of the connector may be carbon steel, at the vendors option, but must be nickel plated to prevent corrosion.

Detailed drawings and specifications for the connector and cable shall be submitted for approval as part of the requirements of Section 7.1.

4.21 PUMP CONDITIONING, FINAL PREPARATION AND LEAKAGE CURRENT TEST

Following final assembly each pump will be "conditioned" by baking at a minimum of 200^{0}C for at least 12 hours under vacuum. Rough pumping shall be by cryosorption pumps only or University approved equal. Upon cooling, pump must achieve a final pressure of 1x10E-9 Torr or less in order for conditioning to be completed. Following conditioning, pump shall be pinched off under vacuum and the leakage current shall be measured. Leakage current must not exceed 1 micro amp using the required power supply. The pump shall have all external surfaces conditioned by glass bead blasting, if necessary, to remove oxides from bakeout.

Each pump shall then be fitted with magnets and have a final test of internal pressure with the pump operating. Pump current shall be equal to or less than a pressure equivalent of 1.5x10E-9 Torr, per the manufacturers pressure vs pump current curve.

4.22 SERIAL NUMBERS

Each pump shall have a serial number assigned to it. Serial number shall be permanently engraved on the pump body in the general location indicated on the pump outline drawings attached. Any sequential numbering system is acceptable so long as number are not duplicated on different sized pumps. Marking shall be a minimum of 1/8" high numerals and be by means of vibrator engraver or other University approved method.

4.23 FINAL ACCEPTANCE

Notwithstanding the inspection requirements at the vendor's plant as described herein, final acceptance of all pumps shall take place following delivery to and testing by the University.

The University reserves the right to perform any or all tests which would be required to verify that the pumps and flanges attached thereto conform to the requirements of this specification. Units which fail any of the tests performed will be deemed unacceptable and returned to the vendor for replacement at no cost to the University. Shipping costs of return and replacement shall also be borne by the vendor.

4.24 SPARE PARTS

The vendor is required to provide a list of all spare parts which may be required for repairing or rebuilding pumps. Spare parts list shall include: complete electrode systems, single parts of the electrode system such as sputter elements and ceramic insulators, high voltage feedthroughs, permanent magnets and all other parts which may be required for replacement.

4.25 INSTRUCTION MANUAL

At the time of delivery of the pumps vendor shall supply five copies of an instruction manual for each size pump. Manual shall contain a detailed technical description of the pump, a parts list and information necessary to operate, disassembly and rebuild the pump. A complete set of drawings of the pump with all its components shall accompany each instruction manual.

4.26 WARRANTY OF PUMP AND PARTS

Vendor must warrant the following:

a. Field strength of the pump magnets shall not be reduced by more than 5% of the original value within one year after acceptance of the pump.

b. The pump must be warranted for one year for performance characteristics and against material and manufacturing faults. The warranty period begins at the time of acceptance of the pumps by the University.

If a single component fails, vendor must replace it.

If the pump as a whole is found not to satisfy the specified performance requirements before the end of the year after acceptance, vendor is free either to repair the pump at no cost to the University or to provide a replacement.

c. Spare parts per Section 4.24 shall be available for a period of 5 years from the date of acceptance of the final pump provided under this procurement.

5.0 INSPECTION, TEST PROVISIONS AND QUALITY CONTROL

5.1 SOURCE INSPECTION

A University representative shall be permitted access to witness any phase of manufacturing, testing and conditioning of these pumps. Upon request, vendor shall make available to the University all records and data on materials and procurement on tests, and manufacturing, and other operations which pertain to these pumps.

Upon request, vendor shall notify the University no less than 24 hours in advance of any function or operation chosen to be witnessed or inspected by the University representative.

5.2 PERFORMANCE TESTS

Pumps furnished under this specification may be subject to the following tests by the University:

Leakage Current
Ultimate Pressure
Pumping Speed
Seismic Load

Data from the results of such tests performed by the vendor on identical pumps would be useful to the University in verifying the above performance characteristics.

5.3 SEISMIC TESTS

Vendor may be required to demonstrate, by actual test with magnets attached, the capability of withstanding 5 "drops" (with an accelerometer attached) of .75G. For the purpose of these tests, pump A shall be supported by the inlet flange only. Pumps B and C shall be supported by the mounting brackets or supports provided, or as specified by the vendor.

Seismic tests shall be performed in three planes normal to each other, one being axial to the pump inlet. Following the tests, each pump must remain vacuum tight to the requirements of Section 4.15 and not suffer any internal damage which affects operation or function of the pump.

5.4 TEST MONITORING

A University representative may be present to witness performance tests made by the vendor. Vendor must notify the University a minimum of 48 hours in advance of beginning the tests.

5.5 TEST RECORDS

A record shall be kept of all such pump tests performed. The record shall give date, name of person(s) performing tests, environmental conditions, duration of tests, equipment used, test procedures, diagrams for test set-ups, all test data and any irregularities observed during testing. All records of tests made at the request of the University shall be available for inspection by the University and copies provided if so requested. Records of calibration of test instruments used in conjunction with above tests shall be made available.

5.6 MATERIALS CERTIFICATION

Vendor is required to obtain and make available for inspection by the University, certifications of all materials used in construction of pumps and internal parts. Certification shall be in the form of original source test reports of mechanical properties, chemical composition, or other requirements called out in the specifications.

6.0 PREPARATION FOR DELIVERY

6.1 PRESERVATION AND PACKAGING

Pumps shall be shipped under vacuum in a pinched-off condition as described in Section 4.21. When packaged, pumps shall be free of moisture, dirt, soils or any residues from surface preparation. All painted surfaces must be thoroughly dry. Type A pumps may be shipped in individual corrugated cardboard boxes. Type B and C pumps shall be in totally enclosed wooden boxes, or sealed within a minimum .006 inch thick polyethelene sheet and be lashed down by metal strapping to a wooden pallet. Pallet must have skids of sufficient height to permit pickup by fork lift. A protective barrier shall be placed between metal straps and pump surfaces. No more than two pumps may be placed on a pallet. Vendor may be required to provide an example (at the vendor's place of business) of the complete packaging method to be used for shipment of pumps. University approval of packaging is required prior to making the first shipment. Electrical connectors and instruction manuals shall be shipped separately from pumps, as will certifications or other records requested.

6.2 MARKING FOR SHIPMENT

Exterior of shipping containers shall be adequately and properly marked for identification. All containers shall include the following minimum exterior marking:

a. Addressee

b. Shipper

c. SLAC subcontract or purchase order number

d. Special markings, warnings or tags in accordance with ICC regulations.

7.0 DRAWINGS, TECHNICAL DATA

7.1 REQUIRED DRAWINGS

Vendor must submit three complete sets of drawings for each pump showing all dimensions and details of all parts internal and external, which comprise the pump, flanges, feedthrough, connector and cable. The orientation of the leak check groove must be shown on all flange details. If not shown on the drawings, all materials of manufacture shall be included in a specification which must accompany the drawings. Prior to beginning manufacturing, vendor must receive written University approval of all drawings. University approval of the drawings in no way relieves the vendor from responsibility to meet all requirements of this specification.

TECHNICAL SPECIFICATION

CONTOURING
OXYGEN FREE HIGH PURITY
COPPER TUBING FOR ULTRA
HIGH VACUUM APPLICATIONS

PS-202-631-12 RO

Submitted by ________________ Mechanical Engineering Department
Thomas R. Winch

Approved by ________________ Group Leader
Norman R. Dean

Approved by ________________ Department Head
Robert A. Bell

PEP Project
Stanford Linear Accelerator Center
Stanford, California
March 1, 1978

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1.0 INTRODUCTION

1.1 The oxygen free high purity copper tubing made to this specification will become part of the primary beam chamber of the Positron-Electron Project (PEP) Storage Ring, a joint project of the University of California Lawrence Berkeley Laboratory and Stanford University, hereinafter referred to as The University.

This specification is for the forming of round copper tubes to approximately a diamond shapped cross-section except for the ends of the tubes which will remain round (as specified in PEP drawings). The material to be supplied to the vendor will be OFE high purity copper tubing as per PEP technical specification PS-202-631-08. After forming, the tubes are to be tested and approved for ultra high vacuum use by the University. Stainless steel flanges and other components will then be affixed to the copper tubes by The University. The fabrication techniques include forming, high temperature dry hydrogen braze cycles above 1000°C and gas tungsten arc welding. All completed assemblies operate at 10^{-10} torr and are thermal cycled to 200°C.

2.0 SCOPE

2.1 This document specifies the minimum requirements for producing copper tubes of the necessary quality such that they are acceptable for their intended use.

This specification also includes the requirements for quality assurance and inspection of the copper tubing and for reporting same. Also included are requirements for the preparation and delivery of the copper tubes.

3.0 REQUIREMENTS

3.1 MATERIAL

The University furnished tubing shall be made from and meet all the requirements of Oxygen-Free, Electronic (OFE) Copper Alloy UNS Number C10100.

Vendor may witness any tests performed by the University on the copper tubing.

The temper of the round tube as received by the University prior to forming shall be an as manufactured temper. The University shall then hydrogen anneal the tube to a temper designated by the vendor.

3.2 DESCRIPTION OF PART

The dimensions of the tube as received from the vendor shall be as specified in drawings furnished by the University. The inside of the tubes are to be free of scrathes, nicks, and inclusions. The surface finish to be a uniform 63 rms microinch.

3.3 FORMING OPERATION

A. Any forming, cutting or sawing operations requiring coolants or lubricants must use sulfur-free and silicon-free coolants consistent with electron device and high vacuum fabrication practices. The University's written approval shall be obtained before any coolants and/or lubricants are to be used. Also, abrasives, such as grinding wheels or emery cloth, may not be used on the tubes. Forming practices must be approved by the University.

