Liquid Processing & Assay Systems for the SNO+ Experiment

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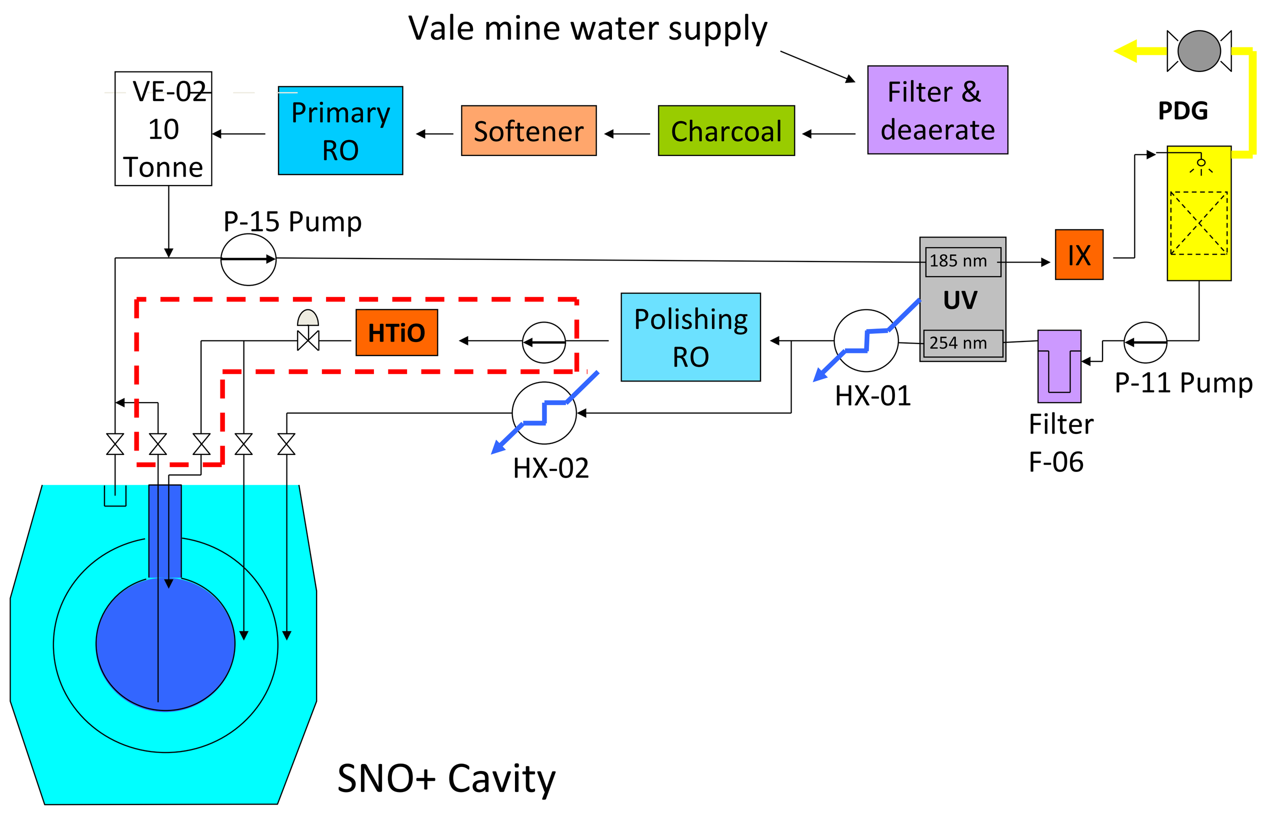
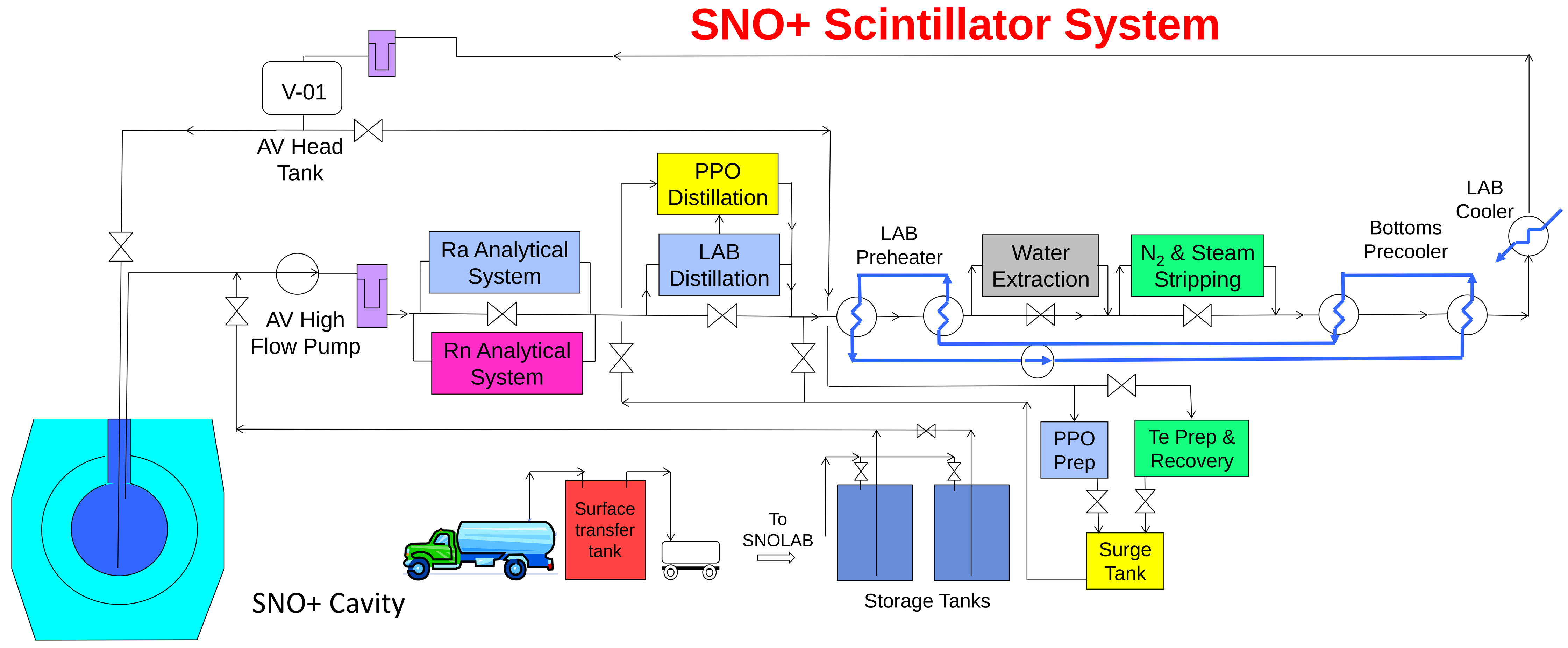
The SNO+ Experiment

