CRYOGENICS

Lowest Temperature in World

Scientists around the world are working at one-hundredth of a degree absolute to discover more about matter, but a side result could be cheaper electricity, Ann Ewing reports.

➤ COLD as it may now be at the wintry South Pole, scientists every day in laboratories around the world are producing extremely low temperatures, only one-hundredth of a degree above absolute zero, the point of complete absence of heat, where all motion stops.

Absolute zero is 459.7 degrees below zero Fahrenheit. In this sub-sub-freezing world, even atoms slow their ceaseless dance. Of all known elements, only helium remains liquid; others are frozen solid.

The lowest temperature ever reached is only one-millionth of a degree above absolute zero. Although scientists investigate matter near such temperatures to learn more about how it is put together, cheaper electricity may result.

Superconductors for Power

At these frigid temperatures, an electrical current once started in metals and alloys, called superconductors, continues forever. Engineers envision future power systems using superconducting transformers, generators and motors.

Some even suggest that electrical power will be transmitted over superconducting lines. A transmission line made of superconducting niobium-tin, and roughly the diameter of an arm, could carry as much power as the peak load now being used in the entire United States.

Some 300 materials, 25 elements and the rest alloys or compounds, are now known to be superconductors.

However, all metals may become superconductors at extremely low temperatures if they are pure enough. For example, research this year showed that two elements, molybdenum and iridium, became superconducting when very, very pure.

Superconductivity was discovered at the University of Leyden in 1911 by the late Dr. H. Kamerlingh-Onnes, who won a Nobel Prize in 1913 for his earlier work liquefying helium. However, it was not until 1957 that theory caught up with experiment. Then 1956 Nobel Prize winner Dr. John Bardeen of the University of Illinois, with Drs. Leon N. Cooper and J. Robert Schrieffer, also at the University of Illinois at that time, presented a theory of superconductivity, the first to account for most of the important facts.

It is based on quantum mechanics, a highly theoretical branch of physics dealing with the motions of atoms, the electrons that whirl ceaselessly around them and their nuclei. Interplay between the motion of electrons and atomic vibrations, according to this theory, causes many electrons in a superconductor to be associated in pairs and to move only in pairs.

Also dependent upon quantum theory was the recent discovery that the magnetic field produced by an electric current flowing in a superconductor is "quantized," that is, its strength can be increased only in packages of definite, predictable sizes. Part of a package will not do.

One reason scientists are so interested in what happens at the really low temperatures near absolute zero is that, with atomic motion so much slowed, atomic behavior is much easier to check. Chemical and physical reactions are in slow motion.

A by-product of such research could be not only cheaper electric power but a method of building an experimental plant to control the fiery fusion of the hydrogen bomb reactions for peaceful purposes, through use of superconducting, high magnetic field materials.

Low-temperature research has already yielded super-strength steels, and it promises to have even more application for materials engineered to resist the vacuum cold of outer space.

Storage of energy may be possible by trapping large amounts of energy in solids at extremely low temperatures and then releasing the energy as needed.

The science of low temperatures is called cryogenics. Several years ago scientists in Cambridge, Mass., built an electronic computer using cryotrons, low-temperature switching devices.

