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READ BEFORE THE

ENGINEERING SOCIETY

OF THE

SCHOOL OF PRACTICAL SCIENCE

TORONTO

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PREFACE.

THE Engineering Society of the School of Practical Science was founded in the Spring of 1885 through the exertions of a few of the students in the Department of Engineering, Messrs. Herbert Bowman, of the third year, and T. Kennard Thompson, of the second year, being the principal promoters. Meetings are held every second and fourth Tuesday of each month during the session, at which papers are read and engineering questions discussed. In order to keep alive the interest of graduates in the success of the Society some of the leading papers contributed during the previous session are published annually. It has been thought that the interest in these papers would be increased if they were published as soon as possible after being read. This edition, therefore, contains not only the principal papers read during the session of 1888-89, but also those read during the first term of the present session. The majority of the writers are students, the greater part of whose time is necessarily spent in acquiring information already in the possession of the profession, and who can ill afford to spend much of it in original investigations. Notwithstanding this, however, most of the contents of the papers are the results of their individual observation or experience, or at least the writers have some practical knowledge of the subjects dealt with.

It is hoped by the general committee of the Society that graduates of the school and former students, who are now engaged in active work, will make endeavours to contribute papers relating to their work to be read at meetings of the Society.

The present edition consists of one thousand copies, which will be widely distributed among Engineers and Surveyors.

CONTENTS.

ENGINEERING SOCIETY

OF

THE SCHOOL OF PRACTICAL SCIENCE

TORONTO.

PRESIDENT'S ADDRESS.

Gentlemen :—

In reading over, some three weeks ago, the inaugural address of the president of the British Association, on " The Civil Engineer and what he has done for the Advancement of Science," I hesitated whether it would not be the best thing to read that instead of my own. I decided not to, because I thought it would be a bad precedent to establish, and, besides, you can all read it for yourselves.

I must ask your pardon, gentlemen, for the disconnected way in which mine is written. I feel greatly the lack of experience, and the poorness and weakness of many of my ideas and arguments. I have not spent sufficient time and thought on the subject. I only wish I had some six months more in which to improve the crude ideas I have now, and to connect them in some more intelligible way. I believe it is customary in an inaugural address to sketch the advances made during the past year in those subjects to which the Society devotes itself. This is highly interesting and instructive to those who are in actual practice and know the condition of affairs at the beginning of the year, but to us, who are still at the theory and know very little of the actual practice of engineering, I think it would be more interesting to devote ourselves to the subject of our own Society. To those who are coming here for the first time, I think some explanation of the objects of the Society is due.

To begin, then, with the history of the Society. The Society was founded some three years ago—in the Spring of 1885. It was called " The Engineering Society of the School of Practical Science." It is a students' Society, and only those connected with student life in the School of Practical Science and the University of Toronto 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 practice of the profession of engineering.

Meetings of the Society are held twice a month; at these meetings, papers on Engineering and Scientific subjects are read by students and professors, and also general discussions are held on various subjects. Periodicals on the various branches of engineering are subscribed for by the Society and these are circulated among its members.

Two years ago the more important papers read before the Society were printed in the form of a pamphlet in an edition of 500 copies, at a cost of $90—$60 odd of which were paid for by advertisements. Last year an edition of 1,000 copies was published at a cost of $112—some $55 of which were met by the advertisements. These pamphlets are exchanged with other engineering societies. The fame of the Society has spread far and wide owing to the distribution of these pamphlets. Only the other day we had a letter from a library in England asking for some copies.

The Society has 137 ordinary members and 4 honorary members. The officers of the Society are President, Vice-President, Secretary-Treasurer, Corresponding Secretary, and five representatives—one from each year, and from the special students and from the graduates. One of these representatives is Librarian. The annual fee is one dollar.

Thus, you see, gentlemen, that our Society is in its fourth year. It is firmly established here and will last as long as there is an Engineering Course in the University of Toronto.

Thus, in arranging our plans for the future, we must take into consideration that they will benefit not only ourselves, but the next few generations that are going to follow us here. Think of what value and interest these papers and periodicals will be one hundred years hence! Think of the opportunities we have, and, consequently, the responsibilities which devolve upon us.