B. The copper tubes are to be formed to the shape specified in drawings furnished by the University. Any tube which deviates from the drawings shall be rejected.

3.4 ACCEPTANCE TESTS

A. Hydrogen Firing
The formed tubes when received by the University shall be vapor degreased, chemically cleaned, fired for 30 minutes at 850°C to 900°C in dry hydrogen (dew point -27°C) and examined for blisters and pits. The tube shall be rejected if blisters and/or pits are discovered. Criteria for the existance of blisters and/or pits lies totally with the University.

B. Vacuum Integrity

After hydrogen firing, the tubes will be vacuum tested on a mass spectrometer helium leak detector. The formed tube must indicate no leakage when tested on a leak detector whose sensitivity has been calibrated to a minimum of 2×10^{-10} std. cc/sec helium.

3.5 FINAL ACCEPTANCE

Final acceptance of all formed tubes shall take place following delivery to and inspection and testing by the University within 30 days from the time of delivery.

3.6 REPLACEMENT OF DEFECTIVE TUBES

Formed tubes which fail to meet any of the requirements of this specification, as determined by the tests and inspections performed by the University shall be replaced at no additional cost to the University, within 90 days of notification by the University. Replacement tubing shall be purchased only from the University.

4.0 TEST PROVISIONS, QUALITY ASSURANCE AND INSPECTION

4.1 SOURCE INSPECTION

A designated University representative shall be permitted to witness any manufacturing or forming operation. When so requested, the vendor or former shall notify the University 48 hours prior to the performance of a given test, inspection, manufacturing or forming operation. In addition, the University reserves the right to inspect any other process of procurement or manufacturing pertaining to these tubes.

5.0 PREPARATION FOR DELIVERY

Due to the soft nature of the copper tubes, packing procedures and shipping containers must be designed and constructed to prevent damage in transit. Care must be taken to protect the copper tube surfaces from deep indentations, inclusions and deformation due to normal handling. Each shipping container shall be clearly labeled as to contents and subcontract number in addition to the customary packing slip. The containers shall be designed to be easily handled by fork lift truck.

TECHNICAL SPECIFICATION

OXYGEN FREE HIGH PURITY COPPER TUBING FOR ULTRA HIGH VACUUM APPLICATIONS

PS-202-631-13 R0

Submitted by ___ Thomas R. Winch ___ Mechanical Engineering Department

Approved by ___ Norman R. Dean ___ Group Leader

Approved by ___ Robert A. Bell ___ Department Head

PEP Project
Stanford Linear Accelerator Center
Stanford University
Stanford, California
March 1, 1975

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1.0 INTRODUCTION

1.1 The oxygen free high purity copper tubing made to this specification will become part of the primary beam chamber of the Positron-Electron-Project (PEP) Storage Ring, a joint project of the University of California Lawrence Berkeley Laboratory and Stanford University, hereinafter referred to as the University.

The round copper tubes furnished per this specification will subsequently be dry hydrogen fired and tested by the University. After acceptance by the University, the copper tubes will be formed by another subcontractor to approximately a diamond shaped cross-section except for the ends of the tubes which will remain round. Stainless steel flanges and other components will then be affixed to the copper tubes by the University. The fabrication techniques include forming, high temperature dry hydrogen braze cycles above 1000°C and gas tungsten arc welding. All completed assemblies operate at 10^{-10} torr and are thermal cycled to 200°C.

2.0 SCOPE

2.1 This document specifies the minimum requirements for producing copper tubes of the necessary quality such that they are acceptable for their intended use.

This specification also includes the requirements for quality assurance and inspection of the copper tubing and for reporting same. Also included are requirements for the preparation and delivery of the copper tubes.

3.0 APPLICABLE DOCUMENTS

3.1 Specifications

The applicable provisions of the following documents of issue in effect on the effective date of award shall become a part of this specification, to the extent specified herein.

1. ASTM B251-76 "Standard Specifications for General Requirements for Wrought Seamless Copper and Copper-Alloy Tube".
2. ASTM B601-74 "Standard Recommended Practice for Temper Designations for Copper and Copper Alloys - Wrought and Cast".
3. ASTM B224-73 "Standard Classification of Coppers".
4. ASTM F68-68 (Reapproved 1972) "Standard Specification for Oxygen-Free Copper in Wrought Forms for Electron Devices".
5. ANSI/ASTM B75-77 "Standard Specification for Seamless Copper Tube".
6. ASTM B170-74 "Standard Specification for Oxygen-Free Electrolytic Copper Wire Bars, Billets, and Cakes".

4.0 REQUIREMENTS

4.1 Material

The tubing shall be made from and meet all the requirements of Oxygen-Free, Electronic (OFE) Copper Alloy UNS Number C10100.

Tubing shall be manufactured according to and meet the requirements of ANSI/ASTM Specification Number B75-77 and as stated herein. Requirements stated herein shall take precedence if in conflict with the above specification or any specifications referred to therein.

The temper of the round tube as received by the University shall be an as manufactured temper.

A certification shall be made as one basis of acceptance of the material. This shall consist of a copy of the manufacturer's test report accompanied by a copy of the test results, that the material has been sampled, tested, and inspected in accordance with the provisions of the specification. Each certification so furnished to the University shall be signed by an authorized agent of the seller or manufacturer.

4.2 Description of Part

The dimensions of the round tubes to be supplied are as specified in the draft purchase order. The inside of the tubes are to be free of scratches, nicks, and inclusions. The surface finish to be a uniform 63 rms microinch. The tubes are to be furnished in straight lengths. The dimensions of the tubes shall not exceed the permissible variations as stated in ASTM Specification B251-76 section 5. The maximum curvature (Depth of Arc) shall be 0.50 inch over the total length.

4.3 Forming Operation

Any fabrication, forming, cutting or sawing operations requiring coolants or lubricants must use sulfur-free and silicon-free coolants consistent with electron device and high vacuum fabrication practices. The University's written approval shall be obtained before any coolants and/or lubricants are to be used. Also, abrasives, such as grinding wheels or emery cloth, may not be used on the tubes. Fabrication or forming practices must be approved by the University prior to award.

4.4 Acceptance Testing

Every tube shall have two coupons, one taken from each end, submitted for each of the following tests. Failure of any coupon to pass its intended test shall reject the tube from which it was taken. All coupons and tubes shall be appropriately labeled and identified. Results of the tests are to be kept with the corresponding coupons and shipped with the appropriate tubes.

A. Microscopical Examination
Section 5.6 "Microscopical Examination" of Specification ASTM F68 for "Tubes for Exhaust Purposes and Waveguides" subsection 5.6.2.1.

B. Embrittlement Test
Section 5.2 of Specification ASTM F68.

C. Chemical Analysis

Section 7.2 of Specification ASTM B170-72.

D. Electrical Resistivity

Section 5.1 of Specification ASTM F68.

E. Scaling

Section 5.3 of Specification ASTM F68.

F. Macro Examination

Section 5.5 "Special Macro Requirements" of Specification ASTM F68 for "Waveguides" subsection 5.5.2.

4.5 Additional Acceptance Tests

A. Hydrogen Firing

The round tubes when received by the University shall be vapor degreased, chemically cleaned, fired for 30 minutes at 850°C to 900°C in dry hydrogen (dew point -27°C) and examined for blisters and pits. The tube shall be rejected if blisters and/or pits are discovered. Criteria for the existence of blisters and/or pits lies totally with the University.

B. Vacuum Integrity

After hydrogen firing, the tubes will be vacuum tested on a mass spectrometer helium leak detector. The tube must indicate no leakage when tested on a leak detector whose sensitivity has been calibrated to a minimum of 2×10^{-10} std. cc/sec helium.

4.6 Final Acceptance

Final acceptance of all tubes shall take place following delivery to and inspection and testing by the University within 30 days from the time of delivery.

4.7 Replacement of Defective Tubes

Tubes which fail to meet any of the requirements of this specification, as determined by the tests and inspections performed by the University shall be replaced at no additional cost to the University, within 90 days of notification by the University.

5.0 TEST PROVISIONS, QUALITY ASSURANCE AND INSPECTION

5.1 Responsibility for Tests

Except for section 4.5 of this specification and as noted, all tests and inspections required herein shall be performed by the vendor without additional cost to the University. Equipment and test apparatus used by the vendor shall be properly maintained and operated according to the manufacturers instructions. The use of faulty test equipment will void any tests performed. It is the vendor's responsibility to provide personnel qualified to operate the equipment and perform the tests.

5.2 Source Inspection

A designated University representative shall be permitted to witness any or all of the test and inspection provisions herein required. The representative shall also be permitted to witness any manufacturing or forming operation. When so requested, the vendor shall notify the University 48 hours prior to the performance of a given test, inspection, manufacturing or forming operation. In addition, the University reserves the right to inspect any other process of procurement or manufacturing pertaining to these tubes.

6.0 PREPARATION FOR DELIVERY

Due to the soft nature of the copper tubes, packing procedures and shipping containers must be designed and constructed to prevent damage in transit. Care must be taken to protect the copper tube surfaces from deep indentations, inclusions and deformation due to normal handling. Each shipping container shall be clearly labeled as to contents and subcontract number, in addition to the customary packing slip. Identically labeled copper tubes and samples per section 4.4 shall be shipped together. The containers shall be designed to be easily handled by fork lift truck.

SCOPE:

This specification outlines standard procedures to be followed in the fabrication of components for Ultra High Vacuum systems. This is a general specification meaning not all sections will necessarily apply to all drawings which refer to this specification. You must check the individual part drawings to determine which requirements pertain to that particular component.

