LIGO VACUUM EQUIPMENT
FINAL DESIGN REPORT
VOLUME II Part I
ATTACHMENT 5 SPECIFICATIONS/MISC

LIGO-C960965-01-V

updated by revision 2 LIGO-C970091-00-V

CONTRACT NO:	**PC 175730**
PSI DOCUMENT NO:	**V049-1-097**
PROGRAM I.D.	**LIGO VACUU[illegible]MENT**
CDRL NO:	**03**
APPROVAL STATUS:	**A**

Process Systems International, Inc.
20 Walkup Drive
Westborough, MA 01581

CALIFORNIA INSTITUTE OF TECHNOLOGY LIGO PROJECT
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

VOLUME II ATTACHMENTS

ATTACHMENT 5

4. **SHOCK, VIBRATION, AND ACOUSTICS ANALYSIS**

5. **DESIGN GOALS/REQUIREMENTS** **V049-2-095** **REVISION 0**

6. **SPECIFICATIONS**

TITLE	DOCUMENT NO.	REVISION
I. Equipment Specifications		
(Deleted)		
Main Roughing Pump Carts	V049-2-001	3
Main Turbomolecular Pump Carts	V049-2-002	4
Auxiliary Turbomolecular Pump Carts	V049-2-003	3
Ion Pumps	V049-2-004	2
112 and 122 cm Gate Valves	V049-2-005	3
6", 10" and 14" Gate Valves	V049-2-006	2
Vacuum Gauges	V049-2-007	1
Bakeout Blanket System	V049-2-009	4
Clean Air Supplies	V049-2-011	1
LN_2 Dewars	V049-2-013	2
Vacuum Jacketed Piping	V049-2-016	1
Bellows Expansion Joints	V049-2-017	5
Ambient Air Vaporizers	V049-2-055	1
80K Pump Regeneration Heater	V049-2-056	1
Small Vacuum Valves	V049-2-059	1
Clean Qtr Turn Valves	V049-2-060	1
Cryogenic Control Valves	V049-2-062	2
Bakeout Cart	V049-2-068	5
80K Pump, Burst Disc	V049-2-138	1

TITLE	DOCUMENT NO.	REVISION
II. Equipment Specifications		
80K Pump, Manual Regen Valve	V049-2-140	1
80K Pump, Vent Heater	V049-2-141	0
Clean Room Fan/Filter Modules	V049-2-142	2
HAM Cleanroom Panels	V049-2-144	0
BSC Cleanroom Panels	V049-2-145	0
Portable Gowning Room	V049-2-157	0
80K Pump, Vent Line Check Valve	V049-2-162	1
80K Pump, Reservoir Relief Valve	V049-2-164	0
80K Pump, Manual Bypass Valve	V049-2-165	0
LN_2 Thermal Relief Valve	V049-2-166	0
LN_2 Manual Cooldown Valve	V049-2-167	0
80K Pump, LN_2 Supply Line Filter	V049-2-176	0
80K Pump, Derime Valves	V049-2-177	0
III. Instrument & Control Specifications		
Deleted		
Instrument List	V049-1-036	2
Personal Computers	V049-2-049	0
Bakeout System Thermocouple Measurement System	V049-2-050	2
T/C Measurement PLC Interface	V049-2-051	1
Bakeout System PC-PlC Interface	V049-2-057	0
Bakeout System PC Interface Software	V049-2-058	0
Flow Meter	V049-2-079	1
Differential Pressure Transmitters	V049-2-088	0
Level Transmitters	V049-2-089	3
Pressure Transmitters	V049-2-090	4
Temperature Elements	V049-2-091	0
Interlocks, Permissives and Software Alarms	V049-2-092	0
IV. Material Specifications		
Piping Design and Material	V049-2-037	3
Stainless Steel Vessel Heads	V049-2-039	4
Stainless Steel Flange Forgings	V049-2-040	6
Stainless Steel Vessel Plate	V049-2-041	3
O-Rings	V049-2-045	5
Rings Cut From Plate	V049-2-134	1

MEASUREMENT AND ANALYSIS OF LIGO VACUUM SYSTEM SHOCK VIBRATION, AND ACOUSTIC NOISE

(Rev. 1)

Prepared by:

Kyle Martini, Klaus Kleinschmidt, Joel Garrelick, Carina Ting

May 6, 1996

Report U-2379-2041

Prepared for:

Process Systems International, Inc.

20 Walkup Drive

Westborough, MA 01581-5003

Cambridge Acoustical Associates, Inc.

200 Boston Avenue, Suite 2500

Medford, MA 02155-4243

TABLE OF CONTENTS

I. INTRODUCTION AND SUMMARY

The LIGO specification places special operational constraints on the functioning of a number of devices that make up the interferometer vacuum system. Consideration has been given to these devices as sources of noise, vibration, and shock and their effect on the sensitivity and alignment of the interferometer. In conjunction with Process Systems International, Inc. a plan was proposed in PSI's proposal of June 19, 1995 to reduce the risks associated with these issues. The plan included selecting the proper equipment, measuring the noise, vibration and shock of the equipment, designing the first order mitigation treatments and analyzing performance with the treatment in place to determine the degree of compliance with the LIGO specification.

At this time there is no equipment available to obtain actual source strengths and the design of the vacuum equipment system is just being finalized. The analysis is therefore preliminary using extrapolated data provided by the turbo pump vendor to estimate the source level. The focus of the analysis is the end station. The end station is the least complicated to model, contains all the sources, and is anticipated to produce the highest levels at the receiver because of the close proximity between source and receiver with a minimum number of discontinuities.

The analysis of the vibration and shock path utilizes three different models to predict the receiver response over the entire frequency range. The first model is a low frequency finite element beam and plate model. This model is extended large distances to capture the primarily low frequency influence of the boundary on the transmission path. In the frequency range where the influence of the boundaries is less important but the response of the path structure still exhibits distinct modal peaks, a mid frequency finite element shell model is used. In the high frequency region where modal overlap is strong a statistical energy analysis is performed.

Results for the turbo pump nearest the beamsplitter indicate that in the low-to mid frequency range where modal peaks are dominate, the predicted levels exceed the LIGO specification by 20-40 dB. The beam tube manifold between this particular turbo pump and the beamsplitter does not have a bellows in contrast to the situation at most of the other locations. It is estimated that such a bellows will reduce the levels by 20-40 dB except at the very low frequencies.

A transmission path/room acoustics model has been used to estimate the noise level in the end station's vacuum equipment area. This model indicates that 1) noise from the turbo pump will produce a 27 dB excess re: NC-20 in the 500 Hz octave band frequency; 2) noise from equipment in the vacuum support equipment room will cause levels to exceed the NC-20 criteria by 8 to 10 dB. The latter transmission of this noise is due to leakage via the pass door between the two rooms.

Transmission path analyses are scheduled to be completed by the end of May 1996. Included in the analyses will be low and high frequency vibration models and acoustic models of the corner, mid and end stations. The mid frequency vibration analysis will be performed for selected worst case locations in the three stations.

Source measurements for the turbo pump are scheduled for June, the gate valves will be tested in June and July and the ion pump, cryo pump and vent and purge system will be tested in August. The equipment source levels and measured impedances will be input to our transmission models to predict the levels at the various receivers.

II. LIGO SPECIFICATIONS

A. VIBRATION

The LIGO vibration specification (Ref. 1) for the spectral density of the allowable displacement δ on the walls of any vacuum chamber or on the floor within 1 meter of any chamber is shown on Fig. 1a. This spectral density represents the allowable level of a tone having a bandwidth of 1 Hertz at any frequency between 0.1 Hz and 10 kHz. Because acceleration sensors are used more commonly than displacement sensors to measure equipment vibrations, it is useful to recast the displacement specification of Fig. 1a as an acceleration specification by multiplying by ω^2 (where ω is radian frequency) and expressing the result in $\mu g/\sqrt{Hz}$. The resulting acceleration spectral density is shown on Fig. 1b.

B. NOISE

The specified acoustic noise limit from all simultaneously operating vacuum equipment in normal operation at any location within the LIGO vacuum equipment and laser areas is NC-20 (Noise Criterion) (Ref. 2). This noise criterion, shown on Fig. 2 is defined in terms of octave band levels starting at the 63 Hz center frequency band and extending to the 8 kHz band.

C. SHOCK

Valve actuation or other intermittent device operation shall induce no more than 0.01 g peak-to-peak acceleration at any point within 1 meter of any vacuum chamber.

III. APPROACH TO SPECIFICATION COMPLIANCE

A. OVERALL PLAN

A comprehensive plan has been put in place to identify all potential sources of significant areas of noise, vibration, and shock, in the vacuum equipment, to determine the degree of compliance with specifications, to design and evaluate control measures proposed in PSI's proposal, and to test installed vacuum equipment operation in the LIGO facility. The objective is to achieve the lowest possible impact on the gravity wave instrumentation. This plan, which is under way, consists of the following four parts:

1. Vacuum system equipment is evaluated with respect to vendors' stated vibration, noise, and shock performance and the inherent equipment design features that impact these characteristics.

2. Tests will be made on selected operating equipment in a qualified test facility to verify vendor claims and to supplement vendor data with detailed measurements to cover the full range of the LIGO specifications. Because the specified vibration levels are extremely low, low noise instrumentation and specialized equipment mountings will be used to enhance the capability to obtain measurements over the full frequency range specified.

3. Vibration, noise, and shock mitigation requirements as defined by PSI's proposal will be implemented. Constraints imposed by the LIGO facility will be incorporated into the treatment design.

4. Transmission of shock, vibration, and sound from the sources to the vacuum chambers and to the laboratory floor within one meter of any vacuum chamber are analyzed mathematically. Estimated levels with first order treatment in place are compared with LIGO specifications. Regions where compliance with specifications is not achievable are identified for further review and assessment.

B. SOURCES OF EQUIPMENT VIBRATION, NOISE, AND SHOCK

1. Mechanical Roughing Pumps

These first stage roughing pumps are not subject to vibration specifications.

2. Turbomolecular Roughing Pumps

Turbomolecular roughing pumps achieve their pumping capability by multi-stage vanes rotating at high speed (approx. 27,000 RPM). Pump shafts are driven by brushless motors. Shaft bearing designs include ceramic ball and magnetic.

The principal vibration source of these pumps is the unbalance in the rotor which produces a spectrum with a line at the rotational speed and at its odd and even harmonics. Vibrations at the power line frequency, typically around 1 kHz, and its harmonics result from magnetostrictive effects in the stator pole structure. Finally, with non-magnetically levitated bearings, broadband noise, (e.g., due to the interaction of the balls with the lubricant) is generated.

3. Ion Pumps

Ion pumps operate without moving parts. They are energized by high voltage DC from an AC powered controller. Ion pump vibration and noise is primarily associated with the high voltage power supply and controller which incorporate cooling fans and transformers.

4. Cryogenic 80K Pumps

These pumps consist of exposed surfaces refrigerated to a cryogenic temperature upon which gases are condensed. The proposed pumps use liquid nitrogen that boils at atmospheric pressure at a temperature of 80°K. The boiling action of liquid nitrogen involves cavitation (i.e., vapor bubble formation and collapse) which produces broad spectrum pressure pulses that act on vessel and liquid/air surfaces to produce noise and vibrations.

5. Purging and Venting Compressors

Non-reciprocating screw compressors are planned for this purpose and will be located in adjacent Mechanical Equipment Rooms.

6. Gate Valves

Gate valves are subject to the shock specification which limits the peak vibrational amplitude induced by their operation. Primary mechanisms of shock are deceleration and seating. Both electric and pneumatic valve actuators are used for various LIGO locations.

C. VERIFICATION TESTING

1. Test Chambers

The background acoustic and vibration levels of the test areas must be equal to or less than equipment levels being measured. A special acoustically treated chamber has been built at PSI to test the Turbomolecular pump, its backing pump and the ion pump. A prototype beamsplitter is being built to test the short cryopump. The gate valves with actuators and the vent and purge system have higher levels of noise and vibration and will be tested at the vendors' facility.

2. Equipment Mounting

Equipment to be tested will be suspended or supported compliantly to isolate it from the test chamber and allow the measurement quasi-free vibration levels required for the analysis.

3. Test Instrumentation - Sensors

a. Vibration

When equipment levels are below the measurement capability of general purpose accelerometers, high-sensitivity ultra low-noise accelerometers will be used to define equipment vibration levels. Two such sensors are available to span the full frequency range of the LIGO specifications. The Wilcoxon Research model 731A accelerometer (10V/g, 600 gm) has a useful bandwidth from 0.1-300 Hz. The Wilcoxon Research model 916BTO-1 (7.5 V/g, 700 gm) provides low noise capability above 300 Hz. The equivalent acceleration spectral densities corresponding to the electronic noise floors of these sensors are shown on Fig. 1b. Above 10 Hz, the noise floor of the model 731A is lower than the specified amplitude. Above 300 Hz, the noise floor of the 916BTO-1 is below the specified amplitude. When a measurement equals the sensor's noise floor, the vibrating amplitude of the test device is at least a factor of 3 dB lower than the noise amplitude.

Low noise measurements require limiting the electronic noise that occurs outside the frequency bandwidth of interest by using high-order bandpass filters.

b. Noise

Operating equipment noise will be measured using a Bruel and Kjaer type model 2236 Precision Sound Level Meter octave band analyzer. Acoustic power measurements will be made for use in assessing the overall sound pressure level in the Laser and Vacuum areas of the LIGO facility.

c. Shock

Shock measurements will be performed at the gate valve vendor site using small, lower sensitivity accelerometers such as Bruel and Kjaer model 4384 or 4366.

4. Test Instrumentation Data Analysis and Processing

a. Vibration

Vibration signals will be acquired on a digital recorder and processed to obtain frequency spectra in the form of spectral densities. Acquisition and processing of these signals will be performed using a CAA's computer-based SIGNAL system.

The duration of the signal acquired must be sufficiently long to insure confidence in the measured spectral amplitudes. Signal duration criteria for autospectral density functions are given in Ref. 3. The variance of the estimated autospectral density function ($\hat{G}(f)$) for a band-limited Gaussian noise signal is related to the resolution bandwidth B in Hertz and the total signal duration T in seconds as follows:

$$Var[\hat{G}(f) = \frac{G^2(f)}{BT} \qquad (1)$$

where $G(f)$ is the actual autospectral density. Therefore, a time-bandwidth product (BT) of unity yields a variance equal to the actual function. For purposes of estimating test requirements, we select a time-bandwidth product of 10. This yields signal acquisition requirements of 100 seconds for a 0.1 Hz bandwidth and 10 seconds for 1 Hz resolution. During these acquisition times, the equipment would have to be stable in its operation, and the test would have to be free from outside interference.

b. Noise

Acoustic measurements will be made using a Bruel and Kjaer type 2236 precision sound level meter. Noise levels in the octave bands between 63 Hz and 8 kHz will be recorded. This meter has a noise floor corresponding to less than NC-10.

c. Shock

Measurements of shock-induced vibration due to operation of the gate valves will be made by recording the output of accelerometers oriented in three orthogonal directions and mounted on the gate valve fixture. The signal will be recorded during the entire duration of the closing event, and the peak acceleration amplitude will be obtained.

D. VIBRATION MITIGATION

1. Design Approach

The overall approach to mitigating equipment induced vibration encompasses both the equipment source and the vibration transmission paths to the LIGO test hardware. In the initial review of vendor-supplied information, recommendations were provided for treatments that are easily applied to the equipment. Vibration transmission paths are treated using the approaches described in the following sub-sections.

The equipment vibration measurements will be used to characterize the source levels. The LIGO specification limits the vibration level at the receiver, on the chamber or on the ground within 1 meter of any chamber. To determine the extent of the mitigation required analyses are performed to predict the vibration level at the receiver.

When the source can be effectively isolated, the equipment vibrations characterize the source output. When the path from the equipment to the receiver is not capable of being effectively isolated, it will be necessary to supplement the vibration levels measured on the equipment with estimates or measurements of the structural impedance of the equipment at its attachment. Estimates of vibration transmission will then make use of an equivalent vibration source using Thevenin or Norton equivalent system representations (Ref. 5).

The method of modeling the path between the source and receiver is determined by its complexity and the frequency range of interest. For simple paths analytical models are used. For more complex paths, finite element methods are used at the low-mid frequencies where the modes of vibration are well separated. Statistical energy analysis (SEA) methods are used for the higher frequencies where modal overlap is strong.

Because vibration limits are specified over a broad frequency range (i.e., 5 decades), multiple strategies may be necessary to reduce equipment vibration across the entire range. Structural elements having low stiffness relative to their mating structures provide effective vibration isolation at frequencies below the range where the elements become resonant or wave-bearing structures. Compound equipment mounts obtained by connecting multiple isolator stages in series can be used to enhance vibration isolation effectiveness. Use of compound mounts is primarily limited by space availability.

Above the frequency range where isolators behave as simple compliant elements, vibration energy is transmitted along these elements in the form of propagating structural waves. This mode of energy transmission can be reduced with a combination of "blocking" masses and damping. The concept of blocking masses is to provide an impedance discontinuity along the energy transmission path to reflect propagating waves. Since this approach does not dissipate structural energy, damping treatments are added to the isolator. Damping treatments using viscoelastic materials applied to the external surfaces of the isolator can be designed in the form of both unconstrained and constrained layers.

2. Mitigation for Specific Equipment

a. Main Turbomolecular Pumps

Each of the main turbomolecular pumps is separated from its backing pump. The turbopump is placed on its own cart and separated from the interferometer by a soft bellows. The turbopump/cart is anchored to the floor to prevent the bellows from compressing axially due to the external pressure. High frequency isolators in the form of rubber bushings and washers isolate the turbopump from the cart.

The backing pump, which is a much greater source of vibration than the turbopump, is placed on its own cart and located in the Mechanical Equipment Room. The backing pump cart has its own vibration isolators.

b. Ion Pump Power Supplies

The source of vibration with the ion pumps are the power supplies. For the large ion pumps the power supplies are located in the Mechanical Equipment Room. Vibration isolators will be used if needed. The small ion pumps' power supplies are located in the Vacuum Equipment Room and rest on vibration isolators. The cable will be flexible and incorporate "drip loops" to enhance flexibility.

c. Cryogenic Pumps

The 80K pumps will produce vibrations due to the formation and collapse of bubbles in the liquid nitrogen. An experiment using air and water to simulate the two phase flow of the nitrogen entering the 80K pump showed that the generation of large bubbles via the inlet pipe can be reduced by bringing the stratified flow from the inlet pipe above the liquid reservoir. The incoming liquid flows gently down a chute into the reservoir while the gas escapes without bubbling through the liquid. The bubbles generated from the boiling liquid in the reservoir are smaller and generate higher frequencies. Vibration transmission into the interferometer resulting from this action is reduced by low frequency isolators.

An additional source of vibration from the 80 K pump operation is due to vibration in the supply and return lines. Flex lines are used to attenuate the vibration.

d. Purging and Venting Compressors

The vent and purge system will be skidded and placed inside the Mechanical Equipment Room. The skid is mounted on vibration isolators. The discharge and suction side of the system in the corner station have mufflers or sound attenuators. The mid and end station's systems are not operated during interferometer operation.

e. Equipment Located in Adjacent Mechanical Equipment Rooms

The turbomolecular backing pumps, vent and purge compressor skids, and the ion pump controllers are located in Mechanical Equipment rooms. These rooms are located adjacent to the vacuum equipment area on separate floor slabs. All lines going from the mechanical room to the vacuum equipment area will have flex connectors.

E. NOISE MITIGATION

1. Design Approach

Noise radiated by operating pumps and electronics can be mitigated by reducing the vibrations of the external structural surfaces of the equipment. Measures to accomplish this include externally applied structural damping treatments. Vibration isolation may also be required as a component of noise control.

2. Implementation

A computer model of the vacuum equipment areas is utilized to predict the combined noise levels in the specified NC contour octave bands from 63 Hz to 8 kHz from the various vacuum pumps and auxiliary equipment located in these areas. The input to this model is the acoustic power measurements performed on the operating equipment. Any remotely located equipment that could contribute to the noise via transmission through walls, doors, ductwork, and other flanking paths is also included. The model includes the sound absorption and scattering effects of major equipment such as chambers, beam tubes, large diameter piping, and other large objects, as well as the sound absorbing properties of the room boundaries. Equipment identified by the model as exceeding the NC-20 noise specification will be evaluated for 2nd order noise reduction treatment (if authorized by LIGO).

Noise measurements on representative vacuum system components will be made either at PSI, a vendor's facility, if suitable, or at a commercial acoustical laboratory. Measurements will include octave or third octave band over the NC frequency range. Depending on the test facility, either sound pressure at a given distance and at various positions around the source or sound power will be measured. From this data and the room model discussed above an initial prediction of total noise at various locations in the Laser and Vacuum area will be made.

Specific noise control second order options for the vacuum system components are indicated below (note these options are not included in the current contract).

a. Main Turbomolecular Pumps

If necessary the pump and motor housing will be shrouded with loaded vinyl sheet laminated to open cell foam. Damping treatments, discussed above, can also be used to reduce sound radiation from support structures.

b. Cryogenic 80K Pumps

The magnitude of acoustic noise emissions of the boiling nitrogen inside the shroud needs to be measured. It is anticipated that the insulating vessel required for the shroud may be sufficient to preclude the need for further noise reduction.

c. Equipment Located in Adjacent Mechanical Equipment Rooms

The turbomolecular backing pumps, vent and purge compressor skids, and the ion pump controllers are located in Mechanical Equipment rooms. These units can take advantage of the noise control provisions required to adequately isolate auxiliary equipment (e.g., fans, chillers, pumps) located in these rooms from the vacuum equipment areas. Airborne noise isolation required for mechanical equipment to achieve the project noise goal in the vacuum equipment areas through walls, doors, windows, ducts, and roof/ceiling design is assumed to be adequate for isolation of the vacuum equipment to be located in the Mechanical Equipment rooms as well. If authorized by LIGO, supplementary noise control treatments, recommendations of the vacuum equipment can be provided should the noise isolation in the Mechanical Rooms be found to be inadequate for meeting the project noise goals in the vacuum equipment areas.

F. SHOCK MITIGATION

The gate valves are located in close proximity to the chambers. With the exception of adding a short flexible bellows, blocking the shock path is not an option. In this regard therefore we have required the valve manufacture to reduce the shock at the source. The valves will be compliantly supported from below to isolate them from the facility floor.

IV. SOURCE MEASUREMENTS

At this time there is no equipment available to obtain source measurements. The turbomolecular pump vendor provided vibration data for a similar pump. This will be used to estimate vibration levels at the end station. The vibration levels used for the analysis is shown in Figure 3. For the acoustic analysis, estimates of sound levels were obtain by either measurements on similar equipment at vendors facility or from experience.

V. TRANSMISSION ANALYSIS

A. VIBRATION

The modeling of the transmission path between the source and receiver is divided into three frequency regions, low, mid and high. In the low frequency or large structural wavelengths region the vacuum equipment and connecting manifolds are model with beam finite elements, the foundation slab is represented by plate elements and lossy springs represents the soil. The model can be extended large distances and captures the primarily low frequency influence of the boundary on the transmission path.

The transition from the low to mid frequency region begins when the structural behavior is no longer compact and circumferential shell modes exist in the equipment or the manifold. In the mid frequency region the transmission path is modeled with axisymmetric finite elements. The model assumes the structure is symmetric but applied loads, boundary conditions and displacements need not be axisymmetric. The mid frequency model is limited by size of the model and the influence of the boundaries where the model is artificially terminated. Typically boundaries become less important with increasing frequency. By varying the boundary conditions, the impact of the boundary is determine in the analysis.

The limitation of CAA's computer and the Nastran finite element program determines upper frequency limit of the mid range. Above this frequency statistical energy analysis is performed. With this technique the structure is divided into subsystems and the power flow between subsystems is calculated based on coupling loss factors.

Transmission path models of the vacuum system are currently being developed. The following sections describe preliminary models and results for the vacuum equipment in the end station (Figure 4).

1. Low Frequency Model

A Nastran [6] finite element beam representation of the equipment is plotted in Figure 5. Beam cross sectional properties are calculate for all the equipment and their supports. Stiffeners, flanges and non-structural parts are modeled as mass. The 30" concrete floor is model with plate elements and the soil is model as lossy springs. The soil properties were obtain from Parsons report [7].

The upper frequency limit of this model is approximately 50 Hz. Above this frequency circumferential shell modes occur. Below this frequency the body of equipment and the manifolds behave as a rigid mass on the flexibility of the supports and bellows.

Unit forces in each of three directions are applied at the two turbo pump locations, the floor below the turbo cart and at the cryopump. Observation locations were with 1 meter of the beamsplitter on both the manifold and the concrete slab. Large transmission losses are observed across the bellows and via the concrete slab path.

Estimates for source levels are available for only the turbomolecular pump (see Figure 3). Norton theorem is used to convert the acceleration levels to forces. The pump is connected to the manifold tube by a soft bellows. The bellows axial spring rate (60 lb/in) is much less than the stiffness of the pump. The pump then can be consider a pure velocity source and a force across the spring into the manifold can be computed. Results are listed in section 4.

2. Mid Frequency Model

The purpose of this section is to describe the finite element analysis that we performed to study the mid-frequency behavior of a portion of the end-station structure adjacent to the beam-splitter. Figure 4 is a sketch of the portion of the LIGO vacuum equipment that we refer to as the end-station structure. We developed a finite element model of a portion of end-station structure, indicated in Figure 6, for a preliminary study of the vibration levels produced near the beam splitter due to mid-frequency vibrations from the turbopump. The Nastran computer plot of the model is shown in Figure 7.

The mid-frequency model consists of Nastran axisymmetric conical shell and trapezoidal solid elements. These Nastran elements can only in themselves model axisymmetric structures; however, the applied loads and displacements need not be axisymmetric, as the element formulations use a Fourier expansion about the azimuthal coordinate [6]. The conical shell element, used primarily to model the thin shell/plating that predominates the structure, includes both membrane and bending flexibility (with the possible inclusion of transverse shear flexibility). The non-axisymmetric features of the structure, such as the ion pump and supports, are not modeled in this stage in the analysis, but it would be a straightforward task in the future to model some of these features via concentrated loads simulating lumped impedances, such as simple inertia or compliance. The attachment of the manifold tube to the beam splitter is modeled at this time as a fixed boundary condition. Future models would possibly include other boundary conditions at the beam splitter end or the use of a terminating structure simulating the impedance seen by the manifold tube at the splitter. The bellows, on the other end of the structure, is modeled with conical shell elements fixed at the far end with properties assigned to give an effective axial stiffness of 6514 lb/in (specified by bellows manufacturer) and a negligible bending stiffness.

The vibration of the turbo-pump was simulated by point loads in the radial, axial, circumferential direction applied at the center point of the location of the turbo-pump. The Nastran direct frequency formulation was used for these calculations. The analysis was performed to 500 Hz. Higher frequencies will be computed in the future.

We obtained the radial, axial and tangential components of the acceleration response of the model at various azimuthal locations and axial locations within 1 meter of the splitter end. We examined these results and present those that appear to represent the "worst" cases of vibration transmission in Section 4.

3. High Frequency Model

a. Introduction

In this section we present a high frequency analysis of structureborne noise propagation along an end section structure from a gate valve to the beam splitter. For the thin shell and plated box-like structures along this path the predominant high frequency wave motion tends to be flexural. By high frequency we mean frequencies at which the flexural wavelengths are small relative to the structural scales, such as the lengths and diameters of the tubular sections. For thin steel plating the flexural wavelength is given by

$$\lambda_f = 2\pi/k_f = 6x10^2\sqrt{h(in.)/f(Hz.)} \qquad (2)$$

where h is the plating thickness and f is frequency. To illustrate, with 1/4 in. plating at 1 kHz., $\lambda_f \approx 12.$ in. Structureborne noise levels will attenuate as they propagate from a noise source to a receiver. The overall attenuation is the result of both a spreading of the vibration energy and its dissipation, that is conversion to heat. Along two dimensional plated structures the spreading is cylindrical with acceleration levels decreasing as $r^{-1/2}$

where r is the distance (range) along the plating from source to receiver. Dissipation associated with flexural wave propagation is conveniently expressed in terms of a structural loss factor η. Here the associated attenuation is of the form $\exp(\; k_f r\eta/4) \; \exp(\; \pi\eta r/2\lambda_f)$. Dissipation may also be associated with parallel propagation paths that do not measurably couple to the receiver. For example for the problem of interest, the vibrational energy transmitted to the concrete slabs and in turn the ground via the manifold tube supports is believed to fall into this category.

Statistical energy analysis (SEA) is an analytical formulation that captures the phenomena described above and allows one to estimate absolute levels at receiver locations, e.g., the beam splitter, in terms of the noise source strength (input power). The technique is briefly outlined below and applied to the end station in the following section.

b. Statistical Energy Analysis (SEA) Concepts

With this technique the structure to be analyzed is divided into subsystems each "large" in terms of the characteristic wavelengths. For each subsystem "j" a steady state power balance is imposed

$$\Pi_j^i \quad \Pi_j^d \quad \sum \Pi_{j,k}^c \tag{3}$$

where Π_j^i is power input to the subsystem, Π_j^d is the power it dissipates and $\Pi_{j,k}^c$ the power "lost" to neighboring subsystems. A fundamental SEA concept is that the above dissipated and "coupled" powers are proportional to the space-averaged stored energy of the subsystem, <E>. Specifically [8],

$$\Pi_j^d \quad \omega\eta_j \langle E_j \rangle \tag{4}$$

and

$$\Pi^c_{j,k} = \omega[\eta_{j,k}<E_j> - \eta_{k,j}<E_k>] \quad (5)$$

here ω $2\pi f$ and η_j and $\eta_{j,k}$ are defined as dissipation and coupling loss factors. For structureborne noise

$$<\ddot{w}_j> = \omega^2<E_j>/M_j \quad (6)$$

where $<\ddot{w}_j>$ is the subsystem space-averaged squared acceleration and M_j the subsystem mass. The analysis is executed by defining the appropriate subsystems, using Eq. 2 to formulate a set of simultaneous equations in the unknown stored energies, obtaining the required loss factors [9], defining the source strength(s) solving the equations and finally using Eq. 5 to obtain the desired response. This is described below for the end section structure pictured in Fig 8.

c. SEA Model of LIGO End Section Structure

The section being analyzed is shown in Fig 8. There are twelve subsystems in our SEA representation, each a uniform section of the tubular manifold. Power is coupled among them across structural discontinuities of various types, viz., stiffening ribs modeled by their inertia, bellows characterized by their compliance, and section radius changes. Power may also be transmitted through the supports and lost to the floor slab. In addition it propagates beyond the modeled sections where it is "lost" to the beam splitter on one end and the continuation of the manifold on the other.

As is common practice with this approach, we obtain the required coupling loss factor expressions from the analytical solutions to highly idealized, so called "canonical", problems. For coupling from one manifold section (i) to another (j) we take all such problems to be one-dimensional with a loss factor of the form $\omega\eta_{i,j}$ $\Pi^c{}_{i,j}/M_i<v_i^2>$

where $\langle v_i^2 \rangle$ is the mean squared velocity of subsystem i. Also manifold curvature is ignored, thus limiting the validity of the analyses to frequencies above the ring frequency ($\Omega \;\; \omega a/c \;\; 1$) of the smallest diameter (44 in.) manifold section, roughly 1.4 kHz.

For coupling across a bellows the coupling loss factor is obtained from the model sketched in Fig 9a. Coupling is through shear forces inducing flexural vibrations. Assuming a high performance bellows and in turn "weak" coupling the result is

$$\omega \eta_{i,j} = 2(k_{bel}/\omega)^2 Re[Y_j]/m_i \tag{7}$$

where $k_{bel} \;\; K_{bel}/2\pi a_i$ and $m_i \;\; M_i/2\pi a_i$ are respectively the spring constant of the bellows and the total mass of subsystem i both per unit distance around the circumference. $Y_j \quad (Z_j)^{-1} \quad [(1 \;\; i)\omega(\rho h/k_f)_j/2]^{-1}$ is the admittance of the subsystem j plating taken to be semi-infinite in extent with $k_f \;\; \gamma\sqrt{3.46\omega/ch}$ the flexural wavenumber in the plating, c is the material sound speed and h the plating thickness [10]. The factor $\gamma \;\; [1 \;\; \Omega^{-2}]^{1/4}$ is introduced to account for the stiffening of a tube owing to its curvature as the frequency approaches its ring frequency from above [11].

Coupling across a rib or a flange at a section radius change, modeled via their mass per circumferential distance (m_{rib}), is analyzed similarly as shown in Fig 9b. Here the coupling loss factor is given by

$$\omega \eta_{i,j} = |Z_i Z_j / Z_{rib}|^2 Re[Y_j]/m_i \tag{8}$$

with $Z_{rib} \;\; i\omega m_{rib}$ and again we have assumed a strong discontinuity and hence weak coupling.

Finally, in Fig 9c we sketch the model for estimating the coupling loss factor from manifold plating into the floor slab via a support. The plating and slab are modeled as effectively infinite plates and the (point) support is massless and rigid. The plating discontinuity provided by the support nulls the motion at the interface and in so doing generates a force that is transmitted to the slab where the energy dissipates. Here the coupling loss factor becomes

$$\omega\eta_{i,slab} = 2(Z_{pltg}/M_i)(Z_{pltg}/Z_{slab}) \quad \textbf{(9)}$$

where Z_{pltg} $(4/\sqrt{3}(\rho c h^2)_i$ is the drive point impedance of the manifold plating assumed to be of infinite extent [12] and Z_{pltg}/Z_{slab} $(\rho c h^2)_i/(\rho c h^2)_{slab} \ll 1.$ is the ratio of plating to slab point impedances.

For this preliminary evaluation, 1. we let η_d 0.04 for all subsystems typical of fabricated structures, and 2. the parallel path through the concrete slab is ignored. Our excitation source is the turbomolecular pump located in subsystem 5. The input power is taken to be that for a compact radial force, $F_{TP(5)}$, driving the tube plating as if of infinite extent, P_i $F^2_{TP(5)}/Z_{pltg}$.

In the following section results are presented for the mean squared accelerations in the driven section (5) and downstream in Section 1, closest to the beam-splitter.

4. Results

In the implementation of all three models a force is applied to the turbomolecular pump's connection to the manifold tube in the radial direction. The drive point accelerance at this location, or the averaged drive compartment accelerance in the high frequency range, is plotted in Figure 10. The data from the three models collapse at the drive point. The transfer function accelerance from the drive point to locations within one meter of the beamsplitter is plotted in Figure 11. In the low to mid frequency range there is a 10-20 dB reduction from the drive point location. In the high frequency range the discontinuities in the system, as modeled, produce much greater reductions.

The turbo pump source levels shown in Figure 3 have been applied to the models and the estimated accelerations near the beamsplitter computed. These levels are compared to the LIGO specification levels in Figure 12. In the low- to mid-frequency range where the source levels can only be roughly approximated from the available information, the predicted levels exceed the LIGO specification by 20-40 dB.

B. NOISE

1. Acoustical Modelling for Airborne Noise in LVEA's Overview

The purpose of the acoustical models is to predict the noise level at specific receptor locations in the various Laser Vacuum Equipment Areas of the LIGO End Station at the Washington Site generated by vacuum pumps and auxiliary equipment provided to LIGO by PSI to which the project specified operational noise criterion spectrum of NC-20 applies. Noise from other ventilation and other machinery or personnel is not included in this acoustical analysis.

The elements incorporated in the model include the following:

Noise Sources - sound power [or equivalent sound pressure and distance] in octave bands from 31.5 to 8 kHz center frequencies.

Room Acoustics of Vacuum Support Equipment Rooms [VSER] - The End Station has a room dedicated to vacuum pump support equipment.

Noise Reduction of Envelope of VSER - partition, door, and other components of VSER's contributing to airborne sound transmission to the LVEA..

Room Acoustics of LVEA - acoustical treatment of ceiling and sound absorption of other surfaces; effect of scattering by large equipment; distances between sources and receptors.

These model elements are handled by spreadsheet computer programs [Lotus 123] customized for this project. Source noise outputs are based on either manufacturers' data, measurements performed by CAA / PSI as described in the statement of work, or estimates based on information in our files of the closest equivalent equipment where information is not available at the time of the initial computations.

2. Equipment Included in the Acoustic Models

As previously stated, the sources included in the acoustical models are vacuum pumps and auxiliary equipment manufactured or procured by PSI for the LIGO project to which the project specified operational noise criterion spectrum of NC-20 applies. In Corner Stations a segment of the LIGO system may be in operation while another is sealed off temporarily from the operational segment for repairs or modifications. In such situations the Vent and Purge Equipment would be in operation and it's noise sources must be included in determining the acoustic levels at critical operational vacuum components. segments.

It is assumed, initially for lack of complete noise level information, that the Small Ion Pump Controllers produce no significant noise; that the Cryopump produces a noise spectrum that matches the ambient noise level, and that the Vent and Purge Compressor noise equals that of a specific Siemens Side Channel Compressor [2CH4] having a capacity similar to that of the compressor in the selected system. For the Large Ion Pump Controller a haystack spectrum of modest level similar to typical fan cooled electronic equipment is used. The TMP is assumed to be operating, however, the calculation can be repeated without its contribution, to model the more typical condition.

3. Room Acoustical Models

a. Model of vacuum support equipment rooms

The acoustical model of these equipment spaces assume that there is no special sound absorbing treatment installed and that all room surfaces have very low sound absorption coefficients over the frequency range of the model [31.5 Hz to 8 kHz, octave band center frequencies]. However, due to the closely spaced array of equipment there is considerable diffusion and multiple reflection of sound waves resulting in an effective sound absorption coefficient for the nominal room boundary surfaces, i.e., floor, ceiling/roof, and walls, that is typically found to be higher than that for surface. The model uses absorption coefficients that lie between 10 and 20%, varying with frequency. If a particular machine or the dominant noise source of a machine is close to a wall there is no reduction due to room reverberation and, in fact, a small enhancement of the sound pressure on such a surface may occur.

Basically, the sound power of each source is reduced by the effective absorption characteristic of the equipment room, taking note of any non-qualifying machine locations. It is further reduced by the combined sound transmission loss of the room envelope components in common with the receiving space, the LVEA. The resulting sound pressure is assumed to radiate from the envelope into the LVEA with an equivalent acoustic power in proportion to the associated radiating area.

b. Model of end station laser vacuum equipment areas

The most critical receiver locations in the LVEA's are Beam Splitter Chamber vessels and beam tubes or beam manifolds which intercept the airborne sound and transmit them [as structureborne sound or vibrations] to nearby sensitive optical components in the LIGO system. The sound sources include the envelope elements of the VSER as well as equipment located directly in the LVEA, including Small Ion Pump Controllers, 80K Cryopumps.

The acoustical nature of the larger LVEA's, especially the Corner Stations, have larger volumes which contribute to longer reverberation times, however, this undesirable effect is largely cancelled out by the sound absorbing ceilings which have relatively high absorption coefficients [averaging around 60%].

Acoustic levels from sources that are *not* directly adjacent to the sensitive receptors will decrease substantially with distance, primarily because of the absorptive ceiling but also because the large vacuum equipment will provide the scattering and multiple reflection effects described above for the VSER's. The room corrections in each octave band and for each source - receiver pair incorporate both the distance and sound absorption factors as well as small adjustments, as appropriate, based on experience.

4. Sound Transmission Calculations

The primary paths of sound transmission from VSER to the LVEA are the common partition and the single access door. Their construction, e.g., thickness and type of material, e.g. gypsum wall board [GWB] determines the transmission loss versus frequency obtained through laboratory measurements of specific partitions. Using information on these partitions obtained from the Ralph M. Parsons Co., the facility designer, we can determine the needed information even if the exact construction does not precisely duplicate any of the tested partitions using our prior job files and a large quantity of published information on this subject. For the door, a standard office door that is fully gasketed is assumed and, as will be seen, a special acoustically rated door may be desirable for meeting the noise criterion.

5. Results of Initial Calculations

The results of the noise analysis for end station is shown in Figure 13. The calculations indicate that 1) the TMP cart creates sound levels at the vacuum vessel or beam tube which it is servicing that exceed the noise criterion by as much as 27 dB [in the 500 Hz Octave Band] and 2) that noise from support equipment in the VSER exceeds the criterion by 8 to 10 dB in most octave bands. The latter transmission is, however, dominated by leakage via the pass door between the VSER and the LVEA.

VI. LIGO COMMISSION TESTING

During the commissioning process of the installations in Hanford, WA and Livingston, LA, measurements of vibration and noise generated by vacuum system equipment will be conducted. Vibration measurements will be made on one each of the following chambers: horizontal access module;zbeam splitter modules (WA site only). At each chamber, normal vibration (i.e., single axis) measurements will be made at one location on the floor within 1 meter of the chamber. Tri-axis measurements will be made at two locations on each chamber. Measurements will be made with and without operating auxiliary equipment for the purpose of establishing ambient levels.

Additionally, sound pressure levels will be measured in the vicinity of each chamber with all vacuum system components in normal operation.

Shock measurements will be made on representative chambers during the operation of the gate valves. For the baseline tests, the beam-splitter chamber located at the vertex will be instrumented for tri-axis shock measurements during the operation of the 35 and 15 cm gate valves on the chamber and of the nearby 122 cm gate valve. Tri-axis shock measurements will also be made on the following: (1) one mid or end station chamber during the operation of a nearby . 112 cm gate valve.

REFERENCES

1 Vacuum Equipment Specification, LIGO Facility, LIGO-E94-0002-01-V, Rev. 1, 28 March 1995, p.11.

2 C.M. Harris, Handbook of Acoustical Measurements and Noise Control, (3rd Ed., McGraw-Hill Book Co., NY, 1991)pp. 43.4-43.5.

3 J.S. Bendat and A.G. Piersol, Engineering Applications of Correlation and Spectral Analysis, (John Wiley & Sons, NY, 1980) pp. 264-270.

4 Summary of Concepts and Reference Design for LIGO, Cal. Instit. of Tech, February 1992.

5 C.M. Harris and C.E. Crede (Ed), Shock and Vibration Handbook, Vol. 1, (McGraw-Hill Book Co., NY, 1961)pp. 10.24-10.25.

6 The NASTRAN" Theoretical Manual, NASA SP-221(04), National Aeronautics and Space Administration, Washington, DC (1977).

7 LIGO Technical Foundation Analyses Executive Summary and Discussions, The Ralph M. Parsons Company Contract Number: PP150969, December 4, 1995.

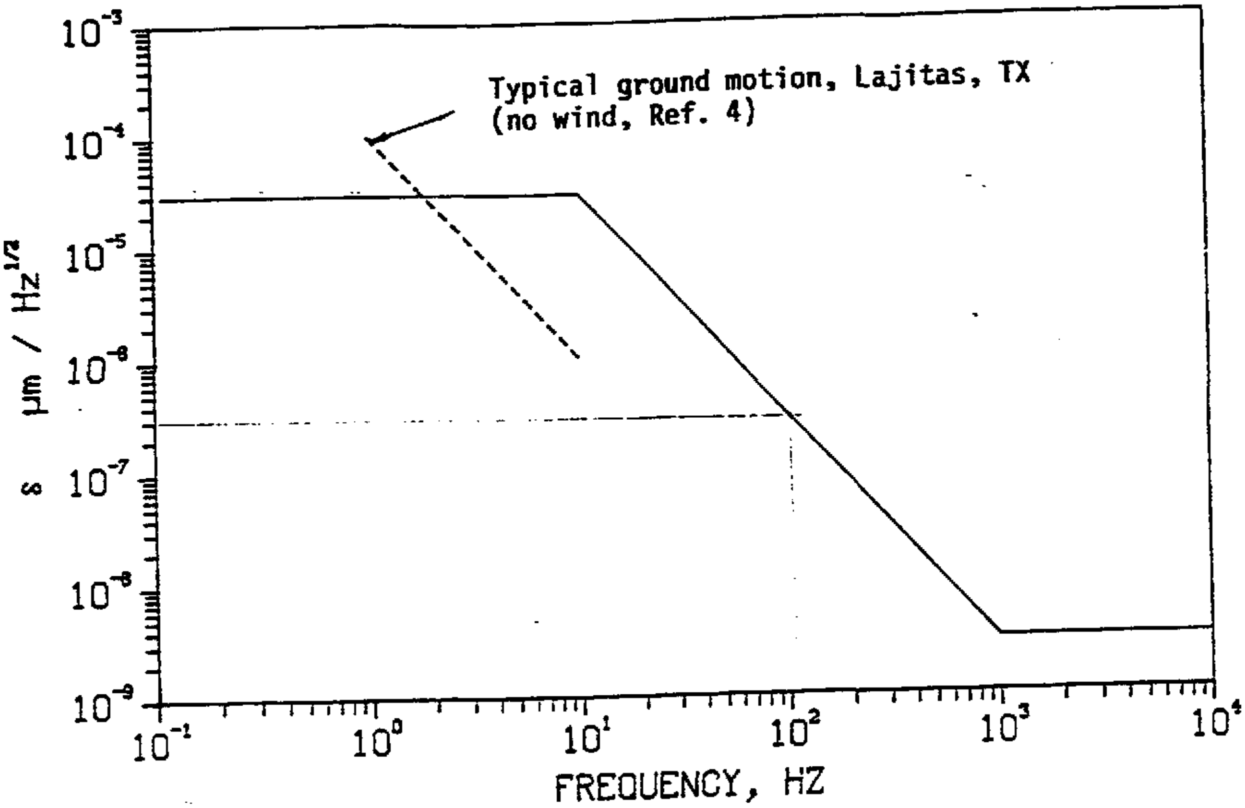
8. Richard H. Lyon, Statistical Energy Analysis of Dynamical Systems, The MIT Press, Cambridge, MA, 1975.

9. S. H. Crandall and R. Lotz, On the Coupling Loss Factor in Statistical Energy Analysis, J. Acoust. Soc. Am., 49, 352-356 (1971). Also, J. Garrelick, Dynamic Response of Coupled Systems: A Comparison Between Statistical Energy and Deterministic Systems, CAA Technical Report U-392-213 prepared for The Office of Naval Research under Contract N-00014-69-C-0056 , Structural Mechanics Program, September 1972.

