Teaching Pyrometry in Technical Schools

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(Chicago Meeting, September, 1919)

For the purpose in hand, pyrometry may be taken to include all temperature measurements from, say, 200° C. to the highest attainable, especially when considered from the technical or applied side. It will be convenient first to consider the entire content of a course of study grouped under the headings of the various methods of measurement, which are quite distinct in principle and involve different equipment. Brief suggestions will be given under each heading, and the summary will be followed by comments on the purpose of such a course and methods of conducting it.

1. Expansion and pressure methods: mercury thermometers (glass and quartz), liquid, gas, and vapor-pressure thermometers, especially recording instruments. Especial attention should be given to the limitations of these methods, which, particularly in high-temperature mercury thermometry, are often overlooked. Range approximately to 700° C.

2. Resistance thermometers: both bridge and potentiometer methods, of indicating and recording. Calibration; lead compensation; design of thermometers for special purposes. Range to 1200° C.

3. Thermoelectric pyrometers: potentiometer and deflection methods indicating and recording. Calibration, leakage errors, contamination errors, base and noble couples. Range to 1500° C.

4. Total radiation methods: thermoelectric, resistance, and expansion indicators, mirror and lens collectors, calibration, permanence of characteristics, absorption errors. Range, to highest attainable temperatures. Methods of producing perfect radiators—true, and virtual or "black body" temperatures.

5. Partial radiation methods: absorption and spectroscopic methods of getting partial radiation, various comparison sources, polarization, electric, sector, and absorption methods of controlling intensity (Morse, Lummer, and Wanner types). Calibration, permanence of calibration, absorption errors. Methods of producing perfect radiators—improvised methods; true, and virtual or black-body temperatures.

It is not necessary to go into the detailed working out of a course to cover the ground outlined, but certain general questions present them-

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selves and must be answered. For example, should the course be planned as one strictly dealing with high-temperature measurement, or should it deal more broadly with the measurement and production of high temperatures? The latter arrangement adds to the interest of the course, and the combination is quite logical. If this choice is made, we can proceed to consider the distribution of time. The total time may be taken at from twelve to eighteen periods of 3 or 4 hr. each, and the content must be varied somewhat to suit the time available and the special conditions.

During the first half of the course, attention should be concentrated rather on the methods of measurement, the simplest and most reliable means being provided for giving steady temperatures just sufficiently high for the purpose, as uncertainties are apt to increase greatly at higher ranges. For certain parts of the work, these devices can be of low thermal capacity (such as heated strips, lamps, etc.) that will reach a steady state very quickly, so that no time will be lost in waiting for things to "settle down." In other cases, it will be necessary to use furnaces or boiling tubes, and arrangements should be made so that these can be started before the regular laboratory period. With proper care, it will be possible during this part of the course to do effective work in the laboratory during 2 or 3 hr. of the total period; the remaining time should be devoted to classroom discussions on topics such as these: Fundamental ideas of temperature and the temperature scale, standard fixed points, theory of bridge and potentiometer measurements, laws of radiation, perfect and ordinary radiators, ideas of thermal conductivity and thermal capacity applied to furnace construction.

The latter half of the course may be devoted to the application of the methods, the technique of which has been briefly studied, and to the measurement of temperatures under conditions closely approximating those actually found in practice. More attention should also be paid to the methods used in the production and maintenance of high temperatures, and the range of temperatures used should be extended. The exact content of this part of the course can be greatly varied, depending on the equipment available, but the various furnaces should follow standard practice, on a reduced scale, and, if possible, should be designed to bring out the different limitations and advantages of the several methods of measurement. Interest would be increased if the temperatures measured were those concerned with or controlling important high-temperature phenomena; that is, melting points (for standardization), recalescence points, reactions, crystalline transformation, increase of conductivity in substances normally insulators, etc. The reason for dividing the work rather sharply into two parts as has been suggested, is obvious.

The difficulties involved in the mere production and control of high temperatures are in themselves considerable, and increase rapidly at the higher ranges. If the student is confronted at the same time by these difficulties and those inherent in the various methods of measurement, the result is sure to be confusion and discouragement. A large part of this can be avoided by the scheme proposed.

Another general question that arises is, should the apparatus be so designed and arranged as to be "fool-proof" or "fool-killing"? The difference is clear. According to the first, every effort would be made by choice of equipment, arrangement, and instructions to insure that all the experiments proceed smoothly and without interruption or mishap, very little of the assembly of apparatus being left to the student, who is not made to feel much responsibility for its successful operation. In this case the thoughtful student will get an excellent idea of the maximum possible accuracy of the methods used, while the poor student will get an entirely erroneous idea of the ease with which the work may be done, and neither will appreciate fully the effort and thought expended on the design and arrangement, in order to produce the result. By the second method, in which the equipment is intentionally chosen in more disconnected elements which must be assembled or connected up by the student, and in which the "eternal cussedness of inanimate things" is allowed to display itself in more normal fashion, the thoughtful student will get more insight into the difficulties of the situation and be stimulated to overcome them by his own initiative, but the poor student will be well-nigh hopelessly muddled and discouraged and ultimately dropped. Which of these is chosen must depend on circumstances, on the relative importance attached to numbers as compared to quality of students, and on the extent of equipment available. In most cases a compromise is necessary and probably desirable.

Finally comes the question as to where the course should be given; that is, in what department. The situation demands a combination to insure the best results. On the one hand is needed that interest in precision, in method, and in working out new methods, which is more apt to be found in departments of physics; on the other hand, it is essential to have an immediate contact with real problems and real conditions, such as would exist in departments of metallurgy, electrochemistry, or similar engineering groups. If the course could be given by a combination of a physics and an engineering department, not only would the proper balance of the course be maintained, but an important step taken to insure that close coöperation of departments of pure and applied science which everyone believes to be most stimulating and wholesome for both. Unfortunately, such coöperation in course giving, while possible at smaller institutions, becomes very difficult at the larger and more elaborately organized universities, where the dividing line between departments and between groups of departments unfortunately tends to become more marked. Though his situation frequently involves high-temperature phenomena, they are not measurable by our methods and therefore do not concern us.