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LIQUID NEON HEAT TRANSFER AS APPLIED TO A 30 TESLA CRYOMAGNET

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INTRODUCTION

Superconducting magnets cooled by liquid helium are limited to magnetic fields of about 18 teslas. When higher fields are required for research into solid-state physics, other types of magnets must be used. The Lewis Research Center now has a liquid neon cooled 20 tesla magnet system, Refs. 1 and 2, that is being upgraded to reach steady-state fields of 30 teslas. This advance in magnet technology requires a new coil design and a change in the technique used for the cooling.

The 20 tesla magnet, cooled by natural convection pool boiling, had relatively large coolant passages (width = 0.762 cm, depth = 0.15 cm) to permit the vapor to escape through the coil windings. The magnetic field was heat transfer limited by the maximum heat flux that could be removed by pool boiling. The large size of the coolant channels also limited the total current density that could be achieved in the coil windings.

The 30 tesla magnet design calls for forced convection liquid neon heat transfer in small coolant channels (width = 0.445 cm, depth = 0.038 cm). Since these channels are too small to handle the vapor flow if the coolant were to boil, the design philosophy calls for suppressing boiling by subjecting the fluid to high pressures. The magnet coils will, therefore, be enclosed in a pressure vessel (fig. 1) maintained at about 27 bars which is the critical pressure of liquid neon. The high pressure on the liquid will also reduce the possibility of the occurrence of system flow instabilities that are more prevalent at low pressures.

The experimental program reported herein was initiated to support the design study for the 30 tesla magnet because liquid neon forced convection heat transfer data are not available In fact, very little neon heat transfer data have been obtained and they are for the boiling regime.

The forced convection heat transfer data presented herein were obtained by using a blowdown technique to force the fluid to flow vertically through a resistance heated, instrumented tube.

Apparatus and Operations

The joule heated inconel test section shown in Fig. 2 is 12.7 cm long by 0.198 cm I.D. and 0.256 cm O.D., with a resistance of approximately 0.063 ohms. An a.c. power supply provided up to 3 volts across the test section, for a maximum heat flux of 16.5 watt/cm^2. The 40 gage Chromel-Constantan thermocouples located at 2.54, 4.88, 7.23, and 10.8 cm from the lower heater flange (with lead wires wrapped around the test section) were referenced to the fluid temperature in the inlet mixing chamber. Platinum resistance thermometers measured the inlet and outlet temperatures, and mixing chamber pressure taps provided for pressure measurements

The flow rate was determined by using an orifice in conjunction with measurements of local temperature and pressure near the bottom of the liquid neon dewar.

Before using any of the liquid cryogens shown in Fig. 2, we took gaseous heat transfer data and compared it with heat transfer predictions from the Dittus-Boelter equation. When these results were within ±10 percent of the Dittus-Boelter equation, the system was considered operational. Prior to the initial transfer of liquid neon, the system, including the radiation shield, was precooled to approximately 25 K using liquid helium This minimized the neon boiloff losses during the initial transfer The pressurizing gas, either helium or neon, was precooled to approximately 80 K to reduce fluid heating.

The flow rates and desired pressure level were set using a combination of the flow control valve and the pressure control valve, Fig 2. These two valves in close proximity to the test section provide stable operation of the flow system.

Although the system vacuum often rose to 300 millitorr, the temperature difference between the test section and the radiation shield was always less than ±10 K, thus assuring minimal heat gain from external sources. Extraneous heat leaks make the attainment of good heat transfer data at low temperatures and small temperature differences difficult to achieve

Data and Results

Liquid neon forced convection heat transfer data were obtained at inlet temperatures between 28 to 34 K and system pressures between 28 to 29 bars. Fluid velocity was varied between 250 to 800 cm/sec and heat fluxes varied from 7.5 to 16.5 w/cm^2

The data are shown on Fig. 3 in the conventional manner, i.e., $Nusselt/(Prandtl)^{0.4}$ as a function of Reynolds number. The experimental data show reasonably good agreement with the Dittus-Boelter equation represented by the solid line. *

The amount of data scatter is modest considering the small (ΔT) existing between the tube wall and the bulk fluid. It should be emphasized that the data correlation is limited to a very narrow range of test conditions because these tests were designed to simulate the heat transfer characteristics in the coolant channels of the proposed 30 tesla cryomagnet. These results can, therefore, be applied directly to the design of the magnet system. Pool boiling heat transfer data already in the literature (ref. 3) will be used to design the heat exchangers (fig. 1) required to transfer the heat from the coolant loop to the liquid neon reservoir.

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*The small differences between the data obtained by pressurizing with helium or neon gas have not been resolved.