Now, gentlemen, as to the objects of the Society. Of course *the* object is to benefit its members, a selfish object perhaps, but, nevertheless, *the* object, and the ways and means of attaining this end, and the prospects and probabilities of the result are what I want to discuss this afternoon. The question is: In what manner can we best benefit ourselves? It certainly must be a benefit to our brain and reasoning powers, not physical benefit or mere pleasure that we must seek after. What are we all here for? What is the object of spending three years of our life at this school? To get a diploma you say. Well, I suppose it is; but what does getting a diploma entail? Does it mean only the learning of some few facts and formulæ and methods? *No*, it means learning to *think*, to reason aright, as well as these facts and formulæ. Can we do better than assist ourselves in learning to *think*?

Gentlemen, how many of us can hit the bull's eye at five hundred yards with a rifle? Not one of us unless he has had a great deal of practice. Some of us might hit the target at fifty yards. We all can at least fire off the rifle, and in time would hit the bull's eye. So with thinking; we can all think just as we can fire off the rifle, but how many of us can think and reason accurately and clearly about the harder problems which crop up every day? Just as we can't walk a tight rope without practice, so with thinking—we can't think without practice.

Let us take a hypothetical case. Suppose it were possible to attend all the lectures, get up all the facts and formulae and methods, pass the exams and get the diploma without being able to think and reason accurately and clearly; would it be of any use? *None whatever.* And again, won't he who is able to think best and reason and make his deductions from the facts and formulæ most easily, won't he be far better off than the others?

It is in these meetings where we have to think on subjects that are not fully treated of in any one particular book, where we have to exercise our ingenuity and originality, that we get our practice of thinking.

Gentleman, what was our Euclid for? Weren't we told that it was an exercise in thinking? Take our course here; we have the reasoning in the abstract pure and simple—euclid and algebra. That is, we are taught a way of thinking. Next we have our statics and dynamics showing how this way of thinking may be applied to matters concrete.

Again, our analytical geometry—conics—another way of thinking and looking at things; and, again, the application of this in the theory of the strength of materials; and still, again, our calculus, something entirely new to us in reasoning and thinking. This shows the necessity of knowing how to think.

Another thing—clearness of thought. How often when we have read a thing, that is, followed out somebody else's thoughts and reasoning, we think it is quite easy and plain, but when we come to write it out or explain it to someone else it is not quite so easy and so plain. We leave out steps, we get "muddled"; due, gentlemen, to a lack of clearness, to a bad way of thinking. There is nothing so conducive to clear thinking as writing or explaining to others. This the Society gives ample room for practice in.

Again, gentlemen, we don't all look at things in the same light. We look at this in widely different ways. What is the result? When the ways are made known we see that it is possible to see things differently and to attack them from different sides to those we have been accustomed to, and consequently our minds gradually begin to look at things not only as they used to but as some others do. Thus, there is less chance of mistake; in fact our minds become broadened. If there is one mistake that we ought to fight against with all our might it is *narrow mindedness*, and the tendency to run in fixed grooves. This can be greatly overcome by the exchange of ideas, and the open discussion of various subjects.

Again, gentlemen, we are too fond of doing nothing but reading books and following lectures. That is, we only follow other people's ideas and reasoning—very good as far as it goes—but in this way we practise our own thinking powers very little indeed. There is no originality, and when we are left to ourselves we are at a standstill. We can follow a game of tennis, and see how every stroke and rally and everything is done, in fact, know all about it, but when we come to take the racquet ourselves, where are we? Here, again, the Society helps us greatly. It give us opportunities for original thought. So much for the improvement of our thinking powers.