SECTION 1 : MATERIALS SPECIFICATIONS AND CERTIFICATIONS

All materials must be purchased to an ASTM or University approved equivalent specification. Original Mill source certifications must be obtained; ordinary "certs" are not acceptable. As a minimum, certifications must include the heat number and the results of chemical analysis and mechanical properties tests. Copies of certifications must accompany delivery of the finished parts to the University.

Section 2 : FABRICATION

1. The knife edge sealing surface of U.H.V. flanges must be kept covered at all times. The best protection is a copper gasket. Other methods which permit machining without removal of the protection may also be used. Flanges with even the least defect on the knife edge will be rejected without discussion.

2. Metal working Lubricants which contain sulphur or silicone are prohibited. Use only the following:

Aqua Syn 55	Cimcool 5 Star 40	Cimperial #1011
Cutzol EDM 220-30	Dip Kool 868	Dip KUT 819H
Haloform CW-40	Kool Mist #88	Mo Sul #6871
Rapid Tap	RD2-195	Pearl Kerosene by Chevron Chem Co.
Relton A-9	Rust-Lick G-25-J	Sunnen MAN-852 Honing Oil
Tap Magic	Tapmatic #2	Tapmatic #1
Tool Saver by Do All Corp.		Trim Tap
Vytron Concentrate		Wheelmate #203

3. Break all sharp edges and inside corners approximately 0.015" radius unless otherwise noted.

4. Use of abrasive cloth or paper is prohibited. Grinding wheels prohibited except with prior written permission of the University.

5. When machining aluminum to stainless steel transition material:
   A. Use care not to put excessive stress on bonded joint.
   B. Use adequate cooling so that part temperature does not exceed 150 degrees F.
   C. If transition material is serialized, an identification number will be marked on rough stock. Insure that the I.D. number is transferred to the finished part by electric vibrator engraver or University approved equivalent.

6. Finished parts must be wiped down to remove excess lubricants. Vapor degreasing by vendors is prohibited.

(CONTINUED OVER SIDE)

STANFORD LINEAR ACCELERATOR CENTER U.S. ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION STANFORD UNIVERSITY STANFORD CALIFORNIA	PROCESS SPECIFICATION FABRICATION OF ULTRA-HIGH VACUUM COMPONENTS
ENGR U. Cummings DATE CHK APPROVALS UC 3-87 3/10/77	FP-202-631-14 R2

7. After QC./inspection, all parts must be individually wrapped to prevent damage in transit. Exception: very small parts may be wrapped together at vendors option.

Section 3 : UHV HANDLING

1. The use of masking tape on the surface of any UHV part is absolutely prohibited. If adhesive backed tape is necessary use only 3 M #471 vinyl electroplaters tape.

2. If chemical cleaning is required, the appropriate specification will be identified in the purchase order and made available by the University.

3. Parts which have been UHV chemically cleaned, furnace brazed, hydrogen fired, etc, shall not be touched with bare hands. Handle only with new or freshly laundered University provided or approved nylon/polyester white gloves. For storage or transit, wrap parts with University provided or approved lint free paper[1] and/or designated UHV aluminum foil[2]. Parts must then be placed in clean, sealed container. Tote boxes covers must be sealed with 3 M #471 tape. Very large parts such as long stainless steel tubes, or aluminum extrusions may be wrapped in "blue line" neutral kraft paper after first sealing all openings with the above mentioned paper and foil. All handling and assembly of "UHV Clean" parts must only take place in a Clean Room area designated for UHV welding and assembly. Use only materials and methods, apparel requirements, and other constraints appropriate to U.H.V. technology.

Section 4 : LEAK TESTING

Leak test part with a Mass Spectrometer Helium Leak Detector calibrated to a minimum sensitivity for helium of 2×10^{-10} std. CC/sec. per leak rate meter division on the most sensitive range. Reject any part which, when probed with helium for at least one minute, results in a 2% of full scale deflection on the most sensitive range. Any use of Silicone grease is absolutely prohibited. A thin film of Apiezon L or Celvacene Light may be used on the seal itself only with prior written permission of the University.

Section 5 : WELDING

Unless other wise specified, all welds will be made by GAS TUNGSTEN ARC process, (GTAW).

Section 6 : HIGH TEMPERATURE FURNACES

All furnace firing for stress relieving, annealing, brazing, "clean firing" or other purpose shall be in Hydrogen or inert atmosphere. Vacuum furnaces are also acceptable with prior approval of the designated University representative.

Section 7 : PARTS INSPECTION

Individual parts shall be inspected for conformance to the drawing both in dimensions and other requirements. Copies of such inspection reports must be made available to the University representative upon request.

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[1]Approved lint free paper, "Grade 875-S", is available from: Berkshire Paper Co. Great Barrington Mass 01230, available in 9" x 9" or 18" by 18" sizes.

[2]Aluminum foil, specially prepared for U.H.V. applications, available from Kaiser Alum. & Chem. Corp. Oakland, CA 94643. "Item 25 UHV" is 24" by 1000', "Item 26 UHV" is 12" by 500'.

TECHNICAL SPECIFICATION

FOR

CHEMICAL CLEANING TANKS

PS-202-631-70-R1

Submitted by ______ PEP Vacuum Department
Bruce G. Walker

Approved by ______ Mechanical Fabricating Shops
James A. Pope

Approved by ______ Group Leader
Norman R. Dean

Approved by ______ Department Head
Robert A. Bell

PEP Project
Stanford Linear Accelerator Center
Stanford University
Stanford, California
October 29, 1976

TABLE OF CONTENTS

1.0 *INTRODUCTION*

1.1 The chemical cleaning tanks, plywood liners and support structure fabricated to this specification will be used to clean vacuum chamber components that will form the primary beam chamber of the Positron-Electron-Project Storage Ring, a joint project of the Lawrence Berkeley Laboratory and the Stanford Linear Accelerator Center hereinafter referred to as The University.

1.2 The vacuum chamber components must be cleaned to reduce the contaminants on the metal surfaces. In order to achieve the ultra-high-vacuum necessary for Electron-Positron storage ring operation, the outgassing rate of the vacuum chamber walls must be minimized by the reduction of these contaminanants. This reduction is accomplished by the chemical cleaning process.

1.3 The chemical cleaning tanks, plywood liners and support structure must be manufactured to this specification and the indicated drawings. Failure to do so will be cause for the University to reject the work or material and require replacement of the work or material.

1.4 The tanks, plywood liners and support structure as described in this specification will be delivered by the contractor in place, inside the Cleaning Facility Building No. 030 at Stanford Linear Accelerator Center, 2575 Sand Hill Road, Menlo Park, California.

1.5 At the time that the cleaning tanks, plywood liners and support structure are to be delivered and installed, other contractors and/or SLAC technicians may be working in or around Cleaning Facility Building 030. If so, the contractor must schedule his work with the other contractors and the University representative in order to cause the least inconvenience to all parties.

1.6 Where these specifications describe a particular product or fixture by name, such reference shall be interpreted as establishing a standard of quality and not as limiting competition. Substitutions must be approved by the University as equal in quality and utility. In this specification, "or approved equal" is intended to mean a substitution that has been approved by the University representative.

1.7 All work covered by this specification shall be done in strict accordance with the following list of drawings:

Drawing No.	Title
SA-202-531-01	Tanks
SA-202-531-02	Center Floor Plate
SA-202-531-03	End Floor Plate
SA-202-531-04	Framing Plan-Support Structure
SA-202-531-05	Framing Elevations
MA-202-531-06	End Post Weldments
SA-202-531-07	Part of 06
SA-202-531-08	Part of 06
SA-202-531-09	Part of 06
SA-202-531-10	Floor Plate Location
SA-202-531-11	End Plate 'A' - Support Structure
SA-202-531-12	End Plate 'B' - Support Structure
SA-202-531-13	End Plate Assembly
SA-202-531-14	Plywood Side and BTM Liners Support Structure

2.0 SCOPE

2.1 The manufacture and installation of chemical cleaning tanks, plywood liners and support structure described by this specification shall include.

a. Manufacture of tanks as specified.
b. Manufacture of steel support structure as required.
c. Manufacture of plywood liners as required.
d. Installation of support structure into Cleaning Facility Building No. 030 as specified.
e. Installation of plywood liners into support structure as specified.

f. Installation of tanks into support structure.

g. Painting of support structure plywood liners and carbon steel tanks as specified.

h. Proof testing the tanks to ascertain that they do not leak.

2.2 Interior lighting, 110 VAC electrical outlets, and compressed air will be available in cleaning facility building 030 for use by the contractor.

2.3 Two crane rails, each designed to support a 1/2 ton monorail hoist are provided in building 030

3.0 TANKS

3.1 All stainless steel sheets shall have number 2B finish per ASTM A480.

3.2 The contractor shall furnish two type 316 stainless steel flanges for tank drains of the type 316 stainless steel tanks.

3.3 The contractor shall furnish two type 316 stainless steel blind flanges for tank drains of the type 316 stainless steel tanks.

3.4 The contractor shall furnish a total of 20 type 304 stainless steel flanges for the five type 304 stainless steel tanks.

3.5 The stainless steel flanges shall be 3" Ladish Iron Pipe size corrosion weight forged flanges or approved equal.

3.6 The contractor shall furnish four 3" 150 # Raised Face flanges per ASTM A181/GR1 for the two 1018 carbon steel tanks.

3.7 All joints in the stainless steel tanks shall be Tungsten Inert Gas welded. Inside tank welds shall not be ground, brushed, or cleaned after welding.

