Pipe Flow Characteristics of Alternative Agent/Nitrogen Mixtures*

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ABSTRACT

The evaluation of alternative agents for application in engine nacelle fire protection includes delivery efficiency of agent from a remote storage bottle through piping to the nacelle injection location. Present military requirements for halon systems specify a maximum discharge time from the remote bottle to the injection location of 1 second. A similar performance criterion for the replacement agent delivery will more than likely be required. The applicability of retro-fitting existing systems or optimal design of new systems necessitates a thorough understanding of the two-phase flow in piping. As part of the halon replacement project, an experimental pipe flow apparatus was constructed and is being used to examine alternative agent flow in various horizontal piping configurations and conditions. The selected agents for engine nacelle fire protection are CF_3I, HFC-227ea, and HFC-125. Halon 1301 is included in this study in order to establish a reference for comparison.

The experimental apparatus, shown in Fig. 1, consists of a 4.1 ℓ pressure vessel, a fast-opening valve connected to the bottom of the vessel, piping, agent recovery tanks, and nitrogen make-up tanks connected to the top of the pressure vessel and isolated by an electric solenoid valve. A test can be run either at constant head, where make-up nitrogen flows into the vessel during discharge to maintain the ullage pressure, or a standard test where no additional nitrogen is added to the ullage during discharge, as is the case for actual systems. Measurements include pipe and ullage pressure traces during discharge, and a limited number of high speed movies of the discharge viewed through a clear section of piping. Strain-gage type pressure transducers flush-mounted in the piping are used to record temporal pressure variation. An example of a pressure trace is shown in Fig. 2.

The effects of the initial vessel temperature, fill condition (amount of agent and nitrogen superpressurization), pipe diameter and length, and piping configuration are being studied.

A typical experiment consists of filling the pressure vessel with a known amount of agent to some fill condition (typically 1/2 or 2/3 filled); then nitrogen is added to the vessel from an access port in the fast-opening valve, allowing it to bubble through the liquid. The bubbling facilitates the dissolution of the nitrogen. If a constant-head test is to be run, the make-up tanks are pressurized slightly above the vessel pressure, and the valve from the make-up tanks to the vessel opens approximately 20 ms before the fast-opening valve to the piping. The contents from the pressure vessel flows through the piping to the recovery tanks (15 ℓ total volume) which are chilled with dry ice, allowing the agent to condense for reuse.

Tests performed with halon 1301 show the expected result that the pressure drop is non-linear; the pressure drop increases as the fluid travels down the piping. The pressure in the recovery tanks starts to increase almost as soon as the agent is released, and increases at an approximately constant rate until

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the pressure reaches the final value at the end of the test. The increasing pressure in the recovery tanks has no significant effect on the flow during the constant-head tests. After the pipe fills with agent, the pipe pressures remain constant until presumably the liquid runs out, in which case a steady mass flow rate can be estimated. The pressure drop for a given pipe length in the constant-head tests are equivalent to the pressure drop in the standard tests when the bottle pressures are equal. Therefore, for the most part, one can assume that the standard test proceeds in a quasi-steady manner.

Two-phase pipe flow characteristics for other agents and under various experimental conditions will be presented and discussed.

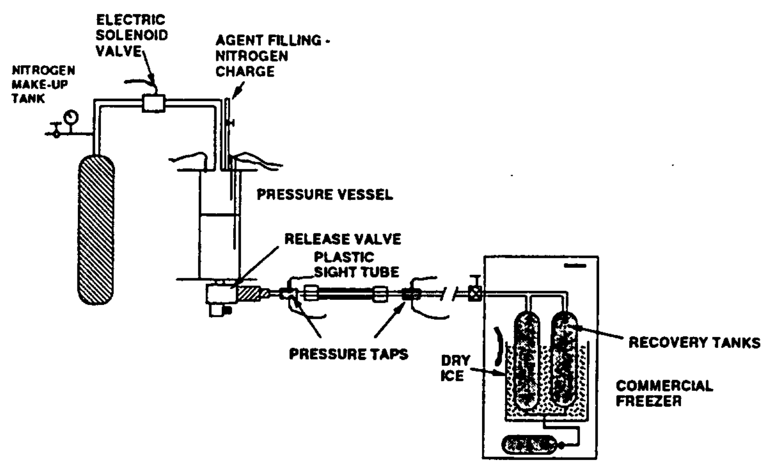

Figure 1. Schematic diagram of experimental apparatus.

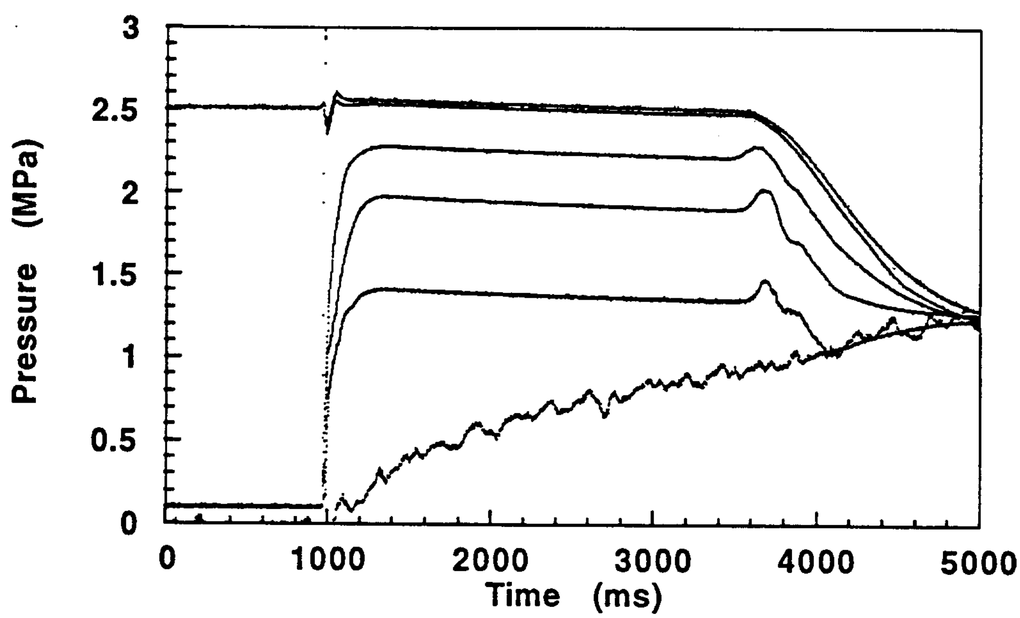

Figure 2. Pressure trace from a constant-head run with halon 1301 in 3 m of straight pipe, 95 mm in diameter. The top trace is the vesel ullage pressure, the next four traces are pipe pressure near the vessel exit then in 1 m increments, and the bottom trace is of the recovery tanks. The make-up tanks valve opened at 1 s, the vessel valve opened at 1.02 s and the make-up tanks valve closed at 3.5 s.