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LIGO Design Review Report

LIGO VACUUM EQUIPMENT FINAL DESIGN REVIEW

Title

Review Board: W. Althouse (Chairman), F. Dylla, G. Giberson, A. Lazzarini, B. Lucas, R. Raab, W. Tyler, R. Weiss

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This is an internal working note of the LIGO Project

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REPORT ON THE FINAL DESIGN REVIEW OF THE LIGO VACUUM EQUIPMENT

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The LIGO Vacuum Equipment was designed and is to be fabricated and installed by Process Systems International, Inc. (PSI) under contract to the LIGO Project. The Final Design Review for the LIGO Vacuum Equipment was conducted on May 22, 1996 in Marlborough, Massachusetts, near PSI's facilities in Westborough. This report documents the observations and recommendations made by the review board. The review board membership and charter are provided in LIGO-L960307 (Attachment I). The agenda for the review are presented in Attachment II.

The review consisted of presentations by PSI describing their detailed designs and fabrication and installation plans, with questions and answers interspersed with the presentations. During the review, board members were encouraged to record their observations, concerns and recommendations by completing a "Recommendation for Action" (RFA) form and submitting it to the review board chairman. At the end of the presentations, the review board met in executive session and discussed each RFA.The review board chairman held subsequent follow-up discussions on selected topics with individual board members and LIGO representatives. These consensus and follow-up discussions serve as the basis for this report and are summarized below.

The review board did not systematically examine the detailed design drawings, technical specifications, procedures or backup analyses and calculations furnished with the Final Design Review Data Package, relying instead on the summaries presented by PSI.

We commend PSI for a very professional review presentation and fully expect their efforts on behalf of LIGO to be successful.

SUMMARY RESPONSE TO THE REVIEW BOARD CHARTER

We summarize the review board charter (Attachment I) and our responses below. Please see the following section for detailed observations and specific recommendations.

CHARGE: Evaluate PSI's design and assess compliance with the technical specification for LIGO Vacuum Equipment, and advise whether PSI's design work is sufficiently complete to begin fabrication.

Response: With a significant exception related to the acoustic and vibration noise specification, PSI's design appears to be an effective solution to the myriad requirements contained in the technical specification. We recommend that the LIGO Project approve PSI's final design and go forward with PSI's fabrication activities while the recommendations detailed in the following section are being addressed.

CHARGE: Make an independent judgement of the risks involved in PSI's design approach.

Response: PSI's design approach appears to be sound and presents no extraordinary technical risks.

CHARGE: Identify any concerns or other factors which might affect the success of the LIGO Project.

Response: All concerns arising from this review board are noted in this report. Many of the observations arising from this review are directed toward LIGO long-term planning and do not affect PSI's design. These are recorded at the end of the following section.

OBSERVATIONS AND RECOMMENDATIONS

Recommendations are set in *italic* type.

Technical Specification Compliance:

1. The predicted acoustic/vibration noise produced by the Vacuum Equipment does not meet the requirements of the technical specification. However, it does meet contract requirements, because the contract requires only that PSI perform an analysis of the vacuum equipment noise contribution, and waives the technical specification in this area. This fact created much confusion during the review, because the contract relaxes the standard (the technical specification) by which we were charged to measure PSI's design. *We recommend that the technical specification be modified to correctly reflect the effort being implemented by PSI.* PSI's analytical work is being carried out by Cambridge Acoustical Associates, Inc. (CAA). We believe that the value (both to PSI and LIGO) of CAA's effort would benefit substantially from direct contact between LIGO scientists and CAA analysts. *We recommend immediate direct contact between LIGO scientists and CAA, in a manner which does not usurp the PSI/CAA contractual relationship; this contact should focus on enhancing the utility of CAA's efforts, particularly the modeling associated with the 80 K pumps, and should be done in time to influence the prototype testing of the 80 K pump mock-up and allow test results to influence the design.*
2. PSI is currently considering fabricating portable clean rooms in house, a step which we favor. Because this is a recent consideration, there are no design drawings for the portable clean rooms available for review at this time. *We recommend that PSI provide detailed design drawings and specification to LIGO for review and approval when available, prior to beginning fabrication of the portable clean rooms.*

Process Control and Quality Assurance:

3. PSI plans to perform post-weld heat treatment in a gas-fired oven, with the vacuum surfaces directly exposed to the combustion flue gases at high temperature. We are concerned that the process may lead to deposition or cracking of hydrocarbon components on the vacuum surfaces. While the early bench tests appear encouraging, *we recommend careful analysis of the BSC prototype tests to demonstrate that this process does not lead to excessive hydrocarbon outgassing.*
4. PSI plans to accept the certifications of vendors as evidence of compliance with specifications. Experience shows that certifications alone are not sufficient to ensure that the vendor's understanding of a particular requirement matches PSI's intent. For example, PSI's specification for expansion joints contains a requirement that no chlorinated compounds are to be used in their manufacture, but others have experienced failures of installed stainless steel bellows, procured to similar specifications and certified to be chloride-free, due to stress corrosion cracking induced by exposure to chlorinated compounds during manufacture. Verification of compliance by after-the-fact inspections often suffer from similar limitations. *We recommend that PSI evaluate where in-plant or in-process witnessing by PSI representatives at vendors' facilities would be prudent, and plan on physical verification, at the vendor, of compliance with identified requirements during production pro-*

cesses. We recommend that LIGO QA support and participate in the PSI effort.

