Acrylic Vessel Cleanliness.

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Summary:

The status of acrylic contamination is reviewed. While the handling of panels by RPT is adding more Th than is desired it is not a show stopper and realistic improvements may be impractical since they would require modifications of RPT procedures and a greater SNO presence at RPT. Decisions must be made on what happens to the panels in the car wash, the type of gloves to be worn underground and how to clean and keep clean the panels after bonding. Samples from QW #2 are required for NAA analyses and for alpha spectroscopy. Acrylic witness plates could be set up in the mine and at RPT. There are a number of items all adding Th to the acrylic inventory i.e. Th in the virgin acrylic, Th embedded during thermoforming, recoils from dust on the surface for extended periods, dirt in bond joints and dust on the final vessel and consideration should be given to reducing the total inventory.

Introduction:

Acrylic cleanliness issues are:
1) The dirt inventory in the cavity should not be significantly increased during panel transportation.
2) The surfaces to be bonded must be free of grease and fingerprints so that a structurally sound bond can be made.
3) The Th and U content of the acrylic vessel when completed should be kept below the specifications.

1) Minimizing dirt inventory.

The panels are to be cleaned, prepared for bonding and bagged in Grand Junction before shipment to Sudbury according to RPT

procedure 8004 . A SNO representative is supposed to witness this cleaning. In Sudbury the panels are to be transferred to a sealed container for transportation underground. In the car wash they will be removed from the sealed container and at this point either

a) the protective bag could be rinsed down to improve dust inventory
or
b) the bag could be removed resulting in a naked panel transfer to the cavity site
or
c) two bags could be place around the panel in Grand Junction and one of the bags removed at the car wash site.

2) Clean bond edges.

The intention is to clean the edges with alcohol and water before bagging at Grand Junction. They should be cleaned again before they are placed on the jig in the cavity. All workers underground should be wearing gloves at all times. The best glove design has not been selected. The cotton ones being used in Grand Junction may not be the best. Finally, just before the bond gap is sealed the surfaces should be wiped with a cloth on a tongue suppressor.

3) Th/U in or on the acrylic.

This issue includes a number of components which can be discussed separately. They include Th and U
a) in the virgin acrylic.
b) trapped in the bond.
c) added to the surface at RPT.
d) added to the surface during vessel fabrication
e) daughters embedded in the acrylic surface

a) The levels of Th and U in the virgin acrylic have been extensively measured by mass spectrometry and neutron activation analysis. The concentration of their radioactive daughters have been measured in a few samples by alpha spectroscopy. The conclusions is that the

levels are an order of magnitude below the design criterion of 2 pg/g of Th. See SNO-STR-93-42, revised Jan 24, 1994.

b) Bonds made in Santa Ana, including samples from QW #1, and in the 4600' SNO laboratory have been checked for Th and U by neutron activation. Visual examination of the bonded surfaces do show dust particulates on those surfaces trapped by the bond. While the concentration of Th/U in the bonds is higher than in the virgin acrylic it is still acceptable to SNO especially when one considers the relative volumes of the bonds and the vessel. See SNO-STR-94-10. We have not yet measured samples from QW #2.

c) Measurements of samples taken from acrylic handled by RPT at Grand Junction do show significant increases in the level of Th. The increased Th levels are still within the SNO specification of less than 2 pg/g Th. These increases are assumed to occur during the thermoforming process since at that time the acrylic is at a relatively high temperature or near a plastic state. Steps have been taken to improve the cleanliness during this component of the fabrication. We have not checked that these steps have been successful. It is assumed that dirt accumulating on the panels during handling at RPT, other than during themoforming, can be cleaned off at a later stage. From time to time RPT does clean the panels but there is a lot of handling and exposure of the naked surfaces to room dust and there is no consistent cleaning program in place. It has become worse since RPT modified their panel lifting procedure to require that the panels be naked during lifting with suction cups as compared to an earlier procedure where the panels could be lifted with the gemmac attached. It will be informative to have samples from QW #2 for testing since the wall has been sitting unprotected for an extended period of time. During the dry fit the panels have received an extended exposure to dirt from the air and from handling. SNO-STR-94-10 & 29. See also SNO-CRL-95-02 (Th in polished acrylic)

d) If the experience with the dry fit at RPT is a guide we can expect the panels to become unacceptably dirty during fabrication in the mine. A cleaning procedure for the finished vessel must be established. If it is only dust then water should be sufficient to remove it but workers will have to wear gloves at all times to avoid fingerprints etc and if the gloves get dirty with grease than water will not be sufficient. Alternatives

- a water wash down of the completed vessel. This might be sufficient if surface dust is the only problem.
- an alcohol and water rinse immediately followed by a protective coating during construction. The coating to be removed after the vessel has been constructed. This would be satisfactory except we don't know how to do it.