Now, there is another thing which the engineer requires very much, that is, the power of observation. The observing of facts and methods, and the remembering of them, and the power to reason about them, and to base deductions on them, and to draw logical conclusions from them. This is most necessary. To be able to reason and think we must have a foundation of facts to go upon. These the Society can give us. In the Society all may get the benefit of the reading of one. Thus, you see what a large amount of knowledge we can get together; also, by means of our magazines. Books concerning the practice of engineering in this age of rapid advancement are always behind the times. Experimenting men have not the time to write a book, and even if they had they are not willing to take the trouble over it till they have finished their investigations. But a short magazine article can always be written, and is generally upon the very latest developments. Magazine reading gives us the latest facts and methods, opens our minds and gives us subject for thought. We get ideas in magazines that we never get in lectures, and ideas of great value to us.

Another thing, and here, I think, the Society can help us wonderfully, and in a way we could not get in books or in years of thinking. I mean, that if we possessed in our library copies of plans and specifications, estimates and contract forms connected with engineering, also such original tables as Mr. Russel gave us last year, and also plans of culverts, small bridges, drains, sanitary appliances—in fact anything of that kind, it would be of great use to us.

There are yet ways in which the Society can help us. Many of us come here from the country, I know I did, not accustomed to associate with many other fellows, not accustomed to make our ideas known to others by writing or speaking, never having had to speak before an audience. Here is the place to learn to do this, here, where there are no strangers, and where we are all in the same position. It will be of great use to us in after life. Here also we are all together with one common aim, the only time in which we are. Here, gentlemen, we all meet on an equal footing; the first year has equal privileges with the third year, and though perhaps not so much can be expected of them, still we certainly shall expect them to take part in the discussions, and give us an occasional paper with the results of their own experience and observation.

Now let us run over the advantages of the Society to its members:

1st. It affords practice in thinking.

2nd. It tends to clearness of thought.

3rd. It tends to originality of thought.

4th. It widens our minds.

5th. It tends to make us more observant.

6th. It gives us opportunities of seeing the actual practice of engineering through the magazines.

7th. It can give us access to plans and forms and other things which in no other way we could get.

8th. It gives us practice in public speaking.

These are all I have mentioned. The next question is—How are we going to make the best of each of these possible advantages? Let us take them up one by one.

Firstly—Practice of thinking. This depends on each of us individually, but still if only one of us were to practise he would not do nearly so much as if the practice were more general. I mean thinking leads on to more thinking, and the more general the thinking the more active will the thinking be individually. We must each of us take up every subject for discussion and work at it and think about it, and see if we cannot find out something about it that will be new to the others; and even the papers, we must not leave it entirely to the writers, we must at least find out enough on the subject to be able to appreciate it and to make an interesting and instructive discussion on it afterwards, and if we can't find out anything on the subject we can at least find out points about which we are ignorant, and ask questions. Don't be afraid to ask questions. If we don't think ourselves we can at least set the others thinking.

Secondly—It tends to clearness of thought. A most important thing. We can't depend on our thinking if it is not clear. We can't trust ourselves. We never can know whether we are right or wrong. The hurried way many of us have of reading our books is very likely to produce lack of clearness. It is easy enough to follow the reasoning of the author, and we are too apt to imagine we see things when we don't. How often have we found great trouble in writing out a proof in an examination which we saw so clearly when reading it over before. This writing of our thoughts is extremely good for us. How often we are unable to explain to others what we think we see so well ourselves. By writing papers and preparing for the discussions and taking part in them we can help ourselves greatly to get out of this bad way of thinking.

Thirdly—It tends to originality of thought. This, gentlemen, in the engineer is most necessary. At every turn in his work problems crop up that have to be treated differently from anything he ever heard. or read of before. As I said before, we do very little but follow the reasoning and thoughts of others. This is all very well as far as it goes. When we were learning to swim we had a float of some description to help us, and how well we could get on with this help; but directly we left go we lost confidence and sank. The tendency of fellows working for examinations is to let all original thinking go and to follow only the lectures and text-books; and we get so out of the habit of thinking for ourselves that when we come to something entirely new we are floored. Again and again have I been going over somebody's notes of a lecture a week or so old and we have come to some step or steps that we could not follow, and which, to us, were evidently wrong. "Oh," my friend would say, "that is what Professor got, it must be right." He had more confidence in his eye and ear and power of writing correctly than he had in his own thinking powers. We should be so practised in thinking out everything for ourselves that we would far rather trust our reasoning than our sight or hearing.

