DISCUSSION ON "THE ATTITUDE OF THE TECHNICAL SCHOOL
TOWARD THE PROFESSION OF ELECTRICAL ENGINEERING"
AND "ON THE CONCENTRIC METHOD OF TEACHING ELECTRICAL
ENGINEERING", AT NIAGARA FALLS, N. Y., JUNE
27, 1907

V. Karapetoff gave an abstract of his paper and said in conclusion: I appear with this paper before the Institute, because of my conviction that the Institute is competent, as a body, to dictate to the technical schools the requirements which their graduates ought to possess. I hope to see the day when the management of the Institute will appoint a committee on technical education. We now have thirteen committees—not a very lucky number—I wish this number could be increased to fourteen and the committee I have suggested be appointed.*

F. B. Crocker: Professor Norris says:

Electrical engineering is taught as an application of mechanics, the only difference from other branches of mechanical engineering being in the source of the forces and the methods of transferring and transforming energy.

I object to that expression, because it is not true. Mechanical engineering is a fine profession, no one has greater respect for it than myself, but electrical engineering won its independence some years ago, and I think it is a little late to speak of electrical engineering as being a branch of mechanical engineering. Another reason why I object to it is that it leads to unpleasant feelings. Taking another step backward, we find that the civil engineer considers that every engineer who is not a military engineer is a civil engineer. I presume that Professor Norris used that expression in a general way, meaning that we are dealing with mechanical problems; but in the Engineers' Building in New York the mining engineers, mechanical engineers, and electrical engineers are certainly on terms of equality, and I cannot see any reason for subordinating one to the other. It has usually been the custom in the education of electrical engineers in this country to consider electrical engineering as part of mechanical engineering or physics. Nearly all courses of electrical engineering were grafted on, or formed parts of a course in mechanical engineering, or a course in physics. Columbia University, with which I am connected, started a course of electrical engineering in 1889 which was not part of mechanical engineering or of physics. It was as distinct as any other course in the university. We took that stand 18 years ago and have had no occasion to recede from it. I think there is a strong tendency for others to take the same position.

Professor Norris, in his history of the development of electrical engineering education in this country, overlooked the fact that we have courses which are specifically electrical engineering and not appendages to mechanical engineering or physics.

* Such an Educational Committee has since been appointed.

In Professor Karapetoff's paper, what he advocates is not only very radical, but opposed to the whole history of education, which from the very beginning has dealt first with the simple and later with the complex. When I say "simple", I do not mean necessarily the most easily understood, but the idea involving the fewest things to think of at one time; that is, principles should precede practice. I think this is natural in education. It certainly is the historical method. Furthermore, we have experience bearing upon that point. Take an institution like the Troy Polytechnic, which for many years taught theory almost exclusively with very little laboratory or other practical work, that institution has been successful and has turned out a number of eminent engineers. While it may have modified its course somewhat recently, this experience shows that it is possible to turn out successful engineers on this plan. Perhaps that is going a little too far, but it shows it is possible to do that. On the other hand, the trade-school, which deals with practical matters almost entirely, is very well in its way, but it does not produce the highest intellectual results.

Furthermore, we must have some sort of a *pons asinorum* for weeding out the incompetent men. I think that we should not make it too easy, or too pleasant, to get into the electrical engineering profession. At West Point, for example, the cadets are made to do exactly what they don't want to do. That is what a man should be taught to do. This leading a man by the hand to pleasant places does not meet my approval; in professional education a student cannot learn electrical engineering by sitting in the park and looking at beautiful scenery. That is too easy. A student must be capable of abstraction; he must be capable of self sacrifice; he must do the very thing he does not like to do, and do it well. I consider West Point the best technical school in the world, and in itself a very strong argument in favor of technical education.

