Use of Urethane Foam for LAr Tank Insulation

Hans Jostlein 3/16/2009

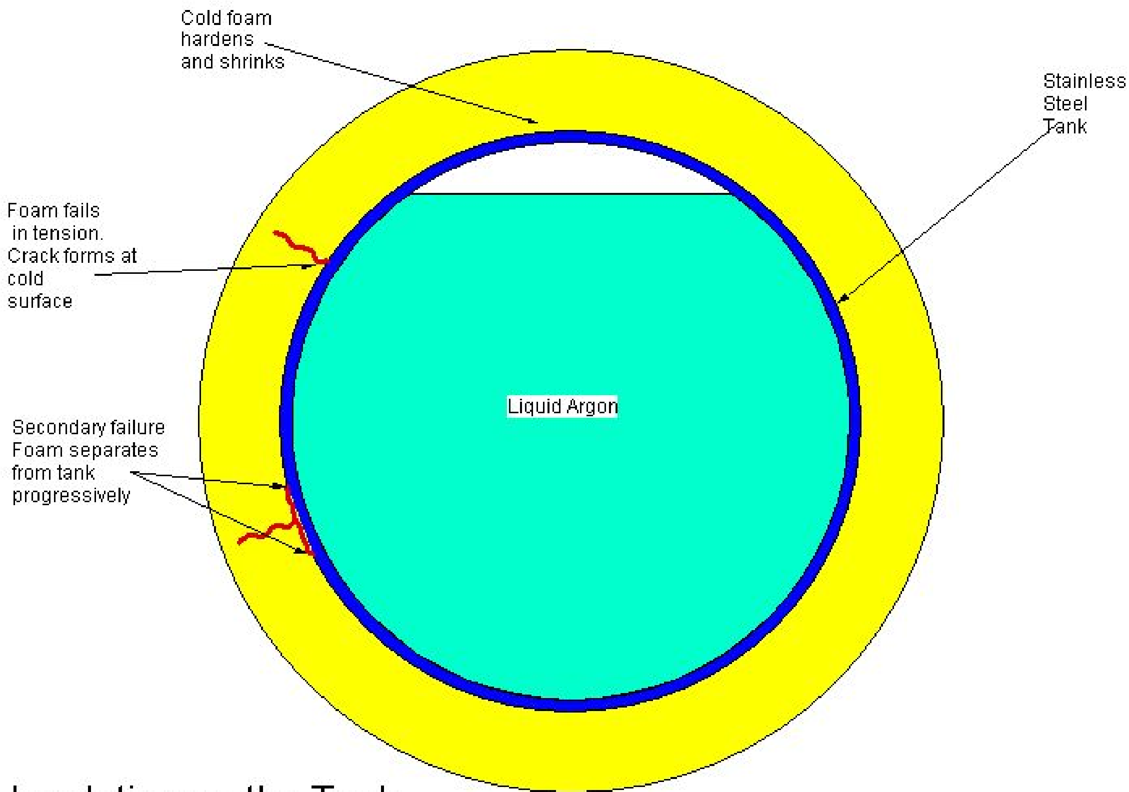
Introduction

The liquid Argon tank proposed for the Microboone neutrino experiment is a single shell stainless cylinder without vacuum insulation. The thermal insulation will be provided at the outside of the tank.
Several insulating methods have been considered.

The one examined here, blown-in place Urethane has several attractive features:
--good seal against water vapor and air infiltration
--easily adaptable to complex surfaces (supports, pipe connections, flanges)
--uses minimal space
--widely used commercially
--fast and inexpensive installation

There are, however, serious concerns, mostly relating to thermal contraction stresses:
--will the foam crack on cool-down?
--will the foam separate from the tank surface in a progressive failure mode?
--will radial cracks form on the tank surface and propagate radially outward?

Minor concerns are:
--what water vapor barrier to use on the outer surface
--protection from UV light
--protection from physical damage
These latter concerns are shared with industrial insulated tanks and have well-known solutions.