One good example of original thinking is in the solution of "deductions" in Euclid. How easy it is to follow the propositions in the book? How difficult to work out the most simple deduction for ourselves until we have had practice! The Society makes us think for ourselves. We discuss subjects upon which we have neither books nor lectures. We *have* to think for ourselves.

I think I am taking up rather too much time on this "thinking," but I have so felt the necessity of it myself that I feel as if I could not impress it upon you too strongly. I would like to skip the next point for the present and take the fifth and third together.

Originality of thought and observation. They work together; the more we observe the more do we think upon what we observe, and the more we think about these things the more we observe, and the more closely. It soon becomes natural for us to ask "why" or "how" about everything we see. One would be inclined to think that we would be interrupted continually by these questions, but the question comes up and is answered almost unconsciously if at all simple, and we have added something to our experience almost without knowing it. There seems to be an undercurrent of thought which goes on unconsciously, and which seems to work with memory. We ought to cultivate to the utmost of our ability this power of observation. It ought to be as necessary to us as being able to read. An aid to our observing is a subject for us to think and observe upon.

Now, the Society has its discussions. What better inducement could you wish for? The subject for discussion is always announced at least a week beforehand and sometimes a month or more. Besides the discussions the members are at liberty to ask questions, and the more questions asked the better. It makes the others think.

Now, gentlemen, rake up questions; don't be afraid of their being too simple, but ask questions on everything that comes under your notice that has anything whatever to do with engineering.

Now, to come back to number four. It widens our minds. How important to the engineer, more than anyone else, is the wideness of his mind! I think that you will all admit that studying with the object of standing well in the examinations tends to narrow mindedness. Now, gentlemen, how many of us are studying with this object in view? By far the larger number of us. Now, if the Society can help to counteract this tendency it will benefit greatly a large number of us. Now, the number of widely different subjects discussed before the Society, and the different opinions and experiences on every subject, must help to counteract this. I would like to say more on this, but have not the time.

Sixthly—It gives us opportunities of seeing the actual practice of engineering through the magazines. Now, as I mentioned some time ago, magazine reading makes us observe and think more, widens our views and gives us a large number of practical facts and methods. We hope, this year, to make our stock of magazines of more benefit to the members. We have obtained the use of a small room downstairs, and the General Committee are having it fitted up with shelves so that our very large number of papers can be spread out and kept in good order, and be easily obtained.

We want to appoint a committee of three librarians, whose duty it shall be to look after these, and to take certain days for the distribution of them, They will keep a book, and every member's name will be entered. and the numbers of the copies he takes out. Thus, there will be no trouble in getting the papers as there has been in other years. Besides these old copies, we hope to take in several new periodicals. I think it would be advisable to appoint a committee to investigate and find out the best periodicals, and to appropriate a certain amount to be spent by them. We should have papers on the various branches of engineering; railroad engineering, architecture and sanitation, mechanical and mining engineering, besides general scientific papers.

Seventhly—As to these plans and documentary forms—Members last year were asked to obtain or make tracings of anything they came across in their office work; also to make or obtain copies of any contract forms, specifications, etc., and present them to the Society. As yet I don't think any have been sent in. Now, if we had a good collection of these, besides catalogues of instruments and books, lists of engineers and companies to whom we might apply for work, patent laws and regulations, prospectuses of engineering schools throughout the world, copies of field-notes as kept by different engineers, etc., etc., and any general or particular information that would be useful to the young engineer, it would be of great advantage to us. In fact the library should be a complete reference book on all subjects connected with the engineer. I think in this way the library can do a great deal of good at a very small expense. The best way to proceed would be to appoint a committee to investigate the matter, and let them report to the Society, and the Society can then give them power to act.

Now, we come to the last—It gives us practice in public speaking. Never again, gentlemen, shall we have this opportunity. Once we are graduates we shall have no more student life; our meetings will be in public, we shall be among strangers instead of companions and friends. So, gentlemen, let us make the most use of our time here, and cultivate to the best of our ability this most useful accomplishment.

