CFCs and Cooling Equipment: The Size of the Problem

As recently as ten years ago, only a few experts appreciated the potentially disastrous consequences of releasing chlorofluorocarbons (CFCs) into the environment. Today it is generally believed that chlorine from CFCs is destroying stratospheric ozone, which shields the earth from the sun's ultraviolet radiation, and that the resulting increased ultraviolet radiation will soon lead to millions of fatal and nonfatal skin cancers and cataracts, to other threats to human health, and to severe damage to agriculture and ecosystems. To mitigate those effects, the United States and most other countries have committed themselves, through the 1987 Montreal Protocol on Substances That Deplete the Ozone Layer and its later revisions, to rapid elimination of CFC production.

The rate of CFC production, though being reduced, is on the order of a million tons per year. CFCs are used extensively as working fluids in refrigerators and air conditioners, as cleaning solvents in electronics and sheet-metal fabrication, and as foaming agents in foam insulation and cushions. CFCs have the advantage for many purposes of being almost chemically inert (their behavior in the upper atmosphere is an exception); in particular they present no fire or poison danger. In addition their lack of interaction with the lubricants used in refrigerator compressors improves the efficiency and the lifetime of the refrigerator. Cooling-system efficiency has major economic and environmental impacts. Cooling consumes about 20 percent of the nation's electricity, at a cost of tens of billions of dollars per year. Kitchen refrigerators alone use 8 percent of the nation's electricity. Most of that electricity is produced by burning fossil fuels. Congress is accordingly requiring ever more efficient cooling equipment; for example, kitchen refrigerators built in 1993 must use 30 percent less electricity than those built in 1990. Clearly the elimination of CFCs should not involve making refrigerators that are much less efficient than present models. Therefore the use of CFCs in cooling is the most difficult of their common uses to eliminate.

The cooling industry is enormous. Cooling equipment worth $40 billion is sold in the United States each year, and, since it has a long useful lifetime, the total value of installed equipment is about $200 billion. Thus the appliance industry and other cooling-equipment manufacturers face a daunting challenge. The prospects of millions of fatal cancers, tens of millions of cataracts, and continued enormous energy consumption and attendant greenhouse-gas emissions have led to government regulations that are driving a $40-billion-per-year industry to an unprecedented crisis. The situation dwarfs the problems of the DOE's nuclear-weapons complex, a mere $12-billion-per-year industry responsible for less environmental and human-health damage.

Stopgap solutions to the CFC crisis are required immediately and are, in fact, in progress. Industry has begun extensive recycling of CFCs, especially in air-conditioner repair. Some new appliances will soon use hydrochlorofluorocarbons, which tend to break down and then rain out before carrying their chlorine to the stratosphere, and hydrofluorocarbons, which contain no chlorine at all. One German manufacturer is using ordinary hydrocarbons (a mixture of propane and butane) as working fluids, recognizing that their flammability poses negligible danger since only small quantities are used.

But these new chemicals have disadvantages. They are less compatible with lubricants than are CFCs, so they may cause present compressors to wear out more quickly. HCFCs and HFCs also significantly reduce the efficiency of cooling machinery. They are also greenhouse gases, with roughly 1000 times the global-warming potential of carbon dioxide per molecule, so their use will probably eventually be limited by international agreements. Finally, as they do not occur in nature, their release into the environment in million-ton quantities, like the release of CFCs, will be an experiment in atmospheric chemistry with unpredictable consequences.

Completely different cooling technologies that don't use any of these chemicals are still needed. Many are being developed, including Rankine cycles using CO_2, Stirling cycles using helium, and cooling by the Peltier (thermoelectric) effect. Almost by accident three new cooling technologies—thermoacoustic refrigeration, the related Sonic Sompressor, and Malone refrigeration—have been developed in part here at the Laboratory; each may become part of intermediate or long-term solutions to the CFC problem. They are described in the accompanying articles. □