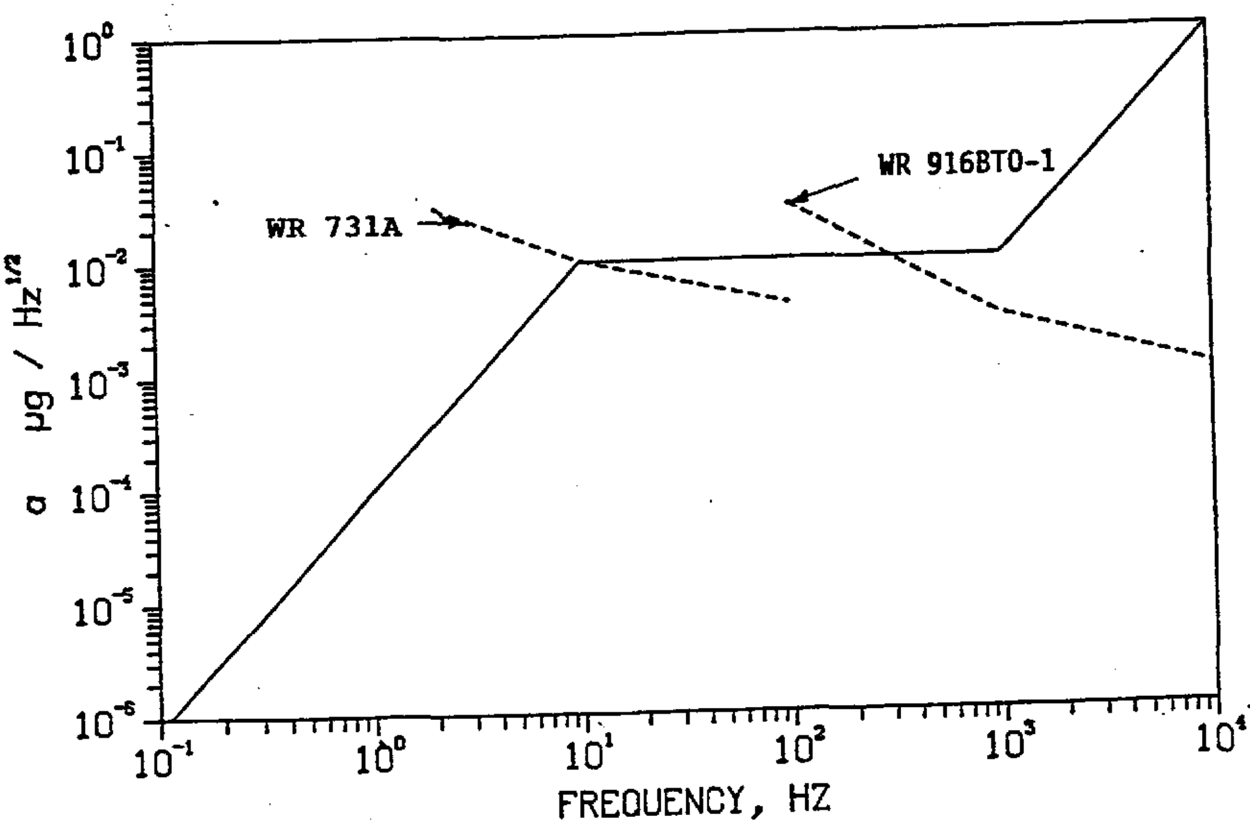
10. L. Cremer, M. Heckl and E.E. Ungar, Structure-borne Sound, Springer-Verlag, Berlin, 1973, Ch V.

11. Miguel C. Junger and David Feit, Sound, Structures and their Interaction, The MIT Press, Cambridge, MA 1986, Ch 7.

12. ibid, Eq 7.80c with n v 0.



(a) Displacement



(b) Acceleration

Fig. 1 - LIGO Displacement and (equivalent) acceleration specifications

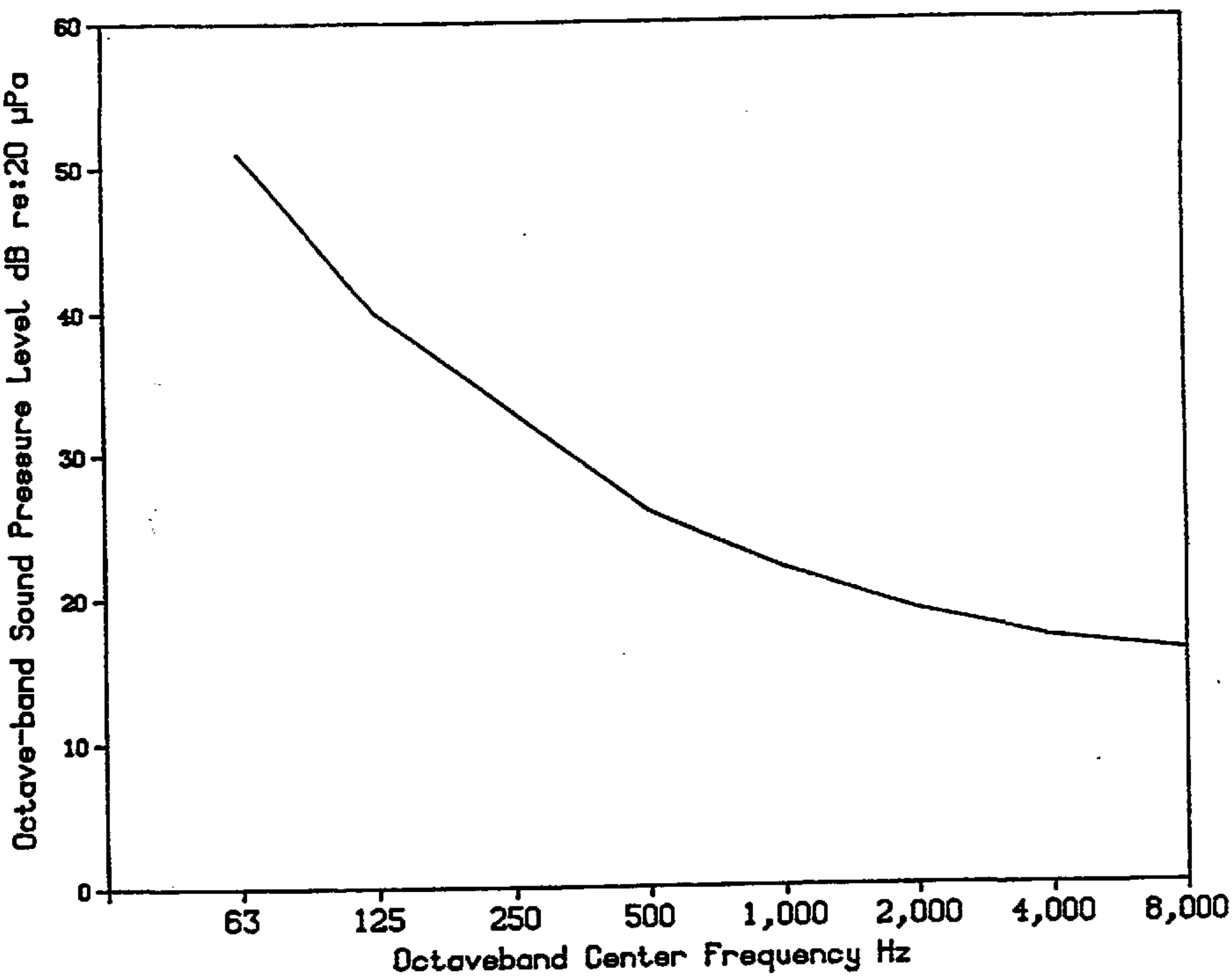


Fig. 2 Noise criterion-20 (NC-20) octave band sound pressure levels.

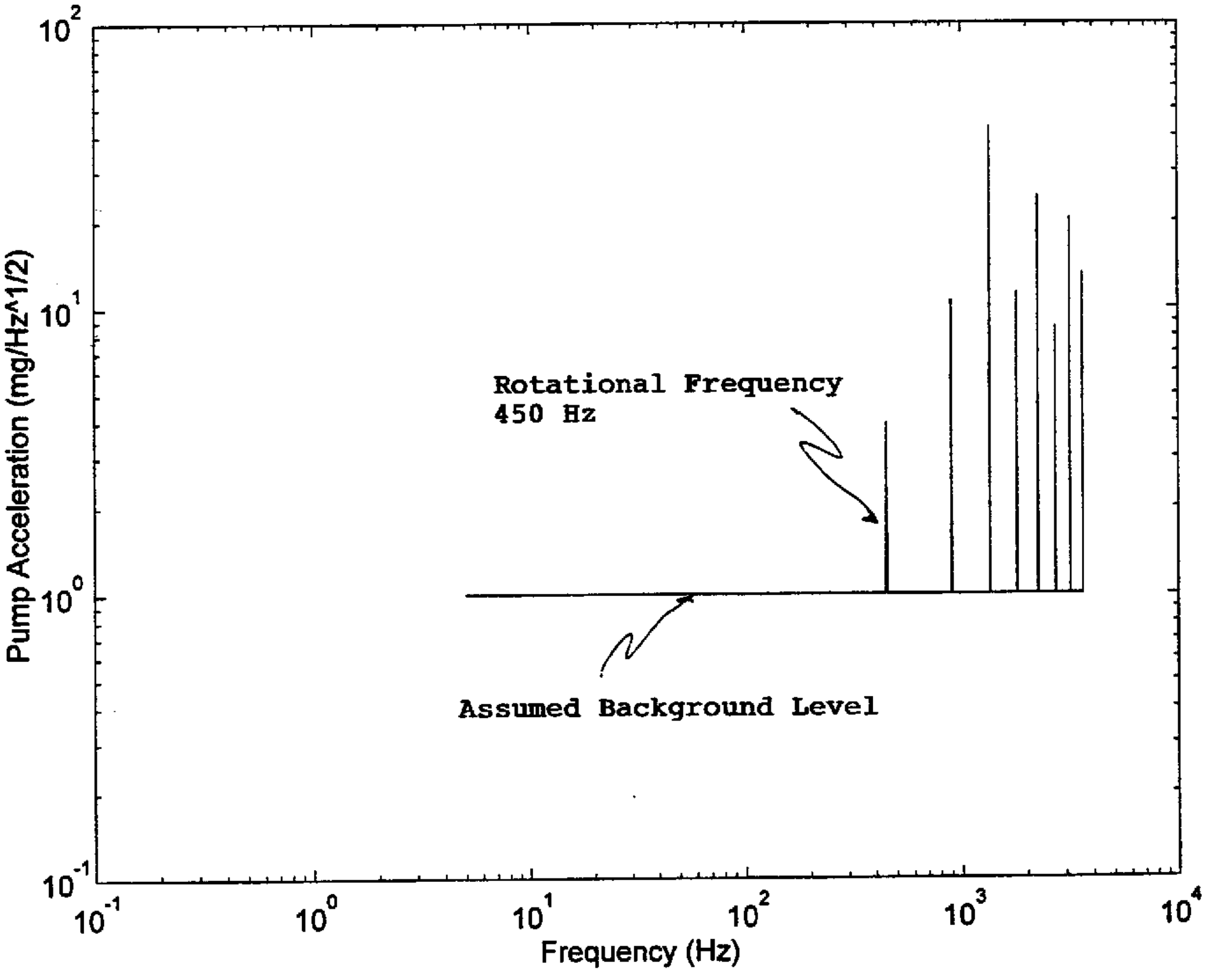


Fig. 3 Estimated source level of turbomolecular pump.

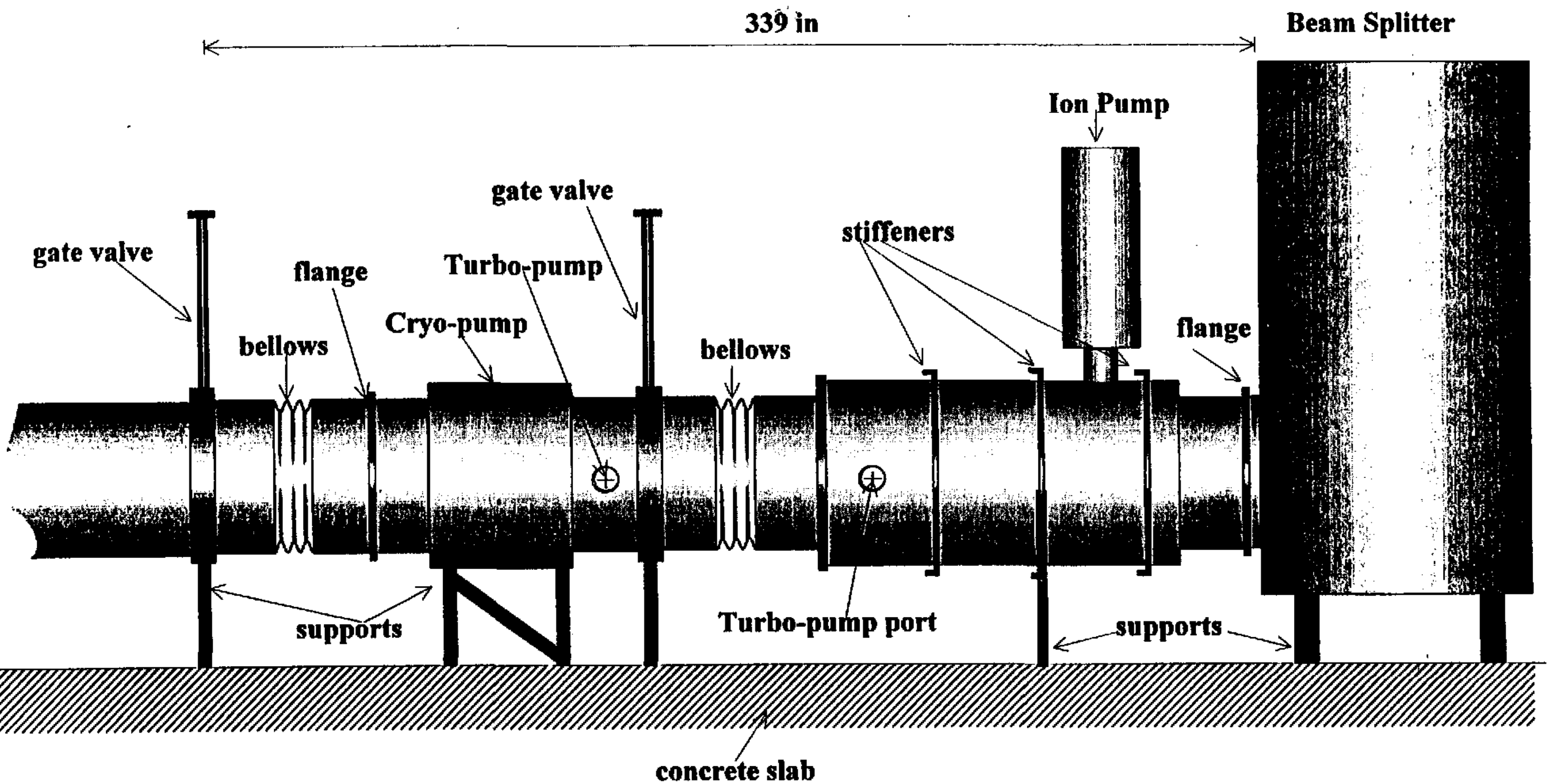


Fig. 4 Sketch of end station vacuum equipment.

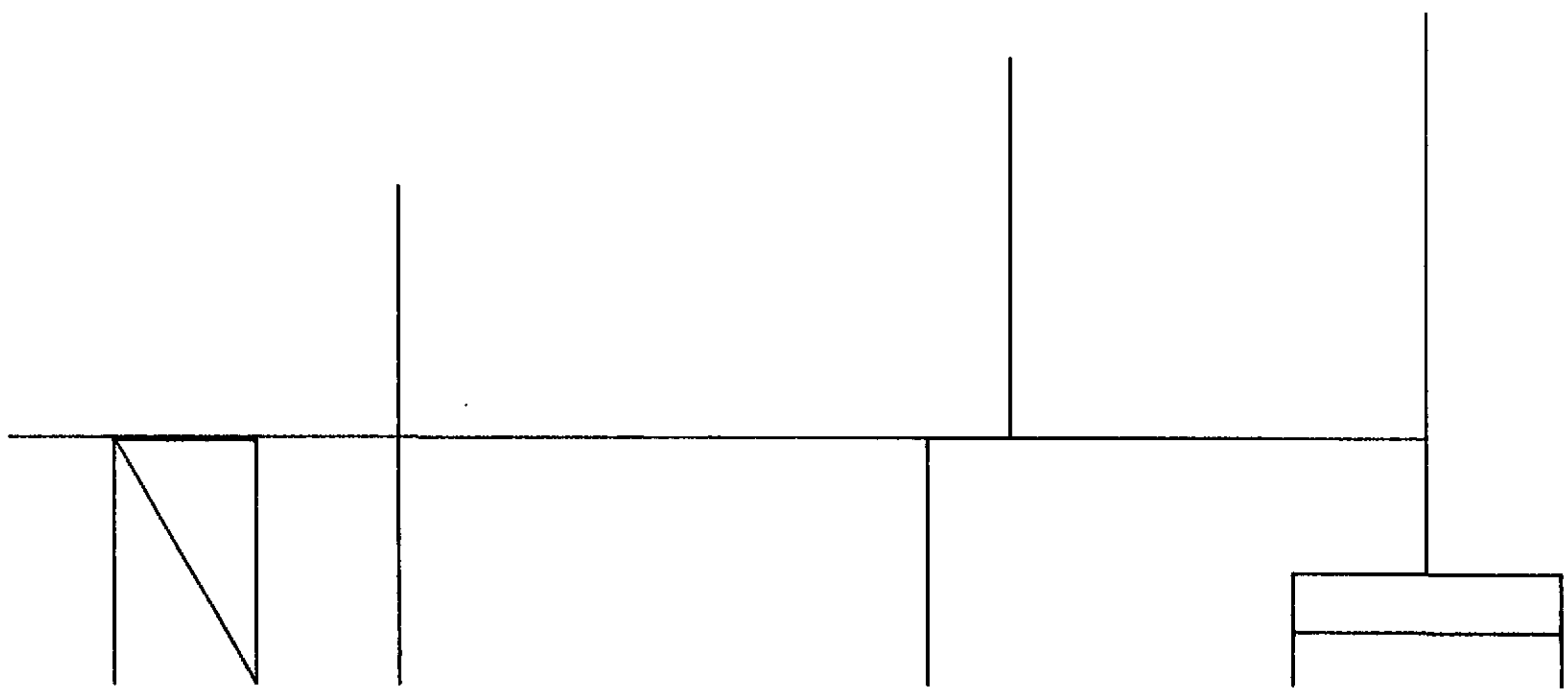


Fig. 5 Nastran plot of low frequency beam model.

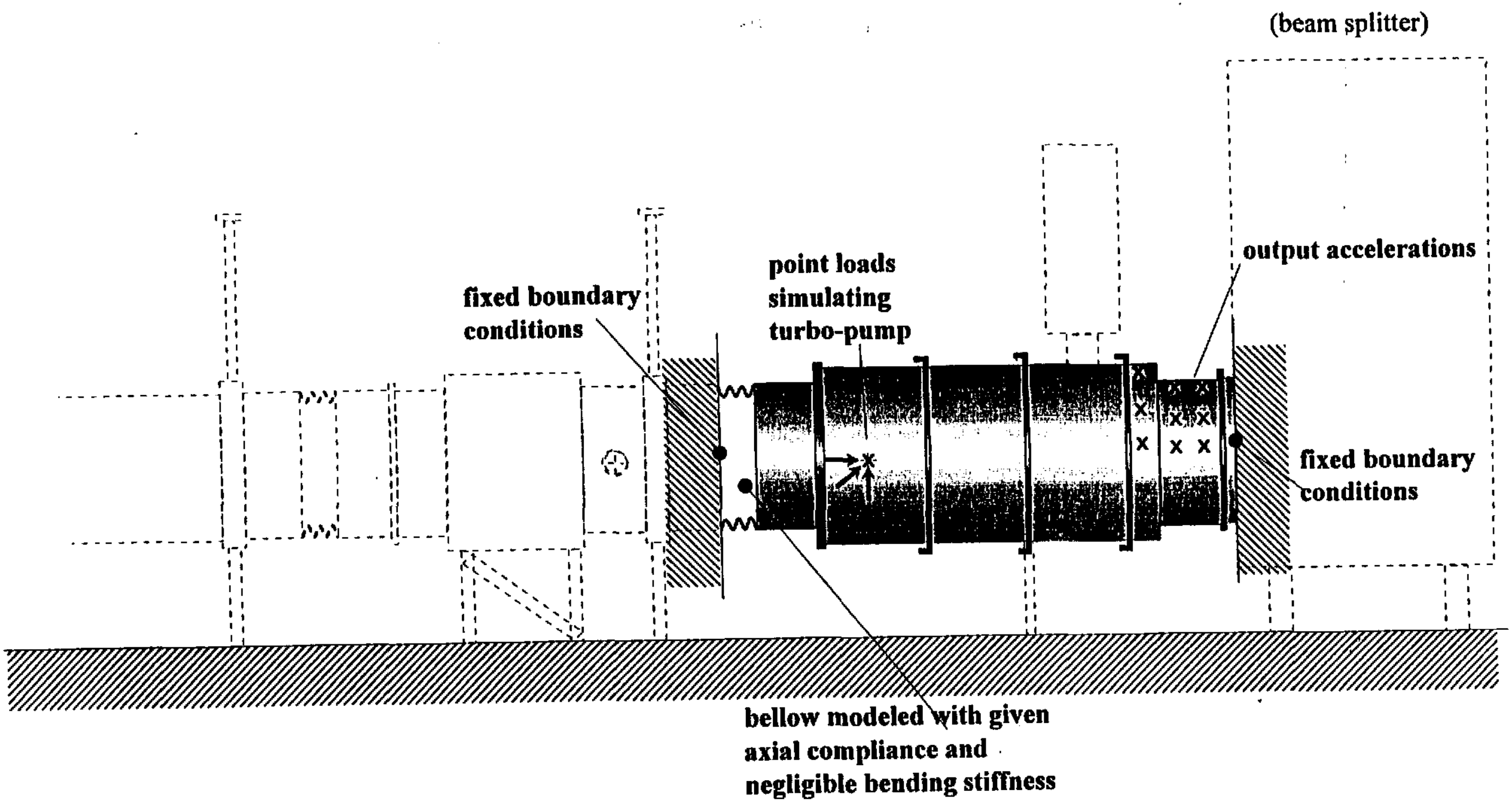


Fig. 6 Portion of end station included in midfrequency model.

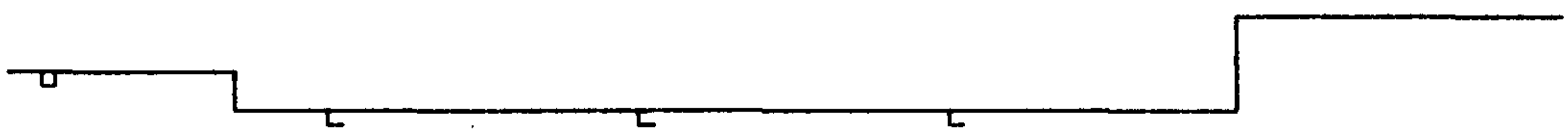


Fig. 7 Nastran plot of midfrquency axisymmetric model.

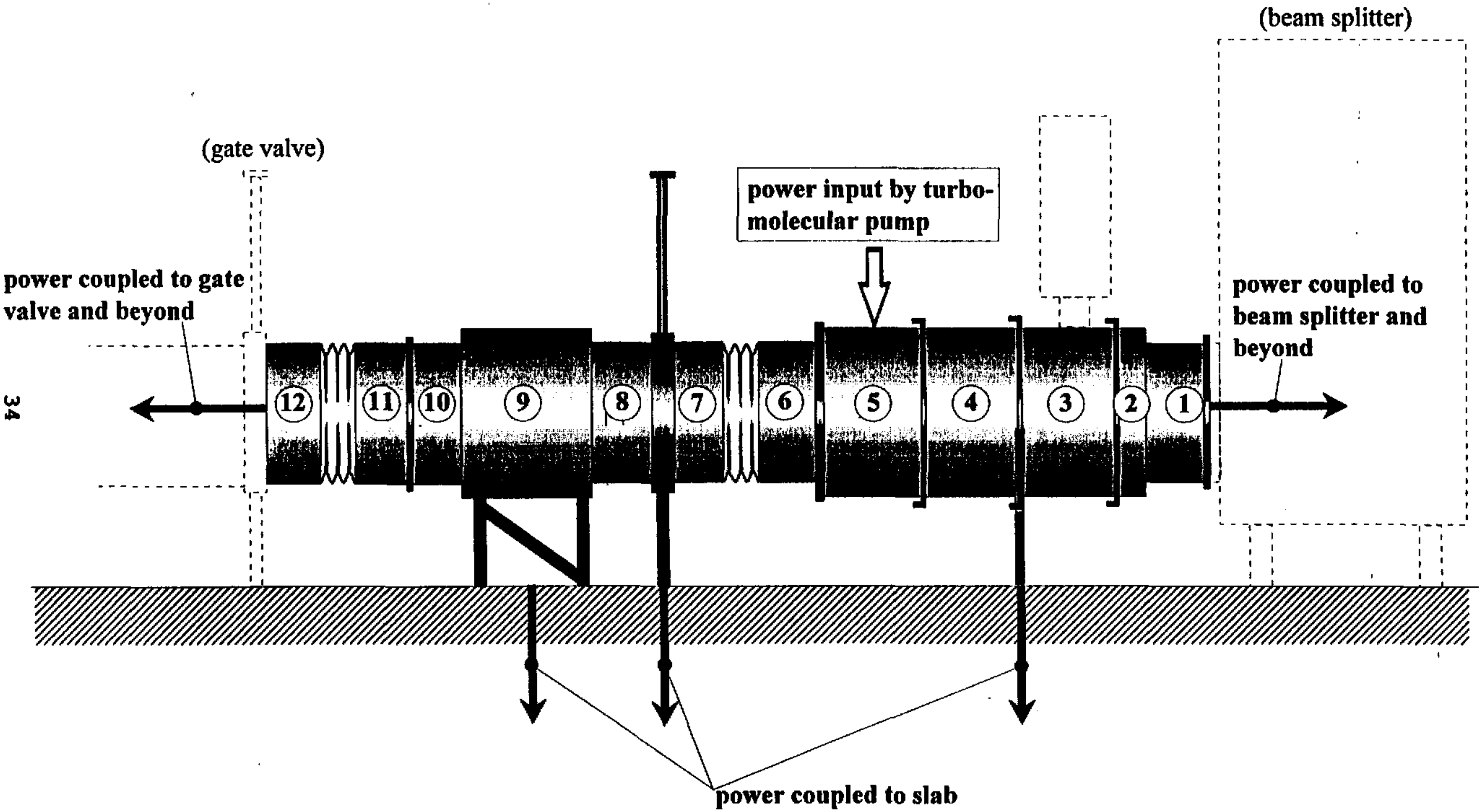
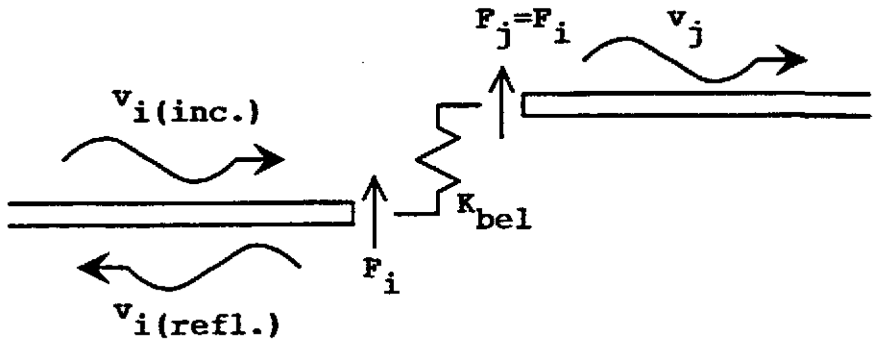
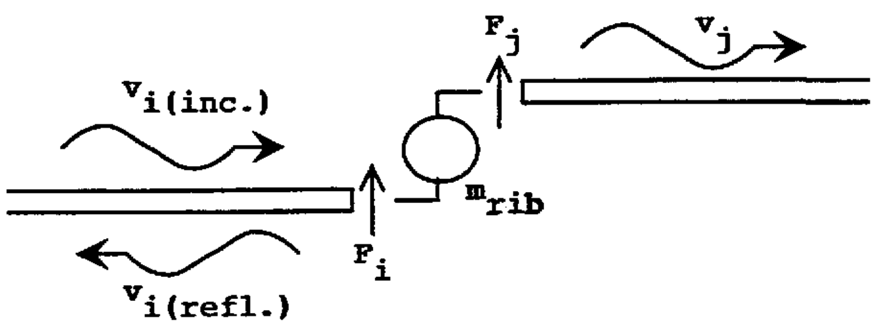


Fig. 8 SEA subsystem representation of end section structure.

a Subsystem Coupling Through Bellows



b Subsystem Coupling Across a Rib or Radius Change Flange



c Subsystem Coupling Through a Support to The Floor Slab

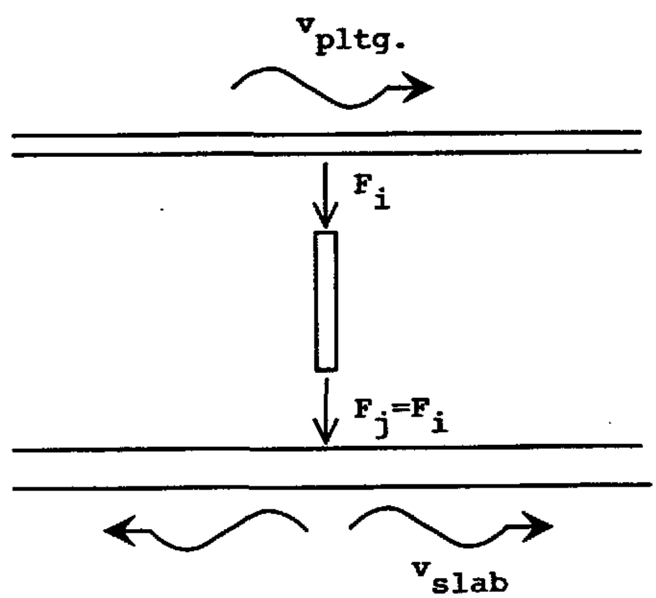


Fig. 9 Models for computing subsystem coupling loss factors.

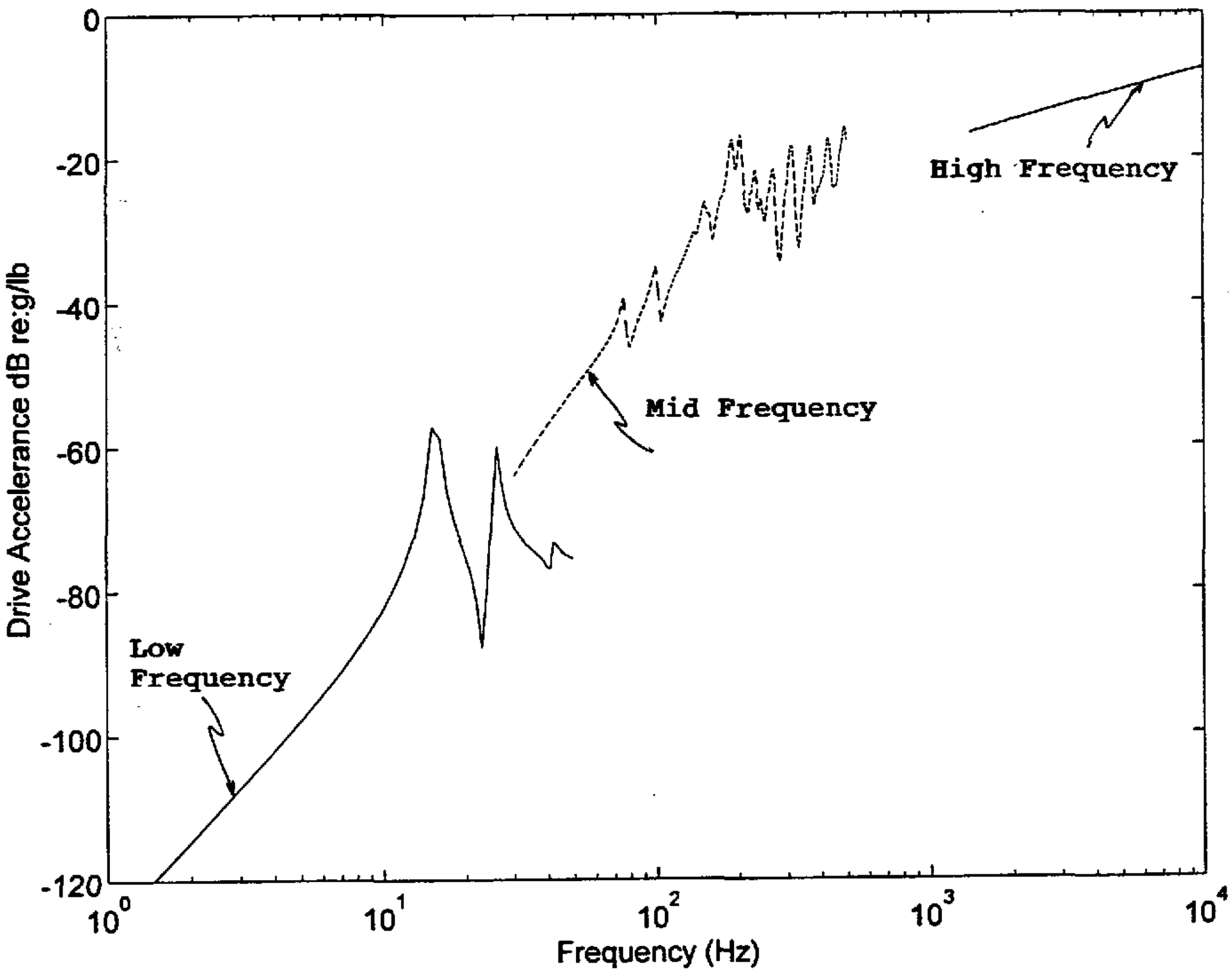


Fig. 10 Drive point accelerance at turbomolecular pump (radial direction

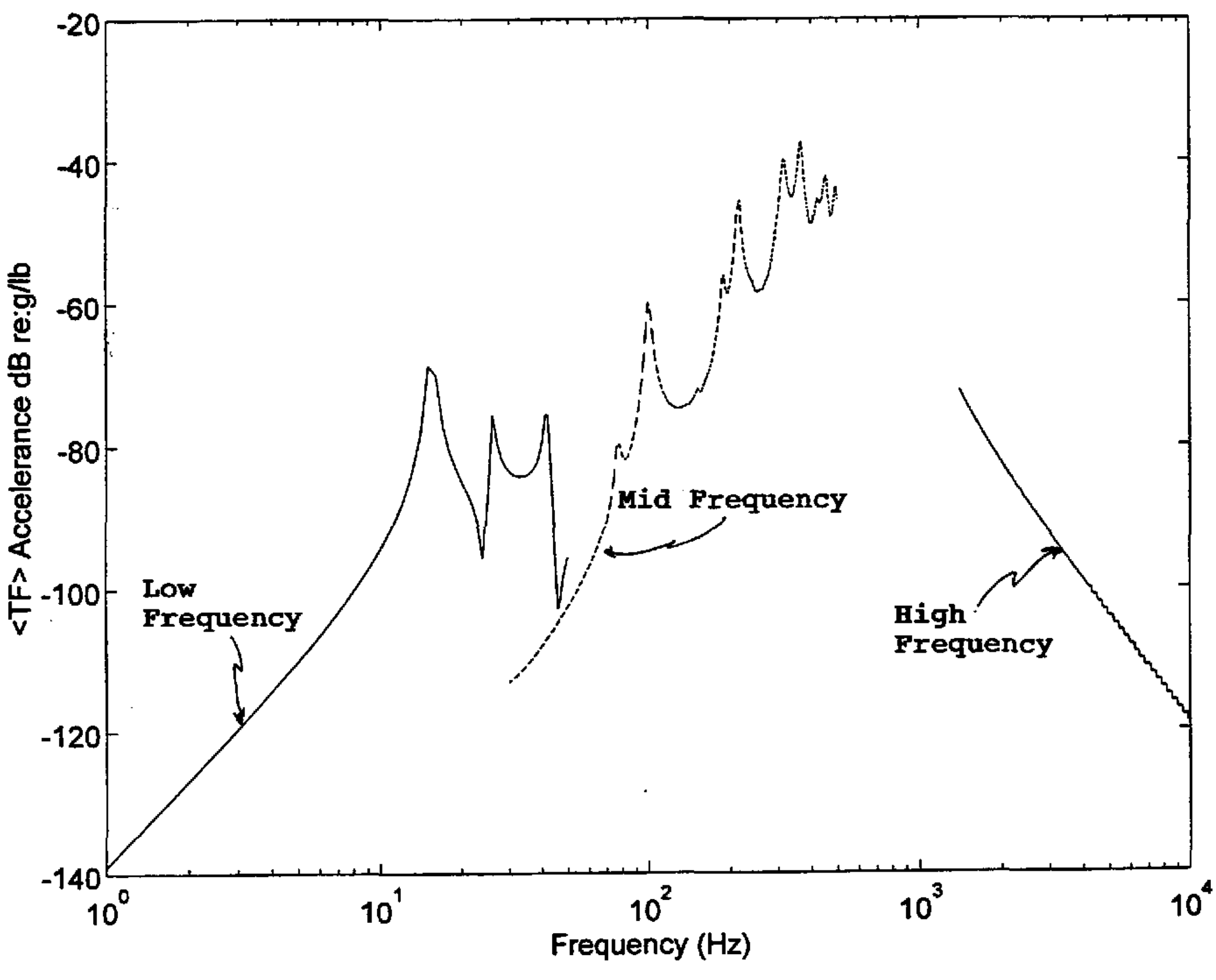


Fig. 11 Transfer accelerance from turbo pump to beam splitter.

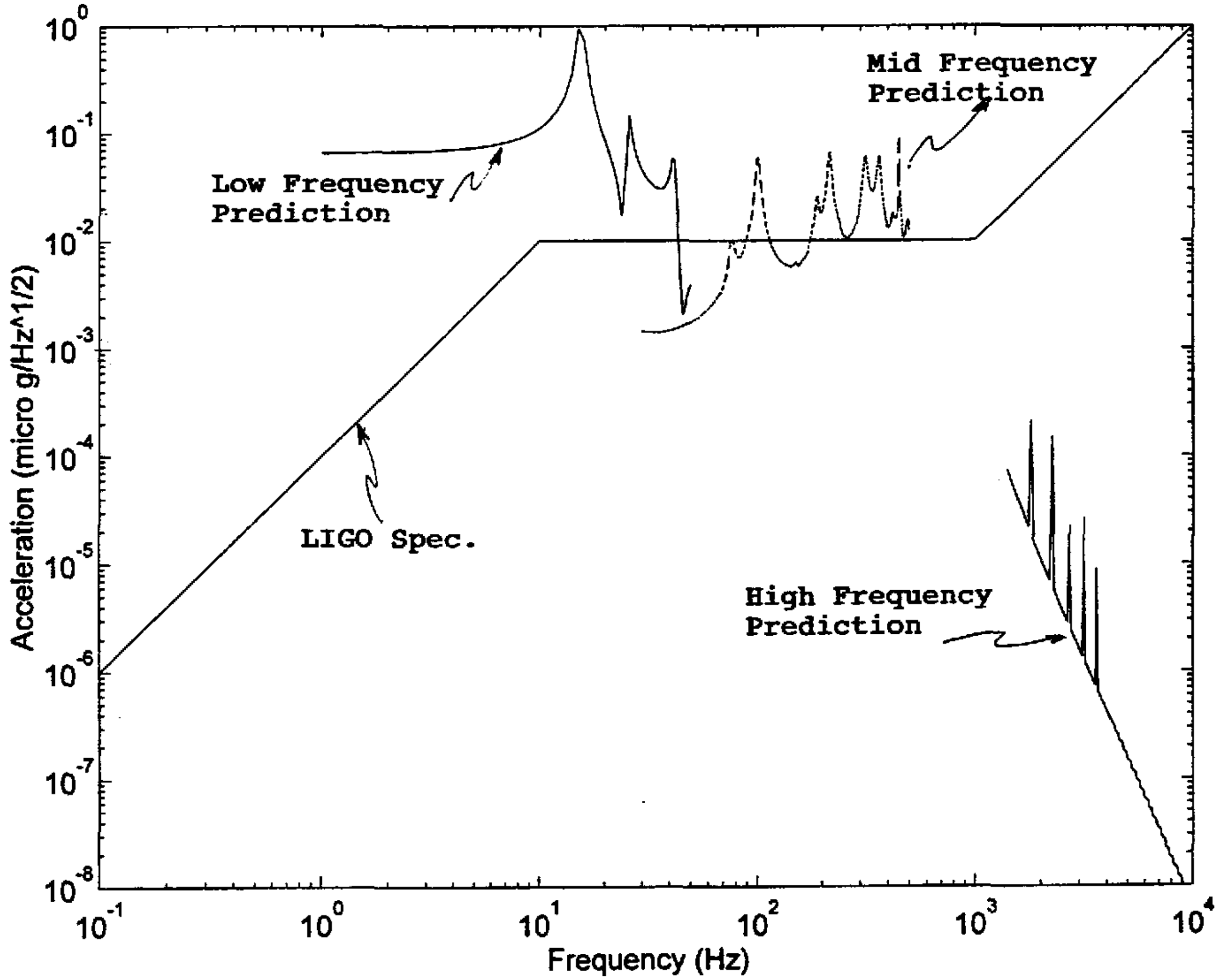


Fig. 12 Predicted acceleration levels at beam splitter compared to LIGO spec.

OCTAVE BAND FREQ, Hz:	63	125	250	500	1k	2k	4k	8k
SOURCES IN VSER								
Lw of Edwards QP-80 Backing Pum	82	66	63	79	79	79	81	73
Lw of Large Ion Pump Controller	60	62	64	65	66	66	65	60
Combined Lp on Surface of VSER in common with LVEA	59.1	38.8	26.7	34.3	30.6	30.2	30.8	18.7
SOURCES IN LVEA								
Lw of Turbomolecular Pump	65	60	55	60	53	45	46	40
Lw of Cryopump	59	48	41	34	30	27	25	24
SOUND PRESSURE LEVELS								
Lp @ BEAM SPLITTER CHAMBER DUE TO ALL SOURCES	61.5	52.9	47.9	52.9	45.8	38.5	39.5	33.0
Lp Criterion, NC-20:	51	40	33	26	22	19	17	16
EXCEEDANCE	11	13	15	27	24	19	22	17
Octave Band Freq.,Hz	63	125	250	500	1k	2k	4k	8k

Lw = Sound Power Level in dB re 10^-12 watt

Lp = Sound Pressure Level in dB re 20 microPascal

Fig. 13 Predicted noise level in end station.

Title: DESIGN GOALS/REQUIREMENTS PROCEDURE

DESIGN GOALS /REQUIREMENTS PROCEDURE

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

QUALITY ASSURANCE: Alan L Bradford

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: [signature]

Information contained in this specification and its attachments is proprietary in nature and shall be kept confidential. It shall be used only as required to respond to the specification requirements, and shall not be disclosed to any other party.

Ø	D. McW 5-1-96	RGB 5/1/96	ISSUED PER DEO 0152 FOR FDR
REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

PROCESS SYSTEMS INTERNATIONAL, INC.					SPECIFICATION	
INITIAL APPROVALS	PREPARED D. McW	DATE 5-1-96	APPROVED RGB	DATE 5/1/96	NumberA V049-1-095	Rev. 0

1.0 PURPOSE

The purpose of this procedure is to define instructions for preparing the **Design Goals/Requirements Form** for the LIGO project.

2.0 GENERAL

As part of the LIGO project management plan, PSI has committed to generate design criteria for for each subsystem and major component. The design criteria is to be listed on the **Design Goals/ Requirements** form. The **Design Goals/ Requirements** form is to be completed as an initial activity and serves as a baseline document against which the design is developed. The purpose of the **Design Goals/ Requirements** form is to assure that the resulting design is compliant with all of the requirements of the Contract, Statement of Work, Technical Specification , and good engineering/design practice.

A project **Design Goals/ Requirements** master file is maintained by the technical director. As with other documents the **Design Goals/ Requirements Form** should be dated and if changes are made they should be noted by the revision level.

3.0 RESPONSIBILITY

It is the responsibility of the cognizant engineer to prepare and issue the **Design Goals/ Requirements** form. The form is to be reviewed by the technical director prior to issue. Each element of the **Design Goals/ Requirements** form should be signed off when the requirement has been completed by incorporation into lower level project documents including calculations, specifications, drawings, manufacturing, test, and installation procedures. The **Design Goals/ Requirements form** is to be reviewed, updated and issued as part of each design review meeting minutes.

4.0 ATTACHMENTS

Attached is a list of components/subsystems for which a **Design Goals/ Requirements** form is issued.

