TWO-PHASE CHOKED FLOW IN TUBES WITH VERY LARGE L/D

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INTRODUCTION

Currently, the shuttle engine turbopump is required to boost propellant pressures to 30 MPa with proposed second-generation engines requiring propellants to be delivered at pressures to 50 MPa. The problem of fluid leaking past the sealing surfaces in rotating machinery is compounded with cryogenics, high pressure, large temperature gradients, very high speeds of rotation, and static seal requirements. At lower pressure and rotation speeds, self-energizing pumping seals with very close clearances have been successfully employed in a variety of sealing applications [1]. These seals frequently have very large length-to-hydraulic diameter ratio (L/D) passages. At the proposed operating pressures, design innovations to minimize losses are required, but choked flow data and models to make such calculations are lacking. A similar problem occurs in very long cryogenic transmission lines.

Most two-phase choked-flow data reported in the literature are from experimental devices with low L/D sections with little attention given to large L/D lines. The literature has been well surveyed by others [2-4]. In previous experiments, the authors have studied two-phase choked flows in a variety of geometries [5-11] including the orifice as a limiting case. Other studies [12-16] have considered short tubes; in general for L/D < 3 short tubes behave much like the orifice and the effects of friction may be neglected. For larger L/D the effects of friction become increasingly important in determining the limiting mass flow rate and pressure drop. The question of two-phase choked flows in large L/D tubes does not seem to have been resolved. Toward this end, experimental two-phase choked-flow data for fluid nitrogen in a tube of 16,200 L/D are presented herein.

These results should have several applications, including aerospace, aeronautical, and stationary engines where higher pressure components will be used to achieve higher efficiencies; high-operating-pressure evaporators, liquefiers, and condensers associated with the cryogenic and petrochemical industries and geothermal power production pipelines for transmission of energy/power. In addition the results should be an aid in defining the ultimate cooling capacity of a fluid in a heat exchange device; and an aid in defining the nature of metastability and reasonable boundaries for metastable operation.
DESCRIPTION OF THE APPARATUS AND PROCEDURE

The flow system (Fig. 1) is essentially that of Hendricks et al.\textsuperscript{[17]} but modified for the present test. The test section was a coil which normally served as a heat shield for other test sections. By a fairly easy rearrangement of the piping the flow could be diverted through the coil.

The 16,200-L/D test apparatus was made by winding a coil of 54 turns of 0.64 cm OD by 0.48 cm ID copper tubing on a 45.7-cm-diameter drum, yielding a 78.3-m tube length. Coil spacing is maintained at 0.64 cm by three Bakelite strips which also support the coil. The exterior of the coil was covered with 1.25 cm of multilayer insulation and, as shown in Fig. 1, the entire apparatus was located in an evacuated environment.

The pressure taps were fabricated from 0.32-cm-diameter tubing silver-soldered to the tube along the inner surface of the coil at 10-coil intervals except for the last tap. The axial distance between static pressure measurements is given in Table I in terms of $L/D$ with the first location on the tube taken as zero.

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![Fig. 1. Schematic of test installation.](image-url)