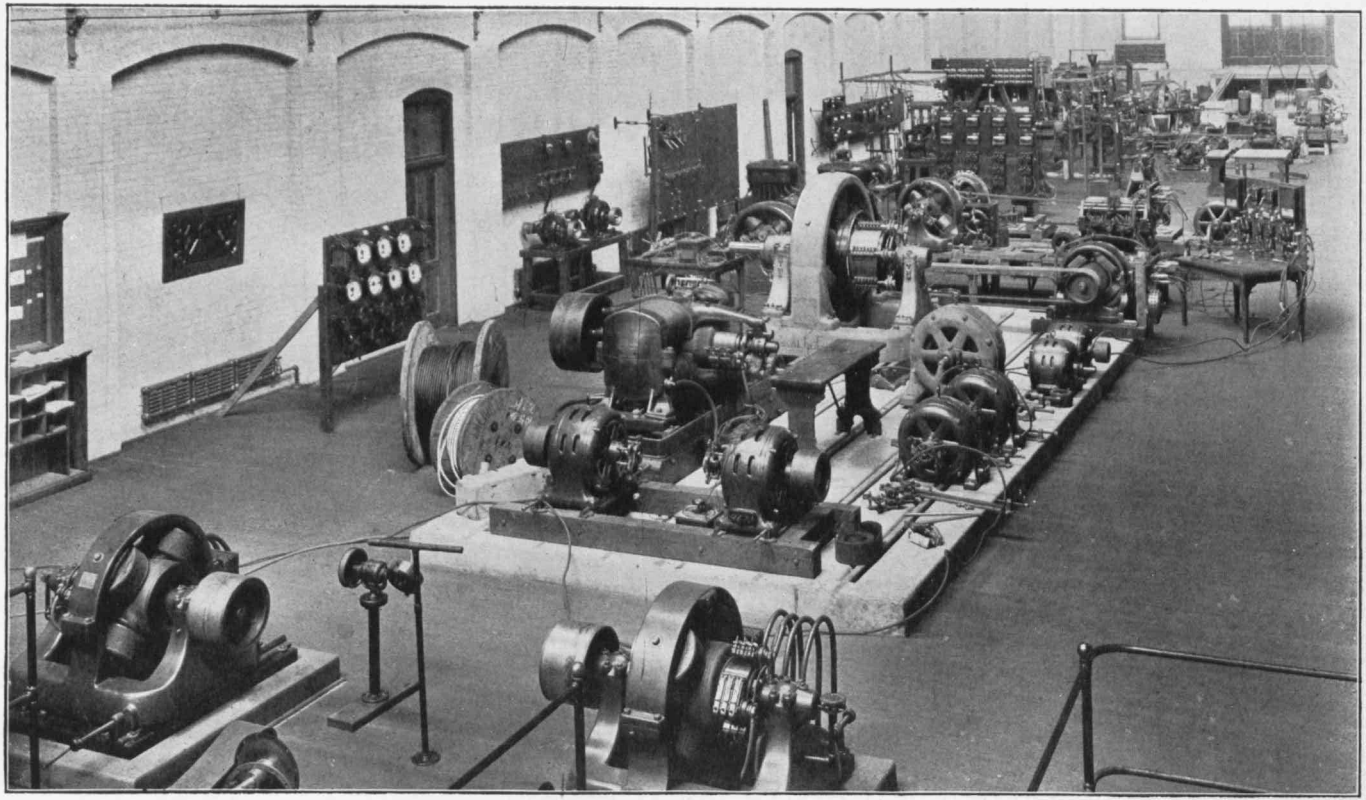

LABORATORY OF DYNAMO-ELECTRIC MACHINERY, LOOKING SOUTH

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THE AUGUSTUS LOWELL LABORATORIES OF ELECTRICAL ENGINEERING

If one were to express briefly the distinction between the engineer and the skilled artisan, he would characterize the ability of the one as determined by his length of head and of the other by his length of arm. With the engineer the prime motor is brain, with the artisan muscle. This in no sense indicates a lack of intelligence among artisans, and it is in fact just this intelligence which has given the United States her present industrial supremacy. But the point is just this. The engineer thinks out a problem, and then directs the way to its successful accomplishment; while the artisan, unless working under direction, accomplishes, if at all, by trial and error.

