



Theoretical analysis and experimental investigation on performance of the **thermal shield** of accelerator cryomodules by **thermo-siphon cooling** of liquid nitrogen

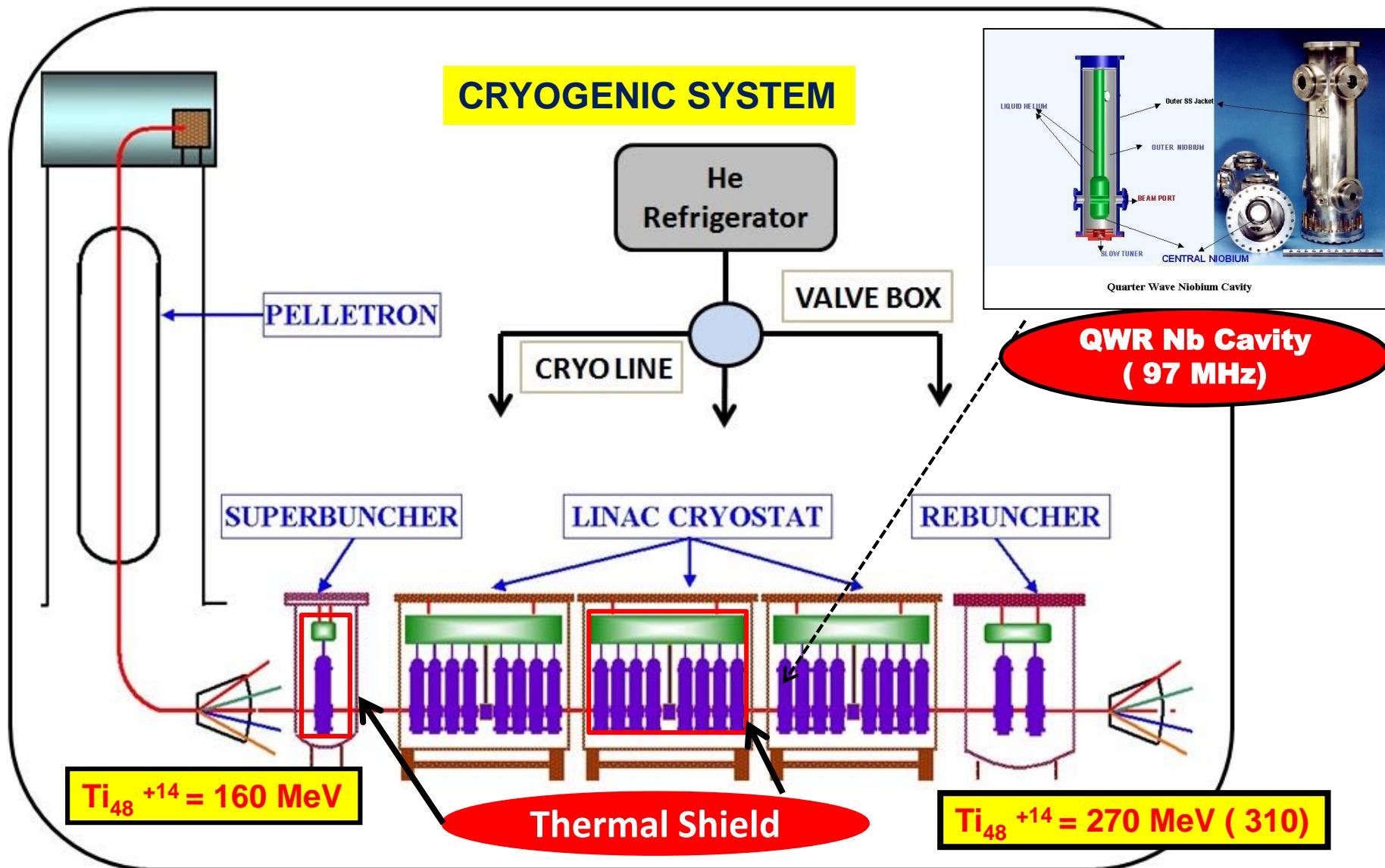
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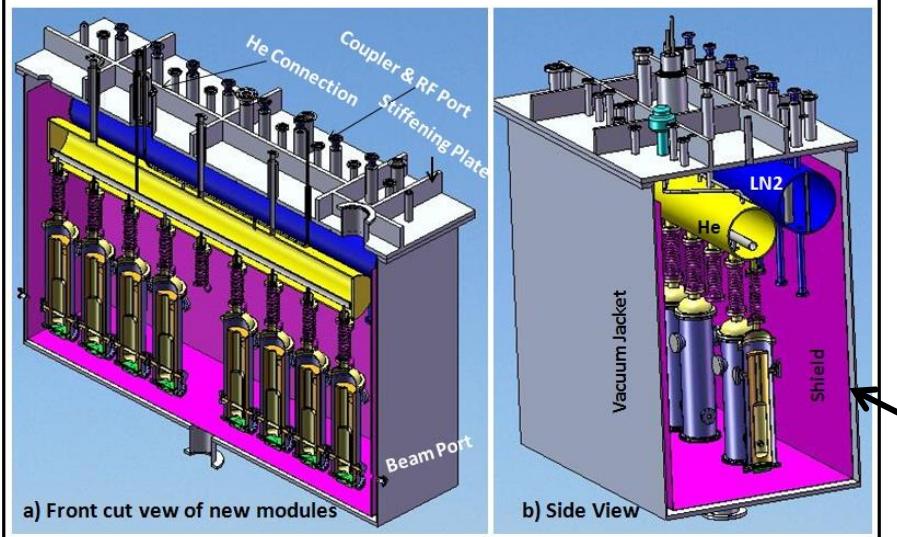
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S. Babu, S.K Sahu)**