In closing, gentlemen, I would say that the more activity and life in the Society, the greater will be the advantages derived from it. I would like to impress it upon you all that it does not depend upon the General Committee or on the readers of papers, or on anybody in particular, but on the individual effort of each and every member.

Gentlemen, let us read, observe, and, above all things, think, and give to the Society that which is due to it, and let us strive to the utmost to increase tenfold the usefulness of this, our Society.

October, 1888. H. E. T. HAULTAIN.

A SHORT HISTORICAL REVIEW OF SANITARY SCIENCE AND THE "GERM THEORY."

By Cesare J. Marani.

"We live, we die, live well or miserably, live our full term or perish prematurely, according as we shall wisely or otherwise determine."

What is Sanitary Science? It is an application of the laws of physiology and general pathology to the maintenance of the health and life of communities, by means of those agencies which are in common and constant use.

What is Sanitary Drainage? It is *one* of the principal agents in bringing about the above desired conditions.

Has Sanitary Science been in existence for many years, or is it of recent origin? To this we would answer that though Sanitary Science might at first appear to be of recent origin owing to the wonderful development it has undergone of late years, and to the strong onward impulses it received about thirty years ago from the labours of such men as Lyon Playfair, Smith, Edwin Chadwick, Southwood and others, it can be traced notwithstanding this, through the filth, dirt, and darkness of the Middle Ages, through Rome's triumphant days, through that memorable epoch when Egyptian architectural skill was at its best, right back to the earliest Persian and Chaldaean dynasties. The Mosaic code of Laws—the most ancient on record—shows that the health of the Jewish population was a subject of no small interest in as much as it was a subject of legislation. (Leviticus, xvi. 37-42; Deuteronomy, xxiii. 12 and 13.)

Space prevents the giving of even a short account of the growth of Sanitary Science from these early times. How its importance rose or fell, how its dictates were carried out at certain times or altogether abandoned, according as the monarchy became powerful, imperative and rich, or sank in consequence of wars and defeats into inactivity and subjection; how it has undergone many a severe collision with superstition, custom, and pagan idolatry, and what the consequences have been; how certain ideas were put to test, certain symptoms carried out and what resulted from them; all this and more would take up as much space as George Rawlinson's "History of the five great Monarchies of the ancient Eastern World," published in three volumes, and could not therefore be introduced here.

We know of no book published containing an arranged compilation of all the facts recorded from the earliest times relating to, or bearing in any way on Sanitary Science including, of course, Sanitary Drainage. Such a book there may be, and certainly there should be, since there is more than ample material in that direction. For the present the inquisitive student must be willing to wade through numerous translations and reprints of old records, most of them written for an entirely different purpose, and filled with other matters. This then necessitates a great deal of judicial reading, and proves the truthfulness of the old saying, "There is no royal road to learning"; but nevertheless the reward is more than can be anticipated before the start is made. He will find that the onward progress of Sanitary Science with its peculiar variableness of speed takes place right through the history of the world. There is only one place where it seems to have retrograded like most other good things, and that is during the "Dark Middle Ages." *We* should be thankful to find ourselves beyond the influences of that "Slough of Despond." Like a small silver thread of limpid water among some rugged mountains —the early races of humanity—we find our little rivulet of Sanitary Science battling against, and being often turned aside owing to its feebleness, by the rocks and pebbles of barbarism and superstition. Notwithstanding these and other obstructions, as want of experience and facilities for observation, we follow it as it gradually finds its way towards certain depressions,—the basins of learning in those early days.