References

1. G. V. Brown and W. D Coles, 'High-Field Liquid-Neon-Cooled Electromagnets," in Advances in Cryogenic Engineering, Vol. II, Plenum Press, New York (1966), p. 638.
2. J. C Laurence, "High-Field Electromagnets at NASA Lewis Research Center," NASA Tech. Note TN D-4910 (November 1968).
3. J. M. Astruc and P. Perroud, "Étude des échanges thermiques dans les fluides cryogéniques," Centre d'Etudes de/'Energie Nucleaire, Grenoble, France, No. 132 (December 1968).

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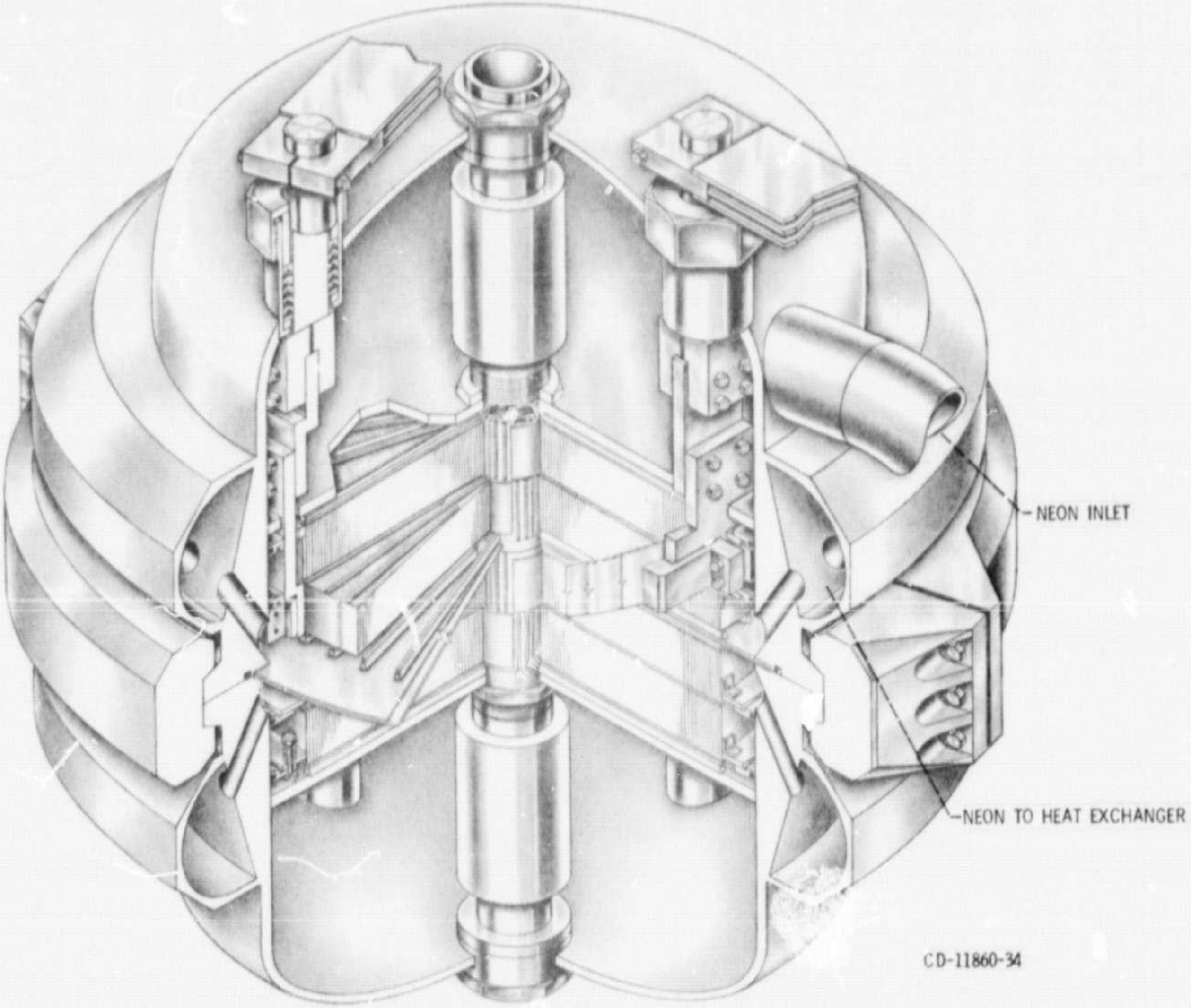

Figure 1. - Conceptual design of 30 tesla liquid neon cooled magnet. (Entire system immersed in cryostat.)