**Inter University Accelerator Centre
New Delhi. India**

Superconducting LINAC at IUAC, Delhi

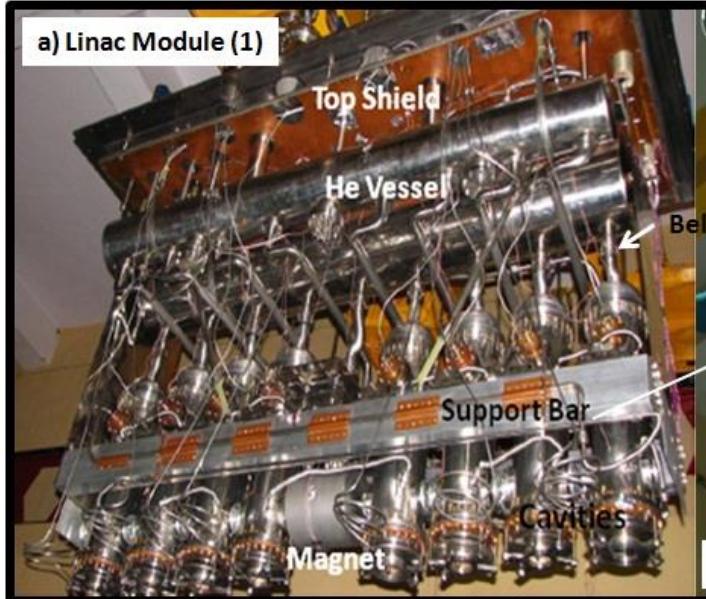


MAIN CRYOMODULES

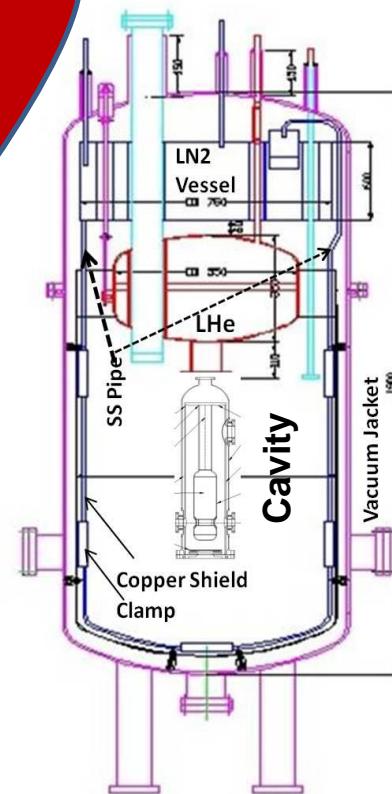


1. BEAM LINE & CRYOSTAT VACUUM COMMON. 10^{-8} TORR. NO MLI
2. 80 K THERMAL SHIELD BY LN2

LINAC CRYOMODULE



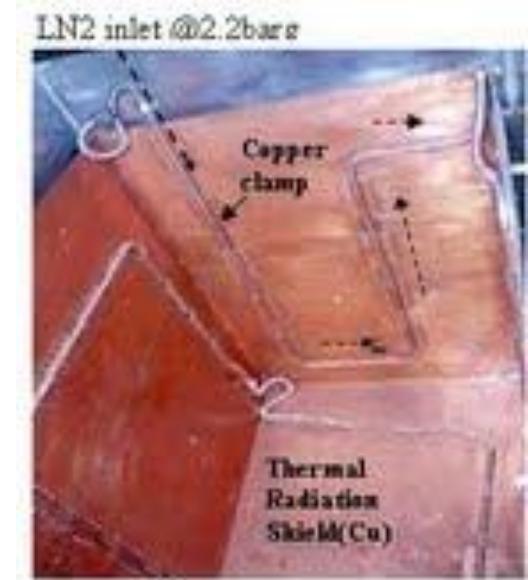
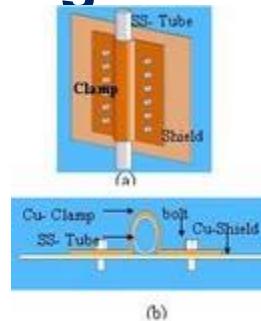
Superbuncher & Rebuncher
Cryomodule