It increases in size and momentum when a crowned head begins to discover the inert virtues that lie hid in its waters and sets about straightening the channel and facilitating its onward flow—like King Khammarabi. Further on we find our rivulet arrested and almost hidden by marshy grounds and lofty reeds—which represent on the one hand, the inactivity and stagnation that often overtook the different empires of the Old World, caused largely by those terrible wars into which they would dash, regardless of life and everything else, every robust male being called to fight, while women, children, and the sick were left to carry on the sanitary works and the affairs of the state; and, on the other hand, the smothering effect that their tyrannical systems of government had on scientific research and science at large. Happily for us, we find that our stream breaks forth at last from these destructive surroundings and resumes its onward flow towards a gap in the mountain tops, where, after leaping down a considerable height, it strikes on some projecting rocks—the religious customs and superstitions that sprang up in the Eastern World just before the invasion by the rising Greeks—only to dance off again with greater fury, forming a serpentine course down the valley of human civilisation. As we turn the pages of history we find it gradually assuming the dimensions of a river. We find the Laws of Lycurgus, and such men as Hippocrates, the celebrated physician, saving lives and even whole towns from certain plagues, then rampant all around, by forcing the dictates of sanitary science to be put into immediate execution. His cardinal hygienic formula, so well known to everyone, stands unalterable even unto this day. How promising, important and indispensable is this, our river of life-giving principles, as it flows past the highest and boldest cliffs of Roman supremacy! Among ancient nations the Romans seemed to have been fastidiously clean, both in their persons and in their dwellings. They made free use of water, and were fond of the bath. They were also the first, as far as we can ascertain, to use the water-closet. They made the Campagna ot Rome as healthy and fertile as any of our best fields to-day by a good system of drainage, the importance of which they very well knew. These drains were afterwards allowed to go to ruin, and today the same Campagna is the source from whence springs up what is so well known to all travellers as the "Roman fever." They even had their Cloacae well ventilated to the end that pure air might oxidise and destroy the poisons arising in the gases given off by decomposing sewage. Even before this the Roman people, notwithstanding their military occupations, found time to build what now stands as an indestructible memorial of their knowledge and attention to sanitary matters, namely, the "Cloaca Maxima."

The ruins round Rome substantiate this, and also show that aqueducts were made to cover miles of the surrounding plain for the purpose of supplying Rome with an abundance of pure water that was beyond the slightest doubt untainted by sewage in any shape or form. They even founded a college of the *Archiatri Populares* or state physicians, whose duties were to look after the health of the public, and this may be regarded as the earliest type of our General Medical Council. Can we not then justly attribute a great deal of the glory, learning, and success of the Romans to their quick apprehension of the vital importance of Santary Science and Drainage at large?

But ah! Further on our fair river widens, and where the Roman crest sinks, and receding backwards is lost in the surrounding hills, we find it running shallow, losing its speed, and breaking up into several disjointed branches. Presently it seems to stagnate and vanish in the ground, and we can only find a very small and turbid stream continuing to drag its sluggish waters through the gloom and darkness of the Middle Ages.

We are indebted for the preservation of this remnant of a once flourishing branch of scientific knowledge to the rituals and peculiar customs of a church which, with all its faults did its duty and proved the best for the times, but which has since been making room for a better.

Macaulay speaking of the comparison made by some divines between the Church of Rome and the Ark, says, "Never was the resemblance more perfect than during that evil time when she alone rode amidst darkness and tempest, on the deluge beneath which, all the great works of ancient power and wisdom lay entombed, bearing within her that feeble germ from which a second and more glorious civilization was to spring." The monasteries and abbeys indeed proved a protection to sanitary science as well as to other branches of knowledge, and when at last men began to try and regain what they had lost, and things in general began to wear a different and more promising aspect, then and only then do we find our little stream, issuing from cells, cloisters, and monastic retreats, once more widening its banks of authority and increasing its power and force, until it falls a clear beneficial stream of knowledge into the grand valley of the nineteenth century. Here again it more than doubles itself owing to the boiling and surging waters that issue on every side to reinforce it, and so prolific of these springs of knowlege is the nineteenth century that our stream becomes at last commanding, irresistible, greater and even broader than during Rome's best days, and of recognized importance and value. This then is intended to give the reader an idea of the continuous though changeable flow of sanitary science since the earliest times.

The first appearance of what has now grown into a wonderful plant, stretching its many branches into as many different directions, namely the *Art* of sanitary drainage, seems to date as far back as the 16th century B.C.

