A Review Paper on Heat Exchanger with Liquid Helium Chamber for Cooling Of Supercritical Helium

Hardik K Vaghasia[1] A. K. Sahu[2] J. M. Patel[3]
[1]M.E. Student [2]Devision Head, LCPC (Scientist-Engineer SF) [3]Associate Professor
[1,3]Department of Mechanical Engineering
[1,3]L.D. College of engineering, Ahmedabad [2]Institute for Plasma Research, Bhat, Gandhinagar

Abstract— The Proposed indigenous helium plant will have mixed mode operation (simultaneous operation as liquefier and as refrigerator) provision having equivalent 2 KW refrigeration at 4.5 K at IPR. there will be a liquid helium chamber will contain a heat exchanger to cool the supercritical helium from about 6 K to 4.8 K. this project will involve the design and optimization of this LHE chamber and internal component of it.this vacuum chamber of cold box will be a horizontal cylinder with tentative diameter of 2.5 m and length 7 m. This vacuum chamber will contain many cold component to produce liquid helium. A part of the flow will be taken to the LHe chamber though J-T valve to produce liquid helium and cool the supercritical helium coming out of the cold circulator using heat exchanger. This cold circulator (CC) will circulate helium in closed loop within the cold box. This CC will provide 300 g/s supercritical helium flow at 4 bar pressure and 6 K temperature. The heat energy going to the supercritical helium due to pumping work and external heat load of the CC need to be removed by heat exchanger contained in liquid helium chamber. The vapour from the chamber will return to the low pressure cold return line passing though the heat exchanger of the main cycle of the helium plant. As this chamber will be within the vacuum vessel, its size has to be minimized considering the size of the heat requirement of operation of helium plant when external helium Dewar is not available, in which this internal LHe chamber will be used to produce liquid helium for performance test of helium plant. This project will involve design and analysis taking into account of manufacturing assembly and maintained aspect and different off-normal condition.

Key words: Stainless Steel, Fiberglass, liquid helium chamber

I. INTRODUCTION

The supercritical helium used in the superconducting elements because of it easy handling. So it gains the heat from the heat reservoir.

So cooling of the supercritical helium is important. This is done by heat exchanger in a liquid helium chamber.

Here the supercritical helium cooled by liquid helium bath and goes to the application when needed. Cold circulator circulates the supercritical helium at 4 bar pressure and 6 k temperature. The liquid helium boils up due to the heating load of supercritical helium

The liquid helium chamber acts as the heat transforming media in which 4.5 k temperature is maintained. The generated helium vapour goes to the main circuit of the system where it is used for further cooling of the incoming helium gas

So heat exchanger design is important for cooling with liquid helium chamber so optimum design is used and maximum utilisation of space is used in liquid helium bath.

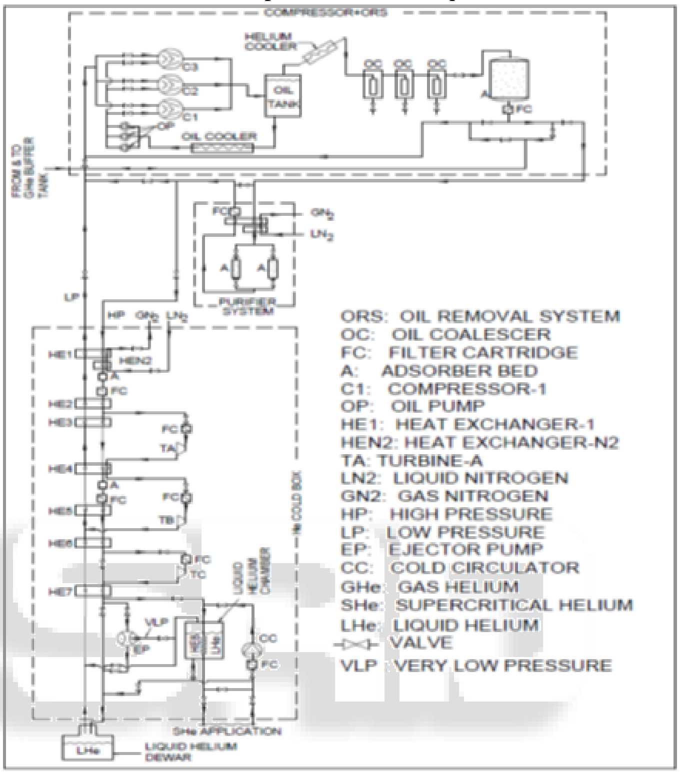


Fig. 1: helium liquefaction plant

In shown fig, helium liquification plant constructed at ipr. There is the compressor and the all the heat exchanger for liquification of helium.

