SNO-STR-90-112

Sudbury Neutrino Observatory

Design Criteria DC.17.340.01.A

Revision A

PMT Support Structure

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Reviewed by (LBL)

Reviewed by (Monenco)

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Approved by

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Preliminary

PMT Support Structure Design Criteria

1. Introduction

The purpose of this document is to describe the design criteria applying to the PMT Support Structure (hereafter known as PSUP) of the Sudbury Neutrino Observatory (SNO) and to indicate the design approach that will be followed during its design.

2. Design Requirements

The PSUP shall be a structure to support the PMT assemblies required to view the cherenkov light produced in the active detector regions of the Sudbury Neutrino Detector. As a support structure it must accomplish the following tasks:

i) it must provide a stable and accurate platform for the mounting and positioning of the PMTs assemblies to view the active detector regions,

ii) it must serve as a light screen separating light originating from events from behind the PSUP detector plane from events originating inside of the PSUP detector plane,

iii) it must serve as a water baffle to insure outward flow of water from the water recycling system past the plane of the PMT assemblies,

iv) it will be called upon to mount a smaller number of PMTs assemblies to act as a veto detector which will view the region outside of the PMT assemblies,

v) it must permit expedient installation and replacement of the PMT assemblies,

vi) its design must be such that the PSUP or its components will not pose a significant risk to the Acrylic Vessel,

vii) the PSUP may be called upon to provide a mechanism to protect adjacent PMTs of the risks of stimulated implosion,

2.1 Components and Definitions

2.1.1 PMT assemblies

The PMT assemblies that PSUP will be required to mount will consist of a Photo Multiplier Tube specified by the collaboration and a light concentrator which is to be mounted in close conjunction to the PMT (also to be specified by the collaboration) and the attachments between the PMTs, concentrators and the panels. The PMT assemblies are defined and illustrated in DWG LBL-23H0014-1 without defining the attachments. The number of PMT assemblies to be mounted will be greater N_{min}, which is based upon the physics specifications of the Temple Review (Oct., 1989), and less than 10,500, which is based upon estimates of the maximum number of PMT assemblies LBL felt sure could be accommodated in the design. The estimate of 10,500 does not take into account those PMTs which would be excluded due to interferences between the PSUP and the acrylic vessel and its supports and chimney. The actual number of PMT assemblies to be mounted facing inwards will be specified by the collaboration. This number is presently defined to be 9500.

2.1.2 Structure

The structure will be an external skeleton which will be the principal load bearing structure to support the dry and wet loads resulting from the PMT assemblies, electronic cabling, water baffles, and light screen components. The present design uses a geodesic structure.

2.1.3 Panels

The PMT Assemblies will be individually supported by a rigid panel or lattice work which is supported by the geodesic structure. The panels may be further subdivided or tessellated.

2.1.4 Suspension

The PSUP will be suspended from the Deck Structure in the cavity and secured to the bottom of the cavity. The method of suspension

will be by cables, the properties of which will be specified below. The PSUP may further be restrained with attachments to the cavity walls.

2.2 Configuration, Dimensions, Location, and Tolerances.

2.2.1 Coordinate systems

The following coordinate system will be used to reference the PSUP: we will use spherical coordinates (r,theta,phi). The zero of the coordinate system will be defined as the center of the Acrylic Vessel, the zero of the polar angle, theta, will be chosen as the vector opposed to the local gravity (up), and the zero of the azimuthal angle, phi, will be chosen to be the center of the upper access drift [magnetic north, true north].

2.2.2 Dimensions and Tolerances

The positioning of the PMTs will be close to spherical and concentric with the Acrylic Vessel. The plane of the front face of the PMT light concentrators will be established by compromising the demands between radioactive shielding requirements (PMTs from cavity walls and PMTs from Acrylic Vessel), light collection efficiency of the PMTs, and maximizing the number of PMTs which can be supported by the PSUP. The nominal distance from the center of the Acrylic Vessel to the plane of the front face of the PMT concentrators will be taken to be 334.65 inches (8.5 m). This distance can be varied by ± 9.84 inches (+/- 0.25 m) to optimize the above mentioned parameters. Individual PMT assemblies may vary by as much as ± 6 inches (15.24 cm) radially from this nominal value. Panels may vary by as much as ± 6 inches (15.24 cm) in radial displacement. The center of the PSUP will lie within ± 6 inches (15.24 cm) of the center of the Acrylic Vessel.