LIGO Project Design Requirements/Goals

System	Component	number pages	Assignment
Vacuum Enclosure			
	BSC, HAM, Adapters & Spools	3	R. Ciatto
Pumping System			
	Vacuum Pump Carts	2	S. Motew
	Main Ion Pumps	1	F. Bark
	Annulus Ion Pumps	1	F. Bark
	80 K Cryopumps	3	D. Moore
Valve System			
	112 &122 cm Gate Valves	2	T. Starr
	6,10, 14 " Gate Valves	2	T. Starr
	Angle Valves	1	T. Starr
Control System			
	Vacuum gauging	2	F. Bark
Vent & Purge System			
	Portable Clean Rooms	1	T. Starr
	Cl 100 air compressors	1	T. Starr
Bakeout System			
	Bakeout Blankets	1	Fadi Bark

Project Design Requirements/Goals

Project :	*Ligo Vacuum Equipment*	*Prepared By:* R. D. Ciatto (signature)	Date:	4/30/96
Project No:	V59049		Last Review	11/22/95
Specification No:	LIGO-E940002-V	Approved By: D. A. McWilliams (signature)	File:	LIGODR.WB1
Rev:	2		Quantity:	BSC: 15+ 1 prototype
Date:	August 31, 1995			HAM: 19
System or Component	**BSC, HAM, Adaptors & Spools**			Adapters: numerous

Item	Spec Referenc	Description of Design Requirement	Action, Conclusion, or Assignment	Action By	Date Required	Status
	5.1	Compatible with 1x10-9 torr	Matl selection, processing, cleaning			
			leak rate <1x10-9 torr-l/s,virtual leaks,			
			double O-ring, permeation, baking			
	5.1.1	Materials/304L or 316L	Use 304L for low cost			
			Dual rating 304/304L required for shells	D.Curtis		Spec complete 11/22/95
			Dual rating 304/304L OK for Heads	D.Curtis		Spec complete 11/22/95
			304L for flanges	D.Curtis		Spec complete 11/22/95
	5.1.2	Cleaning	Reference cleaning procedure	T. Starr	4/15/96	
	5.1.3	Welding	Weld procedure	P Ferland		Spec complete 3/14/96
		TIG per ASME &UHV practice	Develop Plasma Weld Procedure	P Ferland		Spec complete 3/14/96
		internal welds continuous		P Ferland		Spec complete 3/14/96
		external welds intermittant	skip weld	P Ferland		Spec complete 3/14/96
		heat affected zone contamination	argon purge	P Ferland		Spec complete 3/14/96
	5.1.4	Alignment				
		Align to optical axis	Installation procedure	R. Ciatto	4/15/96	
		Tranverse +-2mm	oversize 60 "nozzles to maintain clear			complete
			aperture			
			Individualy adjustable jacks at each leg	S. Dangel	4/25/96	Complete
		axial +- 25 mm				
		tolerances				
		+/-3mm, +/-1deg, +/- 3mm/3m	Fabrication procedure	D. Curtis		Spec complete 3/19/96
	5.1.5	Mechanical Loads				
		HVAC	Covered by Bakeout case	R.Ciatto		complete
		Atmospheric pressure	Design pressure = 14,7 psi	R.Ciatto		complete
		Vacuum Cycling	Consider all external load cases	R.Ciatto		complete
		Bakeout	Design temp = 190 C	R.Ciatto		complete
		HVAC failure	Covered by Bakeout case	R.Ciatto		complete
	5.1.6	Design				
		ASME VIII, Div1	Design Calculations	R.Ciatto		complete
		interchangeable parts	Fabrication procedure	D.Curtis		complete
		clearances for flanges	Retractable bellows	D. Curtis		complete

		access for leak checking	Design task	D. Curtis		complete
		lifting lugs >50lbs	Design Task	D. Curtis		complete
		ground connection	I/E to determine requirements	F.Bark		complete
		Reinforcement calcs	Use "Compress" program	R.Ciatto		complete
		loads per applicable codes &standards	Yes	R.Ciatto		complete
		free standing for leak checking	Yes	R.Ciatto		complete
		Earthquake per ANSI A58.1	Design Calculations	R.Ciatto		complete
	5.1.7.1	Configuration per Figure 8	Detail on Assembly Drawing	D. Curtis		complete
	5.1.7.2	Configuration per Figure 9	Detail on Assembly Drawing	D. Curtis		complete
		HAM ports				
	5.1.8	Brackets per Figure 10	Detail on Assembly Drawing	D. Curtis		complete
	5.1.9	Flanges and Ports				
		Dual O-ring,non lubed Viton	determine O-ring parameters	S. Motew		complete
		O-Ring retention Groove	Dove tail on ID	S. Motew		complete
		Flange centering pins	Request spec relief			
		Port Design				
		Max aperture,min length	Use 1/8 rollups where possible,	D. Curtis		complete
			1/4 wall on cover ports for reinforcement	D. Curtis		complete
	5.1.10	Access Connectors	Not Applicable			
	5.1.11	Optical Baffles	Not Applicable			
	5.1.12	Annular Spaces .3L/s	Change to .2 L/S per V049-1-012	R.Than		approved by TIM 18
	5.1.13	Fasteners				
		non lubed or plated except floor anchor	Spec plating	R.Ciatto		complete
		plate nuts preferred	Use only on CF flanges up to 8"	K. Rintala		complete
	5.1.14	Component Leak Rate				complete
		<1x10-9 torr-L/s	weld procedure, flange design	R.Ciatto		complete
		ASTM E498	Spec RGA with proper sensitivity	S. Chevaroli		complete
			Investigate He alternates for annulus test	R.Than		Verify on BSC prototype
	5.1.15	Workmanship				
		weld spatter	Full penetration weld from inside/weld	D. Curtis		complete
			detail on drawing			
		cutoff spatter	Full penetration weld from inside/weld	D. Curtis		complete
			detail on drawing			
		free iron	Reference cleaning procedure/Metalurgist	B. Newmark		
			to advise sequence			
		weld oxidation	Reference cleaning procedure/ purging,	T. Starr		
			acid cleaning			
		defects	Develop repair procedure	A. Bradbrook		complete
		no grinding or abrasion	weld procedure/ prohibit grinding,	A. Bradbrook		complete
		finished welds	controlled welding technique			complete
		vacuum surfaces	per fabrication procedure			complete

	Other Design					
	Requirements					
1	1	Cost Effective Design	-------------	-----	-----	-----
		1.1 Minimize material costs				
		1.1.1 Minimize material thickness within	Fiinite element analysis	R. Ciatto		complete
		constraints of code and deflection	Buckling analysis			
		requirements	Use dual rated 304/304L in high stress			complete
			areas			
		1.1.2 Minimize special material finish	specify hot rolled,annealed, and pickeled	D. Curtis		complete
		or handling requirements				
2	2	Maintain a leak tight pressure boundary	Design bolted flanges to maintain seal	R. Ciatto		complete
3	3	External Design Press & Temp	Design for vacuum &max operating	R. Ciatto		complete
		compatible with 150 C vacuum bakeout	temp +tol+ SF	R. Ciatto		complete
			150C+20C +20C= 190C			
4	4	Internal Design Press &Temp	Determine Max allowable pressure using	R. Ciatto		complete
		compatible with clean air purge	RT allowable stresses.			
	5	Unit must be shipped in horizontal	shipping supports lugs required	S. Dangel		
		position	compatible with flat bed truck shipment			
	6	Class 100 interior	Shop cleaning procedure	T. Starr	4/15/96	complete
			packaging procedure	D. Curtis	4/25/96	complete
			ship under vacuum. Design shipping	R. Ciatto	4/25/96	complete
			covers			
			Installation Procedure	D Evers	4/25/96	complete

Project Design Requirements/Goals

Project : Ligo Vacuum Equipment
Project No: V59049
Specification No: LIGO-E940002-02-V
Rev: 2
Date: August 31, 1995
System or Compone VACUUM PUMP CARTS

Prepared by: SM 5/1/96
Approved by: D.A. Mueller 5-1-96

Date: 5/1/96
File: LIGODR1.WB1
Quantity:

Item	Spec Ref	Description of Design Requirement	Action, Conclusion, or Assignment	Action By	Date Required	Status
1		Cost Effective Design	------------	-----	-----	-----
	4.2	PUMP DOWN TIME:ATMOS. TO 1E-6 TORR	PSI SPECS. V049-2-001 R3,V049-2-002 R4			
		FOR ISOLATABLE SECTION=24 HRS.				
		NOISE/VIBRATION EXEMPT FIRST 4 HRS.				
		TURBO PUMPS ALWAYS NOISE EXEMPT.				
		2 PUMP CARTS ON VERTEX /DIAGONAL				
		1 PUMP CART ON OTHER SECTONS				
	4.6.4	ELEC. EQUIP. MUST MEET COMM. EMI STDS.	PSI SPEC V049-2-033 R2, 5.2.1.2			
	4.6.5	EQUIP. SUITABLE FOR CL.50000 CLEAN RM.	PSI SPEC V049-2-033 R2, 5.1.7			
			V049-2-001 R3,4.1.2;V049-2-002 R4,4.1.2			
	4.8	*DESIGN LIFE: 20 YEARS*	PSI SPEC V049-2-033 R2, 5.1.8			
	5.2	PUMPDOWNS				
		760 TORR-1 TORR,4 HRS.:ROOTS PUMP.	VO49-2-001 R3, 3.3			
		1 TORR-<1E-6 TORR,24 HRS.:TURBO PUMP	VO49-2-002 R4, 3.0			
		LOW NOISE /VIBRATION REQ.	VO49-2-002 R4, 4.0.2			
	5.2.1	*ROOTS EXEMPT FROM NOISE/VIBRATION.*				
		TURBO MUST MEET NOISE/VIBRATION PER 4.6.	PSI SPEC V049-2-033 R2, 5.1.5			
		ROOTS/TURBO SHALL NOT CONTAM. CHAMBERS.	V049-2-001 R3,4.1.7;V049-2-002 R4,4.1.7			

Project Design Requirements/Goals

Project : Ligo Vacuum Equipment
Project No: V59049
Specification No: LIGO-E940002-02-V
Rev: 2
Date: August 31, 1995
System or Compone VACUUM PUMP CARTS

Prepared by: SM 5/1/96
Approved by: D. A. McWilliams

Date: 5/1/96
File: LIGODR1.WB1
Quantity:

Item	Spec Ref	Description of Design Requirement	Action, Conclusion, or Assignment	Action By	Date Required	Status
			-------------	-----	-----	-----
	5.2.1.1	4 ROOTS+BACKING PUMP CARTS REQ.	PSI SPEC. V049-2-001 R3,PARA :			
		500 CFM AT 1 TORR	3.3			
		1000 CFM AT 0.1 TORR	3.3			
		NO OIL IN PUMPING PATH.	4.1.7			
		INTERLOCKED TO PREVENT VENTING.	4.2.2.2			
		2000 M^3 WITHOUT OVERHEATING.	3.1			
		PROVISION FOR CONN. TO CONTROL SYS.	4.2.2.1			
		PROVISION FOR CONN. TO EXHAUST SYS.	4.1.6			
		V.E. GAGE ON ROOTS & BACK.PUMP INLET.	4.2.1.1			
		AUX. VALVED LEAK DETECTOR PORTS.	4.2.1.2			
		BLANKOFF FLANGES ON UNUSED PORTS	4.2.1.3			
	5.2.1.2	10 TURBO CARTS REQ.	SPEC.V049-2-002 R4, PARA :			
		WIDE RANGE MAG. LEV. TURBOMOLECULAR	4.1.1			
		BACKED BY OIL FREE DIAPH.,PISTON,SCROLL.	4.1.1			
		1400.L/SEC N2 AT 1E-3 TORR.	3.0			
		THRUPUT: 5 TORR-L / S AT 1 TORR BACK.PRES.	3.0			
		2000 M^3 WITHOUT OVERHEATING.	3.0			
		INTERLOCKED TO PREVENT VENTING / CONTAM.	4.1.3			
		PROVISION FOR CONN. TO CONTROL SYS.	4.2.2.1			
		PROVISION FOR CONN. TO EXHAUST SYS.	4.1.6			
		V.E. GAGE ON ROOTS & BACK.PUMP INLET.	4.2.1.1			
		AUX. VALVED PORTS FOR L. DETECT. / AUX .TURBO	4.2.1.2			
		BLANKOFF FLANGES ON UNUSED PORTS	4.2.1.3			

Project Design Requirements/Goals

Date: 5/1/96

Project : Ligo Vacuum Equipment
Project No: V59049
Specification No: LIGO-E940002-02-V
Rev: 2
Date: August 31, 1995
System or Compone VACUUM PUMP CARTS

Prepared by: Am 5/1/96
Approved by: D. A. McWilliams

File: LIGODR1.WB1

Quantity:

Item	Spec Ref	Description of Design Requirement	Action, Conclusion, or Assignment	Action By	Date Required	Status
			-----------	-----	-----	-----
	5.2.4	10 AUX. TURBO CARTS REQ.	PSI SPEC V049-2-003 R3,PARA :			
		OIL FREE BACKING PUMPS	4.1.6			
		INTERLOCKED TO PREVENT VENTING.	4.2.2.2			
		PROVISION FOR CONN. TO CONTROL SYS.	4.2.2.1			

Project Design Requirements/Goals

Project:	LIGO Vacuum Equipment		**Date:**	1/22/96
Project No.:	V59049		**File:**	LIGODR.WB1
Specification No.:	LIGO-E940002-V		**Quantity:**	18
Rev:	2			
Date:	8/31/95		**Prepared by:**	F. Bach
System or Component:	Main Ion Pumps		**Aproved by:**	D. W. McWilliams

Item	Spec. Reference	Description. of Design Req'ts.	Action, Conclusion, or Assignment	Action By	Date Req'd	Status
		Cost Effective Design	---------	---------	---------	--------
1	E940002V/5.2.2	N2 pump speed.	V59049-2-004 section 3.1.1			
2	E940002V/5.2.2	Minimum pump life.	V59049-2-004 section 3.1.3			
3	E940002V/5.2.2	*Pump type.*	V59049-2-004 section 3.1.3			
4	E940002V/5.2.2	Multiple Electrical Feedthrus.	V59049-2-004 section 3.1.4			
5	E940002V/5.2.2	Maximum starting pressure 1x10E-5 torr.	V59049-2-004 section 3.1.4			
6	E940002V/5.2.2	Rack mountable power supply.	V59049-2-004 section 3.1.1			
7	E940002V/5.2.2	Power supply remote capabality	V59049-2-004 section 3.1.2			
8	E940002V/5.2.2	Documentation and Warranty	V59049-2-004			
9						
10						
11						
12						
13						
14						
15						
16						

Project Design Requirements/Goals

Project:	LIGO Vacuum Equipment		**Date:**	1/22/96
Project No.:	V59049		**File:**	LIGODR.WB1
Specification No.:	LIGO-E940002-V		**Quantity:**	43/32
Rev:	2			
Date:	8/31/95		**Prepared by:**	F. Bark
System or Component:	Annulus Ion Pumps		**Aproved by:**	D.a. McWilliams

Item	Spec. Reference	Description. of Design Req'ts.	Action, Conclusion, or Assignment	Action By	Date Req'd	Status
		Cost Effective Design	---------	---------	---------	---------
1	E940002V/5.2.4	Pump type..	V59049-2-004 section 3.2.1 and 3.3.1			
2	E940002V/5.2.4	Minimum pump life.	V59049-2-004 section 3.1.3			
3	E940002V/5.2.4	Minimum size.	V59049-2-004 section 3.3.2			
4	E940002V/5.2.4	Maximum starting pressure 1x10E-5 torr.	V59049-2-004 section 3.1.4			
5	E940002V/5.2.4	Rack mountable power supply.	V59049-2-004 section 3.1.1			
6	E940002V/5.2.4	Power supply remote capabality	V59049-2-004 section 3.2.2			
7	E940002V/5.2.4	Documentation and Warranty	V59049-2-004			
8						
9						
10						
11						
12						
13						
14						
15						
16						

Project Design Requirements/Goals

Project :	Ligo Vacuum Equipment	Prepared By: David Moore	Date: 1/9/96
Project No:	V59049	Approved By: DA McWilliams	
Specification No:	LIGO-E940002-V		File: 80Kpmp .wb1
Rev:	3		
Date:	November 21, 1995		
System or Component	**80K Pump**		Quantity: 12

Item	Spec Ref.	Description of Design Requirement	Action, Conclusion, or Assignment	Action By	Date Req'd	Status
1		Cost Effective Design	-------------	-----	-----	-----
2	5.1	Compatible with 1x10-9 torr	Matl selection, processing, cleaning	D. Moore		
			leak rate <1x10-9 torr-l/s,virtual leaks,			
			double O-ring, permeation, baking			
3	5.1.1	Materials/304L or 316L	Use 304L for low cost, mill test reports	D. Moore		
			(chamber, tube, & flange)			
4	5.1.2	Cleaning	Reference cleaning procedure	D. Moore		
5	5.1.3	Welding	Weld procedure	P. Ferland		
		TIG per ASME &UHV practice				
		internal welds continuous				
		external welds intermittant	skip weld			
		heat affected zone contamination	argon purge			
6	5.1.4	Alignment		T.B.D.		
		Align to optical axis				
		Tranverse +-2mm				
		axial +- 25 mm				
		tolerances				
		+/-3mm, +/-1deg, +/- 3mm/3m				
7	5.1.5	Mechanical Loads		R. Ciatto		
		HVAC				
		Atmospheric pressure				
		Vacuum Cycling				
		Bakeout				
		HVAC failure				
8	5.1.6	Design				
		ASME VIII, Div1	Design Cond: -320F, 40 psid;	R. Ciatto		
			400F, 25 psid; 70F, 14.7 psid			
		interchangeable parts		D. Moore		
		clearances for flanges		D. Moore		
		access for leak checking		D. Moore		
		lifting lugs >50lbs		D. Moore		

		ground connection		D. Moore		
		Reinforcement calcs		R. Ciatto		
		loads per applicable codes &standards		R. Ciatto		
		free standing for leak checking		R. Ciatto		
		Earthquake per ANSI A58.1		R. Ciatto		
9		Deleted				
10		Deleted				
11	5.1.9	Flanges and Ports		R. Curtis		
		Dual O-ring,non lubed Viton				
		O-Ring retention Groove	dove tail on ID			
		Flange centering pins				
		Port Design				
		Max aperture,min length	Ref: Calculations and sketch			
12	5.1.10	Access Connectors	Not Applicable			
13	5.1.11	Optical Baffles	Not Applicable			
14	5.1.12	Annular Spaces .3L/s	Annulus calculations	R.Than		
15	5.1.13	Fasteners				
		non lubed or plated except floor anchors	Spec plating	R. Ciatto		
		plate nuts preferred				
16	5.1.14	Component Leak Rate				
		<1x10-9 torr-L/s	weld procedure, flange design	P. Ferland		
		ASTM E498	Spec RGA with proper sensitivity	R.Than		
17	5.1.15	Workmanship	Fabrication spec.	P. Ferland		
		weld spatter	Fabrication spec.			
		cutoff spatter	Fabrication spec.			
		free iron	Fabrication spec.			
		weld oxidation	Fabrication spec.			
		defects	Fabrication spec.			
		no grinding or abrasion	Fabrication spec.			
		finished welds	Fabrication spec.			
		vacuum surfaces	Fabrication spec.			
18	5.2.3	Removeable beam tube section at one		R. Curtis		
		end, min. length = 60 cm.				
19	5.2.3	Reduce vaporization in the	Reduce supply line size if possible.	D. Moore		
		supply line	Test program.			
20	4.6.2	Keep noise generation low (secondary)	Minimize heat leak. Avoid slug flow.	D. Moore		
21	4.6.3	Reduce vibration transmitted into beam tub	Bellows, elastomeric material			
			at support hanger	D. Moore		
	Other Req'ments					
22		Maintain a leak tight pressure boundary	Design bolted flanges to maintain seal	R. Ciatto		

23		External Design Press & Temp	Design for vacuum &max operating	R. Ciatto		
		compatible with 150 C vacuum bakeout	temp +tol+ SF			
			150C+20C +20C= 190C			
		Internal Design Press &Temp	Determine Max allowable pressure using			
		compatible with clean air purge	RT allowable stresses. Ref: structural pkg			
24		Prevent water backstreaming and	Heat exchanger at discharge of vent lin	D. Moore		
		forming ice				
25		Minimize heat leak to minimize dewar size	Use low e liner, and radiation shield(s)	D. Moore		
			around pump			
26		Protect vacuum equip. in the event	Rupture disc on vacuum chamber	D. Moore		
		of LN2 pipe break				
27		Evacuation of LN2 reservoir , leak checking	Reservoir to be designed for full vacuum	R. Ciatto		

System or Component: Large Gate Valves

Item	Spec Ref.	Description of Design Requirement	Action, Conclusion, or Assignment	Action By	Date Req'd	Status
18	5.1.6	Design to standards	Spec 033, 5.1.2			
19	5.1.6	Interchangeable separable parts	Spec 033, 5.1.10			
20	5.1.6	Lifting lugs	Spec 033, 5.1.12			
21	5.1.15	Workmanship, finish, and appearance	Spec 033, 8.5			
22	5.3.1	Non-contam. & non-migratory lub.	Spec 005, 4.1.2. Dry film lub will be used			
23	5.3.1	Double Viton gate seals	Spec 005, 4.1.4			
24	5.3.1	Gate seals less than 1 x 10-9 leakage	Spec 005, 4.1.4			
25	5.3.1	Valves of same size and type identical	Spec 005, 4.1.5. Order not split between vendors.			
26	5.3.1	10,000 Cycle rating	Spec 005, 4.1.5			
27	5.3.1	Protection from inadvertent operation	Spec 005, 4.1.10. Padlockable (no damage if inadvertent actuation is attempted).			
28	6.1.2.3	Valve leak tests	Spec 005, 6.1. Added requirement to use oil-free pump and detector.			
29	6.1.2.3	Demonstration of operation	Spec 005, 6.3. 20 Cycles required.			

Project Design Requirements/Goals

Project : Ligo Vacuum Equipment
Project No: V59049
Specification No: LIGO-E940002-V
Rev: 2
Date: August 31, 1995
System or Component: 6", 10" & 14" Gate Valves

Prepared By: Thomas M. Stan (signature)
Approved By: D. A. McWilliams (signature)
Note: The vendor has committed to meeting all specification requirements.

Date: 12/8/95
File: ligodr.wb1
Quantity: 7/25/18

Item	Spec Ref.	Description of Design Requirement	Action, Conclusion, or Assignment	Action By	Date Req'd	Status
1		Cost Effective Design	-------------	-----	-----	-----
2	4.1	Leaks greater than 1 x 10-9 repaired	Spec 006, 4.3. Total valve leak less than 10-10			
3	4.2,3	Pumpdown time, ultimate pressures	Spec 006, 4.13. Final cleaning and assembly in cleanroom. 4.1. Metal bellows stem seals			
4	4.4	Controls for safe and reliable operation	Spec 006, 4.12. Limit switches provided for 6" and 10" valves.			
5	4.5	Bakeout to 150 C +/- 20 C	Spec 006, 4.11.			
6	4.6.1	Shock limited to 0.01 g p-p within 1 m of any HAM or BSC chamber	Spec 006, 4.10. Limit put on valves themselves. (Valves are manual.)			
7	4.6.5	External particulates	Spec 033, 5.1.7			
8	4.8	20 Year design life	Spec 033, 5.1.8			
9	4.9	Environmental exposure	Spec 033, 5.1.9			
10	5.1.1	Type 304L or 316L material, prebaked	Spec 006, 4.1			
11	5.1.1	Viton for seals	Spec 033, 6.3. Special grade of Viton specified			
12	5.1.2	Cleaning to approved procedures	Spec 006, 4.13. Final cleaning and assembly in cleanroom. Spec 006, 7.0. Black light and RGA inspections			
13	5.1.3	Welding requirements	Spec 033, 8.0.			
14	5.1.5	Mechanical loads	Spec 006, RFQ: Option quoted to strengthen 14" valves for 1500 lb ion pump mounting.			
15	5.1.6	Design to standards	Spec 033, 5.1.2			
16	5.1.6	Interchangeable separable parts	Spec 033, 5.1.10			
17	5.1.6	Lifting lugs	Spec 033, 5.1.12			
18	5.1.15	Workmanship, finish, and appearance	Spec 033, 8.5			
19	5.3.1	Non-contam. & non-migratory lub.	Spec 006, 4.2.			
20	5.3.1	Gate seals less than 1 x 10-9 leakage	Spec 006, 4.4			
21	5.3.1	Valves of same size and type identical	*Spec 006, 4.6. Order not split between vendors.*			
22	5.3.1	10,000 Cycle rating	Spec 006, 4.6			
23	5.3.1	Protection from inadvertent operation	Spec 006, 4.8. Padlockable			
24	6.1.2.3	Valve leak tests	Spec 006, 6.1. Added requirement to use oil-free pump and detector.			
25	6.1.2.3	Demonstration of operation	Spec 006, 5.0. Functional test report req'd			

Project Design Requirements/Goals

Project : Ligo Vacuum Equipment
Project No: V59049
Specification No: LIGO-E940002-V
Rev: 2
Date: August 31, 1995
System or Component: Angle Valves

Prepared By: Thomas M. Stein
Approved By: D. A. McWilliams

Date: 3/29/96
File: ligodr.wb1
Quantity: 310

Item	Spec Ref.	Description of Design Requirement	Action, Conclusion, or Assignment	Action By	Date Req'd	Status
1		Cost Effective Design	-------------	-----	-----	-----
2	4.1	Leaks greater than 1 x 10-9 repaired	Spec 059, 3.4. Total valve leak less than 10-9			
3	4.2,3	Pumpdown time, ultimate pressures	Spec 059, 3.3. Metal bellows stem seals Spec 059, 3.2. CF flanges			
4	5.1.1	Type 304L or 316L material	Spec 059, 3.1			
5	5.1.1	Prebaked Viton for seals	Spec 033, 6.3. Special grade of Viton specified			
6	5.1.2	Cleaning to approved procedures	Spec 059, 6.0. Black light inspection			
7	5.1.6	Interchangeable separable parts	Catalog items			
8	5.3.1	Non-contam. & non-migratory lub.	Spec 059, 3.6. Non-lubricated int. mechanisms			
9	5.3.1	Gate seals less than 1 x 10-9 leakage	Spec 059, 3.4. Total valve leak less than 10-9			
10	5.3.1	Valves of same size and type identical	Order not split between vendors.			
11	5.3.2	Bakeout to 150 C +/- 20 C	Spec 059, 3.8.			
12	5.3.2	10,000 Cycle rating fo metal-sealed vlvs				
13	6.1.2.3	Valve leak tests	Spec 059, 5.0.			

Project Design Requirements/Goals						
Project:		LIGO Vacuum Equipment		**Date:**	4/20/96	
Project No.:		V59049		**File:**	LIGODR.WB1	
Specification No.:		LIGO-E940002-V		**Quantity:**	24WA/13LA/4 PSI	
Rev:		2				
Date:		8/31/95		**Prepared by:** F. Bart		
System or Component:		Pirani Gauges		**Aproved by:** D. McWilliams		
Item	**Spec. Reference**	**Description. of Design Req'ts.**	**Action, Conclusion, or Assignment**	**Action By**	**Date Req'd**	**Status**
		Cost Effective Design	----------	---------	---------	--------
1	E940002V/5.6.1.1	Bakable to 250 deg C	V59049-2-007 section 4.1.2			
2	E940002V/5.6	0-10V output	V59049-2-007 section 4.2.2			
3	E940002V/5.6	24VDC supply	V59049-2-007 section 4.2.2			
4	E940002V/5.6.1.1	CF Flanges	V59049-2-007 section 4.1.1			
5	E940002V/5.6.1.1	Range: ATM to 1x10E-3	V59049-2-007 section 3.2			
6	E940002V/5.6.1	Smart Electronics/Removable	V59049-2-007 section 3.1.2			
7	E940002V/5.6.1.1	Controller setpoint	V59049-2-007 section 4.2.2			
8	E940002V/5.6.1	Locking connector/feedthru	V59049-2-007 section 4.2.1			
9						
10						
11						
12						
13						
14						
15						
16						

96:009.FB

Project Design Requirements/Goals

Project:	LIGO Vacuum Equipment		**Date:**	4/20/96	
Project No.:	V59049		**File:**	LIGODR.WB1	
Specification No.:	LIGO-E940002-V		**Quantity:**	24WA/13LA/4 PSI	
Rev:	2				
Date:	8/31/95		**Prepared by:**	F. Bark	
System or Component:	Cold Cathod Gauges		**Aproved by:**	D. McWilliams	

Item	Spec. Reference	Description. of Design Req'ts.	Action, Conclusion, or Assignment	Action By	Date Req'd	Status
		Cost Effective Design	---------	---------	---------	--------
1	E940002V/5.6.1.2	Bakable to 250 deg C	V59049-2-007 section 4.1.2			
2	E940002V/5.6	0-10V output	V59049-2-007 section 4.2.2			
3	E940002V/5.6	24VDC supply	V59049-2-007 section 4.2.2			
4	E940002V/5.6.1.2	CF Flanges	V59049-2-007 section 4.1.1			
5	E940002V/5.6.1.2	Range: 1x10E-2 to 1x10E-9	V59049-2-007 section 3.3			
6	E940002V/5.6.1	Smart Electronics/Removable	V59049-2-007 section 3.1.2			
7	E940002V/5.6.1.2	Controller setpoint	V59049-2-007 section 4.2.2			
8	E940002V/5.6.1	Locking connector/feedthru	V59049-2-007 section 4.2.1			
9	E940002V/5.6.	Max. Oper. Press. 1x10E-2	V59049-2-007 section 3.3			
10						
11						
12						
13						
14						
15						
16						

96:009.FB

Project Design Requirements/Goals

Project : Ligo Vacuum Equipment
Project No: V59049
Specification No: LIGO-E940002-V
Rev: 2
Date: August 31, 1995
System or Component: Portable Clean Rooms

Prepared By: Thomas M. Starr

Approved By: D.A. McWilliams

Date: 3/25/96

File: ligodr.wb1

Quantity: 14

Item	Spec Ref.	Description of Design Requirement	Action, Conclusion, or Assignment	Action By	Date Req'd	Status
1	5.4	Class 100 Equivalent	Spec 010, 3.0.			
2	5.4	Federal Std. 209 Design	Spec 010, 4.1.1.			
3	5.4	Airflow to optimize particulate removal	Spec 010, 4.1.2.			
4		Extended filter life	Prefilters on blowers			
5		Easy handling	Separable ceiling units with lifting lugs			
6		Portability	Casters			
7		Flexibility	Joinable to make larger working spaces Wall seals for various size tubes Blank cover for BSC dome opening Additional active unit for BSC dome opening Adjustable legs on BSC clean rooms Separate controls for fans and lights Convenience outlet			

Project Design Requirements/Goals

Project : Ligo Vacuum Equipment
Project No: V59049
Specification No: LIGO-E940002-V
Rev: 2
Date: August 31, 1995
System or Component: Clean Air Supply Systems

Prepared By: Thomas M. Stan
Approved By: D McWilliams

Date: 3/22/96
File: ligodr.wb1
Quantity: 6/2

Item	Spec Ref.	Description of Design Requirement	Action, Conclusion, or Assignment	Action By	Date Req'd	Status
1		Cost Effective Design	-------------	-----	-----	-----
2	4.4	Controls for safe and reliable operation	Vent control valves provided for controlled system venting.			
3	4.6.3	Vibration	Spec 011, 4.1.3. Spec doesn't apply, but reasonable measures required.			
4	4.8	20 Year design life	Spec 033, 5.1.8			
5	4.9	Environmental exposure	Spec 033, 5.1.9			
6	5.1.1	Type 304L or 316L material	Spec 011, 4.1.4. Filters and downstream material SS.			
7	5.1.2	Cleaning to approved procedures	Spec 011, 4.1.8 Cleaning of piping by PSI as part of installation.			
8	5.1.6	Interchangeable separable parts	Spec 033, 5.1.10			
9	5.1.6	Lifting lugs	Spec 033, 5.1.12			
10	5.1.15	Workmanship, finish, and appearance	Spec 033, 8.5			
11	5.4	Air quality	Spec 011, 3.0. Class 100, -60 C dp, 30 psig. Spec 011, 4.1.8			
12	5.4	Valved and pressure limited	PSI P&ID's call for regulators, valves and controls Spec 011, 3.0			
13	5.4	No hydrocarbons introduced	Spec 011, 3.0. Non-lubricated compressors. Spec 011, 3.0. Carbon filters. Spec 011, 4.1.9			
14	5.4	Allow for air shower manifolds	PSI P&ID's call for connections to each chamber.			
15	6.1.3.4	Test for cleanliness	To be developed as part of commissioning.			

Project Design Requirements/Goals

Project:	LIGO Vacuum Equipment	**Date:**	2/26/96
Project No.:	V59049	**File:**	LIGODR.WB1
Specification No.:	LIGO-E940002-V	**Quantity:**	
Rev:	2		
Date:	8/31/95	**Prepared by:**	F. Bart
System or Component:	Bakeout System	**Aproved by:**	D. McWilliams

Item	Spec. Reference	Description. of Design Req'ts.	Action, Conclusion, or Assignment	Action By	Date Req'd	Status
		Cost Effective Design	---------	---------	---------	---------
1	E940002V/5.5	Bakeout Temp. 150^{0}C	V59049-2-009, 3.0			
2	E940002V/5.5	2" Insulation Thickness	V59049-2-009, 4.1.3			
3	E940002V/5.5	K=.043 W/M-K	V59049-2-009, 3.0			
4	E940002V/5.5	$\Delta \pm 20^0$C	V59049-2-009, 3.0			
5	E940002V/5.5	180 KW Limitation	V59049-2-009, 4.2.3.3			
6	E940002V/5.5	2 TC's Per Blanket & Plug	V59049-2-009, 4.2.1.1			
7	E940002V/5.5	Power Plug Per Blanket	V59049-2-009, 4.2.3.2			
8	E940002V/5.5	250^{0}C for Gauges Bakeout	NA for Prototype			
9	E940002V/5.5	200^{0}C in 48 hrs Capability	V59049-2-009, 3.0			
10	E940002V/5.5	Class 50,000 Cleanroom	V59049-2-009, 4.1.2			
11	E940002V/5.5	25 KW Max For BSC	V59049-2-009, 4.2.3.3			
12	E940002V/5.5	Type "J" TC's #20	V59049-2-009, 4.2.1.1			
13		Tagging	V59049-2-009, 4.1.7			
14		Documentation	V59049-2-009, 5.0			
15		Warranty	V59049-2-009, 8.0			
16			& V59049-2-034, Article 40			

96:009.FB

SPECIFICATION FOR

ROUGHING PUMP CARTS

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY: David Moore

QUALITY ASSURANCE: Alan L Brodbook

TECHNICAL DIRECTOR: D.A. McWilliams

PROJECT MANAGER: [signature]

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
3	DM 3/20/96	D. McW 3-20-96	REVISED PER DEO 0100
2	DM 12/26/95	D. McW -2-96	REVISED FOR PURCHASE DCO 0034
1	DM 11/9/95	D. McW 11-10-95	REVISED PER CLIENT COMMENTS DEO 0015
0	DM 10/16/95	D. McW 10-28-95	REVISED AND ISSUED FOR QUOTATION & APPROVAL / DEO 0004
P1	TAS 9-26-95		REVISED FOR UPDATED PRELIMINARY DESIGN

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION	
INITIAL APPROVALS	PREPARED: D Moore	DATE: 6/14/95	APPROVED: BEB	DATE: 9/26/95	Number V049-2-001 A	Rev. 3

TABLE OF CONTENTS

1.0 SCOPE

This specification covers the minimum requirements for the design, materials, fabrication, assembly, inspection, testing, preparation for shipping, and shipment of roughing pump carts. Separate carts shall be provided for the roots-type pump and for the backing pump.

All attachments are part of this specification.

The specified equipment is intended for use as part of the Vacuum Equipment supplied for the Laser Interferometer Gravitational-Wave Observatory (LIGO). LIGO, which is operated by Caltech and MIT under an NSF contract, includes two installations at widely separated sites: near Hanford, WA and Livingston, LA. Each installation contains laser interferometers in an L shape with 4 km long arms, a vacuum system for the sensitive interferometer components and optical beams, and other support facilities.

Information contained in this specification and its attachments is proprietary in nature and shall be kept confidential. It shall be used only as required to respond to the specification requirements, and shall not be disclosed to any other party.

2.0 SCHEDULE

2.1 Equipment delivery (for pairs of carts) shall be as follows:

	Quantity	Date
Washington Site:	2	8/1/96
Louisiana Site:	2	8/10/97
Total Required	4	

2.3 Acceptances at the sites (the start of Vendor's warranty periods) are expected to occur on a staggered basis, with final acceptance to occur no later than 6 months after delivery.

3.0 EQUIPMENT REQUIREMENTS

3.1 Each pump cart (set) shall be capable of roughing down a volume of 2,000 cubic meters from 760 torr to 1 torr without overheating.

3.2 Deleted.

3.3 The minimum required pumping speed at the pump inlet at 1 torr is 500 cfm; at 0.1 torr the minimum required pumping speed is 1000 cfm. The pump set shall be capable of roughing a volume of 200 cubic meters from atmosphere to 1 torr in 4 hours or less.

3.4 Vendor to specify system performance when cart is separated (see paragraph 4.1.1).

4.0 DESIGN REQUIREMENTS

The pumpcarts will be required to operate under two distinct operating conditions: Beam Tube evacuation and Vacuum Equipment evacuation.

1. Beam Tube Pumping

The main roughing pumps will be used to evacuate the 2000 m^3 beam tubes. For this case the roughing pump carts will be separated by approximately 10′. It is the intent of this specification to allow this cart configuration to be the suppliers standard design.

The beam tube evacuation will occur during initial stages of construction prior to completion of the Vacuum Equipment Building. During this phase, a temporary structure will house the pumping cart system. The pumping carts will be located on the Beam Tube Anchor Foundation (see Attachment D).

2. Vacuum Equipment Pumping

For evacuating Vacuum Equipment during installation and maintenance, the pumping carts will be separated into two sections. The first stage blower will be close coupled to the Vacuum Equipment in the Vacuum Equipment room. The first stage pumps will discharge into a vacuum header connected to the second stage blower and backing pumps which will be located in a separate Mechanical Equipment Room (to minimize noise and eliminate the requirement for supplying large quantities of cooling water into the Vacuum Equipment Room). The vacuum equipment support structure for the final configuration of the first stage blower will be provided by PSI.

4.1 Mechanical Requirements

4.1.1 Each cart set shall consist of a roots-type blower cart backed by one or more mechanical pumps on a separate cart, and accessories described below and on the attached P&ID Bypass valves shall be provided if required by the vendors design. Initial operation will have the blower and backing pump separated via the 10′ of flex hose between blower discharge and the backing pump. Future operation will have the carts separated via 10′ of flex hose and a vacuum header.

4.1.2 Each cart shall be a complete system mounted on a frame suitable for operation in a Federal Standard 209 Class 50,000 environment (cleanroom). Vibration isolation supports shall be included. Castors or pallet jack access must be provided for each cart.

4.1.3 The design of the carts shall preclude contamination of the vacuum chambers during the life of the equipment, even in the event of equipment failure or operator error.

4.1.4 The process inlet to the cart shall be supplied by others. Seals shall be non-lubricated baked Viton O-rings.

4.1.5 The process outlet from the roots-type pump cart shall incorporate a 10' long flex line for connection to the backing pump or in the future a vacuum header. This connection shall, depending on the required tube size, be an ISO Quick Flange or Large Flange with double claw clamps. Seals shall be non-lubricated baked Viton O-rings.

4.1.6 Provision for sealed connection to a ducted facility exhaust system shall be provided on the backing pump outlet.

4.1.7 There shall be no oil in the pumping path.

4.1.8 Any required utility connections (such as for cooling water) shall be manifolded to a single connection point and terminated appropriately (such as with an isolation valve and a 1/2" quick disconnect fitting). Filtered cooling water will be provided as follows:

Supply Temperature:	20 - 25C
Supply Pressure:	3. - 5. bara
Return Temperature:	25 - 30C
Return Pressure:	2. - 4. bara

Cooling water hose kits shall be provided to interconnect the blower cart and the backing pump. The hoses shall be 15′ long.

4.1.9 The roots pump cart inlet nozzle shall be located at as low an elevation as possible. A blind flange with a gauge connection and suitable volume for shop speed testing shall be provided.

4.1.10 The acoustic noise and vibration requirement detailed in Section 5.1 of Attachment A do not apply to the roughing pump carts.

4.2 Electrical Requirements

4.2.1 Instrumentation Requirements

4.2.1.1 There shall be Pirani vacuum gauges located at each pump inlet (both the roots pump and the backing pump). Bakeable vacuum gauges are required only for the inlet (chamber side) of the roots blower. A local vacuum gauge readout controller shall be provided. The vacuum gauges will remain with the roots blower when the backing pump is remotely located.

4.2.1.2 There shall be auxiliary valved (manual valves) ports to allow connection of a leak detector.

4.2.1.3 All unused ports shall be fitted with blankoff flanges.

4.2.1.4 A purge gas flow switch (or pressure switch) shall be provided to shutdown the cart when there is insufficient purge gas flow (or pressure). An adjustable 10-60 second delay timer shall be included in the shutdown logic to prevent spurious shutdowns.

4.2.2 Controls Requirements

4.2.2.1 Controls for local operation shall be provided. The Buyer will interconnect the cart wiring when they are installed in the split location for Vacuum Equipment pumping (terminals to be provided by the vendor). In addition, provide terminal strips in a junction box to interface with the future LIGO control system. The following signals shall be provided:

Description	Signal Type
Pump Running (Each Pump)	Dry Contacts
Auto. Valve Open	Dry Contacts
Roots Pump Inlet Vacuum	0 - 10 VDC
Backing Pump Vacuum	0 - 10 VDC
Purge Gas Shutdown	Dry Contacts

4.2.2.2 The pump carts shall be self-contained so that, under power failure or pump failure, interlocks shall prevent pumped chambers from being vented or from being exposed to a non-operating pump.

4.2.2.3 A manual gate valve on the chamber nozzle will be provided by others. A fail closed pneumatically actuated 6" UHV gate valve (with pilot solenoid and open and closed limit switches) shall be provided on the inlet of the roots pump cart. The controls necessary to close this valve on pump failure shall be incorporated into the cart controls.

4.2.2.4

4.2.2.5 Pumps shall be stopped and started by pushbutton switches located on the blower cart. The backing cart shall be capable of being started and stopped by a signal from the blower cart.

4.2.2.6 Vendor must list in his quotation all safety devices (such as flow switches, pressure switches, temperature switches, safety relief valves, etc.) supplied with the systems.

4.2.2.7 Vendor must provide in his quotation a brief description of all operational sequences such as startup, normal quotation, normal shutdown, safety shutdowns, etc.

4.2.3 Power Requirements

4.2.3.1 Power connection to the cart shall be by an appropriate 20' long cord with twist-lock, NEMA type plug configuration (a single connection for the cart including controllers when configured as one assembly). Required controllers and overload protection shall be provided on the cart. Vendor must provide specifications for the power and control cables needed to connect the separated cart components. The field wiring cables will be provided by the Buyer when the blower is remotely located. Vendor will provide the cables needed when the carts are located together.

4.2.4 Purge Gas
Clean, dry, air will be supplied at 80 psig for use as seal purge gas for the vacuum pumps requiring this utility.

5.0 REQUIRED DOCUMENTATION

Documentation requirements listed in Attachment B and attached Q.A. requirements form, Attachment A shall be provided according to the Buyer's schedule.

6.0 SHOP TESTING

In addition to the Vendor's standard tests, each electrically powered vacuum pump cart shall be tested for speed, ultimate pressure, leakage and operation of protective features. All safety interlocks shall be tested for proper operation by simulating the faulted condition.

7.0 INSPECTION

All testing and inspections called for in Attachment B (Specification V049-2-033 General Equipment Requirements) shall be performed by the Vendor. Additional quality assurance requriements are listed in Attachment A, Quality Assurance Requirements Summary.

8.0 WARRANTY

Refer to Specification V049-2-034, Equipment Purchase Commercial Requirements for Warranty Requirements

Number

Rev.

ATTACHMENT "A"

LIGO QUALITY ASSURANCE REQUIREMENTS SUMMARY

LIGO VACUUM EQUIPMENT	VENDOR:	JOB NO.: V59049
EQUIPMENT: ROUGHING PUMP CART	VENDOR ENG. OFFICE:	DWG. NO.:
PSI P.O. NO:	VENDOR FACTORY:	SPEC NO.: V049-2-001

TESTING INSPECTION AND DOCUMENTATION RECORD	Submittal After P.O.	Witnessed by PSI	Approval by PSI	Copies Req'd for PSI Files	Record in Mfr's File	Remarks:	Inspector: Date:
MILESTONE SCHEDULE	2 Wks.		X	2	X		
VENDOR Q.A. PLAN	2		X	2	X		
PREP FOR SHIPMENT PROCEDURE	2		X	2	X		
ASSEMBLY DRAWINGS	6		X	2	X		
DESIGN REVIEW	4	X			X		
IN-PROCESS INSPECTIONS		X		2	X	Prior to release for fabrication.	
OPERATION & MAINTENANCE MANUALS	TBD			5	X		
SHOP TEST PLAN	8		X	2	X	Prior to release for fabrication.	
SHOP TEST (WITH REPORT)		X		2	X	Prior to release for shipment.	

SPECIFICATION FOR

MAIN TURBOMOLECULAR CARTS

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY: David Moore

QUALITY ASSURANCE: Alan R Bradbrook

TECHNICAL DIRECTOR: D.A. McWilliams

PROJECT MANAGER: Richard Bayley

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
4	Dm 3/20/96	D. McW	REVISED PER DEO 0100
3	Dm 12/26/95	D. McW 1-2-96	REVISED FOR PURCHASE DEO 0034
2	Dm 11/9/95		REVISED PER CLIENT COMMENTS DEO 0015
1	Dm 11/2/95		REVISED ATTACHMENT C P&ID V049-0-041 TO P2
0	Dm 10/16/95	D. McW 10-20-95	REVISED & ISSUED FOR QUOTATION & APPROVAL DEO 0004
P1	JM 9-26-95		REVISED FOR UPDATED PRELIMINARY DESIGN

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION	
INITIAL APPROVALS	PREPARED	DATE	APPROVED	DATE	Number V049-2-002	Rev.
	D Moore	6/14/95	KEB	9/26/95	A	4

TABLE OF CONTENTS

1.0 SCOPE

This specification covers the minimum requirements for the design, materials, fabrication, assembly, inspection, testing, preparation for shipping, and shipment of the main turbomolecular pump carts (and backing pump carts).

All attachments are part of this specification.

The specified equipment is intended for use as part of the Vacuum Equipment supplied for the Laser Interferometer Gravitational-Wave Observatory (LIGO). LIGO, which is operated by Caltech and MIT under an NSF contract, includes two installations at widely separated sites: near Hanford, WA and Livingston, LA. Each installation contains laser interferometers in an L shape with 4 km arms, a vacuum system for the sensitive interferometer components and optical beams, and other support facilities.

Information contained in this specification and its attachments is proprietary in nature and shall be kept confidential. It shall be used only as required to respond to the specification requirements, and shall not be disclosed to any other party.

2.0 SCHEDULE

2.1 Equipment delivery (for pairs of carts) shall be as follows:

	Quantity	Date
PSI (Westboro, MA)	2	4/1/96
Washington Site	4	8/1/96
Louisiana Site	4	8/10/97
Total Required	10	

2.3 Acceptances at the sites (the start of Vendor's warranty periods) are expected to occur on a staggered basis, within 6 months of delivery.

3.0 EQUIPMENT REQUIREMENTS

The main turbomolecular pump carts are to be used to pump down large volumes from 1 torr to 1×10^{-6} torr. The minimum speed at the inlet port shall be 1,400 l/s for nitrogen at 1×10^{-3} torr. The pump set shall be capable of a throughput of at least 5 torr-liters per second at a backing pressure of 1 torr. The pump set shall be capable of pumping a volume of at least 2,000 cubic meters (from 1 torr to 1×10^{-6} torr) without overheating.

The backing pump will be used to rough pump volumes up to 70 m^3 from atmosphere. The cart shall be equipped with a bypass line and manual valving to allow the turbo pump to be bypassed during early stages of pumpdown.

3.1 Vendor to specify system performance (speed vs. pressure curve) when the cart is separated (see paragraph 4.1.1).

4.0 DESIGN REQUIREMENTS

The main turbo pump carts will be required to operate under two distinct operating conditions: Beam Tube Evacuation and Vacuum Equipment Evacuation.

1. Beam Tube Pumping

   The main turbomolecular pumps will be used initially to evacuate the 2000 m^3 Beam Tube. For this case all of the vacuum pump components will be mounted on a single cart (or two frames bolted together). It is the intent of this specification to allow this cart configuration to be the suppliers standard design.