It is shown that the design of heat exchanger insude the liquid helium chamber is important due to the various aspect of mode.

Cold circulater will circulate the supercritical helium so the mass flow rate coming into the heat exchanger is very high.then return stream is going to the all the heat exchanger where it is used for incoming stream coming in the heat exchanger

II. LIQUID HELIUM CHAMBER

Cryogenic storage Dewar's are specialised types of vacuum flask used for storing cryogens (such as liquid nitrogen or liquid helium), whose boiling points are much lower than room temperature. Cryogenic storage Dewar's may take several different forms including open buckets, flasks with loose-fitting stoppers and self-pressurising tanks. All dewars have walls constructed from two or more layers, with a high vacuum maintained between the layers. This provides very good thermal insulation between the interior and exterior of the Dewar, which reduces the rate at which the contents boils away. Precautions are taken in the design of Dewars to safely manage the gas which is released as the liquid slowly boils. The simplest Dewars allow the gas to escape either through an open top or past a loose-fitting stopper to prevent the risk of explosion. More sophisticated dewars trap the gas above the liquid, and hold it at high pressure. This increases the boiling point of the liquid, allowing it to be stored for extended periods. Excessive vapour pressure is released automatically through safety valves. The method of decanting liquid from a Dewar depends upon its design. Simple Dewars may be tilted, to pour liquid from the neck. Self-pressurising designs use the gas pressure in the top of the Dewar to force the liquid upward through a pipe leading to the neck.

A. *Material:*

1) Stainless Steel: All welded construction, very rugged and highly polished for great looks.
2) Aluminium Fiberglass: Vapour shielded aluminium fiberglass is the most popular style for bucket Dewars. This style Dewar fills fastest and requires no liquid nitrogen maintenance. 'Belly' options are available to increase the liquid helium volume. The epoxy fiberglass necks have helium gas diffusion barriers. The highest efficiency is obtained by a combination of 'hard' shields and multiple 'soft' shields, located in the insulating vacuum space.
3) Fiberglass: Constructed from all G-10 (Epoxy Fiberglass), this liquid helium dewar design uses no metal or metal vapor barriers.

III. TYPES OF DEWAR

A. *N2 Reservoir LHe Chamber:*

In this type of Dewar outside LN2 bath is present in the Dewar. So the heat in leak is minimized in dewar.multi-layer insulation is used in the Dewar. The LN2 is surrounded by the outer insulation which have low thermal conductivity material at temperature and inner insulation is also provide for less heat in leak in the system

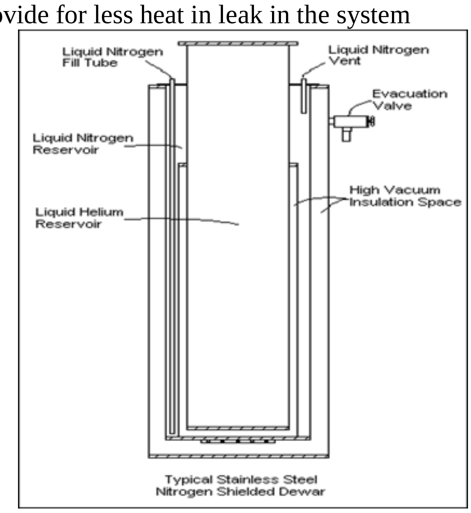


Fig. 2: LN2 Cooled Vessel

B. *Vapour Shielded LHe Dewar:*

This type of Dewar is generally not required the nitrogen. But between the two insulation the vacuum jacket is provided for the heat loss generated into the vessel.