80 K THERMAL SHIELD

1. Forced flow of Liquid nitrogen

Outlet Two Phase
Flow (Linac Cryostat)



2. Gravity (Thermo-siphon) flow

Optimized Use of
LN2 (Buncher)

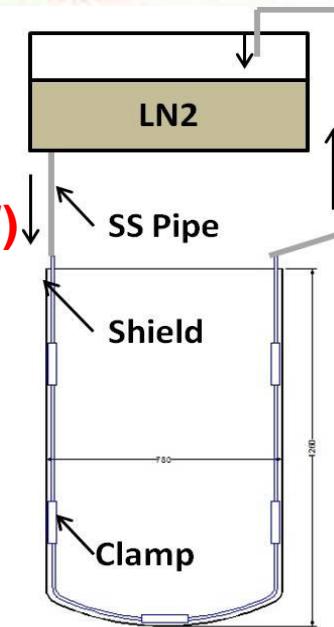
Contact Resistance (0.8 K/W)

$$T_S = T_f + Q \left(\frac{1}{h_{tot} A_C} + \frac{R_C}{N} \right)$$

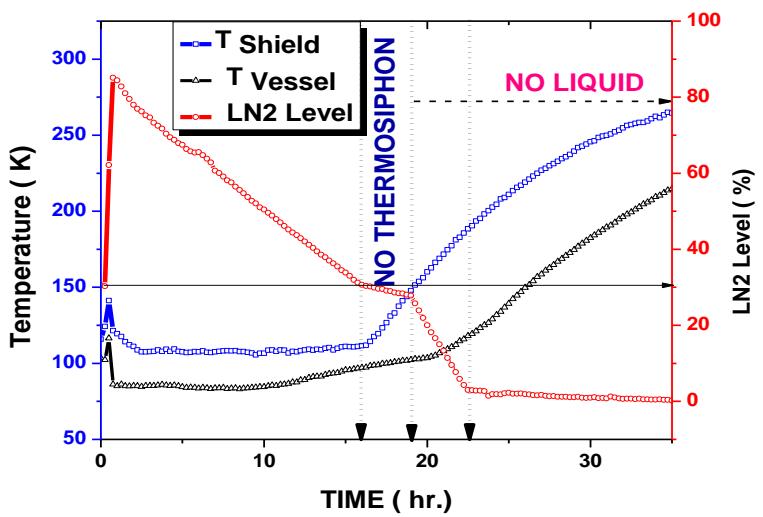
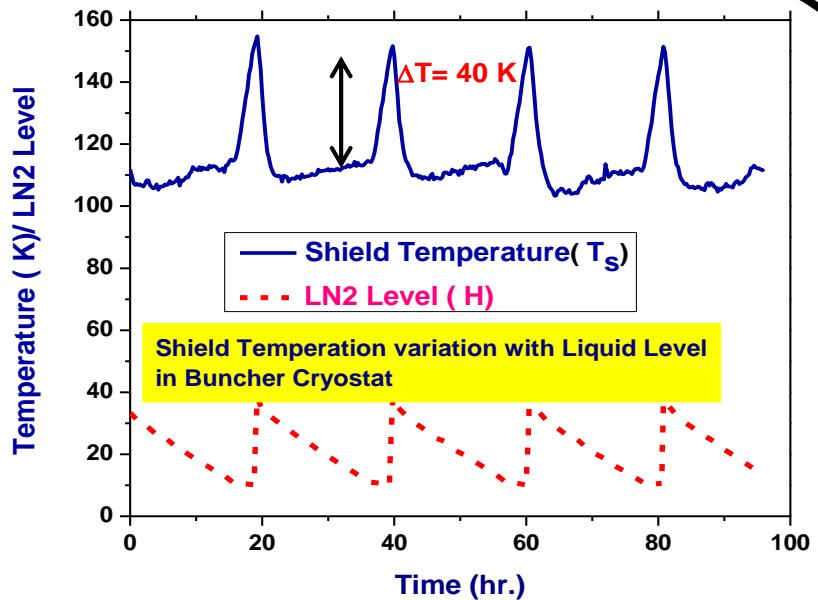
Shield Temp Fluid Temp (80K) Heat Load

