News and views

Giauque-Kelvin Proposal

IN 1939 Professor W. F. Giauque, of the University of California, proposed that we change the manner of defining the number scale of the absolute, thermodynamic (Kelvin) scale of temperatures by assigning a number to a *single* reproducible thermal state (e.g., triple point of H_2O). At present the number scale is defined by assigning a number (100) to the interval between *two* fixed points ("ice"[1] and normal boiling points of H_2O). J. P. Joule and Lord Kelvin[2] made the same proposal one hundred years ago but it was forgotten until it was made anew by Giauque. Joule and Thomson in 1854 said the proposed change in definition "must be adopted ultimately" because the definition based on a *single* fixed point is "preferable".

The calibration of the first "precision" gas thermometer, constructed in 1702 by Amontons, was calibrated with a *single* fixed point (boiling point of H_2O). The use of *two* fixed points was introduced later as an expedient for getting better agreement between the scales of different liquid-in-glass thermometers. Lord Kelvin defined the thermodynamic temperature scale, which he introduced, so as to make it agree with the practical scale then in use, which was based on two fixed points. Now, for the triple point of water on the newly defined scale, it is proposed to select the average of the most recent determinations of the triple point temperature on the present Centigrade-Kelvin Scale.

Adoption of the Giauque-Kelvin Proposal was officially recommended by the International Union of Pure and Applied Physics at its meeting in Amsterdam in 1948, and by the International Union of Pure and Applied Chemistry at its meeting in 1953. Both Unions have sent requests to the International Committee on Weights and Measures asking this International Committee to select the defining number for the triple point of H_2O. In 1948, the International Committee on Weights and Measures and the General Conference on Weights and Measures approved the principle of an absolute thermodynamic scale of temperatures based on a *single* fixed point.

It is anticipated that the Giauque-Kelvin Proposal will be considered by the (SUN) Commission on Symbols, Units, and Nomenclature of the International Union of Pure and Applied Physics during the coming meeting of the Union, July 8–10, 1954, in London. A recommendation of the SUN Commission, if acted upon favorably by the General Assembly of the Union, would have the approval of the Union.

All that is needed now to complete the adoption of the Giauque-Kelvin Proposal and get the new definition into use is for the International Committee on Weights and Measures and the General Conference on Weights and Measures to approve a defining number for the triple point of H_2O on the new scale.

A meeting is scheduled this year in Paris (Sèvres) of the International Committee on Weights and Measures, and after it, a General Conference on Weights and Measures. Two divisions of the National Research Council, the Division of Physical Sciences and the Division of Chemistry and Chemical Technology, jointly appointed, June 1953, an Ad Hoc Committee[3] on the Temperature Scale to canvass the opinions of Americans interested in the thermodynamic scale of temperatures and to make a recommendation on behalf of American scientists for the guidance of other committees and bodies concerned with temperature scales.

The NRC Ad Hoc Committee has found that interested American opinion is strongly in favor of: (1) putting the Giauque-Kelvin Proposal into use as soon as possible by the adoption of a defining number for the triple point of H_2O by the International Committee and General Conference on Weights and Measures this year, and (2) the selection for the triple point of H_2O on the new scale of 273.170 which is the average of the recent determinations of this temperature in several different countries.

The adoption of the Giauque-Kelvin Proposal will not in any way affect the practical scale of temperatures, which is the International Temperature (Celsius) Scale, since the practical scale has its own independent definition based on six fixed points. The advantages claimed for a definition of an absolute thermodynamic scale based on a *single* fixed point are: (1) it will simplify fundamental gas thermometry and reduce its errors since a gas thermometer will be calibrated at a *single* fixed point and calibrations at the steam point, which are more difficult and inaccurate, will become

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[1] The "ice" point is a state of equilibrium between pure ice and air-saturated water in intimate contact at a pressure of one normal atmosphere. It is 0.010 degree (Centigrade) lower than the triple point of H_2O which is the state of equilibrium of solid, liquid and vapor, all in a *pure* state. The "ice" point lacks the precision of the triple point as a thermometric fixed point because as ice melts it surrounds itself with pure water and prevents intimate contact of ice and air-saturated water. The International Committee on Weights and Measures and the General Conference on Weights and Measures in Paris (Sèvres), 1948, adopted a resolution recommending the triple point of H_2O for precision measurements. Consequently, the triple point has been selected for the fundamental fixed point in the new definition (Giauque-Kelvin) of the absolute, thermodynamic scale of temperatures.

[2] J. P. Joule and W. Thomson, *Phil. Trans.* 1854, Vol. CXLIV, page 321.