Insulation on the Tank

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Tests on Foam – Shrinkage and Allowable Tension

We visited a vendor/ installer of Urethane foam insulation:

Office Location
Innovative Insulation Solutions Ltd.
300 Scott Street
Elk Grove Village, Illinois 60007
Phone: 847.454.9081
Fax: 847.454.9620
Email: Foam@gotfoaminsulation.com

They have insulated tanks :

They blew foam over several SS pieces I brought.
The foam generally adhered well and was of very consistent cell size.
We cold-shocked the pieces a few times by filling the SS side with LN2 and warming up again.
No cracking or delamination was observed.

However, such pass-fail testing is insufficient to guarantee success on a much larger installation.

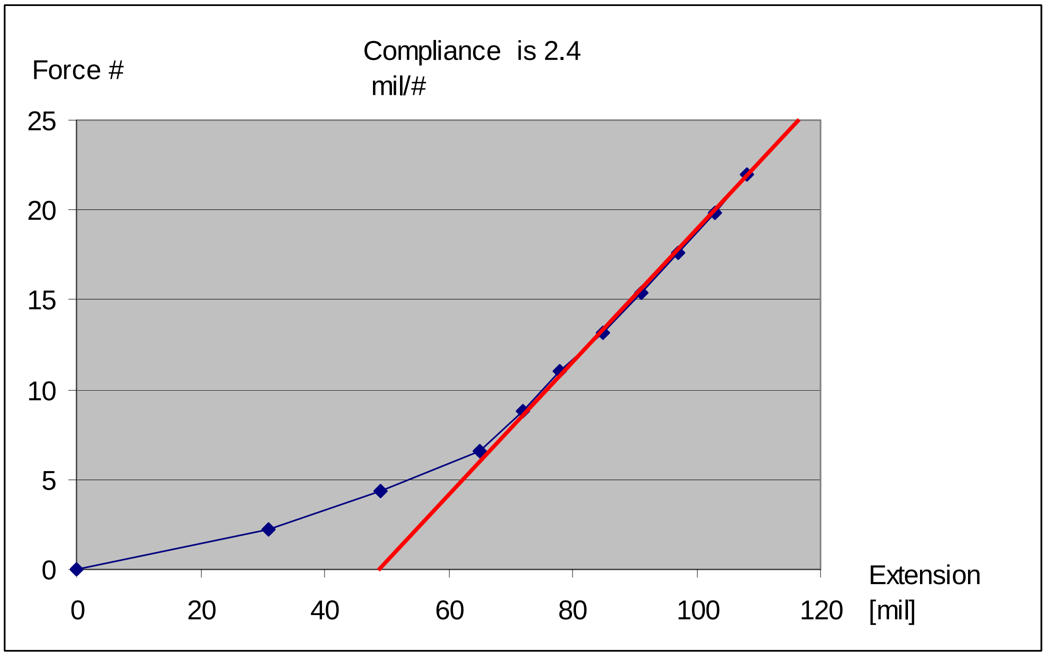
Therefore we decide to measure the actual tension on cooldown, and to jmeasure the breaking tension of the cold foam.
The ratio of breaking tension over tension on colldown is the safety factor against failure of the cold foam in tension.
We measure three such samples:

Foam samples being prepared for cold testing.
The foam was cut from larger pieces and expoxied to aluminum end plates with threaded holes in them.

