PHYSICS

Exploring the Extremes of Temperatures

Conquerors of the Lower Temperature Scale, Scientists Consider Creating on Earth the Heat of Giant Stars

By D. LINDSAY WATSON

INTENSE COLD, lower in temperature than the extreme chill of empty interstellar space, is within the reach of man. Extreme cold has become a tool for physicists in their study of the nature of matter.

But the most extreme temperature in the universe, believed to exist in the center of the hotter stars to the astounding heat of some 72,000,000 degrees Fahrenheit, has not yet been approached on earth. An exploding electric wire with a temperature of 45,000 degrees represents the maximum temperature scientists have reached. This is, however, many times the heat produced by the hottest of practically useful temperatures, that used in welding wth atomic hydrogen flames, which reaches some 7,640 degrees Fahrenheit.

At the cold end of the temperature scale is absolute zero, a point that probably is not attainable either by man on earth or under natural conditions outside the earth. There, all motion of the very elements of matter, the atoms, ceases. Electricity would find no resistance in a conductor at absolute zero, but would flow on forever. Absolute zero on the Fahrenheit scale is 459 degrees below zero.

Tripoli Hottest

Man has pushed his temperature explorations down to within 1.6 degrees Fahrenheit of absolute zero. This intense cold, lower than that of the space between the stars which Prof. A. S. Eddington estimates to be 5.4 degrees Fahrenheit above absolute zero, was reached at Leiden, Holland, a few years ago. In the production of liquid helium at a temperature of 3.4 degrees Fahrenheit above absolute zero at the National Bureau of Standards this year, the record low temperature for the United States was reached. Helium becomes liquid somewhat higher at 7.4 degrees above absolute zero.

Contrast these extreme temperatures of science's making with the highest and lowest temperatures made by weather.

The hottest climatic temperature ever reported is 136 degrees Fahrenheit in the shade, in Azizia, Tripoli. Two degrees less has been felt by Americans in Death Valley, California. Water boils at 212 degrees Fahrenheit or 671 on the absolute thermometer.

The coldest temperature made naturally on earth is believed to be somewhere in northern Siberia, where temperatures of 90 degrees below zero Fahrenheit have been observed. Actually this is still 369 degrees above the absolute zero of cold.

Man's highest artificial temperature, 45,000 degrees, is obtained for a brief instant by passing a 50,000 volt current through a fine wire of tungsten. There is a blinding flash, a bang, a puff of air and a light 100 times as bright as an equal area of the sun. The chromosphere or outer layer of the sun is actually at about 11,000 degrees Fahrenheit. The temperature of the explosion is measured by comparing its brightness with that of the sun.

The exploding wire cannot be used for any practical purpose. Atomic hydrogen flames, however, at 7,600 degrees, devised a short time ago by Dr. Irving Langmuir of the General Electric Company, are now being used for welding ships and pipes. The hydrogen is first broken up into its atoms in an electric arc and these are burned in oxygen to give a greater heat than ordinary molecular hydrogen. The usual oxyhydrogen blowpipe flame gives only 3,600 degrees Fahrenheit.

The blinding bluish-white flame of the oxyacetylene torch seen in many manufacturing plants is at 5,500 degrees. This is somewhat less than the estimated heat of the center of the earth, 6,000 degrees, approximately the temperature at which tungsten melts.

The best electric furnace gives only 4,900 degrees, though this is more than enough for many purposes. Iron melts at 2,745 degrees and is dull red at about 1,500.

Another attempt to achieve an extremely hot temperature was made recently at the Westinghouse Research Laboratories in East Pittsburgh. Here a large current was carried by an arc in a vacuum, not by a wire, and concentrated on a small spot on a metal plate. Early hopes that star temperatures had been produced by this method were dashed, but some 5,400 degrees Fahrenheit was reached.

These are poor efforts, however, compared with temperatures found at great distances from the earth. By juggling some mathematical formulae Prof. Eddington has calculated the giant stars to have 72,000,000 degrees at their cores.

