The Electrical Engineer of Today

By B. G. LAMME, '88

Chief Engineer of the Westinghouse Electric & Mfg. Company

The AUTHOR of the following article is probably one of the first pioneers in the education of "educated men." He early realized the value of selecting and training more intensively technical school graduates, developing them eventually into stars in his own profession. Mr. Lamme has spent considerable time in developing promising engineers and this occasion of being able to read some of his own ideas on this subject is certainly an opportunity all engineers, no matter what their specialty, should appreciate.—EDITOR'S NOTE.

The early engineering in any field is usually of the "cut-and-try" kind, followed later by the refinements of more highly trained specialists. A comparatively recent development in industrial and manufacturing engineering is the analytical engineer. By this is meant the engineer who translates facts into relationships, formulae and figures, and eventually retranslates them into other facts. The analytical engineer in this sense does not mean the mere user of figures and formulae. He starts with fundamental principles and laws from which he then draws his conclusions, the applications of which are made directly to the final product without intermediate experimentation. The analytical engineer has led the way to new and more difficult fields of endeavor and many of our most rapid advances have been made under his guidance.

Electrical engineering, which is one of the youngest of the engineering lines of endeavor, was at first mostly cut-and-try like the others; but this period, unlike that of the others, was of comparatively short duration. The coming of the analytical engineer was almost coincident with the rise of electrical engineering as a business. This branch of engineering deals with more or less obscure phenomena, of which there are only indirect evidences in many cases. Many of the laws primarily are only mathematical relationships. Many of them can only be grasped or handled by those who have considerable analytical and mathematical ability. In consequence, even comparatively early in the work, the highly technical engineer was a necessity. Probably in no other branch of engineering, since its first development, has there been as large percentage of men, having high technical training, engaged in the work; and as a consequence, in no other lines of engineering has there been as rapid growth as in the electrical.

Coincidently with the growth of electrical engineering, there have been rapid advances in the older and better established lines of engineering, especially in those which have been rather intimately associated with the electrical industry. The steam turbine, which now dominates the field of steam prime movers, received its greatest impetus in connection with electrical work, and its present high development may be said to be the product of the analytical engineer. Waterwheel development has also made great advances under much the same conditions.

One characteristic of the analytical engineer of the present time, especially in electrical work, is that he is very often working far ahead of his available data. He is obliged to plot his existing data and experience and then exterpolate for the new points which he finds necessary in his work. He is thus working in the unknown to a greater or less extent, but his ability to analyze and correlate very often leads him to be fairly certain of his results. It is this ability to work with confidence in comparatively unknown fields, which has produced such astonishing results in electrical engineering.

The analytical engineer of today, whether electrical or otherwise, must foresee, through his analysis of data and practice, what the trend of future practice will be. If his analysis shows him that certain lines of development are scientifically more consistent than other lines, he will naturally tend to work along what he considers to be the correct direction. If he sees that certain practices are fundamentally wrong and represent only makeshift conditions, or merely commercial expediency, he will naturally feel that such practices eventually will be replaced. He must weigh both theoretical and practical conditions in determining which direction to work.

With the true analytical engineer there will be no standardization of practice unless such practice has good fundamental reasons back of it. His tendency is rather toward standardization according to certain scientific principles and limitations than by practices which have insufficient basis. The latest standardization rules of the American Institute of Electrical Engineers represent an attempt along this line, and it is a pretty safe prediction that the basic features of these new rules will be retained for many years to come.

Analytical engineering, of a very advanced kind is represented by the modern research and testing departments and laboratories of the big engineering concerns who do electrical and other manufacturing. Much of the technical data, which the designing, developing and manufacturing departments require, is a direct product of such departments. No progressive industrial establishment of the present time can get along without extensive research departments. One of the few large engineering establishments which has attempted to work along without adequate research and experimental departments is the United States Navy. However, recently Congress has approved of a large Naval Laboratory for research and experimental work, in line with other engineering and industrial organizations, and it is earnestly hoped that this need of the Navy will be filled before long.

