



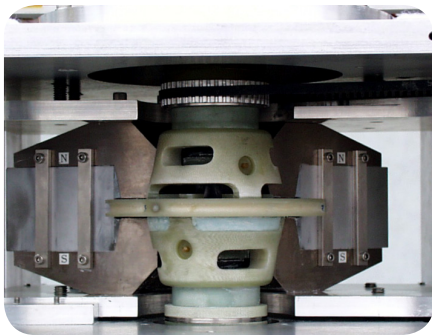
THE Ames Laboratory  
Creating Materials & Energy Solutions

## Room-Temperature Magnetic Refrigeration

*An Ames Laboratory Innovation Could Transform Cooling Devices*

Nearly all refrigeration devices work by compressing and then decompressing gases. But thanks to research at the U.S. Department of Energy's Ames Laboratory, that technology may one day be replaced by an entirely different cooling method, one that uses permanent magnets and specialized alloys. The result would be refrigerators, air conditioners and giant warehouse freezers that are greener, quieter and far more energy efficient than their predecessors.

Magnetic refrigeration works because of a phenomenon known as the magnetocaloric effect that was discovered



*A rotating magnetic refrigerator developed by Astronautics Corporation of America Ltd. in collaboration with the Ames Laboratory.*

in the 1880s. When a magnet comes in close contact to a metal, its field quickly aligns the metal's unpaired electrons, i.e. magnetic spins. Constrained by the field from moving about freely, the magnetic spins result in enhanced lattice vibra-

tions in order to keep the overall disorder in the material the same, which causes the temperature of the metal to rise.

Remove the magnet, and the temperature quickly lowers once again. All magnetic materials exhibit the magnetocaloric effect to some degree. However, with some metals, gadolinium being one, the change in temperature is far more pronounced than with others.

All else being equal, the degree of temperature change depends on the strength of the magnetic field. For that reason, magnetic refrigerators have until recently used high-powered superconducting magnets that were cooled using liquid helium in order to maximize the magnetocaloric effect. These experimental refrigerators were successful at producing temperatures below 1 Kelvin, though their use was necessarily limited to laboratory applications.

### **Stronger magnets, cheaper materials**

Ames Laboratory researchers Karl A. Gschneidner Jr. and Vitalij K. Pecharsky are credited with developing the first material that can work in a magnetic refrigerator able to operate at room temperature without the need for superconducting magnets or liquid helium. The pair's breakthrough opens the door to widespread commercial applications, and it came about as a result of key advances, which took place at the



*Gadolinium crystals*

Ames Laboratory. The first was a newly designed permanent magnet created by Ames Lab researchers David Jiles and Seong-Jae Lee, along with Pecharsky and Gschneidner. Their magnet was configured in such a way as to produce a magnetic field nearly double that of previous designs. This greatly enhanced the device's efficiency.

To further enhance a magnetic refrigerator's efficiency, Gschneidner and Pecharsky needed to boost gadolinium's magnetocaloric effect. They and their colleagues did this by adding silicon and germanium to the metal. Equally important, the resulting  $Gd_5Si_2Ge_2$  alloy was produced using commercial grade gadolinium (as opposed to research

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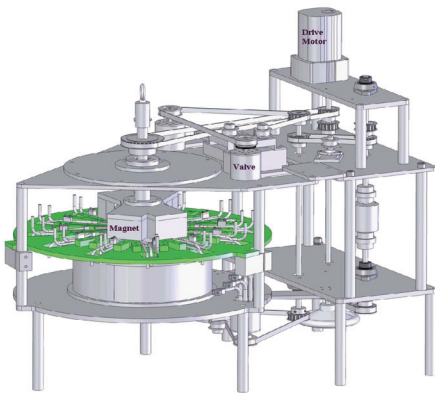
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grade) via a process the Ames Laboratory researchers devised. This enabled the team to create larger quantities of the material, and it suggested that commercial-scale production of the gadolinium alloy could be done economically.



*A rotating magnetic refrigerator developed by Astronautics Corporation of America Ltd. in collaboration with the Ames Laboratory.*

As a next step, the Ames Lab team incorporated their groundbreaking magnet and gadolinium alloy into a prototype device, developed in collaboration with Astronautics Corporation of America. The refrigerator consists of a wheel that contains sections filled with the gadolinium alloy. The wheel revolves around a high-powered, rare-earth permanent magnet. As it revolves, it passes through a gap in the magnet at the precise point where the magnetic field is concentrated. When exposed to this field, the gadolinium alloy in the wheel heats up.

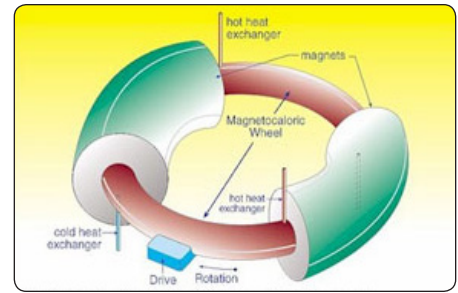
After entering the field, water is circulated to draw the heat out of the metal.

As the gadolinium alloy leaves the magnetic field, the material cools further. A second stream of water is itself cooled by the gadolinium alloy. This water is then circulated through the refrigerator's cooling coils.

### Global implications

While Gschneidner and Pecharsky's prototype was a landmark event in the field of magnetic refrigeration, it would likely remain nothing more than a curiosity were it not for the fact that the team's device is more energy efficient and environmentally friendly than virtually any conventional refrigerator on the market today. Because the relatively inexpensive permanent magnet handles the cooling without the need for additional energy input, electricity is only needed to turn the wheel and circulate the streams of water. For its part, water, even when combined with an environmentally friendly antifreeze, is more benign than the chemical coolants presently in use.

Over the long term, the savings in energy and the resulting decrease in greenhouse gases and other potential environmental damage could be enormous. As emerging nations rapidly adopt the commercial, home and vehicle cooling devices that are a fundamental part of the developed world, the Ames Laboratory discoveries could spawn an entirely new and much-needed industry.



*An artist's rendition of a rotary refrigerator.*