The SNO+ detector is a renewal of the Sudbury Neutrino Observatory (SNO) heavy water Cherenkov detector, in which an organic liquid scintillator (linear alkyl benzene or LAB) replaces the heavy water in the acrylic vessel core. The science program – the study of low energy solar neutrinos, geo-neutrinos, neutrinoless double beta decay, reactor anti-neutrinos and supernova neutrinos – requires extremely low levels of high-energy beta and gamma ray background activities from ^{214}Bi, ^{212}Bi, ^{210}Bi , the ^{238}U and ^{232}Th decay chains and ^{40}K.

SNO+ Water System



SNO+ Scintillator System



SNO+ Water System Development and Testing

In preparation for an initial “water phase” running of the SNO+ detector, the water system used in the SNO experiment has been reconditioned and configured for supplying the cavity shielding water and water for the central acrylic vessel. To re-commission the hydrous titanium oxide filter system used for radium analysis, an extensive set of calibrations and testing is in progress. Steps involved in this technique along with recently measured efficiencies for each (using spike testing) are outlined below.

HTiO Analysis Steps	Efficiency ^{226}Ra (%)	Efficiency ^{224}Ra (%)
Preparation: The HTiO adsorbent is formed as a white colloidal suspension by hydrolyzingTi$(SO_4)_2$.		
HTiO Deposition: Deposition of HTiO on memtrex pleated filters with Ti coverage of 2.5g/m².		
Extraction: Flow H_2O through HTiO loaded columns	95 ± 5*	95 ± 5*
Elution: Removal of Ra from the loaded filters using 15L of 0.1 mol/L HCl.	90 ± 10*	90 ± 10*
Secondary Concentration: • 12.0g of DOWEX 50 WX8 resin • 100mL of 0.25 M EDTA (pH 11.5) • Decomposition of EDTA - boil with HNO_3 • Co-precipitation of Ra with HTiO (60mg of Ti) and 10M NaOH • Centrifuge, dissolve in 1.5mL conc. HCl, dilute with UPW to 8mL	58 ± 6*	37 ± 10
Total Chemical ($\varepsilon_{ext} \cdot \varepsilon_{elu} \cdot \varepsilon_{conc}$)	50 ± 8	33 ± 8
Counting: Sample is added to 42g of liquid scintillator for beta-alpha coincidence counting.	60 ± 10*	45 ± 5
Total ($\varepsilon_{ext} \cdot \varepsilon_{elu} \cdot \varepsilon_{conc} \cdot \varepsilon_{count}$)	30 ± 7*	15 ± 4
* Efficiencies from SNO (^{226}Ra) – ref. 1		

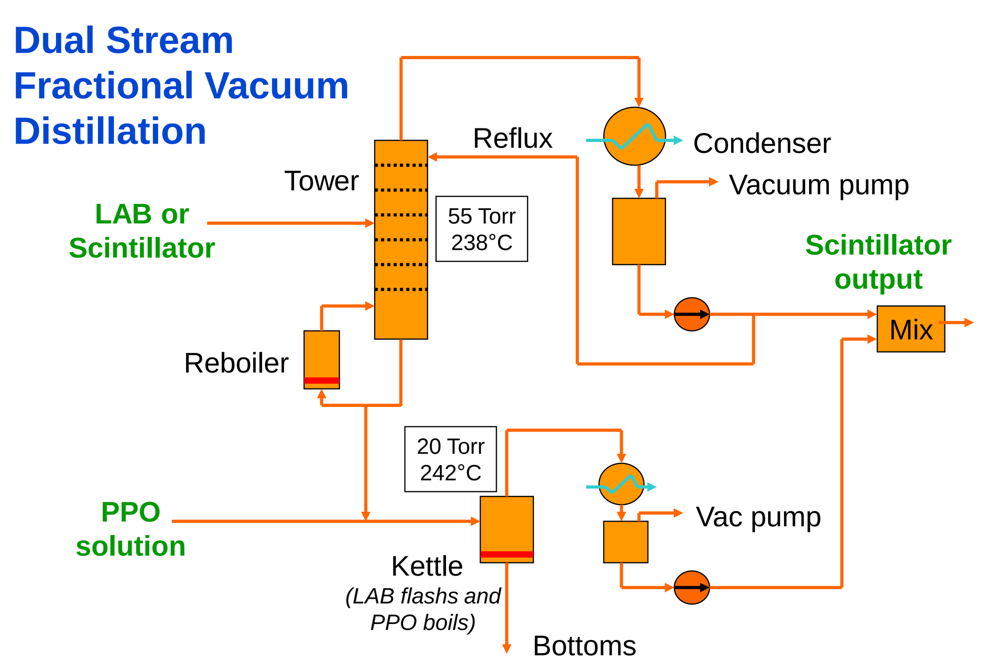
Work is progressing on improvements to the secondary concentration technique using a crystallization step to remove the EDTA, instead of the decomposition procedure. An alternative Ra analysis scavenging technique using QuadraSil AP (as for the LAB scintillator) is also being developed. An upgrade of the process degasser unit used for oxygen and Rn removal is nearing completion and Rn analysis tests with a separate degasser and Lucas cell counting will be started shortly.