In selecting some illustrations of modern electrical design work of a highly analytical character, the present turbo generator may be chosen as a shining example. The present huge capacity high speed machines are almost beyond the dreams of ten years ago. These machines are almost entirely the product of the analytical designing engineer. In these machines nearly all previous developments and experience in other lines of apparatus have counted for little. New methods, new materials, new practices and new limitations have been established in these machines, and for this reason, the turbo generator engineer has been compelled to work ahead of his data and experience much of the time. For example: the twenty thousand kilowatt, 1800 R. P. M., 60 cycle, turbo generator was undertaken when the ten thousand kilowatt machine of the same speed and frequency was the nearest size from which to obtain data, and this smaller size unit had already been carried up to what were considered as the permissible limits, in many ways. In such case obviously the designer had to overstep his data and limits, and depend very largely upon analysis.

Another good example of analytical engineering is found in the induction motor. While such motors possibly could have been developed by cut and try methods, at great expense and with many failures, yet the present advanced status of this type of apparatus can be considered only as the product of the analyst. The production of cage-wound induction motors with good starting torque, suitable for general purposes, was the result of analysis, not experiment. Many examples of this sort could be selected throughout the whole field of electrical endeavor; in fact, as stated before, the whole electrical field of today is almost entirely the result of analytical engineering.

In the electrical manufacturing industry the analysts, as represented by the designing engineers, hold an important place. The term is here used broadly to include the designers of systems, applications, methods, etc., as well as apparatus. They form a very necessary part of the organization, especially so in connection with those departments where cut-and-try methods have been largely eliminated. It has been brought out before that the experienced electrical designer of today is working to a considerable extent in the unknown. Many of the largest engineering undertakings are on customers' orders, covering apparatus which has never been built before. In most cases, by the time any tests of the completed apparatus are obtainable, the work as a whole has progressed beyond the point where any important changes can be made. Even such preliminary tests as are obtainable in the shop are liable not to tell the whole tale, for the important test or proof of the adequacy of the design comes from duration tests furnished by actual service. The real troubles may not show up until six months or a year after the apparatus has been put in service. Here is one of the difficulties that the designing engineer encounters; and, the more progressive he is, the more liable he is to run into this very difficulty, simply because he is pushing further into unknown ground. A serious difficulty possibly develops a year or so after the apparatus has been put in service. Then he is criticised both for not having foreseen and for not having immediately corrected it. Such criticism might be considered, in one sense, as complimentary, for it is an assumption that he knows much more than he really does. However, most engineers are not particularly pleased over such criticism, for they usually find it hard enough to cure an unknown and unforeseen trouble, without being told that they were careless and did not use proper foresight. A true engineer has pride in his work, and a defect or failure, in itself, usually hurts him very much. He also feels that when a man has done the best he can and has attempted something never accomplished before, he should have sympathy in his trouble, not criticism.

It may be added here that in addition to ability to undertake and carry through a given design, it is important that the engineer be able to "let go" of it at the proper time. Each new development or test shows the way to still further improvements or developments, and if each of these are to be incorporated in the design, then it will never reach completion until absolute perfection is attained or the designer has reached the ultimate limit of his ability. Neither of these conditions are practicable in a live manufacturing business, and, therefore, the engineer should be able to let go of his design when a sufficiently good practical result is obtained. Some engineers seem to know just when to stop. This is to some extent dependent upon a proper appreciation of commercial requirements.

To be a successful electrical engineer does not mean one is fitted to be a manufacturing engineer; further, one may be a very good electrical manufacturing engineer and yet not be fitted for electrical design, for this latter is a branch of the industry which requires rather special characteristics. Experience shows that the designing engineer must have a special aptitude for such work regardless of his education or general abilities, if he is to be thoroughly successful. In design work, experience has also shown that combinations of the requisite natural aptitude and the necessary technical training are comparatively rare, and the really successful men in this line of work are but very few in number.

If certain aptitudes and characteristics are essential for the designing engineer it might be asked—what are these essentials? However, it is almost impossible to pick out any characteristic which could be considered as the one essential in the electrical designing engineer, except, possibly, good sense; but as this is at the bottom of all true success, it should not be considered as peculiarly characteristic of the engineering profession.

