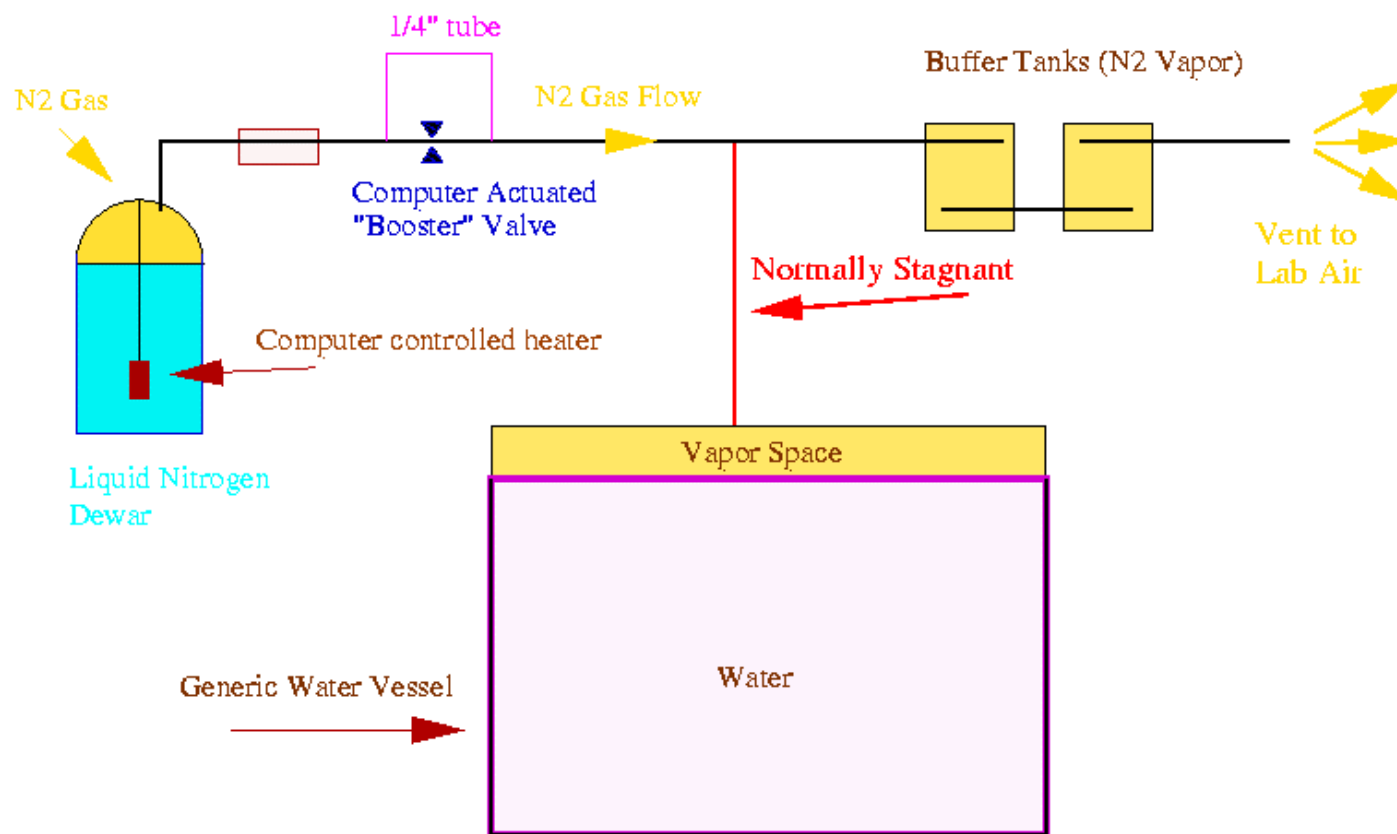# The SNO Cover-Gas System

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For the SNO Collaboration

The pages of the following Poster should be displayed as shown below. (This is page 0….)

