Freeze-Tolerant Condensers

Two designs offer similar advantages.

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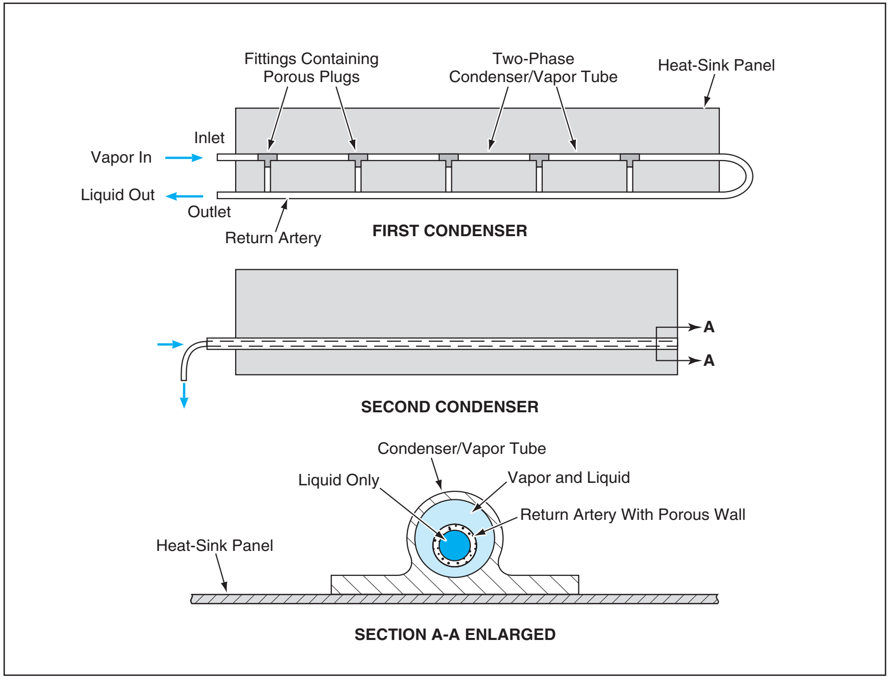
Two condensers designed for use in dissipating heat carried by working fluids feature two-phase, self-adjusting configurations such that their working lengths automatically vary to suit their input power levels and/or heat-sink temperatures. A key advantage of these condensers is that they can function even if the temperatures of their heat sinks fall below the freezing temperatures of their working fluids and the fluids freeze. The condensers can even be restarted from the frozen condition.

The top part of the figure depicts the layout of the first condenser. A two-phase (liquid and vapor) condenser/vapor tube is thermally connected to a heat sink — typically, a radiatively or convectively cooled metal panel. A single-phase (liquid) condensate-return tube (return artery) is also thermally connected to the heat sink. At intervals along their lengths, the condenser/vapor tube and the return artery are interconnected through porous plugs. This condenser configuration affords tolerance of freezing, variable effective thermal conductance (such that the return temperature remains nearly constant, independently of the ultimate sink temperature), and overall pressure drop smaller than it would be without the porous interconnections. An additional benefit of this configuration is that the condenser can be made to recover from the completely frozen condition either without using heaters, or else with the help of heaters much smaller than would otherwise be needed.

The second condenser affords the same advantages and is based on a similar principle, but it has a different configuration that affords improved flow of working fluid, simplified construction, reduced weight, and faster recovery from a frozen condition. The major difference between the second and first condensers are the following:

- In the first condenser, the condenser/vapor tube and the return artery lie alongside each other. In the second condenser, the return artery is narrower than it is in the first condenser and lies within the vapor/condenser tube, as shown in the lower part of the figure.
- In the second condenser, there are no discrete porous interconnections. Instead, the wall of the return artery is porous along the entire common length of the return artery and condenser/vapor tubes. The porous return artery can be fabricated by any of a variety of techniques, including micromachining of a narrow tube, rolling metal screens, or extrusion of initially porous tubing material. The pores must be narrow enough that the capillary pressure exceeds the total pressure drop from the vapor inlet to the return-artery outlet, so that vapor does not blow through the pores to the return artery.
- A small, possibly optional, electrical "starter" heater is located at the condenser inlet.



These **Freeze-Tolerant Condensers** differ in their flow geometries and the distributions of their porous interconnections.

The second condenser weighs less than the first condenser does because the return artery in the second condenser is (1) narrower than that of the first condenser and (2) can have a very thin wall without risk of rupture because, unlike in the first condenser, it is not a significant pressure boundary. In comparison with the first condenser, the second condenser is both simpler to construct and more reliable because, in the absence of the discrete porous interconnections and the associated fittings, fewer welds are needed. Finally, the continuous distribution of porous interconnection in second condenser (in contradistinction to the discrete porous interconnections of the first condenser) make it possible for the second condenser to be thawed more rapidly.

This work was done by Christopher J. Crowley and Nabil Elkouh of Creare, Inc., for **Johnson Space Center**. *Further information is contained in a TSP (see page 1)*

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