As the competent electrical designing engineer must necessarily be an analyst, obviously analytical ability, in the broad sense, must be one of his foremost characteristics. He must also have a certain amount of mathematical ability and training. In general, skill in the ordinary mathematics, such as in algebra and analytical trigonometry is of more use than a mere working knowledge of the higher mathematics. There are certain lines of work in which the higher mathematics are, of course, very valuable and necessary. These, however, represent a relatively small percent of the total field. The young engineer should not become unduly impressed with the idea that ability to use extremely complicated mathematics is the prime requisite. He should, however, recognize that without aptitude of any sort, he is very greatly handicapped. The "handy man" with mathematics appears to have a decided advantage over others, in practical work.

The engineer who can develop a mental picture or a "physical conception" of what is going on in a machine, in distinction from a purely mathematical conception, appears to have a very considerable advantage over his fellows. The man with both the physical conception and with good mathematical ability will probably go further in analysis than any of the others.

Let us return to one of the conditions which is very necessary in all engineering, namely—a good knowledge of fundamental principles. The engineer should know the derivation of his various methods and formulae. Many of these which are now used by rapid workers are really short cuts or empirical methods which are primarily based upon correct but more complex mthods. Their use, without a proper knowledge of their derivations and, therefore, their limitations, is dangerous and not infrequently leads to serious trouble. Above all the electrical designing engineer should have a broad conception of certain fundamental relationships or laws entirely apart from the mathematics of the case. With a clear understanding of fundamental principles there is much less liability of waste of time and effort from following out impracticable schemes.

There was a time, and not so many years ago, when an electrical engineer could cover almost the entire field. At that time a fairly complete training in the various branches of electrical engineering was possible, but with the widening of the field, it has become too great for the single individual to cover, and the problems have become too difficult for any one man to handle all of them. Therefore, it has become necessary for individual engineers to devote themselves to some special field of endeavor and to leave the broad field to be covered by the co-operation of many specialists. Consequently, the engineering of today is sub-divided into many groups, each more or less distinct in itself, but each overlapping and interrelated with many other groups. The engineer of today is, therefore, always some kind of a specialist, for it is impossible to be otherwise if he is to lead in anything.

It is on account of this specialization that it is so important that the young engineer of today obtain a broad knowledge of the fundamentals of his chosen line of engineering. The same fundamentals underlie the whole electrical field, so that a knowledge of them is about as near as he can come to a broad knowledge of the whole. Such should be obtained as early as possible in his career, for, after specialization begins, his own particular field of endeavor is liable to absorb all of his efforts.

It is now being recognized by the ablest engineers that much specialization in the schools is not an advantage to the student. If the colleges could confine themselves to a broad teaching of fundamental principles they would turn out vastly more effective men than at present. Analytical ability (not necessarily mathematical) is one of the crying needs of the electrical industry of today, as regards its young men. And this need exists in spite of the fact that this industry doubtless gets its full share of the analytical men turned out by the schools. An analytical man per se is one who thinks for himself and, therefore, the problem really narrows down to the thinking man. If the schools could turn out a much higher percentage of thinking men, the engineering profession would be vastly benefitted.

There is another quality or characteristic which, while possibly not as valuable as analytical ability, goes a long way toward success, namely—persistency. A brilliant mind with but little persistency back of it, will usually accomplish less than a much less brilliant mind backed by great persistency. This latter characteristic has turned many an apparent failure into positive success. A brilliant man without persistency is liable to pass from scheme to scheme and perfect none of them. However, persistency alone usually accomplishes no more than brilliancy alone. Men have expended years of patient effort along lines which a little common sense analysis would quickly have shown to be impracticable. Here is persistency gone to waste.