3.8 Filler rod used in the welding of type 304 tanks shall be columbium stabilized type 347.

3.9 Filler rod used in the welding of the type 316 tanks shall be columbium stabilized type 347.

3.10 All flange bolt holes shall straddle the horizontal and vertical center lines.

3.11 All tanks shall be fabricated in strict accordance with drawing No. SA-202-531-01-RO.

4.0 SUPPORT STRUCTURE AND PLYWOOD LINERS.

4.1 The support structure shall be fabricated as a single structure to support a total of ten tanks. Eight are to be installed under this specification; two are not included.

4.2 The support structure shall be secured in place by welding to floor plates provided in the floor of Cleaning Facility Building No. 030 for this purpose. The weld-joint shall be a fillet weld 3 inches long in 48 places as shown in drawings SA-202-531-02 and SA-202-531-03.

4.3 The support structure may be fabricated in place inside Cleaning Facility Building No. 030. Subassemblies may be assembled elsewhere and transported to building 030.

4.4 The support structure is to be fabricated in strict accordance with the following drawings:

DRAWING NO.	TITLE
SA-202-531-02	Center Floor Plate
SA-202-531-03	End Floor Plate
SA-202-531-04	Framing Plan-Support Structure
SA-202-531-05	Framing Elevations
MA-202-531-06	End Post Weldments
SA-202-531-07	Part of 06
SA-202-531-08	Part of 06
SA-202-531-09	Part of 06
SA-202-531-10	Floor Plate Location
SA-202-531-11	End Plate 'A'-Support Structure

SA-202-531-12	End Plate 'B'-Support Structure
SA-202-531-13	End Plate Assembly
SA-202-531-14	Plywood side and BTM Liners Support Structure

4.5 Plywood liners shall be fabricated in strict accordance with drawing SA-202-531-14.

4.6 All tolerance listed on the drawings must be strictly observed. The failure of the tank(s) to fit within the support structure as specified will be cause for the work and material to be rejected by the University.

4.7 The work will be inspected regularly by the University representative.

4.8 All workmanship shall be equal to the best standard practice in modern steel fabricating plants.

5.0 INSTALLATION

5.1 The tanks, plywood liners and support structure will be installed in Cleaning Facility Building 030 per a schedule agreed upon by the contractor and the University Representative at least two weeks prior to the beginning of installation. Installation shall begin January 31, 1977 and be complete no later than February 24, 1977.

5.2 Installation of the support structure will include welding the frame to the floor plates as shown on drawings SA-202-531-02 and SA-202-531-03.

5.3 The contractor will fabricate and install the plywood liners as shown on drawing SA-202-531-14.

5.4 Plywood sheathing shall be APA standard Structural I, c-c exterior grade.

a. Side panels will be 3/4" thick.

b. Bottom panels will be 1-1/8" thick.

5.5 All plywood panels shall be fastened to the support beams with Hilti drive pins or approved equal. Panels shall be secured by no less than three pins per beam, spaced no more than 12 inches apart.

5.5 The end plates will be secured to the end posts with a spring assembly as specified in drawing SA-202-531-13. The spring assemblies must be fabricated in strict accordance with the drawing. Spring tensions specified must be strictly observed.

5.6 Side panels shall be glued to the bottom panels with waterproof resorcinal formaldehyde glue.

5.7 Side panels shall butt together only at support posts in the support structure.

5.8 The tanks shall be installed in the following order:

a. Tank number one shall be the first tank at the East end of Cleaning Facility Building No. 030.
b. Tank number one shall be 1018 carbon steel.
c. Tank number two shall be type 304 stainless steel.
d. Tank number three is not included.
e. Tank number four shall be type 316 stainless steel.
f. Tank number five shall be type 304 stainless steel.
g. Tank number six shall be 1018 carbon steel.
h. Tank number seven shall be type 304 stainless steel.
i. Tank number eight is not included.
j. Tank number nine shall be type 304 stainless steel.
k. Tank number ten shall be type 304 stainless steel.

5.9 The spring-tension assemblies shall be installed before the installation of the plywood liners are complete.

5.10 Installation of the tanks, plywood liners and support structure shall not be complete until approved by the University representative.

5.11 Floor beams of the support structure shall be shimmed to the level of the beams at the center of the floor. The slope away from the center of the floor is 0.3%. Shimming of the floor beams shall be done per drawing SA-202-531-05.

6.0 PAINTING

6.1 All structural steel, carbon steel and plywood surfaces shall be coated with a corrosion resistant covering as specified in this section.

6.2 All plywood liners, surfaces and edges shall be coated with 5 mils of Cordurite catalyst epoxy paint, gray, or approved equal before being assembled into the support structure.

6.3 All structural steel used in the fabrication of the support structure shall be prepared for coating with Cordurite catalyst epoxy paint, gray, by commercial sandblasting on all surfaces.

6.4 All structural steel used in the fabrication of the support structure coated with Zinc Chromate Epoxy Primer applied for a dry-coat thickness of 1.5 mils on all surfaces.

6.5 Structural steel used in the fabrication of the support structure shall be top-coated with Cordurite catalyst epoxy paint, gray, or approved equal. Application shall be for 5 mils dry-film thickness on all surfaces.

6.6 Tanks number one and number six, of carbon steel construction, shall be commercial sandblasted on the outside surfaces only in preparation for primer.

6.7 Tank liners number one and number six shall be coated with Zinc Chromate Epoxy Primer or approved equal applied for a dry-film thickness of 1.5 mils on the outside surfaces only.

6.8 Tank liners number one and number six shall be top-coated with Cordurite catalyst epoxy paint, gray, or approved equal applied for a dry-coat finish of 5 mils on the outside surfaces only.

6.9 Primer and paint shall be applied within 24 hours of sandblasting an item.

6.10 All plywood panels shall be coated with a suitable wood primer before application of epoxy top-coats.

6.11 Drying time between top-coats shall be no less than 24 hours.

7.0 TESTING

7.1 The contractor will be responsible for the set up of testing and the actual testing for leaks of all of the tanks. It shall be the responsibility of the contractor to provide certification to the University representative that each tank has been tested and that all tanks are free from leaks.

7.2 Leak testing of each tank shall consist of a dye penetrant test of each weld and a hydrostatic test with the tank filled to its maximum capacity.

7.3 The contractor shall use a wetting agent, Sodium Laurel Sulphate, or approved equal, to reduce the surface tension of the testing solution to approximately 35 dynes per centimeter.

7.4 The contractor shall provide to the University for approval a plan describing the leak testing process at the time of bid.

7.5 The contractor shall provide the University Representative with a schedule for leak testing at least two weeks prior to the start of the testing process.

7.6 The contractor shall repair any and all leaks indicated by the tests required in this specification. Weld-joints found to leak will be rewelded as described by paragraphs 3.7, 3.8 and 3.9 of this specification.

7.7 Any leak indicated by the tests required by this specification that is not repaired will be cause for the University to reject the tank(s).

7.8 The University representative may be present to witness all tests required by this specification.

TECHNICAL SPECIFICATION

FOR

PIPING AND DUCKBOARDS

PS-202-631-71-RO

Submitted by	Bruce G. Walker	PEP Vacuum Department
Approved by	James A. Pope	Mechanical Fabricating Shops
Approved by	Norman R. Dean	Group Leader
Approved by	Robert A. Bell	Department Head

PEP Project
Stanford Linear Accelerator Center
Stanford University
Stanford, California
November 19, 1976

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1.0 INTRODUCTION

1.1 The piping installed to this specification will supply water to chemical cleaning tanks and hot-water heating elements in the chemical Cleaning Facility Building 030. Parts to be cleaned in these tanks will be the vacuum chamber components for the Positron-Electron-Project Storage Ring, a joint project of the Lawrence Berkeley Laboratory and the Stanford Linear Accelerator Center (SLAC) hereinafter referred to as the University.

1.2 The piping and duckboards, fabricated and installed to this specification shall be completed in strict accordance with this specification and the indicated drawings. Failure to do so will be cause for the University to reject the work or material and require replacement of the work or material.

1.3 The piping and duckboards described in this specification shall be installed by the contractor inside the Cleaning Facility Building 030 at Stanford Linear Accelerator Center, 2575 Sandhill Road, Menlo Park, California.

1.4 At the time that the piping and duckboards are to be installed, other contractors and/or SLAC employees may be working in or around the Cleaning Facility Building 030. If so, the contractor must schedule his work with the other contractors and the University Representative in order to cause the least inconvenience to all parties.

1.5 Where these specifications or drawings describe a particular product or fixture by name, such reference shall be interpreted as establishing a standard of quality and not as limiting competition. Substitutions must be approved by the University as equal in quality and utility. In this specification, "or approved equal" is intended to mean a substitution that has been approved by the University representative.

1.6 All work covered by this specification shall be done in strict accordance with the following list of drawings:

Drawing No.	Title
ID-202-531-17-RO	Tank Heating and Distributed Piping
ID-202-531-18-RO	Tank Supply Piping
ML-202-531-19-RO	Material List
DL-202-531-20-RO	Drawing List

2.0 SCOPE

2.1 Piping systems will include compressed air, cold domestic water, cold distilled water and hot water and Nitrogen.

2.2 The fabrication and installation of piping and duckboards as described by this specification shall include:

a. Fabrication of piping systems as specified.
b. Installation of piping systems as specified including piping, insulation, valves, heating plate coils and temperature regulators.
c. Heating plate coils and temperature regulators as shown on Dwgs. ID-202-531-17 and ID-202-531-18 will be supplied by the University.
d. Float level valves will be supplies by the University.
e. Duckboards shall be fabricated as specified.
f. Duckboards shall be installed to provide a walkway as specified.

2.3 Interior lighting and 110 VAC electrical outlets will be available in Cleaning Facility Building 030 for use by the contractor at the beginning of the work described in this specification.

