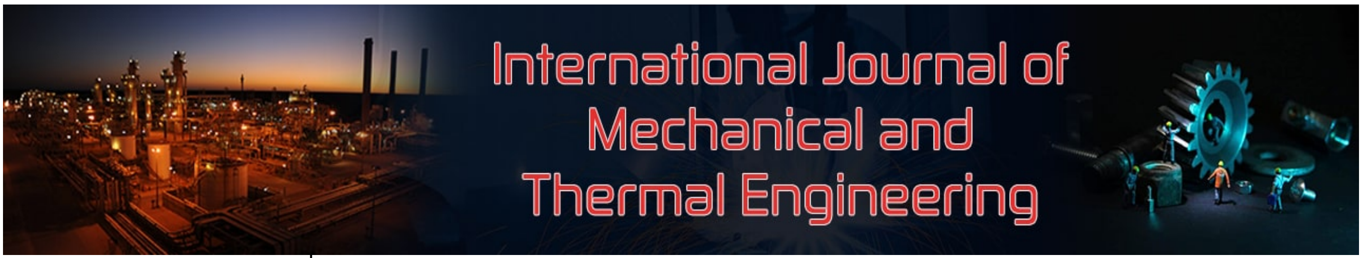

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Shrabani Ghosh
Centre for Rural andCryogenic Technologies, Jadavpur University, West Bengal, India

Swapan C Sarkar
Centre for Rural and Cryogenic Technologies, Jadavpur University, West Bengal, India

Corresponding Author:
Swapan C Sarkar
Centre for Rural and Cryogenic Technologies, Jadavpur University, West Bengal, India

Efficiency evaluation of a laboratory scale cryogenic Dewar through evaporation loss

Shrabani Ghosh and Swapan C Sarkar

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Abstract
Heat is transferred across the annular space of a vacuum-insulated cryogenic vessel by radiation from the hot outer jacket to the cold inner vessel and by gaseous conduction through the residual gas within the annular space. Hence to minimize gaseous conduction, the annular space is degassed at an elevated temperature during the evacuation, and a very high vacuum (10^{-6}Torr) is maintained. The inner vessel is further wrapped with several layers of radiation shields resulting in a Multilayer insulation system which is the most effective thermal insulation for cryogenic storage vessels.

The effectiveness of cryogenic insulation of a cryo container is more often judged by the evaporation rate of the cryogen.

In this regard, static evaporation losses of liquid nitrogen from a small indigenously built Cryocan Dewar with respect to time by using a continuous weight loss method are presented. The results are encouraging.

Keywords: Cryogenics, thermal insulation, evaporation, liquid nitrogen

Introduction

The various types of insulation used in this storage and transfer of cryogenic liquid can be conveniently subdivided into five categories: vacuum, multi-layer insulation, powder and fibrous insulation, foam insulation, and special-purpose insulation. Thermal insulation is the most vital factor in the design of any cryogenic system to prevent all possible modes of heat leak and to control the rate of evaporation [1-2].

Sources of heat leakage into inner vessels are due to

a) Conduction through neck and inner vessel supports
b) Convection and conduction from annular residual gas in the vacuum interspace.
c) Radiation through walls.
d) Direct gas convection, and radiation through the mouth opening

Minimization of these sources of heat in leak into the systems gives minimum evaporation loss of cryogen during storage In the present case, super insulation i.e., several layers of aluminized mylar with 12-micron thickness is used as a reflecting shield along with a vacuum in the annular space to reduce the rate of evaporation. Measurement of loss of cryogen from the Dewar is an indication of the efficiency of the storage vessel [3-4].

Materials and Methods

Description of indigenously built cryo can

For large vessels, 9% nickel steels are commonly used with higher boiling cryogens (T_b > 75K), whereas aluminum and austenitic steels can safely be used over the entire range of liquid temperatures. The thickness of the inner shell should be made as thin as practically possible and is only designed to withstand the maximum internal pressure which reduces cool-down time and lowers the cost of cooling down of the container. Stiffening rings attached to the inner vessels are designed to support the fluid’s weight. The inner shell thickness is designed as per ASME Section-VII.