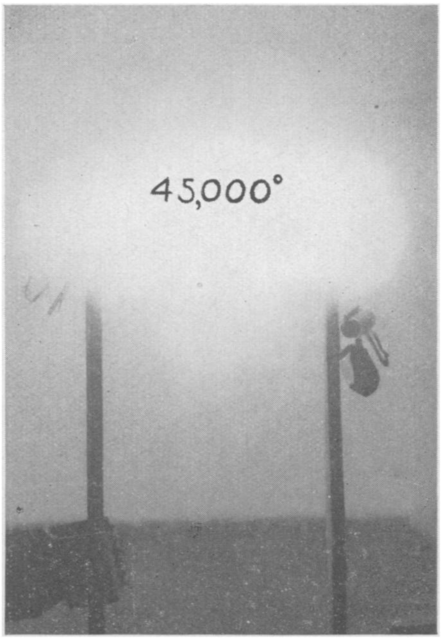
On the other hand, the universe can hardly improve man's best cold, for the absolute zero which we have approached within a degree or two cannot be surpassed by any agency in this world or the next.

Liquid Air Made Industrially

Here are some other low temperatures:

Liquid hydrogen is at 36 degrees above absolute zero or — 423 degrees on the Fahrenheit scale.

Liquid air made industrially in large quantities and used at the rate of 100 quarts a day at the Bureau of Standards, has a much higher temperature. Its liquefying point or the boiling point of



A PUNY EFFORT

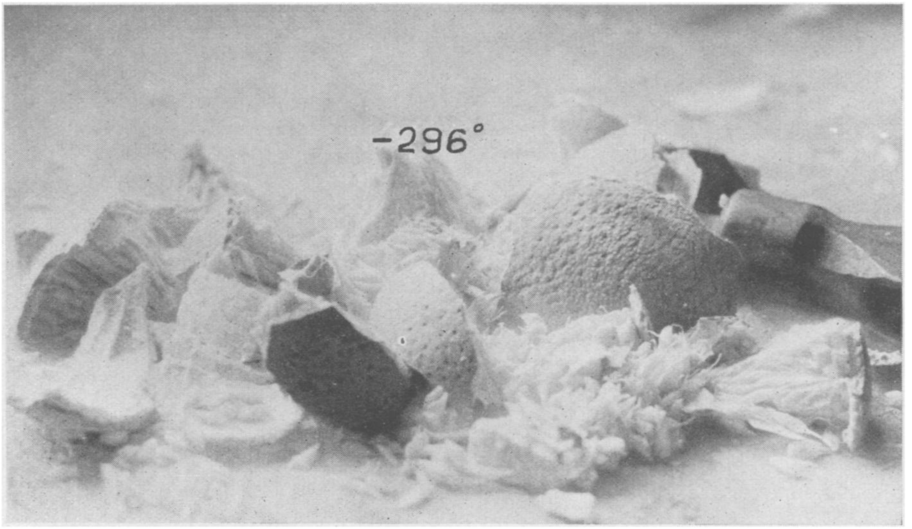
An exploding wire at 45,000 degrees Fahrenheit, man's greatest temperature, but a trivial accomplishment compared with the 72,000,000 degree estimated temperature of giant stars at their cores.

liquid air on the Fahrenheit scale is — 296 degrees. Liquid air is now made on a large scale industrially for the preparation of oxygen.

Solidified carbon dioxide gas, which is now gaining wide use as a refrigerant, is the coldest substance in everyday use. Its melting point is — 112 degrees, still higher and very near that Siberian temperature of — 90 degrees Fahrenheit.

If the pressure on liquid helium is reduced so that the helium evaporates rapidly, it is cooled still further. By compressing this super-cooled liquid, helium was solidified in 1927 at the University of Leiden, Holland, by Prof. W. K. Keesom, colleague of the great Kamerlingh Onnes. Prof. H. Kammerlingh Onnes, the dean of low temperature researchers, was himself the first to make liquid helium.

