D_2O Radon Considerations

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1 Conversion Factors

D_2O inside the acrylic vessel	1000 tonnes
Recirculation rate	100 liters/min for 8 hours a day
Turnaround time	21 days
D_2O in equilibrium with air	0.4 pCi/liter (=7000 Rn/liter)

D_2O at 1×10^{-14} gU/g has 60 ^{222}Rn per tonne or 0.06 Rn/liter

Storage time	Factor 10	12.6 days
	Factor 50	21.4 days
	Factor 100	25.2 days

2 Waiting Time after the Fill

It takes about 60 days to fill the acrylic vessel to the bottom of the neck with D_2O and another 30 days to finish filling the cavity to the top with H_2O. During this time there is no recirculation of the D_2O planned.

If the D_2O initially contains the **worse case** level of 0.4 pCi/liter of radon, then when the acrylic vessel is full to the bottom of the neck, the radon content is 0.4 / (λ_{Rn} $\times$ fill time) = 0.4 / (0.182 $\times$ 60) = 0.037 pCi/liter. Now the period of 30 days to finish the H_2O fill allows the D_2O to decay to 1.6×10^{-4} pCi/liter (or 4.5×10^{-13} gU/g equivalent).

Hence we need a wait of 21 days after the H_2O is full to allow the radon in the D_2O to decay to 3.4×10^{-6} pCi/liter (10^{-14} gU/g) level. This 21 days is well within the waiting time required to allow the H_2O to come down to its acceptable level.

3 Why not Degas the D_2O ?

The reasons for not degassing the D_2O during recirculation are as follows:

The greatest decrease in the radium level in the D_2O comes about by trapping it in a filter and changing the filter. If the D_2O has a low level of radium to begin with, then the filters probably do not have to be changed because very little radon is returned into the D_2O (see B. Sur, Degassing – Why and How Much).

For radium that is immobilized on the acrylic surface we might consider using EDTA to complex it so that it gets into the D_2O and can be removed by recirculation.

There are no significant sources of emanated radon in the heavy water because very little material is submersed in it. The turnaround time (1000 tonnes to go through recirculation) for the D_2O is about 21 days so the decay of radon in the acrylic vessel would dominate any degassing removal of radon anyway.

4 Makeup D_2O

Assume there is 10 liters/day of makeup needed and the radon is at the worse case level of 0.4 pCi/liter. Then this makeup water adds 7×10^4 radon into the water daily compared to the 6×10^4 radon supported by 1000 tonnes of D_2O at 10^{-14} gU/g.

Hence we need at least a factor of 50 decay in the makeup D_2O to bring its contribution to a negligible level. This factor of 50 can be achieved with a hold time of 21 days. An air-tight holding tank of at least (21 days $\times$ 10 liters/day) = 210 liters is required.

5 Cover Gas for the D_2O

Because the D_2O has to be at a very low level of U (10^{-14} g/g) and Th (10^{-15} g/g), the cover gas in the acrylic neck has to be very low in radon. It has to be separate system from the H_2O cover gas. It has to vent to atmosphere when the atmospheric pressure drops and has to be "topped" up with very clean cover gas when the atmospheric pressure rises. The largest ingress of radon is expected to occur when the top of the neck is opened periodically to lower a calibration source into the D_2O.

The estimated acceptable level of radon for the cover gas above the D_2O is 2×10^{-5} pCi/liter (see B. Sur, Some Elementary Considerations about Cover Gas).