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H. E. T. Haultain

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# THE YOUNG GRADUATE AND THE PROFESSION OF MINING ENGINEERING*

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Both in my own experience and in my observation of young graduates from engineering schools in all parts of the world, I have found a general ignorance of the profession as a whole, generally coupled with a very much distorted view of the young graduate's position in, and relation to, his profession. This is probably to a very large extent unavoidable, but it has always seemed to me a very important point, and I should strongly like to see a series of lectures on the subject embodied in the general curriculum of the school. Doubtless very much of such knowledge must be personally and painfully learned by experience, but a very valuable skeleton of information could be built up in the lecture room. In the short time at my disposal, I will attempt an outline of the profession of mining engineering as I in my limited experience have found it, and attempt to deal with some of the more prominent difficulties that will be encountered in the early days of the Young Engineer's career.

Kipling says:

> "When the waters were dried an' the earth did appear,
> The Lord, He created the Engineer."

And, from the first, the mining engineer must have been a man of prime importance in his class. As time went on, and all structues depended more and more, either in their fashioning or in their material, upon the supply of metals, so would the importance of the miner become greater. In France and Germany this is recognized, and mining engineering ranks ahead of all other branches of engineering, but in our English-speaking communities it is not officially accorded the same recognition, and possibly the miner is often considered rough and unfinished in his methods, a pioneer

*An address delivered before the Engineering Society in 1902. This will be followed by an article, "The Mining Engineer and his Relation to the Public," with particular reference to Ontario.

**See Biography in Section 2, page 3.

occupied in coping with nature in the rough and lagging far behind the polish and finish of the scientific engineering of the cities. It is true he is a pioneer and that he deals with the forces of nature in her crudest and roughest forms, but he does it with a wider range of scientific knowledge than that possessed by any of his engineering brothers. He needs and he makes use of the specialized knowledge of all other branches of engineering in addition to such that is peculiarly his own.

The profession of mining engineering embodies very much more than any one man's mind could possibly encompass, and there is a limitless number of subdivisions or combinations of subdivisions for the specialist in which to bury himself.

In general, mining engineers are divided into two main classes, viz., Mining Engineers and Metallurgical Engineers. Under this classification in its closest sense, the mining engineer has to do with the getting of ore to the point where it lies in a broken state at the surface, and the metallurgical engineer carries on the work from this point until the metals are finally extracted from the ore. But as a general rule the metallurgical engineer's work is confined to smelting operations, while the processes of mechanical concentration of ores, and even the leaching and lixiviation processes are in the hands of the mining engineer in charge of the other mining work. The reason of this is to be found in the fact that as a rule the mechanical concentration and lixiviation of ores is carried on at the mines under the one management; while smelting is generally done at some central point at a distance from the mining operations. The department of smelting I must leave out of consideration, and trust some other graduate will take up this very important branch.

Of mining engineers proper, there is a rough classification that will divide them into two classes: the engineers connected with the large permanent mining centres, usually coal and iron; and those connected with the general mining industry scattered all over the world. It is with the work of the latter class that my experience has been and it is with them that I will deal. This class of mining engineers is again subdivided into two main classes—the consulting engineer and the managing engineer, and the thoroughly competent consulting engineer will have passed through the stage of managing engineer. The work of the consulting engineer can be divided into two main divisions—reporting on the value of properties and reporting on the management of properties. The term managing engineer would embody in its general sense all the engineers resident about a mine, and would include assayers, chemists, surveyors, mechanical engineers, electricians and those engineers skilled in concentration and lixiviation processes.

The prominent consulting engineer would have his headquarters at some commercial centre—London being the particular home of this class—and he might or might not have assistants or partners in parts of the world nearer to the mining centres. A large part of his work—perhaps his sole work—would be the examining of and reporting on, the value of mining properties in various parts of the world. This is of course most important work and is correspondingly paid for. In this work experience and judgment, built upon a foundation of wide scientific knowledge, coupled with a well balanced commercial sense and the necessarily ever present disinterested integrity, are the main requirements. It is a position of the utmost commercial responsibility, a single report often controlling the investment of millions. The keynote of success is of course Reputation, and before a man could expect to succeed at this work, he must have built up a reputation, and have made friends. The fees for this kind of work are high. Among prominent London engineers the fee for a report of any consequence would not often be under $5,000.

Consulting engineers located in either commercial or mining centres also undertake the reporting on the management of mines. They may visit the mine at intervals, or they may simply base their reports and advice on the information, accounts, etc., supplied to the company by the mine manager; and their advice might extend to the supplying of detailed plans for development or for machinery. Consulting engineers in this capacity are frequently engaged by London companies owning mines abroad.

The position of consulting engineer, with a reputation, able practically to choose his own work, travelling in many parts of the world, returning always to his headquarters, and receiving most substantial fees, is a most enviable one, and is one looked forward to as a natural consequence of years of successful work in the field.

But it is to the position of managing engineer, and the steps subordinate to that position that I would more particularly draw your attention. Perhaps I could not do better than outline the duties and responsibilities in an actual case.

Take the case of the manager of an English Company owning mining territory in Africa. They have one mine partially developed and several prospects giving more or less promise of good values. This Company is managed in London by a board of directors—non-technical men—with a chairman at their head. This Board will meet once a month, or once a fortnight, and will outline the general policy of the Company. The details as far as the London end is concerned are in the hands of the chairman, who relegates them largely to the secretary, who corresponds with the manager in Africa. The manager will have a wholesale power of attorney to do anything and everything in Africa, and will be answerable for all his actions directly to the Board. He will have an agreement or engagement as manager, terminable as a rule by six months notice on either side. He must of necessity have had the full confidence of the

Board before he was apppointed, and must retain this to the full or his position will become untenable. The Board will be completely at the mercy of the manager—their only information being what he chooses to give them in his letters and reports, together with that obtained through an annual visit of a director or a consulting engineer. The manager in turn will be very much at the mercy of the misunderstandings and disappointments of the Board, and nothing but full confidence can keep things running. The keeping of the Board well and judiciously supplied with information is perhaps one of the most important functions of the manager.

Coming nearer to his work, we find him in charge of an isolated community twenty miles or more from a settlement—100 miles from a railway—with slow-going ox-wagons as the only means of freight transport.

First and foremost he must examine his ore deposits and then with all the knowledge that he possesses of geology and minerology, he must form some opinion of their probable value and outline a method of development. With his already partially developed ore deposit, all his past experience of the costs of mining and ore treatment, together with all the information he can obtain in a raw country concerning labor, power, fuel, transportation and markets, will leave him in no high degree of certainty as to probable profits. He has to study the resources of the country, and to design his plant accordingly. He is alone, single-handed, and up against the real thing. And he has to organize in a bare wilderness a large and complex business. While keeping his mind keenly on the deep scientific problems of the various and varying ore deposits, on the problems of haulage, timbering and ore treatment, he has to arrange for the establishing of his camp, the housing of his men and animals, the purchase of innumerable supplies and transportation over difficult country. He has to procure, and very often to a large extent must be prepared to train, a most varied gang of workmen, skilled and unskilled, in all branches of labour. He has to control a most mixed lot of the roughest class of men, both white and black ; at all times he must preserve his personal influence and tone. He is the single-handed autocrat of an isolated community, with nothing to maintain his authority but his own personality. He is spending large sums of money, and spending it in innumerable ways that are difficult to trace and check. On all sides are men trying to get the best of him in every proposition, and he must have the business side—the commercial side—of his work organized to a degree unthought of in many establishments nearer the centres of civilization.

While organizing and personally controlling these varied complexities, he must ever keep a clear mind for the constant, careful and well balanced study of the intricate scientific problems of his work.

Let us consider some of these engineering problems.

In the first place his ore bodies differ in many respects from any he has had any previous knowledge of—no two ore bodies are the same. Nothing but experience—wide and varied experience —founded on scientific training, is going to save him in the solution of the problems involved in the exploration of his ore bodies.

He has one ore body so far opened up that sufficient values are in sight to justify the installation of machinery on a large scale for the breaking, mining and treating of his ore. Upon all the intricate details I cannot touch, but let us look at some of the main problems involved.

The first problem of mining his ore and protecting his underground workings is one depending almost entirely upon judgment and foresight based on experience, and is one that no amount of training or reading can solve for him. In any case he must work tentatively—must feel his way. That probably is the keynote of all underground work—certainly of all the early stages. It is impossible to see far ahead, and one must feel his way foot by foot —planning tomorrow's work by today's results.

But the planning of the ultimate development which must soon be taken in hand is a large problem involving work spread over many years, and the general skeleton of the plan must be laid out and undertaken at once. Upon the position of the main working shaft or tunnel the position of his surface works will to a large extent depend. Into this problem must enter the problems of pumping, ventilation and haulage, and much calculation and well balanced judgment are required for a satisfactory solution. The problem involves not only a very large sum in itself, but will always very seriously affect the working costs.

Inseparable from this problem is the question of power. The case I have in view has practically unlimited water power five miles away, so that the question of power does not affect the hoisting question; and it is found that for the first few years the most satisfactory course is the running of a low level tunnel which will give several years ore supplies above it, and which will always be the main working tunnel.

The next problem is the treatment of the ore, and though the manager ought to be capable of dealing with this problem himself, he may call in the assistance of a consulting specialist.

And here comes in a very nice point:

It is of course out of the question that our mine manager should know everything, or that he should know as much of detail as a specialist in any branch, and very naturally the average business man will say: Here is an isolated problem, let it be solved by the specialist.

In the large mining centres are to be found consulting engineers, who are disinterested specialists in milling and lixiviation processes, and who make a business of such problems. They often are called upon to supply complete plans.

In the first place, there is one statement that will hold under all circumstances:—There is no isolated problem connected with any mine. The mine and everything connected with it is one vast complex machine, with all its parts and details interdependent, and smooth running—successful running—depends on the balance between all its parts, and upon their perfect interworking. This can only be achieved in one mind. There can only be one controlling hand, and though it is not necessary for the manager to design all the details, he must fully grasp the essentials of every department. He must be responsible for everything.

If outside consulting advice is called in, it must be in consultation with the manager, and if the manager is incapable of dealing with the subject, a most dangerous element of failure is at once introduced. This is a most essential element of mine management, and I will refer to it later on.

If a thorough professional consulting engineer with a reputation is called in to settle the problem of ore treatment, he may be prepared to deal with it in its entirety, in which case he would go carefully into all the conditions surrounding the problem from the ore deposit to the market, and would do this in close consultation with the manager, whom also he would carefully consider as an important condition. Then after designing the plant he would to a certain extent supervise construction, and on its completion would personally attend to the early stages of its operation. For an ore treatment plant is not like a small steam engine which will run when supplied with steam. Even after most careful and capable designing, there will have to be much adjusting of its method of operations before the best results are obtainable, and this adjusting must be done by a capable and responsible head.

If the specialist's connection ceases on the delivery of the plans, the manager's responsibility will only then commence, and if there be any failure in results the manager will blame the design and the designer will blame the method of operation, and the company will be in the position of the man trying to sit on two chairs. This is one of the commonest causes of failure and trouble in mining, and every mining man can point to many incidents of this kind.

In the case I have described the specialist's fee would be enormous—probably much larger than the manager's annual salary.

Most frequently it would not be possible to obtain the services of a distinguished specialist and recourse is often had to the manufacturers of mining machinery. They call themselves specialists in such matters and very often are so, and have much experience and data at their command, but we then have the anomalous position of the consulting engineer and the contractor being one and the same person. It is surprising how frequently this is the case, and it is not surprising that this is most frequently a cause of disaster.

The manufacturer can never be a disinterested party. Conditions do not permit him to make a thorough examination of all the conditions. He will tell you what machinery to put in; it will be his own, and there will be as much as possible of it; it will be good machinery, and he will guarantee the smooth running of individual machines, but he will not guarantee the results. And he will have many excuses to show that the blame of failure is not attachable to him. He will tell you that the ore treated in the mill differs from the sample sent him; that the construction was poor and the operation is worse. You cannot pin down the manufacturer to results—he is too old a bird at the game.

What then is the manager to do?

He ought to be capable of designing his own plant. If he feels doubt about it, let him engage a man who has knowledge of such matters, engage him as an assistant—as a head of a department—and let this man experiment on a laboratory scale in co-operation with the manager.

After the manager, with or without outside aid, has decided that his ore is a free milling ore requiring a subsequent treatment of tailings by cyanide, and has decided on the general main idea of his plant, he can safely go to the manufacturer for his machinery, trusting largely to him for all details—for the details are the work of a mechanical engineer, and in this department the manufacturer is the highest specialist.

The first plant will doubtless be a small one, designed with a view to further increase, and also with a view of permitting considerable experimenting.

What I have said in regard to the ore treatment plant also holds good with the tramway from the mine to the mill, and with the water power plant, and with the electric transmission plant, with of course some modifications.

Aerial tramways come nearer to being isolated problems than does any other part of the plant, and they are very frequently given over to contractors, who guarantee to erect the tramway and run it for a short time. To a certain extent the tramway can be looked upon as an isolated machine of the nature of a steam engine. But again to make the contractor and the consulting engineer the same person, even in so simple a matter as a tramway, tends to an unnecessary waste of money and consists in paying to a contractor very much more than what is already paid to the manager or his staff for the same work.

In the case of electric machinery—electricity is perhaps somewhat removed from the mining engineer, but is daily becoming less so, and though the mining engineer would certainly never attempt to design his dynamos, he certainly ought to know enough to decide whether he wanted direct current or alternating machinery, and to be able rationally to check over the electrician's figures as to line loss, etc., etc.

To sum up this question of machinery, the manager should be thoroughly conversant with all the standard types of machinery of all the prominent manufacturers that might possibly be of use in mining work, and this includes practically everything except heavy ordnance and marine engines. With the detailed design of this machinery he need not unduly burden himself beyond understanding the why and the wherefore of every part. The manufacturer can be depended on for excellence of detail. Thereon depends his existence.

The erection of his plant is an all-important part of the manager's work or of a most trusted assistant. To let this by contracts generally ends in disaster unless most competent and keen watch is kept on the contractor. Generally speaking, in all mining construction, it is more satisfactory and more economical to watch over a good foreman than to check a contractor. The contractor, like the Indian, will be bad if he can be.

The operation of the plant will be the work of the heads of departments, always under the personal eye of the manager.

This is a bare skeleton of the work of the mine. It is filled in with an interesting network of details of every kind, from the niceties of subtle chemical investigation to the handling of a drunken mob, and through it all must run side by side the deepest scientific thought and the most cold-blooded business methods, tempered always by the truest disinterested professional tone.

The manager will have to assist him at his work, besides his own personal assistant, several heads of departments—a commercial superintendent in charge of the buying and of the books and the commercial side of the business generally; a surveyor, an assayer, superintendents or head foremen of mine, mill and cyanide plant, a master mechanic, and foremen of the various subdepartments, and with these the successful manager will keep in very close, intimate touch.

There is another phase of the manager's work that I have not yet touched upon—a department in which he remains alone.

The mine is the property of a company, and the public pay very much more attention to the shares than they do to the mine and the majority of shareholders expect to make very much more out of the fluctuation in the price of shares than they do out of the mine. There is a constant active buying and selling of shares. Now the manager's regular reports to his Board can very materially affect the price of shares, and his plans of operations do also very materially affect the price of shares; discoveries will be made in the mine that will make enormous differences in the value of the stock. In very many ways the manager has a very large control over the price of the stock, and if there be any deviation on his part from strict honesty, from the true professional spirit of disinterestedness, he may be in a position to make much money for himself or his friends. Here is a wide open temptation—a temptation so coarse and glaring—so palpable—that it will in general be easily avoided, but it has also its more subtle aspects, and the only protection a man has lies in the inherent honesty, the professional spirit and the tone of the true engineer.

This is an outline of the position of a manager of by no means large property, and may be taken as a fair general example.

As an example of the extent to which the business of mine management may grow, I would cite the case of The Consolidated Gold Fields of South Africa. In 1897, in their engineering offices in Johannesburg, they had fifteen draughtsmen in the surveying department, and seventeen more in the general department. Their chief engineer drew a salary of $60,000 a year, their chief mechanical engineer drew $25,000, and so on. Of course this office did all the engineering work for a large group of mines.

But it is the smaller propositions that tax the resources of the mining engineer most severely, for in these cases he must himself control every department, and must carry out works that in larger concerns would be in the hands of heads of departments in themselves specialists capable of carrying responsibility.

In an examination of the duties of mine manager, as I have outlined, what do we find as the more prominent points? I think that we shall find that the most important point of all is confidence—mutual confidence between the directors and the manager. To obtain this the manager must be a man of experience—a man with a record—a man who has made friends. The next point of importance is the fact that the whole concern, first, last and all the time, is a business proposition undertaken with the sole and only purpose of making money, and as far as our engineer is concerned, making money legitimately, though—and this is a point ever to be remembered by the young graduate—there are always those seeking to make money illegitimately. The whole concern in every department must be organized on a commercial basis. The third point of importance is the essentially scientific character of all the problems involved in the finding, winning and treating of the ore. In the young graduate's technical course, his whole time and energies being occupied with this latter point, he is apt to lose sight almost altogether of the other two. But these three points are as inseparable as the three dimensions of space, and any proposition founded on two only will be a failure.

Of course there is an exception to this rule—the factor known as luck may upset all rational conceptions.

Besides these three fundamental points there are others of nearly equal importance. All mining work is new work; every problem is a new one, differing in many respects from the engineer's previous experience; every problem is complex, involving a large number of facts and conditions often very obscure. The engineer must be a man of varied experience, not only conversant with a wide range of scientific knowledge, but with a very wide range of actual experience. He must be essentially quick witted and he must have a lively technical imagination, ever ready to imagine new combinations and possibilities. But his temperament and technical character must be strong enough to allow this imagination full play, without it carrying him off his feet into a wilderness of conjecture.

He must be physically strong—able to live anywhere and eat anything; he must ever be ready to pack his blankets and his scientific knowledge on his own back.

He must be a professional man in the fullest sense of the term. He must have tone; I cannot define tone, it marks quality, or shall I say quality marks tone. And tone is as unassailable as it is hard to define. From the first step to the last the mining engineer is surrounded by temptations of every kind; every tendency within him will have free opportunity to pull him towards disaster. From the start he is away from the influence of custom and social ties, and he who has never been absolutely free from these influences can have little conception of the extent of their controlling power. But the temptations arising from avarice and ambition are the most continually and persistently present. And these temptations are often of the subtlest kind—most frequently not having even the appearances of temptation, and this is a phase of his work in which the engineer stands alone—a game in which he must play a lone hand.

Disinterestedness is the foundation and skeleton framework of the whole structure of the professional man. If he is not disinterested he is nothing. He is an employee and his interests always must be on behalf of his employer. This explains how the mine manager can be a business man and still a professional man. He is carrying on business for another and he can carry it on only in the cleanest and straightest of business methods.

Another thing to be observed in the work of our mine manager is that he has more to do with human nature than with any of the other forces of nature. He has to deal with his directors on one hand, and with his employees with the other. He has to deal continually with the cleverest scoundrels and rogues of all classes and kinds. He has to depend on his judgment of character in black, red, yellow and white.

Well, gentlemen, have I painted an impossible picture for you? I have outlined the main skeleton frame of a possible structure—a structure for which there is an enormous demand; the completion of the edifice depends upon the individual.

So much for what there is in front of us. Let us now consider our first steps.

The young graduate, despite his hard work and scientific attainments, is, as an engineer, well nigh as useless as the newborn babe. I know you will not believe this—it is not compatible with your years and your efforts—it is probably just as well that you don't believe it, but it is one of the first important things that you must learn in the outside world.

How is this so? Thus: the young graduate has had no experience (I know there are exceptions), consequently can have no judgment, and therefore is absolutely incapable of responsible initiative.

Many people will tell me I am entirely wrong—that the young graduate is full to overflowing with judgment—that he will judge anything or anybody, and as for initiative, he has the nerve and the supreme self-confidence to tackle any proposition —to initiate anything. Exactly—that emphasises what I mean—he has no judgment—that is, no judgment that can be depended upon.

In England they put the embryo engineer in an incubator—that is—he is articled as a pupil for one, two or more years to an engineer of standing and experience, and for this privilege he will pay as much as $1,000 a year, and will receive no pay of any kind in return for his work. With this idea I would be wholly in accord, if the conditions in the colonies permitted it. I would not advise for a colonial mining graduate an articled pupilage in England; but if a western mining engineer would take him, he could not possibly do better. But out here the conditions are different, and we have to face conditions as we find them.

In the first place, many of our technical graduates have not the means to pay any pupilage fees, nor even to give their services and time for nothing; they must earn soon after graduation. And again I do not think you could persuade any mining engineer in active work on this continent to accept pupilage fees or to have about him a pupil working for nothing.

The young graduate must earn money, and it is a function of the technical school to leave him in a position to do this, and there are two or perhaps three or even four branches of work in which the technical schools can turn out commercially useful men. I refer to assaying and surveying, and to a certain extent, draughting.

The school can—if it chooses—turn out men who could take hold of the position of assayer or of surveyor at any small mine or who would make excellent assistants on a large property. These positions require practically no judgment or initiative, and the main difference between the work at the school and the work at the mine consists in the rapidity that is required in commercial work, and a certain ability to make shift with the anything but ideal conditions and appliances that one may be up against. If to a smooth working knowledge of assaying and surveying, the young graduate has added an active knowledge of bookkeeping and cost-keeping, he has three strings to his bow that will earn him a living in any active mining camp.

It is a common saying in the West that if you cannot get one job you should take two, by which is meant that you may often be able to get a job as an assayer and bookkeeper combined where you could get nothing if you applied for either singly. My advice to any technical school would be—make bookkeeping and cost-keeping and the commercial organization of engineering business, an important part of your curriculum. My advice to any student of a school where this is not part of the curriculum is, to take steps to make a special study of these subjects at the earliest possible opportunity.

The obtaining of a position as assayer or surveyor, and, from that position, studying the actual working conditions of a mine, to be ready for further advancement in your profession, is the orthodox method.

The surveyor has the better opportunity— he is here, there and everywhere on the property—mixed with everybody and sees everything that is going on, and will be more naturally given the position of acting manager or assistant manager.

However, before going any further, let us consider more fully the functions of the first few years after graduation. The first function doubtless is the earning of a living, and the orthodox way of doing this I have outlined. But if you stop at that, you will never be an engineer. The main function is to get experience—wide, varied experience—of everything you will need in after years. Another function is to make professional friends, but the main point is experience.

In your S. P. S. course you have had a most excellent training. You have been trained to think—to reason—to read and to a certain extent to observe—you have been trained to ask the question " why" and to make an effort to rationally answer that question. You have learnt much about the physical laws underlying all engineering problems. The excavations have been dug and a very substantial foundation has been laid for a very elaborate superstructure; and further than this, the skeleton steel frame work has been in part erected; and even still further, if the material for further erection has not been gathered, the method of obtaining it has at least been indicated. You can live in the cellar if you like, but that will never make a house of it—you will never be an engineer. You must build on the foundation. You must fill in the skeleton frame work —you must erect extensions to your frame work—this you must do alone. Nobody else can do it for you. The elaborating of the structure is by personal experience. In my student days Prof. Galbraith advised us to devote the first ten years after graduating to the sole function of gaining a varied experience. I think this most excellent advice. No matter what position you hold you will be gaining experience and to gain a varied experience you must not stay too long in one position. But you must not trust to haphazard luck in the positions you get. There are several points to be remembered. In the first place in your early days you can do things that later on in your professional life, you could not do. For instance, on graduating you could work as a mucker or common laborer underground—or you might innocently be employed by some notoriously corrupt men or companies. In neither case would your reputation suffer, and you would be the gainer by some valuable knowledge.

The most prominent feature of mining work in all parts of the world (and in Canada and Ontario have we had most scandalous examples of it) is the extreme corruption, crookedness and dishonesty that frequently accompanies it. This exists to a degree beyond all conception by those who have not actually seen it. If you keep this fact in view and remain always ready to quit a job when it looks dirty, you can in your early years take pretty nearly anything you can get, but later on you must be more careful what you do. Then the main point would be to get near good men, near good companies and successful concerns.

In your early years there are several very unorthodox things that I would advise. In all mining work the biggest item is for labor, and there is no other item of expenditure in which money may be lost or saved to the same extent. The human machine is not only the most used, but it is the most complex, and to be a successful mining man you must understand your workman. The best place to study your workingman is alongside of him. I strongly advise every young mining graduate to work as a mucker or trammer underground in some fairly large mine. To do this properly you must do it thoroughly and drop all your engineering business, and your diploma and all that, and get into dirty overalls and get your job from the foreman and sleep in the bunk-house and keep away from the office. This I know is often advised, and in Cornwall and Freiberg there are regular practical courses underground where the students play more or less seriously at work, and learn after a fashion to swing a hammer and frame a set. Candidly I don't think much of that—I do not see that such work is of very much use, and in those practical courses you don't learn anything of the men—you don't get round to their point of view. This to my mind is the essential point, and my advice is to get a mucker's job and hold it at least over one pay day and over several if you can. It will hurt and it will be hard, but it will be worth it.

Again, if you have any inclination towards carpenter's work or machine fitting or any opportunity to follow up such work, I say by all means do so. I know of no better qualification for a young man seeking mining experience than a knowledge of machine fitting. There is no part of a mine free from machinery, and the fitter is wanted everywhere and gets a job more easily than any other class of skilled or semi-skilled workman; while a carpenter can often get a job on mill construction or the like that will give him an insight into construction that he could get in no other way. These are not short cuts to success or by-paths—they are stepping stones and most valuable ones at that. I would strongly advise the mining student to spend at least one of his summers in a machine shop or in a carpenter's shop. I would consider this better than a summer spent in an assay office, on survey, or in a mine.

The next question is as to where the young graduate is to go on graduation. Into the question of a post-graduate course I cannot go beyond saying that I am in favor of a post-graduate course, and would still recommend Freiberg despite all the advances made by technical schools on this continent.

After the completion of his technical course he should go to some active mining camp, and I certainly would choose the Western States. I am enthusiastically a Canadian, but I do not advise the young mining engineer to remain in Canada. He should go to an older mining country for his experience, and the United States—the Western States—has trained and still is training the world's most prominent engineers. And when you go west leave your diploma behind you, also your testimonials and recommendations. You will be looking only for subordinate positions, and for these positions men will size you up by looking at you and will discharge you as casually as they engage you. Never be afraid of quitting a job. It is no disgrace—very often it is not a bad thing to be discharged. A willingness to turn your hand to anything and everything that comes your way and do it with your best effort, are traits that will help you more than others. It will be several years before you get to what your heart pines for—that is real engineering work—but you must not neglect it for that reason; your eyes must always be open to everything about you, and you must read everything you can lay your hands on—technical magazines and catalogues in particular.

You will probably find the life a hard one, full of painful physical effort—full of misunderstandings and disappointments. Hope will be long deferred. Your scientific attainments will seem lost—swallowed up by chance and the force of circumstances. You will think you are losing all your finer feelings—your social niceties; the latest operas and plays will hardly be known by name to you and the popular airs will be three years old when they reach you. Life will be anything but a soft snap and your only consolation will often be: "Well, it's good experience, and anyway, it's all in the day's work!" You will find that you will have to give up very much, if not all that went to make life pleasant, and you will get in return—if you are lucky—work—and in many years—if you are lucky—well paid work.

But you will see—and if your eyes are open, life will be very full—you will play your own game with a freedom and a scope unknown in any other profession. You will have opportunities to carry your tendencies to the full. You will be with men and you will work with men, and the conditions and surroundings will be such as to bring out, in full prominence, the characters good and bad of men. Veneer and polish will be absent, and if you are a lover of men you will love your life. If you want an easy life leave mining alone. If you are not a tramp and want everything settled—if you are contemplating early marriage—don't go in for mining, for you will have to live and work where it would not be fair to take her.

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## PRELIMINARY STUDIES IN CONNECTION WITH THE DEVELOPMENT OF HYDRAULIC POWER

H. G. ACRES, '03

It is not within the scope of this article to fully discuss such a subject as this, as every hydraulic problem involves features peculiar to itself, which require special study and treatment. For this reason it will be necessary to make certain assumptions and follow out a line of reasoning based upon them.

Assuming, therefore, the existence of a stream upon which, at one or more points, power development is structurally and economically feasible, the first point to note is that the very fact of development being economically feasible implies the existence of a market for the power output, or at least the certainty of establishing one within a reasonable time. So that before the hydraulic features of the problem are considered in detail, the commercial possibilities must first be studied with a view to ascertaining whether or not there is sufficient inducement offered to proceed with development.

The character of the market available to any source of power will vary widely with its geographical situation. In some localities the power output of the plant will be disposed of at the turbine-shaft, as is generally the case in the manufacture of pulp, lumber, flour, etc. In other localities it may be necessary to transform the mechanical output into electrical energy to meet the requirements of the market.

In the first case the problem is a comparatively simple one, it being simply necessary, in the majority of cases, to instal sufficient hydraulic capacity to meet a steady demand for power, the amount of which can be very closely estimated. In the second case, however, owing to the wide range of industrial uses to which hydraulic energy can be electrically applied, the question becomes much more complex, and for its proper study requires careful investigation and the exercise of conservative judgment, for the conclusions arrived at will have an important bearing upon the general design and lay-out of the plant and perhaps also upon its location, where more than one site is available.

The topographical features of the power site and the conditions of flow will of course be the main consideration in connection with the method of development, and will determine the limiting capacity. Apart from this, in so far, at least, as the installed capacity is concerned, deductions derived from a study of the market will be the controlling factor. It is to be noted in this connection that estimates of required capacity should not be based upon the lump sum of all contracts entered into or in sight, but upon estimates derived from a classification of these contracts according to the hours of service called for. It will then be possible to arrive at an approximation of the installed capacity required to handle the peak load, this being the value which obtains when the simultaneous demands of the power-users become a maximum.

An estimate of the average load can also be approximated, and from this an idea can be formed as to the proper capacity of the individual units to be installed, with a view to handling the variations of load with a maximum of efficiency.

This may be summed up by stating that for a maximum of operating efficiency, the lay-out of the plant and the individual capacity of the units will depend upon the load-factor, which is the ratio between the maximum and the average load; thus in the general case a small load-factor will call for individual units of small capacity, and as the load-factor approaches unity a smaller number of units having larger capacity will give the best economy. It is to be noted in the latter case, however, that where continuity of service is of first importance, the concentration of capacity may make the installation of a spare unit necessary.

A general investigation having established the fact that a suitable market is available, the hydraulic features of the problem may then be taken up in detail. The first point to be considered in this connection is the amount of water available, and a reconnaissance survey should be made of the watershed from which the supply is drawn. In this way information will be obtained as to the area of the watershed, the gradient of the stream, and general topographical features, such as the nature of the soil, amount of wooded and cultivated land, and the number and extent of lakes, marshes, etc.

An approximation close enough for practical purposes can usually be arrived at with reference to the area of the watershed from existing maps of the district. In Canada the Geological Survey maps answer very well, especially in the unsurveyed districts, as they are fairly accurate and contain a considerable amount of detail. The standard topographical maps published at Ottawa under the direction of the Dominion Geographer are still better, but these maps so far embrace a comparatively small area. Both classes of maps are plotted to a four-mile scale and notes can conveniently be made upon them in the field.

During reconnaissance particular attention should be paid to the possibilities of artificial storage along, or at the headwaters of the stream. Owing to the fact that the quantity of continuous twenty-four hour power available per foot of head depends upon the amount of water discharged under conditions of minimum flow, any steady increment which can be added to the minimum flow will increase the continuous twenty-four hour capacity in the direct proportion; and, if the maximum available head at the power-site has been utilized, and the market has absorbed the continuous capacity derived from minimum flow, the only way of "hydraulicly" meeting any further demand for continuous power is to augment in some way the natural low-water flow. This is generally accomplished by improving the natural storage facilities of the watershed, and, as before stated this is one of the most important points upon which information is to be obtained during reconnaissance.

The field work in this connection consists in collecting information as to the area of the various lakes and other adaptable storage basins above the site of development. Lake outlets should be carefully examined with a view to obtaining suitable cross-sections for damming, the topographical advantages of these locations being offset against the possible liability to land damages resulting from the construction of dams. If the watershed contains much cultivated land and the scheme of development is at all extensive or elaborate, all these storage basins should be traversed, dam-sites cross-sectioned and flood contours established. This will furnish sufficient information to establish the location, method of construction and extent of storage works and to admit the computation of flooded areas. To supplement this, data should also be obtained from the nearest weather station concerning the value of the mean annual precipitation, snow being reduced to water, and also the value of the mean annual temperature. It is well to get these records for as many years back as they extend. Empirical formulae giving a value for annual evaporation have been derived which involve the values of mean annual precipitation and temperature, but they are not safely applicable in a general way, owing to the fact that the constants involved have been based upon local data. Generally all that can be done is to obtain from the yearly records the minimum value of mean annual precipitation. This value, used in conjunction with the area, will give the probable minimum value of the total annual precipitation over the watershed.

From data collected during reconnaissance it will now be possible to assume a value for the "run-off" factor by which is meant the percentage of total annual precipitation which will be available for power purposes after allowance has been made for dissipation by evaporation, seepage, and the requirements of vegetation. This quantity varies widely with the locality and depends largely upon climatic conditions but also upon the topographical features of the watershed and the gradient of the stream; thus, in a watershed containing a large proportion of cleared and cultivated land with small lake areas and steep stream gradient, maximum values of the run-off factor would obtain, owing to the fact that a large portion of the precipitation would be carried off by freshets, while it would tend toward a minimum in the case of a sluggish stream draining a watershed containing a large proportion of open hard-wood forest and large lake area, these conditions tending toward a maximum of evaporation and seepage, and absorption by vegetation. The value of this run-off factor is generally from 30 to 60 per cent., but it often runs below 30 and sometimes reaches a value of 80 per cent. in the case of short mountain streams.

In Ontario the rivers tributary to the Lower Lakes will probably deliver 25 to 50 per cent. of annual precipitation, while those tributary to Lake Huron and Lake Superior and throughout New Ontario generally will deliver 40 to 60 per cent., some of the shorter and more turbulent rivers probably running as high as 70 per cent. The higher values are assigned to the northern rivers chiefly because their watersheds are largely covered by evergreen forest, which protects the ground surface from the sun and wind.

It should be noted that this exceedingly approximate method of estimating run-off is permissable only when it is impossible to obtain more exact data or in cases where the minimum natural flow is known to be sufficient to abundantly cover all estimates of market requirement. This applies only to rivers like the St. Lawrence and the Niagara.

In most cases, however, although such an estimate may be made valuable by the exercise of experienced judgment, it is necessary to supplement it with data derived from direct and frequent measurements of discharge. Too much stress cannot be laid upon the importance of this phase of the investigation and any appropriation reserved for its furtherance in the consideration of a power scheme can be well and profitably applied. The more frequently these gaugings can be made the better, once a week at least, and for a period extending at least over one cycle of the water year.

Extract from Water Supply and Irrigation Paper No. 80, U. S. Geological Survey, by G. W. Rafter:

"The writer has found it very convenient to divide rainfall and run-off records into three periods, those of Storage, Growing and Replenishing, with a water year beginning December 1 and ending November 30. The storage period includes the months from December to May inclusive, during which the evaporation and absorption by plants is relatively slight, and a very large proportion of the rainfall appears in the streams.

"The growing period, June to August, inclusive, includes the period of active vegetation, when evaporation and absorption by plants is most notable. During this period frequently not more than 0.1 of the rainfall appears in the streams, and sometimes not more than 0.05 and even less. Ground water tends to become lower and lower during this period, unless the rainfall is much higher than the average.

"In the replenishing period, September to November inclusive, with the normal rainfall, ground water tends to recover, and the run-off is larger than in the preceding period. This period is replenishing in that there is a tendency to return to normal conditions."

Records thus obtained will furnish evidence in connection with two conditions of outstanding importance: namely, the minimum and the maximum flow. From the first, the minimum continuous power per foot of head can be deduced, while the second forms a basis for the design of permanent works and computations with reference to overflow and sluiceway discharge area. Also, these with the intermediate values of discharge, will make it possible to calculate the amount of the annual run-off without assuming a value for the run-off factor.

As to methods of discharge measurement, that of the current-meter only will be discussed, as, with proper management, this is the most accurate, satisfactory and generally applicable of all, and the following is based upon the assumption that a current-meter will be used.

The best time to locate a gauging station is during the period of low water, because a stretch of river that may have a very appreciable current at high stages may become a quiet pond during the low-water period. For this reason, it is well if possible to establish the gauging cross-section somewhere near the head of a flat rapid, above rough water, where there will be a measurable velocity at all stages of flow. Moreover, a cross-section like this usually has the advantage of being more or less permanent, as it will have a rocky or gravelly bottom which will not be materially affected by floods.

Having decided on the gauging section, the establishment of a gauge for recording water-levels is the next step. This gauge should be set with reference to a bench-mark well out of reach of flood-water, so that if the gauge is destroyed by flood or other means, it can be replaced without affecting the relation of subsequent readings to those taken from the old gauge.

Soundings may be most conveniently taken, on a river of moderate size, by means of a tagged rope or cable which may be permanently stretched across the stream, or else placed at the time of gauging, this point depending upon local conditions. The zero point of this rope or cable should always be set to a fixed point upon the shore above high water mark. In this way the individual soundings of every series will be taken over fixed points in the bed of the stream, these fixed points having their elevations established with reference to bench-mark mentioned above. From the data thus obtained it will be possible to plot a profile of the bed of the stream and as much of each bank as is necessary to bring the end elevations of the profile beyond the reach of flood-water.

This profile can be laid out to scale upon section paper and will prove valuable for computing discharge areas during periods of flood. Under ordinary conditions of discharge, soundings and velocity measurements can be obtained directly in the usual manner. In time of flood this is often impossible, but the water-level can easily be obtained with reference to the bench-mark and laid off upon the profile above described. From this the discharge area can be very closely estimated, assuming of course that the flood has caused no change of any account in the bed of the stream. At times when it is impossible to use the current-meter, surface velocities may be estimated by timing the passage of cakes of ice or floating debris over various portions of the discharge area. By using these in conjunction with the discharge area derived from the plotted cross-section, and applying the necessary velocity constants, a reasonable estimate of the flood discharge can be obtained.

The level-gauge should always be read upon the occasion of each gauging, and daily readings should be taken if possible. By plotting the gauge heights as abscissae and the corresponding discharges as ordinates, a discharge or "rating curve" is obtained, which is very useful in estimating discharge during extreme high water and for interpolating discharges to correspond to certain gauge-heights where opportunity for direct measurement has been lacking.

In connection with estimating annual run-off from discharge measurements, it should be noted that a value obtained in this way can only be termed an average one at best, and can be assumed as a minimum only if the annual precipitation for that particular year appears to be a minimum. An idea can be formed as to this by consulting the government records, if any exist, for the district in which the operations were carried on.

A reasonable indication of the run-off characteristics having been thus obtained, the question of artificial storage may be taken up as above described, provided the market demand makes such a course necessary.

Where more than one development location is available for any specific scheme, the question of choice of site opens up a wide field for discussion. From a hydraulic standpoint, the comparison would be based mainly upon available discharge and natural head, but if the scheme involves the generation and transmission of electric power, the location of the point of local distribution with reference to the sites of development introduces a new and important factor into the discussion, and it becomes largely a question of off-setting natural advantages against transmission distance.

Assume two sites upon the same stream having, as is often the case, approximately the same amount of water available, one site being adjacent to the point of electrical distribution and the other some distance away but having a considerably greater natural head.

As a general rule, the capital cost and annual charges for development will vary inversely with the head for the generation of a given amount of power; that is, the cost of a low head plant will be greater than that of a plant of the same capacity operating under a higher head, owing to the greater amount of water to be handled and the greater expense of low speed machinery. In the case under consideration, however, it is evident that the saving due to the development of the higher head must be offset against the capital investment and annual charges for transmission and transformation.

Here again the question of market requirement presents itself. Assume that the low head installation has sufficient capacity to meet the immediate demands of the market, and that, all things being considered, the comparative estimates place the balance to the credit of this plant as regards capital cost and fixed charges. Again, suppose twice this head is available at the other location. It is then evident that in the event of development, this plant, after meeting the market requirements, would have a reserve capacity equal to its already developed output, and the possible revenue to be derived from future market extension will be a measure of the value of this reserve power.

In the final analysis, therefore, the problem would resolve itself to this: Will the prospects of future market extension be such as to justify the additional capital expenditure and fixed charges, and the additional risk of service interruption, due to transmission and transformation?

It is to be understood that this is only one of an infinite number of cases that may be presented for solution, but the above will have served its purpose if it indicates in a general way the manner in which a hydraulic problem may be approached, and also the way in which the location, design and lay-out of a power plant may be influenced by the character and extent of the market.

In conclusion it may be said that on the part of the engineer, conservative judgment tempered with experience is very necessary, as the science of hydraulics, in so far at least as it deals with the phenomena of flow in natural channels, is based upon very approximate assumptions and is governed by obscure natural laws. For this reason an engineer may manipulate coefficients and constants in such a way as to involve very elaborate and impressive calculation, while an error in some fundamental assumption may discount his results to the point of absurdity. In the finer points of design, accuracy is of course essential, but in the preliminary studies it is a hundred times more important to be safe.

# COPPER ANODES IN CHLORIDE SOLUTIONS

SAUL DUSHMAN

In the following paper I intend to give a summary of an investigation undertaken with the object of explaining the anomalous behavior of copper as anode in chloride solutions. Preliminary experiments showed that copper dissolved with a valency ranging from 1 to 2, according to the experimental conditions. It was observed that in concentrated hydrochloric acid solution, it dissolved as a univalent metal, while in more dilute solution the valency was greater, and finally attained a value of 2 for very dilute solutions. The particular concentration of hydrochloric acid at which the copper ceased to dissolve as purely univalent (i.e., cuprous) varied with the rate of stirring, rate of circulation, current density, and other factors. Increased stirring or circulation caused the metal to dissolve much more as cuprous, while increasing the current density, under otherwise constant conditions, increased the proportion of cupric.

Although several hypotheses could have been made to explain these experiments, the one chosen seems to be in best accord with the quantitative experiments described below. *It is assumed that the copper anode dissolves by the action of the current in such a manner that, at the boundary between solution and electrode, the chemical equilibrium between the cupric and cuprous salts in hydrochloric acid solution is maintained.*

The investigation therefore naturally divided itself into two parts: (a) Investigation of the chemical equilibrium. (b) determination of concentrations at the electrode in the electrolytic experiments. The chemical equilibrium between cuprous and cupric salts has been investigated by E. Abel,* R. Luther,** and Bodlander and Storbeck.*** A large number of experiments performed by myself, in which the methods of analysis and manipulation were different from any of the above, proved in conformity with those of the last named authors. The equilibrium between copper, cupric and cuprous salts in presence of hydrochloric acid is represented by two equations:

$$Cu + CuCl_2 \rightleftarrows 2\ CuCl \quad \ldots\ldots\ldots\ldots\ (1)$$
$$CuCl + HCl \rightleftarrows HCuCl_2 \quad \ldots\ldots\ldots\ldots\ (2)$$

Cupric chloride dissolves metallic copper, according to (1), with the formation of a cuprous chloride. As well known, the latter is insoluble in water, but is soluble in hydrochloric acid solution, this fact being explained by the formation of the "complex salt" $HCuCl_2$, according to (2). Each of the above reactions is a reversible one; it ceases when there is attained in the solution a definite ratio between the products of the concen-

*E. Abel, Zeit. f. Anorg. Chem., 26, 361.
**R. Luther, Zeit. f. Physik. Chem. 36, 385.
***G. Bodlander and O. Storbeck, Zeit. f. Anorg. Chem., 31, 1, 458.

trations of the reacting substances on both sides of the equation. This last state is defined as an equilibrium. Assuming dissociation of the various salts taking part in the above reactions, the equations may be written thus:

$$\overset{o}{\mathrm{Cu}} + \overset{++}{\mathrm{Cu}} \rightleftarrows 2\,\overset{+}{\mathrm{Cu}} \quad \ldots\ldots\ldots\ldots \quad (1a)$$

$$\overset{+}{\mathrm{Cu}} + 2\,\overline{\mathrm{Cl}} \rightleftarrows \overline{\mathrm{CuCl_2}} \quad \ldots\ldots\ldots\ldots \quad (2a)$$

According to the "Mass Law," when equilibrium is attained between copper, cupric and cuprous salts in hydrochloric acid solution, we must have the following relations:

$$\frac{(\overset{++}{\mathrm{Cu}})}{(\overset{+}{\mathrm{Cu}})^2} = k_1 \ldots\ldots\ldots\ldots (1b)$$

$$\frac{(\mathrm{Cu}\overline{\mathrm{Cl}_2})}{(\overset{+}{\mathrm{Cu}})\,(\overline{\mathrm{Cl}})^2} = k_2 \ldots\ldots (2b)$$

where the symbols in brackets denote the concentrations of the particular ions. Bodlander and Storbeck determined the values of the constants $k_1$ and $k_2$ to be $1.4 \times 10^4$ and $4 \times 10^4$ respectively, concentrations being taken in mols (formula-weights) per litre.

The second part of the investigation had for its object the determination of the concentration at the anode during the electrolytic experiments, so that the values of $k_1$ and $k_2$ might be calculated from these and compared with those obtained from the equilibrium experiment. Fig. 1 is a diagram of the electrolytic cell used. It consisted of two porous cylinders, $P_1$ and $P_2$, between the ebonite discs, *E E*, two concentric glass cylinders, *L* and *M*, also held between ebonite discs, and a rotating copper anode, *A*, making contact with a shaft and holder, *H*. To prevent liquid from entering within the anode tube, two ebonite plugs (the lower of these having a glass tip, *T*) were provided with threaded holes, so that they could be tightened against the copper, as shown in the diagram. The tube could therefore be taken off the plugs and weighed. Its area was about 40 square centimetres. A rubber tube, with stopper, *S*, fitted over the upper plug. The electrolyte entering *B* passed between the two porous cylinders, through holes in the center disc, *E*, and the glass cylinder, *M*, and up and around the anode, leaving by means of the exit tube, *D*. The cathode consisted of a platinum gauze, *C*, attached around the discs *E*. The different parts were cemented together. Cork wedges between the discs and the glass container, *F*, prevented any lateral motion of the discs when the anode was set rotating.

Since hydrochloric acid containing air in solution dissolves copper even without current, the solution to be electrolyzed was always freed from air by exhaustion, and then saturated with carbon dioxide. Blank experiments showed that in such a solution the copper dissolved only very slightly. A large bottle filled with stock solution was permanently connected with a carbon dioxide generator, and as the solution ran out into the cell, the gas took its place. After circulating through a cell once, the electrolyte passed into a measuring cylinder, and was then discarded. A copper coulometer and ammeter were placed in series with the cell. During the experiment, the rates of circulation and stirring were kept nearly constant, the average speed of rotation being about 1,500 per minute in all the experiments.

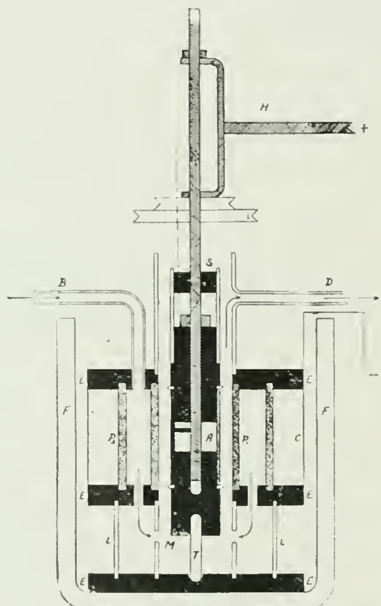


Fig. 1

The anode tube was weighed before and after electrolysis and the loss compared with the gain at the cathode of the coulometer. By means of the measuring cylinder the total volume of solution, V ccm, passed through the cell during the electrolysis, was also determined.

It has been mentioned above that copper dissolved in these solutions with a valency ranging from 1 to 2; that is the ratio of anode loss to coulometer gain varied from 2 to 1. Denoting this ratio by $1 + a$, it is evident that for every 96540 coulombs, $(1-a)/2$ formula-weights cupric salt ($CuCl_2$) and $a$ formula-weights cuprous salt ($CuCl$) would enter the solution. Hence the average concentrations in the solution, during the electrolysis, would be $(1-a)/2V$ and $a/V$, in formula-weights (or *mols*) per ccm. That, however, these would not be the same as the concentrations just at the electrode surface, is evident from the following:

In Fig. 2, let $OA$ represent a section of the electrode, whose area is $S$. Let $OX$ represent the distance from the electrode. It has been shown by Nernst and Brunner that in a rapidly stirred solution the diffusion is limited to a very thin layer close to the electrode, the thickness $L$ decreasing with increasing rate of rotation. Outside this layer, the solution is of uniform composition. The concentration of $\overset{++}{Cu}$, for example, at the electrode and in the solution are represented by $O\ C$ and $B\ c$, respectively. Owing to the circulation of the electrolyte, the concentration in the solution rapidly attains the constant value $B\ c$, and the distribution of concentrations in the layer is given by the line $C\ c$. Now since all the concentrations remain constant during the electrolysis, it is evident that the following relation exists between $O\ C$ and $B\ c$:

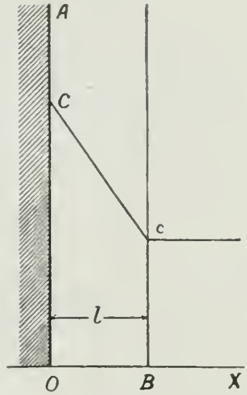

Fig. 2

*The amount of cupric ion entering the layer in any time is equal to the amount diffusing out into the solution, together with the amount transported in the same time, or*

$$\frac{(1-a)\,i\,t}{2 \times 96540} = \frac{D_1\,S\,t\,(C-c)}{L} + \frac{(1-a)\,n\,i\,t}{2 \times 96540}$$

where $i$ = current in amperes,
$t$ = time in seconds,
$D_1$ = diffusion constant in cms/sec.,
$n$ = transport number of ion in the solution.

Since $c = (1-a)it/(2 \times 96540\ V)$ where $V$ = volume in cc., as shown above.

$$C = \frac{(1-a)\,i\,t}{2 \times 96540}\left(\frac{1}{V} + \frac{L\,(1-n)}{D_1\,S\,t}\right)$$

It will also be observed that the concentration of Cu in the solution was assumed to be the same as that of $CuCl_2$. The cuprous salt was, however, present in the solution as Cu and $\overline{CuCl_2}$, the ratio between these being determined by the value of the concentration of $\overline{Cl}$, according to equation (2b) above. Denoting by $b$, the fraction of cuprous salt present at $CuCl_2$, and remembering that the average concentration of cuprous salt in the solution would be $ait/96540\ V$, it is evident that

$$C^1 = \frac{abit}{96540}\left(\frac{1}{V} + \frac{L\ (1-m)}{D_2\ S\ t}\right) \ldots\ldots\ \ldots\ldots (4)$$

where $C^1$ = concentration of $\overline{\mathrm{CuCl_2}}$ at anode surface

$D_2$ = diffusion constant of $\overline{\mathrm{CuCl_2}}$ in cms/sec.

$m$ = transport number of ion in the solution,

while the other letters denote the same quantities as in (3).

Since the equilibrium (2a) must hold at the anode surface as at every other point in the solution, it follows from (2b) that

$$\left(\overset{+}{\mathrm{Cu}}\right) \text{ at the anode, } = \frac{C^1}{k_2(\mathrm{Cl})^2} \ldots\ldots\ldots\ldots (5)$$

Having obtained in this manner the concentration of $\overset{+}{\mathrm{Cu}}$ at the anode, it remained to calculate the value of $k_1$ according to (1b), by making use of equations (3) and (5).

The values of $D_1$, $D_2$ were calculated from the mobilities according to the formulae of Nernst, Abegg and Bose: while the value of $L$ was determined experimentally by a separate set of measurements. The thickness of the layer in which diffusion took place was found to be about $25 \times 10^{-4}$ cms, with the rate of rotation used in this investigation. The fall in concentration in this layer was found to be very great. Thus, in one experiment with N/200 HCl, the concentration of $\overset{++}{\mathrm{Cu}}$ at the anode was $0.8 \times 10^{-3}$ while in the solution it was $0.5 \times 10^{-3}$.

The concentrations of HCl and $\mathrm{CuCl_2}$, rate of circulation and current, were varied in different experiments, and after calculating the concentrations of $\overset{++}{\mathrm{Cu}}$ and $\overset{+}{\mathrm{Cu}}$ at the anode surface, the values of $k_1$ were determined according to (1b).

With constant rate of circulation, the value of $k_1$ was found to be constant, and independent of concentrations of HCl and $\mathrm{CuCl_2}$, as well as of the current. But with increased rate of circulation the value of $k_1$ increased also, varying from about $0.5 \times 10^4$ for low rates to $2 \times 10^4$ for extremely rapid circulation. It was only after a great many experiments had been performed, and apparently useless results had been reconsidered from this basis of rate of circulation during the electrolysis, that this conclusion became evident.

But why should $k_1$ vary with rate of circulation? Our initial assumption does not allow for any such variation; $k_1$ should be a constant under all conditions. The only practical explanation seems to be increased oxidation of cuprous salt in the solution as the rate of circulation decreased. For suppose that in those experiments where the circulation was very slow, the cuprous salt in the solution became oxidized; then the calculated value of $(\overset{+}{\mathrm{Cu}})$ would be too high, while that of $(\overset{++}{\mathrm{Cu}})$ would be too low, and hence $k_1$ also too low. On the other hand, with very rapid rate of circulation, there would not be any time for the $\overset{+}{Cu}$ to be oxidized while in the cell, and hence the calculated would approach more and more nearly the actual values as the rate of circulation increased; that is, $k_1$ would become more and more nearly equal to the correct value.

It will probably be possible to test this assumption by electromotive force determinations of the ratio of the concentrations of $(\overset{++}{Cu})$ and $(\overset{+}{Cu})$ in the circulated electrolyte. All I can state is that qualitatively the experiments fit in with the above oxidation theory; whether there is also quantitative agreement remains to be determined by the further work in which I am at present engaged.

## THE DESIGN OF CANAL DIVERSION WEIRS ON A SAND FOUNDATION.

W. G. BLIGH, M. Inst C.E.*

Sand is proverbially an unsuitable material on which to found a solid structure of any kind, but, when this structure in addition acts as a dam in holding up water, nine persons out of ten would consider that its stability under such circumstances was absolutely impossible.

Such, however, is by no means the case, and the object of this paper is to show the means adopted to insure the safety of structures such as river weirs, which are not only exposed to undermining by their foundation being washed out by subsoil percolation, but are also subject to the erosive action of the powerful current of a river in flood, which completely submerges the whole work. Not having its base resting on solid impervious material as clay or rock, the masonry of which the weir is composed is further subjected to the disability of loss of weight by displacement, which often amounts to one half of its weight in air.

When a dam of earth, as a reservoir embankment, is thrown across the sandy bed of a stream, leakage will necessarily take place beneath the base of the dam. With a low level of water in the reservoir this leakage may be quite harmless, that is to say, the percolating water will not carry with it any particles of sand; when, however, the depth of the water in the reservoir, that is, the head acting on the base, is increased, the percolating undercurrent will likewise increase in volume and velocity and will eventually convey particles of sand along with it and so gradually undermine the dam.

The weight of the dam is naturally the same whatever be the depth of water impounded, and further, sand is practically incompressible, consequently the imposed load must be ruled out

Extracts from an address delivered before the Engineering Society Oct 14th, 19[illegible] as a determining factor in this case. The real factor influencing the safety of the work is the length of the enforced percolation. or as it is technically termed the creep of the undercurrent, which is clearly identical with the base width of the earthen dam. This length of percolation must naturally be some multiple of the head of water acting on the work, and if we can only find out a safe value for this multiplying co-efficient, suitable to the particular sand under consideration, we shall be enabled to design any structure on a sand foundation with perfect confidence as regards its safety with reference to statical considerations.

An example of the successful construction of a dam on a sand foundation is that of the Amani Shah storage reservoir at Jeypore in India. This dam upholds a depth of over 30 ft. of water. It is built of sand and is founded on pure sand, but its base width is exceptionally great, being over 350 ft., i.e., 12 times the head. The silting up of the river bed, which occurred before the full flood level was reached, increased the effective value of the length of creep by over 100 feet, and thus enabled the work to stand an increased head of 44 feet in perfect safely. This dam is not water tight, and does not pretend to be so, but the visible leakage is unimportant.

The natural question will arise, if this is the case, why are the foundations of bridges over rivers, reservoirs, dams, etc., always carried down to solid rock or clay? The answer is that in these cases it is cheaper to do so. As we shall see later, the correct value of the requisite base width will be from 10 to 20 times the head, consequently in case of a dam 60 ft. high founded on sand, a base width of say $15 \times 60 = 900$ feet would be necessary for safety. Thus it would, as a rule, be more economical to adopt a deep foundation. As regards a river bridge, isolated piers of great depth are generally the only practicable and economical method of construction.

In large rivers the bed of sand is often of great depth, the piers of the Benares Railway Bridge over the Ganges River had to be sunk over a hundred and fifty feet through the sand before clay was met with; consequently, for a continuous work, like a river weir, a deep foundation is an economic impossibility.

The definition of the term weir, in contradistinction to that of dam, implies that the river water falls over its crest, whereas in the case of a dam the surplus flood water is conveyed either through the body of the work, as in the case of the Assuan Dam in Egypt, or else its escape is provided for by a specially built waste weir distinct from the dam itself. Weirs built across rivers, with sand beds of great depth, are invariably what are termed "diversion" weirs, that is to say, their function does not include that of the storage of water, but is limited to the diversion of a portion of the discharge of the river down a canal through an intake; a good example of this is the Calgary canal head in Alberta.

The function of a weir is to raise the water of the river when the latter is at a low level, in order to pass a sufficient supply down the canal. During flood time, or whenever the supply exceeds the demand, the crest is topped and the surplus water follows its course down the river. Owing to the sandy nature of the bed, which in part is carried along in suspension during floods, deposit takes place in rear of the weir almost to crest level, and in some cases even higher, so that during low water there is but a narrow channel from which supply can be drawn. This channel is artificially conserved by the adoption of weir scouring sluices in close proximity to the canal intake. As canals, when on sand, mostly take off at not more than 2 to 5 feet above river bed level, and their full supply depth seldom, if ever, exceeds 10 feet, it is clear that the height of these submerged diversion weirs will not be greater than 15 feet, the general average being 10 or 12 feet. On boulder or clay formations much greater heights are practicable.

A dam is subjected solely to hydrostatic pressure, but a weir on the other hand has also to withstand the dynamic scouring action of water. The design, however, is mainly influenced by hydrostatic considerations, for which alone precise rules can be framed, with, however, this proviso that the design of the work must also suit what may be termed the hydrodynamical side of the question.

The following facts may here be noted:—

The hydrostatic pressure on a weir is greatest when the head water stands exactly at crest level, the river bed being empty below; when this occurs the hydrodynamical forces are nil.

Again, when the latter forces are a maximum, *i.e.*, during full flood, the hydrostatical pressure on the weir foundation is at a minimum.

The hydrostatic problem, with water at rest, will first be considered as follows:—

Figure 1 represents a pipe line BC, proceeding from the bottom of a reservoir of water. The original head $H$ is the

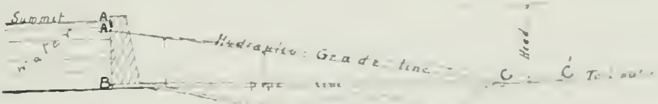


FIG 1

difference of levels between A, the summit level, and C, the tail water, it being presumed that the outlet at C is free and unrestricted. The line $A_1$ C drawn from a point near the summit level to C, is termed the hydraulic gradient, or grade line, and the hydrostatic pressures on the pipe at any point are measured by vertical ordinates drawn up to this line. The distance AA′ is the head due to the uniform velocity of the current in the pipe plus a further small quantity representing loss of head at entry.

Fig. 2 represents a simple section for a low masonry weir, built on river sand, supposed, as is usually the case, to be completely submerged during floods. Such a work must necessarily consist of a vertical wall of masonry, or any other material, whose function is to uphold the water, connected with which, is a horizontal apron of some description, for protection against erosion of the river bed by falling water. In this particular case an impervious masonry floor is provided. The base of this floor C D, rests on a stratum of pure sand. The vertical wall holds water up to the summit level H, the tail level, *i.e.*, the original low water level of the river, is supposed to be at B, *i.e.*, coincident with the floor surface. The head $H$ is the difference of level between the summit and tail levels, which is a maximum when the reservoir level is flush with the weir crest. The reason for this is that when the water overtops the crest

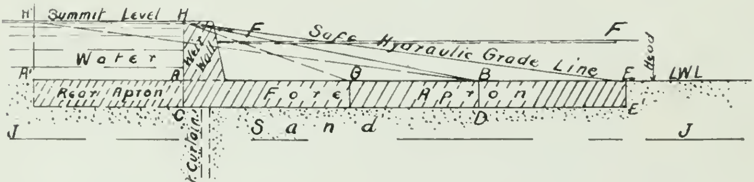


Fig. 2.

the velocity of the film passing over exceeds that of the tail water in the normal channel below, consequently the rise of the tail water will be more rapid than that of the head water—the ratio being from 2 or 3 to 1, varying mainly with the slope of the river bed. The action of the impounded water in its endeavor to reach its own level, a property inherent in liquids, is to force a passage through the sand stratum underneath the impervious floor, the particles of liquid taking a curved course, first downwards then horizontally, and once the obstructing plane is passed, upwards.

The proposition here presented is exactly similar to that in Fig. 1, the only difference being that instead of the water being confined in a pipe of a limited size, it is confined within the sand substratum, being prevented from rising above it. The theoretical velocity due to the head of water, is reduced in the pipe by friction against its sides to a smaller constant velocity right through; in exactly the same way, reduction, or neutralization of head is effected by friction in the passage of water between the particles of the sand. The greater the length of the confined passage, the less will be the velocity of the slowly percolating stream.

It is evident that under similar conditions of head and base length, the velocity of the current in different weir beds must vary with the nature of the sand stratum in accordance with its qualities of fineness or coarseness. Fine sand will be closer in texture, passing less water at a given head than a coarser variety, at the same time fine sand will be disintegrated and washed out under a less pressure. The problem now to be solved is evidently what proportion the base CD, or $l$, should hold to the head $H$ in order to insure safety from washing out or from what is technically termed "piping." This value can only be obtained experimentally, that is, by deduction from sections of existing successful river weirs. Fortunately there are also some most instructive examples of failures due to insufficient length of base, so that the safe value of the relation of $l$ to $H$ can be deduced with absolute certainty.

In Fig. 2, supposing the length of the base CD or $l$, of the floor (which clearly must be some multiple of $H$) provides a length of creep or percolation sufficient to reduce the head, or, strictly speaking, the velocity of the current, to such proportions, as will just prevent piping. Then the hypothenuse HB will represent the hydraulic gradient. This slope starts from the summit level itself, for this reason, that the velocity head is insignificant and the loss at entry is nil. This gradient is found to be about 1 in 10 for fine sands and 1 in 8 for coarse sands, and might be termed the equilibrium gradient. Now the water having free egress at the point D, the conditions are identical with those in Fig. 1, and the upward head of water, acting on the base of the floor CD will be correctly represented by the vertical ordinates of the figure HCDB, and the total pressure by the area HCDB.

In this discussion the symbol $W$, commonly employed to represent the unit weight of water, *i.e.* the weight of one cubic foot, approximately 62.5 pounds, is invariably omitted. Where weight comes under consideration it is represented by Volume Specific Gravity, or by $V\rho$, the Greek letter $\rho$ being used to indicate Specific Gravity, being preferred to the letter $G$ sometimes employed for the same purpose, since the latter may possibly be confounded with the recognized symbol denoting Gravity. In the same way, the pressure of water is represented by $H$, the head, it being actually of course $HW$.

With regard to the value to be assigned to $l$, in actual construction a considerable factor of safety is necessary, so that the safe value of $l$ must be half as much again as its bare value. If the floor be thus increased in length to the point E, so that CE=$1\frac{1}{2}$ CD, the safe hydraulic gradient will be HE, and the value of $c$ in the expression $l=cH$ will become 15. This lengthening of the floor will, however, have the effect of increasing the upward pressure on it in proportion as the ordinates of HCE′E are greater than the ordinates of HCDB, consequently there is a positive disadvantage in lengthening the impervious floor beyond what is necessary to insure an absolutely safe base length, *i.e.*, one sufficient to prevent disintegration of the sand substratum by piping.

Supposing the length of floor reduced below the minimum CD, to CG, the hydraulic gradient then will be HG. The ordinates of the pressure figure are less than in either of the preceding cases, but failure will take place by piping, the floor becoming gradually undermined, by the sand being slowly washed out, the reduction of the velocity effected by friction in this shorter length being insufficient to overcome the disintegrating horizontal influences of the current of water. Two such cases have actually occurred in the case of the Chenab and the Jhelum weirs.

It is self-evident that the effective weight of the floor must equal or exceed that of the upward hydrostatic pressure unless its construction is such as to render it capable of resistance to bending stress. In the case of Narora weir a floor of insufficient weight has been known to stand for several years, but eventually, owing to a comparatively small increase in the upward pressure, it blew up. Weight in the floor and superstructure generally, well in excess of the hydrostatic pressure, is always a desideratum, and is only limited by considerations of economy.

We have already seen that the proportion of $l: H$ or the value of $c$, the expression $l=cH$ varies in different rivers. River sands will be classified according to the following known qualities.

Class 1a—The Nile River sands. Coefficient adopted 18.

Class 1—Fine light micaceous sands such as are found in rivers taking their source in the Himalayas, including the Ganges, Jumna, Indus, and the four main Punjab rivers; to this class belong also the sands of the Colorado River. Coefficient adopted 15.

Class 2—The coarse-grained sands of the rivers of Central India, Madras and Bengal; most river sands belong to this class. Coefficient adopted 12.

Class 3—Boulder and sand formation. Coefficient adopted 6 to 9.

The coefficients are all obtained from actual examples.

With regard to hydrostatic pressure on the base the following points require notice.

In Fig. 2, if a hole were bored in the floor CE′ and a pipe inserted, the water would rise up as far as the existing hydraulic gradient HE. The head acting on the base CE′ at that point would thus be represented by the ordinate of the figure HCE′E, and not of the triangle HAE. That is, to what may be termed the external head is added that due to displacement. To avoid confusion, the extraneous head of water symbolized by H, which always means the difference of levels above and below a weir or regulator, will be kept distinct from that due to displacement or immersion, this latter pressure being allowed for by reduction in the effective weight of the immersed body. As is well known a solid material immersed in water loses effective or sensible weight corresponding to the weight of water displaced. Thus a body whose specific gravity is $\rho$ has a weight in air of $V\rho \times 62.5$ pounds, if $V$ be its volume in cubic feet, but when immersed in water its effective weight is $V(\rho—1) \times 62.5$ pounds.

In the figure when the low water level is at E the floor ACEE′ is clearly just immersed, and the upward pressure due to displacement will be equivalent to the weight of water displaced. When the tail water is at some higher level, as at FF, the status as regards upward pressure due to displacement is in no way altered, the increase of upward pressure below the slab, due to the greater depth of immersion, being compensated for by a similar increase in the downward pressure upon the top of the slab.

When the tail water is at the level CDE′, the weight of the floor is clearly unimpaired by flotation, when intermediate, the effective weight of that portion of the floor lying below the level has alone to be considered as thus impaired.

When the floor is built well above LWL, as when the LWL is at JJ, the sand substratum being porous, the water level will rise up to the base of the impervious floor thus practically reducing the head from HJ to HC. The acting head therefore cannot be taken as extending below the actual impervious base of the weir, except as regards calculation for base length, or length of creep.

In Fig. 2 it is evident that the value of $l$ is in no way affected, whatever be the position of the vertical drop wall with regard to the horizontal floor. For instance suppose the floor extended backwards to A′ and AA′ made = BE, then the action of the head of water is thrown back from H to H′ the hydraulic gradient will be H′B parallel to HE, and the statical condition is in no way altered.

This rear projection is termed the rear apron. Its value in design has only recently been recognized. The upward pressure acting beneath the rear apron will be simply that due to displacement, and as the value of $\rho$ for the materials employed in the construction of the apron is greater than unity, this upward pressure due to flotation is more than counterbalanced by the downward pressure due to the weight of the floor. As the rear apron is in addition free from the erosive action of falling water, it can be constructed of less expensive material than the fore apron or floor. On the other hand it must be impervious and must have a water-tight connection with the weir wall, otherwise the head may act between it and the weir wall, thus practically isolating it from the rest of the work. This actually occurred in the case of Narora weir. Another weir, the Chenab, failed by sinkage of the floor, the sand base having been gradually washed out by the undercurrent.

Theoretically, the rear apron would be effective if only a thin impervious layer, but practically it is considered that unless constructed of a definite weight, water passing underneath it would partake of the nature of a surface current and so the apron would not be effective in the neutralization of head.

With weirs of ordinary height, with a sand coefficient of 12 to 15, and with a value of $H$ up to 15 feet the economical length of the rear apron will not exceed 3 to 5 $H$. The reason being that the rear apron performs but one function, namely, statical, whereas the fore apron in addition to this, acts as an anti-erosive shield; consequently material placed in front of the drop wall is of greater value than that in rear, and if the rear apron is designed too long there will necessarily be excess material in the whole section, which by a more economical distribution could be avoided. The reason for this is that dynamical considerations cannot be lost sight of and the requirements to meet this second governing condition demand a certain minimum length of fore apron symbolised by $L$ which is measured from the toe of the drop wall. This length consists in part of the masonry floor designed to meet the requisite length of creep, i.e., for statical requirements, and when this length falls short of the minimum the balance has to be made up by loose stone rip rap as a further protective covering to the sand. This latter portion is termed the talus.

The value of $L$ is influenced by the erosive power of the current, which again is dependent on the proportional obstruction afforded by the weir, i.e., the height of the masonry crest combined with the shape of its profile, and the velocity of approach at flood times. These several considerations will determine the designer as to what value will be suitable for adoption, having due regard to precedent.

For direct overfalls with floor at LWL the value of $L$ may be taken as from 15 to 20 H for class 1, and 12 to 16 H for weirs of class 2, H in this case not being necessarily the maximum statical head but the height of the permanent masonry weir crest above floor level.

The summit level in all modern weirs is raised by means of collapsible crest shutters, which fall automatically in flood times, to a height varying from 2 to 6 feet above the solid masonry weir crest. This device lessens the permanent obstruction to the normal river waterway.

We have hitherto been considering only a section which has no vertical depressions in the base line. The creep of water beneath an impervious apron is known to hug all vertical sinuosities. Thus if a row of sheet piling or some other impervious curtain were inserted below the base CE in Fig. 2, the line of creep would be forced down one side of the vertical obstruction and up the other. This added length of creep is thus twice the depth of the curtain. The insertion of sheet piling or other form

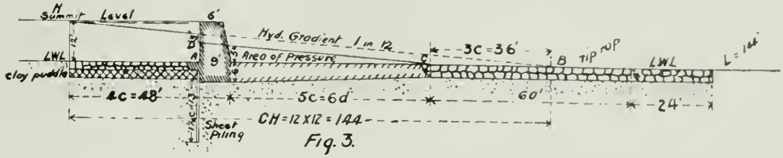


Fig. 3.

of curtain-walling is thus a most valuable means of increasing the length of creep and thus saving length in the expensive horizontal apron.

An example of the method of applying the principles already enunciated will now be given for the design of a weir under assumed conditions, viz. :—

$$H=12 \text{ feet.}$$

River, Class 2 with $c=12$. Whence $l = c \times H = 12 \times 12 = 144$ feet.

The first point to be decided is the length to be given to the rear apron, and the depth of the sheet piling, as it is proposed to adopt a curtain below the weir wall. The thickness of the fore apron at the toe of the drop wall, which is the crucial point in the whole design, is determined by the values thus adopted, for this reason, that the unbalanced hydrostatic upward pressure is here first felt and the neutralization of head up to this point should be sufficient to reduce the required depth of floor to reasonable and economical dimensions. The minimum average thickness of the fore apron is obtained by the empirical formula $T = \sqrt{\frac{3h}{2}} + 1\frac{1}{2}$ where $h$ = height of solid masonry weir in feet and $T$ = thickness of fore apron in feet. In this case $T = \sqrt{18} + 1\frac{1}{2} = 5\frac{1}{2}$ feet nearly.

In designing these weirs it is a great convenience to make all dimensions multiples of the coefficient $c$, as then each unit represents a neutralization of one foot of the original head. The length of the rear apron should be measured back from the toe of the drop wall. In the design this length is made $= 4c = 48$ feet. Deducting the base thickness of the weir wall, which is 9 feet, the actual length of the rear apron is about $3c$ feet. This, if anything, is somewhat short, a length of $3\frac{1}{2}c$ feet would give better results. The thickness of the rear apron, composed of puddle covered with stone rip rap, will be 5 feet, it cannot be less.

Now we come to the sheet piling, steel or concrete steel. This is made $1\frac{1}{2}c$ or 18 feet in depth, consequently the total neutralization of head effected up to the toe of the weir wall is $(4 + 3)$ ft. $= 7$ feet, leaving 5 feet hydrostatic pressure head acting here. The value of $\rho$ for the material in the masonry fore apron will be taken as 2 (a common low value). The apron is submerged, lying below L.W.L., its effective weight will therefore correspond to $(\rho-1)$. Now, as the effective weight of the floor should (it is deemed) exceed the upward pressure by at least one-fifth, as a precautionary measure, with a hydrostatic pressure due to 5 feet of head the necessary thickness of masonry with an effective weight corresponding to $(\rho-1)$ will be $5 + 1$ or 6 feet. The length of the fore apron will be the remaining balance of $cH$, or $(12-7)c = 5c$ or 60 ft., and the terminal thickness, theoretically nil, is made 4 ft. for other than statical reasons. This ends the design as regards statical requirements. For anti-erosive purposes the floor will have to be continued as a talus of loose stone pitching for another 84 feet, giving a length, measured from toe of drop wall, of $12H = 144$ feet. This, as we have seen, is obtained from an empirical rule, and can be varied as experience may dictate. The minimum length of fore apron is 4 to $5H$.

The graphical method of design is shown on the same figure and is very simple. From the extremity of the rear apron the total requisite base length, $= cH = 12 \times 12 = 144$ feet is set out to the point B. The line HB then is the hydraulic gradient of 1 in 12. From B set back BC = vertical portion of the base length $= 3c$ or 36 feet, and from the point C draw a line CD parallel to HB up to D, its intersection with a continuation of the vertical curtain.

The triangle DAC is the triangle of pressure.

The thickness of the drop wall at its base is found by the following formula: $\frac{H'}{\sqrt{\rho}}$ in which H′ is the height above floor of the head water at the time when the tail water is level with the crest, being generally 1½ times the height of the solid drop wall. But when the maximum statical head, *i.e.*, to shutter crest exceeds this, $H'$ will become $H$ and the formula $\frac{H}{\sqrt{\rho}}$

We will now give another example of design of a direct overfall weir with floor at LWL, viz., that of an alternative design for the Chenab weir. The actual given conditions are:—

$H = 13$ $c = 15$. Whence $l$ must $= 13 \times 15 = 195$ feet.

In this design the original arrangement is followed of having the permanent drop wall of low elevation, the requisite summit level being obtained by the use of steel collapsible crest shutters As in the existing work, the level of the crest of the drop wall is placed at seven feet above extreme low water, while the remaining 6 feet required to bring the summit level to RL 728 is provided by the shutters. (See Figure 4.)

The commencement of the rear apron is placed $4c = 60$ feet behind the toe of the weir wall, below which sheet piling $1c$ or 15 feet in depth is provided. These neutralize 6 feet of head leaving a balance of 13—6 = 7 feet, hence a farther base length of 7 × 15 = 105 has to be provided in the fore apron. This is too long for actual requirements, which are 5 $H$ = 65 feet, consequently another row of sheet piling is introduced at the end of the floor with a depth of ½$c$ = 7½ feet. This admits of the curtailment of the floor by $c$ or by 15 feet, reducing it to 6$c$ or 90 feet. There are thus two vertical depressions in the base line.

The graphical diagram is shown in figure 4A. First, the total required base length or 15$H$ = 15 × 13 = 195 feet is measured off from the commencement of the rear apron, and the hypothenuse is drawn in from the point thus obtained. Secondly, the respective values of the two vertical depressions are set back, viz., 2$c$ = 30 feet, and $c$ = 15 feet. A line parallel to the hydraulic gradient is then drawn from the first-mentioned point up to its intersection with a vertical through the first row of piling. A second parallel cannot be drawn from the second

C=15 H=13'

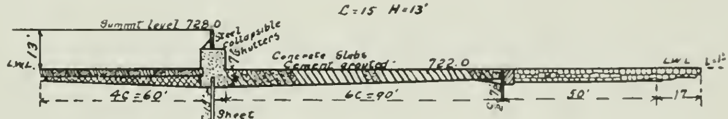


Fig. 4.

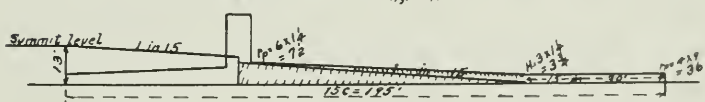


Fig. 4A

point as the intersection with the vertical is at the same spot, consequently the second step occurs at this very point. The outline of the pressure area below the weir wall is not a triangle, as heretofore, but a trapezium. The value of $\rho$ is here 2¼; the thickness of floor necessary to counterbalance by its weight the hydrostatic pressure will thus be about 6 feet. (See figure.) This thickness is hardly sufficient and should be increased to 7 feet at least.

The rear apron is composed of puddle overlaid with concrete slabs, the weir wall is of concrete, the fore apron is of concrete slabs laid on a slope, breaking joint, subsequently cement grouted. This is a novel but economical method of subaqueous construction, and was first adopted at the Colombo breakwater.

This design would, (it is now considered), be improved by increasing the length of the rear apron from 4$c$ to 5$c$, and correspondingly reducing the fore apron to 5$c$ or 75 feet, the thickness could then remain as it is in the drawing. This example is useful as showing the ease with which the design can be altered by manipulation of the length of the rear apron and depth of rear curtain, till the most economical arrangement is arrived at.

# THE NEW THERMODYNAMIC AND HYDRAULIC LABORATORIES OF THE UNIVERSITY OF TORONTO

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During the past years the growth of the Faculty of Applied Science and Engineering has been very rapid indeed, and as is common in such cases, the increase in accommodation has not kept pace with the increase in the attendance. On this account the buildings have been overcrowded in every way and the consequent pressure has become very great.

This pressure has been felt very greatly in the Thermodynamic and Hydraulic laboratories, where, partly on account of the somewhat rapid development of steam and gas plants and the desire on the part of Canadians to develop their water-powers, and partly because of the growth of the Faculty, the attendance has increased rapidly from year to year. To meet the increased demands new apparatus has from time to time been installed until the available space has been used up, and the crowding has caused complications to arise between the two laboratories, making the work difficult. It has also been impossible to give any work in these laboratories to the Third Year students, so that they have been unable to follow up the lecture work with experiments which would illustrate the points brought out. To overcome these defects the new laboratories are being built.

The new building, known on the architect's plans as the Thermodynamics Building, contains a Thermodynamic laboratory, an Hydraulic laboratory, a boiler room, some private rooms for the staff and study and work rooms for the students.

The building faces the west and the front part of it, only a portion of which is now being erected, will contain in the basement students' rooms and a machine-shop, and on the upper floors the offices and study rooms connected with the work. This section of the building is the only part not now being completed.

On the south side of the building is the Thermodynamic laboratory, one storey high, covering a space 155 feet by 60 feet, the light all being obtained from the roof. This laboratory, which is high and airy, is divided into two parts, one of which is 40 feet wide and runs the full length of the building. In this part all the steam and gas engines will be installed as well as some other machines, and the whole area will be served by a travelling crane 40 feet long running from end to end of the building. This section is to contain a triple-expansion engine, simple and compound engines of various types, an air compressor, steam turbines, apparatus for testing injectors, indicators, etc., gas and oil engines of various types and other apparatus of similar nature. Most of this apparatus will be put in as soon as the building is completed. The other part of the laboratory, which is 20 feet by 155 feet, is partly taken up by the goods entrance but mainly by small laboratory rooms about 15 feet by 20 feet each. It is intended to equip these rooms with such apparatus as a refrigerating machine, air brake apparatus, a suction gas plant, valve setting engines, apparatus for testing the value of lubricants, etc., and they are so arranged that they will accommodate a small number of students who will be able to carry out experiments and be comparatively free from the noise and steam of the main part of the laboratory. These rooms have brick walls on three sides and open off the main steam laboratory by means of doors in a glass partition.

To the east of the Thermodynamic laboratory and at the back of the building is the boiler room, 45 feet by 70 feet, which is also lighted from the roof. This room will contain four boilers, three of which are now being installed and which are capable of running at a pressure of 200 pounds per square inch. One of the boilers is also arranged with a superheater. These boilers will be so piped up to the engines that complete engine and boiler tests may be made. The room also contains two chimneys specially arranged for the study of problems connected with chimney draft and capacity, and the necessary pumps and other apparatus. The boilers in this room are exclusively arranged for experimental work and are not used for regular service work.

The Hydraulic laboratory occupies the northern side of the building and this part contains three floors, the lower two of which are for the hydraulic laboratory and the upper one for study rooms. Each of the floors of the hydraulic laboratory is 40 feet by 112 feet, the distance between floors being 18 feet and 15 feet respectively, so that the rooms will be well ventilated and give good head room. This laboratory is lighted from the north and east sides by large windows running through the two storeys which occupy about three-fourths of the entire wall space.

The main or upper floor of the Hydraulic laboratory will contain a large weir tank capable of measuring six cubic feet per second, reaction turbines, impulse turbines and necessary tanks, orifice and weir tanks, various water meters, centrifugal pumps, apparatus for measuring the friction of water in pipes and hose, apparatus for the use of Pitot tubes, etc. A large pressure tank running through the two floors and up into the roof discharges into the large weir tank.

The lower floor is largely occupied by the measuring tanks and the pumps and engine for driving the latter. The pumps are high-lift turbine pumps specially arranged to give great flexibility for the purpose of laboratory work. In addition to the above there will be an open trough 5 feet wide, 4 feet deep and running the full length of the building, with a weir at the end, in which experiments on current meters and other apparatus may be made.

In designing the laboratories, care has been taken to provide for proper light and air, to arrange for the convenient handling of all apparatus, and to accommodate comparatively large classes of students. With this in view the arrangement will permit of the use of almost every piece of apparatus in the building at the same time and without interference of the experiments one with another. An endeavor has also been made so to arrange the apparatus that pieces especially adapted for research work may be continuously available in order that the work may be well carried out.

At a later date a more complete description with plans and drawings will be given.

# APPLIED SCIENCE

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**Transactions of the University of Toronto Engineering Society**

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## Editorial

**Dean Galbraith**

"Occasionally a man comes into the fruition of his life work while there is yet time to make it complete in the stimulating joy of appreciative recognition." This applies with special force in the case of Dean Galbraith. Largely through his initiative and untiring energy, the present Faculty of Applied Science of the University has developed from a very humble beginning to almost a commanding position among the Faculties. It will ever remain a fitting monument to his honor and to his memory.

To few men has the privilege and power been given to so indelibly stamp his impress upon those with whom he came in contact. The only regret is that the increasing growth of the School renders it impossible for undergraduates to come in personal touch with the Dean, as was the case in less prosperous days.

It was with considerable pleasure that the graduate and undergraduate bodies united to present his portrait to the University to show their appreciation of him. It is the earnest wish of all that he may be long spared to continue the work he has so ably planned and carried on to its present successful issue.

**Prof. G. R. Mickle**

Prof. George R. Mickle, who has been with the School of Practical Science for fourteen years, first as Lecturer and later as Professor of Mining, resigned last summer to give his whole time to his work with the Government. Ever since the early days of Cobalt, Prof. Mickle has been a prominent figure in that district as an official of the Ontario Bureau of Mines, as the first Inspector of Claims, later as the Head Inspector of Claims and for the past year as Mine Assessor. He is a Canadian, born at Guelph, educated at Upper Canada College and the University of Toronto, where he took honours in Classics. On receiving his B.A. he took the general engineering course at the S. P. S., graduating in 1888, and then spent two years in post-graduate work at Freiberg. Returning to Canada, he practised his profession as a Mining Engineer for several years at Sudbury. He was appointed Lecturer in Mining at the S. P. S. in 1894, and Professor of Mining in the University of Toronto in 1905. His summers were spent in the field in mining and exploration work in British Columbia, on Hudson's Bay and in other parts of Canada and the States until 1904, since when he has been with the Bureau of Mines. As Inspector of Claims he had to bear the burden of the difficulties encountered in the enforcement of the inspection clause which was so rigidly carried out in the Cobalt area and which played so important a part in the locations of that district. As the area increased and a large number of inspectors were employed, Prof. Mickle was placed in general charge of their work. Eighteen months ago he was appointed Mine Assessor and after carrying on this work jointly with his University work for one year, this work claimed all his time and he resigned his position as Professor. He is the second professor to join the Bureau of Mines. Dr. Miller, the Provincial Geologist, was also won from the academic life, he having been Professor of Mining at Queen's for some ten years. Conditions have not permitted such an extensive growth in the Mining department of the University as for example in the Mechanical and Electrical departments, but Prof. Mickle has built a splendid foundation for metallurgy and for mining. The laboratories in these departments, though not so heavily equipped as others of older growth, will hold their own with any in the Dominion in the possibilities of their teaching functions. The foundation is laid down on safe and broad lines and competent judges have expressed their satisfaction at the unselfish, broad-minded way in which these were laid, the funds available being spent entirely on fundamental essentials that often lent no outward lustre to his department but which meant much for the future. His career in the S. P. S. was marked by sterling loyalty and this same spirit has characterized his work in the field. The Government Department of Mines has given him the most difficult positions in their work; positions that require the most careful judgment, where decisions must be rendered that must be unassailable not only in their knowledge of mining but in their absolute fairness and impartiality. Had Prof. Mickle not left the academic life the Government would have been hard put to it to have found a man to fill his place in the field, and if the School has lost a valued colleague and friend, the Government and the field have gained a man whom most men like and whom everybody respects and admires. He is still in Ontario and will often be consulted in the policy of the School.

