Hans Jostlein 4/20/2009

Microboone Tank Insulating support

Abstract

It has been proposed to support the MicroBooNE tank with load bearing foam insulation.

We identify some concerns and propose two coherent concepts in response.

Insulating Support Materials

Two Materials have been considered so far: high density (12 #/cf) Polyurethane foam [ref. 1] and foam glass [ref. 2]. They differ largely in their amount of thermal contraction on cooldown.

In the first section of this note we will consider Polyurethane (PU) foam, in the second section we will briefly consider the use of foam glass.

Polyurethane Foam Support Issues

Issues with Bonded PU Foam

PU can be bonded to the SS, or a slip plane can be inserted, e.g. by wrapping the SS in polyethylene (PE) foil.

When the foam is bonded to the SS, it cannot shrink on cooldown, This creates a tension in the foam and shear stress across the bonding layer (adhesive layer).

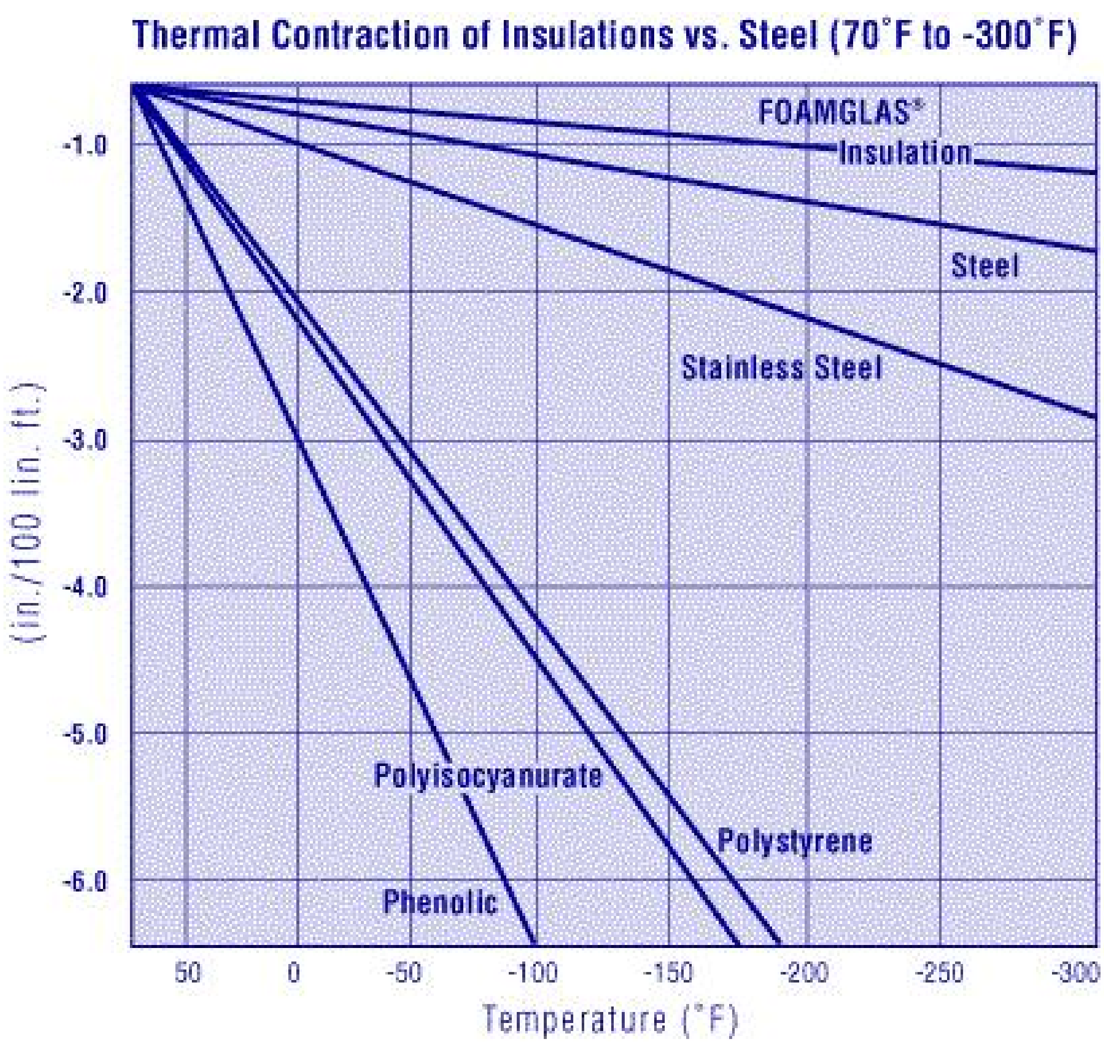
PU shrinks by 1.0 % during cooldown to Lar temperature (about 87 K) [see below and Ref. 4].