For the SNO+ experiment, the cavity has been prepared with the installation of a hold-down rope net and anchors for the acrylic vessel (required because the LAB scintillator has a density only 85% of the surrounding water), the replacement of the floor liner and anchor seals, and the replacement of defective photomultiplier tubes. In recent months the cavity has been filled with water to a level just below the acrylic vessel and systems for circulating, cooling and purifying the water are in operation. Preliminary water purities comparable to those for the SNO experiment have been achieved.

SNO+ Scintillator Plant Features

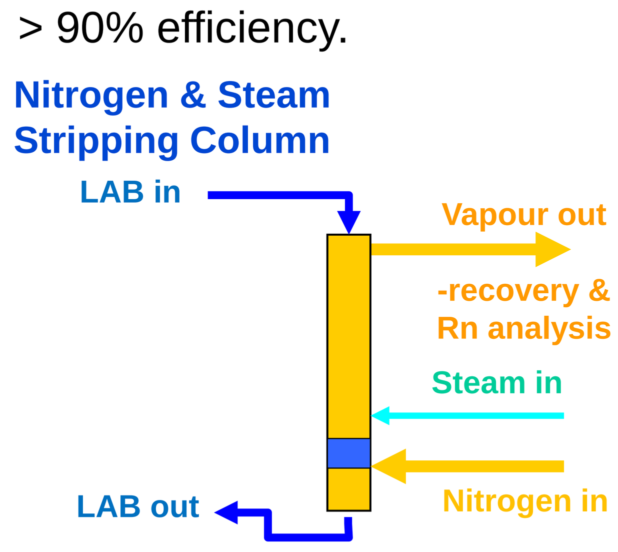
As shown in the flow diagram (above), the Linear Alkyl Benzene (LAB) scintillator processing plant for SNO+ consists of a new stainless steel transport and circulation system including the following purification elements: filtration, distillation, liquid-liquid extraction, nitrogen & steam stripping as well as facilities for handling PPO and Te double beta decay additives to the LAB and several radio-purity assay facilities. The system is currently under construction in the underground laboratory.

Purification

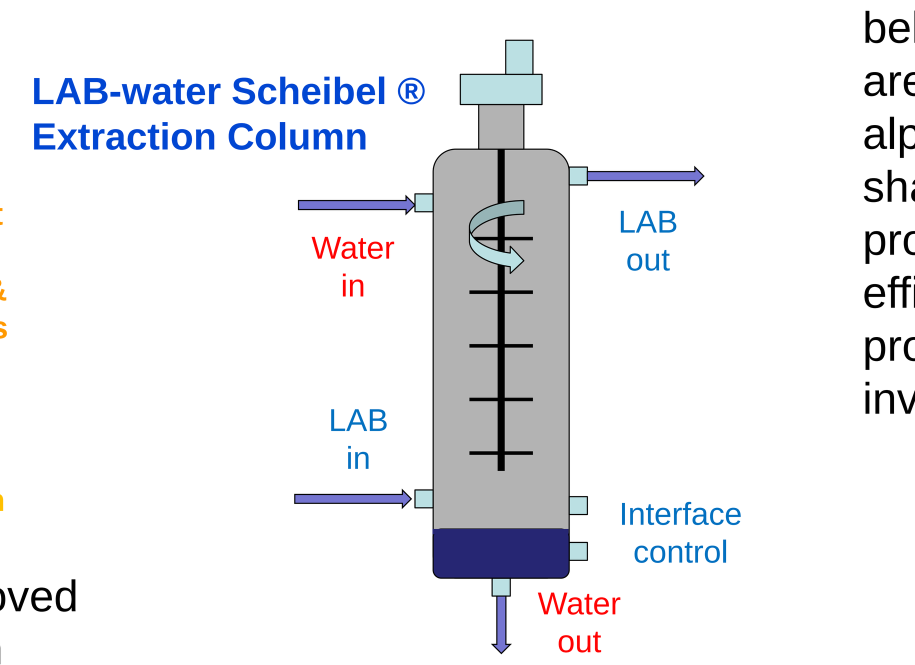


This 15 L/min distillation, performed as the LAB is moved underground, improves the optical path length and removes ^{7}Be, Pb, Th, U with > 90% efficiency.

