**Copper Tubes Withstand Very High Pressures in R744 Gas Coolers**

*High Strength Alloy and Smaller-Diameter Tubes Spell “Success” in Gas Cooler Design*

**New York, New York (25 July 2019)** – The Earth’s atmosphere would benefit from ecofriendly refrigeration and air-conditioning technology. One technology that is poised to grow in the coming years is the use of carbon dioxide as a refrigerant. This technology has been under development for decades and is now commercially feasible as the technology advances for various components, such as compressors, refrigerant lines and gas coolers.

**High Temperatures, Too**

A major difference between carbon dioxide (also known as R744) and other refrigerants has to do with the very high pressure and relatively high temperatures of the R744 refrigeration cycle.

For transcritical refrigeration cycles, operating pressures of 12 MPa (1740 psi) or more are typical. Considering that 0.10 MPa = 0.987 atm = 14.5 psi, a pressure of 12 MPa is about 118 times atmospheric pressure, a very high pressure indeed! By comparison, the discharge pressure for a typical R-410A refrigeration cycle is less than one-quarter as high.

Furthermore, the transcritical cycle could involve cooling the CO2 in the gas cooler from well above 100 °C down to about 31 °C (*i.e.,* from well above 212 °F to about 88 °F). The critical point for CO2 is 31 °C (88 °F) and 7.4 MPa (1071 psi). Above that point, CO2 behaves as a supercritical fluid (SCF), which has properties between a gas and a liquid. It is very dense, which permits high mass flow rates; it also has a very low viscosity, which reduces the inside-the-tube pressure drop.

**Compact Coils**

Since the pressures are very much higher for R744 in a gas cooler than for a conventional refrigerant in an air-cooled condenser, special measures are required to withstand these very high pressures. First, copper tubes with small diameters are preferred in gas coolers. As a first approximation for thin-walled tubes, the “hoop stress” equals the internal pressure times the radius of the tube divided by the tube wall thickness. Hence, a 3/8 inch (9.525 mm) tube diameter is large for an R744 gas cooler. Tube diameters of 5/16 inch (7.9375 mm) or 1/4 inch (6.25 mm) are more common.

The hoop stress in the tube drops in the ratio of 6 to 5 to 4 as the diameter is reduced from 6/16 to 5/16 to 4/16 inches, respectively (that is, from 9.525 mm to 7.9375 mm to 6.350 mm). Some coil manufacturers are using copper tube diameters of only 5 mm since such smaller diameter tubes can withstand high internal pressures with thinner walls.

Secondly, tubes made from a high strength copper alloy can withstand higher pressures. Some coil makers successfully use this approach to increase the pressure rating of the coil itself. More commonly, system designers use a high strength copper alloy for the refrigerant lines that run to-and-from the gas cooler. The copper-iron alloy UNS C19400, which contains a small amount of iron, has a yield strength that is more than fifty percent higher than UNS C12200 copper.

Finally, another way to increase the pressure rating is to increase the tube wall thickness. Doubling the thickness roughly halves the stress in the wall of a tube for a given internal pressure. Conversely, either of the first two approaches, *i.e.*, using a smaller diameter tube or a high strength copper alloy, allows one to use thinner tube wall thicknesses. Thin walled tubes decrease the cost and the weight of heat exchangers.

For more information, see the recent slideshow titled “Advantages of Small Diameter Tubes in Transcritical Refrigeration Cycles” presented by Yoram Shabtay. (See link below.)

“We are at the beginning of a new era for air-cooled gas coolers and copper is leading the way,” said Nigel Cotton, MicroGroove Team Leader for the International Copper Association. “Copper is living up to its reputation for reliability, strength and manufacturability. Major coil manufacturers are building compact and efficient gas coolers for R744 applications. MicroGroove coils offer many benefits to end users.”

The website www.microgroove.net includes additional data on heat exchanger design and manufacturing technology. It also includes links to the MicroGroove series of webinars. A technical literature section provides links to technical papers relating to laboratory experiments, tube circuitry optimization, fin design and manufacturing equipment.

**Reference**

Yoram Shabtay, “Advantages of Small Diameter Tubes in Transcritical Refrigeration Cycles” ATMOsphere America Conference, Atlanta, Georgia. June 2019. [www.slideshare.net/EdaIsaksson/advantages-of-small-diameter-tubes-in-transcritical-refrigeration-cycles](http://www.slideshare.net/EdaIsaksson/advantages-of-small-diameter-tubes-in-transcritical-refrigeration-cycles)

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