Stainless steel (SS) tank material shrinks less 0.3 %.

(Foamglas shrinks 0.07 %)

The tension in the foam depends on temperature, and is highest near the SS surface, tapering to zero tension at the warm foam surface. The maximum tension can be estimated as the product of the elastic modulus of the cold foam and the shrinkage factor wrt. room temperature. For the foam under consideration [ref. 3] we find safety factors of about 4x:

	General FR-3700	Units	General FR-3700	Units
Foam density	12	#/cf	15	3/cf
Cold modulus	15200	psi	21923	psi
CTE (-50F to 200F)	3.40E-005	K^-1	3.40E-005	K^-1
Cold Foam dL / L	0.00775		0.00775	
Integral shrinkage	0.00995		0.00995	
PU ï SS shrinkage	0.00695		0.00695	
Cold Foam breaking strength	420	psi	600	psi
stress from cooldown	105.64	psi	152.36	MPa
Safety factor	3.98		3.94	



In several cold shocked samples of the foam, laminated to SS, we have not observed any cracking of the foam. However, there are concerns at the foam /SS interface.

We have done a few bonding tests using the 3M "Scotchweld" epoxy, which is one of the stronger general purpose epoxies. We have degreased the SS surface and dry sanded it for optimum adhesion. Yet in all cases we have either observed delamination over most of the surface, or heard loud cracking noises when cooling the SS wit liquid nitrogen (LN2), indicting at least partial bonding failure. This does not prove that there is no bonding material that may work , but points out a possible failure mode.

Note that, while the tension in the foam is reasonably uniform, except for its temperature dependence, the shear stress in the bonding layer is zero everywhere except at the periphery of the bonded area. This is a bit counterintuitive, but can be visualized by imagining stretched rubber membrane fastened to a circular stiff disk. If the membrane is well anchored around the periphery of the disk, there is no shear stress present or needed to maintain the tension in the rubber. If the shear stress exceeds the strength of the adhesive (which can happen at the periphery of the bonded area), then the adhesive delaminates locally and the line of high shear stress moves inward, This is an example of a progressive failure, where the delamination can eventually occur over the whole bonded area.

PU Foam on a Slip Plane

The concerns about stress in the foam and, particularly, shear stress in the bonding interface to the tank can be avoided by allowing slippage at the contact plane. This can be easily accomplished by, e. g ., wrapping the contact area of the tank in polyethylene (PE) foil. I measured the static slip angle to be about 0.25, which means all forces are reduced by a factor of 4. Note that a grout has to be applied over the foam (and below the slip-foil) to assure uniform loading of the foam.

For a 1 m wide foam support the slippage is a total of 1 cm, split evenly into a 0.5 cm slippage at each end face (the slippage is symmetric due to the force distribution). The low density blown-in foam [ref. 3], that covers most of the tank, can break away from the high density support foam at the faces. This can be prevented by installing a flexible insulating blanket (e. g. a bonded fiberglass mat) over the cold part of the faces before foaming in. Even covering the cold half of the foam support with a separation foil (e. g. PE) will prevent cold leaks there.

Lastly, even at the reduced friction coefficient of 0.25, the foam support suffers an avoidable shear stress at cool-down. The stress can be sharply reduced by building one of the foam supports on top of an array of roller-pipes, as shown in Figs. 3 and 4 . The pipes are kept parallel and evenly spaced by pairs of cam rollers, screwed into a longitudinal bar at each end of the pipe field. The expected friction factor will be about 0.05, essentially removing the shear stress in the support.