$$= Sh_{nb} + Fh_{tp}$$

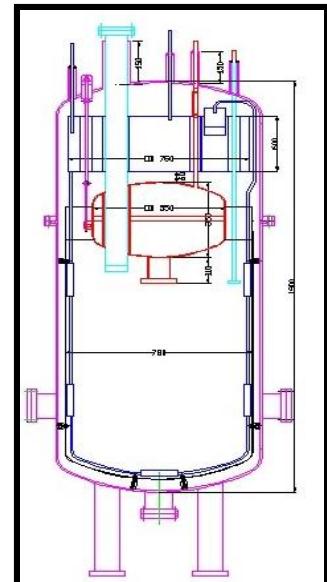
$f(m)$



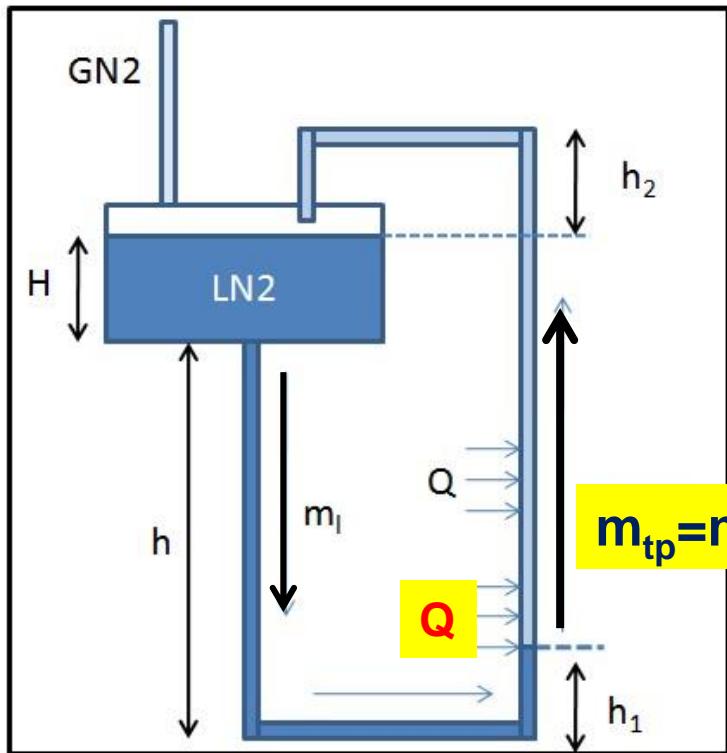
SHIELD PERFORMANCE OF BUNCHER



BUNCHER CRYOSTAT



THERMO SIPHON CALCULATION



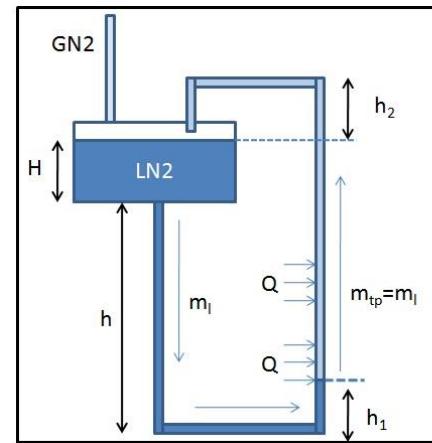
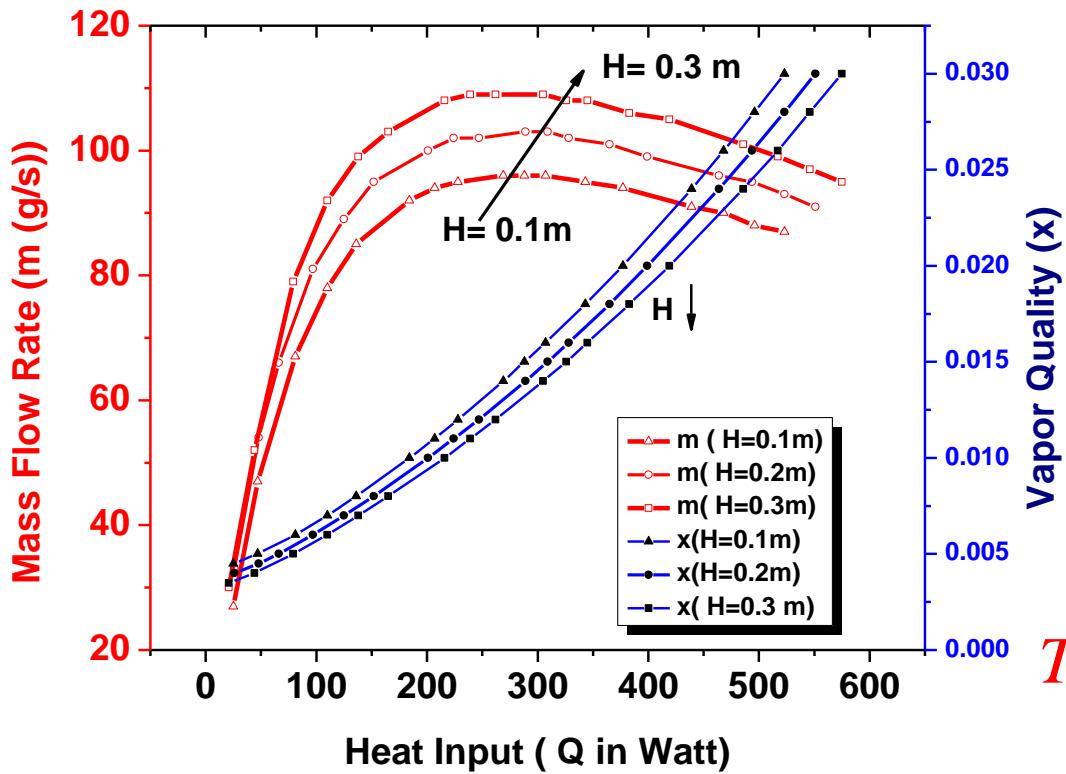
$$\Delta p_d = \Delta p_f + \Delta p_a$$

$$\Delta p_d = g(H + h - h_1)(\rho_l - \rho_{tp}) - gh_2\rho_{tp}$$

$$m \propto Q$$

$$g(H + h - h_1)(\rho_l - \rho_{tp}) - gh_2\rho_{tp} =$$

$$m^2 \left[(h + h_1 + L) \frac{f_l}{2A_c^2 D \rho_l} + (h - h_1 + h_2)(1-x)^{1.75} \phi_l^2 \frac{f_l}{2A_c^2 D \rho_l} + v_{fg} x \right]$$



