Implications of Calculated Backgrounds for Cavity Construction Quality Control

SNO-STR-91-20

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Introduction

The following represents the quality control implications of the external shielding requirements. In several instances these requirements do not pose the most stringent demands on the relevant components. Therefore this document should be viewed as a partial picture of overall quality control for these components, and it is assumed that a more general Quality Control Document will be produced which will subsume the considerations listed below.

Waist and Bottom Shield

The concrete for the shield is specified to have 260 ng/g of U and 110 ng/g of Th and is required not to exceed 1.3 μg/g of U/Th. If we assume that 1.3 μg/g of U/Th is the contamination limit and that the contamination is coming from mine dust which has 5.3 μg/g of Th and 1.2 μg/g of U, then the installed concrete can have no more than about 20% rock dust incorporated into the bulk of the material. This could come either through bulk contamination of the concrete or through contamination of the water used to make the concrete. The manufacturer should be asked to agree to SNO tests of radioactivity of manufactured shielding blocks in order to assure that they meet the contamination standards.

Mortar placed between the blocks should have or incorporate sufficiently little contamination so that the total activity of the combined shielding blocks and mortar satisfies the above contamination limits set for the shield.

Surface contamination due to dust settlement on the concrete (if in block form) can be treated as bulk contamination for all but the surface next to the steel liner, which will be treated as contamination of the steel liner.

The effectiveness of the concrete shield for neutrons depends on its hydrogen and boron content. The manufacturer should be asked to agree to a procedure to assure that the boron content and the hydrogen content of the concrete blocks meets the minimum requirements of 0.5% boron and 0.8% hydrogen by weight.

Concrete backfill behind the waist and bottom shield or in the unshielded taper or bottom sections, either as blocks, shotcrete or as a mortar, in principal can have a contamination level comparable to that of the norite, but it would seem reasonable to adhere to the same standard of cleanliness as that for the concrete shield unless it would be too costly.

Any materials to be placed between the concrete shield and the steel liner should be subject to the same contamination level criteria as the shield, and samples of all components to be used must be submitted to SNO so that their radioactivity properties can be assessed.

Stainless Steel Liner

The specification of the activity of the stainless steel liner in terms of high-energy γ-ray backgrounds is that the liner could tolerate up to 30 μg/g of

U/Th by weight effective contamination. It would be effectively impossible to reach this level with rock dust contamination since the rock dust itself is only at the 5 μg/g contamination level. In fact, the limit to the activity levels tolerable in the stainless steel liner and its surface properties is set by water cleanliness considerations which will not be dealt with here.

Welding joints can be expected to comprise from 0.5% to 1% of the steel liner mass. If the welding material were to provide the total U/Th contamination load it would be limited to less than approximately 1 part per thousand by weight in U and Th. The welding rods must not be thoriated.

It should be sufficient for SNO to do batch radioactivity tests of the stainless steel sheets and welding rods before final acceptance. Dust contamination must be dealt with in the inner detector construction and water purification cleanliness considerations.

Deck

The radioactivity limits for the deck are such that for the production of high-energy γ-ray backgrounds, the effective contamination limit of 3 parts per thousand U/Th by weight required to significantly increase that background would produce an unrealistically high tolerance to rock dust. In fact much more stringent limits to rock dust are set by the cleanliness requirements for access to the heavy water and for construction inside the steel liner. These limits will not be discussed here.

The activity limit for the inherent steel deck radioactivity remains at 3 parts per thousand as stated in the Cavity Specification Document. This level of cleanliness can be achieved readily by batch testing of the steel to be used for the deck. The manufacturer should be asked to agree to these tests of the steel, although it is not very likely that there will be a problem with acceptance of the steel.

It should be noted that in this document it is assumed that the materials immediately surrounding the acrylic neck is presumed to be associated with the *glove box*. The glove box will have much more stringent limitations to the inherent activity levels of its components. These values have