[3] NRC, Ad Hoc Committee on the Temperature Scale: John G. Aston, Pennsylvania State University; James A. Beattie, Massachusetts Institute of Technology; H. A. Boorse, Barnard College; F. G. Brickwedde, Chairman, National Bureau of Standards; R. L. Dolecek, Naval Research Laboratory; W. F. Giauque, University of California; E. F. Hammel, Los Alamos Scientific Laboratory; William V. Houston, Rice Institute; C. T. Lane, Yale University; Earl A. Long, University of Chicago; D. W. Osborn, Argonne National Laborartory; K. S. Pitzer, University of California; F. D. Rossini, Carnegie Institute of Technology; Henry B. Silsbee, University of California; and R. E. Wilson, Emerson Research Laboratories.

unnecessary; (2) the relation between the triple point of H_2O on the Celsius (International) Scale (0.010°) and on the Kelvin Scale will be fixed by definition; and (3) the limits of uncertainty, or probable errors, in the "best" values for the gas constant, R, and the Boltzmann constant, k, can be reduced.

The International Committee on Weights and Measures is composed of 18 members who act as individuals and not as representatives of their countries or laboratories. Dr. E. C. Crittenden, retired Associate Director of the National Bureau of Standards, is a member of this International Committee. The International Committee has working committees, called Advisory Committees, composed of technical experts. The National Bureau of Standards is U.S.A. representative on these Advisory Committees. The International Committee receives recommendations from its Advisory Committees upon which it acts and sends recommendations for final approval or change to the General Conference on Weights and Measures, a body composed of official delegates from the governments of 33 countries. The U.S.A. delegate is designated by the United States, Department of State. The International Bureau of Weights and Measures at Sèvres (Paris), France, is the laboratory and secretariat of the Advisory and International Committees and the General Conference on Weights and Measures. It is probable that the Advisory Committee on Thermometry and Calorimetry will meet in Sèvres about July 1, this year, the International Committee in September, and the General Conference in October. The International Committee normally meets biannually, and the General Conference at six year intervals.

F. G. Brickwedde
Chairman, NRC Ad Hoc Committee on the Temperature Scale

Bevatron Launched

PUBLICITY accorded to power reactor development and to noises from the Marshall Islands notwithstanding, the Atomic Energy Commission still has a healthy interest in those parts of its programs which are devoted to fundamental physical research. A prominent example is the AEC-financed $9 million Bevatron recently completed at the University of California Radiation Laboratory in Berkeley. Housed in a circular building that rests in a depression of Charter Hill overlooking the University campus, the 10 000-ton proton accelerator was first successfully operated at an initial energy level of 20 Mev on February 15th. By March 12th the energy had been gradually increased to 5 billion electron volts and, according to a University announcement, efforts are continuing to reach the machine's full design energy of 6.25 Bev.

The Bevatron, now the most powerful member of the family of particle accelerators, is expected to be useful in extending the spectrum of laboratory meson production still further than has been possible with the 2.3 Bev Cosmotron at Brookhaven National Laboratory or with other high-energy machines at Columbia, Chicago, and Caltech.

Edward Lofgren, physicist in charge of the Bevatron, is credited with bringing the accelerator into successful operation. He has indicated that most of the effort of the laboratory staff in the next few months will be spent on perfecting the machine's operation, determining the nature of the proton beam, and identifying the nuclear particles generated when the protons strike target nuclei.

Particular attention will be given to the artificial production of heavy mesons, ranging in mass up to the mass of the proton, and of hyperons, of mass intermediate between that of the neutron and the deuteron. V-events arising from the decay in flight of such particles have been observed in very rare cases in cloud-chamber photographs of cosmic-ray events and in experiments at the Brookhaven Cosmotron. Hope has been expressed that the more powerful Bevatron can be used to produce a number of different types of these heavy particles for analysis under controlled laboratory conditions. In this connection it might be noted that the Bevatron has been equipped with a specially designed continuous cloud chamber (also the largest in the world), measuring 4 feet by 8 feet by 7 inches. The instrument, built primarily by Kenneth Relf under the supervision of cloud-chamber expert Wilson Powell, will be used in part to determine the characteristics and scattering of the Bevatron beam in addition to its employment in the actual research program.

The Bevatron was first suggested, according to the University, by William Brobeck, assistant director of the Radiation Laboratory, in 1947. Making use of the theory of phase stability developed independently two years earlier by E. M. McMillan of Berkeley and by V. Veksler of Russia, Brobeck conceived a basic design for the machine and, after the AEC had allocated funds for the project in 1948, he supervised the design and construction. Theoretical computations incorporated in the design were made by Lloyd Smith.

In operation, the Bevatron makes use of a compact, 500 000 electron volt Cockroft-Walton generator which feeds protons into a linear accelerator where their energy is increased to 10 Mev. Passing between a pair of strong focusing magnets which bunches them together, the protons travel through the electrical field of a specially designed "inflector" which brings the beam into the Bevatron's accelerating chamber at such an angle that the particles are caught by the magnetic field and guided over a precise orbit. The Bevatron's huge electromagnet, which stands 14 feet high and has an outside diameter of 135 feet, is powered by two generators capable of supplying 100 000 kilowatts of power each time a bunch of protons is accelerated. When the protons enter the accelerating chamber, the magnetic field is relatively weak (about 300 gauss), but as they gain energy the field is gradually increased to a peak strength of about 15 500 gauss. The proton energy is boosted with increasing frequency by an electrode and oscillator located at one of the interspaces of the magnet.