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Refrigerant Oil Additives

Refrigerant oil additives are liquids designed to be introduced into all sorts of refrigeration systems, including air conditioners and chillers. According to vendors, these additives mix with refrigerant oil and improve heat transfer within refrigeration system heat exchangers. Vendors assert that the use of their products yields energy savings ranging from 5 to 30 percent of overall system energy consumption.

It's not clear that these additives can consistently produce savings in the ranges that vendors claim—in fact, lab and field tests by independent, qualified laboratories indicate that the savings claims may be exaggerated. In addition, there's a body of research that disassociates large gains in heat-exchanger efficiency from large gains in overall system efficiency.

But new research on the use of nanoparticles—extremely tiny particles—shows promise. Nanoparticles could be very effective as refrigerant oil additives because they're more thermally conductive than existing additives, and they're also much cheaper. The particles are composed of metal oxides or carbon and are being used today in products such as paints and certain food items for coloring. This technology has yet to be commercialized, but it holds promise as a cost-effective retrofit to existing air conditioners.

UNCERTAINTIES RAISED BY TESTS

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Three laboratory tests and one field test conducted by independent laboratories, including two by the US Department of Energy's national laboratories, reported energy savings that were significantly lower than those claimed by vendors (**Table 1**). All of these tests were performed on packaged air-conditioning systems, and one even found that the efficiency of an air conditioner was reduced by 6.2 percent due to the introduction of the additive. The highest savings achieved in these selected tests was an efficiency improvement of 2.6 percent. Most of the researchers judged these savings to be insignificant because the values fell within the accuracy range of their tests.

Table 1: Several independent tests show little or no efficiency improvement

Three laboratory tests and one field test of refrigerant oil additives done by qualified laboratories showed that little or even negative savings were achieved by adding a refrigerant oil additive to air-conditioning equipment.

Testing organization	Year	Product	Number of units tested	Size (tons)	Efficiency improvement (%)	Type of system
Florida Solar Energy Center	2003	Polarshield	2	2.5	2.1	RTU
				10.5	–6.2	RTU
Intertek Testing Services	2001	Polarshield	2	27.5	2.0	RTU
				25.0	0.7	RTU
Lawrence Berkeley National Laboratory	2006	Unnamed	1	1,000.0	0.0	Chiller
Oak Ridge National Laboratory	1996	Frigaid	1	3.0	2.6	RTU

Note: RTU = rooftop (air-conditioning) unit.

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Although numerous tests of oil additives are available, these four were the only ones we found that met our selected criteria: The test was performed in an environment where the most important system variables were held constant or where the procedure was normalized for natural variances; it was conducted by an independent, industry-recognized group; and the results were provided in sufficient detail to reassure us that rigorous experimental procedures had been followed.

UNCERTAINTIES ABOUT SAVINGS MECHANISMS

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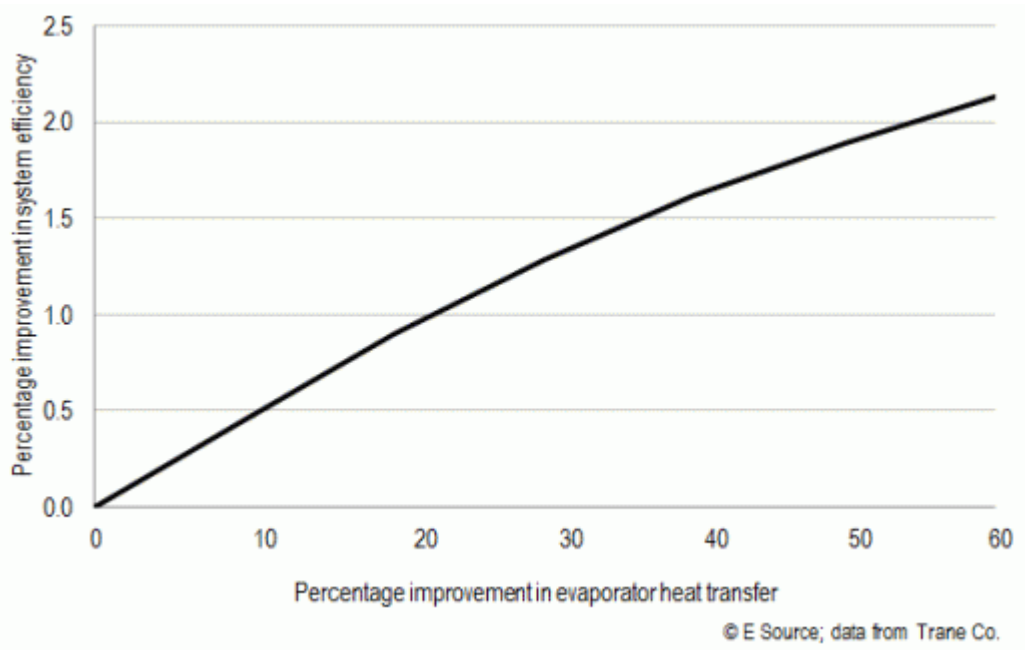
According to vendors of these additives, the key mechanism by which these products improve the efficiency of refrigeration systems is improved internal heat transfer in the evaporator. Although there's evidence that refrigerant oil additives can significantly increase heat-exchanger performance, we're aware of three research efforts that reveal that large heat-exchanger efficiency improvements don't translate into whole-system improvements. These efforts included a set of simulations for heat pumps, a set of simulations for chillers, and an engineering analysis for chillers.