The physical location of each PMT assembly will be determined by survey of the principal nodal locations of the geodesic structure. PMT assemblies' location will then be interpolated from detailed knowledge of each panel design. Each PMT assembly's location will be calculated and tabulated to within ± 3 inches (7.62 cm) radially and within ± 3 inches tangentially on the projected spherical surface of the PMT assemblies. Survey

marks will be obtained from the Acrylic Vessel surveys and absolute reference will be made relative to the Acrylic Vessel.

2.2.3 Alignment of PMT Assemblies

The PMT assemblies will be aligned so that the symmetry axis of each PMT assembly intersects the center of the Acrylic Vessel (the PMT assemblies will be aimed and centered on the Heavy Water). The PMT assemblies' attachments which mount the PMT assemblies to the panels will be designed so that each PMT system will be positioned within ± 0.7 degrees of theoretical. Each Panel will be mounted so that the entire panel will be positioned within ± 0.1 degrees of theoretical.

The attachments for the PMT assemblies will be designed to mount and position each PMT and its concentrator. The attachments will be designed to assure that the symmetry axes of both are collinear within ± 0.9 degrees (angle alignment) and within ± 0.060 inches axial displacement and ± 0.180 inches tangential displacement.

The reference for the alignment of the PMT assemblies will be chosen to be the symmetry axis of the PMT [center of concentrator entrance?] and the front face of the concentrator.

The fail-safe devices to prohibit the PMTs from breaking loose and threatening the Acrylic Vessel will be incorporated into each PMT assemblies' attachments and the panel design.

2.2.4 Wet/Dry Displacements

The maximum displacement of the center of the PMT assemblies' sphere between its fully erected dry stage and full immersed wet stage will be 6 inches (15.24 cm). The maximum displacement of any node between the two stages will be 6 inches (15.24 cm).

2.3 Materials

All materials used in the construction of the PSUP will be required to conform to the specific properties listed in Section 2.4.

2.3.1 Geodesic Structure

The geodesic structure struts and nodes will be fabricated from aluminum: an alloy will be selected with the appropriate machining and fabrication properties. Fixtures and fasteners will be fabricated from other materials which meet the requirements of Section 2.4.

2.3.2 Panels

The panels assemblies will be fabricated from aluminum: an alloy will selected with the appropriate machining and fabrication properties, fixtures and fasteners will be fabricated from other materials which meet the requirements of Section 2.4.

2.3.3 Attachments

The PMT system attachments will be fabricated from materials which meet the requirements of Section 2.4.

2.3.4 Suspension

The suspension and restraining cables will be fabricated from a materials which meet the requirements of Section 2.4.

2.3.5 Other Materials and General Requirements

Other materials may be used in the PSUP and its support system provided that they conform to the requirements of Section 2.4 and they are acceptable to the collaboration.

The components will be cleaned and packaged in an acceptable manner to ensure the cleanliness requirements of the project. Specific details of cleanliness will be defined in the QA/QC manuals.

2.4 Specific Material Properties

2.4.1 Radioactivity

The permissable concentrations of uranium, thorium, and other radioactivities including daughters of these products contained in the PSUP and its components are in general geometry dependent and require

individual analysis by the Monte Carlo Group of the collaboration. The limits in this design are:

	Struct. & Suspension	Panels & Attachments	PMTs	Cables & Bases
U (ng/g)				
Th				
^{60}Co				
K				
γ production[1]				
n capture[1]				
others				

[1] γ and neutron production due to external sources of radiation (such as fluorescing PSUP components with the PMT assemblies' radioactivity).

2.4.2 Leaching and Burden on Water Systems

The quantity of material leached by the PSUP and its components must not place undue burden on the water purification systems. These limits are principally dominated by surface area of the components. In those cases where undue burden is established or deemed to exist, surfaces will be protected by approved methods which do not compromise the other material properties requirements. The bare metal surfaces will be painted with a suitable paint to reduce leaching to suitable levels. Members of the collaboration Water Systems Group will approve leaching rates and quantities.

