Specification Document for Cavity Shielding

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Revisions

1. Nov 2 1990 (top water)
2. March 11 1991 (top water, backfill and bottom water)

Introduction

External shielding for the SNO detector is used to attenuate γ-rays and neutrons generated by natural radioactivity in the rock surrounding the cavity [1-8]. Because of the different geometries of the cavity (barrel) and the detector (sphere), the effectiveness of shielding is not uniform. Shielding is most useful in the region horizontally opposite the center of the acrylic vessel.

The external γ-ray spectrum forms a continuum extending up to about 10 MeV. However it is only the γ rays with energy greater than 5 MeV or so that are of concern for the external shielding because the low-energy background from the PMTs, acrylic vessel and light and heavy water dominate at lower energies. The external γ-rays are generated predominantly by the (n,γ) capture reaction on the component elements of the rock, the concrete and the steel liner. Of these, neutrons produce the most severe background when captured in steel. Therefore shielding plays *both* the role of attenuating high-energy γ-rays produced in the rock (and γ-rays produced in the shield itself) and removing neutrons through a combination of hydrogen (water) and boron (which does not create high-energy γ-rays when it absorbs a neutron) so that they cannot be captured in the steel liner.

Rationale for Specifications

Limits for cavity dimensions have been taken as the values given in ref. [9]. Limits on other quantities have been derived from the level that would produce a 10% increase in the overall external background. Physical properties of the shield and concrete and water thicknesses are those used in background calculations, and in particular reference [1].

Specifications

The cavity and acrylic vessel dimensions and relations were originally as shown in the Project Specification Document [9] but have been updated as shown in Fig. 1 (except for the bottom, as discussed below). The concrete shield is to be not less than 25 cm thick, not less than 9 m high, centered horizontally opposite the center of the spherical acrylic vessel (the waist). The shield is to be composed of low-activity concrete (presently expected values are 260 ng/g of U and 110 ng/g of Th, they are not to exceed 1.3 μg/g of U/Th) with a bulk density of not less than 2.37 g/cm^3, a hydrogen content of not less than 0.8% by weight, and loaded uniformly with not less than 0.5% boron by weight.

The consequences to shielding due to alterations in the cavity shape defined in the Project Specification Document that have occurred since the first version of this document are discussed in the relevant sections.

Liner (waist)

In the waist region the stainless steel liner is to consist of not more than a 1/8" thick stainless steel sheet, with steel fittings at the liner surface comprising less than 25% of the liner weight in this region. (If the effective liner thickness were increased by a factor of 4, then the water thickness would have to be increased by approximately 25 cm to bring the background back to the previous level.) The liner should be in contact both with the water and with the concrete shield. If it is necessary to interpose the insulating filler between the liner and the shield, its overall uranium/thorium contamination level should be less than that of the shielding concrete.

The uranium/thorium content in the steel liner would produce a 10% increase in the overall γ-ray background from the shield at the 30 μg/g level. Since this is an extremely high level, the practical limit to acceptable steel contamination levels will be set by water purity considerations.

Liner (non-waist)

The requirements for the liner thickness and fittings can be relaxed away from the waist zone. If the effective thickness of the stainless steel liner (liner plus fittings) were doubled along the top 6.9 m or the bottom 4.5 m of the liner, only a 0.5 % increase in the overall γ-ray background would result. The corresponding values for the bottom will be provided when the detailed bottom calculations have been completed.

Note: These estimated effects are only correct if the backfill condition is equivalent to no concrete. This is discussed under backfill.

Water Levels

The initial requirement for water cover was not less than 5.5 m vertical thickness of light water between the wall of the acrylic vessel and the stainless steel liner at the centre of the bottom of the cavity. The water thickness was subsequently altered to 5.00 m. This alteration made a bottom shield section necessary, whose dimensions have not yet been determined. This will be the subject of a separate report.

The original requirement for the top water thickness of 6.20 m between the wall of the acrylic vessel and the bottom of the deck was not satisfied when the acrylic vessel specification introduced a 1.8 m drop in water level in the neck of the acrylic vessel relative to the outside water. This change introduces major increases in the γ-ray and neutron background from the deck region. In order to recover from this change two steps have been taken. The first is to increase the top light water coverage to 6.55 m minimum height from the top of the acrylic vessel (12.55 m from the center of the vessel), and the second is to specify the region immediately surrounding the acrylic vessel neck at the deck level as the *glove box*, which will require a separate background evaluation, yet to be done.

There shall be not less than 4.67 m horizontal thickness of light water between the inner wall of the acrylic vessel and the stainless steel liner at the centre of the concrete shield.

Deck

The estimate for the top water thickness assumes that there is a total deck *etc.* steel mass of 29 tonnes with a safety factor of 1.8 for that mass. If the background from the deck were doubled, the top water thickness would have to be increased by 25 cm to compensate.

As discussed in the water levels section, the lowered water level in the neck region means that a separate section labelled the *glove box* is now characterized separately from the deck. This section will be characterized after sufficient detail about the components in the immediate neighbourhood of the neck is available. It is expected that considerably more stringent conditions will attain for the glove box than for the deck in general.

The uranium/thorium contamination level allowable in the deck is not at all stringent because of the large water attenuation for activity from the deck. An average contamination level of 3 mg/g of U/Th would contribute a 10% increase in the external background. This is an improbably high contamination.