QuadraSil AP scavenger columns are highly efficient in removing heavy metals (Th,Ra, recoil ^{210}Pb (ref. 2), ^{210}Bi) from LAB and the array shown gives150 L/min filtration. Columns are regularly regenerated using HCl.

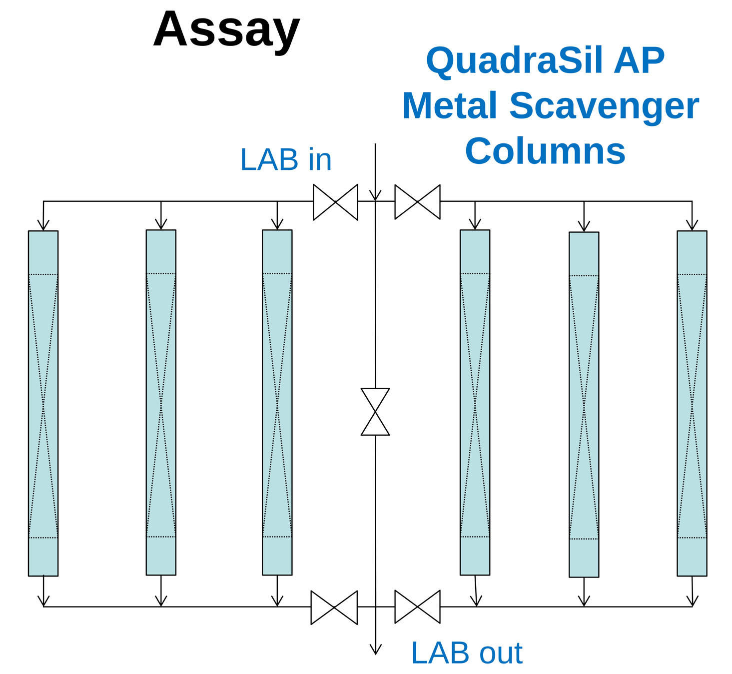


Rn, O_2, Kr and Ar will be removed by the stripping column. A Rn analysis facility has been prepared for use with this column (using cryo trapping and Lucas cell counting techniques) and efficiency tests are in progress.

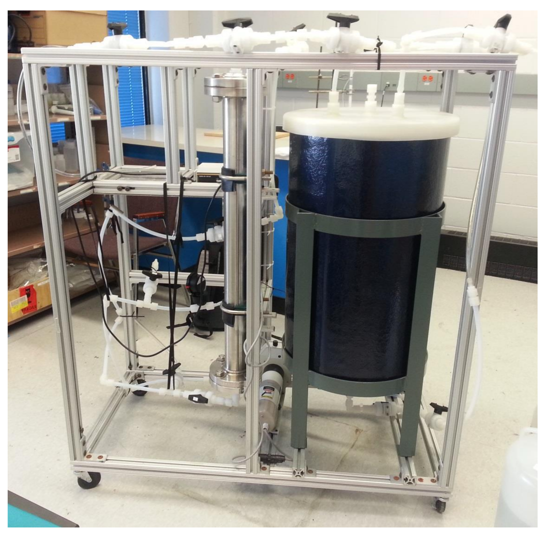


This 150 L/min process has been shown to remove ^{40}K and Ra and is also effective for removing recoil ^{210}Pb (see ref. 2). It will be used in the solar neutrino & double beta decay phases.

Assay



Concentrated effluent from the regeneration is further processed in the scavenger extraction skid (shown below). Trace radioactive elements are measured by coincident alpha/beta counting using pulse shape discrimination. A spike test program (using ^{212}Pb) to establish efficiencies and detection limits is in progress.. ^{210}Po removal is also being investigated.



References

1. B.Aharmim *et al* Nucl. Inst .Meth**. A 604** 531-535. (2009)
2. R.Ford *et al*, LRT 2010 AIP Conf.Proc. **1338**, 183-196, (2011).