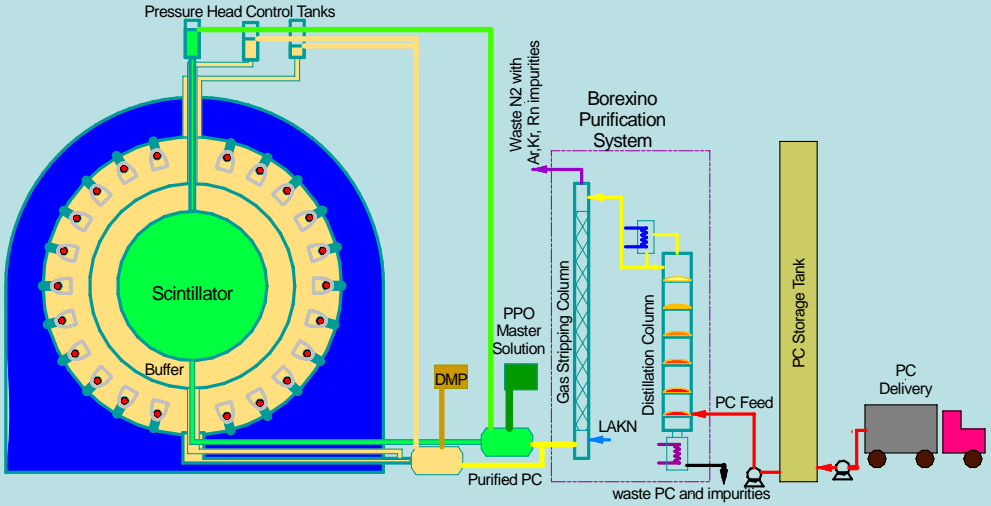


# BOREXINO PURIFICATION SYSTEM

## OVERVIEW OF THE SCINTILLATOR PURIFICATION SYSTEM

The radioactive background impurities in 1000 tons of liquid scintillator and buffer were reduced to rates sufficient to permit real time detection of the  ${}^7\text{Be}$  neutrino flux that is 0.05 mBq/100 ton in the 200-850 keV range. This unprecedented purity for a large-scale liquid scintillator detector was achieved by the Borexino experiment with a purification system that emphasized cleanliness and leak tightness. Pseudocumene (PC), the scintillator solvent, was delivered by tanker truck to the underground lab at Gran Sasso. It was loaded into storage tanks and then purified at a rate of 800 L/h. The PC was fed to a 6 m tall, 0.75 m diameter 6 tray vacuum distillation column to remove low volatility radioactive impurities (e.g. U, Th, K). After distillation the PC was stripped of radioactive noble gas impurities ( ${}^{39}\text{Ar}$  and  ${}^{85}\text{Kr}$ ) with specialty nitrogen low in Argon and Krypton (LAKN). Gas stripping was done in a 8 m tall, 0.15 m diameter column filled with structured packing. Purified PC was mixed with either a pre-purified concentrated solution of the fluor (PPO) or quencher (DMP) to fill the scintillator and buffer volumes respectively. Five 860 L batches of concentrated fluor master solution (140 g-PPO/L-PC) were purified by a combination of water extraction, filtration, single stage vacuum distillation and nitrogen stripping. The scintillator and buffer regions were filled by periodically switching between volumes to maintain equal levels and hydrostatic head in all three volumes of the Borexino detector.



## ASSEMBLY AND INSTALLATION OF THE PURIFICATION PLANT



### CLEANING

All the equipment was stainless steel, electropolished, to be non-particulating and corrosion resistant. The equipment was all precision cleaned to better than level 30 (Mil Std1246C) and assembled in the Princeton class 100 clean room. The photo at the left shows the distillation column being prepared for installation of the precision-cleaned sieve trays. In the center a Princeton technician is installing a sieve tray in the distillation column.

### LEAK TIGHTNESS

All flanges were double sealed and purged with nitrogen. Large tanks and heated vessels had metal gasket seals. After final assembly each part of the entire system was vacuum leak checked to the level of  $10^{-8}$  mbar-L/sec. All critical valves and fittings leading the purified scintillator to the Borexino detector were covered with special boxes purged with nitrogen. At the right is a view of the electropolished surfaces in the distillation system. The double gaskets seals can be seen on the far right.



Installation of the structured packing into the gas stripping column. The packing had been precision-cleaned by Astro Pak and shipped to Princeton.



The purification system was skid mounted. After assembly at Princeton it was shipped to Italy. At left: loading the skids for shipment from Princeton. At right: positioning the skid in Hall C at LNGS



## CONCLUSIONS

Effective purification by Borexino has been demonstrated by the low backgrounds achieved; the  ${}^7\text{Be}$  neutrinos were detected after the initial purification and filling! The backgrounds achieved are close to or below the design levels except for  ${}^{210}\text{Po}$ . Results show a disequilibrium exists between  ${}^{210}\text{Bi}$  and  ${}^{210}\text{Po}$ , with a larger  ${}^{210}\text{Po}$  background than desired. (Fortunately the  ${}^{210}\text{Po}$  background can be excluded from the neutrino spectrum by  $\alpha$ - $\beta$  discrimination). Effective purification was also demonstrated during water filling where the  ${}^{222}\text{Rn}$  level in the water was reduced from 300 mBq/m<sup>3</sup> to ~ 1 mBq/m<sup>3</sup>.

Radioisotope	Typical Concentration in equilibrated organic	Design Level	Level achieved in Borexino
${}^{14}\text{C}$	$\frac{{}^{14}\text{C}}{{}^{12}\text{C}} \sim 10^{-12}$	$\frac{{}^{14}\text{C}}{{}^{12}\text{C}} \leq 10^{-18}$	$\frac{{}^{14}\text{C}}{{}^{12}\text{C}} = 2.7 \times 10^{-18}$
${}^7\text{Be}$	$2.7 \times 10^3$ cpd/ton	<0.01 cpd/ton	Undetermined
${}^{238}\text{U}$	$10^{-6}$ g-U/g-dust $10^4$ cpd/ton	< $10^{-17}$ g-U/g-scintillator <0.01 cpd/ton	< $2 \times 10^{-17}$ g/g < 2 cpd/100 ton
${}^{232}\text{Th}$	$10^{-5}$ g-Th/g-dust $10^4$ cpd/ton	< $10^{-16}$ g-Th/g-scintillator <0.01 cpd/ton	< $7 \times 10^{-18}$ g/g < 0.2 cpd/100 ton
${}^{210}\text{Pb}$	$2 \times 10^4$ cpd/ton (as ${}^{210}\text{Bi}$ & ${}^{210}\text{Po}$ )	<0.01 cpd/ton ${}^{210}\text{Bi}$ & ${}^{210}\text{Po}$	<15 cpd ${}^{210}\text{Bi}$ /100 ton 6000 cpd ${}^{210}\text{Po}$ /100 ton
${}^{40}\text{K}$	$10^{-6}$ g-K/g-PPO 2700 cpd/ton	< $10^{-14}$ g-K/g-scintillator <0.027 cpd/ton	< $3 \times 10^{-14}$ g-K/g-scintillator <6 cpd/100 ton
${}^{39}\text{Ar}$	16 mBq/m <sup>3</sup> -air 218 cpd/ton	<500 nBq/m <sup>3</sup> - N <sub>2</sub> <0.01 cpd/ton	Undetermined
${}^{85}\text{Kr}$	1 Bq/m <sup>3</sup> -air $4.3 \times 10^4$ cpd/ton	<100 nBq/m <sup>3</sup> -N <sub>2</sub> <0.01 cpd/ton	<35 cpd/100ton