What's Up With CO_2?

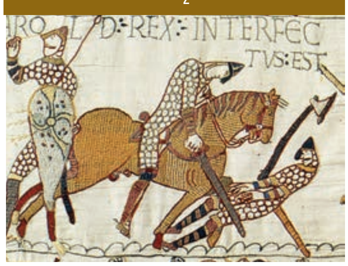
BY ANDY PEARSON, PH.D., C.ENG., MEMBER ASHRAE

There has probably been more written about possible applications for CO_2 as a refrigerant in the last 20 years than about any other refrigerant at any time in the history of mechanical refrigeration.

The classic text "1066 And All That," a spoof history of England, characterizes all history as either "a good thing" or "a bad thing," or occasionally "a very good thing" or "a very bad" thing. Here is the same technique used to analyze the prospects for CO_2 refrigeration.

CO_2 contributes more than any other gas to global warming—this is clearly a bad thing. However, without global warming the earth would be uninhabitable, with an average surface temperature of –2°F (19°C). This is a very bad thing, so global warming is a good thing provided, as Ralph Waldo Emerson said, we have "moderation in all things, especially moderation." So CO_2 as a substitute for high-GWP HFC refrigerant can help reduce the additional global warming that pushes the thermometer beyond the tolerable band to which we have been accustomed for at least the last thousand years.

King Harold couldn't see why there was such a fuss about CO_2.



CO_2 systems have to run at very high pressure, typically eight to 10 times higher than an average ammonia system, for them to be cooled by the surrounding air. Equipment needs to be designed to contain this pressure safely; this is clearly a good but expensive thing. Many people seem to be put off exploring the possibility of using CO_2 for this reason, so it has a bad consequence. However, those who persevere and spend the little extra it takes to accommodate higher operating pressures have learned that there are lots of reasons to like CO_2—more of this good thing later. One hundred years ago CO_2 systems were commonplace, often capable of operating at pressures up to 1,500 psig (over 100 bar gauge), but they were relatively expensive compared to lower pressure refrigerants, so they fell out of favor.

CO_2 systems cooled by the surrounding air operate on their high pressure side above the maximum pressure at which the gas can be liquefied by cooling. This is a confusing thing and has led to a lot of latter-day mythology about these so-called "transcritical" systems. In reality, they are not so different from what we are used to; their major challenge is that the system capacity is greatly reduced on a hot day, which is not just a bad thing, but bad timing, too.

However, this high pressure makes CO_2 gas very dense, which delivers the opportunity to do amazing things with system design. Pushing the discharge pressure above the condensing zone results in a temperature drop as the gas cools, but on the low pressure side of the system the temperature remains constant as the liquid evaporates. This is a "best of both worlds" deal: glide on the heating side and no glide on the chiller side—allowing CO_2 to be used in high temperature heat pumps very effectively.

High operating pressure delivers the good things about CO_2—the small compressor size, the low pressure loss in suction pipes and the good heat transfer in heat exchangers, so it ought to be welcomed. The high density allows crazy things to be done in the evaporator design department, even for very low temperature systems such as cooling to –50°F (–45°C) without suffering large pressure drop.

I have never yet been able to design a CO_2 evaporator that suffered from the circuits being too long, despite trying several times. The circuits are almost impossible to overload, especially in chill applications. As we push toward making system efficiency better, this radical feature of CO_2 will be crucial to the success of new system designs. Unfortunately, system designers and particularly evaporator designers are following old rules for old refrigerants and are not capitalizing on this advantage. This is a bad thing, but it is not irredeemable. ■

Andy Pearson, Ph.D., C.Eng., is group engineering director at Star Refrigeration in Glasgow, U.K.