**H. E. T. Haultain**

H. E. T. Haultain is a Canadian by education and adoption. He was born in Brighton, England, in 1869, but was taken from England when only three months old. He was educated at the Public School and Collegiate Institute at Peterborough, Ontario, and graduated in the regular course in Civil Engineering at the School of Practical Science in 1889. He was prizeman in his first year, secretary-treasurer of the Engineering Society in his second and president of the Engineering Society in his third, being the first student president, succeeding Prof. Galbraith, who had been president during the first years of the Society.

On graduating he went to England and joined a mining engineer in London practically under the English form of pupillage, and was sent by him in charge of small operations in the South of Ireland, and afterwards to the St. Mauritius tin mines in Bohemia. While here he designed and operated the first electric mining hoist on the Continent of Europe (end of 1890). He subsequently took post-graduate work, first in London and then at Freiberg, and in 1893 joined the late Maurice Bucke in British Columbia and has been engaged in mining work ever since, in British Columbia, South Africa and several of the Western States. He returned to Ontario in 1905 to take charge of the Canada Corundum Co.'s works at Craigmont. His specialty is the mechancial treatment of ores but from the academic point of view his important specialty is the variety of his experience. He has held all positions from that of laborer with pick and shovel to that of general manager. He has worked all over the world in ores of tin, copper, silver, gold, lead, zinc and corundum. He has always maintained a high professional tone and of late has taken an aggressive public attitude against the wild-catting in Northern Ontario. He is a member of the two English exclusive technical societies, being an Associate Member of the Institution of Civil Engineers and a Member of the Institution of Mining and Metallurgy. He is a Member of the Canadian Society of Civil Engineers and a Member of Council of the Canadian Mining Institute and holds the degree of C. E. of the University of Toronto. His appointment to the only chair of Mining Engineering in this University was confirmed on October 8th last under the title of Associate Professor.

When asked why he deserted the field for the academic life, he replies that he has not entirely deserted the field, that he hopes there is room for both academic and field work and quotes from Sir Alexander Kennedy's presidential address to the Institution of Civil Engineers:

"It has been, no doubt, a source of regret to many, as it is to myself, that as years go on and experience accumulates, one's work comes always more and more to deal with men and matters, with general schemes and methods, even with financial means and possibilities, and less with the directly mechanical problems which fascinated us when we were younger, and for the sake of which—probably—we took to engineering at all in the first instance."

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"The resignation of Professor George R. Mickle from the Professorship of Mining in the Faculty of Applied Science of Toronto University, in order to more closely identify himself with the provincial administration of the mining industry, has made it possible for his successor to be Mr. H. E. T. Haultain, a thoroughly equipped, admirably-poised, versatile, British born, Canadian bred and cultured, engineer. To succeed Professor Mickle, who enjoys the respect and confidence of higher educational authorities and mining scientists, is in itself an honor. Had Mr. Haultain not been what he is the selection might have brought to him the onerous task of measuring attainments with his predecessor. It is such exchanges, in which the Ontario Ministry and Toronto University Faculty have been happily fortunate, which give substance to the expectation that the mining sciences of Canada are to be exalted beyond mercenaries." —The Mining Journal (London).

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**The Demand for Research Work**

It is felt throughout the undergraduate body in Applied Science that more adequate provision should be made for those who desire to follow up their regular course by an additional year on research work. Of course under the conditions now existing with present equipment, post-graduate work in many of the courses is impossible. But this is not true of the mining and chemical courses, and no doubt much good work might be done in many of the other departments.

What, then, deters the men who may be desirous of extending their knowledge of any particular branch, from putting in an extra session's work? Granting that work could be done in the laboratories if such were requested, why is there no desire on the part of the graduates to continue investigations they may have begun? No doubt such desire on the part of the graduates does exist, but certain factors must be changed before there will be visible expression of that desire. No incentive now exists for a man to take up post-graduate work except his own interest in the investigations, and while this should be of paramount importance, still there must be some other goal in sight than the mere feeling of having thrown some new light on an old subject.

It is not intended to criticize present conditions, for it is understood that what at present exists is a result of past policies, but these observations are now offered in the light of the fact that the four year course will soon be an accomplished fact and as an expression of a strong sentiment among the graduates that something must be done in the immediate future.

Under the new regime, a strong interfaculty spirit is being developed throughout the University which is tending towards a sympathy of action and a unity of aim and purpose, and is gradually eliminating any sectional prejudices which may have heretofore existed.

If this feeling is to be fostered, there must be just and equal treatment to all, and this treatment may have to be granted perhaps at the expense of traditional rights and privileges.

**Aids to Research in Other Faculties**

A comparison with what is done towards rewarding a man for additional or post-graduate work, in other faculties, with what is done at the School, will be instructive. In the Arts faculty, a man who has shown capacity for original work may be granted a fellowship with a salary of $500. At the same time while holding this fellowship he is allowed to take a prescribed course of work, including lectures, and write off an examination leading to the degree of Master of Arts. And if he shows exceptional ability he is permitted to hold the fellowship for two more years and proceed to the degree of Doctor of Philosophy, during all this time following a course of lectures laid down by the University.

**Disabilities for Research Work in Applied Science**

For many reasons this is impossible for a graduate of Applied Science to do. First, his whole time is required of him for the accomplishment of the academic work allotted to him, and again no lecture courses in the University which deal with his work, are arranged for. Even supposing he were allowed a portion of time for work other than that allotted to him, still he would have no reason for following up a subject of interest to him other than the pleasure he might derive from his work. It is true that the degree of Doctor of Philosophy is now nominally open to graduates in Applied Science, but it is also true that in the list of subjects and courses given, there is absolutely nothing which is either of interest to them or which has the slightest bearing on their work. A glance at the list given in the University Calendar will satisfy anyone on this point. It may be said that provision is made for at least the mining and chemical men in the Ph.D. work, but these departments include an exceedingly small portion of those in attendance and no provision whatever is attempted for the Civil, Mechanical or Electrical men. Even the work which the miners and chemists might take does not approach the end aimed at, in their case.

**Lack of Scholarships**

Another point of interest in connection with the work in the Faculty is the lack of scholarships. It is appreciated that new conditions have arisen since the closer union of S. P. S. with the University, but the graduates feel that these new conditions require in turn a rearrangement of the old traditions and this rearrangement will not come until it is shown that it is required.

**Disabilities of Applied Science**

In looking over the regulations respecting scholarships, one is struck by a statement made there, that all undergraduate scholars must sign a declaration of intention to proceed to a degree in Arts in the University, before a scholarship will be granted. Surely a man holding a mathematical scholarship should be allowed the option of a course in the Faculty of Applied Science, for it is here the mathematical men naturally gravitate.

**1851 Science Scholarship**

Again, the 1851 Exhibition Science Research Scholarship of an annual value of $750 is awarded each alternate year to a University graduate. Under the general regulations governing this scholarship, it is stated that *the scholarship is intended to enable graduates to continue the prosecution of science in its application to the industries of the country*. Naturally, then, this scholarship should be given to the Faculty of Applied Science. In the last ten years, this scholarship has been taken by students of the Engineering Faculty at McGill. But here we do not even find the scholarship listed in the Applied Science Faculty Calendar, but placed in the Arts Calendar. However, in the Senate regulations, it is shown to be open to Engineering students. But let us look at the last award. Last year the scholarship was won by a thesis entitled "On Variations in the Conductivity of Air Enclosed in Metallic Receivers," and "On an Improvement in the Determination of Visibility Curves"

—*physical researches in pure science.* At the same time were entered two theses from Engineering students and one of these was on "the Discovery of a New Process of treating Cobalt Ores." No doubt from a pure science standpoint the first rightly won the scholarship, but considering the intention for which the grant was made, as an incentive for research of an industrial nature, the second certainly merited consideration.

In the light of the above facts, what changes should be suggested? It is the opinion of many of the graduates that post-graduate work should be allowed men who are holding fellowships, and a new Master of Science degree established, to be granted after a year's post-graduate work and under the same conditions as the M.A. degree; that the Ph.D. degree be made applicable to Applied Science graduates; that the 1851 Science Scholarship be handed over to the Faculty of Applied Science, or at least the intention of the founders of the scholarship be more rigidly adhered to, in the consideration of the subjects for theses.

**Conclusions**

## NOTICE—PRIZES OFFERED

To stimulate the interest of undergraduates, a prize of $10 in books is offered in each section for the best paper presented for publication in "Applied Science," such papers to be available for sectional meetings if required.

## THE ENGINEERING SOCIETY—OCTOBER

As usual, the first week or two were marked by very heavy work in the supply department. This year sees prices down practically to cost and the gain to the student body has been very material. That this was realized was shown by the very heavy purchasing in the supply department.

The first general meeting of the Society was held October 7th in the large lecture hall of the new Physics Building. Dean Galbraith was warmly received by the men as he delivered an informal opening address. The paper of the evening was presented by W. G. Bligh, C.E., of the Indian Government Service, on "The Design of Canal Diversion Weirs on a Sand Foundation." Mr. Bligh's address proved to be of special value to those of the men who are specializing on hydraulic work, as well as of general interest to all. Several elections were necessitated by the non-return of three officers of the Engineering Society. These resulted in the election of Mr. A. R. Duff, vice-president of Chemists' and Miners' Section; Mr. F. H. Moody, '08, recording secretary; Mr. S. S. Gear, Fourth Year representative; and Mr. L. E. Jones, First Year representative.

Owing to the special convocation of October 21st to confer the degree of L.L.D. on Earl Roberts and Lord Milner, the regular sectional meetings of the Society were postponed until October 28th. The Civil and Mechanical Sections combined to listen to a most interesting address by Rev. Dr. Crummy, B.Sc., D.D., on "General Engineering Development in Japan." Dr. Crummy, having spent a number of years in Japan, was able to point out many features of engineering which were instructive and in numerous instances highly humorous.

Following Rev. Dr. Crummy's address, a paper prepared by Mr. S. S. Gear, '08, on the "Lackawanna Steel Works," proved of great interest to the men. Plans of the works prepared the men to quite an extent for the visit to the works on the annual excursion.

The sectional meeting of the Chemical Section was addressed by Dean Galbraith on "Steel Manufacture." This address was listened to with intense interest by a large body of the men in anticipation of the excursion.

On Saturday, October 31st, what was probably one of the best annual excursions held by the School ran to Buffalo, some two hundred and fifty men turning out. The excursion was accompanied by Dean Galbraith, Prof. Wright, Prof. Bain, and several other members of the Faculty, and their co-operation as leaders of parties contributed largely to the success of the day. The reception accorded in Buffalo could not have been more cordial. The City Council very kindly granted permission to inspect the fire tugs, harbor and other interesting points, and the City Engineer did all in his power to make the visit profitable. At the Lackawanna Steel Works, Mr. Sheddon, general manager, and Mr. Davis, Chief of Police, gave every opportunity to the men of inspecting the various processes and operations. The hearty thanks of the Society is due especially to Mr. Davis for his personal efforts in supervising the arrangement of the various groups and sections.

We are pleased to note, just before going to press, the enthusiastic meeting of the Engineering Society on Wednesday evening, November 4th, in Convocation Hall. The occasion was the presentation of a portrait of Dean Galbraith to the Board of Governors of the University by the undergraduates and graduates in Engineering of the University and S. P. S. The presentation was made by E. W. Stern, '84, New York, one of the School's earliest and most distinguished graduates, and the portrait was received on behalf of the Governors by Dr. John Hoskin. President Falconer, Dr. Ellis and Prof. Haultain all spoke in a happy strain. The Dean received an ovation on rising to speak, making a characteristic and witty address. The portrait is by J. W. L. Forster, who has expressed most faithfully the personality of his subject. A more extended account is reserved for next issue.

## WHAT THE GRADUATES ARE DOING

Mr. W. J. Francis, C.E., who graduated from the School of Science in 1893, and who now has a consulting practice in Montreal, is at present contributing a series of papers to British technical journals on engineering in Canada. In one of these papers published in The Engineer, dealing especially with engineering at Toronto University, he has classified, according to geographical distribution and employment, the graduates of S. P. S. up to and including the class of '04, approximately 500 in all. His fiindings will be read with interest. Canada retains 75% ; United States has absorbed 24% and 1% are found in other countries. With employment as a basis of classification it is found that 69% have remained in engineering, 14% have gone into contracting or manufacturing and 17% into other lines. The distribution is as follows:

| | | |
|---|---|---|
| Engineering:— | | |
| Private practice and employment as engineers. | 39% | |
| Government and municipal engineering work.. | 15% | |
| Railway engineering ........................ | 10% | |
| Light, heat and power engineering .......... | 5% | |
| | —— | 69% |
| Industrial lines:— | | |
| Contracting ................................ | 8% | |
| Manufacturing .............................. | 6% | |
| | —— | 14% |
| General business pursuits .................. | 4% | |
| Educational work and professions other than engineering ........................ | 13% | |
| | —— | 17% |
| Total ...................................... | | 100% |

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### Meeting of Past Presidents

A rather unique meeting took place at the King Edward Hotel, Toronto, on Thursday, November 4th. It consisted of a reunion of all the past presidents of the Engineering Society in the city, together with the present president. Out of the twenty-one men who have held the position, the following responded: H. E. T. Haultain, '88-'89; C. F. King, '96-'97; W. E. H. Carter, '98-'99; E. A. James, '04-'05; T. R. London, '05-'06; K. A. MacKenzie, '07-'08; T. H. Hogg, '08-'09; R. J. Marshall, '09-'10. These together with C. H. Mitchell were the guests of Prof. Haultain at a dinner in honor of E. W. Stern, who had come up from New York on purpose to present the portrait of Dean Galbraith to the University. A very full discussion took place on how the interests of Engineering at the University might be advanced, particularly in the line of post-graduate work. It was decided to push the matter of scholarships, etc., at some future time. In the meantime it was considered advisable to try to obtain equal footing with other faculties in the matter of scholarships at present in existence. More will be heard of this later.

It is interesting to note the whereabouts of the remaining presidents.

F. W. Thorold, '00-'01, is at present in Toronto, but this was not known at the time.

D. Sinclair, '02-'03, and J. D. Shields, '93-'94, are also in Toronto, but the former was seriously ill and the latter indisposed.

R. W. Thomson, '91-'92, mining engineer, passed through city the previous day, on his way to Nova Scotia to report on a mining proposition.

A. E. Blackwood, '94-'95, is manager New York office of the Sullivan Machinery Co.

G. M. Campbell, '95-'96, is superintendent, power apparatus shops, Western Electric Co., Chicago.

H. S. Carpenter, '97-'98, Dist. Eng., Department of Public Works, Regina.

Thos. Shanks, '99-'00, Department of the Interior, Ottawa.

J. F. Hamilton, '03-'04, D. L. Surveyor and Engineer, Lethbridge, Alberta.

J. A. Duff, '89-'90, J. K. Robinson, '90-'91, W. A. Lea, '92-'93, R. H .Barrett, '01-'02, are deceased.

R. A. Ross, E.E., '90, of the firm of Ross & Holgate, Montreal, a graduate of the School in 1890, has been engaged by the Faculty of Applied Science at McGill to deliver a course of lectures on the Commercial Side of Engineering, dealing with organization and operation of companies; with purchase and sale of materials; with accounting, estimates, specifications, contracts and reports. Mr. Ross' wide experience pre-eminently fits him for such a course of lectures. It is to be hoped the new curriculum in course of construction will provide a similar course at Toronto.

E. S. G. Strathy, '07, has sailed for Porto Rico. He will be on the Engineering Staff of the U. S. Government, engaged on irrigation work.

J. M. R. Fairbairn, '93, formerly C. P. R. divisional engineer at Toronto, and later at Montreal, has been appointed principal assistant engineer of the Canadian Pacific Railway.

W. G. Chase, '01, of the firm of Smith, Kerry & Chase, has removed to Winnipeg to take charge of the municipal power plant for his firm. Mr. Chase had the refusal of the position of Chief Electrical Engineer for the city of Toronto, but preferred the freedom of private practice.

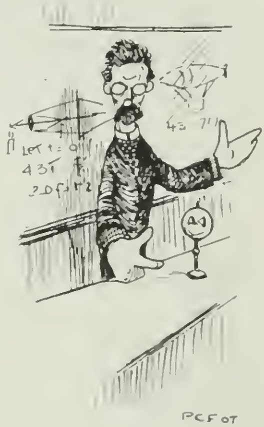
# FIVE MEN IN AN AIR-SHIP

## (To Say Nothing of Me and the Dog.)

John A. Stiles.

Being the true and authentic record of the culminating triumph of the Science of Ballistics, as discovered and perfected by several professors from the Oriental School of Signs and Wonders.

(Note.—Man can never be considered a complete success in any line until he has sacrificed himself on the altar of his ideal, or in other words, have you the courage of your convictions to such an extent that you would even get inside of them?)



During a lecture on Light as a Force, a small glass bulb containing a miniature windmill was thrust in the path of the lantern's light and almost immediately the mill began to revolve and was soon spinning so rapidly that it could scarcely be seen. Professor Photos claimed that this was a substantial proof that light possessed a remarkable force. Very interesting doubtless, but the dear old professor fell to expanding the idea and to plastering the board with a lacework of equations until I could have thought that we were undergoing a spasm known as the Theory of Probability or wallowing in the slough of Theoretical Astronomy. I yielded to the influence of the soporific atmosphere and was soon adrift in the darkness. For the rest of the period the Rarebit Fiend and I went off on a species of neurotical jambourees.

Now in front of me were two large buildings. From the first issued a loud rumbling noise and from the second a lurid stream of light was directed high into the heavens.

I advanced and was startled by coming face to face with Photos.

"Hello!" he exclaimed, "I am glad to see you taking such an interest in your work and mine."

I wondered what that was, but concluded that he must know the answer.

"The object of my life is about realized," he continued: "a trip to Mars." He stood smiling at me in that benign, expectant way of his, his curly hair rustling gently in the night breezes. As for me and mine, I sang the Scotchman's national anthem "Hoot mon!" I shouted, and my pulmonary artery swelled within me.

"Now see here," he said, looking off into the distance, as one who sees things the morning after, "Ballistics is the science of throwing massive bodies through long distances, and has as its fundamental law the reciprocal of the famous gravity formula vee-squared over twice gee. I discovered it in the nucleus of its germination during an exhaustive search for a scheme to get more apparatus for my laboratory."

He entered the first building and I followed. I felt as if I had stepped in at the touch-hole of some gigantic cannon, for I had not entered a building as I supposed, but a cylinder some forty or fifty feet long and about ten feet in diameter, which was pointed into the sky at about the same angle as I had noticed the light was directed. To describe it more particularly, it was a large cigar-shaped vessel which was divided into three. Professor Photos made his way to the last room and opening the lid of a large box padded with batting, remarked rather suggestively that it would make a good bed for some one soon.

At last I seemed to realize. "Can it be possible, sir," I exclaimed, "that you are really going to attempt a trip to Mars?"

"Attempt it?" he almost shouted. "I intend to do it, and you shall accompany me."

Accompany him! I almost fainted.

A quick application of two or three of the more general principles of the art of Ju-Jitsu and I found myself snugly tucked away in the padded box.

I blinked blindly and in terror at the big-eyed caricature of Photos as he bent over me fastening a few necessary straps. He seemed quite cool but my heart was beating as one who had been running a dog-churn for his wife, trying to make butter out of skim milk.

"You remember," he continued, "my telling you several times that in the ether that surrounds our atmosphere and takes up the remaining part of space not occupied by ourselves or the United States, there is comparatively little force at work. You understand, there are no wind storms or anything of that kind. Space always remains in a dead calm. I have no doubt if someone could only invent a method of creating a good windstorm in space, that it would wreck the whole universe and send stars, the moon and the planets bumping against each other like forty cats in a fit. Now, my vessel is built first of aluminum, that is the outer walls are of that substance, while next to that lies a layer of mica and inside of that a covering of asbestos. The object of each substance is as follows: the aluminum is made in such a fashion that it can be raised or opened like the slats in shutters. The mica under the aluminum, being transparent, after the asbestos is pulled down, will enable us to see clearly objects of interest, which we may pass. When we are not passing anything we can sit around the sides of the vessel and put in the time reading novels or planning for the return journey."

"But, sir," I interrupted, anxious to make time, "please explain to me how you purpose transporting your wonderful vessel into the ether or space you speak of far enough to be beyond the attraction of gravity."

"Simple as Taylor's Theorem. Newton and I have long ago discovered that the gravitational force decreases directly as the square of the distance. So you see it is merely a matter of distance. My plan is this: Behind and below this building is a large cylinder running underground for over half a mile. This cylinder is rapidly being filled with a fulminate made from the gasefication of the governors' meditations. A meter at the door registers the amount of contemplated force thus being accumulated. Then taking into account the exact coefficient of resistance, which Professor Hydros has kindly worked out for me, I have computed that it will take about steen pounds pressure to the square inch to hustle us without the jurisdiction of this globe. Then what ho! the rest is easy and I'll get my name in the *Globe*. That reminds me, I must see Mr. Marconi about a little matter regarding communication with home. You see my wife will likely be anxious."

"What about air?" I panted. "We must have air to breathe and this vessel will not hold enough."

"Do not worry about that. In the other end of this car stands a drum of vitrified air sufficient to refill these compartments one hundred and fifty times or more."

"The distance—is it not too great to attempt to cross before we shall all be dead?" I asked.

"The distance is a mere bagatelle. You will recall, doubtless, the many lectures I have given you on Light as a Force. Very well; my plan is this: Upon being shot away from the earth an immense light will be turned upon us which will increase our velocity from 15 to 29.995 per cent. per second. A little problem in acceleration for you. You see in space power gained is power retained, and a little mental arithmetic will show you that at the end of an hour's time we shall have attained a speed of seven thousand miles per minute. Then the rest will be easy. All we shall have to do will be to sit there and go, simply go! go! I have got the problem of food and all that sort of thing solved long ago."

The rest was easy, sure enough, for he put a sponge to my nose and the last thing I remembered was wondering whether I would be back in time to take a demonstratorship or not.

A frightful pain in my left arm awakened me. Surely I must be at sea. How dreadfully the ship was rolling! How dark it was! I struggled to get up but found that I was firmly bound. Now I remembered everything. I was out in space careering along at seven thousand miles a minute. There was some satisfaction in the fact that we were going pretty fast. As I lay thus musing, someone opened the lid of my box and I found myself blinking at the dazzling light of the sun. My next impression was that it was very cold in the car.

"Don't you think it's time you got up?" said Photos. "I don't know what time it is, for my watch seems to have stopped, but I shall call up Toronto in a minute. I want to speak to the Dean. I have just remembered that I have forgotten to get leave of absence and I suppose he'll be properly mad over it." He went to the end of the car and worked a telegrapher's key for a few minutes. Then a moment's wait and he began to write rapidly. "The explosion which sent you into space brought down City Hall tower, also Science buildings; all exams. off. Special meeting of Council. Warrant out for your arrest. Full page article in all papers. Keep us advised. Dean says doesn't see how he can let you go. Great opportunity working for moving picture shows when you return. Time 9.30 a.m."

"Hem," said the professor. "They won't think me so slow after all, will they? I wish the shock had killed a man I know, but that's neither here nor there. At least I mean, thank goodness I am away from him, at any rate. Now I suppose we had better wake the rest, since it is long past breakfast time."

Imagine my surprise to see him open five boxes similar to the one in which I had been imprisoned. Professor Looby yawned, stretched, looked about him, smiled good naturedly, asked if we were out of sight of earth yet, and turned over for another snooze. Professor Walkembust was already awake and anxious to be up. "Good morning," he said, stroking his hairless pate. "How are chances to get something to eat?" Professors Statish and Kemoss were not so easily wakened, the effect of the anaesthetic not having worn off yet. However, by the time the occupant of the last couch had been liberated and pacified all were ready for something to eat. The last named individual being none other than our old friend Tige, the dog. The poor brute seemed to take in the situation at a glance and gazed up into our faces with a look which seemed to say, "Well, I'm next all right, but what's the answer?"

After breakfast Looby opened a paper door and crawled up to the top of the car along which ran a huge telescope. "I shall now determine our whereabouts," he remarked quite cheerfully His face was not so cheerful, however, a moment later when he slid down from his perch and announced that we were heading straight for the moon.

"Gentlemen, I might as well break it to you at once. Get ready for a bump, for I think there is going to be one. Even now we have covered over half of the distance between the earth and the moon."

Then followed many hours of wonderful events. We all, including the dog Tige, stood gazing through the transparent sides of the car at the objects we were passing and some that passed us. Kemoss remarked with a grim smile that most of the things we saw were going in the opposite direction to that in which we were inclined to believe they were travelling. Many times we rushed by huge masses of rock, the aluminum sides often brushing them so roughly as to jostle the car. Had they not been travelling in the same direction as ourselves they would have passed us so rapidly as to forbid our seeing them.

A white light was seen before us. Slowly we ran it down. Now we were close behind it. It was a mountain of rock at a white heat. Gradually, very gradually, we gained upon it, and as we did so we became conscious of its great heat. Like a fiend the car seemed to recognise a comrade and was diving straight toward it. The heat became so intense that we were compelled to lie upon the car floor and let down the aluminum flanges. Poor Tige seemed to scent the danger, for between his pantings he would stop to whine and look up into the faces of each of us in turn.


During all the mad race Kemoss had not uttered a sound, but just as the car seemed about to touch its nose to the rock he stepped quickly to the front, took a look, and said, "I think we had better change the air in the car. It is getting rather close in here. I do not think that there is much cause for alarm at our present situation. If you will enter the next room and close this door I will show you how we purpose defeating such fiery friends as that ahead of us." We obeyed. The snout of the car was almost among the flames when the professor opened two valves in the head of the car. A hiss—a roar—an intolerable odor. As Kemoss returned to us and we pulled open the door to receive him the rush of air from our room nearly overbalanced him. A shrill whistling from the valve on the vitrified air drum and the car was once more filled with precious air. We raised the flanges now and all rushed to the head of the car. The rock was gone, having been blown completely clear of our path. We were saved for the present at least. We could hardly avoid the thought, however, that perhaps the next monster would not be travelling with us but against us. Walkembust remarked with a smile that it would have been a quick business if our friend had been coming to school instead of going home.

It was now about twenty hours since we had been hurled into space and since Looby assured us that we would not be near the moon for another day at least, our speed having so decreased, someone suggested that we take a snooze. I did not feel inclined to re-enter my bed. It was too much like trying to sleep in one's coffin, so I imitated the example of the others and lay down with my feet towards the head of the car.

How long I slept I don't know, but I was awakened by hearing the rest of the company talking excitedly. I rubbed my eyes, got up and gazed about. We were quite near the moon now, very near it, too uncomfortably near. Contrary to our expectations, however, the bump did not come, for we shot past the satellite like a cannon ball. We were standing looking at one another wondering what would happen to us next, when the strange conviction was forced in upon me that our car was not travelling as fast as formerly and I was not surprised to hear Looby say, "I thought so. Now we are going to go back to the moon." True enough, like a shot out of a gun we swept past it again, stopped on the other side and made the return journey, though with less force. The truth of the matter was that we were virtually playing the part of a satellite to the moon, running around and around it like the gyrations of a moth about a candle flame. Our speed decreased. Once we thought we were going to run into another rock, but it proved to be only a flaming bag of gas and we shot through it, scarcely feeling the heat.

As our velocity decreased it became possible to make a more careful inspection of our new home. It was much as we had seen in magazines, spinning always with the same side to the earth. As we shot once more around it we noticed that it was bowl-shaped, the side away from the earth being hollowed out like a walnut shell. We sped back and forth about this strange satellite for two or three hours, but always getting closer and finally tripping over the edge of the bowl and soaring down like a bird. As we were nearing the ground I could have screamed with excitement.

"Down with the flanges," hissed Photos, and they went down with a crash just as the car alighted. There was a tremendous jolt that sent everything, ourselves included, into a heap at the front of the car.

Tige was the first one to raise his voice on the new planet. Something had fallen on him and he was yelping loudly. He was soon located and bounded about over everybody and everything in the dark. Then began a rummaging among the debris for the box with the tapers. We succeeded after a time in getting a light and proceeded to take stock of our mixed merchandise. The partitions and everything belonging to them had been swept away, but notwithstanding the great crash the car was even now air-tight.

Outside we could hear a light tapping on the car and directly above our heads we noticed a sound as of some one drilling. To this part Professor Statish gave his whole attention, murmuring something about the horizontal resolved part of the resultant. Mounting on a box he listened intently. The drilling continued for some time, probably an hour, when finally the professor's vigil was rewarded. The sharp point of a green-colored instrument pierced the mica. The professor immediately seized and held it and instructed me to mount on his shoulders and ascertain if possible, by peering through a crack in the flanges, what sort of a creature was doing the damage. By the aid of a piece of glass I was at length enabled to catch a glimpse of the figure, which was crouching on the roof of the car trying to withdraw the tool. It was a creature about four feet high, pearl-colored and shone in the sun, as if it had been highly polished. It was proportioned exactly like a man and I noticed that it had no hair. In fact there did not seem to be room for any hair, for a row of rabbit-like eyes ran completely round its head. At first I was inclined to think it had no ears, but a moment later I discovered that it had one nearly as large as a saucer placed exactly on top of its head.

The professor now released his grip and the boring tool was jerked out, but immediately upon its being withdrawn there was a rush of air. I saw the pearl-colored creature duck his head as if to listen to the noise and then away he flew high into the air kicking and squirming. The hole was quickly closed by placing pieces of paper over it.

Descending from our perches we now held a council of war. There was no doubt about it, the Moonites were evidently very curious or else were openly hostile.

"I tell you what," said Statish, "I know something about the horizontal resolved part of the resultant. When that little beggar drilled an opening through our roof the air cooped in the car puffed him high sky. Well, I advocate cutting similar holes on all sides of the car. Let us cover them with pieces of paper and then raise the flanges. As soon as those creatures see us they will likely make a charge and clamber all over the car and when the car is well covered with them we will pull away the paper."

"A very good idea," assented everybody, "though it is strange that you should have thought of it since your science only deals with stationary bodies and that makes a noise like dynamics."

"You're all wrong," said Photos. "It makes a noise like the Science of Ballistics and I am the one that should have thought of it."

"Well, well, don't quarrel, gentlemen. Let's get to business," said Walkembust.

Immediately we began cutting small holes in the mica with our knives and soon had one hundred and fifty holes made and each covered with several plies of thick brown paper.

"Now, up with the flanges." Up they went and the car was once more flooded with sunlight, which so affected our eyes that we were unable to see for some moments.

When our eyes had gained sufficient strength to bear the light, a scene was unfolded before us which was somewhat startling. At two or three hundred yards distance stood about a thousand of the pearl-colored men, glistening like so many granite tomb-stones. Picking up a telescope, I directed it towards the crowd. It was composed of beings similar to the one we had first seen. Their hands and feet were shaped like cups. Suddenly they turned and rushed towards the car.

As they came forward we perceived that they each carried strange instruments which resembled egg-beaters. They were rapid runners and soon reached the car, clambering over it like a cloud of locusts. The mica was several inches in thickness and while they were boring we charged the car well with air. Then stationing ourselves about the car we began jerking the paper from the holes, replacing the pieces immediately. As each aperture was uncovered there was a zip of the escaping air and one and sometimes two of the Moonites were hurled high into the air, to alight some twenty or thirty feet away apparently uninjured but not anxious to repeat the experiment. Pop! pop! pop! Away they flew like toy balloons, alighting some head first, on their backs or rolling over and over like empty baskets chased by the wind.

Photos now unlocked the sliding door and for the first time in six weeks we stood on terra firma. It occurred to me that Tige might like a scamper as well as ourselves, accordingly I opened the door and let him out.

"Phew! we should have tied a stone to Tige to keep him down," said Kemoss.

Big Tige went crazy for the time being. With two great bounds he was close to the group of Moonites. One more and he had sailed completely over their heads. He turned quickly and jumped at them again. Whether he had made up his mind to devour the whole tribe or not I cannot say, but at any rate he had to exercise great patience before he could get near enough to even get a sniff at them. Each bound sent him twenty yards farther than he intended to go. Nor could he seem to understand, for he flew over and over the terrified creatures, and his barking sounded like the roar of a hundred cannon. At last it seemed as if the Moonites could stand it no longer and we were surprised to see them all standing on their heads, their one ear buried in the loose yellow sand. We noticed that as we spoke to one another our voices sounded ten times louder than was natural and over and above all sensations was an all-pervading odor of Welsh rabbit. At times it was almost stifling. The ground on which we were endeavoring to walk was like flour but was a kind of chrome yellow. We had scarcely time to consider this when Tige, having given up pursuit, came sailing back to us like a toy balloon in the breeze. With a frightened yelp he went careering over car and all. He now seemed to have an inkling that something very peculiar was the matter and turned and commenced crawling very slowly along the ground to us. We caught him and tied him to the car door. Our enemies had now resumed their former upright positions and began rubbing and pushing one another with their cup-like hands, but we heard no sound from them. Considering that they had learned enough of our powers, we ventured to move a little away from the car. "Great guns! here they come!" shouted Photos, his voice almost deafening us. "What shall we do? We have not a thing with which to hit them and we are cut off from the car." However, as we hesitated the solution was shown us by Tige. About a hundred of them had made toward him. He rose to the occasion and although tied to the car succeeded in raising car and all in a great bound. Finding that he could not fight thus encumbered he contented himself with waiting for the others to assail him. Ten of the bravest charged him with their egg-beaters. Waiting until they had advanced to within a few feet of him he barked. That was enough. The dog's breath was too much of a gale for the pale faces and they fell over one another in great confusion. What happened to Tige after that we were unable to say for we had troubles of our own. Hundreds of the Moonites charged us. Professor Statish drew a long breath and stepping forward greeted ten or fifteen of them with a tremendous puff, which sent them all down like nine-pins. It was my turn next. About twenty of the many-eyed creatures came at me. I filled my lungs as I had seen the professor do, but alas! I could not keep from laughing and exploded long before my foes could reach me. It was Kemoss that did the mischief. He was down on his hands and knees trying to bark like a dog and succeeding very indifferently. A moment more and we were in the midst of them. They seemed numberless, climbing over each other in their desire to get at me. Help! Help! I screamed and my voice cleared a space around me for a moment. Then they were at me again and stabbing and drilling at me with their egg-beaters.

It was Kemoss that saved the day. He had fought his way back to the car and returned with a drum of compressed air and a hose. The rest of the battle was as easy as watering the lawn. Swish! Swish! and there was a space clear in front of us "Save Walkembust!" shouted Photos, who was now struggling toward us, "he is down!" We shouted and dragged the hose after us as we blew a path to where we had last seen him.

Swish! Swish! went the nozzle and the professor lay before us. His face was completely covered with minute red specks. We turned the air in his direction and greeted him with a refreshing breeze that soon revived him. •

We could no longer reach our enemies by means of the air blast, so as a last resort I slipped back to the car and let the dog loose. Just the chance that Tige wanted. Barking savagely he rushed towards them, jumping over and over them but occasionally lighting right in the midst of a frightened crowd, knocking them right and left. Within five minutes we made out a party of our assailants coming towards us. They advanced running for some distance, then falling to the ground began working their way towards us on all fours. Occasionally they would stop and wave their handless arms demonstratively in the direction of the dog. At last we understood their meaning and whistled for the dog and chained him up.

We then made signs that we were not anxious to resume hostilities if they would throw down their egg-beaters, which they promptly did and advanced fearlessly towards us. The smallest individual among them advanced at once to Professor Walkembust and began gently to stroke his wounded face and bald head. The red specks left immediately and we were more than surprised a few minutes later to see a luxuriant crop of golden hair and a beard appearing. He was jubilant and was constantly thereafter coaxing us to tell him what he looked like.

It was not long until Walkembust's instincts began to assert themselves and he started walking across country, followed at a respectful distance by the Moonites. We crossed great fissures in the loose yellow ground by simply leaping them, the Moonites going around. Walkembust seemed greatly perplexed at the rock formations and when we questioned him as to their technical name, he said that as time went on he was more and more convinced that it was a species of rock which is usually found in table lands and called Limberg-Silurian. We crossed the bottom of the bowl, so to speak, and were now crawling laboriously up the side to the edge of the dish when I slipped and fell. To save myself I dug my heels deep into the earth and went ploughing down the slope. I was somewhat behind the rest of the party now and was about to redouble my efforts to reach them when the earth beneath my feet smelt so strongly of Welsh rabbit that I yielded to the temptation to taste it. My suspicions were confirmed but I said nothing to anybody.

Having rejoined our party we proceeded up the slope, reaching the top just as the sun was setting behind us. From our new point of vantage we could now make out that which we had seen before our car landed, viz: that the moon was shaped like half a walnut shell. The edge of the shell was fringed with a strange kind of string-like grass, which very much resembled cotton rope. Kemoss, seated in the midst of this, had pulled a pad out of his pocket and was making a rather careful sketch of the United States and Canada. I asked him if he thought that he could see Toronto. He said he didn't, but ventured the remark that he thought he could see Chicago and pointed to a black mark beside a lake. I looked a moment and asked, "Are you sure it isn't a volcano?" "Quite sure!" he rejoined; "I know Chicago well."

The outer surface of the moon looked like a sheet of coarse canvas that had been painted yellow, something like the old-fashioned bass-wood hams.

Being somewhat fatigued with our journey, we reclined in different postures on the brow of the hill, now watching the affairs of earth and ever and anon looking back into the darkening valley behind us. We were some distance from our car and I for one was ravenously hungry. I whispered this to Professor Walkembust so as not to disturb the rest with unnecessary fears. He looked at me and smilingly whispered back: "If you are hungry why don't you eat? You are fond of cheese, are you not?" I admitted that I only cared for old cheese. "Well," he continued, "this should be old enough for you," and he knocked a corner off a neighboring rock and began nibbling at it. I followed his example. Soon the secret was out and all the party were gorging themselves.

The moon, then, was nothing more nor less than a gigantic cheese. As the Moonites observed us eating the ground upon which we stood, one of them advanced to my side and stooping down touched my forehead gently. I was surprised at the sensation. A quiver ran through me and an impresion in my mind rapidly shaped itself into words which said, "Do you like it?" The Moonites, then, had no language, but communicated their thoughts from one to the other by the "touch method." Then followed a long conversation, for I discovered that this creature was able to read my thoughts without even so much as touching me. I always was a plain thinker. Professor Looby had adopted different tactics. He had one of the handsomest Moonites on his knee. He smiled at it and it smiled back and fed him with choice pieces of cheese gathered from the neighboring rocks. The dear little creature indeed had a most kissable looking mouth but I didn't think that Looby would do it, but he did. I looked towards the young Moonite and in its row of eyes distinctly read, "Please tell him not to do that again. It tickles. Oh, isn't he awful!"


If the moon was cheese, then this rope-like grass must be the rind. Calling one of the Moonites to me, I elicited the information that once the moon was round but that it had all been eaten away until now little more than the mere shell of the original moon remained.

We spent the night on top of the edge of the bowl and in the morning were awakened from a short nap by hearing Tige's barks. Convinced from the noise that he was making that there must be something unusual the matter, we hurried back to the car and a sight greeted our eyes that was more than ordinary even for this strange country. The car was completely surrounded with the most peculiar looking animals. They looked like immense white snakes. They were covered with long, straggly hair and deep wrinkles. As we approached waving our arms and shouting they jumped away. I say jumped away because that was what they literally did, for their mode of locomotion was beyond description, though done something after the following fashion : When one wished to change its position it placed its head on the ground, arched its body and brought its tail close to its head, then with a tremendous bound went spinning through the air. As we were gazing at them in terror I noticed Walkembust smiling. "Don't you know what they are?" he asked. We all admitted that they were a new variety of snake to us. "They are not snakes at all," he laughed. "They are skippers."

The following days were all filled with pain and trouble. We had nothing but cheese and fresh skippers to eat. First Tige took sick and died; then Looby startled us by saying that his nose itched so terribly that he could scarcely stand it, and we realized that it was the result of eating too much cheese. Oh, it is too terrible to tell in detail. One by one all of our party was wiped out, dying of that terrible disease known only in the moon "itchy nose." Died of cheese and were buried in cheese.

As for me, when Photos died, the thought that his examinations would all be called off was too much for me and I awoke from my dream to find the lecture on Light as a Force still in progress and the board about a foot deep in equations.

J. Galbraith

*From painting by J. W. L. Forster*

# Applied Science

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## ADDRESS BY MR. E. W. STERN

NOVEMBER 4th, 1908.

On the occasion of the presentation of portrait of Dean Galbraith to the University.

This honor conferred on me by my fellow graduates and the undergraduates in Applied Science of the University of Toronto is one which is most flattering, and which I most deeply appreciate and can never forget. No greater pleasure could come to me, than to return to my old home and old college after many years, to be with you all and to be asked to participate in such an event as this, the public expression of the appreciation in which our beloved preceptor is held.

There might have been selected one far more worthy of this honor and more able to express eloquently the thoughts which an occasion as memorable as this should bring forth, but none more in sympathy with it, nor more impressed with the sterling worth of the man in whose honor we have met this night.

I do not propose to speak a eulogy of Dean Galbraith, because as we are all one of his family, so to say, it might perhaps not be in good taste, and besides a parent should not be praised too much by his children, it might spoil him, and he might take advantage of us; nor to refer, except briefly, to the evolution of the School of Practical Science into the Faculty of Applied Science of the University of Toronto and its steady growth under his fostering care, with the loyal support of his able colleagues, from its modest beginnings, some thirty years ago, to the great institution it now is, because such a recital would deal practically with the commencement and development of technical education in this province with which his career has been most intimately associated, and there are those much better qualified to speak of this than I; but rather to try and express what we, his old pupils, know of the man, and our appreciation of him and to tell you of those sterling qualities of mind and heart, the modesty, the thoroughness, the patience as a teacher, the kindliness and the human attractiveness of his personality, the interest in the welfare of his old pupils, all of which has so endeared him to us, and has had such a strong influence upon our lives.

My first acquaintance with him goes back a long, long while ago—twenty-seven years—when most of the young gentlemen now before me had not yet made their appearance. I called at the old brick school-house to ask him about the studies which were taught in the School of Practical Science. My notions about the profession of civil engineering were very vague, and I asked for enlightenment. As a result of our interview, I was so taken by some indefinable quality in his personality, that I decided to enter this school and learn civil engineering.

It was then a very modest school, only three students in the third year, three or four in the second, and about one dozen of us freshmen. The faculty in Engineering consisted of Prof. Chapman, Dr. Ellis, Dr. Pike and Prof. Galbraith, and we had a few hours a week in University College, under Prof. Loudon and Baker. All the Engineering lectures were given by Prof. Galbraith as well as the field instruction in surveying, and for three only too short, happy years, he led us all the way through the mysteries of mechanics, thermodynamics, descriptive geometry, hydraulics, etc.

We were indeed fortunate in those days on account of the small size of the classes in having so much of our preceptor's attention; we could not help but learn under him, and learn to think for ourselves. The class was thoroughly in earnest in its desire for knowledge, for such was the inspiration of his teaching. His patience was untiring and he never hesitated to go over and over again, a subject which we could not understand, until we had it. While he maintained discipline, it was done without harshness, his teaching was thorough without being pedantic. He impressed us with the importance of getting at the bottom of things and of trying different methods. His lectures were informal, his methods not academic. He would put down a difficult problem on the blackboard, and sit down and think it out with us. If the problem were one involving a knowledge on our part, say of certain theorems in calculus or algebra which we were supposed to know but which we were not clear about, he would go back and drill this into us before proceeding with the problem in hand.

I can recall to this day, how persistently he kept at us until he made us understand that in a beam, the neutral axis corresponds with the centre of gravity of the cross section, and that $\frac{M}{I} = \frac{p}{y}$. Rankine (peace to his ashes) was even made plain. He untangled many of his knotty theorems. As I think back, I can still remember away off in the distant past something about the internal stress, which we underwent to understand the ellipse of stress, adiabatics, isothermals, and to draw the shadow which a cone casts on a parabaloid of revolution. He really did clarify in our minds these mysterious things.

The lectures would be enlightened with flashes of keen humor. I remember that once in expounding the theory that the forces acting on a body are in equilibrium when it is either at rest, or in motion through space at uniform velocity, I asked the question, "What would happen if the body struck me?" The answer came quick with a mischievous twinkle of the eye, "Well, let us see—if it struck your head, it would depend on its quality as to whether it rebounded, or went through."

His technical qualifications and breadth of view were such that we soon realized we were under the guidance of a master mind. It was, however, the human quality of the man, his fineness, his way of thinking and talking straight, his kindliness and interest in each of us and his sympathetic nature, which appealed most to us. He was a man, every inch of him, and one of nature's own noblemen. He never preached at us, nor did he ever talk about what was right or wrong, but somehow or other, remarkable to say, we absorbed ethical teaching from him. I have spoken with many of our graduates, and they all agree with me in this;—we seemed to feel what he thought was the right thing to do.

He was not only popular with us his students, but he was appreciated by all sorts and conditions of men. The Ojibwa Indians call him by a name which means "The Little Chief with the noonday face." I recall personally, a suggestive incident bearing on this phase of him. Twenty-six years ago, during my summer vacation, I was on a surveying party in Nipissing; one night our party were encamped near a Hudson Bay post called Fort McLeod, at the mouth of Sturgeon River. In talking with the factor, whose name I cannot just now recall, he asked me if I knew a little professor from Toronto—John Galbraith by name. I told him that I did know him and that I was then studying under him. He said to me: "He is the finest man I have ever met, he tells the best stories—I would like him to visit here again. You come with me and sleep in a bed to-night," and we drank the professor's health from a black bottle, and thanks to him, I slept in a bed that night, the first in four months.

There were five of us who graduated in the class of 1884, a striking contrast with present times. I shall never forget his farewell address. Calling us together, he told us that now having completed our course at the school, we must start out in the world with the idea in our minds that we knew nothing whatever about engineering, and should commence our practical work at the bottom. It was characteristic of the man's modesty and thoroughness; never was better advice given, for we started out in the world with no false notions of our importance, and worked our way up gradually without friction.

Those of our younger graduates whom I have met in recent years, as well as the older ones, have nearly all appeared to me as having some certain characteristics in common, namely, thoroughness and modesty. I know of none who have been failures in life.

After leaving the school his personal interest did not cease, for he looked upon his old students as his children. My own correspondence with him has been kept up steadily during the past twenty-five years, and so it has been with many others.

Dr. Galbraith brought to his life's work a rare fitness for it, for besides the personality which I have spoken of, not only were his academic attainments of the highest, but his practical experience in his profession, in railroad work, on surveys, and in the shops was most thorough. His broad experience, therefore, enabled him to separate as it were the wheat from the chaff, in our work, and temper theory with practical experience. He impressed us with the fact that while theory was right as far as it went, we were liable to forget some very important things in our premises, and that therefore we should always scan our conclusions from the perspective of common sense, always seeking for and considering carefully, the results of practical experience.

Had he chosen to follow the practice of his profession rather than teach, he would undoubtedly have been, before this, at the top of his profession in Canada. Only recently, as a member of the Royal Commission on the Quebec Bridge disaster, together with his able colleagues, Messrs. Holgate and Kerry, he labored most indefatigably without cessation for eight long months, and the report submitted by this commission was characterized by the leading technical journals in the United States as being the most able, thorough and valuable that has ever been published, in any language, of a great engineering disaster, the lessons of which, not only from the technical standpoint, but from that of organization, morale and business methods, are so clearly set forth as to make it a most valuable contribution to engineering literature and worthy of the careful study of any engineer, no matter in what special lines he may be working. I may note, too, that in this report, while the facts have been most clearly set forth, the human spirit of charity and sympathy with the unfortunate engineers upon whose shoulders the responsibility for the disaster rests, permeates it.

Of this commission, a colleague, Mr. Kerry, formerly a professor at McGill University, and now a very prominent consulting engineer, who had been closely and intimately associated with Dr. Galbraith for months, told me that he was one of the most likable men he had ever met and asked me if we, his old pupils, realized how big a man he was. Very quickly I reassured him on this point.

I will digress a minute to quote further what Mr. Kerry has to say about him from an article in Engineering News, published a few months ago, when Dean Galbraith was elected president of the Canadian Society of Civil Engineers. He says:—

"To the development of the School of Practical Science Dr. Galbraith has devoted the whole of his time and abilities, consistently refusing to undertake professional work as a consulting engineer whenever it was likely to interfere with his duties as a teacher. The School of Practical Science is to-day the largest and most rapidly growing engineering school in Canada. This, while in a measure due to the great prosperity of the Province of Ontario, must in large part be credited to the work that has been done by Dr. Galbraith; for the successive classes of graduates have recognized the thoroughness of their training, the simple devotion to duty of their professor, the soundness of his professional knowledge and the manliness of his personal character so fully that it is questionable whether any other engineering school on this continent gets such enthusiastic advertising and such active personal support from its own graduates. It is characteristic of the man, and of his estimate of his own attainments, that he has repeatedly refused permission for the publication of his lectures and has contributed but little to the sometimes too-swollen stream of technical literature. Dr. Galbraith's work since 1878 may be aptly described as that of a fashioner of tools which have been widely used by other men in the construction of the great engineering works of Canada; the standing of the graduates of the School of Practical Science is evidence of the thoroughness of his fashioning."

It is quite evident from this article that Mr. Kerry, like all of us, has been unable to resist hypnotic influences.

As I have already said, there is no question but that Dr. Galbraith would have become a leader in his profession, had he chosen to follow it. In fact, his ethical and technical qualities would have made him a leader in whatever line of work he would have pursued, for his personality is such as to inspire confidence in those who might have availed themselves of his services, and also, would cause those who were under him to work most loyally and efficiently for their chief. But he could not have become greater than he now is. His service to the state and society from his long years of steady, devoted adherence to his life's work has been invaluable. He would have been wealthier without doubt, but he is one of the few who, having placed duty above material things, has set an example for us all.

The growth of the Faculty of Applied Science has been phenomenal. In thirty years it has grown from about 30 in all the classes to 770. This great increase has involved a tremendous amount of work on the part of the faculty and its leader, for not only was the great increase in numbers of pupils to be taken care of, but these past thirty years have been most prolific in advance in engineering science, and the School under his able leadership has kept fully abreast of the times, so that now it stands second to none in America in thoroughness and efficiency and ranks among the leading technical schools of the world.

The great success of this institution has undoubtedly been due to Dr. Galbraith, but we give full credit also to the very able, efficient and loyal support he has had from his colleagues in the faculty, and to Dr. Ellis in particular I may refer as being one of the old guard whom we remember most pleasantly and gratefully from the old days.

Dr. Galbraith's life furnishes an object lesson to every one of us—the value of thoroughness, modesty, and human sympathy in all the walks of life; and although all cannot be at the top of the ladder, we still can be steadfast and conscientious in our day's work, and above all, be respected wherever our lot in life should happen to fall.

We, his old pupils, are his life-long friends. We owe him a debt which can never be repaid. We wish him many, many more happy years of life and usefulness, and we give him our blessings.

This portrait, the work of Mr. J. W. L. Forster, is the gift of practically all the graduates and undergraduates in the Science Department, and our sincere thanks are due him for the faithful and sympathetic likeness which he has produced.

As marking the anniversary of the thirtieth year of Dean Galbraith's connection with this institution, and as a small token of our appreciation of his services to us, we take great pleasure in presenting to you, sir, for the University of Toronto, this, the portrait of one of its most gifted and worthy sons, and of one of its most beloved preceptors.

## ADDRESS—ROBERT MOND*

Gentlemen—Principal.

Your Professor Haultain has requested me to address a few words to you, a request which gives me peculiar pleasure to be able to accede to.

You who have assembled here from all parts of the Dominion in order to acquire the knowledge requisite for the development of the many and varied mineral resources of the northern and greater part of this Continent are squaring your shoulders to take up a burden whose magnitude and whose importance are scarcely to be over-estimated.

All the faculties with which your forbears and surroundings have endowed you will find scope for their widest development. Only by your whole-hearted devotion and attention, accompanied by reverence, both to those who teach you by word and by letter, will enable you to worthily prepare yourself for your life's work.

Those of you who are preparing yourselves for mining will have to acquire a moral and mental probity and rectitude such as is demanded of few of your fellow mortals. On your opinion, though not directly expressed for publication, not only fortunes but the weal or woe of widows and orphans may depend. You will be responsible for the welfare of many individuals of various types and nationalities. You will be held responsible for the safety of irresponsible subordinates. And proceeding to technicalities you will have to recognize the occurrence and size of the ore deposit, determine its position, decide its development, the correct system of drainage, the methods of concentration, of roasting and smelting, possibly of refining, and the arrangements for transportation. This involves a knowledge of geology to determine the stratification and geotectonic structure of the environment, mineralogy to enable you to identify your minerals, chemistry to enable you to assay your ores and understand the theory of your smelting process, the mechanical parts of physics to understand the principles of your concentrating processes; mechanical engineering to keep your plant running; electrical engineering, where electricity is available; civil engineering for your methods of transporting, and architecture, as it applies to the buildings which you will have to erect.

It would not be humanly possible, and no one would expect it of you, to be pastmasters in the formidable list of different branches of knowledge I have thus enumerated; but the more you know of all these branches, and especially the more efficient you are in any one of them the more useful and efficient will you be in your future career.

And here let me warn you. You must not anticipate that the few years you will spend at this University will enable you

* Delivered before Mining Section of the Engineering Society, November 5th, [illegible].

to attain to this knowledge. That is not its object. But you will be taught and you will acquire the system and method which will train your mind to assimilate this knowledge from hour to hour and day by day, when you have said farewell to your Alma Mater, and as you advance in years your thoughts will turn in deep and earnest thankfulness to those who have aided you in your own evolution.

You will be called upon to go forth to the uttermost corners of the earth among strange people, and stranger conditions, to examine strange propositions. You will be unaided, unguided and unchecked, surrounded by people whose self-interests may be diametrically opposed to yours or those of your employers.

You will be exposed to personal discomfort, if not danger, to the wiles of the unscrupulous, and to the facile lie of ignorance. You will have to read human characters and learn to use your enemies as well as your friends. You will be liable to maligning, overt or dissimilated attempts at corruption; hence I say to you that you require a code of honor, a standard of morality higher than is generally demanded of mankind.

In the management of men there is only one rule which is universally accepted, and that is an absolute fairness and justice, well designated as square dealing, with those one employs. All favoritism is as disastrous to an employer of labor as it ever was to the proudest monarch history records.

A thorough knowledge of geological principles will prevent you from searching for one where it could not possibly occur, it will give you valuable information in regard to folds and faults, but it will never tell you whether the ore is payable.

The use of mineralogy in enabling you to properly classify your ores is self-evident, but chemistry is your most important helpmate.

It tells you whether your ore or your rock goes on the dump, whether your stopes are worth working, whether your tailings are not richer than your ore, whether your water corrodes your pumps and boilers and whether your coal is not heating air instead of water. And in smelting and refining you are dealing with purely chemical reactions. There chemistry will tell you whether your cyanide runs down the drains or your metals away with the slags, whether your water is fit to drink or your air fit to breathe; and chemistry not only warns you, but also tells you how to rectify any error thus made.

In concentration plants, either dry centrifugal magnetic or wet, with or without oil, the physical properties of matter are of the greatest importance. Your processes depend on graduation both of volume and weight and you will find by careful and conscientious experiments, that concentrating plants and concentrating plant manufacturers' catalogues are not synonymous.

One of your most important and conscientious tasks will be that of sampling. Here again it is only by fully understanding the underlying principles that you will be able to adapt methods to your materials which will give you concordant results.

You will have to be expert surveyors and neat and quick draughtsmen or your experience may tally with that of the Roman engineer who, in the second century A.D., having to drive a tunnel for the conveyance of water through a mountain in the ancient province of Mauretania (the present Morocco) surveyed the mountain and started to work from each end. After some time the contractor was sent for by the Governor of the Province, as the work showed no sign of completion, and it was found that each party of miners deviating slightly to the side had nearly driven two tunnels through the mountain.

Of mechanical, electrical and civil engineering you will acquire the rudiments and you will have many opportunities of perfecting your knowledge by subsequent experience. Mining engineering proper you can only learn in a mine. But your own personal experience will of necessity be limited to special cases, and you must seek every opportunity, both by reading and seeing, to acquire as extended a knowledge as possible.

The correct type and use of rock drills, the most advantageous methods of blasting, the correct methods of supporting the roof of the mine, the timbering of shafts and of levels, the methods and means of extracting the ore, the determining of the boundaries, all so varied in application, are still reducible to a few leading principles which you will have to acquire.

And as regards exploration, the first necessity for this is an adequate knowledge of similar ore deposits situated in the vicinity, or in other parts of the world, which from analogy enable you to understand their general mode of occurrence, their recognized methods of extraction and their probable origin. We are not endowed with a sense which enables us to see through a piece of rock, and the mechanical means which have so far been elaborated—magnetic surveys, diamond and other drilling, stripping cross-cut pits and shafts are both expensive and laborious methods of acquiring uncertain information. You must consequently be well acquainted with the use and abuse of these methods so that you can employ them as useful tools for aiding your judgment and keep continually aware of their strict limitations.

In whatever branch you may be occupied one thing above all others will be required of you, and that is, that you embody your observations or findings in a clear, logical and concise report. To few is given the gift to do so, therefore the greater the necessity of acquiring the habit of study. It is of equal advantage to the writer and to the recipient, as it compels the former to recapitulate and arrange in his mind the data for which he is responsible, whilst for his superior or employer the reports are the best means for gauging his capacity and character irrespective of the value of the report as regards the matter in hand.

A knowledge of book-keeping and store and stock-keeping should be acquired. The methods are simple, and proper organization immensely facilitates one's work and prevents waste and worry.

And, finally, if you have discovered and developed a mine, extracted, concentrated under economical conditions a valuable ore, this is only the first step in making the metal therein contained available for human use. It now has to undergo a refining process and be converted into a shape such as is required by the market.

This involves an entirely new state of affairs. Up to this stage all the necessary operations have had perforce to be carried on in close proximity to the mines so as to reduce to a minimum the transport of waste material.

In the refinery the ore is only one of several raw materials. It is usually the most valuable, and hence best able to stand heavy transportation charges. Others, such as fuel, fluxes, power, acids and other chemicals are more bulky and mostly less valuable than the ore. Proximity to the readiest means of transportation giving access to the world's markets for the finished products and bye-products will be the determining factor of its location.

Refineries are also associated with a large number of cognate industries who draw upon the refinery for their raw material. Their proximity not only reducing cost of transporting, but also enabling the consumer to speedily obtain rectification of errors and attention to his individual requirements an element of the utmost importance in the rational and logical development of an industry.

Those of you who will hereafter be associated in the manufacture of the numerous alloys of iron, will learn the part the composition of your ore will play in the subsequent usefulness of the pig iron produced. How phosphorus silicon, manganese, chronium, tungsten, titanium nickel and vanadium, not forgetting carbon will essentially alter its character. Even the student of history and political economy will be surprised at the overwhelming importance the use of metals has played both in the ancient and the most recent times, even as the neolithic stone age was conquered by copper, this by bronze, and that by iron and steel. We find that in the 17th century the adoption of coal by the iron industry abolished the iron industry of the South of England, and drove it into the coal fields. Mr. Gilchrist Thomas' invention of the basic, instead of the acid lining of the open hearth furnace enabled Germany to build up its immense iron industry on the phosphate iron ores of the Rhenish Province, Westphalia and Luxemburg. The celebrated Saracenic Damascus blades of the time of the Crusaders owned their excellence to an admixture of nickel which now again is used in our most powerful engines of war.

The search for ores and refining of metals provided one of the earliest means of human interchange. We learn that Egyptian Kings of the 3rd Dynasty about 4,000 B.C. secured copper ores in the Sinai peninsula. We have plans and workings of the time of Seti of the XIX Dynasty about 1300 B.C., Crete and Cyprus grew rich on copper, Athens on the lead silver mines of Laurin. The Etruscans based their industry on their copper and tin mines, the Phoenicians sought gold in Africa and tin in Cornwall. The Romans worked tin, gold, silver, lead and copper mines over the whole of their Empire up to its confines in Northumberland and Spain, and in turn the Spaniards overthrew the Empire of the Inca s and Aztec's in their search for gold on the South American Continent. German miners brought over by Queen Elizabeth revived the mining industry of England, and thence the mines of the most distant parts of the world, from the Yukon to Tasmania, have had to yield their share of the world's riches.

And through these ages the advance of metallurgy can be traced through the successive recognition of the elements of which middle ages are composed. From the middle ages onward before which only the four elements of Aristoteles were admitted each succeeding generation succeeded in isolating, and hence learning to separate from additional metal or element, and this process is so far from being exhausted that my friends, Lord Rayleigh and Sir William Ramsay, only recently succeeded in finding in ordinary air a new constituent gas, organ which constitutes nearly one-hundredth part of its volume, whilst subsequently Sir William Ramsay has succeeded in finding some three more. Uranium has yielded radium to Madame Curie, Bismuth polonium and thorium actinium, whilst my friend, Sir William Crookes, has still quite a number of undefined rare earths of the Didymia-Yttria type awaiting complete isolation.

Complete analysis of the metal-bearing constituents of the Igneous rocks have taught us of the wide dispersion of the elements in the earth's crust, whilst the recent application of such rare elements as Thorium and Cerium to the incandescent gas mantel, as discovered by Dr. Auer, from Welsbach, plainly teaches the impossibility of predicting the useful application of an obstruse scientific discovery, which is equally borne out by the recent industrial application of Osmium and Tantalum to electric lighting.

These recent discoveries should be auguries of great hope to all of you, demonstrating the great harvest that awaits a reaper and which can only be garnered by undeviating devotion and application to the subject of one's study. No reaction is so obstruse and no object so insignificant that a diligent study will not yield a rich reward to the searcher. The collection and classification of a few petrefactions and fossils has enabled us to actually determine the relative successions of the layers of the earth's crust, and just as finding a few fossils characteristic of the strata underlying the coal will convince us of the futility of further search for coal similarly the determination of the beds overlying it will give you the desired indication.

The way which has to be traversed from the experimental determination in a scientific laboratory to the practical application on a large scale under technical conditions is a long one and fraught with many difficulties. The peculiar aptitude of mind which is best adapted for solving scientific problems in the laboratory is only very rarely accompanied by the power of expansion and assimilation required by the new set of factors involved by operations on a technical scale. Hence no new process fresh from the laboratory can hope for success unless those who take it in hand have both knowledge and perseverance which will enable them to laboriously and systematically grapple with the difficulties as they arise, and use their accumulated experience to the solution of the problem. It has often been said that we only learn by failure. Unfortunately in technical processes no records of the failures are extant from which we might learn what to avoid. Hence we see many promising processes involve the ruin of their inventor, whilst in subsequent years the same process may become one of world-wide adaptation, and if we search for the cause we frequently find that another invention of an entirely different nature has bridged a gap or made some operation economically possible. I might give you as an example the improved treatment of the extraction of gold from the ores, first by the introduction of the cyanide process; secondly, by the application of this process to still poor and formerly unremunerative ores by the adoption of a new and more economic crushing apparatus, namely, the tube mill instead of the battery stamp. Neither of these have any reference to the cyanide process, yet a more efficient crusher has materially increased our resources. I could cite you many similar examples, and also the converse, where some new invention has facilitated a large number of known processes such as application of electricity as a motor power to scattered units, or to the application of steel specially prepared for armour piercing shells to the jaws of the stone crusher, or the application of ice-making machinery to shaft sinking and quicksand.

In this connection I may be permitted to refer to my father's discovery of the extraction of nickel from its ores by the nickel carbonyl process.

My father, Dr. Ludwig Mond, had devised a method for obtaining hydrochloric acid directly from the ammonium chloride, which is a by-product of the ammonia soda process.* The method consisted in passing the vapour of $NH_4Cl$ over magnesia, and the apparatus was fitted with nickel valves, because this metal is not acted upon by the vapour of $NH_4Cl$. On the laboratory scale these valves worked perfectly, but on the manufacturing scale they became covered by a black crust of carbon and became leaky. This was traced to the presence of a trifling quantity CO in the large scale plant and this led to the investigation of the action of nickel on carbon mononide. This finely divided nickel reduced by hydrogen at a temperature of 400°C was treated with CO in a glass tube at varying temperatures for a number of days, and was then cooled down in a current of CO. To get rid of the poisonous CO the gas was lit as it escaped from the apparatus. When the apparatus was cooling down the gas became luminous, and increased in luminosity as the temperature fell below 100°C. On a cold plate of porcelain put into this luminous metallic spots were deposited similar to the spots of arsenic in Marsh's test. On treating the tube through which the gas was passing a metallic mirror was obtained and the luminosity disappeared. These mirrors were found to consist of pure nickel. The best results were obtained by treating nickel with CO at 50°C, and by passing the gas so obtained through a tube cooled with snow and salt liquid nickel carbonyl was obtained, freezing at —25°C, boiling at 43°C and decomposing at 150° into its components, CO being set free and nickel being deposited as a dense metallic film on the side of the vessel in which it is heated. A large plant was erected near Birmingham to utilize these discoveries for the production of nickel from Canadian nickel copper matte from Sudbury.

The matte which contains 40% nickel and an equal quantity of copper is carefully roasted to drive off sulphur, and is then subjected to the action of water gas or producer gas rich in hydrogen in an apparatus called a "reducer", at a temperature never exceeding 400°C. From this apparatus the substance now reduced to the metallic state is carried to the "volatilizer", in which it is subjected at a temperature not exceeding 80°C to the action of CO gas.

The CO gas charged with nickel carbonyl leaving the volatilizer is passed through tubes or chambers heated to 180°C, in which the nickel is deposited and the CO is used over again.

But the main lesson brought out by these considerations is the interrelation of all branches of human knowledge and endeavor. We all and each one of us are conscientiously or unconscientiously increasing the scope of human knowledge, and the more facile we are in the task allotted to us, and in seeking for the truths with a single "I", the further shall we proceed in the direction of increasing the productivity of the individual, assuring him of a greater share in the world's goods and of leisure to partake of them, while his work shall become his most enjoyable occupation.

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# A PLEA FOR THE BUSINESS TRAINING OF THE ENGINEER

R. A. ROSS, E.E., (Toronto).

The only justification in the eyes of the community for the existence of the engineer are the results which he obtains. His business is a purely utilitarian one, the object being the production of value. Value is not measured by the cost of an engineering construction, but by the results obtained therefrom when used as a tool for the extraction of dividends. The value of the engineer to the community being determined by the results obtained from his engineering, it becomes pertinent to inquire when such results are shown. These become apparent only when the work for which he was responsible has been in operation for a time and operating profits or losses can be determined.

Without drawing the lines too closely there may be conceived to be three stages in the life of an enterprise:

1. The scientific—when the tool is forged by the engineer.
2. The business—when methods of using the tool are evolved and used.
3. The economic—when the results of the tool and its handling become apparent.

The engineer as a purely technical man will consider his work done at the end of the first stage, leaving to other hands the completion of the task and the obtaining of results therefrom. This tendency is fathered by the purely technical nature of the training which he has received, fostered by a lack of business knowledge in which he finds himself deficient and ingrained in his system by the attitude of the business world towards him, which believes the engineer to be lacking in business ability whereas it is only lack of training and confidence.

The general result so far as the engineer is concerned is that by keeping his nose so closely to the technical grindstone he has little opportunity, or even desire, to look up and see what the larger business world is doing with his product: he therefore does not take his real position in the scheme of things and attract that attention to himself and his profession which he should, nor does he do that full justice to the community which has educated him, and which has a right to demand the highest dividend possible on capital invested in his training.

No remark is more frequently heard, especially among financial and business men, than that the engineer does not understand business. And this is in general true. He is therefore hired by a company, and regarded by it merely as a species of glorified plumber. He constructs the tool with which the

*Mr. Ross is of the firm of Ross and Holgate, Consulting Engineers, Montreal, and has recently been engaged to deliver a course of lectures on the Business of Engineering, at McGill University.

financial man works and without which he could have no standing in the community, and being given this tool he is able to bring business methods to bear and produce results, for which he and not the engineer is given credit and reward.

The engineer is a man with a trained mind, trained to logical reasoning and deduction, brought up on good, old Euclid, thoroughly grounded in rigid scientific principles and taught to think straight. If, therefore, he applies his logically trained mind to business and economic matters with one-half the diligence which he exercises in his purely engineering functions, it is difficult to see why he should not obtain better results than the business man who generally has had no real training in business, but has absorbed such knowledge as he possesses from the business atmosphere surrounding him—does not read, study, or examine into the real reasons of things, and knows only business usage and custom. If this be doubted, inquire from business friends as to the amount of reading and real study they have given to business matters, it will be found to be inconsiderable. As a matter of fact, the engineer side-steps a business proposition whenever he can, stating in effect, if not in words, that his business is engineering and leaves the business of what should be his work to others, when given a certain amount of study and courage he could settle these questions satisfactory for himself and to the benefit of the public. The reason for this attitude on his part toward the field which promises him an improved status as a citizen, a broader knowledge of the world at large, and increased dividends, is to be found in the fact that the business part of his training is not taken up or even hinted at during his college course.

It is, of course, impossible that an art such as business is can be taught in a college devoted to science, but neither can the art of engineering be taught there. Whether there is a science of business is very questionable. There is certainly nothing in the nature of an exact science, nor even of an approximate science, but there are certain laws and general principles which if absorbed by the student during his college course would give him a different outlook and broaden his horizon. He would at least learn that there is nothing weird and incomprehensible in ordinary business terms or business methods and therefore be encouraged to extend his field of operation beyond the technical so as to embrace the business and economic end of the subject.

If, however, through lack of ability or aptitude in business matters, or through the bent of his mind being purely scientific, he does not find an opportunity to expand in the direction indicated, yet he will at least be able to understand the terms used, and to talk intelligently to men in the business world.

This expansion of the Engineer's sphere of usefulness is evidenced in the career of certain engineers in other countries who, beginning as purely technical men, have since launched out into contracting, and finally added financing and operating, so that they in their business have forged the tools, have used them and have obtained results, and the credit and returns are all theirs.

The rapid expansion of industrialism is making its demands for trained men felt more and more, and engineers are being chosen for administrative offices in large corporations and as the directing forces in large enterprises, and this tendency must of necessity increase, and who are better fitted to operate under directions of the laws of men and with a knowledge thereof than those who have built well under the much more rigid and exacting laws of nature.

In any system of engineering training, science must of necessity be the foundation, but upon this foundation the engineer may erect a superstructure which will be visible to the public, and attract attention to the fact that he is a power in the community. This superstructure, which may readily be a part of engineering, is dedicated to the business and financial departments of his business; without the foundation the structure is useless, but the foundation itself not being visible receives precious little attention from the community when the building is complete. The basement rentals are also low.

The institutions wherein engineers are taught must in justice to the profession keep pace with this tendency, and that they are beginning to do so is evidenced by the fact that a number of colleges in other countries have added to their purely technical studies a course on the business and economic aspects of engineering. In this country, McGill is about to set the example, and it would appear that the other technical schools will have to follow suit or their graduates will be distanced in the race for preferment.

There are two arguments against adding a course of this kind to the curriculum of a science school—

1. That the students are already overburdened with work.

2. The reluctance of the authorities to teach anything but science.

As regards the first, it seems to be a question as to whether certain of the more purely scientific studies could not if necessary be dropped in favor of the more practical course here-advocated, but it is thought that this may not be necessary as a fairly extensive course can be given, covering only the principles of business, without overburdening the student, for the reason that his training having been along rather strenuous lines, demanding a high degree of concentration, the study of the mechanism of business will be found to be child's play by comparison.

The second objection can be met by asking whether the college is not for the inculcation of principles. If this is true as regards science, why not as regards the business of engineering.

The engineer as he develops and gets away from purely technical routine work is supposed to be able to draw up specifications, make contracts, hire and direct labor, and report on properties. These are within his legitimate field as at present understood, and yet all of these demand that he should have in reason a knowledge of money and values, of business methods and some knowledge of law, and that he should be able to present his reports in such a way as to be readily understood by business interests.

The mere expansion of these functions with the same knowledge of principles brings him to a point where he should be able to present a financial scheme for the consideration of financial people, and practically to act as their engineer, promoter and director of the scheme at its inception and thereafter. He should be able to operate it to a successful issue, to obtain commercial results and dividends. To this end, in addition to the knowledge of business which the engineer should have to enable him to draw up specifications, contracts, etc., he should have a knowledge of the general business methods of the community in which he lives. He should understand something of stocks, bonds, bills of exchange, notes, the formation of companies, of partnerships, the general laws relating thereto, the functions and powers of different corporation officials, and the method of incorporating companies. These are matters, the principles of which an engineer trained to study can acquire. To practice is of course a different matter, and results will depend upon his ability in dealing with the world as a business proposition.

His scientific training has taught him to deal with the laws of nature. His business training should teach him how to deal with men and money and the laws relating thereto. Business has not been taught or developed as a science, and it is therefore considered an art, and ability therein can only be developed by practice. But this is so even in engineering, the science of which is taught in the colleges and the art developed later in the larger world of practice.

It is not expected, nor is it desirable that the engineer should by thus expanding his functions, eliminate the lawyer or financier. But his knowledge of business should on the other hand indicate the necessity for these gentlemen's services, and above all show just when and where their services are needed and enable him to appreciate them at their proper value when given.

In short a business training should develop a new view of his relations to other professional men and place him in the position of engaging their services rather than acting as their servant.

The engineer is a utilitarian to a commanding degree and much more so than the other professional men, such as the doctor, lawyer and clergyman. The lawyer is a special pleader and does the best he can with the case given him. The doctor buries his mistakes. The clergyman deals in the future, but the engineer has to deliver the goods and the goods have to be commercial, therefore why restrict an engineer's education to purely scientific subjects, and why not expand his horizon to enable him to take the position in the community which he deserves and can command, and enable him to reap the rewards both in credit and dividends for which such training fits him.

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## NOTES ON BRICK AND BRICK PIERS.

P. GILLESPIE, B. A.Sc.

A close approximation to uniformity in physical properties is not usually revealed by a series of tests on bricks in which raw material and method of manufacture are known to be substantially the same. Bricks taken from the same locality in a kiln will show results in testing which differ by considerable magnitudes. If different experimenters have operated, the results will differ much more widely. With steels and irons on the other hand, much greater uniformity is found where circumctances lead us to believe uniformity exists. Results obtained from tests on samples of these materials in cases where the process is known to be constant, differ by probably ten per cent. at the outside. What is the explanation of the difference?

In the first place, this phenomenon is due to lack of uniformity in the clay product; in the second place, to the fact that the methods of conducting tests on bricks have not been standardized to the same extent as tests on steels and irons have been. An illustration will make this clear. In conducting the crushing test, some operators employ steel plates. Some crush between cushions of blotting paper while others imbed in a batter of neat cement or of plaster of Paris. Manifestly, even if the material *were* of uniform quality, comparable results would under such diverse methods of manipulation, be very difficult of attainment. To illustrate the effect of such non-uniformity of method, a series of tests reported in Tests of Metals, 1901, is valuable. Crushing tests were made on nineteen varieties of brick, each variety being tested in three different ways, viz.—with a plaster of Paris bedding, between cardboard cushions, and between pine boards. The first method in most cases gave the greatest strength and the last the least. Of course there are exceptions, but in a range covering nineteen varieties, the general conclusion will be significant.

## RESUMÉ OF RESULTS.

| | Mean Strength pds. per sq. in. | Relative Strength. |
|---|---|---|
| **Tests of Whole Bricks—** | | |
| **Plaster Bedding** | 9,060 | 100 |
| **Cardboard Cushions** | 7,380 | 81 |
| **Pine Cushions** | 5,480 | 60 |
| **Tests of Half Bricks—** | | |
| **Plaster Bedding** | 5,640 | 100 |
| **Cardboard Cushions** | 4,430 | 79 |
| **Pine Cushions** | 4,540 | 81 |

Suppose, now, these details of method and other local settings are unknown. Suppose that different experimenters have obtained these results by different methods and, as is often the case, have neglected to state the *modus operandi*. How much accuracy in such an instance would the ordinary layman's opinion contain?

The reports of the Watertown arsenal, extending over a period of many years, contain a vast amount of experimental data on bricks and brick piers as well as on other materials. Conclusions, however, are rarely drawn and deductions from experiments seldom appear in these volumes. The reader is left to make his own generalizations, which task where data are insufficient is sometimes a difficult one indeed. At the outset then, one must be careful as to what conclusions can in fairness be drawn. If the data concerning the tests be meagre; if the results have been obtained by different operators; if the methods and materials have not been identical, and finally if the number of experiments be not large, generalizations must be made with the utmost caution. The purpose of this short article is to examine the records of tests on brick and brick masonry with a view to showing some of the peculiarities and limitations of the latter and the precautions which in manufacture or construction contribute to its strength.

In order first of all to get a conception of the position occupied by brick among the various materials employed in masonry construction, crushing strength alone considered, the following table has been compiled. The data have been selected from the records of experiments conducted in the Engineering Laboratory here on Canadian building materials at various times during the past ten or twelve years. As the method of conducting the tests has been uniform throughout, it is believed that the values given are indicative of the strength of the materials tested and enable us to place them in something approaching their true relative positions.

| | | | |
|---|---|---|---|
| Concrete Blocks | 400 to 1,500 | lbs. per | square inch |
| Sand Lime Brick | 1,250 to 3,600 | " | " |
| Soft Burned Clay Brick | 1,000 to 2,000 | " | " |
| Hard Burned Clay Brick | 2,000 to 5,700 | " | " |
| Pressed Brick | 3,500 to 5,400 | " | " |
| Vitrified Paving Brick | 6,000 to 13,000 | " | " |
| Roman Stone (Artificial) | 1,500 to 5,000 | " | " |
| Credit Brown Sand Stone | 10,000 to 15,000 | " | " |
| Granite, New Brunswick | 15,000 to 16,000 | " | " |
| Longford Limestone | 19,400 to 22,300 | " | " |

## POROSITY AND STRENGTH.

In the Report of Tests of Material collected at the Louisiana Purchase Exposition, St. Louis, Mo., 1904, may be found the record of upwards of 400 compression tests conducted on many different varieties of brick representing all sections of the United States. On some 113 of these, absorption tests were also made, and these too are reported. The times of immersion averaged 15 days. A study of the relation between porosity and crushing strength is interesting. That the absorption test has a value in determining the hardness or degree of burning for different deliveries of the same kind of brick is generally conceded. That it is of very much less value in comparing bricks from different localities and by different manufacturers is also pretty generally acknowledged. To some extent, the absorption is a criterion of the crushing strength. The 113 absorption tests furnished the data for a plot, the ordinates being crushing strength and the abscissae the percentage absorption. A study of this plot reveals a kind of hyperbolic relation connecting the two variables. Where the absorption is high, the strength is likely to be low. Whether it is permissible to reduce to a formula, a law with which 50% of the determinations disagree to the extent of 20% or less in either direction, may well be doubted. There is, however, a *tendency* of which this is a rough expression—

$$p\,a = 65{,}000$$

where $p$ is crushing strength in pds. per sq. in. and $a$ is percentage absorption.

It should be observed, too, that as different methods of conducting both the compression and absorption tests will modify results, it will be scarcely fair to apply this rule where the method of conducting either test is radically different from that adopted in the tests referred to. The following illustrations are taken at random from the Report:—

| BRICK | Absorption | Strength Lbs. per sq. in. |
|---|---|---|
| Dark buff | 6.2% | 8,620 |
| Common red | 13.9 | 4,700 |
| Light red, face | 20.4 | 3,050 |
| Dark red, paver | 3.5 | 11,990 |
| Light gray, sand lime | 13.2 | 5,280 |

The extent of the disagreement with the formula in two selected cases is shown in the following:—

| BRICK | Absorption | Strength Lbs. per sq. in. |
|---|---|---|
| Red, Laclede paver........ | 1.0% | 4,850 |
| Dark red, vitrified........ | 13.7 | 13,560 |

## WEIGHT AND STRENGTH.

From the following table representing but eight tests conducted on dry-pressed and mud brick, it appears as though there is also sometimes, a relation between weight and strength.

| BRICK | Weight per cubic foot | Crushing Strength lbs. per sqare in. |
|---|---|---|
| Dry Pressed........ | 128.3 | 10,300 |
| do ........ | 127.2 | 8,740 |
| do ........ | 124.3 | 5.940 |
| do ........ | 119.8 | 3,480 |
| Mud ........ | 144.3 | 19,170 |
| do ........ | 136.4 | 15,670 |
| do ........ | 130.6 | 10,420 |
| do ........ | 125.4 | 10,870 |

In this series, the strength is apparently nearly proportional to the excess of weight over 114 pds. per cu. ft. The relation

$$p = \frac{2000}{3}(W - 114)$$

where $p$ is the crushing strength and $W$ is the weight in pds. per cubic foot will be found to give values fairly close to those given in the table. It is not for a moment supposed that this relation has an extensive application. It is just possible though that for bricks from the same locality and of the same process of manufacture, some such relation might be found to exist. The numerical constants would doubtless vary quite widely in different cases, and their determination would entail the examination of many individual cases.

Mr. James Howard in the Proceedings of the American Society for Testing Materials, 1907, reports a test conducted on a vitrified shale brick manufactured by the St. Louis Vitrified and Fire Brick Company, whose crushing strength reached the phenomenal figure, 38,446 pds. per sq. in. This is the highest crushing value that has come under our notice and indicates the great possibilities for strength possessed by clay products. Howard reports also a crushing test on a brick pier of 5,608 pds. per sq. in., probably one of the greatest on record. He believes too, that the maximum of strength has not yet been reached and looks for higher results from the use of some of the stronger brick which are now on the market. That such may be possible is evidenced from the fact that the greatest strength in piers, as will be subsequently seen, has been obtained from a combination of the strongest cement jointing and the strongest brick.

## MORTAR JOINTING A VARIABLE.

The superiority of cement mortar over lime mortar is well illustrated in the following series of tests reported by the Watertown Arsenal for 1904. In the tabulated results it will be observed that in the case of each kind of brick, supposedly the same in structure and manufacture, three kinds of jointing were employed, viz.: Neat Portland cement, a cement-sand mortar, and a lime-sand mortar. The piers were substantially alike in height and method of construction. From other data published in the same volume, the average crushing values of the bricks (plaster of Paris bedding) have been obtained and are included in the table. The relative strength of pier and brick in each case has been computed also. The piers were 12″ × 12″ × 8′ high.

| Pier. | Jointing. | Age. | Strength of Pier, yards per square inch. | Strength of Brick, yards per square inch. | Strength of Pier in Terms of Strength of Brick. |
|---|---|---|---|---|---|
| Face, dry-pressed | Neat Cement | 1 mo. | 2,880 | 9,490 | .30 |
| do | 1 C : 3 S | 6 mo. | 2,400 | " | .25 |
| do | 1 L : 3 S | 6 mo. | 1,517 | " | .16 |
| Face, repressed | Neat Cement | 6 mo. | 1,925 | 6,780 | .28 |
| do | 1 C : 3 S | 6 mo. | 1,670 | " | .24 |
| do | 1 L : 3 S | 6 mo. | 1,260 | " | .18 |
| Face, wire cut... | Neat Cement | 6 mo. | 4,021 | 13,720 | .29 |
| do | 1 C : 2 S | 1 mo. | 2,410 | " | .18 |
| do | 1 L : 3 S | 6 mo. | 1,420 | " | .10 |
| Hard, W. Cambridge... | Neat Cement | 1 mo. | 4,700 | 10,490 | .45 |
| do | 1 C : 3 S | 1 mo. | 1,800 | " | .17 |
| do | 1 L : 3 S | 6 mo. | 991 | " | .09 |
| Light Hard W. Cambridge... | Neat Cement | 1 mo. | 1,510 | 7,090 | .21 |
| do | 1 C : 3 S | 6 mo. | 1,519 | " | .21 |
| do | 1 L : 3 S | 6 mo. | 732 | " | .10 |
| do | 1 L : 3 S | 5 mo. | 809 | " | .11 |
| Hard, East Brookfield.. | Neat Cement | 6 mo. | 1,969 | 4,840 | 40 |
| do | 1 C : 3 S | 6 mo. | 1,800 | " | .37 |
| do | 1 L : 3 S | 6 mo. | 733 | " | .15 |
| do | 1 L : 3 S | 5 mo. | 866 | " | .18 |
| Light Hard, East Brookfield.. | Neat Cement | 6 mo. | 1,061 | 4,470 | .24 |
| do | 1 C : 3 S | 6 mo. | 1,224 | " | .27 |
| do | 1 L : 3 S | 1 mo. | 465 | " | .10 |
| Hard, Mechanicsville... | Neat Cement | 6 mo. | 1,400 | 5,810 | .24 |
| do | 1 C : 3 S | 6 mo. | 1,411 | " | .24 |
| do | 1 L : 3 S | 6 mo. | 718 | " | .12 |

From the above, we obtain the following averages:—

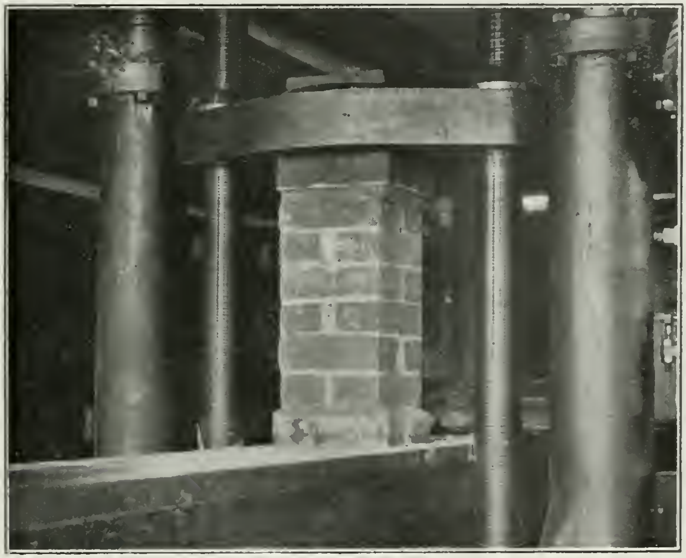
Strength of Pier in Terms of Strength of Brick.

When laid in neat cement, 30%.
" " cement mortar, 25%.
" " lime mortar, 13%.

These may be expressed in terms of the weakest as follows:

Pier having lime mortar, 100.
" " cement mortar, 192.
" " neat cement, 231.

The slight lack of uniformity as to age is not specially significant. A uniform age of six months would doubtless have made these average perecntages somewhat more divergent. It will be observed that weak bricks with a strong jointing or



Brick Pier—Before Crushing

strong bricks with a weak jointing give strengths in piers less than when bricks and mortar are of the strongest possible kind.