1	2		8	9
13(portrait layout)	4		10	11
5	6	7		12

The drawings and graphs don't show up so well here. Duplicates are attached to this same log book entry for those who want to see higher quality images

1/4" tube

N2 Gas

N2 Gas Flow

Buffer Tanks (N2 Vapor)

Computer Actuated "Booster" Valve

Vent to Lab Air

Computer controlled heater

Normally Stagnant

Liquid Nitrogen Dewar

Vapor Space

Generic Water Vessel

Water

Conceptual Design of the SNO Cover Gas System.

Normally, no flow in or out of vessel vapor space.

Flow of Rn–free N2 gas past the vapor space.

Buffer volume of relatively clean vapor in buffer tanks for quick pressure fluctuations.

Computer control of boil off rate (internal heater and "booster valve".)

Purpose:

1) Protect detector water from ^{222}Rn and O_2 in laboratory air:

- H_2O O_2 <50ppb, Temp ~ 10°C (Biology)
- D_2O < $3.7*10^{-15}$ gTh/gD_2O and < $4.5*10^{-14}$ gU/gD_2O
- H_2O (fiducial) < $3.7*10^{-14}$ gTh/gH_2O and < $4.5*10^{-13}$ gU/gH_2O
- Laboratory air has radon levels ~10^5 times higher than target for U-chain.

2) Protect structural integrity of water vessels:

- ΔP (due to mine ventilation changes or water circulation.)

Design Concept:

1) Gas above water normally stagnant → ^{222}Rn in gas space will decay, leaving radon free gas "blanket" over water.

2) System has both passive and active response to air ingress.

- System has vent open to laboratory air to allow pressure in vapor space to equalize.
- ^{222}Rn-free N_2 gas in "buffer tanks" available when P_{lab} > P_{vessel}.
- Boil large quantities of nitrogen from liquid N_2 dewar when environment changes.

Detailed figure of cover gas system should be here (see end of document. This figure will be shown in Portrait mode)

Details of System:

1000 liter liquid N_2 dewar with computer controlled internal heater to boil liquid nitrogen. Typically supply ~30 liters gas/ minute (lpm).
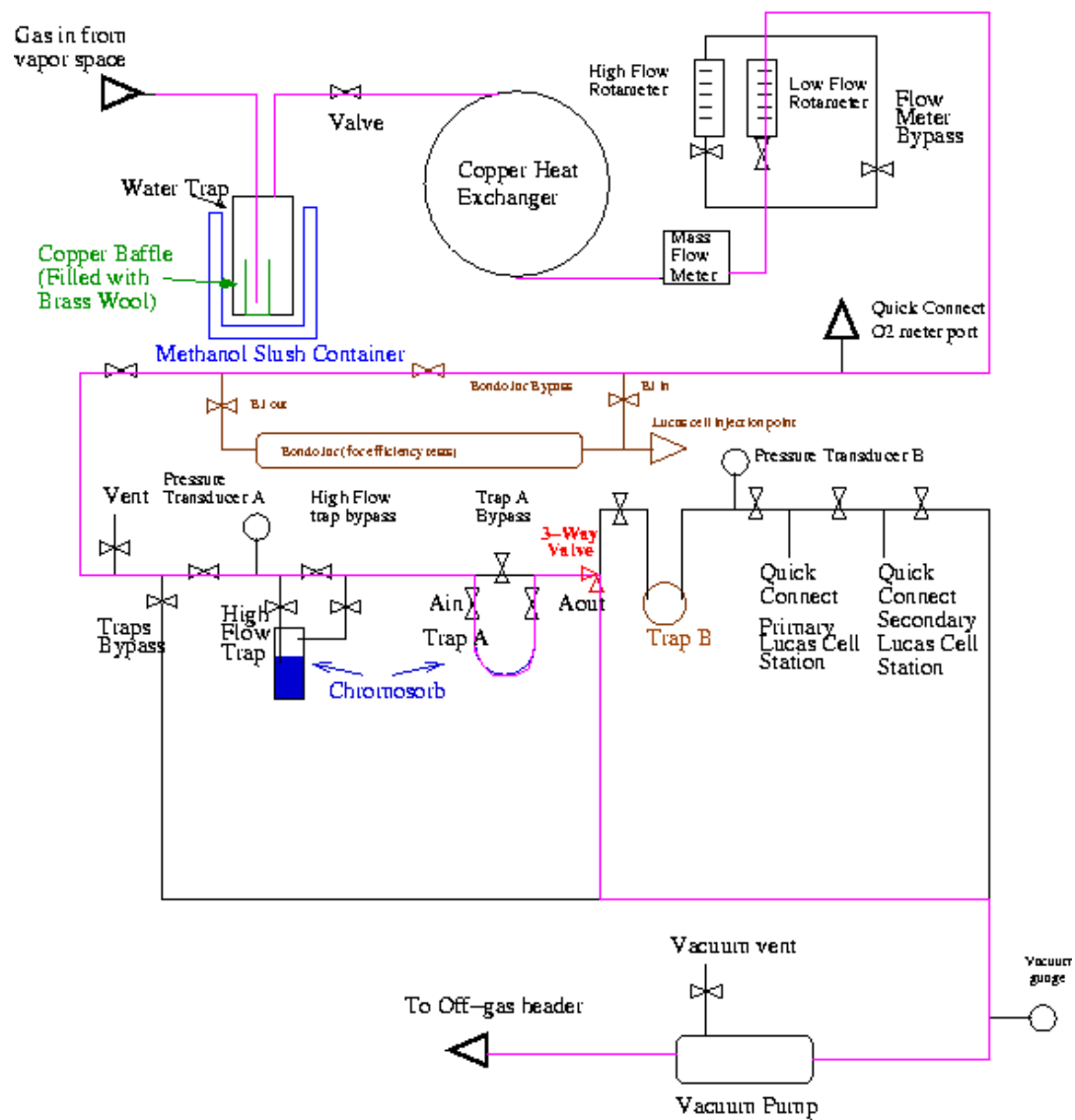
A direct line from the dewar to the D_2O vapor space provides ~10 liters/minute to "flush" radon enriched gas away from the D_2O and maintain radon concentration at ~ 10 atoms/liter gas.

When lab pressure swing is detected, buffer tanks supply initial protection to vapor space. Simultaneously, internal heater turns to full power and high conductance path is opened ("booster valve"), generating ~ 200 lpm N_2.

Vapor space of entire system ~150 m^3.

Not shown are dedicated cover gas assay lines.

Not shown is the in-line humidifier for the flush line (necessary to prevent "neck events" - light generated due to flow of extra dry gas through plastic.)

Radon Board for the Cover-Gas System.

How Radon contamination is measured for the Cover Gas System.

Assay when vapor space is expected to have low Rn concentration*:

Gas is drawn from the vapor space of interest, using a vacuum pump. Vapor first passes through a methanol-slush cooled (-98°C) water trap to remove water vapor. The gas then goes through a heat exchanger, mass flow meter, and rotameter. The gas then goes through a Chromosorb * filled U-tube (trap A), cooled with liquid nitrogen (-196°C), trapping Rn and CO_2 while most of the O_2 and N_2 are pumped out of the lab. After a sufficient sampling time, the liquid N_2 bath is replaced by a methanol slush bath to remove residual O_2 and N_2. The trap is then connected to a condensing trap (trap B, volume ~2cc) Trap B is cooled with liquid nitrogen, while trap A is heated (+200°C). After 1 hour of cryopumping, trap B is connected to an evacuated Lucas cell (volume ~15.5cc) and radon is transferred to the cell by volume sharing. The radon board has a measured efficiency of about (69±2)%. The 3 quick succession of α decays of [222]Rn, [218]Po, and [214]Po are observed with photomultiplier tubes and, using the volume of gas assayed, are used to infer the amount of radon in the sample gas ([210]Po which builds up in the cell forms a constant background.) The counting efficiency of this kind of cell has been measured to be about (63±3)%.