It should be noted that Th on the inside surface of the vessel is more serious than Th on the outside or in the acrylic since the decay products will migrate into the D2O and not just produce a background at the vessel boundary. The SNO specification for Th on the inside surface of the vessel is more severe than for Th in the acrylic. The level of dust on the completed vessel should be; inside - $< 0.04\ \mu g/cm^2$ and outside - $< 0.4\ \mu g/cm^2$ SNO-STR-91-009.

e) Th daughters embedded in the acrylic. Recoils from the decay of Th resting on the surface of the acrylic will be trapped in the acrylic and subsequently produce backgrounds, particularly neutrons into the D_2O. This contamination can not be measured by NAA but could be measure at some level by alpha spectroscopy.

- ^{232}Th decays with a 4 Mev alpha. Thus the energy of the ^{228}Ra recoil is about 70 keV.

- The program TRIM calculates that the range of a 70 keV Ra ion in concrete (density=2.34) or norite, SiO_2 (density=2.87) is 320 angstroms. The range is 533 A in plexiglas.

- The number of ^{232}Th atoms in a layer of dust (density=2.5) 320 angstroms thick (i.e. 8 $\mu g/cm^2$), if the dust has 5 ppm of Th, is 10^{11} atoms per cm^2. The norite is at 5 ppm. Concrete is 3 ppm.

- The half life of ^{232}Th is 1.4×10^{10} years so in 1 month 0.4 atoms out of the 10^{11} atoms decay into 4 π. Not more than 25% of these will reach the acrylic surface. Therefore the concentration of ^{228}Ra in the acrylic surface is of the order of 0.1 atoms per cm^2 and there are two surfaces to the vessel or 0.2 atoms per cm^2 of vessel.

- The SNO specification for acrylic is 2 ppt ^{232}Th or 6×10^9 atoms per cm^3. Such a ^{232}Th concentration, in equilibrium with ^{228}Ra, gives 2.4 atoms of ^{228}Ra per cm^3.

- The vessel is about 5 cm thick so that the specifications require the ^{228}Ra per cm^2 of surface to be less than 12 atoms which is a factor of sixty more than the limit calculated above from a month of dust.

It would appear that unless there is a lot of dust on the acrylic for extended periods there is not a serious problem as compared to the specifications. Especially when you consider that 8 $\mu g/cm^2$ is really rather filthy. However there is another worry and that is the probability that with this amount of ^{228}Ra near the inner surface of the acrylic what is the migration of daughters into the D_2O?

The specifications require that dust on the inner surface of the completed vessel be < 0.04 $\mu g/cm^2$. Such a dust layer at 5 ppt ^{232}Th has 5 x 10^8 atoms/cm^2 of ^{232}Th and 0.2 atoms/cm^2 of ^{228}Ra which is similar to the 0.1 atoms calculated to be embedded in the inner surface from the recoils. So the estimated embedded dust contribution is a problem of the same order as a finished vessel dust layer of 0.04 $\mu g/cm^2$. All these factors are additive, of course.

Wilhelmy's estimate on embedded dust.

Jerry Wilhelmy has done the recoil calculation independently.
His assumptions c.f. (mine) were
range - 450 (320) A
dust density - 2 (2.5) gm/cm^3
Th in dust - 12 (5) ppm
The range and density cancel out to give nearly the same dust density of 9 (8) $\mu g/cm^2$ but the higher Th concentration results in a factor of 2.9 more recoils into the acrylic c.f. to my estimate. His justification is that its the Grand Junction dust that is relevant not the norite or shotcrete dust and Colorado is high in Th and U. On the other hand it may be that a lot of the Grand Junction dust is acrylic dust from the plant and also we don't know what the level of dust on the acrylic at Grand Junction is.

