SNO-STR-92-056

MEMO ON THE USE OF POLYPROPYLENE PIPING AND MATERIAL IN THE SNO HEAVY WATER SYSTEM

From: B. Sur

Calculation of the Radon ingress, and Heavy Water (vapor) outflow due to concentration driven diffusion in the proposed SNO heavy water purification/ recirculation system piping and holding tanks.

I. Assumed system parameters:

1) 3000 feet of 2" diameter piping: Surface area = 185.33 sq. meter
2) 2 X 60 cubic meter tanks -- assumed cylindrical with
 diameter = height = 4.24 m : Surface area each = 84.8 sq. meter

Total area = 270 sq. meter.

3) Mine Air Rn concentration = 3 pCi/liter [Ref. Hallman et al.]
 = 52.6 Rn atoms / c.c.

II. Diffusion parameters:

1) Radon: Could not find a diffusion constant (permeability) for Radon in polypropylene. An examination of permeabilities measured by Bigu et al. (SNO-STR-91-069) shows "good" plastics (except Kapton polyamide) having Rn permeabilities in the range (1-5)E-8 cm^2s^-1. This is confirmrd by other numbers in the literature. Therefore.
 Best case (D =) k = 1E-08 sq. cm per sec
 Worst case (D =) k = 5E-08 sq. cm per sec

10 T surge
5 T purif, recirc loop
2 active source

Radon lifetime = 5.5 days, diffusion length = (D t) ^ (1/2)
 = 0.154 cm (0.060") worst
 = 0.07 cm (0.028") best

2) Formulae used:
Assuming zero Rn concentration on the water side (an excellent approximation) and a planar geometry (good because of the aspect ratio), the transmitted flux through a layer of thickness a is:

$$j = \frac{2D}{x} \frac{C\_air}{[\exp(a/x) - \exp(-a/x)]}$$

where x is the diffusion length.

The total number of Rn atoms supported in the 1000 tonnes of heavy water by this Rn ingress is:

N = j A t

where A is the total area and t is the lifetime (5.5 days) of Radon.

3) Calculations for various scenarios (after talking with Dave Sinclair)

a(inch)	D(E-08sq.cm/s)	j(atoms/sq.cm/s)	Radon loads per tonne through: pipes	1 tank	total
1/4	1	1.73E-09	1.52	0.7	2.22
1/4	5	5.53E-07	485	223	708
5/16	1	1.8E-10	0.16	0.07	0.23
5/16	5	1.97E-07	173	79	252
3/8	1	1.84E-11	0.016	0.007	0.023
3/8	5	7.01E-08	61.5	28.2	90

Total loads for 3000 ft x 2" dia 1/4" thichness pipe and one 3/8" wall thickness 60 cubic meter tank:
for D=1E-08 cm^2s^-1; load =1.53 Rn atoms / tonne
for D=5E-08 cm^2s^-1; load = 513 Rn atoms / tonne

2000 ft max.

These numbers are to be compared with the design goal of 1E-14 g/g eq. U in the D2O which would support 60 Rn atoms per tonne.

→ permeab. of PP to radon
test on thick sample
this sample as realistic as possible.
pipe + sheet in various thicknesses

4) The reason for the separation of the two scenarios in each thickness case is that the diffusion length which is proportional to the sqare root of the diffusion constant appears in the exponent in the expression for the flux, j.

a) Clearly the permeability of PP to radon must be determined under realistic conditions ie. water logged, thick, welds etc.

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Mostly 2" PP: Sched. 80

b) Perhaps one can proceed with 1/4" or 5/16" wall pipe and make provisions for coating the pipes with a material of considerably less permeability if Rn permeation turns out to be a problem. Such material are polyamides (k ~ 1E-10 cm^2/s) or metals. For a factor of 100 reduction, one would need about 4.6 diffusion lengths or about 0.015" thickness of such coating.

tube.
fiberglass/epoxy $\frac{1}{4}''$ $\frac{5}{16}''$ $\frac{3}{8}''$
PP $\frac{1}{2}$ or more

c) Another option would be to switch at this stage to plastic lined metal piping. The Rn emanation of SS measured at the WET lab is LESS THAN 0.3 Rn atoms per sq. meter per hour. This corresponds to j = 8.3E-09 atoms per sq. cm per sec and would support LESS THAN 7.3 Rn atoms per tonne due to the piping alone.

d) The most exotic option is to use a double walled plastic piping. Except for the cost, this would be very attractive because one could get away with thinner plastic, and also minimize D2O losses and Rn ingress by sweeping the intermediate gap with cover gas.

0.036

$\frac{15}{1000}$ .0.59 $\frac{36}{1000}$ cm = 360 ~~36~~ micron

III. Heavy Water vapor loss due to diffusion through pipes.

1) Used experimental determinations of solubilities and diffusion constants of plastics by Waltham et al. [SNO-STR-091-018??] Though these vary widely, there appears to be an anticorrelation between solubility and diffusion constant so that the permeability = solubility * diffusion constant does not vary much between plastics. I determine that for 5/16" thick generic plastic, one would reach equjilibrium conc. distribution in 2 months to a year, and lose 10 to 15 kg of water a year. This is probably as big a loss as any other single loss mechanism in the heavy water system. The loss will increase linearly as the thickness is

decreased.