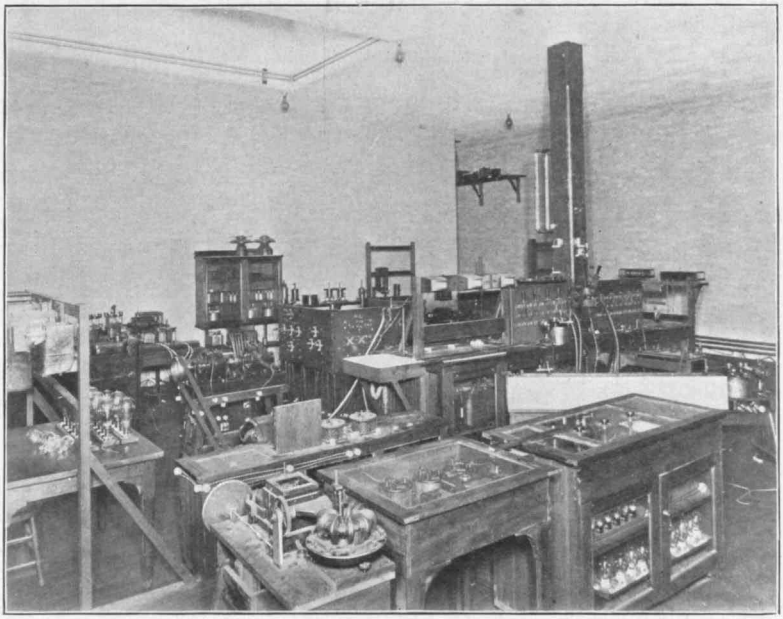
Any system of technical education which does not fit its students to *think* out the problems of engineering is certainly not the highest type. To get the student to bring to bear upon any question the sum of knowledge which he has acquired in his course of training is something very difficult of accomplishment. With the facilities of the modern engineering laboratory it is so much easier to experiment than to think; and it is frequently the case that the obtaining of results takes the place of their being assimilated and properly understood.

The satisfaction of the student in mere performance is

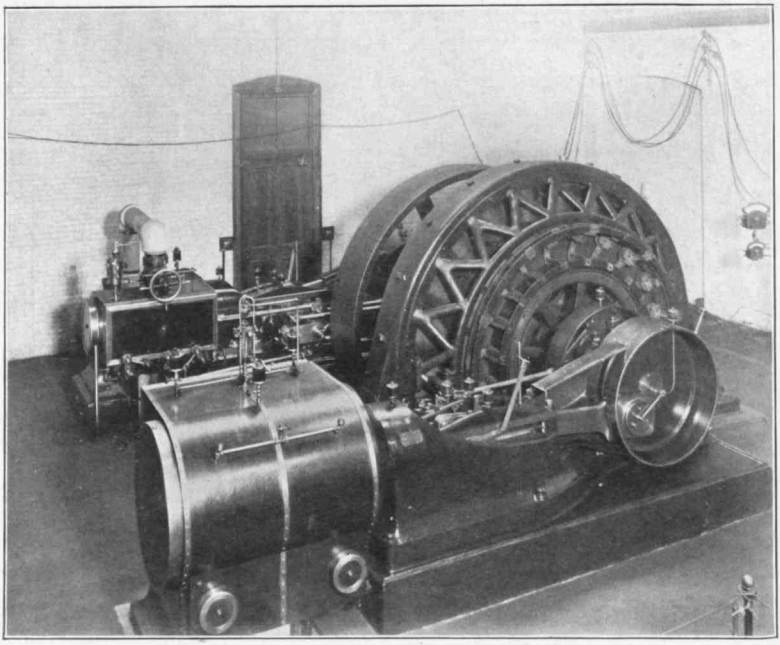
a real menace to the success of the laboratory system. How frequently do we observe the carrying out of some piece of complicated experimentation, requiring the services of fifteen or twenty students, each one of whom performs some part in the securing of the required data, without any general discussion of the problem in hand, the significance of the results, their bearing on and relation to current engineering practice. In fact, a process of digestion and assimilation is lacking. The food is there, properly, and frequently too attractively, prepared; but the organs of digestion never have the opportunity to act. In much of the laboratory work of to-day there is too often the suggestion of the predigested food. The student finds apparatus in adjustment, takes certain readings, enters his results on sheets specially furnished, makes certain plots on properly prepared paper, and passes on to some other experiment. He has no opportunity to show his appreciation of the apparatus in hand, to apply his knowledge of fundamental principles, nor is there any test of his conception of the bearing of his work on engineering reality. All this is no help to virility of mind, to sense of personal responsibility, to power of analysis, to the exercise of judgment, to the most important thing of all, the acquirement of the scientific spirit.

