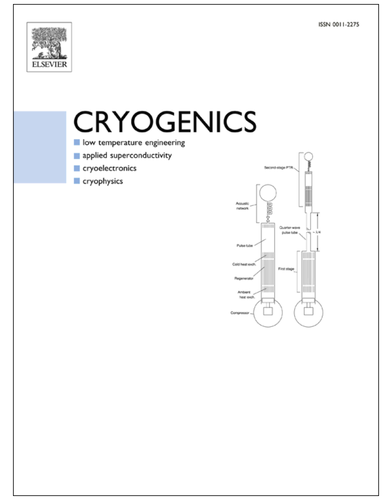
Accepted Manuscript



Characterisation and optimisation of flexible transfer lines for liquid helium. Part II: Thermohydraulic modelling

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PII: S0011-2275(16)30079-0
DOI: http://dx.doi.org/10.1016/j.cryogenics.2016.07.014
Reference: JCRY 2611

To appear in: *Cryogenics*

Received Date: 14 April 2016
Revised Date: 26 July 2016
Accepted Date: 29 July 2016

Please cite this article as: Dittmar, N., Haberstroh, Ch., Hesse, U., Krzyzowski, M., Characterisation and optimisation of flexible transfer lines for liquid helium. Part II: Thermohydraulic modelling, *Cryogenics* (2016), doi: http://dx.doi.org/10.1016/j.cryogenics.2016.07.014

Characterisation and optimisation of flexible transfer lines for liquid helium. Part II: Thermohydraulic modelling

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Abstract

In part one of this publication experimental results for a single-channel transfer line used at liquid helium (LHe) decant stations are presented. The transfer of LHe into mobile dewars is an unavoidable process since the places of storage and usage are generally located apart from each other. The experimental results have shown that reasonable amounts of LHe evaporate due to heat leak and pressure drop. Thus, generated helium cold gas has to be collected and reliquefied, demanding a huge amount of electrical energy. Although this transfer process is common in cryogenic laboratories, no existing code could be found to model it. Therefore, a thermohydraulic model has been developed to model the LHe flow at operating conditions using published heat transfer and pressure drop correlations. This paper covers the basic equations used to calculate heat transfer and pressure drop, as well as the validation of the thermohydraulic code, and its application within the optimisation process. The final transfer line design features reduced heat leak and pressure drop values based on a combined measurement and modeling campaign in the range of $0.112 < p_{in} < 0.148$ MPa, $190 < G < 450$ kg/(m^2 s), and $0.04 < x_{out} < 0.12$.

Keywords: liquid helium, cryogenic transfer line, cryogenic heat transfer, two-phase pressure drop

2010 MSC: 00-01, 99-00

1. Introduction

Single-channel flexible transfer lines without an active shield cooling are widely used at small- to mid-scaled helium liquefiers to transfer liquid helium (LHe) into mobile dewars. Since the liquefaction is characterised by a specific energy demand of 2.0 to 4.5 kWh$_{el}$/l$_{LHe}$, reduced transfer losses increase the capacity and efficiency of the whole liquefaction system. In order to optimise the transfer line design a thermohydraulic code has been developed and validated by a thorough measurement campaign (see part one of this publication [1]).

The thermohydraulic code had to be developed since published codes, like [2; 3], only cover the case of rigid transfer lines that are barely used at LHe decant stations. The developed code is based on fundamental equations of heat and mass transfer. Equations of cryogenic heat transfer by conduction, radiation, single-phase convection and flow boiling are taken from [4]. The heat transfer through the multi-layer insulation (MLI) is difficult to calculate accurately. This is especially true for the used single-aluminized Mylar foil which is hand-wrapped on the process line. Nevertheless, an equation published in [5] is used to examine the influence of the insulation design on

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