3.0 PIPING

3.1 The contractor shall provide all materials, tools, services, labor and transportation necessary to fabricate and install the piping systems described in this specification. All work and miscellaneous items not specifically described but necessary for a complete installation will be provided by the contractor.

3.2 The systems covered by this specification shall include:

a. Connection to existing facilities.
b. Distribution of piping as indicated on drawings ID-202-531-17 and ID-202-531-18.
c. Installation valves and fixtures as indicated on drawings ID-202-531-17 and ID-202-531-18.
d. Supporting and securing piping as indicated on drawings ID-202-531-17 and ID-202-531-18.

3.3 The following documents, standards and specifications form a part of this specification:

3.3.1 American Society for Testing and Materials (ASTM) latest revision

a. ASTM A 53 Spec. for Welded and Seamless Steel Pipe.
b. ASTM B 61 Spec. for Steam or Valve Bronze Castings.
c. ASTM B 62 Spec. for Composition or Ounce Metal Castings.
d. ASTM A 120 Spec. Black and Hot dipped Zinc-Coated (Galvanized) Welded and Seamless pipe for ordinary purposes.
e. ASTM A 181 Spec. for forged or rolled steel pipe flange, forged fittings and valves and parts for general service.
d. ASTM A 234 Spec. for pipe fittings of wrought carbon steel and alloys steel for moderate and elevated temperature.

3.3.2 American National Standards Institute (ANSI) latest revision:

a. ANSI B1.1 Unified Screw Threads
b. ANSI B2.1 Pipe Threads
c. ANSI B31.1a

3.3.3 American Welding Society Standard Specification 1964

AWS B3.0-41T Standard Qualifications Procedure.

3.4 The extent and general arrangement of the systems to be fabricated and installed to this specification shall be in strict accordance with this specification and indicated drawings. The contractor shall be responsible for properly fitting materials and fixtures at indicated locations without substantial alterations.

3.5 No departures from the work shown and specified shall be made without prior approval of the University Representative.

3.6 Where departures from the work shown or specified become necessary, the contractor shall submit details, reasons and proposed alterations in writing to the University Representative for approval prior to the implementation of said alterations.

3.7 All workmanship shall be of the highest quality and shall be subject to the approval of the University. Rejected work shall be replaced or repaired by the contractor as directed by the University Representative.

3.8 The hot water supply and return piping shall be insulated using one inch nominal thickness, pre-molded mineral fiber insulation having 6-ounce canvas jacket or approved equal. The insulation shall be installed according to the manufactuer's recommendations and as directed on drawing ID-202-531-17 and ID-202-531-18.

3.9 Domestic water distilled water and compressed air systems primary service pressure and temperature rating is 125 PSIG at 350^{o} F.

3.10 Distilled water piping shall be PVC schedule 80 threaded pipe.

3.11 Heating hot water system primary service pressure and temperature is 125 PSIG at 350^{o} F.

3.12 The contractor shall use Teflon ribbon tape on all threaded pipe joints.

4.0 DUCKBOARDS

4.1 After piping is fabricated and installed to this specification and indicated drawings and tested (Testing: section 5 of this specification), the contractor shall fabricate and install duckboards as specified in this section.

4.2 Duckboards shall be constructed of standard dimension fir lumber. The width shall be no greater than 4 inches and no less than 3-1/4 inches. The thickness shall be no greater than 2 inches and no less than 1-5/8 inches. All boards shall be of the same thickness to 1/8 inch. The 1-5/8" to 2" dimension shall form the surface of the walkway.

4.3 Lumber used in the duckboards shall be kiln dried clear vertical grain Douglas Fir.

4.4 Spacing between the boards shall be no less than 1/2" and no greater than 3/4".

4.5 Support frames for the duckboards shall be fabricated with construction grade fir lumber.

4.6 Duckboards shall be installed to provide a walkway over the piping and drainage gutter as indicated on drawing ID-202-531-17 and ID-202-531-18.

4.7 Duckboards shall not extend past the ends of the drainage gutter.

4.8 Steps shall be constructed at each end of duckboard walkway to the level of the floor. The steps shall not extend past the ends of the drainage gutter.

4.9 The height of the duckboard walkway shall be no less than 15" and no greater than 18". Duckboard width shall be 6' 9" and the walkway length shall be made up of sections not exceeding two feet.

4.10 A removable section shall be constructed where ever necessary to provide access to valves installed under section 3 of this specification. All removable sections shall be constructed according to the specifications in this section.

5.0 TESTING

5.1 All piping systems shall be tested and approved prior to the installation of the duckboards described in section 4 of this specification.

5.2 Domestic, distilled and heating water piping shall be subject to a test of 187 PSIG prior to connecting to the existing utilities. The system tested shall be pressurized and valved off. The pressure shall not drop more than 1 PSIG in a 24 hour period.

5.3 Compressed air piping shall be subject to a test of 187 PSIG prior to connecting to the existing utilities. The system tested shall be pressurized and valved off. The pressure shall not drop more than 1 PSIG in a 24 hour period.

5.4 All piping shall be connected to the mains and proven to be free from leaks subject to the approval of the University representative. Weld joints shall not be covered with insulation at the time of testing.

5.5 All leaks indicated by the tests specified in this section shall be repaired to the satisfaction of the University representative.

5.6 The University representative will be present to witness any or all tests specified in this section.

5.7 The University representative may be present to witness any or all of the work done to this specification.

5.8 The work to be done to this specification shall not be complete until accepted and approved by the University representative.

6.0 CLEANING

6.1 All piping will be cleaned by the University before installation. Material shall be delivered to SLAC for cleaning prior to 2-24-76 and shall be accompanied by a schedule describing installation of the piping.

6.2 The contractor shall remove all excess material and debris from the site and leave the site clean.

6.3 After installation, all piping, outer surfaces and joints shall be cleaned to be free of dirt and grease.

6.4 The work to be done to this specification shall not be complete until the work and work site is cleaned to the satisfaction of the University representative.

TECHNICAL SPECIFICATION

FOR

ALL METAL ISOLATION VALVE

PS-202-631-72 R1

Submitted by ______________________ PEP Vacuum Department
Ralph Gaxiola

Submitted by ______________________ Engineering Physicist
Terrence W. Martin

Approved by ______________________ Group Leader
Norman R. Dean

Approved by ______________________ Department Head
Robert A. Bell

PEP Project
Stanford Linear Accelerator Center
Stanford University
Stanford, California
October 20, 1977
November 27, 1978

1.0 Introduction

1.1 The ultra high vacuum all metal valves made to this specification will be used to isolate sections of the vacuum system for the positron-electron project (PEP) storage ring, a joint project of the University of California Lawrence-Berkeley Laboratory and Stanford University hereinafter referred to as "The University".

The valves, beam chamber and other system components will all be operated at a pressure of 10^{-10} torr. In order to achieve and maintain this low pressure, all vacuum system components will be thermally cycled from ambient to 200°C. The entire system must withstand a minimum of 50 thermal cycles of 150 hours duration each and retain leak tightness of minimum 2×10^{-10} standard cc/sec helium.

In selecting the most satisfactory valve for use in the PEP storage ring, the University will require the vendor to demonstrate, by the test specified herein, all the pertinent operating characteristics judged essential to our application. These requirements call for high reliability in the design of the valve, for great care in the selection of materials and for special handling in machining, welding, chemical cleaning, and assembly.

2.0 Scope

2.1 This document specifies the minimum requirements for producing valves of the type described in the introduction, Paragraph 1.1. This specification also includes the requirements for evaluation testing of several parameters for quality assurance in manufacturing and for preparation for shipment.

3.0 Applicable Documents

3.1 The applicable provisions of the following documents of issue in effect on the effective date of award shall becom part of this specification, to the extent specified herein.

a. ASTMA A-240-75a "Heat-resisting Chromium and Chromium Nickel Stainless steel Plate, Sheet and Strip for fusion welded unfired pressure vessels".
b. AMS 5513b "Steel sheet, strip and plate corrosion resistant (304)".
c. AMS 5511c "Steel sheet, strip and plate corrosion resistant (304L)".
d. ASTM A-269-76 "Seamless and welded austenitic stainless steel tubing for general service".
e. AMS 5566f "Steel tubing, seamless or welded, corrosion resistant (304)".
f. SLAC/PEP Specification PS-202-631-04 R0 "Stainless Steel Flanges for U.H.V. Applications".
g. SLAC Specification QC-034-100-01 R3, "Quality Control Workmanship Standards".
h. AMS 747h "Bolts and Screws, Steel, Corrosion Resistant (Roll Threaded).
i. SLAC technical note SLAC-TN-73-13 "Specifications for Vacuum Systems and Components which Interface with the SPEAR Vacuum Systems".

4.0 Requirements

4.1 General

The University requires that the vendor be responsible for assurance that the valves and any other parts supplied with the valves meet all the requirements of this specification. Inspection of procedures and records by the university does not alter that responsibility in any way. No deviation from this specification or those stipulated herein will be permitted without prior written permission of the University, including alternatives specified as "University Approved Equal".

4.2 Valve Description

The valve shall be a gate type with a straight through bore diameter of nominal 148.6mm. The body shall be made of wrought stainless steel type 304 or 304L. All internal parts shall be metal and approved by the University. Gate design must allow replacement of seal plate without having to machine valve body.

4.3 Leak Integrity

Leak tightness across the gate seal in either direction with atmospheric pressure of Helium on one side and vacuum on the other shall not exceed 1×10^{-7} std. cc/sec helium. The criteria for vacuum tightness of the valve body is as follows:

Test with a mass spectrometer helium leak detector calibrated to a minimum sensitivity for helium of 2×10^{-10} std. cc/sec per leak meter division on the most sensitive range.

