# Teaching Pyrometry

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THE measurement and control of temperatures have assumed positions of great importance in many industries. The manufacturers of by-product coke and carbureted water gas find that proper temperature control helps to produce a better product and economizes in the use of raw materials. In the manufacture of glass, enameled ware, brass, and high-temperature refractories, temperature control is now regarded as being coördinate in importance with the control of materials used. To control such processes as malleablizing cast iron, and hardening, tempering, and annealing of steel in a manner to meet exacting market requirements has, within recent years, involved the installation of large and expensive pyrometer equipments. In many of these installations, it was necessary not merely to measure but also to record the temperatures over a period of time and thus obtain a record of the entire heat treatment and an effective check on the workmen in charge.

In view of the importance of temperature measurement and control in such a wide variety of industries and the necessity for proper supervision of the installation and operation of the outfits, the following questions may be pertinent: What instruction is offered by the engineering colleges and what departments in the colleges are responsible therefor?

The latest available catalogs of ten prominent engineering colleges east of the Mississippi River showed courses in high-temperature measurements given by the departments of physics. These courses, in general, were described as comprising classroom and laboratory instruction in the theory of high-temperature measurements, together with exercises in the calibration of the various devices used. In some cases it was stated that consideration would be given, in the courses, to the practical applications in the industries. In only one college was the course required of all engineering students; in most colleges it was optional; in a few colleges, it was required only of certain groups. In colleges offering a course in metallurgical engineering, instruction in pyrometry was always given in connection with metallurgical laboratory work. The students in ceramic,

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chemical, and metallurgical engineering in three colleges were given somewhat formal instruction in pyrometry by their respective faculties. It did not appear that mechanical or electrical engineering students in any of the colleges, except one, were scheduled for instruction in pyrometry, although such students, after graduation, are frequently engaged in work requiring heat treatment of metal or temperature control.

Is a special course in pyrometry in the curricula for ceramic, chemical, mechanical, and metallurgical engineers justifiable? This may be a debatable question. Local conditions and plan of organization of the college usually govern the feasibility of such a requirement. Considerable time, however, is given to instruction of students in the above courses in the determination of the heating values of coal and gas, the quality of steam, the composition of gases, and the measurement of electrical energy. Is it probable that all these students, after graduation, will make use of the instruction in any of the above determinations more frequently than of a proportionate amount of instruction in pyrometry? The field of usefulness of pyrometers will be extended in keeping with the improvements in the instruments and a realization of the necessity for accurate temperature measurements and control. In view of the present wide application and importance of pyrometry, instruction in it should receive at least the same emphasis in the curricula for ceramic, chemical, and mechanical engineering that it apparently receives in the curriculum for metallurgical engineering in most colleges.

It would be difficult to prescribe the content of a course in pyrometry to meet the conditions in all colleges. Since most engineers will have to do with the measurement and control of temperature in industrial operation, it seems desirable to confine the scope of this discussion to industrial needs. The operation of the law of the survival of the fittest seems to have left the thermocouple, the radiation, and the optical pyrometers in possession of the field of high-temperature operations. Thus, a minimum content of course ought to include instruction in the principles of operation and the calibration and applications of each of these types. Historical matter and development of the fundamental temperature scales need be only briefly considered; but some time can profitably be devoted to the study of the construction of auxiliary equipment, such as furnaces, heat regulating and insulating devices.

The thermocouple is no doubt more widely used than any other device for measuring high temperatures, and it is also much abused. The instruction concerning it might well include: method of making, calibration by determining the electromotive force at the melting points of pure metals, calibration against a standard couple, effect of depth of immersion on resultant electromotive force due to heterogeneity, and protection against contamination. The measurement of the electromotive forces of couples by millivoltmeters and potentiometers may be studied with

special reference to low against high resistance millivoltmeters, millivoltmeters against potentiometers with different depths of immersions, and varying temperatures in the lead wires.

Radiation pyrometers of the fixed and movable focus type and optical pyrometers of the Wanner and Morse types should be studied with reference to the principles involved in each, the construction, the methods of calibration, the limitations of each for various kinds of work, and the ease with which they may be manipulated. Special optical pyrometers, involving the matching of colored screens in the instrument against the field of vision, can be given some consideration.

Due to the limited use of resistance thermometers in the measurement of furnace temperatures, less emphasis may well be put on them than on thermocouples. It is worth while to point out the principles involved, the construction of the apparatus, and the methods of calibration. If the time can be spared, actual calibrations from fixed points are greatly worth while.

Since check calibrations on pyrometer installations are always necessary and since the engineer in charge will many times have to do such work with meager equipment, it will be worth the time spent to teach the student how to construct furnaces and heat-regulating devices. It may not be advisable to require the student to construct the furnaces used in the course, but it is desirable, wherever possible, for him to make the repairs.

The interest of the average student is not sustained in a course in pyrometry if it is devoted exclusively to problems in calibration, such problems being long and somewhat tedious. He takes a much greater interest, however, if he is given exercises that bring out the limitations and sources of error in the particular pyrometer employed. Among the problems that have been found stimulating to the student are: the determination of the temperature gradient in various kinds of firebricks; the temperature of decomposition of limestone; comparison of thermocouples with Seger cones, or with "Sentinel pyrometers" frequently used in the heat treatment of steel; and dehydration temperature of clay. The determination of the transformation temperatures in steels of various carbon contents by the differential couple and the simple cooling curve seldom fails to arouse interest; it also ties the principles of metallography and pyrometry together. The measurement of the temperature of molten copper in a ladle, with and without the oxide film, simultaneously with a thermocouple, a radiation pyrometer, and optical pyrometers of the Wanner and Morse types, is an excellent exercise to show the effect of emissivity. Many other problems can be devised; these are suggestions. Such correlation has been found to work well here and in other colleges because it gives an opportunity to link together a number of lines of study through the teaching of pyrometry.