   The Beam Tube evacuation will occur prior to completion of the Vacuum Equipment Building. During this phase, a temporary structure will house the pumping cart. The pumping cart will be located on the Beam Tube Anchor Foundation (see Attachment D).

2. Vacuum Equipment Pumping

   For evacuating the Vacuum Equipment during installation and maintenance, the pumping carts will be separated into two sections (by the buyer). The turbo molecular pump will be close coupled to the Vacuum Equipment in the Vacuum Equipment Room. It will discharge into a vacuum header connected to dry backing pump which will be located in a separate Mechanical Equipment Room (to minimize noise and vibration).

   The turbomolecular cart will be modified by PSI to reduce vibration transmission into the vacuum vessels and into the floor.

4.1 Mechanical Requirements

4.1.1 Each turbomolecular pump set shall consist of a "wide range" magnetically levitated turbomolecular pump backed by an oil-free pump (diaphragm, piston or scroll pump) on separate carts. Also included on the carts are the accessories described below and on the attached P&ID. Initial operation will require the turbo cart to be mounted on top of the backing cart. Future operation will have the turbopump and backing pumps separated via the following vacuum header: 240' of 4" diameter pipe, (6) 90 degree elbows, (1) 45 degree elbow, (1) tee (branch), 10' of 1 1/2" flex hose between turbopump discharge and header.

4.1.2 Each cart shall be a complete system mounted on a frame suitable for operation in a Federal Standard 209 Class 50,000 environment (cleanroom). Vibration isolation supports shall be included.

4.1.3 The design of the carts shall preclude contamination of the vacuum chambers during the life of the equipment, even in the event of equipment failure or operator error.

4.1.4 The inlet connection to the turbomolecular pump will be a 12" O.D. conflat. Turbomolecular pumps shall be supplied with protective inlet screens.

4.1.5 The process outlet from the turbo pump cart shall incorporate a 10' long flex line for connection to a vacuum header. This connection shall, depending on the required tube size, be an ISO Quick Flange or Large Flange with double claw clamps. Seals shall be non-lubricated baked Viton O-rings.

4.1.6 Provision for sealed connection from the backing pump outlet to a ducted facility exhaust system shall be provided.

4.1.7 There shall be no oil in the pumping path.

4.1.8 Any required utility connections (such as for cooling water) shall be manifolded to a single connection point and terminated appropriately (such as with an isolation valve and a 1/2" quick disconnect fitting). Filtered cooling water will be provided as follows:

Supply Temperature:	20 - 25C
Supply Pressure:	3. - 5. bara
Return Temperature:	25 - 30C
Return Pressure:	2. - 4. bara

4.1.9 The turbo pump shall be portable and connected to the pumpcart by 10ft. long flex line for vacuum, power, and cooling water. For pumping of the Beam Tube the TMP will be mounted horizontally and hard piped to an isolation valve mounted on top of the Beam Tube. A blind flange with a gauge connection and suitable volume for shop speed testing shall be provided.

4.1.10 Insulated heating jackets with temperature controllers for the turbo pumps and inlet piping (flex) up to the turbo inlet flanges will be provided by the buyer. The heaters shall be capable of temperature control up to 120 C.

4.2 Electrical Instrumentation Requirements

4.2.1 Instrumentation Requirements

4.2.1.1 There shall be vacuum gauges located at each pump inlet (both the turbomolecular pump and the backing pump). The inlet to the turbomolecular pump shall have both a Pirani gauge and a cold cathode gauge, and the inlet to the backing pump shall have a Pirani gauge. All vacuum gauges remain with the turbomolecular pump when the backing pump is remotely located. Bakeable (to 250C) vacuum gauges are required only for the inlet (chamber side) of the turbopump. A local vacuum gauge controller shall be provided with each cart.

4.2.1.2 There shall be auxiliary valved (manual valves) ports to allow connection of a leak detector.

4.2.1.3 All unused ports shall be fitted with blankoff flanges.

4.2.1.4 A purge gas flowswitch (or pressure switch) shall be provided to shutdown the cart when there is insufficient purge gas flow (or pressure). An adjustable 10-60 second delay timer shall be included in the shutdown to prevent spurious shutdowns.

4.2.2 Controls Requirements

4.2.2.1 Controls for local operation shall be provided. The buyer will interconnect the cart wiring when they are installed in the split location for vacuum equipment pumping (terminals to be provided by the vendor). In addition, provide terminal strips in a junction box to interface with the future LIGO control system. The following signals shall be provided:

Description	Signal Type
Pump Running (Each Pump)	Dry Contacts
Auto. Valve Open & Closed	Dry Contacts
Turbo Pump Inlet Vacuum (2)	0 - 10 VDC (2)
Backing Pump Vacuum	0 - 10 VDC
Purge Gas Shutdown	Dry Contacts

4.2.2.2 The pump carts shall be self-contained so that, under power failure or pump failure, interlocks shall prevent pumped chambers from being vented or from being exposed to a non-operating pump.

4.2.2.3 A manual gate valve on the chamber nozzle will be provided by others. A fail closed pneumatically actuated valve (with pilot solenoid and open and close limit switches) shall be provided on the outlet of the roots pump cart. The controls necessary to close this valve on pump failure shall be incorporated into the cart controls.

4.2.2.4

4.2.2.5 Pumps shall be stopped and started by pushbutton switches located on the turbo cart. The backing cart shall be capable of being started and stopped by a signal from the turbo cart. The control system must include a safety permissive that requires the turbomolecular pump foreline pressure to be < 2 torr before the turbo pump is allowed to start.

4.2.2.6 Vendor must list in his quotation all safety devices (such as flow switches, pressure switches, temperature switches, safety relief valves, etc.) supplied with the systems.

4.2.2.7 Vendor must provide in his quotation a brief description of all operational sequences such as startup, normal operation, normal shutdown, safety shutdowns, etc.

4.2.3 Power Requirements

4.2.4 Purge Gas

Clean, dry, air will be supplied at 15 psig for use as seal purge gas for the vacuum pumps requiring this utility.

4.2.3.1 Power connection to the cart shall be by an appropriate 20' long cord with twist-lock, NEMA type plug configuration (a single connection for the cart, including controllers when configured as one assembly and two cards and plugs when separated into two sections). Required controllers and overload protection shall be provided on the cart. Vendor must provide specifications for the power and control cables needed to connect the separated cart components. Field wiring cables will be provided by buyer when the turbopump is remotely located. Vendor will provide the cables needed when the turbopump is located on the cart.

5.0 REQUIRED DOCUMENTATION

Documentation requirements listed in Attachment B and the QA requirements form, Attachment A, shall be provided according to the Buyer's schedule.

6.0 SHOP TESTING

In addition to the Vendor's standard tests, each electrically powered vacuum pump cart shall be tested for speed, acoustic noise, ultimate pressure, leakage and operation of protective features. All safety interlocks shall be tested for proper operation by simulating the faulted condition.

7.0 INSPECTION

All testing and inspections called for in Attachment B (Specification V049-2-033, General Equipment Requirements) shall be performed by the Vendor. Additional quality assurance requirements are listed in Attachment A, Quality Assurance Requirements Summary.

8.0 WARRANTY

Refer to Specification V049-2-034, Equipment Purchase Commercial Requirements for Warranty Requirements.

ATTACHMENT "A"
LIGO QUALITY ASSURANCE REQUIREMENTS SUMMARY

LIGO VACUUM EQUIPMENT	VENDOR:	JOB NO.: V59049
EQUIPMENT: MAIN TURBOMOLECULAR PUMPS	VENDOR ENG. OFFICE:	DWG. NO.:
PSI P.O. NO:	VENDOR FACTORY:	SPEC NO.: V049-2-002

TESTING INSPECTION AND DOCUMENTATION RECORD	Submittal After P.O.	Witnessed by PSI	Approval by PSI	Copies Req'd for PSI Files	Record in Mfr's File	Remarks:	Inspector: Date:
MILESTONE SCHEDULE	2 Wks.		X	2	X		
VENDOR Q.A. PLAN	2		X	2	X		
CLEANING PROCEDURE	2		X	2	X		
PREP FOR SHIPMENT PROCEDURE	6		X	2	X		
ASSEMBLY DRAWINGS	4		X	2	X		
DESIGN REVIEW		X			X	Prior to release for fabrication.	
IN-PROCESS INSPECTIONS	TBD	X		2	X		
OPERATION & MAINTENANCE MANUALS	8			5	X		
SHOP TEST PLAN			X	2	X	Prior to release for fabrication.	
SHOP TEST (WITH REPORT)		X		2	X	Prior to release for shipment.	

SPECIFICATION FOR

AUXILIARY TURBOMOLECULAR PUMP CARTS

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY: David Moore

QUALITY ASSURANCE: Alan L. Benbrook

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: Richard Bagley

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
3	DM 3/20/96	D.McW 3-20-96	REVISED FOR PURCHASE DEO 0100
2	DM 12/26/95		REVISED FOR PURCHASE DEO 0034
1	DM 11/9/95		REVISED PER CUSTOMER COMMENTS DEO 0015
0	DM 10/16/95		REVISED & ISSUED FOR QUOTATION & APPROVAL / DEO 0007
P1	TMS 9-26-95		REVISED FOR UPDATED PRELIMINARY DESIGN

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION	
INITIAL APPROVALS	PREPARED: D Moore	DATE: 6/19/95	APPROVED: AEB	DATE: 9/26/95	Number V049-2-003 A	Rev. 3

SPECIFICATION TABLE OF CONTENTS

1.0 SCOPE

This specification covers the minimum requirements for the design, materials, fabrication, assembly, inspection, testing, preparation for shipping, and shipment of the auxiliary turbomolecular pump carts. The Vendor shall quote 1) complete packages and 2) individual components.

All attachments are part of this specification.

The specified equipment is intended for use as part of the Vacuum Equipment supplied for the Laser Interferometer Gravitational-Wave Observatory (LIGO). LIGO, which is operated by Caltech and MIT under an NSF contract, includes two installations at widely separated sites: near Hanford, WA and Livingston, LA. Each installation contains laser interferometers in an L shape with 4 km arms, a vacuum system for the sensitive interferometer components and optical beams, and other support facilities.

Information contained in this specification and its attachments is proprietary in nature and shall be kept confidential. It shall be used only as required to respond to the specification requirements, and shall not be disclosed to any other party.

2.0 SCHEDULE

2.1 Equipment delivery shall be as follows:

	Quantity	Date
PSI (Westboro, MA)	2	4/1/96
Washington Site:	2	8/1/96
Louisiana Site:	2	8/10/97
Washington Site:	3	9/1/97
Louisiana Site:	1	3/1/98
Total Required	10	

2.2 Acceptances at the sites (the start of Vendor's warranty periods) are expected to within 6 months of delivery.

3.0 EQUIPMENT REQUIREMENTS

The auxiliary turbomolecular pump carts are to be used to rough pump annular spaces between flange seals in various components. The minimum speed at the inlet port of the turbo pump shall be 50 l/s for nitrogen. (Once the annular space is roughed to, it will be maintained by an ion pump supplied by others.)

4.0 DESIGN REQUIREMENTS

4.1 Mechanical Requirements

4.1.1 Each turbomolecular pump set shall consist of a turbomolecular pump backed by an oil-free pump (diaphragm, piston or scroll pump). Also included on the carts are the accessories described below and on the attached P&ID. If a manual bypass around the TMP is necessary to permit operation from atmosphere pressure, it shall be provided by the vendor.

4.1.2 Each cart shall be a complete system mounted on a frame suitable for operation in a Federal Standard 209 Class 50,000 environment (cleanroom). Vibration isolation supports shall be included.

4.1.3 The design of the cart shall preclude contamination of the vacuum chambers during the life of the equipment, even in the event of equipment failure or operator error.

4.1.4 Deleted.

4.1.5

4.1.6 There shall be no oil in the pumping path.

4.1.7 Any required utility connections (such as for cooling water) shall be manifolded to a single connection point and terminated appropriately (such as with an isolation valve and a 1/2" quick disconnect fitting).

Filtered cooling water will be provided as follows:

Supply Temperature:	20 - 25C
Supply Pressure:	3. - 5. bara
Return Temperature:	5 - 30C
Return Pressure:	2. - 4. bara

4.1.8 The process inlet to the cart shall include a flex line or bellows for connection to the roughing ports (ISO Quick Flange or Large Flange with clam shell closure, depending on the required tube size to meet the required pumping speed). Seals shall be non-lubricated baked Viton O-rings. Other connection types shall be as indicated on the attached P&ID.

4.1.9 The Buyer will supply insulated heating jackets with temperature controllers for heating the turbo pumps.

4.2 Electrical Requirements

4.2.1 Instrumentation Requirements

4.2.1.1 There shall be vacuum gauges located at each pump inlet (both the turbomolecular pump and the backing pump). The inlet to the turbomolecular pump shall have both a Pirani gauge and a cold cathode gauge, and the inlet to the backing pump shall have a Pirani gauge. Bakeable vacuum gauges are required only for the inlet (chamber side) of the turbopump (to 250^0C). A local vacuum gauge readout controller shall be supplied with each cart.

4.2.1.2 There shall be auxiliary valved (manual valves) ports to allow connection of a leak detector to the inlet and oulet of the TMP.

4.2.1.3 All unused ports shall be fitted with blankoff flanges.

4.2.2 Controls Requirements

4.2.2.1 Controls for local operation shall be provided. In addition, provide terminal strips in a junction box to interface with the future LIGO control system. The following signals shall be provided:

Description	Signal Type
Pump Running (Each Pump)	Dry Contacts
Auto. Valve Open	Dry Contacts
Roots Pump Inlet Vacuum	0 - 10 VDC
Turbo Pump Inlet Vacuum (2)	0 - 10 VDC (2)

4.2.2.2 The pump cart shall be self-contained so that, under power failure or pump failure, interlocks shall prevent pumped volumes from being vented or from being exposed to a non-operating pump.

4.2.2.3 A manual gate valve on the chamber nozzle will be provided by others. A fail closed pneumatically actuated valve (with pilot solenoid) shall be provided on the inlet of the TMP. The controls necessary to close this valve on pump failure shall be incorporated into the cart controls. An automatic vent valve and associated controls shall be provided to properly vent the TMP during a shutdown.

4.2.2.4

4.2.2.5 Pumps shall be stopped and started by pushbutton switches located on the cart.

4.2.2.6 Vendor must list in his quotation all safety devices (such as flow switches, pressure switches, temperature switches, safety relief valves, etc.) supplied with the systems.

4.2.2.7 Vendor must provide in his quotation a brief description of all operational sequences such as startup, normal, operation, twist-lock, NEMA type plug configuration normal shutdown, safety shutdowns, etc.

4.2.3 Power Requirements

Power connection to the cart shall be by an appropriate 20' long cord with (a single connection for the cart, including controllers). Required controllers and overload protection shall be provided on the cart.

5.0 REQUIRED DOCUMENTATION

Documentation requirements listed in Attachment B and the Q.A. requirement form, Attachment A, shall be provided according to the Buyer's schedule.

6.0 SHOP TESTING

In addition to the Vendor's standard tests, each electrically powered vacuum pump cart shall be tested for speed, acoustic noise, ultimate pressure, leakage and operation of protective features. All safety interlocks shall be tested for proper operation by simulating the faulted condition.

7.0 INSPECTION

All testing and inspections called for in Attachment B (Specification V049-2-033, General Equipment Requirements) shall be performed by the Vendor. Additional quality assurance requirements are listed in Attachment A, Quality Assurance Requirements Summary.

8.0 WARRANTY

Refer to Specification V049-2-034, Equipment Purchase Commercial Requirements for Warranty Requirements.

SPECIFICATION FOR

ION PUMPS

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY: D Moore

QUALITY ASSURANCE: Alan L Bradbrook

TECHNICAL DIRECTOR: D. C. McWilliams

PROJECT MANAGER: Richard Bayley

2	3-13-96	REB	RELEASED FOR PURCHASE PER DEO # 0092
1	2-14-96 SSC	REB	RELEASED FOR PURCHASE PER DEO 0063
0	SJC 11-16-96		RELEASED FOR APPROVAL & QUOTATION PER DEO 0018
P1	10-19-95	REB	Released per DEO 0005
P1	TMS 9-26-95		REVISED FOR UPDATED PRELIMINARY DESIGN
REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION	
INITIAL APPROVALS	PREPARED	DATE	APPROVED	DATE	Number V049-2-004	Rev.
	D Moore	6/14/95	REB	9/26/95	A	2

SPECIFICATION TABLE OF CONTENTS

Number | Rev.

1.0 SCOPE

This specification covers the minimum requirements for the design, materials, fabrication, assembly, inspection, testing, preparation for shipping, shipment and delivery of the ion pumps for the LIGO vacuum system. The ion pumps will be used to perform the following functions:

a) Maintain an ultra high vacuum in the equipment at the corner, mid and end stations of the LIGO interferometer (main ion pumps).

b) Maintain an ultra high vacuum in the annular spaces between dual-sealed flanges on the chambers (chamber annulus ion pumps).

c) Maintain an ultra high vacuum in the annular spaces between the double gate seals and dual seal flanges of the large gate valves which isolate sections of the interferometer from each other (valve annulus ion pumps).

All attachments are incorporated herein by reference and made a part of this specification.

The specified equipment is intended for use as part of the Vacuum Equipment supplied for the Laser Interferometer Gravitational-Wave Observatory (LIGO). LIGO, which is operated by Caltech and MIT under an NSF grant, includes two sites (Hanford Reservation, near Richland, WA and Livingston, LA). Each site contains laser interferometers in an L shape with 4 km arms, a vacuum system for the sensitive interferometer components and optical beams, and other support facilities.

Information contained in this specification and its attachments is proprietary in nature and shall be kept confidential. It shall be used only as required to respond to the specification requirements, and shall not be disclosed to any other party.

2.0 SCHEDULE

2.1 Equipment delivery shall be as follows:

Main Ion Pumps (2500 l/s)

Total Qty.	Description	PSI Part #	Lot *	Qty.	Delivery Date
18	2500 l/s Noble Diode Pump w/2 electrically isolated sections controlled by 2 individual feedthroughs	V0492004 P1	L1	1	7/1/96
			L2	12	5/1/97
			L3	5	11/1/97
18	2-3/4" CF Roughing Port	V0492004 P2	L1	1	7/1/96
			L2	12	5/1/97
			L3	5	11/1/97
18	8" CF Additional Port	V0492004 P3	L1	1	7/1/96
			L2	12	5/1/97
			L3	5	11/1/97
20	150' HV Cables	V0492004 P4	L0	2	5/1/96
			L2	10	5/1/97
			L3	8	11/1/97
16	250' HV Cables	V0492004 P5	L2	12	5/1/97
			L3	4	11/1/97
18	Multivac base unit w/Remote Interface/Setpoint Board	V0492004 P6	L0	2	5/1/96
			L4	16	5/1/97
36	Large HV Card w/programmable voltage	V0492004 P7	L0	4	5/1/96
			L4	32	5/1/97
13	Rack Adapter Kit	V0492004 P13	L0	1	5/1/96
			L4	12	5/1/97

CONTROLLERS CHAMBER AND BEAM MANIFOLD ANNULUS ION PUMPS AND 75 l/s ION PUMP					
Total Qty.	**Description**	**PSI Part #**	**Lot ***	**Qty.**	**Delivery Date**
43	75 l/s Noble Diode Pump	V0492004 P8	L0	4	5/1/96
			L2	28	5/1/97
			L3	11	11/1/97
43	2-3/4" CF Roughing Port	V0492004 P2	L0	4	5/1/96
			L2	28	5/1/97
			L3	11	11/1/97
43	10' HV Cables	V0492004 P9	L0	4	5/1/96
			L2	28	5/1/97
			L3	11	11/1/97
43	Minivac Power Supply	V0492004 P10	L0	4	5/1/96
			L2	28	5/1/97
			L3	11	11/1/97

VALVE ANNULUS ION PUMPS AND CONTROLLERS 25 l/s ION PUMP					
Total Qty	**Description**	**PSI Part #**	**Lot**	**Qty**	**Delivery Date**
32	25 l/s Noble Diode Pump	V0492004 P11	L2	20	5/1/97
			L3	12	11/1/97
32	2-3/4" CF Roughing Port	V0492004 P2	L2	20	5/1/97
			L3	12	11/1/97
32	10' HV Cables	V0492004 P9	L2	20	5/1/97
			L3	12	11/1/97
32	Minivac Power Supply	V0492004 P10	L2	20	5/1/97
			L3	12	11/1/97
1	AVS Speed Test	V0492004 P12	Per Spec		

*L0 = PSI Site; 5/1/96

L1 = PSI Site; 7/1/96

L2 = Washington Site; 5/1/97

L3 = Louisiana Site; 11/1/97

L4 = PSI Site; 5/1/97

Above is for pumps and cables. All main ion pump controllers will be shipped to PSI (Westboro, MA) on specified dates listed above except for Lot 1.

Lot 1 (Qty 1) and Lot 3 (Qty 1) will be shipped on 5/1/96. Remaining controllers from Lot 3 will be shipped as specified above.

2.2 Acceptances at the sites are expected to occur on a staggered basis, with final acceptance at Washington expected to occur about May 31, 1998, and about November 30, 1998 in Louisiana.

3.0 EQUIPMENT REQUIREMENTS

3.1 Main Ion Pumps

3.1.1 The main ion pumps shall have minimum nominal pumping speeds at the pump inlet of 2,500 liter/sec for nitrogen at 1×10^{-6} torr and 4,700 liters/sec for hydrogen at 1×10^{-9} torr. The minimum guaranteed pumping speeds for other gases at the partial pressures specified in Table 1 shall be stated. The pumping speed for nitrogen for total pressures ranging from 1×10^{-6} torr to 1×10^{-10} torr shall be stated.

Table 1

Species	Partial Pressure (Torr)	Min. Required Pumping Speed
H_2O	5×10^{-9}	2940 l/s
H_2	5×10^{-9}	4700 l/s
N_2	5×10^{-10}	2500 l/s
CO	5×10^{-10}	2350 l/s
CO_2	2×10^{-10}	2940 l/s
CH_4	2×10^{-10}	2150 l/s
He	5×10^{-10}	295 l/s
Ar	5×10^{-10}	590 l/s

3.1.2 A single large pump shall be provided.

3.1.3 Noble gas diode-type ion pumps with a minimum life of 40,000 hours or more at an operating pressure of 10^{-6} torr shall be used.

3.1.4 Main Ion Pumps (cell design and feedthroughs) shall be designed to allow starting at pressures of at least 1x 10^{-5} torr (two feedthroughs).

For this requirement, the vendor shall provide a design that electrically connects one half of the pump to one feedthru, while the remaining cells are connected to the other feedthru.

3.1.5 The vendor shall supply a controller for each main ion pump with sufficient current capability to start the pump at a pressure of at least $1\text{x}10^{-6}$ torr and run all cells of the pump under normal operation ($1\text{x}10^{-6}$ torr and lower).

3.1.6 Dual cabling shall be provided from controller to pump.

3.2 Chamber Annulus Pumps

3.2.1 Noble gas diode ion pumps, each with a capacity of 75 l/s of air at 1 x 10^{-6} torr, shall be provided for each chamber to maintain the annular vacuum for dual-sealed flanges.

3.2.2 The vendor shall supply a controller for each annulus ion pump with sufficient current capability to start the pump at a pressure of at least $5\text{x}10^{-6}$ torr.

3.3 Valve Annulus Ion Pumps

3.3.1 Noble gas diode ion pumps shall be provided for each large gate valve to maintain the annular vacuum at the valve flange dual seal annuli, as well as the dual gate seals when the valves are closed.

3.3.2 Each valve annulus ion pump shall have a capacity of 25 l/s of air at 1 x 10^{-6} torr..

3.3.3 The vendor shall supply a controller for each annulus ion pump with sufficient current capability to start the pump at a pressure of at least $5\text{x}10^{-6}$ torr.

4.0 DESIGN REQUIREMENTS

4.1 Mechanical Requirements

4.1.1 The main ion pump shall be a single pump. The pump will be supplied with a 14" O.D. tube on which a 16.5" Conflat Flange (CF) is mounted. The pipe or manifold on which the ion pump mounts will be the responsibility of the Buyer.

4.1.2 The chamber annulus ion pumps will be supplied with a 2.5" O.D. tube on whch a 4.5" CF is mounted.

4.1.3 The valve annulus ion pumps will be supplied with a 1.5" O.D. tube on which a 2 3/4" CF is mounted.

4.1.4 Electrical feedthroughs shall be protected from mechanical damage.

41.5. All annulus pumps shall have a minimum life of 40,000 hours or more at an operating pressure of 10^{-6}.

4.1.6 The vendor shall provide mounting or internal supports for the main pump (if necessary) to allow the pump to be mounted vertically from the CF. Lifting lugs shall be provided. See attached drawing.

4.1.7 All ion pump shalls be supplied with a 2 3/4" CF roughing port.

4.1.8 All main ion pumps shall be supplied with an additional 3" Conflat Flange (CF) and 8" CF blank.

4.2 Electrical Requirements

4.2.1 Instrumentation Requirements

4.2.1.1 The cables to interconnect the main ion pumps and controllers shall be provided. 20 cables will be 150' long. The remaining 16 will be 250' long.

4.1.1.2 The cables to interconnect the annulus ion pumps and controllers shall be provided. The cable length is approximately 10 feet for each pump.

4.2.1.3 Unused ports shall be fitted with blankoff flanges.

4.2.1.4 The vendor will submit full load power requirements for each controller.

4.2.2 Controls Requirements

4.2.2.1 The main ion pump controllers shall be rack mountable in standard 19 inch rack consoles (supplied by others). These consoles may be located up to 250 feet (cable length) away from the pumps. Rack mount hardware should be included with the power supplies.

4.2.2.2 All main ion pump controllers shall be supplied with (2) HV cards installed by the vendor that will provide a combined capacity of 800 MA.

4.2.2.3 All main ion pump controllers shall have remote capabilities that include the following:

Run Status	Dry Contact Output
Pump Fail	Dry Contact Output
Current Trip	Dry Contact Output
Standby Mode	Dry Contact Input
Start	Dry Contact Input
Stop	Dry Contact Input

0-10VDC analog output proportional to ion pump current.

0-10VDC analog output proportional to ion pump voltage.

4.2.2.4 All annulus pump controllers will have a single 0-10VDC analog output proportional to the ion pump current.

4.2.2.5 All annulus pump controllers are not required to be rack mountable and will be located within 10 feet of the pumps.

4.2.2.6 Vendor shall provide max. starting pressures for all controller/pump combinations.

5.0 REQUIRED DOCUMENTATION

Documentation requirements listed in Attachment B shall be provided according to the Buyer's schedule (schedule later).

6.0 SHOP TESTING

In addition to the Vendor's standard tests, the first lot (Lot #1) of pumps shall be tested for speed, ultimate pressure, leakage and normal operation, referencing Table #1 located in Section 3.1.1 of this specification. All safety interlocks shall be tested.

7.0 INSPECTION

The inspections called for in Attachment A & B shall be performed by the Vendor. Each pump shall be inspected for dimensional ionformance to approved assy. drwings.

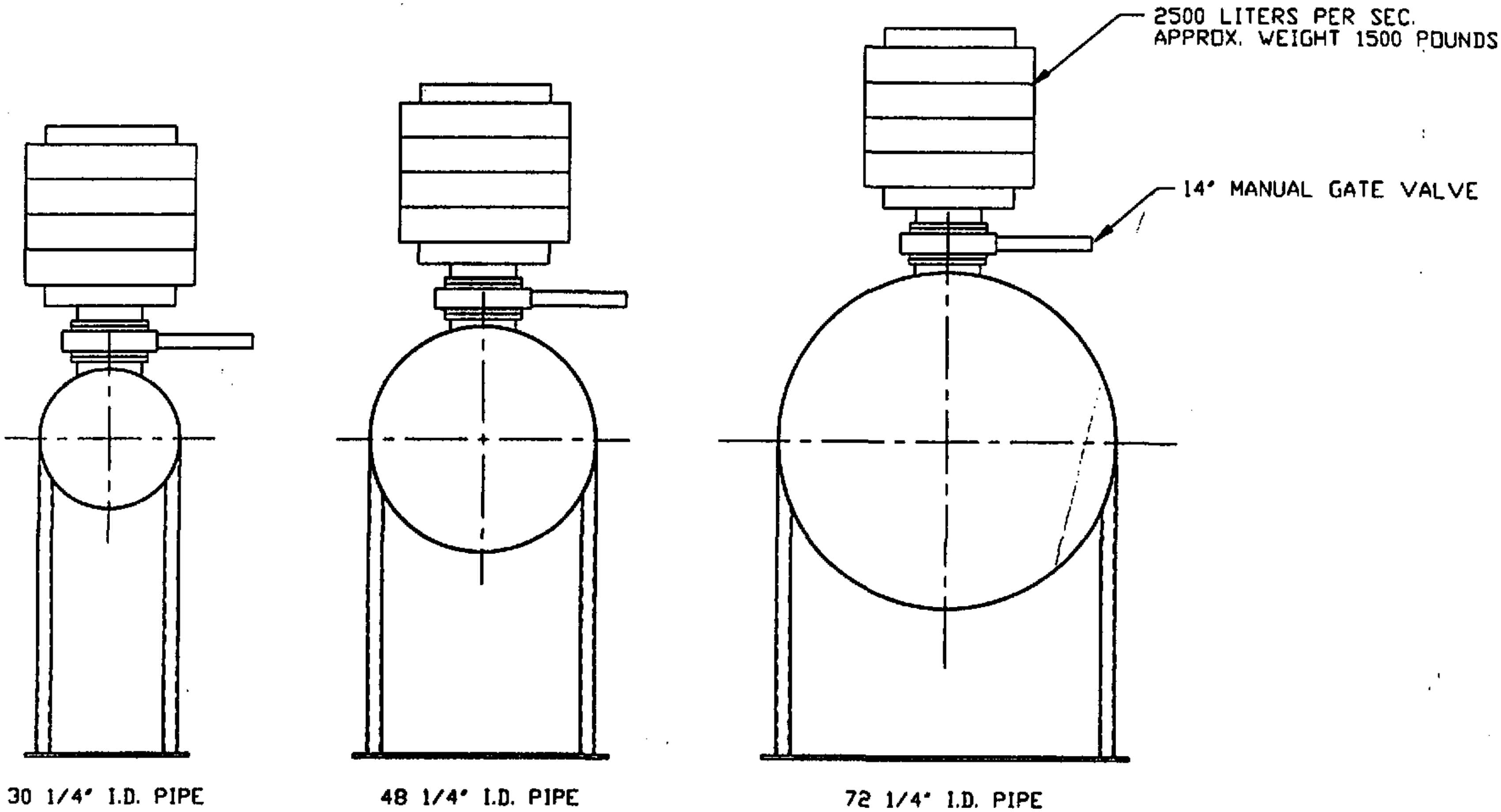
8.0 WARRANTY

Refer to RFQ for warranty requirements.

ATTACHMENT "A"
LIGO QUALITY ASSURANCE REQUIREMENTS SUMMARY

LIGO VACUUM EQUIPMENT	VENDOR:	JOB NO.: V59049
EQUIPMENT: ION PUMPS	VENDOR ENG. OFFICE:	DWG. NO.:
PSI P.O. NO:	VENDOR FACTORY:	SPEC NO.: V049-2-004

TESTING INSPECTION AND DOCUMENTATION RECORD	Submittal After P.O.	Witnessed by PSI	Approval by PSI	Copies Req'd for PSI Files	Record in Mfr's File	Remarks:	Inspector: Date:
MILESTONE SCHEDULE	4 Wk		X	2	X		
VENDOR Q.A. PLAN	4 Wk		X	2	X		
CLEANING PROCEDURE	4 Wk		X	2	X		
PREP FOR SHIPMENT PROCEDURE	4 Wk		X	2	X		
ASSEMBLY DRAWINGS	8 Wk		X	2	X		
DESIGN REVIEW	*	X			X		
IN-PROCESS INSPECTIONS	*	X		2	X		
OPERATION & MAINTENANCE MANUALS	12 Wk			5	X		
SHOP TEST PLAN	8 Wk		X	2	X		
SHOP TEST (WITH REPORT)	*	X		2	X		
SHOP DIMENSIONAL INSPECTION	*	X		2	X		
* PER APPROVED VENDOR SCHEDULE							



UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
TOLERANCES:
FRACTIONAL ±
ANGULAR/MACH
TWO PLACE DECIMAL ±
THREE PLACE DECIMAL ±
FINISHED SURFACE
BREAK CORNERS
REMOVE ALL BURRS

DO NOT SCALE THIS DWG.

USED ON:
NEXT ASS'Y:

REV	DESCRIPTION					CHKD	DRWN	DATE	DCO#

ISSUE DESCRIPTION

PROCESS SYSTEMS INTERNATIONAL INC.

ION PUMP SUPPORTS
LIGO VACUUM EQUIPMENT

CAD FILE	SIZE	DWG. NO.	REV.
IONPUMP	B		0
SCALE N.T.S.		SHEET 1 OF 1	

Sept 27, 1995 - 14:07:43

SPECIFICATION TABLE OF CONTENTS

1.0 SCOPE

This specification covers the minimum requirements for the design, materials, fabrication, assembly, inspection, testing, preparation for shipping, shipment and delivery of the 112 cm and 122 cm gate valves for the LIGO vacuum system.

All attachments are incorporated herein by reference and made a part of this specification.

The specified equipment is for use as part of the Vacuum Equipment supplied for the Laser Interferometer Gravitational-Wave Observatory (LIGO). LIGO, which is operated by Caltech and MIT under an NSF grant, includes two sites (Hanford Reservation, near Richland, WA and Livingston, LA). Each site contains laser interferometers in an L shape with 4 km arms, a vacuum system for the sensitive interferometer components and optical beams, and other support facilities.

Information contained in this specification and its attachments is proprietary in nature and shall be kept confidential. It shall be used only as required to respond to the specification requirements, and shall not be disclosed to any other party.

2.0 SCHEDULE

2.1 Equipment delivery shall be as follows:

Type	Delivery Site	Quantity	Ends	Date
112 cm Valves (Electric)	Washington	6	BW/Flg	8/16/96
		6	Flg/Flg	9/19/97
	Louisiana	2	BW/Flg	8/10/97
		2	Flg/Flg	3/1/98
	Total	16		
112 cm Valves (Pneumatic)	Washington	2	BW/Flg	8/16/96
		2	Flg/Flg	9/1/97
	Louisiana	2	BW/Flg	8/10/97
		2	Flg/Flg	3/1/98
	Total	8		
122 cm Valves (Electric)	Washington	4	Flg/Flg	9/1/97
	Louisiana	2	BW/BW	8/10/97
		2	Flg/Flg	3/1/98
	Total	8		

2.2 Acceptances at the sites are expected to occur on a staggered basis, with final acceptance at Washington expected to occur about May 31, 1998, and about November 30, 1998 in Louisiana.

2.3 A "first article" valve shall be manufactured and tested (per Section 6.0 of this specification) as early as possible to allow design changes to be incorporated in the production lot of valves. Additional valves shall not be manufactured until the Buyer accepts the design of the first article valve after testing.

3.0 EQUIPMENT REQUIREMENTS

The 122 cm gate valves (mating to beam tubes) are used to isolate sections of the interferometer vacuum envelope from one another. The 112 cm gate valves serve the same function but are located near the 80K cryopumps.

4.0 DESIGN REQUIREMENTS

4.1 Mechanical Requirements

4.1.1 Gate valves shall be stainless steel (304L or 316L) with flange connections designed for double O-ring seals with grooves in the mating flanges supplied by others, or weld fittings as specified. Valves shall also have SS metal bellows stem feedthroughs, and shall be designed to seal in both directions.

4.1.2 Only non-contaminating and non-migratory lubrication shall be used on the internal mechanisms.

4.1.3 Valve body and flange leakage shall be measured to be less than 10^{-10} torr liter/sec of helium before shipment. Body flange faces shall be flat to within 0.010".

4.1.4 Gate valves shall have double viton gate seals and bonnet seals. Annular spaces between gate seals and bonnet seals shall be isolatable and designed to be pumped with an ion pump (supplied by others). Gate seals and bonnet seals shall be leak free to a level of 10^{-9} torr liter/sec of helium. Seal O-ring and annulus groove designs shall be subject to Buyer acceptance.

4.1.5 Valves of the same size and type shall be identical to minimize the number of required spare parts. Valves shall be rated for 10,000 cycles before service is required.

4.1.6 Valves shall be installed vertically with the actuators on top. Provision shall be made for supporting the valves from below. It is anticipated that four attachment points will be required.

4.1.7 Valves shall be bakeable to 150 C +/- 20 C (170 C maximum).

4.1.8 The valves (including their actuators) are exempted from the acoustic noise and vibration requirements of paragraphs 5.1.4, 5.1.5 and 5.2.1.3 of Attachment C of this specification.

4.1.9 Valve actuation shall induce no more than 0.01g peak-to-peak acceleration at any point on the valve mounting flanges or weld stubs.

4.1.10 Gate valves shall have a positive, padlockable device to prevent opening or closing. The valve shall be designed so that no damage occurs to the valve or to its actuator if valve actuation is attempted while the valve is locked open or closed.

4.1.11 Valve end connections shall be flanged or butt welded as denoted in Section 2.1, above. For valves with at least one end flanged, the valve shall be designed with the gate adjustment system facing a flanged end (accessible from that end when the valve is closed). For butt welded valve connections, the weld stub shall be 49.12" +/-0.02" ID with a 0.127" +/-0.007" wall thickness and a 10" length. For the two valves for shipment 8/10/97 to Louisiana, the length of the weld stubs shall be equal and sized to provide a total end-to-end dimension of 1 meter. The ends shall be square butt with the surface perpendicular to the tube axis and flat within 0.001". The surfaces shall be cylindrical and unobstructed for 6" from the end on the ouside, and for 2" on the inside. The sulfur content of the weld stub material shall not exceed 0.02 percent.

4.1.12 Gate valves shall be capable of stroking from fully open to sealed in 5 minutes or less, and from sealed to fully open in 5 minutes or less.

4.1.13 Valves shall be electrically or pneumatically actuated as denoted in Section 2.1, above.

4.1.14 Notwithstanding Paragraph 4.1.11, above, valves shall be designed to maintain the gate seal with vacuum or atmospheric pressure on either side of the gate. The valves shall also be designed for a piping load of 21,000 pounds in addition to the pressure load of vacuum on either side of the gate.

4.1.15 The clear aperture through the valve shall be not less than the nominal size (112 cm or 122 cm).

4.1.16 For flanged valves, the flange shall be consistent with the mating flanges shown in Attachment B. The flange face that mates with the O-ring seals shall be machined to a 32 microinch finish using a circular lay. Final flange mating details shall be subject to Buyer's acceptance.

4.1.17 Final assembly and cleaning of valves shall take place in a Federal Standard 209 Class 100 cleanroom environment.

4.2 Electrical Requirements

4.2.1 Instrumentation Requirements

Valves shall be provided with limit switches to indicate the fully opened and fully closed positions.

4.2.2 Controls Requirements

Each valve shall be provided with a controller for local open, close and stop operations. In addition, provide terminal strips in a junction box to interface with the future LIGO control system for remote open, close and stop operations. A bracket shall be provided for mounting of required controllers (e.g., speed controllers) at working height (exact location later). Controls shall be completely assembled, wired and tested prior to shipment.

4.2.3 Power Requirements: See Attachment C.

5.0 REQUIRED DOCUMENTATION

In addition to the documentation listed in Attachment C, the following documentation shall be provided prior to shipment:

- Leak test procedure and report (including data).
- Shock test procedure and report (including data)
- Manufacturer's standard QA reports (including final functional test reports)

6.0 SHOP TESTING

61 Operation of each valve for 20 cycles shall be demonstrated. This shall be done prior to final gate seal leak testing.

6.2 Each valve shall be tested for leakage per Paragraph 4.1.4 (using oil-free pumping equipment and leak detector) prior to shipment from the manufacturer. Each valve shall be baked at 150 C prior to leak checking. For dual gate seals and end seals, each seal shall be individually tested. For the end seals, the Vendor's test fixture shall allow testing of each seal individually. An RGA with calibrated leak shall be used in performing the leak testing.

6.3 One valve of each size and type of actuation shall be tested for shock. The valve shall be tested in the vertical position resting on a pad that deflects at least 0.1" under the static load of the valve, so as not to simulate a "hard mount". Testing shall be done both at atmospheric pressure and with the valve under vacuum. An accelerometer shall be mounted near a connecting flange (or weld stub) on the valve housing or near the edge of one of the flange covers. Separate measurements shall be taken in each of the three axes. The Buyer reserves the right to conduct an independent shock test.

7.0 INSPECTION

7.1 The inspections called for in Attachment C shall be performed by the Vendor.

7.2 Also, each valve shall be inspected for cleanliness by black light and RGA prior to shipment. Valves shall be recleaned if any contamination is found. Partial pressures of hydrocarbons greater than 2.0×10^{-10} Torr for any species shall be cause for rejection.

7.3 All valves shall be inspected for dimensional conformance to approved assembly drawings.

8.0 WARRANTY

Refer to Specification V049-2-034, Purchased Equipment Commercial Requirements (attached to the Request for Quotation), for warranty requirements.

SPECIFICATION FOR

6", 10" AND 14" GATE VALVES

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY: Thomas M. Starr

QUALITY ASSURANCE: A.R. Bradbrook

TECHNICAL DIRECTOR: D. C. McWilliams

PROJECT MANAGER: Richard Bayley

2	SM 10/21/96	DMcW 10-22-96	REVISED PER DEO 0316
1	TMS 2-22-96	D. McW	REVISED FOR PURCHASE PER DEO 0070
0	TMS 11-2-95	DMcW 11-3-95	REVISED AND RELEASED FOR QUOTATION AND APPROVAL / DEO 0011
REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION	
INITIAL APPROVALS	PREPARED	DATE	APPROVED	DATE	Number V049-2-006	Rev.
	T. Starr	11-2-95	D. McW	11-3-95	A	2

SPECIFICATION TABLE OF CONTENTS

1.0 SCOPE

This specification covers the minimum requirements for the design, materials, fabrication, assembly, inspection, testing, preparation for shipping, shipment and delivery of 6", 10" and 14" gate valves for the LIGO vacuum system.

All attachments are incorporated herein by reference and made a part of this specification.

The specified equipment is for use as part of the Vacuum Equipment supplied for the Laser Interferometer Gravitational-Wave Observatory (LIGO). LIGO, which is operated by Caltech and MIT under an NSF grant, includes two sites (Hanford Reservation, near Richland, WA and Livingston, LA). Each site contains laser interferometers in an L shape with 4 km arms, a vacuum system for the sensitive interferometer components and optical beams, and other support facilities.

Information contained in this specification and its attachments is proprietary in nature and shall be kept confidential. It shall be used only as required to respond to the specification requirements, and shall not be disclosed to any other party.

2.0 SCHEDULE

2.1 Equipment delivery shall be as per the purchase order.

		Quantity
Valve Usage:		1
Washington Site:		
	6"	4
	10"	16
	14"	12
Louisiana Site:		
	6"	3
	10"	9
	14"	6
Total Required		
	6"	7
	10"	25
	14"	18

2.2 Acceptances at the sites are expected to occur on a staggered basis, with final acceptance at Washington expected to occur about May 31, 1998, and about November 30, 1998 in Louisiana.

3.0 EQUIPMENT REQUIREMENTS

The 6", 10" and 14" gate valves (mating to 8" OD, 12" OD and 16 1/2" OD CF flanges, respectively) are used to isolate chamber vacuum roughing pump ports.

4.0 DESIGN REQUIREMENTS

4.1 Gate valves shall be stainless steel (304L or 316L) with CF flanges (see 3.0, above), and SS metal bellows stem feedthroughs, and shall be designed to seal in both directions.

4.2 Only non-contaminating and non-migratory lubrication shall be used on the internal mechanisms.

4.3 Valve body and flange total leakage shall be measured to be less than 10^{-10} torr liter/sec *of helium before shipment.*

4.4 Gate seal leakage shall be less than 1x 10^{-9} torr liter/sec of helium.

4.5 Gate seals shall be nonlubricated, prebaked Viton (DuPont Type E60C, Type A500 or Type V75, or Buyer-accepted equal).

4.6 Valves of the same size and type shall be identical to minimize the number of required spare parts. Valves shall be rated for 10,000 cycles before service is required.

4.7 Valves shall be manually actuated by a handwheel.

Valves shall have a visible position indicator showing the location of the valve gate relative to the fully open and fully closed positions.

Valves shall be marked with "open" and "close" handwheel rotation arrows.

4.8 Gate valves shall have a positive, padlockable device to prevent opening or closing.

4.9 The valves are exempted form the acoustic noise and vibration requirements of paragraph 5.1.4 and 5.1.5 of Attachment B of this specification.

4.10 Valve actuation shall induce no more than 0.01g peak-to-peak acceleration (shock) at any point on the valve mounting flanges.

4.11 Valves shall be bakeable to 150 C +/-20 C (170 C maximum).

4.12 6" and 10" valves shall be provided with limit switches for the fully open and fully closed positions.

4.13 Final assembly and cleaning of valves shall take place in a Federal Standard 209 Class 100 cleanroom environment.

4.14 Each 14" valve shall be equipped with a 1 1/2" connection on the housing to allow rough pumping of the isolated equipment. This connection shall have a 2 3/4" CF flange with a blind, and shall be located so as to permit connection of an angle valve and pumping line.

4.15 Each 14" valve shall be sufficiently strong or reinforced to be able to be operated when installed in the horizontal position with a static load of 1,500 pounds immediately above it.

4.16 Valves shall be supplied with suitable lifting lugs or eyes for handling during installation or maintenance operations.

4.17. Valves shall be supplied with removable studs made of a non-galling material such as silicon bronze or silver plated stainless steel. Studs shall have U.S. standard threads and be of an appropriate length for mating flange installation.

5.0 REQUIRED DOCUMENTATION

In addition to the documentation listed in Attachment A, the following documentation shall be provided prior to shipment:

- Leak test procedure and report (including data).
- Shock test procedure and report (including data).
- Manufacturer's standard QA reports (including final functional test reports)

6.0 SHOP TESTING

6.1 Each valve shall be tested for leakage (using oil-free pumping equipment and leak detector) prior to shipment from the manufacturer. An RGA with calibrated leak shall be used in performing the leak testing.

6.2 One valve of each size shall be tested for shock. The valve shall be tested in the vertical position resting on a pad that deflects at least 0.1" under the static load of the valve, so as not to simulate a "hard mount". Testing shall be done both at atmospheric pressure and with the valve under vacuum. An accelerometer shall be mounted near a connecting flange on the valve housing or near the edge of one of the flange covers. Separate measurements shall be taken in each of the three axes. The Buyer reserves the right to conduct an independent shock test.

