arms of a Wheatstone bridge. The rise of temperature of the grid when exposed to radiation is measured by its increase of resistance in the usual manner. In order to compensate for changes of temperature of the surrounding air the balancing resistance is made of a precisely similar grid, placed in close proximity to the first but screened from radiation. The foil should be as thin as possible consistent with strength, in order to secure the maximum sensitiveness. For spectroscopic work a single strip or linear bolometer is employed. For absolute measurements, where it is necessary to absorb the whole radiation admitted through a given area, two grids are placed with the strips of one behind the inter­spaces of the other.

32. *Absolute Measurement of Radiation.—*In many cases the object is not to secure the maximum degree of sensitiveness, but an absolute measurement of the intensity of the radiant energy, in calories per square centimetre per minute, or other suitable units. For this purpose some form of radiation thermometer is generally employed, but the method of procedure is modified. The earlier methods as exemplified in C. S. Μ. Pouillet’s pyrhelio­meter, or L. T. G. Violle’s actinometer, consisted in observing the rate of rise of temperature of a small calorimeter, or thermometer of known thermal capacity, when exposed to a given area of the radiation to be measured. To secure greater sensitiveness A. P. P. Crova substituted a copper disk with an attached thermocouple for the calorimetric thermometer. The method is very simple and direct, but has the disadvantage that the correction for external loss of heat is somewhat uncertain and difficult to apply, since the conditions are unsteady and the observation depends on rate of change of temperature. For this reason static methods, depending on the steady temperature finally attained, in which the rate of loss of heat is directly determined by an electric compensation method, have come more prominently into favour in recent years. In K. J. Angstrom’s pyrheliometer *(Acta Soc. Upsala,* 1893) two similar blackened strips of equal area and resistance are fixed side by side in a suitable case in such a manner that either may be exposed to the radiation to be measured while the other is simul­taneously heated by an electric current. Attached to the backs of the strips, but insulated from them by thin paper, are the two junctions of a thermocouple which indicates when the temperatures are equal. When this condition is secured the intensity of the radiation is equal to the rate. of generation of heat per unit area by the electric current, which is deduced, from a knowledge of the resistance and area of the strip, by observing the current required to balance the radiation. The instrument is very quick and sen­sitive in action, and the method avoids any assumption with regard to the rate of loss of heat, except that it is the same for the two similar strips at the same temperature. The accuracy of the method is limited chiefly by the measurement of the resistance and width of the strips, and by the difficulty of securing exact similarity and permanence in the attachment of the junctions of the thermocouple. Small differences in this respect may be elimi­nated by interchanging the strips, but there remain outstanding differences between different instruments of the same make which often exceed 5 per cent.

An electric method proposed by F. Kurlbaum *(Wied, Ann.,* 1898, 65, p. 748) consists in observing the rise of temperature produced by radiation in a . bolometer grid, then cutting off the radiation and observing the increase of current required to produce the same rise of temperature. There is no difficulty in this case in measuring the area exposed or the resistance of the bolometer, and no uncertainty can arise as to the temperature of the strip, because the heated strip itself serves as its own thermometer. The current is easily deduced from a knowledge of the resistances and the E.M.F. of the battery. The chief source of uncertainty mentioned by Kurlbaum lies in possible differences between the effects of radiation and current-heating near the ends of the strips, the area so affected representing a large proportion of the whole area. In Angstrom’s method this is not so important because the temperature indicated by the couple is that near the middle of the strip. In the case of the bolometer this end-effect may be com­pensated, as explained by Callendar *(Proc. R. S.,* 1907, 77 A, p. .7), in the same manner as for sensitive thermometers, by employing two similar bolometers with strips of different lengths..