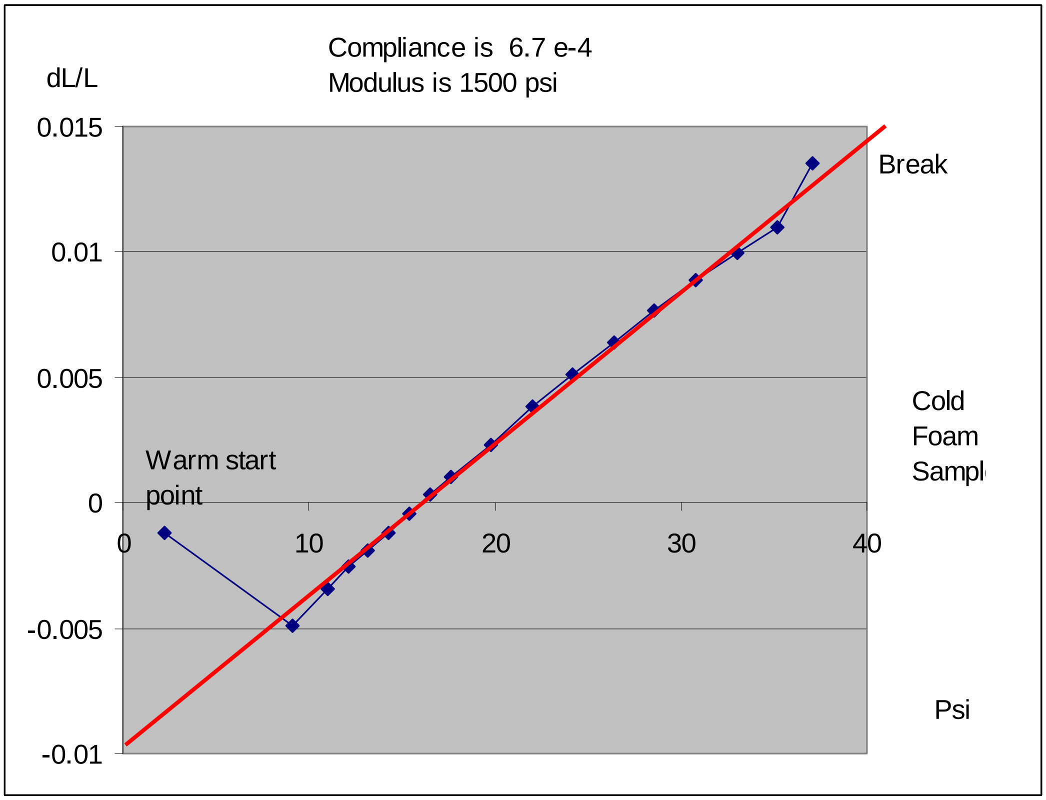
A stainless cup (shown inverted here) was prepared with a ¼-20 threaded rod installed through the bottom.
The cup was later insulated with “great stuff” urethane foam.

The insulated cup is shown here on our stress/strain tester.
The sample is installed in the cup by threading it on the rod.
The bottom end of this rod is mounted on the arm that pushes on the digital scale on the right.
The screw jack on top is used to pull on the sample.
The travel is read out with the dial gauge below the screw jack.

(Detail)



Tester compliance:
The tester has large compliance, due to the fact (later discovered) that the digital scale has a flexible SS deck. We will fix this later.
However all data have been corrected for this compliance.