2.4.3 Biological Growth

The materials used in the PSUP and its components must not support or stimulate biological growth. Members of the collaboration's Water Systems Group will approve materials as biologically acceptable.

2.4.4 Electrolysis

Electrolytic action between dissimilar materials in the PSUP and its components and between the PSUP and other elements within the cavity may deteriorate the physical properties of the elements. Members of the collaboration's Water Systems Group will approve material selections for electrolysis compatibility. [Who will oversee the entire problem of electrolysis between different parts, such as SS liner and the PSUP? Monenco?]

2.4.5 Engineering, Safety Requirements, QA and QC

Monenco, INCO, LBL, and the collaboration, when appropriate, will review documents, documentation, design material, drawings and designs for compatibility with appropriate safety and engineering requirements. It shall be the duty of Monenco to assure that such review is properly scheduled and conformity assured. Agreement shall be reached between LBL and Monenco regarding Quality Assurance and Quality Control issues and procedures. It shall be the responsibility of Monenco to assure the QA and QC procedures conform to all Provincial, National (U.S. and Canadian), and Industrial standards and codes which apply.

2.5 PSUP Details and Provisions

When information or data is required by the PSUP design group, it will be the responsibility of Monenco to assure that timely transfer of the requested information or data occurs.

2.5.1 Locations and Clearances on Acrylic Vessel Chimney

Dimensions and clearances on the Acrylic Vessel chimney will be supplied in a timely manner by the Acrylic Vessel Group and Monenco.

2.5.2 Locations and Clearances on Acrylic Vessel Suspension Cables

Dimensions and clearances on the Acrylic Vessel support systems will be supplied in a timely manner by the Acrylic Vessel Group and Monenco.

2.5.3 Support of PMT Electrical Cable Systems

Criteria and dimensions on the PMT cables and bases will be supplied in a timely manner by the PMT and Electronics Groups and Monenco.

2.5.4 Water Recycling Details

Criteria and dimensions on the water recycling will be supplied in a timely manner by the Water Systems Group and Monenco.

2.5.6 Water Baffle Requirements

Criteria and specifications on the water baffle requirements will be supplied in a timely manner by the Water Group and Monenco.

2.5.7 Light Opacity Requirements

Criteria and specifications on the light opacity requirements will be supplied in a timely manner by the Monte Carlo Group and Monenco.

2.6 PSUP Supports

The PSUP, its subcomponents, and associated systems will be supported from the cavern deck and the cavern liner on the bottom with provision for restraining the PSUP from the cavern liner on the sides. The design of the support system shall:

support the Structure, Panels and subassemblies against all loading conditions listed in Section 2.8;

ensure that the loads on the PSUP from the support system are equally distributed

minimize the interferences between the supports with the Acrylic Vessel and its supports and permit expedient installation of the PSUP and Acrylic Vessel.

2.7 Design Life

The PSUP shall be designed for a life of at least that of the Acrylic Vessel. This time is presently (Reference DC.17.310.01.B) 10 years with the option of extending the life to 15 years being investigated.

The PSUP shall be designed to meet the same conditions of filling as the Acrylic Vessel. The PSUP shall be also designed for the load changes that it will see due to seismic effects defined by Reference #.

2.8 Loads and Operating Conditions

2.8.1 General

The loads imposed upon the PSUP and its support system include gravity loads, hydrostatic and other pressure loads, the effects of differential temperature, seismic loads including loads due to rock bursts, loads due to the implosion of a PMT system. Loading conditions shall include those when the cavity is full of light water as well as those occurring during the filling and emptying cycles.

The designer shall specify the relationship between water levels inside and outside the PSUP (in the event that good water seals are required, Section 2.5.6).

2.8.2 Operating Pressures

The free surface of the liquids covering the PSUP will be at atmospheric pressure, 18.1 PSI in the present case. The liquid will be covered with a cover gas. The nominal pressures of the cover gasses will be atmospheric.

2.8.3 Operating Temperatures

The temperature of the water inside the cavity will vary between 5 and 20 C. The difference between the average temperature across the light water shall not exceed ??? C.

2.8.4 Dynamic Effects

The PSUP shall be designed to withstand loads due to seismic effects including rock bursts, actual loads and displacements being derived from the appropriate project documentation. Seismic effects may in turn cause the water to "slosh about", an effect which shall also be considered.

