Fermilab

Particle Physics Division
Mechanical Department Engineering Note

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Project: NOvA

Title: Scintillator Expansion

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Key Words: NOvA, Scintillator

Abstract Summary: Calculate the relative expansion of the NOvA scintillator in the detector

Applicable Codes: None

It all comes down to the difference in the thermal expansion between the PVC and the scintillator.

Linear Thermal Expansion Values (alpha) for PVC ($\Delta L = L_0 \alpha \Delta T$):
(from Ryerson Plastics) Type I 5.5 x 10-5 in/in/deg. F (I convert this to 55 x 10-6 in/in/deg. F)
(from Ryerson Plastics) Type II 2.95 x 10-5 in/in/deg. F (I convert this to 29.5 x 10-6 in/in/deg. F)
Vic's # 0.00007 in/in/deg K (I convert this to 38.8 x 10-6 in/in/deg. F)
Generic PVC from (http://www.engineeringtoolbox.com/thermal-expansion-pvc-d_782.html) converts to 30 x 10-6 in/in/deg. F

So Vic's number happens to be darn close to the average value of 55, 29.5, and 30. Good enough. I'll use 38.8 x 10-6 in/in/deg. F

Volumetric Thermal Expansion Values (beta) for Mineral Oils ($\Delta V = V_0 \beta \Delta T$) :
White Mineral Oil, USP/NF used as a heat transfer fluid
(http://www.therminol.com/pages/products/xp.asp) at 200 C
0.000495/°F (495 x 10-6/deg)
Mineral Oil (heat transfer fluid) (see http://www.multitherm.com/multitherm-ig-1.html) 0.00054/°F (I convert this to 540 x 10-6 /deg. F)
Generic Lube Oil: 6.4 X 10-4 /°C (I convert this to 355 x 10-6 /deg. F)
Olive Oil (quoted by Vic from the CRC handbook) is 0.000742 /°C (I convert this to 412 x 10-6 /deg. F)

So I'll use β = 450 x 10^-6 /degree F since this is about the average value.

So, to compare the volumetric change of one cell:
interior volume is 37.1 mm by 59.4 mm by 610 inches (15494 mm) is 34.145 x 10^6 mm3

Use a 5 degree F temperature change (assume start at 72 F and warm up by 5 F or cool down by 5 F).

Scintillator volume change for one cell is: $\Delta V = V_0 \beta \Delta T$ ΔV = 34.145 x 10^6 mm3 * 450 x 10^-6 /degree F * 5 deg F = 76.826 * 10^3 mm3
One cell changes the scintillator volume by 0.0768 liters. 32 cells by 2.45 liters for a 5 degree temperature swing.

Cell volume change (for one cell) is ΔV = ((L1 + ΔL1)*(L2 + ΔL2)*(L3 + ΔL3)) - (L1*L2*L3)

L1 + ΔL1 = 37.1 + 37.1 mm*38.8* 10^-6 mm/mm/deg. F*5 deg. F = 37.1 mm+0.0072 mm = 37.1072 mm
L2 + ΔL2 = 59.4 + 59.4 mm*38.8* 10^-6 mm/mm/deg. F*5 deg. F = 59.4 mm+0.0115 mm = 59.4115 mm
L3 + ΔL3 = 15494 mm + 15494 mm*38.8* 10^-6 mm/mm/deg. F*5 deg. F = 15494 mm+3.0 mm = 15497 mm

((L1 + ΔL1)*(L2 + ΔL2)*(L3 + ΔL3)) = 37.1072 mm * 59.4115 mm * 15497 mm = 34.165 *10^6 mm3
ΔV = 34.165 *10^6 mm3 - 34.145 x 10^6 mm3 = 19.6 * 10^3 mm =
ΔV = 0.0196 liters for one cell. ΔV = 0.6272 liters for 32 cells.

So, for one module, the scintillator expands (contracts) by 2.45 liters while the PVC expands (contracts) by 0.63 liters.
This gives a net excess of scintillator of 1.8 liters when the thing warms up.

Conclusion: A 2 liter (half gallon) expansion tank makes sense. It would also be good to measure the relative expansion of the scintillator in our PVC compound in the lab to remove uncertainty.