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# Standard Guide for Expression of Temperature<sup>1</sup>

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## 1. Scope

1.1 This guide covers uniform methods for expressing temperature, temperature values, and temperature differences.

1.2 This guide is intended as a supplement to [IEEE/ASTM SI-10](#).

1.3 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

## 2. Referenced Documents

2.1 *ASTM Standards:*<sup>2</sup>

[E344 Terminology Relating to Thermometry and Hydrometry](#)

[IEEE/ASTM SI-10 Standard for Use of the International System of Units \(SI\): The Modern Metric System](#)

## 3. Terminology

3.1 *General*—Standard terms used in this guide are defined in Terminology [E344](#) and in [IEEE/ASTM SI-10](#).

## 4. Basic Concepts

4.1 Temperature is a fundamental measurable quantity designated by the symbol  $T$  or the symbol  $t$  (see [5.1](#)).

4.2 A temperature value is expressed in terms of a temperature scale. The complete description consists of a numerical value designating the magnitude, a unit, and, where appropriate, a tolerance or uncertainty. Both the numerical value and the unit depend upon the scale.

4.3 A unit of temperature is understood to mean an interval on a temperature scale.

<sup>1</sup> This guide is under the jurisdiction of ASTM Committee [E20](#) on Temperature Measurement and is the direct responsibility of Subcommittee [E20.91](#) on Editorial and Terminology.

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<sup>2</sup> For referenced ASTM standards, visit the ASTM website, [www.astm.org](http://www.astm.org), or contact ASTM Customer Service at [service@astm.org](mailto:service@astm.org). For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

4.4 A temperature difference, interval, or increment is also described by a sign, a numerical value designating the magnitude, a unit, and, where appropriate, a tolerance or uncertainty.

## 5. Temperature Scales

5.1 *Thermodynamic Temperature Scales:*

5.1.1 By international agreement, the theoretical temperature scale to which all temperature values should be ultimately referable is the Kelvin Thermodynamic Temperature Scale (KTTS). A value of temperature expressed on the KTTS is known as a thermodynamic temperature, symbol  $T$ .

5.1.2 The unit of thermodynamic temperature is the kelvin, symbol K. The kelvin is a base unit in the International System of Units (SI). Note that the symbol for the kelvin is the capital letter K only; the degree sign ( $^{\circ}$ ) is not used.

5.1.3 The expression of a value of thermodynamic temperature is written:

$$T = n_k \text{ K} \quad (1)$$

where:

$n_k$  = a numerical value designating the magnitude,  
K = the symbol for the unit kelvin.

The magnitude may also be represented by the notation  $T/\text{K}$ .

5.1.4 A thermodynamic temperature may be expressed as a Celsius temperature. The symbol  $t$  is to be used to designate a Celsius temperature, but if this symbol leads to a conflict in notation in a given context, it is acceptable to use the symbol  $T$  instead to designate a Celsius temperature.

5.1.5 The unit of Celsius temperature is the degree Celsius, symbol  $^{\circ}\text{C}$ . The degree Celsius is a derived SI unit. Note that the symbol for the degree Celsius consists of the degree sign ( $^{\circ}$ ) followed by the capital letter C. Neither the degree sign nor the letter C alone represents the degree Celsius. The Unicode value for the degree sign is 00B0 in hexadecimal, 0176 in decimal. The symbol may be represented by the two separate Unicode characters, the degree sign ( $^{\circ}$ ) followed by the capital letter C. The Unicode character “ $^{\circ}\text{C}$ ” with the hexadecimal value 2103 (decimal value 8451) may also be used as the degree Celsius symbol.

5.1.6 The expression of a value of Celsius temperature is written:

$$t = n_c \text{ }^{\circ}\text{C} \quad (2)$$

where:

$n_c$  = a numerical value designating the magnitude,  
 $^{\circ}\text{C}$  = the symbol for the unit degree Celsius.

The magnitude may also be represented by the notation  $t/^{\circ}\text{C}$ .

5.1.7 By definition, at any temperature, a temperature increment of one degree Celsius is equal to a temperature increment of one kelvin.

5.1.8 By definition, the Celsius temperature  $t = 0^{\circ}\text{C}$  is the same as the thermodynamic temperature  $T = 273.15\text{ K}$ . The relation between numerical values associated with both expressions of a temperature is therefore given by:

$$n_c = n_k - 273.15 \quad (3)$$

where:

$t = n_c^{\circ}\text{C}$  is the same temperature as  $T = n_k\text{ K}$ .

## 5.2 Practical Temperature Scales:

5.2.1 Practical temperature scales have been established by international agreement for the practice of temperature measurement. Practical scales are designed so that a numerical value of temperature expressed on the scale is close to the numerical value of thermodynamic temperature. Because the KTTS is difficult to implement, the vast majority of temperature measurements are based on a practical scale.

