Experimental Thermal and Fluid Science 35 (2011) 311–318

Contents lists available at ScienceDirect

Experimental Thermal and Fluid Science

journal homepage: www.elsevier.com/locate/etfs

Performance comparison between no-vent and vented fills in vertical thermal-insulated cryogenic cylinders

Caili Wang, Yang Li, Rongshun Wang *

Institute of Refrigeration and Cryogenic Engineering, Shanghai Jiaotong University, 800, Dongchuan Road, Shanghai 200240, PR China

ARTICLE INFO

Article history:
Received 5 April 2009
Received in revised form 22 August 2010
Accepted 28 September 2010

Keywords:
Vented fill
No-vent fill
Performance comparison
Temperature distribution
Pressure

ABSTRACT

Vented and no-vent fills are two main techniques applied in cryogenic fields for different purposes. No-vent fills are promising for dangerous or precious cryogens, especially in a low-g environment. This paper is to present the comparative results of both pressure and temperature in the vented and no-vent fills for a 180-L cryogenic cylinder. Emphases are laid on the analysis of temperature distribution of cryogens and wall temperature, and analysis of comparison between incoming temperature, saturation temperature and bulk temperature. By test comparison of vented and no-vent fills, different thermodynamic states in the receiver tanks with different filling configurations are revealed. The experimental data are provided as supports of valid assumptions and are useful for modification of models.

1. Introduction

It is challenging to fill tanks with cryogens, not only because of the special characteristics of cryogens but also due to the surrounding constraints in working atmosphere. To maintain low tank pressure and steady inflow rate during a fill in a normal gravity environment, a top vent is kept open to vent the vapor generated during the filling process, which is called as the vented fill. As a conventional method for filling, vented fill is widely applied in industrial applications. However, if it is used in outer space, the vapor may not vent since the position of the vent opening relative to the vapor cannot be predicted [1,2]. In addition, most of the cryogens are either dangerous or rare. For liquid hydrogen (LH_2) and liquid natural gas (LNG), serious leakage from vessels or pipes into air can cause a big fire or explosion even with a subtle sparkle. For liquid oxygen (LO_2), liquid helium (LHe) and liquid argon (LAr), it is costly to purify and liquefy such precious cryogenic resource, which means that the mass loss of such cryogens caused by vented fills leads to great economic loss. Consequently, as a promising technology, no-vent fill has been a research focus in the field of cryogenic fuel resupply system and transportation of cryogens.

Many researchers undertook an effort to obtain experimental data on the no-vent fill process for ground-based configurations [3,4]. Test tanks of different size were constructed to examine the feasibility of no-vent fills and to investigate the influencing factors such as tank dimensions and inflow rate in NASA Lewis Research Center [5]. Results of the performance testing with 5 m^3, 2 m^3 and 0.143 m^3 tanks were respectively reported in Chato [6–8]. Results of the 34-L test tank were summarized in Moran et al. [9]. Different filling configurations were examined and modified for years [10–12].

Based on the experimental analysis, several models were established to predict the thermodynamic state in the receiver tank during the filling process. Fester et al. [13] assumed that there existed temperature difference between the bulk liquid and the ullage space, but each was uniform in temperature. Vaughan [14] complicatedly divided the whole research system into seven sections to study the filling process, while Fite divided the tank system into four lumps in his model [15]. Tayor and Chato [16] adopted thermodynamic equilibrium correlations to solve the problem of heat and mass transfer. Some models were compared with their own data and showed that overestimation of pressure occurred especially in the stage of first pressure rise.

Within the existing literature, the radial temperature distribution in the receiver tank was not typically reported, and most of the models assumed a uniform temperature in radial direction [17]. Former experiments laid emphasis on the pressure history in the receiver tanks and showed less attention to temperature distribution which is another key thermodynamic parameter for the establishment of models. In this paper, pressure and temperature tests of no-vent fills have been conducted and compared with the vented ones in a cryogenic thermal-insulated cylinder with a volume of 180 L. The inner wall temperature and temperature distribution at different directions in the receiver tanks are analyzed

* Corresponding author. Tel./fax: +86 21 34206055.
E-mail address: rswang@sjtu.edu.cn (R. Wang).

0894-1777/$ - see front matter © 2010 Elsevier Inc. All rights reserved.
doi:10.1016/j.expthermflusci.2010.09.013