5. PSI plans on testing Viton O-ring outgassing and mechanical properties in order to select the best Viton material and processing for the application. These tests should prove very useful for optimizing the choice of Viton material and processing, and *we recommend involving the vendors in the planned testing of Viton O-rings so that there can be feedback in the event that it is desirable to modify the Viton processing or formulation specifications.*
6. PSI's specification for large gate valves specifies the acceptance criterion for hydrocarbon contaminants in units of partial pressure, rather than flow (V049-2-005, ¶7.2). (This makes the acceptance criterion dependent on details of the vendor's test setup.) It is also good practice to specify partial pressures as N2 equivalent, in order to avoid ambiguities in interpretation and calibration. In addition, the large gate valves are required to function at 150° C during the beam tube bakeout, but the specification is silent about this application nor does it specify a leak rate at bakeout temperature (which needn't be as stringent as the room temperature leakage requirement). *We recommend that acceptance criteria for contaminants be specified as outgassing in flow units (torr-l/s), that all pressure specifications be expressed as N2 equivalent (similarly, leak rates should be expressed as He equivalent), and that consideration be given to the 150 °C leak performance of gate valves.*
7. It has been reported that some suppliers test HEPA filters by spraying them with a atomized hydrocarbon (dis-octyl-phthalate, or DOP). While such a test may be effective in establishing the filter's ability to trap particulates, it can also introduce hydrocarbon contamination into the filter. *We recommend that PSI take steps to ensure that vendors provide HEPA filters which have not been exposed to concentrated hydrocarbon contaminants.*
8. PSI is continuing the development of chamber cleaning equipment and procedures using the bench test chamber to evaluate process alternatives, and expects the BSC prototype tests to validate the final choices. We note that while earlier bench tests were conducted after a bakeout temperature of 150° C, PSI allows temperatures during bakeout to be as low as 130° C (this is permitted by the LIGO technical specification). Outgassing results obtained from bench tests may not be achievable at the lower temperature. *We recommend that PSI consider using their lowest allowed system bakeout temperature during future bench testing to establish confidence in the results. We also recommend that PSI specify and control the quality of deionized water used during the final chamber rinse. The specification should require at least a resistivity measurement.*
9. PSI's design for bakeout heater blankets involves some 600 individual heaters and control points for the vertex chamber cluster. These blankets are intended to be shipped from the LIGO Hanford site to the Livingston site for reuse during system installation there. They will then be available for future bakeout at either LIGO site. The technical specification requires equipment to be designed for a 20-year service life. *We recommend that several apparently unexplored topics regarding the reliability and reusability of these blankets should be evaluated: reliability (including failure rate data from the manufacturer, wear and tear during installation/removal, tolerance of the control system design to failure of individual blanket elements), planned spares, replacement availability, and shipping and storage (special shipping containers or fixtures, packaging for shipment, storage environment, location, space needed, labeling/sorting of different configurations, record keeping*

needs) and shipping.

10. Design or process changes initiated by PSI may have an impact on LIGO even if they do not deviate from LIGO specifications. *We recommend that PSI send a copy of all change notices (RFCs) for LIGO designs and process specifications to the LIGO Task Leader as information.*

11. PSI representatives stated that they depend on the LIGO CDS control and monitoring system to carry out their planned acceptance tests. Given the inherent simplicity (highly desirable) of the PSI-supplied equipment, this dependency seems unnecessarily strong. Although LIGO plans to have the CDS equipment available to support these tests, *we recommend that consideration be given to measures which might be taken so that PSI's acceptance testing can be completed even if the CDS equipment is not fully functional.*

LIGO Operations, Long-Term Planning and Safety:

12. Ion pumps are known to be emitters of ultraviolet (UV) radiation and LIGO mirror coatings are known to be damaged by UV exposure. *The LIGO Project should gather information or perform measurements necessary to estimate UV exposure to mirrors from ion pumps and develop mitigation measures (e.g., installing baffles) if the potential for damage to mirrors from ion pump emissions is excessive.*

13. Ion pumps are known to release particles during operation. It is important to establish that such particle releases do not interfere with IFO operation. PSI needs to be aware of and sensitive to this concern. *When detailed configuration drawings of the ion pumps become available from PSI, LIGO should review geometry and construction details to ensure that particulates released from the pump cell regions cannot produce excess noise in optical beams.*

14. *LIGO should consider the use of a hot N_2 gas purge in the vacuum region of the 80 K pumps during regeneration*; this will aid in preventing the condensate from the pump surface from re-absorbing onto the vessel walls.

15. *LIGO should plan on optimizing the sequencing of pumps during pumpdown after installation of the initial interferometers.* In particular, if the 80 K pumps are exposed too early in the pumpdown cycle and are allow to accumulate significant quantities of CO_2, this may delay achieving ultimate pressures.

16. *LIGO operations safety procedures must ensure that high-vacuum valves are positively locked from operating when personnel are present inside a chamber* (particularly those connected to adjacent volumes under high vacuum).

17. There is enough LN_2 stored on site to deplete oxygen from closed areas such as the LVEA/VEA in the event of a mishap, creating a severe safety hazard. *Consider including an oxygen sensor monitored and alarmed by CDS in each LVEA/VEA as a permanent safety fixture.*

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COMMENTS:

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