Note that loads due to earthquakes and due to rock burst need not be considered to act simultaneously.

The PSUP sh l be designed to withstand, without failure, the effect of the implosion of PMT whatever its position in the PSUP and whatever the water levels t the time of the event.

The PSUP must also be able to withstand the effect the failure of more than one PMT at once unless it can be shown that the likelihood of such an occurrence is less than 1 event per thousand years. [Where did Ken get this?]

2.9 Analysis Requirements

The PSUP shall be stress analyzed using finite element methods in order to determine the stresses and permissible deflections. Allowable stresses and the real factor of safety against failure shall be based on structural building codes.

The analyses shall consider the PSUP in the following operating conditions:

1) PSUP installed and instrumented with the cavity empty;
2) PSUP installed and instrumented with the cavity filled with water;
3) PSUP installed and instrumented during the light water filling process;
4) PSUP partially installed and partially instrumented during the erection of the Acrylic Vessel

The effect of a seismic event and of the failure of a PMT shall be considered for each one of the above operating conditions. The consequences of a PMT failing whilst one of the PSUP support cables has failed or during a seismic event shall be evaluated, but the design need not be capable of resisting these combinations or conditions at normal stress levels.

The analyses (both stress and buckling) shall study the following:

1) the effect of the variation of mechanical and physical properties with time and/or with immersion in water;
2) the effects of filling on the deflections and stresses in the PSUP in order to establish acceptable limits;
3) the consequences of the failure of one of the PSUP supports;
4) the need for lateral support of the PSUP shall be established and if required, lateral supports shall be provided. The effect of these supports on the PSUP stresses shall be established;
5) the effects of tolerances of members on the deflections and stresses in the PSUP;
6) the natural frequency of the PSUP for dynamic conditions analysis.

2.10 Allowable Stresses

Maximum allowable stresses are a function of type of stress (compression, tension, and shear), their duration (long term in the case of static loads and short term in the case of dynamic and temporary loads) and their location. The basic allowable stresses of each type will be analyzed. These stresses must be multiplied by one or more of the factors, as appropriate, to take into account the reduction in allowable stress at the joints, nodes, and fixture points, the increase in allowable stresses permitted when loads are due to short term effects and the relaxation of requirements.

2.11 Code Requirements

To the extent that it applies and can be applied to this structure and to the extent that it is not superseded by the requirements of this Design Criteria, the PSUP shall be designed and fabricated in conformance with the requirements of the which the Project Management Team, U.S. Department of Energy (LBL), and SNO deems appropriate.

2.12 Shop Fabrication and Field Erection

All processes used in the fabrication and erection of the PSUP shall be developed and qualified (by the Fabricator) and procedures for them written, tested, submitted for approval and approved. Where necessary, the

laborers carrying out work shall be trained and qualified for the processes in question.

2.13 Quality Assurance

The PSUP shall be designed, fabricated, erected and tested following the requirements of the project Quality Assurance Program.

2.14 Special Considerations

The PSUP will be erected in an underground mine and its design shall cater to the special requirements that this involves. These include (and are not necessarily limited to) the following:

there are limitations on the size of crates that can be handled in the mine hoist and on the cars in the mine drift, the requirements are given elsewhere;

approval is required for all substances used underground. These substances include, amongst others, solvents, adhesives, cleaning agents and leak test fluids as well as any fluid which may be used in bonding processes. (The concern include, health hazards, fire and explosive mixtures of dusts and vapors):

special cleanliness precautions are required for underground work (particularly in the bonding process of the acrylic vessel) and site cleanliness requirements and precautions shall be specified;

special requirements may be imposed upon the ventilating system of the assembly cavern;

there are special codes and regulations governing work underground to which the project must conform.

2.15 PSUP Instrumentation

The need for on-line monitoring of stresses and deflections of the PSUP will be evaluated. Proposals for this instrumentation will be presented to Monenco for approval and conformity.

3. Design approach

3.1 PSUP Description

The details of the structure, the panel assemblies, and the attachments are under development. The basic details of the PMT assemblies are given in DWG. LBL23H0004.

3.2 PSUP Analysis

The PSUP will be analyzed using finite element methods. Monenco will approve analysis techniques and will independently confirm such analyses as they deem necessary.