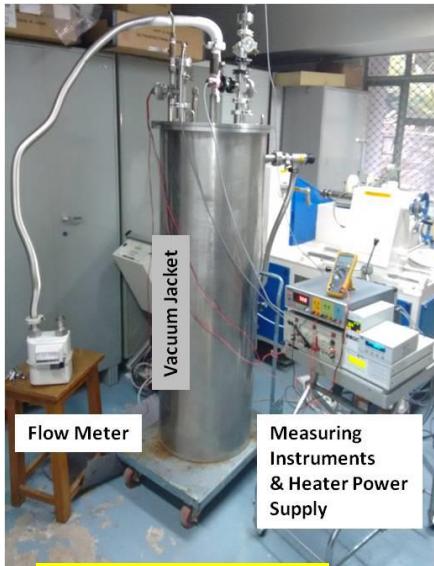
$$T_S = T_f + Q \left(\frac{1}{h_{tot} A_C} + \frac{R_C}{N} \right)$$

Superbuncher : Load is 100 W, Flow rate (m) of LN2 is very high and Convective resistance will be much less compared to Contact resistance

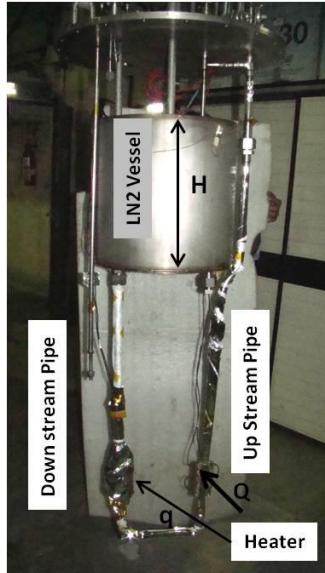
With liquid level (H) variation, mass flow rate (m) changes only 10 %, Practically T_s should not change with level. But T_s with level (H) is noticed in superbuncher !!!

What is the reason ??