A comparison of costs for piers similarly laid is interesting. Brick work laid with 3/8" to 1/2" joints requires 1-3 cu. yd. of mortar per cu. yd. of masonry. If we assume lime at 30c per hundred pounds, sand at 50c per cubic yard, cement at $1.50 per barrel, and labor at current rates, we will find the prices of mortar to be substantially as follows:—

Lime one, sand three, $1.75 per cu. yd.
Cement one, sand three, $3.93 per cu. yd.
Neat cement..........$11.60 per cu. yd.

If the cost of the lime-sand brickwork be assumed to be $8.50 per cu. yd., that of cement-sand brickwork will be $9.23, and of neat cement brickwork, $11.78 per cubic yard. The relative costs will be:

Brickwork laid in lime mortar, 100.
" " cement mortar, 109.
" " neat cement, 139.

From this, it would appear that for the prices assumed, an increase in cost of 9 per cent. through the use of Portland cement will give an increased strength of 92 per cent, and that from an increased outlay of 39 per cent. the strength is augmented to the extent of 131 per cent. These are ample returns indeed and if strength be a desideratum, the use of Portland cement in the

Brick Pier—After Crushing

mortar jointing is an economical method by which to secure it. Outside of experimental laboratories neat cement mortar is almost never used. Moreover, mortars high in cement do not trowel as nicely as those containing lime. In cases where working stresses are low, and where water is not likely to be encountered, the lime mortar jointing for brick masonry will commend itself because of its cheapness.

## AGE A VARIABLE.

An examination of the results of tests with a view to discovering the effect of age on the strength of piers supposed to be of the same material and method of manufacture, shows that in most cases the strength increases with age. The exceptions to the general rule can usually be attributed to differences in material or structure that were not at first known to exist. The unwisdom of making general inferences from few examples must be guarded against. Indeed it is sometimes observed that differences in strength in a series of tests, where there is no intentional variable, is about as marked as where the age varies greatly. From Tests of Metals, 1907, the following are taken :—

Piers of Johnsonburg Pavers laid in neat cement.

| Test No. | Age | Strength | Relative Strength |
|---|---|---|---|
| 1760 | 4 days | 4,218 lbs. per sq. in. | 100 |
| 61 | 7 " | 5,608 " " | 133 |
| 67 | 1 month | 4,281 " " | 101 |
| 68 | 1 " | 5,003 " " | 118 |

Piers of Shawmut Pavers laid in neat cement.

| Test No. | Age | Strength | Relative Strength |
|---|---|---|---|
| 1762 | 4 hours | 2,106 lbs. per sq. in. | 100 |
| 63 | 2 days | 3,733 " " | 177 |
| 64 | 7 " | 4,514 " " | 215 |
| 80 | 4 months | 4,089 " " | 195 |

Piers of Wire cut Red Brick.

| Test No. | Age | Mortar | Strength | Relative Strength |
|---|---|---|---|---|
| 1820 | 5 months | 1C : 1S | 2,300 lbs. per sq in. | 100 |
| 1816 | 24 " | 1C : 2S | 3,662 " " | 142 |

In this last instance, the added strength is due doubtless to the stronger mortar as well as to the increased age. There seems to be little doubt that age will contribute strength to brick masonry. That mortar increases in strength with age is well authenticated by numerous experiments and general observation, and since the strength of brick masonry is dependent partly on the character of the jointing, this inference is quite logical. It is probable that the variation would be more marked with lime than with cement mortar.

## WORKING STRESS ON BRICK MASONRY.

From the cases previously cited, the average crushing strength of matured brick piers laid in 1-3 lime mortar is about 80 tons per sq. ft., and for 1-3 cement mortar, 140 tons. A safety factor of 10 will give working stresses of 8 and 14 tons per sq. ft. respectively and these, having regard to indeterminate irregularities in both workmanship and material, do not seem too large. In many cases, the direct compressive stress on brick masonry due to its own weight only, is but a small fraction of its ultimate crushing strength. A brick wall of uniform thickness weighing 125 lbs. per cubic foot would need to have a height something in excess of 1200 feet in order to exert by its weight alone, a crushing stress of 80 tons per sq. ft. at the base. In buildings where roof and floor loads are carried to walls or piers and supported thereby, high compressive stresses may be developed in the masonry. Wind action, on walls and chimneys for example, produces additional compressive stresses on the leeward side and possibly tensile stresses on the windward. Baker cites a case of a brick chimney in Glasgow, Scotland, 468 ft. high at the bottom of which the stress due to dead load alone is 9 tons per sq. ft. It is estimated that in heavy gales this is increased on the leeward side to 15 tons per sq. foot. Roof and arch thrusts operate outward and earth pressures inward in certain cases, both giving rise to secondary stresses. These considerations will serve to show that stresses exceeding those due to direct loading only, have frequently to be provided for, and where these additional stresses cannot be computed, a wider margin of safety must be allowed. A reference to the building codes of several representative American cities shows the following to be the maximum permissible stresses for brick masonry. The stresses are given in tons per sq. ft.:

| | Boston | Buffalo | New York | Chicago | St. Louis | Philadelphia | Denver | Toronto | Montreal |
|---|---|---|---|---|---|---|---|---|---|
| Hard Burned Brick Laid in | | | | | | | | | |
| Portland Cement Mortar .... | | | 15 | 12½ | 15 | | | 12 | 15 |
| Cement Mortar and Lime..... | 12 | | 11½ | | 11½ | 12 | | 9 | 12 |
| Lime Mortar... .............. | 8 | 6 | 8 | 6½ | 11 | 8 | 8 | 6 | 8 |

## HEIGHT A VARIABLE.

In column formulae generally, we observe on the part of the designer, a recognition of the principle that the strength of a post reduces, other elements constant, as the slenderness increases. That the same is true of masonry columns is no doubt true, but the exact place where the effect of slenderness is likely to manifest itself in reduced strength is difficult to determine. The character of the material and workmanship and possible eccentricity in loading while in service are elements difficult of computation.

The Watertown Arsenal Report for 1886 contains a report of a series of tests on fifty-three brick piers, the chief variables being height and sectional area. An effort, somewhat successful, it is believed, was made to maintain brick, mortar and workmanship constant in quality. From these reports, two typical series have been selected, and of these, a summary is given in the tables below:

| Test No. | Height. | Ultimate Strength. Pds per square inch. |
|---|---|---|
| 851 | 2′ | 2,428 |
| 852 | 2′ | 2,117 |
| 853 | 4′ | 2,050 |
| 854 | 4′ | 1,944 |
| 855 | 6′ | 1,950 |
| 856 | 6′ | 1,750 |
| 857 | 8′ | 1,691 |
| 858 | 10′ | 1,677 |
| 859 | 10′ | 1,811 |

| Test No. | Height. | Ultimate Strength. Pds. per square inch. |
|---|---|---|
| 875 | 2′ | 2,327 |
| 876 | 2′ | 2,466 |
| 877 | 4′ | 1,687 |
| 878 | 4′ | 1,950 |
| 879 | 6′ | 1,700 |
| 880 | 6′ | 1,644 |
| 881 | 8′ | 1,461 |
| 882 | 8′ | 1,610 |
| 883 | 10′ | 1,347 |

In order to obtain if possible the law connecting strength and slenderness a plot was made on which strength and the ratio of length to diameter were the co-ordinate axes. The various tests were plotted, each test being indicated by a point. A string stretched taut was then employed to obtain the best average straight line for each series. The equations of the straight lines were then obtained and are given below.

Straight line Formulae for the Strength of Matured Brick Piers laid in 1 C: 2 S Mortar:

Eight inch piers, face brick:

$$p = 2400 - 50 \frac{L}{D}$$

Twelve inch piers, common brick:

$$p = 2100 - 75 \frac{L}{D}$$

where $p$ = ultimate crushing strength, pds. per sq. in.
$L$ = length and
$D$ = diameter.

The agreement between the actual values obtained by test and those given by the equations is rather striking. The following table gives the comparison for the first of the two series. It will be observed that the average error is approximately 5% :

FACE BRICK PIERS.

Comparison between Strength as determined by Actual Test, and Strength as computed by Formulae.

Cross Section, 8″ × 8″; mortar, 1C : 2S; age, 21 mos.

| Height | Actual Strength. Pds. per square inch. | Computed Strength Pds. per square inch. | Error. |
|---|---|---|---|
| 2′ | 2,428 | 2,250 | −7 % |
| 2′ | 2,117 | 2,250 | +6 % |
| 4′ | 2,050 | 2,100 | +2 % |
| 4′ | 1,944 | 2,100 | +7 % |
| 6′ | 1,950 | 1,950 | 0 % |
| 6′ | 1,750 | 1,950 | +10 % |
| 8′ | 1,691 | 1,800 | +6 % |
| 10′ | 1,677 | 1,650 | —2 % |
| 10′ | 1,811 | 1,650 | —9 % |

An examination of the results for the entire series of fifty-three piers shows that the strength varies with the cross-section as well as with the height, from which it would seem that the ultimate resistance depends in some way upon the volume.

The following straight line formulae by Kidder for the working stresses on brick piers evolved "from numerous tests and from some formulas published by Professor Ira O. Baker and from personal observation" are the results of an effort to recognize the column principle. Kidder suggests that they be applied in cases where the length exceeds six times the least diameter.

Safe loads in pds. per sq. in.

Piers laid in rich lime mortar.

$$p = 110 - 5 \frac{L}{D}$$

Piers laid in 1 to 2 natural cement mortar.

$$p = 140 - 5\tfrac{1}{2} \frac{L}{D}$$

Piers laid in 1 to 3 Portland cement mortar.

$$p = 200 - 6 \frac{L}{D}$$

For a pier 10 ft. high and 1 ft. square, the safe loads in accordance with these formulae would be:

4.3 tons if laid in lime mortar,
6.1 tons if laid in natural cement mortar
and 10.0 tons if laid in Portland cement mortar.

## SUMMARY.

1. Bricks of the same material and process of manufacture exhibit considerable variation in physical properties.
2. Results of tests by different experimenters are frequently not comparable owing to difference of method.
3. Where the absorption in bricks is low, the strength is likely to be high, and *vice versa*.
4. The crushing strength is dependent to some extent on the specific gravity of the brick.
5. The strongest piers are those made from the strongest brick in conjunction with the strongest jointing.
6. The use of cement mortar is an economical method of giving increased strength to brick work.
7. The strength of brick masonry improves somewhat with age.
8. The strength of brick piers is a function of their slenderness.

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The following is a reprint of an article published in the Transactions of the Engineering Society in 1896, together with some additional matter. The original paper was prepared by Mr. Jos. Keele, B. A. Sc., as a result of experiments conducted in '95-'96 by himself and Professor C. H. C Wright in the Engineering Laboratory of the School of Practical Science. Subsequent experiments, performed from time to time up to the present, have furnished the additional matter, in the collection of which, the assistance of Mr. W. G. Swan, Demonstrator in Strength of Materials, is gratefully acknowledged.

## BRICKWORK MASONRY.

Results of Tests made in the Laboratory of the School of Practical Science, Toronto, during the session of 1895-6, by Messrs. Wright and Keele.

JOS. KEELE, B.A.Sc.

## BRICKWORK PIERS.

The following tests were made with the object of determining the resistance to crushing offered by piers of ordinary brick, constructed in the same manner and of such materials as those most commonly used in practice in Toronto. These materials will fairly represent those in use throughout the Province of Ontario.

For this purpose a bricklayer and his assistant were engaged to procure from four different brickyards a quantity of each of their grades of bricks, the bricks being taken from the kiln as they came to hand.

The different bricks used were Kingston Road, first, second and third quality; Humber, first and second; Yorkville, first and second; Carleton, clinker and first, and Don Valley pressed brick, buff and red.

An individual test of each class of brick was made to determine its crushing strength and absorption. The absorption test was made as follows: The dry brick was carefully weighed, then immersed in water, and at the end of twenty minutes the brick was taken out, the surface water dried off, and again weighed. The brick was again immersed until the total time of immersion was thirty minutes, and again weighed.

This was the longest time allowed in water, it having been found in former tests of the same nature that the absorption of water by the brick is practically complete in thirty minutes.

The table of absorption is given below:

| Kind of Brick | Weight Dry | | Weight after 20 min. in water | | Weight after 30 min. in water | | Absorption in ounces | Absorption in p.c. |
|---|---|---|---|---|---|---|---|---|
| | lbs. | oz. | lbs | oz. | lbs. | oz. | oz. | |
| Kingston Road, 1st class..... | 5 | 5¾ | 6 | 0 | 6 | 0 | 10¼ | 11.9 |
| " " 2nd " .... | 5 | 5½ | 6 | 2¼ | 6 | 2¼ | 12¾ | 14.9 |
| " " 3rd " .... | 5 | 1¾ | 6 | 2¼ | 6 | 2¼ | 14¼ | 17.1 |
| Carlton Clinker.............. | 5 | 0¼ | 5 | 10 | 5 | 10½ | 10¼ | 12.7 |
| " " 1st class...... | 5 | 0½ | 5 | 13½ | 5 | 13¾ | 13¼ | 16.4 |
| Yorkville, 1st class.......... | 4 | 10½ | 5 | 11¾ | 5 | 11¾ | 17 | 22.7 |
| " 2nd " .......... | 4 | 11¾ | 6 | 0 | 6 | 0 | 20¼ | 26.7 |
| Humber, 1st class............ | 5 | 7½ | 6 | 2½ | 6 | 2½ | 11 | 12.6 |
| " 2nd " ............ | 5 | 8 | 6 | 6¾ | 6 | 4¾ | 14¾ | 16.7 |
| Don Valley Pressed, red...... | 5 | 13¾ | 6 | 6 | 6 | 6½ | 8¾ | 9.3 |
| " " buff.... | 5 | 0 | 5 | 15½ | 5 | 15¾ | 15¾ | 9.7 |

To ascertain the crushing strength of each quality of brick, two fair and sound samples were selected and bedded between thin layers of Portland cement, thus giving two parallel planes without injury of any kind to the brick.

Ultimate Crushing Strength of Common and Pressed Brick

| Class of Brick | Height | Area Exposed to Crushing in inches | Area sq. ins. | Ultimate Load in pounds | Crushing Strength in lbs. per sq. in. |
|---|---|---|---|---|---|
| Kingston Road, 1st class.... | 2½ | 8¾ x 4 | 35 | 132,400 | 3,783 |
| " " 2nd " .... | 2½ | 9 x 4⅛ | 37 | 62,000 | 1,670 |
| | 2½ | 8⅞ x 1⅛ | 36.6 | 63,000 | 1,721 |
| " " 3rd " .... | 2⅝ | 9 x 4⅛ | 37 | 67,600 | 1,821 |
| | 2⅝ | 8⅞ x 4⅛ | 36.6 | 68,000 | 1,857 |
| Carleton Clinker........... | 2½ | 8⅝ x 3⅞ | 33 4 | 190,000 | 5,685 |
| " " 1st class... | 2½ | 8¾ x 4 | 35 | 112,000 | 3,200 |
| Yorkville, 1st class........ | 2⅝ | 8⅝ x 4 | 34.5 | 160,000 | 4,637 |
| " 2nd " ....... | 2½ | 8¾ x 4 | 35 | 107,000 | 3,057 |
| | 2½ | 8¾ x 4 | 35 | 112,000 | 3,200 |
| Humber, 1st " ....... | 2¼ | 8⅞ x 4 | 35.5 | 43,400 | 1,222 |
| | 2½ | 8⅝ x 4 | 34.5 | 50 000 | 1,449 |
| " 2nd " ...... | 2½ | 8⅞ x 4¼ | 36 6 | 72,000 | 1,966 |
| | 2½ | 8⅞ x 4¼ | 36.6 | 61,000 | 1,748 |
| Don Valley, red .... ..... | 2⅜ | 8⅜ x 4 | 34 3 | 184,000 | 5,372 |
| " " buff ......... | | 8½ x 4⅛ | 35 | 125,000 | 3,571 |

The piers were built by a skilled bricklayer, who also provided the lime mortar, which consisted of $4\frac{1}{2}$ yards of Bloor street coarse sand to ten barrels of lime, this being about the proportion of two parts sand to one part lime. The cement mortar was mixed in the proportion of three parts sand to one part of good Portland cement. While the piers were being built, two cubes of each class of mortar were prepared and set aside for the purpose of ascertaining their resistance to crushing, thus giving a complete record of all the materials used.

Ultimate Crushing Strength of Mortar, 2½ months old

| Class | Height in inches | Area Exposed to Crushing in inches | Area sq. ins. | Ultimate Load in pounds | Crushing Strength in lbs. per sq. in. |
|---|---|---|---|---|---|
| Lime Mortar, 2 to 1. . | 5 | 4⅝ x 4⅞ | 22.5 | 1,200 | 53 |
| " " 2 to 1. | 4⅞ | 4⅝ x 4¾ | 22 | 1,700 | 78 |
| Cement Mortar, 3 to 1 | 5 | 5 x 5 | 25 | 33,800 | 1,352 |

The piers were built and laid aside to harden in the mechanical laboratory of the School of Practical Science, in a temperature which averaged about 60° Fahrenheit, and were prepared for the test as follows: A thin mortar of neat cement was spread on a smooth cast-iron plate, and the pier placed upon the mortar and left until the cement hardened. The bottom bed was then trimmed off flush with the sides, the pier placed on the testing machine, and a layer of neat Portland cement mortar was placed on top, the pier was slid under the head of the machine, and the head was brought to its bearing while the mortar was yet soft.

This method ensured two parallel beds and gave a uniformly distributed stress on the pier. The load was applied slowly and continuously, until complete failure of the pier occurred.

Pier No. 1:

Description—Humber, 1st class, laid in lime mortar, ⅜ in. joints.

Size of pier, 9″ × 9″..........area, 81 square inches
Length, 24 courses .........................73 inches
Age ........................................10 days
Ultimate load ........................23,600 pounds
" strength per sq. inch ............291 pounds
" " " foot ..............20.9 tons

This pier was built on the testing machine; with lime mortar on top and bottom bed, the head of machine was brought down to a level bearing, and pier allowed to harden in position for ten days.

The pier failed by spreading a little at the head, a wide crack running down the centre to about half the height of the pier.

Pier No. 2:

Description—Kingston Road, 1st class, laid in lime mortar with 3/8″ joints.

Size of pier, 8 7/8″ × 8 7/8″....area, 78.75 square inches
Length, 8 courses ........................23 inches
Weight ................................114 pounds
Age .....................................2½ months
Ultimate load ........................ 44,000 pounds
Crushing strength per square inch........558 pounds
Crushing strength per square foot............40.2 tons

The pier sustained a high load without sign of fracture, but was completely destroyed under the ultimate load.

Pier No. 3:

Description—Kingston Road, 2nd class, laid in lime mortar with 3/8″ joints.

Size of pier 9″ × 9″............area, 81 square inches
Length, 8 courses ........................24 inches
Weight ................................114 pounds
Age .....................................2½ months
Crushing strength per square inch } Not determined
Crushing strength per square foot } by experiment.

The bottom bed used in this case was the one-inch board upon which the pier was originally built; the board appeared to be slightly warped, and split under the application of the load, causing a variation in the stress, to which is due the early failure of the pier.

Pier No. 4:

Description—Kingston Road, 3rd class, laid in lime mortar with 3/8″ joints.

Size of pier 9″ × 9″............area, 81 square inches
Length, 8 courses ........................24 inches
Weight ................................ 110 pounds
Age ..................................... 2½ months
Ultimate load ........................ 24,000 pounds
Crushing strength per square inch ...... 296 pounds
Crushing strength per square foot .......... 21.3 tons

Failure occurred by splitting of the bricks in the upper courses, then wide vertical cracks opened throughout the whole length, and under highest load every brick in the pier was shattered.

Pier No. 5:

Description—Humber, 1st class, laid in lime mortar.

Size of pier, 9″ × 9″ ........ area, 81 square inches
Length, 8 courses ........................ 24 inches
Weight ................................ 122 pounds
Age ..................................... 2½ months
Ultimate load ........................ 28,000 pounds
Crushing strength per square inch ........ 346 pounds
Crushing strength per square foot ........ 24.8 tons

The pier held well together until near the ultimate load, then long continuous cracks appeared, with final rupture of the whole pier.

Pier No. 6:

Description—Humber, 2nd class, laid in lime mortar.
Size of pier, 8¾" × 8¾" .... area, 76.5 square inches
Length, 8 courses .................... 23½ inches
Weight .............................. 118 pounds
Age .................................. 2½ months
Ultimate load ....................... 22,400 pounds
Crushing strength per square inch ...... 293 pounds
Crushing strength per square foot ............ 21 tons

All the bricks in the upper portion were completely shattered, the principal failure occurring along one corner of pier.

Pier No. 7:

Description—Carleton Clinker, laid in lime mortar with ⅜" joints.
Size of pier, 8⅝" × 8⅜" ........ area, 72 square inches
Length, 8 courses ...................... 22 inches
Weight .............................. 114 pounds
Age .................................. 2½ months
Ultimate load ...................... 44,000 pounds
Crushing strength per square inch ........ 609 pounds
Crushing strength per square foot .......... 43.8 tons

The pier failed, with continuous lines of fracture up and down the four sides, only one brick on the lower bed being uninjured after the test.

Pier No. 8:

Description—Carleton, 1st class, laid in mortar with ⅜" joints.
Size of pier, 8¾" × 8¾" ...... area, 76.5 square inches
Length, 8 courses .................... 23½ inches
Weight .............................. 110 pounds
Age .................................. 2½ months
Ultimate load 41,000 pounds
Crushing strength per square inch ........ 535 pounds
Crushing strength per square foot ........ 38.5 tons

The pier was completely shattered under the highest load. The mortar crumbled out like sand, and had very little effect in holding any portions of the pier together.

Pier No. 9:

Description—Yorkville, No. 1, white brick, laid in lime mortar with ⅜" joints.
Size of pier, 8¾" × 8¾" ...... area, 76.5 square inches
Length, 5 courses .................... 14½ inches
Weight ............................... 65 pounds
Age .................................. 2½ months
Ultimate load ...................... 39,000 pounds

Crushing strength per square inch ........ 509 pounds
Crushing strength per square foot ........ 36.6 tons

Small cracks appeared as the load was put on. As the highest load was approached portions of the pier spalled off, and finally shattered to fragments under the highest load.

Pier No. 10:

Description—Yorkville white brick No. 2, with pinkish shade, laid in lime mortar with 3/8" joints.
Size of pier, 8¾" × 8¾" ...... area, 76.5 square inches
Length, 8 courses .................... 23½ inches
Weight .............................. 105 pounds
Age ................................. 2½ months
Ultimate load ...................... 30,000 pounds
Crushing strength per square inch ...... 392 pounds
Crushing strength per square foot ........ 28.2 tons

Fine cracks appeared early in the test, which increased to long vertical cracks, running the length of the pier, portions of the brick spalled off, and under the highest load given above the pier was totally destroyed.

Pier No. 11:

Description—Don Valley pressed brick, buff color, laid in lime mortar.
Size of pier, 8⅝" × 8⅝" ...... area, 74.4 square inches
Length, 8 courses ...................... 21 inches
Weight .............................. 97 pounds
Age ................................. 2½ months
Ultimate load ...................... 51,000 pounds
Crushing strength per square inch ........ 686 pounds
Crushing strength per square foot ........ 49.4 tons

As the highest load was approached, fine cracks appeared, which were confined to individual bricks, and were not continuous down the length of the pier; the fracture was rather of a crumbling nature.

Pier No. 12:

Description—Don Valley pressed brick, red color, laid in lime mortar.
Size of pier, 8½" × 8½" ...... area, 72.25 square inches
Length, 8 courses .................... 21½ inches
Weight .............................. 110 pounds
Age ................................. 2½ months
Ultimate load ...................... 88,000 pounds
Crushing strength per square inch ...... 1,218 pounds
Crushing strength per square foot .......... 87.7 tons

The failure of this pier was of somewhat the same nature as that of the last, but the brickwork held together better under the ultimate load.

## CEMENT PIERS.

Pier No. 13:

Description—Yorkville, 1st class, white color, laid in cement mortar.

Size of pier, 8⅝″ × 8⅝″ ...... area, 74.4 square inches
Length, 8 courses ........................ 24 inches
Weight ............................... 110 pounds
Age .................................. 2½ months
Ultimate load ........................ 79,000 pounds
Ultimate load per square inch ........ 1,062 pounds
Ultimate load per square foot ............ 76.5 tons

The pier held together well, and did not show much sign of failure until the highest load was reached; the pier was destroyed in the test, probably owing to the brittle nature of this brick.

Pier No. 14:

Description—Yorkville, 2nd class, color white with pink tint, laid in cement mortar.
Size of pier, 8¾″ × 8¾″ area, 76.5 square inches
Length, 8 courses ........................ 24 inches
Weight ............................... 111 pounds
Age .................................. 2½ months
Ultimate load ........................ 78,000 pounds
Ultimate strength per square inch ...... 1,018 pounds
Ultimate strength per square foot ........ 73.3 tons

This pier was well built, and shows the value of a cement mortar for laying brickwork, as its binding qualities allow the brick to develop nearly its full strength.

Pier No. 15:

Description—Humber, 2nd class, laid in cement mortar.
Size of pier, 9″ × 9″ .......... area, 81 square inches
Length, 8 courses ........................ 24 inches
Weight ............................... 124 pounds
Age .................................. 2¼ months
Ultimate load ........................ 91,600 pounds
Ultimate strength per square inch ........ 1,131 pounds
Ultimate strength per square foot .......... 81.4 tons

Fine cracks occurred in some of the bricks only under nearly the highest load, but total destruction of the pier took place under the ultimate load, but did not shatter so badly as in the case of those laid in lime mortar.

Pier No. 16:

Description—Kingston Road, 2nd class, laid in cement mortar.
Size of pier, 9″ × 9″ .......... area, 81 square inches
Length, 8 courses ...................... 23½ inches
Age .................................. 2½ months
Ultimate load ........................ 69,000 pounds
Ultimate strength per square inch ...... 852 pounds
Ultimate strength per square foot .......... 61.3 tons

This pier held together even under the ultimate load, the failure occurring through actual crushing of some of the upper bricks. After pier was removed from the machine, only small portions of it could be forced away from the mass.

Pier No. 17:

Description—Carleton Clinker, laid in cement mortar.

Size of pier, 8½" × 8½" ...... area, 72.25 square inches
Length, 8 courses ...................... 22¾ inches
Weight ................................ 115 pounds
Age .................................. 2½ months
Ultimate load ..................... 174,000 pounds
Ultimate strength per square inch ...... 2,408 pounds
Ultimate strength per square foot ........ 173.4 tons

Fine cracks appeared toward the end of test; these cracks were not continuous down the length of pier, nor did they increase much in width under the highest load.

Pier No. 18:

While working on this pier the friction clutch of the machine gave way, and the tests were discontinued for the present.

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Pier No. 1:

Description—The pier in question was tested in December, 1904. It consists of Kingston Road brick, best quality, built in 8 courses and laid in 3:1 cement mortar. The joints were ⅜" thick.

Size, 8½" × 8½" ........... area 72.25 square inches
Height ...................................... 2 feet
Age ...................... 8 years (built in 1896)
Ultimate load ....................... 184,150 pounds
Crushing strength per square inch ...... 2,550 pounds
Crushing strength per square foot ........ 183.5 tons

Pier No. 2:

Description—This pier was tested in January, 1906. It consisted of Carlton 2nd class brick, built in 6 courses, laid in 2:1 lime mortar. The joints were ⅜" thick.

Size, 8½" × 8½" ......... area, 72.25 square inches
Height .............................. 16 inches
Age ..................................... 6 years
Ultimate load ...................... 75,150 pounds
Crushing strength per square inch ......1,040 pounds
Crushing strength per square foot .......... 74.4 tons

Pier No. 3:

Description—This pier was tested in January, 1906. It consisted of Kingston Road 1st class brick, built in 5 courses in 3:1 cement mortar. Joints ⅜".

Size, 8¾" × 8¾" ......... area, 76.56 square inches
Height .............................. 14 inches
Age ..................................... 1 month
Ultimate load .................... 117,200 pounds
Crushing strength per square inch ...... 1,530 pounds
Crushing strength per square foot ........ 109.4 tons

Pier No. 4:

Description—The pier in question was tested in January, 1906. It consisted of Carleton brick, 2nd class, built in 6 courses and laid in 2:1 lime mortar. The joints were 3/8" thick.

Size, 8½" × 8½" ............ area 72.25 square inches
Height ........................... 1 foot, 5 inches
Age ...................... 6 years (built in 1900)
Ultimate load ........................ 75.000 pounds
Crushing strength per square inch ...... 1.040 pounds
Crushing strength per square foot ........ 74.9 tons

Pier No. 5:

Description—The pier in question was tested in December, 1907. It consisted of Yorkville brick, 2nd class, built in 5 courses and laid in 2:1 lime mortar. The joints were 3/8" thick.

Size, 8¾" × 8¾" .......... area, 76.56 square inches
Height ........................ 1 foot, 2½ inches
Age .................................... 2 years
Ultimate load ...................... 106,000 pounds
Crushing strength per square inch ........ 1,382 pounds
Crushing strength per square foot ........ 99.5 tons

Pier No. 6:

Description—This pier was tested in January, 1908. It consists of 2nd class Yorkshire brick, built in 5 courses and laid in 3:1 cement mortar. The joints were 3/8" thick.

Size, 8¾" × 8¾" .......... area, 76.56 square inches
Height ........................ 1 foot, 2½ inches
Age .................................... 2 years
Ultimate load ....................... 87,000 pounds
Crushing strength per square inch ...... 1,140 pounds
Crushing strength per square foot ........ 81.43 tons

Pier No. 7:

Description—The pier in question was tested in January, 1908. It consisted of 5 layers of Humber brick, 2nd class, laid in 2:1 lime mortar. The joints were 3/8" thick.

Size, 9" × 9" ................ area, 81 square inches
Height ........................ 1 foot, 2½ inches
Age ........................... 2 years, 1 month
Ultimate load .............. ........ 43,000 pounds
Crushing strength per square inches .... . 531 pounds
Crushing strength per square foot ....... 38.2 tons

Pier No. 8:

Description—This pier was tested in March, 1908. It consisted of Kingston Road 2nd class brick, built in 12 courses, laid in 2:1 lime mortar. The joints were 3/8" thick.

Size, 8¾" × 8¾" .......... area, 76.56 square inches
Height .......................... 2 feet, 10 inches
Age .................................. 12 years
Ultimate load ...................... 67,200 pounds
Crushing strength per square inch ........ 878 pounds
Crushing strength per square foot .......... 62.71 tons

Pier No. 9:

Description—This pier was tested in March, 1908. It consisted of Carlton 1st class brick, built in 6 courses, laid in 3:1 cement mortar. The joints were ⅜" thick.

Size, 8¾" × 8¾" .......... area, 76.56 square inches
Height .......................... 1 foot, 4 inches
Age .................................. 2 years
Ultimate load ...................... 74,600 pounds
Crushing strength per square inch ...... 2,281 pounds
Crushing strength per square foot ...... 163.94 tons

Pier No. 10:

Description—This pier was tested in March, 1908. It consisted of Don Buff Pressed brick, built in 4 courses, laid in 3:1 cement mortar. The joints were ⅜" thick.

Size, 8⅝" × 8⅝" .......... area, 74.4 square inches
Height .................................. 11 inches
Age .................................. 2 years
Ultimate load ...................... 75,000 pounds
Crushing strength per square inch ...... 1,008 pounds
Crushing strength per square foot ........ 72.00 tons

Pier No. 11:

Description—This pier was tested in March, 1908. It consisted of Kingston Road 2nd class brick, built in 5 courses, laid in 2:1 lime mortar. The joints were ⅜" thick.

Size, 8¾" × 8¾" .......... area, 76.56 square inches
Height ................................ 14 inches
Age .................................. 2 years
Ultimate load ...................... 59,000 pounds
Crushing strength per square inch ........ 772 pounds
Crushing strength per square foot ........ 55.14 tons

# INTERPOLE MOTORS*

F. R. EWART, B.A.Sc.

The use of interpoles, or auxiliary fields of any kind, is mainly to overcome commutation difficulties in machines employed under severe conditions of service. For this reason I shall first describe the process of commutation, then show the effect of induced voltages in the short-circuited coil, proceeding to show how the voltage depends on field form, and how field form is affected by armature reaction. I shall show how the effects of armature reaction may be overcome and under what circumstances an auxiliary field is necessary. And lastly I shall discuss the application of the interpole motor and its many advantages.

Figure A of Figure 1 represents diagrammatically the flow of current in an armature. The coil C carries full current in

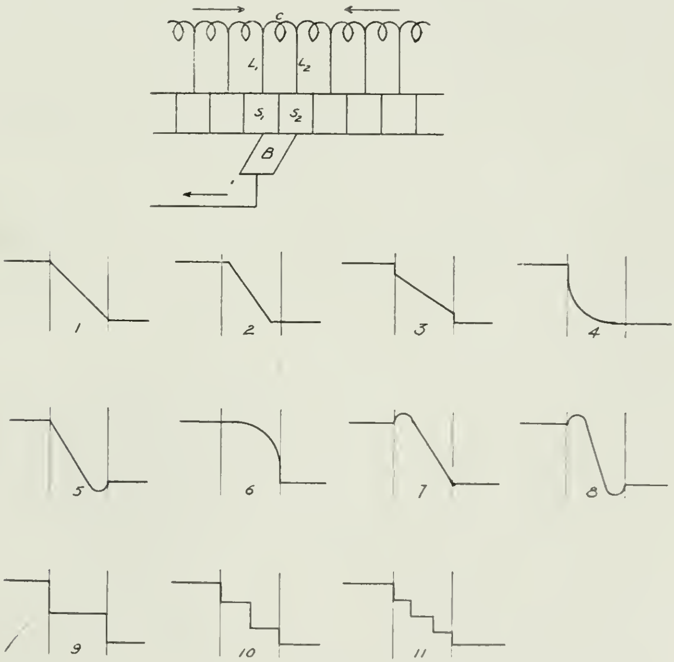


Fig. 1

the right hand direction, and the lead $L_1$ carries none until the edge of the segment $S_1$ reaches the heel of the Brush B. As the brush passes over the segment the current is gradually diverted from C through $L_1$ till half of the brush rests on $S_1$. The current

Read before the S.P.S. Electrical Club Thursday, December 10th, 1908 will then pass entirely through $L_1$, that is the coil is short circuited. As the brush continues its motion the current in $L_2$ will gradually be shifted to the coil C, until the toe of the brush leaves $S_2$ and the coil is carrying full current in the left hand sense. That is, the current in the coil is commutated or reversed.

This change may take place in many ways, a few of which are shown in curves 1 to 11, Figure 1. These are curves of current plotted on time interval as base, the distance between the vertical lines representing the time one commutator bar takes to pass a given point. Curve 1 shows the whole time taken in changing the current, while in curve 6 the current hangs on and reverses suddenly, i.e. very little current is diverted by the leading edge of the brush, but is impeded till it has to flow through the trailing edge. This has an effect equivalent to decreasing the width of the brush and increasing the current density. Thus the steepness of the curve indicates the current density at any point. The worst place to have high current density is at the trailing edge of the brush, as this is the point where a segment finally leaves the brush and where a spark once started will be most inclined to be drawn out and maintained. Curve 1 shows ideal commutation, giving uniform and minimum current density in the brush. This condition is most nearly realized by using brushes whose resistance is high in proportion to that of the coil, so that the ratio of currents flowing by $L_1$ and $L_2$ depends on the ratio of the surfaces of $S_1$ and $S_2$ covered by the brush. This suggests at once one good reason for the use of carbon brushes. If the resistance of the brush is low compared to that of the coil we will get commutation something like curve 9, where the coil is short circuited immediately after the edge of the brush touches its segment.

Armature coils being wound on an iron core and generally deeply imbedded in slots on it, are always highly inductive, so that it is impossible for currents in them to die down rapidly. This self-induction has the effect of producing commutation as in curve 6, causing high density at the trailing edge of the brush, a condition which we have seen to be very harmful.

If we have an active *E. M. F.* in the coil which is counter to the flow of the current and will assist in reversing it, we may get something like curve 4. Evidently the introduction of such an *E. M. F.* might be used to counteract the effect of self-induction, thus effecting a compromise between curves 4 and 6 and securing something near the straight line variation of curve 1.

If, on the other hand, the *E. M. F.* be in the same direction as the current, it will tend to maintain it, and the result may be that the current will be practically undiminished, when the segment leaves the brush and thus force the whole current to arc over from the segment to the brush after they have parted. This would mean sparking of the most vicious kind, a condition which must be remedied at all costs.

For a given speed of rotation, the *E. M. F.* in a coil at any position depends on the density of the magnetic flux at that point. A curve of flux densities on angular positions as a base,

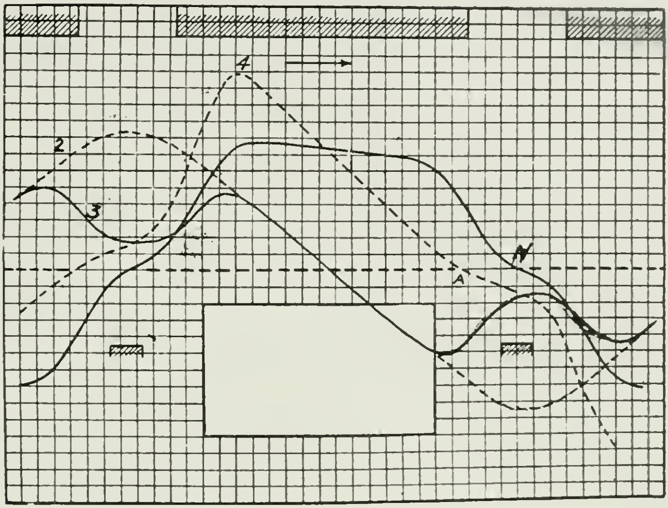


Fig. 2

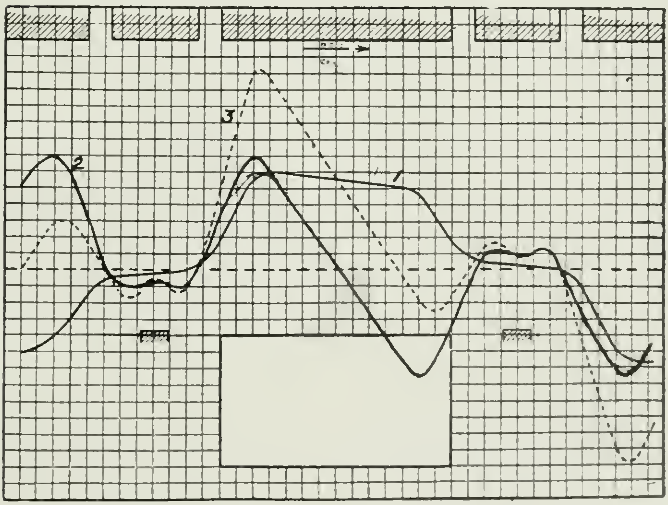


Fig. 3

is called a field form. Curve 1 Fig. 2 is an example of the field form of a shunt motor at no load. The flux is nearly uniform over the face of the pole but rapidly decreases to zero at the point X in the centre of the interpolar space. The point X is called the neutral point.

Field distribution curves may be determined in three different ways:—

(1) By exploration about the commutator with a voltmeter. This method may be used whether the machine is loaded or not, but in the former case readings in the region of commutation are unsatisfactory, since they are affected by the voltage of self-induction. Thus the main benefit from such measurements is entirely lost.

(2) By means of a fluxmeter and exploring coil. An exploring coil connected to a fluxmeter or galvanometer is inserted in different positions about the field and the kick noted when the coil is withdrawn or the field current cut off. This method can only be employed when the machine is still and can therefore only be used to give the no load curve. The method is therefore of little value in the investigation of field distortions leading to commutation troubles.

(3) The third and best method is to bring out leads to collector rings from two segments at the ends of a coil and take oscillograms of voltage. This method may be used under all conditions of speed, load, etc., and will give an absolutely faithful record of the *E. M. F.* variations in the coil. This will be the same as the field form except when the coil is commutating, where reactance voltage modifies it. But in any case the curve shows the net voltage which is employed to effect commutation, and it is this net voltage upon which commutation mainly depends.

Curve 1 (Fig. 2) is then the no load field form of a shunt motor and is the field produced by the main field alone, being only slightly distorted by the small no load current of the motor. This main field is constant for a definite shunt field excitation and is always in the same position. When the motor is loaded the armature produces a field of its own (Curve 3) which combines with the main field to produce a resultant field as shown in Curve 4.

This armature field varies in magnitude with the armature current, i.e. with the load, and its position is determined by the setting of the brushes. It is evident that an armature has a magnetization due to its own current and that the line of action of this magnetization is determined by the position of the brushes, since that is what determines the points where the current changes its sense. In fact the armature *M. M. F.* is said to be in phase with the brushes, and if commutation were taking place along the neutral axis it would be in quadrature with the *M. M. F.* of the main field. If the machine had a uniform air gap all around the armature, the maximum flux would evidently be at the brushes and zero flux at points half way between. That is we would have an armature flux as shown in Curve 2. The difference between Curves 2 and 3 is caused by the high magnetic reluctance of the circuit in the interpolar spaces.

Remembering that in the case of the motor, the flow of current is opposite to the induced *E. M. F.*, we see that we must commutate at some point a little before the point of no voltage N is reached, if we are to have a small voltage in the commutating coil acting against the current to overcome the effect of self-induction and obtain sparkless commutation. That is we must shift the brushes back a little and commutate in the "back field" or "fringe." This is in fact the method used to obtain a commutating field on any constant speed shunt motor, and is always easy of accomplishment because the main field is always stronger than the armature field and a fringe (or flux beyond the pole tip) always exists, i.e. the point of no voltage is always outside the pole tip.

But in the case of a variable speed motor, where the high speeds are attained by using a greatly reduced main field, it frequently happens that there is no fringe, i.e. the point of no voltage is under the pole tip. This is the case shown by the full load curve of Fig. 2. In this case it is impossible to get sparkless commutation by shifting the brushes backward because it is impossible for the brushes to catch up to the point A. This is because the armature flux moves with the brushes and when the brushes move under the pole tip, the arm flux at the brush is no longer that shown in Curve 3, but becomes that shown in Curve 2, so that the point A recedes before the brush and cannot be overtaken by it. It must be remembered too, that shifting the brushes backward increases the demagnetizing effect of the armature and decreases the capacity of the motor, and therefore must not be indulged in too freely.

Evidently then under extreme conditions, such as a variable speed motor, where a back field is not available for commutating purposes, a special commutating field must be provided separately. One form of auxiliary field is the winding, which was invented in 1895 by Prof. Ryan and has been called after him. It consists of a winding placed in slots on the pole face and carrying full load current. The direction of these currents is opposite to those of the armature conductors, so that the armature flux is almost exactly counterbalanced at all points. Thus the resultant full load field form differs only slightly from that at no load. This method works excellently, but has one great objection. It is very expensive. It is still used extensively on Series *A. C.* motors, where careful compensation of armature reaction is absolutely essential. But in the case of *D. C.* machines, quite as good results are accomplished much more cheaply by the use of interpoles.

These interpoles are placed in the centre of the interpolar spaces and are wound with series windings, which carry load current in such a sense that their magnetization opposes that of the armature. They are wound with sufficient turns to not only neutralize the armature flux but to produce a slight extra flux in the opposite sense, to serve as a commutating field. The field distribution curves are shown in Fig. 3. Curve 1 is for no load. Curve 2 shows flux due to armature and interpoles, and Curve 3 shows the resultant field form.

Since the interpoles are excited by the load current, their magnetization bears a constant ratio to that of the armature, and is therefore able to produce a commutating field in the right direction at all loads. It will be noticed that armature reaction is neutralized only in the region of commutation. This is just a narrow spot of unvarying width. "The question then might be asked, whether the same excitation is required on the interpoles for a given load at both high and low speeds. Experiment has proven that if the excitation of the interpoles is correct for high

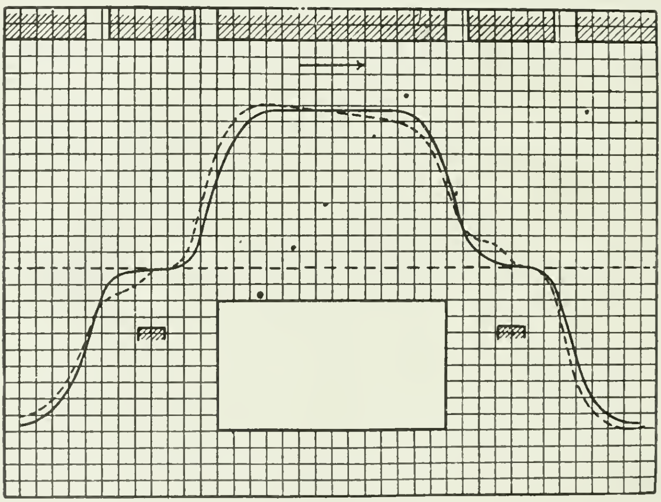

**Fig. 4**

speeds it is also correct for all lower speeds. For although the same commutating flux is created at a given load irrespective of the speed, yet the *E. M. F.* generated in the short circuited coil is proportional to the speed. Thus a high *E. M. F.* is provided for the very quick reversal of the current at high speed and a much lower *E. M. F.* is provided for the slower reversal at low speed."

Fig. 4 shows the field forms at low speed, i.e. strong main field. The curves are consequently plotted on a much smaller scale than in the other figure, so that the distortion due to armature reaction and interpoles appears relatively small.

The speed regulation of the interpole motor is about the same at all speeds. That is, the rise of speed in *R. P. M.* from full load to no load is nearly the same for all excitations. The armature $I R$ drop at full load is a definite fraction of the terminal voltage irrespective of the excitation and must consequently tend to cause the same percentage decrease of speed from no load to full load. This drop would be greater than in the ordinary shut motor since $R$ includes both armature and auxiliary field winding and is consequently comparatively high. This, however, is compensated for by the fact that the auxiliary field tends to weaken the field at full load, thus causing a tendency for the speed to rise. This fact may be verified by a comparison of the curves in Figs. 2 and 3. These two effects combine to give the machine a speed regulation which is quite as good as that of the average shunt motor of the same rating.

The efficiency for any given load is practically constant. When load is constant, armature current is constant, and then torque varies directly with the armature flux, whereas speed varies inversely as the flux. Since power output varies as the product of torque and speed, it is evident that power output is independent of field flux, i.e. it is constant for a constant value of armature current or power input. Thus the efficiency is constant.

These facts are substantiated fairly well by the curves of Fig. 5, which are derived from a recent test on the interpole motor in the Electrical Laboratory. It will be noticed that the speed regulation seems to show a constant difference in R. P. M. from full load to no load instead of a constant percentage, the variation seeming to be about 60 or 70 R. P. M. for all speeds.

The greatest application of the interpole motor is for machine tool drive. In fact it was for this class of work that the interpole motor was developed, and its advantages for this and other work were brought to the notice of the engineering profession. "The requirements of a variable speed drive demand a motor, in which all the speed variation desired may be obtained in the motor itself without the necessity of either a variable voltage supply or a mechanical speed changing device." Evidently the interpole motor fits these requirements exactly. The elimination of the multi-voltage system effects a great saving in wire, and tends to simplicity in both the generation and application of power. The advantage of a uniform speed gradation. over the wide speed changes effected by any mechanical device. need scarcely be emphasized. The speed ratios employed in practice vary all the way from 2-1 to 6-1.

The motors are generally handled by controllers of the drum type, having contacts for line, armature, and starting resistance on the drum and a field rheostat at the bottom, whose arm is keyed to the main spindle and moves with it. The contacts of the drum are so arranged that the armature polarity may be reversed thus changing the sense of rotation. This also reverses the polarity of the auxiliary field, thus ensuring a commutating field that is always in the proper sense. One common form of controller has 16 forward running positions and 6 backward.

It is common practice to use resistances between points of such values, that the successive speeds are in geometric progression. Thus for 16 running speeds and a 3-1 ratio we have a step to step variation of $\sqrt[15]{3} = 7.6\%$ and for 6-1 ratio $\sqrt[15]{6} =$

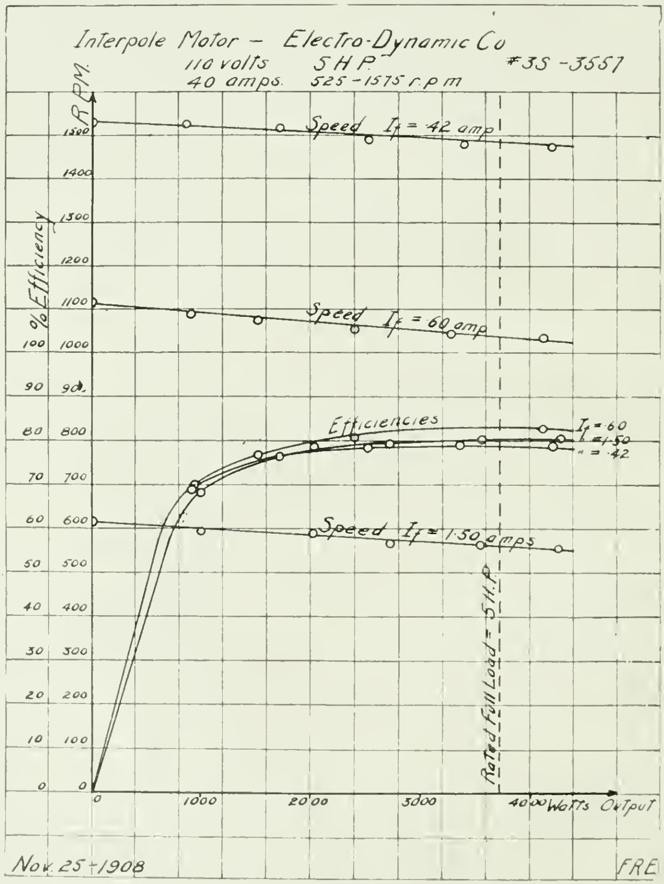


Fig. 5

12.7%. The controller may be mounted in any convenient place and position, and with long lathes is frequently mounted on the tool base so that the workman may always control the speed while standing close to his work.

Several special advantages are claimed for the use of variable speed motors in machine shop work.

(1) Elimination of line shafting.

This not only saves considerable power, but gives greater convenience and flexibility in the placing of machines.

(2) Safety and cleanliness.

Belting is always more or less dangerous and noisy and inclined to throw oil and dust.

(3) Improved and cheapened product.

Machine work is always cleaner cut when turned out at its proper speed. Then, too, the workman can push the work well up to the safe limit and loses no time in gear changing, etc. The Firth-Sterling Steel Co. found that they were able to produce 46% more work from interpole motor driven machines than from corresponding belt driven machines in the same time.

Another important use for interpoles is on railway motors. They are found to have a good effect on commutation, preventing most of the arcing and flashing which so frequently occurs when the motor is starting or is subjected to a heavy momentary overload of any kind. One great advantage of the interpole railway motor rests in the fact that the improvement in commutation permits much higher voltages to be used with safety. E. H. Anderson, designing engineer of the G. E. Co., claims that the commutation is better on an interpole motor at 1200 volts than on a corresponding type without interpoles at 600 volts. He claims that 2500 volts per motor would be quite possible; so that by using two motors in series in a car, and a double track system having the rails as a grounded neutral, 10,000 volts between trolleys might be realized. This would aid materially in the solution of the problem of long interurban lines.

Interpoles have also been frequently applied to generators on account of the advantages gained in regulation and commutation.

The interpole motor has many advantages besides improved commutation, though most of them are the direct result of this improvement.

(1) A cleaner and safer motor on account of the reduction of carbon and copper dust from brushes and commutator.

(2) Increased life of brushes and commutator.

(3) Lower core densities may be used and less iron, hence smaller iron losses; also smaller commutator losses. Thus a higher efficiency.

(4) Heating instead of commutation becomes the determining factor in the output of the machine, so that every pound of material may be worked to its greatest limit.

(5) The permissible reduction of iron raises the proportion of copper to iron, i.e. makes it "a copper machine not an iron machine." Thus a smaller and neater motor, though probably not any cheaper.

(6) Possibility of higher voltages.

(7) Greater facility in design.

(8) Possibility of increasing service capacity of motors by use of forced ventilation.

(9) Gives a perfectly reversible motor.

"It would probably be impossible to construct a commercial 5 *H.P.* shunt motor which could be suddenly reversed at full load without producing any sign of sparking, yet when commutating pole motors are subjected to such treatment the resultant sparking is not noticeable."

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# APPLIED SCIENCE

INCORPORATED WITH

**Transactions of the University of Toronto Engineering Society**

DEVOTED TO THE INTERESTS OF ENGINEERING, ARCHITECTURE AND APPLIED CHEMISTRY AT THE UNIVERSITY OF TORONTO

Published Monthly during the College year by the University of Toronto Engineering Society.



## Editorial

### The Widening Field of the Engineer

This is an era of expansion and conformably with the change in commerical conditions the function of the engineer is rapidly enlarging. From his capacity of an engineer, limited to the determination of technical questions, the engineer of to-day has come to assume an economic importance in those branches of industry dependent upon engineering skill for development.

He is indeed an engineer of limited usefulness who does not go farther professionally than to submit a purely technical report on the subjects presented for his consideration. While he has the same responsibility as formerly in the solution of the technical problems involved, he is further expected to supplement his report with advice on the financial and commercial aspects of these problems. For the great majority of problems presented to the engineer ultimately involve the determination of the pecuniary relations of the proposition under discussion.

This is a phase of engineering education which has been sadly neglected, with the result that the average engineer gets the scientific part ground into him to such an extent that he never gets into the real game and seldom takes his proper place in the community.

Owing to the ever widening field for engineers which is embracing all sorts of business the purely scientific engineer is becoming a very decided minority. One of our most prominent graduates took stock of his work recently and found that from two-thirds to three-fourths of his time was taken up in what might be called the business side of engineering and very little with purely technical matters. In other words reporting on and operating properties and dealing with business situations was of greater importance than his purely technical work, besides it paid much better

The question arises can this commercial side of engineering be recognized in the curriculum of an engineering college? While it cannot be hoped that an art such as business is can be taught in schools where science is the main subject—a course of lectures could be of value if they indicate to the student that there is a world outside the purely technical that is awaiting him, and which he can occupy if he will recognize the fact that it is his. This century belongs to the engineer more even than the last. We recognize this broadening field and his education has got to cover it. The only difficulty will be the overloading of the student who already has more subjects than he can conveniently assimilate. So much is the case that he really has little time to think for himself, but only to absorb lectures. Does the answer lie in cutting out some of the more purely scientific subjects or demanding a higher standard of entrance? However, let the details of working out be what they may, it is expedient that the University of Toronto should do something in this line, and not let her rivals outdistance her. No criticism is more often heard of the young graduate than that he does not understand business. This criticism is made by the man who will employ him. Our graduates should therefore be in a position to understand something of the rules of the game, so as to be able at least to talk intelligently to the financial man, with whom he will inevitably have to deal.

**The Ideal Lecturer**

Much has been written from time to time about the ideal teacher in secondary education, but for some reason very little has been said about the ideal lecture and lecturer in higher technical education. At the same time there is no class of men who lecture before a student body which is so capable of giving an intelligent criticism in its broadest sense of what is offered them. This criticism, picking out both good and bad, would be welcomed by all professors and lecturers who sincerely pray with Burns, "O waud some power the giftie gie us to see oursel's as ithers see us."

With this end in view, Professor Haultain has offered a prize of the choice of a book on engineering to the undergraduate or graduate submitting the best essay of two or three thousand words on the Ideal Lecture and Lecturer in Technical Education. These essays will be of course impersonal. Pseudonyms may be obtained from the President of the Engineering Society. The judges will be E. A. James, Editor, Canadian Engineer; J. C. Murray, Editor, Canadian Mining Journal; K. A. MacKenzie, Editor, Applied Science. The essays are to be submitted on or before February 1st, 1909, and will be printed in the February Applied Science.

**The School Reunion Dinner.**

It has been definitely decided to hold the annual dinner of the Engineering Society on either Wednesday or Thursday of the last week in January. It is expected that this will be the climax of a series of such functions. All circumstances seem to be working together to ensure its success. The original plan of having a reunion dinner for both graduate and undergraduate bodies is still in view, but added to this it has been decided to take advantage of the fact that the annual meeting of Canadian Society of Civil Engineers is being held in Toronto, for the first time, on that date.

This in itself will attract to the city a great number of our graduates, who are connected with the larger society.

Added to these it is hoped a number from a distance will be attracted by the cheap fares available on the railroads.

A thoroughly organized effort will be made by the members of different graduating years to get a large representation out. All graduates are urged to turn in and make the dinner a memorable one. It will undoubtedly be a success.

It is just possible that there may be some who harbor a feeling of resentment at not being invited to the presentation of the portrait to the university. As it was not thought advisable to in any way detract from the success of the dinner by splitting the attendance on the two occasions, hence only the city graduates were specially invited.

There will be a meeting and dinner of the graduates of the School of Practical Science and of the Faculty of Applied Science of the University at the St. Charles Hotel on Tuesday evening, December 15th at 6 o'clock.

## THE ENGINEERING SOCIETY.

The Engineering Society held its second general meeting on Wednesday, November 4, at 8 p. m., in the University Convocation Hall. That the meeting was enthusiastic and largely attended goes without saying, it being the occasion of an event that will go down with honor and distinction in the records of the Engineering Society—viz., "The Presentation of the Portrait of Dean Galbraith" to the Board of Governors of the University. It was brought about through the combined efforts of the graduates and undergraduates of the Faculty of Applied Science.

Among those present on the platform were President Falconer, Dr. Hoskin, E. W. Stern, Prof. Haultain, Dr. Ellis and Dean Galbraith. After a very fitting address, and a few humorous remarks, bringing back fond reminiscences of the early days at the School, Mr. E. W. Stern, one of the School's early and most distinguished graduates, presented the portrait, which was received, on behalf of the Board of Governors, by Dr. John Hoskin, who in a few well chosen words, thanked the graduates and undergraduates for the great honor they had bestowed on the University, and at the same time paid numerous compliments to the worthy original. President Falconer and Dr. Ellis were quite profuse, and rightly so, in their praises for Dr. Galbraith, enumerating the many things he had done in the interests of the students in engineering and of the engineering profession in general, and also the parts he had played in the uplifting of the standard of the Faculty of Applied Science to the proud position it now holds. H. E. T. Haultain, our recently appointed professor of mining engineering, and a graduate of the School, addressed the meeting and took great pride, he said, in being able to compare our graduates most favorably with graduates of any other technical school in the world. Dean Galbraith was then called upon to address the meeting. He thanked the graduates and undergraduates for the honor they had done him, and then gave them an idea of the pleasant task he found that of sitting for a portrait to be.

On November 18, the regular sectional meetings were held. At the Mechanical and Electrical sectional meeting papers were given by Mr. F. Hagerman, '09, on "The Installation of the College Telephone System," and by Mr. C. Hughes, '09, on the "Toronto Waterworks Tunnel." The papers were well written, and especially well delivered. Both being of local interest they provoked a considerable amount of discussion, in which many good points were brought out.

The regular Civil and Architect sectional meeting was addressed by Mr. C. F. King, a graduate of the School in '08 and a past president of the Engineering Society, on "Conditions in Northern Canada." Mr. King was a member of the famous Neptune expedition sent out by the Dominion Government for exploration purposes in the Far North.

## WHAT THE GRADUATES ARE DOING.

E. W. Stern, on whom the honor fell of presenting the portrait of Dean Galbraith to the University, may be regarded as one of the "School's" most successful graduates. He was born in Toronto, August 20th, 1865. After obtaining his diploma in 1884, he entered railway work on the old Northern and Pacific Junction railway, first as rodman and then as assistant engineer in charge of construction. Returning to the School the following year he became one of its first Fellows, and on leaving he entered the employ of the Passaic Rolling Mill Co., Paterson, N. J. With this company he was employed mostly on the shop plans of the Washington bridge over the Harlem river, a 500 ft. girder arch. In 1887 he went west to Chicago as an assistant engineer on construction of the cable railway. He, however, soon left this to enter the employ of the Chicago Bridge & Iron Co. From this period on his time has been employed almost entirely on the design and construction of steel structures of various sorts—bridges, roof trusses, buildings, etc. Such structures as the bridge over the Mississippi at Winona, Minn., and the Coliseum at St. Louis are examples of his work. He returned east to New York in 1898 as chief engineer of the Jackson Iron Works. While with this company he was in full charge of the design and supervision of construction of buildings, the contract price of which amounted to nearly three million dollars. From 1902 to the present he has been engaged in professional practice as consulting engineer, making a specialty of buildings and foundations. During this period he has designed or supervised the constructional work of fifty-three buildings, the contract price of the engineer's work of these amounting to about four million dollars. Among these are the new Terminal station at Hoboken, N.J., the new ferry stations at 23rd Street, New York, for the Lackawana & Erie Railroads; the B. Altman's store at Fifth Avenue and 35th Street, National Park Bank, Travelers Insurance Co., Hartford; New York Evening Post, State Library and Supreme Court Building, Hartford. He was associated with S. C. Weiskopf on the construction of the thirty-two storey City Investing Building on pneumatic caisson foundations; also on the Union Passenger station, Chattanooga, Tenn., and the State Armory, Hartford, Conn. He was elected a member of the American Society of Civil Engineers in 1897. In 1899 he married Miss Dorothy Kohn of New York. He has two children, Helen, aged 8, and Theodore, aged 1 year.

B. Nielley, '07, has accepted the position of assayer at Silver Queen mine, Cobalt.

N. P. F. Death, '06, is with Death & Watson, electrical engineers and contractors. They are specializing on illumination.

Frank Barber, '06, has been appointed county engineer of York County.

## Index to Advertisers

W. H. Ellis

# Applied Science

INCORPORATED WITH

## TRANSACTIONS OF THE UNIVERSITY OF TORONTO ENGINEERING SOCIETY

Old Series Vol. 22 JANUARY, 1909 New Series Vol. 2, No. 3

## THE YOUNG CIVIL ENGINEER.

EUGENE W. STERN.

The question which a young man keeps asking himself continually through his college days, and especially just before he graduates, is, "What shall I do next?"

It is a very important question, and one that should be carefully considered, for this is really a critical stage in his career. I shall try to help a little by drawing from my own experiences, confining my remarks to the work of the Civil Engineer, that being the profession I have followed, and I trust that this paper will be freely discussed and criticized by many of our graduates.

Although some of my remarks may apply to the work of the young mechanical and electrical engineer, my opinions in these branches of the profession would be largely that of a layman, and I will, therefore, leave this part of the field to others more familiar with it. In Mining Engineering Prof. Haultain has already covered the ground in his very interesting and valuable paper, recently published in "Applied Science."

Now what line of work or specialty is the young graduate aiming to follow later in life? Does he wish to be in professional practice as a consulting engineer, or be the engineer employed by a railroad or other corporation or contractor, or does he wish to engage in contracting or manufacturing?

This question need not be answered at once, nor can it be until he has had some years of varied practical experience and is able to judge for himself.

Now, I think it will be conceded that to be a successful engineer, or to be really successful in the broad sense in any of the higher callings, a clear knowledge of a large area of life should be acquired, because only this can give breadth and poise and ability to handle large problems and develop in one executive ability and what may be called the ethical qualities, or qualities of leadership, as distinguished from the technical.

Technical qualifications there must be, but these alone will not place one among the chosen of his profession. There must also be the ability to inspire confidence in those desiring to make use of one's services, which confidence can only be based on character, temperament, and training, and the ability to inspire employes with a love of system and order, to maintain discipline without harshness, and economy without parsimony.

There must be endurance of mind and body, and adaptability, thoroughness, efficiency, intensity, and imagination for possibilities. Having thus briefly outlined the necessary qualifications for the successful engineer as they appear to me, let us see now how the necessary preliminary training may be obtained without too much loss of time.

The young engineer, when he graduates at the University of Toronto, has a splendid technical foundation. I do not believe a better one can be obtained anywhere else. He has been thoroughly trained in the fundamental principles of his profession, and no college or university should try to do more than this. There may be post-graduate work along special lines of investigation, it is true, but the *real* post-graduate work can only be done out in the world when he commences to take a hand in the game of life.

The college cannot place responsibility on one's shoulders, whereas as soon as practical work is begun this burden immediately commences to be felt, even if the position held is a very subordinate one.

In college the young engineer has just commenced to learn engineering, having completed only the ground work of his education, and he should begin at the bottom in practical work.

Such was the advice given by Dean Galbraith twenty-four years ago to our graduating class, and my experience has been that there could have been none better.

The first years after leaving college, therefore, should be spent in obtaining experience, as broad as possible, just as the young graduate physician does in going from one hospital to another to improve himself and broaden his training.

In our profession in the early stages, the old motto about "The Rolling Stone" does not apply. While the young engineer does not gather moss he gathers what is much better, experience —experience of the world, experience of men and of things, and his corners get rounded off.

It was just for this reason that in former days the artisan, having completed his term of apprenticeship, started out as a journeyman, to improve himself by travel and variety of experience through contact with the outside world in different places before settling down to his vocation.

The young engineer, therefore, should commence at the bottom, seeking that employment which will bring him out on the work, so that he can see how engineering construction is actually carried on, and how men are handled. He should learn as early as possible to understand men, not only the man with the pick and shovel, the iron erector, or the concrete mixer, but also the man above him. This knowledge cannot be acquired too early, nor can the subject be studied too carefully. It is of much greater importance to his future advancement than technics alone.

He will soon learn some fundamental things. He will find that the day labourer is a human being, having all the human weaknesses of character which we have, perhaps more accentuated on account of his lack of education, but having at the same time a sense of right and wrong. It will be found that he can be reasoned with and under proper leadership takes pride in his work.

It will be found that the man who is able best to direct these men is not the loud-swearing boss, but the quiet-mannered man of firm character, who thoroughly knows his work, and gets it done right without much friction. He has a pleasant word for everyone who is doing his duty. And those who are not doing their duty are not on the job; but let it not be forgotten that this type of leader knows his work thoroughly. In his spare moments he is thinking out methods of how to economize in labor and how to protect his men against accidents, and also how to conserve his employer's interests; he is never found drinking with his men; they *must* respect him.

There are such men as these, born leaders, on all kinds of work—in the backwoods, on construction, and in the shop. Even if one never becomes a contractor nor employs labor, he must learn to appreciate this type of man, because some day when he is high enough up there will be such men under him, and he must know how to win their respect and confidence.

The engineer may be ever so successful as an office man, still some day he will find that his lack of knowledge of men is a very serious obstacle in his upward career, for an engineer to rise to the top must be a leader among men.

My advice, therefore, on starting out in life to the young engineer is that he should not put on any academic frills or patronizing airs. There will be very unpleasant experiences otherwise, and such deportment is a great handicap. He should be modest and thorough. If he is of the right stuff he is bound to come up, without any such useless accessories.

Now, what kind of work will enable one to gain the best experience in the shortest time, for mass of experience alone does not count unless it is broad and varied.

Railroad construction on heavy work, especially in unsettled countries or out-of-the-way places, is, I believe, the very best kind of experience to get immediately after leaving college, because one gets up against first principles, as it were, and sees how things are done from the very bottom.

The life breeds self-reliance and disposition to stand physical hardships, both of which are indispensable, and should be learned early, and the staff is thrown into more intimate relationship than in more settled communities. Besides railroad construction will enable one to see all kinds of work under way—the surveying, the clearing of the timber, earthwork, rock excavation, masonry, concrete, pile-driving, bridge building, track laying, and ballasting, and perhaps tunneling, and it will be a life out in the open air, and the further away from civilization for a time the better the experience.

It may be necessary to commence the work in the wilderness, where even food supplies at first may have to be brought in on the backs of men, exemplifying the earliest and most primitive methods of transportation; and when the work is finally completed and the welcome locomotive appears at the end of track, one engaged in such work will have seen the quick evolution in a few short months, from the most primitive to the most advanced method of transportation, made possible by the gradual progress of science throughout the many centuries, by the knowledge it has given the modern engineer to enable him to control the forces of nature for the benefit and use of mankind.

The lessons thus learned are never forgotten. Often do I find myself recalling with profit some experience gained on my railroad and survey work of many years ago. Even the hardships, the rough life, the plain food (and sometimes even the lack of this), the mosquitos and black flies and other things, are remembered with pleasure, for it was a life of strenuous work along the blazed trail, through the unknown forest and over the hills, and it was a struggle with the elemental forces of nature, and somehow most of us have enough of the primitive man in him to instinctively enjoy what our ancestors had to do.

After having two or three years' experience on railroad or other constructional work in a more or less subordinate position, it is time for a change back to the office; and I would suggest entering a bridge or structural shop, commencing in the draughting-room on shop drawings.

I have suggested a bridge and structural shop for the first experience at the shop, because the training there obtained is fundamental. All the methods are generally developed to a high dgree of refinement, and economy has been very carefully studied both in manufacture and handling of the material.

A large concern is not desirable, because the detailing work is very much sub-divided; however, a few months' experience in such a place would do no harm, if only to learn their methods; but in a smaller concern there is more chance of seeing what is being done in the shop, and very often it is possible to be sent out on the erection.

One will be able to learn the fundamentals of shop work at first hand, such as template and pattern-making, the use of the tools, the handling of the material by cranes and derricks, and the making of erection plant and rigging.

In the office the instruction is also fundamental, and the knowledge gained applies to many branches of engineering outside of buildings and bridges.

It must not be thought for one instant that a draughtsman is an engineer. An engineer must be a draughtsman, just as he must know a good deal about surveying, although a surveyor is not necessarily an engineer.

He should spend every moment of his spare time in watching the work he details go through the shop, and, if possible, should see how it is erected. In my early days I used to put in the time after draughting hours, and even at nights, when the shop was working overtime, in the shops, in order to get posted on the process of manufacturing. No reasonable employer will refuse this permission, and if such is not granted I would advise a change to some other establishment. It has been my experience that the high grade employer was very willing and anxious to have his office men take an interest in such things—he is looking for just that kind of men.

One should be punctual, and not be the last to come in and the first to quit work. He should be diligent and intense in his work, and not loaf or "soldier" like the old fellows—they remain draughtsmen all their life. He should be thorough, using great care to be exact when necessary. For instance, very often drawings may be freehand sketches if the figures are correct, and all the information given. Shop drawings, nowadays, are largely conventional. It is not really draughting in the broad sense of the word at all; therefore, do not waste time on unnecessary work, but be very careful not to omit information that the man in the shop needs. These remarks do not, of course, apply to scale drawings, which should be carefully and neatly made.

It is of great importance to know how to letter neatly and rapidly. It very often aids one to obtain the first position in the draughting-room, for very likely the first question asked the applicant is, after having stated, that he has had a technical education, is to see samples of his draughting, and if the lettering is done neatly, not only may it get him a position, but secure his advancement much more rapidly from the draughting of shop details to the making of general plans.

It is not necessary or advisable to stay for months on shop details of simple work. After the routine is acquired, one should try to get advanced to more difficult work by winning his employer's confidence in his ability to do it.

He should not get despondent if, by reason of lack of openings, he has to stay longer in a subordinate position than he feels he ought to. He will know, if he is honest with himself, when the time comes to make a change to another employer.

He should be very careful, however, not to change unless for a very good reason. "Stickativeness" at the right time is a valuable asset, but when he does leave he should try his level best to make his departure a source of regret, rather than of joy, to his former employer.

While at the bridge shop the method of organization should be thoroughly studied. It is as plendid opportunity, and should not be lost.

Carnegie was once asked to write an article on Organization. He said he would, but his price would be very high. "How high?" was asked. "Five million dollars," was his answer. The knowing *how* to create such an organization as the Carnegie Steel Co. was worth that amount to anyone who really wanted to know. He further said: "You may take all the machinery, all the plant, all the business, away from the Carnegie Steel Co., but leave me my staff and organization, and I will have it all back in five years." He has often said that his success in life has been due to his knowledge of men.

The knowing how to perfect an organization of human machinery is the most valuable knowledge one can have, and exceeds technical qualifications, but one must know the technics in general to be able to perfect an organization.

One should stay at the shop long enough, if he ultimately thinks of becoming a bridge or structural engineer, to know how to design, detail, build in the shop, and erect buildings and bridges. In my opinion, no engineer is thoroughly competent to *design* unless he knows also how to *construct* the work which he designs.

After being at this work three or four years, and having already been on construction two or three years, the young engineer will have completed the bottom course of his foundation in practical work. He will have been up against first principles, as it were, in both construction in the field and in the shop. He should now look about him, and try to see whither he should begin to steer. He will by this time be able to tell from his own experiences, whether or not he wants to remain a professional civil engineer with some specialty untimately in view or whether or not to go into some line of manufacturing work or contracting.

If at this time he has the means to travel he should spend a year abroad if he intends being a professional engineer, studying European methods and designs. This study should be abroad and far-reaching.

He need not hesitate about engaging in manufacturing or contracting work if he has the taste for it. The technical training and practical experience already obtained are a splendid foundation for this. He will be able to tell when the time comes whether or not he is fitted for this kind of work. One's temperament has a great deal to do with his success as a contractor or manufacturer.

It is of value to know something about bookkeeping and stenography might be valuable, as there are many cases where private secretaries have been able to rise to very important positions.

Another important thing is the keeping of costs of all kinds of work. My practice has been to keep these on regular card index-filing cards. The cost memos should, to be of any value, record not only the amount of the material used and the price per unit for this material, but also the number of hours and rate of wages of the different kinds of labor.

The salary which an engineer receives during his first years is of the least importance. In seeking employment it should be the value of the experience in building his foundation of knowledge which should count, unless, of course, there are special reasons why he should earn as much salary as possible.

I do not mean to say he should be satisfied with a nominal salary or less than what is the prevailing rate of compensation for the same kind of work. This he should obtain, as he would be doing both himself and his profession an injustice if he does not. What I mean to say, however, is that if two positions are offered, in one of which the salary is less than the other, but in which there is a chance of obtaining more varied practical knowledge and ultimately securing greater salary, the former should be selected instead of the latter.

Each position, no matter how subordinate, should be looked upon as a stepping-stone to something better, and every experience, even if unfortunate, be remembered, for such lessons are of great value. One actually learns more from his failures than from his successes.

I have been asked frequently by young engineers if they should accept positions in the tropics in unhealthy districts, and my advice has always been not to do so, for one should not handicap his whole future career by risking his health in his early years, and it is not at all necessary. There are plenty of positions open in Canada and the United States, and there is always a scarcity of thoroughly competent men to fill them.

As to positions in Municipal Bureaus or under the Government, I would advise against these in the earlier stages of practical work, because I think that broad and strenuous experience is better gained elsewhere. It is time enough after the foundation has been thoroughly laid to step into a position under Government, if it is desirable.

And now, just a few words more of advice to the young engineer. He should not drag out the work he has to do, in attempting a degree of refinement which it does not warrant, yet he should not get careless; when he feels that he is getting that way he should shake himself up a bit, or the boss, if he is of the right kind, will surely do so. He should apply the rule of common sense to everything he does. After having completed a design, for instance, let him forget all about the theory and mathematics involved, and try to look at it from the standpoint of practicability—the shop processes, the erection of the work in the field. Let him seek eagerly the results of practical experience, and listen with respect to advice of even the rule-of-thumb practical man who knows his work. He should not try to get another man's job. He should be loyal to the man above him. If he cannot be so on account of this man's lack of integrity, he should either ask for a change or resign. But only a peculiarity of temperament in his employer is not a sufficient excuse for a change. One *must* learn to be tactful and to get along with people both above and below him.

A tendency to change one's position too often without just cause shows a lack of steadfastness.

An employer always wants to know why one seeking employment has changed from one position to another, and the reasons given are carefully considered in the estimate he forms of the applicant's character.

I would advise in making application for positions to clearly but *briefly* state exactly what the previous positions have been, and the experience obtained, and the reasons for leaving each of these.

A copy of a testimonial from each employer should be sent with the application. A personal interview is always to be desired if possible, as it enables the employer to "size up" his man.

The young engineer should associate himself with the local engineering club if one happens to exist, and should early join the Canadian or American Society of Civil Engineers, or both, and keep fully abreast of the times in technical matters. He should mix with those in other professions and with business men, and become known in the place where he lives. Besides, he should not neglect his general education, for after leaving college he has only commenced to be educated in the broad sense. His reading should be as diversified as possible—in history, economics, and general literature, so that some day he may become a well-balanced all-around man, not only a credit to the noble profession he has chosen for his life's work and to his Alma Mater, but also to the community wherein he lives.

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[This paper of Mr. Stern's cannot but be of mutual interest to the undergraduate and young civil engineer. Mr. Stern and the editor are anxious to have the article freely discussed. Applied Science will print the discussion. Mr. Stern will sum up and complete the same in the April number. Next year it is intended to take up the discussion of "The Young Electrical and Mechanical Engineer."—Editor.]

# A NOTE ON THE RELATION OF THE MINING ENGINEER TO THE PUBLIC.

H. E. T. HAULTAIN.

"The learned professions" was a term of our fathers. They had the Church and Law and Medicine and to these they perhaps added as an "honourable" rather than as a learned profession that of Arms, and this covered the list of the professions as distinguished from other walks of life. We still use the term and in an unthinking way with about the same limitations. But —nowadays, is not engineering one of the professions?

What is a profession? Who defines the word? What is not a profession? In these days what is not learnéd? Many trades call for mental activity of a higher order and for more knowledge than did the professions of our grandfathers. Should we use the term or drop it? Should we modify it by the words learned or honorable or both? In contradistinction to what other terms should we use it?

I am in the dark. I grope. I would grasp that quality or that function of engineering which makes it one of the professions. But perhaps it is not a quality nor a function, nor even an essence, but rather a blending so subtle as to defy isolation or definition. My engineering spirit rebels. I not only want to isolate this something but I want to measure it and having failed my engineering spirit shies away, retires in disappointment at failure, and goes back, content, perforce, with the overalls and the rule and the things with which they fit. But we really are with the Doctors and with the Divines and with the Lawyers. But how? Are we not learned? We are honourable. Are we? Is that the essence that we must isolate and measure. Who defines honour? If it is a function how do you express it. If it is a quality how do you measure it. Is it also a complex blending?

Perhaps the term profession *should* be shied away from. Are there not other words that we shun? Honour, for example, yes! and gentleman. In all probability their undefineableness preserves their sacredness and their strength, yes, and strange as it may seem perhaps their educative value. Gentleman is often a much abused and a hateful word and so is perhaps honourableness. But still they have a great educative value and we must not lose them.

Is it not perhaps in public service and honourableness that are to be found the main characteristics uniting the professions? Learnedness counts for little in these days where there is high mental activity in so many directions. Public service alone is not a characteristic of the professions, though Kipling tells us that Lalun's was the most ancient of professions.

But these are wanderings. I want to bring the mind of the Engineer and more particularly the Mining Engineer to the question of public service and honourableness in his profession and this can be done by the consideration of a particular phase of his work. The Consulting Mining Engineer sits in his office waiting the call of the public just as do the Doctor and the Lawyer. He has to live so he charges a fee as do the Doctor and the Lawyer. But before the fee is arranged for, and even without a fee the Doctor and the Lawyer and the Engineer are honourable men to whom personal secrets may be safely told. And the best of information and advice is at the service of the would-be client.

The client gets a disinterested opinion to the best of the ability of the Lawyer or the Doctor or the Engineer. Disinterested was the word I used. That is the quality of honourableness that we can isolate and measure. If disinterestedness is not the all of honourableness it is the main ingredient of the blend.

The professional man considers only the good of his client —if he cannot do so he does not accept the client as his. But is this all? Another client visits the Doctor and is prepared to pay a large fee and demands the best treatment at his hands, but he finds this client has smallpox and immediately his attitude towards him is somewhat changed. His first thought is not for the client but for the public. He will do the best he can for his client but subject always to the good of the public. The client cannot be allowed to travel to his friends—he cannot have the most comfortable of quarters—he cannot even have his secrecy and privacy entirely preserved. The public is the Doctor's first client, and takes right-of way. The Doctor's will in this respect is strengthened by the law of the land, but the law had its inception under the guidance of the Doctors.

The Lawyer's philosophy is not quite so fine. The Lawyer is a special pleader and will accept as a client an enemy of the public good and will protect him from the public.

Is this quite true? Nominally, No! but in reality—yes! But with this difference, the Lawyer does this only in open court where the public also has its Lawyer to defend itself and the game is played in the open. But we must remember that the Lawyer is a special pleader and presents his case from his client's point of view even to the extent of withholding truths and distorting evidence.

This is much below the standards of the Doctor and yet is compatible with honourableness for this reason and only this reason that it is done publicly and openly in the presence of an opposing counsel and a controlling, judgment giving judge.

How is it now with our Engineer and his client? A client says: I am thinking of buying B's mine. Will you examine and report on it. The Engineer does so and condemns the mine, and advises A not to purchase. B goes to the Engineer and says: I want to sell my mine to the public at a large figure. I am going to promote a company and I want an Engineer's report for the prospectus.

Now, what is this Engineer going to do? Is he a special pleader taking his client's fee and making the best of his client's case by withholding some truths and even distorting some evidence that his client may sell his mine to the public? No! most decidedly, No! Unfortunately, he cannot publicly proclaim the man as does the Doctor with his case of smallpox. All he can do is to refuse a garnished report. Now here is the danger and the trouble of it all. The man with the no-good mine goes to another man who says: I am an Engineer; I will make you out your report. This other man may have no claim whatever to be an Engineer but the public does not know this. But there are others who have been Engineers who now do this kind of thing because of greater or easier gain, but they are the prostitutes of the profession, and they should be ostracized.

The Doctors have their Medical Council—the Lawyers have their Law Society and they tell the public who are Doctors and who are Lawyers and they exercise some control over the standards of their professions. But in Canada we have no Society of Mining Engineers corresponding in any way with the Law Society and we have no publicly recognized ethics of Engineering. Is not the larger duty before the Engineer in all branches to-day the recognition of the public service and of the honourableness of his profession?

## PLATE GIRDER WEB SPLICES

C. R. YOUNG, B.A.Sc.

Except in the case of plate girders of small size, it is generally impracticable, and sometimes impossible, to construct a girder without one or more web splices. The rolling mills do not manufacture plates over certain extreme lengths depending upon the width and thickness, and these limits cannot, therefore, be exceeded in design. The price per pound of the extreme sizes of plates is at the same time higher than for those of more moderate dimensions, so that the use of several plates with splices might be a cheaper arrangement than employing a single plate. It also frequently happens that the necessity for despatch in the work does not permit waiting for the delivery of full-length plates from the mills, and so the girder is made up of shorter ones which chance to be in stock at the time.

The splice provided at a given section must obviously be capable of safely resisting whatever stresses exist in the web at that section under the most unfavorable condition of loading. What this latter is must be ascertained by calculation. In the case of girders carrying moving loads it may chance that the splice will be more heavily stressed under the maximum shear at the section with the corresponding moment than under the maximum moment with the corresponding shear. This is not likely to occur, however, for splices nearer the centre of the girder than one-quarter of the span length, and, as will be shown later, the splice will generally be amply strong if designed for the maximum moment sustained by it, without regard to the effect of the corresponding shear. In keeping with the common practice of making the details of a structure such as to develop the full strength of the main material, web splices are, however, frequently designed to develop the full capacity of the net section

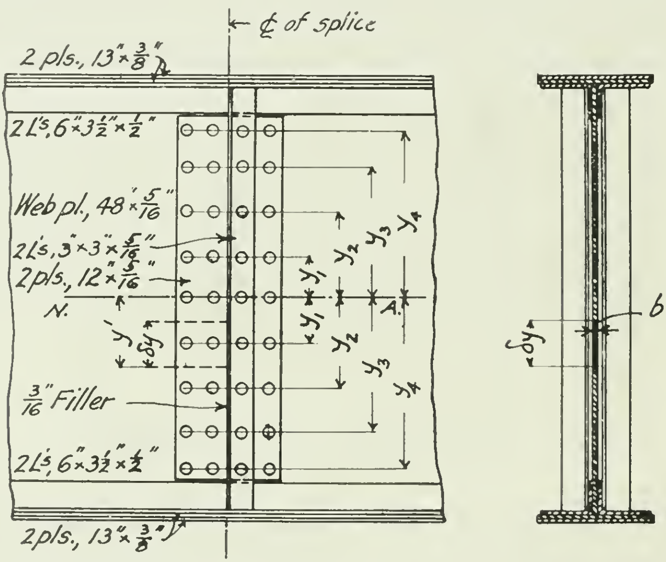


Fig. 1

of the web, and not merely to resist the calculated stresses that might arise at the joint.

When the arbitrary assumption is made, as some specifications require, that the web is not to be regarded as resisting any of the bending moment, the splice need not be proportioned to take bending stresses, but merely the shear at the section. It then consists, as shown in Figure 1, of two vertical plates, one on each side of the web, extending from the inside edges of one pair of flange angles to the inside edges of the other pair and having not less than two vertical rows of rivets on each side of the splice. The two plates are generally chosen to make up a combined thickness of one and one-half times to twice the thickness of the web. A pair of stiffener angles are commonly placed at the splice to give effective lateral support.

Although the splice is required to transmit only the vertical shear across the joint, one designed in strict conformity with this requirement would not be allowable since fewer rivets would be employed than practical considerations of rivet spacing will permit. This may be seen from a discussion of the splice illustrated in Fig. 1, which occurs at 12 feet from one end of a girder 40 feet centre to centre of bearings carrying a total static uniform load of 5000 pounds per lineal foot. The total shear at the joint is 40,000 pds. and this must be resisted by the two rows of rivets on either side of the splice. The assumption is generally made that this shear is uniformly distributed among the rivets sustaining it, which is probably not far from the truth. In addition to the direct effect of the vertical shear there is a turning moment brought to bear upon the rivets on either side of the joint equal to the vertical shear multiplied by the distance between the centres of gravity of the two groups of rivets on opposite sides of the splice. This arises from the necessarily eccentric application of the vertical shearing force. The effect is not large, however, since the splice generally constitutes a deep connection, and it is generally neglected. Using ¾-inch rivets and assuming the safe shearing and bearing stresses for rivets at 11,000 and 22,000 pds. per sq. in. respectively, the least value of one ¾-inch rivet is found to be 5160 pds., its bearing value on the 5/16-inch web plate. The number of rivets required on one side of the splice would therefore be 40,000 ÷ 5160 = 8. Since, however, the vertical rivet spacing should properly not exceed 16 times the thickness of the splice plates or 5 inches, using 5/16-inch splice plates, 18 rivets must be used on each side of the splice instead of 8. Thus it is necessary, practically, to make the splice much stronger than the requirements of stress-resistance would dictate, in this case almost enough to provide for the total end shear, or in other words, enough to develop the full capacity of the web. The total end shear being 100,000 pds., and one rivet having a value of 5160 pds., only 19 rivets would be required for this service, and therefore it is apparent that the splice might as well be at once designed to equal in strength the net section of the web plate.