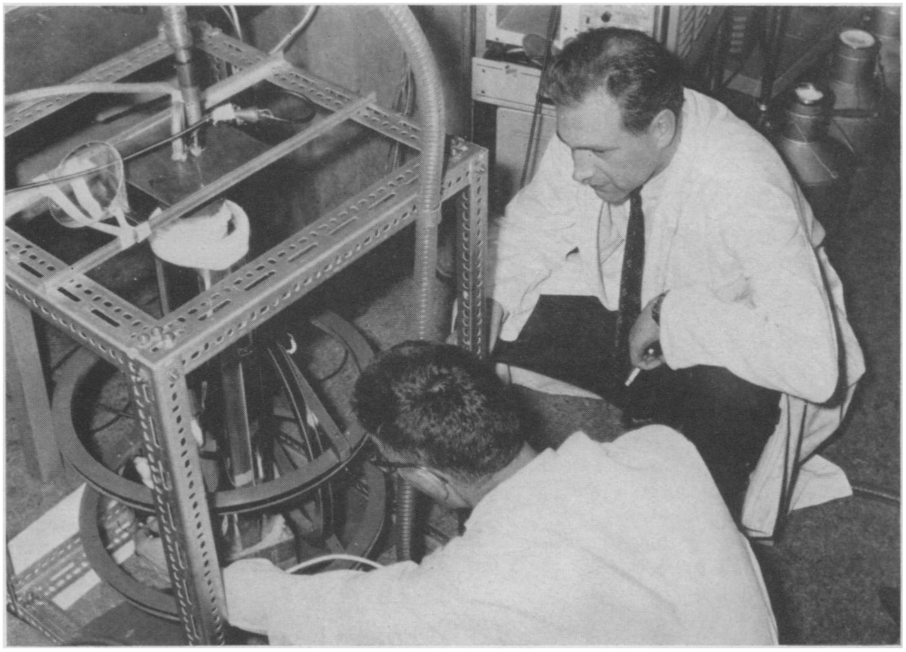
Experiments near absolute zero also helped prove one of the most important theories in physics in recent years, the so-called nonconservation of parity. This means that there actually is a left-handed direction and a right-handed one, instead of just being mirror images as previously thought.

One of the most recent advances in cryogenic research was the first demonstration that a magnetic field reverses direction passing through a superconducting thin film.

The world of extremely low temperatures is full of other surprises besides superconductivity. If liquid helium is poured into a flask separated into two chambers by a partition, the two levels quickly become equal. The liquid helium seeps through invisible holes. This is known as superfluidity.

The magnetic behavior of a superconductor is as surprising as its electrical behavior, and is the basis for many likely applications. Magnetic lines of force penetrate only a very narrow layer at the surface of a superconductor. Thus a magnet placed above a superconductor literally floats in the air.

However, when an applied magnetic field reaches a certain critical value, the superconductor is changed to the normal state.



CRYOGENIC RESEARCH—Scientists M. K. E. Drangeid (left) and R. Sommerhalder of International Business Machines Corporation Research Laboratory, Zurich, Switzerland, are shown with the experimental apparatus they developed which produced the first experimental evidence that a magnetic field reverses its direction, or sign, as it passes through a super-conducting thin film.

If just the right magnetic field is applied, an intermediate state can be produced—portions of the sample being normal and portions superconductive.

Another reaction of superconductors discovered only recently is known as "tunneling," which has been observed in devices consisting simply of two metal films separated by a thin insulating layer. One or both of the metal films can be in the superconducting state. Until this discovery, the only wide use of electron tunneling was in the semiconducting tunnel diode, which is used in computers for very fast action. Now it has been shown that tunneling occurs in a broader class of materials than semiconductors.

Thus, although the world of extremely low temperatures is only about 50 years old, new discoveries are being made that bring cryogenic applications closer and closer to every day use.

Many degrees above absolute zero but still very frigid by any everyday standards are the low temperatures used in rocket research, perfecting the boosters that lift satellites into orbit and probes into interplanetary space.

Liquid oxygen, called LOX, is extensively used as the oxidant in rockets and provided the propulsion power for the first practical long-range rocket, the German V-2. Oxygen becomes a liquid at 297 degrees below zero Fahrenheit.

Many years ago liquefying helium was such an expensive and difficult process that only the wealthiest laboratories could afford to do low temperature work. Now there is a fairly simple, small and relatively inexpensive machine that reduces the temperature. It is known as a helium cryostat and is now in use at hundreds of universities and industrial laboratories throughout the world.

At cryogenic temperatures, strange things happen. Rubber shatters like glass. Lead rings like a bell when struck and air freezes into a solid block.

These things, however, are no more startling than the more difficult to understand discoveries now being made about superconductivity.

• Science News Letter, 82:106 August 18, 1962

Questions

Photographs: Cover, U.S. Department of Agriculture; p. 99, Carl Byoir & Associates, Inc.; p. 101 (bottom), Shell Oil Company; p. 101 (top), Carl Byoir & Associates, Inc.; p. 103, Bell Telephone Laboratories; p. 106, International Business Machines Corporation; p. 112 (top), The Wurlitzer Company; p. 112 (bottom), U.S. Department of Agriculture.