Thermo- Siphon Experimental set up was developed

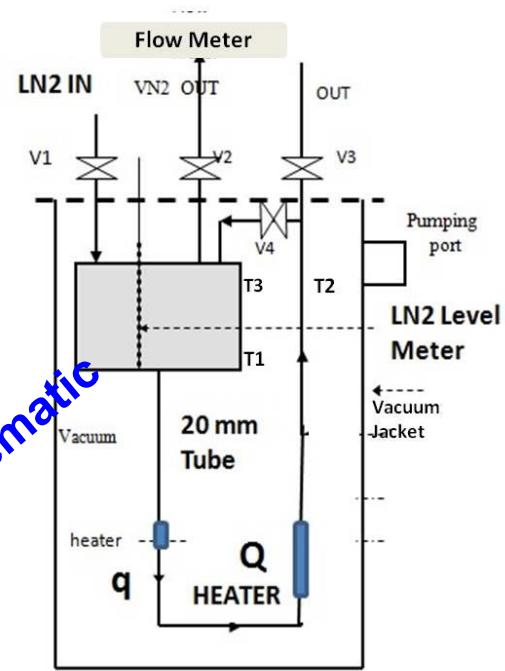


Expt. Set Up



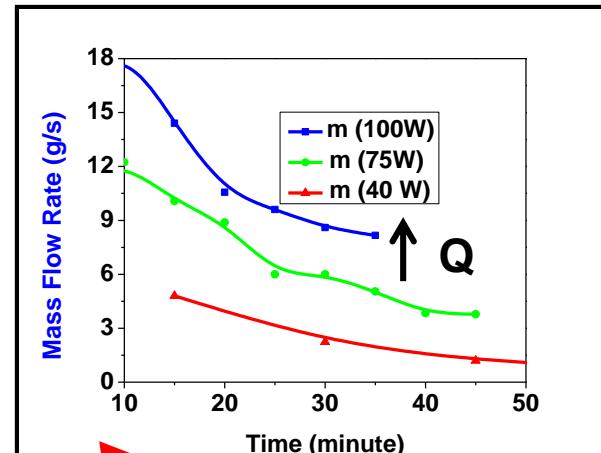
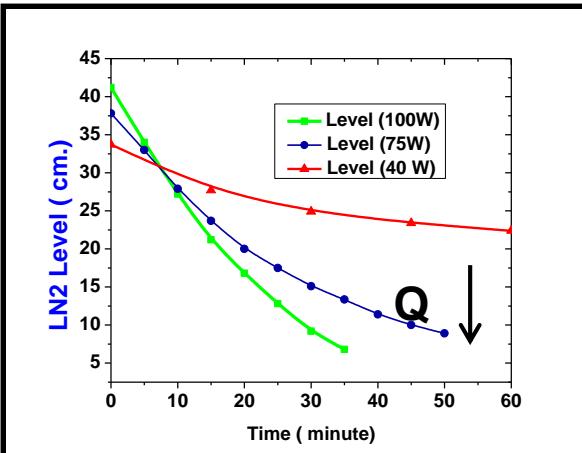
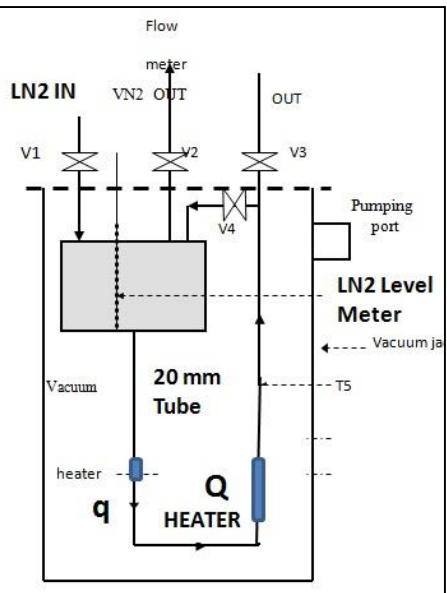
Inside Assembly