The necessity of serving the large classes who now make demands upon the laboratories of the technical schools is sometimes offered as an excuse for requiring less in initiative from the student. Would it not conduce to sounder and more valuable training if these same large classes were given fewer experiments, but were required to get at the significance of those actually performed?

One of the most important functions of the laboratory is to supplement the work of the class-room and to illus-



Standardizing Laboratory

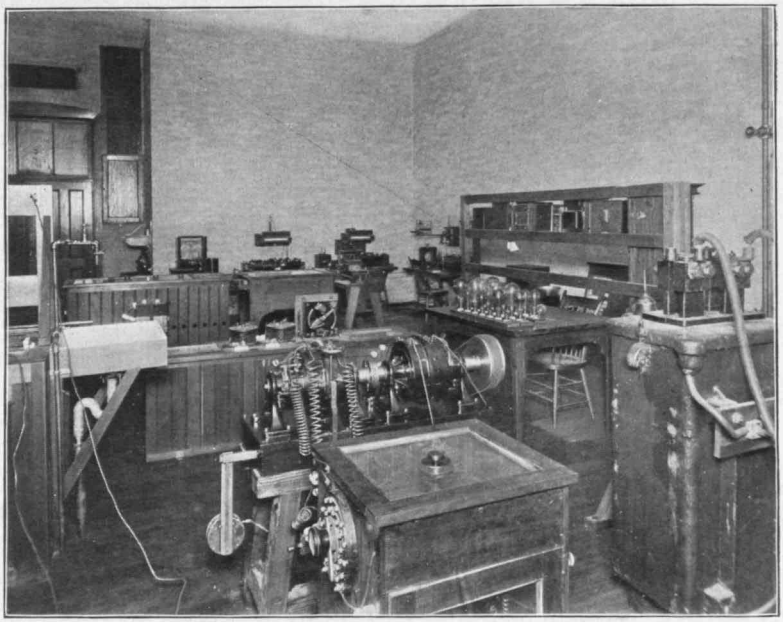


480 Kilowatt Double-current Generator, direct-connected to Cross-compound Engine

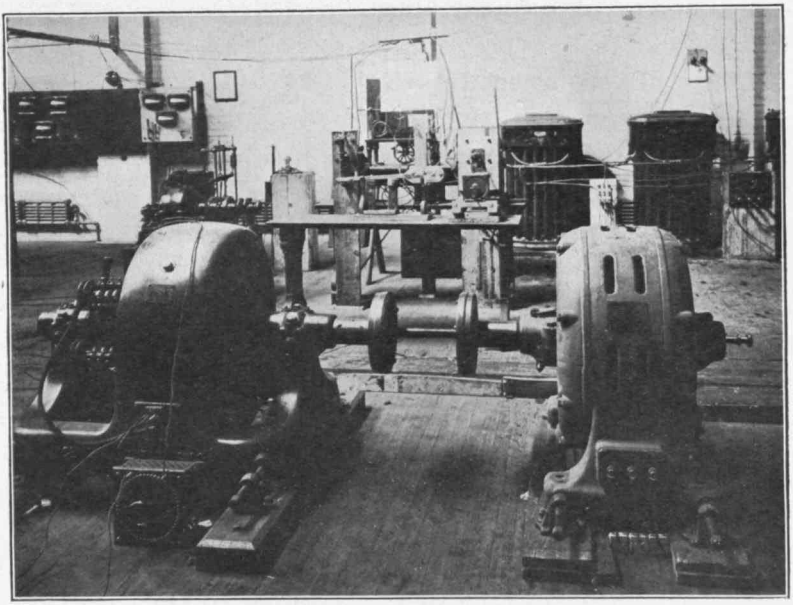
trate and emphasize the broad application of those theoretical principles which are the fundamentals in the education of any engineer. How often do we hear the laboratory work spoken of as "practical," indicating presumably that what is done with one's hands is practice, theory being reserved in its application to the use of the intellect! But the best practice and the best theory must ever be identical, only theory must precede practice. In planning, then, the work in the laboratory of electrical engineering, there should be kept constantly in mind the necessity for the most intimate relationship of this to the instruction in theoretical electricity. Certain of the experiments may well be laid out to illustrate certain points of theory which have been discussed in the class-room; and in connection with each laboratory experiment there should be certain questions proposed for discussion, which will require some analysis on the part of the student and the application of fundamental principles.