7.0 INSPECTION

The inspections called for in Attachment A shall be performed by the Vendor. Also, each valve shall be inspected for cleanliness by black light and RGA prior to shipment. Valves shall be recleaned if any contamination is found.

8.0 WARRANTY

Refer to Specification V049-2-034, Purchased Equipment Commercial Requirements (attached to the Request for Quotation), for warranty requirements.

ATTACHMENT "A"
LIGO QUALITY ASSURANCE REQUIREMENTS SUMMARY

LIGO VACUUM EQUIPMENT	VENDOR:	JOB NO.: V59049
EQUIPMENT: 10" and 14" GATE VALVES	VENDOR ENG. OFFICE:	DWG. NO.:
PSI P.O. NO:	VENDOR FACTORY:	SPEC NO.: V049-2-006

TESTING INSPECTION AND DOCUMENTATION RECORD	Submittal After P.O.	Witnessed by PSI	Approval by PSI	Copies Req'd for PSI Files	Record in Mfr's File	Remarks:	Inspector: Date:
MILESTONE SCHEDULE			X	2	X		
VENDOR Q.A. PLAN			X	2	X		
CLEANING PROCEDURE			X	2	X		
PREP FOR SHIPMENT PROCEDURE			X	2	X		
WELDING PROCEDURES			X	2	X		
ASSEMBLY DRAWINGS			X	2	X		
DESIGN REVIEW		X			X		
CERTIFIED MATERIAL TEST REPORTS				2	X		
IN-PROCESS INSPECTIONS		X		2	X		
OPERATION & MAINTENANCE MANUALS				5	X		
SHOP TEST PLAN			X	2	X		
SHOP TEST (WITH REPORT)		X		2	X		

SPECIFICATION FOR

VACUUM GAUGES

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY: Thomas M. Stan

QUALITY ASSURANCE: Alan L. Bradbook

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: Richard Bagley

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
1	FAB 7-31-96	D.M.W. AEB	RELEASED FOR PURCHASE PER DEO # 0234
O	SJC 1-31-96	D.M.W.	RELEASE FOR QUOTATION PER DEO 0055
P1	10-19-95		Released per DEO 0005
P1	TMS 9-26-95		REVISED FOR UPDATED PRELIMINARY DESIGN

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION	
INITIAL APPROVALS	PREPARED	DATE	APPROVED	DATE	Number V049-2-007	Rev.
	T. Stan	6-14-95	REB	9/26/95	A	1

TABLE OF CONTENTS

1.0 SCOPE

This specification covers the minimum requirements for the design, materials, fabrication, assembly, inspection, testing, preparation for shipping, and shipment of the vacuum gauges for the LIGO vacuum system. Gauges are arranged in pairs, with each pair consisting of a Pirani gauge and a cold cathode gauge.

All attachments are part of this specification.

The specified equipment is intended for use as part of the Vacuum Equipment supplied for the Laser Interferometer Gravitational-Wave Observatory (LIGO). LIGO, which is operated by Caltech and MIT under an NSF contract, includes two installations at widely separated sites: near Hanford, WA and Livingston, LA. Each installation contains laser interferometers in an L shape with 4 km arms, a vacuum system for the sensitive interferometer components and optical beams, and other support facilities.

Information contained in this specification and its attachments is proprietary in nature and shall be kept confidential. It shall be used only as required to respond to the specification requirements, and shall not be disclosed to any other party.

2.0 SCHEDULE FORMAT

2.1 Equipment delivery shall be as follows:

Destination	Quantity	Mfg. Release Date	Delivery Date	Description
Washington Site:	24	4/28/97	9/1/97	Vacuum gauge pair, mounted on 2 3/4" CF Flange, 2 3/4" tee mounting (include gasket, bolts and any needed accessories).
	1	4/28/97	9/1/97	Spare Vacuum Gauge Pair
Louisiana Site:	13	10/26/97	3/1/98	Vacuum gauge pair, mounted on 2 3/4" CF Flange, 2 3/4" tee mounting (include gasket, bolts and any needed accessories).
	1	10/26/97	3/1/98	Spare Vacuum Gauge Pair
Total Required	39			

2.2 It may be required to ship several of the above items to the Buyer directly (Westboro, Massachusetts).

2.3 Acceptances at the sites (the start of Vendor's warranty periods) are expected to occur on a staggered basis, with final acceptance at Washington expected to occur no later than May 31, 1998, and no later than November 30, 1998 in Louisiana. Portions of the equipment will be accepted earlier.

3.0 EQUIPMENT REQUIREMENTS

3.1 General

3.1.1 The vacuum gauges shall be provided in pairs consisting of one Pirani gauge and one cold cathode gauge to cover the pressure range from atmospheric down to 1×10^{-9} torr (nitrogen equivalent).

3.1.2 Gauges shall have local transmitters which shall be removable for bakeout.

3.2 Pirani Gauges

Pirani gauges shall operate from atmosphere to 10^{-4} torr.

3.3 Cold Cathode -Gauges

Cold cathode gauges shall operate from 1×10^{-3} torr to 1×10^{-9} torr.

4.0 DESIGN REQUIREMENTS

4.1 Mechanical Requirements

4.1.1 The gauges shall be supplied mounted on 2 3/4" OD CF flanges on a piping tee for installation by others on the chambers.

4.1.2 Gauges shall be bakeable (if necessary to remove electronics, state max. bakeout temp. with electronics). To:

Pirani Gauges	275^0 C
Cold Cathode Gauges	275^0 C

4.2 Electrical Requirements

4.2.1 Instrumentation Requirements

Connectors for the gauges shall have locking, positive contact to the mating vacuum feedthrough, properly shielding the high voltage and signal connectors, and providing proper strain relief.

4.2.2 Controls Requirements

The transmitters shall operate on 24 VDC power and have analog outputs of 0-10 VDC and an adjustable setpoint switch contact. (Please state power requirements)

5.0 REQUIRED DOCUMENTATION

Documentation requirements listed in Attachment A shall be provided according to the Buyer's schedule (schedule later):

6.0 SHOP TESTING

The Vendor shall perform his standard tests.

7.0 INSPECTION

The inspections called for in Attachment A shall be performed by the Vendor:

8.0 WARRANTY

Refer to Attachment A, Section 15.0, and to Attachment B, General Provisions, Article 40 for warranty requirements.

ATTACHMENT "A"

LIGO QUALITY ASSURANCE REQUIREMENTS SUMMARY

LIGO VACUUM EQUIPMENT	VENDOR:	JOB NO.: V59049
EQUIPMENT: VACUUM GAUGES	VENDOR ENG. OFFICE:	DWG. NO.:
PSI P.O. NO:	VENDOR FACTORY:	SPEC NO.: V049-2-007

TESTING INSPECTION AND DOCUMENTATION RECORD	Submittal After P.O.	Witnessed by PSI	Approval by PSI	Copies Req'd for PSI Files	Record in Mfr's File	Remarks:	Inspector: Date:
MILESTONE SCHEDULE			X	2	X		
VENDOR Q.A. PLAN			X	2	X		
ASSEMBLY DRAWINGS			X	2	X		
OPERATION & MAINTENANCE MANUALS				4	X		
SHOP TEST PLAN			X	2	X		
SHOP TEST (WITH REPORT)		X		2	X		

Title: SPECIFICATION FOR BAKEOUT SYSTEM

SPECIFICATION FOR

BAKEOUT BLANKET SYSTEM

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY: [signature]

QUALITY ASSURANCE: [signature]

TECHNICAL DIRECTOR: D. C. McWilliams

PROJECT MANAGER: [signature]

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
4	GW 10/2/96	RES 10/9/96	RELEASE FOR PURCHASE (PER DEO # 0288)
3	DP 6/28/96	D. McW	RELEASE FOR RFQ (PER DEO # 0198)
2	FAB 5-2-96	D.McW 5-2-96	RELEASE FOR FDR (PER DEO # 0164)
1	4-5-96	4-5-96	RELEASE FOR INFO (PER DEO # 0111)
0	2-27-96	2-28-96	RELEASE FOR PURCHASE (PER DEO # 0073)
P2	1-15-96	1-15-96	RELEASE FOR QUOTE (BSC-PROTOTYPE ONLY)

PROCESS SYSTEMS INTERNATIONAL, INC.					SPECIFICATION	
INITIAL APPROVALS	PREPARED	DATE	APPROVED	DATE	Number V049-2-009	Rev.
	F. Bach	1-15-96	D. McW	1-15-96		4

SPECIFICATION TABLE OF CONTENTS

Attachment A	LIGO Quality Assurance Req'ts Summary
Attachment B (General Equipment Requirements)	V049-2-033, Rev. 2
Attachment C	Isolatable Bakeout Section - Drawings
Attachment D	Equipment Drawings
Attachment E	V049-2-019, Sheets 1 & 2, Rev. 1 (Heater Bakeout System - Power and TC Cable Connectors)

1.0 SCOPE

1.1 General Information

1.1.1 This specification covers the minimum requirements for the design, materials, fabrication, assembly, inspection, testing, preparation for shipping, and shipment of the bakeout blanket system for the LIGO vacuum system.

1.1.2 All attachments are part of this specification.

1.1.3 The specified equipment is intended for use as part of the Vacuum Equipment supplied for the Laser Interferometer Gravitational-Wave Observatory (LIGO). LIGO, which is operated by Caltech and MIT under an NSF contract, includes two installations at widely separated sites: near Hanford, WA and Livingston, LA. Each installation contains laser interferometers in an L shape with 4 km arms, a vacuum system for the sensitive interferometer components and optical beams, and other support facilities.

1.1.4 AutoCAD R12 electronic files of V049-4-series of drawings will be available to Vendor for blanket design. Fabrication drawings for all of the LIGO Vacuum Equipment components requiring bakeout will be sent to Vendor as they become available.

1.1.5 Information contained in this specification and its attachments is proprietary in nature and shall be kept confidential. It shall be used only as required to respond to the specification requirements, and shall not be disclosed to any other party.

1.2 Heating Blankets

1.2.1 Furnish a system of reusable heating blankets that consists of enough blankets to bakeout the largest isolatable section of vacuum equipment (An isolatable section is a section of vacuum equipment that is closed off by one or more 44" or 48" gate valve, e.g. Vertex section corner station). Only one isolatable section will be baked out at the same time as indicated on each drawing of Attachment C.

These blankets should be also designed to be reusable on any of the remaining isolatable sections as equipment configuration permits. Equipment configuration shape may necessitate additional blankets if some blankets from the largest isolatable section cannot be reused on the other isolatable sections.

1.2.3 Portion of supports (legs) near equipment attachment require heating blankets.

Support Leg Blankets: Blankets for support legs need only be heated from the outside surface, that is there is no need to have a heating surface on the inside of the square tube. For supports which have a complex shape, such as the saddle legs on the HAM chamber, a boxed blanket configuration is adequate, that is the blanket need not follow the shape of the support.

1.2.4 Tubing that connects to the vacuum equipment requires heating blanket coverage up to and including the isolation valve.

Back to air line including the angle valve
10" pumpout port including 10 inch gate valve
6" pumpout port including 6 inch gate valve
14" port including 14" gate valve and ion pump

Annulus tubing: the annulus tubing require only insulation from the connection at the large flange for over a length of approximately 12 inches.

The largest isolatable section will (have) require blankets for:
4 main ion pumps _ 4 gate valves - 14 inch
One 6" Port + 6" gate valve
One 10" Port + 10" gate valve
One Back to air connection + isolation valve

The other isolatable sections will have less than 4 main ion pumps, one 6" port, one 10" port and one back to air connect.

1.2.5 At annulus piping, brackets, and thermocouple access patches, furnish insulation similar in construction to heating blankets, but non-heating.

1.3 Heating Blanket Controls

The Buyer will furnish equipment to control a separate 277V circuit to each blanket and to monitor the blanket's temperature.

2.0 SCHEDULE

2.1 Furnish bakeout blanket sets as listed on Attachment D and deliver to PSI (Westborough, MA).

2.2 Acceptances at the sites (the start of Vendor's warranty periods) are expected to occur on a staggered basis, with final acceptance expected to occur no later than May 31, 1998. Portions of the equipment may be accepted earlier.

3.0 EQUIPMENT AND BAKEOUT REQUIREMENTS

3.1 General Blanket Requirements

The bakeout (heating) system is used for initial conditioning of the LIGO vacuum vessels and components, and for periodic reconditioning. The blankets will be used to heat the system to 150°C $\pm$ 20°C @ a rate of 1.8°C/hr. For design purposes, the blankets shall be capable of heating the vessels and components to 200°C in 48 hours except to 250°C at gauge pairs. The blanket control system shall be capable of ramping the setpoint temperature to a desired target temperature at a desired rate, and maintain the target temperature +/-20°C for all vessel or component surfaces.

The Buyer will furnish the programmable blanket controls, power distribution with overload protection, and interconnecting cables.

3.2 Gauge Pair Blanket

Each gauge pair heating jacket shall be an independent controlled heating zone and shall be capable of heating the gauge pair to 250°C in 48 hours. Gauge pairs consists of a Convectron and cold cathode gauge mounted on a 1.5" TEE with 2-3/4" Conflat flange fittings. Two thermocouples shall be furnished to monitor temperature on each gauge surface. The approximate dimensions of a gauge pair assembly are 12" x 6" x 12".

3.3 Equipment Support Legs

To maintain temperature at the vessel wall, where the supports attach the to vessel, heater blankets are required at the support legs. These heater blankets shall partially or fully cover the legs depending on length and power density of the heating blanket. The vendor shall furnish adequate power density and blanket coverage of the support legs. Tradeoff can be made between power density and coverage requirements. The support legs are made of carbon steel.

The following are estimated power densities and coverage requirements. Less blanket coverage at the support leg may be furnished if a higher power density is used to maintain the required bakeout temperature of the vacuum equipment. Further dimensional details are given in the Attachment D drawings.

Component	Estimated Minimum Power Density	Blanket Coverage	Support Leg Dimensions
BSC Support Legs	600 W/m^2	Fully	8"X8" X 0.63" Tube x 48" Tall
HAM Saddles	3500 W/m^2	Fully	66" x 0.5" x 14" Tall At Valley x 28" Tall At Edges
Mode Cleaner Tube Support Legs	600 W/m^2	Partially (48")	2" x 3" x 0.13" Tube x 70" Tall
72" Dia Beam Manifold Support Legs	600 W/m^2	Partially (48")	4"x 2" x 0.31" Tube x 75" Tall
48"/44" Gate Valve Support Legs	600 W/m^2	Partially (48")	I Beam 4" x 4" x 0.25" x 36" Tall
Cryopump Support Legs	600 W/m^2	Partially (48")	4" x 4" x 0.5" Tube x 70" Tall
48" Dia Spool Support Legs	600 W/m^2	Partially (48")	4" x 4" x 0.5" Tube x 70" Tall

3.4 Vacuum Equipment Adjacent to The Isolatable Bakeout Section

When one isolatable section is being baked, the spool piece on the other side of 48" gate valve needs to be heated to maintain the bakeout temperature of the gate valve . The required power density for a blanket length of 0.3m is 1700 W/m^2. For spool pieces adjacent to gate valves that are longer than 0.3m, at least 0.3m minimum length of the spool shall have blanket coverage at a power density of 1700 W/m^2, or a tradeoff can be made for a longer blanket section at a lower power density but in any case sufficient to keep the gate at 150°C.

Spool Piece	Power Density W/M^2	Minimum Length With Higher Power Density Heater
WA-15A	1700	0.3 m (Entire spool)
WA-15B	1700	0.3 m (Entire spool)
B-6 or B-7	1700	0.3 m
B-4B or B-4A	1700	0.3 m
WA-3A	1700	0.3 m
WA-3B	1700	0.3 m

4.0 GENERAL EQUIPMENT REQUIREMENTS

4.1 Disregard parts of Attachment "B" (Specification # V049-2-033) not applicable to this work.

5.0 DESIGN REQUIREMENTS

5.1 Mechanical Requirements

5.1.1 Bakeout blanket sets shall be based on Attachment D equipment drawings. Blankets shall be of durable construction, designed to be installed, removed and reinstalled on the vessels without degradation.

5.1.2 Blankets shall be constructed to be non-shedding and suitable for installation, removal and storage in a Fed. Std. 209 Class 50,000 cleanroom.

5.1.3 Insulation thickness shall result in a cost-effective system design (2 inch min.). The Vendor shall indicate the design heat loss with this proposal. K thermal conductivity, Cp specific heat, and density data of the insulation shall be provided.

5.1.4 Components shall be identical to the maximum possible extent to minimize the number of required spare parts.

5.1.5 The size of each blanket shall be suitable for installing without the use of special equipment.

5.1.6 Each blanket shall be capable of being secured properly on the equipment in any position (horizontal, vertical) without sliding off its desired location and without gaps between blanket and surface being heated. The blankets shall accommodate equipment expansion caused by bakeout heating.

5.1.7 Provide blankets with flaps made of fiberglass fabric and Velcro, lacing ties or lacing hooks to interconnect blankets without gaps.

5.1.8 Provide blankets with strap loops and nylon straps to ensure that the individual heating blankets are held tight against the body being heated.

5.1.9 Non-heated patches are acceptable for thermocouple access opening and for annulus piping, brackets, lifting lugs and other appendages where thermal insulation is needed.

5.1.10 Each blanket shall be properly tagged with a permanent label identifying the blanket and noting its wattage and measured ohmic resistance. Locate labeling on the blanket outer cover near the power cable. Blanket identification shall match the bakeout blanket layout configuration as shown on Vendor's drawings. Tag numbering method shall be coordinated with PSI.

5.1.11 Each blanket shall have an approximate 3" x 5" removable patch to allow the installation of the thermocouples onto the metal surface. This patch shall be in the middle of the blanket.

5.1.12 Outer and inner blanket cover material shall be submitted to the customer for acceptance prior to fabrication. Outer jacket shall be the low emissivity type.

5.2 Electrical Requirements

5.2.1 Instrumentation Requirements

5.2.1.1 Each blanket shall have two thermocouples. Attach thermocouples to opposite sides of 3" x 5" blanket opening. Provide a type "J", #20 AWG stranded, shielded, 300 volts, 260°C Teflon insulated thermocouple cables with non-rusting braided jacket. Make one end of each cable 24" long and terminate with male connector as indicated on Attachment E drawing. Tag cables near connector with blanket number. Make other end of each cable 12" long with junction in ring type terminal and isolate cable shield from ring terminal as indicated on Attachment E drawing. As an option, quote ungrounded (electrically insulated from shield) thermocouple junction.

5.2.2 Controls Requirements

5.2.2.1 Controls for local operation will be furnished by the Buyer.

5.2.3 Power Requirements

5.2.3.1 The system shall be powered from 480Y/277V, grounded power system.

5.2.3.2 Each blanket shall be rated for a 277V source and shall have a 2-foot long (minimum) power cable terminated as indicated on Attachment E drawing. Locate emerging cable through eyelet at least 12" from 3" x 5" blanket opening and anchor cable to blanket cover. Power wiring shall be stranded copper, 600V, 260°C minimum. Power requirements shall not exceed 8 amps per blanket. Tag cable bear connector with blanket number.

5.2.3.3 The maximum power allotments at each isolatable section are as follows:

ISOLATABLE SECTIONS see Attachment C drawings	**MAX**
Vertex section (sheet 1)	180 kW
Left beam tube manifold section (sheet 2)	140kW
Right beam tube manifold section (sheet 3)	140kW
Diagonal section (sheet 4)	180 kW
Right mid station (sheet 5)	105kW
Left mid station (sheet 6)	105kW
Right end station (sheet 7)	70kW
Left end station (sheet 8)	70kW

6.0 REQUIRED DOCUMENTATION

In addition to the documentation listed in Attachment A & B, the following documentation shall be provided prior to manufacturing:

- Catalog data sheets or other published materials showing appearance, electrical ratings, and performance characteristics of blanket components.
- Blanket drawings detailing each blanket.
- Blanket heat transfer calculations.
- Blanket layout drawings for each bakeout configuration along with blanket identification (TAG number).
- Blanket tag number versus power consumption table.

7.0 SHOP TESTING

The Vendor shall submit standard testing procedures for acceptance. The Vendor shall test blankets and repair defective components. Submit test reports. The Buyer reserves the right to witness shop testing.

8.0 INSPECTION

The inspections called for in Attachment A & B shall be performed by the Vendor.

9.0 WARRANTY

Refer to V59049-2-034 (Commercial Requirements), General Provisions, for warranty requirements.

SPECIFICATION FOR

GENERAL EQUIPMENT REQUIREMENTS

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY: Thomas M. Stern

QUALITY ASSURANCE: Alan L Bradbrook AB

TECHNICAL DIRECTOR: D.A. McWilliams

PROJECT MANAGER: Richard Bagley

JAN 03 1996

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
2	AM 12/26/95		REVISED ATTACH. A PARA C.5.1 DEO 0034
1	TMS 11-9-95	D. McW 11-9-95	REVISED PER CUSTOMER COMMENTS/DEO 0014
0	TMS 10-14-95	D. McW 10-18-95	REVISED AND ISSUED FOR QUOTATION AND APPROVAL /DEO 0004

PROCESS SYSTEMS INTERNATIONAL, INC.					SPECIFICATION	
INITIAL APPROVALS	PREPARED: TMS	DATE: 10-26-95	APPROVED: RCB	DATE: 10/27/95	Number: V049-2-033 A	Rev. 2

SPECIFICATION TABLE OF CONTENTS

Number

Rev.

1.0 DEFINITIONS

1.1 The "Vendor" is defined as the successful bidder accepting responsibility for meeting all requirements of this specification.

1.2 The "Owner" is defined as the California Institute of Technology (Caltech) in partnership with the Massachusetts Institute of Technology (MIT), under a grant from the National Science Foundation.

1.3 The "Buyer" is defined as Process Systems International, Inc. (PSI).

1.4 The "sites" are located on the Hanford reservation near Richland, Washington and in Livingston, Louisiana.

2.0 DELETED

3.0 GENERAL REQUIREMENTS

3.1 The Vendor shall be responsible for coordination of all subsuppliers and for overall warranty and guarantees of all equipment, including their compatibility. The Vendor shall comply with all applicable referenced specifications and standards and invoke them on each subsupplier purchase order.

3.2 Equipment will be installed at Hanford (near Richland), Washington and in Livingston, Louisiana. Unless otherwise indicated, equipment shall be capable of continuous service in an indoor location with a controlled temperature of 23 ± 1.5 C and a relative humidity controlled at 40 ± 5%. The equipment will, however, be exposed to diurnal and seasonal ranges during shipment, construction and power loss. It shall, therefore, not be damaged by exposure to temperature in the range of -20 to +40 C, or a humidity of 100%.

3.3 The Buyer shall be notified at least 10 working days prior to the start of major fabrication, assembly or testing.

3.4 Non-escort privileges for Buyer, Owner, Government and Owner representatives to all areas of the facilities where the work is being performed shall be arranged. This will include access to fabrication, assembly, cleaning and test areas for the purpose of monitoring activities.

4.0 CODES AND STANDARDS

4.1 Priority of Codes and Standards

1. Codes
2. Standards
3. Data Sheets
4. This Specification

4.2 All conflicts shall be brought to the attention of PSI for a written resolution prior to award of a purchase order. If more than one document applies to a technical requirement, the more stringent requirement shall have precedence.

4.3 Applicable Codes and Standards:

American Society of Mechanical Engineers (ASME) Boiler and Pressure Vessel Code
- Pressure Vessels: Section VIII, Division 1
- Welding and Brazing Qualifications: Section IX

American National Standards Institute (ANSI)
- ANSI A58.1: ASCE Minimum Design loads for Buildings and Other Structures

International Standards Organization
- ISO Standard 2861: Flange Standards

Expansion Joint Manufacturers' Association (EJMA)
- EJMA Standards

Government Standards
- Building and safety codes: local, state and federal, including OSHA
  - Federal Standard 209 for Cleanrooms

5.0 DESIGN REQUIREMENTS

The construction of equipment shall be performed in the highest manner of workmanship using only new and unused top quality materials. The equipment shall be guaranteed against defects in design, materials and workmanship as required elsewhere in the Contract.

5.1 Mechanical Requirements

5.1.1 Equipment feet or mounting plates shall have machined surfaces. Shim stock used shall be stainless steel.

5.1.2 Each vacuum element greater than 12" in diameter shall be designed, fabricated and tested in accordance with the latest edition of the ASME B&PV Code, Section VIII, Division 1, and subsequent addenda (except as noted under section 8.0, Welding), even though vacuum chambers lie outside of the scope of that document..

5.1.3 Bolt holes in flanges shall straddle natural centerlines.

5.1.4 Reasonable measures shall be taken to minimize noise. The goal is for acoustic noise to not exceed NC-15 when measured at any point within 1' of the equipment.

5.1.5 Reasonable measures shall be taken to minimize vibration. The goal is for the vibration of any item of equipment not to induce motion of the walls of any vacuum chamber or of the facility floor within 1 meter of any chamber which exceeds the following spectral density limits:

Frequency Band, Hz	Vibration Limit, m/√Hz
0.1 - 10	3×10^{-11}
10 - 1000	$3 \times 10^{-9} \times (1/f)^2$
1000 - 10000	3×10^{-15}

The above limits apply when all simultaneously operating equipment is running, and in the absence of vibration from other sources. Limited narrow band exceptions may be permitted, subject to Buyer's acceptance. Compliance with this requirement may be demonstrated by any combination of measurements and analysis, subject to Buyer's acceptance.

5.1.6 ANSI Standard A58.1 shall be applied to determine the probability of earthquakes and seismic coefficients at the two sites.

5.1.7 No equipment shall emit or harbor particulates at a level inconsistent with maintenance of a clean environment conforming to Federal Standard 209 Class 50,000.

5.1.8 The equipment shall be designed for a minimum serviceable life of 20 years.

5.1.9 Exposure of the equipment to ambient conditions during construction, power failure or control failure shall not result in damage.

5.1.10 Separable parts shall be fully interchangeable between assemblies.

5.1.11 Adequate clearance shall be provided for assembly of mating flanges and for handles. External access shall be provided to all vacuum seams for leak checking.

5.1.12 Elements heavier than 50 pounds shall have lifting lugs installed.

5.1.13 Vendor shall specify all bolt torque requirements in the equipment operating and maintenance manual.

5.2 Electrical Requirements

5.2.1 General Electrical Requirements

5.2.1.1 Electrical equipment and wiring shall conform to the National Electric Code.

5.2.1.2 All electrical equipment shall meet commercial standards for EMI (see Attachment A).

5.2.1.3 Electrical equipment shall meet the acoustic noise and vibration requriements of Sections 5.1.4 and 5.1.5, above.

5.2.1.4 See Attachment A for other electrical requirements.

5.2.2 Instrumentation Requirements

5.2.2.1 Instrumentation shall be of industrial quality and shall be subject to the acceptance of the Buyer.

5.2.2.2 Vibration monitoring is <u>not</u> a requirement of this specification.

5.2.2.3 Unless otherwise indicated, analog instrument signals shall be 4-20 ma or 0-10 VDC.

5.2.3 Controls Requirements

Control signals shall be 24 VDC.

5.2.4 Power Requirements

5.2.4.1 Motors shall comply with the Vendor's standard specifications, unless otherwise required by this specification. The minimum service factor of motors shall be 1.15. Motors shall be sized so that they can start and accelerate their loads to design speed at 90% voltage, and shall be energy efficient, if required by local or state codes.

5.2.4.2 Motors less than 3/4 HP shall be 120 VAC, 1 phase, 60 Hz. Those 3/4 HP to 200 HP shall be 460 VAC, 3 phase, 60 Hz.

6.0 MATERIALS

6.1 Materials used for pressure or vacuum retaining parts, nuts, bolts and studs shall be new. Where practicable, materials shall be of US origin; where not, materials from Canada, the European Community or Japan may be used. The Vendor's quotation shall identify the country of origin and how he intends to establish material traceability and conformance of composition and properties to applicable codes.

6.2 Copies of mill test reports of chamber and flange materials shall be furnished. Other nozzles, small parts, small flange nozzles, and bolting materials shall be furnished with a Certificate of Compliance.

6.3 Fabricated components exposed to vacuum shall be made from type 304L or 316L stainless steel using low carbon weld filler wire, where required. Standard catalog items of 304 or 316 stainless steel are acceptable if not available in 304L or 316L. Copper, aluminum and prebaked Viton (Dupont Type E-60C, manufactured by Parker or Buyer-accepted equal) must be used for seals. Vacuum feedthroughs must utilize UHV compatible glass or ceramic. All other materials are subject to Buyer's acceptance.

6.4 Vacuum surfaces shall not be allowed to come into contact with carbon steel or oil, including during forming, handling or manufacture. Machining fluids shall be water soluble and free of oil and sulfur.

6.5 When manufacturing materials are marked for material identification or traceability, marking shall be done on the outside, and not on surfaces that will be exposed to vacuum.

7.0 UTILITIES

The following utilities are available. The vendor shall state in his proposal the usage of each utility.

7.1 Electric Power

120 VAC, 1 phase, 60 Hz
480 VAC, 3 phase, 60 Hz or 208/120 VAC, 3 phase, 60 Hz

7.2 Instrument Air: 80 psig, -60 C Dew Point

7.3 Deleted.

8.0 WELDING

8.1 Welding exposed to vacuum shall be done by the gas tungsten arc inert gas (GTAW) process, with a 100% Argon shield and purged back gas.

8.2 Welding techniques shall deviate from the ASME Code in accordance with the best ultra high vacuum practice to eliminate any "virtual leaks" in the welds. Wherever practicable, welds shall be internal and continuous. External welds for structural purposes shall be intermittent to eliminate trapped volumes.

8.3 Defective welds shall be repaired by removal to sound metal and rewelding.

8.4 Vacuum weld procedures shall include steps to avoid contamination of the heat affected zone with air, hydrogen, hydrocarbons or water. This requires that inert purge gas, such as argon, be used to flood the vacuum side of heated portions. All vacuum surfaces and weld wire shall be cleaned prior to welding

8.5 The finished product shall be free of weld spatter, cutoff spatter, free iron, weld oxidation and defects. There shall be no grinding or abrasion of completed welds or internal vacuum surfaces. Completed welds shall only be cleaned with SS wire brushes that have not previously come in contact with carbon steel.

8.6 All welding procedures, procedure qualifications and welders employed on this job shall be qualified in accordance with ASME Section IX, latest edition.

9.0 REQUIRED DOCUMENTATION

9.1 Drawings

9.1.1 Assembly drawings shall be submitted for the Buyer's review prior to fabrication. They shall include all pertinent design data and calculations, including design pressures and temperatures.

9.1.2 Drawing acceptance must be obtained from the Buyer prior to the start of fabrication. Drawing acceptance does not constitute acceptance of any errors or of any deviation from these specifications or any instructions relating to the work. The Vendor shall call attention to any such deviations by separate written notice. Unless specific written acceptance is obtained from the Buyer, deviations are not acceptable.

9.1.3 If changes are made to any drawing subsequent to acceptance, drawings shall be resubmitted with all changes clearly identified. "As-Built" drawings shall be submitted.

9.1.4 Drawings in AutoCad, Release 12.0 are preferred. All documents stored electronically (procedures and CAD drawings) shall be backed up daily and the back-up tape shall be stored in a fire-proof safe.

9.2 Mechanical Data

9.2.1 Dimensioned outline drawings (indicating weights and center of gravity). These shall be submitted with the Vendor's proposal.

9.2.2 Connection sizes and ratings, design and test pressures and temperatures.

9.2.3 Cross-section drawings of all seals identifying all seal parts and materials.

9.2.4 Allowable nozzle loads, if applicable.

9.2.5 All procedures to be utilized shall be submitted for acceptance prior to use. This includes welding, QA, cleaning, testing, welding, Heat Treating, leak testing, etc.

9.3 Electrical Data

9.3.1 Electrical schematics and wiring diagrams

9.3.2 Control logic documentation

9.3.3 Instrument data sheets

9.3.4 Motor data sheets

9.4 Acoustic Noise and Vibration (See Sections 5.1.4 and 5.1.5)

9.4.1 A plan describing how the Vendor will address the design issues associated with acoustic noise and vibration is to be submitted.

9.4.2 An analysis of the equipment's design dynamic characteristics (mass, center of gravity, isolator stiffness, transmissibility). The analysis shall support the Vendor's claim of meeting or not meeting the specification requirements. In the case that the requirements are not met, the Vendor shall show that all reasonable engineering attempts have been made to meet them, and the design will be subject to the Buyer's written acceptance prior to the start of manufacturing.

9.5 Test and QA Data

The following shall be submitted where applicable:

9.5.1 Manufacturer's Code Data Report

9.5.2 Nameplate facsimile

9.5.3 Hydrotest results (Deleted)

9.5.4 Performance and leak test procedures and results

9.5.5 Mill test reports and certificates of conformance per Section 6.2

9.6 Other Documentation

9.6.1 Schedule, including design, material procurement and fabrication activities

9.6.2 Priced spare parts list with recommended spares

9.6.3 Installation, Operation and Maintenance Manual, including drawings

9.6.4 A status report with updated schedule shall be submitted monthly

10.0 NAMEPLATES

10.1 Each separable part (except fasteners, seals and interchangeable, standard blank flanges) shall be permanently marked with a unique identification number in a location readily viewable.

10.2 Each item shall have a stainless steel nameplate (permanently attached if practical). Nameplates shall include the Vendor's standard data. Where provided, each motor shall also have a nameplate.

11.0 CLEANING AND PAINTING

11.1 Equipment internals shall be cleaned and free of all foreign materials.

11.2 External carbon steel surfaces shall be cleaned and painted. The Vendor's standard is acceptable if it meets specification requirements and is compatible with federal standard 209 class 50,000.

11.3 Surfaces exposed to vacuum shall be cleaned in accordance with procedures accepted by the Buyer prior to fabrication and installation. Surface recontamination during subsequent processes shall be prevented. Cleaning procedures for ultra high vacuum service shall be required.

11.4 Items shall be wrapped or sealed after cleaning to maintain cleanliness through handling, transportation and storage. Care shall be taken to minimize exposure to corrosive environments, such as those containing chloride compounds.

12.0 QUALITY ASSURANCE REQUIREMENTS

The responsibility for inspection and testing rests with the Vendor. However, the Buyer reserves the right to review equipment at any time during the fabrication to assure that the work performed is in accordance with this contract. The Vendor shall give the Buyer 10 working days notice prior to the start of major fabrication, assembly or testing so that his representative may witness these tests.

The vendor shall have implemented inspection system in effect at all times during this contract. The inspection system shall comply with the following:

Design Control And Change Control
Provide a system to control the issuance of documents and drawings including changes to the locations where the work is being performed. The system shall address both electronic files and hard copies.

Material Control
Provides system that controls materials from receipt through the finished product. This system shall assure that only accepted items are used and installed. Physical identification shall be used to the maximum extent possible.

Quality Planning (Traveler)
A system of shop travelers shall be established for all work in process. The traveler shall contain Hold/Witness points of the Vendor, the Buyer and the Owner. All planning documents shall be submitted to the buyer for acceptance prior to fabrication.

Receiving Inspection
Measures shall be established to inspect incoming materials to the applicable procurement documents. Status of materials shall be visible, by tagging or marking.

In-Process And Final Inspection
A system of inspection and test status shall be maintained using tags, markings, shop travelers, stamps or inspection records.

Control Of Special Process' And Testing
A system shall be established to assure that welding, heat treatment, cleaning and NDE are accomplished under controlled conditions, in accordance with written procedures, using qualified personnel, to the applicable codes and standards.

Calibration Of Measuring And Test Equipment
A system shall be established and documented to assure that tools, gages, instruments and other inspection, measuring, and testing equipment are of the proper range, type and accuracy. The above shall be controlled, calibrated, and certified against nationally known standards (NIST).

Control Of Non-Conformances
A system shall be established and documented to control items or services which do not conform to requirements. The system shall include appropriate procedures for identification, documentation, segregation, disposition and notification.

Documentation And Records
Sufficient records shall be prepared as work is performed to furnish documentary evidence of the quality of items and activities affecting quality.

13.0 PREPARATION FOR SHIPMENT

13.1 Items shall be completely drained and dried.

13.2 Bolted connections shall be made up before shipment.

13.3 Aluminum plate shipping covers shall be attached with bolts to flanged connections, and with suitable attachments to other connections.

13.4 Units shall be completely covered for protection against the ambient and weather conditions expected during transportation. Units shall be adequately protected for unsheltered storage at the sites.

13.5 The Vendor shall have a signed "Release for Shipment" form provided by the Buyer's Quality Assurance representative prior to full or partial shipment of product.

13.6 Shipping crates shall have the Buyer's purchase order number, Vendor's name and list of tag numbers or part numbers on the outside of each crate.

13.7 Surfaces that will see vacuum shall be further protected by, after final cleaning, sealing openings with oil-free heavy duty aluminum foil, attaching the nozzle cover and applying shrink wrapped plastic.

14.0 STARTUP ASSISTANCE

The services of a qualified startup assistant shall be provided on request of the Buyer or the Owner to provide operator training and startup assistance at the sites.

15.0 DELETED

Title

ATTACHMENT A

OTHER ELECTRICAL REQUIREMENTS

JAN 08 1996

Number

Rev.

1.0 DEFINITIONS

Indicated	Shown or noted.
Labeled	Approved by nationally recognized testing company.
Permitted	As by code, Contract Documents, or Buyer.
Provide	Furnish and assemble.
Buyer	Process Systems International (PSI)
Required	As by Contract Documents and/or applicable codes and standards.
Submittal	Information required to show that the proposed equipment meets project requirements.
Use	Provide material or equipment referenced.
Vendor	Successful bidder accepting responsibility for equipment fabrication.
Work	Material, equipment and fabrication and other requirements as established in the Contract Documents.
Wire (Verb)	Connect to equipment indicated and provide wiring required for connection.
Wiring	Conductors, raceways, and accessories as required for a complete installation.

2.0 EXCEPTIONS

If the Vendor cannot meet requirements established under this specification and its attachments, provide a list of deviations with your proposal. In the absence of a list of deviations, it shall be deemed that the Vendor's product is fully in compliance with this specification.

3.0 CODES AND STANDARDS

The assembly shall comply with applicable parts of latest editions of publications by the following organizations:

American National Standards Institute, Inc. (ANSI)

Code of Federal Regulations (CFR) Title 47, Part 15

Electrical Standards for Industrial Machinery (NFPA 79) unless otherwise indicated

Factory Mutual (FM)

Federal Communications Commission (FCC) Part 15

Institute of Electrical and Electronics Engineers (IEEE)

Insulated Cable Engineers Association (ICEA)

National Electric Code (NFPA 70)

National Electrical Manufacturers Association (NEMA)

Underwriter's Laboratories (UL) or equipment and installation standards by other nationally recognized testing companies

4.0 LABELED AND LISTED EQUIPMENT

Provide UL label (or that of other nationally recognized testing company) or listed components where such standards exist.

5.0 GENERAL ASSEMBLY REQUIREMENTS

5.1 Arrange and assemble components in accordance with their manufacturers' specifications.

5.2 Label components with the equipment designation as indicated using adhesive backed labels with 1/8" high lettering.

5.3 Label terminal strips as indicated using printed manufacturer's labels.

5.4 Where air-actuated valves require pilot solenoids, mount the solenoid valves on the air operated valves.

6.0 WIRING

Install wiring in raceways, wireways, or neatly tirewrapped wire bundles. Provide product data for all cables.

6.1 Power Wire

6.1.1 Provide #12 AWG or larger single, stranded copper conductors with Type THHN-THWN or MTW insulation rated 90 C, 600 volts.

6.1.2 Use black colored insulation, except green for equipment grounding conductors.

6.2 Control Wire (Discrete Signals)

6.2.1 120 VAC: Provide #14 AWG, stranded copper, multiconductor cable with Type THHN-THWN or MTW insulation rated 90 C, 600 volts.

6.2.2 24 VDC: provide #16 AWG stranded copper, twisted pairs, single or multipair cables rated 90 C and 300 volts.

6.2.3 Color code conductors as follows:

120 VAC—Line	Red
120 VAC—Neutral	White
24 VDC	Blue
External Source	Yellow
Ground	Green

6.2.4 Identify each single conductor at each end with wire number or designation. Use printed, sleeve type wire marker.

6.3 Instrument Wire (Analog Signals)

6.3.1 4-20 mA: Provide #16 AWG or larger, stranded copper, individually shielded twisted pairs, single or multipair cables rated 90 C, 300 volts unless otherwise indicated. Where practicable, install cables spaced at least 12 inches away from power and control wiring.

6.3.2 Provide shielded twisted pair cables with one black and one white conductor.

6.4 Thermocouple Wire

6.4.1 Provide #16 AWG solid thermocouple extension cable shielded, rated 105 C, 300 volts of type required.

6.4.2 Provide thermocouple extension wire in accordance ISA color coding standards.

6.5 Wire and Cable Installations

6.5.1 Identify each cable end with cable number or designation. Use printed sleeve wire marker.

6.5.2 Provide sufficient wire length to permit grouping and training the wires and cables. Where applicable, use self-locking nylon wire ties; cut off loose ends. Do not exceed manufacturer's wire bending radii. Do not allow wiring to bear against edges of enclosures. Replace wiring cut too short to meet installation requirements.

6.6 Wiring Terminations and Connectors

6.6.1 Control Wiring

6.6.1.1 To terminate #10 AWG and smaller conductors to buses, enclosures, and similar applications, provide compression (crimp) terminals.

6.6.1.2 To terminate #8 AWG and larger conductors, provide either compression (crimp) connectors using matching installing tool or mechanical screw type connectors.

6.6.1.3 Where more than one conductor requires termination, provide screw or pressure type insulated terminal blocks.

6.6.2 Instrument Wire

6.6.2.1 Use insulating sleeve to secure shielding at instrument end of cable. Clip shields to avoid protruding from insulating sleeve.

6.6.2.2 Coil, insulate, and label ends of spare conductors.

6.6.2.3 Remove insulation from ends of conductors using mechanical or electric heat type stripper.

6.7 Equipment Grounding

6.7.1 Bond motors, heaters, and other electrical equipment to skid base. Weld to diagonal corners of skid base a 4 by 6 by 1/2 inch steel plate with two 3/8"-16 tapped holes spaced two inches apart, or if steel base is at least 1/2 inch thick, tap holes directly into steel base.

6.7.2 Do not ground instrument shielding. Use insulating tape or heat shrink to secure shielding at instrument end of cable. Connect shielding at other end of cable to junction box terminal. (Shielding connects to a single ground reference point at Owner's controller or I/O rack.)

6.7.3 Completely remove paint, dirt, and corrosion down to bare metal where connectors, lugs, and other metal components are attached to mounting panels and enclosures to assure grounding continuity.

6.7.4 Where a grounding stud or existing panel mounting bolt is used, the Vendor may provide the grounding conductor with a ring-tongue terminal and a "star" type washer installed between the panel and terminal. Use hexagon nut to secure tightly.

7.0 FIELD CONNECTION BOXES

7.1 To facilitate field wiring, provide separate power, control, and instrument NEMA 4 or 12 type enclosures, unless otherwise required, with terminals and a minimum of 20 percent spare terminals.

7.2 Arrange surrounding work and location of boxes to permit box accessibility and to permit (bottom, sides, top, and rear) entrance of field conduits.

7.3 In power box, segregate voltage systems using barriers or separate boxes. Use box to terminate motors, heaters, and other branch circuits with #8 AWG and small wiring. PSI will field wire larger circuits directly to equipment junction boxes.

7.4 In instrument box, segregate temperature element wiring using barriers or separate boxes.

8.0 TESTING

It is the Vendor's responsibility to conduct the following tests without damage to equipment.

8.1 Wire Testing

8.1.1 Check point-to-point continuity of each conductor to ensure that wiring is intact and terminated at the proper place at both ends.

8.1.2 Verify wire connections are made in accordance with terminal wiring diagrams and schedules.

8.1.3 Deleted

8.1.4 All defective wiring shall be replaced and the unit retested.

8.2 Motors

8.2.1 Before connecting motor, measure motor winding resistance in accordance with manufacturer's recommendations.

8.3 Test each three-phase motor for proper rotary direction.

8.4 Submit a signed test report for each electrical test conductor.

9.0 Deleted

10.0 MOTOR DATA SHEETS

The attached motor data sheets shall be completed by the Vendor and submitted to the Buyer with the Vendor's proposal.

Title

MOTOR DATA SHEET - DESIGN PARAMETERS

ITEM	DESIGN PARAMETERS	MOTOR DATA	MOTOR DATA	MOTOR DATA	MOTOR DATA
1	Motor Identification (tag)				
2a	Volts				
2b	Phases				
2c	Hertz				
3	Synchronous RPMs				
4	Efficiency (premium/energy/norm)				
5	Service Factor				
6	Load Brake Horse Power				
7	Starting Torque				
8	Type Load (fan/pump/comp)				
9	Drive (belt/direct couple)				
10	Rotation (CW/CCW)				
11	Enclosure				
12	Mounting (horz/vert)				
12a	NEMA Type Flange				
12b	Vertical Trust (up/down)				
13	Indoor/Outdoor Use				
14	Space Heater, 120V (no/watts)				
15	Winding Temp Sensor (yes/no)				
16	Bearing Temp Sensor (yes/no)				

Number

Rev.

