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ENGINEERING LABORATORIES.

BY R. C. CARPENTER, ITHACA, N. Y.

It is the object of the present article to point out how an Engineering Laboratory can be equipped for a comparatively small expenditure.

In discussing the subject I shall confine myself purely to the educational features and will not consider the laboratory as a place for investigation or solution of advanced engineering problems. I may also be permitted to say that there are few colleges in America, perhaps in the whole world, in which students, as a rule, gain sufficient culture, or indeed have sufficient time to undertake the work of investigation of engineering problems, in an undergraduate course. It is only in those courses where a great number of graduates are to be found that problems of research have any legitimate home.

The undergraduate laboratory should be equipped so as to demonstrate in a practical and convincing way the principal laws or facts that the student must master in order to finish his course. Its course of instruction should be such as to require systematic work of the student, teach him how to observe, how to use apparatus, how to deduce conclusions from his mass of data and finally how to make a neat and systematic report of his work.

Having that object in view, the best methods or means of execution remain to be sought. In this respect two courses will be open, one, which at first may seem simpler and better, consists in laying out on a single schedule all the experiments that can possibly be performed by the students, with the apparatus at command. Students are assigned to these various experiments as they report for duty.

The other consists of a course in which are put the more important experiments; every student to take in turn each experiment. In laying out a system of such work it will be necessary to have a series of independent experiments for each term, so that the order in which they are taken is immaterial.

From personal experience I am positive that the latter is the only way to successfully conduct an engineering laboratory, unless you are possessed of an almost infinite equipment, an unlimited patience, and an entire disregard of order, and even then a great number of students, working in as many lines, would be certain to cause vexation, delay or trouble in some direction. Besides all this the amount accomplished by an individual student is generally small, since a large part of his time has to be devoted

to preparation, looking up apparatus, and in finding people willing to lend.

By arranging for a certain definite number of experiments each day, which are sufficient for all the students reporting that day, and repeating these day by day until each student has performed each experiment, the conditions are not only more favorable for systematic orderly work, but a minimum amount of apparatus will be required and more efficient and better directed instruction can be given. In such a case the apparatus is easily kept where needed and in good order, and the student can devote the required time purely to the experimental work. I will not deny that the work of preparation and of looking up apparatus is of benefit to the student, but it is not experimental work and should have a place in some other part of the curriculum.

I hope I may be excused for devoting so much time to this discussion, but I feel that it is an important matter, and vital to the subject of the article. In the physical or chemical laboratory I believe that the best results are obtained by the first system, since working apparatus is portable, experiments quickly arranged and the results more definite and constant in character, and the same system is likely to be applied to engineering, thought not being given to the facts, that engineering constants are seldom more than coefficients, and the value is affected by the method used in testing. In many engineering experiments the method is of equal or greater importance than the results.

For the reasons just stated I would advise a limited number of experiments each term and require each student to take the course as laid out. I am positive that the better instruction obtained will more than offset any loss due to the want of selection.

The nature of these experiments must depend upon the apparatus, but I will, however, refer to a course which might be pursued in case the equipment was extremely small. Suppose, first, the course to be in civil engineering, in which case the laboratory work will relate principally to strength of materials and hydraulics, field work and astronomy, the two latter will not, however, be included in this laboratory course. The apparatus needed might be certainly as much as could be purchased, but one testing machine of 50,000 pounds capacity, arranged for testing in tension, compression and transverse, a cement testing machine, a small drop of 100 pounds falling ten feet, and a wooden beam twenty feet long and four by eight inches in dimensions, will be found to be sufficient apparatus to keep four experiments, two men at each, in operation the entire time. The cost of such apparatus will probably not exceed \$1,000 and possibly might be less.

The experiments that might be performed are almost infinite in variety in the line of strength of materials, and the students could not only obtain skill but also valuable knowledge respecting the properties of materials.

Some of the most interesting experiments are performed with little or no apparatus, as, for instance, by loading a beam in different ways and studying the effect on the elastic cam produced by the load in various positions.

For hydraulics, little is needed but what can easily be made by resident mechanics, excepting tanks and weighing scales. Weir notches and hook gauges are readily made and ensure materials for an almost endless variety of experiments.

Small water motors and pumps are quite inexpensive, so that probably for \$500 an equipment that will give six experiments and keep twelve men at work constantly can be had. If a student could spend six hours a week, which is about the amount required to complete a single experi-