they cannot be certainly determined. Thermometers containing these gases are generally taken as the ultimate standards of reference in practical thermometry.

Mercurial Thermometry

5. The most familiar type of thermometer depends on the apparent expansion of a liquid hermetically sealed in a glass bulb attached to a graduated stem of fine bore. Of all liquid­in-glass thermometers those containing mercury are almost invariably selected for scientific purposes, although at first sight mercury would appear to be the least suitable liquid, on account of its small coefficient of expansion. The smallness of the expansion necessitates an extremely fine bore for the stem, which introduces errors in consequence of the high surface tension of mercury. The considerable density of the liquid also tends to exaggerate the effects of change of position due to variation of the pressure exerted on the interior of the bulb by the liquid column. These errors are small and fairly regular, and can be corrected within certain limits. A much more serious source of trouble, especially at high temperatures, is the imperfect elasticity of the glass, which causes more or less irregular changes in the volume of the bulb. The effect of these changes on the readings of the thermometer is enhanced by the smallness of the expansion of mercury, and might be reduced by employing a more expansible liquid. It is more likely, however, that the defect will be remedied by the con­struction of thermometers of fused quartz, which is the most perfectly elastic solid hitherto discovered. For work at low temperatures the range of a mercury thermometer is limited by its freezing-point (—39° C.).

These are the serious disadvantages attending the use of mercury, but in other respects it possesses so many advantages over alcohol or other substitutes, that it will in all probability continue to be used almost exclusively in thermometers of this type for scientific work. Among its chief advantages may be reckoned its high boiling-point (357° C.), and the absence of evaporation from the top of the thread, which is so serious a source of error with the alcohol thermometer. With mercury the evaporation is almost inappreciable at 100° C., and can in all cases be avoided by exposing the upper parts of the emergent thread to the temperature of the air. Although an evacuated mercury thermometer cannot be safely used at temperatures over 300° C., owing to the breaking up of the thread of liquid in the stem, it has been found possible, by filling the upper part of the stem with nitrogen or carbon dioxide under high pressure, to extend the range to 550° C. A more important advantage for accurate work is the fact that mercury does not wet glass, and avoids any possible errors due to adherent films of liquid on the walls of the tube. This greatly facilitates observations, and also renders it possible to calibrate the thermometer *after* construction, which cannot be satisfactorily accomplished with other liquids. The process of construction and calibration is further facilitated by the fact that mercury does not dissolve air to any appreciable extent. In consequence of the regularity of expansion of mercury at ordinary temperatures, the scale of the mercury thermometer agrees very closely with that of the gas thermometer. The liquid is very easily obtained in a high state of purity by distillation, and has practically no chemical action on glass. In this respect it is superior to the liquid alloy of potassium and sodium, which has been employed in some high-temperature thermometers, but which rapidly re­duces silica at high temperatures. The high conductivity and low specific heat of mercury as compared with most other liquids tend to render the thermometer quick and sensitive in action. Its opacity considerably facilitates accurate reading, and even the smallness of its expansion has one great countervailing advantage, in that the correction for stem-exposure is pro­portionately reduced. This correction, which (even in the case of mercury) may amount to as much as 40° C. at 550° C., is far the most uncertain in its application, and is the most serious objection to the use of the liquid-in-glass thermometer at high temperatures.

6. *Construction.—*The construction of the most accurate type of mercury thermometer has undergone some changes of detail in recent years. The range of the most accurate standards is generally restricted to the fundamental interval. The length of a degree on the stem can be increased to any extent by en­larging the bulb or diminishing the bore of the stem, but it is found in practice that there is no advantage in making the scale more open than one centimetre to the degree C. in standard instruments, or in increasing the number of divisions beyond ten or at most twenty to the degree. Enlarging the bulb makes the instrument sluggish, and exaggerates the errors due to imperfect elasticity. Diminishing the bore of the tube increases the errors due to capillary friction. Even one centimetre to the degree is an impracticable scale for thermometers graduated continuously from oo to 100° C., owing to the excessive length of the stem. In order to secure so open a scale, it is necessary to limit the range to 35°, or at most 50°. The fixed points 0°and 100° may still be retained, for purposes of testing and re­ference, by the device, now commonly employed, of blowing auxiliary bulbs or *ampoules* on the stem, the volume of which is carefully adjusted to correspond with the number of degrees that it is desired to suppress.

In the best instruments for work of precision the bulb is not blown on the capillary tube itself, but is formed of a separate piece of tube fused on the stem. It is possible in this manner to secure greater uniformity of strength and regularity of dimensions. The thickness of the glass is generally between half a millimetre and one millimetre. The advantage in point of quickness gained by making the glass thin is more than counter­balanced by increased fragility and liability to distortion. The best form of bulb is cylindrical, of the same external diameter as the stem. The bore of the stem should also be cylindrical, and not oval or flattened, in order to diminish errors due to capillarity, and to secure the greatest possible uniformity of section. The glass should be clear, and not backed with opal, both to admit of reading from either side, and to minimize risk of bending or distortion. In the commoner sorts of ther­mometers, which are intended for rough purposes and to be read without the application of minute corrections, it is not unusual to divide the tube into divisions of equal volume by a preliminary calibration. In the most accurate instruments it is preferable to divide the tube into divisions of equal length, as this can be more accurately effected. The corrections to be applied to the readings to allow for inequalities of bore can be most satisfactorily determined in the case of mercury thermo­meters by calibrating the tube after the instrument is completed (see Calibration). This correction is known as the “ cali­bration correction.” Instead of being separately determined it may be included in the scale correction by comparison with a standard instrument, such as a platinum-resistance ther­mometer.

7. *Corrections.—*The corrections to be applied to' the readings of a mercury thermometer, in addition to the calibration correc­tion, may be summarized under the following heads: '(i.), Zero. (ii.) Fundamental Interval. (iii.) Internal and External Pres­sure. (iv.) Stem Exposure. (v.) Scale Correction, including Poggendorff’s correction.

(1) The *changes of zero* are of two kinds. (a) *Secular rise* of zero due to gradual recovery from changes or strains acquired by the bulb during the process of manufacture. This process may be hastened and subsequent changes practically eliminated by anneal­ing the bulb after manufacture, and before final adjustment, at a high temperature, such as that of boiling sulphur (about 450° C.). A thermometer which has not been so treated may show a rise of zero amounting to as much as 20° or 30° when exposed for some time to a temperature of 350° C. *(b) Temporary depression* of zero after each exposure to a high temperature, followed by a slow recovery which may last for days or weeks. The best thermo­meters of hard glass show a depression of zero amounting to about one-tenth of 1° C. after exposure to 100° C. In softer glass the depression is usually greater and more persistent, and may amount to half a degree after 100° C. At higher temperatures the depres­sion generally increases roughly as the square of the temperature above 0° C. It may amount to 2° or 3° at 300° C. The effect cannot be calculated or predicted in any series of observations,