If in the design of the girder the reasonable assumption is made that the web plate develops the full moment of resistance of which it is capable by virtue of its net area, the web splices must be proportioned to transmit bending, as well as shearing, stresses across the point. Assuming that the bending stress in the web increases uniformly from the neutral axis to the most remote fibre, it follows that the stresses on rivets in a web splice due to bending increase uniformly from zero at the neutral axis to a maximum at the rivet most remote from that axis. The resisting moment which a rivet will therefore exert against the bending moment will vary directly as the square of its distance from the neutral axis, since the resisting moment equals the resisting force generated by the rivet multiplied by its distance from the neutral axis. Hence it is evident that the rivets farthest away from the neutral axis are more effective in resisting bending moment than those nearer it and that those lying on the neutral axis have no value as far as resisting moment is concerned.

For this reason the type of splice shown in Fig. 1 generally proves inadequate where bending stresses have to be provided for, unless a great number of rivets are used by adopting very close vertical spacing or widening the splice plates and introducing another line of rivets on each side of the splice. Such an arrangement is highly uneconomical, for a large proportion of the rivets—those near the neutral axis—have very little value in resisting bending stresses. More efficient means have to be devised, therefore, for splicing webs in girders of the kind under discussion.

A form of splice frequently used in such cases is that shown in Fig. 2, and which has been designed for the girder of Fig. 1, the section of which is revised in conformity with the assumption that one-eighth of the gross area of the web may be considered as flange area. Instead of carrying the two vertical splice plates from flange to flange, two horizontal splice plates are placed on the web just inside the inner edges of each pair of flange angles and the vertical plates terminate at the inside edges of the horizontal plates. The latter are generally of about the same thickness as the former, that is the two plates on opposite sides of the web together make up a thickness of one and one-half times to twice the web thickness. By the employment of a splice of this type it is possible to locate a large percentage of the rivets used at a considerable distance from the neutral axis where they are highly effective in resisting bending moment. So much resisting moment is developed by the rivets in these horizontal splice plates that some designers assume that it is all generated by them and that the vertical shear is wholly resisted by the rivets in the vertical splice plates, the numbers of rivets used in these plates being arrived at on the basis of the foregoing assumptions.

While this is an ideally simple arrangement from the standpoint of the designer, it has the disadvantage of giving rise to secondary stresses of considerable magnitude in the web. The provision of a stiff, closely-riveted splice just inside each pair of flange angles has the effect of throwing most of the bending stress into the horizontal splice plates because of the principle that a load which has to travel over several paths divides itself up among these paths directly as their rigidities. This concentration of bending stress into relatively small areas of the web cross-section produces an effect of somewhat the same kind as that which would be produced if single pins were used at the ends of the horizontal splice plates and the web were not reinforced at these points. Such localizing action is evidently not to be commended.

That the concentration of large numbers of rivets at certain points in the web splice is not consistent with the assumption of uniformly-varying bending stresses on the web section may readily be shown. Referring to Fig. 1, the resisting moment of any element of the web of height $\delta$ and thickness $b$ is equal to $\frac{f^1}{y^1} I^1$, where

$f^1$ = the stress in pds. per sq. in. on the extreme fibre of the element.

$y^1$ = the distance from the neutral axis to the extreme fibre of that element.

$I^1$ = moment of inertia of the cross section of the element about the neutral axis of the girder $= I + Ay^2$.

$I$ = moment of inertia of cross-section of element about an axis through its own centre of gravity.

$A$ = sectional area of element.

$y$ = distance of centre of gravity of element from neutral axis of girder.

Since the moment of inertia $I$ of the small area $A$ about its own gravity axis is negligible compared with the term $Ay^2$, we may write $I^1 = Ay^2$, approximately. Now since uniform variation of stress has been assumed

$$\frac{f^1}{y^1} = \frac{f}{\frac{d}{2}}$$

where $f$ = permissible stress at the extreme fibre of the web, which is assumed to be at the centre of gravity of the flange.

$d$ = effective depth of girder which is assumed to be equal to the depth of the web.

The resisting moment of the element therefore equals $\frac{2\,A\,f\,y^2}{d}$

Now since the stress on rivets due to bending effect increases directly with the distance from the neutral axis, if a rivet in the gauge line of the flange angles have a safe value of $r$, then the greatest permissible stress on a rivet one inch from the neutral axis would be $\frac{r}{\frac{d}{2}}$, assuming that the gauge line is at the same distance from the neutral axis as the centre of gravity of the flange. A rivet at a distance $y$ from the neutral axis would then carry a stress of $\frac{2\,r}{d} \times y$, and its resisting moment would be $\frac{2\,ry^2}{d}$

The number of rivets in the element should therefore be

$$\frac{2\,A\,f\,y^2}{d} \div \frac{2\,ry^2}{d} = \frac{A\,f}{r}.$$

This quantity is independent of the value of $y$, and therefore the spacing of rivets should be uniform from top to bottom of girder in order that the assumption of uniformly-varying stress may be realized. Though the concentration of rivets as far as possible from the neutral axis in a splice of the type shown in Fig. 2 is economical in the matter of riveting, this saving is effected at the expense of preventing the web at the splice from acting in the same manner as elsewhere, and probably overstressing it at certain points.

This type of splice has at the same time the minor defect

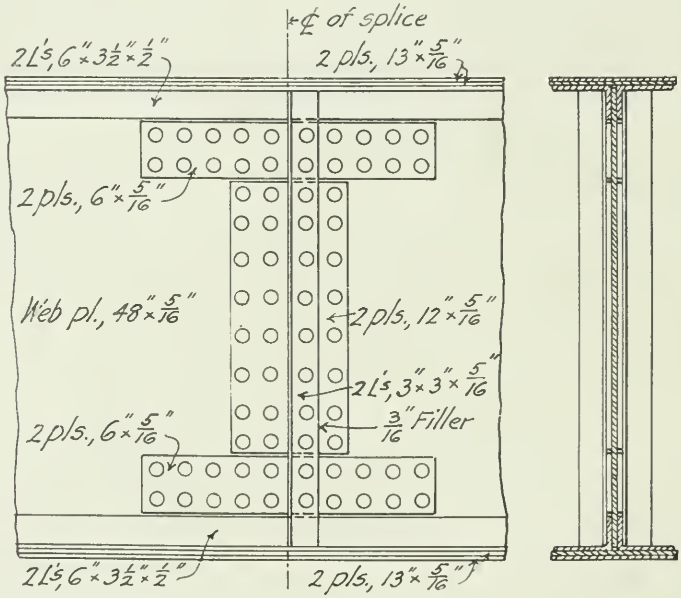


Fig. 2

of not presenting a very pleasing appearance to the eye. A suggestion of "patching" is borne to one who is not oblivious of all save the requirements of strength and dimension.

A more satisfactory form of splice is that shown in Fig. 3. In this, the vertical splice plates, which are of similar thickness to those used in the types described above, run from flange to flange and horizontal splice plates are put on either side of the vertical legs of the flange angles. The rivets in the vertical splice plates are spaced about 4 inches apart vertically and as uniformly as possible, the shorter spaces, if any, being placed at the ends. Using two rows of rivets on each side of the splice in these plates is generally not sufficient to develop the full bending value of the web plate, and instead of introducing another row, the horizontal splice plates are employed. If the full value of the web were developed by the rivets in the vertical splice plates, the splice would not be well designed, for the part of the web lying between the two vertical legs of the flange angles should be spliced as well as the part covered by the vertical splice plates. Obviously the horizontal splice plates should be strong enough, and contain enough rivets, to develop the difference of resisting moment of the net section of the web and of the splice as provided by the vertical splice plates and the rivets in them. It might be urged that where more than four rivets were required in the horizontal splice plates on each side of the splice (see Fig. 3) to develop this difference of resisting moment, it is equivalent to concentrating the rivets at this point. In answer it can be said that the part of the sectional area of the horizontal splice plates and of the rivets in them which is not utilized for splicing the portion of the web between the vertical legs of the flange angles may be regarded as affording an increment in flange section in the region of the splice. Increasing the flange section at the splice makes is unnecessary to splice the web up to its full bending value and whatever resisting moment is developed by this increment of flange section need not be provided by the web splice proper.

The objection is sometimes raised against the form of splice under discussion that the horizontal splice plates necessitate additional fillers under the stiffeners which come at the splice or crimping different from that used for the other stiffener angles. These disadvantages are never serious and are preferable to the use of an arrangement by which only the part of the web between flanges is spliced either by the use of three vertical rows of rivets or two rows and horizontal splice plates on the web with the attendant concentration of rivets near the inner edges of the flange angles. Even if additional fillers have to be used under the stiffener angles at a splice of the form advocated, its superior economy of material and rivets over the splices of the two other forms mentioned above will nearly counterbalance the increase of weight necessitated by the extra fillers. Very often the crimping of the stiffeners at the web splice, if they be crimped, is, or may be made to be, the same as for the other stiffeners. This is possible when the horizontal splice plates can be made of the same thickness as the vertical splice plates, which is frequently the case.

One of the reasons given by some authorities for not using this type of splice is that the rivets in the horizontal splice plates on the vertical legs of the flange angles are put under double duty. Except in the case where the splice occurs at a point of zero shear, a certain number of rivets per lineal inch are required in the flange angles in the region of the splice for the purpose of transferring the increment of flange stress from the web to the flange angles and plates, and therefore the rivets in the horizontal splice plates are only *partially* available for the purposes of the web splice. There is no reason, however, why the rivet spacing in these plates cannot be shortened up, so as to accommodate such a number of rivets, that allowing a *part* of each rivet for purely flange riveting purposes the requirements in this respect would be fully satisfied while at the same time the remaining *parts* of rivets would fully provide for the web splice.

To illustrate the method of designing a web splice of the last type discussed, the splice shown in Fig. 3 will be investigated in detail. This joint occurs 15 feet from one end of a girder 60

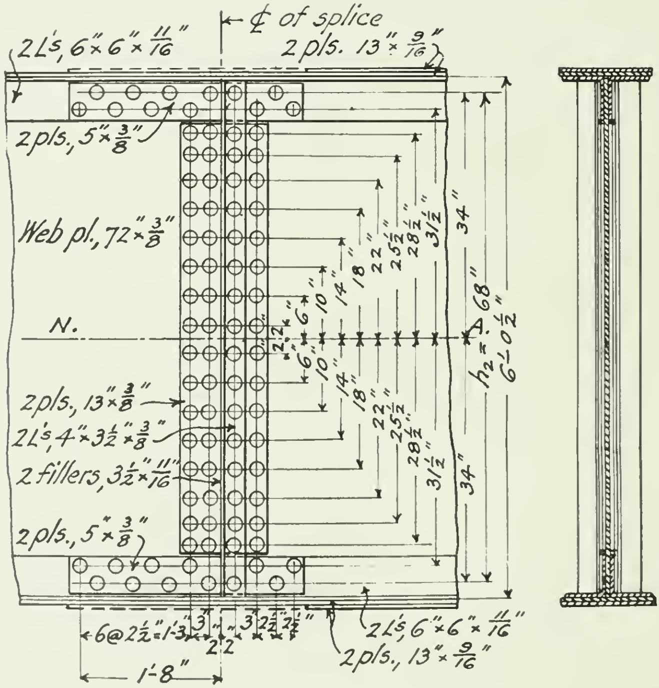


Fig. 3

feet centre to centre of bearings, carrying a total static uniform load of 6000 pds. per lineal foot. It was figured on the assumption that one-eighth of the gross area of the web acted as flange area, the permissible fibre stress in bending being taken at 16,000 pds. per sq. in. net section. The safe shearing stress on the web was taken as 10,000 pds. per sq. in., net section, the rivets being ⅞-inch in diameter and the assumed safe shearing and bearing stresses being 11,000 and 22,000 pds. per sq. in., respectively.

Since, in general, it is not possible to locate a web splice where there is an excess of flange area, the splice will be designed to develop the full bending value of the web. In the present instance it would be permissible to splice the web for only a part of its bending value if the outer cover plates which theoretically terminate about a foot to the right of the joint were carried past that point, as shown dotted in the figure. By this device no excess material is utilized, however, but the flange is reinforced to relieve the web of part of the bending stress. The same results are attainable in a preferable way, by reinforcing the vertical legs of the flange angles. In the problem under discussion the full resisting moment of the web is equal to one-eighth its gross area multiplied by the permissible fibre stress and by the effective depth of the girder which will be assumed as the depth of the web. This gives $\frac{1}{8} \times (72 \times \frac{3}{8}) \times 16{,}000 \times 72$ 3,880,000 in.-pds.

The vertical shear at the section, which is readily found to be 90,000 pds., must also be transferred across the joint simultaneously with the bending moment. It will be shown, however, that if the splice is capable of withstanding the bending stresses it can resist the shear at the same time without revision of the design.

The most ready method of proportioning the splice is to assume the size of the two vertical splice plates and the arrangement of rivets in them, and then having calculated the resisting moment of these rivets, it becomes an easy matter to ascertain the number of rivets needed in the horizontal splice plates on the flange angles to develop the remainder of the required resisting moment. In the case at hand, the two vertical splice plates will each be assumed as 13″ × ⅜″ and the vertical spacing of the rivets will be chosen as 4 inches with a few shorter spaces at the ends. The net section of the plates should in all cases be capable of developing the same resisting moment as the rivets connecting them to the web, but this will be realized for ordinary cases if the two plates have a total thickness of about twice the thickness of the web and the calculation generally need not be made.

The resisting moment of the rivets in the vertical splice plates on one side of the splice may, from what has already been said, be set down as $\frac{r}{\frac{1}{2} h_2} \Sigma y^2$ where

$r$ = least value of one rivet.

$h_2$ = distance apart of outside gauge lines in the flange angles.

$y$ = distance of any rivet from neutral axis.

The least value of one ⅞-inch rivet will be its bearing on the ⅜-inch web plate, or $\frac{7}{8} \times \frac{3}{8} \times 22{,}000 = 7{,}220$ pds., and $h_2 = 68$ inches. The resisting moment which these rivets can safely develop is therefore

$$= \frac{7220}{34} \times 4 \left\{ (2)^2 + (6)^2 + (10)^2 + \dots + (28.5)^2 \right\}$$

$$= 212 \times 10426 = 2{,}210{,}300 \text{ in.-pds.}$$

The difference between this and the total resisting moment of the web, or 1,677,700 in.-pds. must be made up by the rivets in the horizontal splice plates. The permissible stress on a rivet at one inch from the neutral axis due to beding being 212 pds., as determined above, the resisting moment developed by a rivet on the inner and outer gauge lines of the flange angles will be $212 \times (31.5)^2$ and $212 \times 34^2$, respectively. Assuming that $m$ rivets are required on the inner gauge line and $n$ on the outer one, we may then equate the resisting moment of these rivets to the balance of resisting moment left undeveloped by the rivets in the vertical splice plates, or

$$2\,m \times 212 \times (31.5)^2 + 2\,n \times 212 \times (34)^2 = 1{,}677{,}700.$$

Solving by trial it is found that $m$ and $n$ in whole numbers must each be equal to 2, these rivets being momentarily regarded as wholly available for the web splice.

The effect of the shear at the splice will now be investigated. Due to bending, the rivets in the outside gauge line of each pair of flange angles will be the ones most severely stressed. At the same time these rivets must resist their share of the vertical shear of 90,000 pds. which is assumed as uniformly distributed over all the rivets in the two vertical gauge lines on one side of the splice, in this case 36 rivets. The test of the sufficiency of the splice is therefore the determination whether the rivets most remote from the neutral axis are capable of withstanding the total stress, from both causes, brought to bear upon them. Since slightly less than two rivets were required in each gauge line of the horizontal splice plates for the development of resisting moment, if two are provided in each gauge line, the stress on the outer rivets need not be as much as the full value of the rivet, but the same proportion of it as the required resisting moment of the splice is to the provided resisting moment. The latter is made up of the resisting moment of the rivets in the vertical splice plates which equals 2,210,300 in.-pds. and the resisting moment of the four rivets in the horizontal splice plates which equals $4 \times 212 \times (31.5)^2 + 4 \times 212 \times (34)^2 = 1{,}821{,}700$ in.-pds. The total provided resisting moment therefore equals 4,032,000 in.-pds., assuming the extreme rivets to be stressed up to their full capacity due to bending alone, and hence the necessary stress on these rivets to develop the required resisting moment is $7220 \times \frac{3{,}888{,}000}{4{,}032{,}000} = 6950$ pds. Combining with this horizontal stress the vertical stress due to shear which is $90{,}000 \div 36 = 2500$ pds., we have a resultant stress of $\sqrt{(6950)^2 + (2500)^2} = 7390$ pds. on any one of the extreme rivets, or an excess of 2.4 per cent. over the permissible stress on a rivet according to the assumed rivet specification. This increase in stress is scarcely large enough to make the addition of another rivet necessary, and the case chosen is fairly representative of the most of web splices. It can generally be said, therefore, that if the splice is designed to provide for bending it will resist the corresponding shear without modification. The only case where revision might be necessary would be where the splice comes near the end of the girder, where it may have to be designed for maximum shear with the corresponding moment.

Whether the horizontal splice plates on the vertical legs of the flange angles are regarded as web splice-plates or as reinforcements of the flange, they must have sufficient net area to develop the same resisting moment as the rivets in them, it being assumed for the present that all these rivets are wholly available for the purposes of the splice. This resisting moment has been found to be 1,821,700 in.-pds., and the net area of the two plates multiplied by the permissible fibre stress in them and by the distance between a line midway between the two gauge lines in one flange to the corresponding line in the other flange should be equal or greater than this resisting moment. The permissible fibre stress in these plates will be the permissible stress at their

centres or $16000 \times \frac{32.75}{36} = 14{,}550$ pds. per sq. in., and the net

area of two plates will be $1{,}821{,}700 \div 14{,}550 \times 65.5 = 1.91$ sq. ins. Two $5'' \times \frac{3}{8}''$ plates will be used giving a net area of 3.00 sq. ins.

The length of these plates must be chosen so that the rivets in them on the side of the splice nearest the support will be enough to satisfy the requirements of the web splice and at the same time transfer to the flanges the increment of flange stress which is developed between the last rivet in the plates and the centre of the joint. The result is best arrived at by trial. Assume four extra rivets in the end of these plates, the last rivet coming 20 inches from the centre of the splice. At the splice the spacing for purely flange purposes must be 5.52 ins. in the top flange and the same will be adopted for the bottom. Hence in 20 inches, $20 \div 5.52 = 3.6$ rivets are needed to transfer the increment of flange stress from the web to the flanges. The four extra rivets will be enough for this purpose and the four already provided are required for the web splice. The slight excess of 0.4 of a rivet will be required, since the rivet spacing for flange purposes near the end of the horizontal splice plates should be less than 5.52 inches.

On the other side of the splice only enough rivets are required to develop the net strength of the plates, the least value of the rivets being their double shearing value. This is the case since the most direct route for the stress in these plates to follow is from the plates directly into the flange angles and not into the web and then back into the flange angles. The net area of the two plates being 3.0 sq. ins., and the value of a $\frac{7}{8}$-inch rivet in double shear being 13,220 pds., 3.6 rivets are required. Four rivets will be used. The increment of flange stress required to be transferred from the web to the flanges in the distance from the centre of the splice to the end rivet in these plates will not increase the number of rivets, since in considering the two effects simultaneously the least value of a rivet becomes very large—its bearing value on the two flange angles which are together 1⅜ inches thick.

## INSULATION TESTING.

E. M. WOOD, B.A.Sc.

Tests on insulation are usually made for one of two purposes—to determine the insulating value of various sorts of materials, or to find out if the insulation of some particular piece of elec-

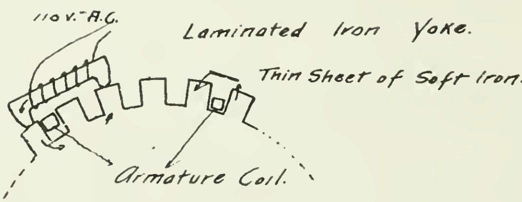


Fig. 1 — Device for locating Short Circuits in Armature Windings.

trical apparatus is sufficient to justify its being put into use, or continued in use. Tests for the first purpose are almost exclusively confined to samples of insulation, and are made in the research or testing laboratories of manufacturing concerns. Tests of the second sort should be made on every piece of electrical apparatus before it leaves the factory, and may, with advantage, be made from time to time on the apparatus as it continues in use. It is with tests of this latter sort that this article will deal.

There are two classes of insulation used in electrical apparatus; first, the "minor" insulation, separating the turns and layers of the winding from each other, and, secondly, the "major" insulation, which separates the winding as a whole from other windings and from the supporting frame or case.

The insulation between turns may be tested by generating in the windings a voltage greater than their normal working voltage. This may be done in the transformer by applying twice normal voltage for one minute, or three times normal voltage for fifteen seconds to some section of the windings, thus inducing the same proportion of voltage in other windings on the same core. The applied voltage should be at as high frequency as possible to keep down "exciting" current.

For a generator, the over-voltage may be obtained by driving it above normal speed, on open circuit, with all the excitation possible. One and a half times normal voltage will be about the maximum obtainable by this method.

There are various methods of testing the wound armatures of generators and motors for short circuits between turns. One typical method is indicated in Figure I:

The portable laminated yoke shown is excited by current at 110 volts, *A. C.* The magnetic circuit is closed through the iron of the armature to be tested, so that the alternating flux surrounds one or more slots with their conductors. This sets up an *E.M.F.* in the conductors, and if there is a short circuit in the coil, heavy local currents in that coil are set up. The presence of these currents can be detected by the flux set up around the other leg of the coil in another slot, use being made of a piece of soft iron to detect the presence of this flux. In the case of a closed winding there will be current and flux anyway, but the presence of the flux is much more noticeable if there is a short circuited coil.

The most important insulation test is the test for the strength of the "major" insulation. This is practically always applied from a testing transformer. The voltage to be applied depends on the rated voltage of the piece of apparatus and the use to which it is to be put. The following table is taken from the Standardization Rules of the A. I. E. E., sections 220-226:

| Rated terminal voltage of circuit. | Rated output | Testing voltage. |
|---|---|---|
| Up to 400 volts | Under 10 *K.W.* | 1,000 |
| " " | 10 *K.W.* and over | 1,500 |
| Over 400 and less than 800 | Under 10 *K.W.* | 1,500 |
| " " " | 10 *K.W.* and over | 2,000 |
| Over 800 and less than 1,200 | Any | 3,500 |
| Over 1,200 and less than 2,500 | " | 3,500 |
| 2,500 and over | " | Twice rated voltage |

There are certain special exceptions noted. Transformers with primary pressures, 550-5,000 volts, whose secondaries are to be directly connected to consumption circuits should have a testing voltage of 10,000, to be applied between primary and secondary windings and between primary winding and core.

Field windings of synchronous machinery to be started by *A. C.*, with fields not excited, should be tested at 5,000 volts.

The above voltages should be applied to the machine at the temperature attained in continuous operation. However, the above voltages should be applied to new machines only, or to machines newly insulated. For old insulation the test voltage should be lower, say from 50% to 75% than given in the table, depending on the condition of the machine.

Practically all electrical apparatus exhibits under high potential test more or less electrostatic capacity. The windings and the iron act as the two plates of a condenser, with the insulation as the dielectric. This capacity requires charging current of the value, $I = C w E$ where $E$ is the test voltage, $C$ the capacity in farads, and $w$ the frequency in radians per second. The capacity of the testing transformer should be such that it can supply to the test, the above current without instability of voltage ratio and without undue heating of its windings. Mr. C. E. Skinner, in an article on "Testing of Insulation," in the *Electric Journal*, Vol. II., page 538, gives the following table of suitable capacities for various kilovolt ratings:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| E. M. F. Kilovolts | 2 | 6 | 10 | 30 | 50 | 100 | 250. |
| Rating K. W. | 1 | 3 | 5 | 30 | 50 | 100 | 250. |

Since the tendency of an alternating voltage to break down insulation depends on its maximum instantaneous value, and since all *A.C.* voltage measuring devices indicate the square root of the mean of the squares of the instantaneous values, it is evi-

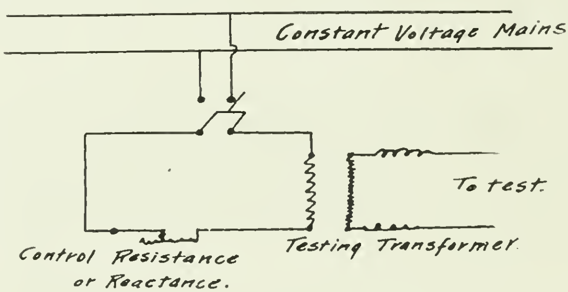


Fig 2. —Testing Set with Resistance or Reactance Control.

dent that for the same voltmeter indication *A.C.* waves of different shapes have different power to puncture insulation. Therefore tests, to be consistent, should be made with *A.C.* waves of standard form, namely sine wave form. The testing apparatus should be of such a nature as to produce, under conditions of test, a voltage wave form as nearly sinusoidal as possible. All tables of testing voltages, and all guarantees of insulation strength assume that the tests shall be made with *A.C.* waves of such form.

The severity of the test for a given voltage depends to a certain extent on the frequency, it being generally true that the higher frequencies give the more severe tests. Tests should then be made at some standard frequency, say 60 cycles, or better, at the frequency of the circuit on which the apparatus is to be used.

The test method of application of the testing voltage depends on conditions. Five of the more useful methods will be outlined.

1. By direct application from a constant potential circuit. This method may be used in all cases up to, say 2000 volts, and in case of switches, insulators, etc., which have little electrostatic capacity, for any voltages.

2. Voltage from constant potential circuit with testing transformer. Control of voltage is obtained by means of a resistance or reactance in the primary circuit as shown in Figure 2.

A water rheostat, or a variable reactance, for example a "theatre dimmer," makes a suitable form of control. The reactance has the advantage of consuming less power, and of giving steadier control, as the water resistance is liable to fluctuate, due to the formation of gas on the plates. The method is useful for voltages up to 25,000. It has the disadvantage that the controlling resistance or reactance necessarily distorts the wave form of voltage. This is not of vital importance in tests up to 25,000 volts, but eliminates the usefulness of the method for higher voltages.

3. Voltage from generator with testing transformer, control

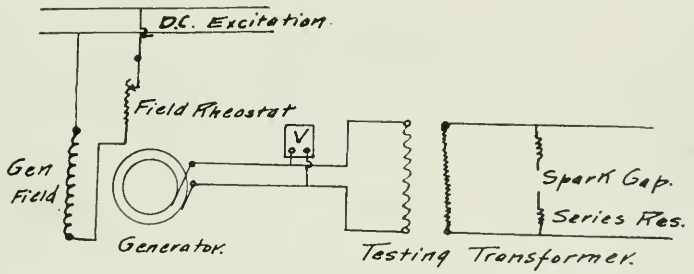


*Fig. 3—Insulation Testing Set with Generator Field Control.*

is obtained by variation of generator field. Connections are as shown in Figure 3.

The method is available for any voltage and any capacity. It has the disadvantage that it requires a special generator as part of the testing set. The method gives best results when the generator is worked at approximately normal voltage, practical limits of allowable variation being from 50% to 125% normal voltage. If these limits are exceeded the wave form is liable to be distorted by the load, and especially at low excitations the voltage will be unsteady if the transformer is loaded with "leading" current, as is the case in tests on high tension power transformers, cables and all apparatus with high electrostatic capacity between windings and frame. This method or the previous one is highly satisfactory for all high potential tests on other classes of electrical machinery. For testing apparatus like high voltage transformers and cables, one of the following methods is preferable.

4. From a constant potential circuit with a testing transformer, with voltage control by auxiliary transformers whose sections are cut in or out by dial switches. Various forms are in use, one of the best of which is shown diagrammatically in Figure 4.

This uses two regulating transformers besides the testing transformer. The voltage variation is in steps of one-quarter of one per cent. from zero voltage to full rated voltage, each of the regulating transformers being in 20 sections. The variation from step to step is made without opening the primary circuit, a very important advantage, especially in tests at high voltages. In case of break down the circuit breaker C.B., opens and allows the current to pass through the choke coil, permitting the fault to be burned out if desirable.

The voltage supply is usually from some generator which gives a proper wave form. This generator may supply power for more than one testing set if required. It may be conveni-

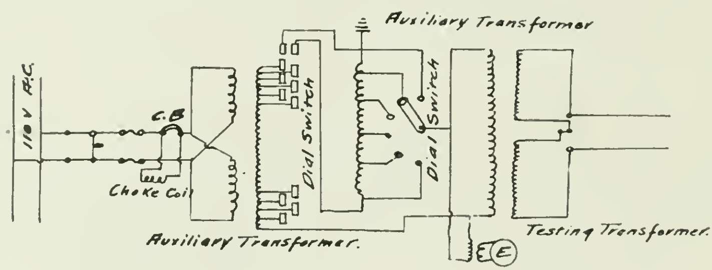


Fig.4 – Testing Set with control by Auxiliary Transformers.

ent to make the testing set portable, and to bring out terminals from the supply generator at proper places throughout the factory, so that the set can be rapidly connected to any set of terminals.

The above method is a perfectly satisfactory one for all conditions of high voltage testing.

5. Voltage from constant potential circuit with transformer, controlled by means of a single phase induction potential regulator in its primary circuit, as shown in Figure 5.

The regulator must be of special design, with the same voltage in secondary as in primary, or in other words, with a "buck" or "boost" of 100% of the line voltage. Then when working on 500 volt circuit, with primary in maximum lowering position, the voltage at the transformer primary terminals will be 500—500=0 volts. The voltage can be raised gradually, by turning the hand wheel, until the primary is in maximum "boost" position when the voltage at the primary of the testing transformer is 500 + 500 = 1000 volts. The worm-gear and wheel should be cut with a compound thread so as to give a very gradual variation of voltage. The regulator should work "snugly," so that there is no "play" in the movable parts, but should not be so tight that it cannot be turned steadily by hand.

This method is quite satisfactory for all kinds of insulation testing. It has one advantage in that the experienced operator can judge by the way in which the "wheel" turns, approximately what is happening in the apparatus under test.

It is, of course, of great importance to be able to measure with some degree of accuracy, the voltage applied in the test. There are at present no entirely satisfactory methods, though there are several in use.

1. By ratio of transformation, with voltmeter on low tension side of testing transformer. This method neglects "regulation" and is only useful where accuracy is not important, that is in tests up to 10,000 volts.

2. By special "voltmeter coil" of known number of turns on the core of the testing transformer. This is more accurate than

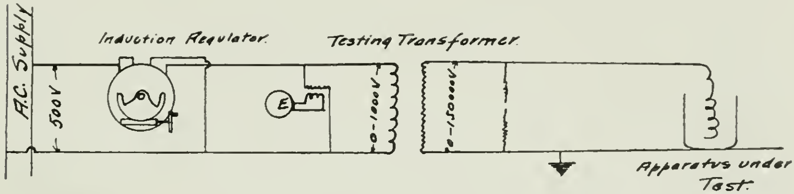


*Fig. 5 – Insulation Testing Set with control by Induction Regulator.*

the first, for it eliminates that part of the regulation due to the primary.

3. By special "voltmeter coil, this being part of the high tension winding. This is theoretically an improvement on 2, but it must be taken off next to grounded terminal of the winding, and unless this is the middle of the winding these turns are liable to be not representative of the rest of the winding, on account of leakage fluxes, etc.

4. By voltmeter in the high tension circuit. This is the ideal method, but unfortunately it has serious practical limitations. The use of series resistance of potential transformer, with a voltmeter for 20,000 volts or over, would be too expensive and consume too much power for commercial use for measurement of test voltages. The static voltmeter, if there is a reliable one on the market, would be the best method available for the measurement of high voltages.

5. By spark gap in the high tension circuit. This method is the one most frequently used. It is not absolutely reliable, but with care yields fair results. The Standardization Rules of the A.I.E.E. state with regard to the use of the spark gap (Sec-

tion 245): "The spark points should consist of new sewing needles supported axically at the ends of lineas conductors, which are each at least twice the length of the gap. There should be no extraneous body near the gap within a radius of twice its length."

To prevent a large rush of current and consequently high voltage surges when the gap breaks, there should be inserted in series with each of its terminals, a resistance of one-half ohm per volt. These resistances may be carbon resistance rods, similar to those used in lightning arresters. These resistances usually decrease the gap setting for a given voltage by an amount which should be determined experimentally (about 5%).

Moderately low voltage tests, say up to 30,000 volts, require no particular care in application, except that they should be isolated so that no one will get hurt, and that the application of voltage should be fairly smooth. Voltages over 10,000 should be checked by spark gap in high tension circuit.

Voltages, 30,000 to 80,000, require more care in applying the voltage smoothly and removing it smoothly, that is, without sudden vibrations. The spark gap should be set for the required testing voltage, with the apparatus to be tested connected in as shown in Figure 5, and the voltage raised until the gap arcs over. Just *before* the break, a voltmeter reading should be taken. As soon as the gap breaks, the voltage should be lowered to zero and the gap opened say 10 % beyond the setting for the required voltage. Then voltage should be applied again with the same voltmeter reading, and held one minute, then lowered to zero. A break is indicated by the drop of the voltmeter needle to zero, and by the action of the apparatus, as burning usually follows a break-down.

At voltages higher than 80,000, with apparatus of high electrostatic capacity, it is dangerous to break the gap at full test voltage, for the arcing gap sets up voltage surges of the worst sort. The difficulty may be obviated as follows: The gap may be set at two-thirds the required voltage, and broken, with the transformer in circuit, the primary voltage being read just before the break. The voltage should be reduced to zero, and the gap opened to 10% above the distance for required testing voltage. The voltage should be then applied till the voltmeter reading is three-halves its former value, held for one minute and lowered gradually to zero. This method is sometimes satisfactory and sometimes not satisfactory. Variations are suggested by experience to fit the various conditions that arise with the different sorts of apparatus that are to be tested.

There is another insulation test, the measurement of "Insulation Resistance." This may be done roughly by a well-known high resistance voltmeter method, or by direct reading megohmmeter. It is chiefly of value in determining the state of the insulation with regard to moisture, since the greater the degree of moisture, the lower the insulation resistance. Any piece of apparatus that shows low insulation resistance (below one megohm) should be carefully dried out before an application of high potential is made.

This article will conclude with a few general practical suggestions on making the insulation tests.

1. Since the voltages used in insulation testing are all dangerous to life, too great care cannot be taken to prevent any person coming in contact with the live circuits.

2. When a machine has more than one winding, all windings except the one under test should be carefully connected to the frame, which should preferably be grounded. This is to prevent undue electrostatic stresses being induced, tending to break down the insulation from these windings to ground.

3 If there is more than one accessible point in any winding to be tested, all accessible parts should be carefully connected together electrically. This is to insure uniform application of voltage to all parts of the winding, and is a very important point. It often makes the difference for a piece of apparatus between standing the test, and failing.

4. Application of voltage should be gradual, without sudden variations but not too slow, as the severity of the test depends on its duration. For a test of 160,000 volts to a large transformer, it would be a good rule to take one minute to raise the voltage from 0 to 160,000 volts, hold at that value for one minute, and take one minute to lower the voltage to zero. No apparent impending breakdown should induce the operator to make a sudden reduction in testing voltage, for if he does, the break will become a certainty.

5. Any means possible of reducing the static discharge in a high tension test, is of advantage for the static discharges are liable to set up surges which may cause break down of insulation.

6. All connections should be made tightly and with good contact.

# SOME RECENT ADVANCES IN ELECTRO-CHEMISTRY AND ELECTRO-METALLURGY.

SAUL DUSHMAN

The application of electrical energy to the performing of a large number of reactions previously carried out by purely chemical methods, has at the present time attained to a position of great commercial importance. This has been due largely to the rapid developments that have taken place in methods of power production. So long as the cost of electric power was high, the idea of supplanting ordinary chemical or metallurgical processes by the more simple electro-chemical ones could not be entertained, and electro-chemistry remained practically a laboratory science. But it was during this period that the foundations were laid for many of the most important electro-chemical industries of the present time, and, as a result, the advent of cheaper electric power found the electro-chemist prepared to utilize the advantage which was thus held out, and during the last decade the progress in electro-chemistry has been so enormous that in very many cases the electric power plant has been installed on account of the electro-chemical consumers.

Some of the electro-chemical industries, such as the carbide, carborundum, aluminium, copper-refining and caustic soda processes, have long since passed beyond the experimental stage, and their products have become vital necessities in the industrial world. Other processes, however, have obtained a great deal of prominence in the last few years, which cannot be said to be as yet in a state of assured stability, and these, since they are probably not so familiar to many of our readers, form the subject of the present article.

It is a long step from the time of Cavendish to the present, but the relatively unimportant fact discovered about the year 1776, that an electric spark passed through a moist mixture of oxygen and nitrogen will produce nitric acid, is the basis of a large number of projects, that have recently become technically important, for the fixation of atmospheric nitrogen. As is well known, our wheat crops require for their successful growth, a certain amount of fertilizer to be supplied to the soil. Nitre, or Chili saltpeter has been the substance chiefly used for this purpose in the past; but the beds of nitre in Chili are gradually becoming exhausted, and even if the supply be available for a much longer period than Crooks averred in 1892, the world has come to realize that some other source of fertilizers must be sought for, if its food supply is to remain assured. The essential requirement of a fertilizer is that it shall contain nitrogen, in a form which can readily be absorbed by plants; this condition is fulfilled very well by nitrates. Now all around us, constituting the very atmosphere we breathe are present the essential components of nitric acid, and it is therefore not surprising that the old experiment of Cavendish has again been brought to light and the question has arisen, how the fixation of atmospheric nitrogen may be performed on a commercial scale?

Lack of space will not permit us to review the preliminary work of different experimenters in Germany and England who, during the years 1897 to 1904, sought to solve the problem. Their experiments, although they did not result successfully from a commercial point of view, led to the conclusion that the main reaction in the electric arc is the formation of nitric oxide according to the equation,

$$N_2 + O_2 \rightleftarrows 2NO,$$

the amount of NO increasing with the temperature and depending at constant temperature on the concentrations of the components, according to the Mass Law. It was also shown by Nernst* that the proportion of air converted into nitric oxide is always very small, and even at 2600° *C*, it amounts to only two per cent. by volume.

These investigations thus prepared the way for the first commercial process, that devised by Birkeland and Eyde in 1904. They use a 5,000 volt alternating current arc between water-cooled copper electrodes, and by means of a magnetic field at right angles to the latter, the arc is spread out into a disc over 2 metres in diameter, thus causing almost the whole volume of air in the furnace to be raised instantaneously to a very high temperature. Owing to the circulation of air through the furnace, the nitric oxide formed there is cooled before it has a chance to dissociate, and combines, at 600° *C*, with oxygen to form the higher oxide, $NO_2$. This is passed through a series of towers washed with water and gives a 50 per cent. nitric acid, which is then saturated with lime and converted into a basic nitrate useful as a fertilizer. The furnaces used by Birkeland and Eyde are each of 500 kilo-watt capacity, and while in their original plant at Notodden, Norway, only 1,500 kilo-watts were used, this has since been increased to 40,000 *KW*. The yield is 70-83 grams pure nitric acid per kilo-watt hour, which corresponds to 500-600 kilograms per *KW* year, and the inventors claim that this figure can be considerably increased.** It may, however, be stated in this connection that the main reason for the success of this process is the fact that power in Norway can be obtained at the extremely low price of approximately $5.00 per *HP* year, a figure which is probably much lower than that quoted in other countries.

Simultaneously with the Birkeland-Eyde process there has been developed another one by the Badische Anilin and Soda Fabrik. "They employ an arc in a long tube through which air is passed in a whirling motion. Since 1907 they have operated

*Nernst, Zeit. f. Elektrochem. 12, 527.

**Erlwein, Elektrotech Zeit, Jan., 1907.
Edstrom, Trans. Am. Electrochem. Soc., 1904.

an experimental plant of 2,000 *HP*, and are now planning the erection of a large 120,000 *HP* plant."*

The problem of the fixation of atmospheric nitrogen has also been solved in a totally different manner. A few years ago the search for a commercial method of producing cyanide of potassium led Drs. Frank and Caro to the discovery that when nitrogen is passed over calcium carbide at a high temperature, such as that of the electric furnace, there is produced a compound having the formula $Ca\ CN_2$ and known as cyanamide. This substance is capable of yielding a large number of interesting derivations by treatment with suitable reagents; ** thus by melting with certain fluxes it yields potassium and sodium cyanides; by the action of steam it gives off ammonia which may be converted into ammonium sulphate, and it has also found application in the organic dye industry as well as in the tempering and hardening of steel. But its most important use has been found to be as a fertilizer. Investigations by Dr. Hall at Rothamstead have shown that as a manure it is equal to nitre or any of the artificial fertilizers. It is, morever, cheaper than the basic nitrate produced by Birkeland and Eyde. According to Dr. Frank, "to replace the present consumption of Chili nitrate by cyanamide would require something like 800,000 *HP*, and works are springing up all over the world to produce it wherever water-power is abundant and cheap."*** The original works of Frank and Caro at Piano d'Orte, in Italy, are being extended at the present time to an output of 10,000 tons and numerous plants are installed or being contemplated in various European countries as well as in America. The United States Cyanamide Company is erecting a 5,000 to 6,000 tons works, at Niagara Falls, Ontario, and will shortly build another installation in Tennessee.

While important progress has thus been made in processes for the utilization of atmospheric nitrogen, electrical methods have also been invading a field in which at first there seemed to be little probability of their gaining a foothold. But the cheap, efficient manner in which electrical energy can be applied instead of coal in many branches of the iron and steel industry has caused the new methods to become an important factor even here. During the latter part of the nineteenth century immense strides had been made in both the theory and practice of iron smelting. The conditions governing the nature of the product obtained in the blast-furnaces were investigated thoroughly; so that the iron metallurgist could produce an iron of any desired quality. Similar progress had been made in the manufacture of steel. But the scarcity of coal in many places where both ore and cheap power are available caused many persons to consider the advisability of using electricity to do the work ordinarily per-

*Electrochem. Ind. VI. 478, Dec., 1908.

**Erlwein, Elektrotech. Zeit, Jan., 1907; also Chem. Ind., 1907.

***Report of a lecture to the Faraday Society, Electrochem. Ind., VI. 311, Aug., 1908.

formed by coal. The report of the Canadian Commission has been long enough before the public for all to become fairly familiar with its contents, and a great many Canadians have come to realize the immense possibilities of electro-thermic processes in this country. However, the time seems hardly ripe for an extensive development of electrical iron smelting, and we cannot do better than quote, in this connection, the opinion of Mr. J. Harden, a noted metallurgist.* After comparing the two processes for reduction of iron ore, he concludes that "where conditions are the same in both cases, as to the class of ore, amount of labor, and class of fuel available, the electric smelting furnace requires an expenditure of $9.70 per ton of produced iron, while the blast furnace requires only $6.84 or $2.86 less per ton of iron." He then reviews the difficulties which have occurred in the various types of electric furnaces, and makes the following noteworthy remarks:—

"It is certainly not our intention to stamp the electric smelting furnace as a hopeless impossibility—far from it; but it is only intended to state things as they are at the present, and keep some of those optimists a little nearer the earth who dream that the days of the good old blast furnace are doomed, and must give way to the more modern electric smelting. We certainly believe that the smelting furnace is capable of attaining perfection, like everything new, but all improvements must go steadily forward, not in leaps and bounds, as the effects of undue rashness are only leading us astray." His conclusion is that electric smelting would be justifiable only in such regions as India or Western States of U.S.A., where there is practically no coke, while there are large deposits of cheap ores and abundant water-power. The carbon required for the chemical reduction could be obtained by converting wood and forest waste (which may be had there in large quantities) into charcoal.

While the success of electric smelting is thus still a probability, the production of steel in the electric furnace has become an established process. The first steps in this direction were made by the carbide and aluminium producers at a time when an over-production of these products on the European market threatened many electro-chemical installations with absolute ruin. Naturally, the products initially turned out were more or less novelties, like the ferro-alloys. A gradual education of the steel consumers has, however, not only led to a greatly increasing demand for such special alloys, but has also encouraged the electro-chemical manufacturers to enter upon the production and refining of steel. Here the electrical processes possess undoubtedly superior advantages, both from the point of view of efficiency and of ability in controlling the quality of product; and when Mr. Chas. M. Schwab** states that in his opinion the

*Electrochem. Ind. VII. p. 16, Jan., 1909.

**Report of Mr. Schwab's testimony before the Ways and Means Committee in the recent tariff hearings, as given in Iron Age, 1908.

near future will see the electric steel furnace an essential part of all existing steel plants, it is evident that the advantageous results to be obtained by using the new process have been perceived by the most important steel producers.

Out of the large number of new developments that have occurred in this industry within the last couple of years, two are especially worth noticing. One of these is the Lash steel process, the object of which is to make any desired steel by properly mixing ore, cast iron and carbon and then subjecting the mixture to heat. "The essential features in the process seem to be the fine state of division of the constituents of the mixture, their intimate association, and the use of iron containing metalloids in considerable quantities."*

The other great development has been the Roechling-Rodenhauser modified induction furnace. The ordinary induction furnace is in reality a transformer in which the secondary is constituted by a ring of molten metal. Owing to the high temperature of the latter, careful heat insulation has been found necessary from both the primary and magnetic iron core. The result has been a considerable magnetic stray flux and consequently a low power-factor. Attempts have been made to reduce this defect by lowering the frequency of the alternating current generators, and frequencies as low as 15 have been used. But the most recent innovation due to Messrs. H. Roechling and Rodenhauser of the Roechling iron and steel works in Voelkingen, Germany,** consists in having an additional secondary coil connected with metal plates which are separated from the molten bath by a refractory electrolytic conductor of the same kind as used in the Nernst lamp, so that the metal is heated not only by induction currents but also by currents passing through it between the electrode plates. Single-phase current was originally used in this furnace, but more recently three-phase current has been used successfully,*** and it has been found possible to operate such furnaces economically with alternating current of ordinary frequency, so that the necessity of building special and expensive generators is thereby obviated. The principal use for this type of furnace is in further refining the steel after it is blown in the converter, the additional cost of electric refining being more than compensated by the greater density and homogeneity of the product. It is also interesting news that by this method more than 1,000 tons of steel rails have been made and sold by the above iron works to German railroads.

Not only in the electro-metallurgy of iron and steel but also in other fields of electro-chemistry there have been many signal advances. Acheson's deflocculated graphite and Potter's "Monox" form the latest additions to the already large number of electric

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*Electrochem. Ind. VI, 493, Dec., 1908.

**Stahl u. Eisen, Nov. 6, 1907.
Electrochen, Ind. VI, p. 10, Jan., 1908.

***Electrochem. Ind. VI, p. 457, Nov., 1908.

furnace products. The former of these is the result of Mr. Acheson's discovery that fine, pure graphite (which he succeeded in producing during 1906) when digested with water containing a trace of tannin becomes capable of remaining suspended in the water for an indefinitely long time, forming as it were a colloidal solution. In this condition, the graphite is designated by its inventor as "deflocculated," and the aqueous suspension has the singular property of being an excellent lubricant. When added to oil, deflocculated graphite reduces its coefficient of friction considerably. It therefore seems as if it will obtain important commercial application.

Dr. Henry Noel Potter has obtained silicon monoxide by reducing silica at the temperature of the electric arc either by silicon or coke.* The temperature thus produced which has the formula $SiO$ (analogous to $CO$), has been called "monox" by its inventor. In the air, it burns very readily to silica and this explains why it has not been obtained under the conditions existing in the carborundum furnace. In the furnace designed by Dr. Potter a mixture of sand and coke, or carborundum fire sand, is subjected to the action of an electric arc between two horizontal electrodes which are covered by the charge. As soon as the reaction begins, the monox vapor produced blows a funnel-shaped hole through the charge and is then chilled by contact with the walls of a large enclosed drum which covers the top of the charge. As this drum is practically free from air, the vapor does not burn but is condensed as a deposit on the walls of the container. The solid monox is a fine, opaque, light-brown powder which possesses many interesting properties. It has been found to be a valuable pigment in certain oil paints, in particular paints for brick-work and paints for protecting structural iron from rusting. It is also a good addition to black printing inks; and the probabilities are that many other uses will be found for it.

This completes our brief survey of some of the recent advances in electro-chemistry and electro-metallurgy. A great many things have necessarily been omitted; such as the work done by Edison and others on the iron-nickel accumulator; the electrolytic refining of lead, silver, and gold; the production of caustic soda and chlorine in the Townsend cell; the aluminium rectifier, and numerous other topics. But perhaps even the above few remarks may serve to show that not only has the development of electro-chemistry in recent years taken place in many directions that even the most imaginative scientists of twenty years ago did not foresee, but also the future will probably see more and more of the ordinary chemical and metallurgical operations replaced by electro-chemical processes. Especially will this be so for our own province, where, as well known, hydro-electric power is readily available, and there is an abundance of the choicest raw materials.

*Trans. Am. Electrochem Soc. 12, 1907, p. 217.

# FERTILIZERS AND THEIR MANUFACTURE*

F. K. HARRIS, '09

The object of a fertilizer is to supply to the soil those elements and constituents which the plants have absorbed in the process of their growth, and, generally speaking, there are three primary elements which need to be supplied, namely:

(1) Ammonia or nitrogen.

(2) Phosphate of bone containing about 50 per cent. free phosphoric acid.

(3) Sulphate or muriate of potash, sulphate being the best.

These three ingredients mixed with pure sand and water will stimulate the growth of vegetation, and as the sand has not the elements that will sustain plant life the test shows that the added fertilizer supplies the necessary food.

A rich land has all the elements to a greater or lesser degree, while a poor land lacks some, or nearly all, and some land will have all the elements but one. But no matter how rich the land is an addition of fertilizer generally proves a benefit, increasing the yield with the same labor. There are two general classes of fertilizers:

(1) Indirect fertilizers.

(2) Direct fertilizers.

An indirect fertilizer is one which does not in itself furnish directly to the soil any needed plant food, but whose chief value depends upon the power it has of exchanging unavailable into available forms of plant food. Those which are employed most commonly are lime, gypsum and common salt.

Gypsum, known also as calcium sulphate, or sulphate of lime, in some manner aids the process of nitrification, by which the ammonia and the nitrogen of organic matter are converted into nitric acid and nitrates. It also acts on the insoluble forms of potash and other elements of plant food, converting them into soluble and available forms. It is of value to such plants as clover and peas, etc.

Quick lime, or burnt lime, or calcium oxide, commonly called lime, change both the physical and the chemical character of soils. Freshly burned lime acts by decomposing vegetable and mineral matter already present in soil and changing them into forms which are available as food for the plant. Thus lime acts upon insoluble mineral substances containing potash and converts them into soluble forms. Lime aids in decomposition of animal and vegetable matter, such as vegetable mold, stable manure, etc., and tends to convert them into available plant food. Lime should be used along with other fertilizers.

Common salt has an indirect fertilizing value, which is mainly due to its power of changing unavailable forms of plant food into available, especially potash.

*Read before the Chemical and Mining Section of Engineering Society, Nov., 1908.

Hence we see if these were used alone the soil would soon become exhausted, and become of no value.

Direct fertilizers contain forms of plant food which contribute directly to the growth and substance of the plants. Such materials may contain either nitrogen or potash, or phosphoric acid compounds, or any two or all three of these forms.

Some of these direct fertilizers are:

Nitrate of soda, known as Chili saltpetre, found in Chili and Peru of S. A., contains 15½ to 16% of nitrogen.

Sulphate of ammonia is formed from waste products produced in manufacture of illuminating gas or coke. This contains about 25% of $NH_3$, which is equivalent to about 20½% of nitrogen.

Cottonseed meal is product form, after extraction of oil from cottonseed oil. This contains about 7% nitrogen, 3% phosphate and 2% potash.

Tobacco stems are refuse from tobacco factories, and consists of 5-8% potash, 2-3% nitrogen and small quantity of phosphoric acid.

Dried blood consists of blood obtained from slaughtering animals. It is prepared by evaporating, drying and grinding. This contains 10-15% nitrogen.

Dried fish scraps and ground fish are refuse from canneries and contain 7-8% nitrogen, together with as much insoluble phosphoric acid.

Meat scraps and tankage are slaughter-house refuse, dried and ground. Good tankage contains 10% or more of nitrogen and as much phosphoric acid.

Nitrogenous guanos are formed in dry regions. The Peruvian guano contained 7% of nitrogen, 7-12% phosphoric acid and about 1% potash.

Bones.—These consist mostly of calcium phosphate, which consists about 3/5 wt. of the bone. The remaining portion is a soft, flesh-like substance, called gelatine, which is rich in nitrogen. Bones which are used in making commercial fertilizers contain from 4-5% of nitrogen, and 20-25% of phosphoric acid, of which 1/3 is available.

A fertilizer largely used in Southern States at present is known as rock phosphate. The chief rocks which are used are apatite, caprolite and phosphorite. Until recently a large quantity of apatite was exported from Canada to Southern States from around Ottawa district for this purpose. But the discovery of the rocks of this nature having been made in the States the trade in Canada came suddenly nearly to a standstill.

In Southern States phosphate rocks are named by names which designate localities from which they come, as South Carolina rock, Florida rock, etc., and contain as much as 25-30% phosphoric acid. These rocks are in an insoluble condition, and of no use as they are. To make them available they are allowed to weather along with sulphuric acid, 100-lb. rock being treated with about 60 lbs. acid. This weathering takes from 4-6 months, in order that the rock may be thoroughly disintegrated. As much as 64% phosphate has been obtained in this way.

Market fertilizers contain, according to requirements for different plants for which they are used, from 2-8% $NH_3$, from 6-10% of bone phosphate and 4-10% potash, the balance being a filler, so that when a market product is mixed about these percentages of plant food are used with enough cheap ingredients, such as ashes and dirt, to make required weight and bulk.

Another form of fertilizers which has found its way into the market during this last century is the slag, which is run off from the basic furnaces used in the iron manufacture. These furnaces are lined with basic materials, such as lime, and during the blasting the lime absorbs the phosphorus from the iron forming the calcium phosphate. This forms the slag. It is run off while molten steam is blown through, which makes it porous and light.

This is now ground up and sold under the name of the "Thomas slag." It is very rich in the phosphates, the chief one being calcium phosphate.

This was first used in Germany and it is estimated that 1.000,000 tons are used yearly for this purpose.

An analysis of this slag is approximately as follows:

| | | |
|---|---|---|
| $P_2O_5$ | - | 16 20% |
| CaO | - | 40-50 |
| MgO | - | 2-5 |
| Si | - | 6 |
| FeO<br>$Fe_2O_3$ | - | 8-15 |
| MnO | - | 5-11 |
| Al | - | .5-.6 |
| S | - | .5 |

We will now consider the manufacture of tankage fertilizer and bone meal from raw material to the finished product.

The raw material is obtained from packing houses, abbatoirs, slaughter-houses and butcher shops. It consists of the refuse from these places, such as carcasses of dead animals, offal and blood from slaughter-houses, bones and tallows and fats from the butcher shops and bye-products, such as meat scraps, etc., from packing houses. This is hauled either by teams or railroad to rendering works. Here the hides of dead animals are taken off and placed in the tanning room. The carcasses are quartered and placed in large iron tanks, which vary in sizes according to size of plant. The most modern ones are about 5-6 ft. diameter and 20-25 feet long, the capacity of these being about 10 tons.

The different kinds of refuse are placed in different tanks. The butcher bones and cattle heads are placed in one tank, the tallow and fat in another, and likewise the offal in another.

When the day's run is in these tanks, whose lids are screwed down in order to stand pressure without allowing any gas or steam to escape, the contents are cooked. This is done by allowing live steam from the boiler to pass in.

All pipes leading from the tanks being shut off by means of valves a pressure is created in the tank, which is allowed to run up from 15-20 lbs., denoted by means of a steam gauge. Under this pressure the length of time of cooking for different materials varies. A tank of 10 tons capacity, when filled with bones, etc., requires from 10-12 hours, while a tank of same capacity of offal requires about 8 hours.

After the cooking or rendering is completed pressure is allowed to go off. This escaping steam is laden with odors, which, if allowed to escape in air, would create a nuisance, hence a device must be had to do away with this.

Some plants lead their exhaust pipes through coils immersed in water, and from there lead into a cavity dug in the earth, where gases condense. Some lead the gases into a water tower, and there in contact with water some of them condense along with steam, while the remaining gases are drawn by a fan and are used for a draught for fires under boilers, there being burnt and allowed to pass out the chimney.

When pressure has all escaped the lid of tank is raised and the grease and oil are skimmed off. This is done by a pipe which is about ¾ way up the tank. In case the oil is lower than pipe liquor from another tank is pumped into the bottom, thus raising the oil.

After the oil has been taken off the tanks are drained of the liquor they contain. This is run by means of a pipe from the bottom of the tank into another division of the factory, called the wet tankage plant. This is done to each tank. After draining off the liquor from the tanks they are dumped. This is done by means of a slide attached to a wheel. They are dumped into vats. From here the bones from bone tanks go through the process of riddling while the offal and the carcass tank are washed with water, in order to obtain as much grease as possible, and then pressed in the hydraulic press.

The process of riddling which the bones undergo is similar to panning gold. The flesh on the bones after being cooked only slightly adhere to bone, hence may easily be separated. The riddle is a round vessel with a meshed bottom, each mesh being about 1″ square. A man shovels the cooked material into one of these riddles and then washes it under water by shaking. The flesh falls through the riddle and the bones are sent along to the drying room.

After being riddled the meat is then placed in an hydraulic press and pressed under a pressure of 120 lbs. for about 2 hours. This removes excess of water and grease and now the product is known as crude wet tankage. This tankage contains about 50-60% of moisture, and in order to make it into a product which could be shipped in bulk without any fear of decomposition the moisture must be reduced to at least 10%. To do this it is passed through what is called dryers. There are many types and descriptions. One of the oldest consists of a brick work enclosing a boiler. Pressure was kept up in this boiler to about 60 lbs.,

The tankage was fed into a worm by a man and shovel. This worm led it to slot where it dropped, and by means of a long shaft fitted with paddles it was made to pass over the boiler. At end of first shaft it was dropped into another slot, where it was carried back by means of a shaft running in the opposite direction. Then it was returned by means of a third shaft and passed out containing from 6-10% moisture. This method was slow and continuous and required two men, one to feed it and one to take it away and keep up steam; hence it incurred a greater expense which the more modern ones do away with.

The more modern ones consist of an cylindrical iron vessel. about 6′ in diameter and about 18-20′ long. This is encased in another cylindrical vessel about 12″ greater in diameter.

The tankage is carried by means of a worm into the inside of the inner encasement until charged. The capacity of this ranges from 1,800 to 2,200 lbs., depending on nature of tankage. When charged the lid is placed on feed box and steam is turned on from the boilers. This steam enters between the two encasements and causes the moisture to evaporate from tankage as it comes in contact with encasement. The exhaust steam is let off. The water vapour from the tankage is carried away and allowed to condense in condensing chamber.

The length of time it takes to dry varies with the various kinds of tankage. If too much grease escapes previous operations it has a tendency to form in balls. This outer portion of ball will dry out and harden, while the inner portion will contain as much as 30% of moisture. This is one reason, other than that of value, why grease should be removed as much as possible.

The time it generally takes to dry is about two hours. When dry it contains about 8-10% moisture and is dumped and shipped as crude tankage to mixers, where it is mixed with potash, etc., as is needed by consumers.

In order that the tankage may be brought in contact with the hot encasement of the dryer the latter is fitted with a shaft runing through the centre. Connected with the shaft are paddles. These paddles revolve and carry with it the tankage. This serves also to prevent the tankage from forming hard lumps as previously stated.

The liquor from the tanks is run over to the wet tankage plant. Here it is allowed to settle in vats or cess pools. Any solid matter carried by the liquor settles to the bottom and any grease that has escaped rises and is skimmed off.

The liquor now is evaporated down to a semi-fluid condition in vacuum pans.

These are generally set up in pairs. The first pan is run at about 13 inches vacuo and the second effect at about 26 inches vacuo.

The vacuum draws the liquor into the pan from the settling vat by means of a pipe. Since the liquor is under vacuum pressure, the temperature required to boil it would be less than if it were boiled under ordinary conditions. Hence the exhaust steam from the engine can be used to do this.

In the first pan it is boiled down to a certain consistency (about that of cylinder oil) and then it is drawn over into pan No. 2. This pan being under greater vacuum will draw it from the first pan, and under this greater vacuum the temperature required to boil it is still less. Thus the vapour which comes oft from the first pan is hot enough to evaporate the liquor in the second pan.

In the second pan the liquor is evaporated to the consistency of about 18° Beaumé, and contains 40-50% moisture. This is pumped when hot into barrels, or it may be fed into the dryer with the tankage. It contains a very high percentage of ammonia, and, in mixing it with the tankage, raises the quality of latter and consequently the value.

In some cases this evaporated liquor, or, as it is known commercially as "stick tankage," may be dried to a powder.

This kind of dryer consists in a revolving cylindrical vessel about 12′ feet long and 4′ in diameter. Steam is passed to the inside, and on side of this dryer is a pan containing the semi-fluid. As this dryer revolves it passes through the liquor, which adheres, and as it revolves the temperature of surface is great enough to drive off the moisture and dry the material.

On the opposite side is a knife, which fits closely to the dryer and scrapes off the dried material into a vat, from which it is placed in the storage room.

The fertilizer, as it now is, is sold to the manufacturers of mixed fertilizer and is sold on the basis of analysis. The two constituents which are of value are ammonia and phosphate of lime. The former being about twenty times more valuable than the latter, hence it is sold on so much per unit of ammonia and so much per unit of phosphate.

To make what is known as bone meal fertilizer the bones are cooked under pressure until they become porous and mealy. This takes about two hours longer than the previous operation. These are then treated similarly to the other fertilizer. It contains 20-30% bone phosphate of lime. The amount of phosphate of lime is estimated on amount which the land will absorb.

It was found that the amount absorbed by the land in course of time was equivalent to the amount which would be dissolved in an ammonium citrate solution. This, along with those phosphates which were soluble in water, were called the available phosphoric acid. But when the "Thomas slag" was used it was found that the ammonia citrate would not dissolve any of the phosphate, but that 1% citric acid solution would dissolve an equivalent amount. Therefore, instead of ammonium citrate 1% citric acid solution is used, and available phosphoric acid is the sum of phosphoric acid which is soluble in water and that soluble in a 1% citric acid solution. The nitrogen is estimated as ammonia by the Kjeldal's method. The nitrogen is changed to ammonium sulphate by means of strong $H_2SO_4$, and the ammonia is driven off by addition of KOH. The ammonia is caught in a known amount of standard acid, and the excess of acid being titrated off, the amount of ammonia can be calculated.

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## W. HODGSON ELLIS, M.A.M.B.

Dr. Ellis' connection with the School of Practical Science dates from the year 1878, when, on the organization of that institution, he became Assistant to the Professor of Chemistry, Dr. H. H. Croft. Prior to this, he had been a practising physician in this city, but this he gave up in the early seventies on receiving an appointment on the staff of the College of Technology, then located in the Mechanics' Institute building, the present Public Library. This College of Technology was the prototype of the School of Practical Science, now the Faculty of Applied Science and Engineering of the University of Toronto.

No professor of this Univeristy has won the respect and affection of associates and students to a greater degree than has Dr. Ellis. No professor's judgment on matters of academic policy was ever saner and no one's advice has carried more weight than has his. Of ripe scholarship, varied attainments, unexcelled honesty and broad sympathies, he has filled a place in university life larger than that which most men occupy. He combines to a very unusual degree a fine literary and artistic taste with rare attainments of a scientific character. His popularity was never greater than it is to-day and his colleagues and students sincerely hope that he may long be spared to continue the work which for over thirty years he has done so efficiently and honorably.

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# APPLIED SCIENCE

INCORPORATED WITH

**Transactions of the University of Toronto Engineering Society**

DEVOTED TO THE INTERESTS OF ENGINEERING, ARCHITECTURE AND APPLIED CHEMISTRY AT THE UNIVERSITY OF TORONTO

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## Editorial

**T-o-r-o-n-t-o's Opportunity**

It had been our intention to write at length on the duty of every Toronto graduate, and undergraduate, in Applied Science and Engineering to take full advantage of the Annual Meeting of the Canadian Society of Civil Engineers which takes place in our city during the last week of this month. The letter of Mr. W. J. Francis, which is published in full on another page, renders this unnecessary. Everyone should read it carefully. For many years "Toronto" men have not interested themselves in the welfare of this great society as they should. The credit for the wonderful advances the society has made in the last few years must to a great extent be awarded to our friendly rival, McGill University, and its graduates. There are probably special reasons for this not apparent to us; but with this convention comes Toronto's opportunity. Let us not be slow in seizing it. Every third and fourth year man should between now and the date of the convention seek to identify himself with the society as a student member and endeavor to attend every meeting. It is not too much to expect that the council will call off lectures in these years, so that not only the undergraduates but the staff may have an opportunity of attending all sessions.

It is gratifying to know the Engineering Society is going to entertain the national body. Let this dinner be a success. Every "School" man should lend his presence and enthusiasm in making it so.

**The Ideal Lecturer**

Attention is again called to the essay on "The Ideal Lecturer." A full discussion on this subject from the standpoint of the undergraduate cannot help but be interesting and must be instructive. While there will be as many "ideals" as there are idealists, it is probable that they can be readily divided into classes according as they view the aim of an engineering education. On the one hand are those who take for their motto, "Knowledge is power." These attempt to cover just as much ground as possible in a limited time. The extreme example is the lecturer who has thoroughly covered his subject. He rushes to his class and the blackboard and the entire hour is taken in a race to give and copy notes, which are afterwards memorized by the students. Everything has reached such a mechanical level that the personal equation of the lecturer is almost entirely lost. His place could be almost taken by lantern slides and a phonograph, with about as good results.

On the other hand there are those who claim that the ultimate test of a man's efficiency is not what he knows but what he can do, and that it should therefore be the aim of an engineering education to produce men who have the power to solve the industrial and engineering problems of the day.

Thus the lecturer must not only give his classes permanent possession of those kinds of knowledge which are most essential, but he must also teach them how to use that knowledge just as a mechanic is taught to use his tools. A mistake is made in giving the student more than he can ever assimilate. He should be taught how to meet and solve problems, so that he can go out into the great world with a confidence that he can solve its problems, one by one.

While the personal equation of the lecturer will always be the pre-eminent factor of his success, he must have the power of imparting his knowledge. He should have some idea of the psychology of teaching, for after all engineering faculties are schools, not colleges. A good engineer will not necessarily make a successful lecturer. The real test of a lecture course is the amount of benefit the students derive from it and consequently the lecturer should frequently apply the written test. These tests offer splendid opportunities of inculcating habits of accuracy, reliability, clearness of expression, and he should insist that the work be carried out in such a manner that these benefits will result.

Personally the ideal lecturer will be a thorough master of his subject. He will be clear and forceful in his delivery. His lectures will be logically developed, his language perfect, his blackboard work neat and accurate; his personality will be such that he will gain the good will and confidence of his classes; while firm he will clothe his lectures with an interest that discipline in a college class will be a negligible quantity. Should for some reason or other he lose control he will be big enough and strong enough not to take a coward's advantage of his class to vent peevish spite or biting sarcasm on the class either as a whole or on the individual who cannot hit back. He will be genial and sympathetic, easily approachable, and will always encourage his students to come to him with their knotty problems and at the same time will encourage in them a spirit of original research.

**The Reunion Dinner**

Since the last issue of Applied Science most of the plans for the Twentieth Annual Dinner have been completed, only some minor details have yet to be arranged. The Canadian Society of Civil Engineers have graciously accepted the invitation extended to them by the Engineering Society. This in itself will give our annual function more than its ordinary significance.

The graduates have taken hold of their end of the plans with an energy, a will, and an enthusiasm, they have never before shown in connection with any of our functions. Some of them, who are busy men, are taking a holiday and coming a long distance to be in Toronto for that evening.

Among the undergraduates also there is a real live enthusiasm. Every one feels that this event marks a new era in the history of the Applied Science Faculty, for upon the success of this enterprise, to a large extent, depends the amount of influence wielded by the Engineering Society.

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A. E. Nourse, '07, is with the Expanded Metal Co. of Canada.

We regret to note the death of James McDougall, B.A., who was one of the School's earliest graduates, having graduated in 1884. A full obituary will appear in our April issue.

Messrs. Sinclair and Smith (both S.P.S.) consulting engineers, have rearranged their business arrangements and work will now be carried on under the name of Sinclair, Sutcliffe & Neelands. H. W. Sutcliffe and E. W. are both '07 men.

# SOME RANDOM THOUGHTS FROM THE TORONTO GRADUATES' DINNER.

F. H. CHESNUT

At the St. Charles Hotel on the evening of January 13th, a number of graduates (about 50 in all) of the Faculty of Applied Science again congregated to discuss such points of interest as might be brought forward in connection with the improvements of the course in Applied Science at Toronto University and also to consider the means by which the standing of the Engineer in this country may be improved.

The following paragraphs give in substance the proceedings of the meeting and also the writer's views on the subjects under discussion.

The first matter brought before the meeting was a plea for higher standing of matriculation into the Faculty of Applied Science.

Many persons have commented on the fact, that a very large percentage of the students of the first year fail in their examinations. What are the causes of this? The question may be answered by either one or all of the following:

(1) The papers may be too difficult.

This is unusual and may be eliminated.

(2) The student may not take enough interest in his work due to either carelessness (which then puts him on his own responsibility) or due to his being discouraged by the amount of new work which confronts him. This latter would not be the case had he obtained a thorough working knowledge of Algebra, Euclid, Trigonometry and Analytical Geometry. The fact of the matter is that the jump is too great from the standard of the High School to the standard of the first year Science.

(3) The student may not be of sufficient age to grasp the subjects of the first year. The only solution of this difficulty is the establishing of a standard of admission in this respect.

There is still another side to the question. It is claimed that even if the standard of entrance be raised that no material difference would be shown in the results of first year examinations. It seems reasonable to admit that in the natural course of things the standard of the first year examinations would be automatically raised and if so there would still be the long list of tail-enders.

Considering both sides of the question it would then appear that the raising of the standard would not materially effect the number of successful candidates at the first year examinations, but it will be admitted that an engineer with a thorough grounding in the subjects spoken of (which are indeed perhaps the only subject he remembers after leaving college) is in a position to handle the average problem which he meets in practice.

### RELATIONS WITH FACULTY OF EDUCATION

It was next brought to the notice of the meeting that the requirements for entry to the Faculty of Education were such that a graduate holding the degree of B.A.Sc. was not eligible while on the the other hand, a holder of the certificate of Senior Matriculation was eligible.

This seems a rather peculiar state of affairs but no doubt exists through an oversight on the part of the Council of the Faculty of Education, and needs but a suggestion to them to be rectified.

Along this line it might be suggested that demonstrators and lecturers of the Faculty of Applied Science be required to take a course in the Faculty of Education before being eligible for positions on the staff. It must be admitted that such a course might do a world of good and at any rate is worth a trial.

A good suggestion was next brought forward regarding the proposed study of English in the new course which is being formulated by the Council.

It was suggested that a system of English recitation be adopted, by which it was meant that the student would be required to write reports on different engineering problems. For instance, the Civil section might be required to make a survey of the Ravine and report on the feasibility of a bridge or an embankment across it, giving reasons for and against each proposition. Reports should be logical and concise, thus teaching the student the use of English in the practice of engineering.

### MATHEMATICS IN ENGINEERING

Following this was a discussion as to the amount of higher mathematics which the average graduate carries away with him when he leaves the College Halls.

The speaker advocated a thorough working knowledge of Analytical Geometry and the Calculus.

There is no doubt that in many ways an engineer who can apply the Calculus would be master of many a situation; but it must be admitted that the brain with which most of us are provided is one of limited capacity; and it is almost a well known fact that the man who has his brain loaded down with numberless formulae is usually unable to apply a tithe of what he knows. We will admit, however, that there are exceptions. It seems more reasonable, however, to use the Calculus as more of a mind trainer than as a subject to be considered seriously in the everyday life of a practical engineer.

The Faculty of Applied Science does not attempt to turn out machines into which are fed problems and out of which come answers; it rather attempts to turn out men who by their college education have become fitted to handle problems in a logical, business-like manner. When the young engineer leaves the life of school to enter the school of life he should realize that he has not a formula to apply to each problem but better still a reasoning brain to apply to all problems.

We should realize as young engineers that we cannot all be inventors of new thoughts and methods; other great minds have gone before us and by thought and research have discovered and established certain facts and in many cases compiled them in the convenient Hand Book form. Hence, a close study of the Hand Books on different subjects would be of far greater benefit to the student than an attempt to become proficient in deriving Taylor's Theorem.

### THE STATUS OF THE ENGINEER

The next subject brought forward is one which will no doubt be within the limelight in this country in a short time. It is that of protection by law of the Engineering profession.

What is required is legislation preventing any one from calling himself an engineer without first having passed the examination set by an Engineering Council appointed by the Legislature.

Is there any more reason why the country should be protected against incompetent men practicing medicine than against incompetent men practicing engineering? Why should the municipalities, the railway companies, private individuals, or any person or persons who employ an engineer be subjected to loss of life, property and money due to the incompetence of the engineer? But this state does exist and always will exist until the status of the engineering profession is established.

Again, the engineer of good standing must protect himself, for if one of his profession or one who presumes to call himself an engineer makes a blunder due to insufficient knowledge, the whole profession is lowered in the eyes of the employing public.

The matter has reached such a state at the present time that all engineering organizations throughout the country should rise up and demand legislation and should also see that the act is rigidly enforced.

Among those present at the dinner were: '88—C. H. C. Wright; '89—D. D. James, H. E. T. Haultain; '90—R. A. Ross, Montreal; '91—R. W. Thomson; '92—C. F. Mitchell; '93—A. F. Macallum, A. L. McAllister, W. J. Francis; '95—A. W. Connor; '99—W. A. Hare; '00—W. F. Evans, F. W. Thorold; '03—S. B. Wass; '04—E. Wade, W. G. McFarlane; '05—T. R. London, W. G. Swan; '06—C. B. Hamilton, C. S. Dundass, F. Barber, D. E. Beynon, F. M. Byam, J. O. Roddick, J. C. Armer, W. L. Amos, E. M. Wood.

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C. C. Forward, '06, has been appointed to the staff of the Dominion Analyst, at Ottawa.

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# THE CANADIAN SOCIETY OF CIVIL ENGINEERS.

## The University of Toronto.

Dean Galbraith.

Montreal, Jan. 6th, 1909.

My Dear Mr. MacKenzie: —

In connection with the coming Annual Meeting of the Canadian Society of Civil Engineers, I would suggest that "Applied Science" say some very important things in the January number and say them in the most pointed language at your command. For this event, to which we are all looking forward with much interest, committees are working and individuals are working. Applied Science, however, stands in a very different relation to the great body of students and graduates from that occupied by committees and individual members who must necessarily work by themselves. Applied Science speaks to all and on this occasion it should speak with no uncertain sound. This Annual Meeting of the Canadian Society of Civil Engineers will be one of the most important in the history of that organization,—an organization which may easily lay claim to being the most important scientific body in the Dominion of Canada to-day. To it practically all the engineers of this great Dominion belong, and the leading engineers of Canada will be at the meeting. The chief officer of this important body is our honored Dean. The students and graduates of the Faculty of Applied Science and Engineering of the University of Toronto owe it to the Society, to the University and to Dr. Galbraith to make the coming meeting an event which will long be remembered with pleasure by all who may have the opporunity to attend.

The Annual Meeting arranged for the 28th, 29th and 30th instants, is the only the second that has been called outside of headquarters of the Society at Montreal. On the former occasion in 1906 the first outside annual meeting was an unqualified success. The next meeting should be and will be a still greater success, and it is indeed gratifying to note from the official programme that the members of the Canadian Society of Civil Engineers are to be entertained by the undergraduates at the great school reunion on the 28th inst. This is "Toronto's" opportunity. It has been my good fortune for many years to have the privilege of attending meetings at the headquarters of the Society, and to have observed with great pleasure the manner in which McGill has thrown itself into the work of that organization. The high standard of the Canadian Society of Civil Engineers to-day is largely due to the unstinted labors of many connected with the staff of the great Montreal University. McGill has done what she ought to have done and she has left undone those things she ought not to have done and her efforts are appreciated. The coming occasion will be **T-o-r-o-n-t-o's** first opportunity to show her regard for the Canadian Society of

Civil Engineers and assert herself in the eyes of the engineering profession.

The occasion has still greater interest for the S.P.S. men. Our honored Dean will preside at the Society meetings in his capacity as President, and at the close he will hand the reins of office to a worthy successor. An unusual opportunity is thus afforded to all "School" men to show to Canadian Engineers and to the world at large in a very tangible way how highly they esteem and revere that man whose name is dear to every one of us. No truer heart ever beat in human breast. No better friend ever existed than he. Let us show our hand. The name Galbraith will go down to history as having occupied one of the high places in engineering education and it is gratifying to think that he is yet in his prime to appreciate the position he holds in the hearts of his students and his graduates, and the esteem in which he is held by the profession generally.

I wish you would point out also the importance of the continual attendance at every meeting of the coming Convention of every member of the School staff connected with the Canadian Society of Civil Engineers. This may seem at first a difficult to thing to do, but they should bear in mind that a great number of men will be present from all parts of Canada at great expense to themselves, and, in comparison with these, the staff members are under no expense whatever. The opportunity has never occurred before in such a broad way. It may never occur again. They owe it to themselves, to the Society, to the School and to the Society's President to follow this suggestion.

If time would permit, I should like to say a word to the graduates of the School concerning their connection, or, rather lack of connection, with the great professional engineering body of Canada. There is altogether too much indifference on the part of Toronto Engineering graduates toward the Canadian Society of Civil Engineers. Comparatively speaking, very few applications are put in, and too many of those who have attained the grade of Associate membership are content to remain in that class after they are long fitted to rank as full members in which grade they would be welcomed by the Society. There is no reasonable excuse for this. Branches of the organization exist, one might say—from ocean to ocean. In their own behalf and in behalf of the profession the graduates should take an active interest in the Society's affairs. Connection with the Society is a privilege and an honor all should covet.

In conclusion, let me again say that you cannot point out too strongly the importance of "Toronto" asserting herself by interest and attendance at the coming annual convention. The parties concerned are a great professional body, a great academical body and a great man—the Canadian Society of Civil Engineers, the University of Toronto and John Galbraith.

Yours sincerely,

WALTER J. FRANCIS.

ENGINEERING BUILDING, UNIVERSITY OF TORONTO

The old school which must soon be replaced by a larger and more modern structure

# Applied Science

INCORPORATED WITH

## TRANSACTIONS OF THE UNIVERSITY OF TORONTO ENGINEERING SOCIETY

Old Series Vol. 22 FEBRUARY, 1909 New Series Vol. 2, No. 4

## APPLIED SCIENCE DINNER.

A. D. LePAN, B.A., Sc.

On the evening of Friday, Jan. 31st, 1890, the first annual dinner of the Engineering Society of the then School of Practical Science was held at the Hub where, in all, 54, including guests, Faculty, graduates and undergraduates, formed a company who though optimistic to the fullest degree, little dreamed to just what proportions this little affair might grow.

Twenty years later some of the same men and a "few" others sat down to another dinner held by the same Society of the now Faculty of Applied Science of the University of Toronto. Before going further some may ask: why speak of the dinner of 1909; for every graduate or undergraduate attended it or should have attended it, and to those who did, every event of that evening is and will remain for many years as clear as at the time of happening. In a large measure this is true, but still there are those who were unable to be present, though perhaps deeply interested in the Society, and to these and to posterity we owe some record of one of the evidences of the admission of this Faculty to its proper place in the University and of its immeasurable influence, wielded through its graduates, in every phase of national life.

Many circumstances this year tended to make this the largest dinner and most noteworthy social function ever held in connection with Applied Science in the University of Toronto. First, there is that exuberant and deeply rooted spirit of loyalty which every School man bears to his University as evidenced by his attitude towards his Alma Mater, its Faculty and all associations connected with them. In the days of the "Ink" age this spirit was manifest in the readiness and eagerness with which he cultivated his artistic sense at the expense of his opponents, but to-day, through assimilation, this much abused fluid of other days flows through saner channels tracing on its course an indelible record of growth substantial and lasting, of appreciation genuine and sincere and of acknowledgment of our greater responsibility and privileges through this growth.

Then, too, the Canadian Society of Civil Engineers met in

Toronto and the Engineering Society was fortunate in having as its guests 200 of the members of this sister society. The circumstance was all the more auspicious since Dr. Galbraith, as President of C.S.C.E., delivered on the evening of the dinner, his valedictory address dealing, in masterly detail, with engineering problems of to-day; and in no small measure was this dinner intended as a personal tribute to Dean Galbraith and Dr. Ellis, two of the charter members of this Society who through years of faithful and untiring service have endeared themselves to each succeeding graduating class. Considering all these facts, it is little wonder that the advent of the School dinner was eagerly looked forward to on all sides.

As early as 7.30 intending diners commenced to arrive, those of older years to be present at the Canadian Society meeting, and the more frivolous youth to roam the corridors which first resounded with his clear and blithesome "Toike Oike" and later with his almost agonized appeal for dinner, for, in the excitement, caused by the change from the short blue jumper, which now hangs in the laboratory, now forms a missile intended for some industrious embryo engineer and now as a duster for the School boilers as its prisoner blinkingly treads these oft-explored passages, to the silk lined flowing garment, emblem of social pleasure and obligation, many an expectant youth had forgotten the commoner things of life and now awaited the opportunity of presenting himself at the festive board for the third time that day, or possibly the second for to many breakfast is often "run fast" from bed to lecture. Under these circumstances it is recognizable that when the doors of the banquet hall were opened at 9 p.m. and the guests and more privileged persons had gained admission, that some slight anxiety might be manifest on the part of the undergraduate body to satisfy the natural demands of the inner man. Evidence of this was obtained, if in no other way, from the over-turning of a row of chairs in Convocation Hall and the releasing of a door from its normal position in spite of the efforts of the genial Christie and our own "Jock," but soon the good-natured crowd were all in the banquet hall with the exception of about 40 who for lack of accommodation were forced to sit down in the tiled corridors of Convocation Hall.

The drafting-room transformed into a banquet hall could hardly be recognized by the embryonic engineers who strugggle in vain to keep the dread "See Copy" off their alleged works of art and engineering skill, for in the place of solid rows of sombre work tables, the room is filled with long tables draped for the present in spotless white and decked with a profusion of flowers rarely seen by the engineer who with long boots and almost longer whiskers tramps the wilderness, drawing imaginary lines, or who, with grimy hands seeks to solve the mysteries of the invisible and illusive "current." Extending the full length of the hall we have the guests' table and on the wall over its centre a huge shield of welcome draped with a profusion of flags.

Directly opposite on the other wall we see amid a mass of flags and bunting, a portrait of Dean Galbraith. But this transformation did not in the least seem to perturb any of those present and soon with amazing rapidity all were invited to partake of a menu "I am part of all that I have met" which diverted the attention of even the most aesthetically inclined to the baser yet essential things of life. During the serving of an excellent repast the sense of humor of the man, who had not partaken of the necessaries of life since his regular noon-day struggle with a so-called sirloin or his perhaps indelicate queries as to the contents of the indeterminate Hamburg steak, began to rise; much hilarity was indulged in and as the meal progressed these individuals accepted with the utmost grace their ice-cream as a filler between the reverse side of a plate and the erstwhile spotless linen.

But all pleasures must end and this as others did, only to be succeeded by pleasures of different forms, for with the tables cleared and with the man who believes it is better to smoke here than hereafter indulging, President Marshall, chairman of the evening, proposed the toast to the King. He then introduced a second toast of the evening—"Canada" and connected with its proposal A. D. LePan who, in a brief speech, dealt with the comparisons between the past and present in the engineering history of this country, the transportation problems and possibilities of increased activity along engineering lines as evidenced by the prevailing excellent financial conditions, and introduced in reply Byron E. Walker, Esq., as "A man who fingers with a touch, perhaps the most sensitive in Canada to-day, the throbbing pulse of Canadian life and conditions."

In rising to reply, Mr. Walker was enthusiastically received, and immediately won the closest attention and interest of his hearers. He outlined with vigor his belief that the young men of to-day, and especially the engineers, should study as well as development, a conservation of Canada's resources from the grasping need of a world which is rapidly becoming poor in the very iron, timber and other treasures of which Canada has such stores.

"A great trust has fallen upon you young gentlemen," said the speaker. "Do not be proud of Canada because you are Candians, but because the trust falls upon you to develop and conserve our wealth. We and you shall be judged some day by the use we make of it. We in Canada are in great danger to-day. No other country of only 7,500,000 people has such great resources and has at the same time lying to the south the most profligate user of natural resources in the world and one which to-day has practically exhausted all that it once possessed. Our problem to-day is not to develop Canada's wealth, but to conserve it. If it be true that in a comparatively few years the iron and timber of the United States will be exhausted, do you think that when that time comes we shall be allowed to enjoy our own resources at our leisure? The United States will turn like lightning upon them and devour them as fast as it can. So I say learn to conserve what we own. If we do in future centuries Canada will be master of the steel trade and rich in lumber and water powers. All the nations will have to come to her. If you do not, if you cannot awaken your own consciences and the conscience of the public to the menace of our timber, our water ways, our fisheries, and our farm land which lie in the demands of a profligate age, you will have occasion to glory in being cowards. You will have been false to your trust."

The deep interest with which these remarks were received showed that the speaker had indeed struck a responsive chord in all his hearers and had impressed them not only with the glorious heritage which is ours, but also with the responsibilities which ownership of this trust involves and with the fact that conservation should not be sacrificed to development.