The set of simulations for heat pumps was prepared for Intertek Testing Services, the international testing, inspection, and certification company that owns the Energy Testing Laboratories brand. The study concluded that for every 10 percent improvement in a unitary air conditioner's internal heat transfer coefficient, the overall efficiency of the

simulated air conditioner improved by only about 1 percent. The other set of simulations—for chillers—was done by Trane Co., a major manufacturer of chillers and other HVAC equipment. In this study, researchers at Trane found an even smaller effect—overall chiller efficiency improved only around 1 percent for about every 25 percent improvement in the simulated chiller's internal heat transfer (**Figure 1**).

Figure 1: Big changes in internal heat-transfer coefficient lead to small overall efficiency improvements

Trane Co. ran a series of chiller simulations based on a 500-ton chiller (model number CVHF485) running at standard conditions established by the Air-Conditioning and Refrigeration Institute. For each simulation, Trane changed only the heat-transfer coefficient of the chiller's evaporator. As this chart shows, for about every 25 percent improvement in the heat-transfer coefficient, the overall efficiency of the chiller improved by about 1 percent.



The engineering analysis was done by Mark Kedzierski from the National Institute of Standards and Technology (NIST) as part of a study on heat transfer. His analysis investigated the impact of an improved evaporator heat-transfer coefficient for a 1985-era centrifugal chiller. Kedzierski found that a heat transfer coefficient improvement of 100 percent produced about a 1 percent boost in overall chiller efficiency, but a 225 percent heat transfer coefficient improvement only produced a 1.5 percent boost. He also told us that a chiller with a better baseline efficiency would have even less room for system improvement.

WHAT'S NEXT?

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From the ongoing research into refrigerants and lubricants, another type of refrigerant additive has emerged. Lubricants called nanolubes, which are based on the use of nanoparticles, show some promise to be a cost-effective efficiency booster for air-conditioning systems. These new additives use tiny particles—composed of either metal oxides or carbon—that are no larger than a virus cell. The metal oxides used are classified as advanced or technical ceramics, not to be confused with traditional ceramics that are commonly associated with pottery or tile. Traditional ceramics are silicate-based and crystalline in nature, giving them their brittle, nonconductive characteristics. Advanced ceramics, on the other hand, can exhibit a plethora of superior characteristics, including thermal conductivity. Because these additives are more thermally conductive than refrigerant oil, it's plausible that they have the potential to improve heat transfer in refrigeration systems by a large enough margin to make a significant difference in overall efficiency.

Mark Kedzierski from NIST has also been researching nanolubes. He was part of a research team that documented an enhancement to the heat-transfer rate of a system by as much as 275 percent by adding copper-oxide nanoparticles. According to Kedzierski, this type of refrigerant additive is attractive because the nanoparticles are very cheap. The challenge is to produce a solution that's concentrated enough to be poured into a refrigeration system without having to drain and filter out any of the existing oil. NIST, with funding from the US Department of Energy, is working to commercialize this technology. Kedzierski says it will likely take another couple of years to figure out whether a viable product can be commercially produced.

NIST is not alone in its attempt to commercialize nanolubes. ACTA Technology—a Boulder, Colorado, start-up—is aiming to commercialize its own product made from charged carbon nanotubes, which are about four times more conductive than copper. Ed Clancy, the chief technical officer at ACTA, claims that in lab tests, his product has improved the thermal conductivity of an oil and refrigerant mixture by 194 percent. However, at the moment, ACTA has been unable to secure additional funding, so development has been paused. It is, however, pursuing another additive for use in ground-source heat pumps. Clancy told us that adding nanoparticles to the fluid in this case increased heat transfer by 48 percent.

Additionally, Kedzierski mentioned that there may be some competition from abroad—reportedly, a team in China claims to have improved the efficiency of a refrigerator by 9.6 percent using titanium-dioxide nanoparticles.

CONCLUSION

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Given all these uncertainties, there's good reason to be concerned that the actual energy savings achieved by refrigerant oil additives could be substantially lower than vendors claim. But the science of refrigeration lubricants continues to advance. Better lubricants are under development, and research also suggests that there's the potential to develop additives that could predictably improve the performance of existing lubricants.

FURTHER READING

this section

Effect of Refrigerant Oil Additive on R134a and R123 Boiling Heat Transfer Performance and Related Issues for GSA (2004), Mark Kedzierski, National Institute of Standards and Technology (NIST)

Influence of Concentration and Additives on R123/Paraffinic Material Oil Boiling Heat Transfer Performance, Appendix A: Additive Potential (PDF), Mark Kedzierski and D.H. Han, NIST (2006)

Effect of CuO Nanolubricant on R134a Pool Boiling Heat Transfer, M.A. Kedzierski and M. Gong, International Journal of Refrigeration (2009)

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