The emphasis placed upon the above mentioned characteristics is not intended to belittle other very important ones, such an initiative, originality, resourcefulness, etc. These qualities might be classed even higher than analytical ability and persistency by some persons, and possibly rightly in some lines of effort. But in the higher electrical work the conditions may be otherwise. Here one may have strong initiative, but be utterly unable to make any great progress due to lack of analytical ability; he may have great originality, but, lacking the fundamentals, be unable to touch on the higher work; he may be exceedingly resourceful, but be limited only to lesser things due to lack of knowledge of basic principles, and, thus, inability to handle advanced work. However, a leader must have all of these qualities to a certain extent. Now and then a man is found who has all of them to a fairly high degree, combined with unusual analytical ability and perseverance. Such a man eventually is liable to become known as a genius, but it should be remembered that genius is of two kinds,—creative, in the sense of being able to think in new fields, and constructive, in the sense of being able to use all facts and principles available to bring about successful results.

Then there is another feature which may be referred to, namely, the commercial side of engineering. An electrical manufacturing business lives by the goods, not the engineering, which it sells. The successful designer of such goods must, therefore, have considerable knowledge of commercial conditions or he cannot design adequate or competitive apparatus. This is a feature of the business about which the young engineer, fresh from school, knows nothing. This appears to be a very difficult thing for some engineers to acquire, while certain of them never really do so. On the other hand, it has been said of some very good engineers that they ought to have been salesmen, because they grasped so readily the customer's conditions and requirements. The broad gauge electrical designer is usually quite successful in aiding the salesman, because he sees the commercial bearing of his engineering work.

This relation of the engineer to the commercial side of the business brings up another point, namely, his ability to talk clearly and logically in private and in public. It was once supposed that an engineer never had to talk in public and that all he had to do was to go off in a corner, by himself, and use a slide-rule. But that day is long past, for now the man who knows most about the apparatus must be able to tell others what he knows. Presumably in all large concerns there are men who are seldom or never sent outside on account of their inability to make a good presentation of a subject. Assuming equal ability otherwise such men are of less value than those who can make a good presentation of any given matter. In general, a good logical thinker can develop into a fairly good logical speaker through practice.

The foregoing has had most to do with electrical designing engineers, but while they are a very important part of the industry, yet they are not the only engineers in the electrical manufacturing business. In fact, the electrical industry today is handled almost entirely by men who should be classed as engineers. A large percentage of the electrical salesmen of today have had a very good engineering training of one kind or another. In fact, in many lines they must have such training in order to be successful. In the manufacturing part of the business, many of the leading men are also very good engineers. Even many of the high executives in the industry are trained engineers of high grade.

In conclusion it may be said that this is an age of engineering construction. It is, or rather it foreshadows, the golden age of the engineer. His successes and attainments have led him to view hopefully hitherto totally unattainable things, and in consequence his problems are becoming increasingly difficult. At no time has such boldness been shown in attacking the problems of nature for the benefit of mankind, and it is the engineer in one guise or another who is behind the attack, and his aim almost invariably is something which is ultimately for the advancement of humanity. Construction, not destruction, is his preference. He is an optimist and not a pessimist. In research work he is delving into the unknown in search for properties, principles and laws of nature and of material. He is making vast strides in the conservation of natural resources, by the economical generation and utilization of power. In transportation he is bringing the whole world together. He is making steel and concrete the rule in constructions, doing away with more perishable materials.

Engineering should be considered of highest rank among the professions. No engineer need apologize for his calling. He should feel the greatest pride in it, for it may be said that it is the very heart and soul of material progress.

LORD HALL

This is to introduce THE OHIO STATE ENGINEER to the graduates, ex-students, students and friends of the College of Engineering of The Ohio State University. We trust you will give it a hearty reception and will find it worthy of enthusiastic support. We believe it will render a valuable service to you and to the college, if you will give it the aid and encouragement which it deserves.

Although it is entirely a student enterprise, this issue certainly shows it to be a creditable one. If the students of other engineering colleges are capable of publishing technical magazines, we should have sufficient confidence in our students to believe that they can do as much.

Assuring you of our confidence in this enterprise and hoping that all of you who may be fortunate enough to read this first issue will immediately send a check for a year's subscription, I am

Yours truly,

E. F. CODDINGTON,

Acting Dean, College of Engineering.