An important defect of all the methods so far considered is that the measurement depends on the coefficient of absorption of the black with which the receiving surface is coated. The error is probably small, of the order of I or 2 per cent., but is difficult to determine accurately, and varies to some extent with the quality of the radiation. The absorptive power is generally less for rays of great wave-length than for visible rays. If we assume that the loss of heat by conduction and. convection is independent of the nature of the surface the defect in question may be avoided by the following method. Two bolometer strips, one bright and the other black, but otherwise exactly similar, are simultaneously exposed to the radiation to be measured, and are traversed by the same electric current. The black strip will be more heated by the. radiation than the bright, but the rise of temperature of the bright strip due to the current will be greater than that of the black strip because its emissive power is lower. If the current is adjusted until the temperatures of the two strips are equal the losses by convection and conduction will be equal, and also the rate of genera­tion of heat by the current in each strip. The rise of temperature must therefore be such that each strip loses as much heat by radia­tion to the surrounding case as it gains from the incident radiation to be measured. Assuming Kirchhoff’s law, the ratio of the emissive to the absorptive power is the same for all bodies at the same temperature, and is equal to the emissive power of a perfectly black body. The rise of temperature of each strip, when, balance is attained, will be the same as that of a perfectly black strip under the same conditions of exposure. The electric current in this method serves to eliminate losses by convection and conduction, and the result is obtained in terms of the observed rise of tempera­ture and the radiation constant for a black body. The method works well for a source at 100° C.; but, for a high temperature source, a correction is required because the absorptive powers of the strips may differ appreciably from their emissive powers.

Another electric compensation method of special interest is the method of the Peltier cross.” A small disk of copper is sup­ported by two thermoelectric couples forming a cross.. One of the couples serves to measure the rise of temperature, while the other is traversed by an. electric current, which may be employed to compensate the radiation by the heat absorption due to the Peltier effect. The advantage of this method is that the Peltier effect is easily determined from an observation of the thermoelectric power (see Thermoelectricity) in absolute measure, and that it is proportional to the first power of the. current. Loss or gain of heat by conduction from the supporting wires, and changes of temperature in. the surrounding case, are readily compensated by mounting two similar disks side by side. Small differences between the disks are eliminated by exposing them to radiation alternately, with reversal of. the current, so that the irradiated disk is cooled or the other disk heated by the Peltier effect. The current is adjusted in each case so that the temperatures of the disks are equal, as indicated by the. second couple connecting the disks. The method is about equal in sensitiveness to that. of Angström, but it is easier to secure conditions of exact similarity and to measure the quantities involved in the absolute determination, namely, the area of the hole through which the radiation is ad­mitted, and the coefficient of the Peltier effect. . The uncertainty due to imperfect blackness of the disks may be eliminated by using cups in place of disks; and the sensitiveness and range may be increased by using thermopiles in place of single couples.

33. *Optical or Radiation Pyrometers.*—Since the intensity of radiation increases very rapidly with the temperature of the source of radiation, instruments for measuring radiation may be applied for measuring temperature, assuming that the laws connecting radiation and temperature are known. The advantage of this method is that the measurement may be made from a distance without exposing any part of the measuring apparatus to the destructive action of high temperatures. Apart from the diffi­culty of calibrating the measuring apparatus to give temperature in terms of radiation, the chief source of uncertainty in the appli­cation of the method is the emissive power of the source of radia­tion. The methods principally employed may be divided into two classes:—(1) Radiation methods, depending on the measurement of the radiant energy by means of a radiometer, thermocouple or bolometer; (2) optical or photometric methods, depending on the colour or luminous intensity of the radiation as compared with a suitable standard.

Of the radiation methods the simplest in theory and. practice depends on observing the total intensity of radiation, which varies as the fourth power of the absolute temperature according to the Stefan-Boltzmann law (see Heat) for a perfectly black body or full radiator. In applying this method it is very necessary to allow for the emissive power of the source, in case this does not radiate as a black body. Thus the emissive power of polished platinum at 1000° Abs. is only 10 per cent., and that of black iron oxide about 40 per cent. of that of a black body; and the percentage varies differently for different bodies with change of temperature, and also for the same body according to the part of the spectrum used, for the measurement. Owing to the rapid increase of radiation with temperature the error due to departure from black body radiation is not so serious as might be imagined at first sight. If the temperature of a polished platinum strip at 1500° C. were estimated by the radiation formula, assuming the constant for a perfectly black body, the error for red light would be about 125°, for green about 100°, and for blue about 75°. Such errors may be corrected when the emissive power of the source at various tem­peratures is known from previous experiments, but it is preferable to observe, whenever possible, the radiation from the interior of a uniformly heated enclosure which approximates very closely to that of a black body (see Heat).

Radiation pyrometers of this type are generally, calibrated by the method of sighting on the interior of an electric furnace con­taining a thermocouple or gas-thermometer by which the tempera­ture is measured. The gas-thermometer has been employed for verifying the law of radiation up to 1500° C., but the difficulties of obtaining accurate results with the gas-thermometer increase so