A Coherent Concept For a Foam Support

The concept, as shown in Figs. 1 and 2, has two foam supports, each about 1 m wide. One of them sits on an aluminum sheet, supported by pipe rollers. The other foam support sits on an equal- height shim plate. The supports are grouted to the plates for even loading. The tops of the supports, which are cradle-shaped, are also covered with grout where they contact the PE foil-covered tank.

On cool-down the fixed support stays in place, while the support on the roller-pipes moves to accommodate the shortening of the tank , a little over 1 cm between the supports.

A Coherent Concept For a Support on Foamglas

Foamglas , a Corning trademark, Ref. [2], provides attractive thermal insulation and compressive strength. It also shrinks very little, less then the SS tank. For a tank support using Foamglas, most of the earlier considerations apply. A support concept based on Foamglas could look very similar to that shown for the high density foam. Depending on the cost of machining the Foamglas to the required radius, it may be advantageous to weld a SS support to the tank to provide a flat interface to the foam glass, as shown in Fig. 5 .

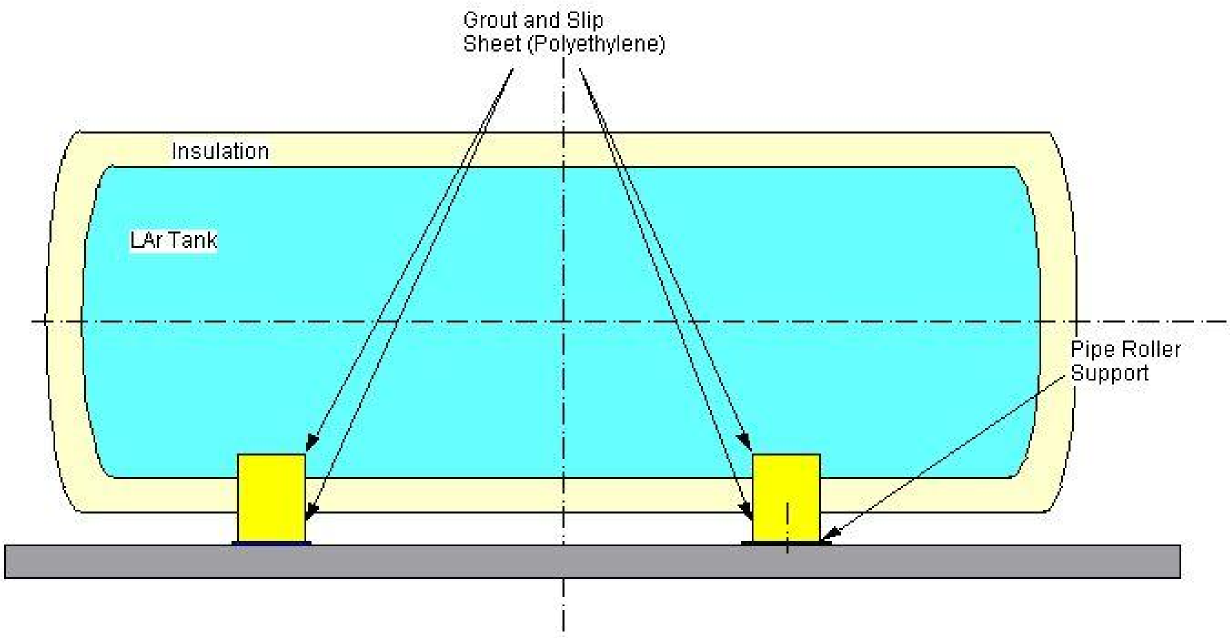
References

[1] General Plastics Manufacturing Company, www.generalplastics.com

[2] Pittsburgh Corning USA , www. Foamglas.com, 800 Presque Isle Drive Pittsburgh, PA 15239, USA