Reject any part which, when blanketed with helium for at least one minute, results in a 2% deflection on the most sensitive range of the leak detector.

4.4 Bakeout Requirements

The valve in the open or sealed position shall be able to withstand a minimum of 50 thermal cycles from ambient to 180°C for 150 hours duration each cycle without compromising the stated leak integrity requirements. Each cycle will require at least 8 hours to attain 180°C from ambient temperature.

4.5

The valve will respond with fast and slow actuation speeds as determined by seperate electrical commands. A "fast" actuation time of one second or less is required for the gate to be closed and sealed starting from the fully open position.

A "slow" actuation speed of up to 5 seconds will be acceptable for the same operation.

With the gate closed and sealed the time required to fully open the gate shall not be more than 5 seconds.

4.6 Seal Life

The valve must withstand 1000 slow speed open and close cycles at environmental conditions stated in Paragraph 4.16, plus bakeout requirements and maintain leak integrity. The valve must withstand 100 fast speed open and close cycles under the same conditions.

4.7 Actuator

Valve actuator shall be air or nitrogen gas operated with an electrical solenoid construction. All electrical actuators shall operate on 24V D C , and the valve should assume and maintain a closed position with loss of electrical power.

4.8 Open, Close Status

One SPDT Limit Switch shall be positioned to indicate open status, and another SPDT Limit Switch shall be positioned to indicate the gate closed status.

4.9 Flanges

Flanges and /or flange connections shall meet the requirement of SLAC/PEP Spec. PS-202-631-04 or be Varian manufactured Conflat [R] Flange.

4.10 Flange Gap Ring Cut Out

A notch will be provided on the inside corner of the flange face to permit usage of a HOM copper gap ring. The dimensions as shown in SLAC drawing PF-202-061-38 RI indicate a diameter of 151.3 mm + 1 mm - 0 mm with a depth of cut of 2.67 mm $\pm$ .05 mm from the face of the flange.

4.11 Total Outgassing Rate

The total outgassing load should be no more than 3×10^{-9} torr l/sec after bakeout. In addition when the valve is opened, the valve shall not release a gas load greater than 3×10^{-6} torr/ℓ after being closed with atmospheric pressure on one side of the valve for a period of seven days.

4.12 R.G.A.Analysis

With the valve body at a temperature of 150°C for 24 hours the partial pressure of all species above 50 AMU shall not exceed 1×10^{-11} torr as measured on an RGA with a sensitivity of 300 Amp/Torr.

4.13 R.F. Shorting Requirement

The valve shall be constructed to provide a smooth bore with a good lateral electrical surface conductivity in the open position. The production valve gate sealing/RF shorting design must be approved by the University prior to production.

4.14 Cold Welding

Valve must be free of any persistent cold weld contact problems on any sliding or moving parts in any pressure range.

4.15 Magnetic Properties

The magnetic permeability of the valve body must not exceed 1.04.

4.16 Dimensions

The thickness of the valve should be no more than 14 centimeters. The height shall be less than 1.2 M. The width shall be less than 0.35 M. No dimension shall exceed 76 cm. from the center of the through bore.

4.17 Valve Mounting

The valve will be mounted with the axis of the through bore in a horizontal position. The operation of the valve must be independent of any mounting position satisfying the above constraint.
Valve body design shall incorporate integral or welded mounting brackets. Brackets shall be capable of withstanding minimum vacuum loading of 500 lbs. Mounting bracket design shall be approved by the University prior to production.

4.18 Environmental Conditions

All valves and attachments thereto must be designed for and warranted to operate (for the period of warranty) at a temperature range of 10^oC to 45^oC exterior temperature and 20^o to 100^oC interior (bore) temperature range, with the exterior relative humidity up to 80% water vapor. The valve and actuator assembly must tolerate an integrated dose of 10^{-10} rads as well as small exterior concentrations of ozone and HNO_3.

4.19 Seismic Requirements

All valves must be designed for, and be capable of withstanding an acceleration of .75G.

4.20 Materials and Parts

All parts and materials for valves and actuators shall be new and compatible with the design and performance requirements of this specification. All individual components and spare parts of the valves and actuators must be functionally and dimensionally interchangeable. All metals which become part of the valve must be purchased to a specific specification, either ASTM, AMS, or other certifications obtained for same. Metals for which a certification is not available, shall not be used.

Materials and parts which are finished by painting, plating or other surface preparations must meet the requirements of SLAC Specification No. QC-034-100-01.

4.21 Welding

All welding of the valve body shall be by the gas tungsten arc (GTA) process by fusion welding. Filler metal for a specific weld will only be permitted if the vendor indicates such requirement on the drawings submitted and receives approval of same.

All welds shall be made on the vacuum side if the valve design permits. Otherwise, they shall be welded with full penetration from the atmosphere side. Interior surfaces of full penetration welds shall be smooth and free of drop through.

4.22 Lubricants and Finishing Materials

All lubricants, cutting fluids, etc., used in manufacturing must be "sulphur-free". Upon request, vendor must provide the University representative with all information needed to identify the source and constituents of all fluids and lubricants used. The use of abrasive cloth or paper, buffing or polishing compounds, or resin bonded grinding wheels is prohibited in finishing any part of the valves. Material removal must be accomplished with the use of metal tools.

4.23 Chemical Cleaning

Valve body internal sufaces will be thoroughly chemically cleaned. One step of chemical cleaning process shall be acid etch solution to remove surface oxides and expose the base metal. Subsequent rinses must be thorough and leave no residues.

Chemical cleaning of the valves may be inspected by the University representative. All chemical cleaning should be compatible for UHV operation as specified in SLAC note--SLAC-TN-73-13.

4.24 Final Acceptance

Notwithstanding the inspection requirements at the vendors plant as described herein, final acceptance of all valves shall take place following delivery to and testing by the University.

The University reserves the right to perform any or all test which would be required to verify that the valves delivered conform to the requirements of this specification. Units which fail any of the tests performed will be deemed unacceptable and returned to the vendor for replacement at no cost to the University. Shipping costs of return and replacement shall also be borne by the vendor.

4.25 Spare Parts

The vendor is required to provide a list of all spare parts which may be required for repairing or rebuilding valves.

4.26 Instruction Manuals

At the time of delivery of the valves vendor shall supply five copies of the valve instruction manual. Manual shall contain a detailed technical description of the valve, a parts list and information necessary to operate, disassemble and repair the valve. A complete set of drawings of the valve with all its components shall accompany each instruction manual.

4.27 Serial Numbers

Each valve shall have a Serial No. assigned to it. Serial Number shall be permanently engraved on the valve body. Any sequential numbering system is acceptable. Marking shall be a minimum of 1/4" high numerals and be by means of vibrator, engraver, or University approved equal.

4.28 Warranty of Valve and Parts

a. All parts of the valve will be warranted for two years against material and manufacturing faults. The warranty period begins at the time of acceptance of the valves by the University.

b. If the valve as a whole is found not to satisfay the specified performance requirements before the end of two years after acceptance, not including requirements of Paragraph 4.5, vendor is free either to repair the valve at no cost to the University or to provide a replacement.

c. Spare parts per Section 4.25 shall be available for a period of 6 years from the date of acceptance of the final valve provided under this procurement.

5.0 Inspection, Test Provisions, and Quality Control

5.1 Source Inspection

A University representative shall be permitted access to witness any phase of manufacturing, testing and conditioning of these valves. Upon request, vendor shall make available for inspection to the University all records and data on materials and procurement on tests, manufacturing, and other operations which pertain to these valves.

5.2 Test Monitoring

A University representative will be present to witness all performance tests made by the vendor. Vendor must notify the University a minimum of one week in advance of beginning the tests.

5.3 Test Records

A record shall be kept of all such valve tests performed. The record shall give date, name of person(s) performing tests, environmental conditions, duration of tests, equipment used, test procedures, diagrams for tests setups, all test data, any any irregularities observed during testing. All records of tests made at the request of the University shall be available for inspection by the University and copies provided if so requested. Records of calibration of test instruments used in conjunction with above tests shall be made available.

5.4 Materials Certification

Vendor is required to obtain and make availabe for inspection by the University, certifications of all materials used in construction of the valve, valve parts, and actuator. Certification shall be in the form of original source test reports of mechanical properties, chemical composition, or other requirements called out in the specifications.

6.0 Preparation for Delivery

6.1 *Preservation and Packaging*

All valves shall be furnished with a non-rotatable blank-off flanges attached to the inlet flanges. Inlet blank-off flanges must also meet the requirements of SLAC/PEP Spec. PS-202-631-04 or be a Varian manufactured Conflat^R Flange. These blank-off flanges will not be returned to the vendor. When packaged valves shall be free of moisture, dirt, soils or any residues from surface preparation. Vendor shall fully describe the complete packaging method to be used for shipment of valves. University approval of packaging is required prior to making the first shipment of valves.

6.2 Marking for Shipment

Exterior of shipping containers shall be adequately and properly marked for identification. All containers shall include the following minimum exterior marking.

a. Addressee
b. Shipper
c. SLAC subcontract or purchase order number
d. Special markings, warnings or tags in accordance with ICC regulations.

7.0 Drawings, Technical Data

7.1 Required Drawings

Vendor must submit three complete sets of valve drawings showing all dimensions and details of all parts internal and external, which comprise the valve. The orientation of the leak check groove must be shown on all flange details. If not shown on the drawings, all materials of manufacturer shall be included in a specification which must accompany the drawings. Prior to beginning manufacturing, vendor must receive University approval of all drawings. University approval of the drawings in no way re ves the vendor from responsibility to meet all requirements of this specification.