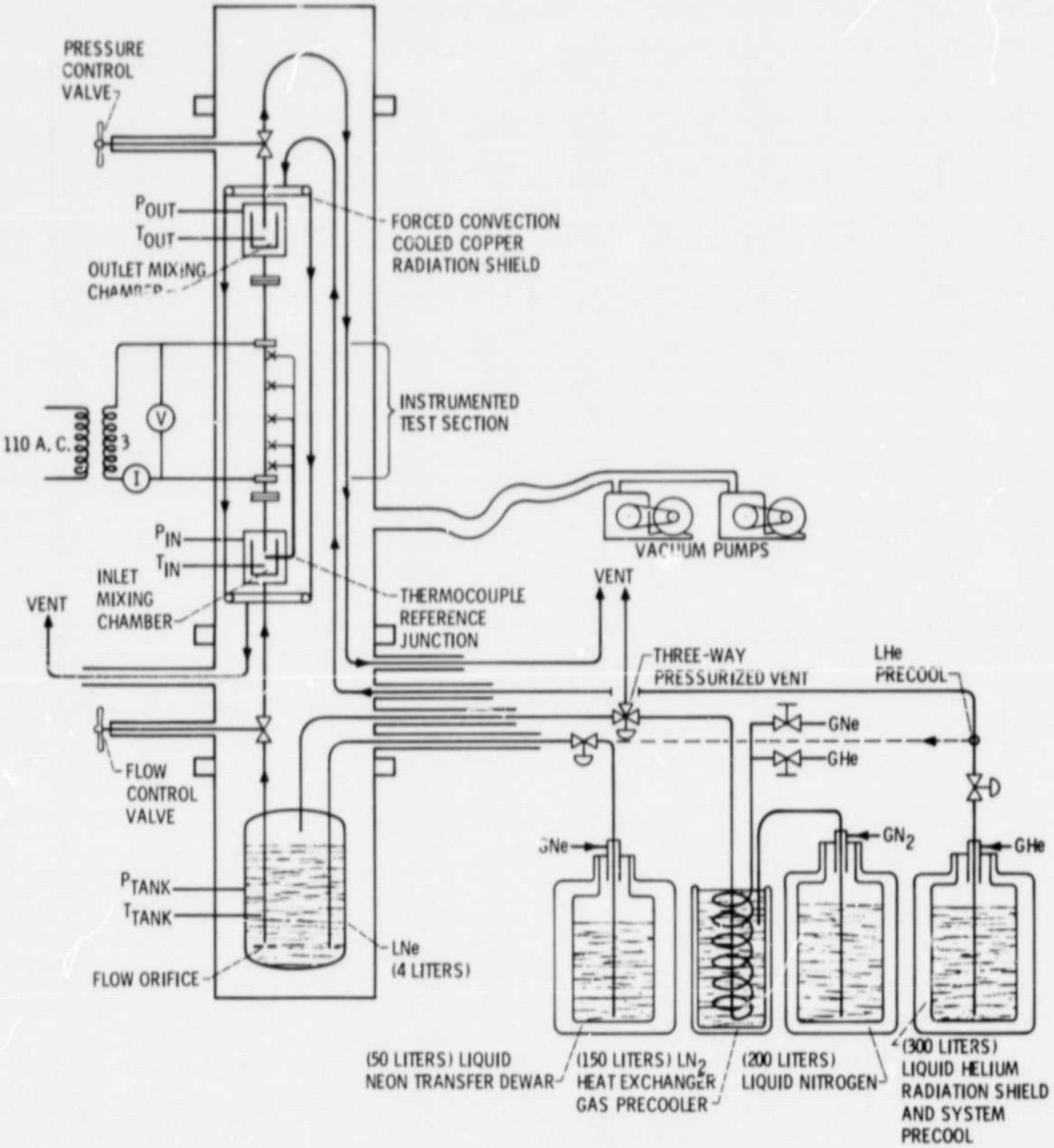

Figure 2. - Schematic - liquid neon heat transfer facility.

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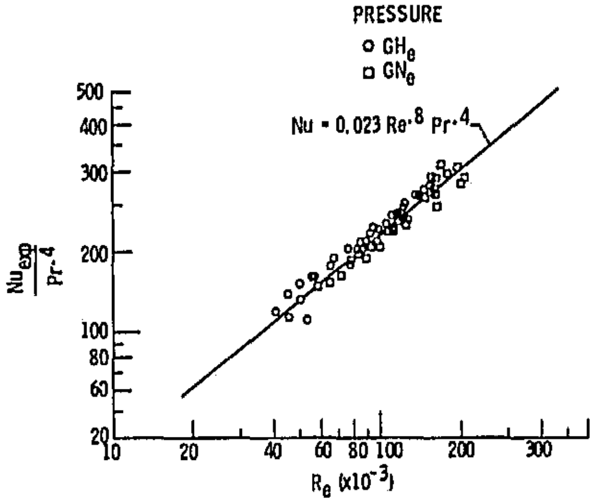

Figure 3. - Liquid neon ≈ 28 bars.

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