Title

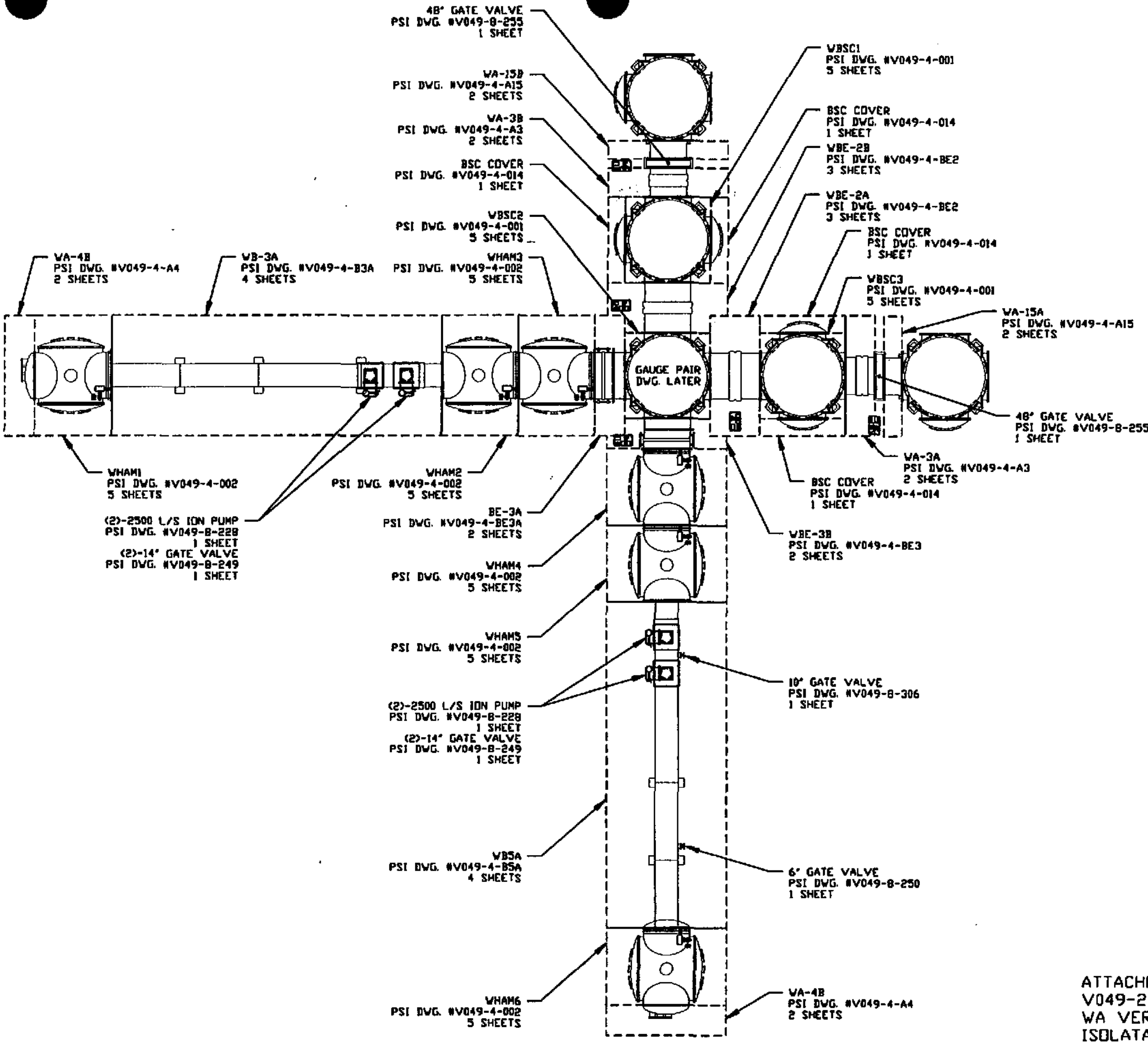
MOTOR DATA SHEET - MANUFACTURER'S NAMEPLATE

ITEM	MANUFACTURER'S NAMEPLATE	MOTOR DATA	MOTOR DATA	MOTOR DATA	MOTOR DATA
1	Motor Identification (tag)				
2a	Mfr:				
2b	Type				
2c	Frame Size				
3	Horsepower Output				
4	Time Rating (NEMA MG1-10.35)				
5	Max Ambient Temperature				
6	Insulation System				
7	RPM @ Rated Load				
8	Frequency				
90	Phases				
10	Rated Load Amps				
11	Voltage				
12	Locked Rotor Amps or NEMA Code Ltr				
13	NEMA Design Letter				
14	Efficiency				
15	Service Factor				
16	Thermal Protectors				

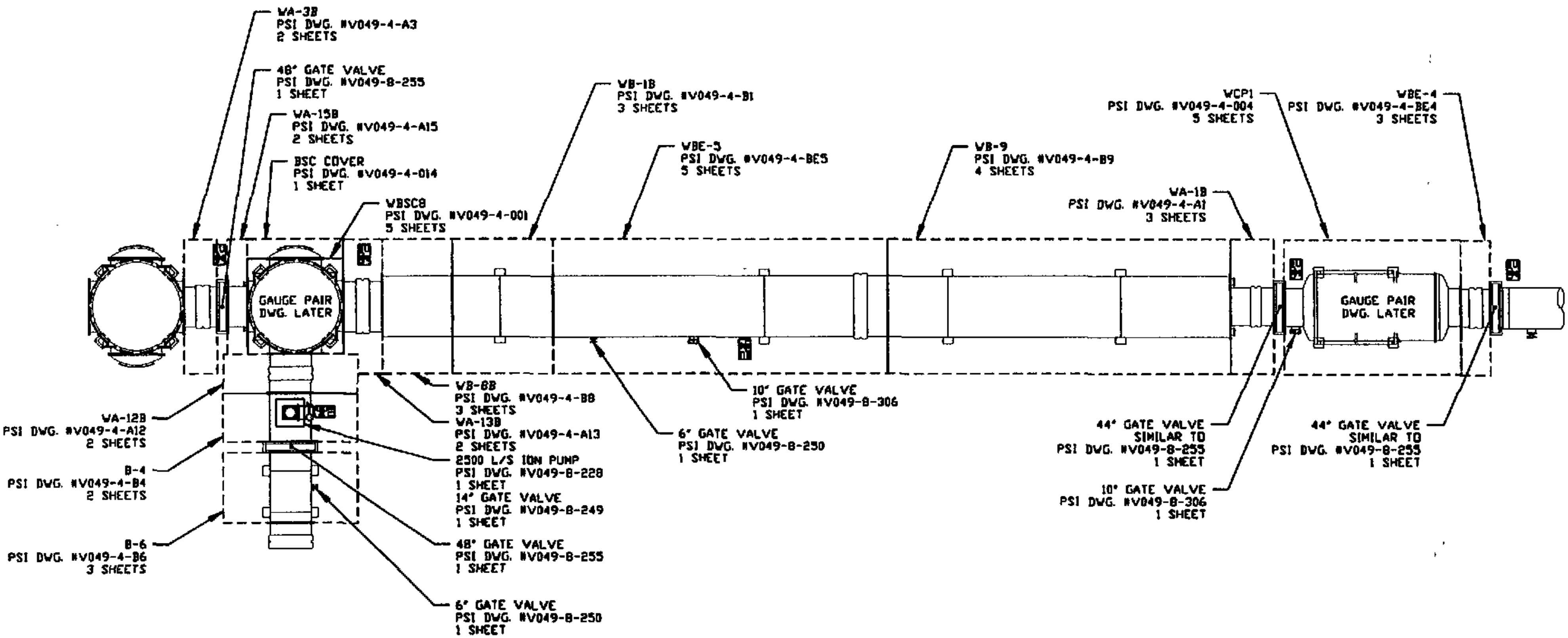
ITEM	MANUFACTURER'S DATA	MOTOR DATA	MOTOR DATA	MOTOR DATA	MOTOR DATA
1	Motor Identification (tag)				
2	Bearing Type				
3	Bearing Lub				
4	Efficiency @ Full Load				
5	Efficiency @ 3/4 Load				
6	Efficiency @ 1/2 Load				
7	Power Factor @ Full Load				
8	Power Factor @ 3/4 Load				
9	Power Factor @ 1/2 Load				
10	Space Heater Voltage				
11	Space Heater Watts				

Number

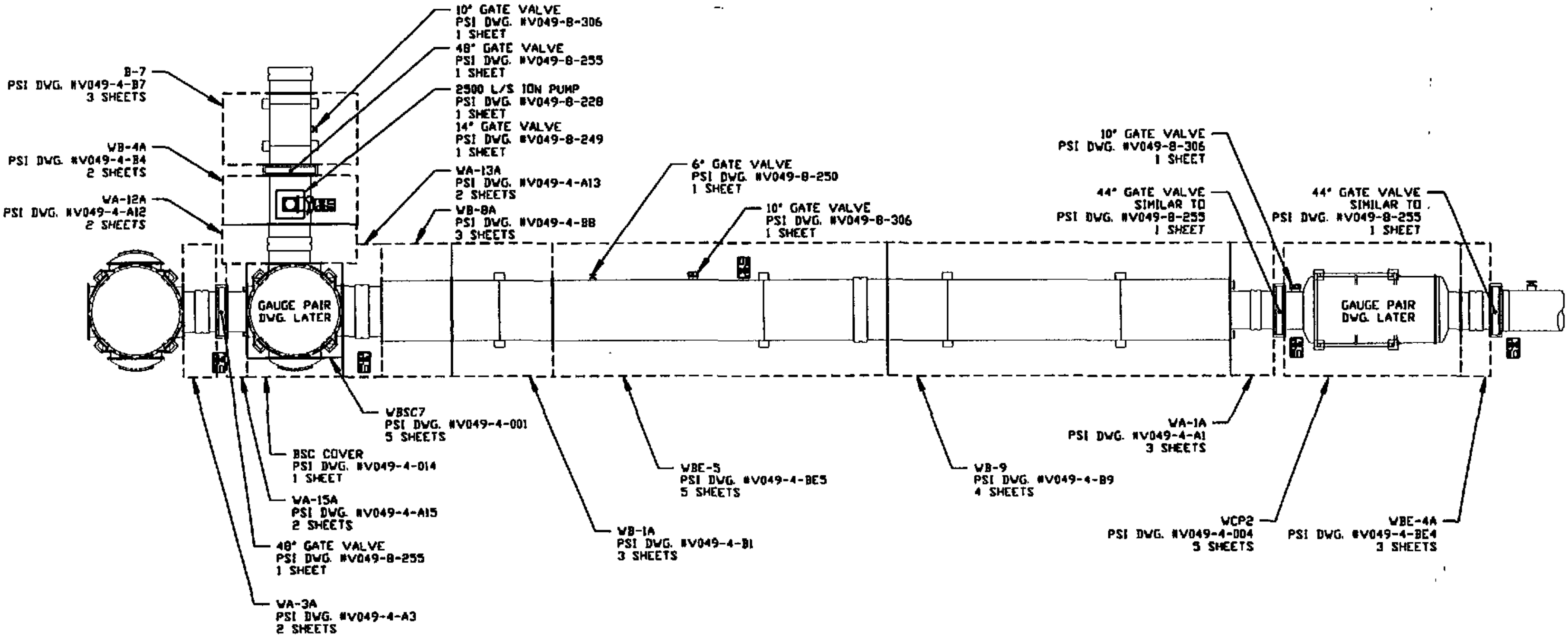
Rev.



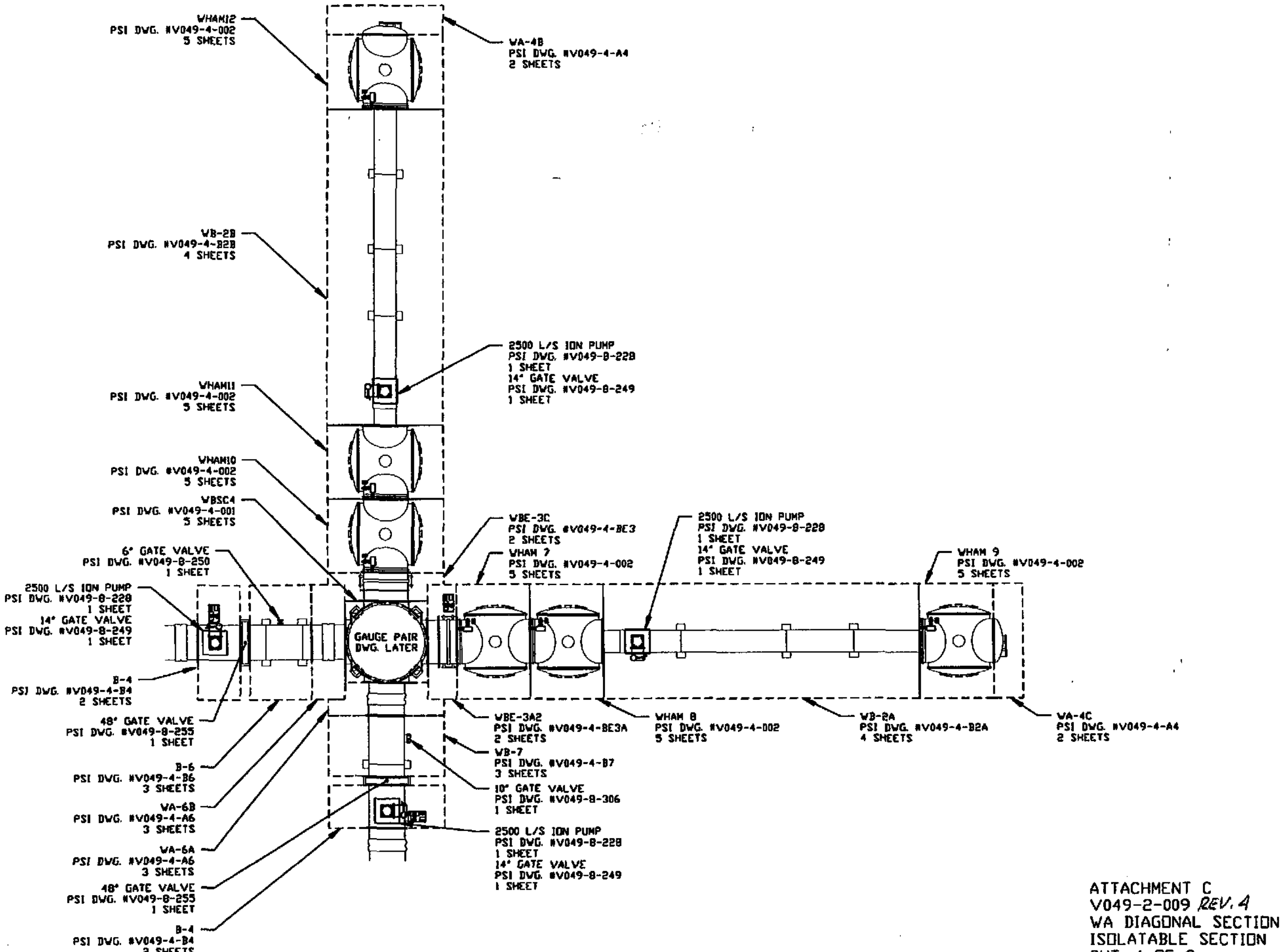
ATTACHMENT C
V049-2-009 REV. 4
WA VERTEX SECTION
ISOLATABLE SECTION
SHT. 1 OF 8



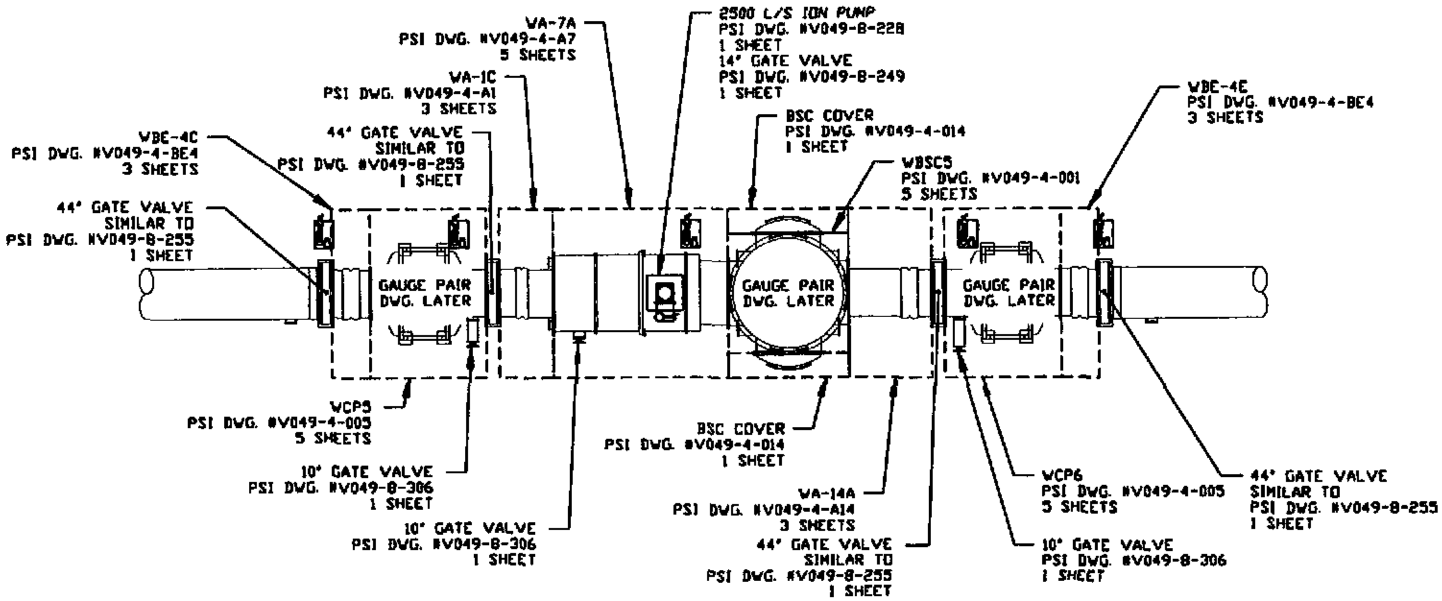
ATTACHMENT C
V049-2-009 *REV. 4*
WA LEFT BEAM MANIFOLD
ISOLATABLE SECTION
SHT. 2 OF 8



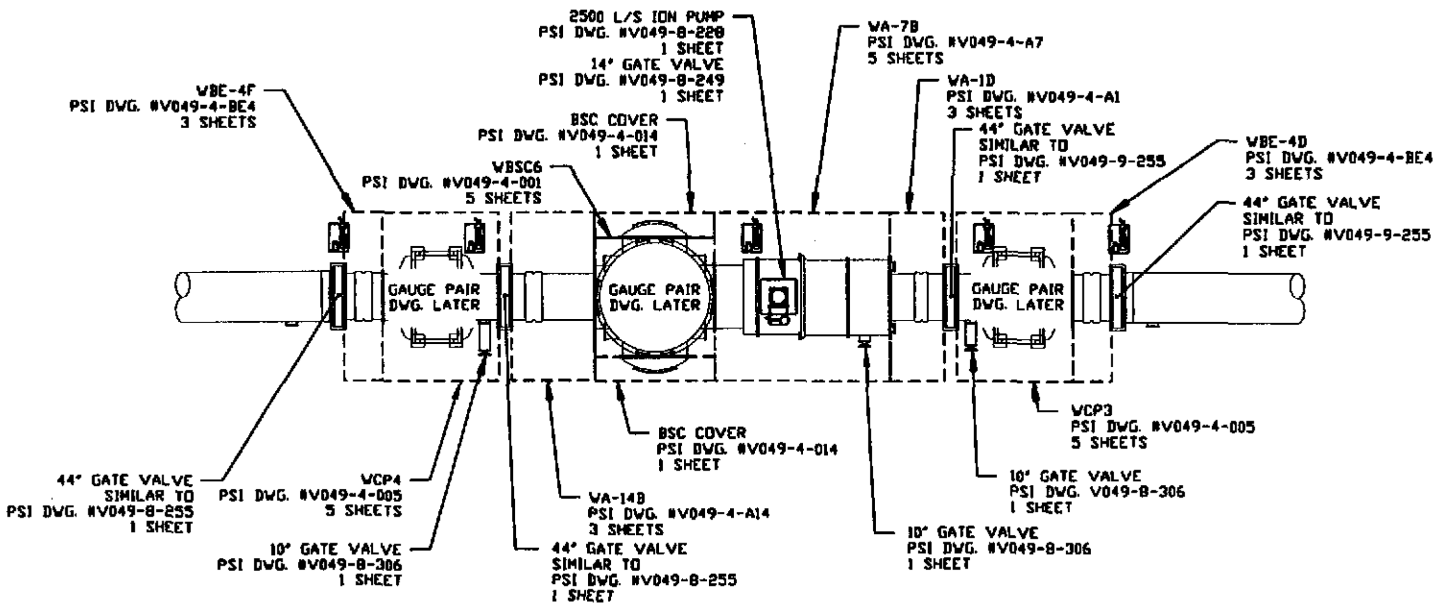
ATTACHMENT C
V049-2-009 *REV. 4*
WA RIGHT BEAM MANIFOLD
ISOLATABLE SECTION
SHT. 3 OF 8



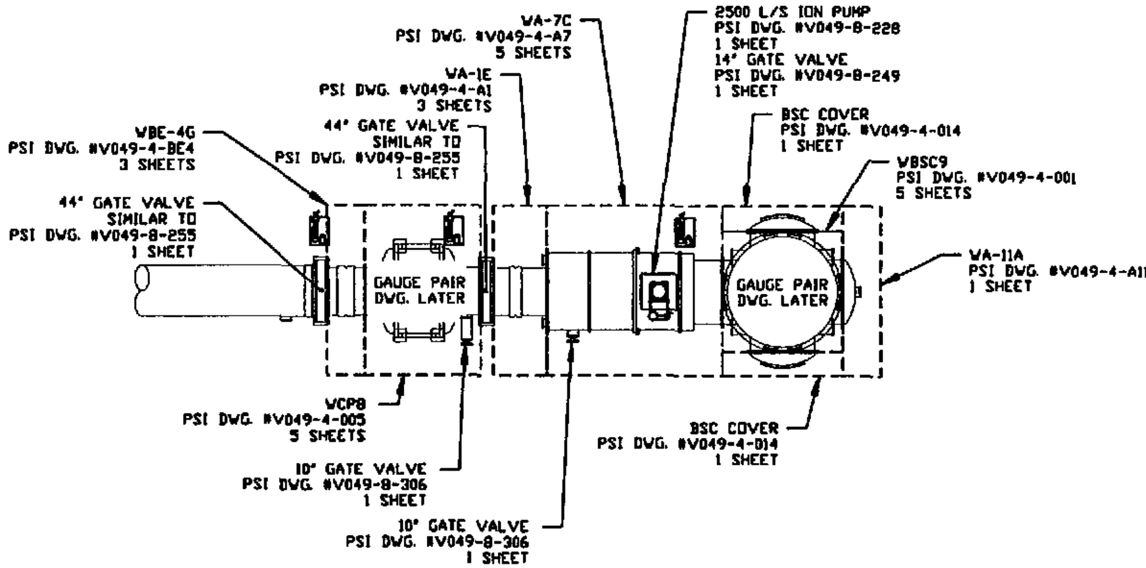
ATTACHMENT C
V049-2-009 REV. 4
WA DIAGONAL SECTION
ISOLATABLE SECTION
SHT. 4 OF 8



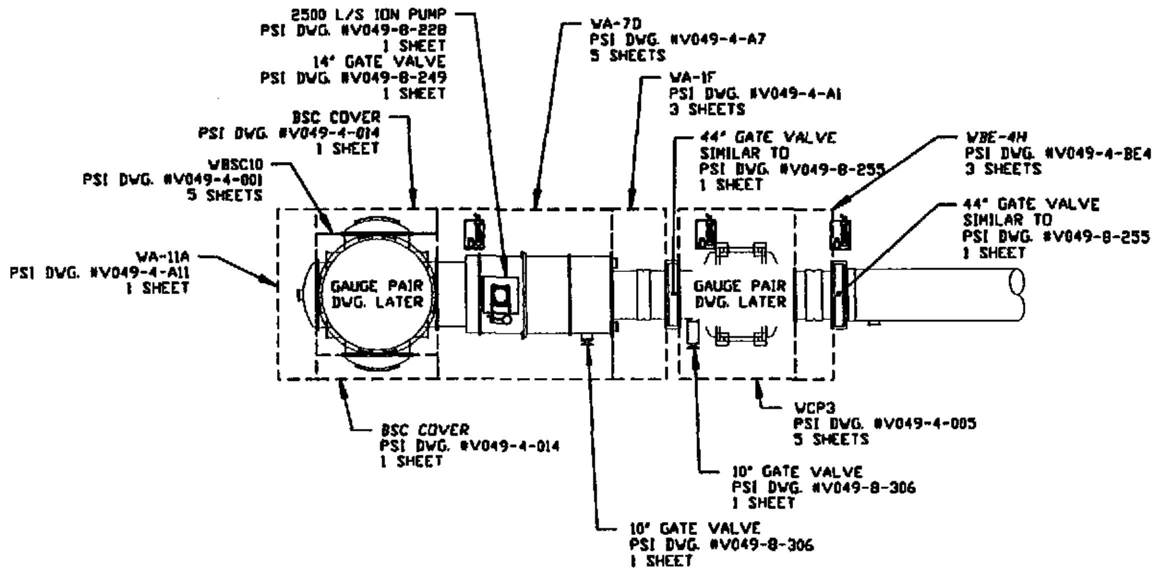
ATTACHMENT C
V049-2-009 *REV.4*
WA RIGHT MID STATION
ISOLATABLE SECTION
SHT. 5 OF 8



ATTACHMENT C
V049-2-009 REV. 4
WA LEFT MID STATION
ISOLATABLE SECTION
SHT. 6 OF 8



ATTACHMENT C
V049-2-009 REV. 4
WA RIGHT END STATION
ISOLATABLE SECTION
SHT. 7 OF 8



ATTACHMENT C
V049-2-009 *REV. 4*
WA LEFT END STATION
ISOLATABLE SECTION
SHT. 8 OF 8

ATTACHMENT D
TO SPECIFICATION V049-2-009, REV.4
LIGO BAKEOUT BLANKETS
FOR VACUUM EQUIPMENT

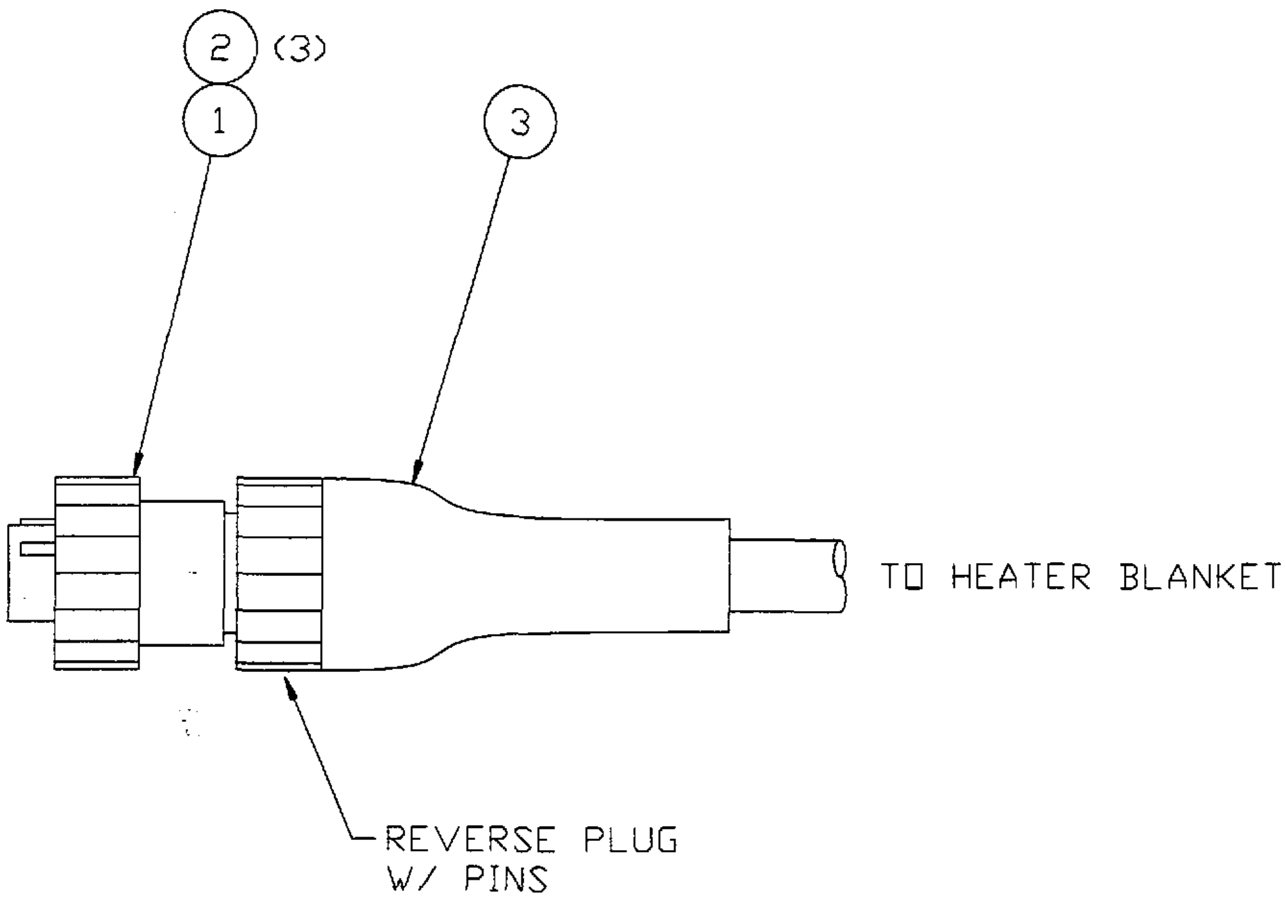
DRAWING NUMBER	REV	DESCRIPTION	QTY	ASSEMBLY DWGS REQ'D BY DATE	BLANKETS REQ'D BY DATE
V049-0-001	0	P & ID VAC EQUIP LEGEND	-	-	-
V049-4-101 (1 SHEETS)	0	BEAM SPLITTER CHAMBER (BSC) SEE ANNULUS PIPING, V049-4-025 SEE BELLOWS TIE ROD, V049-4-040 SEE RGA/AUX. TURBO CONN., V049-4-045 SEE 75 L/S ION PUMP, V049-4-077 SEE COVERS, V049-4-014 & V049-4-A11	1 2	11/29/96	01/17/97 09/05/97
V049-4-002 (1 SHEETS)	0	HORIZ. ACCESS MODULE (HAM) SEE TYPE A4 COVER, V049-4-A4 SEE BELLOWS, V049-2-53 SEE ANNULUS PIPING, V049-4-054	1 5	11/01/96	12/13/96 09/05/97
V049-4-004 (5 SHEETS)	0	80K CRYOPUMP LONG GENERAL ARRG. SEE CLEAN AIR PIPE AND VALVE V049-5-014, SECTIONS L & M	1	11/15/96	01/03/97
V049-4-005 (5 SHEETS)	0	80K CRYOPUMP SHORT GENERAL ARRG SEE CLEAN AIR PIPE AND VALVE, V049-5-019, SECTION D V049-5-023, SECTION D	1	11/15/96	01/03/97
V049-4-014 (1 SHEET)	0	COVER TYPE I BEAM SPLITTER CHAMBER	4	11/15/96	01/03/97
V049-4-025 (1 SHEET)	1	BSC ANNULUS PIPING ARRANGEMENT	1 2	11/29/96	01/17/97 09/05/97
V049-4-040 (1 SHEET)	3	HAM BELLOWS TIE ROD ASSEMBLY SEE V049-4-001	-		
V049-4-045 (1 SHEET)	0	RGA/AUX TURBO CONN ASSEMBLY	-		
V049-4-053 (1 SHEET)	0	60.5 ID METAL BELLOWS HORIZONTAL C SEE V049-4-002	-		
V049-4-054 (1 SHEET)	0	HAM ANNULUS PIPING	2 4	11/01/96	12/13/96 09/05/97
V049-4-077 (1 SHEET)	1	75 L/S ION PUMP - BSC SEE V049-4-001	-		
V049-4-A1 (3 SHEETS)	0	ADAPTER A-1 44 5/8 ID x 60 1/2 ID	1	12/13/96	02/07/97
V049-4-A3 (2 SHEETS)	0	ADAPTER A-3 48 1/4 ID x 60 1/2 ID SEE CLEAN AIR PIPE AND VALVE V049-5-014, SECTION C	2	12/13/96	02/07/97
V049-4-A4 (2 SHEETS)	0	60 HAM COVER GROOVED TYPE A4	2	11/01/96	12/13/96
V049-4-A6 (3 SHEETS)	0	ADAPTER A-6 48 1/4 ID x 60 1/2 ID	2	12/13/96	02/07/97
V049-4-A7 (5 SHEETS)	0	ADAPTER A-7 60 1/2 ID x 72 1/4 ID SEE CLEAN AIR PIPE AND VALVE V049-5-019, SECTION E V049-5-023, SECTION E		12/13/96	02/07/97
V049-4-A11 (1 SHEETS)	0	BSC END COVER TYPE A11	1	11/29/96	01/17/97

ATTACHMENT D
TO SPECIFICATION V049-2-009, REV.4
LIGO BAKEOUT BLANKETS
FOR VACUUM EQUIPMENT

DRAWING NUMBER	REV	DESCRIPTION	QTY	ASSEMBLY DWGS REQ'D BY DATE	BLANKETS REQ'D BY DATE
V049-4-A12 (2 SHEETS)	0	ADAPTER A-12 48.25 ID x 60.50 FLANGE	1	12/13/96	02/07/97
V049-4-A13 (2 SHEETS)	0	ADAPTER A-13 60.50 ID x 72.25 ID	1	12/13/96	02/07/97
V049-4-A14 (3 SHEETS)	0	ADAPTER A-14 44 5/8 ID x 60 1/2 ID	1	12/13/96	02/07/97
V049-4-A15 (2 SHEETS)	0	ADAPTER A-15 48 1/4 ID x 60 1/2 ID	2	12/13/96	02/07/97
V049-4-B1 (3 SHEETS)	0	SPOOL B-1 72 1/4 ID	1	02/07/97	03/28/97
V049-4-B2A (4 SHEETS)	0	SPOOL B-2A 30 1/2 ID x 60 1/2 ID SEE CLEAN AIR PIPE AND VALVE V049-5-014, SECTION F	1	12/13/96	02/07/97
V049-4-B2B (4 SHEETS)	0	SPOOL B-2B 30 1/2 ID x 60 1/2 ID	1	12/13/96	02/07/97
V049-4-B3A (4 SHEETS)	0	SPOOL B-3A 30 1/2 ID x 60 1/2 ID SEE CLEAN AIR PIPE AND VALVE V049-5-014, SECTION C	1	02/07/97	03/28/97
V049-4-B4 (2 SHEETS)	0	SPOOL B-4 48 1/4 ID	2	01/17/97	03/07/97
V049-4-B5A (4 SHEETS)	0	SPOOL B-5A 30 1/2 ID x 60 1/2 ID	1	02/07/97	03/28/97
V049-4-B6 (3 SHEETS)	0	SPOOL B-6 48 1/4 ID SEE CLEAN AIR PIPE AND VALVE V049-5-014, SECTION E	1	02/07/97	03/28/97
V049-4-B7 (3 SHEETS)	0	SPOOL B-7 48 1/4 ID	1	02/07/97	03/28/97
V049-4-B8 (3 SHEETS)	0	SPOOL B-8 72 1/4 ID	1	02/07/97	03/28/97
V049-4-B9 (4 SHEETS)	0	SPOOL B-9 72 1/4 ID	1	01/17/97	03/07/97
V049-4-BE2 (3 SHEETS)	0	SPOOL BE-2 60 1/2 ID	2	01/17/97	03/07/97
V049-4-BE3 (2 SHEETS)	0	OFFSET SPOOL BE-3 60 1/2 ID	1	02/07/97	03/28/97
V049-4-BE3A (2 SHEETS)	0	OFFSET SPOOL BE-3A 60 1/4 ID	1	02/07/97	03/28/97
V049-4-BE4 (3 SHEETS)	0	SPOOL BE-4 44 5/8 ID	2	01/17/97	03/07/97
V049-4-BE5 (5 SHEETS)	0	SPOOL BE-5 72 1/4 ID SEE CLEAN AIR PIPE AND VALVE V049-5-014, SECTION D	1	01/17/97	03/07/97
V049-4-BE6 (5 SHEETS)	0	SPOOL BE-6 72 1/4 ID SEE CLEAN AIR PIPE AND VALVE V049-5-014, SECTION D	1	01/17/97	03/07/97
V049-5-002 (1 SHEETS)	0	EQUIP. ARRG ISO CORNER STATION (WA)	-		
V049-5-010 (1 SHEETS)	0	EQUIP. ARRG ISO RT. MID STATION (WA)	-		
V049-5-011 (1 SHEETS)	0	EQUIP. ARRG ISO RT. END STATION (WA)	-		
V049-5-014 (1 OF 2 SHEETS	0	PIPING ARRG SECS CORNER STATION (W SEE CLEAN AIR PIPE AND VALVE			
		SECTION C (WB-3A)	1	03/28/97	09/05/97
		SECTION F (WB-2A)	1	03/28/97	09/05/97

ATTACHMENT D
TO SPECIFICATION V049-2-009, REV.4
LIGO BAKEOUT BLANKETS
FOR VACUUM EQUIPMENT

DRAWING NUMBER	REV	DESCRIPTION	QTY	ASSEMBLY DWGS REQ'D BY DATE	BLANKETS REQ'D BY DATE
		SECTION D (WBE-5)	1	03/28/97	09/05/97
		SECTION E (WBE-6)	1	03/28/97	09/05/97
		SECTION L (WCP2)	1	03/28/97	09/05/97
		SECTION M (WCP1)	1	03/28/97	09/05/97
V049-5-019 (1 SHEET)	0	PIPE ARRG SECS RIGHT MID STATION (WA			
		SEE CLEAN AIR PIPE AND VALVE			
		SECTION D (WCP5)	2	11/29/96	01/17/97
		SECTION E (ADAPTER A-7)	1	03/28/97	09/05/97
V049-5-023 (1 SHEET)	0	PIPE ARRG SECS RIGHT END STATION (W			
		SEE CLEAN AIR PIPE AND VALVE			
		SECTION D (WCP8)	1	11/29/96	01/17/97
		SECTION E (ADAPTER WA-7C)	1	11/29/97	01/17/97
V049-8-255 (1 SHEETS)	0	ASSEMBLY G48E (48" GATE VALVE)	2	03/28/97	09/05/97
V049-8-228 (1 SHEETS)	9	2500 L/S ION PUMP, QUOTATION DWG.	4	03/28/97	09/05/97
V049-8-249 (1 SHEET)		GATE VALVE 14" ID DIM DWG	1	12/13/96	02/07/97
			2		09/05/97
V049-8-250 (1 SHEETS)		DIMENSIONAL DWG LIGO VALVES (6")	2	03/28/97	09/05/97
V049-8-306 (1 SHEET)		SCHIEBER ND 250 (10" GATE VALVE)	2	11/01/96	12/13/96
			1		09/05/97
V049-8-XXX (NA)		ASSEMBLY G44E (44" GATE VALVE)	4	03/28/97	09/05/97
		SIMLAR TO V049-8-255			
V049-8-XXX (NA)		GAUGE PAIRS	3	03/28/97	09/05/97



NOTES:
1.) THE SMALLEST WIRE SIZE SHALL BE #18 AWG.
2.) THE WIRE SHALL BE RATED 10 AMPS MIN. PER N.E.C.

ITEM	QTY	VENDOR	PART NO.	DESCRIPTION
1	1	AMP	206429-1	PLUG, REVERSE SEX, 600VAC, 10A
2	3	AMP	66361-2	PIN, #14 AWG, 600VAC, 10A
3	1	AMP	54010-1	CABLE ENTRY SEAL, STRAIN RELIEF

REV	DESCRIPTION		CHKD	DRWN	DATE	DEO#
2	CHANGED CONNECTOR TYPE	D.McW	JW	EA	10/2/96	0286
1	REVISED PER DEO	D.McW	JDP	BAR	6/20/96	0205
	ISSUED FOR RELEASE	D.McW	FAB	BAR	4/2/96	

DO NOT SCALE THIS DWG. | USED ON: | NEXT ASS'Y:

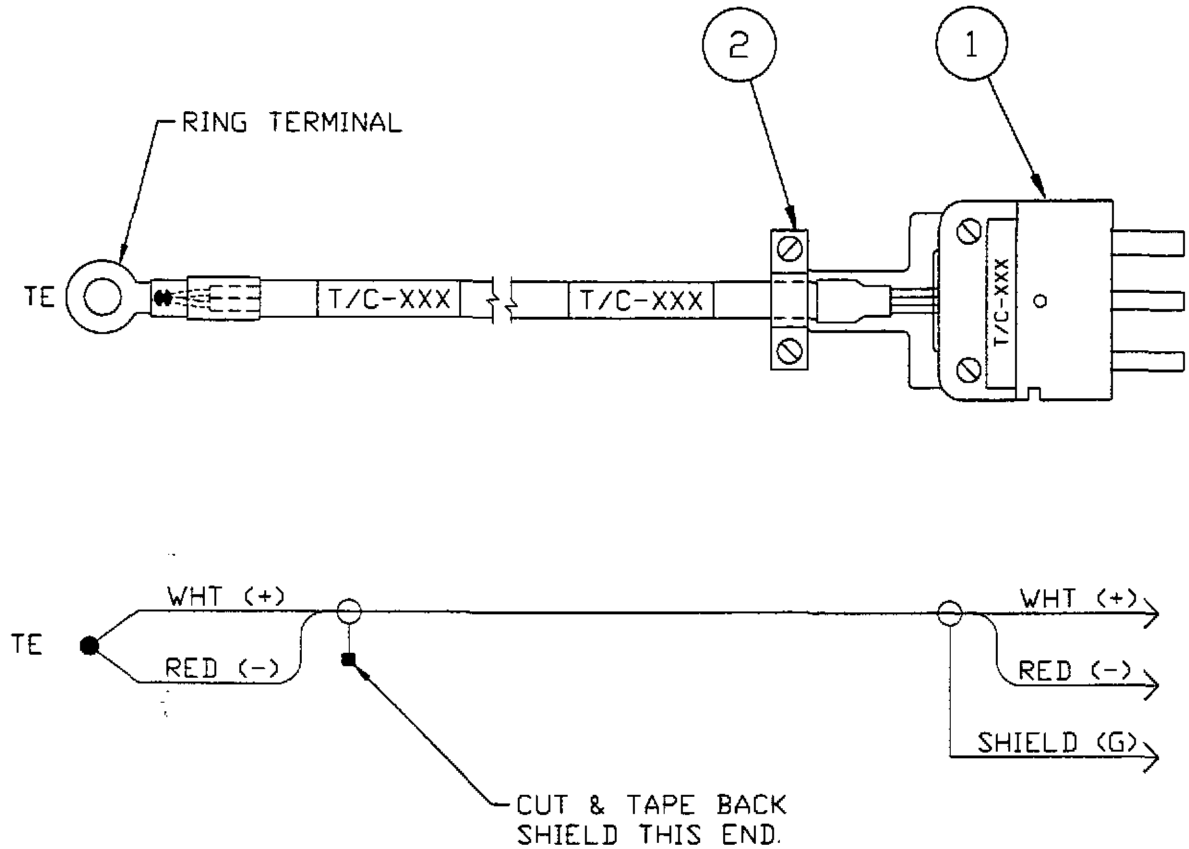
PROCESS SYSTEMS INTERNATIONAL INC.
20 WALKUP DR. WESTBOROUGH, MASSACHUSETTS 01581 USA

HEATER BLANKET
POWER CABLE END CONNECTOR
LIGO HEATER BAKEOUT SYSTEM

CAD FILE	SIZE	DWG. NO.	REV.
3019S1	A	V049-3-019	2

SCALE NONE | SHEET 1 OF 3

Oct 02, 1996 - 14:36:05



NOTE:
1.) REFER TO PSI SPEC. V59049-2-009 FOR WIRING REQUIREMENTS.

ITEM	QTY	VENDOR	PART NO.	DESCRIPTION
1	1	OMEGA	OTP-J-M	TYPE "J" T/C CONNECTOR, MALE
2	1	OMEGA	PCLM	CABLE CLAMP

PROCESS SYSTEMS INTERNATIONAL INC.
20 WALKUP DR. WESTBOROUGH, MASSACHUSETTS 01581 USA

HEATER BLANKET
THERMOCOUPLE END CONNECTOR
LIGO HEATER BAKEOUT SYSTEM

CAD FILE	SIZE	DWG. NO.	REV.
3019S2	A	V049-3-019	2
SCALE NONE		SHEET 2 OF 3	

Oct 02, 1996 - 14:36:28

Title: SPECIFICATION FOR CLEAN AIR SUPPLY SYSTEMS

SPECIFICATION FOR

CLEAN AIR SUPPLY SYSTEMS

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY: Thomas M. Stan

QUALITY ASSURANCE: Alan L Bradbrook

TECHNICAL DIRECTOR: D. C. McWilliams

PROJECT MANAGER: [signature]

Information contained in this specification and its attachments is proprietary in nature and shall be kept confidential. It shall be used only as required to respond to the specification requirements, and shall not be disclosed to any other party.

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
1	TMS 3-5-96	D McW	REVISED FOR PURCHASE PER DEO 0081
0	TMS 12-14-95	DMcW 12-14-95	REVISED & RELEASED FOR QUOTATION
P1	10-19-95		Released per DEO 0005
P1	TMS 9-26-95		REVISED FOR UPDATED PRELIMINARY DESIGN

PROCESS SYSTEMS INTERNATIONAL, INC.					SPECIFICATION	
INITIAL APPROVALS	PREPARED: T. Stan	DATE: 6-14-95	APPROVED: RCB	DATE: 9/26/95	Number: V049-2-011	Rev.: 1

SPECIFICATION TABLE OF CONTENTS

1.0 SCOPE

This specification covers the minimum requirements for the design, materials, fabrication, assembly, inspection, testing, preparation for shipping, shipment and delivery of clean air supply systems for the LIGO vacuum system. The systems will supply clean and dry air for equipment venting and purging, and for air showers in various vacuum vessels.

All attachments are incorporated herein by reference and made a part of this specification.

The specified equipment is intended for use as part of the Vacuum Equipment supplied for the Laser Interferometer Gravitational-Wave Observatory (LIGO). LIGO, which is operated by Caltech and MIT under an NSF grant, includes two sites (Hanford Reservation, near Richland, WA and Livingston, LA). Each site contains laser interferometers in an L shape with 4 km arms, a vacuum system for the sensitive interferometer components and optical beams, and other support facilities.

Information contained in this specification and its attachments is proprietary in nature and shall be kept confidential. It shall be used only as required to respond to the specification requirements, and shall not be disclosed to any other party.

2.0 SCHEDULE

2.1 Equipment delivery shall be as follows:

	Quantity	Date
Westboro (PSI)		
50 CFM	2	11/1/96
200 CFM	0	11/1/96
Washington Site:		
50 CFM	4	9/1/97
200 CFM	1	9/1/97
Louisiana Site:		
50 CFM	0	3/1/98
200 CFM	1	3/1/98
Total Required		
50 CFM	6	
200 CFM	2	

2.2 The first unit of each size shall be a "prototype" and shall be inspected for cleanliness prior to the release for subsequent units. The first units will also be tested for noise and vibration by the Buyer.

2.3 Acceptances at the sites are expected to occur on a staggered basis no more than 120 days after delivery, with final acceptance at Westboro expected to occur about January 2, 1997; about May 31, 1998 in Washington; and about November 30, 1998 in Louisiana.