TECHNICAL SPECIFICATION

GUIDELINES FOR PURCHASING STAINLESS STEEL MATERIAL FOR ULTRA HIGH VACUUM APPLICATIONS

PS-202-631-73 RO

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INTRODUCTION

This specification reviews guidelines to aid engineers when purchasing austenitic stainless steel material for use in an ultra high vacuum (UHV) system. Austenite is the gamma phase of iron which has an FCC crystal morphology. 18-8 stainless steel primarily consists of iron in this phase, which is paramagnetic. There are many other complicated factors which define austenitic stainless steels. For instance, the quanties of iron, chromium, nickel and other elements such as silicon and manganese can contribute to the existence of the austenite phase of 18-8 stainless steel.

When ordering material for a part the first step is to read the material call-out on the drawing. Many times the drawings are vague, or non-descript. Often times "stainless steel material" is the only detail given. The engineer must decide what type, shape, and sometimes method of fabrication to use for the stainless steel. This specification will be an outline for ordering stainless steel and choosing the material type, shape, testing methods; method of fabrication; as well as discussing the industry wide accepted standard specifications governing stainless steel material.

A MATERIAL TYPE

The most common material types used for ultra high vacuum are: 304, 304L, 316, 316L 321, and 347. The nominal chemistries of these material types are listed below:

NOMINAL CHEMICAL COMPOSITION (% BY WEIGHT)

	304	304L	316	316L	321	347
C -	0.08 mas	0.03 max	0.08 max	0.03 max	0.08 max	0.08 max
Ni -	8-10.5	8-12	10-14	10-14	9-12	9-13
Cr -	18-20	18-20	16-18	16-18	17-19	17-19
Fe -	BAL	BAL	BAL	BAL	BAL	BAL
Mo	-	-	2-3	2-3	-	-
Ti	-	-	-	-	5xC min	-
Cb+Ta-		-	-	-	-	10xC min
Mn-	2.00 max	2.00 max	2.00 max	2.00 max	2.00 max	2.00 max
P -	.045 max	.045 max	0.45 max	0.45 max	.045 max	0.45 max
S -	.030 max	.030 max	.030 max	.030 max	.030 max	.030 max
Si-	1.00 max	1.00 max	1.00 max	1.00 max	1.00 max	1.00 max

Type 304 is by far the most popular, cheapest and readily available stainless steel on the market. Type 316, 321 and 347 are referred to as stabilized materials. The additions of molybdenum, titanium, and columnium and/or tantalum, respectively are used to "tie up" the carbon so that it does not come out of solution during heating and from chromium and other deleterious carbides. These carbides can precipitate in the grain boundaries and cause embrittlement of the material. This will alter the mechanical properties and form potential leak sources or paths. The low carbon stainless steels type 304L and 316L contain carbon contents of .030% maximum. These materials are also used when carbide precipitation may be a problem.

When materials are to be used in temperatures above 650 C one of the stabilized or low carbon stainless steels should be considered.

If parts are to be heated in a hydrogen atmosphere (during stress relieving or brazing) do not use type 321, titanium stabilized, stainless steel. As noted earlier titanium is used to tie-up carbon atoms. It has been discovered that some of this titanium is free to form other compounds such as titanium hydrides. If this material is heated after seeing a hydrogen atmosphere these hydrides will decompose liberating hydrogen gas. Thus a virtual leak is created.

As noted, in the chemical compositions of the stainless steels listed, sulphur content is .030% maximum. Sulphur and its compounds have a very high vapor pressure and are a great source of contamination in an UHV system. Sulphur levels should never be above this maximum amount. At elevated temperatures sulfide inclusions can vaporize and create bursts of gas. For example, during welding these inclusions can breakdown leaving behind voids and porosity. Thus, a virtual leak. Usually vacuum melted materials have low sulfur contents of approximately .005%.

B MATERIAL SHAPE:

There are many commonly available shapes to choose from when purchasing stainless steels. These are: plate, sheet, strip, tube, pipe, bar and wire. The two considerations for selection of a certain shape are the machining cost and the "directional" properties of a material. Pipes, seams, cracks, porosity, segregation, or any other defects will usually, or can be more pronounced, in the worked (rolled) direction or axis of the material. These flaws could be detrimental to a vacuum system, as a source of leak paths, as well as compromising mechanical properties.

One example illustrating the importance of directional properties for an UHV part would be to use a rolled and welded plate instead of an extruded tube. The rolling axis of the plate will be perpendicular to any possible leak path. If extruded tube were used the worked direction would be along the longitudinal axis of the tube and therefore, would become more susceptible to forming leak paths. A second example, would be to use plate stock for a tube cap or flange connection, instead of round bar stock. Here again the rolling axis of the plate will be perpendicular to possible leak paths.

If it is critical or difficult to choose a material shape that does not exhibit deleterious directional properties, cross forging the part is recommended. This process can be costly and the economics must be considered when selecting this fabrication method.

Cross forging is a process that upsets the material in many different directions thereby removing the original worked axis of the material. Hence, cross forging rearranges any pattern of potential leak paths formed by the original fabrication process. Cross forging is highly recommended for large parts and flanges above 2-3/4" in diameter.

C VACUUM MELTED MATERIAL:

For highly critical parts where inclusion content (see section F1), outgassing or high heat applications (above 650 degrees C) are important vacuum melted material is highly recommended. There are four common types of vacuum melting processes, these are (in order of material "cleanliness"): vacuum induction melting (VIM) plus consumable electrode vacuum arc remelting (VAR), vacuum arc melting, vacuum induction melting, and electro-slag remelting (ESR). These processes have improved workability and mechanical properties but are significantly more costly than the standard argon-oxygen decarburization (AOD) melting process.

Many shapes and sizes are availble in the vacuum melted form.

D MATERIAL SPECIFICATION:

There are many acceptable industry wide standard material specifications for different material shapes and processes. An outline of some of the commonly used American Society for Testing Materials (ASTM) standard specifications and titles are given below.

For Plate, Sheet and Strip: ASTM A-167: Stainless and heat-resisting chromium-nickel steel plate, sheet and strip.

ASTM A-240: Heat resisting chromium and chromium-nickel stainless steel plate, sheet and strip for fusion welded unfired pressure vessels.

ASTM A-666: Austenitic stainless steel, sheet, strip, plate and flat bar, for structural applications.

For Tube: ASTM A-213: Seamless ferritic and austenitic alloy steel boiler, superheater and heat exchanger tubes.

ASTM A-249: Welded austenitic steel boiler, super heater, heat exchanger, and condenser tubes.

ASTM A-269: Seamless and welded austenitic stainless steel tubing for general service.

ASTM A-632: Seamless and welded austenitic stainless steel tubing (small diameter) for general service.

ASTM A-688: Welded austenitic stainless steel feed water heater tubes.

For Pipe: ASTM A-312: Seamless and welded austenitic stainless steel pipe.

ASTM A-358: Electric fusion welded austenitic chromium nickel alloy steel pipe for high temperature service.

ASTM A-376: Seamless austenitic steel pipe for high temperature central station service.

ASTM A-409: Welded large diameter austenitic steel pipe for corrosive or high temperature service.

ASTM A-530: General requirements for specialzed carbon and alloy steel pipe.

For Bar: ASTM A-276: Stainless and heat resisting steel bars and shapes.

ASTM A-314: Stainless and heat resisting steel billets and bars for forging.

ASTM A-479: Stainless and heat resisting steel bars and shapes for use in boilers and other pressure vessels.

Forgings: ASTM A-182: Forged or rolled steel pipe flanges, forged fittings and valves and parts for high temperature service.

ASTM A-473: Stainless and heat resisting steel forgings.

There are many other institutions which publish industry accepted specifications for stainless steel materials. Some of these are: American Society of Mechanical Engineers (ASME): Society of Automotive Engineers (SAE); American Metals Society (AMS); Federal Government and Military branches, etc. For cross referencing these specifications, refer to a volume entitled, "Unified Numbering System for Metals and Alloys."

E MATERIAL CERTIFICATIONS: When purchasing materials for use in a UHV system a good rule of thumb would be to request material mill certifications and actual chemical test reports traceable to the heat lot number. One should always check the certification upon receipt of material. A common mistake is requesting and/or receiving a certificate of conformance which is a standard form written by the supplier. It does not, generally, give the same information usually found in a mill certificate.

A mill certification lists the following: heat lot number; date of melt; material type, shape and size; actual chemical test results of a melt sample; mechanical properties (i.e. tensile, yield, elongation, hardness, etc.); material condition (annealed, pickeled, tempered, etc.), grain size; and applicable specifications. This information will be helpful in understanding the material and ensure that the proper material has been delivered.

If in doubt, or the parts to be fabricated are critical (i.e elevated temperature environment or thin sections, etc.) testing the material may be a comforting option. In many cases material testing should be required.

F MATERIAL TESTING: Material testing is a fool proof way of guaranteeing that the material received conforms to the specifications and properties required. The testing methods used for stainless steel UHV material are:

1 Metallographic: The microstructure of a material sample

(see section G) can be examined metallographically for inclusion content, pipes, porosity, and directional properties. A sample is usually examined at a magnification of 100X but other magnifications can be used, as needed.

Acceptable maximum inclusion content ratings per the specification ASTM E-45, "Determining the Inclusion Content of Steel", following method "D" are as follows:

For standard AOD melted stainless steel:

	Thin	Heavy
A	2	1.5
B	2.5	2
C	2	1.5
D	2.5	2

For vacuum melted stainless steel:

	Thin	Heavy
A	1	1/2
B	1.5	1
C	1	1/2
D	1.5	1

When ordering vacuum melted stainless the above requirements should be included in the purchase order.

For pipes and porosity there is no specification covering acceptable quantities. Judgment and experience must be used to decide what is acceptable.