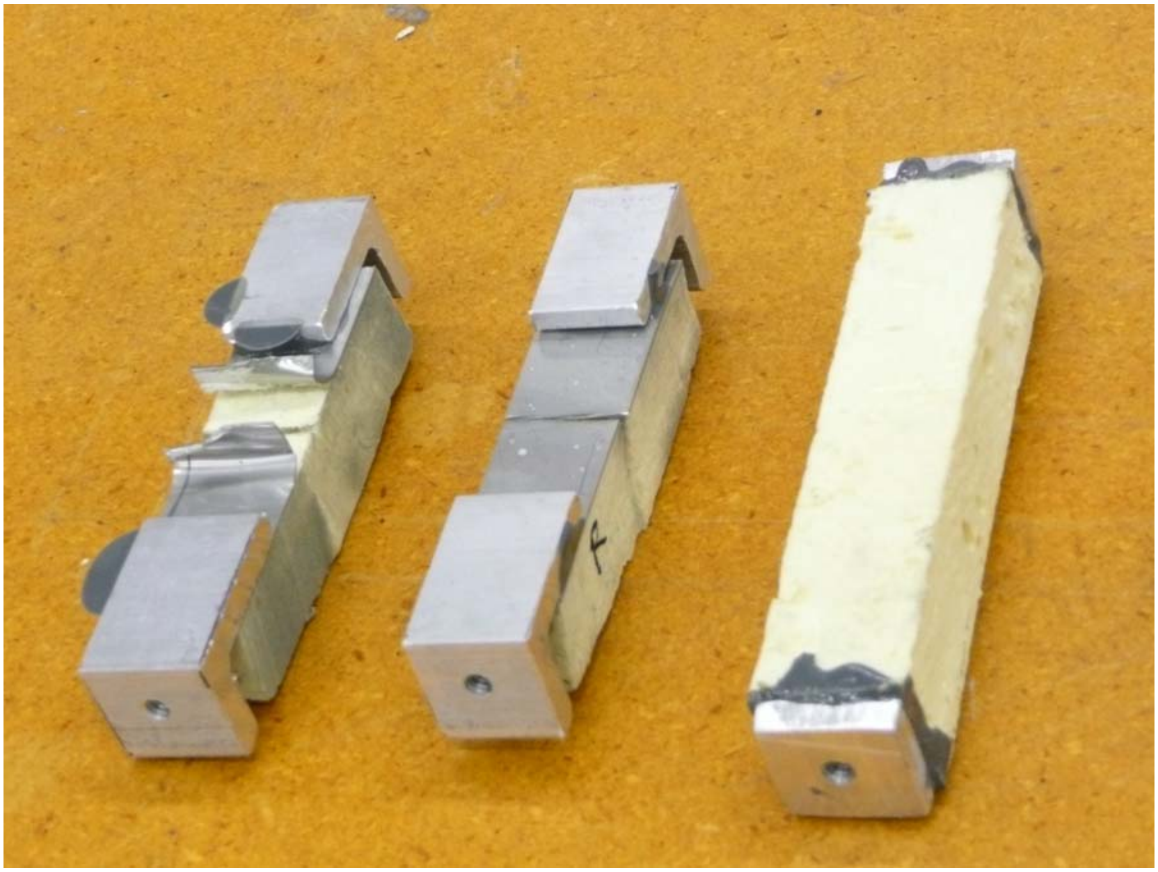
The warm sample gad a stress of 2 psi applied.
On cooldown the tension went to 9 psi, an increase of 7 psi.
The break occurred at 38 psi,
Hence the safety factor is 38/7 = 5.4
Two more samples were tested.
Sample #2 broke at 36.7 psi,
Sample #3 broke at 44.7 psi

Testing for Shear Strength at the SS Surface

It would be highly desirable to measure a safety factor for delamination of the foam from the substrate. We made two attempts, and in both cases the foam failed in the bulk before delaminating.
This is a common problem in engineering, e.g. when trying to prove that a weld is stronger than the bulk material.