In proposing the toast to the University W. B. Redfern, '08, in an excellent speech, eulogistic of President Falconer, said in part:

"Speaking on behalf of the undergraduates, the graduates, and I believe on behalf of every member of the staff as one Faculty among several others in this great University, we hope that we may all be so harmonized and blended in spirit and aim, that the day is past when it was natural for one Faculty to work in isolation and aloofness and that instead even over past prejudice, past jealousy and past traditions we may have an interchange going on in increasing measure, an interchange that helps him who gives and him who takes, an interchange in which each Faculty is the gainer, in this way making our University truly one integral and unanimous whole.

"The interests of education are in these days so closely bound together that a gain anywhere is a gain everywhere and the feeling which unites universities in all parts of the world by common interest in the advancement and dissemination of knowledge is growing stronger year by year. As one university in the great sisterhood of universities in Canada, we hope that we may all be so refined in spirit and aim, that we may be the embodiment of an ideal which will eventually give to this young and fair dominion the noblest and truest type of citizenship and that it may truly be said of us that we are discharging our duties and measuring up to our responsibilities, in other words, gentlemen, if weighed in the balance, we hope we shall not be found wanting."

From the reception tendered to President Falconer, who replied to this toast, there can be no doubt as to the respect and esteem with which he is held by the graduates and undergraduates of the University of Toronto. Cheer after cheer greeted the speaker and it was only to sing the parody

**F-A-L-C-O-N-E-R-!**
That's the way you spell his name,
Astray you can't go far,
When you hear it,
How we'll cheer it,
Everywhere we are.
**F-A-L-C-O-N-E-R-!**

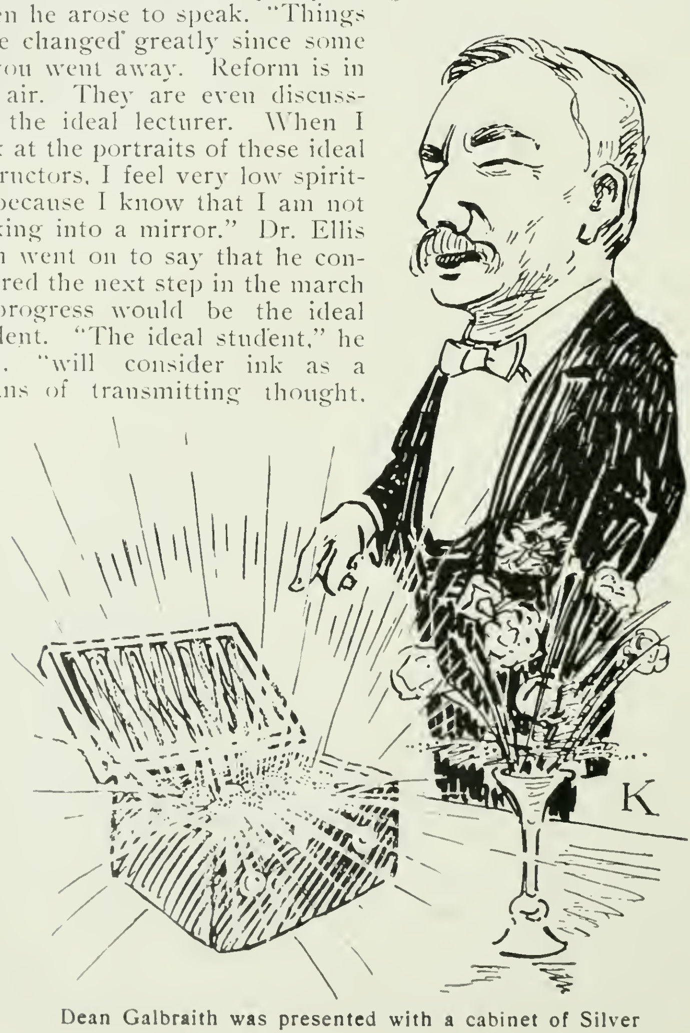
flashed on the screen that anyone desisted. It is fortunate that such demonstrations do occur for there are times when in a moment of thoughtlessness the action of the undergraduates belies his thoughts and respect apparently finds no place in the category of his attainments. But this reception rang true and clear and was indeed a tribute to the man who by his fairness, his masterly control and scholarly attainments has in so short a time endeared himself to the University of Toronto. After this spontaneous reception, President Falconer's address was listened to with rapt attention.

President Falconer has since coming to Toronto shown himself to be one of the happiest speakers we have. He always speaks briefly and he always has something to say that his hearers go away determined to remember. On this occasion he spoke with his usual brevity and impressiveness urging the undergraduates present to bear in mind the advice they had received from Dean Galbraith, that the importance of the man has to be considered as well as that of the engineer and that self-control is absolutely necessary. He told of crossing the ocean a couple of years ago and of observing the splendid discipline of the ship under a cheerful and observant captain with whom he had several pleasant conversations. In the management of that ship every man played his part all under the direction of this one quiet and competent man. "The master of that vessel," he said, "was Captain Sealby who showed the world the other day the strength that self-control gives a man over himself and others." President Falconer, on behalf of the university, extended a warm welcome to all the graduates, the majority of whom he had never seen, as they received their degrees before his term of office began.

Then followed one of the most pleasant events of the whole evening, the chairman intimated that Mr. J. L. Morris, the first graduate of the School of Practical Science was present and that gentleman after dealing in interesting comparisons between the School of the past and present noted that through all this growth and transformation could be seen the guiding hand of men who even in his days had labored unselfishly under most adverse conditions that their ideal might be realized. It was indeed gratifying that these men should see their most optimistic hopes fulfilled and fitting it was that those who had received so much through personal contact with these men and through the realization of their ambitions should be privileged to show their appreciation. When he presented to Dean Galbraith on behalf of the graduates in Science, a cabinet of silver, enthusiasm knew no bounds. When the chorus of "He's a Jolly Good Fellow" and "What's the matter with Johnnie?" "He's all right" died away, Dean Galbraith feelingly thanked the graduates, modestly associating with the success of the School many able assistants who had worked with him on the staff.

In a happy speech of eulogistic reference, Mr. J. W. Tyrrell, of the class of '84, presented to Dr. Ellis a beautiful gold watch and chain, also on behalf of the graduates. Again enthusiasm arose to the extreme, and Dr. Ellis did not belie the chorus "See him smiling."

"I never saw so many of you together before," said Dr. Ellis, when he arose to speak. "Things have changed greatly since some of you went away. Reform is in the air. They are even discussing the ideal lecturer. When I look at the portraits of these ideal instructors, I feel very low spirited because I know that I am not looking into a mirror." Dr. Ellis then went on to say that he considered the next step in the march of progress would be the ideal student. "The ideal student," he said, "will consider ink as a means of transmitting thought,




Dean Galbraith was presented with a cabinet of Silver not as an agent for decorating his fellow beings, he will look upon snow as a wonderful form of water rather than a missile. His taste for music will be so cultivated that he will not convert the furniture of the lecture room into sounding brass and tinkling cymbal." The speaker then turned the drift of his conversation in his usual happy manner, "but I find that that student is already here," he said. "He is the man who goes out and wins fame and riches in his profession and then comes back and gives most of the credit to his old teachers."

After the presentations the spirits of the audience were raised to such a pitch that they felt it necessary to have a song from Hugh Ritchie. Accordingly the big fellow, in spite of his struggles, was hoisted on a table and kept there until he rendered three stanzas of "Stop your tickling, Jock," in the most approved style to the great delight of all present.

The chairman then called on P. R. Brecken, '08, to propose the toast to "Our Guests." He spoke of the privileges of entertaining such distinguished guests as the Members of the Canadian Society of Civil Engineers, and of the intimate relation of the Engineering Society as a feeder to the more mature Society. The importance of the engineer in moulding the destinies of this country was emphasized, for on him as much as on the financier depends the support accorded by the investing public. Upon his good judgment and ability are often dependent the lives of hundreds of human beings, not to mention the safeguarding of thousands of dollars. In the matter of reports he must be a man whose one idea is to serve in the most efficient manner or he will often be influenced to make his power subservient to the selfish interests of the few.

Mr. George A. Mountain, Chief Engineer of the G.T.P. and President-elect of the C.S.C.E., in reply, referred to the development in the profession and emphasized the importance of maintaining that high standard so essential in the varied interests of engineering. He also referred to the gratifying growth of the Society and spoke in optimistic terms of its future.

Mr. Kennard Thomson, one of the founders of the Engineering Society, introduced by the chairman as a Scotchman, spoke very happily about the growth of the School and the pleasure that visits of a nature such as this afforded the older graduates. He spoke briefly of the formation of the Engineering Society and stated how utterly impossible it would have been to have formed a Society "but for the encouragement and guiding hand of that incomparable man, Dean Galbraith." He also spoke in a highly complimentary vein in regard to the work of Dean Galbraith on the Bridge Commission and deplored the fact that in New York for some of the investigations then under way, commissions of such a calibre had not been appointed. As a School man, now resident in New York, he spoke in no uncertain terms of the esteem in which our engineers are held and the reception accorded to Canadian engineers who decided to desert their native land

Geo. A. Mountain, C.E.
President Elect Canadian Society Civil Engineers
Courtesy of "Construction."

and cast in their fortunes with those of the neighboring Republic. "Another reason why Canadians are liked in the States is because they are always loyal to the land of their birth, to the land of their adoption, and to the Anglo-Saxon race." In closing, Mr. Thomson extended a most cordial invitation to all to visit his office when in New York, for "we are always glad to see Canadians."

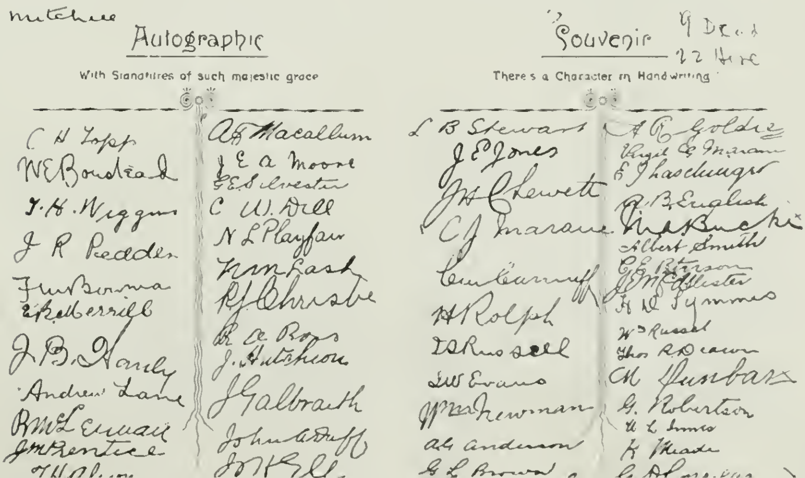
R. A. Sara, '09, in a humorous and entertaining speech, proposed the toast "To Our Graduates." In a happily used illustration from Mark Twain he emphasized the need of scientific training, and as an evidence that this Faculty is ably meeting the demands made upon it, indicated with pride the graduates present, who, endowed with the engineering knowledge obtained at the School, had gone forth and in a world of men are doing men's work. He also expressed the hope that the undergraduates would maintain the high standard set in engineering practice.

A high tribute was paid to Mr. C. H. Mitchell, who replied, for although late his very interesting address was listened to with close attention. He spoke very entertainingly of the first Engineering Society dinner and showed a slide of the menu used on that occasion, which is given below. His speech is given in full elsewhere.

Mr. L. E. Jones, '11, in a brief speech, proposed the toast to "Sister Institutions," and after replies by different representatives, the company sang the National Anthem and broke up about 1.30 a. m. During the evening musical numbers were rendered in excellent style by an octette, composed of Messrs. W. C. Blackwood, A. A. Kinghorn, J. Stuart, H. Stuart, W. Boulton, J. Craig, J. McKinnon, A. Sedgewick, and by Messrs. F. H. Chestnut, E. V. Chestnut, V. S. Chestnut, H. F. Secord in an orchestra with W. C. Collett as pianist and C. E. Bush as conductor.

T. K. Thomson

This feature was indeed a most acceptable contribution to the evening's enjoyment, as evidenced by the unstinted applause accorded the rendering of each selection. Needless is it to say, that in every respect the dinner was an unqualified success and too much credit cannot be given to the Committee who so ably assisted by Professor C. H. C. Wright and Mr. T. H. Hogg, demonstrated the feasibility of a function of such magnitude.

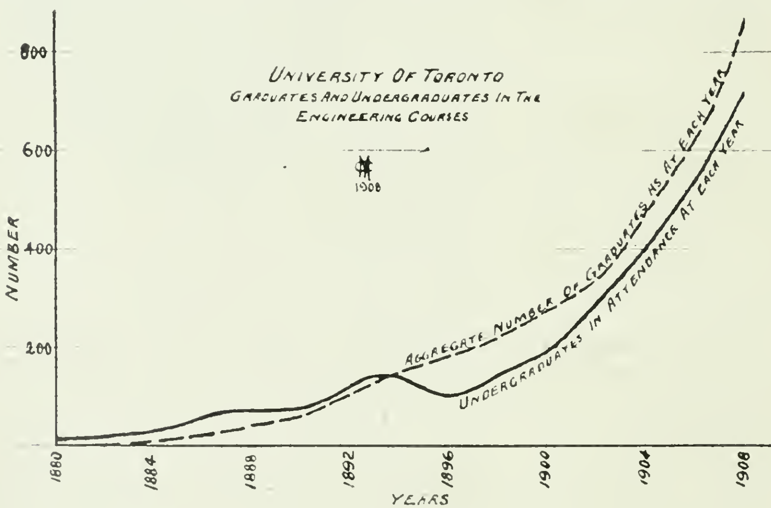


# THE ENGINEERING GRADUATES—A RETROSPECTION

CHARLES H. MITCHELL, C.E. (Tor.), '92.

The reunion of graduates of the School of Practical Science and of the University in engineering at the recent banquet was an occasion to afford considerable retrospection. Perhaps the term and process of introspection might also be included as part of the operation of interviewing and inspecting ourselves as we hundreds of graduates of the past quarter century came together from the four quarters of the Dominion.

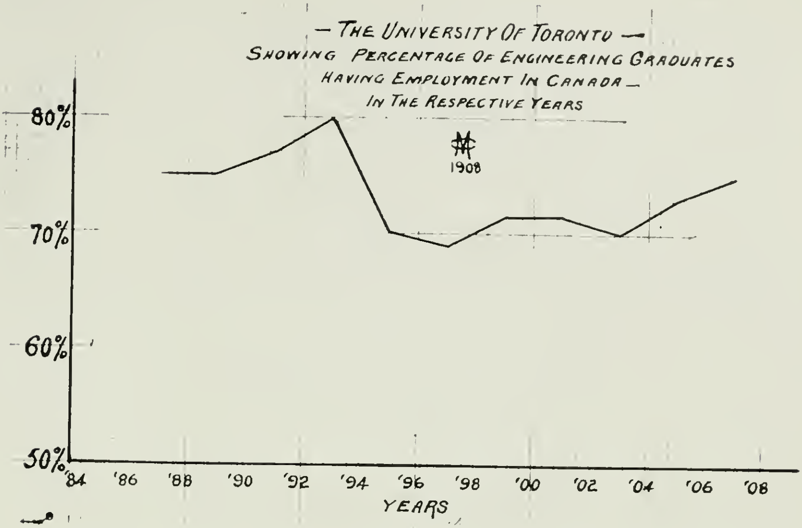
During the few days of the reunion and the hours of the banquet itself, the numerous groups of graduates intent upon each other after long separation, betokened the sifting out of many years' aggregate of experience and happenings. By the end of the period the sifting process was well advanced, the



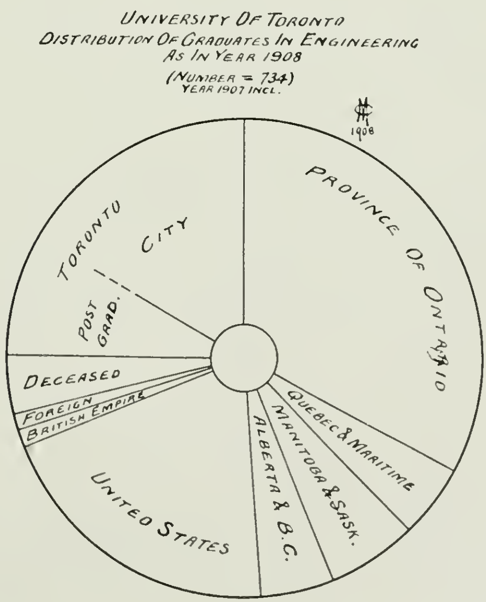

No. 1

sizing and the classification of the various experiences being so complete that one so inclined could begin to find real mathematical laws and in some cases, almost actual formulae, by which the varions graduates' work could be represented. That sounds academic perhaps, but there is "but little here below" that modern engineers cannot reduce to a science even if they are such vague matters as the wanderings of the peripatetic graduate, his various tastes for work and his probable earning power.

It was with some half formed notions along these lines that, when, being honored with the request that I reply to the toast of the graduates at the reunion banquet, I assented and set myself


— The University Of Toronto —
Showing Percentage Of Engineering Graduates
Having Employment In Canada —
In The Respective Years
1908
80%
70%
60%
50%
'84 '86 '88 '90 '92 '94 '96 '98 '00 '02 '04 '06 '08
YEARS

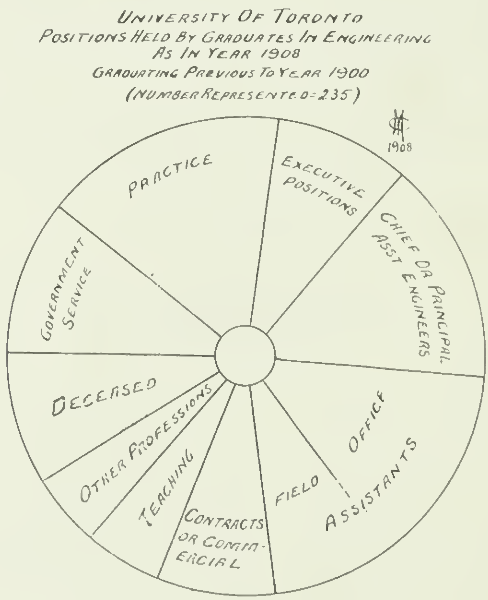
No. 2


University Of Toronto
Distribution Of Graduates In Engineering
As In Year 1908
(Number = 734)
Year 1907 Incl.
1908
Province Of Ontario
Toronto City
Post Grad.
Deceased
Foreign
British Empire
United States
Alberta & B.C.
Manitoba & Sask.
Quebec & Maritime

No. 3

the task of trying to represent the characteristics and movements of our graduates by graphical means. The novelty of this was my sole excuse for adopting such a means of delivering an after-dinner speech. The use of the lantern slide and screen as a medium of after-dinner speaking will, I hope, commend itself to the profession by reason of its practical features and its dumb eloquence so well adapted for service by the "Silent Faculty."

If an apology is needed for presenting the various graphical productions which follow I can only repeat that I believe this method of representation will more readily than any other, bring home to the university authorities and to ourselves the growing importance of the Engineering courses in the University of Toronto and the very intimate connection between its graduates

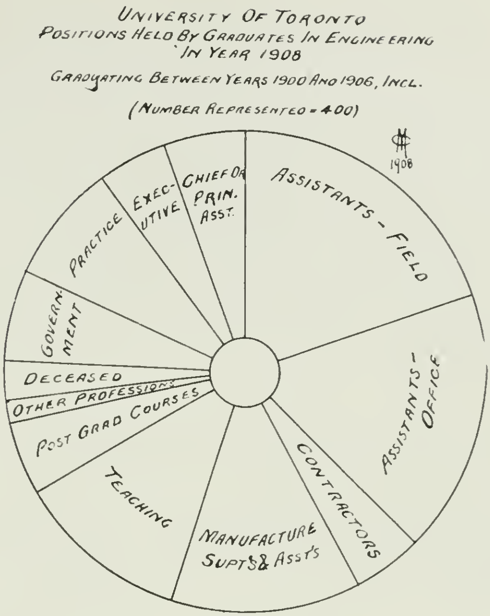



No. 4

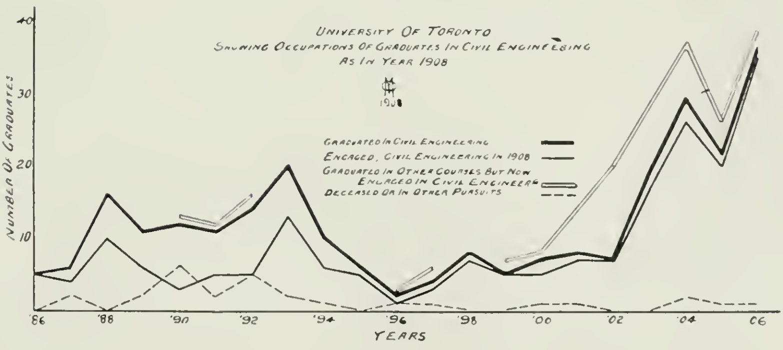
and the vast country which we are all so busily engaged in developing.

The broken line shows the aggregate number of graduates up to any year while the full line shows the number of undergraduates in attendance in that particular year. The former is always increasing, the latter may vary. Note the extraordinary coincidence of the increase of students in attendance at the same rate and number as the graduates. This shows the rapid growth of the faculty.

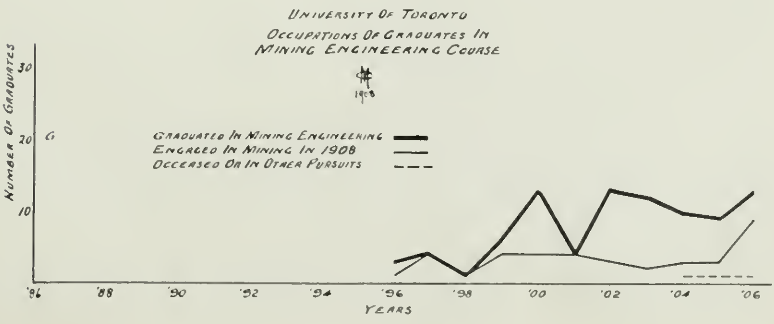
The percentage of graduates finding employment in Canada as the years progress. The curve is obtained by finding the


University Of Toronto
Positions Held By Graduates In Engineering
In Year 1908
Graduating Between Years 1900 And 1906, Incl.
(Number Represented = 400)
1908
Assistants - Field
Assistants - Office
Contractors
Manufacture Supts & Asst's
Teaching
Post Grad Courses
Other Professions
Deceased
Govern-ment
Practice
Exec-utive
Chief Or Prin. Asst.

No. 5


University Of Toronto
Showing Occupations Of Graduates In Civil Engineering
As In Year 1908
1908
Graduated In Civil Engineering
Engaged, Civil Engineering In 1908
Graduated In Other Courses But Now Engaged In Civil Engineering
Deceased Or In Other Pursuits
Number Of Graduates
Years

No. 6

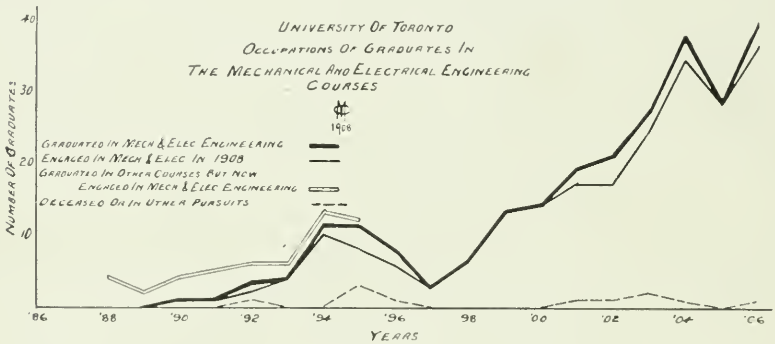

University Of Toronto
Occupations Of Graduates In Mining Engineering Course
1908
Graduated In Mining Engineering
Engaged In Mining In 1908
Deceased Or In Other Pursuits
Number Of Graduates
Years

No. 7

percentage of graduates as registered in the School calendars from year to year, commencing in 1884. The financial depression of 1893 in the United States is clearly shown by the large percentage (80) of graduates who returned home to Canada and as the better times came the percentage remaining rapidly decreased until late years when it is increasing in a very marked manner due to the large works now in progress in this country.

Based on the graduates list in the Calendar of 1908 comprising the 734 graduates up to and including those of 1907.

Based on the list in Calendar of 1908, representing 235 graduates. Note that half the number of these older graduates were engaged in Government service, practice, executive positions and as chief or principal engineers, while those who were




**No. 8**

assistant engineers were less than a quarter of the whole.

Based on the list in Calendar of 1908 comprising about 400 graduates between 1900 and 1906 inclusive. In this the four divisions named in diagram No. 4 constitute only a quarter of the whole while the assistants are over a half.

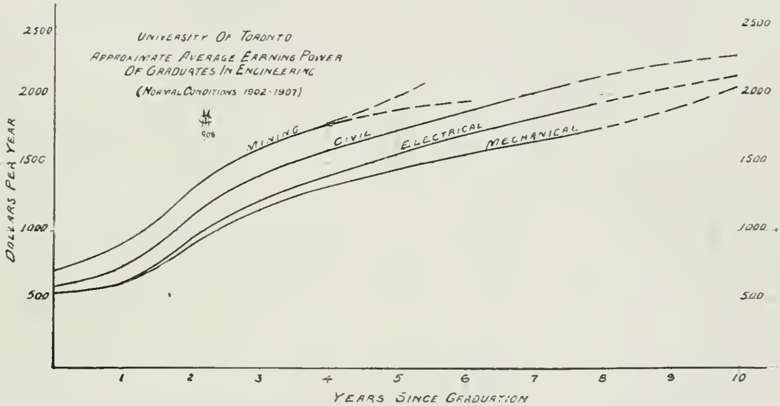
This diagram represents a concise history of the graduates in civil engineering year by year. The heavy full line shows the number of graduates in civil engineering in each year. The light full line shows the number of those of each year who, in 1908, were still engaged in civil engineering work, the remainder (i.e., represented by the space between these two curves) being either deceased or in other pursuits than engineering. The broken line shows the number of those deceased or in other pursuits. The double line, or rather the space between the double line and the heavy line, represents those graduates who were educated in other courses than civil engineering but who in 1908 were engaged in that branch of work; note this large increment between 1900 and 1905.

The fairly uniform number graduating in the civil course between 1888 and 1894, the small number between 1896 and

1902 and the rapidly increasing number since 1902 are to be noted as indicating development of the country.

This is drawn on similar lines to that of civil engineering. This course was instituted in the early 90's. It is to be noted, however, that there has been a very remarkable departure of graduates in mining from their specialty between 1899 and 1905, most defections being to the civil engineering as indicated in Diagram No. 6. This fact reflects the conditions of the country at that time. There had been a mining boom previous to 1900 which quickly died out and only within the past few years has activity in this branch of engineering again occurred. This is shown in the rapidly rising line at the end.

This diagram is similarly constituted to those of the other




No. 9

branches. The first graduate in this course was in 1890 and with the exception of the depression in 1897 common to all courses, the number of graduates has rapidly increased to the present. It is agreeably noticeable that nearly all graduates in this course have remained engaged in this branch and specialty and that the deaths and departures to other pursuits have been very small. The increment from other courses between 1888 and 1895 is due to the fact that in these earlier years there was no course in the School in mechanical and electrical engineering and this increment is composed of men who graduated in civil engineering.

This diagram is offered for criticism and discussion with some misgivings. It will probably appear to be a very audacious method of indicating the dollars and cents side of the professional career of the young engineer. It must always be remembered, however, that the curves indicate the probable average earning power and that there are many exceptions to them, exceptions in the matter of high salaries and other emoluments which are well known amongst the graduate body.

These have been compiled having regard to the approximate earning power of the man and the money value of the position which he fills. Consultation with numerous graduates of different periods who are well acquainted with their fellows has formed the basis of the general trend of these curves, but at best they are of course the merest approximations, as no definite law can be deduced especially after five or six years out of college.

The mining graduate is undoubtedly the better paid immediately after graduation, largely due to his location and to the larger ratio of his muscle value to brain value. After four years, however, the miner appears to vary considerably and there are instances of mining graduates of five or six years' standing who are earning twice the amount indicated herein at that time.

All courses run fairly parallel the first two or three years with a rapid rise in all in the second year. The civil and electrical men run evenly side by side, the curves after six or eight years tending to flatten, although the electrical may trend upwards again with time as the graduate gets business connections of a larger horizon.

The mechanical graduate is apparently the most poorly paid in the first six or eight years, but after that period there is every indication that, as he begins to get an interest in the business with which he is connected, his curve rises steadily and, as he becomes a "manufacturer" in the broad sense, it will doubtless cross the other two curves. This is gratifying because it is an incentive to the young men to follow mechanical engineering pursuits in order to become manufacturers and thus provide what this country is most in need of.

It is hoped that this diagram will bring out considerable discussion and if the truth is to be told, it was largely with this in view that it was prepared.

# HISTORY OF SCHOOL OF PRACTICAL SCIENCE.

W. HODGSON ELLIS, M.A., M.B.

Until the middle of the nineteenth century no attention was paid in England, and very little in America to the organized teaching of science and in particular to science in its applications to industry. Up to that time chemistry had been looked upon only as a part of a medical curriculum; engineering (other than military engineering) was learned only by apprenticeship; mineralogy and geology were not taught at all. The Exhibition held in 1851—parent of a numerous progeny—directed public attention in England to the possibilities of scientific invention and scientifically directed industry. The interest so awakened took the form, in the first instance of an attempt to teach elementary science to the artisan. This movement, of which South Kensington is the symbol, was called "Technical Education." It was begun with much enthusiasm. It gave rise to some disappointment. The efficiency of the British workman was not found to be perceptibly increased by his listening to lectures on technical science given by lecturers who often knew little of science and less of technology. Of course, much of the instruction was of quite a different character and excellent work was done in certain cases. On the whole, however, the results of this popular education did not come up to the expectations of its promoters.

In the United States scientific education followed the German model more closely than in England. There institutions after the model of the German Technical High Schools—that is, training schools for engineers and chemists—were established with most satisfactory results. When the need for technical education began to make itself felt in Ontario a commission consisting of Dr. I. G. Hodgins and Dr. McHattie was sent by the Provincial Government to study the question in the United States and Europe. As a result of their report a bill was introduced in the Legislature in 1871, by the Premier, Mr. John Sandfield Macdonald, providing for the establishment of a College of Technology for teaching mathematics, chemistry, modern languages, civil and mechanical engineering, and drawing.

The bill was strongly opposed in the House on the ground that its objects would be better met by giving additional aid to the Provincial University; but in the end it was carried and a grant of $50,000 made for the purpose of equipping a building for carrying out the plans. The building at the corner of Church and Adelaide streets, then occupied by the Mechanics' Institute, afterwards the Public Library, was purchased by the Government and fitted with the necessary laboratories, lecture rooms and drafting rooms. It was intended to combine the English and American systems of technical education by teaching regular

W. H. Ellis

students in engineering and chemistry during the day, and giving lectures to working men in the evening. Just before the new building was ready for occupation, the Sandfield Macdonald Government was defeated on another issue, and Mr. Alexander Mackenzie was called upon to form a new cabinet.

The members of this Government had, before they came into power, strongly apposed the scheme, which was now left to them as a legacy by their predecessors; and they did not carry it out without important modifications.

At first only the evening classes were organized. To conduct these Mr. James Loudon, afterwards President of the University, Mr. Wm. Armstrong, C.E., and the writer were appointed instructors. The classes, particularly Mr. Armstrong's classes in drawing, were largely attended.

The year 1877 marked the beginning of a new stage in the development of the young institution. In that year the Hon. Adam Crooks, Minister of Education, with the approval of the Lieutenant-Governor in Council, changed the name from "College of Technology" to "School of Practical Science," and recommended the erection of a building in the University grounds for the accommodation not only of the students of the School, but also for the science teaching of University College so that the School and the College might mutually help each other. This plan was devised by the Minister with the advice and assistance of the Hon. Mr. Justice Thomas Moss, Vice-Chancellor of the University, Dr. (afterwards Sir Daniel) Wilson and Professor James Loudon.

In accordance with this plan, the north wing (just condemned as unsafe) of the present Engineering Building, was erected; and it was opened on the 1st of October, 1878. This building contained a chemical laboratory under the charge of Professor Croft to whom the present writer was assistant. The chemical laboratories were in the rooms just vacated by Mr. Anderson and Professor Wright and all the chemical teaching of University College and of the School was carried out there and in the lecture room in connection with them.

The basement was occupied by Professor Chapman as an assay laboratory. There was another lecture room on the first floor and a drafting room (at the east end). This constituted the quarters of the Engineering Department and was under the charge of Professor Galbraith. The floor above was devoted to the Department of Biology and was presided over by Professor Ramsay Wright. Professor Loudon had a room on the ground floor, but all his teaching was done in the round tower at the west of the main building.

Professor Croft was Chairman of the Board and Professor Ramsay Wright secretary. The whole of the engineering teaching, including the drawing, was done by Professor Galbraith.

In those days the School of Practical Science was in fact, though not in name, an integral part of the University. It was supported by annual grant of the Legislature, not out of the University endowment; and it was not under the control of the Senate; but the students received instruction side by side with the students of University College, from the same professors; and it was governed by a Board of whose seven members, five, including the chairman and secretary, were professors in University College.

In 1889 there was another change. The University Federation Act was passed in 1887 establishing a University Teaching Faculty, and removing the professors of chemistry, physics, mineralogy and geology, and biology from University College to the Teaching Faculty of the University. This severed the connection between the School and University College. In October, 1889, the School of Practical Science was affiliated to the University of Toronto and in November of the same year Professor Galbraith was appointed principal and the management of the School was "entrusted to a Council composed of the Professors, Lecturers and Demonstrators appointed on the Teaching Faculty of the School."

The first Council was composed of: Principal Galbraith, Professor of Engineering, Chairman; W. H. Ellis, Professor of Applied Chemistry; L. B. Stewart, Lecturer on Surveying, Secretary; C. H. C. Wright, Lecturer on Architecture; and T. R. Rosebrugh, Demonstrator in the Engineering Laboratory.

The University Departments of Biology, Mineralogy and Geology, and Chemistry were now removed from the School to quarters of their own.

The next step forward was the enlargement of the Engineering Building and the equipment of the engineering and metallurgical laboratories.

The diploma of the School of Practical Science was at first given only in Civil and Mechanical Engineering and Analytical and Applied Chemistry. Subsequently Mining Engineering and Architecture were added.

In 1892 a fourth year of instruction was added to the three required for the diploma, at the end of which the student might obtain the degree of B.A. Sc. In 1900 the Senate of the University passed a statute adopting the School of Practical Science as the Faculty of Applied Science of the University of Toronto. In 1901, the Chemistry and Mining Building was begun and relief given for the time to the overcrowded condition of the laboratories and drafting rooms which had become serious.

On the 3rd of October, 1905, a Royal Commission was appointed to enquire into and report upon a scheme for the management and government of the University of Toronto and University College. The advisability of the incorporation of the School of Practical Science with the University of Toronto; and certain other subjects. In April, 1906, the Commission reported, recommending, among other things, as follows:—

1. The powers of the Crown in respect to the control and

management of the University, should be vested in a Board of Governors chosen by the Lieutenant-Governor-in-Council.

2. The Senate should direct the academic interests of the University.

3. The School of Practical Science should be united with the University as its Faculty of Applied Science and Engineering.

On the 14th of May of the same year, the Legislature passed the University Act carrying out the recommendations of the Commission, clause 6 of which reads:

The School of Practical Science is hereby united with and shall form part of the University and constitutes the Faculty of Applied Science and Engineering thereof.

On the 15th day of the following June this Act went into force and with that the School of Practical Science became de jure what it had always been de facto—the Faculty of Applied Science and Engineering of the University of Toronto.

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## HISTORY OF THE APPLIED SCIENCE BUILDINGS.

C. H. C. WRIGHT, B.A. Sc.

In order to furnish accommodation for the teaching of engineering, in accordance with the proposition of the Hon. Adam Crooks, the north wing of the present Engineering Building was erected in 1877-78, and called the School of Practical Science. This building was heated with hot air and the furnaces together with their flue and supply of coal occupied a large portion of the basement. In the western portion, however, there were situated the mineralogical and assaying laboratories, over which Professor E. J. Chapman presided. The ground floor was occupied by Professor H. H. Croft and his students in chemistry. The western wing of the first floor was also devoted to chemistry, while the remaining five small rooms in the centre and eastern wing were devoted to engineering, and here Professor J. Galbraith with his small class started work in 1878. In the attic the department of biology was presided over by Professor R. Ramsay Wright. Thus, this small building housed the departments of mineralogy, geology, chemistry, engineering and biology, and in it were trained side by side students in Arts, Medicine and Engineering.

In order that the Province of Ontario might keep pace with other countries in the education of the engineer, it was decided in 1888, to establish engineering laboratories in connection with the S.P.S., in which might be studied those important problems in strength of materials, hydraulics, thermodynamics and electricity, which were occupying the attention of the engineering world. This rendered necessary extensive equipment as well as considerable building accommodation.

For this purpose, the construction of the central portion and southern wing of the present Engineering Building was undertaken immediately. This addition was completed and first occupied in the fall of 1890. In the spring of this same year the eastern portion of the Main Building of the University, in which was situated the library, was destroyed by fire, and until the new library building was erected, the library was provided for on the

C. H. C. Wright, B.A. Sc.

top floor of the central portion of the S. P. S. Reading room accommodation was obtained by building an extra story over the eastern and western parts of the present north wing of the School.

Gradually, by the erection of new buildings, the Arts departments were removed, until in 1894, the S.P.S. was devoted entirely to the work of the School. The Chemistry and Mining Building, facing College Street, was completed in 1905, and provided accommodation for the departments of chemistry, mining, mineralogy and geology of the School, and for those of mineralogy and geology of the University. Immediately to the north of the Chemistry and Mining Building was erected about the same time the Milling Building, for the accommodation of that branch of Mining. In the fall of 1901, a small observatory was built for the department of Astronomy of the S.P.S. This building was replaced by the larger one now in use, which provided in addition to the observation room, a small calculating room. It is hoped that by October, 1909, the new building to the east of the Main Building of the University will be completed and occupied by this department.

At present there is under construction to the south of the Engineering Building a laboratory for thermodynamics and hydraulics, which promises to be ready for the work of the coming session, 1909-10, and will provide excellent facilities for the advancement of this very important branch of engineering education. In addition, it will also offer opportunities for research work along these lines.

For the past two sessions the Second Year draughting has been accommodated in the Examination Hall of the University, and during the present session, the Third Year draughting in the departments of Civil and Mining Engineering has been accommodated in the Physics Building.

It is apparent to anyone who has studied even casually the progress of engineering education, that thirty years ago the demands for building accommodation were very few:— a lecture room together with a draughting room for the engineering side of the work; a lecture room for mathematics, and space for a little chemistry and physics, was all that was deemed necessary. However, as the benefits of education suitable for the different divisions of engineering, civil, mining, mechanical and electrical, became apparent to the world, the demands for laboratory accommodation have increased very rapidly. In addition to the increase in accommodation required for improvements in the educational requirements, must be considered that due to the increased numbers of students taking these courses; and, if the University of Toronto and the Province of Ontario wish to maintain the good name won by the School of Practical Science, they must be prepared to provide large additions in building and equipment in the immediate future. Situated as Toronto is in the centre of the clay industries (the largest industries of the Province) something should be done for Ceramics. Electrical engineering demands the lower floors of a large building, and at the same time, the requirements for the study of the strength and properties of building materials, including cement and reinforced concrete, must not be neglected.

President Falconer, writing on "The Needs of the University of Toronto" in the pages of "The University Monthly," says: "The University has within a short time become one of the larg-" est in the British Empire and stands in the front rank on this " continent." . . . . "During the last two years, not in-" cluding the present, the ratio of increase in the Faculty of Ap-" plied Science has been thirty-two per cent., a larger proportion-" ate increase than in any other Faculty." . . . "The most " urgent pressure for accommodation during the past winter, " apart from the necessity for schools for the Faculty of Educa-" tion, was in the Faculty of Applied Science. This Faculty is " housed in the old Engineering Building built for the School of " Practical Science, and in the new Science building facing on " College Street, commonly known as the Chemistry and Mining " Building. These buildings are not sufficient for the needs of " this Faculty."

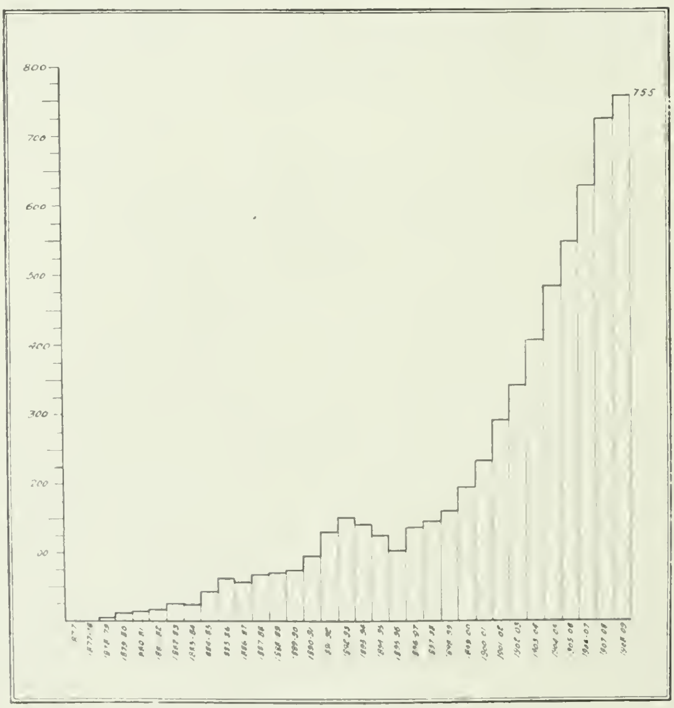


Diagram Showing the Growth in Attendance

# THE NEEDS OF THE FACULTY OF APPLIED SCIENCE.*

PRESIDENT R. A. FALCONER

Unless all omens fail the Faculty of Applied Science will soon become the second in size in the University, and may creep up upon the Faculty of Arts, though Arts has such a lead that it will probably hold the first place for many years. During the last two years, not including the present, the ratio of increase in the Faculty of Applied Science has been thirty-two per cent., a larger proportionate increase than in any other Faculty. It is also worth mention that a much larger proportion of the students of this Faculty than of those in the Faculty of Medicine come from the city of Toronto. About a third of the whole number have their homes in this city, the reasons for which may not be very difficult to discover.

This Faculty has developed healthfully and in conformity with the demands of the country. Ontario has become a great manufacturing province without at the same time ceasing to develop its agriculture. The Agricultural College at Guelph is a splendid evidence of the good hope that lies before our farming population. For the other side of our life we also need leaders—in opening up new country by railways, in constructing large works, in developing mines. For producing men who will direct these activities there is the Faculty of Applied Science, formerly known as the School of Practical Science.

A distinction must be kept clearly in mind. The aim of the Faculty of Applied Science is not to be confounded, as is sometimes done, with the work of technical education. The latter consists on the one hand of giving artisans and the youth in school instruction in the scientific principles that underlie the various trades in which they may be engaged, and on the other hand of instruction in the principles and technique of the actual trades. Technical education is meant for the man who, whether as foreman or skilled workman, is engaged in some trade. And a highly honorable function does this man perform for the commonwealth. More and more demand arises for a supply of such intelligent, well-trained, capable men who take pride in their trade. Those men who are seeking to direct the attention of the public to the necessity of providing this technical education are engaged in a good work.

In the Faculty of Applied Science, however, students are being trained who will become the directors of the works in which the technically trained men will be employed. They should be trained men of the manifold industrial activities of the

* This is one of a series of articles on "The Needs of the Univerity of Toronto," contributed to the *University Monthly* by President Falconer.

Robt. A. Falconer.

country. As workmen they may perhaps be actually unskilled, but they must know how the work should be done, and be able to detect its worth and appraise its value.

The complexity of our industrial life, the variety which is daily increasing, and the rapid expansion of our population, as well as the rise in the scale of comfort, will not only bring more students into this Faculty, but will occasion additions to the departments taught within the Faculty. At once the question arises, is there to be no limit to this development? Are we to keep on adding new departments indefinitely? We have not as yet gone far beyond the ordinary branches, the object of the Faculty having been to lay deeply and well the principles of science by means of concrete applications of these principles in the few leading departments into which most students turn. There are at present the departments of Civil Engineering, Mining Engineering, Mechanical and Electrical Engineering, Architecture, Analytical and Applied Chemistry and Chemical Engineering. As has already been remarked, these have been established to meet the requirements of the life of the Province. The relative numbers in attendance in the past may very probably change in the future, as for example in mining, as Ontario becomes increasingly a mining province.

In connection with this Faculty there is the pressing need of more room. One of the best objective evidences of its growth is shown by looking at the northern part of the old Engineering building which was erected in 1878 for the school of Practical Science, and then turning to the buildings now used by this Faculty. This old building has been greatly enlarged but has been long filled. Then came the new building on College Street, one of the best in the whole group on the University grounds. In the old building there are the departments of Electrical Engineering, Strength of Materials, Surveying, Drafting, Physics and Architecture, and at present also Thermodynamics and Hydraulics. In the new building are Chemistry, Electro-chemistry, Geology, Mineralogy and most of the lecture-rooms used by this Faculty. In its eastern wing is the valuable palaeontological museum. The mining department is housed in a building in the rear.

Last year the plans of the Convocation Hall were further enlarged by the erection in the rear of the large hall. It is used for examinations and also for drafting. So far the Drafting has been confined to the students of the second year. A large amount of space is required for this department inasmuch as the policy of the Faculty has been to give each student a desk at which he is supposed to spend all the time that he is not at lectures or in some laboratory. Drafting thus occupies a very large share of his attention. Hitherto each student has had his own desk, and unless it should be found possible in some of the work to have two students at one desk, there must be an increased space devoted to Drafting.

Until the new building for Thermodynamics and Hydraulics was under way it was impossible to draw up a four years' course in this Faculty. The structure is to be ready for occupation by the autumn and with its equipment will provide ample opportunity for this important side of Engineering. The removal of the Thermodynamic department from its present extremely congested quarters will allow for some expansion of the departments of Electrical Engineering and Strength of Materials, though if the increase of students continue this cannot be much more than a makeshift for a short time. According to the plans of the architect a handsomely designed addition to the new Thermodynamics and Hydraulics laboratory facing on the main entrance to the University from College Street will serve both to adorn the approach and to provide some much needed accommodation until part or all of the old Engineering building can be replaced by a new structure.

In a Faculty where so much of the instruction must be given in laboratories equipped with expensive apparatus or machinery it is necessary to spend money on buildings. And most of these buildings hitherto erected have been devoted to departments already taught in the Faculty. But, as has been stated, new departments must be originated. With the development of the mines of Northern Ontario an immense impetus has been given to this side of industrial life. Fortunately our mining equipment is good, and under the direction of Professor Haultain, who has had a thorough experience in mining, we may reasonably expect that the University of Toronto will have a large share in training those who are to develop the immense mineral resources of the Province. Closely akin to Mining is Metallurgy. There is metallurgy of gold and silver, but more important for a Province with large manufactures is the metallurgy of iron and steel. It cannot be long until the instruction now given in this subject will be greatly increased. Other departments in which extension may be demanded within a short period are Architecture and Applied Chemistry. Already the architects have approached the University with the object of getting additions made to the department in the way of practical design. In Applied Chemistry there will come developments in the application of chemical science industrially. Even if we do not adopt the policy of attempting to provide for every branch of Engineering education, we must at least prepare men for launching and guiding those industrial activities which are most adapted to the natural resources of this Province. All development of this kind is expensive, both for the undergraduate and the graduate student.

In considering the necessary additions to the staff occasioned both by the rapid increase of the students and of the subjects to be taught, it is necessary to bear in mind that men fitted to develop important departments of the Faculty of Applied Science are able to earn good incomes at present, and that there are also many opening for young men of ability which will bring them in much more within a few years than they would earn in the University in the same time. And yet it is of immense importance for us to have men who have some training of a practical character besides their academic equipment. Their experience is extremely valuable in giving them selective faculty and power of adjustment of theory to practical necessities. This has to be taken into account when any addition to the staff or department is contemplated. While a few men will be content with a small salary in a university faculty because the position is supposed to be secure and free from many of the difficulties of a practical engineer's life, many of the brightest and most energetic minds are drawn to the active exercise of their profession. Some men of this sort are required in a faculty; and the salary is a factor that cannot be neglected.

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## THE ENGINEERING SOCIETY OF THE UNIVERSITY OF TORONTO

T. H. HOGG, B.A.Sc.

The Engineering Society of the Faculty of Applied Science and Engineering of the University of Toronto was founded in 1885, being known at that time as the Engineering Society of the School of Practical Science. The names most intimately connected with its beginning are Messrs. Herbert Bowman and T. Kennard Thomson, who were undergraduates at that time. It is essentially a student's society and only graduates and undergraduates in Engineering of the University are admitted as ordinary members.

The objects of the Society according to the Constitution are:

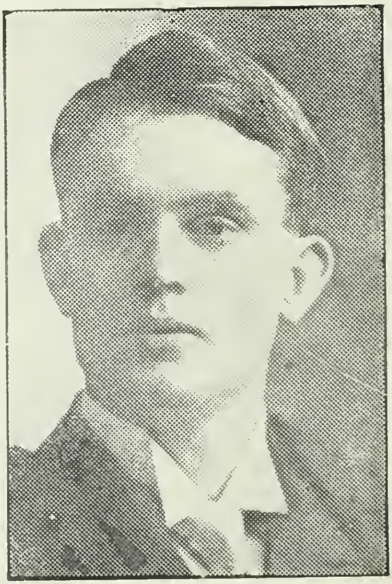
1. The encouraging of original research in the Science of Engineering.
2. The preservation of the results of such research.
3. The dissemination of these results among its members.
4. The cultivation of a spirit of mutual assistance among the members in the practise of the profession of Engineering.

The membership of the Society has risen steadily in point of numbers since its inception. It began with a total membership of about thirty. At the present time of ordinary members there are 750 with a life membership of about the same, making a total of nearly 1,500.

For the first few years of its existence, membership for the undergraduates was optional, but recently through the co-operation of Dean Galbraith, it has been made compulsory for all in attendance in the Faculty, a fee of $1 per year being imposed and collected with the regular tuition fees.

Until the fall of 1908 meetings were held each alternate week of the academic year: that is from October until April. The Executive Committee then decided that the time had come for a division of the Society, as the meetings were becoming too large and unwieldy, for good discussions of the papers presented. The constitution, too, had become inadequate, not having been revised since the founding of the Society. A new constitution was therefore drafted and in this provision was made for sectional meetings, the members being grouped according to the courses taken, the Civils and Architects, Mechanicals and Electricals, and Miners and Chemists forming three divisions. These smaller meetings are held alternate to the general meetings, and at them papers of more specialized interest are read. By this means a

H. E. T. Haultain
First Student President of Society



R. J. Marshall
Present President of Society

much freer discussion is obtained and many more of the undergraduates are enabled to prepare papers and deliver them. These smaller meetings are presided over by the vice-presidents of the respective sections, and no business of a nature affecting the Society as a whole is transacted. The general meetings are reserved for business and for topics of general interest to the student body. As a natural outcome the papers given at the sectional meetings are nearly all by undergraduates while those given at the general meetings are by graduates and men prominent in the outside world.

The appointment of a permanent secretary in the fall of 1908 marks a turning point in the affairs of the Society. For a number of years, certain supplies had been handled for the students, the revenue accruing from the sale of these being used for the expenses of carrying the Society along. This branch became so large that it was found necessary to appoint a secretary who would devote his time to the ordering and sale of supplies, and the other work incidental to the organization. The Society now handles, at a slight increase in cost, all draughting supplies, etc., used in the Faculty, thus affording a great reduction over the old prices.

In its infancy the question of funds was a serious one with the Society, but happily that worry is now over. Each undergraduate in the Faculty pays an annual fee of $1. This, with the income from the sale of supplies makes a sum which allows of the handling of many departments of advantage to the students and to the Faculty in general. Probably the most important of these departments is the publication of the Society monthly, "Applied Science." Before saying more of this, we must trace its development. In the early days of the Society the transactions, containing the papers read at the meetings, were issued yearly. The first volume of the Transactions was published in 1886, and was a pamphlet of 43 pages. In the then financial condition of the body this was a serious undertaking, as about 500 copies were issued. A gradual increase in membership together with a great development in enthusiasm caused the sending out in 1895, of advance proofs of the papers read, for discussion. This was too much of a forward step and in consequence the Society was nearly swamped. Eventually it recovered its lost ground and from that time until 1906 there was a continuous development in the size of the pamphlet. The No. 20 issued in 1906-1907 had about 250 pages and was very fully illustrated.

With the division of the Society into sections and the increased number of papers forthcoming on that account, it was decided to change the publication to a monthly. This was done in 1907, and the monthly, "Applied Science," was enthusiastically received by all the graduates.

At the present time "Applied Science" is a thoroughly progressive and up-to-date periodical, not of interest merely to graduates of the Faculty nor courting inspection as an academic journal, but resting on its merits as an engineering magazine. It has to-day a circulation of 1,700 copies. There are exchanges with all engineering societies and periodicals in the United States and Canada. The articles appearing in it have been copied in nearly all the leading engineering publications. "Applied Science" in its short life has done much towards cementing together the graduate feeling, and according the Faculty the recognition among engineers and the general public which it deserves.

As the organ of the Engineering Society, and as an outward manifestation of what the Society is, the monthly has well justified its existence.

As the membership increases and each year of added tradition puts new enthusiasm into the work of the Society, one looks back on a connection with the Society with pride, and a feeling arises that, with the strong cohesion and power of initiative exhibited by its executive committees in the past, there must certainly be a broad field of action for the Society in the future. While it is true that its work is mainly carried on by students, still not all of its benefits are conferred on its members alone, and we hope in the future that the Engineering Society with its strong, compact organization, will do much towards procuring for engineers the recognition from the general public which they deserve.

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## ADDRESS—DEAN GALBRAITH.*

Gentlemen, — Custom in this Society demands of the retiring president, whether wisely or otherwise it is not for me to say, an address at the close of his term of office. Fortunately for him no by-law exists governing either the form or matter of his essay. He is not required to confine himself to the third person and has all the freedom implied in the declaration, printed in every volume of the "Transactions," that "the Society will not hold itself responsible for any statements or opinions which may be advanced in the following pages." Answerable thus to no one and confined only by my natural limitations, I jotted down from time to time, by way of gathering material, ideas as they occurred to me. When a sufficient number had accumulated to enable me to form a judgment of their suitability for the purpose in view, I was dismayed to find that my stock was shopworn and that it would not be an easy task to work it into presentable shape. However, it was then too late to throw it away. After a period of severe reflection I convinced myself that it might be of some value to the younger members of the profession and that even the seniors might be interested in the viewpoint of an engineering teacher, differing as it does in many respects from their own. I decided, therefore, to form my material into a paper under the somewhat hackneyed title of "The Engineer and His Work."

In tracing backwards the history of the engineer to classical times, two words stand out with marked prominence— *μηχανή* and *ingenium*. The root idea of the former is contrivance, resource, ways and means; of the latter, nature, intelligence, ingenuity. The phrase "mechanical genius" describes the highest attribute of the engineer, the control of mind over matter, the

* Address by Dean Galbraith, Retiring President of the Canadian Society of Civil Engineers, delivered at the annual meeting of the Society in Toronto, January 27th, 1909. Printed with the permission of the Council.

power of bending the forces of nature to the use and convenience of man. The antiquity of the words and the continued application of their derivatives down to the present day to the same set of ideas are evidence that the art and craft of the engineer are not of yesterday nor the outcome of modern conditions. The remains of the great structures of ancient civilizations — temples and amphitheatres, baths, aqueducts and sewers, walled cities and military roads, are witnesses to the genius of engineers whose names have been long forgotten, of men skilled in surveying, levelling, drawing, hydraulics, excavation and construction. The entrenched camp, the tunnelled approach, the battering-ram, catapult and moving tower were the devices of the engineer. He had a great part then as now in the arts of peace and war.

An inscription on a marble altar discovered in 1866 near Lambaese, Algeria, of date A. D. 152, contains a petition from Varius Clem-

J. Galbraith, M.A., LL.D.

ens, governor of Mauritania, to Valerius Etruscus, governor of Numidia. It reads as follows:

"Varius Clemens greets Valerius Etruscus and begs him in his own name and in the name of the township of Saldae to dispatch at once the hydraulic engineer of the Third Legion Nonius Datus with orders that he finish the work which he seems to have forgotten." The petition was favorably received by the governor and by the engineer Nonius Datus, who when he had fulfilled his mission wrote to the magistrates of Saldae the following report:

"After leaving my quarters I met with the brigands on my way, who robbed me even of my clothes and wounded me severely. I succeeded after the encounter in reaching Saldae where I was met by the governor, who after allowing me some rest took me to the tunnel. There I found everybody sad and despondent; they had given up all hopes that the two opposite sections of the tunnel would meet, because each section had already been excavated beyond the middle of the mountain and the junction had not yet been effected. As always happens in these cases, the fault was attributed to the engineer, as though he had not taken all precautions to ensure the success of the work. What could I have done better? I began by surveying and taking the levels of the mountain; I marked most carefully the axis of the tunnel across the ridge; I drew plans and sections of the whole work, which plans I handed over to Petronius Celer, then governor of Mauritania; and to take extra precaution I summoned the contractor and his workmen and began the excavation in their presence with the help of two gangs of experienced veterans, namely a detachment of marine infantry and a detachment of Alpine troops. What more could I have done? Well, during the four years I was absent at Lambaese expecting every day to hear the good tidings of the arrival of the waters at Saldae, the contractor and the assistant had committed blunder upon blunder; in each section of the tunnel they had diverged from the straight line, each towards his right; had I waited a little longer before coming, Saldae would have possessed two tunnels instead of one."

Nonius Datus, having discovered the mistake, caused the two diverging arms to be united by a transverse tunnel; the waters of the Ain-seur could finally cross the mountain and their arrival at Saldae was celebrated with extraordinary rejoicings in the presence of the governor, Varius Clemens, and of the engineer. (Lanciani—Ancient Rome in the Light of Modern Discoveries.) We can, I am sure, sympathize with our confrere the engineer of the Third Legion in his difficulties, and rejoice with him in his triumph.

The Romans as a rule constructed their aqueducts with grades approaching those of our modern railways. They tunneled mountains and bridged valleys, not, it must be remembered, that they were ignorant of the fact that water could be carried across valleys in inverted siphons, but because they were unacquainted with the use of cast iron. There is at least one instance of a masonry or perhaps a concrete pipe constructed by the Romans which was able to withstand pressures as high as ten atmospheres.

The first advance in engineering after the time of the Romans was due to the invention of gunpowder in the beginning of the fourteenth century, or perhaps it may be more correct to say, to its introduction into Europe about that time. By it the methods of excavation and of attack and defence were revolutionized.

The next great step was the introduction of iron as a structural material, which was rendered possible by the use of coke as a blast furnace fuel in the early part of the eighteenth century. Following the manufacture of coke iron came Watt's epoch-making improvements in the steam engine in the latter part of the same century—the separate condenser, expansive action, the double acting cylinder, the steam jacket, the parallel motion, the throttle valve, the governor, the water gauge, the indicator, and many others. Watt also conceived and patented in 1782 the idea of the compound engine, which he thus described: "A new compound engine or method of connecting together the cylinders and condensers of two or more distinct engines so as to make the steam which has been employed to press on the piston of the first act expansively on the piston of the second, etc." Watt, in fact, gave the world the steam engine which exists to-day, the improvements made since his time being as nothing compared with his. The achievements and personality of James Watt cannot be better described than in the words of Sir Walter Scott after meeting him in 1818:

"There were assembled about half a score of our Northern Lights. . . . Amidst this company stood Mr. Watt, the man whose genius discovered the means of multiplying our national resources to a degree perhaps even beyond his own stupendous powers of calculation and combination; bringing the treasures of the abyss to the summit of the earth—giving the feeble arm of man the momentum of an Afrite—commanding manufactures to arise as the rod of the prophet produced water in the desert—affording the means of dispensing with that time and tide which wait for no man and of sailing without that wind which defied the commands and threats of Xerxes himself.

This potent commander of the elements, this abridger of time and space—this magician whose cloudy machinery has produced a change on the world, the effects of which, extraordinary as they are, are perhaps only now beginning to be felt, was not only the most profound man of science, the most successful combiner of powers and calculator of numbers as adapted to practical purposes—was not only one of the most generally well-informed, but one of the best and kindest of human beings.

There he stood, surrounded by the little band I have mentioned of northern literati, men not less tenacious generally speaking of their own fame and their own opinions than the national regiments are supposed to be jealous of the high character they have won upon service. Methinks I yet see and hear what I shall never see or hear again. In his eighty-second year the alert, kind, benevolent old man had his attention alive to every one's question, his information at every one's command. His talents and fancy overflowed on every subject. One gentleman was a deep philologist—he talked with him on the origin of the alphabet as if he had been coeval with Cadmus—another a celebrated critic—you would have said the old man had studied political economy and belles-lettres all his life—of science it is unnecessary to speak, it was his own distinguished walk. And yet, Captain Clutterbuck, when he spoke with your countryman, Jedediah Cleishbotham, you would have sworn he had been coeval with Claver'se and Burley with the persecutors and persecuted, and could number every shot the dragoons had fired at the fugitive Covenanters. In fact we discovered that no novel of the least celebrity escaped his perusal, and that the gifted man of science was as much addicted to the productions of your native country, in other words as shameless and obstinate a peruser of novels as if he had been a very miller's apprentice of eighteen."

One scarcely knows which to wonder at most, the genius of the engineer or the vision of the poet.

Sir Humphrey Davy said of Watt: "He was equally distinguished as a natural philosopher and a chemist and his inventions demonstrate his profound knowledge of these sciences."—(Muirhead's Life of James Watt.)

Watt was not only the greatest of mechanical engineers—he was an expert surveyor and civil engineer as well. He spent several years of his life in making surveys and reports on harbors, docks, canals, water works, bridges, etc. He invented a quadrant, a surveyor's micrometer, clock, and other instruments of precision. As an illustration of the rate of pay of civil engineers in 1770, Watt's charge for the survey of the Strathmore Canal may be of interest. The field work covered 43 days for which he charged £80 including travelling and living expenses; for the preparation of the report he was paid the further sum of £30.

The manufacture of iron on the large scale has been accompanied within the last thirty years by an enormous expansion in the manufacture of Portland cement and the consequent return to the use of concrete as a structural material. Within the same period the development of the dynamo has marked another advance comparable in importance only with that of the steam engine. It is not to be supposed, however, that these modern features have entirely absorbed the energies of the engineering and industrial world. Few of the ancient arts and manufactures have lost their importance. They have undergone development and transformation under the light of modern science and the stimulus of modern conditions. Through all these changes man, their author, seems to survive almost unchanged. The human race, civilized or savage, is, man for man, very much the same as it was three thousand years ago. Nonius Datus had the full qualifications for admission into the Canadian Society of Civil Engineers. No one would recognize any essential difference between him and other members, except perhaps that he was better educated, being able to talk Latin.

It will be unnecessary to recite to an audience of engineers in any minute detail the various fields of activity now open to the profession. It may be useful, however, to attempt a classification of the functions of the engineer irrespective of the special branch in which he may be engaged. They may be roughly analyzed as follows:

1. Design—the preparation of the drawings, specifications and estimates of cost for works not yet in existence—the study of the problem, the devising of ways and means—in short, the consideration of all questions affecting the construction and efficiency of the contemplated work.

2. Survey and inspection—making the examination of existing works or ground for the purpose of determining necessary extensions and changes—laying out new work—measuring work done—inspection of materials and workmanship, and generally, the superintendence of construction.

3. Superintendence of the operation and maintenance of works in running condition.

4. Determining and estimating costs of various kinds.

5. Reporting upon various physical and financial features of existing or proposed works.

To successfully perform these functions the engineer must have knowledge, training, experience, judgment, resourcefulness, business capacity and ability to deal with men, in fact the qualifications which are necessary for success in any line of life. It goes without saying that he should be an educated man in the best sense of the term. It has sometimes been said that the engineer should be forty per cent. engineer and sixty per cent. man; one might better say that he should be one hundred per cent. engineer and one hundred per cent. man, the terms engineer and man not being, it is to be hoped, mutually exclusive. It is necessary that he should have a thorough grasp of the objects and methods of the promoters and proprietors of the works on which he is engaged and be quick to discern where expense may be saved, keeping the necessary efficiency in view. It is not requisite that he be an expert mathematician, chemist, physicist, geologist, biologist, metallurgist, mechanic, accountant, lawyer or political economist, but it is desirable that he be an expert engineer. For this purpose he should have a sound acquaintance with the principles and possibilities of various branches of specialized knowledge in so far as they bear upon his own work.

In other words, he should have a clear perception of how and how much these branches may aid him in his own problems and be able to determine at any time to whom he should go when his own knowledge is insufficient. He must know the limitations of his own profession and therefore should know something of the fields which surround his own. Often it happens that some particular fence has almost disappeared and it becomes difficult to determine where the engineer ends and the neighboring proprietor begins. Indeed, it may be said that the fences are continually changing so that the engineer never can hope to be in the position of not requiring to study non-engineering things. The training to be given in the engineering schools should deal more with subjects which are not engineering than with those which are, the reason being that the time for such training is short whereas that to be devoted to engineering is long. Above all, the curriculum should be educative, the student should be trained in clear thinking and in clear expression. When he graduates he should have acquired a sufficient knowledge of his geography to have some idea of where he is in the world in general and in the engineering world in particular. It is now recognized that the study of the applied sciences has all the educational advantages usually attributed to that of the pure sciences. They involve the same principles, exercise the same faculties and produce the same educational results as the pure sciences. The fact that their objects are wholly economic does not detract from their educational value but provides an additional stimulus to scientific effort. The term "applied science," at one time suitable, is now rather misleading in connection with the science taught in the engineering schools. It suggests the idea that the business of the teachers in these schools is to train their students in the application to practical purposes of pure science. This is far from being the truth. The necessities of the practical world have developed great bodies of science with which the investigators in pure science are more or less unacquainted and are unable to take part in, either in the way of investigation or teaching, on account of the natural limitations of time, opportunity and taste. The term "practical" better described the engineering and technical sciences and the term "applied" should be discontinued in this connection. The practical sciences are taught in the engineering schools and are applied by the engineer in his work. The teachers of practical science should keep in touch with the requirements of engineers and manufacturers and not develop merely into laboratory investigators following their own lines of thought, indifferent to where these may lead. This is right and proper in the region of pure science, but those engaged in practical science must deny themselves the pleasures of unrestricted freedom. They cannot afford to soar too long in the clouds but must return again and again to earth. They must never forget that their only reason for being is the assistance they give as educators or investigators to the actual workers in the industrial fields. It is essential for the success of their work that they should be officially independent of the teachers in pure science in the university organization. They should have experience in engineering work, not for the purpose of teaching it, for there is little engineering which can be profitably taught in a school, but in order that they may be able to properly direct their true work, the teaching and investigation of practical science.

The engineer is not simply an applier of the sciences. He comes into contact with men as well as with things. He should understand the principles underlying commerce and finance, company organization, cost keeping and accounts. A financial statement ought not to be a mystery to him nor a railway report past understanding. He should have, at least, as clear a conception of the meaning of a contract as the lawyer who drafted it. He should be able to write a report in clear and expressive English. The engineering schools are beginning to understand that these subjects are not altogether above and beyond them, nor yet beneath them. It is true that an expert business man cannot be trained in a school; no more can an expert engineer. Business science, however, can be taught just as successfully as chemistry or physics. Business men are said to have a prejudice against academic training in business. Engineers once had a similar prejudice against engineering schools. With a better understanding of their field on the part of the schools will come a better appreciation on the part of the business man. The schools should devote their energies to the teaching of principles. The teaching of practical methods should be chiefly for the purpose of making the connection between theory and practice, thus clarifying and impressing the principles on the student's mind.

One of the most difficult subjects in the curriculum is English. It should not be taught as are French and German for the purpose of giving the student access to its literature, engineering or otherwise. Students can, as a rule, get the information they want from English books without the aid of a professor of English. The object in teaching English in the engineering school should not be to give the student a grasp of the principles underlying the formation of words and sentences. It should be assumed that his high school training in grammar is sufficient for this purpose. The instruction most necessary under present conditions is training in the use of the language. However, there may be a better way. There does not seem to be any good reason why the course of instruction in English in this country should not be turned end for end. Why should not the secondary school teach the boy to use his mother tongue and the university teach grammar?

One of the dangers to be avoided in the academic course of the engineer is over-specialization. It should be remembered that the graduate does not always find work in the branch to which he has devoted his four years of academic life. If his course, therefore, has not included a reasonable number of subjects more or less common to all branches of engineering he will have good cause of complaint against the educational authorities. A properly educated graduate ought to be able by his own reading to adapt himself to any situation wherein he may be placed. A broad education is the best preparation for specialization in after life.

The academic requirements for young men entering the profession would be better determined by the discussions of practising engineers than of any other body of men, and yet they seem to have little or nothing to say on the subject. There seems to be something in the work of the engineer which suppresses talk, even useful talk. This is very well in a way but may be carried too far. Engineers ought not to hide their light under a bushel and expect the world to reward them for their silent work's sake. The world is too busy a man to study engineering and would perhaps take more interest in engineers if they were to take the trouble to explain things. However, this disability is probably on the decrease owing to the influence of the engineering schools; and engineers are not as silent as they once were. They show signs of awakening and will not long be content to act simply as advisers or scientific hired men, indifferent to the big world as long as they get their pay. The engineer of the future will force his ideas of engineering education on the public and force them more effectively than his predecessors of the past and present.

The engineer should have a thorough knowledge of the materials with which he has to deal. The laboratory investigations of the chemist, the physicist and the biologist have added greatly to the store of knowledge at his disposal. Laboratory results, however, often require modification in as much as the artificial conditions surrounding them may differ essentially from the conditions of practical work. Thus it is not sufficient to accept materials of construction simply because they have passed the specified short time tests. The engineer should know in addition as much as possible of the history of his materials, their sources, methods of manufacture, modes of growth, etc.; without this knowledge the rapid examinations in the laboratory and testing room may altogether fail in their purpose of excluding unsuitable materials. Similarly in construction, it is not sufficient to examine the completed work and see that it complies with certain specified final conditions. It is necessary to watch the whole process of manufacture and construction from the beginning to the end. In other words, no short time tests or inspection will relieve the engineer from the necessity of knowing the whole history of his materials and construction. It is this fact which has forced on the profession what one may call standardized materials and methods of construction developed from experience. New materials and new processes are wisely looked upon with distrust and can achieve success only after a long period of trial. The life of a structure or machine is not only shortened by imperfections of material and workmanship and the corroding action of the elements, but by being subjected to heavier service than was anticipated in the original design. The engineer must therefore combine the functions of the prophet and the actuary and decide to what present expense it is worth while going in view of future contingencies.

There is more or less doubt in the minds of engineers as to the degree to which details of workmanship, manufacture, modes of construction, materials, etc., should be covered in their specifications. The only answer is "that depends." Where in these respects standardization has taken place and the engineer knows that the results are good, the task of specifying is comparatively simple. Much may be left to the contractor and manufacturer. Where, on the contrary, customary methods and materials are not appropriate to the work, the specifications of the engineer must be given in greater detail. Thus between the extremes of simply specifying the results desired, leaving methods and materials to those who do the work, and specifying how everything is to be done and the actual materials to be used there is wide latitude, and the medium to be adopted in every case depends largely on the general conditions of available manufacturing and contracting skill and capacity. Whatever may be the degree of detail to which he may carry his specifications the engineer cannot be relieved from the obligation of being well acquainted with the current practice of manufacturing and contracting firms, and with the materials with which he has to deal whether they be materials of construction or obstruction. The young graduate can have no better position in which to gain experience than that of contractor's engineer.

It would be well for specifications to cover not only the work to be performed by the contractor but also the data and assumptions underlying the engineer's project. While not absolutely necessary for the prosecution of the work, such information would be useful to the profession and for future reference, not to speak of its effect upon the engineer himself in increasing his sense of responsibility. The different classes of drawings referred to in the contract should be carefully defined in the specifications, otherwise ambiguities and uncertainties in interpretation will arise. Drawings may be looked upon as a species of shorthand invented to save words, time and expense, and the engineer should be an expert in reading drawings, and in writing them in such a way as to convey his exact meaning. Correct drawings and correct English both imply a competent knowledge of the subject of which they are the expression.

The engineer should know the cost of the work done under his supervision, not merely the cost to the proprietor, for that goes without saying, but also as far as possible the cost to the contractor. Not only should he keep in touch with the labor market, but he should take an interest in the physical and social welfare of the men under his charge. They should look upon

Convocation Hall, University of Toronto, where the joint meeting of the Canadian Society of Civil Engineers and Engineering Society was held him as a friend and not as an impersonal being concerned only in the results of their work. As between the contractor and the proprietor he must occupy the position of an impartial judge and not that of an advocate. The more thoroughly he knows his work the better able will he be to do his duty in this respect, and to retain the confidence of both parties. His knowledge of law and business should be sufficient to enable him to act harmoniously with those in charge of the legal and commercial interests connected with his work. In fine he must be a many-sided man, thoroughly acquainted with his own side of the work and able to cooperate with all sorts and conditions of men.

Engineers are naturally divided into classes according to the special nature of their work. For the purpose of mutual improvement in their specialties, these classes form societies, of which the main features are the reading of papers, the interchange of ideas and the extension of personal acquaintance. While these societies do a vast amount of good within their own spheres they are not capable of dealing with the question of the improvement of the engineering profession as a whole. The Canadian Society of Civil Engineers was formed in 1887 with this object. The charter reads: "The Canadian Society of Civil Engineers having for its objects and purposes to facilitate the acquirement and interchange of professional knowledge among its members and more particularly to promote the acquisition of that species of knowledge which has special reference to the profession of civil engineering, and further to encourage investigation in connection with all branches and departments of knowledge connected with the profession," etc.

The second by-law reads: "The term Civil Engineer as used in this Society shall mean all who are or have been, engaged in the designing or constructing of railways, canals, harbors, lighthouses, bridges, roads, river improvements or other hydraulic works, sanitary, electrical, mining, mechanical or military works or in the study and practice of navigation by water or air, or in the directing of the great sources of power in nature for the use and convenience of man."

It must be confessed after an existence of twenty-one years that the Canadian Society has not succeeded in gaining recognition by the various classes of engineers in the country as the representative and authoritative engineering society. Even in England the term "civil engineering" has not gained full recognition as embracing all branches of the profession.

The "New English Dictionary" edited by Sir James Murray and recognized as one of the greatest authorities on the language, gives among others the following definitions of the word engineer:

"2b. One who designs and constructs military works for attack or defence.

"3. One whose profession is the designing and constructing of works of public utility such as bridges, roads, canals, railways, harbors, drainage works, gas and waterworks, etc. From 18th century also civil engineer, not in Johnson 1775 or Todd 1818. The former has only the military sense to which the latter adds 'a maker of engines,' citing Bullokar.

"In the early quotations the persons referred to were probably by profession military engineers though the works mentioned were of a 'civil' character. Since 2b. has ceased to be a prominent sense of engineer the term 'civil engineer' has lost its original antithetic force but it continues to be the ordinary designation of the profession to which it was first applied, distinguishing it from that of mechanical engineer. Other phraseological combinations, as electric, gas, mining, railway, telegraph engineers are used to designate those who devote themselves to special departments of engineering.

"1792 Smeaton, Reports (1797) I Pref. 7. The first meeting of this new institution, the Society of Civil Engineers, was held on the 15th of April, 1793.

"1793 Edystone L. Introd. 8 'my profession of a civil engineer.'"

As Smeaton died in 1792, the dates 1797 and 1793 are probably the dates of publication of the reports. According to Sir Alexander Binnie, the first society of civil engineers in England was formed in London about the year 1760 by engineers who were in attendance at the Session of Parliament.

It seems, therefore, that the term "civil engineer" in England dates from about 1760 and that in the opinion of the editor of the New English Dictionary, who may be assumed to represent the public, it applies at present to engineers having to do with works of public utility such as those mentioned, but it is to be distinguished from the term mechanical engineer.

The same tendency to restriction of the term "civil engineer" exists in Canada and the United States not only among the public but in the profession as well. In all the great engineering schools this tendency is reflected.

The question now arises, is it worth while to expend further energy in resisting what appears to be a natural tendency? The only reason for the introduction of the term "civil" was that the word "engineer" had previously been monopolized by those engaged in military works; now that this distinction has lost its importance, would it not be better to drop the term "civil" as applied to the whole profession and confine it to the special applications justified by modern custom?

The profession as a whole should be represented in Canada by a single authoritative body somewhat after the pattern of the Medical Council or the Benchers of the Law Society in Ontario, to which should be entrusted the subjects of engineering education, qualifications for professional standing, professional ethics, etc., in short all questions of general professional interest. It is only by the hearty co-operation of the various classes of engineers that such a movement could succeed. The Canadian Society of Engineers with its Council would thus exercise functions which are necessary for the strengthening of the profession in its relations with the public, and which lie outside the province of the special engineering societies.

As a rule the engineer does not come immediately into contact with the public. At the same time there are questions of public interest in which he, in common with the chemist, the metallurgist, the biologist, the medical practitioner, the forester and others, is regarded as an authority. The public expects the engineer to aid by his advice in the improvement of transportation, the prevention of railway accidents, the abatement of smoke, the preservation and improvement of public health, transmission of power, the irrigation of arid lands, the economical management and conservation of forests and mines, the improvement of agricultural soils, the conservation of river flow, etc., etc. Such questions are matters of municipal and governmental policy and cannot be properly controlled by money-making corporations or individuals. Before a move can be made in these matters a strong body of enlightened public opinion must be formed, and who should be better qualified for the task of stimulating and guiding this public opinion than the engineer? If he is too busy or too backward to undertake this duty of his own accord, what about the editor of the engineering newspaper? The latter is never hampered by modesty and should write not only for his subscribers but for the public as well. He need not fear that his work will be lost; the lay press will print his good articles and give him due credit for them.

Mr. Carnegie is reported to have made the statement that at the present rate of consumption, the supply of iron ore (presumably the more important and richer ores) of the United States would be exhausted in forty years and the supply in England within seven years. He based this opinion on the best expert evidence he could obtain. If this statement be correct, what a prospect does it not open for the vast iron resources of Canada, and yet at the same time what a warning does it not convey to the government which controls these resources! In the United States the total production of pig iron up to the present is 350,000,000 tons of which over one-half has been made within the last ten years. The production of the world in 1907 was 61,000,000 tons, of which the United States are to be credited with 26,000,000, Germany with 13,000,000, Great Britain with 10,000,000 and other countries with 11,000,000. Canada produced 600,000 tons less than one per cent. of the total. In the United States the acid Bessemer process seems to have reached its maximum output and in the future will rapidly diminish in importance owing to the increasing scarcity of the requisite ores and its inability to use scrap. It is being rapidly superseded by the basic open hearth process, which can utilize ores containing a larger percentage of phosphorus and also all kinds of scrap.

The future of electric processes in iron and steel production in Canada will depend more upon the cost of hydro-electric power than on any other factor. Closely connected with the conservation of the iron and timber resources of America is the great Portland cement industry, which has sprung into importance within the last twenty years. The Canadian production in 1907 amounted to 2,400,000 barrels, the United States production to 49,000,000 barrels. Concrete and ferro concrete will replace steel and wood in construction in ever increasing quantities. As in the case of the electrometallurgy of iron, the cost of hydro-electric power is a large item in the manufacture of cement.

The conservation and regulation of river-flow for water power alone, to say nothing of transportation and irrigation, is a necessity for the future industries of the country. The regularity and volume of river-flow in its turn is dependent upon the preservation of forest growth, especially in the mountainous and upland regions. Forest conservation in fact is one of the fundamental conditions of future prosperity. And so one might go on, and enumerate one after the other, various sources of wealth and well-being now extravagantly exploited which demand for their wise development the knowledge and skill of the engineer. It is to be hoped that the conferences initiated by President Roosevelt to consider the conservation of natural resources will bear fruit in pointing the way to practical solutions of these national problems. Canada has already made a good beginning both in collecting information regarding our resources and in passing legislation.

One of the most striking illustrations of modern economic tendencies is the increase which has taken place in the voltage of power transmission lines. Within the last twenty-five years the practicable voltage has been increased from 1,000 to 110,000 volts, thus immensely extending the possible area of distribution from the hydro-electric power plant.

In the machine shop, complex machine tools, largely the inventions of the mechanic, high speed tool steels, electric motor drives and high class organization have immensely increased the output and decreased unit costs. The steam turbine, the improved hydraulic turbine, electric lighting, electric traction, the gas engine, the great ocean and lake freighters, the monster liners and that concentrated essence of power, the modern battleship, have all come within the present generation and we cannot predict what changes in the application of power and machinery will take place before it passes away. It would not be surprising if the automobile were to displace electric transportation in cities and be replaced for purposes of pleasure by the aeroplane and the dirigible balloon. In the future, electric transportation may be confined to underground tunnels in the cities and largely replace steam power on railway lines through the country. Evidently the end of the work of the engineer is not yet at hand. The inventions of the present day, under the stimulus of science and the ever-increasing complexity of life, crowd so closely upon us that it is impossible to form a just estimate of their relative values. That must be left to the judgment of posterity looking backward through the long perspective of the years.

One of the first duties of a country is to work up within its own limits its raw materials into the forms in which they are to be finally used by individual consumers. Only in so far as this end is successfully accomplished will the manufacturing population of a country be increased and the cost of transportation of its products to a foreign country, in comparison with their value, be diminished. One effect of over-production or decreased profits is to stimulate invention for the purpose of reducing the cost of production and transportation. As a rule the first effect is to throw labor out of employment, but this is no argument against invention. Wages will fall in any case owing to the failing market for the product, and can be maintained only by the discovery of new markets. The decrease of cost due to labor-saving inventions leads to the extension of the markets without which production must be checked and labor seek new fields, or be reduced to a lower standard of living. Thus a country depends for material prosperity as much upon the brains of its scientific men, inventors and engineers as upon its natural resources. Money spent upon unproductive enterprises means waste of labor and the stoppage before long of the wheels of industry. Capital knows no country; it ever flows to the land of promise; let it be our endeavor to make Canada no mere land of promise but a land of fulfilment as well. Fortunate in possessing vast agricultural resources without which no nation can be self-sustaining, Canada can afford to take time in developing its mines. The mines are our treasure houses, which once emptied, can never again be filled—while the scattered gold, silver, copper and iron that remain in the country may to some extent be recovered after having fulfilled their first uses, the coal, oil, and gas once used are gone forever.

The preservation of our fisheries and forests demands our first attention. Their cultivation must begin and their mining must cease, if we are not to lose them altogether. Nor need the engineer fear that under such a policy his opportunities would be deferred or his field narrowed. The conservation of our resources will introduce many new problems, will stimulate research and invention, cheapen production, open up new markets and enable the country to sustain a much larger and more permanent population than we have any right to expect from a continuance of our present ill regulated and short-sighted practice of extravagant consumption and waste.

In conclusion I have to thank the members of the Society for the honor they conferred upon me a year ago in electing me to the highest office within their gift, an honor altogether undeserved on the score of previous service. I have also to thank my colleagues of the outgoing council for the kindly assistance which I have in many ways received from them in the performance of my special duties. I am sure that they join me in wishing the new council an increased measure of success in promoting the interests of the Society.

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# APPLIED SCIENCE

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## Editorial

**To the Graduates**

The vindication of an effort is its object and the result obtained. The best advertisement of an institution is its men. The good name of an institution consists in more than the reputation of the personnel of its staff, and its history in more than a record of its growth in numbers and buildings. It has been shown for years that the best advertisement of the Faculty of Applied Science is the list of graduates showing the positions held by each as published annually in the calendar. With the increasing numbers graduating yearly, the difficulty of having this information as complete as desired has also greatly increased. It is most important both from the standpoint of the institution but more particularly from that of the graduate, that the secretary of the Faculty should be promptly informed of all professional engagements or changes, and to this end the co-operation of each graduate is earnestly solicited. It is desired to make the office of the secretary the headquarters for all such information. The staff views with justifiable pride and satisfaction the reputation given to the institution through the achievements of its graduates and fully recognizes the important part played by them in this connection. In this there has been a laudable spirit of reciprocation, never made more evident than at the last annual dinner, when the institution was brought more prominently into public notice probably than on any previous single occasion. On the one hand the staff, through the senior members, gave free expressions of appreciation of the loyalty with which the graduates had always supported their Alma Mater; on the other hand the graduates were unstinted in their praises of the work done by the institution and thus was manifested that spirit of unity which to a large extent accounts for its prestige in the community at the present time.

There is no doubt that the history of the institution in the broader sense would constitute interesting literature. That part which deals with its growth, buildings and equipment can be obtained through the records and is definite, and is dealt with elsewhere in this issue. There is another part, less definite, it is true, but of equal and ever increasing importance, which might be written upon the experiences and achievements of the graduates and the important and influential part these achievements have had upon the national and industrial development of the country.

**We Want a Complete Record of Graduates**

With a view to collecting this kind of information, it is proposed to issue printed forms to the graduates, asking their co-operation in the acquiring of a systematic professional record to be kept in the office of the secretary. The object of such a record is clear and should appeal to every graduate. It will be used as a means of securing employment for and of furnishing assistants to those desiring such. It is true this feature will appeal more strongly to the younger graduates, but there are many ways in which the information can be made mutually helpful to all and a hearty support of the scheme is solicited. It is needless to say that the information received in this connection will be treated in strict confidence, such of it being used from time to time as will advance the interests of those concerned.

**Cooperation Among Graduates**

The older graduates are to be commended for the way in which they have sought to place the younger men when in need of assistance, and it is desirable that this spirit should be stimulated. The Graduates' Association in New York has taken an important step in this direction in that it has placed itself at the disposal of the younger men who go to that city for employment. Those who go to New York are asked to call at the office of Mr. E. W. Stern, where they will be cordially received and will also be given any information within his power of the association.

Elsewhere in this issue appears a list of graduates whom we desire to locate. We would gladly welcome any information regarding their location and employment.

Let us hope that in the future the graduates will keep the secretary more promptly informed as to their changes and also that they will freely assist in the movement for a complete professional record.

## THE FIRST ANNUAL DINNER

In the first section there appears a cut of a menu card of the first dinner twenty years ago. It is interesting to glance over the list and note what has become of this old guard. On the whole, they have all been successful in life. Of the fifty-one present at the dinner January 31st, 1890, twenty-two were present at the reunion dinner last month. Of the number, nine are known to be dead.