Backfill

The backfill up to 4 meters above the top of the waist and 4 meters below the bottom of the waist is to have the equivalent of a 10 cm thick layer of normal density concrete loaded with 0.2% boron. This layer is to be next to the stainless steel liner. Failure to do this will result in an increase in the overall background from the cavity of up to 14%.

References

[1] E. T. H. Clifford and P. Y. Wong, **Dolomite Concrete vs Sulfurcrete for the 22 Metre Cavity**, SNO-STR-89-48.

[2] R. K. Heaton, H. Lee and B. C. Robertson, **Neutron Yields in Norite based on Mineral Composition**, SNO-STR-88-101.

[3] P. Skensved and B. C. Robertson, **Shielding Update**, SNO-STR-88-54.

[4] P. Skensved and B. C. Robertson, **Spherical Vessel Option**, SNO-STR-88-53.

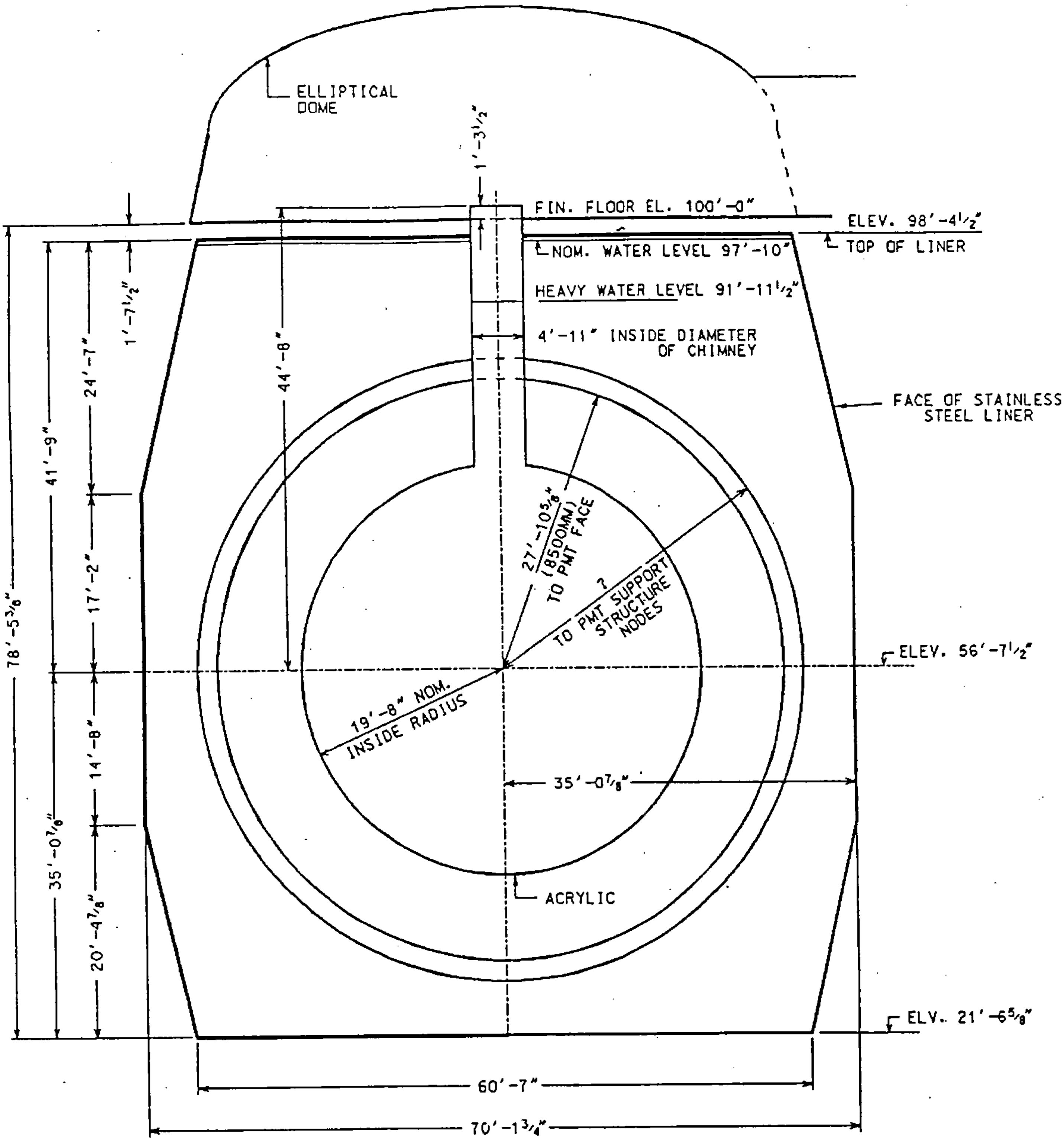
[5] P. Skensved and B. C. Robertson, **Interim Optimization Report**, SNO-STR-88-29.

[6] P. Skensved and B. C. Robertson, **Sulfurcrete Shielding Report**, SNO-STR-88-4.

[7] P. Skensved and B. C. Robertson, **Shielding Report**, SNO Proposal Annex 9, SNO-87-12.

[8] E. D. Earle and P. Y. Wong, **Shielding for the SNO Detector**, SNO Proposal Annex 9, SNO-87-12.

[9] K. M. McFarlane, ed., **Sudbury Neutrino Observatory Mk II Engineering Proposal**, PSD-TM-12 Revision P2.



DETECTOR DIMENSIONS

8/03/91

Mod 3

SK. 17-702-6201

Fig 1