I do not agree with the contention that subjects like chemistry, physics, mathematics, and mechanics, should be taught by engineers, especially electrical engineers. I do not object to a teacher having an engineering interest, a man with a high opinion of engineering, but if he is an electrical engineer and teaches chemistry, mechanics, or physics, he will teach those portions which he *thinks* are important. He may be right at the time, but perhaps five years from then the whole situation changes. I believe in teaching chemistry, physics, mechanics, and mathematics for themselves, and not picking and choosing; if properly taught these subjects, the student will be well equipped and can talk on equal terms with other men who have been taught these general subjects.

Gano Dunn: I wish to express satisfaction with the policy of the Institute, developed in recent years, of devoting so much attention to the subject of engineering education. It has been

said that the civilization of a nation may be measured by the height of the plane upon which it places its women; it is equally true that the proficiency and accomplishment of a profession is in direct proportion to the attention it gives and the respect it has for its educational influence; to the importance it attaches to its universities and colleges. It was a refreshing address that President Hadley of Yale delivered at the dedication of the Engineers' Building in New York. He said if there was any thing that made the nineteenth century different from all the centuries that had preceded it, it was the accomplishment of the engineer—never before in the history of the world had human beings had so much control over the materials and forces of nature, and the result of that control was transforming all human activities. He went so far as to imply that before long the most successful merchant would be the merchant-engineer; the most successful mayor of a town the mayor-engineer; the most successful statesman, if you will, the statesman-engineer. There is something in the method of an engineer's mind that is direct, that goes straight to the truth, and, although we have been discussing a code of ethics to-day which implies that engineers are not honest, I believe that they are naturally honest because their contact with nature has led them to expect the truth and, when they do not find it, to put the blame on their own methods of investigation. They proceed further with confidence that what they are dealing with is absolute truth, and that if they persist the truth will be revealed. The influence of the engineer is extending to all other callings, and the engineer in the future will exert an influence that he has never dreamed of exerting in the past. Consequently, if we are to grasp the glorious future which has been outlined for us, many of us believe we cannot give too much attention to the methods by which we educate our engineers.

Professor Karapetoff's paper interested me extremely because of his concentric method of instruction. I have little cause for complaining of the methods under which I was instructed, but I feel with Professor Crocker that the plan Professor Karapetoff outlines is too radical. I think, however, that our existing methods could be profitably modified to include many of his ideas. For instance, it would have helped me enormously while I was a student if I had had some person in the capacity of a kind friend at college to give me the relations which the studies I was pursuing bore to other studies and to the activities of the world. Instructors are supposed to do that, but, because each man is devoted to his specialty, very often he does not do it. I really think we could profitably establish in our universities a course on the correlation of the student studies, to which might be given a very small portion of time, but that portion of time would be highly efficient. A student could then know it would be worth while for him to study calculus, for the good it would do him. He could have a promise given, on the strength of which he would work hard.

I believe in America we are ahead of Great Britain in technical education. Conversation with the manager of a correspondence school over there revealed that many of his students were obliged to keep secret the fact that they were studying technical subjects. Many of the industrial managers, I have been told, have not had theoretical educations, and they prefer to employ men who have grown up in the ranks of their business, rather than men who have received a technical training. I even know of one Oxford man who wanted to go to Cambridge to take a technical course, and the superintendent preferred he should go straight from Oxford into the factory, feeling that he would do better than if he took a technical training. I can hardly believe it, but it is true.

I should like to expose my ignorance of the law by giving it a dig in passing. I believe that engineers have set the pace for progressive training, and, as a result the engineering mind, as President Hadley described it, has a great future. We come into contact a great deal with the law in the direction of patents, and in many other directions. It seems to me that progress in medicine, in the arts generally, in all commercial industries, in engineering, and in science has been very great, but that progress has not been as great in the law. The law to-day is more complicated and less satisfactory than it was many years ago, and, while it is perhaps idle to discuss the question here, I feel if the engineer uses his influence, whenever he has a chance, to urge the simplifying of legal processes, and expresses his disapproval to lawyers of the complicated processes which they now pursue, and which many of them advocate, some good may be done.