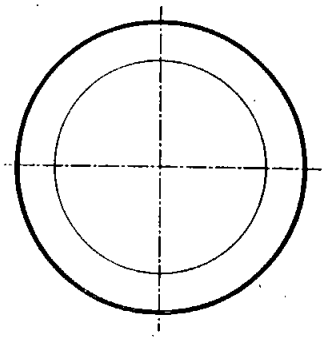
3.3 Design Process

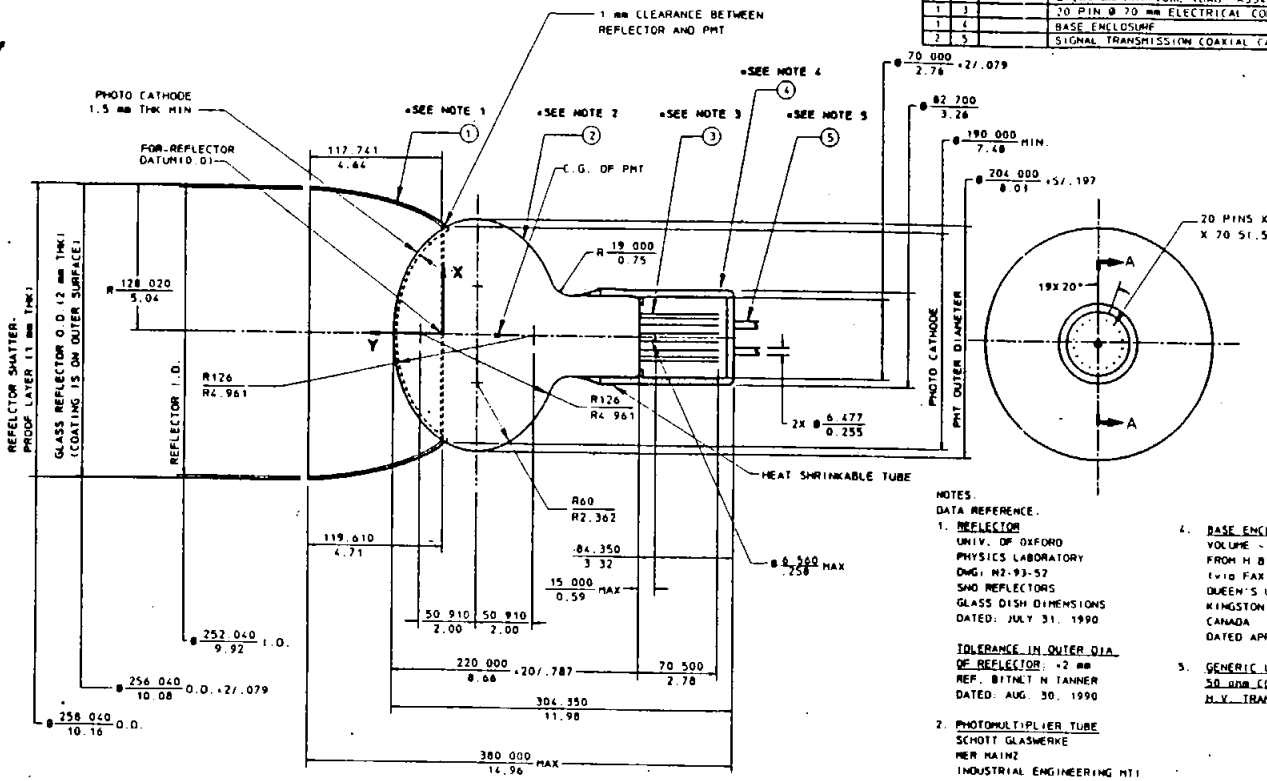
Present plans call for LBL to prepare a preliminary design of the PSUP and to analyze it or have it analyzed. In parallel with carrying out the analysis, Monenco will be sent all drawings and plans. LBL will make every effort, in good faith, to coordinate the LBL design effort with the Project Management Team. It will be the duty of Monenco to assure proper distribution of all relevant materials to the SNO collaboration. Monenco will serve as the official communications channel for all comments, design changes and changes in scope from SNO, INCO, and Monenco to the LBL design effort resulting from review of the PSUP design. Comments will be incorporated into the design where they are considered relevant; the design will also be brought into line with the results of the stress analysis and the process repeated if thought necessary.