Flow Schematic



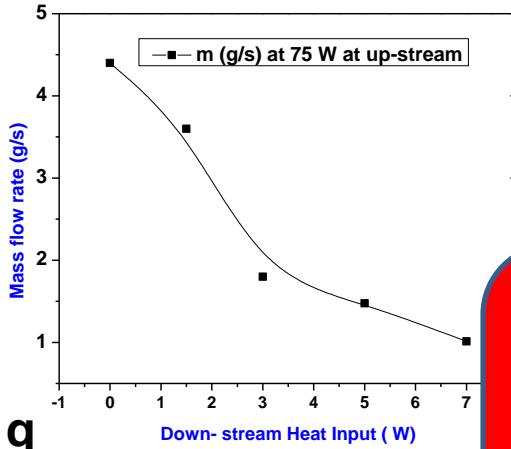
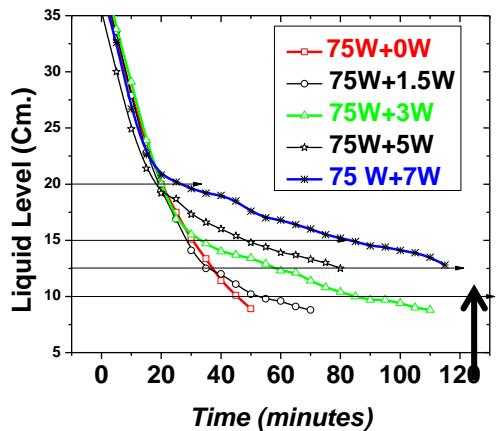
1. On line Venturi flow meter did not work. Mass flow rate was measured indirectly by LN2 level meter
2. Normal evaporation rate and any change of flow rate was measured by Dry Gas Flow meter
3. Temperature was recorded by DT 470 sensor
4. Heater power (6 & 4 ohm) varied by two independent power supply

THERMO-SIPHON EXPT. SET UP



Q = 40- 75- 100W, q = 0 W

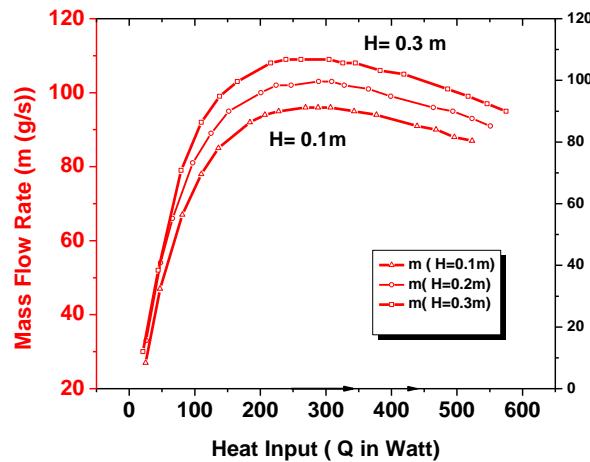
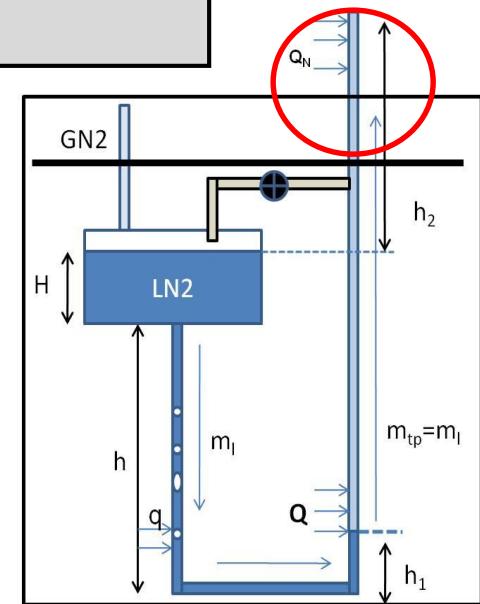
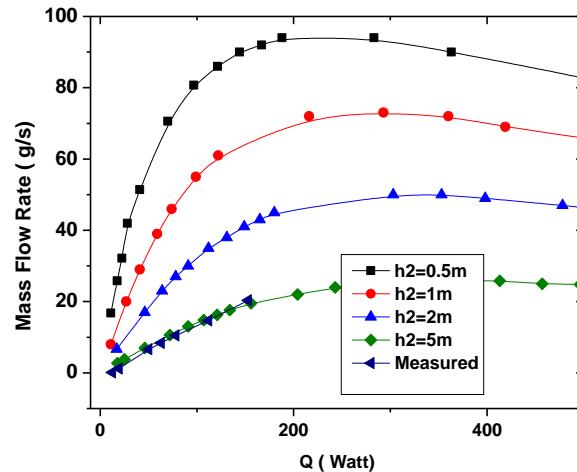
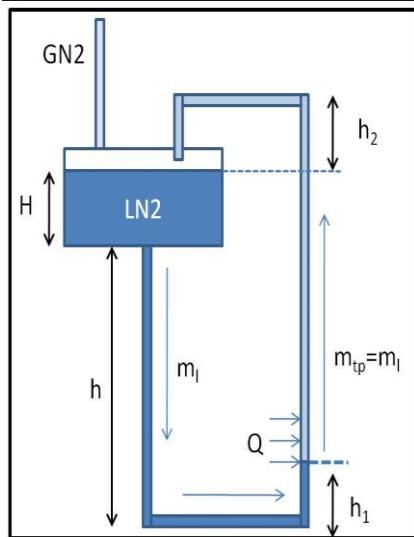
**Q = 75 W
q = 0 -3 -5 -7 W**