*To reduce contamination to the Lucas cell [see poster on Radon assays of Water] with 22-year ^{210}Pb, the cells are filled with uncondensed gas, when radon concentration in a sample is expected to be very high. When intermediate levels of radon are expected, we capture the sample gas in the water trap (1.7 liters) and condense the radon in that gas volume.
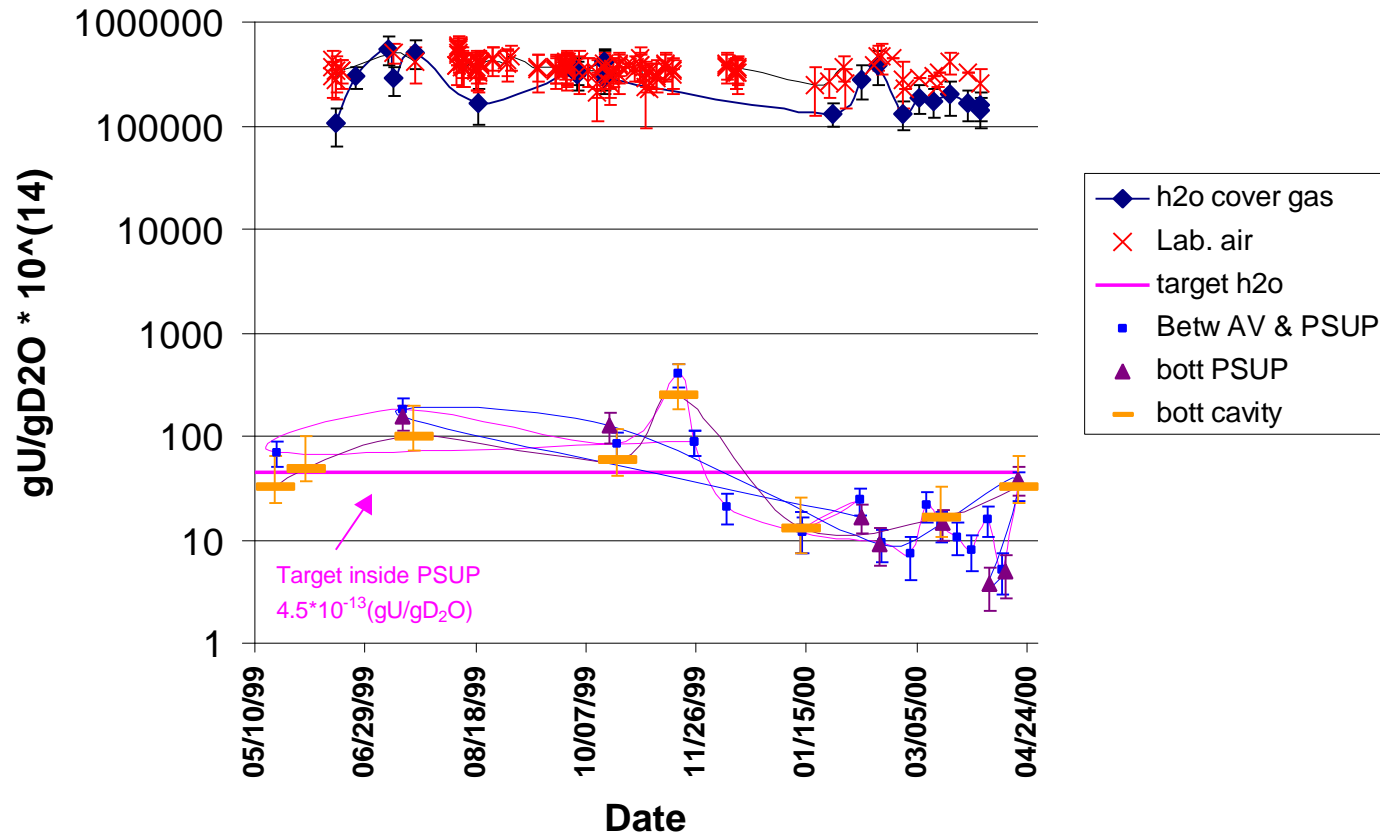
- Chromosorb 102, mesh size 100/120, manufactured by Johns-Manville is a styrene-divinyl benzene polymer with an effective surface area of 300-400m[2]/g. This sorbent is the same as that used by the SAGE and GALLEX solar neutrino experiments.