5.2.2 There are two practical temperature scales now in use, superseding all others. The International Temperature Scale of 1990<sup>3</sup> defines temperatures above 0.65 K. The Provisional Low-Temperature Scale from 0.9 mK to 1 K<sup>4</sup> defines temperatures between 0.0009 K and 1 K.

5.2.3 Examples of previously used practical temperature scales are the International Practical Temperature Scale of 1968, the International Practical Temperature Scale of 1948, and the International Temperature Scale of 1927.<sup>5</sup>

5.2.4 A value of temperature on a practical temperature scale may be expressed either in kelvins or in degrees Celsius using the designations, symbols, and relations given in 5.1.

## 6. Expression of Values of Temperature

### 6.1 Temperature Scale Identification:

6.1.1 In a document containing temperature values, it is important that the temperature scale upon which those values are expressed be identified. When reference to more than one scale is made in a document, or when critical data are presented, scale identification is essential.

6.1.2 Thermodynamic temperatures may be identified as such, or with reference to the KTTS. If values of temperature are expressed on a practical temperature scale, the scale should be identified. The identification may be an abbreviation, as defined in the text of the scale; for example, the International Temperature Scale of 1990 is abbreviated ITS-90 and the

Provisional Low-Temperature Scale from 0.9 mK to 1 K is abbreviated PLTS-2000.

6.1.3 Scale identification may be placed in text, in footnotes, in table headings, or in figures, as appropriate.

6.1.4 A scale may also be identified by a subscript associated with a quantity symbol; for example,  $T_{\text{Th}}$  and  $t_{\text{Th}}$  for thermodynamic temperatures,  $T_{90}$  and  $t_{90}$  for temperature values on ITS-90, and  $T_{2000}$  for temperature values on PLTS-2000.

### 6.2 Numerical Format:

6.2.1 Numerical values of temperature should be expressed as decimal numbers.

### 6.3 Unit Symbol Format:

6.3.1 The unit symbol should be separated from the numerical value by a single space. There should be no space between the degree sign and the letter C. Punctuation is not part of the unit symbol; only punctuation required by context or grammar should follow the unit symbol.

6.3.2 In an expression of a range of temperature values, the same unit symbol should be used with each value in the range; for example: “over the temperature range 16 K to 50 K” or “any temperature between 20  $^{\circ}\text{C}$  and 30  $^{\circ}\text{C}$ .” These examples can also be expressed as “over the temperature range (16 to 50) K” or “any temperature between (20 and 30)  $^{\circ}\text{C}$ ” respectively.

6.3.3 Multiple and submultiple prefixes should not normally be used with the unit for the expression of values of temperature, for temperatures above 1 K. For temperatures below 1 K, a submultiple may be used. The preferred submultiple is 0.001 (prefix “milli,” symbol m).

6.3.4 When a tolerance or uncertainty is associated with a value of temperature, both the value and the tolerance or uncertainty should be expressed with the same unit. Unit prefixes should not normally be used. The unit symbol should follow each numerical value. For example:

$$t_{90} = 60.0^{\circ}\text{C} \pm 1.5^{\circ}\text{C} \quad (4)$$

$$T_{90} = 273.150\text{ K} \pm 0.001\text{ K} \quad (5)$$

6.3.5 When a tolerance or uncertainty is presented in a format not directly associated with a value of temperature, a unit prefix may be used. The preferred submultiple is 0.001 (prefix “milli,” symbol m). For example, the uncertainty  $u$  of a temperature value may be expressed:

$$u(t_{90}) = 0.7\text{ mK} \quad (6)$$

## 7. Expression of Temperature Differences, Intervals, and Increments

7.1 Temperature differences, intervals, and increments are normally understood to be expressed with reference to the same temperature scale as are values of temperature, within a given context. Where there is a possibility of misunderstanding, the temperature scale should be explicitly identified.

7.2 A small temperature difference, interval, or increment may be expressed in terms of a submultiple of the appropriate unit of temperature. The use of unit prefixes to indicate

<sup>3</sup> Preston-Thomas, H., “The International Temperature Scale of 1990 (ITS-90),” *Metrologia*, Vol 27, No. 1, 1990, pp. 3–10. For errata see *ibid*, Vol 27, No. 2, 1990, p. 107.

<sup>4</sup> Rusby, R. L., Durieux, M., Reesink, A. L., Hudson, R. P., Schuster, G., Kühne, M., Fogle, W. E., Soulen, R. J., and Adams, E. D., “The Provisional Low Temperature Scale from 0.9 mK to 1 K, PLTS-2000,” *J. Low Temp. Physics*, Vol 126, 2002, pp. 633–642.

<sup>5</sup> *Evolution of the International Practical Temperature Scale of 1968, ASTM STP 565*, ASTM, 1974.