Grain size can be measured by metallographic examination. Refer to ASTM E-112 "Estimating the Average Grain Size of Metals". Grain size is especially important for sheet, foil and thin parts. If grain size is too large, leak paths can form. A grain size of no more than 5-10% of the cross-sectional thickness is acceptable for materials below .060" thick.

2 <u>Chemical</u>: An easy way to detemine material type is to have a sample tested for chemical composition. If a sample can be supplied in a minimum size of 1 sq. cm. (4 gm. minimum) emmision spectrographic analysis can be performed. This method vaporizes the material and compares the test sample against a known control sample (supplied by the independent testing lab). Although, the laboratory's job will be easier if the suspected sample material type is given, this is not required. This method is a quantitative analysis which is accurate to within 10-20%. Also recommended is a LECO analysis for sulphur and carbon. This method yields very precise results for these elements. This test is usually necessary to make a positive identificationn of the stainless steel material type. Other analysis for specific elements can be performed by atomic absorption or wet chemistry techniques. The latter method is also used if samples are too small (e.g. fasteners) for emission spectrographic analysis. This method is considerably more time consuming and costly.

3 Mechanical: For many UHV parts hardness may be important. Usually, mechanical properties are not critical but must conform to minimum standards.

4 Magnetic Permeability: Magnetic permeability is often important when stainless steel parts are near magnets or particle beams. Magnetic permeability requirements may differ but frequently 1.05 maximum permeability at 200 oersted is the acceptable limit. Checking with the responsible physicist of a project may be necessary to determine what is required. Permeability can be measured using a Severin permeability indicator.

5 Leak Test: If there is concern about potential leak paths in a material, a leak test can be performed. This can be carried out as follows. A sample of the material should be machined to a thin section between .010" to .060" thick. This thin section should be perpendicular to the worked direction if possible. These test pieces shall be chemically cleaned and vacuum fired between 250 - 500 degrees C. The sample should be tested for leakage on a mass spectrometer helium leak detector, per vacuum laboratory requirements.

G SAMPLING: To perform any metalolographic or chemical analysis samples of the material must be supplied. It is recommended that samples from each heat of a delivery (if there is more than one) should be taken. For large orders of 1000 lbs or more many random samples should be taken for analysis.

1 Bar, Tube and Pipe: A coupon should be cut from each end of the length of material choosen for analysis. If convenient, a coupon should also be cut from the center of the length. Judgment must be used to determine the size of a coupon, usually a 1/4" to 1/2" thick piece should be cut. Samples for metallographic and chemical analysis will be cut from the coupon. Two test samples of approximately 1 sq. cm. are needed for metallographic analysis. Two samples are needed to examine directional properties parallel and perpendicular to the worked axis. A test sample of at least 4 grams minimum is required for chemical analysis. Check with the laboratory performing the analysis to get their sampling requirements.

2 Foil, Sheet and Plate:

The most convenient way to sample this type of material is to cut a coupon from a corner of the material if possible. Size and weight of test samples should correspond with the above section.

3 Cross Forgings:

Representitive test samples or coupons should be cut from a cross forging to reveal its cross section. Since forgings come in many shapes and sizes a specific procedure for sampling is difficult to outline.

4 Cutting: Cutting of coupons from the parent length should be performed on a horizontal band saw with sufficient cooling. Cutting test samples from the coupon should be done on an abrasive cut-off wheel also with sufficient cooling. Cutting speeds should be such that the part does not become too hot to touch. If a test sample becomes too hot the microstructure may become altered and metallographic analysis will not reveal the true structure of the material.

TECHNICAL SPECIFICATION

FOR

ALUMINUM TUBING

FOR HIGH VACUUM APPLICATIONS

PS-236-105-07-R2

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TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 The aluminum tubing made to this specification will become the primary beam chamber of the Stanford Linear Collider Arcs, a project of Stanford University, hereinafter referred to as the University. These extrusions will be evacuated to a pressure of 10E-7 torr by means of sputter ion pumps. They must be capable of maintaining continuous leak free operation. Before being put into operation, each extrusion will be tested by the University, using a mass spectrometer helium leak detector. Any extrusion which indicates leakage when tested with a minimum sensitivity of 2 x 10E-10 standard cc/sec per division is not usable for this requirement.

2.0 SCOPE

2.1 This document specifies the minimum requirements for producing aluminum extrusions of the type described in the Introduction, paragraph 1.1. This specification also includes the requirements for providing an extrusion die, for testing the extrusions, including the test tooling and for preparation and delivery of the extrusions.

3.0 REQUIREMENTS

3.1 The University does not require the vendor to be responsible for assurance that the extrusions delivered will meet the leak test requirement described in the introduction. However, the vendor is required to use every possible means to maintain the highest level of manufacturing standards and quality control throughout every step of production to preclude failure of a part under these leak check standards.

Extrusions are to be produced by the Direct Extrusion process. The aluminum alloy shall be type 6061, heat treated to T-6 condition by solution heat treatment or quench at the press. With the exception of the requirements of this specification, the extrusion must be produced to the ASTM standard B221.

3.1 SOURCE INSPECTION

A representative of the University shall be permitted to witness the extrusions, straightening, cutting and testing sequences required in this specification. Die trials may be included in the above. Vendor shall schedule arrangements so as to give the University at least one week notice prior to production. Extrusions shall not be produced prior to the arrival of the University representative.

3.3 DIMENSIONS

a) Outside diameter 0.500" + .003" - .000"
b) Wall thickness 0.035" +/- .002"
c) Straightness 0.010" (max deviation) in 12"

3.4 FINISH

The finish required on the inside surfaces of the extrusion is more critical than the outside surface. Both surfaces must be free from impurities, die lines, scratching, pitting and mars.

3.5 EXTRUSION PARAMETERS

a. Filtered Metal

In the molten state, prior to casting, all billet metal for these extrusions shall be degassed using nitrogen, argon or other combinations of gasses. The maximum level of residual hydrogen resulting from said degassing shall be .22 mil of H2 per 100 gm of aluminum.

Molten billet metal shall be filtered by means of rigid media, spinning nozzle or other process. Filtering must reduce the impurity and contamination level in the billet to meet Class A ultrasonic discontinuity limits when tested per MIL I-8950 B. Certification of conformance to both of the above requirements shall be furnished to the University accompanying other reports called for in Section 4.

b. Billets

Ten billets, taken at random from the above melt, shall have a sample cast, faced off and a quantometer or other spectrochemical analysis taken. A certified report of each piece tested shall be furnished in written form to the University representative at the time the extrusions are produced. The first billet through the press shall be a starter billet, either half or full size. No finished extrusions may be taken from this starter.

c. Lubricant

No grease or other lubricant shall be used on the billets or dummy block, except as specifically approved by the University representative.

3.6 QUENCH

The quench at the press must be carefully controlled so as to produce essentially identical mechanical properties throughout the extrusion cross-section.

3.7 ROUGH CUTTING

The location of the rough cut, with respect to the quench box, shall be chosen so as to preclude the intrusion of water into the ends of the extrusion.

◊◊◊

3.8 NUMBERING

All extrusions shall be sequentially numbered as they come off the press with a crayon. When finished lengths are cut from the extrusion these shall be marked with the sequence number followed by a number to indicate the position in the extrusion from which it was cut.

3.9 INSPECTION

Inspection to ensure that extrusion is dimensionally within tolerance is to take place at approximately every tenth extrusion and shall meet the specifications prescribed in Section 3.3.

3.10 SAMPLES

Before the production run, six finished length samples of the extrusion must be furnished to the University for inspection.

From the front and back crops of every extrusion run a 6" test sample shall be taken immediately adjacent to the finished length cut. For every 50 extrusions an additional sample shall be taken for testing of Mechanical Properties. All these samples are to be marked with an electric vibrating engraver to indicate extrusion identity number and a letter to indicate the location from which the sample was taken.

3.11 FINAL ACCEPTANCE

Notwithstanding the inspection requirements at the vendor's plant, as described herein, final acceptance of the extrusions shall take place following delivery to the University at the Stanford Linear Accelerator Center, 2575 Sand Hill Road, Menlo Park, CA 94305.

4.0 TEST PROVISIONS

4.1 SAMPLE TESTING

The test samples taken are for the purpose of flare testing. A flare test tool consists of a tapered wedge. On each of the [illegible]mples, the flaring tool shall be forced into the passage by means [illegible] aulic or air activated press. The purpose of the flare is to stretch t[illegible]e me[illegible]al in the wall to determine the integrity of the welds. The test is performed by flaring the tube until a separation takes place. If the separation takes place at a weld location and the separation is due to an inadequate weld bond, the finished length of extrusion adjacent to where the sample was cut is rejected. A sample may now be taken from the other end of this finished length. This process is repeated until an acceptable weld bond is obtained. An acceptable weld bond is one on which both parted faces show evidence of longitudinal stream lines and not the random, grainy surface which is characteristic of sound metal.

All flare test samples shall be retained by the vendor until permission for disposal has been received from the University.

4.2 MECHANICAL PROPERTY TESTS

The Mechanical Properties Test Samples taken in Section 3.10 shall be tested and a written report of the results shall be furnished to the University representative. The report shall include the results of testing the ultimate tensile strength, yield strength, elongation and hardness of each sample. The "minimums" prescribed in the Aluminum Association Standards for this alloy, temper designation and class of product must be met before the extrusions are prepared for shipment.

5.0 PACKAGING AND SHIPMENT

Tubing shall be prepared in bundles of no more than twenty-five pieces. Each bundle shall be banded at each end and in the center. Banding should be plastic, no adhesive tape should be used. The bundles should be crated with interleaving between each layer in such a way as to prevent denting or damage