Thermodynamic Temperatures and International Practical Scale Temperatures

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Dr. Ambrose (*1*) performed a useful service in drawing the attention of experimenters to the need to specify the basis of their recorded temperatures. One can wholly support his suggestion that they should include in their texts a sentence such as "Temperatures in this paper are expressed as International Practical Kelvin Temperatures T_{68}, which for most purposes are indistinguishable from the thermodynamic temperatures T", or "which it is convenient to treat as interchangeable with thermodynamic temperatures T where no confusion arises and theoretical considerations do not demand differentiation of the two".

One can feel less happy about his earlier discussion of the difference between thermodynamic temperatures and International Practical Scale Temperatures, in that this tends to perpetuate confusions which have persisted from the days of Kelvin but which have recently been resolved. Although Kelvin himself used the term "absolute thermometric scale", he in fact established, in collaboration with Joule (*3*), not a *scale* but a thermodynamic temperature *function,* namely

$$\frac{T_1}{T_2} = \left(\frac{Q_1}{Q_2}\right)_{\mathrm{REV}}$$

where Q_1 and Q_2 are the heat quantities exchanged by a reversible cyclic heat power plant (cyclic "heat engine") with thermal reservoirs respectively at thermodynamic temperatures T_1 and T_2.

Zero thermodynamic temperature being that temperature to which, with T_1 at a fixed level of temperature, T_2 tends to zero, it is only necessary to assign an arbitrary number to some other temperature level in order exactly to define the *unit* of thermodynamic temperature. This is done by assigning 273.16 kelvins to the triple point of water, so defining the unit of *thermodynamic temperature* as the fraction 1/273.16 of the thermodynamic temperature of the triple point of water, which then has a value of *exactly* 273.16 K.

That there is no need to talk in terms of a *scale* of thermodynamic temperature can be seen by considering how, having defined the unit of thermodynamic temperature in the above way, the thermodynamic temperature of any system may *in principle* be determined in terms of that unit. With reference to the foregoing thermodynamic temperature function, it is only necessary to conceive of a reversible cyclic heat power plant exchanging heat reversibly with the given system as one reservoir and with a second reservoir at the triple point of water. Then, if T_2 denotes the thermodynamic temperature of the triple-point reservoir (namely 273.16 K) and T_1 the required thermodynamic temperature of the system, measurement of Q_1 and Q_2 enables T_1 to be calculated from the relation

$$T_1 = 273.16(Q_1/Q_2) \text{ kelvins}$$

This involves no concept of a temperature scale, but requires only the specification of the above function and the definition of the kelvin unit of thermodynamic temperature.

While it is thus possible, in principle, to determine the thermodynamic temperature, in kelvins, at any given temperature level, *exact* specification of the number of kelvins at any temperature level other than that of absolute zero and the triple point of water is rendered impossible both by the inability to construct a fully reversible cyclic heat power plant and by the inexactitude of all practical measurements. The actual method of making the best possible estimate of the number of kelvins at any given temperature level does not, of course, depend on tests on cyclic heat power plants but, for example, on the application of theoretical thermodynamic relations to the results of experimental measurements on gas thermometers. It was this inability to know the precise number of kelvins at any temperature level other than that of absolute zero and the triple point of water which led scientists and engineers to seek international agreement on an International Practical Scale of Temperature. This is so set out in IPTS-68 (*4*) that *scale temperatures* on it are expressed in kelvins and represent *the best current estimates* of the true *thermodynamic temperature* at each temperature level.

These considerations were set out in a paper by the present writer in 1967 (*2*). While some parts of that paper are now "water under the bridge", the key point is still very relevant and it is interesting to note that the official text of IPTS-68 uses only the term *thermodynamic temperature.* Nowhere does it make reference to a *thermodynamic scale.* When this practice becomes universal, the present confusions will be a thing of the past. In this context, it should be noted that Dr. Ambrose's second quotation on page 140 of his paper, in which the term "thermodynamic scale" appears, was not taken from the IPTS-68 text. One must hope that everyone will in due time follow the good example set in that text.

Literature Cited

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