described by Welsh (Proc. R. S., vi. 181) and Whipple (Phil. Mag., [5], xxi., 1886, p. 27).

The reading of thermometers is greatly facilitated by the process of enamelling the back, and still more by that of entirely surround­ing the instrument with enamel except over a narrow strip through which the mercury is seen.@@1 The enamel must not be allowed to encroach on the bulb, for that would endanger the homogeneity and strength of the glass.

Thermometers Employed for Special Purposes.—Physical and Chemical Work.—For all purposes of minute accuracy where thermometers are applicable standard instruments must be em­ployed. They must be used in one position only. The stem is usually engraved with an arbitrary scale of equal divisions, the total range not exceeding 15o C., and readings are made by a cathetometer at some distance. The use of an intermediate bulb, first recommended by Person, enables the fixed points to be observed on instruments of very short range. Results of great accuracy, certainly to 0o⋅005 C., may be obtained in this way for comparative purposes if sufficient care be taken ; but the greater the sensitiveness of a thermometer the more difficult is it to obtain a series of concordant readings (Heat, vol. xi. p. 562). Pickering@@2 uses thermometers of extreme sensitiveness, in which, by conveying the excess of mercury into an expansion at the top of the stem, he secures that the same part of the short arbitrary scale is used for every temperature that has to be measured. In physical researches thermoelectric junctions are more often used than thermometers for measuring very small differences of temperature.

For ordinary work in a chemical or physical laboratory thermo­meters are used which can be read easily to one-tenth of a degree centigrade, and have a range from 0° to 100o, or in some cases to 350o C. They are always either engraved on the stem or graduated on an included scale (see Heat, figs. 4, 5), and are not mounted on frames of any kind. It is not necessary to calibrate such thermo­meters ; but they should be compared with a standard at several temperatures and frequently verified in melting ice and steam of boiling water.

Zincke’s chemical thermometer for high temperature has a scale commencing at 100° C. In Geissler,s nitrogen thermometer the range is extended by raising the boiling point of the included mer­cury, the upper part of the tube being filled with rarefied nitrogen.

Meteorological.—The thermometer was early applied to the study of differences of climate, and this is still one of its most important uses. The wet and dry bulb thermometers placed in the shade give the temperature and humidity (see Hygrometry) of the surrounding air, but “shade” and “surrounding air” require to be defined. Shade is intended to exclude rain and prevent all radiation ; and the surrounding air is that of the atmosphere in the neighbourhood of the thermometer outside any shelter that may be used. The simplest way of observing is to hang up a thermometer in the shadow of some rather distant object and leave it until it acquires a steady temperature ; but this method has been found impracticable and does not give very exact results.

In different countries different patterns of thermometer shelter are employed and exposure takes place at a different height above the ground. Results so obtained cannot be critically compared, and the relative mean temperatures of the atmosphere in different countries are only known to within one or two degrees. The Stevenson double-louvred screen (see vol. xvi. p. 115), a box open below, provided with a solid roof, is used at all meteorological stations in Great Britain. It is placed 4 feet from the ground, and painted white outside and inside. The results derived from its use are comparable, because the conditions in which it is em­ployed are the same, but the general introduction of a double roof would greatly add to its efficiency. Exposure outside windows or in wall boxes is the rule in Austria. In France the Renou screen is largely used ; it is a flat roof one square metre in extent, and double ; the thermometers are hung under it two metres from the ground. A similar roof, but of much larger size, is employed in Australia, in combination with a metal thermometer-box. A metallic box, constructed of double louvres with an air-space between, finds favour in Spain. In Russia and Switzerland Wild’s shelter is extensively employed. The thermometers are enclosed in a case composed of two or three concentric zinc cylinders per­forated to admit air, and placed 11 feet above the ground. They are protected by a large shelter of wood, the south wall and roof of which are double and made of solid boards, between which air circulates ; the east and west sides are louvred, and the north side entirely open. A similar shelter is used in Canada, to cover a box of single sheet-iron louvres in which the thermometers are placed 4½ feet from the ground. Various systems of exposure were authorized in the United States until 1885. It was then decided, as the result of experiments @@3 carried on for nearly two years, that a uniform pattern of shelter be adopted by the Signal Service. It

is a single-louvred wooden box, 3 feet 6 inches long, 3 feet wide and high, with a movable bottom and a double roof. The louvres are provided with an upright flange on their inner side, designed to keep rain from the thermometers. The bottom of the shelter is to be fixed either 9 feet above a roof or 16 feet above grass.