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



Tank on Foam Support, Side View

Hans Jostlein
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Figure 1

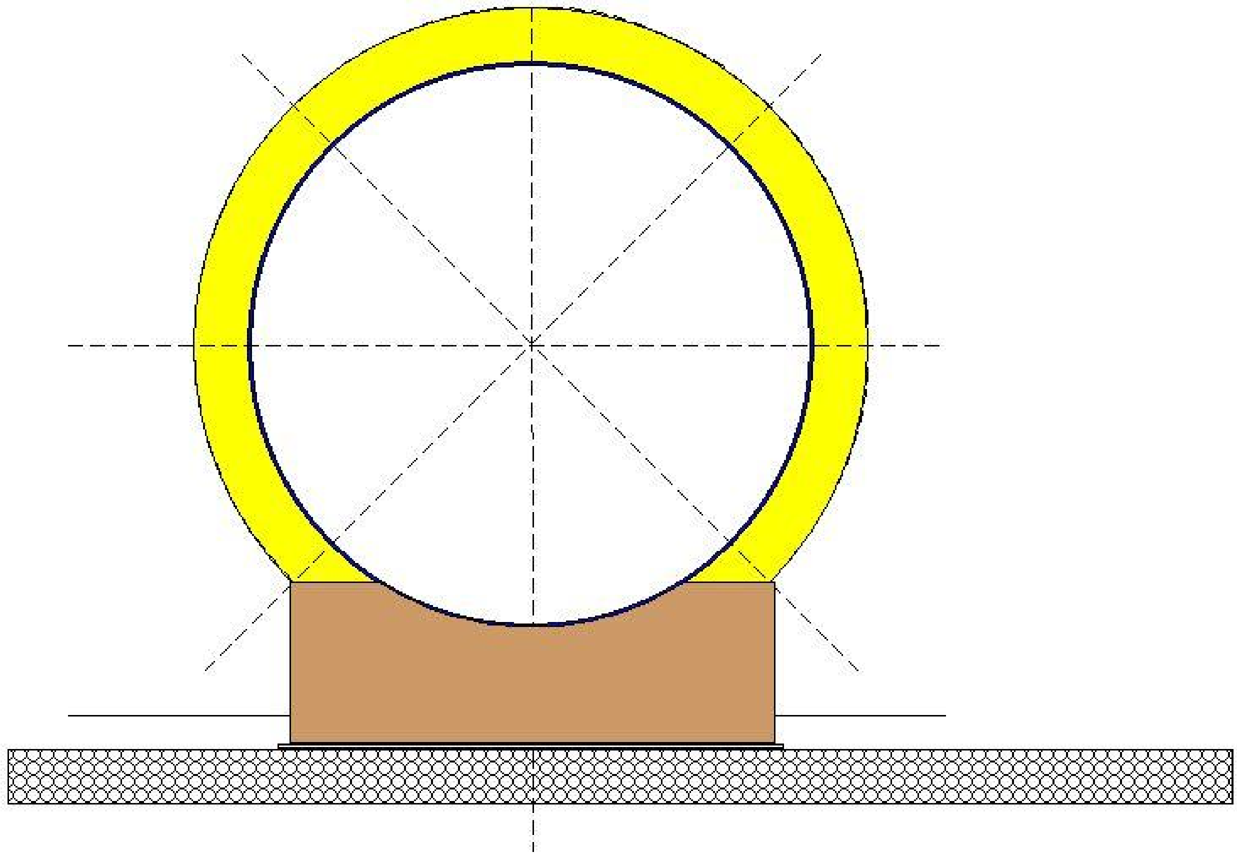

Figure 2