How Radon is measured for the Cover Gas System II.

The largest contributions to systematic uncertainty in the assays are from measurement of the gas volume sampled and from the Lucas cell counting efficiencies. Work is almost complete on calibrating the cells to the ~5% level. The volumetric calibration will be done next.

Source	Estimated Contribution
Gas Volume (filling cells technique)	3.2
Gas Volume (fixed volume [water trap])	1.7
Gas Volume (flow technique)	15.4
Trap B to Lucas cell	1.7
Lucas cell efficiency	15.0
Cell Background	2.3
Radon Board Background	3.8
Combined (filling cells technique)	**16.1**
Combined (fixed volume [water trap])	**15.8**
Combined (flow technique)	**22.0**

H2O (Water & Cover Gas) Rn assays
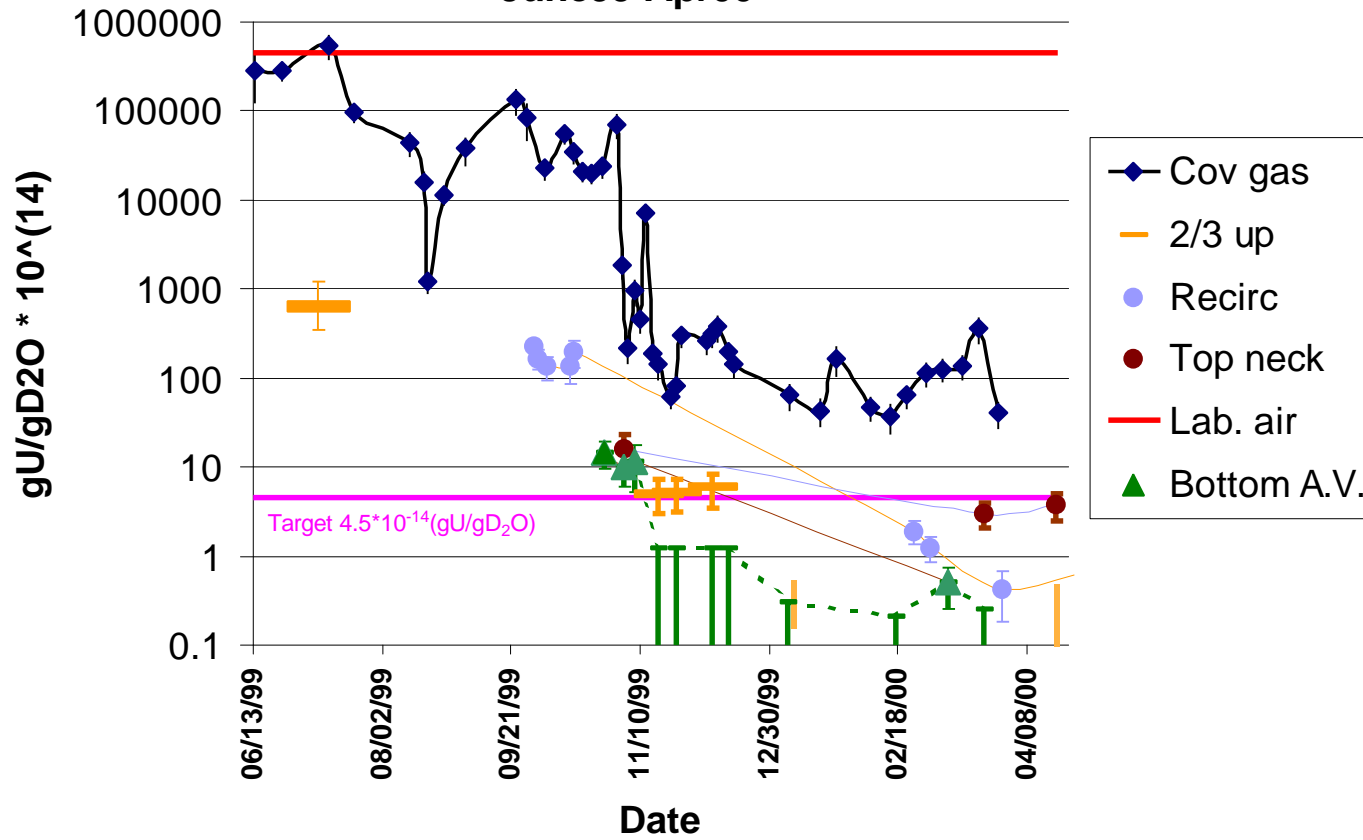June99-Apr00