3.0 EQUIPMENT REQUIREMENTS

The clean air supply systems will be used to provide air for equipment venting and purging, and for air showers in various vacuum chambers. The air at the supply point shall be 50 SCFM (6 systems) or 200 SCFM (2 systems) minimum. It shall be filtered through prefilters and HEPA filters to provide air meeting Fed. Std. 209 Class 100. It shall be dried to -60 C dew point (at atmospheric pressure), and provided at a minimum pressure of 30 psig. Supply air to the systems will be ambient indoor air. Air compressors shall be non-lubricated with filtered suction. Performance for flow, dewpoint and particle count shall be guaranteed. Commercially packaged compressors, dryers and filters (subject to PSI approval) used in these systems need not meet Attachment B of this specification.

As a minimum, the following components shall be provided:

- A receiver with manual drain and automatic start/stop capbilities for the compressor. (System operation will be continuous for periods of several hours to several weeks, with variable flow rates.)
- Hydrocarbon removal adsorbers with sample taps upstream and downstream.
- An inlet air filter capable of taking air from an adjacent room (piping by others).
- Dryer blowdown silencers suitable for locating outside of the building by others.
- A 0.01 micron sterile final filter with stainless steel housing.

4.0 DESIGN REQUIREMENTS

4.1 Mechanical Requirements

4.1.1 Systems of each size shall be self-contained and identical to minimize the number of required spare parts.

4.1.2 Any required utility connections (such as for cooling water) shall be manifolded to a single connection point and terminated appropriately (such as with an isolation valve).

4.1.3 The acoustic noise and vibration requirements detailed in Section 5.1 of Attachment B do not apply to the clean air supply systems. However, reasonable measures shall be taken to minimize vibration.

4.1.4 The final filter and all downstream materials shall be stainless steel (304, 304L, 316 or 316L).

4.1.5 The 200 CFM systems shall be water cooled and the 50 CFM units air cooled.

4.1.6 Manifolding and/or proper compressor cabinet connections shall be provided to allow a single air inlet from an adjacent room (piping and silencer by others). The compressor inlet shall be filtered.

4.1.7 Building access for installation is through 8' wide by 8' high doorways. Therefore, each skid must be sufficiently less than those dimensions to allow adequate clearance. If necessary, it would be acceptable to remove an item from the skid for installation, then reinstall it on the skid. Access space will be provided by others around the skid. Skid equipment arrangements are subject to Buyer's approval. CAD drawings and files are preferred, AutoCAD 12, if possible.

4.1.8 All piping shall be detergent washed and rinsed to remove all traces of oils. No hydrocarbons shall be used on the process surfaces of the compressors during their manufacture, and none shall be used in making up piping joints. All dryer vessels, filter housings and other components shall be free of hydrocarbons, and inspected to ensure that they are clean and dry.

4.1.9 The clean air supply systems shall not introduce hydrocarbons into the air stream.

4.1.10 Blowdown from compressor unloading may be vented into the compressor cabinet if it does not result in a significant increase in noise.

4.1.11 The sample taps upstream and downstream of the hydrocarbon removal adsorbers shall be valved and have 1/4" male Swagelok thread for customer connection.

4.2 Electrical Requirements

4.2.1 Instrumentation Requirements

Appropriate gauges for local operation and monitoring shall be provided.

4.2.2 Controls Requirements

4.2.2.1 Controls for local operation shall be provided. In addition, provide terminal strips in junction boxes with dry contacts to indicate that the systems are running or not.

4.2.2.2Systems shall be stopped and started by hand switches located on the system skid. The compressors shall be started and stopped automatically based on pressure in the discharge receiver tank.

4.2.2.3 Provide a receiver low pressure switch for alarm, wired to dry contacts on terminal strip in above junction box (see 4.2.2.1, above).

4.2.2.4 Provide a dryer failure to switch alsrm wired to the compressor panel, and a common out alarm for the compressor.

Number
Rev.

4.2.3 Power Requirements

4.2.3.1 Required controllers and overload protection shall be provided on the system skids.

4.2.3.2 A single disconnect switch for each system shall be provided on each skid. An additional disconnect for each dryer system shall also be provided.

4.2.3.3 All wiring, conduits and terminations between skid components shall be provided, with only a single power feed necessary for field connection.

4.2.3.4 A single 480/277 V, 3 phase, 4 wire (with ground) circuit will supply power to the system.

4.2.3.5 All starters, switches and overload protection devices shall be provided by the Vendor.

4.2.3.6 All instrument wiring shall be segregated in separate conduits based on signal voltages (one type per conduit). Barriers shall be used to separate terminal blocks of different voltages.

4.2.3.7 The system shall meet the requirements of the N.E.C. and all local codes.

5.0 REQUIRED DOCUMENTATION

In addition to the documentation listed in Attachment B, the following documentation shall be provided prior to shipment:

- System installation and operating manual
- Certified test results

6.0 SHOP TESTING

The Vendor shall perform his standard testing (tests for one system of each size to be witnessed by the Buyer). In addition, the Buyer will make measurements of flow, dewpoint, hydrocarbons and particle count for the delivered air, and noise and vibration.

7.0 INSPECTION

The inspections called for in Attachment B shall be performed by the Vendor. Also, all equipment and components shall be inspected in accordance with Paragraph 4.1.8, above.

8.0 WARRANTY

Refer to PSI Specification V049-2-034, Purchased Equipment Commercial Requirements, for warranty requirements.

ATTACHMENT "A"
LIGO QUALITY ASSURANCE REQUIREMENTS SUMMARY

LIGO VACUUM EQUIPMENT	VENDOR:	JOB NO.: V59049
EQUIPMENT: CLEAN AIR SUPPLY SYSTEMS	VENDOR ENG. OFFICE:	DWG. NO.:
PSI P.O. NO:	VENDOR FACTORY:	SPEC NO.: V049-2-011

TESTING INSPECTION AND DOCUMENTATION RECORD	Submittal After P.O.	Witnessed by PSI	Approval by PSI	Copies Req'd for PSI Files	Record in Mfr's File	Remarks:	Inspector: Date:
MILESTONE SCHEDULE	2 wk		X	2	X		
VENDOR Q.A. PLAN	2 wk		X	2	X		
CLEANING PROCEDURE	2 wk		X	2	X		
PREP FOR SHIPMENT PROCEDURE	6 wk		X	2	X		
Deleted			X	2	X		
ASSEMBLY DRAWINGS	6 wk		X	2	X		
DESIGN REVIEW		X			X	Prior to release for fabrication	
Deleted				2	X		
Deleted		X		2	X		
OPERATION & MAINTENANCE MANUALS	8 wk			5	X		
SHOP TEST PLAN			X	2	X	Prior to release for fabrication	
SHOP TEST (WITH REPORT)		X		2	X	Prior to release for shipment	

SPECIFICATION FOR

LN_2 DEWARS

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY: David Moore

QUALITY ASSURANCE: Alan K Bradbrook

TECHNICAL DIRECTOR: D. C. McWilliams

PROJECT MANAGER: [signature]

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
2	DM 5/20/96	RED 5/21/96	Revised per DEO # 0185 & issued for purchase
1	DM 4/30/96	RED 4/30/96	Revised per DEO # 0154
Ø	DM 3/5/96	D. McW	Initial release PER DEO 0083 FOR QUOTE

PROCESS SYSTEMS INTERNATIONAL, INC.					SPECIFICATION	
INITIAL APPROVALS	PREPARED DM	DATE	APPROVED D. McW	DATE	Number V049-2-013	Rev. 2

SPECIFICATION TABLE OF CONTENTS

1.0 SCOPE

This specification covers the minimum requirements for the manufacturing engineering, materials, fabrication, assembly, inspection, testing, preparation for shipping, and shipment of LN_2 dewars for the LIGO vacuum system.

All attachments are part of this specification.

The specified equipment is intended for use as part of the Vacuum Equipment supplied for the Laser Interferometer Gravitational-Wave Observatory (LIGO). LIGO, which is operated by Caltech and MIT under an NSF contract, includes two installations at widely separated sites: near Hanford, WA and Livingston, LA. Each installation contains laser interferometers in an L shape with 4 km arms, a vacuum system for the sensitive interferometer components and optical beams, and other support facilities.

Information contained in this specification and its attachments is proprietary in nature and shall be kept confidential. It shall be used only as required to respond to the specification requirements, and shall not be disclosed to any other party.

2.0 SCHEDULE

2.1 Equipment delivery shall be as follows:

	Quantity	Date	PSI P/N
10,000 Gallon (minimum net after 90 days)			V0492013P1
Washington Site:	6	9/1/97	Tag nos. WDW3,WDW4,WDW5, WDW6,WDW7,WDW8
Louisiana Site:	2	3/1/98	Tag nos. LDW3,LDW4
Total Required	8		

	Quantity	Date	PSI P/N
12,000 Gallon (minimum net after 90 days)			V0492013P2
Washington Site:	2	9/1/97	Tag nos. WDW1,WDW2
Louisiana Site:	2	3/1/98	Tag nos. LDW1,LDW2
Total Required	4		

2.2 Acceptances at the sites (the start of Vendor's warranty periods) are expected to occur on a staggered basis, with final acceptance expected to occur no later than May 31, 1998. Portions of the equipment may be accepted earlier.

3.0 EQUIPMENT REQUIREMENTS

The dewars shall have minimum usable capacities as shown in Section 2.2, above, after accounting for boil-off losses due to parasitic heat loads over a storage time of 90 days without refilling at an ambient temperature of 100 F. The dewar boil-off rate shall be noted. Each dewar shall be provided with an ambient air vaporizer with associated controls to maintain dewar pressure at a design LN_2 consumption rate of 200 gallons per hour.

4.0 DESIGN REQUIREMENTS

4.1 The Vendor shall use his standard dewar design, subject to the requirements listed below, indicating the design pressure and temperatures. The Vendor shall fabricate and test the vessels according to this specification and the attached drawings.

4.2 Dewars shall have a 9% Nickel steel (ASTM A353) inner vessel and carbon steel outer vessel, with skirts or legs and lifting lugs. They shall be designed to be mounted on a concrete pad outdoors in a vertical position. The suggested footprint for the anchor bolts is a circle with a 52 inch radius. Footpads may extend beyond this circle by a reasonable amount. The Vendor shall advise PSI with his bid if there is a significant deviation from this requirement in his design.

4.3 The inner vessel shall be ASME Section VIII, Division 1 Code stamped.

4.4 Vessels shall have an electrical grounding connection (lug).

4.5 An outer vessel relief device sized in accordance with CGA requirements shall be provided. The inner vessel relief shall meet ASME requirements.

4.6 In addition to the Vendor's standard level gauge, the Vendor shall provide pressure taps to install a level transmitter supplied by Buyer.

4.7 The Vendor shall provide a self-contained vent line back pressure regulator as shown on the P&ID (PSI drawing V049-0-006).

4.8 The Vendor shall provide a self contained pressure regulator for the vaporizer loop to maintain dewar pressure as shown on the P&ID.

4.9 The inner vessel shall have a single relief valve/rupture disc arrangement as shown on the P&ID.

4.10 The bottom liquid draw line will mate with stainless steel vacuum - jacketted pipe (supplied by others). The inlet of the liquid draw line shall be 18" above the bottom of the dewar inner vessel, facing down, in order to minimize the possibility of ice particles being drawn into the line.

4.11 The dewar shall be suitable for the following outdoor ambient conditions:

Winter: 15 deg. F dry bulb
Summer: 96 deg. dry bulb, 68 deg. F wet bulb.

4.12 The following paragraphs of Attachment B are not applicable:

5.1.4	5.1.5	5.1.7
6.3	6.4	6.5
9.4	11.3	11.4

4.13 A vapor line pressure gauge shall be provided with the dewar.

5.0 REQUIRED DOCUMENTATION

Documentation requirements listed in Attachment A shall be provided according to the Buyer's schedule (schedule later). In addition, the following shall be provided:

- Copies of the material test reports for pressure boundary material
- Copies of ASME Manufacturer's Code Data Report.
- All documentation shall be supplied to the PSI Quality Assurance Manager at the time of shipment.

6.0 SHOP CLEANING/TESTING

The Vendor shall follow his standard cleaning and testing procedures.

7.0 INSPECTION

The inspections called for in Attachment A shall be performed by the Vendor.

8.0 WARRANTY

Refer to Attachment A, Section 15.0, and to Attachment B, General Provisions, Article 40 for warranty requirements.

ATTACHMENT "A"

LIGO QUALITY ASSURANCE REQUIREMENTS SUMMARY

LIGO VACUUM EQUIPMENT	VENDOR:	JOB NO.: V59049
EQUIPMENT: LIQUID NITROGEN DEWARS	VENDOR ENG. OFFICE:	DWG. NO.:
PSI P.O. NO:	VENDOR FACTORY:	SPEC NO.: V049-2-013

TESTING INSPECTION AND DOCUMENTATION RECORD	Submittal After P.O.	Witnessed by PSI	Approval by PSI	Copies Req'd for PSI Files	Record in Mfr's File	Remarks:	Inspector: Date:
MILESTONE SCHEDULE	2 Wk		X	2	X		
VENDOR Q.A. PLAN	2 Wk		X	2	X		
CLEANING PROCEDURE	4 Wk		X	2	X		
PREP FOR SHIPMENT PROCEDURE	6 Wk		X	2	X		
ASSEMBLY DRAWINGS	2 Wk		X	2	X		
DESIGN REVIEW	*	X			X	PRIOR TO RELEASE FOR FABRICATION	
IN-PROCESS INSPECTIONS	*	X		2	X	PRIOR TO RELEASE FOR FABRICATION	
OPERATION & MAINTENANCE MANUALS	12 Wk			5	X		
SHOP TEST PLAN	8 Wk		X	2	X	PRIOR TO RELEASE FOR FABRICATION	
SHOP TEST (WITH REPORT)	*	X		2	X	PRIOR TO RELEASE FOR SHIPMENT	
SHOP DIMENSIONAL INSPECTION	*	X		2	X		
WELDING PROCEDURES	4 Wk		X	2	X		
* PER APPROVED VENDOR SCHEDULE						PLUS 4 COPIES OF CODE DATA PACKAGE WITH MANUFACTURER'S CODE DATA REPORT	

Attachment A to V049-2-013

V049-2-002

Title: **SPECIFICATION FOR VACUUM JACKETED PIPING**

SPECIFICATION FOR

VACUUM JACKETED PIPING

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY: Thomas M. Stam

QUALITY ASSURANCE: Alan L Bradbrook

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: Bill Bagley

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
1	TDM 10/9/96	DAMW 10-11-96	General revisions deleting GN2 lines from VJ requirement. Release for requote per DEO ∅296
∅	TDM 6/26/96	DAMW 6-29-96	General revisions. Released for quotation PER DEO ∅211
P1	10-19-95		Released per DEO 0005
P1	TMS 9-26-95		REVISED FOR UPDATED PRELIMINARY DESIGN

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION	
INITIAL APPROVALS	PREPARED: T. Stam	DATE: 6-14-95	APPROVED: RES	DATE: 9/26/95	Number V049-2-016 / Rev. 1

Title: SPECIFICATION FOR VACUUM JACKETED PIPING

SPECIFICATION TABLE OF CONTENTS

SPECIFICATION	
Number A V049-2-016	Rev. 1

1.0 SCOPE

This specification covers the minimum requirements for the design, materials, fabrication, assembly, inspection, testing, preparation for shipping, and shipment of vacuum jacketed (VJ) piping for the LIGO vacuum system. The piping will be used in liquid nitrogen service at the 80 K cryopumps. The cryopumps are identified in the LIGO drawings by the designations, WCPX or LCPX, where X is a numeric identifier of a particular cryopump.

All attachments are part of this specification.

The specified equipment is intended for use as part of the Vacuum Equipment supplied for the Laser Interferometer Gravitational-Wave Observatory (LIGO). LIGO, which is operated by Caltech and MIT under an NSF contract, includes two installations at widely separated sites: near Hanford, WA and Livingston, LA. Each installation contains laser interferometers in an L shape with 4 km arms, a vacuum system for the sensitive interferometer components and optical beams, and other support facilities.

Information contained in this specification and its attachments is proprietary in nature and shall be kept confidential. It shall be used only as required to respond to the specification requirements, and shall not be disclosed to any other party.

2.0 SCHEDULE

2.1 Equipment delivery shall be as follows:

	Quantity	Date
Washington Site:		
LN2 Supply Line	8	9/1/97
Louisiana Site:		
LN2 Supply Line	4	3/1/98
Total Required	12	

2.2 At each of the stations along the interferometer arms where a cryopump is located, the lengths of VJ pipe and the number of piping components is the same as every other cryopump station. However, there are different ways in which the piping is routed. The attached sketches, V049-6-016-SK1 and V049-6-016-SK2 define the ways in which the piping is routed.

2.3 Acceptances at the sites (the start of Vendor's warranty periods) are expected to occur on a staggered basis, with final acceptance expected to occur no later than May 31, 1998. Portions of the equipment may be accepted earlier.

3.0 EQUIPMENT REQUIREMENTS

The piping will be used in liquid nitrogen service at the 80 K cryopumps. The supply line piping shall have a heat leak no greater than 0.581 Btu/hr-ft for LN_2.

4.0 DESIGN REQUIREMENTS

4.1 The piping shall be in accordance with the attached piping arrangement drawings. Vacuum jacketted piping is identified in the drawings with the suffix "VJ".

4.2 The piping shall meet the Vendor's standards. However, the liquid nitrogen process line must be 1/2" NPS SCH 10. No bellows shall be used in the process line supplying liquid nitrogen to the cryopump. If bellows are necessary, they shall be used on the vacuum jacket only. The piping system shall feature intermediate bayonet connections as shown in the attached drawings and wherever else is necessary as determined by the Vendor, so that it can be assembled inside the LIGO vacuum equipment building without resorting to any welding.

4.3 The vacuum jacketted piping shall terminate at the cryopump in male bayonet connections utilizing 1/2" NPS SCH 10 for its process line so that there is a smooth transition in the pipe inner diameter from the supply line through the bayonet to the cryopump. The other end of the piping shall terminate in pant leg/stub end type connections. These connections shall be designed so that the process lines can be butt welded to succeeding runs of pipe which will be covered by mechanical (non VJ) insulation.

4.4 The jacket and process lines shall be grade 304L stainless steel.

4.6 The following paragraphs of Attachment B are not applicable:

5.1.4	5.1.5	5.1.7	14.0
9.4	9.4.1	9.4.2	

5.0 REQUIRED DOCUMENTATION

In addition to the documentation listed in Attachment A, the following documentation shall be provided prior to shipment (schedule later):

1) Isometric drawings of the piping system shall document the design.These drawings shall be updated as necessary and submitted to PSI for approval.

6.0 SHOP TESTING

The Vendor shall perform his standard testing.

7.0 INSPECTION

The inspections called for in Attachment A shall be performed by the Vendor:

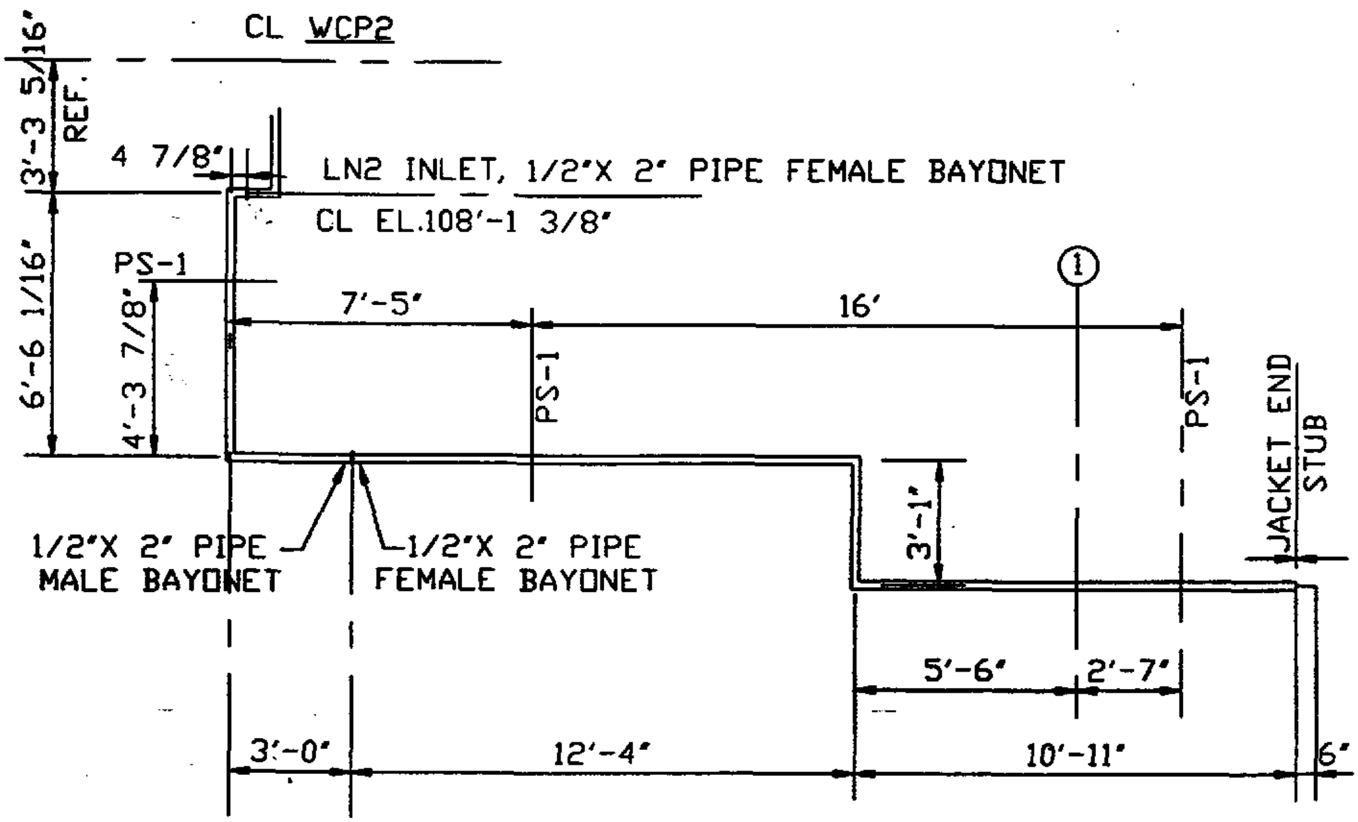
8.0 WARRANTY

Refer to Attachment A, Section 15.0, and to Attachment B, General Provisions, Article 40 for warranty requirements.

ATTACHMENT "A"
LIGO QUALITY ASSURANCE REQUIREMENTS SUMMARY

LIGO VACUUM EQUIPMENT	VENDOR:	JOB NO.: V59049
EQUIPMENT: VACUUM JACKETTED PIPING	VENDOR ENG. OFFICE:	DWG. NO.:
PSI P.O. NO:	VENDOR FACTORY:	SPEC NO.: V049-2-016

TESTING INSPECTION AND DOCUMENTATION RECORD	Submittal After P.O.	Witnessed by PSI	Approval by PSI	Copies Req'd for PSI Files	Record in Mfr's File	Remarks:	Inspector: Date:
MILESTONE SCHEDULE	2 Wks.		X	2	X		
VENDOR Q.A. PLAN	2		X	2	X		
CLEANING PROCEDURE	2		X	2	X		
PREP FOR SHIPMENT PROCEDURE	6		X	2	X		
ASSEMBLY DRAWINGS	4		X	2	X		
DESIGN REVIEW		X			X		
IN-PROCESS INSPECTIONS	TBD	X		2	X		
OPERATION & MAINTENANCE MANUALS	X			X	X		
SHOP TEST PLAN			X	2	X	Prior to release for fabrication.	
SHOP TEST (WITH REPORT)		X		2	X	Prior to release for shipment.	



PLAN VEW

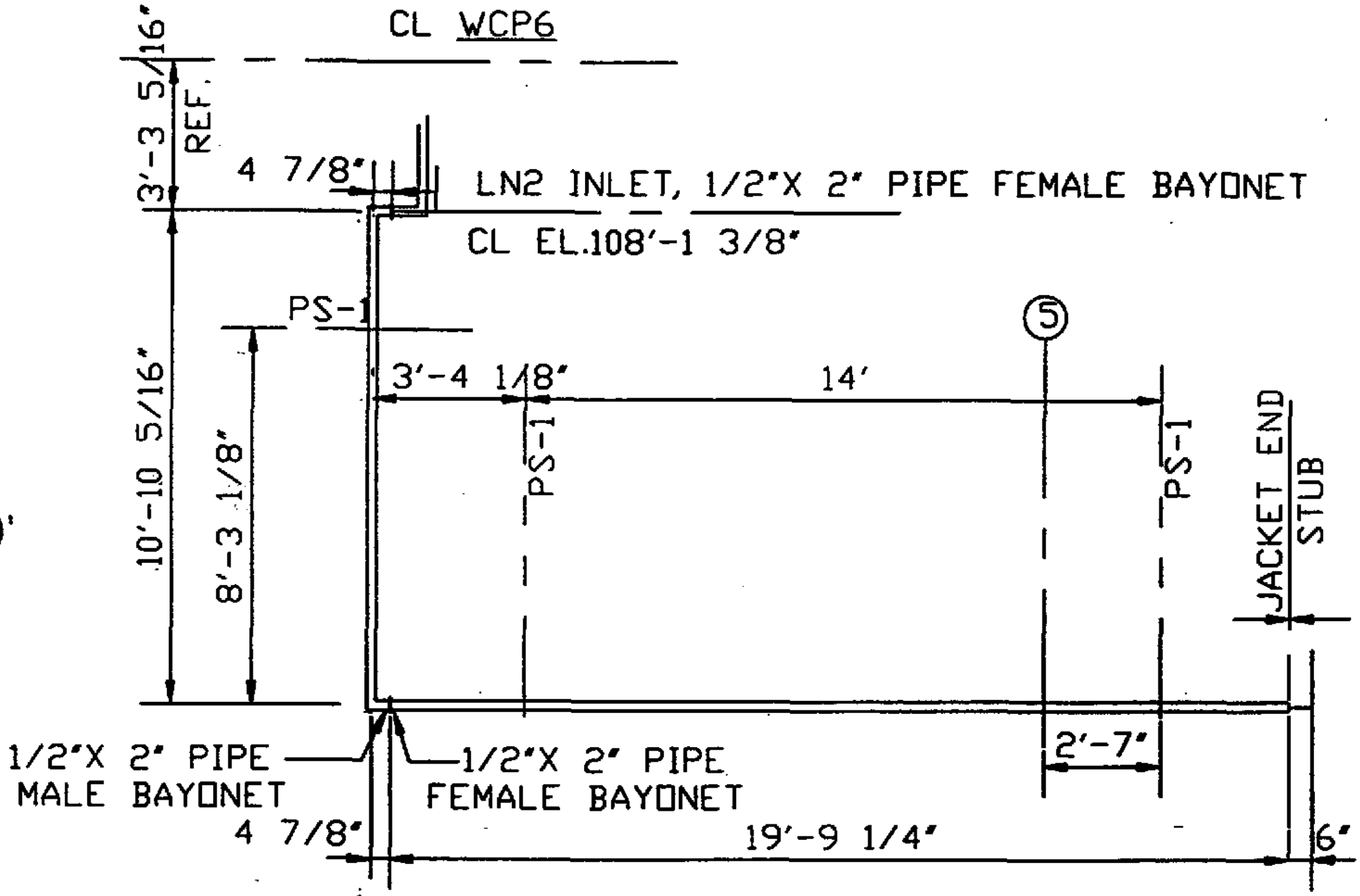
LN2 SUPPLY LINE FOR CORNER STATION.

V049-2-016-SK1

JACKETED LINE: 1/2"IPS X 2"IPS

TOTAL 4 REQ'D
- 2 - AS SHOWN
- 2 - OPPOSITE HAND

Oct. 9, 1996



PLAN VEW

LN2 SUPPLY LINE FOR MID AND END STATION.

V049-2-016-SK2

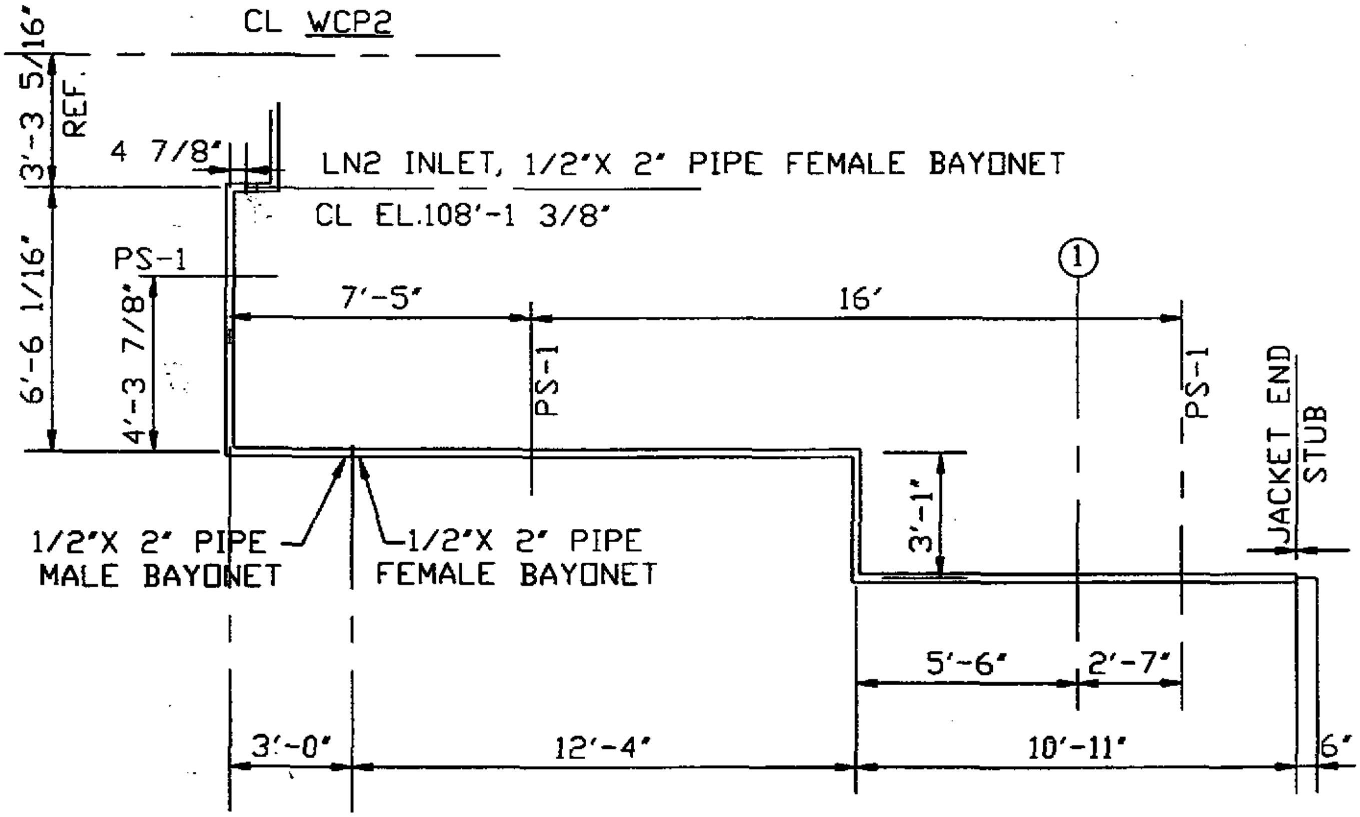
JACKETED LINE: 1/2"IPS X 2"IPS

TOTAL 8 REQ'D

4 - AS SHOWN

4 - OPPOSITE HAND

Oct. 9, 1996



PLAN VEW

LN2 SUPPLY LINE FOR CORNER STATION.

V049-2-016-SK1

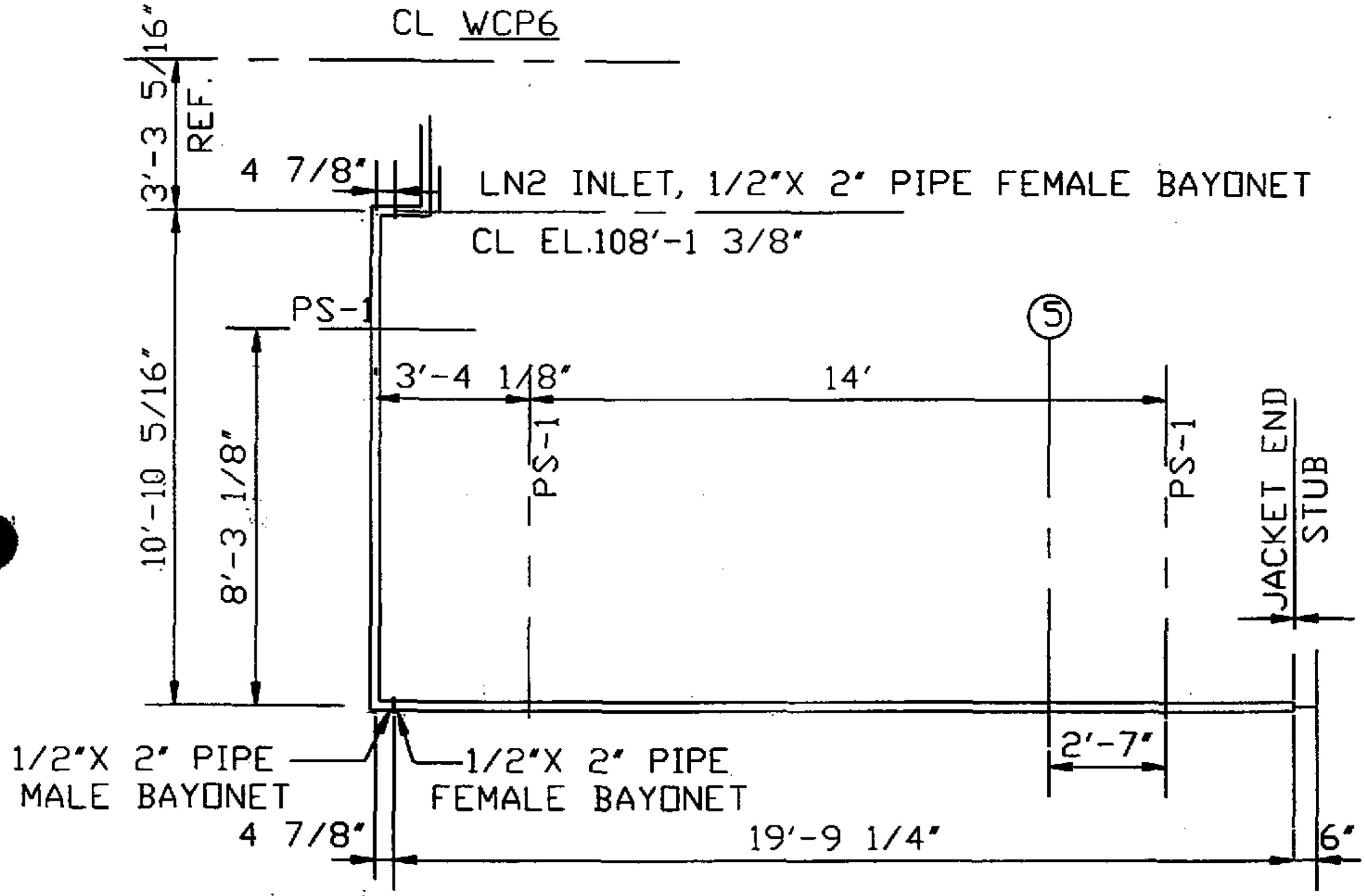
JACKETED LINE: 1/2"IPS X 2"IPS

TOTAL 4 REQ'D

2 - AS SHOWN

2 - OPPOSITE HAND

Oct. 9, 1996



PLAN VEW

LN2 SUPPLY LINE FOR MID AND END STATION.

V049-2-016-SK2

JACKETED LINE: 1/2"IPS X 2"IPS

TOTAL 8 REQ'D

4 - AS SHOWN
4 - OPPOSITE HAND

Oct. 9, 1996

Title: SPECIFICATION FOR BELLOWS EXPANSION JOINTS

RAYMOND D. CIATTO
STATE OF WASHINGTON
REGISTERED PROFESSIONAL ENGINEER

STATE OF LOUISIANA
RAYMOND D. CIATTO
REG. No. 26750
REGISTERED PROFESSIONAL ENGINEER IN CIVIL ENGINEERING

SPECIFICATION FOR

BELLOWS EXPANSION JOINTS

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY: R.E. Curtis 2/7/96

STRUCTURAL ENGINEER: R. D. Ciatto 2/8/96

QUALITY ASSURANCE: R.R. Bradbrook 2/9/96

TECHNICAL DIRECTOR: D. A. McWilliams 2-8-96

PROJECT MANAGER: [signature]

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
5	D. McW 9-17-96	REB 9/15/96	REVISED & ISSUED FOR PURCHASE PER DEO 0266
4	REG 9/11/96	REB 9/11/96	REISSUED FOR PURCHASE. REVISED ATTACHMENT "B" SHT. 1&2. DEO 0261
3	RAC 8-16-96	REG 8/19/96	ISSUED FOR PURCHASE PER DEO 0244
2	RDC 6/24/96	DMcW	REISSUED FOR QUOTES DEO 0210
1	RDC 5/2/96	REB 5/2/96	ISSUED PER DEO 0163 FOR FDR
0	REG 2-7-96	D McW 2-8-96	ISSUED FOR QUOTES DEO 0059
P1	10-19-95		RELEASED PER DEO 0005
P1	TSG 9-26-95		REVISED FOR UPDATED PRELIMINARY DESIGN

Information contained in this specification and its attachments is proprietary in nature and shall be kept confidential. It shall be used only as required to respond to the specification requirements, and shall not be disclosed to any other party.

PROCESS SYSTEMS INTERNATIONAL, INC.

SPECIFICATION

INITIAL APPROVALS	PREPARED	DATE	APPROVED	DATE	Number	Rev.
	REG	2/7/96	D McW	2-8-96	A V049-2-017	5

Title **SPECIFICATION FOR BELLOWS EXPANSION JOINTS**

SPECIFICATION TABLE OF CONTENTS

NOTE: All Sections Revised

1.0 SCOPE

This specification covers the minimum requirements for the design, materials, fabrication, assembly, inspection, testing, preparation for shipping, and shipment of bellows expansion joints for the LIGO vacuum system.

All attachments are part of this specification.

The specified equipment is intended for use as part of the Vacuum Equipment supplied for the Laser Interferometer Gravitational-Wave Observatory (LIGO). LIGO, which is operated by Caltech and MIT under an NSF contract, includes two installations at widely separated sites: near Hanford, WA and Livingston, LA. Each installation contains laser interferometers in an L shape with 4 km arms, a vacuum system for the sensitive interferometer components and optical beams, and other support facilities.

Information contained in this specification and its attachments is proprietary in nature and shall be kept confidential. It shall be used only as required to respond to the specification requirements, and shall not be disclosed to any other party.

2.0 MATERIAL REQUIREMENTS

2.1 All bellows material provided by the vendor shall conform to the requirements of ASME Specification SA-240 Type 304L with the additional supplementary requirements described in this specification. Other vendor supplied materials shall be provided as required by the drawings and bills of material. The bellows material used shall be hot rolled, annealed and pickled. Bright H_2 annealed material is not permitted. If the bellows material is supplied dual certified to grade 304/304L, this will be acceptable to PSI. Vendor or purchaser supplied material for nipples shall be dual certified to grade 304/304L.

2.2 Applicable Codes

2.2.1 ASME Boiler & Pressure Vessel Code, Section II, "Materials", 1992 Edition through 1994 Addenda.

2.2.2 ASTM A-480, "Standard Specification for General Requirements for Flat-Roll Stainless and Heat-Resisting Steel Plate, Sheet, and Strip".

2.2.3 ASTM A-700, "Standard Packages for Packaging, marking, and Loading Methods for Steel Products for Domestic Shipment".

2.3 Any apparent conflicts between the requirements given herein and the applicable ASME Specification shall be brought to the attention of PSI for clarification.

3.0 SCHEDULE

3.1 See Attachment "B" for bellows assembly quantities and delivery schedule.

3.2 All of the above items shall be shipped to the Buyer directly (Westborough, Massachusetts).

3.3 Acceptances at the sites (the start of Vendor's warranty periods) are expected to occur on a staggered basis, with final acceptance expected to occur no later than May 31, 1998. Portions of the equipment may be accepted earlier.

4.0 EQUIPMENT REQUIREMENTS

4.1 The Vendor shall provide the fabricated items identified on the Buyer's design drawings. The bellows detail is shown on Sketch A included in this specification.

4.2 All Bellows and assemblies shall be designed and fabricated to comply with the requirements of the ASME Boiler and Pressure Vessel Code, Section VIII, Division 1, Pressure Vessels, latest edition and subsequent addenda, even though vacuum vessels are beyond the scope of this code. Furnished components need not be code "U" stamped.

4.3 Bellows for the "Adapter and Spool Sections" , except those described in 4.4 below, will to be retracted 3" maximum or extended 1" maximum at installation from the shipping length. Also, bellows will be retracted 3" maximum from the installed position for equipment maintenance and "O-Ring" replacement for approximately 200 cycles (total plant life). The shipping length will be the neutral bellows length without any extensions or compressions.

4.4 Bellows for the HAM nozzles and spools BE-3 and BE-3A cannot be extended because of space limitations, hence, they must be designed to allow from 1 1/2" to 2" in compression from the installed position for "O-Ring" replacement. All other requirements stated in this specification apply. Seller must specify the maximum compression allowed for all adapters and spools.

4.5 For normal operating conditions, thermal expansion movements shown in TABLE 1 are from the installed position and shall be designed for the Seller's normal cycle life (1000 cycles min.). Seller shall specify and complete the dimensional information required in Table 1.

4.6 The bellows spring rate shall be such that the total load (spring rate x maximum displacement) shall not exceed 100 #/inch of circumference at the flange I.D.

4.7 Carbon steel parts including but not limited to tie rods, plate washers and nuts shall be finished by the electroless nickel process meeting the requirements of ASTM B733.

Number

Rev.

5.0 DESIGN REQUIREMENTS

See Attachment "B" for the list of PSI drawings which show bellows spools to be fabricated into bellows assemblies by the Vendor. The bellows shall be provided with end nipples fabricated as shown on PSI drawings, from bulk plate provided by PSI. In addition, jacking lug assemblies and lifting lugs must be installed on each bellows assembly. Design and locations of jacking lug assemblies and lifting lugs will be provided by PSI. Lug & tie-rod material as shown on the PSI drawings shall be provided by Vendor. NOTE: Tie-rod/lifting lugs are to be used as shipping restraints by the bellows vendor.

5.1 "HAM Chamber" bellows shall be provided loose without end nipples.

5.2 Expansion joints shall withstand Ultra-high Vacuum (10E-09 Torr.) at 400 Deg F, bakeout and 2 PSIG internal pressure at room temperature during the purging operation.

5.3 Bellows dimensional limits are shown on PSI drawings. Thermal expansion movements, etc. are shown in Par. 17. The Seller shall provide the actual dimensions and other data requested in the table.

5.3.1 In Par. 17, t is the bellows thickness, O.D. Corr. is the outside diameter of the convolutions, and L is the bellows length. Other dimensions are shown on sketch A.

5.3.2 In addition to the dimensional requirements, the bellows must be capable of permitting a maximum of 1/2 degree of angular offset (bending) while in the installed position.

5.4 Multi-ply bellows are not acceptable for Hi-Vacuum service.

5.5 Except for attachment welds to nipples, circumferential welds in bellows are not permitted under any circumstance.

6.0 MATERIAL TESTING

6.1 One material coupon, 2" x 2" min., from each heat number, lot and thickness of bellows material provided by the vendor must be supplied to PSI for information prior to release for shipment. Each coupon shall be permanently marked/stamped with heat number, lot, etc., for positive identification.

7.0 FABRICATION

7.1 All bellows assemblies shall be furnished complete as shown on the Buyer's drawings, as required by the Purchase Order and as herein noted, and shall include all necessary hardware, such as bolts, washers, and nuts. Tolerances shall be adhered to as specified on the detail drawings.

7.2 For rolling of shells, carbon steel rollers shall be covered with heavy indoor/outdoor carpet or S/S during the rolling process to prevent carbon steel contamination of the stainless steel.

7.3 The seam edges of plates to be rolled are to be preworked to assure roundness of the final cylinder.

8.0 WELDING

8.1 All welding shall be performed in accordance with the ASME Boiler & Pressure Vessel Code, Section IX, Welding and Brazing Qualification, 1992 Edition through 1994 Addenda and other applicable code sections referenced herein.

8.2 All welders shall be certified to ASME Section IX Procedures.

8.3 All vacuum boundary welds shall be continuously welded and shall be on inside per drawing details. Grinding is not permitted; welds shall be smooth but <u>NOT FLUSH</u> & <u>NOT GROUND</u>. Carbide cutting is permitted.

8.4 All welds at vacuum boundaries shall be vacuum tight with a helium leak rate equivalent to a total of 1×10^{-9} torr liters/sec/chamber. PSI will leak test all bellows welds with a helium mass spectrometer. Vendor shall repair all leak areas identified by PSI.

8.5 The Seller's fitup tack welding procedures and procedure qualifications shall be submitted to the Buyer for approval. Approval must be obtained prior to use.

8.6 All weld joint preparation shall be done by tungsten carbide tooling.

8.7 Welding Process

8.7.1. Vacuum boundary and attachment welds shall be gas tungsten arc welds (GTAW) or plasma arc welds (PAW) (see sample Attachment C). The vendor shall submit weld procedures to the Buyer for review and approval prior to fabrication.

8.7.2. All weld repairs shall be performed in accordance with PSI approved procedures.

8.7.3. All weld wire and weld joint preparation areas shall be cleaned with CO_2 scrubbing prior to welding per PSI procedure V049-2-070. Weld wire shall packaged after cleaning to prevent contamination. Weld wire shall be handled only with clean gloves after CO_2 cleaning.

8.8 Backing strips or rings shall not be used.

8.9 Longitudinal seams of the bellows and spools shall be offset.

8.10 Welding shall be done in an area that is separate from dirty processes (MIG welding, grinding, blasting, painting, etc.).

9.0 CLEANLINESS

9.1 This material is intended for use in a high vacuum application. Potential hydrocarbon contamination shall be prevented. Also, the material shall be wrapped and covered at all times the material is not being processed to minimize possible exposure to contaminants.

9.2 No iron, carbon steel or other contaminants (such as grease, oil or hydrocarbons) are to come in contact with the shells. Machining fluids shall be water soluble and free of oil and sulfur. All fluids that come in contact with bellow shall not exceed the contaminant levels permitted as stated below.