Observation

1. Mass flow rate (m) is much less than theoretical value
2. Heat load (q) on Down – stream pipe have significant effect on m

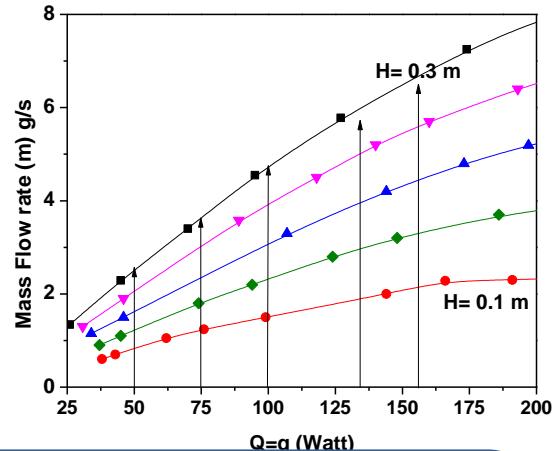
Analysis : Measured Mass flow rate (m) is much less compared to theoretical value



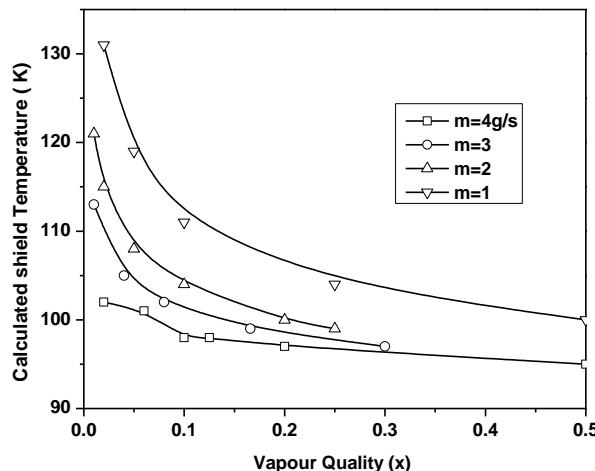
Reason

1. Quality changes and hence pressure drop in the pipe after the top plate
2. Some minor amount of heat load (q) on upstream, driving force is reduced because of low density
3. Measured Value matches with $h_2=5\text{m}$

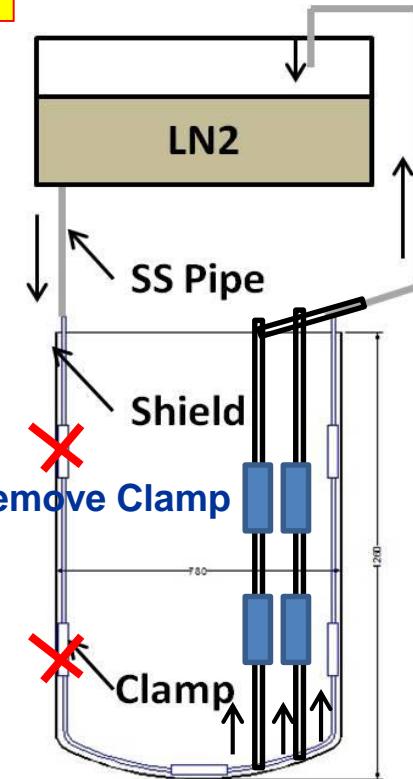
Analysis of Shield Temperature



Mass flow rate with $h_2 = 5\text{ m}$ and equal heat load $Q=q$ shows a variation from 4 to less than 1 g/s with LN2 level



Two phase flow will be in the annular zone and convective two phase (h_{tp}) heat transfer coefficient play a role



Conclusion

1. Down-stream minor heat load have significant effect reduction on thermo siphon mass flow rate and hence thermal efficiency of the shield
2. Modified design with the repositioning of the clamps will improve



ICEC 26 - ICMC 2016

March 7-11, 2016

Manekshaw Centre, New Delhi, India

Thank You



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Abstract submission open : August 17, 2015

Contact : secretariat@icec26-icmc2016.org