C. H. Topp is city engineer of Victoria, B.C.

W. E. Boustead is dead.

T. H. Wiggins is with the Department of Public Works, Regina, Sask.

J. R. Pedden, address unknown.

F. M. Bowman is one of the chief engineers of the Riter Conley Mfg. Co., Pittsburg, Pa.

E. B. Merrill, after being associated with several of the most important hydro-electric developments in Canada, is a consulting engineer in Toronto.

J. B. Hanly is in manufacturing business at Midland, Ont.

Andrew Lane is deceased.

R. McLennan, address unknown.

J. M. Prentice is dead.

T. H. Alison is chief engineer of the Augustus Smith Co., New York.

A. F. Macallum has just been appointed city engineer of Hamilton, Ont.

J. E. A. Moore is a consulting and contracting engineer in Cleveland, Ohio.

G. E. Silvester is chief engineer, Canadian Copper Co., Copper Cliff, Ont.

C. W. Dill is one of Toronto's leading contractors.

N. L. Playfair is superintendent of Playfair Lumber Co., Midland, Ont.

N. M. Lash is assistant electrical engineer for Bell Telephone Co., Montreal.

R. J. Christie is manager of the Christie Biscuit Co., Toronto.

R. A. Ross is associated with Mr. Holgate, and is considered one of Canada's leading electrical engineers.

J. Hutcheon is city engineer of Guelph, Ont.

J. Galbraith, the Dean, is known to all Canadians.

John A. Duff is deceased.

W. H. Ellis is Professor of Applied Chemistry at the University.

C. H. Mitchell is a consulting electrical engineer in Toronto and Niagara Falls.

L. B. Stewart is Professor of Surveying.

J. E. Jones is with a prominent firm of New York consulting engineers.

J. H. Chewett is president Evans Rotary Engine Co., Toronto, Ont.

C. J. Marani is designing and consulting structural engineer for the Russia Cement Co., Anacortes, Wash.

V. G. Marani is a consulting engineer in Cleveland, Ohio.

C. M. Canniff is chief engineer of the Expanded Metal Co. of Canada.

H. Rolph is vice-president, Metcalfe Engineering Co., Ltd., Montreal, Que.

T. R. Russell is a clergyman in Virginia, U. S.

J. W. Evans is a mining engineer, Toronto and Cobalt

Wm. Newman is a consulting engineer at Windsor, Ont.

A. G. Anderson is a hardware merchant at Port Dover, Ont

G. L. Brown, civil engineer and surveyor, Morrisburg, Ont.

R. Russell, civil engineer and surveyor, Pembroke, Ont.

A. R. Goldie, with Goldie & McCulloch, Galt, Ont.

E. J. Laschinger, M.E., is with the Consolidated Gold Fields Co. of South Africa, Johannesburg, Transvaal, S.A.

A. B. English is deceased.

M. A. Bucke is deceased.

Albert Smith is engineer with W. B. Pollock Co., Youngstown, Ohio.

C. E. Peterson, address unknown.

J. E. McAllister is manager of the British Columbia Copper Co., Greenwood, B.C.

H. D. Symmes is a contractor at Niagara Falls, Ont.

W. B. Russel is an engineer and contractor in Toronto, but lately largely interested in Cobalt properties.

Thos. R. Deacon is president and general manager of the Manitoba Iron Works Co.

M. Dunbar is deceased.

G. Robertson, address unknown.

W. L. Innes is manager, Canadian Canners, Ltd., Simcoe, Ont.

H. Meade, address unknown.

G. D. Corrigan is deceased.

## LIST OF GRADUATES WHOSE ADDRESSES ARE UNKNOWN.

Below is a list of graduates whose addresses we have been unable to verify. These men must be known to some. Make it a personal matter to notify "Applied Science" in case you can supply the information desired.

1882—D. Jeffrey.
1885—E. E. Henderson.
1887—A. E. Lott; F. Martin.
1888—D. B. Brown; J. Gibbons.
1889—B. Carey.
1892—J. R. Allan.
1893—W. Mines; R. H. Squire; H. P. Barker.
1894—A. C. Johnston; A. L. McTaggart; S. M. Johnston.
1895—W. M. Brodie; H. S. Hull; R. J. Campbell.
1896—H. P. Elliott.
1897—A. T. Gray, M. B. Weekes, W. R. Smiley, E. A. Weldon.
1898—J. E. Lavrock; J. A. Stewart.
1899—G. A. Clothier; J. C. Elliott; E. Guy; G. E. Revell; C. Cooper; W. E. Foreman; G. A. Saunders.
1900—J. H. Barley; H. A. Dixon; J. C. Johnston; J. G. McMillan; A. Taylor; J. E. Davison; H. S. Holcroft; R. E. McArthur; J. R. Roaf; H. M. Weir.
1901—F. C. Jackson; C. MacMillan; W. C. Lumbers.
1902—J. M. Brown; F. T. Conlon; A. C. Goodwin; R. S. Mennie; H. J. Zahn; W. Christie; H. V. Connor; C. H. Marrs; H. D. Robertson.
1903—J. G. R. Alison; J. A. Horton; M. L. Miller; F. A. Moore; J. P. Oliver; R. E. George; C. A. Maus; R. H. Montgomery; E. E. Mullins.
1904—A. M. Campbell; O. B. McCuaig; C. P. McGibbon, E. E. Moore; J. M. Weir; P. C. Coates; G. G. McEwen; D. McMillan; W. J. Smither.
1905—R. H. Armour; R. B. Ross; F. H. Sykes; D. W. McKenzie; T. E. Rothwell.
1906—W. MacKinnon; R. E. Pettingill.
1907—E. Cavell; G. S. Stewart; S. A. Marshall; A. C. T. Sheppard.

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## ENGINEERING SOCIETY.

The interest in the meetings of the Society was fully sustained during the month, the regular, general and the sectional meetings being held.

The general meeting was addressed by T. W. Gibson, Deputy Minister of Mines, of the Province of Ontario. Mr. Gibson spoke on the Mineral Resources of Ontario; it was a valuable contribution by an authority on the subject. Dean Galbraith and Prof. Haultain took part in the discussion which followed.

On Jan. 20th, the Civil Section listened to an address on the "Detroit River Tunnel Construction," by Mr. C. T. Hamilton, '08. Mr. Hamilton was on this work since its inception and had the story of the undertaking well in hand, and fully illustrated.

The discussion which followed was lead by Messrs. P. Gillespie and C. R. Young.

The Mechanical Section had a double bill. R. Cunningham, '09, spoke on "The Electric Furnace," and H. Irwin, '09, on "Mining and Reduction of Copper Ores."

The Chemical Section provided a joint paper by D. J. Huether, '07, and L. J. Rogers, '07, on "High Temperature Measurements." Dr. Ellis and Prof. Bain spoke briefly at the conclusion of the paper.

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## UNIVERSITY OF TORONTO ELECTRICAL CLUB

A short synopsis of the work done by the club for the present college term will give a fair idea of its possibilities and of the benefits derived by its members. There necessarily is some delay at first, owing to the fact that third year has to be approached and that the greater part of the executive has to be elected.

On November 5th H. Coyne, '08, gave a paper on "Cranes and their Equipment," on November 19th F. H. Moody, '08, read a paper on "A Locomotive Testing Plant at St. Louis," and on December 10th a paper on "The Interpole Motor" was delivered by F. R. Ewart, B.A. Sc, '07, after which W. W. Gray, B.A.Sc., '04, gave an interesting talk on "Producer Gas Plants." All four papers were illustrated by lantern slides. The discussions following have been spirited, indicating the interest taken by the members.

In the spring term four meetings were held. The first meeting in January was devoted to the reading and discussion of a paper on "Electric Traction" by V. C. Thomas and J. N. Leslie. Later in the month Mr. W. H. Price gave a practical demonstration of the oscillograph. The club was indeed fortunate in this —a repetition of his paper before the Canadian Electrical Association. The third meeting was taken up with the discussion of L. S. Odell's paper on Steam Turbines. At the final meeting L. S. Davis read a paper on Rotary Converters.

At the final meeting a change was made in the constitution, changing the name of the club to the University of Toronto Electrical Club. It was also decided that the two councillors of the third year should be chosen, one from the electrical and the other from the mechanical section. This was done to bring the mechanicals more closely in touch with the society.

The executive for next year will consist of N. Porter, president, and E. A. Thomson, secretary-treasurer, the councillors being chosen in October.

During the year excursions were made to inspect the various industries in and around Toronto.

The executive finds engineering firms eager to get into touch with the club and it has received a number of excellent instruction books and bulletins.

The undoubted success of this club should inspire the formation of a similar one in the Civil Department.

## THESIS FOR B.A.Sc. DEGREE

The following are the subjects of the thesis submitted by the members of the fourth year, for the degree of Bachelor of Applied Science. The subjects this year are unusually general, and all exhibit a commendable degree of research both in reading and original work.

H. G. Akers, Factory Testing of Electric Machinery; W. L. Amos, Lightning Protective Apparatus for Transmission Lines and Stations; W. S. Brady, Electric Railways; P. R. Brecken, Irrigation; J. A. Brown, Concrete, Plain and Reinforced; F. H. Buchan, Storage Battery Engineering; C. E. Bush, Concrete Arches; A. W. Campbell, Modern Electric Street Railway Practice; H. R. Carscallen, Hydrographic Surveying; F. H. Chesnut, Railroad Construction; W. C. Collett, Design of a Terminal Station; R. Y. Cory, Canals; G. C. Cowper, Masonry and Concrete Dams; H. Coyne, The Induction Motor; J. V. Culbert, Cyaniding of Gold and Silver Ores, with Special Attention to those of Ontario; A. D. Dahl, A Study of the Black Liquor from the Soda Process for the Manufacture of Wood Pulp; R. S. Davis, Rotary Converters; F. C. Dyer, Concentration of Slimes; C. Edwards, Steel Rails; O. L. Flanagan, Water Supply; A. H. Foster, Concrete, Plain and Reinforced; S. S. Gear, Water Turbines; A. Gillies, Reinforced Concrete Arch; C. L. Gulley, Induction Motors; J. W. Hackner, Producer Gas Engines; K. Hall, Transformers; C. T. Hamilton, Detroit River Tunnel as Constructed from the Windsor Approach; M. C. Hendry, Piles and Piling; D. J. Huether, Chemistry of Carbon Monoxide; A. D. Huether, Foundations and Retaining Walls; A. N. Hunter, D. C. Railway Motors; S. B. Iler, The Synchronous Motor; W. Jackson, Irrigation; J. D. Keppy, Suction Gas Producers; F. C. Lamb, The Pendulum; J. N. M. Leslie, Heavy Electric Traction; L. A. McLean, Base Line Measurements; H. C. McMordie, Irrigation; A. A. McRoberts, The Filtration of Public Water Supplies; R. J. Marshall, Dams and Retaining Walls; J. B. Minns, Transformer Design; E. D. Monk, Electric Power Transmission Line Construction; F. H. Moody, Special Features of Modern Steam Locomotives; J. H. Morice, Switchboards and

Switchboard Apparatus: F. E. H. Mowbray, The Induction Motor; C. R. Murdock, Hydraulic and Placer Mining; W. P. Murray, Steam Locomotives: E. W. Murray, Roads, Their Construction and Maintenance; H. J. Peckover, Municipal Thoroughfares; M. Pequegnat, Sewage and the Disposal of Sewage: M. Pivnick, Gas Engines; F. E. Prochnow, Polyphase Induction Motors; E. M. Proctor, Irrigation; C. F. Publow, Single Phase Series Commutator Type Motor; J. T. Ransom, Time; W. B. Redfern, A General Description of the Hydraulic Features of the Power Plants at Niagara Falls; A. R. Robertson, Concrete in Municipal Work; R. R. Rose, The Concentration of Sands: W. E. L. Shaw, Lightning on Transmission Lines, Cause, Effect and Remedy; H. F. Shearer, Synchronous Machines; W. L. Stamford, The Development of Water Power; R. H. Starr. Electric Car Equipment and Traction; R. B. Stewart, Magnetic Separation of Ores; W. M. Stewart, Precise Levelling and Determination of Elevations; J. L. Stiver, Comparison of the Hydraulic Construction of the Niagara Falls Power Plants; R. B. Stuart, Dams—Their Design and Construction; G. F. Summers, Concrete Dams: V. C. Thomas, Steam Railroad Electrification; J. H. Thornley, Water Power Development in Canada; R. M. Wedlake, Electrical Illumination; W. J. White, The Electric Drive on Draw Bridges; F. D. Wilson, Internal Combustion Engines; A. R. Zimmer, The Distribution of Electric Power.

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## WHAT THE GRADUATES ARE DOING.

G. Galt, B.A.Sc., '07, is at the Northern Lode Mine at Greenwood, B.C.

C. W. Hookway, '06, is with the Allis-Chalmers-Bullock Co., at Montreal.

B. F. Mitchell, B.A.Sc., '06, is in the city engineer's office at Calgary, Alberta.

Geo. S. Hodgins is editor of Railroad and Locomotive Engineer, New York.

A. F. Macallum, '93, has been appointed City Engineer of Hamilton, Ontario.

Walter Malcolmson, '07, is in the office of the city engineer, Niagara Falls, Ontario.

H. V. Serson, '05, is with the Taylor Iron and Steel Co., High Bridge, New Jersey.

D. J. McGugan is on the engineering staff of the Sumas Development Co. at Chilliwack, B.C.

F. A. Danks, '08, is in the office of Hazen & Whipple, consulting engineers, 103 Park Ave., New York.

A. L. Ford, '04, is Government Inspecting Engineer on G. T. P. Railway from Winnipeg to Saskatoon.

C. Fairchild, '92, and W. G. Webster, '05, have formed a partnership, with offices at Brantford and Dunnville.

A. F. Macallum is associated with T. Aird Murray in reporting on a scheme of sewage disposal for New Toronto.

J. M. Wilson, '08, is general manager of W. H. Oliver Co., Chemical and Mechanical Engineers, McKinnon Bldg, Toronto.

A. G. Christie, '01, has been appointed Research Assistant in the Department of Mechanical Engineering at the University of Wisconsin.

S. Wass, '03, has been transferred from Durham to the Toronto office of the construction department of the Canadian Pacific Railway.

Edw. O. Fuce, '03, is located at Galt, Ont., as a consulting civil engineer, specializing on sewage disposal and reinforced concrete work.

G. S. Hanes, '03, till recently City Engineer of Windsor, is now City Engineer of North Vancouver. M. E. Brian, '06, will succeed him at Windsor.

E. V. Neelands, B.A.Sc., has been appointed manager of the Hargrave Mine at Cobalt. G. Johnson is manager of the Silver Cliff mine in the same camp.

W. J. Francis, '93, read a paper before the Ontario Association of Architects at their recent convention, on "The Economical Advantages of Reinforced Concrete."

F. W. Thorold, '00, for some time City Engineer of Calgary, Alberta, has been appointed assistant engineer in charge of outside work on Toronto's new sewage system.

Frank Barber, '06, appeared before the Railway Commission in the recent viaduct case in Toronto to give evidence that an economical viaduct could be built on oblique piles.

W. Fry Scott, '97, consulting structural engineer, has been retained by the Mutual Fire Insurance Company to give manufacturers skilled expert advice on matters of construction and protection.

We regret to report the death of Duncan Sinclair, B.A.Sc., '02, a former president of the Engineering Society, on January 5th last. A full obituary of him, along with others, will appear in No. 6, Applied Science.

S. L. Fear is with the Dunbar & Sullivan Dredging Co. of Buffalo. They are operating at present on the new Livingston Channel—a four-year contract—Detroit River, 24 feet deep, 300 wide, and about 18 miles long.

We regret to report the death of W. F. Ratz, '02, at Ottawa, from typhoid fever. Mr. Ratz had for some years been on the international survey between Canada and Alaska. A full obituary will appear in number six issue.

A. R. Campbell, '02, and A. L. MacLennan, '02, have forsaken engineering for the present and are engaged in manufacturing of a new vacuum massage machine, Mr. Campbell being president and managing director of the Universal Manufacturing Company.

J. D. Shepley, '04, district engineer for Battleford, Sask., called at the school, renewing old acquaintances. He spent this summer running a line north from North Battleford to get in touch with the fur trade of that district. The district is very rough and for some distance covered with fallen timber.

H. D. Symmes, '91, has just finished the contract for the 150-foot extension of the Ontario Power Company's plant at Niagara Falls, in record time. The work included some very complicated concrete construction which, considering the nature of the ground and the location of the plant, was finished with remarkable despatch.

Mr. C. H. Mitchell, C.E., has now associated with him in partnership his brother, P. H. Mitchell, and together they will carry on practice as consulting and supervising engineers. Mr. C. H. Mitchell is too well known to need mention of his work. His brother is also a graduate of Toronto and has had a wide experience in mechanical and electrical engineering, having for some years been employed on the works of the Ontario Power Co. at Niagara Falls and on the Winnipeg Municipal Power Plant, as well as several steam and electric plants. The new firm will attend especially to hydraulic and steam-driven electric power plants, electric railways and electric lighting.

Messrs. Gardner and Wilson, both '03, have opened an office in Niagara Falls, Ontario, to carry on a general practice. They will give special prominence to electric railway and hydro-electric work. J. C. Gardner, B.A.Sc., has been for twelve years on engineering work, having been connected with the construction of the three bridges across the Niagara River below the Falls and of the power houses of the Niagara Falls Power Co. and the Ontario Power Co. He was two years with the Toronto and Hamilton Railway, going to Chili early in 1906 to work on the construction of the Anca and La Paz Railway through the Cordilleros. N. D. Wilson, B.A.Sc., spent two years on bridge and city work, and a year in the office of the late W. T. Jennings, C.E. in connection with the Toronto and Niagara Power Company. He has been on location and construction in Ontario and the West for the G. T. P. and C. P. R.

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## TRANSMISSION LINE FORMULAE


T. R. ROSEBRUGH, M.A.


In making any calculation one may hesitate between a method which neglects quantities that may possibly need to be taken into account, and one which while dealing completely with the problem, is more laborious or intricate, and thus increases the chances of error. The advantage of the method to be described is that it permits a middle course, yielding first a rough result coinciding with that of simpler expressions, to be followed subsequently as far as may be desired, by rough approximations rapidly converging to the true result as term after term is estimated.

The result may be obtained graphically or analytically as may be preferred by the following method.

First reduce the problem, if it relates to three-phase transmission, to one of single phase.

If the connection be star, then in so far as the fundamental is concerned, the neutral points (one at each end) will be at the same potential, and may be treated as if in immediate contact. One-third of the power may then be taken as transmitted by each conductor at the voltage which exists between it and the neutral point, that is line voltage divided by $\sqrt{3}$.

The resistance and reactance are seen to be those of one conductor only, while the capacity and leakage conductance with which we have to do are estimated as the individual branches of a star connection having their common terminals on an imaginary neutral carrying no current.

In the calculation it is indifferent whether the actual arrangement be delta or star.

It is not the purpose of this paper to deal with these line constants, but a few words of caution may not be out of place. In using tables individual numbers may be in error, or a mistake may be made by using a table calculated on a different basis, perhaps with some coefficient not properly belonging, incorporated with it, and the special method of using such table not quoted from the original source.

Let $r$ = resistance of one conductor.
$x$ = reactance of one conductor.
$g$ = leakage conductance.
$b$ = susceptance.

If $x$ be taken from a table, it should be, for the present purpose, one giving the reactance of one conductor at the given frequency, in accordance with

$$x = L\omega = \frac{160930}{10^7\ 109}\left(2 \log_e \frac{2D}{d} + \frac{1}{2}\right) m\,\omega \text{ henries,}$$

where $m$ is the distance of transmission in miles, by stating its value for one mile, or otherwise.

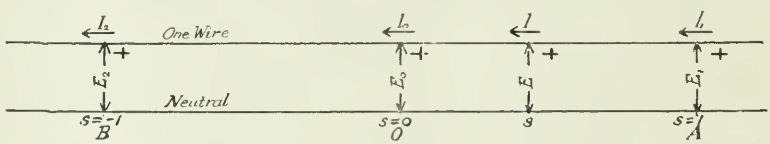
Also $b = C\omega$ should, if obtained from a table, be from one giving values agreeing with

$$C \times 10^6 = \frac{160930}{900000}\, m \div 2\ log_e \frac{2D}{d} \text{ microfarads.}$$

These preliminaries being arranged, and

$$z = r + x\,j$$
$$y = g + b\,j$$

adopted for abbreviation, take $E_0$ and $I_0$ to denote the vectors describing voltage and current respectively at one end of the




line, which for definiteness may be thought of for the present as the receiving end at $O$ in the figure, and taken as the origin.

Take $E_1$ and $I_1$ of corresponding meaning for the other end $A$ at $s = 1$. $E$ and $I$ similarly may be taken as vectors for the arbitrary point on the line whose distance from $O$ is $s$.

The diagram shows the convention adopted for the signs: that is, positive instantaneous values of voltage and current are taken to be of the polarity and sense respectively indicated by the + and the arrow, and relative vector senses chosen accordingly.

Here $E$ and $I$ being functions of $s$ they are given thus by Taylor's theorem:

$$E = E_0 + s\left(\frac{dE}{ds}\right)_0 + \frac{s^2}{2}\left(\frac{d^2E}{ds^2}\right)_0 + \frac{s^3}{6}\left(\frac{d^3E}{ds^3}\right)_0 + \ldots$$

or for short, $D$ denoting differentiation once with regard to $s$, $D^2$ twice, etc.

$$E = E_0 + s(DE)_0 + \frac{s^2}{2}(D^2E)_0 + \frac{s^3}{6}(D^3E)_0 + \ldots$$

$$I = I_0 + s(DI)_0 + \frac{s^2}{2}(D^2I)_0 + \frac{s^3}{6}(D^3I)_0 + \ldots$$

These values may be readily determined thus: With the current as at $s$ remaining constant at the value $I$ the vector voltage difference for the conductor would be $zI$ for the whole length of the line, that is for unit length as we have chosen to call it so, and consequently $\frac{dE}{ds} = zI$, or for short $DE = zI$. Similarly $DI = yE$.

Hence
$$D^2E = D.DE = DzI = zyE$$
$$D^3E = D.D^2E = DzyE = z^2yI$$
$$D^4E = D.D^3E = Dz^2yI = z^2y^2E$$
$$D^2I = D.DI = DyE = yzI$$
$$D^3I = D.D^2I = DyzI = y^2zE$$
$$D^4I = D.D^3I = Dy^2zE = y^2z^2I$$

Therefore $E = E_0 + szI_0 + \frac{s^2}{2} zyE_0 + \frac{s^3}{6} z^2yI_0 +$

and $I = I_0 + syE_0 + \frac{s^2}{2} yzI_0 + \frac{s^3}{6} y^2zE_0 +$

In particular at $A$ the end of the line $(s = 1)$

$$E_1 = E_0 + zI_0 + \frac{1}{2} zyE_0 + \frac{1}{6} z^2yI_0 +$$

$$I_1 = I_0 + yE_0 + \frac{1}{2} yzI_0 + \frac{1}{6} y^2zE_0 +$$

By means of these two expressions the problem (so far as fundamental frequency is concerned) may be solved as accurately as the data permit, for any length of line.

As the length and voltage increase it may be necessary to take in successively additional terms; this may be carried to any extent desired.

The first term for $I_1$ and the first two for $E_1$ give the ordinary solution for short lines at low voltage. The second term for $I_1$ namely $yE_0 = (g + bj)\ E_0$ corrects the current for leakage and effect of capacity. The third term for $E_1$ corrects the drop already calculated for constant current by taking account of its variation along the line due to leakage and capacity. The third term for $I_1$ corrects the error made in calculating leakage and capacity effect on the basis of constant potential throughout.

At or before this point, the requirements of calculations of power transmission are likely to be satisfied, but telephonic transmission with the high frequency of some of the components of sound necessary for clear enunciation, and the long distances which are common may demand several terms more.

It is unnecessary to discuss at length the method of using this formula, as the use of complex quantities is explained in many text books.

Briefly, however, it may be stated as a caution that while the laws of algebra may be applied to the expressions given, yet if $E_0$ is to be taken directly as a number, $I_0$ (not usually being a vector in the same direction) may not be. For example, if the current be 100 amperes at $O$, and be lagging so as to have a power factor of 90%, then if $E_0$ be represented by its value in volts as a pure number, $I_0 = 100\,p - 100\,qj$ where $p = .90$ and $p^2 + q^2 = 1$.

Thus the data may for symmetry be supposed stated in the form

$$E_0 = A_0 + B_0\,j$$
$$I_0 = M_0 + N_0\,j$$

There finally result from the above described calculation

$$E_1 = A_1 + B_1\,j$$
$$I_1 = M_1 + N_1\,j$$

As line drop is stated as the arithmetical difference in value of the line voltages it will be (when only the fundamental is considered)

$$\sqrt{3}\sqrt{A_1^2 + B_1^2} - \sqrt{3}\sqrt{A_0^2 + B_0^2}$$

The power transmitted will be $3(A_1M_1 + B_1N_1)$ watts, and that received $3(A_0M_0 + B_0N_0)$ from which the efficiency is at once found in per cent. $100\,\dfrac{A_0M_0 + B_0N_0}{A_1M_1 + B_1N_1}$

The power factor at $A$ will be

$$(A_1M_1 + B_1N_1) \div \sqrt{A_1^2 + B_1^2}\sqrt{M_1^2 + N_1^2}$$

Again suppose the data given relate to the point $O$ supplying power to the other end $B$ of the line under given conditions represented by the same diagram as before. Then as every point on a continuous line may be considered as receiving power on one side and giving it out on the other, the point $O$ may be so considered and the conditions at $B$ found by inserting $s = -1$ in the formula. This will have the effect of changing from + to — the sign of each even numbered (odd powered) term in both the series given.

Therefore when the vectors $E_0$ and $I_0$ are given for the point $O$, $E_2$ and $I_2$ for the other end $B$ of the line of the same length as before will be given by

$$E_2 = E_0 - zI_0 + \frac{1}{2}\,zyE_0 - \frac{1}{6}\,z^2yI_0 +$$

$$I_2 = I_0 - yE_0 + \frac{1}{2}\,yzI_0 - \frac{1}{6}\,y^2zE_0 +$$

These may be dealt with similarly.

# THE DETERMINATION OF LATITUDE.

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In this article it is proposed to give a brief account of the principal methods of determining latitude which are adapted to the use of the surveyor's transit or the sextant, with a brief reference to the precise methods used in connection with a geodetic survey, or in the astronomical observatory.

The term *latitude* used in this connection applies to the astronomical latitude, which may be defined as the angle which the direction of the plumb line, or normal to the earth's surface, at the point of observation, makes with the plane of the equator. This line in general does not pass through the centre of the earth, the form of the earth being approximately spheroidal; and the angle which the line joining the point of observation to the earth's centre makes with the plane of the equator is termed the geocentric latitude. The latter cannot be found by observation, but its value can be computed in terms of the astronomical latitude, for a spheroid of given dimensions.

In Figure 1 $PEP^1Q$ is a meridian section of the earth; $P$ and $P^1$ the north and south poles, respectively; $EQ$ the inter-

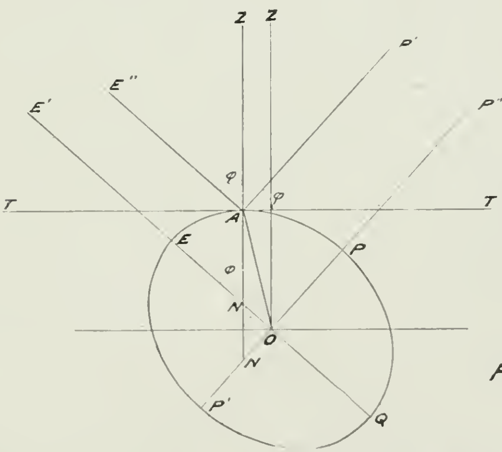


FIG 1

section of the planes of the meridian and the equator; $A$ any point; $AT$ the tangent, $AN$ the normal, and $AO$ the radius at $A$. $AZ$ is the production of $AN$ upwards, determining the point $Z$ the observer's zenith. $AN^1E$ is then the astronomical latitude, and $AOE$ the geocentric.

The maximum value of the angle $OAN$ (the reduction of the latitude) is about 11′ 40″, occurring in latitude 45° 06′ 08″, about; and in latitude 45° the length $ON$ or $ON^1$ is about nineteen miles.

If now $AP''$ be drawn parallel to $OP''$ and $AE^1$ to $OE$, then the angle $ZAE^1$ is equal to the observer's latitude (astronomical), and it is evident also that this angle is equal to $P''AT^1$.

Fig. 2 is a projection of the celestial sphere on the plane of the meridian. It appears to the writer to be more convenient to consider this sphere as infinite, than as finite in extent: we may then assume the parallel lines $AP''$ and $OP''$ to intersect its surface in coincident points at $P$: $AZ$ and $OZ$ in the point $Z$: and $AE^1$ and $OE^1$ in $E$. The latitude of $A$, from what has been shown above, is then equal to the declination of the zenith $EZ$, or altitude of the elevated pole $PN$: so that the determination of latitude is reduced to the determination of one or the other of these arcs.

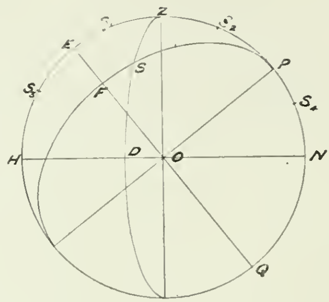

Fig 2

Proceeding now to a discussion of the more usual methods of finding the latitude by observation we shall first describe the various methods depending upon observed altitudes or zenith distances of stars (using the term star to mean any heavenly body), taking first the method.

(1) By meridian altitudes or zenith distances.

It is assumed that the observer is provided with either a transit or a sextant, and knows how to use his instrument, so that we shall confine ourselves to a description of the mode of reduction of the observations only in each case.

If now the star be observed in either of the positions $S_1$, $S_2$, $S_3$ or $S_4$, and we denote by

$\delta$ the star's declination,
$\zeta$ its zenith distance, and
$\phi$ the latitude of the place

then evidently we have for the four positions, respectively

$$\phi = \delta + \zeta \qquad (1)$$
$$\phi = \delta - \zeta \qquad (2)$$
$$\phi = \zeta - \delta \qquad (3)$$
$$\phi = 180^\circ - \delta - \zeta \qquad (4)$$

If a south declination be regarded as negative, then equation (3) is included in (1).

Again, if we denote by

$p$ the star's polar distances, and
$h$ its altitude

then for the positions $S_2$ and $S_1$ we may write, respectively

$$\phi = h - p \qquad (5)$$
$$\phi = h + p \qquad (6)$$

The star's declination is interpolated from the Nautical Almanac for the instant of observation.

Again, for two stars in the positions $S_1$ and $S_2$ we may write

$$\phi = \delta + \zeta$$
$$\phi = \delta^1 - \zeta^1$$

when by taking the mean we have

$$\phi = \frac{\delta + \delta^1}{2} + \frac{\zeta - \zeta^1}{2} \qquad (7)$$

so that it is only necessary to know the difference of the zenith distances of the two stars, not their absolute values. This quantity may be observed as follows with a surveyor's transit: The vertical axis of the instrument having been carefully plumbed, point to one of the stars $S_1$ or $S_2$ when on the meridian and read the vertical circle; then turn in azimuth through 180° and point to the other star when at the instant of transit and read again. The difference of the two vertical circle readings is the required difference of zenith distance.

For this observation the alidade of the vertical circle should be provided with an accurate level to indicate any change of inclination of that part of the instrument.

The method just described is the same in principle as Talcott's method of finding the latitude, the instrument specially designed for the purpose being the zenith telescope. This instrument is essentially an alt-azimuth in which the circles play a subordinate part, being used only for finding; while the important parts of the instrument are the filar micrometer placed in the focus of the telescope, and the sensitive latitude level attached to the alidade. In order that the micrometer may be used to measure the difference of zenith distance of the stars of a pair, they must be so selected that their zenith distances differ by less than the angular field of view of the telescope. In observing, the telescope is set at the mean zenith distance of the two stars, which are then bisected in turn by the micrometer thread of the telescope as they cross the meridian, the instrument being turned through 180° in azimuth between the observations. The difference of the micrometer readings, multiplied by the angular value of a turn of the screw, and corrected for change of inclination as indicated by the level, and for differential refraction, gives the required difference of zenith distance of the two stars. This quantity added to the mean of the declinations gives the latitude, as shown by equation (7).

The advantages of the zenith telescope as compared with the alt-azimuth in taking the above observation are apparent after a moment's consideration. In the first place, other things being equal, the precision of the former instrument should exceed that of the latter in the ratio of the focal length of the telescope of the former to the radius of the vertical circle of the latter instrument. In addition to this, however, there are the errors of a graduated circle, when its diameter exceeds twelve or fifteen inches, due to flexure, varying temperature, etc., as well as those of the graduations themselves, which completely nullify the advantage that would otherwise be gained by increasing its diameter, and thus place still more to the credit of the zenith telescope. The errors and irregularities of a micrometer screw, on the other hand, can be readily investigated.

These advantages, together with the extreme portability of the zenith telescope, render Talcott's method the most useful one known for determining latitude in the field in connection with a geodetic survey.

(2) By an altitude out of the meridian, the time of observation being known.

This method involves a solution of the astronomical triangle $ZPS$ (Fig. 2), the data being:

$$ZS = 90° - h$$
$$PS = 90° - \delta$$
$$ZPS = t \text{ (the hour angle of the star)}$$

and the required part is

$$ZP = 90° - \phi$$

If the body observed is the sun, then $t$ is the apparent time; if a star, then

$$t = a - \Theta \text{ (if east of the meridian)}$$

or $$t = \Theta - a \text{ (if west of the meridian)}$$

In these equations $\Theta$ is the sidereal time of observation, and $a$ the star's right ascension.

The fundamental relation connecting the given and the required quantities is

$$\sin h = \sin \phi \sin \delta + \cos \phi \cos \delta \cos t \qquad (8)$$

which is adapted for use by the introduction of the auxiliary $\theta$ as follows: Writing the equation

$$\sin h = \sin \delta (\sin \phi + \cos \phi \cot \delta \cos t)$$

then assuming

$$\cot \theta = \cot \delta \cos t$$

and substituting, we have

$$\sin h = \sin \delta (\sin \phi + \cos \phi \cot \theta)$$
$$= \frac{\sin \delta \cos (\phi - \theta)}{\sin \theta}$$

whence

$$\cos (\phi - \theta) = \frac{\sin h \sin \theta}{\sin \delta} \qquad (9)$$

$\theta$ being given by the relation

$$\tan \theta = \frac{\tan \delta}{\cos t} \qquad (10)$$

Equations (9) and (10) determine $\phi$.

It is important in using any method to determine under what conditions errors in the data have the least effect upon the quantity computed from them. To investigate this we differentiate (8) and by obvious substitutions obtain

$$d \phi = - \cos C \sec A. d \delta + \sec A. d h + \cos \phi \tan A. d t \qquad (11)$$

in which $C$ is the parallactic angle $ZSP$, and $A$ the azimuth $PZS$. Regarding the errors as differentials this gives the effect of errors in the data upon the resulting latitude. It also shows that in order that the effects of these errors should be as small as possible $A$ must be small and $C$ large: though with small instruments this last condition is not important, as the error in $\delta$ will then be extremely small compared with the errors of the observed quantities. All these conditions are fulfilled, however, in the case of a close circumpolar star observed at or near elongation. This suggests:

(3) The method by an altitude of the pole star.

This method only differs from that last described in the mode of reduction. On account of its small polar distance, the altitude of the star can never differ much from the latitude of the place; the method therefore consists in computing a correction to apply to the former quantity to give the latter. An expression for this correction is derived as follows:

In eq. (8), writing

$$\phi = h + x$$
$$\delta = 90° - p$$

it becomes

$$\sin h = \sin (h + x) \cos p + \cos (h + x) \sin p \cos t$$

Then expanding the sine and cosine of $h + x$, and then the sines and cosines of $x$ and $p$ and retaining only the first and second powers of these quantities, we have

$$\sin h = (\sin h - \frac{x^2}{2} \sin h + x \cos \mathrm{h}) \; (1 - \frac{p^2}{2})$$
$$+ (\cos h - \frac{x^2}{2} \cos h - x \sin h) \; p \cos t.$$

Then multiplying out and re-arranging, we have

$$x = - p \cos t + \tfrac{1}{2} (p^2 + x^2 + 2\, p\, x \cos t) \tan h$$

Then assuming as a first approximation

$$x = - p \cos t$$

and substituting in the second term, we get

$$x = - p \cos t + \tfrac{1}{2} p^2 \sin^2 t \tan h$$

Therefore we have finally, $p$ being in seconds of arc

$$\phi = h - p \cos t + \tfrac{1}{2} p^2 \sin 1'' \sin^2 t \tan h \qquad (12)$$

The omitted terms in this expression will never exceed 0."5.

An example is here given to illustrate the use of this expression.

The following observations were taken by the writer on June 14th, 1904, with a 3-in. transit reading to 1′:

| Circle. | V. C. R. | Watch. |
|---|---|---|
| *R.* | 45° 44′ | 14 h. 50 m. 04 s. |
| *L.* | 45 43 | 53 46 |
| *R.* | 45 45 | 57 10 |
| *L.* | 45 44 | 59 44 |

The watch was regulated to sidereal time and its correction was — 20$^s$.

Taking the mean of the first two observations the reduction is as follows:

| | |
|---|---|
| Mean of altitudes | $= 45° \; 43' \; 30''$ |
| Refraction | $= \qquad\qquad 57$ |
| $h$ | $= 45 \quad 42 \quad 33$ |
| Mean of observed times | $= 14^h \; 51^m \; 55^s$ |
| Correction | $= \qquad\quad -20$ |
| Sid. time | $= 14 \quad 51 \quad 35$ |
| Star's r. a. | $= \;\; 1 \quad 24 \quad 26$ |
| $t$ | $= 13 \quad 27 \quad 09$ |
| | $= 201° \; 47' \; 15''$ |

$$\delta = 88° \; 47' \; 27''$$
$$\therefore \; p = 4353''$$

| | |
|---|---|
| log p | $= 3.638789$ |
| " cos $t$ | $= 9.967813\,n$ |
| " $-$ 4042 | $= 3.606602\,n$ |
| " ´0.5 | $= 1.698970$ |
| " $p^2$ | $= 7.277578$ |
| " sin $1''$ | $= \bar{6}.685575$ |
| " sin $^2t$ | $= 9.139134$ |
| " tan $h$ | $= 10.010752$ |
| " 6.49 | $= 0.812009$ |

| | |
|---|---|
| $h$ | $= 45° \; 42' \; 33''$ |
| 1st correction | $= \;\; 1 \quad 07 \quad 22$ |
| 2nd correction | $= \qquad\qquad 6$ |
| $\phi$ | $= 46 \quad 50 \quad 01$ |

The mean of the last two observations having been reduced in the same manner, the result is

$$46° \; 50' \; 14''$$

and the mean of these two results:

$$\phi = 46° \; 50' \; 08''$$

The seconds are of course uncertain.

We shall proceed next to a description of one of the most useful methods, when small instruments are used, viz:

(4) By circum-meridian altitudes.

This term is applied to altitudes of a star when near the meridian. If a number of altitudes are observed, beginning when the star is east of the meridian and continuing until it has reached about the same hour angle west of the meridian, the method of reduction is to compute a correction to apply to each altitude to give a value of the meridian altitude. The mean of all the values so found is then taken and the latitude deduced therefrom by one of the equations (1), (2) or (3).

To derive an expression for this reduction we again return to equation (8), writing it in the form

$$\sin h = \sin\phi \sin\delta + \cos\phi \cos\delta\, (1 - 2\sin^2 \tfrac{1}{2} t)$$

which becomes

$$\sin h = \cos(\phi - \delta) - \cos\phi \cos\delta .\ 2\sin^2 \tfrac{1}{2} t$$

Then denoting by $\zeta_o$ the meridian zenith distance we have by (1)

$$\phi - \delta = \zeta_o = 90° - h_o$$

$$\therefore\ \sin h_o - \sin h = \cos\phi \cos\delta .\ 2\sin^2 \tfrac{1}{2} t$$

Then substituting

$$h = h_o - x$$

in which $x$ is the required correction to $h$, we have

$$\sin h = \sin(h_o - x)$$

$$= \sin h_o \left(1 - \frac{x^2}{2}\right) - x \cos h_o$$

$$= \sin h_o - x \cos h_o - \frac{x^2}{2} \sin h_o$$

$$\therefore\ \sin h_o - \sin h = x \cos h_o + \frac{x^2}{2} \sin h_o$$

and $\therefore$

$$x + \frac{x^2}{2} \tan h_o = \frac{\cos\phi \cos\delta}{\cos h_o}\, 2\sin^2 \tfrac{1}{2} t$$

Then omitting the term containing $x^2$ for a first approximation and substituting the value of $x$ thus obtained in the omitted term, we obtain

$$x = \frac{\cos\phi \cos\delta}{\cos h_o}\ 2\sin^2 \tfrac{1}{2} t - \left(\frac{\cos\phi \cos\delta}{\cos h_o}\right)^2 \tan h_o\, 2\sin^4 \tfrac{1}{2} t$$

$\therefore$ in seconds of arc

$$h_o - h = \frac{\cos\phi \cos\delta}{\cos h_o} \cdot \frac{2\sin^2 \frac{1}{2} t}{\sin 1''} - \left(\frac{\cos\phi \cos\delta}{\cos h_o}\right)^2 \tan h_o \frac{2\sin^4 \frac{1}{2} t}{\sin 1''} \quad (13)$$

A sufficiently close value of $\phi$ for use in the right-hand member may be found by taking the greatest observed altitude and treating it as the meridian altitude, thus finding $h_o$ and therefrom an approximate value of $\phi$. Tables may be found in most works on practical astronomy that give the values of the terms

$$\frac{2\sin^2 \frac{1}{2} t}{\sin 1''} \ \&\ \frac{2\sin^4 \frac{1}{2} t}{\sin 1''}$$

for argument $t$. The second of these quantities amounts to 1″

for $t = 18^m$, and to $7.''5$ for $t = 30^m$, so that with small instruments this term is seldom required.

Example.—The following observations were taken by the writer with a sextant and artificial horizon on September 2nd, 1893, at a place in approximate longitude $7^h$ $50^m$ W.:

| 2 alt. ☉ | Watch. |
|---|---|
| 89° 59′ 15″ | $12^h$ $32^m$ $36^s$ |
| 90 00 15 | 35 37 |
| 90 00 45 | 38 28 |
| 89 59 15 | 42 57 |
| 89 58 30 | 44 46 |
| 89 57 30 | 46 11 |
| 89 55 15 | 48 13 |

Index error = 0″

Watch correction = — $39^m$ $08^s$

An approximate value of the latitude is found from the maximum observed altitude as follows:

| | | |
|---|---|---|
| Max. 2-alt. | = | 90° 00′ 45″ |
| Eccentric error | = | + 2 00 |
| | 2) | 90 02 45 |
| Observed altitude | = | 45 01 22 |
| Refraction | = | 58 |
| | | 45 00 24 |
| Semi-diam. | = | 15 54 |
| | | 45 16 18 |
| Parallax | = | 06 |
| $h_0$ | = | 45 16 24 |
| $\zeta_0$ | = | 44 43 36 |
| $\delta$ | =+ | 7 37 54 |
| $\phi$ (approx.) | = | 52 21 30 |

The computation then proceeds as follows:

| | | |
|---|---|---|
| App. time at noon | = | $12^h$ $00^m$ $00^s$ |
| Eq. of time | = | —21 |
| Mean time | = | 11 59 39 |
| Watch correction | = | 39 08 |
| Watch time of noon | = | 12 38 47 |

Subtracting this in turn from the observed watch times gives the corresponding hour angles.

$$\begin{aligned} \log \cos \phi &= 9.785843 \\ \log \cos \delta &= 9.996136 \\ \hline \log \cos h_o &= 9.847403 \\ \hline & \phantom{=} 19.781979 \\ & \phantom{=19} 9.934576 \\ \hline \end{aligned}$$

Adding to this logarithm in turn those of

$$\frac{2 \sin^2 \frac{1}{2} t}{\sin 1''}$$

corresponding to the values of $t$ found as explained above, the values of the above term being taken from a table, we obtain the logarithms of the numbers of seconds contained in the second column below. The first column contains the zenith distances of the sun found from the observed double-altitudes in the manner exemplified above.

| $\zeta$ | Corr'n | $\zeta_o$ |
|---|---|---|
| 44° 44′ 21″ | 1′ 05″ | 44° 43′ 16″ |
| 43 51 | 17 | 34 |
| 43 36 | 00 | 36 |
| 44 21 | 29 | 52 |
| 44 43 | 1 00 | 43 |
| 45 13 | 1 32 | 41 |
| 46 21 | 2 30 | 51 |
| | Mean = | 44 43 39 |
| | $\delta$ = + | 7 37 54 |
| | $\phi$ = | 52 21 33 |

This differs by only 3″ from the approximate value above found.

To use either of the last three methods a knowledge of the correction of the watch on local time is necessary; if this be un-

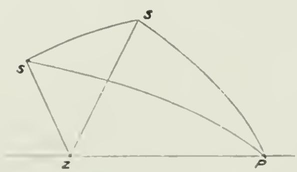


Fig 3

known, it may be determined, as well as the latitude, by the following method:

(5) By two altitudes of a star, or the altitudes of two stars, and the elapsed time between the observations.

$S$ and $S^1$ (Fig. 3) are the two positions, either of the same star or of the two stars, at the instants when they are observed. It is necessary first to find the difference of their hour angles $SPS^1$. If the same star be observed at both observations, it is the elapsed sidereal interval between the observations; but if different stars be observed, and if

$T$ and $T^1$ be the observed times, and

$a$ and $a^1$ the stars' right ascensions,

then the difference of right ascension of the stars must receive a correction equal to the elapsed sidereal interval between the observations, or

$$SPS^1 = T^1 - T - (a^1 - a)$$

Then $PS$ and $PS^1$ being known, the triangle $SPS^1$ may be solved, finding $SS^1$ and the angle $PSS^1$. The three sides of the triangle $ZSS^1$ are now known, so that it may be solved, finding the angle $ZSS^1$. Then $PSZ = ZSS^1 - PSS^1$. In the triangle $PZS$ the two sides $PS$ and $ZS$ and their included angle are now known, so that it may be solved, finding $PZ$ the required co-latitude. Completing the solution of the triangle $ZPS$ we have in addition the hour angle $ZPS$ and the azimuth $PZS$; so that this observation may be used to find the watch correction, and also to establish the direction of the meridian line if a transit be used.

This problem also admits of a graphical solution upon an artificial globe. Thus if the two arcs $PS$ and $PS^1$ be drawn from any assumed point $P$ on the globe, making the angle $SPS^1$ with one another, and if two small circles be described with $S$ and $S^1$ as centres, and having angular radii equal to the zenith distances of those points found from the observations; the intersections of those circles is the position of the observer's zenith; whose angular distance from $P$ is the co-latitude. As the circles must intersect in two points, the solution is ambiguous, but in practice an observer has always a knowledge of his latitude sufficiently close to enable him to determine which of the two values applies to his position.

There is another graphical solution of this problem which may be constructed upon a terrestrial globe, and which will serve to determine the longitude as well as the latitude, if a chronometer is used in the observations whose correction on Greenwich time, or on that of some known meridian, is given. This method is briefly as follows: If the zenith distance of a star be observed at any point on the earth's surface, the position of that point must lie on the circumference of a small circle, traced on the surface of the globe, whose angular radius is the zenith distance of the star, and whose centre is the point on the earth's surface over which the star is vertical at the instant of observation. This latter point is situated at the intersection of the meridian whose longitude is equal to the Greenwich hour angle of the star, with the parallel whose latitude is equal to the star's declination. The observations thus furnish data by which the radii and the positions of the centres of two such "circles of position" may be found; the declinations being of course taken from the Nautical Almanac. The place of observation is then situated at one of the points of intersection of the two circles thus found. That there are two points of intersection shows that there are always two points on the earth's surface at which the same observations may be taken at the same instant of time. As the position of a point is best determined by two circles which intersect at right angles, the observer using this method will consequently choose two stars whose azimuths differ by 90°, as nearly as possible.

All the methods above described depend upon altitudes of heavenly bodies, which are affected by refraction, and which must be corrected therefor; some methods will now be given in which the observed quantity is not affected by refraction. The first to be considered is

(6) By transits of stars across the prime vertical.

Any star whose declination lies between the limits 0° and $\phi$ will cross the prime vertical twice in its diurnal course. In Fig. 4, $S$ and $S^1$ are the two positions of a star when on the

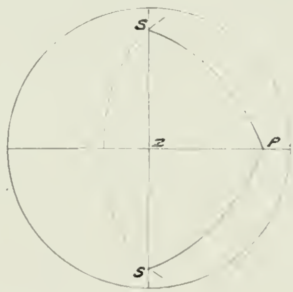


Fig. 4

prime vertical. If now the sidereal times of transit of a star be observed by means of a transit instrument adjusted in the prime vertical, the elapsed interval of time between the transits gives the angle $SPS^1$, and from the equality of the two triangles $ZPS$ and $ZPS^1$ it follows that half the observed interval of time between the transits is equal to $ZPS$, the hour angle of the star when on the prime vertical. The azimuth of the star being 90° we have at once the relation

$$\tan \phi = \frac{\tan \delta}{\cos t} \qquad (14)$$

which gives the latitude.

The altitude and hour angle of a star when on the prime vertical, the latitude being known approximately, are given by the equations

$$\sin h = \frac{\sin \delta}{\sin \phi} \qquad \cos t = \frac{\tan \delta}{\tan \phi} \qquad (15)$$

and the sidereal time of transit then follows from the relation

$$\Theta = \alpha + t$$

These quantities are necessary in preparing for an observation.

This method is not much used with small instruments, but with the portable astronomical transit instrument it is one of the most accurate methods known for determining latitude. It was at one time much used for field observations, but has been superseded by Talcott's method. With the more precise instrument a considerable departure is made, in the reduction of the observations, from the simplicity of the method by equation (14), account being taken of the small deviation of the instrument in azimuth, the inclination of the rotation axis, and the collimation constant; and in some of the modifications of the method the azimuth and collimation constants are determined by the observations themselves, so that their effect upon the resulting latitude is entirely eliminated.

Another method which has recently been developed, and should prove a useful one, is

(7) By observations of stars at elongation.

When at elongation the parallactic angle of a star is a right angle, and the following relation exists between the azimuth and declination of the star and the latitude of the place.

$$\sin A = \frac{\cos \delta}{\cos \phi}$$

If now there are two stars that are at elongation within a few minutes of each other, one east and the other west of the meridian, then we have the two equations:

$$\sin A_1 = \frac{\cos \delta_1}{\cos \phi} \qquad \sin A_2 = \frac{\cos \delta_2}{\cos \phi} \tag{16}$$

whence

$$\frac{\sin A_1}{\sin A_2} = \frac{\cos \delta_1}{\cos \delta_2}$$

from which by composition and division we have

$$\frac{\sin A_1 + \sin A_2}{\sin A_1 - \sin A_2} = \frac{\cos \delta_1 + \cos \delta_2}{\cos \delta_1 - \cos \delta_2}$$

From this we find

$$\tan \tfrac{1}{2} (A_1 + A_2) =$$
$$- \cot \tfrac{1}{2} (\delta_1 + \delta_2) \cot \tfrac{1}{2} (\delta_1 - \delta_2) \tan \tfrac{1}{2} (A_1 - A_2)$$

or $\tan \tfrac{1}{2} (A_1 - A_2) =$

$$- \tan \tfrac{1}{2} (A_1 + A_2) \tan \tfrac{1}{2} (\delta_1 + \delta_2) \tan \tfrac{1}{2} (\delta_1 - \delta_2) \tag{17}$$

Now the sum of the azimuths of the two stars may be observed by pointing the telescope of a transit to the stars in turn, when at elongation, and reading the horizontal circle at each pointing; the difference of the readings is the sum of the azimuths. On finding the difference of the azimuths by equation (17), the sum and difference then give the separate azimuths. The latitude then follows from either of the equations:

$$\cos \phi = \frac{\cos \delta_1}{\sin A_1} = \frac{\cos \delta_2}{\sin A_2} \qquad (18)$$

It can be shown theoretically that the best stars for observation are those whose declinations exceed the latitude as little as possible, and therefore whose azimuths are large and zenith distances small when at elongation. There is a practical limit, however, beyond which this principle cannot be carried; as at small zenith distances the effect of inclination of axis or collimation error becomes very marked. The former varies as the cotang., and the latter as the cosec., of the zenith distance, and therefore the errors in these adjustments will be multiplied by those ratios, so that the total effect of instrumental errors may be very noticeable. This effect, however, may be largely eliminated by observing a second pair, or each alternate pair, of stars, with the instrument reversed.

The above method was due to Prof. J. S. Corti, of the National Engineering School, San Juan (Arg. Rep.)

A few years ago the writer adapted this method to the observation of any number of stars on a given night, observing east and west stars in any order, but preserving an approximate equality in their numbers. Each star observed furnishes an equation of the form

$$d\,\phi \tan \phi^1 \mp c \tan \delta \pm d\,R_o \cot A^1 + \frac{1}{\sin 1''}\left(\frac{\cot \delta}{\sin A^1 \cos \phi^1} - 1\right) = O \qquad (19)$$

in which

$\phi^1$ denotes an assumed approximate value of the latitude,

$d\phi$ a correction to this value, to be determined,

$c$ the collimation constant of the instrument

$d\,R_0$ a correction to $R_0{}^1$, the assumed meridian horizontal circle reading

$A^1$ an approximate azimuth of the star, given by the equation

$$A^1 = (R^1 + b \tan h) - R_0{}^1$$

where

$R^1$ is the horizontal circle reading on pointing to the star, and

$b$ the inclination of the horizontal axis.

Upper signs are to be used for an eastern elongation, and lower signs for a western.

The unknowns in the above equation are $d\phi$ $c$ and $d\,R_0$. An equation is formed for each star observed—the number of stars being at least three—and the resulting equations are solved by least squares. As the collimation constant is determined by the reduction its effect is eliminated from the result.

An account of this method by the writer is given in No. 16 of the transactions of the Engineering Society.

The above methods for determining latitude are the best available when the most precise results are desired. There are, however, some approximate methods which are sometimes useful to the explorer: as, for instance, that by observing the azimuth of a heavenly body with a compass, when rising or setting; or by observing the rate of change of zenith distance of a heavenly body when near the prime vertical. This last method deserves perhaps more than a passing notice, on account of the ease with which it can be applied. By differentiating equation (8) we have

$$\cos h \frac{d\,h}{d\,t} = -\cos\phi \cos\delta \sin t$$

or

$$\frac{d\,\zeta}{d\,t} = \frac{\cos\phi \cos\delta \sin t}{\cos h}$$

But

$$\frac{\sin t}{\cos h} = \frac{\sin A}{\cos\delta}$$

$$\therefore \quad \frac{d\,\zeta}{d\,t} = \cos\phi \sin A$$

or

$$\cos\phi = \frac{d\,\zeta}{d\,t} \operatorname{cosec} A \qquad (20)$$

the required expression for the latitude.

This formula can best be applied by noting the interval of time that the sun requires to change its zenith distance by an amount equal to its angular diameter, by observing its transit across the horizontal thread of a transit, which is firmly clamped in altitude. The observation may also be taken with a sextant, by noting the times of contact of the two images of the sun, keeping the index firmly clamped during the observation. The sun's angular semi-diameter is given by the Nautical Almanac, which is half the change of zenith distance.

The advantage of the method lies in the fact that the declination of the sun does not enter into the problem; and this statement also applies to refraction, as the altitude is the same at both contacts. If the observation is made near the prime vertical the azimuth need only be known approximately.

To show, however, that caution must be observed in using these approximate methods, we shall determine the effect of a small error in the observed interval $dt$. Differentiating equation (20) we find

$$d\phi = \frac{d\,(dt)}{dt \tan\phi \sin 1''} \qquad (21)$$

which shows in the first place that the error diminishes as the latitude increases, assuming that large and small values of $dt$ can be observed with equal precision. Then applying the expression to an example by taking

$$d\,(dt) = 1^s \quad dt = 217.^s6 \quad \phi = 43^\circ\ 40'$$

we find $d\phi = 16'\ 33''$

which is the error in the latitude resulting from an error of $1^s$ in the observed time interval. It is clear then that it is only by taking the mean of the results of a large number of observations that we can hope to obtain even an approximation to the truth.

## DISCUSSION—THE YOUNG CIVIL ENGINEER

### DISCUSSION BY HENRY W. HODGE

At Mr. Stern's request I join in the discussion of his article on "The Young Civil Engineer," though I do not think that I can add anything of value to his able advice to the technical graduate.

The technically educated engineer is rapidly advancing the profession of civil engineering, and we are no longer looked upon as high grade mechanics, as we were but a short time ago, but the public recognize the modern civil engineer not only as a man of high scientific training, but also as a public benefactor, as his achievements have made him a leader in advancing the development of the earth's natural resources and bringing the benefits of modern civilization within the reach of all. It should, therefore, be the aim of all young engineers to keep advancing this standing of the profession, and this can only be done by men of well rounded education and general knowledge; men who can favorably impress other men, and who can "shine" not only among their own professional associates who know their technical ability, but also among men of other walks of life who must be impressed with their ability before they will entrust great enterprises to their direction.

Therefore, I would advise every young engineer to try to add to his general knowledge, either by a classical course in college or by reading and travel, so that he will have a general knowledge of matters outside the world of science, in which we are apt to become uninteresting "experts."

While Mr. Stern's advice to change early positions occasionally so as to gather varied experience is good, I have found the young engineer rather inclined to change too often, as he finds the doing of the same thing for a length of time monotonous, and gets tired and desires a change, so that he is liable to lose that absolute confidence which comes only by doing a thing until it becomes second nature, so my advice is to learn to do at least one thing thoroughly, and if you can properly apply this special ability, you are bound to succeed. There are many brilliant engineers who are unknown because they have not the ability to impress their knowledge on men who require engineering services. You must not only be confident of your own ability to carry out great engineering undertakings, but you must be able to make the "captains of industry" and the "Napoleons of

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Henry W. Hodge, Consulting Engineer, New York City. Mr. Hodge is a graduate of Rensaeller and a member of the firm of Boller & Hodge, who are the leading bridge engineers in professional practice in the United States. They have just been recently retained as engineers for the new bridge to built over the Mississippi River at St. Louis. They were also the engineers for the Singer Tower, New York City.

finance" share your confidence, and to do this you must make clear and concise statements of engineering matters, and yet free from details and technicalities which only confuse the man of affairs, you must be able to write a short letter that clearly defines the subject matter, and you must at all times be sure that your employer is confident that you know what you are about and can rid himself of all responsibility in the assurance that he has a fully competent engineer with good technical training. With a broad general knowledge of men of the world, and a personality which impresses men with your ability, you are bound to succeed, as never was the engineering field so large or the demand for engineers who have the knowledge and the daring to attempt large enterprises so great.

DISCUSSION BY ROBERT BREWSTER STANTON.

Mr. Eugene W. Stern has requested me to discuss his paper "The Young Civil Engineer," published in the January number of "Applied Science." Mr. Stern's paper covers the field so well as to character, duties and work of a young civil engineer which should tend to make him a success in his chosen profession, that I have but one remark to make upon the paper as it is.

The qualifications required to start with, given by Mr. Stern as "endurance of mind and body, adaptability, thoroughness, efficiency, intensity and imagination for possibilities," and all the other good qualities enumerated, are magnificent traits of character, but they are not necessarily peculiar to the make up of an engineer. They are all good and serviceable, but just as applicable to any other profession, trade or occupation. The real—and hence successful—engineering requires something else to start with.

One of my assistants in the building of the Cincinnati Southern Railway, after spending several years on that work in the Cumberland Mountains of East Tennessee, gave the qualifications of a young engineer thus:—"He must be composed of one-third mule, one-third dog and one-third angel; the mule to be able to stand the labor, the dog to stand the kicks, and the angel to enable him to carry through his work in a cheerful manner." These qualities were peculiarly requisite during the earlier railroad construction in the Rocky Mountain region and beyond, where he later went. But my friend left out the one pre-requisite—a quality which he himself did not possess. He had nearly all—if not every one—of the qualities enumerated by Mr. Stern, and a technical education far superior to most suc-

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Robert B. Stanton, New York City. Mr. Stanton is a consulting and mining engineer with an international reputation. In 1889 he made a survey through the Grand Canyon of Colorado—a very daring undertaking. He has also explored in Sumatra and Java. He is a graduate of Miami University.

cessful engineers, and yet he soon quit engineering and went to farming.

This pre-requisite necessity of which I am speaking is very hard to define accurately. To begin with, the engineer—like the poet—is born, not made, and in that borning he is given a quality which I may call the engineering instinct, which can be acquired in no other way. We all recognize the fact that there is an indescribable quality, trait or something that goes to make the poet, the artist, which all the good qualities of body, mind or soul, and all the education in the world cannot produce, though they may train and improve it. Is it not so—and even to a greater degree—with the profession of engineering—whether civil, mining, mechanical, electrical or what not?

If this is so, then the first thing for a young engineer—or more properly speaking, a young man who hopes some day to become an engineer—is to find out whether he possess that inborn instinct. How, with his want of experience, is he to satisfy himself of this fact? That is not an easy question to answer, but the evidence of the fact begins with a love, a real all pervading love, of doing things for the very sake of the things accomplished; that is, a love of accomplishing such things as are included in the noted definition by Telford of the profession of civil engineering, found in the first charter of the Institution of Civil Engineers. The love will become stronger and stronger, and when it is founded on that true, inborn instinct, one can no more help being an engineer than he can help breathing and continue to exist. I spent many years with Mr. Jacob Blickensderfer, that famous railway engineer of the west, in locating and building some of the early Rocky Mountain and Pacific railways, and I said to him one day while he was Chief Engineer of the Union Pacific and nearly 70 years old, "Mr. Blickenderfer, why don't you quit such trying work and rest?" He replied, "I know it is a dog's life, but I can't quit. I love it."

This natural born love of an engineer's work should not be confused with ordinary "bent of mind;" I think it is something more. Robert Burns had a bent of mind for several things other than poetry, but it was his poet's nature and poet's love that compelled him to write those sweet songs that have touched the hearts of men and women all over the world.

The young man, then, the prospective engineer, having discovered that he posseses that inborn instinct, what is his next step? Educate it, cultivate it, in every way possible—in college, in the university, in the professional school. Is a thorough technical training in advance absolutely necessary for the success of every engineer? James B. Eads was a most noted and successful engineer—he was truly born one—yet he lacked in his preparation for his work that thorough technical training such as is now given in our great engineering schools, in fact, he never went to any school after he was thirteen. If any young man has the time and means at his disposal he should go to the very limit in his education—the technical education of an engineer—that is, acquire the most perfect tools with which to execute his future work. If, however, this cannot be done, there is still a place, and a successful career, for a young man with a good, ordinary high school or college education even in the profession of engineering. The necessary technical knowledge can be acquired as he goes on with his work—in his room at night, or around the camp fire in the wilderness. It has been done many, many times, and can be done again, that is, provided he has been educated and trained in his preparatory studies or around the fireside at home, to think clearly, reason correctly, and has the ability to put two and two together when he sees them separately in the many conditions of nature. This may seem a trite remark, but is not the fact that a large proportion of "young engineers" coming from the great technical engineering schools have their brains full of the details of technical knowledge, abstruse deductions and mathematical formulae—usually only committed to memory—and with only a minimum amount of ability to think clearly and reason logically; and the saddest absence of the power to put together the various "twos" found in nature which at first sight seem to be separate and distinct phenomena, and yet which are in truth intimately connected, and when in many cases their union, if recognized, would be found to be the direct cause of the effect so easily and clearly visible to anyone? And again, is not the lack of this ability, as above stated, the cause of the failure of so many young men who start into the profession, to become even "young engineers"? This has been my experience with the majority of young men who have been associated with me in engineering work.

A more extended discussion of this phase of the subject will be found in Vol. 53, page 307, Trans. Am. Soc. C. E., in the writer's discussion of a paper on "Lateral Earth Pressures."

In conclusion, then, the greatest necessity for the young engineer is, in my opinion to acquire the habit of logical analysis, and systematic combinaton, of the phenomena of nature, and in doing this, of course, to exercise every one of the manly qualities so well set out in Mr. Stern's paper.

## DISCUSSION BY OTTO M. EIDLITZ

I have read Mr. Stern's article, "The Young Civil Engineer," and think that he has covered the subject thoroughly. From actual experience in the conduct of my own business there are a few points that might be amplified, although he clearly indicates them in his paper. Many a graduate of a technical school

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Otto M. Eidlitz, New York City. Mr. Eidlitz is graduate of Cornell University in Civil Engineering of the class of 1881, and for many years has been at the head of the most thoroughly efficient firm of builders in that city.

is under the impression that if he has made his degree and received reasonable commendation from his instructors, the training he has imbibed at his college will be the means of immediate and permanent employment.

Although this might have been correct within limits fifteen or twenty years ago, it does not hold to-day, due to the fact that year by year the country is flooded with college graduates; so that to-day the personal equation counts as much, or more, than the work represented by the diploma.

The young engineer who enters an employment to-day must make up his mind that it is not so much his technical training which is of import, as it is his general efficiency, integrity, executive ability and above all, his desire to do as much work as a man can do.

There are few firms or corporations who will not, sooner or later, recognize the unselfish effort and devotion of the college man, provided he does not believe himself above the work allotted to him, and checks the tendency to lord it over any of his colleagues who may not have had his scholastic opportunities. When the opportunity arrives, he may reasonably expect advancement, but he must have patience to wait for it.

Many a man handicaps himself by not remaining long enough in one employment. If he is only seeking an opportunity to have his weekly salary increased, he very often sacrifices his chances for ultimate and permanent success to secure immediate pecuniary advancement. There are, of course, cases where the question of remuneration is crucial, and to that extent the individual in that condition is handicapped.

When the young engineer enters his career, whether professional or otherwise, he should be careful in the selection of his first or second employment, and then stick to it and show by his efforts that his whole aim and object in life is to give the best that is in him for the advancement of the interests of the employment with which he is associated. If he does this and has not an inflated idea of his own value, he will, within a reasonable time become of importance, and advancement will follow. He should not measure his efforts in hours, but let his employer appraise them by the results achieved. He should never forget that there are many abler men who are looking for his place and who are only prevented from securing it by the devotion and intensity of effort which the incumbent displays.

He should realize that a mistake may occur, but appreciate that most employers will condone it if it be frankly acknowledged, but that a concealment or prevarication surely spells disaster.

In short, a college training is of great value, but manhood is of vital importance and will frequently command greater respect and more immediate recognition than technical gifts.

## DISCUSSION BY LOUIS L. BROWN

I have read with a great deal of interest Mr. Eugene W. Stern's article entitled "The Young Civil Engineer," appearing in the January issue of Applied Science.

There is no question about the vast importance to any young man entering the engineering profession of getting his start right. There is a great deal of practical experience, both in the office and in the shop and field, that is absolutely necessary for an engineer to have obtained in order to have a thorough grasp of his profession. This experience can only really be obtained while he is young and willing to stand for a great deal of knocking around, and to pitch in and work in very subordinate positions. I have known young engineers working as regular laborers on construction work.

No one can successfully direct and handle others until he has learnt by practical experience how it feels to be bossed.

Mr. Stern has covered the ground he attempted to in his article admirably and I might say exhaustively. Any young engineer starting out, who reads this article, and lives up to it, will certainly be heard from if he has any natural ability at all.

## DISCUSSION BY T. H. ALISON

The writer has been requested to discuss the splendid paper "The Young Civil Engineer," by Mr. E. W. Stern. It certainly portrays necessary qualifications and their disposition in order to gain success by our young and old graduates in the engineering world. Many such characteristics are necessary to the success of an individual following any profession, but certain factors are especially required of a young civil engineer.

Advice has always been sought, sought of the more successful, but alas! it generally accomplishes little or nothing as it necessitates a perfect knowledge of the thought and conditions under which the seeker labors. Should a young man admire the personality, work and success of an older man, it is advisable that he draw out the latter in discussing his affairs and experiences. In this way many ideas are secured which may influence the younger man in determining what course he will follow. Frequently the young graduate has no particular inclination, in which case the sooner he secures any engineering position, the sooner he will find his natural bend.

Some are born bright and others acquire brightness by persistent plodding. All plod in the engineering profession, and

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L. L. Brown is a graduate of the School of Practical Science of the year 1895, and he is a thoroughly experienced civil engineer on construction, being associated with some of the most important erections of buildings in New York City.

whether or not one is naturally observant and inquisitive, it is essential that these two of many qualities be cultivated. Observation causes one to think, deduce and contrast. Whatever appears in the broad engineering world has been executed for a specific purpose. Whether it be well, reasonably or poorly rendered, it opens the channels of thought and from this one will deduce and contrast. Constant observation will stack a well stored mental library which cannot be taken away, and while books are indispensible, yet the truly cultivated, practical, observant, mind will far-out-act the book-worm and note-book faddist. It is well to remember that the minutest detail has its good purpose in a well designed article or structure. Observation is the best means towards improvement. As a leading graduate has said: "I never designed the same type of work twice without improving on the first, and when the second is finished I see how to improve again."

Inquisitiveness, the suppresser of pride, is not a failing in the young graduate. He is too prone to rely on the accrued theoretical knowledge gained at college. There is not a mechanic or laborer who cannot give practical reasons indispensable to the young graduate. Upon seeking advice of one of the leading engineers a graduate was told: "My boy, my only recommendation to you is to ask questions. Never turn your back on an open drain if there appears something of which you desire to be informed. Some of the best points I have gained have been from conversation with common laborers." Certainly the question of inquisitiveness can be carried too far, and a reasonable and common-sense degree only is advocated.

Mr. Stern's paper has outlined in a comprehensive and efficient manner the many characteristics of an ideal engineer. It is worthy of close attention, and as the graduates grow older, no doubt they will realize more forcibly the good sense therein contained.

No attempt has been made to criticise Mr. Stern's paper, but these two points appeal to the writer as being very essential.

Drive the nail "observation" home with the hammer "inquisitiveness."

## DISCUSSION BY JAS. H. KENNEDY

Having read with considerable pleasure the admirable article of Mr. E. W. Stern in the January Applied Science, it has occurred to me that Mr. Stern has passed over too hastily the real question uppermost in the mind of the student as he is about to graduate from the college and, as the editor invites a discussion of the paper, I cannot resist the temptation to write for the benefit of a few, at least, of the students of our Alma Mater a few thoughts that it is hoped may be of use to them.

If memory serves me correctly, when I was leaving school

Jas. H. Kennedy—A graduate of the School of Practical Science, '82. He is Asst. Chief Engineer of the Vancouver, Victoria & Eastern Railway & Navigation Co.

the question was not so much "What shall I do next?" as "Shall I find anything to do?" and, judging from the number of applications for employment received every spring for several years back, not only from graduates of our Alma Mater but from many other colleges, a great many others have been face to face with the same momentous question, and it will ever be so.

To the young graduate the matter of seeking his first employment is the event of his lifetime, and a little wholesome advice at this point of his career from one who has not only been through the mill and written many applications, but has been the recipient of a fair share of the letters of not only students of our Alma Mater, but of many other colleges, may be a benefit to him. It is a fact that there are but few young graduates or undergraduates who know how to write a letter to an entire stranger asking for employment and, in making this statement, it is not insinuated that Toronto students are any greater sinners in that respect than those of other colleges and schools. The matter of writing a letter making application for employment is of considerably more importance than the average student has any idea of. Many a young fellow upon learning of a probable chance of employment, dashes off a few lines carelessly as if the whole world were waiting for him to get it done, never thinking of correcting his writing or perhaps his spelling, signs it with a flourish and addresses it to an entire stranger with the hope of receiving a favorable reply. Now, I have received many such letters and it may be interesting to some of the boys to hear what becomes of their letters. Of course they are all placed on file for future reference. Strangers are seldom employed while a worthy known young man is available. This fact of itself is generally a hardship upon the worthy student leaving college, but assuming there are no available known men when the staff is to be increased, the file of applications is taken down and letters compared. My advice to a young graduate, if he feels he should make application to a stranger for employment would be to make it his very best effort, give it his very best thought, express his meaning clearly, and in a business like way without flourishes or half written words, and sign his name in a way so there will be no mistaking it. In other words write a letter that will show up to advantage among a hundred others, or do not write at all. What chance has a man who dashes off a signature that requires the aid of the whole office staff to decipher it? Many letters are received that the contents can be easily read but the signatures are incomprehensible and they are consigned to the waste paper basket. Other things being equal the man who writes carefully and with all details accurate will be considered careful in matters of detail, and will be likely to succeed while a slipshod writer will be rejected on account of the fear of slipshod work. Nor should he resort to typewriting instead of showing up his handwriting. Many make this mistake. In order to succeed it is is not only necessary for the application to be on file when a vacancy occurs, but there must be something in that letter to lead to the expectation that the writer is in some way superior to the writers of the other letters; and there must be no available known worthy man in sight for the vacancy. Consequently the chances of securing employment by written application at best are not at all encouraging; but sometimes do succeed. In this connection if a personal reference be excusable the writer has on many occasions, when temporarily out of employment, written, asking for employment, but not in a single instance was a situation ever obtained by a written application to an entire stranger. Possibly nobody succeeded in reading the signature; but on the other hand, in the last few years, of the several hundreds of applications received from other unfortunates, possibly not more than twenty were successful, which is but a small percentage of the total men employed; and that at a time when there seemed to be work for everybody.

To the graduate especially who wishes to take up railway work, if possible for him to do so, the writer's advice would be instead of writing letters and awaiting replies, to go personally to where work is in progress, and be on the ground when the vacancy occurs. Drop into the first opening that offers, whatever it may be, and thus he will form acquaintances among the men who are doing things, and in this way he will work upward. Strive to make up one job lead up to another, as it almost invariably does to the man who does his work well; and no man who does his work better than his fellow workers will wait very long for an opportunity to move upwards. If he does the fault will probably be in himself.

## DISCUSSION OF T. KENNARD THOMSON.

It is with much pleasure that I accede to the request to discuss Mr. Stern's well written paper on what a young engineer should do.

There is a very brilliant Canadian girl in New York, the sister of an old classmate of mine and a member of a very brilliant Canadian family, who now, in one of the New York dailies, answers letters from young people seeking advice. Her counsel is always good and to the point—but she says that people do not want advice, they merely want you to agree with them. So whenever possible she tells them what she thinks they want. This reminds me of a story they tell of Roosevelt (whether it is true or not I do not know) to the effect that he on one occasion asked an old lawyer friend to make a report for him. His friend said: "Why don't you ask one of your cabinet since you have a number of the brightest lawyers in the country around you?"

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T. Kennard Thomson, New York City. Mr. Thomson is a graduate of the School of Practical Science in Civil Engineering of the class of 1886. His wide experience qualifies him to make an authoritative criticism.

Roosevelt is said to have answered: "I have, but they don't agree with me on the subject."

As Mr. Stern has written on what a young man should do, I will take the liberty of writing more of my personal experience and try to give some of the advice I received as I went along and by which I tried to profit.

Before graduating in '86 I spent three summers on the Canadian Pacific Railway, starting at Medicine Hat on the South Saskatchewan River and finishing in the Selkirks. The first two seasons were spent in the bridge department under a very able engineer, Mr. W. A. Doane. Very shortly after starting, on seeing in a Toronto paper, a very inaccurately written article concerning the western country I wrote a letter to the Toronto Globe, giving my impressions and asking what they would pay for similar ones. I was delighted to get a prompt answer offering me $4 a column for all I could send them, so I sent all I could during my three summers there. About this time an old gentleman of whom I thought a great deal, said: "First, write enough to fill a book, and then boil it down to a chapter, and then if possible, condense the information to one page. In other words, cultivate brevity and simplicity. This desideratum should apply to speakers as well as to written language.

During the summer prior to graduation, I succeeded in having myself transferred from the bridge department to the field so that I obtained experience in every branch of railroad location and construction. By working every night I was able to fill two good sized note books with the designs of all the wooden bridges used on that section of the C. P. R. These notes were used as vacation work at college and have since been instrumental in securing or helping to secure several jobs in addition to netting me $75 from a periodical which published a few of them. During the first two summers my pay was $50 a month and expenses. This was raised to $75 per month and expenses for the third summer.

On finishing my work in '85 in the Selkirks I seized the opportunity to take a trip to San Francisco and back, although it made me late in getting back to college. I started by walking the "gap," 90 miles in three days, thence by rail and steamer to that beautiful "English" city of Victoria and by boat to San Francisco. I returned by the same route. As a rule, however, whenever I had to go to the same place on different occasions an effort was made to go by different routes in order to see as much of the country as possible. This enabled me to see Detroit, Chicago, Milwaukee, St. Paul, Minneapolis and Winnipeg before graduating. I had also visited the "Sault" and sailed the Great Lakes. As I was fortunate in those days in seeing a great deal of Mr. James Ross, then manager of construction, an opportunity was taken to ask him if he considered a course in a European university would be advisable after leaving the School of Practical Science. He said: "I used to work on the same road as your Principal Galbraith. He is a good engineer and a brainy man and an engineer should not need any more university training after he turns him out. On the other hand, if you can afford to travel in Europe for perhaps a year, it will be very valuable." This I was unable to do.

About this time an old friend said: "Young man, when you get a position never worry your head about being 'fired,' but do your work in such a way that your employer will be afraid that you will get a better offer from some one else." It has often been said that we learn more from mistakes than from successes and this sage remark suggested to me the wisdom of trying to learn from the other man's mistakes instead of waiting for one's own. There is always an inclination to copy the big men, but while one can always gain much by studying such men, to try to "ape" or copy them will be ruin or dismal failure. For instance, our Duggan, who graduated three years before me and under whom I worked for two years after graduating, is one whom I would have copied if I had not convinced myself that every one has to work out his own individual path to success and follow it in his own way, taking advantage of every legitimate help or assistance that he meets on the road.

Anything that is not worth doing well is not worth doing at all and anything that is done well pays—even if it is only sweeping out an office or playing a game of football. Be accurate first, and then turn out as much work as possible. But, as Mr. Stern has intimated, don't make a calculation to six places of decimals when a hundred or even a thousand pounds or dollars would not affect the result. An illustration or two will show what I mean. An engineer once made a survey of several acres, taking an immense number of levels, every reading being to two places of decimals. After he had calculated the cubic contents required to fill this area to a certain height, having used the two places of decimals throughout, he estimated that as the ground was soft he had better add 12 inches to the depth to be filled. A military gentleman once paced the circumference of a circle and then calculated the diameter to six decimal points. Having known Duggan for some years as he was on the C. P. R. the second and third summers that I was west, I wrote him at the Dominion Bridge Company in the spring of '86 and, thanks to him, obtained the day after I was graduated a position in that concern at $40 a month. In six weeks or so after working as hard as possible and being convinced that my chief was satisfied with my work, I struck for $50 and got it, and about September of the same year got $60.

There is no work that a man can do that teaches accuracy quite as well as the making of drawings in a bridge company's office. Every engineer would be benefitted by such an experience. Every engineer should be able to handle surveying instruments and be able to make good plain drawings. Even now I occasionally go back to the drawing board myself and have been paid $50 or more a day by former employers for making drawings for them for special purposes. This is mentioned because many young men think that they will soon be too big to make drawings themselves and do not take the trouble to become proficient.

While I was getting $60 a month at Lachine, I was offered $100 a month and expenses as resident engineer on a Western railroad, but feeling that I knew enough about that work for the time, and not enough about bridge designing, I refused it. About fifteen months after graduating I asked for $75. This the President of the company told the Chief Engineer he would not pay, as he could get all the men he wanted for $50. He was then paying me $60. I forthwith requested a permanent leave of absence which, after considerable discussion, was withdrawn on condition of a two weeks' vacation being thrown in with the $75 a month. It might be stated here that during my last year at college I had met a Toronto girl whom I made up my mind almost at first sight to marry if I could. I took this vacation to win her consent. Being so fortunate in this respect myself, my strong belief in early marriages (24 or 25) has increased.

Two years at the Dominion Bridge Company which experience included the making of blue prints, tracings, shop drawings, show drawings, bills of material, shipping bills, etc., and the spending of much time in the shop, seemed sufficient, especially as I was in a hurry to get married. I gave up my position and came to New York on "spec," and in four days struck a job in the Pencoyd Bridge Company through calling and introducing myself to Mr. C. C. Schneider, chief engineer, who then had an office in New York and who has done much for me since. I was married that fall, and decided to settle in Philadelphia for some years. The next spring, however, we thought it would be a good scheme to attend the convention of the American Society of Civil Engineers at the Paris Exposition. Not being able to obtain leave of absence it was necessary to resign my position. A glance at the salary diagram will show that nothing was lost by this, for by a curious streak of luck my old company was hard up for men when we returned. I had tried unsuccessfully to get a job in Montreal, Toronto, Detroit and New York.

We have never regretted the four months thus spent in Europe. We again settled down "for years" but in January my first chief, Mr. Doane of the Rockies, offered the position of Bridge Engineer of the Ohio Extension of the Norfolk & Western R. R. at a salary of $150 a month. The Bridge Company, which had raised the salary every time another bridge company made me an offer—one of which came from Duggan—was only too glad to have a believer of Pencoyd secure such a position, and let me go. This position gave me experience in the design and construction of 129 bridges, requiring frequent trips to the most important bridge shops in the country. It was held for one and a half years, until an offer of $200 was obtained with a consulting engineer in New York. After about two years with him, going on the assumption that one can get almost as much for half his time as for the whole of it, I obtained the position of Chief Engineer of one of the best foundation contractors in the country with the privilege of handling all the outside work I could get. This I held for eight years, while working up a good consulting practice.

Naturally, I am grateful for the advice Dean Galbraith gave us on graduating: "Spend ten years getting as great a variety of work or experience as possible and see as much of the country as you can. It has seemed to me that it is nearly always desirable to obtain the largest salary possible on the principle that the employer is going to give the best work to the highest paid men. The most effectual way to obtain an increase in salary after one has made his value felt is to obtain a better offer from some one else. But one who threatens to leave if he does not get a raise and then stays after being refused has given himself a very black eye. Never give your employer a chance to tell you to work harder or longer. In emergencies don't count the hours. I have been 86 hours on a stretch on my feet. As a regular thing an employer is foolish to work his men more than eight hours a day, but in special cases the clock should not be considered.

If you want to get there—whenever you feel that you are losing interest in your work, get out and kick yourself before your employer gets on to you and don't get into a rut. Nothing that is easy to obtain is worth having. One of the most pitiful sights is to see a square peg in a round hole. I knew a beautiful draftsman who was absolutely wanting in the originality essential in an engineer, whose pay after a certain time kept decreasing as well as the quality of his work. He would have made a success on the stage. Another man made a failure as a clerk where he would have been a genius in another line. There was a brilliant chess player who plodded along on a drafting board where he did not belong. There are mighty few industrious, intelligent men who would not obtain great success in some line if they only had the courage to find out what it is and drop what thy are doing.

An old faithful employee, who had fallen into a rut, once went to the head of the firm with whom he had grown old, and bitterly complained that a younger man had been put over him. The employer said: "Mr. Jones see what is making that noise." Jones went to the next room and in a few minutes returned with the information that there was a big crowd in the street. "See what the crowd is doing." Jones came back and said: "They are watching a lot of cattle." "See where the cattle are going." Jones came back and reported: "South." "See how many there are." Jones came back with the approximate number. The employer then asked Jones to sit down while he rang for the young man, to whom he said: "Brown, see what that noise is about." In a few minutes Brown came back and reported: "There is a big crowd of people in the street watching 500 head of cattle which Swift & Co., have sent from Chicago to Jackson & Co. at the other end of the street." The young man retired and the employer kindly turned to his old employee and said: "You see, my friend, why the wide-awake man gets ahead."

But enough of this or your good editor will get so tired that he will throw the whole discussion into the fire. As it is, I must rely on him to blue pencil what he considers of no interest to you, or otherwise objectionable.

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## ALUMINIUM

J. A. McKENZIE WILLIAMS, '09

The present state of the metal market displays an unprecedented condition as regards aluminium.

This metal is now produced in such enormous quantities, compared with the production of a few years since, and the time of expiration of the American patents is drawing so close (Feb. 1909), that the different producers in operation at present are beginning the competitive struggle which has been so notable for its absence during the preceding years.

The range of quotations since Dec. 1907, has been from 42c to 13½c per pound, this latter figure being one of the late quotations in the British market. At the beginning of the year 1908 there was a notable decline in the British market from 33c to 22c, and a corresponding decline in the American market from 38c to 33c.

The American producers have always followed the railroad procedure of "charging all the traffic would bear," and in addition to this have been, and still are, protected by a tariff of 8c. per pound which effectively prevents imports of aluminium from foreign markets, and which keeps the quotations at least 8c higher than European prices.

In Britain and the Continent the various companies were until recently producing under license from patentees, and by establishing an "understanding" were able to prevent any disturbance of the market, and maintain high prices until about the 30th of Sept. of this year when this arrangement terminated, and the free competition began which has so speedily given us the satisfaction of seeing aluminium take rank with the old staples, copper, zinc, tin, etc.

Weight for weight, aluminium is now cheaper than zinc, and bulk for bulk, cheaper than copper at a market of, say, 25c.

It is probable that careful calculation will show the cost of production in America to be about 15c, and in Europe about 17½c on the average, and the present quotation of 13½c cannot be expected to last long. However, the fact remains that aluminium has become one of the staple metals at last, and that from the present division of the price by about two, an enormously stimulated consumption may be expected. In anticipation of this, the present producers in America, Britain and elsewhere are extending their plants by doubling and trebling their present capacities.

An instance of this may be cited, the increased capacity of the various plants of the Pittsburg Reduction Co., which company was using in

| | 1906 | 1907 |
|---|---|---|
| At Niagara, N.Y. | 12,000 | 40,000 |
| Massena, N.Y. | 12,000 | 20,000 |
| Shawenegan Falls (Que.) | 5,000 | 15,000 |
| Or a total horsepower of | 29,000 | 75,000 |

This total capacity should give a total production of 36,000,000 lbs for the continent, of which Canada could produce about 10,000,000 lbs.