All these screens are confessedly imperfect, although most of them are well adapted for the climates in which they are used. Numerous comparisons of different screens with each other have been made,@@4 but in some cases sufficient precautions in the way of using instruments precisely similar and only dissimilarly situated have not been observed, and the results are uncertain. A critical comparison of the leading forms of thermometer shelter in use is still a desideratum.

The sling thermometer@@5 (thermomètre fronde), a small thermo­meter whirled in the air at the end of a string, is often used as a standard, and gives more correct readings than most closed screens. All open screens are untrustworthy. Aitken@@6 has devised a series of thermometer boxes on a new principle, radiation being taken advantage of to produce a constant draught over the thermometer bulbs by the use of a long blackened chimney. These give admirable results. Very small and bright objects are little affected by radiation : hence thermometers with bulbs of small diameter and coated with a bright deposit of gold or silver have been used with­out screens. The air temperature has also been calculated by means of a formula from the readings of two similar thermometers, the bulbs of which are unequally affected by radiation. Some form of sling ther­mometer should always be used for observations at sea; the Board of Trade screen generally employed is thoroughly objectionable, and can only give moderately good results by the exercise of great precautions on the part of the observer.@@7

As a rule, thermometers for meteorological purposes are made with spherical bulbs, although cylindrical reservoirs present cer­tain advantages. To ensure per­fect uniformity in registration, the bulbs should all be as nearly as possible of one size, constructed of one kind of glass, and the mount­ing perfectly uniform. Better-class instruments have the bulb clear of the frame, and the stem attached to a slab of metal, of porcelain, or of glass backed by wood; but sometimes they are simply fixed to a boxwood scale. In all cases they should be graduated on the stem, and compared with a standard, but in view of the uncertainty of the methods of ther­mometer exposure great delicacy is undesirable.

The influence of height on thermometers for ascertaining the temperature of the air has been investigated with somewhat con­flicting results;@@8 the disparity is at least partly due to the use of dissimilar instruments.

Registering Thermometers.—Rutherford’s maximum, invented before 1790,@@9 was an ordinary mercury thermometer placed horizon­tally ; the column pushed before it a small steel index, which was left at the highest point reached. It is little used now. The maximum thermometers in common use for meteorological pur­poses are Negretti & Zambra’s and Phillips’s. The former is a modified outflow thermometer. It is made with a constriction in the tube near the bulb, past which the mercury easily expands, but cannot return when the temperature falls, as the column breaks at the narrowed point when the fluid in the bulb begins to contract. The thermometer acts horizontally, but Everett devised a modification which is hung bulb uppermost, and the mercury, as it passes the constriction, falls down and stands as a column in the inverted tube. The thermometer is set by swinging

@@@1 Whipple, *Brit. Assoc. Reports,* 1885, p. 937.

@@@2 *Phil. Mag.,* [5], xxi., 1886, p. 331; xxiii., 1887, pp. 401, 406.

@@@3 Η. A. Hazen, “Thermometer Exposure," *Prof. Papers of Signal Service,* No. xviii., 1885.

@@@4 Gaster, Quart. *Weather Report for 1879* (1882), Appendix ii. ; Wild, *Mittheil. der naturforsch. Gesellsch. in Bern,* 1860, 108; Marriott, *Quart. J. Roy. Met. Soc.,* 1879, v. 217 ; Stow, *ib.,* 1882, viii. 228; Gill, *ib.,* 1882, viii. 238; Mawley, *ib.,* 1884, X. 1; Aitken, *Proc. R. S. E.,* 1884, xii. 681; Dickson, *ib.,* 1885, xiii. 199; Hazen, *loc. cit.*

@@@5 The first use of this instrument is usually stated to have been by Arago *(Œuvres,* 1858, viii. p. 500), but Saussure employed it for wet-bulb observations, and doubtless invented it (see *Voyages dans les Alpes,* 1796, iv. p. 267).

*@@@6 Proc. R. S. E.,* 1884, xii. 660 ; 1885, xiii. 199 ; 1886, xiii. 632.

@@@7 Caborne, *Quart. J. Roy Met. Soc.,* 1881, vii. 10.

@@@8 Hazen, *loc. cit.;* Wild and Cantoni in *Report* of Vienna Meteorological Con­ference, 1874; Symons, *Proc. R. S.,* 1883, xxxv. 310; Omond, *Proc. R. S. E.,* 1886-87.

*@@@9 Trans. R. S. E.,* iii., 1794, p. 247.