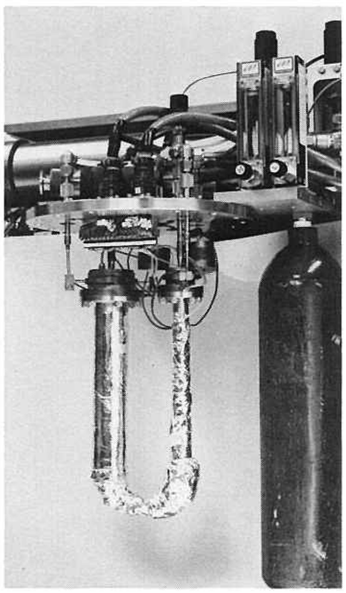
The Coolahoop

Inventors: Gregory W. Swift, Physics Division; Richard A. Martin, Mechanical and Electronic Engineering Division; and Ray Radebaugh*



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The heart of the Coolahoop is this orifice pulse-tube refrigerator, consisting of heat exchangers and a regenerator in series in the U-shaped tube, a flow impedance, and the large ballast tank at right.

Researchers at Los Alamos National Laboratory and the National Institute of Standards and Technology have developed a cooling system with no moving parts that produces very low temperatures and has no apparent limitations on its lifetime. The Coolahoop, so named by the inventors because its acoustic resonator reminded them of a Hula-Hoop, is a breakthrough in cryogenic (ultralow-temperature) cooler technology. The system will make possible long-term, maintenance-free cooling for operations that often occur in remote locations, such as livestock artificial breeding, natural gas production, and climate and resource monitoring by satellite. For inventing the Coolahoop, the researchers won an R&D 100 Award in 1990. *Research and Development Magazine* distributes these prestigious awards annually for the one hundred most significant technical innovations of the year.

The Coolahoop System

The invention is a very simple device, consisting only of assorted tubes and heat exchangers, and it contains very ordinary materials—brass, copper, stainless steel, and helium gas. The Coolahoop uses a thermoacoustic engine—a device in which acoustic resonance converts heat to oscillatory pressure—coupled to and driving a pulse-tube refrigerator.

The pulse-tube refrigerator is a variant of the Stirling-cycle refrigerator, which typically has two pistons (one at the ambient heat exchanger and one at the cold end). The Coolahoop's pulse-tube refrigerator consists of two ambient-temperature heat exchangers, a regenerator, and a cold heat exchanger, arranged in a series and filled with high-pressure helium gas. To eliminate all moving parts, the inventors replaced the cold piston with a passive dissipative structure consisting of a flow impedance and a ballast tank, both at ambient temperature, which absorb energy from the helium gas. They replaced the hot piston with a thermoacoustic engine in which a heat-driven standing sound wave carries the gas back and forth along the temperature gradient between the high-temperature heat source and the ambient-temperature heat sink. The sound wave pressurizes and depressurizes the gas in phase with the attendant thermal expansion and contraction, thereby producing acoustic energy to sustain the standing wave and drive the pulse-tube refrigerator.

Advantages and Applications

The Coolahoop's efficiency is now comparable with that of mechanical cryocoolers; the first prototype required 3000 watts of input power, reached a low temperature of 89 kelvin (–184^{o} Celsius) and had 5 watts of cooling power at 120 kelvin (–153^{o} Celsius). The maintenance-free lifetime and reliability of the Coolahoop, however, are unmatched. Mechanical cryocoolers require maintenance about every two years because of wear on moving parts, plugging of low-temperature orifices, or both. The short lifetime of mechanical cryocoolers renders them useless for satellite cooling and seriously hampers their commercial and industrial applications on Earth. Because the Coolahoop contains no exotic materials, has no pistons or cylinder walls, and requires no close-tolerance fabrication techniques, its manufacturing cost will likely be one-fifth to one-tenth of that for conventional cryocoolers.

