RESEARCH AND TECHNICAL NOTES

An ultra-compact low-cost heat exchanger

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A series of heat exchangers has been tested with particular attention paid to achieving low fluid flow velocities, large contact surface areas, and small fluid passages. The merits of heat exchangers based on these principles are generally recognized.[1]

When combined with the use of fine copper screen given a high temperature oxygen anneal,[2] these principles allow reduction of exchanger volume by two orders of magnitude compared to conventional units. They are smaller than other screen exchangers.[3] In addition, fabrication by diffusion bonding reduces the expected time requirement for production of these exchangers to about one hour each during fabrication of a group of exchangers. The high pressure gas is confined to a tube, insuring reliable confinement.

Reference 4 reports the details of the design, construction, and testing of three different types of such exchangers. The design is useful below about 70 K where copper can be made a very good heat conductor. Reference 4 also discusses the design of a vapour-cooled cryogenic current lead based on the same principles. This brief note outlines the design and performance of one of the exchangers.

Fig. 1 is a cutaway drawing of the concentric heat exchanger. The high pressure gas flows through a copper tube filled with layers of 100-mesh copper screen placed perpendicular to the flow. The low pressure gas is in contact with a much larger area of 100-mesh screen. The unit was built by inserting slightly oversize disks into the 0.7-cm tube; the tube was then heat treated for 15 h in 0.026 Pa (2×10^{-4} torr) air pressure at 900°C. This treatment oxidized the transition metal impurities in the copper and provided a high residual electric resistivity ratio, typically about 1000, and a correspondingly high thermal conductivity.[2] At the same time, the copper screen annuli (1.6 cm od, 0.6 cm id) were slipped over the 0.7-cm tube. The whole unit was again heat treated in 0.026 Pa air at 1010°C for 21 h. This second diffusion bonding and oxygen annealing process could have been combined with the previous heat treatment. Metal headers for the low pressure gas were soldered in place, and a glass cloth-epoxy tube was constructed around the annuli and the headers to contain the low pressure gas. A stainless steel tube may be preferable to the glass cloth-epoxy tube.

The exchanger was designed to handle 3 gs^{-1} flow rate – at 12 atm and 1 atm on the high and low pressure sides, respectively, and at a mean temperature of 7.5 K. This might be used as the J-T exchanger on a 50-W (at 5 K) refrigerator. On the basis of design and tests carried out at flow rates of up to 1 gs^{-1} at mean temperatures of 7.5 K, we expect a pressure drop of 40 KPa (0.4 atm) and 17 kPa (0.17 atm) on the high and low pressure sides, respectively, at 3 gs^{-1}. The number of heat transfer units, NTU, would be eight under these conditions.

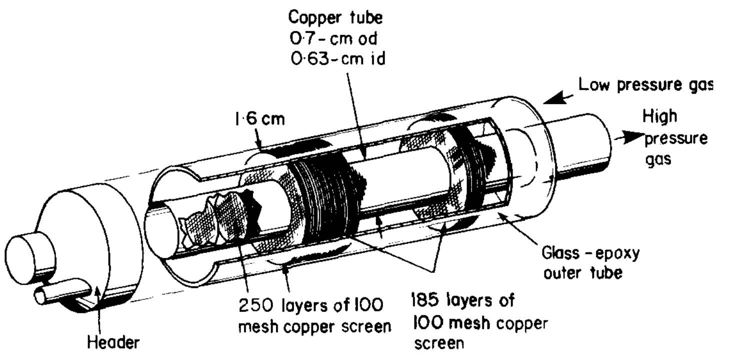

Fig. 1 Concentric tube heat exchanger. A low pressure gas header is shown before assembly. The active length of the exchanger is 10 cm

The exchanger occupies a volume of 20 cm^3. If the high and low pressure screen diameters were doubled and the flow rate were at 3 gs^{-1}, the pressure drops would increase by a factor of about 4 and NTU would increase appreciably. Alternatively, with double the screen diameters 12 gs^{-1} helium flow would be possible with about the same pressure drops and NTU. This screen doubling is possible because of the very high conductivity of the oxygen-treated screen and the good tube to screen diffusion bond. When combined with the favourable circular geometry, these factors provide a very high fin efficiency.

An extension of this design could permit heat exchange between high pressure gas and very low pressure helium evaporating from liquid at 1.8 K, The low pressure disks would be much larger in diameter and would be penetrated by a number of high pressure tubes.

References

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3 See for example, **Vonk, G.** Advances in Cryogenic Engineering vol 13, K.D. Timmerhaus, Ed Plenum Press (1968) 582
4 **Steyert, W.A., Stone, N.J.** Los Alamos Report LA-7395 Low flow velocity fine-screen heat exchangers and vapor-cooled cryogenic current leads

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