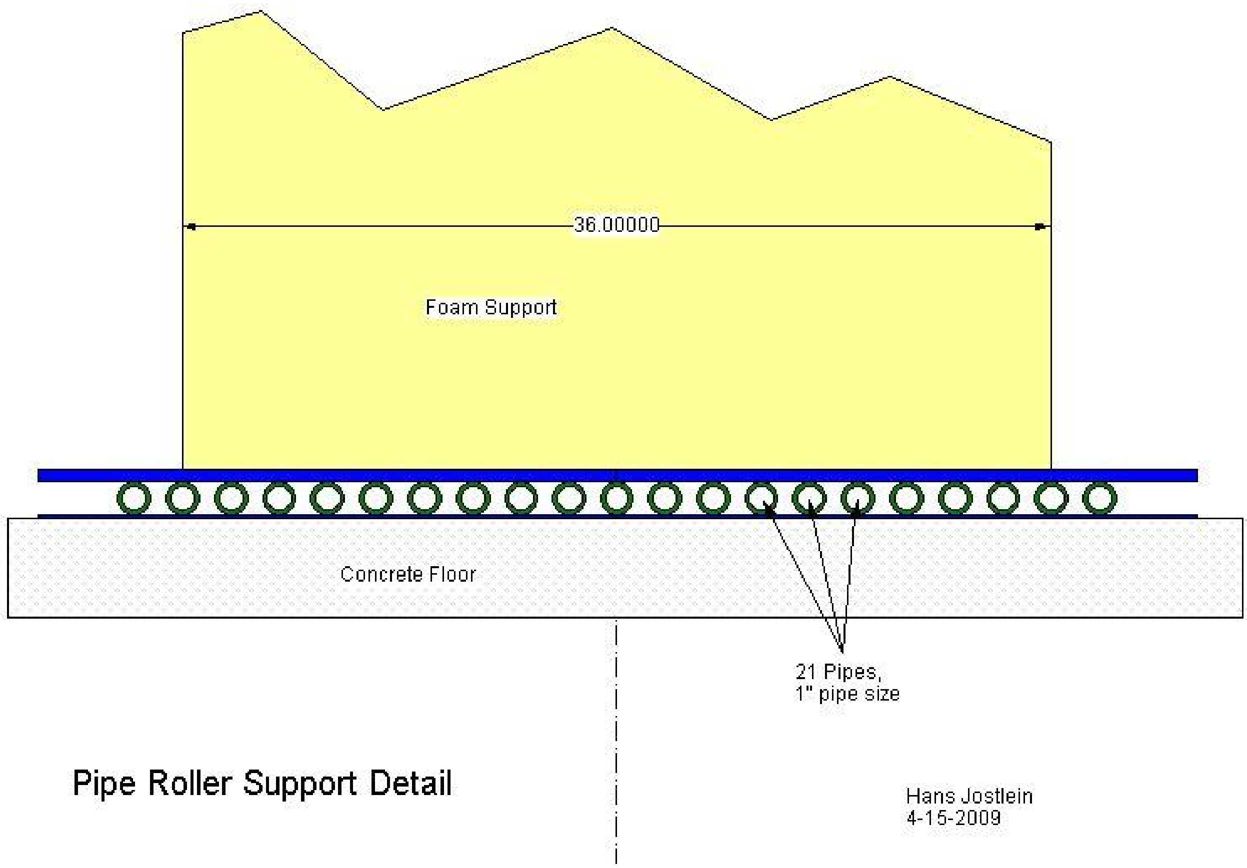
36.00000
Foam Support
Concrete Floor
21 Pipes,
1" pipe size
Pipe Roller Support Detail
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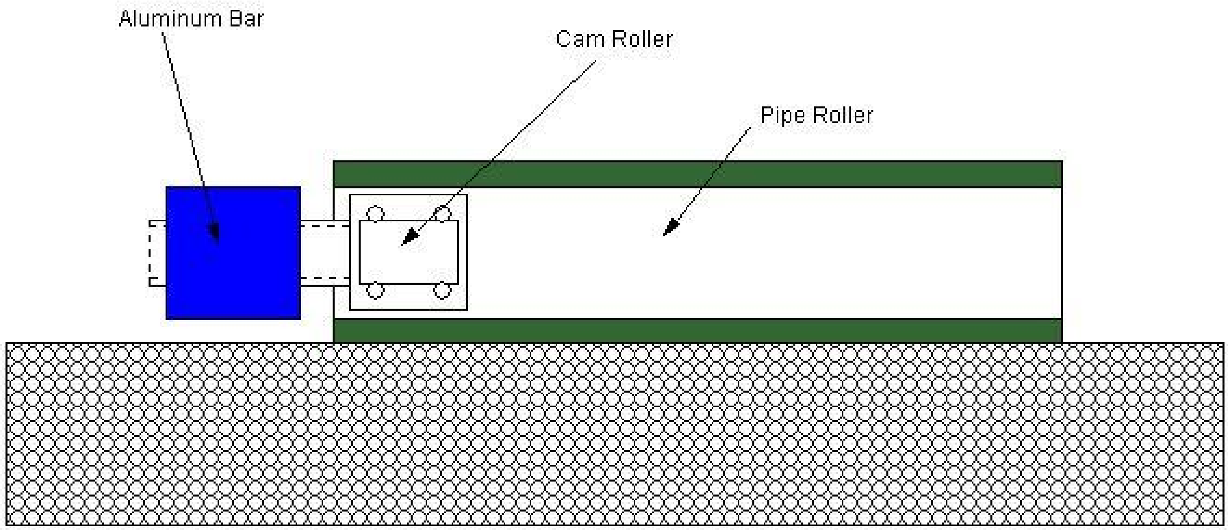
Figure 3