Preparatory to any piece of technical work should be a careful study of the methods of measurement to be adopted, the apparatus to be used, its limitations or special adaptability to the particular problem under consideration. This is equally true when a laboratory investigation is to be conducted, and the facilities for carrying on such preliminary study are furnished in the Department of Electrical Engineering at the Massachusetts Institute of Technology by the Standardizing Laboratory.

Here are provided direct and alternating current, the latter at frequencies of both 25 and 60 cycles, together with standard ammeters, voltmeters, and a potentiometer reading to 1,500 volts. For direct current work, currents of 1,000 amperes and potentials of 3,000 volts are available, and for alternating current work currents of 4,000 amperes



Standardizing Laboratory



Three-phase Induction Motor arranged for Thesis Work

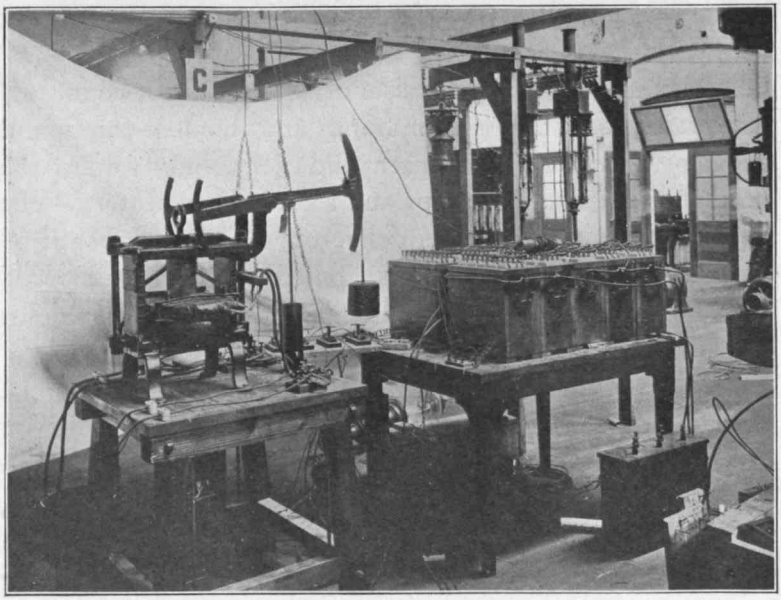
and potentials of 50,000 volts. Not only are currents and potentials of these magnitudes available, but also the necessary auxiliary apparatus for controlling and measuring them. Oscillographs of the Duddell type enable the determination of wave form to be made, a very important factor in many lines of investigation. The laboratory is also provided with sets of standard resistances, certified by the Reichsanstalt, with standards of inductance and capacity and with the necessary apparatus for their use.

For studying the various types of wattmeter two small generators are provided, and are so arranged that the particular instrument under investigation may be tested with varying power factor. The laboratory possesses a number of potential and current transformers which have already proved extremely useful in the study of certain high voltage power transmission problems. Some of the more important pieces of measuring apparatus have been designed in the department, notably some forms of sensitive galvanometer, recording instruments, and a wave-tracing device.