The thickness of the outer shell of a storage vessel has to be designed to take care of the collapsing of the outer vessel shell due to the existing atmospheric pressure exerted on the outside of the outer shell and the vacuum provided on the annular space between the outer shell and inner shell. The failure mechanism has been incorporated also in the ASME Codes section-VIII based on the necessary calculation of a collapsing or critical pressure for various outer vessel designs. Based on these design considerations, a 3-liter cryocan has been indigenously built using stainless steel - 304 grade both for the outer and inner vessel. A tube made of Glass-fiber reinforced –polymer composite is used for its neck. The inner vessel is wrapped with several layers of Aluminized Mylar as radiation shields and the annular space is vacuum is reached of the order of 10^{-6} Torr.

The developed cryo can in weighing condition is shown in figure -1.

Fig 1: a). Developed a 3litre cryogenic container hanging from a weighing machine and (b) a pictorial view of an inner vessel with radiation shields of the cryo can

Experimental method

The weight of the empty container it first taken by hanging it from the weight-measuring instrument. It is then filled with liquid nitrogen (3 liters) and again the weight is taken [5-6]. The weight of the filled container and the corresponding time are noted. The filled container is retained in hanging condition and continuously the weight of the liquid nitrogen container at different time intervals is monitored. The results are shown in table-1.

Table 1: Evaporation rate of an indigenously developed cryogenic container

Weighing of the Cryocan at different duration	Time(hr)	Weight(kg)	Loss of Cryogen(kg)
Weight of the empty vessel (kg.)	00	3.53	00
Weight of the vessel filled with 3 liter liquid nitrogen	00	5.92	00
Weight of the vessel filled with 3 liter liquid nitrogen (after 12 Hour)	12	5.61	0.31
Weight of the vessel filled with 3 liter liquid nitrogen (after 24 Hour)	24	5.20	0.72
Weight of the vessel filled with 3 liter liquid nitrogen (after 36 Hour)	36	4.92	1.02
Weight of the vessel filled with 3 liter liquid nitrogen (after 48 Hour)	48	4.63	1.31
Weight of the vessel filled with 3 liter liquid nitrogen (after 60 Hour)	60	4.34	1.61
Weight of the vessel filled with 3 liter liquid nitrogen (after 72 Hour)	72	4.01	1.94
Weight of the vessel filled with 3 liter liquid nitrogen (after 84 Hour)	84	3.79	2.16
Weight of the vessel filled with 3 liter liquid nitrogen (after 96 Hour)	96	3.56	2.39

Results and Discussion

The efficiency of a cryo container in retaining cryogen at atmospheric pressure can be evaluated by the evaporation rate of the cryogen [7-10]. Therefore, static evaporation losses of liquid nitrogen from a small indigenously built Cryocan Dewar with respect to time by using the continuous weight loss method is presented in table-1.

The weight of the three-liter liquid nitrogen is computed to be 2.4 kg as its density is 0.8 kg/liter. From the experimental results, we found that the weight of the empty dewar is 3.53 kg and the weight of the filled cryocan is 5.92 kg from which the weight of 3 liter liquid nitrogen comes to around 2.39 kg which corroborates the weight calculated based on the density method. It is found that the entire cryogen is evaporated after 96 hours.

Conclusion
The analytical and experimental studies on the rate of evaporation of liquid nitrogen lead to the following conclusions. The liquid nitrogen holding time for the cryo container is 96 hours which is equivalent to an evaporation rate of 0.75 litre /day (25%). It may be interpreted that there will be a further increase in the thermal storage efficiency of cryocan by monitoring the multilayer insulation system along with the vacuum. So, the Dewar developed at this stage can be used comfortably as a medium-performance cryocan for laboratory purposes.

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