and compensator leads are respectively connected, and which serve to connect the instrument to the measuring apparatus., For work of the highest precision these terminals are often omitted, and the leads are directly soldered to a flexible cable in order to avoid possible errors from thermoelectric effects and changes of resistance of the screw terminals. For temperatures above 500° C. the protecting tube must be of porcelain, and the leads of platinum throughout that part of the tube which is exposed to high tem­peratures. For lower temperatures a tube of hard glass and leads of copper or silver may be employed, but it is better in any case to make the lower part of the leads of platinum in order to diminish the conduction of heat along the stem. For laboratory work a tube 30 or 40 cm. in length usually suffices, but for large furnaces the length of the protecting tube is often 5 to 10 ft. In the latter case it is usual to protect the porcelain tubes with an external steel tube, which may be removed for delicate measurements.

29. *Special Forms of Thermometer.—*In the measurement of linear expansion it is a great advantage to employ a thermometer with the bulb or sensitive portion equal in length to the bar or column under test, so as to obtain the mean temperature of the whole length. In measuring the linear expansion of a standard metre or yard, a fine platinum wire enclosed in a glass capillary, or other­wise insulated, is employed, its length being equal to that of the bar. The same method has been applied by Callendar (*Phil. Trans.* A, 1887) and Bedford *(Phil. Mag.,* 1898) to the expansion of glass and porcelain at high temperatures, employing a fine wire sup­ported along the axis of the tube under test. An equivalent method, applied to the expansion of silica by Callendar, is to enclose a rod of the material inside a platinum tube which is heated by an electric current. This is a very rapid and convenient process, since the mean temperature of the rod must be equal to that of the enclosing tube. Any temperature up to the melting-point of platinum is readily obtained, and easily regulated. The temperature may be obtained by observing either the resistance of the platinum tube or its linear expansion. Either method may also be employed in J. Joly’s meldometer, which consists of an electrically heated strip for observing the melting-points of minerals or other substances in small fragments. In observing the temperature of a long column of mercury, as in the method of equilibrating columns for deter­mining the absolute expansion of mercury, a platinum thermo­meter with a bulb equal in length to the column may similarly be employed with advantage. The application is here particularly important because it is practically impossible to ensure perfect uniformity of temperature in a vertical column, 6 ft. or more in length, at high temperatures.

30. *Sensitive Thermometers.—*Where quickness of reading is essen­tial, the mercury thermometer, or the tube form of electric ther­mometer, is unsuitable. In cases where the thermometer has to be immersed in a conducting liquid or solution, the fine wire forming the bulb may be insulated by enclosing it in a coiled glass capillary. This method has been employed by Callendar and Barnes and by Jaeger, but the instrument is necessarily fragile, and requires careful handling. For non-conducting liquids or gases the bare wire may be employed with great advantage. This is particularly important in the case of gases owing to the extreme sensitiveness thus obtained and the almost complete immunity from radiation error at moderate temperatures. Thermometers constructed in the form of a flat grid of bare wire mounted on a mica and ebonite frame have been employed by H. Brown *(Proc. R. S.,* 1905, B 76, p. 124) for observing the temperature of leaves and of air currents to which they were exposed. They have also been employed for observing the air-temperature for meteorological purposes in Egypt and Spain with very satisfactory results *(Proc. R.* S., 1905, A 77, p. 7). The fine wire, owing to its small size and bright metallic surface, very rapidly acquires the temperature of the air, and is very little affected by radiation from surrounding objects, which is one of the chief difficulties in the employment of mercurial ther­mometers for the observation of the temperature of the air.