As between a broad general training in a technical school and a specific training which, of course, must be limited to a few subjects, I prefer the former, and this supports Professor Karapetoff's ideas. A man is better equipped for life if he knows the scope of his field, even though he does not know many specialties in it, than if he is made an extreme specialist in a particular portion of the field which he may not have occasion to use. Not only is he better equipped, because he can realize on his time spent at college, but because his general training has broadened him as a man in a way that the special training would not do. I hope every convention will have some educational papers, and that we will all take pleasure and pride in supporting our universities in every way we can.

William Esty: A number of the subjects brought out at this session seem to me to warrant the adding of some papers on technical education to our convention programs. I agree with Professor Karapetoff that in dealing with young men, say at the college age of eighteen, there is necessity for giving them something concrete to take hold of on which to build up the theory. I think that is the natural order of development in

the child; and with college students some attention must be paid to the natural order of their development. Professor Crocker, in discussing this matter, spoke of beginning with principles because they were simpler than the concrete cases. It seems to me that his idea contradicts the view of Herbert Spencer, who speaks of principles as being a conglomeration of concrete things and of a principle or law being essentially more complex therefore than any one of the concrete facts on which it is based. It seems to me that that is a valid definition of a principle—an aggregation of concrete facts which have finally been formulated into principles from experience. Principles then are more difficult to teach to a freshman than isolated concrete facts: so I think we should have something of the concrete to give him also.

I am going to outline briefly how at Lehigh University we try to accomplish the object of giving the students an idea of some of the concrete facts on which engineering is based, and at the same time give them some theory also. At the end of the freshman year the mechanical and electrical engineers take what we call our "summer school in constructive elements of mechanical and electrical apparatus". The summer school lasts only four weeks, and the students are at work for three hours in the morning and three hours in the afternoon. In that rather brief time we attempt to acquaint them with the elements of mechanical and electrical engineering. For instance, in the electrical end of it, in which I am especially interested, we have them dissect circuit-breakers, rheostats of different types, disassemble motors and generators, lightning-arresters and transformers, and sketch the circuits. We do not attempt at first to teach them the complete theory on which all this apparatus is based, but rapid progress results by having them acquainted with the actual things. We find this plan very advantageous. We have tried it now for six years, and if there is anything in the old adage that, "the proof of the pudding is in the eating", we can show that this pudding has proved good with us. We find, as a matter of fact, that the mechanical and electrical engineers who have taken this supplemental course in concrete facts, with a little theory mixed in on the side, are much better able to grasp the theory of the dynamo and of the transformer later on in their course than are, for example, the civil engineers who do not have this summer school work. We find it saves time in the long run. Our object is to concentrate in that four weeks an experience with the things themselves that these young men might take a year or more to acquire without it. I am not sure whether we are unique in this respect among colleges and universities, but if there are any others that have had similar experience I should like to hear from them.

In summing up this controversy of theory versus practice, it strikes me that it is after all another phase of the old

question as to whether we should have classical education or technical education and as to which does the most for the young man. We have heard this thing wrangled over now for twenty or thirty years, and the end is not in sight. I think both sides of the controversy can certainly come to a common ground if we conclude that what after all is the object of education is the training of a young man to think for himself, and that implies, of course, a knowledge of how to solve problems when they arise. We cannot possibly teach all problems to a young man in college, but we must ground him in fundamental principles, giving him theory even at the expense of practice, so that when he leaves college he will have training which will enable him to solve almost any problem. That, I think, is the aim of technical education.