Wilhelmy calculates the total vessel inventory and compares it to acrylic at 1 ppt ^{232}Th and gets that the recoil contribution is 9.5% of the vessel inventory. I got 1.7% but with less Th in the dust Earle/Wilhelmy (0.1/0.29) and more Th in the vessel Earle/Wilhelmy (2/1). These factors change my 1.7 to 9.8 which is consistent with Wilhelmy's value of 9.5.

Wilhelmy points out that Ra daughters can recoil out into the D_2O from the inner acrylic surface and if all daughters did that the equivalent ^{232}Th inventory in the 1 Mg of D_2O would increase by 1.23 μg c.f. to the 3 μg ^{232}Th D_2O inventory for D_2O at the design specification of 3 x 10^{-15} g/g. Even though the chain has several decays not all of the ^{212}Pb will end up in the D_2O so this recoil contribution is tolerable. This conclusion is similar to the one reached above based on the specification that the dust level on the inner surface of the vessel must be < 0.04 $\mu g/cm^2$.

So the conclusion is that recoils from dust on the surfaces of the acrylic is not a show stopper even if the surfaces are very dusty (8 $\mu g/cm^2$ or larger) for a month. The level of Th daughters from recoils into the acrylic would be less that 10% of the acrylic Th specifications. Also the maximum increased contamination into the D_2O from recoils out of the acrylic is also not a show stopper. However all of these effects, Th in the virgin acrylic, Th embedded during thermoforming, recoils from dust on the surface for extended periods, dirt in bond joints and dust on the final vessel, are cumulative and consideration should be given to reducing the total inventory.

References:

SNO-STR-93-42, revised Jan 24, 1994.
SNO-STR-94-10.
SNO-STR-94-10 & 29.
SNO-CRL-95-02 (Th in polished acrylic)
SNO-STR-91-009

The following are **comments from Peter Doe** after reading the above. These comments direct us to possible actions that should be initiated immediately.

read your report, it's concise, good and should do the job. It also

raises a number of issues which we should address in order to get the cleanest vessel we can:

1) Since we are bagging the panels, shouldn't we double bag them and leave the final bag on until we put the panel on the frame in the cavity?

2) The cotton gloves are pretty poor for handling acrylic (they slip). I think you mentioned those cotton gloves you get from the local hardware store that have little red rubber dots on the fingers, these should give a better grip, they are also more substantial. Let get some and try.

3) I think that when RPT does the final cleaning of a bond surface they wipe with a cloth soaked in monomer. We should check if this is still the way they propose doing things.

4) We should use the QWII to check final cleaning proposals. To check out water use I cleaned 36 square feet of QWII with a soapy sponge wipe followed by a good rinse. The result looked good (no finger prints). I suggest we identify a couple of areas on the wall (front and back) clean one with soap, one with alcohol. Cover both areas with Saran wrap (or whatever) and cut them out for test. Although the soap approach looked good, I worry about residues that are not removed and could be a bug food or light absorber/wavelength shifter.

5) My tests with various cling wrap films suggest that they will not adhere to the inside, inverted surface of the sphere.

6) I believe the dust in RPT consists of concrete dust from the original construction plus acrylic dust. How was the dust in the mine measured and should we do the same thing at RPT? Either way it may be too late to do anything about it.

Hope the above is of some use, all of it is either directly or indirectly referred to in your most excellent report

Bob Stokstad and Martin Moorhead have pointed out that the above recoil assumptions are definitely a worst case senerio in the following sense. The calculation Jerry and I have done assumes the

dust is in the form of a thin film 0.03 microns thick containing Th uniformly distributed over the acrylic. Such a layer is about 8 microg/cm2 thick; however, the dust will actually be in the form of particulates rather than a thin film. Most all of the mass will be in particulates much bigger than 0.03 microns and most of the Th recoils will remain in the particulates because of the relatively short range of the recoil. The dust on the acrylic would have to be several orders of magnitube greater than 8 microg/cm2 in order that the recoils into the acrylic would be as many as calculated assuming a uniform thin film of 0.03 microns. Such acrylic would be very dusty indeed.(However quantitative measurements have not been done at RPT.)

Measurements of the actual dust load at RPT and of the Th content in the ambient dust at RPT would be useful. Ultimately, direct measurements of the Th or Ra content in the surface of the acrylic would show directly the extent of the recoil implantation problem due to exposure to dust.