Procurement documents will be prepared in parallel with this work.

PRELIMINARY

REQ	ITEM	PART NUMBER	DESCRIPTION
1	1		Ø 356 mm GLASS REFLECTOR (DWG. N2-93-52)
1	2		Ø 204 mm PMT TUBE (DWG. A5369-00-02b)
1	3		20 PIN Ø 70 mm ELECTRICAL CONNECTOR
1	4		BASE ENCLOSURE
2	5		SIGNAL TRANSMISSION COAXIAL CABLE 146 LB/KFT





SECTION A-A

COORDINATES FOR REFLECTOR SLOPE

Y	X	Y	X
0.00	94.9	66.78	121.26
1.23	96.47	69.04	122.18
3.05	98.18	71.31	122.58
5.06	99.69	73.58	122.98
9.92	100.90	75.86	123.37
9.05	102.14	78.14	123.74
11.01	103.22	80.42	124.10
12.99	104.27	82.71	124.44
14.99	105.27	85.00	124.77
17.00	106.24	87.29	125.08
19.03	107.17	89.58	125.38
21.08	108.08	91.88	125.66
23.14	108.95	94.18	125.93
15:22	109.80	96.49	126.19
27.32	110.62	98.79	126.43
29.42	111.42	101.10	126.66
31.54	112.20	103.41	126.87
33.68	112.95	105.72	127.07
35.82	113.67	108.03	127.26
37.98	114.38	110.32	127.44
40.14	115.06	112.66	127.60
42.32	115.72	114.98	127.75
44.50	116.36	117.29	127.89
46.70	116.90	119.61	128.02
46.90	117.58		
51.11	118.17	REF	
53.33	118.73	UNIV. OF OXFORD	
55.56	119.27	PHYSICS LABORATORY	
57.79	119.80	DWG. N2-93-52	
60.03	120.30	"GLASS DISH DIMENSIONS"	
62.28	120.79	DATE: 7/31/1990	
64.53	121.26	SNO REFLECTORS	

NOTES.

DATA REFERENCE.

1. REFLECTOR
   UNIV. OF OXFORD
   PHYSICS LABORATORY
   DWG: N2-93-52
   SNO REFLECTORS
   GLASS DISH DIMENSIONS
   DATED: JULY 31, 1990

   TOLERANCE IN OUTER DIA OF REFLECTOR: ±2 mm
   REF. BITNET N TANNER
   DATED: AUG. 30, 1990

2. PHOTOMULTIPLIER TUBE
   SCHOTT GLASWERKE
   MER MAINZ
   INDUSTRIAL ENGINEERING MTI
   DWG: A5369-00-02b
   KOLBEN FOR PHOTOMULTIPLIER
   FA. HAMAMATSU. H6P-204 HE
   ART -NR.
   DATED: DEC 19, 1990

3. PHOTOMULTIPLIER TUBE AND PINS
   H.B. HAK (via FAX)
   QUEEN'S UNIV
   KINGSTON, ONT., CANADA
   FAX COPY OF PMT RFQ.
   DATED: AUG 28, 1990

4. BASE ENCLOSURE
   VOLUME ~.3liter
   FROM H.B. HAK (via FAX)
   QUEEN'S UNIV
   KINGSTON, ONT.
   CANADA
   DATED APRIL 27, 1990

5. GENERIC UNDER WATER 50 ohm COAXIAL SIGNAL H.V. TRANSMISSION CABLE

23H0004

PRELIMINARY

MEETING MATERIALS

SCALE: 0 100 200 250 mm DIM. mm / IN

REV	DWG.	CH.	CHK	DATE	CHANGES

UNLESS OTHERWISE SPECIFIED

SHOP ORDERS

DRAWN T. KAJIYAMA 08-28-90

CHECKED LESKO/LUNDQUIST 09-02-90

LAWRENCE BERKELEY LABORATORY
UNIVERSITY OF CALIFORNIA-BERKELEY

SNO PROJECT
GENERAL

DIMENSIONS OF PMT AND IT'S REFLECTOR

LAYOUT

SIZE A1 HALF

23H0004