G. W. Patterson: As a member of the committee of the University of Michigan on reorganizing our course, I have taken part in a great many consultations as to what a technical school course should include. I must admit that the trend of the work by our committee has been entirely away from what Professor Karapetoff has given us to understand is his notion of the proper thing. We feel that a man who goes to a technical school is a crude product, and that there are many things which he ought to study to make him an educated man before he takes up engineering as a specialty. Without modern languages, without drafting, without a thorough grounding in mathematics, physics and chemistry we feel no man is competent to understand the elements of any kind of engineering, to say nothing of electrical engineering. I am of the opinion that there are some germs of truth in what Professor Karapetoff has told us, but if we examine his paper closer we find that if we adopted his ideas we would in my opinion make a sort of plaything of engineering. Instead of a real training, which should be given to men who are to occupy these important positions, the actual training would fall far short. The engineer should be an educated man; he cannot be educated in a specialty that ignores the elements which go to make a broad education. With us the trend is rather toward a six-year course than to cut off the things which we find necessary to teach in the first year or two under the present plan. In the University of Michigan we have six-year combined courses in which a man registers in the department of literature, science, and the arts, and also in a professional department. At the end of four years he receives the degree of bachelor of arts, and at the end of two years more either that of doctor of medicine, or bachelor of laws. In the engineering department the trend is toward the same thing; that is, a longer course in which we do not cut out the modern languages, or reduce the amount of physics and chemistry in the period of training, but put them in earlier and put in other things. There should be no opportunity for a man to learn engineering without a proper

foundation. Omitting the foundation, is like trying to build a mansard roof first and put on the foundation the last thing.

If Professor Karapetoff's paper be taken seriously, it would, I think, tend to destructive rather than to constructive teaching.

Lester W. Gill: I am interested in this subject, because I have been endeavoring for the past few years to develop a course in electrical engineering in one of the Canadian universities. I am in sympathy with a number of the opinions expressed, but I do not think that it is practicable to introduce the radical changes suggested by Professor Karapetoff. Referring to his proposed schedule, it is noted that mathematics is omitted entirely from the work of the first year, and very little is set down for the second year. My experience has been, not only in my own case but in the case of students in my classes, that if mathematics is dropped even for one year before the student is acquainted with its practical applications, he loses his grasp and consequently his interest in the subject. To most students mathematics is a dry subject unless it is presented in an interesting way; but even admitting that many find it uninteresting, it involves a certain amount of discipline which is quite necessary.

I quite agree with President Sheldon that the greatest difficulty lies in the presentation of the subject, and in my own work I have endeavored to make the elementary subjects practical as well as theoretical. This results in a compromise between the standard college schedule and that proposed by Professor Karapetoff. In this way the elementary subjects—mathematics, physics, and chemistry—can be made as interesting as the purely engineering subjects. As a student I found mathematics the most interesting subject of the whole course, because the teacher knew how to make it interesting. To make these subjects interesting the student should be given examples of the practical applications of the subject as he proceeds, and these examples should deal with things with which he is familiar. This arouses his interest in the theoretical side of the subject and he at once realizes its value. As an illustration, take the case of a student in physics trying to master Ohm's law. If this is presented to him merely as an abstract natural law, he will not find it very interesting, and will consequently get only a superficial conception of it; but give him an illustration of its application; ask him to calculate the voltage at the end of a given trolley line, given the distribution of current, and it will be found that after solving this problem he will look upon this law from an entirely different standpoint.

The above illustrates what I mean by making the elementary subjects of a practical nature. My own opinion is that the weakness in our engineering schools lies in the method of teaching rather than in the arrangement of the schedules. The aim of the teacher should be to develop the student's ability to reason for himself, to think logically rather than to memorize

rules. When a student can take the initiative and reason things out for himself, the technical school has done all it can to make him efficient from a technical standpoint.

L. D. Nordstrum: Referring to Professor Karapetoff's paper—this proposed method is in a sense radical, but I cannot help but agree with him in part. I do not think that the students should have mathematics and physics and kindred sciences taught by engineers. It is well if we can have mathematicians introduce as far as possible the engineering subjects, so as to make them interesting to the student, but for the teaching of these subjects thoroughly we must have a professor of mathematics and a professor of physics, etc., who are, so to speak, specialists in that line. The time is here when the trend is towards specialization, and no man can hope to have the strength of a thorough mathematician, a thorough physicist, a thorough engineer, etc., all in one. The student must get these from individual instructors who devote their entire time to their particular subject.