This same company has also doubled the capacity of its rolling mills at New Kensington, Penn., and is erecting one at Niagara Falls, which will have two-thirds of the capacity of the New Kensington mills. These New Kensington mills are, by the way, the only ones in America producing continuous sheets of aluminium.

In Europe there were only four companies in operation in 1907, but it is probable that there have been many additions during 1908. The total estimated capacities of these four companies in 1908, in terms of horsepower used, is

| | |
|---|---|
| British | 75,000 |
| French | 27,500 |
| German | 75,000 |

having a total of 177,500 H.P., and since 4 H.P. years produce 2,290 lbs. they have a possible production of about 101,400,000 lbs., working at full load.

A comparison of the production at various periods is also very interesting, and to avoid too many figures, production is given for periods about three years apart.

U. S. A. PRODUCTION

| | Lbs. | Value | Per lb. |
|---|---|---|---|
| 1897 | 4,000,000 | $ 1,400,000 | 35c. |
| 1900 | 7,150,000 | 2,288,000 | 32c. |
| 1904 | 7,700,000 | 2,233,000 | 29c. |
| 1907 | 26,000,000 | 10,000,000 | 42c. |

WORLD PRODUCTION.

| | Lbs. |
|---|---|
| 1897 | 6,390,000 |
| 1900 | 14,678,000 |
| 1904 | 16,246,000 |
| 1907 | 65,058,000 |

So great is the present demand that it may be confidently predicted that the output will surpass 200,000,000 lbs in 5 years, and that by the end of 1908, the production will make a significant showing in comparison with copper, taking into account the relative bulks of the two metals.

On account of the present and prospective importance of aluminium, it is interesting to review briefly the past history of the development of the metallurgy of aluminium, and to glance at some of its present uses.

After a century of struggle, investigation and invention, the problem of extraction of this widely distributed element, aluminium, from some of its compounds was finally worked out to a commercial basis. Many processes were devised and suggested, some impossible, some impracticable, and some workable, but ruled out on account of their high cost. Finally from the many, two only survive the test of commercial application, that of Charles M. Hall, of the United States, and that of Paul L. Heroult, of France, and which processes are practically identical.

The various methods of producing aluminium may be classified under one of the three following heads:—

(1) CHEMICAL METHODS.

(2) ELECTRICAL METHODS (Electrical, as distinguished from Electrolytic, i.e., methods which utilize the heating effect only, and which could be carried out by other methods provided the necessary temperature could be attained).

(3) ELECTROLYTIC METHODS:—i.e., methods making use of the chemical effects of the passage of a current of electricity. For example, a common electrolytic process is the passage of a current of electricity through a solution of, say, copper sulphate, as in refining copper. The current enters the solution by a copper electrode, called the anode, passes through the solution of copper sulphate, which is decomposed thereby and is the electrolyte or bath and then out by a second electrode of copper which is called the cathode.

(1) CHEMICAL METHODS—(Running over the principal methods rapidly).

In 1827 Wohler was successful in reducing the anhydrous chloride of aluminium by means of potassium.

In 1855 St. Claire-Deville simplified the method of Wohler by using the double chloride of aluminium and sodium — $Al_2Cl_6 4NaCl$, and using the metallic sodium which was much cheaper than the metallic potassium. This process was conducted in France for the production of aluminium for 30 years, and was finally abandoned on account of the high cost of the sodium and the aluminium chloride, and the successful production by other methods.

In 1855 Rose had proposed the use of the mineral cryolite, i.e., $Al_2F_6.6NaF$, instead of the simple chloride, but this was not followed till 1886, when Grabau, a German, devised another practical process to use the cryolite. In this interesting process, sulphate of aluminium was treated with cryolite, and the sodium fluoride of the cryolite reacted with the aluminium sulphate, and aluminium fluoride was formed. Thus the aluminium was all obtained in the form of the fluoride according to the equation:—

$$Al_2(SO_4)_3 + \underbrace{Al_2F_6.6NaF}_{\text{Cryolite.}} = 2Al_2F_6 + 3Na_2SO_4$$

The fluoride, which is insoluble in water, was separated, dried and heated to redness, and charged into a cold vessel lined with cryolite. The proper amount of sodium to exactly react with this fluoride, and in the form of a cube or cylinder, was now placed on the hot mass, and the whole immediately covered. A quiet action, but accompanied with great heat, then took place, which resulted in metallic aluminium, and the reproduction of an artificial cryolite according to the equation.

$$2Al_2F_6 + 3Na_2 = Al_2 + Al_2F_6.6NaF$$

The metal was found at the bottom of the mass, which was completely fused by the intense heat. The by-product could again be used for the production of the fresh fluoride $Al_2F_6$.

This process had the great advantage that it produced exceptionally pure aluminium, and of all chemical methods, it seems the only one which is at all likely to come into competition with electro-chemical methods, and depends essentially on a cheap sodium.

## 2. ELECTRICAL METHODS.

During the advances along purely chemical lines, experiments were also taking place in which electric current was playing a part, but it was not until the dynamo was invented in 1867 that any of these methods assumed a practical importance.

In 1862, Moncton had taken out a patent in England for a process in which he intended to pass a strong electrical current through a reduction chamber charged with alumina $Al_2O_3$ and granulated carbon, the reduction taking place by means of the carbon which was heated to the high temperature required, by the current. This at the time was not practicable on account of the cost of the current, and also because the aluminium produced absorbed so much of the carbon that the product was a grey, brittle, crumbling mass, scarcely fused, and containing carbides, carbon, and impurities present in the carbon used. Much aluminium was also carried off in the vapors, and some condensed in the upper layers of carbon.

It was not until 1884 that another electrical process, similar to above in principle, was applied, but now with greater success. This was the Cowles process, invented by the Cowles Bros. in an experimental plant at Cleveland, Ohio, and consisted essentially of passing an electric current through granulated material of high resistance, i.e., low electrical conductivity. In consequence of this high resistance, it became red hot, and afforded all the heat required. The substance to be reduced was mixed with this granular material and thus absorbed the heat at the very place of its production.

It is seen that so far Cowles' scheme was identical with that of Moncton, but taking it for granted that satisfactory aluminum could not be so produced, they devoted their attention to the production of alloys, which on account of the high cost of pure aluminium at the time, were more generally used.

This is the key to their great success as it gave aluminum, in the form of its greatly used alloys, at a sixth of the former prices.

To accomplish this, Cowles used the mixture of Moncton, i.e., granulated carbon, alumina, to which he added granulated

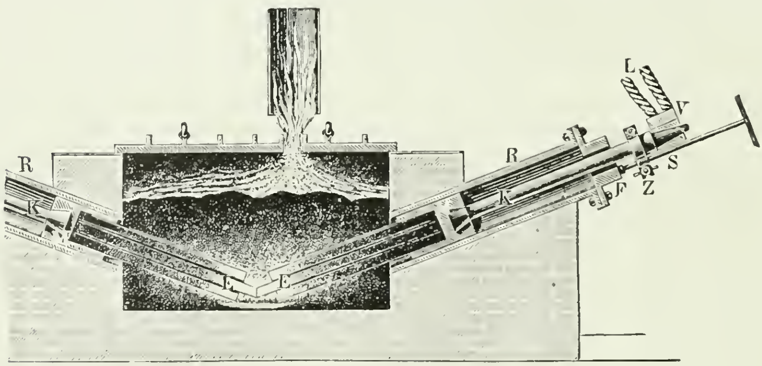


Fig. 1

copper, thus, the aluminium, as soon as produced, formed an alloy with copper, and after the run, was found as a fused mass below.

After a two hours' run, he obtained 5 lbs. of an alloy, aluminium bronze, which contained 15 to 20 per cent. of aluminium. Now by substituting this alloy, instead of copper, in the next run an alloy was obtained containing over 30 per cent aluminium. On this success, the Cowles Co. later re-organized as the Cowles Electric, Smelting & Refining Co., started their works at Lockport, N. Y., and began the production of alloys, not only of aluminium, but using the same principle they produced silicon bronze, boron bronze, and many others of practical importance. Fig. 1 illustrates the principle.

### 3. ELECTROLYTIC METHODS.

Now looking at the electrolytic methods, we find that in this field also there were hosts of suggestions and methods tried for the production of aluminium from aqueous solutions of various aluminium salts, but none with success. However, when the salts alone were used and electrolyzed, the production was successful.

Among the earliest attempts, was that of Davy. He had just succeeded by his classical experiments of 1807 and 1808 in producing potassium and sodium from the fused hydroxides. He also attempted to produce aluminium by the electrolytic decomposition of $Al_2O_3$ alumina, but was unsuccessful. However, he achieved a measure of success when he coated a sheet of platinum, used as a positive electrode or anode, with a paste of moistened alumina, and buried in the mass the end of an iron wire as a cathode. To these two electrodes he connected a voltaic battery of 1,000 cells. On making the connection, the wire was instantly heated to a white heat, and fused at the point of contact with

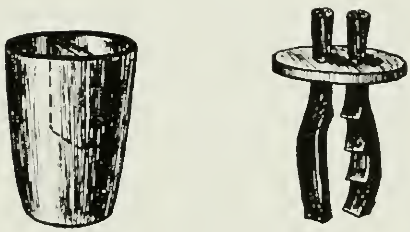

*Fig. 2*

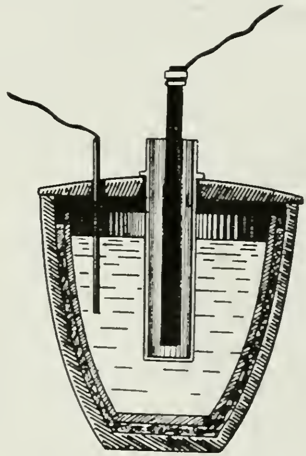

*Fig. 3*

the alumina paste. The metallic mass, after cooling, was both whiter and more brittle than the iron, and on dissolving in acid, a solution was obtained from which alumina could readily be separated—thus Davy had prepared the first alloy of iron and aluminium.

However, it was not until 1854 that the electrolytic production of pure aluminium was first accomplished by Prof. Bunsen, of Heidelburg, who had already produced barium, chromium and manganese. This he accomplished by the same apparatus (Fig. 2) which he had used for production of magnesium, which consists simply of a small crucible in which two small flattened and grooved carbon electrodes were dipped. The compound used was placed in the crucible and fused, the electrodes dipped in, and the current passed through—the metal produced being caught in the grooves. The apparatus was then cooled, and the solidified mass broken and the metal obtained.

St. Claire-Deville, after hearing of Bunsen's previous brilliant successes with chromium, manganese, barium, etc., had meanwhile been applying these methods towards the production of aluminium, and this led to the almost simultaneous discoveries by Bunsen and himself of the same method of preparation. Bunsen had, however, published his account in July, 1854, though St. Claire-Deville succeeded him by only a few weeks in August. St. Claire-Deville had modified the apparatus somewhat. (Fig. 3) and found in addition that $Al_2Cl_6$ could not be used as it volatilized at a low temperature, but found that the double chloride of aluminium and sodium worked well, and was fusible at a comparatively low temperature (186° C).

In carrying out the electrolysis, he gradually increased the temperature of the crucible to a point just below the melting point of aluminium, the current was passed through from the time of fusion, and continued with a gradual increase in temperature till just below the melting point of the aluminium. Now the current was stopped by taking out the electrode, the temperature raised to bright redness, and then the crucible allowed to cool. Afterwards the aluminium was found at the bottom as a regulus.

St. Claire-Deville had exhibited some of his product in 1854 at the French Academy. It was contaminated with carbon from the electrodes, which prevented the formation of a clean button. He also proposed using an anode composed of alumina and carbon, which, as the production of the aluminium proceeded at the cathode, would make up this loss by dissolving.

Interesting as these experiments of Bunsen and St. Claire-Deville were, they were not applied, on account of some practical difficulties, but they at least proved that production from fused electrolytes was possible, and so laid the foundation for the present methods.

Some of the chief difficulties were that—

(1) The carbon electrodes were disintegrated rapidly. These are now made of far greater compactness, and are therefore quite satisfactory.

(2) The fused electrolyte and metal produced, attacked the containing vessel. If a clay crucible, the clay was partially reduced, and silicon freed, and thus contaminated the metal. Porcelain crucibles have these faults, and in addition are fragile and costly. Carbon crucibles were so porous and so much attacked that they could not be used unless protected on the outside with some other substance, and metallic crucibles were unsuitable because they were attacked, and the aluminium produced formed an alloy.

(3) No suitable substance is known for making crucibles for containing the fused Halogen salts which could be heated externally.

Hosts of others in the next 25 years obtained patents on various methods, and among them Henderson in England in a patent in 1886 approached closely to the modern methods, but was at fault in still clinging to the external heating.

The problem had awakened wide interest, and among the ranks of the investigators were found Charles M. Hall and Paul L. Heroult, then both students, both 23 years of age, now world-famed electro-metallurgists. Hall was taking a classical course at Oberlin College, Ohio, and graduated in 1885. During the course he had but one term of chemistry, which, however, so captivated him that he spent his next year in the Oberlin Laboratory with the special object of finding an electrical method of commercially producing aluminium. He used the common voltaic cells, and built up a battery, using a gasoline heater to fuse his electrolyte (Fig. 4).

His method of attack was to find a solvent for alumina which would fuse readily, and from this solution obtain aluminium by electrolysis. At first he was not successful, as his clay crucibles

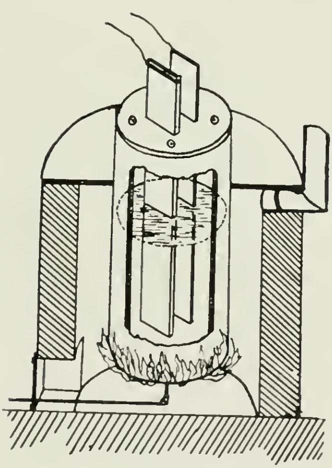

Fig. 4

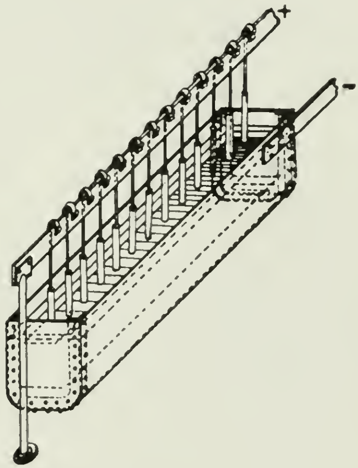



Fig. 5

were destroyed by the fused salt, and it was only when he lined his crucibles with a mixture of tar and ground retort carbon that he was successful in getting a yield of metal. The solvent he used was cryolite, and he found, as is generally the case, that the mixture melted at a lower temperature than either the alumina ($Al_2O_3$) or cryolite alone.

He now went to Boston, raised money to continue experiments and rented power from a small dynamo for four months, and experimented with copper electrodes which, however, were unsatisfactory, and he finally concluded that by improving the carbon electrodes, they would be the most satisfactory of all electrodes, for commercial work.

In July, 1886, he applied for his first patent, the basic principle of which was using as a solvent the double fluoride of aluminium, and some more electropositive metal, in this case ($Al_2F_6.6NaF$) cryolite.

He now returned to Oberlin determined to devise a commercial method, and being without funds, had to content himself with making bichromate cells, and working with a small iron crucible, but the results so encouraged him that in December, 1886, he went to relatives in Cleveland in order to negotiate for funds.

Meanwhile Heroult had patented in France at almost the identical date, the same process, and now had applied for a patent in the United States, and, as Hall had not as yet produced aluminium commercially, the United States Patent Office declared an interference between Hall's and Heroult's application.

He was then forced to make an agreement with Cowles Electric Smelting & Aluminium Company, by which they took an option on the process in exchange for supplying power, and giving Hall an interest if successful.

At the expiration of the time, the Cowles Co. did not take up the option, so Hall, who had now some connection, formed the Pittsburg Reduction Co. in 1888. Meanwhile the interference at the Patent Office had been decided in Hall's favor.

Now, with sufficient funds, Hall went to work on a larger scale, and by so doing was successful. In 1891 the plant was moved to New Kensington, Penn., and in 1893 the Niagara Power Co., which was just starting and looking for consumers for their power, made the Reduction Company an attractive offer at $18 per H.P. a year. This they accepted, and started what is known as the "upper works," and being eminently successful, they added the "lower works" in 1896.

From this time the company has been continuously successful, and constantly increasing their capacity. They found that by increasing the size of the vessel, or cell, that the heat generated by the reaction maintained the temperature sufficiently to keep the bath in a state of fusion, and so they were saved the expense of external heating (Fig. 5).

They also soon found it necessary to purify the bauxite which they used as the source of alumina. This was accomplished by mixing it with enough carbon to reduce all the impurities such as silica, iron oxide and titanium oxide, to the metallic state, and then melting in an electric furnace. The reduced impurities formed an alloy, leaving the alumina above almost chemically pure. This alumina is granular, dissolves easily, and produces a metal of high purity.

Heroult, in 1900, described how he stumbled across his process. He was attempting to electrolyze cryolite $Al_2Fl_6.6NaF$ with an iron cathode and carbon anode, and had added some double chloride $Al_2Cl_6.4NaCl$, to make the mixture melt more easily. He obtained some aluminium alloy at the iron cathode, but observed no evolution of chlorine or fluorine at the anode, which was attacked, however, and yielded CO and $CO_2$. He therefore concluded that some oxide was present as an impurity. Following up this clue, he then added pure alumina $Al_2O_3$, and obtained only $CO_2$ and aluminium.

He immediately obtained a patent, and went to a manufacturer who was producing aluminium by the sodium process. This manufacturer advised him to turn his attention to alloys as the use of the pure metal was limited. This he did, but, after working a couple of years, he learned that Hall was now making pure aluminium successfully. He therefore started production, and placed some of his product on the market about a year after Hall had started commercial production, but it was not until 1890 that he was selling a grade equal to Hall's. Heroult also patented his process in England and on the continent, and production of aluminium was carried on by four companies using his patent under license. These patents nominally expired in 1901 but extension of time was applied for and it was not till 1907 that many outside plants were contemplated in Europe. In America it was not all smooth sailing with the Pittsburg Reduction Co. This company entered suit against the Cowles Co. in 1893, and obtained an injunction restraining the Cowles Co. from the manufacture of aluminium.

Meanwhile Charles S. Bradley a very noted electrial engineer, had patented the idea of internal heating. This patent was fought by the Cowles Co., who had, since the beginning, used internal heating in their production of aluminium alloys. The Cowles Co. won their suit, and now in turn, they fought the Pittsburg Reduction Co., which Company, as was mentioned before, had abandoned their external heating, when they found that the heat evolved by the reaction was sufficient to keep the bath fused. This suit they also won, and the Pittsburg Reduction Co. was compelled to pay heavy damages. As a result of these decisions, the process was tied up, the Cowles Electric Smelting & Refining Co. owning the internal heating part of the process, and the Pittsburg Reduction Co. the electrolysis of alumina in a bath of fused cryolite. Hence neither could work without the other, and, of course, this resulted in a practical amalgamation of interests, till February, 1909, when the Bradley patent expired and the whole process became public property.

The various uses to which aluminium is put, depend for the most part, upon its low Sp. G. 2.6, its relatively high conductivity, its white color, and to the fact that the oxide which forms in air is white, and forms a compact, coherent coating over the metal which is extremely thin, resistant to further oxidation, and therefore does not detract from the appearance of the metal.

Since the Sp. G. of aluminium is 2.6 and that of copper about 8.9, therefore a given weight of aluminium will occupy about four times as great a volume as the same weight of copper; therefore, if we represent a given weight of copper by a solid figure, then the volume of aluminium, being four times as great, would be represented by four similar figures having the same depth. Therefore, the upper surface of the aluminium would be four times that of the copper, of the same weight and depth, and now, since the conductivity of copper compared with that of aluminium, is as 1 to .6, and if we call the conductivity of the copper 1, then the conductivity of aluminum will be four times .6 = 2.4, or say, about twice that of the copper. These two considerations show that with aluminium at the same price as copper, for castings and all work where volume alone is concerned, aluminium would cost one-quarter as much as the same volume of copper, and where conductivity is concerned, since half the weight will give more than equal the conductivity, therefore, the cost would be about half that of copper.

Conductors of aluminium are now in extensive use in electrolytic works, and in electric furnace work where heavy currents at low voltage are required, some of these conductors being of great size, as for example, 2″x4″, 4″x4″, 2″x6″, and look like squared lumber. This use as conductors is not confined to large sizes. Power companies are using aluminium wires and cables, one, at least in Canada, being 90 miles in length. In the Western States aluminium wire is now greatly used, and iron wire coated with aluminium is used in place of the former galvanized products in telephone and telegraph work.

Soldering of aluminium has occasioned much difficulty on account of the film of oxide which rapidly forms on the surface, and prevents ordinary solders wetting the surface. No flux has yet been found which will dissolve this oxide and keep the metallic surface fresh long enough for ordinary soldering. To overcome this, numerous ways have been suggested, and each number of the various technical journals seems to add about as many more. Some claim to solder satisfactorily by using the untinned copper in such a way that it mechanically scratches the surface, i.e., by passing it backwards and forwards, and holding the solder against the copper while this is going on, thus the aluminium is mechanically cleared.

The Autogenous method is however probably the best, as no other metal takes part in the operation, a flux such as an alkali chloride being used, and the two surfaces to be united, pressed firmly together, and heated to a point just above the melting point of aluminium. The mechanical properties of such joints are good, and under the microscope present the same structure as aluminium itself. Sheets of aluminium 15mm. in thickness, and welded in this way have withstood 17 atmospheres. The process is useful, not only for welding wires and cables, but for aluminium apparatus, tubes, pipes, chemical apparatus, vessels, automobiles, etc. Pure aluminium is durable in sea water, but joints soldered with any other metal are attacked very readily.

Aluminium is now greatly employed as a pattern metal, it being light, easily finished with sandpaper and file.

The Wetherill zinc oxide furnace grate is cast in sand, moulded by an aluminium form. When wood was used, a great many small pieces were necessary, and with the aluminium it is all one piece, hence lessening the time and cost considerably.

Many aluminium objects are now prepared by a method similar to lead pipe, i.e., the metal is heated to a point just below melting, and squeezed out of forms continuously. In this way sheet aluminium of all gauges for automobile bodies, signs, cooking utensils, kodaks, etc., is produced. Some of the New York subway cars are lined with sheet aluminium, and the Japanese army was supplied with aluminium cooking utensils in the late war.

Aluminium pipe is also so produced, and is used for all sorts of purposes,—acetic acid plants, nitric acid condensors, in pulp mills, the finest pipe being used as needle indicators on various instruments, as in galvanometers, etc.

Rods of all sorts and shapes, from the enormous bus-bars to the finest thread-like wire for lace fabrics, mouldings of all patterns, and for various purposes are produced in this way.

Aluminium is now extensively used as a deoxidizer to produce sound castings, and many thousands of pounds are used annually for this purpose.

For plating on aluminium, no really satisfactory method yet exists by which one metal may be directly plated on aluminium; this is due to the ever present film of oxide, but it is said that by dipping first in a solution of stannous chloride and ammonium alum, a film of metallic tin coats the aluminium on which a deposit of other metals may then be satisfactorily plated.

## ALLOYS

Among the chief alloys are aluminium bronze, consisting of aluminium and copper. These bronzes are greatly used in machine designs where lightness and strength must be combined, as in automobiles. They are also used for decorative work where a non-tarnishing yellow color is required. A new bronze, consisting of copper 39, iron 34, nickel 18, aluminium 9, is as hard as nickel-steel, is strong, very resistant to sea water, moist air, and acid water. Six parts added to 24 of yellow brass is said to make the brass equal in strength to the best bronze.

Aluminium and zinc alloys are also used in automobile works, alloys containing copper, aluminium, tin, and antimony for horse-shoeing, and many other alloys for special purposes are employed.

Respecting the tensile strength of some of these alloys, it is interesting to compare the tensile strength of some common products with aluminium bronze.

TENSILE STRENGTH

(Pounds per square inch)

| | |
|---|---|
| Cast copper | 24,000 |
| Cast gun bronze | 39,000 |
| Steel plate rolled | 81,000 |
| Aluminium bronze castings | 100,000 |
| Aluminium bronze (with silicon) | 130,000 |

Another important application of aluminium is in what are termed by the inventor, Dr. Goldschmidt, the aluminothermic reactions. When the oxides of such metals as titanium, iron, chromium, nickel, etc., are mixed with aluminium in a fine powder and some hot body applied, as a red hot iron rod, a vigorous reaction takes place by which the aluminium reduces the metallic oxide and leaves the metal in the free state. The aluminium is itself oxidized to the form of $Al_2O_3$, and floats on top as a slag.

This principle has been of great importance for the preparation of pure metals free from carbon. A mixture of iron oxide, $Fe_2O_3$, and aluminium powder is now on the market as Thermit, and finds extensive application in rail-welding and repairing broken castings of all kinds. The Russian army was supplied with Thermit for repairing their heavy ordnance, etc., during the war.

The application is a very simple matter, the greatest time being consumed in preparing the mould around the object to be repaired or welded. A conical shaped crucible is filled with Thermit mixture, a little barium peroxide added to the top, and in this a short piece of magnesium wire is placed. The crucible has an opening at the bottom, which is placed directly over the mould, and which may be opened or closed at the will of the operator. When everything is ready, the magnesium wire is lighted, and the heat soon liberates oxygen from the barium peroxide, which, uniting with the aluminium, starts the rest of the mixture reacting by the heat communicated. After a moment the vent is opened, and the molten metal allowed to flow into the mould. The heat of the reaction is so excessive that the metal it comes in contact with is soon heated to such an extent that a perfect union results.

There are still a great many other applications of aluminium which time prevents mentioning, while the near future is bound to see a great extension in the practical and every-day uses of aluminium.

N.B.—Read at a special meeting of the Chemical and Mining Section held on December 16th, 1908.

# WATER METERS.

J. J. TRAILL, B.A.Sc.

Water meters may be defined as instruments by which the quantity of water flowing in a pipe is measured and the amount passed is recorded automatically. The number of meters devised is legion, if one may draw definite conclusions from patent office records, the British patent office records showing that for one period of ten years there were granted 389 patents of water meters or parts thereof. No perfect meter has been devised as yet, but this is not otherwise than should be expected, for the variety of service to which they are put is so great that most meters are designed to serve well in a few classes of work, while they may be entirely useless in other classes.

The important desiderata of a perfect meter are as follows: It should accurately measure all flows, whether fine or full; should work at very slight pressure; should work at high pressure without shock or water-hammer; should be small in bulk and easy to set and repair; should not be liable to "stick up" or stop, and when not registering when water is being passed through it should give some outward indication of the fact; and, finally, should be incapable of passing water backwards.

Meters are of two kinds, viz.: Positive and Inferential. Each of these classes may be subdivided. Positive meters measure the actual volume of the water by the action of a piston working in a cylinder which is successively emptied and filled at the completion of each stroke. The cylinder being of known dimensions affords a measure of the quantity of water discharged in a given interval of time. Inferential meters measure the velocity of the flowing water, generally by recording the revolutions of a turbine or other water wheel or, in the case of the Venturi meter, the pressure on a gauge.

Nearly all positive meters are included in the following four classes: Single cylinder reciprocating piston meters, double cylinder reciprocating piston meters, rotary piston meters (including the disc meters) and diaphragm meters.

The Kennedy meter shown in figures 1 and 2 is of the single cylinder reciprocating piston type. This meter will register the flow accurately even when so small a quantity as a drop at a time is being discharged. It is very bulky considering the quantity it will discharge, and is not, therefore, used to any extent as a domestic service meter. Its accuracy is such as to recommend it as a test meter and it is often used for this purpose, the meter to be tested being put in series with it, water run through and simultaneous readings taken on the two dials. The meter consists essentially of a cylinder and piston, a two-way cock, a tumbling weight to operate the cock and a dial on which the discharge is registered. Fig. 1. shows a section of the inlet and outlet pipes and the cock; Fig. 2, a side section of cylinder and piston inlet and outlet pipes and cock. The packing of the piston consists of a ring of very pure soft rubber, shown between the piston and walls of the cylinder. As the piston rises water

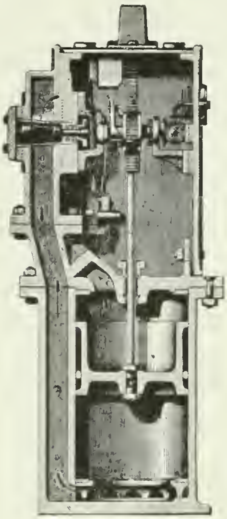

Fig. 1

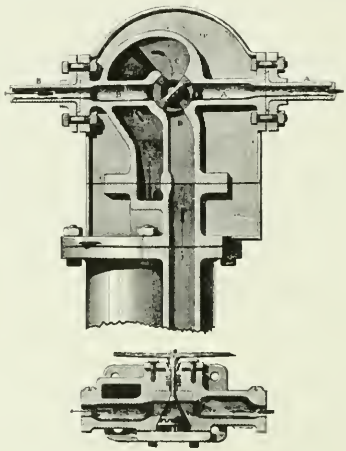

Fig. 2

flows into the bottom of the cylinder, filling it; the rack on the piston rod raises the weight by means of the pinion to which the latter is attached, until, when the end of the stroke is reached,

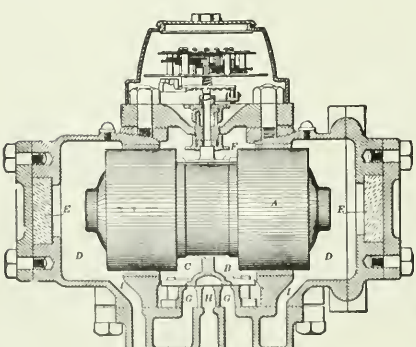


Fig. 3.

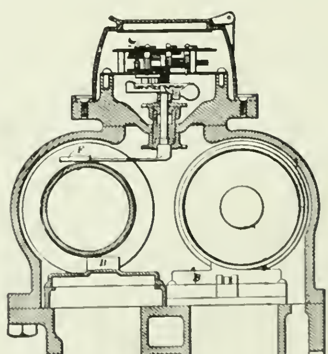


Fig 4.

the rack passes beyond the pinion, the weight falls, reversing the cock and the piston commences the return stroke. Any error which might occur through short stroking is made ineffective by having the counting gear record the distance travelled by the piston. With this meter there is danger of water-hammer if the piston speed becomes high.

Much more compact instruments are the double cylinder reciprocating piston meters. In these one piston actuates the valves of the other cylinder. The cylinders may be the same or different in size. Figures 3 and 4 show sections of a Worthington double cylinder meter in which both pistons are of the same size. Water flows into the cylinder under pressure from the main, displacing the piston, which, in turn, displaces the water in the other end of the cylinder, this flowing through the outlet port of the valve to the services pipes. Thus the plunger in moving displaces a fixed volume of water, discharging it

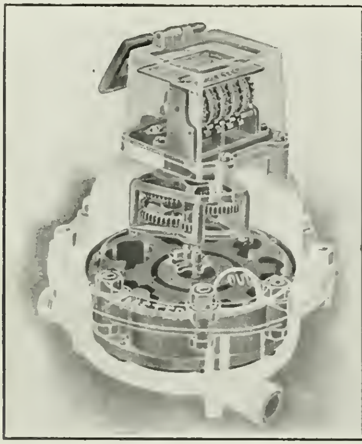

Fig. 5

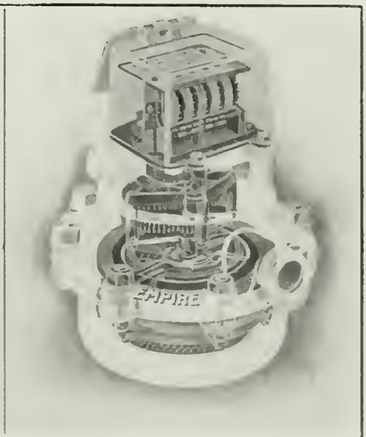

Fig. 6

through the outlet. The arrangement is such that the stroke of the two plungers alternates, the valve actuated by one admitting water behind the other. The plungers come to rest when they reach the rubber buffers at the ends of the cylinders. One plunger imparts a reciprocating motion to the lever F, which operates the counter movement through a spindle and ratchet gear. With this meter, which is otherwise a very accurate and reliable instrument, there is a danger of over-registration at fine flows through a tendency to short stroke.

Rotary piston and disc meters, engravings of which are shown in Figures 5, 6 and 7, are the next in the scale of accuracy where considerable variation in the flow is to be expected. These meters are easily kept in order, there being no valves, and, with the exception of the counting gear and piston or disc, no moving parts. The piston or disc in these meters is usually made of hard vulcanite with a specific gravity, nearly unity, the advantage being a slight reduction in friction. The pistons are of various shapes, generally complicated, but the action of all meters of either class—rotary piston or disc—is essentially the same for the class.

In the rotary piston meters the action is as follows: The centre of the piston has a circular motion, the lobes working in the small chambers of the cylinder, and these alternately cover and uncover the inlet and outlet ports of each chamber. The amount of water passed per revolution is equal to the difference in volume of the cylinder and piston. In these meters provision is made for a small amount of water to pass when, through accident, the piston becomes "stuck up." This is necessary in domestic supply meters, as the meter should not cut off the

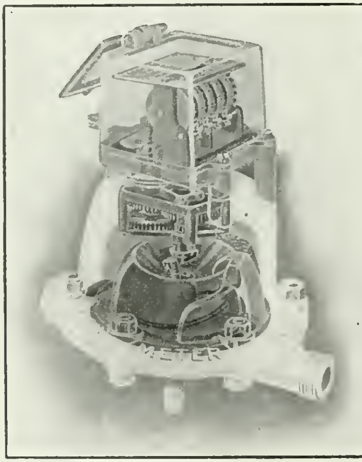

Fig. 7

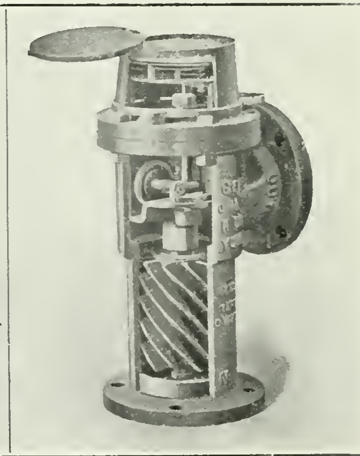

Fig. 8

supply completely, but if not registering should give some decided indication of the fact.

The meter illustrated in Figure 6 is, as it were, a transition from the rotary piston to the disc type. There is, as in the rotary piston meter, a piston, but the arrangement of inlet and outlet ports is exactly similar to that of the disc meter.

In the disc meter shown in Figure 7, a disc with the shape of a flat cone "wabbles" back and forward in such a way that one element of the cone is always in contact with the chamber in which the disc works, thus shutting off free flow from the inlet to the outlet ports. The volume of water passed per revolution is, of course, fixed by the size of the chamber.

Rotary piston and disc meters are in use to a very large extent in America for metering domestic supply. In one instance a city in one of the northern states placed an order for 15,000 disc meters at one time. Both classes are fairly accurate over quite a wide range of flow. The life of the rotary piston meter is longer than the life of the disc meter. It is possible also by a simple repair to take up the wear of the piston for the former, but when the disc and disc chamber of the disc meter become worn the meter's usefulness is ended.

Diaphragm meters are not used to any great extent for water measurement. The meter consists of a pulsating diaphragm, in a vessel of known capacity, which is moved as the side chambers are alternately filled and emptied. The common dry gas meter is essentially a diaphragm meter.

Coming to the second general class, Inferential meters, we have first of all rotary turbine meters, a good type of this meter is shown in Fig. 8. By a comparison of the supply pipe of this meter with that of any of the positive meters it is immediately evident what a great saving in size—and hence in cost—is obtained by using a meter of this kind. The saving is at the expense of accuracy of registration at fine flow, meters of that

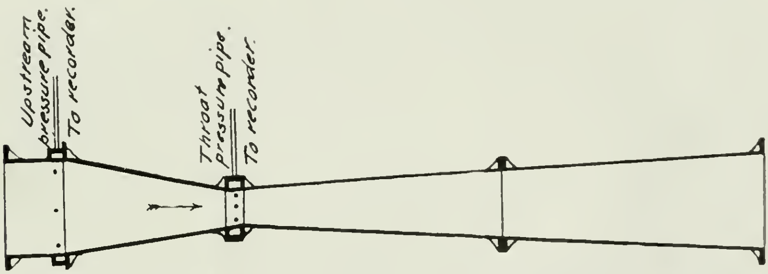


*Fig. 9 Longitudinal section of Venturi Meter*

kind being accurate only for medium or full flows. The action of the meter is evident from the figure.

Rotary fan meters are similar in principle to the ordinary windmill.

The Venturi meter might also be classed as an inferential meter. Briefly, the method of measurement of water by this meter is based on the fact, that when water flows through a pipe of which the section is gradually contracted and subsequently gradually increased, the pressure in the smallest section is much less than in the largest section on either side of the contraction. The discharge through the meter varies directly as the square root of the drop in pressure from the largest section upstream to the throat. For use in pumping stations the meter is furnished with an autographic recorder, which shows, by a diagram, the volume of flow. A diagram of the meter is shown in Fig. 9.

A very decided advantage of the Venturi meter is that the loss due to friction is small. The meter is very accurate, for large discharges, more accurate than any other meter.

For domestic supply the favorite meter in America is one of the positive types, usually the rotary piston or disc meter. The double cylinder reciprocating piston meter is also used frequently. European practice seems to favor the use of inferential meters for this purpose. The explanation is probably found in the different number of persons per service in America and in Europe. In America the number of people using one service is probably about ten on the average. In some cities it is as low as five. In Europe the number is much larger. In Berlin, for instance, the latest figures available state that there are 70 people per service. With this condition the flow would be fairly continuous and a cheap compact meter which will give a reasonably correct measurement is therefore used. The average number of people per service is large in nearly all European cities.

For trade supply inferential meters are almost universally used. It should be noted that inferential meters may pass large quantities of water without registering, as, if they become "stuck up" they offer very little resistance to the flow.

For measurements of municipal supply the Venturi meter is used. The Pitometer, a rated pitot tube arranged to give a photographic record of flow, is coming into use for this purpose also.

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## PRACTICAL METHODS OF CONCRETE CONSTRUCTION*

C. G. CLINE, '09.

This paper is not intended as a discussion of the theory of concrete, either plain or reinforced; it is intended simply to bring out some methods of concrete construction met with by the writer in a somewhat limited experience with this important material of construction.

One of the simplest uses of cement is the making of mortar for brick or stone work. It is often used where mortar made from ordinary lime would not be strong enough; or a small quantity may be mixed with lime mortar to increase its strength. When the masonry is to be exposed to moisture, cement must be used instead of lime, as lime will not set unless thorougly dry, and will gradually dissolve in water.

Cement in the form of concrete is now very commonly used for all kinds of walls, for buildings, retaining walls, dams, etc., and for foundations for buildings and machinery. Wooden forms are built up, the concrete is mixed by hand, or by machine, and placed in them. The concrete takes up the shape of the forms and hardens, so that when they are removed the wall remains.

The forms are almost universally made of lumber. The use

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* Read before Civil and Architectural Section of Engineering Society, December, 1908.

of steel, either for the entire forms or for facings, has not been found satisfactory. The steel plates are easily bent and it is too expensive to be continually straightening them out. A common practice is to use 2" lumber for lagging and 2"x6" for studs. If 1" lumber is used, the studs will need to be much closer and the bracing of the forms very carefully attended to. Even then the results may not be satisfactory; the whole wall may get out of alignment, or some of the boards may spring out of place and leave a rough, uneven surface on the wall.

For rough work, undressed lumber is commonly employed. On one structure, undressed lumber was used for the foundation and inside work where it would not be exposed to view. For finer work, lumber was employed which was dressed on one face and both edges; the edges must be dressed and straightened so that the planks will fit together tightly in the forms and not leave holes for the concrete to run through, making great ridges on the wall. On still more particular work, there was used matched lumber, 2"x8" or 2"x10". The tongues and grooves made the form much more solid and easier to keep in position and gave an even face on the finished wall.

When an especially smooth face is desired, it is a good plan to paint the inside of the forms with a coating of soap dissolved in hot water. This allows the forms to come off clean, without damaging either the lumber or the concrete. It is surprising how tightly a piece of wood will stick to the concrete wall, even when it is merely in contact with it; while if it is partly imbedded in the concrete, it is next to impossible to remove it when once the concrete has set. In foundations for machinery, it is necessary to leave a space around each anchor bolt so that it will have some play when the casting is being placed in position. This is usually done by placing a long, narrow box around each bolt before the concrete is put in the forms. These boxes should be tapered and must be removed before the concrete is entirely set or it will be impossible to withdraw them. After the machine is properly lined in, cement grout is poured into the holes, and when it hardens the machine is held firmly in position.

If it is desired to nail any wood-work to a cement surface, a piece of scantling placed against the inside of the form will become imbedded in the concrete when the form is filled and will make a solid nailing strip to which the wood-work can be fastened.

The form for a concrete wall consists of two walls of lumber. The smooth side of the lumber, if it is dressed, is, of course, placed to the inside. The studs, usually 2"x6", are placed on the outside. The concrete, as generally used, is rather wet and soft, and when placed in the form it exerts considerable pressure in every direction. Concrete is more than twice as heavy as water, and so, although it is not as fluid, it will exert almost as great a pressure as would water. This pressure tends to move the two walls of the form apart and must be provided for in some way.

Where the wall starts from the ground and is only five or six feet high, the two sides may be held in position by braces slanting from the ground. But in very many cases this method cannot be used, and it becomes necessary to tie the two walls together. One very effective method is to use bolts which can be tightened up by nuts, wooden spreaders being used between the walls to keep the form the proper width until the concrete is placed in. In narrow walls the bolts can be driven out after the forms are removed and used again; the holes left in the wall are plastered up. But in many cases the bolts would have to be left in the wall and the ends simply cut off. The rods serve no useful purpose in the wall and their cost is considerable. A plan, which is considerably cheaper and almost as effective is to tie the walls together with strands of wire twisted until a sufficient tension is obtained to resist the pressure of the concrete. As in the last case, spreaders are used to keep the walls properly spaced. They are always removed just before the concrete comes up to them.

To avoid excessive pressure on the forms, and for other reasons, concrete is laid in layers, often not more than two feet. To make a solid wall, it is essential that these separate layers adhere to one another strongly. For this reason, when a fresh layer is being placed, the bottom layer should be perfectly clean and should be wet. The concrete is usually swept as clean as possible, and then washed with water. To make a really good joint, it is a good plan to sprinkle a little neat cement over the bottom. Sometimes the first two or three inches of the fresh layer is mixed with a little less stone in it, to ensure plenty of fine stuff at the joint. When leaving work for the day, it is a good practice to imbed plenty of big, sharp stones in the concrete, leaving half of each stone sticking up to give a good bond for the next layer. In narrow walls, where stones could not be used, short pieces of bars of iron or steel scrap or old pipe will serve the same purpose.

In starting a wall on smooth rocks, especially if the rock be sloping, great care must be taken to make sure that the wall will not slip. The rock surface should be thoroughly cleaned and washed and holes drilled at intervals and fox bolts driven in.

For ordinary work, concrete is usually mixed with a considerable amount of water, so as to make it quite soft. Then, when it is placed in the forms, it will, with the aid of a little tamping, work into all the corners and make a smooth face and a good bond. One defect of this method of mixing is that when the water evaporates it leaves the concrete more porous and diminishes the strength to some extent.

For some work, the concrete is mixed rather dry, almost like moulding sand. If properly tamped, this will be less porous and rather stronger than the other mixture; but it requires a great deal more care in handling it to be sure every corner is filled up and no holes left. If it is not carefully tamped its strength will be greatly impaired. It is not so well adapted for ordinary walls and foundations, but is used where it has to be trowelled, such as for the top coating of floors and sidewalks.

In concrete work it is customary to mix the cement, sand, gravel and stones up to, say, two inches diameter, together in the mixer or on the board. But in most cases it is desired to use stones larger than two inches. These larger stones are taken to the forms by themselves, thoroughly washed and soaked in water, and placed in the form one by one. In a three-foot wall, rocks as big as two feet across may be used if carefully placed; and even in an eight-inch wall, four-inch rocks are all right. In one instance, old bricks were laid in an eight-inch wall with the four-inch side horizontal. Of course, the extensive use of fillers is not permissible on all works; they diminish the strength of the work to some extent and its fire-proof qualities.

In using fillers, care must be taken to keep them back a sufficient distance from the face of the wall. If a flat surface of a rock or brick comes within an inch or two of the face, the thin layer of concrete on it is apt to come off with the forms or be knocked off in some way and leave an ugly hole in the wall, exposing the filler. The same is true, to a lesser extent, of the smaller stones. But these cannot be placed by hand. So it is necessary in every wall to have a man run a spade or other tool up and down against the face of the form in such a way as to work the stones back and to give the fine part of the mixture a chance to make a smooth, even finish.

In most works it is impossible to carry up the whole structure at once. So it becomes necessary to make some provision for joining the different sections together. One method of doing this is put steel rods in the first section, leaving half the length of the rod projecting at the joint. The ends of the rods are usually bent to increase their efficiency. Another method is to nail on the inside of the form several blocks of wood slightly bevelled so that they may be removed readily. This leaves a recess into which the concrete in the other section will run.

In attempting to use concrete in cold weather, the difficulties are greatly multiplied. If concrete is allowed to freeze the setting is arrested, and the strength of the concrete greatly weakened by the destruction of the cement crystals. Another danger in frosty weather is that the grains of sand, the stones, the larger rocks on the bottom of the wall may be coated with ice, so that the cement will be given no chance to adhere to them.

Great care must be taken to see that everything used in the concrete is above the freezing point and will remain so for several hours after being mixed, so that the concrete will have a chance to set properly. The water can be made quite hot by running steam into it. The cement forms only a small proportion of the materials and need not be heated. The stone, gravel and sand are heated by piling them over long flues laid on the ground at a slight inclination. The flues lead the heated gases from fires in the fire-boxes along under the piles of material to a low stack at the upper end. The larger rocks can be conveniently heated by immersing them in hot water, or by keeping them for some time in a large enclosed box with steam turned into it. A good way to warm, and at the same time to clean the concrete at the bottom of the form is to use a steam jet under a low pressure. This will warm the concrete and the forms and thaw any ice which may have been on them and can also be used to blow the dust, saw-dust and chips into little piles where they can be removed. Hot water is not very good for washing the forms in really cold weather, as it will soon cool and freeze, making things much worse than before; the walls should be left as dry as possible until just before the concrete is ready to be put in.

Considerable care is necessary in taking the concrete from the mixer to the forms. If conveyed in steel wheel-barrows or boxes, they should be rinsed out with hot water before being loaded. On one job it was necessary to hoist the concrete with a derrick and then dump it out and shovel it into wheel-barrows. In this case the concrete was dumped into a flat iron box with a fire under it and so kept warm until the wheel-barrows were ready to take it to the forms.

As soon as the concrete has been placed in the form and properly tamped, it should be covered over in some way to keep in the heat. One good method is to have long canvas sacks prepared of a proper size to fit in the walls and fill them with straw. These, when placed over the warm concrete, will keep in the heat for some time.

In one case, on a thin wall on an exposed part of the work, a line of old steam pipe was laid right in the form and left there. The concrete was placed around it and steam was kept running through the pipe for several hours until all danger of freezing was past.

# APPLIED SCIENCE

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## Editorial

### The Young Civil Engineer

Mr. Stern's paper, "The Young Civil Engineer," which appeared in the January Applied Science, is discussed most fully and ably in this number. A great number of the undergraduates and the recent graduates are now at the cross-roads of life and will do well to carefully study not only the discussion but again read the original article. The men who have so kindly contributed are leaders in their profession in America, men who have been through the fight of life in some of its most strenuous scenes, men who have wrestled with opportunity and come out victors, and therefore men whose opinions must and do carry weight.

Too often the young graduate will sacrifice future success for present gain. They seem to forget the fundamental point of all building, that no matter how fine the superstructure is made, if we build high the foundation must be solid.

**The Toronto Graduates' Association**

The most successful of the series of dinners of the Toronto Graduates was held on Friday, March 12th. Nearly one hundred members were present. These gatherings have stimulated wonderfully the interest of the graduates in the welfare of the School. It speaks volumes for the loyalty of the Science Alumni that such a large percentage should be present. Much can be done by such an organization and steps were taken to put it on a more permanent basis. The following officers were elected for the year: President, E. Richards; Vice-President, W. Douglas; Secy.-Treasurer, K. A. MacKenzie; Committee—W. E. H. Carter, J. C. Armer, W. D. Black, president-elect of the Engineering Society.

A resolution was passed instructing the secretary to communicate with the Board of Governors, pointing out to them the great need of a new Engineering building.

After the meeting the members adjourned to the University gymnasium, where the Engineering Society elections were being held. A full report of the elections will be given in April issue.

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Readers of the British technical press of late have been interested in a very excellent illustrated article on "Engineering at the University of Toronto," by Mr. Walter J. Francis, C.E., of Montreal, a distinguished alumnus of the School of Practical Science. Mr. Francis' paper appeared in a recent issue of The Engineer, is partly historical, partly descriptive of present conditions, and partly anticipatory of future developments, and the statistics supplied will give to the British reader particularly, some conception of the phenomenal growth of this Faculty during the decade just closed. It is of interest in this connection also to mention the fact that Mr. Francis contributed to the recent convention of the Canadian Cement and Concrete Association in Toronto an authoritative paper on "Field-Made Concrete." Mr. Francis' extended experience on engineering works of magnitude in Quebec, Ontario and British Columbia enables him to handle such a subject as this in a masterly way. He is possessor of a bright and readable English style.

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R. W. Angus, Professor of Mechanical Engineering, left this week for an extended trip to Europe. His object primarily is to inspect the thermo-dynamic and hydraulic laboratories of the universities of Great Britain and the continent, with a view of incorporating their better features in our new laboratories, now nearing completion. As Prof. Angus has already visited those of the leading American and Canadian universities and as no reasonable expense has been spared, it is to be expected that the Toronto ones will rank among the best in the world.

Professor Angus desires to acknowledge the appreciation of the University of the following presentations of machinery and apparatus, recently offered by various companies. Among those which have already been presented may be mentioned:

Two Leonard engines with different types of slide valves by E. Leonard & Sons, London, Ont.

One rock drill by the Sullivan Machinery Co., New York, through Mr. A. E. Blackwood, '95.

Marine gasoline engine by the Canadian Fairbanks Co., Montreal, Que.

Two water meters by the National Meter Co., New York, through Mr. M. Warnock, Toronto.

In addition to the above gifts, considerable apparatus has been supplied at very low prices, among which should be specially mentioned a Rand air compressor, supplied by the Canadian Rand Drill Co. through Mr. H. V. Haight, B.A.Sc. These indications of practical sympathy with the work which we are doing are much appreciated and it is hoped that other firms will assist us in the same way in so far as it is possible.

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## PROF. C. H. C. WRIGHT HONORED

Some people are so unfortunately constituted that they do not seem able to remember pleasant, agreeable things. The uncharitable and disagreeable so dominate their lives that the happy experiences are forgotten or crowded out.

Not so with the body of men, the past presidents of the Engineering Society of the Faculty of Applied Science of Toronto University, who met in Toronto on the evening of March 30th to do honor to C. H. C. Wright, B.A.Sc., professor of architecture in the Faculty of Applied Science of Toronto University. In their college days they recognized, and have since remembered, the man who, with unfailing good temper, willing always to do his share of the work and more, with a word of congratulation, encouragement or "ginger," inspired, and, by his kindly interest, made pleasant and profitable their year of responsibility as presidents of the students' organization.

Charles Wright was born on shipboard in Chelsey Harbor, Massachusetts, in 1864, and spent his boyhood days in the fishing town of Digby, Nova Scotia. From here he moved to Kingston, Ontario, where he spent three years in the public schools. In 1880 he entered the Pickering College, and under its principal, J. E. Bryant, received his mathematical inspiration.

In the fall of 1885 he registered in the department of civil engineering at the School of Practical Science, Toronto. As a student, he was successful both in the athletic field and in the examination hall, securing in examinations more first places than any other two men of his year.

With his classmates he was popular and was elected to the highest position in the gift of the Engineering Society. His field experience, since graduation, was secured with a Boston firm of building contractors, with whom he rose to the position of chief of the estimating staff. But his work seemed to be academic, and in 1890 he joined the staff of the School of Pratical Science as Lecturer in Architecture. By constant thought, continual study and unfailing industry, he became an authority on materials of construction and on design.

It was not to Wright the student or the college professor that these men assembled to do honor, but to Wright the man and the friend of every undergraduate and graduate of the Faculty of Applied Science. For eighteen years he has planned and worked and organized. He has studied methods and studied men and studied the situation. He has made himself familiar with the conditions in the schools below and in the faculty, in the university at large and in the profession: has weighed carefully the situation, and, having decided on the proper course, has the sand and the staying power to maintain his stand.

All these labors and preparations were undertaken not for selfish reasons, but because he had vision and faith in the future of his profession and of this young country, and that conditions are changing rapidly, and that new policies must be devised to meet the new problems.

The honor done Mr. Wright struck a responsive point of contact among the graduates of his alma mater and in the public mind, and many kindly thoughts and messages will be sent in his direction, for men realize that removed from the grinding routine and petty annoyances of clerical work he is a bigger man; he grows.—E. A. James, in Canadian Engineer.

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## CEMENT*

E. ASHTON HASSAN.

Gentlemen:—It is with a certain amount of diffidence that I stand here this evening, for, appearing before a number of men of your standing and ability carries with it an honor that could not be eclipsed and for the privilege of which I desire to tender my sincerest gratitude. Knowing something of the value of your time, I fear almost to present my material before you, fearing I may fail to some extent and thereby waste your valuable time, and were it not with hopes that my paper would be beneficial to most of you I never would have accepted the invitation.

History chronicles vaguely the events of a period known as the Stone Age, when men wrought with the crudest tools and implements and eked out the merest existence. But man's necessity made him progressive and his cunning taught him to devise instruments superior, of bronze, with which to serve his purpose, only to find them on further advancement inferior to the improved work of his son in the Iron Age. Each plays its part in the economy of Nature, then yields place to its betters and the Stone Age, Bronze Age and Iron Age seem to be yielding the palm to the Imperial Age of Portland cement. Apparently no product in the world has wider application than Portland cement, a man telling me a little while ago that his wife had patched up her leaky wash-tub with it some six months ago and up to date it was still in good condition.

Men are beginning to realize more and more its worth, especially with regard to its fireproof qualities, wherein brick, stone, terra cotta, iron and steel all suffer in comparison with it. The great ultimate strength that can be gotten in conjunction with steel in the form of the now widely known and yet unknown form of reinforced concrete. It is, as we heard a few weeks ago in a lecture—I refer to the "Artistic Bridge Building Design"—the ideal building material in bridge construction, whether for strength, form, beauty or durability. Probably there

*An address delivered before Chemical Section of Engineering Society, January [illegible], and awarded 1st prize for Student's Paper.

is no material on earth better adapted for street paving or sidewalks, etc., and the many objections raised are usually prompted by the inferior workmanship and lack of knowledge concerning this very important branch of construction.

In house construction, although time has not been given as yet to ornamentation, there is no limiting the possibility of cement with regard to the "house beautiful." The exhibition given during the next week will in all probability be a revelation to you in this direction. It has been treated to very good effect, as might be seen in the buildings of St. James Church, Brooklyn, N.Y., club house of Detroit Boat Club, Nassau County Court, Mineola, Long Island, and very many others, a few illustrations of which are here for your approval.

While once the structural steel buildings were thought absolutely fireproof and safe, it is now almost universally conceded that it must be supplanted by reinforced concrete. There seems little doubt but that Portland cement has made work of such magnitude as the Assuan Dam, the marvellous docks of Buenos Ayres and the Panama Canal, engineering feats capable of being successfully handled.

It might be well for us to note with what rapidity the manufacture of this product in the United States and Canada has grown. In the United States, in 1892—547,440 barrels; value $1,153,600; 16 plants; in 1904—26,505,881 barrels; value $23,355,119; 75 plants; in 1908 it had reached 49 millions. I take my last figures from the paper recently read before the Canadian Engineering Society by Dean Galbraith.

While not being able to quote the exact figures for Canada's production, from the business in which we have been engaged during the last few years, it has at least been increased about one-and-a-quarter million barrels and with the two new plants here in Ontario and two near Montreal, you will be able to judge for yourselves its growth.

| Year | Canadian Barrels. | Imported Barrels. | |
|---|---|---|---|
| 1904 .......... | 910,358 | 784,630 | 1,694,988 |
| 1905 .......... | 1,346,548 | 917,558 | 2,264,106 |
| 1906 .......... | 2,119,764 | 694,503 | 2,814,267 |
| 1907 .......... | 2,436,093 | 672,630 | 3,108,720 |
| 1908 .......... | 2,665,289 | 457,408 | 3,122,697 |

Detailed statistics for past two years are as below:

| | 1907 | 1908 |
|---|---|---|
| Portland cement sold ........ | 2,436,093 | 2,665,289 |
| Stock on hand Jan. 1st ...... | 299,015 | 383,349 |
| Portland cement manufactured | 2,491,513 | 3,495,961 |
| Stock on hand Dec. 31st ...... | 354,435 | 1,214,011 |
| Value of cement sold ........ | $3,777,328 | $3,709,063 |
| Wages paid ................ | 956,080 | 1,274,638 |
| Men employed .............. | 1,786 | 3,029 |

There are about twenty-three plants in Canada, of which twelve use marl and clay and ten use limestone and one slag.

Nor can we say that this remarkable progress is to end here, for many have been the calls for the erection of plants, and one firm capable of nearly 3,000 barrels per day capacity, have if their machines run at their full capacity day and night until the end of the year, sufficient orders now to take all they make, and are thus seriously considering the duplication of their plant. If you will pardon an interpolation at this point, may I say that it is an erroneous conception of the manufacture of cement that has led people to believe that plants can be erected and worked profitably on a small scale and at small cost, and to disprove this theory will be in some respects the aim of this paper.

It would be advisable that we at this juncture acquaint ourselves with the material under discussion and find out what Portland cement really is.

There appeared in the Crawford (Nebraska) Tribune in 1906, an article in which the editor, evidently mutilating the words of Prof. Barbour of Nebraska, said: "Nebraska has almost inexhaustible beds of impure limestone, which is the material used in the manufacture of cement, but at the present prices of fuel this wealth of building material cannot be manufactured at great profit. The process of manufacture is very simple. Impure limestone mixed with sand is ground up and water added to make a thick paste. This flows through an iron pipe heated to a white heat so that the paste becomes dry and finally emerges from the end of the pipe as clinkers, which fall into a stone crusher, and pass between rollers, the dust falling into sacks ready for market." Now, gentlemen, this may be an exaggerated case apparently prepared for the mind of a western cowboy, nevertheless something of the above state of affairs exists quite largely in the large and busy cities of this country with regard to Portland cement and its manufacture, a school man asking me a few days ago if plaster of paris was put in to make cement harden.

Cement may be said to be a material which when pulverized and mixed with water into a paste, acquires the property of setting and hardening under water.

In engineering construction three kinds are known: Pozzuolana cement, natural cement, and Portland cement. Pozzuolana is obtained by grinding together an intimate mixture of slaked lime and blast furnace slag or volcanic scoria. The cement is not burned, the hydraulic ingredients being present only as a mechanical mixture, hence it never gained general acceptance. This must not be confused with slag Portland, which is regular Portland, the slag furnishing the silicious ingredients, taking the place of shale or clay in the mix.

Natural cement is the product resulting from the burning and subsequent pulverization of argillaceous limestone or other suitable rock in its natural state, the heat of burning being sufficient to cause vitrification. If, gentlemen, there were more time at our disposal, I might be inclined to give this a further consideration, but it must of necessity, owing to the title of my paper, be relegated to the background with a hope of further study on some future occasion.

Portland Cement.—In what follows in this paper the discussion will be now limited to Portland cement, so that whenever the unqualified term "cement" is employed, Portland cement alone is to be understood.*

Le Chatalier in 1897 published as his thesis for the degree of Doctor of Science a dissertation upon "The Experimental Study of the Constitution of Hydraulic Mortars," in which he propounded a theory that Portland cement was composed of two essential compounds, tricalcium silicate $3CaOSiO_2$ and tricalcium aluminate $3CaOAl_2O_3$. (Journal Soc. Chem. Ind. XI, 1035.) Spencer B. Newberry ten years later confirmed the views of Le Chatelier concerning the tricalcium silicate, but held to the theory that the alumina was present as dicalcium aluminate $2CaO.Al_2O_3$. In 1906, Day and Shephard (Am. Chem. Soc., XXVIII, 1089, also Chem. Eng. IV, 273) read a paper before the American Chemical Society in which they stated that no such compounds as tricalcium silicate exists and that the compound so called by others is a mixture of lime and orthosilicate (dicalcium silicate). We thus find within twenty years three radically different theories and we would expect that these revolutions of theory would have some influence upon the practical manufacture of Portland cement and the ultimate composition of the commercial product.

R. K. Meade analyzed a sample of cement in 1896 and one in 1906 and says: "I doubt if both samples had been drawn at either time, from cement made a few days apart, they could not have agreed more closely."

It must not be supposed, though, from what I have just quoted that cement is not better to-day than ten years ago; that would be fallacious, for in fact it is on an average very much better, but this progress has been due to the improved mechanical appliances rather than to any new ideas of how to make Portland cement, especially with regard to the fine grinding of the raw materials.

The generally accepted theory concerning Portland cement, which by the way is taught in the School of Practical Science, is the one propounded by Newberry, and which leads us as follows: Assuming that the trisilicate and dialuminate are the most basic compounds which can exist in good cements, we have the following formula: $X\ (3CaOSiO_2) + Y\ (2CaOAl_2O_3)$ in which X and Y are variable quantities having different values according to the relative proportions of silica and alumina present in the clay employed.

Ref.—Annoles des Mines, 1887, p. 345, also translation by J. L. Mack; McGraw Publishing Company, New York.

The formula $3CaOSiO_2$ corresponds to 2.8 parts of lime by weight to 1 part of silica.

The formula $2CaOAl_2O_3$ corresponds to 1.1 part of lime by weight to 1 part of alumina, and substituting weights for equivalents we have what is known as Newberry's Hydraulic Index, representing the maximum of lime which should be present in a correctly balanced cement. % lime = % silica × 2.8 + % alumina × 1.1. If we take lime and silica in the proportion of 2.8 and burn them thoroughly, we get hydraulic properties slow setting but ultimately developing great strength. We would draw from this the conclusion that the tricalcium silicate contributes to the cement its ultimate strength and hardness.

On the other hand, treat lime and the aluminate in their proportions above named, burn them thoroughly and on pulverization we get material which exhibits quick-setting properties and we thus judge that the dicalcium aluminate contributes to a cement its quick-setting properties, and that a cement high in the aluminate will be a quick-setting cement. Now taking the formula and using it to calculate the proportion of lime to be used for a clay of a known composition, we proceed: × % of silica by 2.8, the $Al_2O_3$ by 1.1, add the products; the sum will be the number of parts of lime required for 100 parts of clay.

As 2.8 parts of lime correspond to 5.0 parts of carbonate of lime and 1.1 parts of lime corresond to 2.0 parts of carbonate of lime, the calculation for factory work takes the following simple form: 5 times the % of silica + twice the % of alumina = the number of parts of carbonate of lime required for 100 parts of clay. A practical example: Suppose a clay on analysis had this composition: Silica 65.4, alumina 16.5, iron oxide 6.1, lime 2.2; magnesia 1.9; moisture, etc., 7.9; total 100. Let us calculate the amount of lime or carbonate of lime which must be added to this clay to produce a lime correct cement mixture.

| | |
|---|---|
| % silica = 65.4 × 2.8 = | 183.12 |
| % alumina = 16.5 × 1.1 = | 18.15 |
| | 201.27 |
| Less lime in clay | 2.20 |
| | 199.07 parts lime for 100 of clay. |

As 56 parts of lime correspond to 100 of carbonate of lime we have $\frac{199.07 \times 100}{56} = 355.5$ parts of carbonate of lime for 100 parts of clay, the correct mixture now reading:

Clay, 100 parts.

Pure $CaCO_3$ 355.5.

The % of carbonate of lime in this mixture would be 78%. On burning this a high grade cement would result, providing the raw materials were very finely ground and perfectly mixed and fully calcined.

You will understand, of course, that this represents, as was previously stated, the maximum of lime that may be used in safety.

Seeing that of late date magnesia and iron are allowed for, a correction by the way which seems advisable, I will endeavor to give the steps for proportioning a cement mixture accordingly.

Operation 1.— × % of silica in clayey material by 2.8, the % of alumina by 1.1 and the % of iron oxide by 0.7; add the products; subtract from the sum thus obtained % of lime oxide in the clayey material plus 1.4 times the % of magnesia. Call the result *n*.

Operation 2.—Multiply the % of silica in calcareous material by 2.8, the % of alumina by 1.1 and the % of iron oxide by 0.7; add the products and subtract the sum from the % of lime oxide plus 1.4 times the % of magnesia in the calcanous material. Call the result *m*.

Operation 3.—Divide *n* by *m*. The quotient will be the number of parts of calcareous material required for 1 part of clayey material. Example:

Assuming the following compositions of

| | Clay | Limestone |
|---|---|---|
| Silica $SiO_2$ .......................... | 62.2 | 2.4 |
| Alumina $Al_2O_3$ .................... | 16.1 | 2.0 |
| Iron oxide $Fe_2O_3$ .................. | 4.2 | 0.3 |
| Lime (CaO) ........................ | 1.6 | 50.2 |
| Magnesia (MgO) .................. | 1.2 | 1.5 |
| Sulphur trioxide ($SO_3$) ............. | 1.7 | 0.6 |
| Alkalies ($K_2O.Na_2O$) ............. | 0.8 | 0.4 |
| Water, $CO_2$ etc. ................... | 12.2 | 42.6 |

Operation 1. Clay—

| | | |
|---|---|---|
| Silica | $\times 2.8 = 62.2 \times 2.8 =$ | 174.16 |
| Alumina | $\times 1.1 = 16.1 \times 1.1 =$ | 17.71 |
| Iron oxide | $\times 0.7 = 4.2 \times 0.7 =$ | 2.94 |
| | | 194.81 |
| Lime | $\times 1.0 = 1.6 \times 1.0 =$ | 1.6 |
| Magnesia | $\times 1.4 = 1.2 \times 1.4 =$ | 1.68 |
| | | 3.28 |

$\therefore$ $194.81 - 3.28 = 191.53 = n$.

Operation 2. Limestone—

| | | |
|---|---|---|
| Silica | $\times 2.8 = 2.4 \times 2.8 =$ | 6.72 |
| Alumina | $\times 1.1 = 2.0 \times 1.1 =$ | 2.20 |
| Iron oxide | $\times 0.7 = .3 \times 0.7 =$ | 0.21 |
| | | 9.13 |

| | | |
|---|---|---|
| Lime | $\times 1.0 = 50.2 \times 1.0 =$ | 50.2 |
| Magnesia | $\times 1.4 = 1.5 \times 1.4 =$ | 2.10 |
| | | 52.30 |

$\therefore\ 52.30 - 9.13 = 43.17 = m.$

Operation 3.—

$$\frac{n}{m} = \frac{191.53}{43.17} = 4.44 \text{ parts of limestone}$$

to be used for each part of clay by weight.

Again let me remind you that the value given by the above formula represents the highest amount of lime theoretically possible, and under best conditions procurable at the present stage of the industry one needs to reduce this about 10% to get satisfactory results and we may therefore safely state according to above that

4.44 = parts limestone to one of clay.
0.44 = 10% reduction for safety.

4.00 = parts of limestone to 1 of clay to be actually used.

I would like to have given examples to you of the physical tests, but as these are taught in the university you will no doubt at a later date come into intimate contact with them.

Chemical analysis of the finished product is rarely resorted to as hardly any adulteration takes place owing to the fact possibly that it is just as easy to make good cement as a poor one, providing parties have sufficient knowledge of the essentials of its production.

I feel that I have hardly done justice to the most important phase of cement, namely the chemical, but I have attempted in a brief way to bring before your notice its composition and it will, I would presume, stimulate a greater interest in the discussion concerning its manufacture. Speaking personally, I do not feel in any way competent to discuss at great length the subject of which I am here to learn.

We are now fully prepared to deal with the raw materials, and one word here of warning: probably some of my hearers will be called sooner or later to pass judgment upon deposits of marl, lime, clays or shales respecting the advisability of putting in a cement plant. A great responsibility therefore rests upon such a one, and a few important things to bear in mind are:

1. Chemical composition of the material.
2. Physical character of the material.
3. Amount of material available.
4. Location of the deposit with respect to transportation routes.
5. Location of the deposit with respect to fuel supplies.
6. Location of the deposit with respect to markets.

Just a word with regard to No. 3, amount available. A plant running on dry raw materials such as a mixture of lime per kiln; of this about 15,000 will be limestone, 5,000 shale. and shale will use about 20,000 tons of raw material per year Assuming limestone weighs about 4,400 lbs. per yard and the shale 3,300 lbs. per yard, let us remember it would be folly to erect a plant on property with less than twenty years' supply. For each kiln of the proposed plant, then, there must be in sight at least 3,800,000 cubic feet of limestone and 1,600,000 cubic feet of shale.

With regard to fuel supplies, let us remember each kiln with the requisite crushing machinery uses up from 6,000 to 9,000 tons of coal per year.

There are two modes of manufacture of cement, the dry and the wet process, the difference in short being that in the dry process the material enters the kiln dry, while in the wet it is pumped into the rotary as a slurry. Many men have thought that using wet marl constituted the wet process, but such is not the case, for if the mix be dried previous to its entering the rotary it is called the dry process.

Taking the case of a limestone and clay. The limestone is quarried usually by blasting with dynamite and the opening should be so located as to give as little stripping as possible, for stripping is merely dead work, adding greatly to the expense of the product. The prevailing practice is to open up the quarry on a low hillside, so as to give a long working face and blast down in benches. The rock is sometimes loaded in cars hauled by locomotive or horses to the mill, but the better way is to have a cableway installed of the type to be shown in one of the slides, which has a great advantage and is called a twin cableway, and the two towers farthest from the mill are on rails so that they may be moved in any direction and thus facilitate the handling of the rock, also use of two buckets.

In a plant recently erected where the limestone is on the mountain side, the shelf has been cut sufficiently high to allow sufficient grade for cars to run down to the crusher by gravity and situated at the crusher dump is a short car haul lifting the cars onto a trestle bridge where they receive sufficient impetus to go back to the quarry without further aid. This has proved possibly the cheapest method of handling, but natural advantages of this description are not always obtainable. The material is dumped into a Gates crusher or one of similar type, the modern method employed by the largest plants in Canada being to have a No. 7 Gates crusher, the material falling from this into a perforated revolving cylinder, the pieces not going through the perforations falling down into a No. 4 crusher, the aim of the manufacturer being to get the rock into pieces from 1½ to 3 inches in size to make them easier to dry, the material having a like area submitted to the heat, all then being uniform with regard to moisture.

Provision is made for the storage of hundreds of tons of the rock so that in case of bad weather when men cannot work in the quarry, the mill will not suffer and sufficient is usually stored for seven days' run.

The first crusher will take rocks up to 18"x45", and is capable of breaking about 120 tons per hour to 2½", driving pulley running about 350 R.P.M. with a 110-h.p. motor and is worth about \$6,000; while the No. 4 will take the pieces from the cylinder and handle them with a 50-h.p. motor very easily, the price of this being about \$3,000. The two motors will cost about \$2,000.

The rock is taken from the storage by the same conveyor used for filling the storage, the best type being what is known as the Peck overlapping bucket conveyor, which is essentially an endless chain of buckets, each pivoted to a bar so that they might swing on their central axis and maintain an horizontal position when running up the towers. This conveyor runs about 150' per minute and is worth, installed, about \$15 per foot, and is without doubt the most expensive style of conveyor in modern use, but its perfect running and the fact that it never gives occasion for stoppages fully warrant the initial expenditure.

I will endeavor to explain the different modes of conveying and their relative values by means of the slides later.

The material is carried by this to hoppers placed above a dryer, which is, as you will see by drawing exhibited herewith, an iron cylinder about 5' in diameter and 50' to 80' in length, set at an inclination of about ¾" per foot, turning at three revolutions per minute. Inside are four plates (perforated) projecting out from the sides to within eight inches of the imaginary centre. The material is fed through a water-jacketed cast-iron pipe and fire applied by means of a furnace whose gases play directly into the dryer. From this the dry rock is elevated to the Ball mills for grinding. There are several types of pulverizing mills which are used at this stage, one well known and at one time largely used being the Griffin mill, of which I will show a picture later and which I will then describe. There is also the Kent mill, Huntingdon, Lehigh pulverizer and Kominuter. Ball mills are made by a number of manufacturers but the types mostly found in cement plants are the Schmidt, Gates, and Krupp; there is very little difference in their mechanism. I have here for your notice drawings of a Ball mill. The machine has a through shaft with journals running in bearings at both ends. The machine consists of a drum with two strong end plates between which curved drum plates are fixed. These plates do not form a cylinder, but one end of each is set a few inches nearer the centre, thus forming steps, the balls and material falling over these steps when the drum revolves and thus the material is pounded. The drum is surrounded externally by a fine cylindrical phosphor bronze or steel wire gauze fit in narrow sections so that they may be taken out and replaced with finer gauze according to degree of fineness required: the ones often used are 20-mesh \$125 phosphor bronze wire open

.05 — 016 = .034″. Each section requires piece of screen 27″x51″ and twelve to each mill.

The Ball mill contains iron balls as follows: 87 5″ balls, 18 pds. each; 128 4″ balls, 10 pds. each; 300 3″ balls, 5 pds. each; net 4,366 lbs.

The drum revolves at 21 R.P.M., requires a 75-h.p. motor and can grind to a residue of 76.2% on a 100 sieve 21 barrels per hour. A Griffin mill will reduce about 5 bbls. per hour to 95% pass a 100 mesh.

From the Ball mills the rock is transferred by means of a screw or spiral conveyor to large steel wood-lined bins. Experience has led us to always keep steel from contact with the rock or cement as the steel sweats and moisture is thus imparted to the material, while the main idea is to keep it dry. It is during its storage in this bin that the rock samples are taken and analyzed, the bin being partitioned off into six divisions. After analysis it is ready for the scales. While this process has been going on a similar process with the exception of the use of a Blake crusher for reducing to size, has been going on with the clay, and we find bins of like manner but much smaller now filled with coarse ground clay which is awaiting the verdict of the chemist. After the report has been received from the chemist the materials as per his instructions with regard to weight, are now weighed.

From the weighing hoppers the two materials are dropped simultaneously into a screw conveyor which to some extent mixes the two, which is now called the "mix." The mix is elevated and conveyed to hoppers above the tube mills and is automatically fed into them, and by constant turning in the tube becomes perfectly mixed as well as perfectly pulverized.

The tube mill is a cylinder usually about 5′x22′. It is filled to 4″ above centre line with flint pebbles. The mill makes 27 R.P.M., contains about 11 tons of pebbles and requires about 64-h.p. motor. They will grind that 95% pass 100 mesh and residue a 20 mesh. Their capacity is about 13 bbls. per hour, but here are records in which a mill ground 5,854 yards in 963 hours, or 6.07 yards per hour; on another occasion 8,493 yards ground in 1,357 hours, or 6.2 yards per hour. A mill is worth about $2,500 and thus with Ball mills at $4,500 a battery will figure installed at about $10,000.

and is taken to an elevator and lifted to a large bin standing

The mix leaves the tube mills, falls into a screw conveyor above the rear end of the kilns.

We have now arrived at the most important branch of Portland cement production. Given the best chemists and an absolutely perfect mix for combination, carelessness at this stage would prove disastrous.

The rotary kiln as at first used in cement manufacture was only 40′ long and at Sandusky, Ohio, some sixteen years ago two were joined together and new gearing placed in under the superintendence of R. D. Hassan, in conjunction with our foremost cement chemist, Mr. S. B. Newberry. This so revolutionized the manufacture that engineers in the cement industry after visiting Sandusky immediately adopted it and it has been little changed since.

I have here drawings of the friction wheels and driving gear as they are used to-day.

The 80′ rotary, then, is practically the most universal, although at present time we are using 90′ and will in the next factory put in 100′ kilns. Allow me to here state that where the wet process is used the longer the kiln the better, and 150′ is about the most economical for such purposes. They range from 6′ to 9′ in internal diameter. Lined with very resistant fire brick about half-way down the kiln from 6″ to 10″ in depth to withstand both the high temperature to which its inner surface is subjected and also the destructive action of the molten clinker. Our present kilns are not always of equal diameter throughout, some being smaller at the stack end, accomplished by means of a reducing section just beyond the middle in the shape of a frustum or cone.

The theory being based on the gases cooling as they near the upper end should be confined to a smaller area to keep their efficiency.

With a 90′ rotary pushing it very hard it is possible to get 240 lbs. per day.

For the firing of the kiln and burning of the cement, oil, gas and coal have been used. Natural gas is used in some plants both in the States and here in Ontario, and the chief objection is that you cannot force a kiln with gas like you can with coal. Oil is generally accepted to be the best and was certainly at one time the cheapest material for burning cement, 1 gallon of oil being equivalent to 12 lbs. of coal, or 1 lb. of oil = 2 lbs. of coal.

The question of fuel consumption is the one which agitates the mind of the cement manufacturer and it is in this feature possibly more than any other which offers best prospect of improvement in the matter of economy. Owing to diversity of conditions at different factories a calculation can only be approximate. The amount of coal used in burning a barrel of cement is about 110.120 lbs. for dry material and 150 to 160 for wet material 50% water.

The actual burning of cement consumes a definite amount of heat which is absorbed in evaporating, the water contained in the material heating up the dry mixture, decomposing the carbonate and sulphate of lime present, heating the gaseous products to the stack temperature and finally heating the calcined material to the point of sintering. As the specific heats of decomposition of all these substances are known it is possible to calculate approximately the number of heat units and amount of fuel which should theoretically be required to produce a barrel of cement under various conditions.

Let us assume the use of a coal which has a theoretical value of 13,400 heat units and for its combustion requires 10.2 lbs. of air per pd. of coal. Assuming that the temperature of the kiln building is 70° F. and products of combustion escape as they often do at 1500°, we will work out that

| | |
|---|---|
| 2.75 lbs. $CO_2$ sp. ht. .22 at 1500 = | 871 |
| .464 lbs. water sp. ht. .48 | 321 |
| 8.065 lbs. N. sp. ht. 24 | 2,794 |
| | 3,986 |

If 50% more air be added than theoretically required this will absorb 1,763 h.u. The available heat of 1 lb. of this coal will therefore be 13,400.

Products of combustion consume 3986, then heat units available with theoretical air will be 9414 and 50% more air consumes 1763; the heat units available with 1½ theoretical air will be 7,651.

Let us now assume the mix is $CaCO_3$ 75%, $SiO_2$ 15, alumina and iron oxide 5, mg. and alkalies 2.0 combined, water 2.0, $SO_3$ 1.0. 600 lbs. of this mix will give 384 lbs. of cement, the balance representing $CO_2$ water and $SO_3$ passing off in gaseous form at stack temperature.

The heat units will therefore be the mix introduced at the upper end in the form of dry powder and the clinker discharged white hot at a temperature of about 2,500° *F.* and the gaseous products leaving the kiln at 1,500° *F.*

| | | |
|---|---|---|
| 450 lbs. of carbonate of lime decomposed at 765. . | 344,250 | 54.7 |
| 12 lbs. of water evaporated and heated 60° to 1,500° . . . . . . . . . . . . . . . . . . . . . . . . . . | 20,832 | 3.3 |
| 6 lbs. of sulphuric anhydride liberated at 1,890 . . | 11,340 | 1.8 |
| 600 lbs. of mix, heat 60° to 1,000° sp. ht. .2 . . | 112,800 | 18.0 |
| 384 lbs. of clinker heated 1,000° to 2,500° sp. ht. .2 | 115,200 | 18.3 |
| 204 lbs. of carbon dioxide and sulphur dioxide heated 60° to 1,500° at .24 sp. ht. . . . . . . . . | 24,480 | 3.9 |
| | 628,902 | 100 |

∴ coal required per barrel of cement

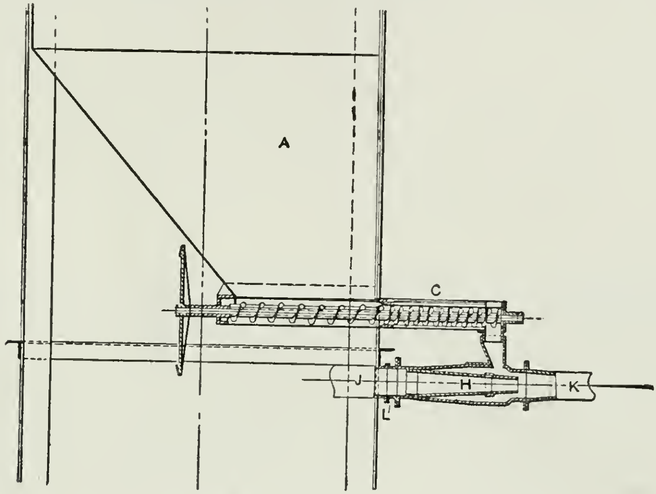
With theoretical air supply 628,902 ÷ 9,414 = 66.9 lbs.

With 1½ times theoret. air supply 628,902 ÷ 7,651 = 82.2 lbs

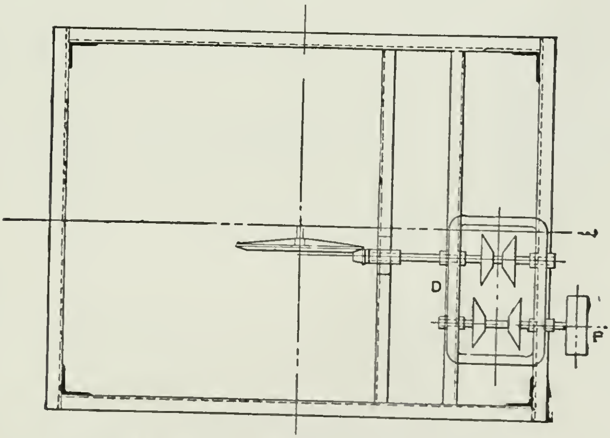
Actually used by us in manufacture, 120 lbs.; difference about 40 lbs.

The above computations are only approximate, but you will readily see that the clinker discharged at 2,500° *F.* will if cooled to 60° give up about 185,000 heat units or enough to heat the theoretical air supply from 60° to 1,143 or 1½ times the theoretical air to 932°. With this in mind the clinker is allowed to drop into a pit from whence the gases and hot air are conducted by means of ducts to the fan for air supply and also to the coal grinding department for use of drying the coal, the hot air being allowed to escape into a rotary drying kiln in which the coal is being passed through.

There is, of course, the gas of the stack yet to deal with, and this could be utilized in much the same way by leading it back over the kiln and using it for air supply, but the foremost cement expert is anxious to keep abreast with the times and is sacrificing




DETAIL ELEVATION OF FEEDING MECHANISM




DETAIL PLAN OF VARIABLE SPEED MECHANISM

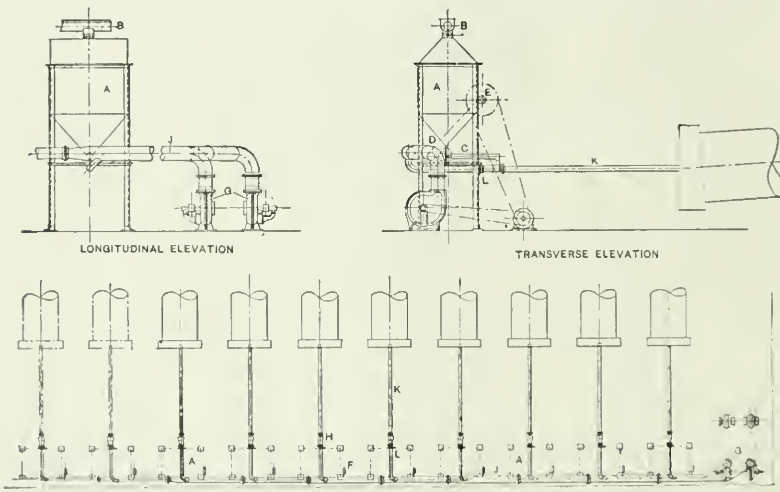
Coal-burning Arrangement, International Cement Co.

at the present time these gases, engaging himself in the design and perfecting of a mode of burning cement by electricity, in which I naturally wish him every success.

The method of feeding the coal into the kiln I will explain by means of a slide later.

Although some seven or eight years ago the clinker on leaving the kiln was run into towers or cylinders for cooling, the modern method is to transfer it to a storage and let it cool gradually itself, capacity being made for about 100,000 barrels. These bins are filled by means of a continuous conveyor which runs in a tunnel below, then up a tower and covers the entire distance of the rotaries, thereby can be made to dump the clinkers into any part of the storage, so that while one end is being filled with hot clinkers, the cold is taken from the opposite end to the Ball mills for grinding.

After the preliminary grinding by the Ball mills, the material is conveyed to scales, where the right proportion of calcium sulphate or gypsum is added to retard the setting. Just a word here with regard to the addition of gypsum. The high limed clinker which is produced in the rotary process is naturally very




Coal-burning Arrangement, International Cement Co.

quick setting and in order to retard this somewhat, sulphate of lime in the form of gypsum is now universally employed. If added in quantities from 2 to 3 % it retards the set of the cement proportionately, and, strange to say, increases slightly the tensile strength, but in greater quantities its retarding influence becomes less and finally negative. Considerable discussion has taken place as to in which form the calcium sulphate should be added. Crude gypsum is natural hydrous sulphate of lime, formulae $CaSO_4 + 2H_2O$. Plaster of Paris is obtained by heating gypsum at 350 to 400° *F.*, the result being that three-fourths of the $H_2O$ is driven off and we have $2CaSO_4 + H_2O$. If this be calcined at temperature above 400 we get the anhydrous plaster or simply $CaSO_4$. A misleading statement has been made, which is in brief that plaster of paris because of its greater chemical activity will be more effective than gypsum, weight for weight. The fallacy involved is revealed when it is considered that the calcium sulphate added to the cement has absolutely no effect until the mixture is gauged with water; and this addition of water will naturally reconvert the plaster of paris immediately into the hydrous lime sulphate, gypsum. Any argument based on relative chemical activity, so called, is therefore fallacious and the sulphate is usually added as gypsum, corresponding to formula $CaSO_4 + 2H_2O$.