H₂O Cover Gas Radon Assay.

The cover gas data are plotted with both statistical and systematic uncertainties.

H_2O deck needs seal to achieve effective cover gas protection.

All reduction in Rn levels in H_2O due to stagnant thermocline and process degasser.

Water radon levels plotted for several different assay points. Combined statistical and systematic errors shown. See radon in water poster for full presentation.

D2O (water & cover gas) Rn assays
June99-Apr00

D$_2$O Cover Gas Radon Assay.

Cover gas data plotted with statistical and estimated systematic uncertainties.
The cover gas data target is described assuming secular equilibrium with ^{238}U.
The target assumes no benefit of stagnation of the water in the AV neck.
Three "dips" in radon levels correspond to flush test, short term flush to test humidification technique, and commencement of large scale humidified flush.

Water radon levels plotted for several different assay points. Combined statistical and systematic errors shown. See radon in water poster for full presentation. Measurements for which only upper limits were derived represented as vertical lines.

The nitrogen flush has been responsible for the dramatic reduction in radon levels above the D$_2$O and in the D$_2$O.
Radon in the D$_2$O can be maintained around target for the neutral current measurement.
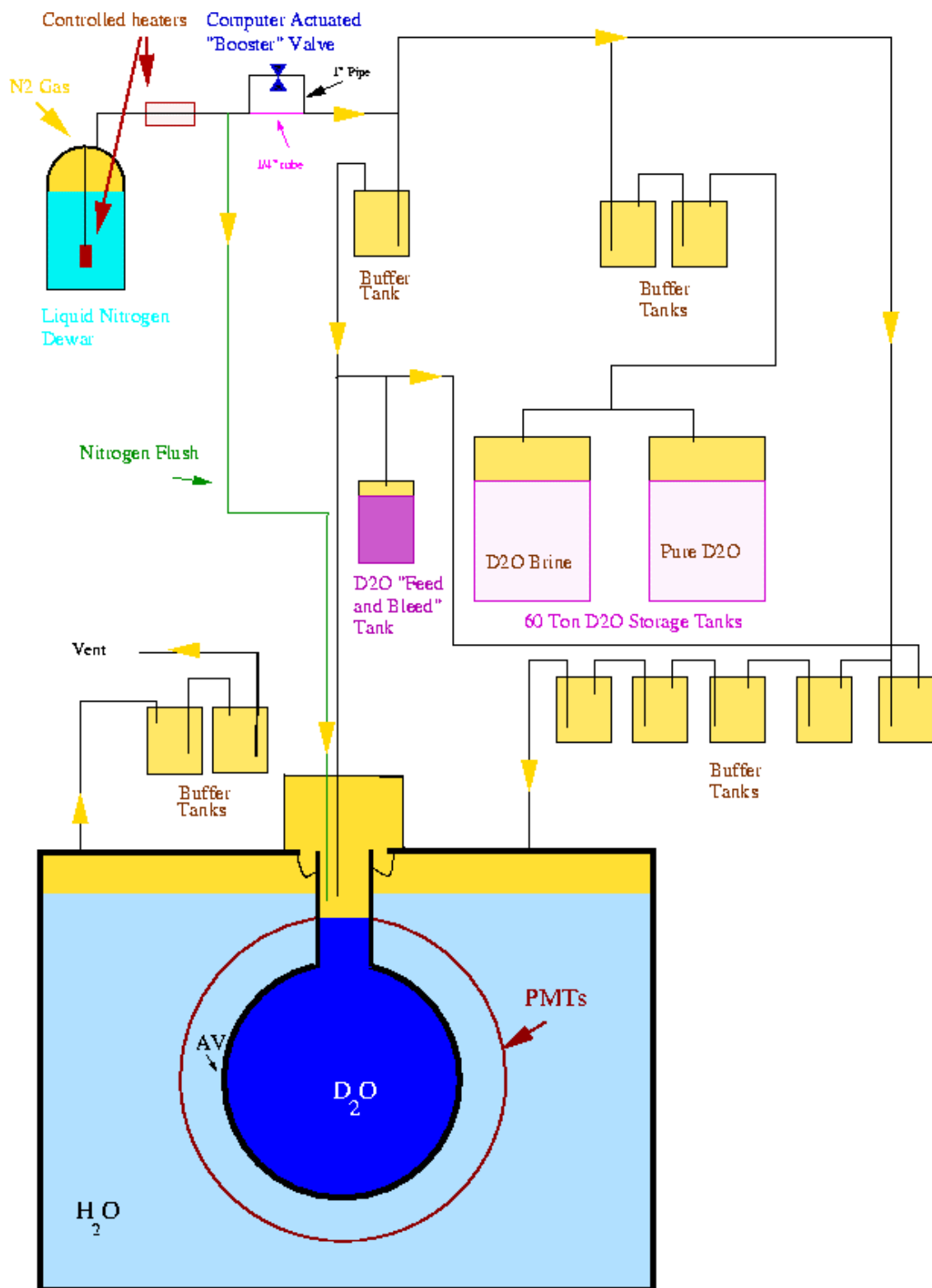
Conclusions

Working to reduce the two largest systematic uncertainties in cover gas radon assays. Lucas cells now undergoing calibration to the ~5% level.

Nitrogen gas supplied by the 1000 liter dewar is sufficiently low in radon to protect the water of SNO. Typically about 0.3 Rn atoms/liter gas (600 μBq/m^3 in ^{222}Rn.)

Even with high radon levels above the H_2O, we are around target for radon in H_2O. This is due to a combination of stagnation in the H_2O thermocline and the operation of the light water degasser. Now working to seal the deck to try to reduce radon in H_2O vapor space. Current goal to have H_2O cover gas at least 10 times lower than laboratory air. This may reduce radon in the H_2O comfortably below target.

An active flush of nitrogen gas in the D_2O vapor space has resulted in a dramatic drop in radon levels above the D_2O. The cover gas, in concert with stagnation in the acrylic vessel neck, keeps radon in the fiducial volume at or below target for the neutral current measurement.

Controlled heaters

Computer Actuated
"Booster" Valve

N2 Gas

1" Pipe

1/4" tube

Liquid Nitrogen
Dewar

Buffer
Tank

Buffer
Tanks

Nitrogen Flush

D2O "Feed
and Bleed"
Tank

D2O Brine

Pure D2O

60 Ton D2O Storage Tanks

Vent

Buffer
Tanks

Buffer
Tanks

PMTs

AV

D_2O

H_2O

The SNO Cover Gas System.