BOREXINO NYLON VESSELS

SCINTILLATOR CONTAINMENT REQUIREMENTS AND DESIGN

CHEMICAL COMPATIBILITY

The vessel that contains the scintillator must survive exposure to both water and the organic solvent, pseudocumene. This would make the use of acrylic, the SNO vessel material, problematic at the least.

MECHANICAL STRENGTH

The vessel must survive buoyant forces due to 0.1% intrinsic density differences between the active scintillator and passive buffer. An additional design goal is to survive temperature differences of up to 5 °C (density differences of 0.1%/°C).

LOW RADIOACTIVITY

To reduce gamma rays from the vessel, a low-mass solution was sought. Instead of a self-supporting but massive shell, thin nylon membranes supported by a rope and strut system were considered. The nylon can be made 0.125 mm thick while still satisfying the strength requirements. It is so low in contamination from ^{238}U decay-chain isotopes that it causes < 2 radon decays per day within the detector's 100-ton fiducial volume.

OPTICAL TRANSPARENCY

Refractions and haze that would complicate position reconstruction, a means to discriminate against events caused by external gamma rays produced in the PMTs and PMT support structure, must be avoided. The indices of refraction of nylon and pseudocumene are the same to within about 1%, eliminating such problems; and sufficiently thin nylon sheets can be made haze-free.

CLEAN FABRICATION

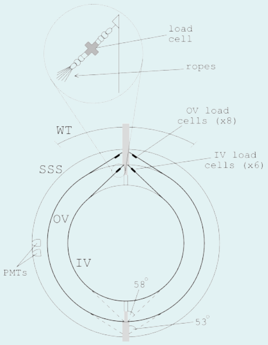
Thin nylon membranes are much easier to fabricate and completely assemble inside a clean room than a thick acrylic shell. Further, because the assembly can be done without inflating them to their final spherical form, they can be manufactured off-site and then shipped much more readily.

LEAK TIGHTNESS

The scintillator containment vessel cannot allow quenching compound to leak into the scintillator volume, nor fluor into the passive buffer.

LOW PERMEABILITY

The vessel must present an effective barrier to radon atoms, which may be produced by radioactivity in the PMTs and the stainless steel sphere that supports them. For this reason, a second, outer vessel was built that divides the passive buffer region into concentric volumes, approximately squaring the effectiveness of the radon barrier.



SKETCH OF THE BOREXINO VESSEL SUPPORT SYSTEM

The concentric circles represent the inner vessel (IV), outer vessel (OV), stainless steel sphere (SSS) which supports the PMTs, and top of the water tank (WT); see also the figure in the introduction, above. The upper and lower end regions of each vessel, shown as gray vertical bars, carry instrumentation and tubing between the external world and the inside of the detector, and also hold the vessels in place within the SSS.

Each vessel has two sets of ropes wrapped around it vertically: a set of ropes affixed at both ends to the upper end regions (shown in bold), constraining the vessels against downward movement; and a set fixed at both ends to the lower end regions (shown as dashed lines), constraining the vessels against upward buoyant forces. At top is shown a blown-up diagram of the point of attachment of one bundle of six rope ends to the upper end region via a load cell. In addition, a third, horizontal set of ropes wraps around each vessel, completing a coarse mesh.

The ropes are made from Tensylon, an ultra high density polyethylene (UHDPE). Though it is not mechanically ideal, Tensylon does not suffer from the potassium contamination, in particular the γ-emitting isotope ^{40}K, found in many other ropes.

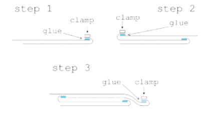
ASSEMBLY AND INSTALLATION

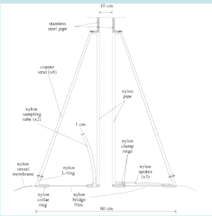
1. Cutting nylon film to the template of the pieces of the vessels to be assembled in the Princeton clean room (above). Additional film hangs in the background, reaching equilibrium with ambient humidity in the air.

