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Heat transfer phenomenon in vertical support of LAr jacketed tank

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Abstract: *Storage of LAr with minimum heat is the primary condition of storage tank. Boiling temperature of LAr is 87K and surrounding ambient temperature is in the range of 293K to 313K C. This is quite vast temperature gradient. LAr storage tank is jacketed with outer tank with perlite insulation with required vacuum level In spite of insulation and vacuum, heat transfer takes place. There is thermal short between inner tank and outer tank through inner support. Heat inflow takes place trough this path to LAr and resulting in to vaporization of LAr. Study required in this area to understand the heat transfer phenomenon in LAr tank. Heat balance analysis gives the critical value of length of conductive path*

I. INTRODUCTION

Heat transfer in the LAr in the tank through various areas viz. Through insulation of cylindrical area, through caps' insulation both from top and bottom, also through inner support between outer and inner tank of LAr.

If we consider all heat transfer area mentioned above then major contribution of transfer of heat from surrounding of tank to the liquid argon in the inner tank is through vertical inner cylindrical support. Purpose of this analysis is to focus on thermal short of vertical cylindrical support between inner and outer tank.

II. SURFACE ENERGY BALANCE

The temperature of liquid argon inside the tank is 87.3 K. Surrounding temperature has vast range from 293K to 318K. Due to this vast temperature gradient, heat inflow takes place from surrounding to liquid argon. There is convection as well as conduction heat transfer to the entire storage tank.

III. NOMENCLATURE AND ITS DESCRIPTION

1. T_1 = temperature of LAr
2. T_2 = temperature of cylindrical support junction
3. T_3 = atmospheric temperature
4. A = Conductive area = $\pi/4(D^2_{osk}-D^2_{isk})$inner cylindrical support
5. L = Length of inner cylindrical support
6. K_m=Mean thermal conductivity $= {}_{77}\int^{300}$=(3060-332)/(300-77.8)
7. A_h=Conductive area = $\{\pi/4[(D_{os} + l)^2-(D_{is} - l)^2]+2*\pi D_{sk}*l\}_{os}$
8. h_S= Convective heat transfer coefficient for still air=8.735 W/m^2 K
9. h_W= Convective heat transfer coefficient for windy condition air=33.40 W/m^2 K
10. T_{ms} = Mean Temp. of convective area when air still
11. T_{mw} = Mean Temp. of convective area when wind blow
12. T_{dw}= Dew point temperature of air
13. l = Assumed length of conductive area
14. $Q_s=K_mA(T_{2-s} - T_1) = hA_h(T_3 - T_{m-s})$= heat gain through inner cylindrical support at still air conduction
15. $Q_w=K_mA(T_{2-w.}-T_1)= hA_h(T_3 - T_{m-w.})$=heat gain through inner cylindrical support when wind blow

IV. RATIONAL

If we observe the LAr tank then we could see the condensation on bottom support of LAr tank. Some time pool of water also observed underneath the LAr tank. Primary condition of this condensation due to less temperature of inner cylindrical support and support surface compare to condensation temperature of air. This is the area of focus for this analysis. This condensation leads to corrosion of outer tank, support and also boils off of LAr.

This phenomenon can be analyzed by considering; ideal heat transfer through vertical cylindrical support and actual temperature of outer surfaces of LAr tank. Theoretical heat transfer calculation and actual temperature measurement.

Following aspects are considered to analyze heat transfer phenomenon.

- Theoretical heat transfer through inner cylindrical support
- Practical method on actual temperature measurement on support area.
- Comparison of theoretical and actual method of heat transfer for conclusion.
- Different atmospheric condition can be calculated from the captioned aspects which gives the realistic results.

By above approach and calculation, minimal heat transfer as well as length of inner cylindrical support can be measured. This is very important analysis for conceptualization of heat transfer in design state.

4.1 Theoretical concept

Conservation of energy for heat balance at LAr tank surface can be written as $E_{in} - E_{out} = 0$ Considering convection heat transfer from surrounding to surface and conducting heat transfer from surface to LAr. We can write this as $Q_{cond} - Q_{conv} = 0$]

In the analysis, the inner temperature $T1$ =87.3 K for LAr, and the outer ambient temp is 313K/40^{0}C in summer. The thermal conductivity integral K_m=12.28W/mK. Cross section area of inner vertical cylindrical support = 0.2724891m^2 and length of vertical cylindrical support is L =1.2m. Convection heat transfer coefficient as per Industrial standards is h_s = 8.735 W/m^{2}K & h_w = 33.40 W/ m^{2}K (R= 1/h = 0.65 & 0.17 for still & windy cond. Convection area is assumed, A_{conv} =7.131m^2, assumed 400mm from the edge of Inner tank support to the outer tank and outer cylindrical base support.

Atmospheric condition: Max. temp. =40^{o}C(313 K), min temp=26^{o}C and max R.H=55% and Min. R.H.=25%, corresponding max. & min. Dew point temp. are 29^{o}C(302K) and 4^{o}C (277 K). For tank to have condensation on the surface, the temperature T_2 should be 29^{o}C (302K) or lower.

Assumptions:

1. Steady state condition
2. One dimensional heat transfer by conduction across the wall of inner cylindrical support.
3. T_m= Mean temperature of convective area = $(T_3+T_2)/2$

Analysis:

The surface temperature at the bottom edge of the cylindrical support may be obtained by performing an energy balance at the outer surface.

