Should we examine an alternate design for SNO?

J.J. Simpson, P. Jagam and J. Law SNO-STR-90-40

The present design for SNO maximizes the information obtainable from 1000 tonnes of heavy water, and is probably the best design one could have. However, it is extremely complicated in construction, and the acrylic vessel may be its Achilles' heel. Both from a construction and a radioactivity point of view, the problems of the acrylic vessel are far from solved. In addition, its presence complicates incredibly the construction of the PMT support and introduces tremendous cleanliness problems. Finally, the longevity of such a vessel is not great, so that it might not be possible to take advantage of the situation where the D_2O becomes available for perhaps a whole solar cycle. Consequently, it might be useful to have a small group examine some other design concurrently with the work on the present design.

One example of an alternate design, in a very preliminary stage, is attached. The main features of this design (see fig.) are a solid tank (stainless steel, perhaps) on which the PMT's are mounted and which contains the heavy water. In addition, there is a transparent bladder of approximately 4 m radius separating an inner region of pure D_2O from D_2O doped with boron. A possible material for the bladder is EPDM synthetic rubber which is completely impermeable to water and hopefully to boron.

Some of the properties of this design can be estimated from our Mark II design. If we assume generic (Hamamatsu) 8" PMT's, then 12700 tubes provide 80% coverage. The mass of glass is 6.9 tonnes, and at 30 ppb levels contains 0.21 g of Th and U each. We assume that the vessel is made of stainless steel ¼" thick and has an approximate mass of 23 tonnes (allowing for caps over the PMT's). If the SS has less than 5 ppb Th and U, then the total inward flux of 2.6 MeV γ's is $\sim 2 \times 10^7$/day, and $\sim 2.7 \times 10^6$/day for 2.45 MeV γ's, for the vessel plus PMT's. Since 470 2.6 MeV γ's produces one neutron in D_2O, we need to attenuate the γ's by a factor of 2.35×10^{-5} which, according to the table 20, Annex 9 of Earle & Wang "Shielding Calculations" is just about what is achieved by 2 m of water. Thus, for the neutral current interaction we must kill the neutrons in the outer 2 m of D_2O, leaving a fiducial volume of 295 tonnes for the neutral current.

For the charged current reaction, it might be possible to have a larger fiducial volume. We have made a crude estimate of what the β-γ PMT background would be for a distance of 1 m from the PMT sphere, based on Beier & Sinclair SNO-89-15.

From fig. 6, we estimate that, in Mark II, there are about 1650 β-γ events ($N_h > 15$) for 4×10^6 Tℓ decays (the number used for fig. 6 - P. Skensved) within a volume 1 m from PMT plane. Thus, per day there will be 10800 events ($N_h > 15$) for Tℓ. Based on information from P. Skensved, there will similarly be about 11800 events from ^{214}Bi, for a total of 22600 events ($N_h > 15$) in a volume 1 m from the PMT phase.

Now, the fiducial volume in the new design, relative to Mark II, is $\left(\frac{5}{7.5}\right)^3 = 0.3$. Since the number of PMT's is the same in both designs and hence the total number of β-γ events is the same (neglecting reflector effects), the density of β-γ events will be 3.3 times higher in the new design. Thus we expect 74600 events/day within 1 m of PMT sphere with $N_h > 15$.

From fig. 3, we deduce that there is an exponential fall off of number of events versus N_h of the form exp-0.75 N_h. Hence, number of events above a certain N_h is also an exponential of the same form. Consequently, one can deduce that, for a PMT β-γ background of 1 event/day, the number of hits must be above 30 (about 3.5 MeV). The fiducial volume in this case is about 580 tonnes.

The feasibility of its most important feature for doing the neutral current reaction, namely some sort of barrier within the D_2O to separate it into boron-doped and undoped regions, is certainly not obvious. Nevertheless, as a comparison of some of the advantages and disadvantages of this design show, it is not in principle without merit. These are speculations until a feasibility design is carried out.

Advantages:

1) Construction of the D_2O vessel is relatively straight forward, using "conventional" materials and construction techniques, and with normal supports attached to walls and floor of the cavern liner. Much safer to construct as well.

2. PMT mounting is also straight-forward.

3. Assuming that a suitable "membrane" separating D_2O and D_2O + B regions can be found, then probably only the inner amount of D_2O has to be tested and filtered for radioactivity levels.

4. Almost the worst possible scenario is the breaking of the membrane. Then we only have a charged current experiment. If the membrane is truly flexible, like a balloon, it might be replaceable without emptying the detector.

5) The whole vessel might be able to last many decades, permitting a number of solar cycles to be examined.

6) About one-half the number of PMT's required, or same number for more coverage without reflectors.