The clean room air was kept radon-free, via a pressure-swing adsorption system, to a level below 2 Bq/m³.

2. How do you assemble a sphere from more than thirty long narrow pieces when the final product will not fit inside the clean room?

The nylon pieces were kept stacked, accordion-style, at all times, and at most one or two folds were opened at a time (below). A precisely controlled resorcinol aerosol spray was used as a bonding solvent.





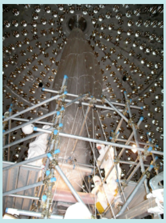
3. Schematic of the upper end region of the inner vessel (above). Scintillator fluid is inserted through a hollow vertical tube (also made of nylon, for improved radiopurity) that, together with a set of copper struts, doubles as a structural support.

4. Insertion of the completed inner vessel within the outer vessel (below), just before the outer vessel was sealed.

In this photograph, the copper support struts of the inner vessel end region are visible, as well as the rope systems and the bellows carrying electrical cables to the load cells.

INSTRUMENTATION on the vessels and end regions includes …

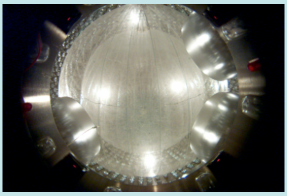
- the load cells used to measure buoyant forces on the vessels;
- the optical fibers and PTFE diffuser bulbs into which lasers can be fed, to act as a visual vessel monitoring and position calibration system;
- the temperature sensors that monitor fluid temperatures;
- the dP sensors that monitor pressure gradients;
- the DeltaV-based control system that permits changing the relative pressures while the vessels are still gas-filled (before liquid filling).



5. A complicated set of winches, pulleys, and scaffolding (left) was used to raise the vessels into position within the steel sphere at Gran Sasso. Problems to be overcome included the fact that the folded film was $\pi/2$ times longer than the eventual diameter of the inflated vessels.

As the vessels were inflated with synthetic air from above, scaffolding was gradually removed to allow them to reach spherical shapes. During the entire installation process, the inside of the sphere was maintained as a class 10,000 clean room.

INFLATION AND FILLING



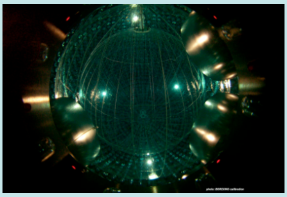


photo: BOREXINO calibration

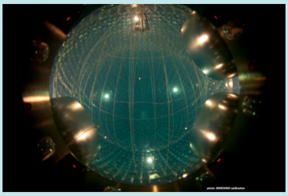
After installation, the vessels were filled, in order, with:

Synthetic air composed of high-purity N_2 mixed with pure oxygen that was aged to reduce its radon contamination. Synthetic air was used for the safety of people in the vicinity of the experiment, until the detector was sealed.

The detector was then purged (upper left) with many detector volumes of **high-purity N_2** and then special **low Ar/Kr N_2** over several months, in order to remove O_2 (which causes scintillator quenching), as well as radioactive ^{39}Ar and ^{85}Kr, from within the vessels. The extended time period gave the gasses time to diffuse out of any materials, such as nylon, in which they were dissolved.

A filling with **ultra-pure water** (lower left) was performed for testing and flushing of the purification plants. The water filling also cleansed the vessel surfaces of nylon monomers (which form a visible haze) and radioactive metal ions (particularly ^{210}Pb) that may have settled onto the nylon during vessel construction.

Buffer and scintillator fluids. At upper right, an intermediate stage while water was being drained and pseudocumene added; at lower right, the vessels full of buffer and scintillator, and the detector now finally ready for data acquisition.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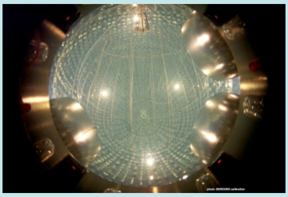
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