Borosus, a Greek writer, informs us of the beginning of the first Chaldæan Dynasty in 2250, B.C. He goes on to show how weak and insignificant Assyria and the other surrounding countries were at that time, through illness and dearth. Some time (date unknown) before the reign of King Khammarabi, who probably reigned from 1546 to 1520, B.C., a plague broke out among the Chaldæans, caused as the writer supposes—and very justly perhaps—by the putrefaction of swarms upon swarms of locusts that had made their appearance in the land, and which had perished, partly by the overflowing of the Tigris. It must be remembered that Chaldæa was then an acrid, low, and very marshy land on the north shores of the Persian Gulf, and subject to annual inundations from the waters of the Tigris. Upon King Khammarabi's accession to the throne, the plague abated, and then disappeared, for it is recorded that the King caused a system of artificial irrigation to be adopted through the entire kingdom. I also find that he is credited with being the first man to conceive such an idea, and therefore the inventor of a system that has gradually assumed different forms for different purposes, and notwithstanding the 35 centuries of developments and so-called improvements it has undergone, has not yet attained unto perfection in its practical sense. This wonderful king also forced his people to live in better and more substantial abodes, having more windows, or rather openings, for the purpose of increasing the amount of light and fresh air in their miserable mud homes. It is a known fact in history that from this time to its fall, Chaldæa stood forth as the great parent of Asiatic civilisation.

As we pass through the history of the different ages down to the birth of Christ, we find that nearly all the plagues which visited mankind in any of the three continents—Asia, Africa, or Europe—are traceable to some hot, filthy and thickly populated spot in Asia—then the most densely peopled of the three—where it would seem, from the frightful state of things, that any compliance on the part of an individual with the simplest sanitary laws was considered a criminal offence, and therefore to be avoided by living in the most disgusting manner. For example, that horrid plague which was remarkable by fierce boils and gangrenes, and which made its last and most devastating appearance in Europe in 1665, and is said to still visit certain remote and degraded tribes in the East, was first noticed among the northern tribes of Media, many centuries before it ever visited Europe. These people, though living to the north of the Chaldæans, their most advanced neighbours, do not seem to have profited by their example in matters pertaining to health and cleanliness, for we are informed by historians of their filthy mode of living. They never would wash, and would rather walk miles than wade through a river. They lived in mud houses without any openings except that through which they crawled in and out. They huddled together inside one of these dens, as many as could lie on the ground, to pass the night in sleep. They never went any distance to deposit their excrement, which was always to be found festering around their dwellings, and which was used, in a great many instances, as plaster to fill up the cracks and openings in the roof, thus cutting off, in the most horrible way, the only ventilation that the filthy den had. A Mercian encampment could be scented miles away. Some of the descriptions are too horrible to reproduce. Plagues seem almost like blessings in such cases.

We find that Egypt during the 194 years of its occupation by the Persians, who then gave some attention to sanitary laws, was free from a plague which is now always associated with the name "Egyptian," owing to its constancy in that country. They then carried out a system something like our "pail system," using their large earthen jars instead. They lived in well ventilated and magnificent buildings; those of the ruling families outshining even our nineteenth century productions from an architectural point of view, and Ewbank, in his work on Hydraulics, makes out that the summer chamber of Eglon, King of Moab, was nothing else than a private closet or privy, while Sir J. Gardener Wilkinson on describing the isolated little rooms that are to be found in one of the halls in most of the ruins belonging to the early Egyptians, says: "These rooms bear a striking resemblance to the before mentioned private room of Eglon." We find these people prosperous in sanitary improvements during the 301 years of the Macedonian dominion, and also during a great portion of that of Rome. About the beginning of the Middle Ages they seemed to have abandoned every rule of cleanliness and decency. Through internal derangements, wars, and other causes, they abandoned sanitary precautions, were then weakened by disease, carried off in large numbers by plagues, and at last they sank into the lowest depths of poverty and degradation. A century ago a people was to be found in Egypt living in mud huts similar to those of the Medes some centuries before the Christian Era. Their lands were scourged yearly by plagues and epidemics. The national spirit, enterprise, and desire for a better and more prosperous state of things which is to be found in most nations, seemed entirely wanting with them. Can, therefore, these people be descended from the early Egyptians of history? Alas, they are! The Fellah, whose mode of living is even more horrible and repulsive than that of any Mede centuries and centuries before, as described above, and who, with the rest of his tribe, is responsible for many of the plagues that crossed over into Europe during the Middle Ages, is none other than the true descendant of the Pharoah who inhabited the lofty palace, in the midst of the ruins of which he rears his miserable hovel.