Pipe Roller Ends Detail

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Figure 4

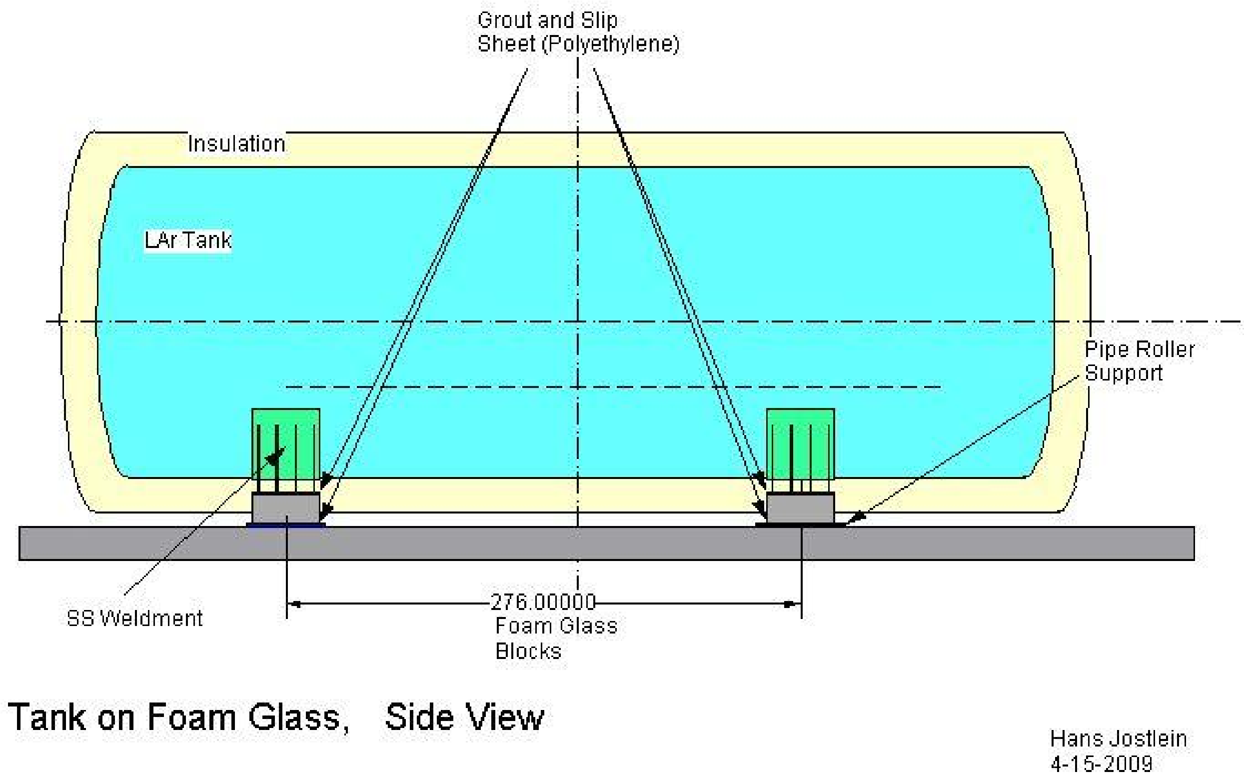
Grout and Slip
Sheet (Polyethylene)
Insulation
LAr Tank
Pipe Roller
Support
SS Weldment
276.00000
Foam Glass
Blocks
Tank on Foam Glass, Side View
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Figure 5