I believe that we can not expect to turn out a finished engineer from our universities. I think all that we can hope to do is to take our student as he enters the college and direct and train his mind properly in the fundamental principles, giving him a good foundation upon which to build. I think it is too much to expect a student in a 'four years' course to gain all that is gained and can only be gained in the practical pursuits of his profession. It is my opinion that a man has never finished his education; his entire life is that of a student. His university years are merely the starting or foundation years.

V. Karapetoff: In reply to Professor Crocker's remarks, I would say that, of course, the instruction should proceed from simple to complex; the point at issue is what to consider as simple and what as complex. This to my understanding varies with time. Twenty years ago it would not have been simple to begin the freshman year with instruction in street-car propulsion and incandescent lamps; but now this is much simpler for the student than an instruction regarding the properties of magnetic poles. We now see street cars and electric lights much more than magnetic poles. Professor Crocker mentioned trade-schools, and I understand him to favor the opposite, or the theoretical courses. I am not in favor of the trade-school idea, or of a theoretical-school idea. I am in favor of the *psychological* idea. Our president and some other speakers compared the student with raw material; there is however a great difference between raw material in a manufacturing sense, and a man. A man is a thinking being, and if you try to make a machine out of him, he kicks at first, and then withers intellectually. The analogy to a machine should not therefore be carried too far.

Mr. Dunn said that my method is very radical. Perhaps it seems radical for electrical engineers, but it is not considered

radical at all among our best educators. It is an already acknowledged fact among our primary and secondary schools. I simply transplanted the psychological ideas that are in use in the primary and secondary schools in this country, schools of which we have good reasons to be proud. With me it is primarily the question of assuring a coöperation of the student. If you do not agree with teaching electrical engineering in the freshman year, there still remains this point—that the coöperation of the student is not secured with the present method of instruction. Hence, you must change your method so as to secure his coöperation. He is a thinking being, he is supposed to enjoy his life while in school, and not simply live in expectation of the things which may come after he has left the school. Professor Crocker thinks that unpleasant things must be connected with the education of young men. I agree with him, and wish to assure him, that even with the concentric method there will be enough left to make the life of a student more or less unpleasant. Professor Crocker objects to mechanics, physics, mathematics, and chemistry being taught by engineers from the engineering standpoint. Surely they should not be, at the *advanced* stage, but at the elementary stage, in order to connect them with the engineering profession. In the courses of studies which I give in my paper, I propose that mathematics and mechanics should be taught in the second year by an engineer.

Expository ability and the raising of salaries of professors have been said to be more needed at present than a change in methods of instruction. I do not quite see how the concentric method could prevent a raising of salaries, or affect the necessity for expository ability on the part of the teachers.

Professor Patterson thinks that I am opposed to general culture. On the contrary, if you will kindly look into my courses of instruction you will find a considerable amount of time devoted to general culture in the first two years. I do this not only for the sake of general culture in itself, but also in order to give the student an opportunity to select intelligently his profession, before he goes into the details of it. This is more important than the general culture, as now understood. It is time to stop calling a study of mathematics and mechanics or even languages in their dry, abstract form, as "general" culture.

In presenting this paper I had in mind two purposes: to criticize the present system of instruction, and to give a new, improved method. Even if the concentric method is no good, there still remains for you to answer the criticisms against the present system, and to develop a better system.

Charles F. Scott: There are some dozen points which I had in mind to bring up, but I will forego doing so at the present time. I will refer to one point, however, the statement made a little while ago that the method proposed by Professor Kara-

petoff would be opposed to the whole history of education. Is not that one of the best recommendations it has? Has not the history of education for the last fifty years been one of advance? Not long ago new sciences were proposed instead of old languages. Then science was degraded by being applied to engineering. Then engineering ceased to be theoretical, and laboratories and machine shops found their way into colleges. Educational ideals and methods have been changing. We have not reached perfection. Engineering methods must be applied to the teaching of engineering, and that means development. Possibly, therefore, one of the best recommendations of this proposed system is that it is radical and is opposed to old ideas. If it is not quite the right thing it is getting closer to it and it merits careful consideration.