Maximum Concentration Limits

Contaminant	Limit
Water Leachable Chlorides	100 ppm
Total Halogens (including Water Leachable Chlorides)	1000 ppm
Total Sulfur	1000 ppm

9.3 Bellows shall be cleaned and dried (air dried) prior to wrapping. The bellows shall be free of all surface contaminants, forming lubricants, free from residue from forming rolls, tools etc. and standing water. The Seller shall submit all cleaning procedures and methods for Buyers approval.

10.0 SHOP TESTING

The Seller shall submit all test methods and procedures that are to be used to verify the leak tightness of the expansion joints (bellows and weld nipples) or bellows (after forming) for the buyers approval. The Seller shall submit the documented results of the tests to the Buyer for his records. The Buyer reserves the right to witness the tests on-site. The vendor shall notify the buyer 5 working days before each lot is leak tested.

Bellows shall be helium leak checked per ASTM E498 to less than $1x10^{-9}$ Torr l/sec.

Liquid penetrant testing shall not be used for testing.

11.0 INSPECTION

11.1 The responsibility for all inspections rests with the Seller, however, the Buyer reserves the right to inspect the components and/or final assemblies at any time during or after fabrication to assure that the workmanship and materials are in compliance with this specification.

11.2 The purchaser shall have the right to witness all manufacturing processes.

11.3 The purchaser shall be informed 5 working days before the scheduled ship date of each lot. A signed release for ship form is required from the purchaser to release each shipment.

11.4 Purchaser supplied material must be inspected by the purchaser before use. (Direct shipment from mills.)

12.0 REJECTIONS AND REPAIR OF DEFECTS

12.1 No weld splices or repair welding is permitted to the formed bellows. The only exception is at the bellows to nipple circumferential seal welds.

12.2 If a weld defect is found in the bellows to nipple weld during PSI's leak test, the weld will be repaired by PSI and the cost back charged to the vendor.

12.3 If a weld or metal defect is found in the metal bellows during PSI's leak test, the bellows unit will be returned to the vendor, and a replacement bellows assembly will be sent to PSI at no cost to PSI.

13.0 IDENTIFICATION

13.1 Identification of the nipple and bellows material shall be maintained and documented through all manufacturing processes (i.e. restamping material heat numbers after each cut).

13.2 If material identity of the bellows or nipples is lost, they shall be requalified by making all tests that were required for the material or as indicated in this specification.

13.3 Marking the finished bellows with marking fluids, die stamps, and/or electro-etching is not permitted. A vibratory tool with a minimum tip radius of .005" is acceptable for marking only the outside of the attached shells (when applicable). All other marking methods must be approved by the purchaser prior to use. All attached nipples shall be marked 2" from the edge. Material heat numbers shall be marked on the outside of all bellows and nipples.

13.4 All bellows and bellows assemblies shall be marked with the Buyer's drawing number plus "P1" and a unique serial number for each assembly (1, 2, 3, etc.) Example: V0494A1P1 Serial No. 1. All quality assurance documentation shall reference this number.

Number Rev.

14.0 DOCUMENTATION

14.1 The Certified Material Test Reports (CMTRs) for vendor purchased material shall be provided to the purchaser with the shipment of the assemblies, and be available for review during inspection visits prior to shipment. See Attachment A for other required documentation.

14.2 Design calculations and fabrication drawings shall be submitted to the purchaser for approval prior to fabrication.

15.0 PACKAGING, STORING AND SHIPPING

15.1 Temporary shipping supports, as required, shall be of the same material as the nipple and attached so that they may easily be removed without damage to the assemblies. All temporary devices shall be clearly marked and tagged "to be removed prior to operation".

15.2 All material and parts shall be covered with a tarp immediately after each processing operation has been completed to minimize contamination. The material shall remain packaged and covered until it is necessary to remove the covering and packaging material for further processing.

15.3 After final cleaning, bellows/assemblies shall be packaged for shipping. All bellows/assemblies shall be wrapped in polyethylene and placed in closed wooden crates with proper supports to prevent shipping damage.

15.4 The bellows shall be shipped as specified in the purchase order (TBD).

15.5 The purchaser shall approve each lot of bellows/bellows assemblies prior to shipment. A signed off (by purchaser) release to ship form shall be included with each shipment.

16.0 NON-ESCORT PRIVILEGES AND INSPECTION RIGHT

Non-escort privileges for Buyer, Owner, Government and Owner representatives to all areas of the facilities where the work is being performed shall be arranged. This will include access to fabrication, assembly, cleaning and test areas for the purpose of monitoring activities.

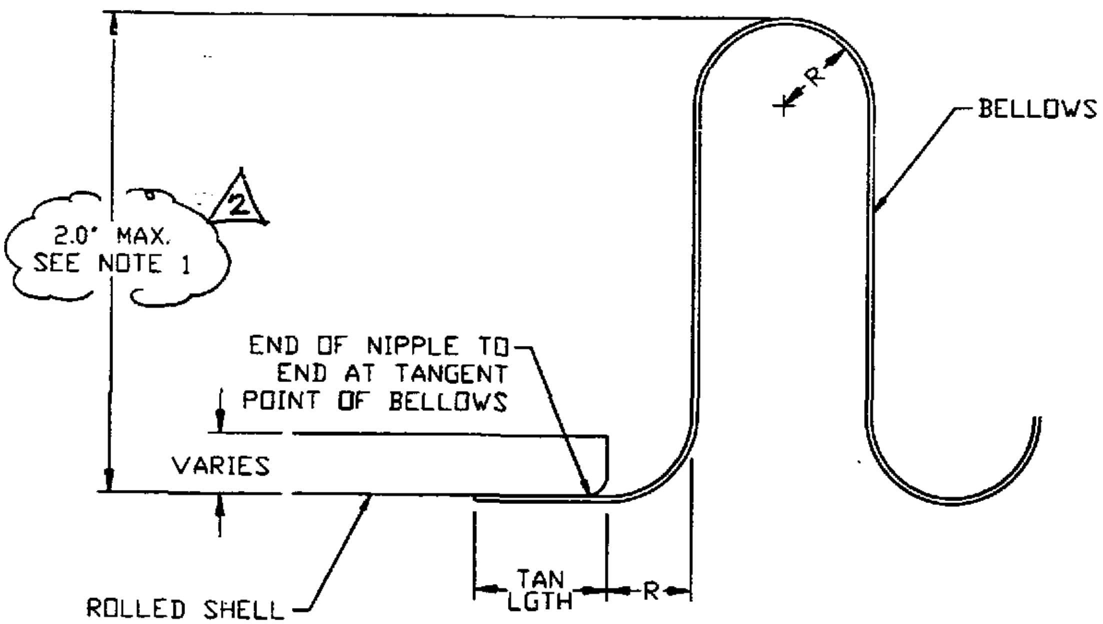
17.0 BELLOWS DESIGN DATA

SPEC. V049-2-017

SELLER TO PROVIDE

REV	ITEM	BELLOWS ID	QTY	MAINT. COMPR.	THERMAL AXIAL COMPR.	MAX. O.D. CORR	"t" (INCHES)	TAN LGTH.	ACT. O.D. CORR	ACT. "L"	NO. OF CORR.	CYCLE LIFE
	V049-4-053 (HAM)	60 1/2"	18	2"	1/2"	63 1/2"						
	ADAPTER -A1	44 5/8"	10	3"	7/16"							
	ADAPTER -A3	48 1/4"	4	3"	9/16"							
	ADAPTER -A6	48 1/4"	2	3"	3/8"							
	ADAPTER -A12	48 1/4"	2	3"	5/8"							
	ADAPTER -A13	60 1/2"	2	3"	9/16"							
	ADAPTER -A14	44 5/8"	2	3"	5/8"							
	SPOOL BE-2	60 1/2"	4	3"	1/2"							
	SPOOL BE-3	60 1/2"	3	2"	1/2"							
	SPOOL BE-3A	60 12"	3	2"	1/2"							
	SPOOL BE-1	72 1/4"	2	3"	5/8"							
	SPOOL BE-4	44 5/8"	12	3"	11/16"							
	SPOOL BE-5	72 1/4"	2	3"	2"							
	SPOOL BE-6	72 1/4"	2	3"	2							
	SPOOL B2A	30 1/2"	1	3"	1"							
	SPOOL B2B	30 1/2"	1	3"	1"							
	SPOOL B3A	30 1/2"	2	3"	1"							
	SPOOL B5A	30 1/2"	2	3"	1"							

NOTE 1: TYPICAL FOR ALL BELLOWS EXCEPT HAM. FOR HAM BELLOWS, THIS DIMENSION SHALL BE 1.5" MAX.



					PROCESS SYSTEMS INTERNATIONAL INC. 20 WALKUP DR. WESTBOROUGH, MASSACHUSETTS 01581 USA
					SKETCH A BELLOWS DETAIL
					CAD FILE NO. V0492017 / SIZE A / DWG. NO. V049-2-017 / REV. 4
REV.	DESCRIPTION	DATE	BY	CHK.	APP.	SCALE: NONE / DRAWN: / SHEET: 11 OF 11

ATTACHMENT "A"
LIGO QUALITY ASSURANCE REQUIREMENTS SUMMARY

LIGO VACUUM EQUIPMENT	VENDOR:	JOB NO.: V59049
EQUIPMENT:BELLOWS EXPANSION JOINTS	VENDOR ENG. OFFICE:	DWG. NO.:
PSI P.O. NO:	VENDOR FACTORY:	SPEC NO.: V049-2-017

TESTING INSPECTION AND DOCUMENTATION RECORD	Submittal After P.O.	Witnessed by PSI	Approval by PSI	Copies Req'd for PSI Files	Record in Mfr's File	Remarks:	Inspector: Date:
MILESTONE SCHEDULE	9/13		X	2	X		
VENDOR Q.A. PLAN	9/13		X	2	X		
CLEANING PROCEDURE	9/13		X	2	X		
PREP FOR SHIPMENT PROCEDURE	9/13		X	2	X		
WELDING PROCEDURES			X	2	X		
ASSEMBLY DRAWINGS			X	2	X		
DESIGN REVIEW							
CERTIFIED MATERIAL TEST REPORTS				2	X		
IN-PROCESS INSPECTIONS		X		2	X		
BELLOWS DESIGN DATA				2	X		
SHOP TEST PLAN (LEAK CHECK, ETC.)			X	2	X		
SHOP TEST (WITH REPORT)		X		2	X		
SHOP DIMENSIONAL INSPECTION		X		2	X		

Title **SPECIFICATION FOR BELLOWS EXPANSION JOINTS**

ATTACHMENT "B"

Drawing List, Schedule of Bellows Assembly Quantities, and Deliveries.

PSI Dwg No.	PSI Part No.	Rolled Nipple I.D.	Quantity (Wash.)	Date	Quantity (LA)	Date	Make From PSI Part No.
V049-4-A1	V0494A1P1	44.63	6	10/25/96	4	2/1/97	V049M159-1
V049-4-A3	V0494A3P1	48.25	2	10/25/96	2	2/1/97	V049M163-1
V049-4-A6	V0494A6P1	48.25	2	10/25/96	0	2/1/97	V049M163-1
V049-4-A12	V0494A12P1	48.25	2	10/25/96	0	2/1/97	V049M163-1
V049-4-A13	V0494A13P1	60.5	2	10/25/96	0	2/1/97	V049M163-1
V049-4-A14	V0494A14P1	44.63	2	11/25/96	0	2/1/97	V049M178-1
V049-4-B2A	V0494B2AP1	30.5	1	11/25/96	0	2/1/97	V049M157-1
V049-4-B2B	V0494B2BP1	30.5	1	11/25/96	0	2/1/97	V049M157-1
V049-4-B3A	V0494B3AP1	30.5	1	11/25/96	1	2/1/97	V049M157-1
V049-4-B5A	V0494B5AP1	30.5	1	11/25/96	1	2/1/97	V049M157-1
V049-4-BE1	V0494BE1P1	72.25	0	11/25/96	2	2/1/97	V049M154-1
V049-4-BE2	V0494BE2P1	60.5	2	10/25/96	2	2/1/97	V049M153-1
V049-4-BE3	V0494BE3P1	60.5	2	11/25/96	1	2/1/97	V049M177-1
V049-4-BE3A	V0494BE3AP1	60.5	2	11/25/96	1	2/1/97	V049M177-1
V049-4-BE4	V0494BE4P1	44.63	8	11/25/96	4	2/1/97	V049M158-1
V049-4-BE5	V0494BE5P1	72.25	1	11/25/96	1	2/1/97	V049M155-1
V049-4-BE6	V0494BE6P1	72.25	1	11/25/96	1	2/1/97	V049M155-1
V049-4-053	V0494053	60.5	12	11/25/96	6	2/1/97	
		Total	**48**	**Total**	**26**		

NOTE: Partial deliveries in advance of above dates are acceptable only with PSI approval.

ATTACHMENT "B"

List of PSI Purchased Plate To Be Sent To Bellows Vendor

Plate P/N	Size	WA	LA	Total PLS
V049M159-1	1/4 x 96 x 142	3	2	5
V040M163-1	1/4 x 72 x 154	4	1	5
V049M178-1	1/4 x 88 x 142	2	---	2
V049M157-1	1/4 x 90 x 98	2	1	3
V049M154-1	1/4 x 120 x 229	---	2	2
V049M153-1	1/4 x 62 x 192	2	2	4
V049M177-1	3/8 x 96 x 192	1	1	2
V049M158-1	1/4 x 66 x 142	4	2	6
V049M155-1	3/8 x 96 x 230	1	1	2

ATTACHMENT "D"

LIGO Project **Release to Ship Form** **Date:**____________

Purchase Order No.:	Lot:
Vendor Name:	
PSI Part Number:	
Description:	
Manufacturers' Model Number:	
Manufacturers' Serial Number:	
Specification Number: V049-	Rev.:
Packaging Requirements: Per V0492017	
Ship Via:	
Bill of Lading:	
Ship to Address: Process Systems International	
20 Walkup Drive	
Westborough, MA 01581	
(508) 366-9111	
FOB:	
Attention of: Receiving Department	
Operating Manuals: with Equipment ; to PSI	
Documentation Package: To be sent to PSI; Attention: Mr. Ronald Bento	
Authorized Signature:	

SPECIFICATION FOR

AMBIENT AIR VAPORIZERS

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY: David Moore

QUALITY ASSURANCE: [signature]

TECHNICAL DIRECTOR: DAVE McWILLIAMS/RSD

PROJECT MANAGER: [signature]

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
1	DM 7/22/96	RSD	Revised per DEO Ø225 & released for purchase
Ø	DM 2/20/96		Initial release DEO # 0067

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION	
INITIAL APPROVALS	PREPARED DM	DATE 2/20/96	APPROVED D. McW	DATE 2-23-96	Number A V049-2-055 / Rev. 1

TABLE OF CONTENTS

1.0 SCOPE

This specification covers the minimum requirements for the design, materials, fabrication, assembly, inspection, testing, preparation for shipping, shipment and delivery of the ambient air vaporizers for the LIGO vacuum system.

All attachments are incorporated herein by reference and made a part of this specification.

The specified equipment is for use as part of the Vacuum Equipment supplied for the Laser Interferometer Gravitational-Wave Observatory (LIGO). LIGO, which is operated by Caltech and MIT under an NSF grant, includes to sites (Hanford Reservation, near Richland, WA, and Livingston, LA). Each site contains laser interferometers components and optical beams, and other support facilities.

Information contained in this specification and its attachments is proprietary in nature and shall be kept confidential. It shall be used only as required to respond to the specification requirements, and shall not be disclosed to any other party.

2.0 SCHEDULE

2.1 Equipment delivery shall be as follows:

PSI P/N	Type	Delivery Site	Quantity	Ends	Date
V0492055 P1	10600 SCFH min. capacity	Washington	2	MPT	8/7/97
		Louisiana	2	MPT	2/5/98
		Total	4		
V0492055 P2	5300 SCFH min. capacity	Washington	6	MPT	8/7/97
		Louisiana	2	MPT	2/5/98
		Total	8		

3.0 EQUIPMENT REQUIREMENTS

3.1 The ambient air vaporizers will be used to vaporize liquid nitrogen at a supply pressure of approximately 10 psig for the purpose of warming up the LIGO 80K cryopumps.

4.0 DESIGN REQUIREMENTS

4.1 Mechanical Requirements

4.1.1 The vaporizers shall be an all welded aluminum alloy construction designed to be used outdoors, and mounted directly to a concrete pad by means of anchor bolts.

4.1.2 The vaporizer duty cycle will be 12 hours of continuous use followed by an extended period (greater than 7 days) during which no gas will be flowing through it.

4.1.3 The vaporizer design shall be based on the flow rates specified in paragraph 2.1, and a 20 deg. F approach temperature under the following ambient conditions:

Winter:	15 deg. F dry bulb
Summer:	96 deg. dry bulb, 68 deg. F wet bulb

4.1.4 The maximum allowable pressure drop across the vaporizer shall be as follows:

10600 SCFH vaporizer	2.0 psid
5300 SCFH vaporizer	1.0 psid

4.2 Electrical Requirements
Not applicable.

4.2.1 Instrumentation Requirements
None required.

4.2.2 Power requirements
Not applicable.

4.2.3 The following paragraphs of Attachment B are not applicable:

3.2	5.1.5	5.1.7
5.1.4	5.2	8.2
8.4	9.3	9.4
11.3	11.4	

5.0 REQUIRED DOCUMENTATION

In addition to the documentation listed in Attachment B, the following documentation shall be provided prior to shipment:

- Manufacturer's standard QA reports (including final functional test reports).

6.0 SHOP TESTING

The equipment shall be tested in accordance with the manufacturer's standard shop test.

7.0 INSPECTION

7.1 All testing and inspections called for in Attachment B (Specification V049-2-033, General Equipment Requirements) shall be performed by the Vendor. Additional quality assurance requirements are listed in Attachment A, Quality Assurance Requirements Summary.

8.0 WARRANTY

Refer to Specification V049-2-034, Purchased Equipment Commercial Requirements (attached to the Request for Quotation), for warranty requirements.

Number

Rev.

ATTACHMENT "A"

LIGO QUALITY ASSURANCE REQUIREMENTS SUMMARY

LIGO VACUUM EQUIPMENT	VENDOR:	JOB NO.: V59049
EQUIPMENT: AMBIENT AIR VAPORIZERS	VENDOR ENG. OFFICE:	DWG. NO.:
PSI P.O. NO:	VENDOR FACTORY:	SPEC NO.: V049-2-062

TESTING INSPECTION AND DOCUMENTATION RECORD	Submittal After P.O.	Witnessed by PSI	Approval by PSI	Copies Req'd for PSI Files	Record in Mfr's File	Remarks:	Inspector: Date:
MILESTONE SCHEDULE	2 Wk		X	2	X		
VENDOR Q.A. PLAN	2 Wk		X	2	X		
CLEANING PROCEDURE	4 Wk		X	2	X		
PREP FOR SHIPMENT PROCEDURE	6 Wk		X	2	X		
ASSEMBLY DRAWINGS	4 Wk		X	2	X		
DESIGN REVIEW						PRIOR TO RELEASE FOR FABRICATION.	
IN-PROCESS INSPECTIONS						PRIOR TO RELEASE FOR FABRICATION.	
OPERATION & MAINTENANCE MANUALS	12Wk			5	X		
SHOP TEST PLAN	8 Wk		X	2	X	PRIOR TO RELEASE FOR FABRICATION.	
SHOP TEST (WITH REPORT)				2	X	PRIOR TO RELEASE FOR SHIPMENT.	
SHOP DIMENSIONAL INSPECTION	*	X		2	X		
WELDING PROCEDURES	4 Wk		X	2	X		
* PER APPROVED VENDOR SCHEDULE							

Title: SPECIFICATION FOR 80K PUMP REGENERATION HEATERS

SPECIFICATION FOR

80K PUMP REGENERATION HEATERS

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY: David Moore

QUALITY ASSURANCE: A K Brookbrook

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: [signature]

ELECTRICAL/ INSTRUMENTATION [signature]

Information contained in this specification and its attachments is proprietary in nature and shall be kept confidential. It shall be used only as required to respond to the specification requirements, and shall not be disclosed to any other party.

REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE
1	DM	AEB	Released for purchase per DEO 226. No spec. changes
Ø	DM	DMW	Initial release

PROCESS SYSTEMS INTERNATIONAL, INC. — **SPECIFICATION**

INITIAL APPROVALS	PREPARED	DATE	APPROVED	DATE	Number	Rev.
	DMoore	2/23/96	D. McW		A **V049-2-056**	1

Title

SPECIFICATION FOR 80K PUMP REGENERATION HEATERS

TABLE OF CONTENTS

1.0 SCOPE

This specification covers the minimum requirements for the design, materials, fabrication, assembly, inspection, testing, preparation for shipping, shipment and delivery of the 80K pump regeneration heaters for the LIGO vacuum system.

All attachments are incorporated herein by reference and made a part of this specification.

The specified equipment is for use as part of the Vacuum Equipment supplied for the Laser Interferometer Gravitational-Wave Observatory (LIGO). LIGO, which is operated by Caltech and MIT under an NSF grant, includes to sites (Hanford Reservation, near Richland, WA, and Livingston, LA). Each site contains laser interferometers in an L shape with 4 km arms, a vacuum system for the sensitive interferometers components and optical beams, and other support facilities.

Information contained in this specification and its attachments is proprietary in nature and shall be kept confidential. It shall be used only as required to respond to the specification requirements, and shall not be disclosed to any other party.

2.0 SCHEDULE

2.1 Equipment delivery shall be as follows:

PSI P/N	Type	Delivery Site	Quantity	Nozzles	Date
V0492056P1	10600 SCFH min. capacity	Washington	2	Flg or BW	8/7/97
		Louisiana	2	Flg or BW	2/5/98
		Total	4		
V0492056P2	5300 SCFH min. capacity	Washington	6	Flg or BW	8/7/97
		Louisiana	2	Flg or BW	2/5/98
		Total	8		

3.0 EQUIPMENT REQUIREMENTS

3.1 The regeneration heaters will be used to heat nitrogen gas at a supply pressure of approximately 10 psig for the purpose of warming up the LIGO 80K cryopumps.

4.0 DESIGN REQUIREMENTS

4.1 Mechanical Requirements

4.1.1 The heaters shall be an all welded stainless steel construction designed to be used outdoors, and mounted on a skid, provided by PSI, by means of threaded studs or bolts. The heater elements shall be accessible and removable by means of a flanged connection.

4.1.2 The heater duty cycle will be 12 hours of continuous use followed by an extended period (greater than 7 days) during which no gas will be flowing through it.

4.1.3 The heater design shall be based on the flow rates specified in paragraph 2.1, under the following ambient conditions:

Minimum Gas Supply Temperature	-5 deg. F.
Required Outlet Temperature	
5300 SCFH Heater	375 deg. F
10600 SCFH Heater	360 deg. F

Ambient Conditions:

Winter	15 deg. F dry bulb
Summer	96 deg. F. dry bulb, 68 deg. F. wet bulb

4.1.4 The maximum allowable pressure drop across the heater shall be as follows:

10600 SCFH heater	1.0 psid
5300 SCFH heater	1.0 psid

4.1.5 Nozzles sizes for the heaters shall be as follows:

10600 SCFH heater	1-1/2 inch IPS inlet 3 inch IPS outlet
5300 SCFH heater	1-1/2 inch IPS inlet 1-1/2 inch IPS outlet

4.2 Electrical Requirements
Refer to Attachment B.

4.2.1 Instrumentation Requirements
Two type "K" thermocouples shall be internally mounted in the heater cavity. One will be used for a high temperature alarm status, The other will be used as a spare. Thermocouples shall be #20 AWG, ungrounded, and shielded. A type "K" female connector and dedicated knockout, separate from power, shall be provided.

4.2.2 Controls Requirements
The Vendor shall supply a zero crossing type SCR controller for adjustment of the power applied to the heater. This unit shall be proportionately sized based upon the the heater power requirements. The input signal will be 4-20 ma. Status indication in the form of relay outputs shall be required, at a minimum for:
a) Shorted SCR indication
b) SCR "on" indication
The SCR unit shall be supplied in a NEMA 4X enclosure.

4.2.3 Power Requirements: A dedicated power knockout and power terminals shall be provided. The available power is a 480V, 3 phase, 4 wire system.

4.2.4 The following paragraphs of Attachment B are not applicable:

5.1.1	5.1.4	5.1.5
5.1.6	5.1.7	5.1.11
5.2.1.3	6.3	8.2
8.4	9.4	11.3
14.0		

5.0 REQUIRED DOCUMENTATION

In addition to the documentation listed in Attachment B, the following documentation shall be provided prior to shipment:

- Manufacturer's standard QA reports (including final functional test reports).

6.0 SHOP TESTING

6.1 The equipment shall be tested in accordance with the manufacturer's standard shop test.

7.0 INSPECTION

7.1 All testing and inspections called for in Attachment B (Specification V049-2-033, General Equipment Requirements) shall be performed by the vendor. Additional quality assurance requirements are listed in Attachment A, Quality Assurance Requirements Summary.

8.0 WARRANTY

Refer to Specification V049-2-034, Purchased Equipment Commercial Requirements (attached to the Request for Quotation), for warranty requirements.

ATTACHMENT "A"

LIGO QUALITY ASSURANCE REQUIREMENTS SUMMARY

LIGO VACUUM EQUIPMENT	VENDOR:	JOB NO.: V59049
EQUIPMENT: REGENERATION HEATERS	VENDOR ENG. OFFICE:	DWG. NO.:
PSI P.O. NO:	VENDOR FACTORY:	SPEC NO.: V049-2-056

TESTING INSPECTION AND DOCUMENTATION RECORD	Submittal After P.O.	Witnessed by PSI	Approval by PSI	Copies Req'd for PSI Files	Record in Mfr's File	Remarks:	Inspector: Date:
MILESTONE SCHEDULE	2 Wk		X	2	X		
VENDOR Q.A. PLAN	2 Wk		X	2	X		
CLEANING PROCEDURE	4 Wk		X	2	X		
PREP FOR SHIPMENT PROCEDURE	6 Wk		X	2	X		
ASSEMBLY DRAWINGS	4 Wk		X	2	X		
DESIGN REVIEW	*	X			X	PRIOR TO RELEASE FOR FABRICATION	
IN-PROCESS INSPECTIONS	*	X		2	X	PRIOR TO RELEASE FOR FABRICATION	
OPERATION & MAINTENANCE MANUALS	12 Wk			5	X		
SHOP TEST PLAN	8 Wk		X	2	X	PRIOR TO RELEASE FOR FABRICATION	
SHOP TEST (WITH REPORT)	*	X		2	X	PRIOR TO RELEASE FOR SHIPMENT	
SHOP DIMENSIONAL INSPECTION	*	X		2	X		
WELDING PROCEDURES	4 Wk		X	2	X		
* PER APPROVED VENDOR SCHEDULE							

Title: SPECIFICATION FOR SMALL VACUUM VALVES

SPECIFICATION FOR

SMALL VACUUM VALVES

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY: Thomas M. Starr

PROCESS ENGINEER: Roberto Thom.

QUALITY ASSURANCE: Alan K Bradbrook

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: Bradley Bayles

1	TMS 7-19-96	DMW	REVISED FOR PURCHASE PER DEO 0224
0	TMS 2-29-96	D.McW	RELEASED FOR QUOTE PER DEO 0075
REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

PROCESS SYSTEMS INTERNATIONAL, INC.					SPECIFICATION	
INITIAL APPROVALS	PREPARED	DATE	APPROVED	DATE	Number V049-2-059	Rev.
	T. Starr	2-29-96	KEB	2/21/96		1

SPECIFICATION TABLE OF CONTENTS

1.0 SCOPE

This specification covers the minimum requirements for the design, materials, fabrication, assembly, inspection, testing, preparation for shipping, shipment and delivery of small (1 1/2" and 2 1/2") high vacuum and ultra high vacuum angle valves for the LIGO vacuum system.

The specified equipment is for use as part of the Vacuum Equipment supplied for the Laser Interferometer Gravitational-Wave Observatory (LIGO). LIGO, which is operated by Caltech and MIT under an NSF grant, includes two sites (Hanford Reservation, near Richland, WA and Livingston, LA). Each site contains laser interferometers in an L shape with 4 km arms, a vacuum system for the sensitive interferometer components and optical beams, and other support facilities.

Information contained in this specification and its attachments is proprietary in nature and shall be kept confidential. It shall be used only as required to respond to the specification requirements, and shall not be disclosed to any other party.

2.0 SCHEDULE

2.1 Equipment delivery shall be as follows:

	Quantity	Date	PSI Part No.
1 1/2" High Vac	137	9/30/96	V049AVHV15
2 1/2" High Vac	70	9/30/96	V049AVHV25
1 1/2" Ultra High Vac	77	9/30/96	V049AVUV15
2 1/2" Ultra High Vac	26	9/30/96	V049AVUV25

2.2 All valves shall be delivered to Process Systems International, Inc. at 20 Walkup Drive, Westboro, Massachusetts, 01581.

2.3 Acceptances at the sites are expected to occur on a staggered basis, with final acceptance at Washington expected to occur about May 31, 1998, and about November 30, 1998 in Louisiana.

3.0 DESIGN REQUIREMENTS

3.1 Angle valves shall be 304L or 316L stainless steel (304 or 316 stainless steel is acceptable if the valves are unavailable in L grade SS).

3.2 End connections shall be CF flanges.

3.3 The valves shall have stainless steel metal bellows stem feedthroughs.

3.4 Neither the body leakage not the seat leakage shall exceed 1×10^{-9} torr liters/sec of helium.

3.5 The valves shall be designed to seal in both directions.

3.6 The internal valve mechanisms shall be non-lubricated.

3.7 Valves shall be manually actuated by a handwheel.

3.8 Valves shall be bakeable to 150 C +/-20 C (170 C maximum).

3.9 The valves shall be cleaned in accordance with the Vendor's standard procedures applicable to the valve service.

4.0 REQUIRED DOCUMENTATION

Engineering drawings shall be submitted for approval prior to fabrication. Manufacturer's standard QA reports shall be provided prior to shipment:

5.0 SHOP TESTING

Each valve shall be tested for leakage (using oil-free pumping equipment and leak detector) prior to shipment from the manufacturer

6.0 INSPECTION

The Vendor's standard inspections shall be performed. Also, each valve shall be inspected for cleanliness by black light prior to shipment. Valves shall be recleaned if any contamination is found.

Title: SPECIFICATION FOR CLEAN QUARTER-TURN VALVES

SPECIFICATION FOR

CLEAN QUARTER-TURN VALVES

FOR

LIGO VACUUM EQUIPMENT

Hanford, Washington
and
Livingston, Louisiana

PREPARED BY: Thomas M. Starr

PROCESS ENGINEER: Roberto Thren

QUALITY ASSURANCE: Alan L Bradbrook

TECHNICAL DIRECTOR: D.C. McWilliams

PROJECT MANAGER: [signature]

Information contained in this specification and its attachments is proprietary in nature and shall be kept confidential. It shall be used only as required to respond to the specification requirements, and shall not be disclosed to any other party.

1	TMS 9-25-96	DMcW 9-26-96	REVISED FOR PURCHASE PER DEO 0274
0	TMS 3-1-96	D.McW 3-5-96	RELEASED FOR QUOTE PER DEO 077
REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

PROCESS SYSTEMS INTERNATIONAL, INC.				SPECIFICATION	
INITIAL APPROVALS	PREPARED: T.M. Starr	DATE: 3-1-96	APPROVED: RES	DATE:	Number: V049-2-060 A	Rev. 1

SPECIFICATION TABLE OF CONTENTS

1.0 SCOPE

This specification covers the minimum requirements for the design, materials, fabrication, assembly, inspection, testing, preparation for shipping, shipment and delivery of 2" clean quarter-turn valves for the LIGO vacuum system. These valves will be used in Federal Standard 209 Class 100 air service.

The specified equipment is for use as part of the Vacuum Equipment supplied for the Laser Interferometer Gravitational-Wave Observatory (LIGO). LIGO, which is operated by Caltech and MIT under an NSF grant, includes two sites (Hanford Reservation, near Richland, WA and Livingston, LA). Each site contains laser interferometers in an L shape with 4 km arms, a vacuum system for the sensitive interferometer components and optical beams, and other support facilities.

Information contained in this specification and its attachments is proprietary in nature and shall be kept confidential. It shall be used only as required to respond to the specification requirements, and shall not be disclosed to any other party.

2.0 SCHEDULE

2.1 Equipment delivery shall be as follows:

	Quantity	Date	PSI Part No.
PSI, Westboro, MA:	21	11/29/96	V049BVCA20

2.2 Deleted

3.0 DESIGN REQUIREMENTS

3.1 The valves shall be either butterfly style, MDC Model No. BFV-200, MDC Part No. 360002.

3.2 The valves shall be 304 stainless steel.

3.3 End connections shall be CF flanges.

3.4 The valves shall be designed to seal in both directions.

3.5 The internal valve mechanisms shall be non-lubricated.

3.6 The valves shall be cleaned in accordance with the Vendor's standard procedure for valves intended for use in Federal Standard 209 Class 100 clean air service..

3.7 Valves shall be manually actuated.

4.0 REQUIRED DOCUMENTATION

Engineering drawings shall be submitted for approval prior to fabrication. Manufacturer's standard QA reports shall be provided prior to shipment:

5.0 SHOP TESTING

Manufacturer's standard testing shall be performed.

6.0 INSPECTION

The Vendor's standard inspections shall be performed. Also, each valve shall be visually inspected for cleanliness prior to shipment. Valves shall be recleaned if any contamination is found.

ATTACHMENT

Butterfly Valves

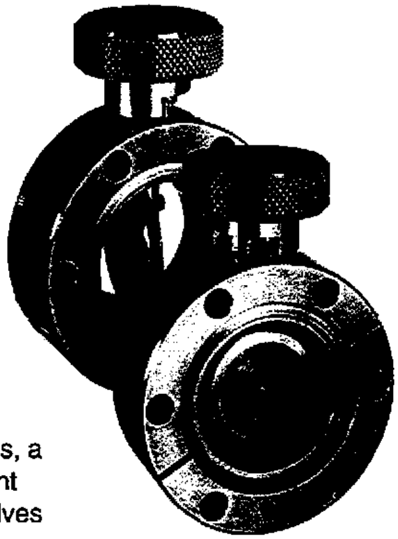
Del•Seal Metal Seal Flange | ***Kwik•Flange*** ISO O-Ring Flange

FEATURES

- Quick open/Quick close
- Positive lock both positions
- Positive Viton® O-Ring vacuum seal
- High conductance
- Choice of *Del-Seal* or *Kwik-Flange*

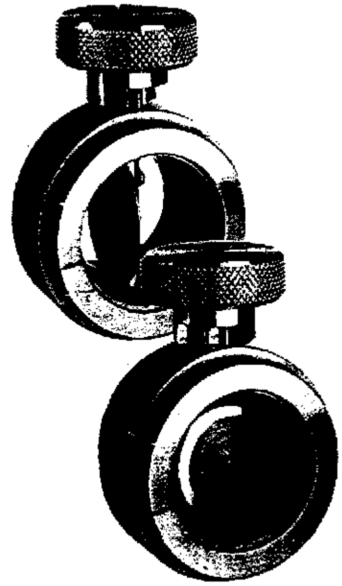
DESCRIPTION

MDC Butterfly Valves require only one-quarter turn rotation of the handle to go from fully open to the fully closed position. In the 1-1/3 Mini *Del-Seal* flange series, a spring loaded ball bearing becomes seated in an indent providing a positive mechanical stop. All other size valves employ a roll pin stop method.



Del-Seal Flange
BFV-150

These quick-acting Butterfly Valves feature an improved sealing action. The opening in the body of the valve has been machined at a slight angle to the plane of the flapper. The flapper is set to rotate slightly off-center. On closure, this causes the sealing pressure to be applied more uniformly all around the O-ring. A reliable, positive seal is made and the tendency of previous designs to roughen the surface of the O-ring and eject it from its groove is eliminated.



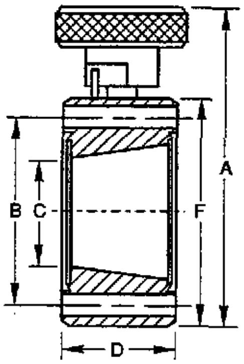
Kwik-Flange Flange
KBFV-150

MDC Butterfly Valves are low outgassing. All internal surfaces are machined from solid stainless steel bar stock. The handle is made of aluminum. A small O-ring on the stem prevents shaft leakage.

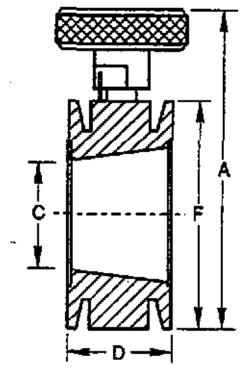
The valves are offered with a choice of *Del-Seal* ultra-high vacuum metal-seal flanges or ISO *Kwik-Flange* O-ring seal flanges.

Butterfly Valves

Toll Free Outside CA 1-800-443-8817



Del-Seal Flange



Kwik-Flange Flange

ORDERING INFORMATION

Please order by Part Number

Valve Nom I.D. Size	Reference	Part Number	Flange F	Flange O.D.	Bolt Holes No.	Ref ISO	Height A	Bolt Circle B	C	Thickness D	Wt Lbs	Unit Price
3/4	BFV-075	360000	*Del-Seal* 1-1/3	1.33	6	-	1.96	1.062	.60	.75	1	$250
3/4	KBFV-075	360010	*Kwik-Flange*	1.18	-	NW16	1.81	-	.56	1.25	1	$250
1	KBFV-100	360011	*Kwik-Flange*	1.57	-	NW25	2.32	-	.87	1.25	1	$255
1-1/2	BFV-150	360001	*Del-Seal* 2-3/4	2.73	6	-	3.81	2.312	1.33	1.00	1	$260
1-1/2	KBFV-150	360012	*Kwik-Flange*	2.16	-	NW40	3.81	-	1.31	1.34	1	$260
2	BFV-200	360002	*Del-Seal* 3-3/8	3.37	8	-	4.46	2.850	1.84	1.00	2-1/2	$360
2	KBFV-200	360013	*Kwik-Flange*	2.95	-	NW50	4.46	-	1.87	1.68	2-1/2	$360

Dimensions are in inches

Title: **SPECIFICATION FOR LIGO CRYOGENIC CONTROL VALVES**

SPECIFICATION FOR

LIGO CRYOGENIC CONTROL VALVES

FOR

LASER INTERFEROMETER GRAVITATIONAL WAVE OBSERVATORY

Job No. V59049

INSTRUMENTATION/ ELECTRICAL ENGINEER: F. Bark

PROJECT ENGINEER: David Moore

TECHNICAL DIRECTOR: D. A. McWilliams

PROJECT MANAGER: [signature]

Information contained in this specification and its attachments is proprietary in nature and shall be kept confidential. It shall be used only as required to respond to the specification requirements, and shall not be disclosed to any other party.

2	DM 9/17/97	D. McW 10/1/97	Revised per DEO Ø267
1	DM 7/2/96	D. McW 7-2-96	Revised per DEO Ø217 & released for purchase
Ø	DM 2/29/96	D. McW	Initial release PER DEOO76 FOR QUOTE
REV LTR.	BY-DATE	APPD. DATE	DESCRIPTION OF CHANGE

PROCESS SYSTEMS INTERNATIONAL, INC.					SPECIFICATION	
INITIAL APPROVALS	PREPARED: DMoore	DATE: 2/29/96	APPROVED: D. McW	DATE: 3-11-96	Number **V049-2-062**	Rev. 2

TABLE OF CONTENTS

1.0 SCOPE

This specification covers the minimum requirements for the design, materials, fabrication, assembly, inspection, testing, preparation for shipping, shipment and delivery of the cryogenic control valves for the LIGO vacuum system.

All attachments are incorporated herein by reference and made a part of this specification.

The specified equipment is for use as part of the Vacuum Equipment supplied for the Laser Interferometer Gravitational-Wave Observatory (LIGO). LIGO, which is operated by Caltech and MIT under an NSF grant, includes two sites (Hanford Reservation, near Richland, WA, and Livingston, LA). Each site contains laser interferometers in an L shape with 4 km arms, a vacuum system for the sensitive interferometers components and optical beams, and other support facilities.

Information contained in this specification and its attachments is proprietary in nature and shall be kept confidential. It shall be used only as required to respond to the specification requirements, and shall not be disclosed to any other party.

1.1 Furnished By The Seller

a. Control valves of the quantity and type designated on the attached valve data sheets.

b. Shop testing and inspection of valves.

c. Drawings and data as indicated in this specification.

2.0 SCHEDULE

2.1 Equipment delivery shall be as follows:

PSI P/N	Type	Delivery Site	Quantity	Date
V0492062	Cryogenic Control Valve	PSI	12	11/30/96

3.0 EQUIPMENT REQUIREMENTS

3.1 The control valves will be used to supply liquid nitrogen for the purpose of maintaining a liquid level in the LIGO 80K cryopumps.

4.0 DESIGN REQUIREMENTS

4.1 In addition to the requirements in this section, process, mechanical, and electrical requirements for the specific application are given on the valve data sheets and/or schedules attached to this specification.

4.1.1 Valves shall be suitable for outdoor service at the LIGO sites located near Richland, Washington and Livingston, Louisiana.

4.2 Valves shall be cabable of being mechanically insulated (a layer of fiberglass insulation with foam insulation around the fiberglass).

4.3 In addition to those listed in Attachment C, the following codes and standards shall apply:

B16.25	Butt Welding Ends
B16.37	Hydrostatic Testing of Control Valves

4.4 Electrical design and material shall conform with the latest edition of the National Electrical Code, and shall carry the Underwriters Laboratory or Factory Mutual label, except for material for which UL listing criterion has not been established.

4.5 Valves for cryogenic service shall be extended stem type.

4.6 The Vendor shall indicate if the "top works" (actuator, etc.) of the valve are self supporting as supplied, or if additional supports are required, and if so, shall indicate support points to be used. This information shall be submitted with the quotation.

4.7 Electrical/Instrumentation Requirements

4.7.1 All instruments shall have watertight enclosures for outdoor service.

4.7.2 All devices and instrumentation shall be mounted on the valve/actuator assemblies with appropriate heavy duty brackets. This includes transducers, positioners, combination electro-pneumatic positioners, solenoids, air regulator sets, etc. All such items shall be tubed to the diaphragm by the Seller.

4.7.3 All solenoid valves shall be stainless steel ASCO or approved equal. When high capacity type solenoids are specified on the valve data sheets, the Seller shall select the orifice size and diaphragm connection so the that Buyer's required closing times are met. All solenoid valves shall be supplied with high temperature coils suitable for the intended service and design ambient conditions. Solenoid coil voltage shall be 24VDC. The solenoid valve shall be a three way ASCO valve installed at the positioner discharge side. It shall exhaust the positioner to atmosphere when de-energized.

4.7.4 Limit switches, as per the data sheet, shall be double-pole, double-thro (DPDT), hermetically sealed proximity type, rated 120 VAC, 5 amps (minimum), (Go Systems or equal).

4.7.5 The I/P shall operate on a 4-20 mA signal. Airsets shall be provided with the valves.

4.8 The following paragraphs of Attachment C are not applicable:

5.1.1	5.1.5	5.1.6	5.1.7
5.1.11	5.2.1.3	6.3	6.4
8.1	8.2	8.4	9.4.1
9.4.2	9.6.1	9.6.4	11.3
14.0			

4.9 Utilities

Refer to Attachment C.

5.0 REQUIRED DOCUMENTATION

In addition to the documentation listed in Attachment B, the following documentation shall be provided prior to shipment:

5.1 Manufacturer's standard QA reports (including final functional test reports).

4.7.2 All devices and instrumentation shall be mounted on the valve/actuator assemblies with appropriate heavy duty brackets. This includes transducers, positioners, combination electro-pneumatic positioners, solenoids, air regulator sets, etc. All such items shall be tubed to the diaphragm by the Seller.

4.7.3 All solenoid valves shall be stainless steel ASCO or approved equal. When high capacity type solenoids are specified on the valve data sheets, the Seller shall select the orifice size and diaphragm connection so the that Buyer's required closing times are met. All solenoid valves shall be supplied with high temperature coils suitable for the intended service and design ambient conditions. Solenoid coil voltage shall be 24VDC. The solenoid valve shall be a three way ASCO valve installed at the positioner discharge side. It shall exhaust the positioner to atmosphere when de-energized.

4.7.4 Limit switches, as per the data sheet, shall be double-pole, double-thro (DPDT), hermetically sealed proximity type, rated 120 VAC, 5 amps (minimum), (Go Systems or equal).

4.7.5 The I/P shall operate on a 4-20 mA signal.

4.8 The following paragraphs of Attachment C are not applicable:

5.1.1	5.1.5	5.1.6	5.1.7
5.1.11	5.2.1.3	6.3	6.4
8.1	8.2	8.4	9.4.1
9.4.2	9.6.1	9.6.4	11.3
14.0			

4.9 Utilities

Refer to Attachment C.

5.0 REQUIRED DOCUMENTATION

In addition to the documentation listed in Attachment B, the following documentation shall be provided prior to shipment:

5.1 Manufacturer's standard QA reports (including final functional test reports).

5.2 Process Data

*1. Confirmation of the required C_V (or C_g) as shown on the attached data sheets, based on the flows and pressure drops allowed.

*2. If no C_V or (or C_g) is indicated on the attached data sheets, the vendor shall supply such data.

*3. A table or graph showing C_V (or C_g) versus percent of valve travel.

*4. Completed PSI valve data sheets.

*This data must be submitted with Vendor's proposal for evaluation prior to award of contract.

5.3 Mechanical Data

1. Outline dimension drawings and weight (including operators and accessories).

2. Identification and description of all components and accessories.

5.4 Assembly Drawings

Assembly drawings shall be prepared by the vendor shall be submitted to the Purchaser for information only. Four (4) copies (two [2] reproducibles and two [2] prints) shall be submitted to the Purchaser within four (4) weeks ARO. This includes drawings of any purchased items. These drawings must show general and overall dimensions, details of internal parts, estimated weights, and all material used for construction. Drawings shall be certified as dimensionally correct. Certified catalog cuts are acceptable.

5.5 Drawing Review

Drawing approval is not required from the Buyer before starting fabrication. The Buyer's review of the Vendor's drawings is of a general nature. Review of any drawings by the Buyer does not serve as acceptance of any errors or deviations from these specifications or instructions relating to the work. The Vendor shall call attention to any such deviations by a separate written notice when submitting the drawings for review. Unless specific written approval is obtained from the Purchaser, deviations are not acceptable.

5.6 Changes

If changes are made to any drawings after drawing submittal the Vendor shall furnish copies to the Buyer showing all changes clearly identified on the drawing.