For the observation of rapidly varying temperatures, such as those occurring in the cylinder of a gas- or steam-engine, an electrical thermometer with very fine wire, of the order of ∙001 in. diameter is practically the only instrument available. The temperature at any particular moment may be obtained by setting a mechanical contact-maker to close the circuit at the desired point. The sen­sitive part of the thermometer consists simply of a loop of fine wire from half an inch to an inch long, connected by suitable leads to the measuring apparatus as employed by Burstall *(Phil. Mag.,* October 1895) in the gas-engine, and Callendar and Nicolson *(Proc. Inst. C. E.,* 1898) in the steam-engine. The explosion tempera­tures cannot be satisfactorily measured in a gas-engine in this manner, because the radiation error at high temperatures is exces­sive unless the wire is very fine, in which case it is very soon melted even with weak mixtures. Callendar and Dalby accordingly de­vised a mechanical valve *(Proc. R. S.,* A 80, p. 57) for exposing the thermometer only during the admission and compression strokes, and have deduced the actual explosion temperatures from the indicator diagram. B. Hopkinson *(Proc. R. S.,* A 77, p. 387) suc­ceeded in following the course of an explosion in a closed vessel by means of a similar thermometer connected to a galvanometer of short period giving a continuous record on a moving photo­graphic film. When the flame reached the wire the temperature rose 1200° C. in about A of a second, which illustrates the order of sensitiveness attainable with a fine wire of this size. O. R. Lummer and E. Pringsheim, in their measurements of the ratio of the specific heats of gases by observing the fall of temperature due to sudden expansion, employed a very thin strip of foil with the object of securing greater sensitiveness. This was a somewhat doubtful expedient, because such a strip is extremely fragile and liable to be injured by air currents, and because the sensitiveness is not as a matter of fact appreciably improved, whereas the radia­tion error is increased in direct proportion to the surface exposed. One of the principal sources of error in employing a short loop of fine wire for observing rapidly varying temperatures is that the ends of the loop close to the thick leads are affected by conduction of heat to or from the leads, and cannot follow the rapid variations of temperature. This error may be readily avoided by the method, first employed by Callendar and Nicolson, of connecting the com­pensating leads with a short length of the same fine wire. The end effect is then eliminated by observing the difference of resist­ance between two loops of different lengths. Thermocouples of very fine wire have also been employed for similar measurements, but they arc more difficult to make than the simple loop of one wire, and the sensitiveness attainable is much less, owing to the small E.M.F. of a single thermocouple.

31. *Radiation Thermoscopes.—*For measuring the intensity of radiation, some form of thermometer with a blackened bulb or sensitive area is employed. It is assumed that the rise of tem­perature of the thermometer is approximately proportional to the intensity of the radiation according to Newton’s law of cooling (see Heat) for small differences of temperature. A mercury maximum thermometer with a small blackened bulb is still very generally employed in meteorological observatories for registering the maximum solar radiation. But the indications are fiable to error and very difficult to interpret, and an, instrument of this type is not sufficiently sensitive or quick in action for weak sources of radiation. Sir John Leslie employed an air thermoscope, similar to that of Galileo (Heat, fig. 1), with a blackened bulb. This has the advantage of a small capacity for heat, and is still employed in various forms for demonstration purposes, but is not sufficiently sensitive for accurate work. Electrical thermometers are now generally employed on account of their superior, sensitiveness, and also on account of the greater facility of adaptation for the require­ments of each particular experiment. The most familiar instru­ment is Μ. Melloni’s thermopile, which is built up of a number of small bars of antimony and bismuth, or other alloys of high thermo­electric power, arranged in the form of a cube with alternate junc­tions on opposite faces. When connected to a galvanometer of suitable resistance, this arrangement gives a high degree of sensi­tiveness on account of the, multiplication of couples, but owing to the large mass of metal involved in its construction it takes a considerable time to acquire a steady state. This defect has been remedied in the radiomicrometer of C.V. Boys *(Phil. Trans.,* 1888, 180 A, p. 159) by employing a single junction attached to a small disk of very thin copper. The free ends of the minute bars forming the couple are connected to a loop of thin copper wire suspended by a fine quartz fibre between the poles of a magnet. This arrange­ment forms a very delicate galvanometer and gives the maximum sensitiveness attainable with a single couple, since all unnecessary connecting wires are avoided. It is incomparably quicker and more dead-beat in action than the ordinary thermopile, but has the disadvantage that it must be set up permanently on a steady support and the radiation brought to it in a horizontal direction. An instrument of similar delicacy is the radiometer, the action of which depends on the repulsive effect of the residual gas in a nearly perfect vacuum on a delicately balanced vane suspended by a fine fibre. An instrument of this type was first constructed by Sir William Crookes (see Radiometer) ; the instrument was applied to radiation measurements, and its sensitiveness greatly improved by E. F. Nichols. It requires a very steady mounting, like the radiomicrometer, but has the additional defect that the radiation must be introduced through a window, which may give rise to selective absorption. Other varieties of thermopile, in which the sensitive parts are constructed, as in Boys' radiomicrometer, so as to have a very small capacity, but are connected like the ordinary pile to a separate galvanometer, have been employed by Lord Rosse for observations of lunar heat and by W. H. Julius and Callendar for the solar corona.

In cases where the radiation can be concentrated on a very small area, such as the receiving disk of the radiomicrometer, the thermoelectric method is probably the most sensitive. But if there is no restriction as to the area of the receiving surface, con­siderable advantage may be gained in convenience of manipulation, without loss of sensitiveness, by the electric resistance method. An instrument of this type was first employed by S. P. Langley *(Proc. Amer. Acad.,* 1881, 16, p. 342) under the name of the bolo­meter, by which it has since been known. The sensitive surface is made in the form of a blackened grid of thin metallic foil, gene­rally platinum coated with platinum black, connected in one of the