7) Smaller cavern required, less light water.

8) Less water purification - only heavy water must be kept clean.

9) More light, if bladder is "completely" transparent, since no acrylic and no light water.

10) Perhaps no biological growth, since no H_2O in front of PMT's.

11) Perhaps we don't need a light water fill, at least initially.

Disadvantages:

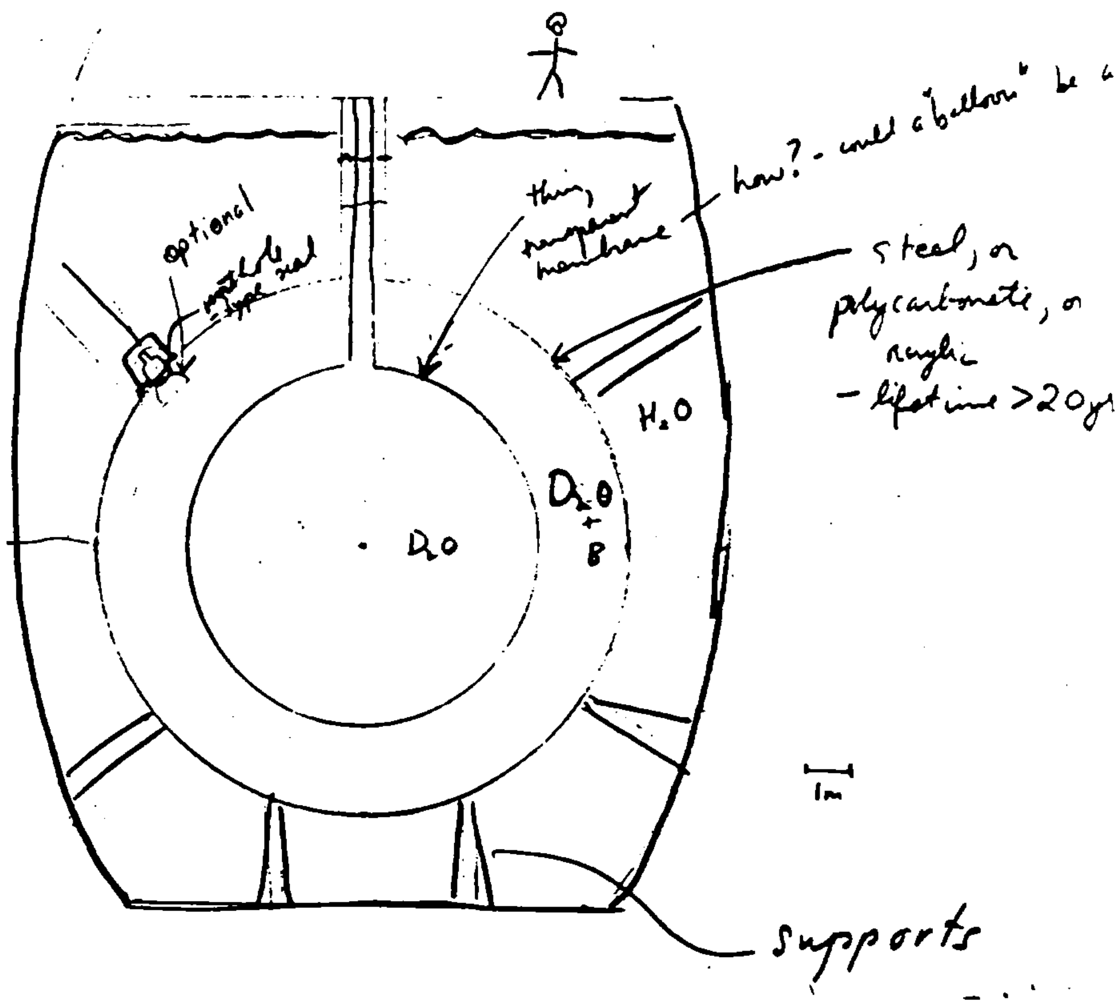
1) The fiducial volume is ~300 tonnes for neutral current.

2) If a suitable membrane cannot be found, or if it breaks and is not replaceable, then the neutral current experiment is probably impossible.

3) The results will always be inferior to those of the best design.

4) The ^{3}He detectors may not be easily implemented.

We therefore propose that a small design committee be set up to look into a design such as this, evaluate the backgrounds and the signal-to-noise ratio expected, and look into the feasibility of all its elements.


optional
porthole-type seal
thin, transparent membrane
how? - could a "balloon" be a
steel, or
polycarbonate, or
acrylic
- lifetime >20 yrs
H_2O
D_2O
+
B
D_2O
1m
supports