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

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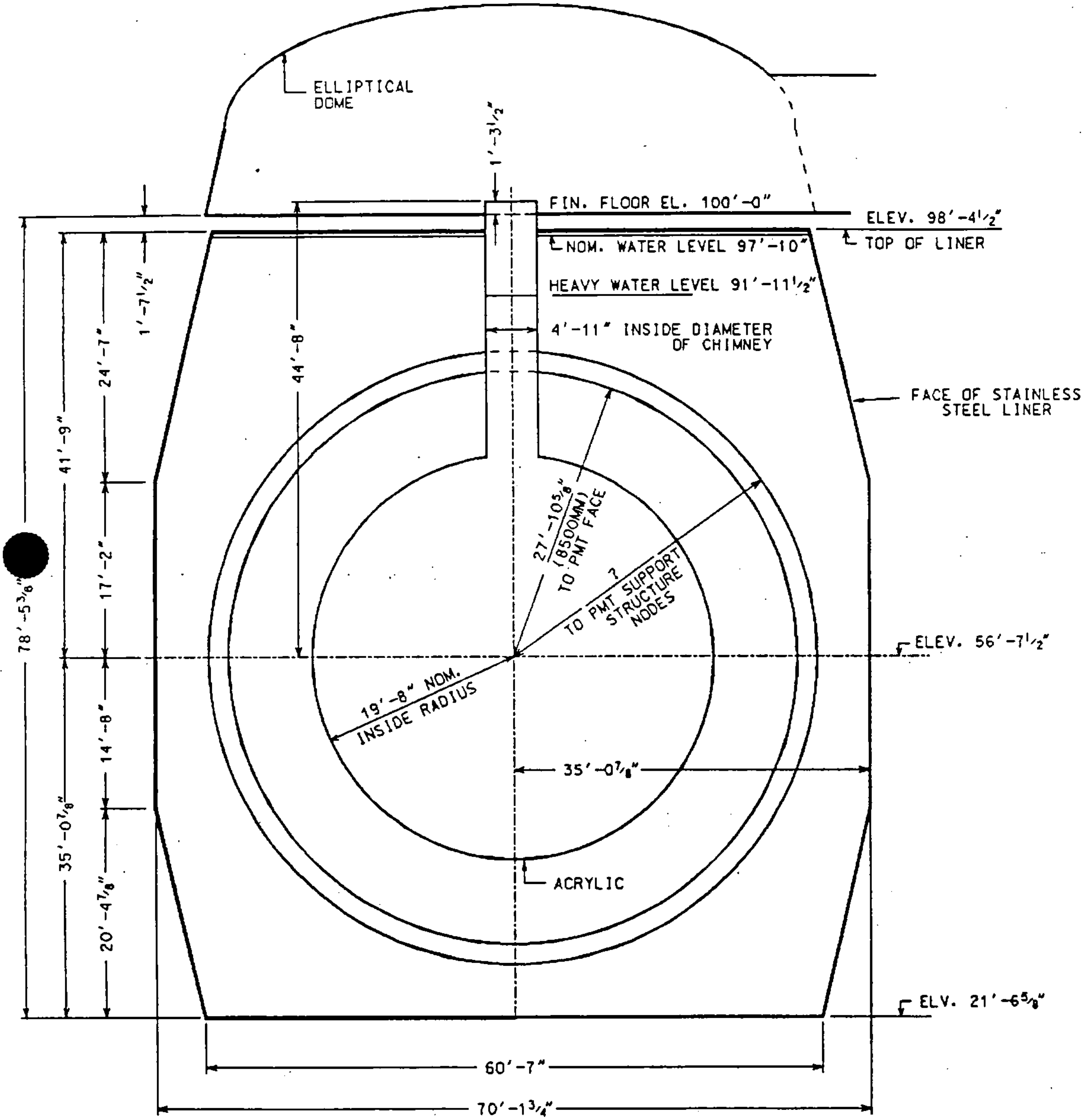

DETECTOR DIMENSIONS

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SNO-STR-91-021

ACCIDENTAL TRIGGER RATES - II
LIQUID SCINTILLATOR

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I. Introduction

The results presented in SNO-STR-90-36 are extended to cases where the PMT singles rates are of the order of 100K/sec. These are the singles rates anticipated from tritium decays if liquid scintillator were placed in the detector. Here one would expect about 86 PMT's to fire for 1 MeV events.

II RESULTS

Fig 1a is similar to Fig 1 in SNO-STR-90-36 with the abscissa now extending up to 500 PMT's firing within a 100 ns time window. The ordinate is $NR\tau$ where N is the total number of PMT's in the detector, R is the singles rates in a single PMT, and τ is the width of the timing window (fixed at 100 ns). Each of the five lines is for a constant accidental rate ranging from 0.01/sec t0 100.0/sec. Fig 1b is a similar set of curves for accidental rates ranging from 1.0×10^{-2}/sec to 1.0×10^{-6}/sec. The numerical results are presented in Table I. It is noted that the accidental rate is extremely sensitive to the number of PMT's required by the trigger. This is better seen in Fig 2a which plots the $\log_{10}$ of the accidental rate (sec^{-1}) vs the number of PMT's required by the trigger, for $R = 100K/sec$, $N = 10{,}000$ $\tau = 100ns$. The accidental rate changes from ≈ 1/sec to ≈ 1/day, when the number of PMT's changes from 165 to 183. The numerical results are listed in TABLE 2a. The plots and numerical summaries for R=150K and 200K are shown in Figs 2b,2c, and TABLES 2b,2c. With the PMT singles rate equal to 200K/sec,the accidental rate can be kept below 1/day by requiring 320 PMT's to fire. Should the electronic threshold have a jitter of 10% (as in Kamioka), then a threshold of 350 PMT's would be required, which is about 4 MeV. To get down to a 2 MeV threshold the singles rates would have to be kept below 100K/sec.