The Coolahoop will be useful for cooling detectors on satellites, such as the infrared detectors used for climate monitoring and surveying the Earth's resources. It can also produce small amounts of liquid nitrogen at low cost and on site for applications such as medicine and the livestock breeding industry. Currently, liquid nitrogen must be produced at large central facilities and shipped to remote sites where it is needed.

Larger Coolahoops, which will be far more efficient than the first prototype, are being developed. These larger Coolahoops will be able to liquefy great amounts of nitrogen, oxygen, and natural gas on site. Costs of the liquefaction will be low because the Coolahoop can take advantage of cheaper energy sources—such as coal or natural gas—than the electricity used to power conventional mechanical cryocoolers. A potential application of

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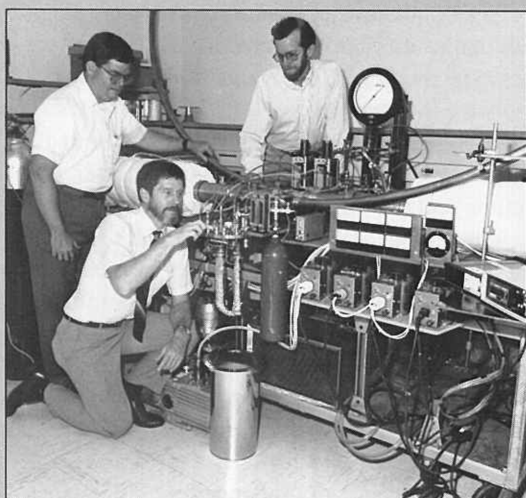
the larger Coolahoops is supplying liquid oxygen for use in the space shuttle engine. Larger Coolahoops could also liquefy natural gas at remote wells where it is not economical to build a pipeline to bring the gas to market. A large Coolahoop could burn a fraction of the gas at the well to liquefy the rest, which could then be trucked to market.

Superconducting materials lose their electrical resistivity when they are cooled to near absolute zero. When these materials reach a more advanced stage of development in the next few years, the Coolahoop's reliability and simplicity will help make widespread, routine use of superconducting devices possible.

A patent was issued for the Coolahoop on September 4, 1990 (Patent No. 4953366, "Acoustic Cryocooler"), and the Coolahoop is now available for licensing.



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Pictured from left are Richard A. Martin, Ray Radebaugh, and Gregory W. Swift.

Los Alamos inventors Gregory Swift and Richard Martin joined efforts with Ray Radebaugh, Group Leader of the Properties of Solids Group at the National Institute of Standards and Technology, to develop the Coolahoop. Their efforts resulted in a 1990 R&D 100 Award, one of seven such awards earned by Los Alamos scientists that year.

Swift obtained B.S. degrees in physics and mathematics from the University of Nebraska in 1974. In 1981, after he earned his Ph.D. degree in physics from the University of California at Berkeley, Swift joined Los Alamos National Laboratory as a Director-funded postdoctoral fellow. From 1983 to 1985, he worked as an Oppenheimer fellow, and in 1986, he joined the Physics Division as a staff member. Swift is a fellow of the Acoustical Society of America and has published numerous papers in the field of thermodynamics, particularly refrigeration technology.

After receiving a B.S.E. degree in aerospace engineering from the University of Michigan in 1966, Martin worked for the National Space and Aeronautics Administration (NASA) Flight Research Center as an aerospace engineer. During his four and one-half years at the Flight Research Center, Martin obtained an M.S. degree in mechanical engineering from the University of Southern California. In 1975, he obtained a doctoral degree in aerospace engineering from Iowa State University and then served for two years as a National Research Council Resident Research Associate at the NASA Ames Research Center. Martin joined Los Alamos National Laboratory in 1977 as a staff member. He has authored about twenty-five publications in the fields of nuclear-fuel-cycle safety and engineering applications in thermophysics. Martin is an elected member of the New Mexico State University Mechanical Engineering Academy and serves on that university's Industrial Advisory Committee.

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