I wrote down two words on this slip of paper a moment before Professor Karapetoff mentioned the same words "educational committee." Accepting the suggestion of Professor Karapetoff as a motive, I am very pleased to second that motion; namely, that the Board of Directors of the Institute be requested to consider the advisability of the appointment of an educational committee.

V. Karapetoff: I shall be very glad to make such a motion. (The motion was put and carried.)

J. J. Carty: A few years ago I would have been quite ready to submit a number of criticisms on our technical schools. But the more information I get upon the subject and the more attention I pay to it, the more difficult it seems to be and the less ready am I to criticize. During the past twenty years I have received into my office a very large number of graduates from the principle technical schools in America, and from this experience I am able to make two generalizations. They are these:

1. That the best men do not all come from one school. The personal equation is so overwhelming that so far as my experience goes, the efficiency of the school from which the men graduate cannot be determined by the relative efficiency of the men themselves after graduation.

2. As a rule, the men are well trained technically but are very often defective in respect to that broad and liberal training which should underlie the technical education of every professional man. This defect is a serious one and very difficult to overcome. I have almost come to the conclusion that it is hopeless to attempt to give in the technical school the necessary broad and liberal foundation studies, and at the same time keep up the arduous work required of the student in connection with the strictly engineering studies. I am coming to the state of mind where it seems to me that the introduction of these so-called broadening studies into the curriculum of the technical school might fairly be likened to the introduction of such studies into a medical school.

As the general scheme of education in this country stands at present, I think that the electrical engineer, for the foundation of his liberal education, must depend solely upon the scientific studies themselves, or pursue his broad studies either before or after his technical course. Helpful as the scientific course is in the development of the student when forming part of a liberal education, it alone is not sufficient if the engineer is to take his place in the world, as he should, with cultivated men of affairs, whether they be physicians, lawyers, or men of business. The engineer should be so equipped that he may attain those ideals so well set forth by President Hadley in his recent address at the dedication of the Engineers' Building, in which he says:

We have outgrown the day when a little common sense was sufficient for managing the affairs of the nation. They are become too complex, and this complexity gives the engineer—if he will add to his training in mathematics a training in ethics and political economy and the fundamental principles of the law—an opportunity such as never before existed to claim and receive the position which rightfully belongs to him.

Further on in his address, President Hadley says:

We celebrate to-day and we are justified in celebrating the recognition of science as a necessary guide in the conduct of the material affairs of each man's business. Half a century hence, when our descendants shall meet in this building, or some yet greater building, I am confident that they will celebrate a yet greater thing—the recognition of the right of men of science to take the lead in enlightening the thought of the people on public affairs and the responsibility of filling the higher positions in the service of the commonwealth.

President Hadley says elsewhere in his address that the course of our technical schools tends to have a narrowing effect upon the student, instead of a broadening one. This is in my judgment often the case. The narrowing effect of this technical training, it seems to me, is a negative one, not due to the technical course *per se*, but due to the fact that technical training is given, to the exclusion of liberal studies. I am hopeful that ultimately our entire scheme of school, college and university training will be modified so as to permit the student to graduate from his professional school at a sufficiently early age, and at the same time have received the necessary liberal education. At present I do not see how this can be done.

How to provide this broad and liberal education and at the same time not encroach upon the legitimate work of the professional school is what I consider to be the problem of engineering education to-day. Until this is settled, I have very little heart in any discussion, such as that pertaining to the relative number of hours which the engineering student should spend in the laboratory, at shop work, or at lectures. Once the engineering student has a proper educational foundation to build upon, his professional studies can no longer be said to be narrowing, for these studies would, in the light of a proper philosophy, take on a new meaning. They would become an absorbing, intellectual pursuit rather than a hard and dis-

agreeable task. They would become to a high degree broadening.

With this large question out of the way, I am satisfied that the problem of the make-up of the curriculum of the engineering school could be satisfactorily solved. If these views which I have expressed should prove to be correct, we would still have before us the most difficult question as to what broadening studies should be specified, and that perhaps equally difficult question as to where and when these studies should be pursued.