The mixture going through the tube mills becomes intimately mixed and is ground to finished product and then conveyed to the warehouse, where provision is made for about 100,000 lbs.

The bins are usually of plank construction, starting with

Exshaw Cement Plant under construction, showing machines on foundations

layers of 2x10 for about four feet, then 2x8, then 2x6, and 2x4 to finish. The material is thus kept from moisture. For preparing for shipment it is conveyed by means of a spiral or belt conveyor in a tunnel to packing room, where it is elevated to hoppers under which are placed scales working automatically, and although their capacity is to bag four per minute, I have run them at six per minute for a considerable period.

In this country a bag contains 87½ lbs., while in the United States they are shipped at 95, four bags to a barrel making a Canadian barrel 350 lbs., and the American 380 lbs.

We have made cement at as low as 55¾ cents per barrel, but if you make them for 90 cents it is considered good work.

A modern six-rotary plant will cost about $800,000, and with a reserve amount of $25,000 per kiln to allow for time, etc., to put the cement on the market, you will readily understand that a million dollars is about the necessary capitalization for a plant to be built and operated successfully. Although we have only built two plants in this country they are the largest and acknowledged to be the best equipped and most modern in the country. One of them last year closed the financial year showing a payment of 18% dividend with $68,000 put to a sinking fund, bringing that up to $250,000.

Never having one bag of cement returned is the record, due I believe to this fact, that the materials during the different stages act so treacherously that it can be said upon the chemist literally hangs the responsibility. I am about to show a diagram showing with what completeness the materials are tested. You will notice sixteen separate tests are made and these through improved storage capacity are made each hour. The samples are being constantly collected. I will show the method.

The two raw materials are correctly analyzed and accurately proportioned before they enter the mill, then a distinct bin analysis is made before mixing.

It is an utter impossibility to produce a uniform Portland cement without a definite mixture of the ingredients or raw materials, hence the great importance of a perfect chemical and mechanical arrangement to accomplish this purpose.

By reason of the prominent place Portland cement now holds in the building arts, more attention is being given to quality by the architect, engineer and builder than ever before in the history of the industry, and it may reasonably be predicted that in the near future the government will inspect and grade cements as they now do other commercial commodities.

NOTE.—During the lecture numerous slides were thrown on the canvas and raw materials in various stages of manufacture were handed around for inspection.—ED.

# NOTES ON THE CONCENTRATION OF SLIMES

F. C. DYER.

If we shake some crushed rock with water and allow it to subside, we notice a coarse part settles almost immediately—that we call "sands"—and another portion that settles but slowly, and is termed "'slimes."

The terms "sands" and "slimes" are two convenient but loosely applied words. Some writers say "slimes" when fairly coarse sand is included, others restrict the word "slimes" to that finest portion of all, that settles with extreme slowness.

Canvas is peculiarly adapted to catch fine slimes. Mechanical difficulties in making it travel over rollers in belt machines have hindered its use to some extent. Vanners are on the market with canvas belts. Either as a stationary intermittent table or as *slowly* travelling continuous belts it is able to catch smaller particles than any other table..

An attempt was made to observe the movements of particles on a canvas table, with a low power microscope.

It was noticed that the rough hairy surface caused the bottom layer of water to move with unusual slowness favoring the settling of fine particles.

2. The small ridges formed by the crossing of the warp and woof act as riffles, collecting the concentrates, but owing to the slowness of the water at the bottom the cleaning was imperfect.

3. The loose fibres entangle mechanically fine particles that would otherwise float off. Both ore and gangue particles are caught, hence the concentrates from a canvas table are rather lower grade than from other tables. Against this may be set the facts that canvas tables are cheap and catch what would be otherwise lost.

Measurements were made of the size of the smallest particles a canvas table would catch. The same ore was used as in other tests. The coarser slimes were taken out with a slime table. The canvas table had just slope enough to carry off the visible white quartz tailings.

The concentrates were sluiced into a pan, allowed to settle three minutes, and the water with the fine particles in suspension poured off. These particles were given time to settle and measured with a micrometer microscope.

The average diameter was .19 mm or about .0075 inches. With concentrates of greater specific gravity, finer particles still would probably be caught.

The Wilfley slimer, though a canvas table, is painted The hairs are "layed" and the "riffles" partially filled up, therefore probably it cannot catch such fine particles as fresh canvas surfaces.

The rubber belts of Vanners are sometimes finely corrugated or riffled to catch more concentrates.

If the waters in the launders and on the tables is carefully examined it will almost always be found to have particles of concentrates floating on its surface.

If by any chance the concentrates become exposed to the air, as soon as the water again touches them a stream of concentrate particles will float out on the water.

This paradoxical floating of high specific gravity particles on water of low specific gravity is the misnamed Greasy Flotation.

Though small at any particular place, this loss multiplied by the long time it operates may amount to a serious quantity in the operation of a large mill.

Sometimes an inclined blade dipping below the surface of the water is placed across launders to force floating particles below the surface. [1]

The term "floating" here always refers to particles swimming *on* the surface while "suspended" refers to particles swimming *below* the surface.

A more serious and difficult loss to prevent occurs in the suspended particles.

Since the volume of a sphere diminishes as the cube of the radius and the surface only as the square, a point must be approached when the resistance to a particle settling, which depends on the size of the particle, must approximately equal the weight which depends on volume. The closer this approximation, the more slowly the particles fall.

The reasons for slow settling of fine slimes are referred to later.

Since a sphere has a maximum volume for a given surface suspended particles of different shape may be comparatively large and have a slower settling rate than spheres.

To illustrate the loss that occurs in the various sizes of particles, an ore of chalcopyrite and quartz was sent over the tables. The ore was crushed under stamps, the coarse sands removed by a classifier and sent to a Wilfley table. The fines were sent to the slime table. Samples of the feed and tails were taken at intervals. They were dried screen sized and weighed. The assaying was done by the Guess-Haultain electrolytic method.

In the drying the finest particles tend to flocculate and even to form hard lumps, and to stick to the larger grains. Gentle rubbing was employed to disintegrate the floccules, but the weights are only approximate, the finest size through 200 mesh probably being most underweight. If great accuracy were required elutriation methods would be necessary. The assay value of the finest sort will be correct, that of the others slightly high.

1 Callow Mining, Vol III, p. 91.

The following table shows the weights and value of the feed to a slime table:

FEED.

| Mesh of Screen | | Per Cent. of Weight | Assay Value Per Cent. of Copper | Per Cent. of Total Copper |
|---|---|---|---|---|
| On | Through | | | |
| 100 | — | 20.49 | 1.88 | 10.8 |
| 120 | 100 | 8.05 | 2.02 | 4.6 |
| 150 | 120 | 3.55 | 1.71 | 1.7 |
| 200 | 150 | 12.92 | 2.64 | 9.3 |
| — | 200 | 53.92 | 4.85 | 73.3 |
| — | Loss | 1.07 | — | — |

The loss is almost entirely of the finest size. Note, over 50 per cent. passes through 200 mesh and carries over 70% of the total values.

Similarly the tails were screen sized and assayed. Small differences will be noticed in the percentage of sizes of feed and tails, due to the difficulty of making an exact separation. The difference is not enough to affect the conclusions drawn.

Again, note the high percentage of finest sort with high assay value, and that this same size carries over 90% of the total loss.

The following table gives the weights and values of the tails:

SLIME TABLE TAILS.

| Mesh of Screen | | Per Cent. of Total Weight | Assay Value Per Cent. of Copper | Per Cent. of Total Copper |
|---|---|---|---|---|
| On | Through | | | |
| 100 | — | 19.5 | 0.25 | 2.1 |
| 120 | 100 | 8.29 | 0.28 | 1.0 |
| 150 | 120 | 3.78 | 0.28 | 0.5 |
| 200 | 150 | 11.08 | 0.54 | 2.6 |
| — | 200 | 55.74 | 3.80 | 93.7 |

Similar results were obtained on another slime table.

SLIME TABLE TAILS.

| Mesh of Screen | | Per Cent. of Total Weight | Assay Value Per Cent. Copper | Per Cent. of Total Copper |
|---|---|---|---|---|
| On | Through | | | |
| 120 | — | 22.8 | 0.27 | 3.7 |
| 200 | 120 | 21.0 | 0.30 | 3.9 |
| — | 200 | 56.2 | 2.67 | 92.3 |

On both tables over 90% of the loss occurred in the finest sizes.

Between molecules exists a state of mutual attraction—a particular form of the universal force of gravitation[1]—of extremely small range.

The molecular attraction is sometimes said to be "insensible at sensible distances."[2]

Though limited in range this force is very powerful.

In the case of a water and air surface the sum of attractions on the water side of the surface is much larger than on the air side, where the molecules are much scarcer. The net result is the attraction of each molecule on the surface towards the interior of the liquid.

If the mass of water is sufficiently small it will take a globular shape. The result is exactly as if the outer layer of molecules were an elastic contractile skin. This effect is known as surface tension. The amount of the tension has been calculated by Sir W. Thompson as 75 dynes per lineal centimetre.[3] A good illustration of the immense force exerted by these surfaces is given by Tait.[4]

Two glass plates 6″ square are separated by a film of water 1/200″ thick. The meniscus of water around the edge of radius 1/400″ exerts a pull of between 6 and 7 lbs. in addition to the adhesion over the surface.

If a solid body instead of air is touching the water the number of molecules on each side of the surface of contact will be more nearly equal. If the attraction by the solid molecules is greater than the water surface tension the body will be wetted. Otherwise the solid will be "nonwettable."

Now, consider a solid particle immersed in water. Let it be unwettable. Allow it to come to the surface. The adhesion between solid and water is less than the surface tension of the surfaces, therefore the film of water will be torn from above the particle. The surface tension tends to pull the whole water surface into a spherical shape, hence the particle is ejected and supported by the outer film of water. A hollow will be formed in the water surface to produce hydrostatic equilibrium. The particle will float unless the weight is great enough to overcome the surface tension.

The maximum size of a particle that can float by greasy flotation depends on the surface tension of the water, the adhesion between water and solid, the length of circumference at the water line and the weight of the particle, or the more irregular and flakey and the more nonwettable, the larger the floating particle.

A wetted particle can never come to the surface. Adhesion

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1 Sir W. Thompson. Constitution of Matter, p. 49.
2 Hawkesbury. Trans. Royal Society, Vol. XXVI, p. 1700.
3 Sir W. Thompson. Constitution of Matter, p. 49.
4 Tait. Properties of Matter, p. 247.

will always keep a film of water over it and render "greasy flotation" impossible.

Now, let the nonwettable particle grow smaller and be immersed. As the radius of curvature decreases the resultant of the surface tension towards the centre of the particle will increase. This resultant plus the attraction between the solid and liquid particles will at some point equal, and then exceed the surface tension of the liquid. The film of water surrounding the solid will be bound firmly to it, and the fine "nonwettable particles act as though wetted, and "greasy flotation for them ceases, consequently there is an inferior limit to the size of floating particles that can emerge. Measurements confirm this.

"Greasy flotation" particles were skimmed from the surface of the water of a table running on chalcopyrite ore. At the same time a portion of the water with its suspended particles was taken in another dish.

The particles were transferred to glass slides and measured with a micrometer microscope. In each field of view a number were actually measured, the size of the remainder estimated by comparison. The numbers of each size were counted. Many thousands of particles were thus measured.

Several days later the experiment was repeated with another lot of ore.

The results are shown on the accompanying curves.

The largest particles are not more than 1/3 of a millimeter. These were flaky triangular pieces. The lower limit appears to be in the neighborhood of .076 mm. Many of the finer particles were carried over with the water when collecting the floating particles and many others would be carried by adhering to the larger particles.

The maximum size of the suspended particles lies between .04 and .03 mm.

No method is known by which a comparison can be made between the sizes found and the theoretical sizes.

"Greasy flotation" has been employed to separate chalcopyrite from its ores. In the MacQuiston process the ground ore is repeatedly poured on the surface of a stream of water. The wettable quartz sinks, the nonwettable floating

The machine consists of four tubes 6'x1'-feet with helical 1½" pitch grooves inside. Tube revolves 3 revolutions per minute. No chemicals are used.[1] It should be remembered that particles too fine to come to the surface are too fine to sink through the surface tension film.

Now, let us consider a bed of wet grains. These grains, if only loosely packed, have a considerable amount of water between them. They easily move on one another. The heavy ores can go to the bottom, the lighter to the top.

If the bed be left undisturbed the particles settle closer

1 Selwyn-Brown. Engineering Mag., Sept. 1908, also Can. Min. Journal, p. 530.

together, the water between particles, if they are wettable, becomes reduced to a mere film, which adhering to each particle acts as a cement.

"Hillgaard regards the particles as irregular spheroids, each of which can contact at best at 3 points with other particles, the cause of aggregation therefore cannot be surface tension, independent of the liquid, and the particle being submerged, there is no meniscus to create adhesive tension. Since experiment shows that the flocculative tendency is measurably increased by the *cohesive coefficient* of the liquid, it seems necessary to assume that capillary films of the latter interpose between the solid surfaces and create adhesive tension."[1]

Why unwettable particles should form a solid bed is not so easily seen. The particles touch each other at points. The spaces between are filled with water. The surface tension drags at the films around the points of contact, attempting to assume a spherical shape of surface, and so pressing together and binding groups of particles more firmly than simple adhesion could. Hence a bed of nonwettable concentrates is solider than a bed of wettable feed.

The object of the vibratory motion on Vanners is to take advantage of this superior solidity of the concentrates and to loosen up the feed alone.

A particle of concentrates coming into contact with a layer of previously deposited concentrates is gripped and held. In this respect these tables have an advantage over jerking tables where no solid bed can form.

The tendency of nonwettable particles to stick to nonwettable particles under water has been advanced as the reason for the peculiar suitability of linoleum for table tops.

Linoleum is composed of grains of cork embedded in a matrix of oxidised linseed oil, of which one material is presumed to be more wettable than the other.

The film of water is anchored down by the wetted parts and bridges over the nonwettable to which the nonwettable grains would stick.

If a drop of water is allowed to run over the surface of linoleum the thin edge where the water was on the point of drying would present a jagged appearance if the above mentioned difference of adhesion was present, but only a smooth continuous edge was found, consequently it must be considered that the friction of the surface is the important thing.

Of all liquids except mercury, water has the greatest surface tension. The use of mercury is usually out of the queston because of its density and price.

If some means could be found to considerably raise the surface tension of water, concentration by "greasy flotation" could be applied to many more minerals and would become a most valuable process. Surface tension can be altered by the

1 Whiley Agric Analysis, Vol. III, p. 180.

addition of different substances, thus surface tension diminishes with increase of temperature[1], the addition of fusel oil reduces it enormously.

A bubble of air or any gas is nonwettable. Many metallic sulphide particles are nonwettable. If the air bubble touches the particle the water forms a meniscus around both, and the bubble sticks to the particle. If enough bubbles stick the grain will float. This is the basis of most flotation processes.

The plan was devised by C. V. Potter at Broken Hill, N. S. W. Acid acting on a carbonate produced bubbles. It was used on zinc-lead ores. It has been superceded by similar but more efficient processes.

Most minerals when exposed to the weather tarnish. The thin film of oxide alters the adhesion and the particle becomes wetted and the bubbles will not stick. To overcome this difficulty acid, usually crude sulphuric, at the rate of 10-20 lbs. per ton, is added to the pulp. It removes the tarnish. It may to some extent alter the surface tension. Common pyrite separates well with acid alone of less than 1% strength.

Other liquids have the property of wetting some bodies and not others. Among these is oil. It has great adhesiveness for some metallic sulphides, but for wetted surfaces none at all. Water will wet gangue minerals but not the metallic sulphides. If an ore is treated with water first and then mixed with oil, the sulphides become oily, the other particles wet. The difference of surface tensions on the gangue and sulphides is greatly increased. Bubbles, being nonwettable, now more readily attach themselves to the greasy particles.

To complete the operation several methods are employed.

The acid-oil process is as follows: Sands and slimes containing about 18% water are agitated with 10-15 lbs. $H_2SO_4$ and 1 lb. crude mineral oil per ton of 2240 lbs. The mixers are heated to 120° F. The mixed pulp is then sent through $5\times5\times5$ ft. V spitskasten and the concentrates floated off. A certain amount of calcite provides $CO_2$ bubbles which attach to the concentrates of zinc and lead sulphides. At Broken Hill the recovery averages 68% of the silver, 80% of lead, 75% of the zinc.[2]

The Krupp process employs heat to expand the bubbles and increase their carrying power. The mixer is a high, narrow cylindrical tank. The flow of concentrates over the top is regulated by the inflow of feed and the outflow of tailings at the bottom. A hot solution of 1% sulphuric acid is admitted through leaden pipes at the bottom.[3]

The Elmore oil process uses an excess of oil, which floats to the surface, carrying the sulphides with it. The oil and acid are mixed in a trough with wooden stirrers. It then passes to

1 Tait, Properties of Matter, p. 247.
2 Williams, Eng. & Min. Journal, 1908, p. 803
3 Eng. Min Journal, No. 86, 830-42.

separators where the oil and watery tailings separate. The oil is turned into a fast-revolving cylinder. The concentrates cake by centrifugal force on the outer wall of the drum. Excess of oil and water flow over the top.

The concentrates are removed at intervals.[1]

The Elmore vacuum process which is the most promising of the acid-oil processes, employs a vacuum to expand the air bubbles. Enough air is contained in ordinary water to supply the bubbles under diminished pressure.

Only enough oil is used to wet the sulphide particles—5 to 10 lbs per ton. Acid is added at the rate of 10 to 15 lbs per

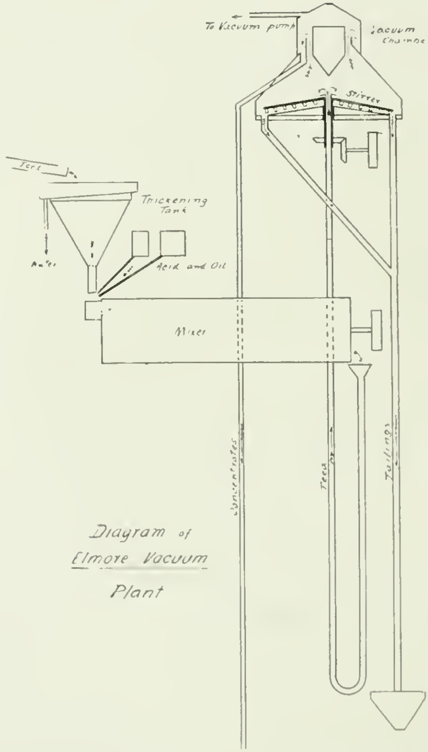



Diagram of Elmore Vacuum Plant

ton. The pulp is stirred in a mixer as in the Elmore oil process. From the mixer the pulp passes up one leg of a syphon and down the other. The upper end of the syphon is enlarged into a chamber several feet in diameter. A revolving stirrer assists the separation of the concentrates as the pulp passes over the floor of the chamber. A vacuum pump removes the air liberated and preserves the continuity of the syphon. The concentrates descend from the surface of the water by a third leg of

1 Eng. and Min. Jour. Vol 74, p. 371. Vol. 75, pp. 262, 292.

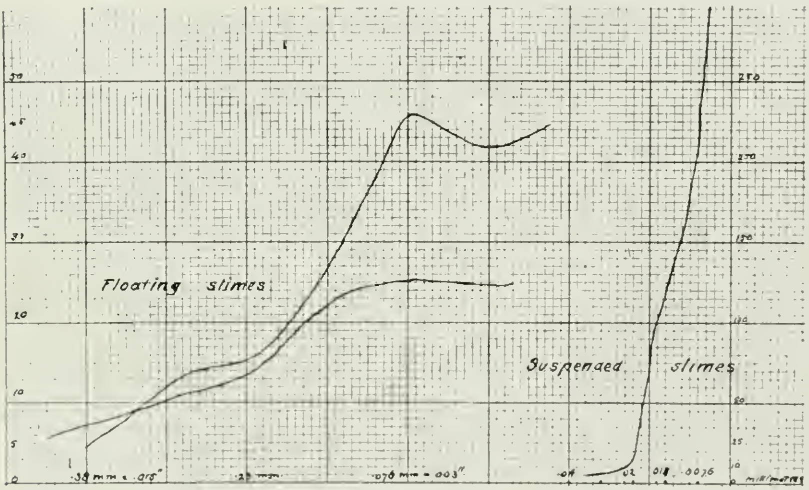
the syphon. The amount of oil used is too small to pay for saving.

This method has a high efficiency, extraction running from 80 to 97 per cent.[2]

Its low working costs render it suitable for low grade ores, having been brought as low as 60 cents per ton.[1]

Another process uses solid greases instead of oil. Crude vaseline is applied by means of a roller and a bath of melted grease to a canvas belt with a woollen face. The belt is set at a steep incline 45° or more and travels upward at a rapid rate two hundred feet or more a minute. The steeper the belt the greater the speed.

The sulphides stick to the grease as the pulp runs down the belt. The rich outer layer of grease is removed by a scraper




and falls into the bath of hot grease. The concentrates sink to the bottom, the grease being used over again. Excess of vaseline is removed by a centrifugal separator similar to Elmore's.

A small board 10 feet long, 1 ft. wide with 1" sides and properly stiffened, was used to make tests of this process. Vaseline was liberally smeared over the board. This grease table was set at a slope just sufficient to create a velocity of flow enough to carry quartz tailings along. Chalcopyrite and quartz ore was choke crushed with a Blake crusher. The over size on a 30 mesh screen was rejected. The remainder was mixed and sampled, 1 kilo was weighed out and thoroughly wetted with water. The slimes were poured into a separate can. The

1 Literature of Ore Concentration, etc., London
2 Can. Min. Inst., 1908, p. 461

coarse particles were poured over the table and repoured three times, each time being followed by a wash of water to clean off the last of the tailings. The surface was rubbed between each pouring to present a fresh surface of vaseline.

The fines were then treated similarly, being poured over the table 10 times.

Examination of the coarse showed it to contain grains of pyrite so large that the flow of water carried them off the board.

The fines still contained pyrite and so the operation was repeated 5 times more.

Area of board 10 sq. feet, therefore the coarse passed over 40 sq. ft. and the fines passed over 150 sq. ft. of grease.

The tailings were dried screen sized and assayed.

The vaseline was scraped from the board, melted on a water bath and the clear vaseline poured off.

From the concentrates the remainder of the grease was removed by gasoline and the concentrates assayed.

This table gives the results:

| | Wt. | Assay Val. | Total copper. |
|---|---|---|---|
| Feed | 1000 grms. | 4.15% | 41.5 grms. |
| Conc. | 103.9 grms. | 28.26 | 30.13 grms. |
| | 6.3 grms. | 19.4 | |

This gives an efficiency of 72.6 per cent. The tailings assay is in the following table:

TAILINGS.

| Size of Screen On | Size of Screen Through | Weight in Grams | Assay Value | Total Amount Grams Copper | Per Cent. of Loss |
|---|---|---|---|---|---|
| 40 | — | 186.51 | 2.18 | 4.06 | 36.0 |
| 60 | 40 | 314.40 | 1.41 | 4.44 | 39.3 |
| 80 | 60 | 87.73 | 0.54 | 0.48 | 4.3 |
| 100 | 80 | 73.70 | 0.36 | 0.27 | 2.4 |
| 120 | 100 | 30.71 | 0.41 | 0.13 | 1.1 |
| 150 | 120 | 21.36 | 0.55 | 0.11 | 1.0 |
| 200 | 150 | 71.05 | 0.69 | 0.49 | 4.3 |
| — | 200 | 102.31 | 1.28 | 1.31 | 11.6 |

These results show the chief losses to lie in the largest and smallest sizes.

A second experiment was tried with the same crushed ore that had lain exposed to the air of the laboratory for two weeks. The saving was extremely small owing to the oxidation of the surfaces of the copper pyrite.

A fresh portion was crushed as before, sifted through an 80 mesh screen to remove the coarsest grains. The efficiency was raised to 82.3%, most of the loss being in the fine sizes.

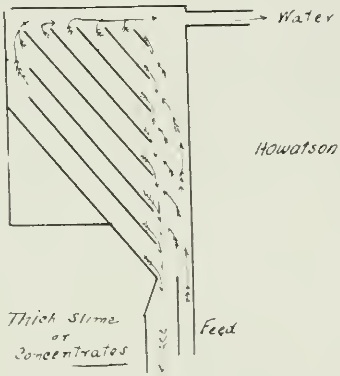
The losses in the fines is, partly at least, due to some of the grains acting as wetted particles.

Because of the similarity of the surface tension actions involved in this process and the Elmore vacuum process it is probable the sources of loss are the same in both.

The flocculative tendency of fine slimes is taken advantage of in the Howatson filter[1], the Durant filter and others. The floccules once formed stand considerable disturbance without breaking up. The finest pulp gives the solidest floccules.[2]

The plup travels upwards and diverges over sloping shelves. The decrease in velocity due to increased space allows the slimes to settle on the shelves. The short distance they have to fall shortens the time required. The agglomerated slimes slide off the shelves and fall through the ascending currents without breaking up.

Other factors beside the density of pulp enter into the settling of slimes. The density and viscosity as they increase




reduce the settling rate, though Dr. Barus states the viscosity had no effect on some fine particles in his experiments [3] with regard to the velocity of fall.

Slimes settle notably fast in distilled or hot water, results due no doubt to the reduced sp. gravity of the medium[4]. Others consider the changes too great to be laid to the charge of sp. gravity[5].

By others the retardation is laid to occluded air and small bubbles [6] but in most cases the effect of air is small[7].

Increase of temperature decreases the flocculative tendency[8].

Ordinary temperature changes are sufficient through convection currents to overbalance the extremely slow falling rate

1 Inst. Min. & Met., Vol. 17, p. 311.
2 Whiley. Agric. Analysis, Vol. 1, p. 180.
3 Richards Ore Dressing, p. 474.
4 Nichols. Inst. Min. & Met., Vol. 17, p. 205.
5 Sulman. Inst. Min. & Met., Vol. 17, p. 312.
6 Richard's Stamp Milling of Gold Ores, p. 126.
7 Nichols. Inst. Min. & Met., Vol. 17, p. 320.
8 Whiley. Agric. Analysis, Vol. I, p. 181.
9 Ibid.

of the finest particles" but experiment proves that particles protected from temperature changes settle very slowly, and that particles held in suspension for weeks are still of measurable size, that is greater than .0001 mm.[1]

Sulman as a result of "measuring the angle of contact between liquids and solids found a rise of temperature modified these angles quite out of proportion to the slight change in density due to heat. He considers, therefore, that heat is a factor producing results inexplicable by change in density alone.[2]

There are two explantions of the slow settling of slimes and both are probably true, i. e., the electrostatic theory and the colloidal theory.

The electrostatic theory is as follows: The molecules of water and the particles of solid become electrified, the solids usually becoming negative and the water charged with positive electricity.

The solid particles being charged alike, repel each other and consequently become diffused through the liquid. This probably explains the increase of settling rate due to removing the bottom slimes.

If an electrolyte be added to the water its molecules become ionized into +ve and —ve ions, which neutralize the —ve and +ve charges on the solids and water, destroying the electrostatic repulsion of the solids. It follows that an increasing quantity of electrolyte will neutralize the charges on an increasing number of particles until the whole are neutralized. This is the point of maximum efficiency. If the number of electrolyte ions is further increased the particles become reelectrified and the action is reversed.

The efficiency of electrolytes to settle particles varies greatly with the nature of the suspended substance.

For metallic sulphides 1 part of common salt to 60 water is only as efficient as 1 to 200 for calcium chloride and for iron, ammonia alum, 1 pt. in 90,000 of water. Thus iron am. alum is more than 1,000 times as efficient as salt.

An excellent description of this theory and experiments in connection with it is in Perrin Journal de Chemie Physique Vol. 2 and 3, and Neues Jahr Buch fur Mineralogie, 1893.

An idea of the great difference in rate of settling may be gathered from this table[3]. The ore was Nova Scotia gold quartz.

| Electrolyte | O added | Na. | Cl. | Am. | Alum | HCl. | $H_2SO_4$ |
|---|---|---|---|---|---|---|---|
| Per cent. added | 0 | 1/2 | 1 | 1/2 | 1 | .19 | .15 |
| Per cent. settled | 22 | 89 | 99 | 97 | 100 | 100 | 100 |
| Time in hours | 1/2 | 1/2 | 1/2 | 1/2 | 3 | 1/2 | 1/2 |

The addition of electrolyte caused the previously invisible

1 Whiley Agric. Analysis, Vol. I, p. 181.
2 Inst. Min. & Met. Vol 17, p. 312.
3 Richards Ore Dressing, p. 1147

particles to agglomerate immediately into visible grains[1]. Nichols states that in the very thin pulps the temperature may be more potent than electrolytes.

In thicker pulps any cause counteracting the repulsion due to electrostatic condition would be more and more potent as the particles crowd together.

In pulps containing more than 15% of solids the effect of electrolytes and change of temperature becomes rapidly obscured[2].

Mill tests were made to test the possibility of utilizing the increased settling rate in the treatment of chalcopyrite on slime tables.

In the first experiments the ore was mixed, divided into three lots. One part was used to adjust the table, the third part mixed with salt at the rate of 2 lbs. to the ton of 2,000 lbs. The second part was left unsalted. The ore was crushed in a stamp mill, the slimes separated by a classifier and sent to a slime table. Samples of the feed and unsalted tails were taken. The salted portion was then worked over and samples taken as before. A decided gain was found.

In a second experiment the ore was crushed under stamps through an 80 mesh screen and sent direct to the tables. The pulp thus contained a large portion of fine sands.

The pulp was divided by a partition in the launder into two equal portions, one of which went to slime table No. 1 and the other to slime table No. 2.

A pail of strong salt water was set on the launder and arranged to deliver a stream of salty water into either half of the divided pulp.

The salt was first added to the No. 2 table feed, and samples taken from both tables.

The salt was then switched to No. 1 table feed and samples taken. No other changes were made.

By running both tables possible variations due to feed, change of temp, inequalities of salt supply, were eliminated.

| | Assay value | Diff. in % | Efficiency |
|---|---|---|---|
| Feed | 3.04 % cu. | | |
| No. 1 table, tailings, not salted | 1.59 | | 59.6 |
| No. 1 table, tailings, salted | 1.53 | .06 | 61.2 |
| No. 2 table, tailings, not salted | 2.17 | | 45.0 |
| No. 2 table, tailings, salted | 2.07 | .10 | 47.5 |

On each table the salt raised the efficiency. Salt was used because of its lesser corrosiveness than acid, and also for the ease of obtaining it. Other electrolytes might have given an even better result.

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1 Richards. Ore Dressing, p. 1140.
Inst. Mining and Met., Vol. 17, p. 238.

# A CIRCLE DIAGRAM FOR THE ALTERNATING CURRENT SERIES MOTOR

It is an established fact that complete and accurate characteristics of an induction motor can be obtained by means of the "circle diagram" of Heyland and others. Taking this diagram

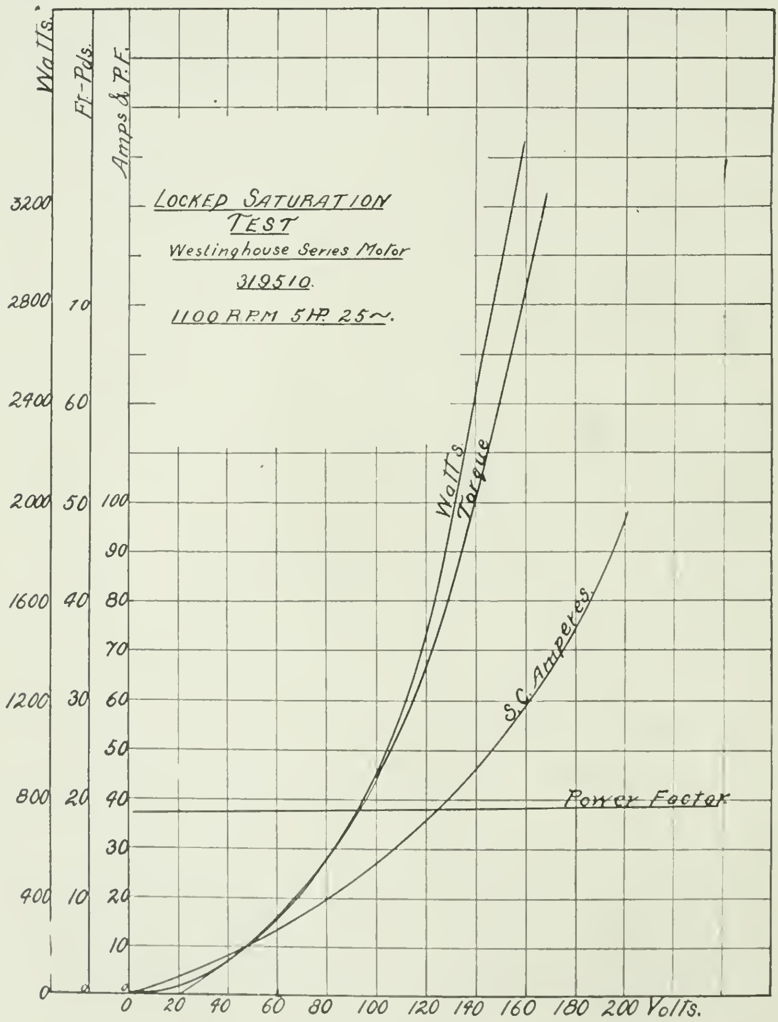



*Fig. I.*

as a basis, the performance and other properties of the single phase series motor may be approximately pre-determined.

### Construction of Diagram.

To obtain data necessary to construct the diagram, two tests, a "locked saturation" test and a "no load" test are required. For the locked saturation test the motor armature is clamped and reduced voltages are applied. Readings are taken of volts, amperes, watts and torque, care being exercised that the frequency is kept constant at rated value. Plot curves of watts,

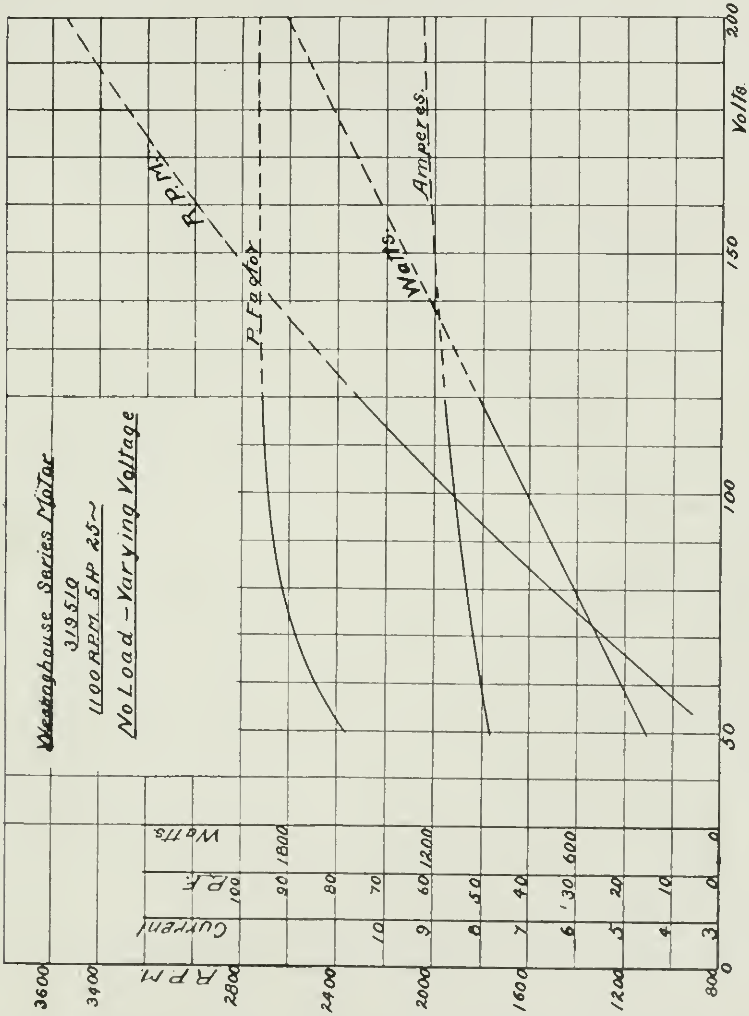



Fig. II.

amperes, torque, and power factor on voltage base and interpolate from the values for results at required voltage. (See Fig. 1.)

For the no load test the machine is run light at reduced voltages up to that pressure causing maximum allowable speed. Readings are taken of voltage, amperes, watts and speed. Observations are again plotted (Fig. 2) on a voltage base and interpolations made for data as in the locked saturation test.

To construct the diagram, proceed as in the case of the "induction motor." Assume the horizontal line *OX*, (Fig. 3,) to represent the direction of the current at zero power factor, and *OY* the vertical will be the direction of the *E.M.F.*

From the locked saturation test (Fig. 1) plot to scale the current vector *OP* in proper phase relation with the impressed voltage, the power factor being then represented by the cosine

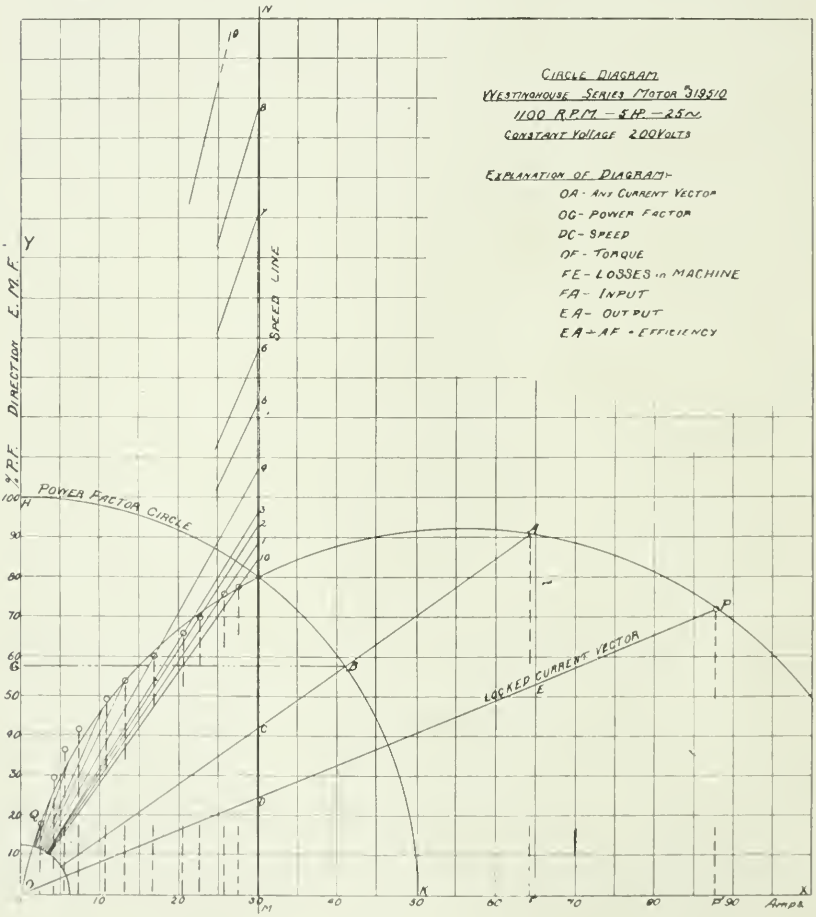



Fig III

of the angle *YOP*. Similarly from the no load test (Fig. 2) plot to scale the current vector *OQ* in proper phase relation, cosine the angle *YOQ* being the power factor, care being taken that both current vectors are taken at the standard voltage and frequency. Through the points *OQP* describe a semicircle, the locus of the current vectors. Centre *O* draw arc of a circle *HBK* also any line *MN* perpendicular to *OX*.

The quantities represented in the diagram can best be shown by a definite example.

### Method of Using Diagram.

*OA* is any current vector at power factor represented by cosine angle *YOA*. This may be read directly as % by length *OG*, where the length *OH* is 100 % power factor. Distances along line *MN* represent to scale the speed of the armature The intersection of this vertical line *MN* and the locked current vector *OP* is zero speed. The vector *OQ* intersects line *MN* at 9. The distance *D*.9. represents the speed of machine at no load, therefore *D.C.* is speed under conditions existing when *OA* is the current vector.

The torque obtained in the locked saturation test will be represented by the length $OP^1$, *OF* therefore represents the torque under assumed conditions. $PP^1$ is the energy component of the locked current and also represents the input and in this instance the losses in the machine. For the assumed conditions *FA* is the total input to the machine *FE* the losses, consequently *EA* will be the output, and finally $EA \div FA$ the efficiency.

### Results.

In the following table, comparisons are given of the results of an actual brake test and the results obtained from the method indicated in the diagram. The performance curves from both methods are shown in Fig. IV.

LOCKED SATURATION TEST.

| Volts | Watts | Amps. | R.P.M. | Torque | Power Factor |
|---|---|---|---|---|---|
| 200 | 7220 | 95 | 0 | 103.8 | 38% |

NO LOAD SPEED TEST.

| Volts | Watts | Amps. | R.P.M. | Torque | Power Factor |
|---|---|---|---|---|---|
| 200 | 1792 | 9.25 | 3520 | 0 | 97 % |

BRAKE TEST RESULTS.

| Volts | Input Watts | Amps. | R.P.M. | Torque | Power Factor | Output Watts | Effcy |
|---|---|---|---|---|---|---|---|
| 200 | 7805 | 47.8 | 723 | 50 | 81.65 % | 5135 | 65.7 |
| | 7620 | 46.0 | 820 | 46 | 82.75 | 5358 | 70.3 |
| | 7010 | 41.7 | 880 | 40 | 84.1 | 4999 | 71.3 |
| | 6625 | 39.0 | 930 | 36 | 84.9 | 4758 | 71.8 |
| | 6032 | 34.5 | 1030 | 30 | 87.35 | 4387 | 72.8 |
| | 5400 | 30.0 | 1180 | 24 | 90 | 4025 | 74.5 |
| | 4940 | 27.0 | 1280 | 20 | 91.45 | 3637 | 73.6 |
| | 3650 | 19.1 | 1800 | 10 | 95.6 | 2555 | 70.0 |
| | 2942 | 15.3 | 2220 | 6 | 96.2 | 1891 | 64.2 |

CALCULATED RESULTS FROM DIAGRAM.

| Volts | Input Watts | Amps. | R.P.M. | Torque | Power Factor | Outpup Watts | Effcy |
|---|---|---|---|---|---|---|---|
| 200 | 2845 | 15 | 1900 | 8.3 | 95.0% | 2240 | 78.5 |
| | 3740 | 20 | 1652 | 12.6 | 93.5 | 2960 | 79.0 |
| | 4600 | 25 | 1418 | 17.3 | 92.0 | 3480 | 75.5 |
| | 5400 | 30 | 1232 | 23.3 | 90.0 | 4070 | 75.4 |
| | 6120 | 35 | 1048 | 30.4 | 87.25 | 4520 | 73.7 |
| | 6840 | 40 | 913 | 37.0 | 85.5 | 4800 | 70.2 |
| | 7450 | 45 | 788 | 44.8 | 82.75 | 5020 | 67.3 |
| | 8000 | 50 | 684 | 53.3 | 80.00 | 5200 | 64.8 |

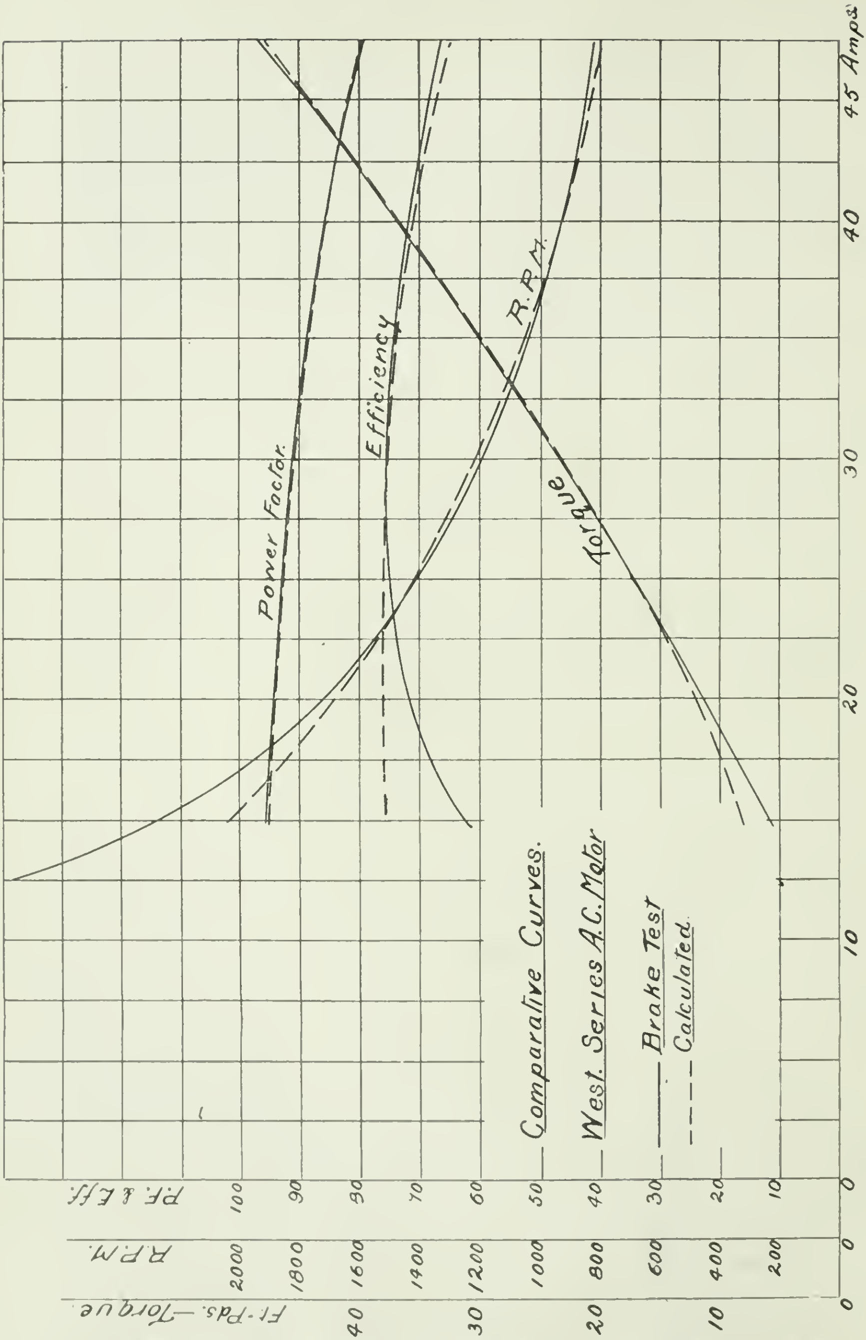



Fig. IV.

NOTE.—"Applied Science" desires to express its appreciation for this article to Messrs. Fierheller, Hopkins and Dundass of the Electrical Engineering Staff.—ED.

# PURE WATER BY MEANS OF ELECTRIC-OZONE.

R. H. Hopkins, B.A.Sc.

The following article is a brief description of a modern method of purifying water by means of electrically produced ozone.

The plant, which is the first municipal ozonizing one in America to treat the entire water supply of a community has just been installed at Lindsay, some seventy miles north east of Toronto. The town is in the centre of a rich farming district. It takes its water supply from the Scugog river, a sluggish, muddy, weedy stream, which in turn receives its supply, some twelve miles up, from Scugog Lake, on which is located the village of Port Perry, which runs its sewage into the lake.

The town receives its water from mains at a pressure of 60 to 120 lbs. this pressure being maintained by means of a standpipe on a hill at the west of the town, to which the water is pumped from the pump house on the banks of the river just above the town. The filtration system in use prior to the installation of the ozone purification plant consisted of a twelve-inch pipe leading from a crib sunk in the river to a rough filter containing some 18 inches of sand, gravel and charcoal and thence to the pure water tank, from which the water was pumped into the mains. The inefficiency of this method was such that the water had a murky, muddy color, a disagreeable odor and bad taste; besides which the germicidal properties of this filter as shown by tests were practically nil.

In april, 1908, the water commissioners made an agreement with Mr. James Howard Budge of Philadelphia, the inventor of the system, to instal on trial an ozone purification plant. The contract took effect September first; and in the remarkably short time of eight weeks the town received ozonized water. This time would have been considerably shortened but for the unlucky fact that an almost impenetrable blue clay was encountered in excavating for the water and ozone mixer.

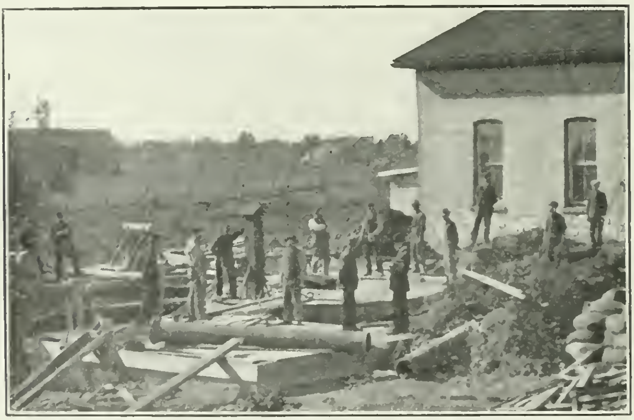
This is not the first time that ozone has been used in the purification of water but hitherto the cost has been excessive as shown by the following extract from the report of Mr. I. M. de Verona, M. Am. Soc. C. E. chief engineer of the Department of Water Supply of the city of New York, on a series of tests made by the officials of that city of an ozonizing plant in 1907.

"'The experiments showed that of the amount of K. W. energy used, about one quarter was consumed by the refrigerating machine, one quarter by the transformer and ozonizer, and one half by the compressor. It appeared that the color might be reduced from about 15 to 5, and bacteria from 100 to 7, by the use of about 3,500 grms of ozone per 1,000,000 gals. with an expenditure of about 800 K. W. hr. electrical energy, 200 of which were expended in the ozonizer and transformer.

With electrical energy costing 2½ cents per K. W. hr. (a low price) it appears that under the conditions of the experiments the process was costing about $20 per 1,000,000 gals., of which perhaps $5 represented the cost of the ozone and the other $15 were chargeable to drying the air and pumping it into the water."

This plant did not run a single day without stopping, but these stops with a single exception were all due to defective working of either the refrigerator or air compressor. The one shut-down due to the ozonizer was caused by a preventible short circuit. The stop was only momentary, however, an extra unit being instantly switched in.

The cost for power here, although stated as low, is excessive (especially as this use for electricity is an all day one, which can be stopped for a few hours at peak loads and there-



Plant Under Construction, Lindsay, Ont.

fore should get special rates), as the following figures will show:

2½ c. a K.W. hr. = $56 H.P. year, 10 hr. day, 300-day yr.

2½ c. a K.W. hr. = $163.80 H.P. year 24 hr. day, 365-day yr.

Power is supplied in Orillia at $16 H.P. year, 24 hr. day, 365 day year; in Niagara, $12 to $25 a H.P. year; in Lindsay, $25 to $35; and it is expected the rate will be $18.20 per H.P. year in Toronto.

A reasonable cost for 24 hour a day power in New York for this style of service would be 1c. a K.W. hour (it can be produced for less than this there). This would bring the cost of the imperfect system there tested to $8.00 per million gallons. In Lindsay it is 77c. per million, which sum with interest and depreciation on the plant is brought up to $2.75 per million. Slow sand filters cost from $7 to $9 per million gallons and mechanical filters cost $10 to $12.50 per million gallons. The results of the New York test, as stated, were not the best obtainable, owing to the ozone used being insufficient. In Europe the standard is 3785 grms. of ozone per million gallons of water. Here are some of the results obtained at the de Fries plant near Paris, by the official authorities of that city:

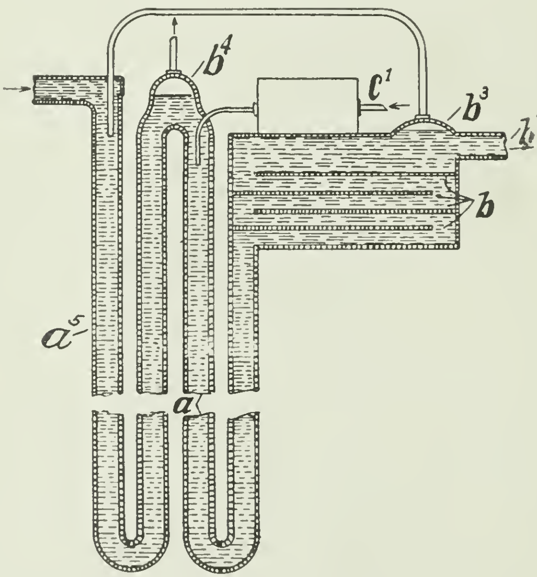
| Grms. of ozone per cubic meter of water. | Bacteria before ozonization. | Bacteria after ozonization. |
|---|---|---|
| 2.216 | 800 | 2 |
| 2.035 | 850 | 3-4 |
| 1.352 | 2682 | 3 |

The Lindsay plant consists of a raw water basin Hungerford sand filter, Asperator sterilizer, ozonizer and pure water

Views of Ozonizer

basin. The filtered water basin of the old plant is utilized, the water passing from these through an 8" pipe into the surface of the sand in the Hungerford filter, losing about 2" of head in so doing. This rough mechanical filter is intended to strain out the suspended matter. The suspended matter is excluded for two reasons, first a question of color, as suspended particles always give water a muddy color which can only be removed by a filter, as ozone has little or no action on suspended matter other than organic matter and bacteria; second a saving of ozone, as organic matter may to some extent be removed by a filter, and therefore the ozone will only have to act on the bacteria and the dissolved organic matter that passes through the filter.

The rough filter consists of a rectangular tank of reinforced concrete 12 by 15 feet deep sunk in the ground. It contains a series of pipes which gradually enlarge as they join each other, finally terminating in an 8″ discharge pipe. Sunk in the upper sides of these pipes are 130 brass sand valves, which allow the water to pass in either direction but exclude the sand. On these valves there is about three feet of sharp hard sand which accomplishes the removal of the grosser particles




Raw water enters the pipe $a^5$ drawing, by suction, unobsorbed ozone from $b^3$. The waste gases escape at $b^4$. The current of water in $a$ sucks fresh ozone into itself from the ozonizer $c$; and after passing around the baffle plates in $b$, the purified water escapes at $b^2$.

of suspended matter. The filter is cleaned by means of a valve so arranged that water from the city mains at a pressure of 60 to 90 lbs. can be passed upward through the valves and sand. The wash water escapes through two valves into the river. This process of washing takes about three minutes and is done every second or third day, depending on the condition of the river.

In flowing through the Hungerford filter the loss in head at 500 gallons a minute is 4′ 8″. It was designed to work at 1000 gallons a minute, but the level of the river during this very dry season has fallen lower than ever before and there is not at present sufficient head to give this large volume of water. Under ordinary circumstances 500 gallons per minute is the pumping rate. This rate, however, is doubled during fires; an auxilliary filter of the same type may be installed to give 1000 gallons a minute at any level of the river.

From the rough filter the water passes into another chamber in which its height is regulated by a butterfly valve and float. Here it flows into an air-tight box of concrete connected to the ozonizer by a 2″ pipe. The water now falls through a number of four-inch pipes, leading to the bottom of a well 30 feet deep, passing in so doing the ends of a great number of small pipes (see diagram for theory). The water by suction thus draws the ozonized air into it; and here is one of the special features of the plant. Other ozonizing plants have used an air compressor to force the ozonized air into the water; and as the compressor has to be worked without lubricants which would otherwise be oxidized by the ozone, such a compressor is a very costly and unsatisfactory machine.

The water and ozonized air now pass slowly upward through a system of baffle plates (see diagram) which prevent the ozonized air from too rapidly leaving the water. The head required to operate this sterilizer when treating 1075 gallons of water a minute is only 20″. If the cost of power and consequently of ozone is high, the partially used ozone after passing from the water, may be collected and used over again. (See diagram.)

The electrical equipment is housed in a small brick "lean-to," 8 by 10 feet, built against the power house. In this building are two 2½ K.W. 60 cycle transformers, transforming from 1040 volts, the town distribution voltage, to 8,000, 10,000 or 12,000 volts, depending on the leads used; a ⅛-h.p. motor driving a small blower to supply air to the ozonizers; and the two ozonizers. t will be noticed that there is no drying apparatus such as is used in European practice, Mr. Bridge having found that the yield of ozone is not increased enough by this to make up for the cost of operating either a refrigerating machine or a mechanical dryer.

The ozonizers (see photo), of which there are two, are quite distinct, in fact each ozonizer, with its own transformer and separate air inlet and outlet, is a separate unit, so that either or both may be operated. Each ozonizer contains 26 electrodes, 13 negative and 13 positive, each protected by its iron fuse. The electrodes are plates of aluminium 20 by 34 inches, and are filled with holes similar to those in a nutmeg grater. By an arrangement of baffles, the insulation being micanite plates and fibre, each little discharge, of which there are five million, encloses a jet of air; and here is one of the fine points of the ozonizers. It is a well known fact that an electrical discharge repels air, and if it were not for the arrangement in the ozonizers the air blown on the discharge would be repelled by it, and not nearly as large a percentage of ozone generated.

The plant as it is at present operated is supplying 4,000,000 to 4,500,000 gallons of water a day. Five hundred gallons a minute are pumped and about 4 h.p. of electricity is regularly used in the ozonizer. This may be increased to 8 h.p. as specified in the contract. The plant is costing the town $7,250; but this cost is low on account of using old filters and excavations. To duplicate it would cost in the neighborhood of $25,000.

The plant to date seems eminently satisfactory, the water after filtration is clear, cold, odorless and in fact looks and tastes like good spring water.

The following is the report of a preliminary report:

## BACTERIOLOGICAL REPORT

March 22, 1909.

Report of water receied from Wm. Hammond, Water Commissioner, of Lindsay, on the 18th day of March, 1909.

We have received the following report of analysis of water from this plant. It speaks for itself:

| Laboratory No. | Sender No. | Where collected from | Number of Bacteria using N. Agar + 10.0 at 18°–22° | at 37°–40° | Strepto cocci | Staphylo-cocci | Colon Bacilli | *Colonoid Bacilli | Chlorine in parts per million |
|---|---|---|---|---|---|---|---|---|---|
| 1299 | No. 1 | Rain Water | 3800 | — | — | — | — | — | 2 |
| 1300 | No 2 | After Ozonizing | 2200 | — | — | — | — | — | 2 |

+ = present.
— = absent.

Colonoid bacilli are such as belong to colon group. Bacterial counts are made only when specimens are still in ice and the "time limit" of ten hours has not been run over.

Remarks: The count speaks for itself.

John A. Amyot.
Prov. Analyst.

# THE YOUNG CIVIL ENGINEER.

## Close of Discussion by E. W. Stern.

To the gentlemen who have so ably and freely entered into the discussion, I wish to acknowledge my thanks and appreciation. They have given us the benefit of their valuable experience and earnest thought; not to mention their time. They have brought to it an intimate and sympathetic understanding of the young graduate engineer's position, as all are college bred men, and have risen from the bottom to the topmost ranks of their profession by sheer ability.

It is my good fortune to know practically all of these gentlemen, and to respect them, not only for their professional ability, but as men. Their ethical standards are of the very highest. They are all leaders in the full sense of the word and are highly appreciated by the community at large. What they have said, therefore, the result of mature thought, and actual experience both as employe and employer, along the very lines which go to make their remarks so very valuable to this discussion, can only be commended by me to your most thorough and serious consideration.

I have only one exception to make. In Mr. Thomson's discussion he states that it is nearly always desirable to obtain the largest salary possible on the principle that the employer is going to give the best work to the highest paid man.

I do not agree with Mr. Thomson in this, nor do other gentlemen who have discussed this paper. My own experience both as employe and employer is that this is not good advice. No better way to become a "floater" could be suggested. Often, when business is brisk and there is a scarcity of well qualified draughtsmen or assistants, a man may demand and obtain a higher salary than he is worth. His position is almost always temporary, for as soon as it is possible to reduce the force, he is among the first to be let go. Furthermore, an employer (if he is a sensible one) will give the best work to the man who is best qualified to do it, regardless of salary.

I have not intended to give advice to old engineers but only to the young graduate for the first few years of his career—in his practical post graduate work, so to say—the idea being that the young skipper sailing his craft in new waters, might be benefitted by the experience of the old mariners, as to just what shoals to avoid. He must soon sail his own craft, however, and steer himself.

The time will come when he will be able to master new situations and problems which present themselves, with tact and skill and the confidence born from experience. He will have found himself.

## IN MEMORIAM.

### James McDougall, B.A., Assoc. M. Inst. C. E.

James McDougall was born at Baltimore, Ont., in 1853. He was educated at Upper Canada College and University College, Toronto, and obtained his B. A. degree in 1880. Having decided upon civil engineering as his future profession, he entered the School of Practical Science, Toronto, in 1881 and graduated in 1884. Subsequently he taught for a short time as a private tutor. He began his professional work under the late Mr. J. T. Stokes, C. E., engineer for the County of York, and was employed on the Welland Canal and on the Canadian Pacific Railway under the late W. T. Jennings, C.E.

Jas. McDougall, B.A.

In 1892, on the death of Mr. Stokes, he was appointed engineer of the County of York, which position he held until his death on 2nd Sept., 1908. He was admitted to the Institute of Civil Engineers, London, England, as an Associate Member in 1906.

In addition to his duties as county engineer he carried on a private practice as a consulting engineer. He was the engineer in charge of the York Radial Railway system and its various extensions—was employed on such questions as the taking over of electric railways by municipalities—was an authority on concrete and reinforced concrete construction, etc., etc. His work was of the best. His ability, tact, good judgment and simple honesty gained for him the respect and confidence of all who came in contact with him in a business way. He combined in a marked degree theoretical knowledge with practical sagacity, kept closely in touch with the latest engineering developments, subscribing for both English and French engineering periodicals. One of his marked personal characteristics was his extreme modesty and dislike for publicity. He never pushed himself nor aided his friends in pushing him. By nature a student, he had the student's fondness for books and was an omniverous reader. I have been told by one of his former class mates in University College, who knew him intimately in after life that he was one of the best liberally-educated men the University ever produced.

While making no pretensions as a critic in literature and art, his tastes were cultivated and his judgment excellent. Among people with whom he felt free he was a delightful talker and a charming companion. He combined in a rare measure strength of intellect with delicacy of perception and refinement of thought. A keen sense of humor served as a shield to his too sensitive nature and saved him from many a trouble. Kindly and generous in disposition he had many friends but few intimate companions.

His memory will long be cherished by those who knew him best.

J. Galbraith

## Duncan Sinclair.

Duncan Sinclair was born on Dec. 6th, 1870. He spent his boyhood days on his father's farm at Cheltenham, Ont., and secured his early educational training in the public school of his native village. Later, he attended Georgetown High School, where he secured his senior Matriculation. Following this he taught school for three years. In the fall of '99 he entered the School of Practical Science, obtaining his degree in 1903, and having been president of the Engineering Society during his final year. He first secured employment with the Hamilton Bridge Works, and subsequently with the Canada Foundry and the Grand Trunk Railway at Stratford. In the spring of 1905, he went to New Liskeard, where he became junior partner in the firm of Blair and Sinclair. In 1906 this was changed to Blair, Sinclair and Smith and in 1908 to Sinclair, Sutcliffe and Neelands.

Of the class of 1902, none was more highly esteemed than Duncan Sinclair. His native ability and industry placed him always well up in the lists and his unfailing cheerfulness won for him many friends. In later years when he rubbed up against the world in a community and an environment where opportunities to leave the path of strict rectitude were frequent and tempting, Sinclair always carried himself with the strictest honesty. He played the game fair and his word was as good as his bond. His illness dated from July, 1908, and although the best medical advice was obtained, permanent relief was not to be had, and he passed away on January 5, 1909, at his old home in Cheltenham. He is survived by his widow, formerly Miss Mary Stewart, of Parkhill, Ont., to whom he had been married only a few months previously. His untimely death has taken one whose capacity for work, whose business ability, whose integrity and whose geniality gave promise of a life of great usefulness.

## Garnett Rae Jardine.

Garnett Rae Jardine was born near Bowmanville on Nov. 2, 1888. His early school days were spent there, and in Western Manitoba. He entered high school in Brandon, but returned, when 17, to Bowmanville, where he claimed honors, and in his final year tied with a comrade for first position.

Garnett Rae Jardine

While there, he decided to attend the School of Science and enrolled in the fall of 1906. At the close of his freshman year, honors again fell to him, which was only natural, since he seemed happiest in the pursuit of his studies.

Much of his second year was spent in chemical research and laboratory work. While thus engaged he unfortunately inhaled a quantity of nitrogen peroxide gas, which later irritated his lungs to a very great extent. His studies, however, did not suffer lack of attention until scarlet fever confined him to his bed, and, on March 5, 1908—less than a week from his last attendance at lectures—his death was reported among his fellow students. Then it was felt that one of the keenest of intellects and noblest of natures had "crossed into that undiscovered country from whose bourne no traveller returns."

When the present shall have crystallized into the past he will be remembered for his extraordinary ability, good fellowship, and genial disposition. When we think of his exemplary habits, moral character and devotion to high ideals, it helps us to better understand that

"Death's but a path that must be trod,
If man would ever pass to God."

## W. F. Ratz.

The late W. F. Ratz, D.L.S., whose death through typhoid fever occurred at Ottawa on the 6th February, 1900, was a graduate of the School of Practical Science of the class of 1902.

Mr. Ratz entered the "school" at the early age of sixteen. In spite of his youthfulness he acquitted himself most brilliantly throughout his entire course, graduating with honors and obtaining the T. Kennard Thomson prize in the Department of Civil Engineering.

Immediately after leaving the University he received an appointment in the Topographical Survey Branch, Department of the Interior, Ottawa, where he remained till the spring of 1905, when he was transferred to the Boundary Survey staff, under the charge of W. F. King, Chief Astronomer. It was at this time Mr. Ratz obtained his Dominion Land Surveyor's certificate, heading the examination lists.

His work on the boundary survey was in Southeastern Alaska. In the year 1907 he was engaged on the Stickine River, and in 1908 on the Endicott River.

His work was always carried on with the greatest accuracy. The service has lost a splendid surveyor, and the country a most promising citizen in the death of Mr. Ratz.

Among those who knew him, Mr. Ratz was a universal favorite, and none regret his untimely death, in his twenty-fifth year, more sincerely than do his fellow graduates of the University of Toronto.

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## PRESIDENT'S VALEDICTORY.

Gentlemen:—I have now come to my last duty as President of the Engineering Society. It is with a feeling of relief that I lay down the responsibilities, and with a feeling of regret that I must sever my connection with a work in which I have been intensely interested and into which I have thrown all my energies. I want to thank your for your co-operation during this past year. I feel that I can truly say, in every enterprise we have undertaken as an executive, we have felt at all times that you have not only approved of our course, but that you were willing to assist us in every way in making the business in hand a success. Much of what has been accomplished this last year can be attributed to your own energies administered at the critical times.

In reviewing the work of the year there are certain features of it which require more than a passing note.

The Supply Department has been reorganized to place it on a sound business basis with business principles as the root of the system. By a new method of keeping an account of the sales and checking stock it is believed we have placed in the hands of the auditors a means of checking the money handled in this branch of our work.

Arrangements have been under way for some time to secure for the Society the sale of text books in our supply department, and I have good grounds for saying that this will in all probability be consummated before the new executive takes over the work. By this means we hope to add another source of revenue to the Society, and also to make it entirely independent of outside assistance. It is thought that, with these improvements, a clerk of supplies could be obtained at a reasonable salary, whose only duty would be to look after the sale of supplies, and this department could then be kept open at all hours of the day.

The present arrangement has been more or less critized, but it seems to me, the chief reason to be urged against it is that it interferes too much with the academic work of the assistant of the paid secretary.

It is hoped also that the revenue derived from this increased business will provide for a larger and better "Applied Science." Throughout this past year it has been our endeavor to keep "Applied Science" up to the standard, and if possible to put it upon a paying financial basis. This journal is one of the most important departments of our work, for through this medium we are kept in constant touch with the graduate body. I think I am safe in saying that "Applied Science" is going to accomplish all that its originators had in view at its inception.

Printed notes of lectures, which have been advocated so frequently in election platforms of recent years, are being obtained, slowly it is true, but nevertheless surely, and no doubt in a few years, will be in use in all departments.

In the Mechanical and Electrical section of the Society a new experiment was tried this year. Excursions were arranged to visit the different manufacturing establishments in and around Toronto and the experiment has proved very successful due partly to the energies of the Vice-President of that section and partly to the assistance given by the Faculty. These excursions could be extended to the other sections and would, in all probability, achieve the same results.

Our sectional meetings have been attended by a fair measure of success. The Vice-Presidents of the different sections have worked hard in their endeavor to make these meetings interesting and instructive, and they deserve credit for their untiring efforts. One feature which has been noticeable by its absence has been discussions on the papers presented: but the incoming Vice-Presidents should overcome this, benefiting by the experience gained by their predecessors. It was thought that the prizes offered in each of the sections at the beginning of the year would have the effect of increasing the number of papers and increasing the interest taken in their presentation. Unfortunately this plan has not had the desired effect this year.

A few alterations have been made in the constitution to suit prevailing conditions. These changes were made necessary by the course of events during our year of office, and we trust that these alterations have made it easier for our successors to effectively and efficiently carry on the business of the Society.

One of these alterations has to do with the elections. This I want to explain. It was found necessary this year to hold the elections partly in the afternoon and partly in the evening, because of the increase in membership, and the University regulation requiring all university buildings to be closed at twelve o'clock. For the future the plan which commends itself, is to have all the voting during the day and then to have a "stag night" at the gymnasium.

The annual excursion, this year, to Buffalo was one of the most successful of its kind in the history of the Society. Over three hundred of the members enjoyed the trip.

The annual dinner, held in Convocation Hall on Jan. 28th of this year, was of more than ordinary importance. It marked the beginning of a closer relationship between the graduates and undergraduates and it also demonstrated to the graduates and our guests the important place the Faculty of Applied Sciences is destined to fill in the engineering world. To the undergraduate it proved that to be a graduate meant to be interested in the wellfare of the Faculty of Applied Science and the Engineering Society. It also had other important results which will benefit this Society and this Faculty. A new record for attendance was established and the event has been characterized as an unqualified success.

An attempt has been made this year to provide accommodation for a reading room in the library, and as a mere beginning covers were provided for the magazines. Of course the accommodation is quite inadequate to our needs but it was thought advisable to insert the thin edge of the wedge at this time. Then when the new buildings are being planned, rooms will be set apart for this purpose.

Much of what has been accomplished during this last year can be directly attributed to the strong Executive Committee which you elected a year ago. This committee has worked earnestly and conscientiously and has devoted a great deal of its time for the welfare and upbuilding of the Society. It has been a privilege for me to be associated with the work of this committee, and I assure you that the executive deserves your thanks.

In conclusion, let me thank the members of this Society for the honor they conferred upon me a year ago in electing me to this position. In giving an account of my stewardship I hope that I have merited, to some extent the confidence they placed in me at that time.

I have much pleasure in presenting to the Society their President-elect for 1909-1910 Mr. D. W. Black.

Yours sincerely

ROBERT J. MARSHALL.

# TREASURER'S REPORT.

RESOURCES REALIZED 1907-08.

| | |
|---|---|
| By cash balance | $329 73 |
| Supply | 46 00 |
| Ads. *Applied Science* | 411 23 |
| Dinner Account | 2 00 |
| Outstanding accounts received | 35 75 |
| | $824 71 |

RECEIPTS 1908-09.

| | |
|---|---|
| Sales Supply Dept. | $4,522 68 |
| Fees | 901 00 |
| Sundries | 294 70 |
| Ads. *Applied Science* and Subscriptions | 240 63 |
| Grant to *Applied Science* | 155 00 |
| Rec. Dinner Account | 524 40 |
| | $7,463 12 |

RESOURCES FROM 1908-09.

| | |
|---|---|
| 226 Orders on Deposit | $ 395 50 |
| Bank balance | 99 53 |
| Outstanding due Supply Dept. | 95 11 |
| Cost Price Stock | 2,319 91 |
| Outstanding, due *Applied Science* | 619 09 |
| | $3,529 14 |

LIABILITIES FROM 1907-08.

| | |
|---|---|
| Outstanding accounts | $125 32 |
| Printing *Applied Science* | 651 28 |
| | $776 60 |

DISBURSEMENTS.

| | |
|---|---|
| General expenses | $ 266 69 |
| Supply Dept. | 3,912 10 |
| Sundries | 716 01 |
| Dinner | 1,128 30 |
| *Applied Science* | 563 89 |
| Bank balance | 99 53 |
| | $7,463 12 |

LIABILITIES FROM 1908-09.

| | |
|---|---|
| Sundry outstanding acounts | $ 145 25 |
| Against supply | 913.45 |
| Against *Applied Science* | 429 78 |
| Surplus | 2,040 66 |
| | $3,529 14 |

We, your auditors, do hereby certify that we have examined the books and accounts with vouchers of your Society for the year from Mar. 27, '08, to Mar. 27, '09, and that the above statement exhibits a true and correct view of the financial standing of the Society as shown by the books of the society

It was impossible to make more than a superficial audit of the supply department, but if the system, as now proposed by Mr. MacKenzie is carried into effect this coming year, the system of checking executed by the Treasurer and Vice-President will be more or less of a daily audit on the supply department, and if then a thorough audit was made at the end of the year, the system of accounting would, in our opinion, be all that could be desired.

S. R. CRERAR
R. S. DAVIS,
Auditors.

Toronto, April 15, '09

APPLIED SCIENCE

INCORPORATED WITH

**Transactions of the University of Toronto Engineering Society**

DEVOTED TO THE INTERESTS OF ENGINEERING, ARCHITECTURE AND APPLIED CHEMISTRY AT THE UNIVERSITY OF TORONTO

Published Monthly during the College year by the University of Toronto Engineering Society.



## Editorial

This issue completes the second volume of Applied Science and closes one of the most successful years of the Faculty of Applied Science and of the Engineering Society. Several decided advances have taken place in each. The new laboratories for thermodynamics and hydraulic will be practically complete by fall and fourth year difficulties will be to a great extent solved. Keen disappointment is felt, however, as the impression grows that the Board of Governors are not going to take any steps towards a new Engineering Building.

We wish to take this opportunity of thanking our contributors for the valuable assistance they have afforded.

Next year plans are already laid to make Applied Science bigger and better than ever. The co-operation of all the graduates is earnestly requested.

# THE STUDY OF ENGLISH LITERATURE IN AN ENGINEERING COURSE

W. B. REDFERN, '08

(1). While engaged in academic work as a student of applied science and engineering, one sometimes considers the advisability and practicability of introducing into our curriculum a course of lectures on the study of English literature, and bearing on this very important question, these few remarks are directed. Let it be understood that this article is not one of protest or dissatisfaction, but rather is it one of suggestion on account of interest in the general welfare of this faculty.

The curriculum at the present time gives us a comprehensive and thorough training in that particular branch of engineering that we are studying, almost entirely from the mathematical and scientific standpoint. We study mathematical subjects as Algebra, Trigonometry, Analytical Geometry, Calculus, etc., and we study scientific subjects as Statistics, Dynamics, Astronomy, Thermo-dynamics, Hydraulics, Theory of Construction, etc. Such a course of studies tends to develop a highly accurate type of mind—a type of mind that wishes and must know the why and wherefore of everything—a type of mind that demands facts, absolute facts, and the causes and effects of the same. As the vast natural resources of Canada become more evident day by day, just so the need for men capable of developing these resources with the best possible results for Canada also increases. And further a country whose population is growing by leaps and bounds is certain continually to present new mathematical and scientific problems for the solution of which all the powers and intellects trained to perfection to deal with such subjects are emphatically needed. Consequently in the efficient and economical development of these resources such a type of mind as above mentioned is required, and will find great scope for the exercise of its faculties.

But need that type of mind be purely scientific and mathematical? Not at all—it may also combine the culture and breadth derived from studying subjects of a nature, not mathematical and scientific, but of a nature entirely different—literary and etymological. In the study of classics and the modern languages entirely different faculties are trained and developed than in the study of the accurate subjects of mathematics and science. In the former case the mind is not constrained to keep within a certain well defined limit of thought and argument, but it may branch out and devote its energies in channels of thought and argument where there is a much greater freedom and latitude. There are no hard and fast limits, but there are excellent facilities for the exercise and development of the imaginative and creative powers, the training of which are even eventually so necessary for engineering design. A piece of translation or an idea may be expressed in a dozen different ways, all equally good but yet following no well defined limits of expression. Of course, no thought whatever is entertained of introducing classics into a course of engineering, although even a transitory knowledge of them is of some value, yet practically the same faculties are involved and developed in the study of English literature as are involved and developed in the study of classics and of the modern languages.

Graduates in engineering upon entering the practical work of their profession wish to guard against the curse, or "bête noir" of professionalism to-day—narrow-mindedness. We hear that it is so easy to "get into a rut" and so difficult to get out of it. The surest and best way of avoiding narrow-mindedness is by frequent indulgence in desultory reading. If one confines himself in his reading to engineering subjects only, naturally his mental vision will not only carry him beyond the horizon of engineering problems and of engineering accomplishments. Hence, if our studies while at college are as comprehensive and inclusive as possible, our mental vision will be extended far beyond the horizon of our profession, so that we may see and understand things that otherwise would remain incomprehensible and imperceptible to us. It is as if we ascended the mountain of culture and knowledge farther, by so doing greatly extending our mental scope and vision. Our sympathy for humanity would be broadened, and instead of being students in engineering only, we would become students of affairs, and accordingly we would be more serviceable to the community in which we live. Therefore if a course of lectures in English literature were introduced into our curriculum, and greater intellectual discipline and culture that we would acquire would develop in us a much higher mental efficiency, a deeper sympathy for humanity and a much broader outlook on our profession.

Francis Bacon has said,—"Reading makes a full man." And it is not only essential that we should read, but it is even more necessary that we should understand what we read, that we should "digest" what we read. To be able to select the best literature written by the greatest and best men and women who have ever lived, and to be able to understand it requires guidance, training and study. Also to recognize and appreciate a good author's particular style of writing and to detect and discriminate his fine shades of meaning requires guidance, training and study just so surely as these are required in the design of a bridge or in the location of a railway.

Where, then, are we to look for this training and study, so essential and important? Most of us have not attended a collegiate institute long enough to acquire this knowledge and culture. So up to the present time it has been necessary for all who were desirous of becoming conversant and familiar with English literature and the English language to do so entirely apart from their academic work. Then again our academic work requires so much time of the average student that very little remains to be devoted to these outside studies, unless he is an omnivorous reader and is determined to find time "come what come may." A stream cannot rise higher than its fountain. Consequently to remedy this defect, to meet this need and to place our graduates on a higher pedestal in public opinion, the study of English literature would do much to attain this end.

Also even from a purely professional standpoint, great personal benefit would accrue to those who have an opportuity of studying English literature and the English language in connection with their college work. Some one has said that language is a "vehicle of the engineer." It is certainly indispensable in his profession. He must be familiar with it, because he must use it every day. In drawing up specifications, in writing reports, in engineering correspondence and in many other ways, he must always have the language at his command. These then are other important reasons why this departure would be desirable and advantageous.

In conclusion, since we are now an integral part of this great university, working in conjunction with the other faculties for its common good, and since a four-year course for graduation is about to supplant the present three-year course, could it not be amicably arranged to introduce into our course in Engineering and Applied Science a series of lectures on English literature for the good of our faculty and for the good of the University as a whole? The time is opportune. If not, why not?

## A CRUISE—A RETROSPECTION.

HYNDMAN IRWIN, '09

[Note.—The class of '09 needs no further mark of distinction. Its curve is high and prominent on the efficiency-time diagram of the Faculty of Applied Science. But before falling down the stairs for the last time, our regard for the other years necessitates a portraiture of this Chapter of the Order of the T-Square.]

On a fair autumn morning in 1906 the renowned class set sail upon the sea of college life in the channel of Applied Science. Our first assemblage in an upper deck apartment was for instruction regarding the manipulation of the lead pencil and the two-foot rule. During the initial week we raised the old flag of yellow, blue and white; and later chose as our captain, "Ginnis" Johnston. On a pennant at the stern was our "Che hee."

Barely had we put forth to sea when, without warning, the crew were called to arms to decide ocean supremacy. This resulted in our being gloriously victorious, the sacrifice of

EXECUTIVE OF GRADUATING CLASS

O. T. G. Williamson — C. Hughes — H. W. Tate — G. Morton — W. S. Collinson

C. O. Hay — T. H. Crosby, Pres. — Dr. W. H. Ellis, Hon. Pres. — G. R. Workman — W. J. Johnston breath and clothing being nothing compared with the glory of the beautiful new war balloon, which was finally forced to enter our domain through a window of the engine room.

The ship was manned by two hundred and eighty-eight tars. At the end of the first voyage, however, a few were induced to remain behind, enticed by an easy landing in Real Estate, a comfortable resting place in an Arts harbor, or a pleasant (?) outlook from a Medical haven. Although the prospect was not entirely one of pleasure, it has not proved a tedious journey by any means. It may be that a few sought pleasure only in the trip. Moreover, it was rumored upon decks that one considered it too lonesome, and changed to a canoe that was built for two. Any one of the boys in our navy will testify, however, that there has been a great deal of fun and pleasure, apart from hydraulics, as applied to the incoming freshmen, or experimental optics, as studied from the upper windows, the incident ray being cast upon pretty forms that harmoniously float by, casting reflecting rays, normal to the focal plane. The main cabin has often been the scene of many amusing incidents especially on the event of the election of officers, when we were frequently honored by the presence of the Admiralty, smoking cherry pipes with us.

After our first furlough, we again embarked, under Captain Campbell, with Dolly Black as first mate, Billy Carlyle as purser, and Cy Danks as our holy man—two hundred and five souls in all, with arms trembling from the many hearty hand-greetings following our five months' leave of absence. Our work about the ship was intercepted here and there by welcomed theatre nights, football and hockey games; while the annual dinners and engineering excursions created a lively interest in the affairs of the college fleet.

Alas! We did not all survive the severe annual April hurricanes, and many were lost in the storm. One hundred and seventy-three of us answered the roll-call when we next headed seaward. We rejoiced to have Crosby piloting our craft assisted by Hay and Workman, with Wilson, Bolton and Duff working vigorously at the helm.

On our journey together we have met many friends and many enemies. With the latter we have had not a few encounters. The barge "Epistaxis" has oftentimes required a reprimand, and so too, a foreign squadron consisting chiefly of blue helmets and large buttons; while we have several times found it necessary to turn hostile towards sister ships belonging to our own flotilla. If we have ever suffered defeat, we have forgotten it, as the truest of subjects should leaving a record of complete victories.

During the trip we have had many narrow escapes. A shoal that was troublesome, although not dangerous, was Thermodynamics; the Scylla that threatened the destruction of our bark was Spherical Trigonometry; the constant shooting of electricity from a rosy sky kept the bravest of us in fear and trembling, (and the hungriest of us from assailing our hard-tack.) Geometry—analytical and descriptive—proved a dangerous coast if approached too closely; and we have been wafted from our course many times by chemistry fumes.

Although three years is not a very long time in which to gain fame and honor, still we have done so. At the Inter-collegiate meets the Science battleships have always had a solid reinforcement from our ship. The Mulock and other cups, have in turn held our mutual joys and tears. We have furnished many of the players in the great teams in football and hockey. Besides, does not the Pride of Cobalt really belong to us?

What we as a class have not learned in our three years of ocean riding, is hardly worth knowing. We know now, that if little is put into study, much cannot be expected. It is simply the working out of the law of conservation of energy.

As for our leaders, they have cheered us on through waves dark and mountain high, and have gained for us the name of being the best mariners that ever manned a ship. And yet, each captain has made his mistakes. His senses were frequently numbed, in dull weather, by moaning fog horns, which proved to be Harper or Cooch, asking a question, or calling for lights, in the middle of a soporiferous discourse. When he warned us that a storm was brewing, it was generally Hagerman brewing mischief. At all events Ginnis, our star ladder scaler would climb the mizzen mast, or go below, in hopes that there might really be something brewing. Or when our musician, Kettle, began to sing, Fate so likened the music to the wind whistling through Doc. James' whiskers that the captain would send them both below, never forgetting that whistling is an ill omen among seamen.

As for our captain of the past year, a page from the log book describes him thus:

"When Manning the ship he was always Kean, but would never Goad us on toward uncertainties. He frequently granted the crew his permission to visit their Holmes, choosing a season in which neither Frost nor Blizzard could mar the pleasure of their holiday. Whenever Sara wandered from sight, the captain would touch a Bell to summon a Workman, whom he would send to Hunter. Then he would Walker about on deck, where he could Vatcher. If he should be down for a Gray snooze and get a cobb Webb in his eye, he would get Crosby degrees, his anger almost immediately subsiding into thoughts of a Greene nook among the Trees on a shady Hill side, with an issue of 'Black and White' to while away the hours. He did not Carrie a Gunn his only weapon for defence being a Key."

We have always been noted for our good behaviour, progressiveness, and curiosity—and generous, even in regard to the Sophomores, although they have not such a high opinion of us, a reflection on their taste. We have always done our part in trying to convince the press that we are of the Faculty of Applied Science, rather than of "Applied Silence" and we are grateful to the Sophomores for their aid.

Thus we have sailed, the golden sunlight, the blue ocean, the white wave crests ever being foremost in our minds. Too soon we leave the pleasant scenes, but all go to knock at the same door—that of the office of Mr. World. When he, grim, as Father Neptune, asks us who and from what craft we are, we need not hesitate to reply:

"Toronto, Toronto, Toronto Varsitee!"

And when he proceeds to inscribe our names in the log of the great ship, "The Future," the shades of Chezy and Rankine, and Kerchhoff, and Berthelot, will, for the moment, step aside, and silently weep in the shadow of Remorse, while our hearts will join with dear old College-day enthusiasm, in a mighty

Chee hee, Chee he, Chee ha, ha ha!
School of Science, Naughty nine,
Rah! Rah!! Rah!!!

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**The attention of all our readers is again drawn to the list of graduates, whose address we have been unable to verify, which appeared in the February issue. Some of these we have located, but the addresses of the majority are yet unknown.**