Fig show the vapour shielded vessel. Different type of material generally use for the different types of application and the temperature

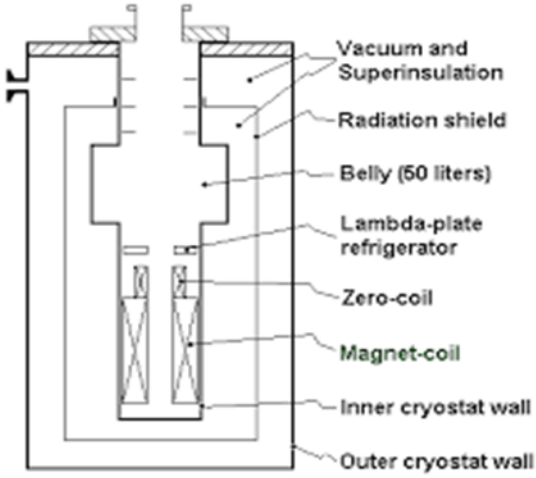
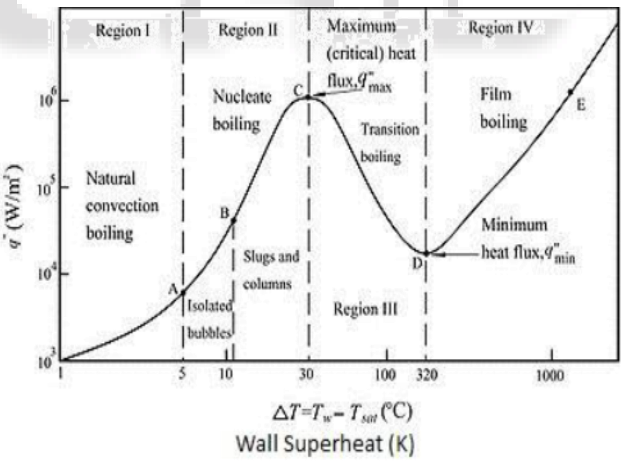


Fig. 3: vapour shielded vessel

IV. LITERATURE REVIEW

A. *Pool Boiling*

The most important features of pool boiling heat transfer are its characteristic pool boiling curve, the heat transfer mechanisms responsible for removing heat from the heated boiling surface, nucleate pool boiling correlations for predicting heat transfer coefficients and the maximum feasible nucleate pool boiling heat flux [3]. This diagram was first presented by Nukiyama (1934) and is often referred to as Nukiyama's curve. It is more common nowadays to plot the wall heat



Mostinski Correlation. Mostinski (1963) ignored surface effects and applied the principle of corresponding states to nucleate pool boiling heat transfer, correlating data as a function of the reduced pressure of the fluid Pf-red and its critical pressure Pcritical. His dimensional reduced pressure correlation gives αnb in W/m2K as:

$$\alpha_{nb} = 0.00417 q^{0.7} P_{crt}^{0.69}$$

The correlation must be used with q in W/m2 and pcrit in kN/m2 (i.e. in kPa, not in N/m2).This Correlation gives reasonable results for a wide range of fluids and reduced pressures.

REFERENCES

[1] Rajput R.K, Heat and Mass Transfer, Revised Edition (2006), S.Chand & Company Ltd, pp.563
[2] Barron RF, Cryogenic Heat Transfer, 1st Edition, Taylor & Francis Publishing Company (1999), pp.1, 265, 296-304, 366
[3] Barron RF, Cryogenics Systems. Second Edition Oxford University Press, Oxford (1985), pp.127, 44, 47,212-217, 93, 85, 86, 109,13-21
[4] Graham Walker, Cryocoolers, Parts-1: Fundamentals, Plenum press, New York and London, Chapter: 6, pp.267
[5] A. Arkharov, Ye. Mikolin, Theory and design of cryogenic systems, Chapter: 5, pp.178
[6] Graham Walker, Cryocoolers, Parts-2: Applications, Plenum press, New York and London, Chapter: 8, pp.1, 4-13, 30-32, 54
[7] Kays W.M. & London A.L, Compact Heat Exchangers, Third Edition, McGraw-Hill Book Company-New York, pp.11,24,16-19, 43, 44, 63,70,109
[8] Shah R.K. & Sekulic D.P., Fundamentals of Heat Exchanger Design, John Wiley & Sons, New Jersey, pp.100,114-121, 381, 400, 418, 419, 475