Some cool ideas

Traditional refrigeration may be eased out by new technologies

THE basic technology of refrigeration has not changed much since the 19th century. Refrigerators (and their cousins, air conditioners) work by compressing a fluid and then allowing it to expand. Compression heats the fluid up, thus heating its surroundings. Expanding it cools it down, thus cooling its surroundings. Arrange for the compression to happen in one place and the expansion in another, and heat will be pumped from the latter to the former. Pick the right fluid and you can move a lot of heat.

Early refrigerators used ammonia, which is poisonous. Then chlorofluorocarbons (CFCs) were discovered. They are not poisonous, and quickly displaced ammonia. But CFCs were implicated in the destruction of the ozone layer that protects the Earth from ultraviolet light, and were banned. So ammonia came back into fashion. Now, technologists are working on several completely different ways of cooling things.

The least different way is called closed-cycle air refrigeration. Instead of employing special fluids such as CFCs or ammonia, it uses air itself as the working fluid.

Open-cycle air refrigeration, in which air is compressed, allowed to shed the heat this generates, and then blown into the space to be cooled, is already used in some sorts of air conditioning—for example, on aircraft. It is safe, since the pressures involved are low, but it is inefficient, because the cooled air is lost to the system.

A closed cycle (ie, a sealed system similar to a traditional refrigerator) can be more efficient than an open one, but that efficiency requires the air to be pressurised to a much higher level. Indeed, the reason why CFCs and ammonia were used in the first place is that they are more compressible than air, and thus deliver more refrigeration for a given pressure. The trick, therefore, is to generate and contain the extra pressure safely.

A collaboration between America's National Institute of Standards (NIST) and several American refrigeration companies has overcome these problems. To generate the 82 atmospheres of pressure needed requires a pump shaft that can rotate 30,000 times a minute, and can do so at temperatures between -50℃ and -100℃. That, in turn, required the development of new seals between the shaft and its housing. These have specially designed spiral grooves that eliminate the need for lubricants, since those can fail at such high pressures and low temperatures.

Besides getting rid of expensive and potentially dangerous coolants, closed-cycle refrigeration chills things faster than conventional refrigeration. That should improve food safety, as packaged frozen foods will spend less time in the temperature range conducive to bacterial growth. Foods frozen using this technique should taste better, too, as faster cooling means less dehydration. All told, NIST says, these benefits should be worth hundreds of millions of dollars a year, even if only a handful of large industrial refrigeration plants switch over.

Sounds good

Closed-cycle air refrigeration still uses the compression and decompression of a circulating fluid. Another new technique abandons even that. Sound is normally thought of as a pressure wave. But, like any other pressure change, it also brings a change in temperature. In an ordinary conversation, that temperature change is a mere ten-thousandth of a degree. But a loud sound in a pressurised gas can cause significant temperature changes. Such sounds can be made without any moving parts by the use of a resonating cavity. The lack of moving parts means that devices depending on “thermo-acoustic” effects can be made to be much more efficient than conventional refrigerators.

A collaboration between America's Los Alamos National Laboratory and Praxair, an industrial-gas company based in Connecticut, is in the process of commercialising this idea. Praxair is interested in using it to liquefy natural gas.

The trick in building thermo-acoustic refrigerators lies in synchronising the pulses of sound in such a way that little packets of cold fluid are pushed one way, while little packets of heated fluid move in the opposite direction. In this case, pressurised helium is used to conduct heat away from the natural gas. The helium is pushed through a thin mesh of steel wires to break it up into packets. By adjusting the size of the resonating cavity, and of the mesh, the sound waves can be made to cool the helium, which in turn cools the natural gas.

An attractive alternative

A third new refrigeration technology may see use not just in industrial plants, but also in the air-conditioning systems of cars, and perhaps even in household refrigerators. It has been known for a long time that certain substances heat up when placed in a magnetic field, and cool down when the field is removed. Unfortunately, this effect is large enough to be useful only in a handful of rather exotic materials, most notably alloys of gadolinium. And the magnetic fields involved need to be very powerful.

Until 2001, superconducting magnets had to be used to produce strong enough magnetic fields. However, in that year Karl Gschneidner, a researcher at Ames, a Department of Energy research lab in Iowa, succeeded in making a magnetic refrigerator using strong permanent magnets. This magnetic refrigerator work by using a rotating wheel containing gadolinium alloy. The rotation takes the alloy in and out of the magnetic field, alternately heating and cooling it. Water cooled by the cold alloy is then circulated through coils like those found in a regular refrigerator. A cool idea indeed.