Neutron Production from ^{24}Na

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Introduction

A non-negligible fraction of the D_2O in the SNO detector is at any given time in the recirculation loop outside the cavity. If NaCl is added to the D_2O there is a possibility of γ's from the rock photo-disintegrating the deuterium with subsequent neutron capture on ^{23}Na. The activated sodium (half-life 14.96 hours) would β-decay in the central volume of the SNO detector followed by a 2.754 MeV γ which again can photo-disintegrate the deuterium and lead to free neutrons.

In this document we calculate the added background from the 2-tonne holding tank, the piping and the 60-tonne tanks.

Calculations

Only the 2.6 MeV γ's from ^{208}Tl and the 2.4 MeV γ's from ^{214}Bi from the rock need to be considered. All other γ's are either too low in energy or too low in intensity. Three different scenarios are considered; bare rock, rock

	Density (g/cc)	Th (ppm)	U (ppm)
Norite	2.82	3.3	1.2
Shotcrete	2.35	1.08	0.70
Concrete	2.35	.499	.156

Table 1: Levels of activity

	2.6 MeV	2.4 MeV
Rock	2943	138.5
Rock + Shotcrete	1969	110.5
Rock + Shotcrete + Concrete	1066	54.2

Table 2: γ-ray flux per day per cm^2

coated with 5 cm of shotcrete and rock with 5 cm of shotcrete covered by 7.5 cm of (clean) concrete. The assumed activity levels are listed in table 1.

These numbers lead to the total fluxes per cm^2 per day summarized in table 2. They are dominated by the 2.6 MeV γ's from Th (95%).

Given the above γ-ray fluxes we can calculate the neutron production and the probability of capture on Na with the Queen's neutron monte carlo code. The tanks are assumed to be made out of stainless steel (5 mm wall thickness) and to contain 2 or 60 tonnes of D_2O with 0.25% NaCl respectively. For the pipes we assume 10 cm diameter with a total length of 500 meters.

Based on runs with 100,000 neutrons we find that the ^{24}Na capture probability is 0.0040 for a 2-tonne tank, 0.0060 for a 60-tonne tank and 0.00003 per meter of pipe.

Since the ^{24}Na lifetime is long we can assume that all of it produced in

	2 tonne tank	60 tonne tank	500 meters of pipe
Rock	1872	27252	103
Rock + Shotcrete	1259	18333	68
Rock + Shotcrete + Concrete	680	9893	36

Table 3: ^{24}Na produced per day

the 2-tonne tank decays in the detector where a fraction of it (one in about 370) will produce neutrons. It is clear that the extra concrete does not buy us very much. Lead bricks is a more effective way to go. Four inches of lead reduces the flux of 2.614 MeV γ's by approximately a factor of 100 which would lead to 0.03 neutrons per day in the detector from the 2-tonne tank.

An alternate way of lowering the number of ^{24}Na is by placing a Boron loaded sphere inside the 2-tonne tank. The code predicts a reduction by a factor 0.64 for a 10 cm diameter sphere of natural Boron.

In addition there are 0.18 n/d from the 500 meters of pipe assuming rock plus shotcrete. To reduce it would require either smaller diameter pipe or shorter runs.

For the 60 tonne tank it is obvious that one cannot easily shield it enough to be effective. This is not a real problem since the NaCl concentration will not change very often. Approximately 50 free neutrons will be produced in the SNO detector every time a 60-tonne tank is emptied.