Optimum Foam Thickness for LAPD and MicroBooNE

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Abstract

We are presenting the heat gain though blown-on polyurethane insulation and compare the insulation cost to the LN2 consumption cost. At the listed "Payback time" the insulation thickness minimizes overall cost. At shorter times the insulation cost dominates, at later times the LN2 consumption costs dominates.

We also consider the ullage area where the temperature is established at that point where the heat leak power equals the thermal radiation power into the cryostat. We find that the ullage area calls for an insulation thickness similar to that of the LAr area, and that the equilibrium temperature is quite low.

Motivation

We are presenting a summary that may be useful to judge quickly the optimum insulation thickness, taking into account the expected operating time of the device. We find that the insulation expected for LAPD (12 inches (?) is reasonable.

The MicrobooNE insulation (16") is optimal for an operating time of just 0.79 years. However, additional considerations such as different funding types must also be considered (not here, though).

Assumptions

We ignore thermal conductivity of the tank material.

We do not include thermal conductivity or convection in the gaseaous Argon.

We do not consider heat gain through supports and ancillary equipment; those do not depend on the choice of insulation thickness and do not affect the optimization.

Input Values

For the 2 #/cft foam we use thermal conductivity values from Sparks and Anderson , averaged over the range from 87 K to room temperature: 20. 5 mW / (m K)

For the foam cost we use the average vendor "guess" of $ 2 / board ft, installed

For LN2 we use $ 0.23 per liter, and do not include in efficiencies and losses but assume that only the vaporization energy is available.

For the dome numbers, we use the Boltzman law power=area * albedo * sigma * Temp^4,

where sigma = 5.67 10^-8 [W / [m^2 * K^4].

For the albedo we use the value of 1.0, which may seem odd at first for shiny stainless steel. However, the power density of black body radiation inside a close volume does not depend on the wall albedo. Multiple reflections see to that.

We do ignore the radiation emanating from the cold fluid. This is small, except for the case of very thick insulation where the dome temperature gets close to the LAr temperature.

Results

For the LAr washed areas we show the heat input power and LN2 use rate per square meter, and time at which the insulation cost equals the LN2 cumulative cost. This is also the time at which the total cost (insulation plus LN2) is optimal.

Liquid Argon Heat loss and Payback Time

Insulation thickness [in]	Power [W/m^2}	N2 use rate [l/day]	Payback time [years]
24	8	4.27	1.78
20	10	5.12	1.24
16	12	6.4	0.79
10	19	10.24	0.31
5	38	20.5	0.08
2	95	51	0.01

For the ullage (Dome) area we show in addition the equilibrium temperature between heat input and radiation loss:

Dome Heat Loss and temperature

Foam thickness [in]	Temp [K]	Power [W/m^2]
24	105	6.9
20	112	9
16	117	10.3
10	130	16.1
5	150	28.3
2	179	58.1

Conclusions:

The insulation anticipated for LAPD and MicroBooNE is certainly in a reasonable range.

For LAPD, where the operating time could approach one year, an increased insulation thickness of 16 inches may be justified.

For MicroBooNE, with an expected operating time of 3 years or more, the present 16" insulation with a payback time of 10 months may be a bit meager. A thicker insulation might save money and help operations by using fewer LN2 trucks.