

Leaching, Cleaning, and Water Specifications

D. Sinclair

3-Dec-1990

1 Radioactivity Specifications

The required radioactive purity of materials used in the SNO detector is strongly dependent on where the activity is produced - the closer the source is to the center of the detector the lower the permissible activity. Our objective in the heavy water is to have a thorium level less than 10^{-15} g/g. At this concentration the number of background neutrons per day from photo-disintegration is 0.3 compared with the lower limit expected for the signal of 3 neutrons per day. For the light water, the concentration permitted near the acrylic can be set by requiring the contribution of this activity to the low energy background to be less than that of the acrylic vessel. If the acrylic contains 2 ppt of Th then the concentration in the H₂O should be less than 5×10^{-14} g/g Th. In each case the uranium concentration should not be greater than that of the Th if it is not to dominate the low energy background. Its contribution to the neutral current signal is, of course, much smaller than that of Th and thus somewhat larger quantities can be tolerated if the low energy cut off is sacrificed. In each case the troublesome activity is near the bottom of the chain and the concentrations given are for the parent assuming secular equilibrium.

The problem is complicated because much of the activity may be mobile and be transported from the source by the water. In particular, when the uranium and thorium chains decay through radon, there may be a high probability that the radon escapes from the host material and enters the water. Alternatively, activity near the surface may leach into the water.

2 Leaching Research

A programme to qualify all materials that are in contact with the water must be set up. The specific quantities which must be determined are the leaching of ^{226}Ra and ^{228}Th , total mass loss to leaching, total ionic loss to leaching, emanation of ^{220}Rn and ^{222}Rn , and the leaching of nutrients which may encourage the biological growth.

The leaching of Ra and Th can be measured by placing the materials under test in a bath at elevated temperature and circulating the water over the material and then over a Ra/Th removing column. The columns can then be assayed for the Ra/Th content. For some materials such as the metals, it may be possible to accelerate the leaching to the extent that samples may be measurable by gamma counting. For example, at 5×10^{-14} g/g Th, the light water would have a total activity of 12 Bq. If the leaching from the SS liner (2000 m²) were to contribute all of this during the water purification time (30 days), and if the leaching rate is increased by a factor of 2 for 10 degree temperature rise, then at 90° 1 m² would leach activity at a rate of 0.05 Bq per day. In a weeks exposure this yields a measurable source. For some materials, counting by Lucas cells, the TPC or some other alpha counting system may be necessary. As a test of this procedure, samples will be placed in large volumes of water for an extended period after which the Ra/Th content will be assayed by measuring the $^{222}\text{Rn}/^{224}\text{Ra}$ content respectively, using the sensitive techniques developed for the water monitoring. Particular attention must be paid to metallic materials and the glass. Plastic materials which have very low radioactive contamination are less likely to give rise to problems and should be deferred until later. Thus the urgent measurements required are on stainless steel, the PMT and reflector glasses, omega reflector, and the PMT support structure materials.

Total mass loss measurements are valuable in determining the loading

on the ion exchange columns in the water recirculation loop. The technique is straight forward but probably applicable only to the glass materials and, perhaps the metals. For the plastic materials the degree of moisture take up probably masks any leaching loss.

The measurement of the rate of change of the conductivity of pure water offers a simple and quick measure of the gross leaching of non-organic materials. It is a suitable survey tool for selecting candidate materials for further study.

Radon emanation may be a problem either because it indicates a surface contamination, for example on metals, or because the radon is mobile as in plastic materials and hence can transport radioactivity out of the material into the water. Specific examples where the latter might be a concern are (a) the co-axial cables where the outer jacket might be expected to be very clean but fluxing agents used within the cable may be active and (b) the PMT base housings where the electronic components might give rise to radon which can escape the housing. Because of its much longer half life, ^{222}Rn is the major concern but some tests for ^{220}Rn must also be carried out.

We do not know what type of organisms might grow in our water so we can not do very specific tests for their nutrients. The suggested broad brush tests are to measure the leaching of total organic carbon (TOC), phosphate, and nitrogen. Facilities for performing these tests are being sought. We have, to date, no quantitative information on what levels are tollerable. Obvious materials which require testing are the plastics. In addition, the impact on light attenuation and scattering must be determined.

A very rough estimate of the number of measurements which may need to be made is given in Table 1.

Material	²²⁶ Ra	²²⁸ Th	Mass	Ion	²²⁰ Rn	²²² Rn	Biol
Acrylic	5	5	-	5	5	5	10
Reflector glass	10	10	10	10	10	10	5
Omega mirror	10	10	10	10	10	10	5
PMT glass	5	5	5	5	5	5	5
PMT Base	10	10	-	-	5	10	10
PMT Boot	10	10	-	-	5	10	10
PMT Cables	5	5	-	5	10	10	10
PMT Support	10	10	-	20	10	10	10
SS liner	10	10	-	5	20	20	10
Water system	10	10	-	-	10	10	10
Totals	85	85	25	60	90	100	85
Prof days	220	100	30	30	360	200	100
Tech days	220	100	30	30	360	200	150

Table 1: Numbers of Leaching Measurements Required

3 Resources Required

3.1 ²²⁶Ra Leaching

Setting up the apparatus for these measurements takes about 3 months of elapsed time and four weeks of professional time. A further 2 months of elapsed time and one month of professional time is required for commissioning the systems. Presumably future systems could be brought on in less time. Each measurement will require about 1 week of exposure in a warm water bath followed by one week of counting by gamma or lucas cell. One large bath is being set up at Oxford and one smaller one at Ottawa. It would be desirable to have a third system. Each measurement will require 2 days of professional time and 2 days of technician time to carry out.