$E_{in} - E_{out} = 0$

It follows that, on area basis,

$Q_{cond} - Q_{conv} = 0$ (1)

Rearranging it by usual notation of Q_{cond} and Q_{conv},

$Q_{cond} = K_m A (T_2 - T_1)/L$ and $Q_{conv} = h A_{conv} (T_3 - T_m)$

Put values in eqn 1,

By equating $Q_{cond} = Q_{conv}$ i.e $Q_{cond} = K_m A (T_2 - T_1)/L$ and $Q_{conv} = h A_{conv} (T_3 - T_m)$ hence,

$$Q = K_m A (T_2 - T_1)/L = h A_{conv} (T_3 - T_m) \quad (2)$$

We can calculate the temperature T_2 and T_m from equation (2) by putting values of K_m ,A, T_1 ,L, h, A_{conv}, and T_3 . By putting values of T_2 we can calculate heat in-leak Q from equation (2). Here variable is T_3, but we can optimize the heat in-leak to the LAr by making the length of cylindrical support 'L' as variable. This value of 'L' we can calculate for simulating different atmospheric condition i.e summer, winter and monsoon by taking different values of atmospheric temperature both in still air and windy air condition. We can also check the condition of condensation on to the vertical cylindrical support by considering various relative humidity values according to the weather condition.

4.2 Practical method

In this exercise, the Measurements of temperature distribution on the field installed Argon tank support junction.

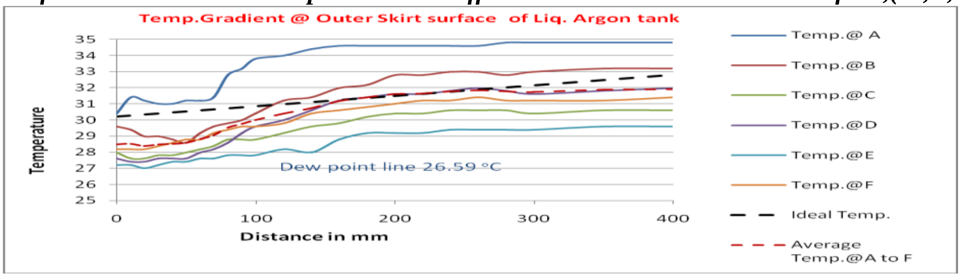
A theoretical calculation for junction temperature of vertical cylindrical support gives the ideal condition, but in actual practice, the temperatures are differs from ideal values. The reasons for the deviation in actual and theoretical temperatures on vertical cylindrical support junction are:

1. The tank has film coating of paint, which has different thermal conductivity than bare metal also the variation in paint coating thickness gives the different values of temperature at same height but different locations
2. The variation in wind speed and whirling action of wind surrounding the tank and wind direction has different impact on temperature distribution.
3. There are chances of human error in temperature measurement
4. The external dirt deposition on the surface of tank leads to deviation in actual temperatures.
5. Sensitivity of Temperature measurement Laser Gun also play important role in measurement of actual temperatures.
6. Angle of laser rays on the surface also plays an important role in deviation of temperature readings.
7. The tank surface is not flat but is curvature in nature leads to deviation in measurement of temperatures.

4.3.1 Thermal performance for LAr:

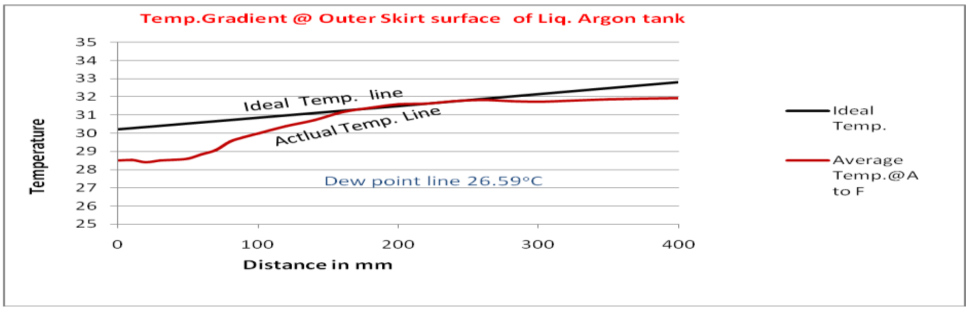
Season	Temperature (Still air) in K	Temperature (windy cond.) in K	Dew point temp. in K	Heat gain in Still air in W	Heat gain in windy air in W
Summer	308.06	311.66	302.21	601.56	621.65
Winter	289.48	292.78	284.61	550.92	569.32
Monsoon	301.02	304.51	299.59	582.37	601.82

4.3.2 Comparison of Ideal versus actual temperatures at different location on Outer skirt surface,(i.e,A,B,C,D,E,F)



Temperature gradient on outer Skirt Surface of LAr tank

4.3.5 Comparison of Ideal versus actual temperatures at different location on Outer skirt surface (i.e, A, B, C, D, E, F)



Temperature gradient on outer skirt surface of LAr tank

V. CONCLUSION

A. Temperature deviation

Heat transfer under Ideal condition through skirt support by energy balance method and the practical method by actual temperature measurement method, the values of temperatures by ideal condition are close to the practical temperature. Hence the approach and the assumptions considered in this analytical analysis work are inline with the final result. The deviation in temperature may be because of the following reasons

i. The tank has film coating of paint, which has different thermal conductivity than bare metal also the variation in paint coating thickness gives the different values of temperature at same height but different locations
ii. The variation in wind speed and whirling action of wind surrounding the tank and wind direction has different impact on temperature distribution.
iii. Sensitivity of Temperature measurement Laser Gun also plays an important role in measurement of actual temperatures.
iv. The tank surface is not flat but is curvature in nature leads to deviation in measurement in temperatures.

B. Condensation on tank support

The condensation on the tank support is normal phenomenon. Following conditions are responsible for condensation on tank support:

i. Higher R.H. value monsoon
ii. When wet bulb depression decreases.
iii. Tank insulation and length of inner skirt also plays important role.

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