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Detector Tank Cryogenic Insulation

The MicroBooNe detector tank contains liquid argon at about 87 K. The tank must be insulated to avoid excessive boiling, to avoid ice buildup and water condensation, and limit the operating cost of the cooling system. The tank will be insulated with foamed-in place Poly-Urethane (PU).

Insulation Performance

The total heat leak through the 16 inch thick tank insulation will be 2300 W. This is for the tank only, not including penetrations and the purification system. The insulation thickness has not yet been optimized for life cycle cost but 16 inches provides adequate insulation to have the argon in decent thermal conditions inside the cryostat.

Insulation Installation

Many contractors [e.g. Ref 1] use foam-in place equipment, mostly to insulate buildings. Two clear low viscosity components are combined in a high pressure nozzle. The mix foams to its final volume in seconds and sets in less than a minute. Typically the foam is built up in "lifts" of 1.5 inch thickness. The foam attaches itself tenaciously to the surface of the tank and to previously installed Urethane layers. (Polyurethane is also sold as a construction adhesive). The spraying is done by a skilled technician. The technician wears a suit and breathing mask, with supplied air as needed. A manlift or scaffolding will be supplied to make the spraying safe and efficient. Foam can be applied to surfaces of any orientation, and is particularly suited to insulate intricate shapes such as pipe penetrations and support structures.

Foam Coatings

The completed insulation must be protected form water vapor diffusion and must meet fire protection requirements. We have identified two coatings, one of which is an excellent vapor barrier [ref 2] and the other is an intumescent thermal barrier foam coating [ref 3]. The Fermilab Fire Protection Engineer has agreed to perform flammability tests on these coatings, as soon as our requested samples arrive.

Foam Mechanical Performance

A concern in using PU insulation for cryogenic applications stems from its large thermal shrinkage (about 1 %) when cooling to 87K from room temperature. By contrast, the stainless steel (SS) tank shrinks about 100 times less. The foam is prevented from shrinking and builds up tension proportional to the relative shrinkage times the foam modulus. We have made several samples of PU foam on SS and cold shocked them a number of times, without any evidence of cracking . While encouraging, these tests cannot tell us if the design is conservative or not.

Therefore we have addressed this concern in three ways:

--using published data [ref 4] on thermal contraction , foam modulus, and foam ultimate strength, we have calculated the safety factor against foam cracking. This safety factor is 1.88 for samples cut in longitudinal foam direction, and 2.35 for samples cut in transverse direction. These data are for the same type of foam and same density (30 kg/m^2) that we intend to use.

-- we have made direct measurement of thermal stress and ultimate strength on 5 foam samples made by our local contractor. This was done in a stress / strain tester with a sample cup that can be filled with liquid Nitrogen. We find a safety factor of 1.7+- 0.4.

-- we will be using additional strengthening of the foam: While localized cracks have little effect of the insulation performance, crack propagation all the way though the insulation layer could lead to foam aiir and water vapor infiltration To prevent crack propagation we will incorporate 3 layers of fiberglass mesh, starting with mesh right at the tank surface, and using mesh after each lift (i.e. after 1.5 and after 3 inches of foam). The fiberglass mesh has a breaking strength of 66 pounds per inch width, very close to the ultimate strength of a 1.5 inch lift of foam. This way we will be doubling the safety factor against cracks, to about 4x. We have worked with the contractor to make a sample with embedded fiberglass. The foam penetrates the mesh well, and fuses intimately to the mesh. It does not peel from the stainless substrate.

Conclusions

Blown-in polyurethane foam will provide the required heat load barrier for the detector tank. The foam is easy to install and has a safety factor of 1.7 against cracking on cooldown. Fiberglass mesh will be installed between lifts to provide an additional similar safety factor against crack propagation. An outer coating will provide a water vapor barrier and will meet flammability requirements.

References

[1]Innovative Insulation Solutions Ltd, http://www.gotfoaminsulation.com/

[2] W.R.Meadows, “Sealtight”, http://www.wrmeadows.com/wrm00059.htm

[3] Flame -Seal TB Foam fire retardant, http://www.flameseal.com/

[4] Thermal and Mechanical Properties of Poyurethane Foams and a Survey of Insulating Concretes at Cryogenic Temperatures, L. L. Sparks and J. M. Arvidson, for the Gas Research Institute, 1984.