With two systems running the measurements would be completed in about 14 months of elapsed time with a total effort of 200 days prof. and 200 days tech time. With three systems the elapsed time would come down to 10 months but a further 20 prof. plus 20 tech days would be required.

3.2 ^{228}Th Leaching

The leaching of ^{228}Th would mainly be done simultaneously with the Ra leaching but the counting may require different techniques. An additional effort of 100 prof. and 100 tech days should be allowed.

3.3 Mass Loss Measurements

Mass loss measurements require stewing of rather small quantities of material in water at elevated temperature for about 1 week and subsequent weighing. Many of the mass loss measurements have been completed. An allowance of 30 prof and 30 tech days should complete the required measurements.

3.4 Ion contamination

The ionic contamination measurements require monitoring the rise in conductivity of water as ions leach into it. The measurement requires access to ultra pure water as a starting point and preferably a gas tight environment to prevent contamination by CO_2 . About half of measurements have been completed. A further allowance of 30 prof and 30 tech days should complete the required measurements.

3.5 ^{220}Rn emanation

The most sensitive techniques for ^{220}Rn emanation studies will be the CPPC at Oxford and the TPC at Ottawa. For use as a routine tool the CPPC requires more work and it is not clear how to make it more reproducible. The TPC requires a further 3 months of development before it is ready for general use and it will then be used primarily for water monitoring studies. New techniques are required to allow routine measurement of the ^{220}Rn emanation. A number of candidate techniques are available including electrostatic extraction with Si counting, cold extraction with Si counting, and either extraction with co-incident scintillator counting. We should have

at least three techniques investigated, each requiring 60 prof and 60 tech days, with the development taking place over the next 4 months. We should then allow one week of counting per sample. Assuming that we get three working systems, 30 weeks counting time are required starting in 4 months for the full programme.

3.6 ^{222}Rn Emanation

Techniques for measuring the emanation of ^{222}Rn are well established for emanation into vacuum. The measurements require one week of collection of Rn in a vacuum cell followed by a week of counting in a Lucas cell. The expected programme will require 33 weeks of elapsed time if three systems can be put into operation. The estimated manpower is 100 days of prof and 100 days of tech effort.

3.7 Biological activity

The tests for the TOC, P and N are straight forward, provided suitable apparatus can be found. There may be a cost associated with getting the measurements made but there seems to be no case for SNO setting up to make these measurements. We will have to prepare the samples and this may involve a water bath separate from that used for the other leaching measurements. In particular, we may wish to leach these materials in SS rather than PVDF to see better the organics. An estimate of the effort required is 50 days of prof and 50 days of tech effort. SNO will have to carry out the optical tests but these might be done on a restricted set of samples. The main time is associated with developing the techniques.

3.8 summary

It seems that the order of magnitude activity required is 4 man years of professional activity and 4 man years of technical effort (which could be undergraduate type activity). In addition, there will be a need for materials and workshop time as well as equipment so that the measuring systems can

be set up. It is difficult to estimate this with accuracy without a detailed knowledge of the existing equipment available.

4 Cleaning

During the manufacturing, shipping and installation of the detector components, there is a risk of contamination and a careful programme is necessary first to minimize the contamination and then to decontaminate before the detector is operated. Because the contamination is almost certainly on the surfaces of the components, we must expect that most of the radon will all emanate into the water. The following analysis assumes that the contamination is mine dust which contains about 5 ppm Th. I will also take the most conservative case of Rn sticking or emanating.

To keep the heavy water below 10^{-15} g/g Th the total dust load in contact with it must be 0.2 g or less. Thus the total load on the inner surface of the acrylic vessel and the water pipes must not exceed this level. For any systems which are in the central volume of the heavy water (such as NC detectors or dividers), I would like to require a total activity 10 times lower than this (i.e. a total Th load of less than 10^{-7} g). In this case, the worst scenario is that the activity stays in place and we have no way of measuring it. Thus we must be certain that it is very small compared with the possible signal.

The activity on the surface of the acrylic vessel should give a background small compared with that of activity in the acrylic itself. In this case, again, the problem is worst if the Rn stays put. Assuming acrylic can be delivered at 2 ppt Th, we require less than 10 g of mine dust on the outer surface.

The requirements on components in the light water is strongly dependent on the degree of water tightness of the PMT support structure. If the structure is sufficiently open that convection mixes the water then to achieve a level of 5×10^{-14} g/g we must keep the total dust to less than 50 g or the dust by itself (ie ignoring leaching and Rn emanation) will give us the maximum permitted contamination. I would like to see us set this as our objective but I expect it is not attainable bearing in mind that some of the

materials such as the cables are very efficient electrostatic dust extractors. If the PMT structure is sufficiently tight that it blocks convection then the activity will probably decay before it has a chance to diffuse to the fiducial volume. In such a case, we can set a requirement that the activity of the dust be less than that of the PMT's. This would imply a total dust load of about 10 kg. I feel that, with care, it should be possible to limit the dirt to less than 1 g per pmt + cable + housing.

A programme of cleaning the detector must be thought through. The most critical component is clearly the acrylic vessel and a technique for cleaning this must be devised. The vessel will be cleaned after some of the PMT's and reflectors are installed and the compatibility of any cleaning materials to be used with these components should be investigated. I expect that the PMT structure and the cables are much too complex to clean once installed (especially after the acrylic vessel is in place). We should therefore plan to clean these fully as part of the installation sequence and ensure that they are kept clean through the subsequent operations.