Extreme cold represents rest, rigidity and fixedness for the ultimate atoms of matter. Heat is excitement, a rushing around of the atoms in great agitation. As we pass to lower temperatures, electrons gradually set into their places on the atom and the commotion subsides, though everything is still gaseous. If we make the atoms even colder, they will form a liquid when they are near enough and quite enough to shake hands with their neighbors continuously. They still slide over each other, but they will not be able to escape and dash around.



AMONG THE FREAKS OF LOW TEMPERATURES

An orange immersed in liquid air, at —296 degrees Fahrenheit, becomes so hard and brittle that it can be broken up with a hammer. Liquid mercury is frozen solid and a flexible rubber hose becomes as stiff as a steel pipe.

The Cold of Death

As the cold increases, they suddenly lock fast to each other to form a solid. The atoms may now quiver more or less, but as the last dregs of heat are taken away, the stillness of death overtakes them. This is the absolute zero, where no motion of the atoms whatever is found. It is now easy to see why you cannot go beyond absolute zero. Once you are dead, you cannot be deader.

At the Bureau of Standards Dr. H. C. Dickinson, Dr. F. G. Brickwedde, W. Cook, R. B. Scott and J. M. Smoot perfected their super-refrigerator just ahead of two other laboratories competing for the honor of being the first to make liquid helium in this country, the Johns Hopkins University and the University of California.

In addition to the Washington apparatus and those of the other two United States laboratories, four or five institutions throughout the world are equipped to outdistance efforts of the severest polar winter. These are the University of Leiden, Holland, the Imperial Insitute in Berlin (Dr. W. Meissner), the University of Berlin (Dr. Franz Simon), the University of Toronto, Canada (Prof. J. C. MacLennan), and the University of Cambridge, England. Liquid helium has been made at all these places except Cambridge.

Why this pursuit of extreme cold? What useful knowledge do scientists hope to find at the low end of the temperature scale?

The magnificent achievements of physicists on the constitution of matter point clearly to low temperature research for the solution of some of its problems. At these intense colds, where the disturbing darting to-and-fro of the atoms is reduced to a minimum, the nature and properties of substances show up more clearly. The amount of heat that matter will hold at these low temperatures will be investigated. At the Bureau of Standards, Dr. Dickinson's group hopes to go on to establish an accurate scale of temperature near the absolute zero, something that is lacking at present.

At the low temperature achieved, every substance except helium itself is frozen hard, even gases like hydrogen, which next to helium is the most difficult gas to liquefy.

Super-electro magnets may soon be made in the cold of liquid helium, because a hundred thousand times more current is carried by metals at the lowest temperatures than under ordinary conditions.

Dr. Peter Kapitza of the University of Cambridge, England, is already busy with this problem. Using giant surges of current up to 70,000 amperes he has already made stronger magnets than were ever created before. By immersing his wires in liquid helium he will be able to use still larger currents and make more powerful magnets.

At the University of Berlin, low temperature technique has reached its highest development. Under the direction of Dr. Franz Simon 13 to 15 quarts of liquid hydrogen per hour are made there.

Again and again a curiosity in the laboratory has become an everyday commodity. Such may easily happen in this case. Commercial liquid hydrogen is certainly an immediate possibility and, at no very distant future, perhaps, commercial liquid helium.

Surpass Absolute Zero?

Are still lower temperatures possible? Can the absolute zero itself be reached or even surpassed? These are favorite questions. At present no other means of lowering further the temperature than that used by Prof. Keesom to make solid helium, is known. So close to absolute zero, every hundredth of a degree is gained at the greatest pains, but no doubt the experimental limit will be lowered.

Matter itself might be destroyed if the absolute zero were reached. Super-X-rays devastating everything in their path, similar to but immensely stronger than the cosmic radiation that streams down into the earth's atmosphere from the depths of space, would result from this achievement.