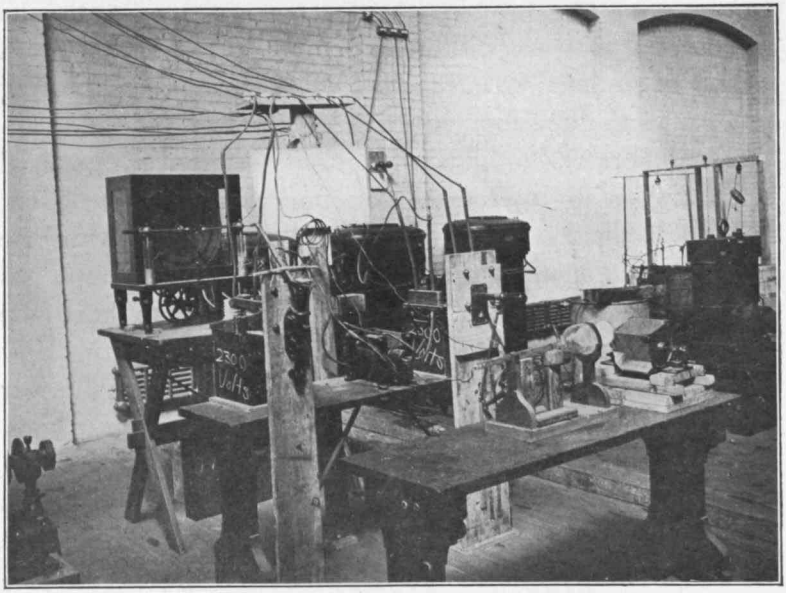
Now that thesis work is so frequently carried on at a distance from the Institute, a careful preliminary study of the methods and apparatus to be used becomes even more important than where the work is carried out in the laboratories of the Institute itself.

In connection with the regular instruction in the Standardizing Laboratory there is a system of conferences in which general methods of measurement for technical work are discussed, and questions of precision of results and economy of time specially emphasized.

The equipment of the Laboratory of Dynamo-electric Machinery includes, in addition to a considerable variety of direct and alternating current apparatus, a complete lighting and power plant used to supply the various Institute



Constant Current Transformer



Thesis Investigation or Oil Switches

buildings. This plant consists of boilers, direct-connected generators, both cross-compound and tandem-compound engines, a surface condenser and a cooling tower, the necessary circulating pumps and a feed-water heater. The output of the generators is delivered to a switch-board of modern type, and may be distributed to the buildings of the Institute or delivered to the mains running throughout the laboratory.

Not only does this permit tests of efficiency for the various units, both mechanical and electrical, when run under various conditions, but also enables the student to determine the actual cost of generation of electric power, from coal pile to switch-board,— a very important factor in the engineering of to-day. Tests of the plant are being carried on this present year, the departments of Mechanical and Electrical Engineering co-operating; and the results are to be discussed in general conferences, from both the mechanical and electrical standpoints. This gives both classes of students an adequate idea of current engineering practice in the development of electric power.

The laboratory equipment has been selected with special reference to its usefulness for purposes of instruction. Although there are of necessity in connection with the power work many large machines, yet the attempt has been made and will in the future be made to keep the laboratory units small, since in this way, and in this way only, can, with a given expenditure of money, a large number of different types of apparatus be obtained and a great body of students, who come simultaneously into the laboratory at a given time in the year's work, be successfully handled. Of course, it is essential that the size of the units shall be such as to illustrate the working characteristics of the particular type in question.

The instruction is planned to give the student at first an idea of the principles of operation of each type of machine as a unit, its efficiency, regulation, and general characteristics being studied. After this has been accomplished, the various machines are combined in a more or less complicated system, illustrating some of the broad principles of engineering operation. The student thus gets a much clearer idea of the relations existing among the various parts of the commercial systems than would be possible in a laboratory where individual units alone were considered. In fact, flexibility in arrangement and operation of the apparatus is one of the important features of the Augustus Lowell Laboratories.

There is being constructed this year in connection with thesis investigation an artificial transmission line, which later will be used in the work of regular instruction in the laboratory. After tests have been made on individual types of polyphase generators, synchronous and induction motors, these will be combined with the transmission line to illustrate some of the principles of high voltage power transmission, such as the relation of motor capacity to line constants, the effect of line unbalancing on current and voltage relations, the influence on transmission of varying the capacity and inductance of the line. A question of some importance which can also be investigated is the effect in an artificial line of the position occupied by the capacity and inductance. All such group experiments as these tend to broaden the point of view of the student,— an extremely desirable result in any system of instruction. It is important to emphasize that the work is in no sense intended to supply practical experience, since this cannot be given in any technical school, but must come after graduation. Too often are the experiments in engineering laboratories planned