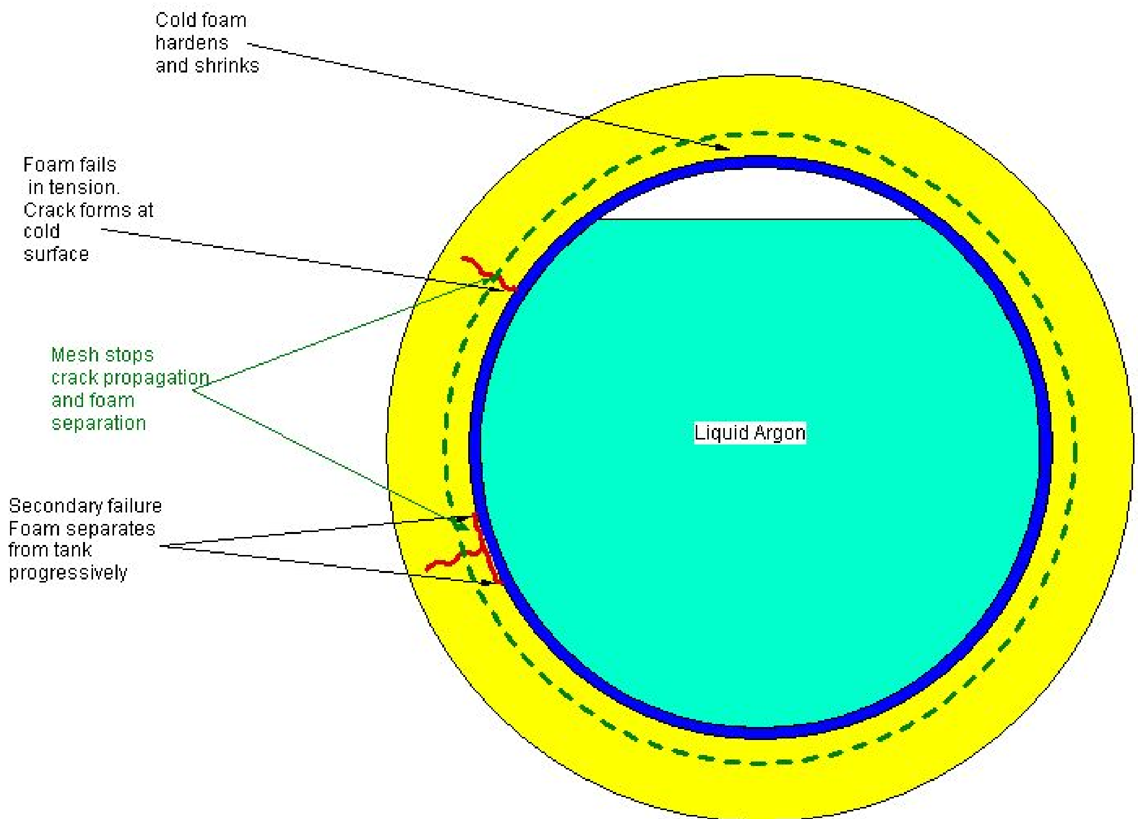
In the first test we used a sample with SS backing on one side, and cut the SS at the midpoint to look for delamination (pictures are coming)
The sample failed at 15.4 psi right at the point of stress concentration.
(The lower stress comes form the concentration due to the unyielding backing strip)

We then modified a sample by peeling back the SS backing to allow progressive delamination to occur.
But, again, the sample failed in tension at about 15 psi.



Use of Reinforcement

While the safety factor for foam failure in tension appears to be generous,
One can take additional precautions at very little cost
We have found a fiberglass mesh that is sold for use with plaster to prevent cracking and crack propagation. The mesh is slightly adhesive to ease installation.
Its strength is 24.5 #/inch.
Several uses may be considered:
--as a first layer on the tank surface to embed in the foam
--after one or two foam lifts (2/5 or 3 inches of foam)
In each case it would suppress crack formation and propagation with confidence.



Use of Fiberglass Mesh

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Here is a test sample of mesh applied to the surface.

After foaming in (with “Great stuff”)

Foam cost, installed

Tank length	60	ft		
Tank diameter	13.5	ft		
Insulation thickness	16	IN	1.333333	FT
Tank inner surface are	2830.96768	sf		
Tank outer surface are	3457.88995	sf		
Average area	3144.42881	sf		
Foam volume	50310.861	board ft		
Foam volume	4192.57175	cft		
foam cost, lower est	$1.50	$/bdft		
foam cost, upper	$2.50	$/bdft		
Total cost, lower	$75,466.29			
higher	$125,777.15			
Mesh cost	$0.10	$/sf		
Total mesh material	$283.10	$/layer		