An eminent English physician in describing the main dwelling place and fortress of Oriental plague goes on to say: "Cairo is crowded with vast numbers of inhabitants who live poorly and nastily, the streets are narrow and close; the heat is stifling. A great canal passes through the city, which at the overflowing of the Nile is filled with water; on the decrease of the river the canal gradually dries up, and the people throw into it all manner of filth, carrion, and offal, the stench which arises from this, and the mud together is intolerably offensive, and from this source the plague constantly springing up every year preys upon the inhabitants and is stopped only by the return of the Nile, the overflowing of which washes away this load of filth." But returning to Egypt as seen under the Persians, Greeks, and Romans who were well versed in sanitary laws, is it not justifiable to infer from the absence of any epidemic for such a long space of time, during which good administration and the sanitary police of the country conquered the producing causes of plagues, that the same means will be followed by the same results?

The Romans, though not the first in art and civilisation, certainly the leaders in all that pertained to luxury and comfort, were the first to use certain forms of seats and water-closets, as we have said before. Some men are always ready to deny any motive, or attribute the motive of a praiseworthy action to selfishness on the part of the actor. Such writers say that this onward progress of the Romans in the practice of sanitary precautions and conveniences was founded more on the gradual acquisition of fastidious tastes, intolerant of whatever might offend the senses, than on any systematic philosophy pertaining to the preservation of life. Be this as it may, we find them using four kinds of receptacles for the excreta. Glen Brown gives them as follows: "Close stools (lasana) in which the rich sometimes used gold and silver bowls; vases (gastra), which were stationed on the roadways; public privies (cloacina), of which Sir William Gell tells us there were one hundred and forty-four in Rome; and privies (latrina) probably for private use."' Besides these, water-closets, with water supply and waste for the water basin, and something in the shape of a drain of some kind to carry off the excreta, were in constant use among the richer class, for Fosbroke, while writing on ancient closets, etc., says: "That in the palace of the Caesars it is adorned with marble and mosaic. At the back is a cistern, the water of which is distributed by cocks to the different seats. The pipe and basin of one still remains at Pompeii, and is like ours" (*i.e.* 1825, A.D.). We have several other writers who have made similar discoveries. Among them may be mentioned Sir William Hamilton, Sir William Gell and F. Liger. We refer the reader to their works.

In the time of Constantine (300 A.D.) and probably earlier, seats in the shape of chairs were used, having arms, backs, and legs elaborately carved.

For nearly a thousand years after the fall of Rome there seem to have been no privies used inside houses. Facilities for ventilation were abandoned, and fresh air had to find its way into their dwellings as best it might. In England no thought was given to drainage in any shape or form. Look at the old forts and towers of our feudal nobility, where in a great many cases more were accommodated than there was really room for. Soldiers, guards, pages, servants, guests, etc., had to crowd into their respective holes—for we cannot call those small and badly ventilated dungeons of darkness and dirt, rooms. The family of the castle, of course, fared considerably better, inasmuch as they had their own apartments. But these places were undrained, unventilated, full of impurities and noxious exhalations, and therefore, what with so many persons together and what with their dirty customs and mode of dispensing with the waste matter of the place, we can well imagine the dangerous state of things, and can heartily sympathise with those who wish they had lived in the "good old times."

We are indebted to the finer tastes and customs of our Norman conquerors for the introduction of sanitary precautions into England. We learn from Viollet-le-Duc that castles (chateaux), at the commencement of the 13th century, were accommodated with privies (latrines). They were generally to be found in a corner made by some buttress with the main wall.

James C. Bayles says: "People often wonder why we do not have such fearful visitations of epidemics at the present day as the plague of London, the ancient spotted fevers, sweating sickness, etc. They forget that we are not yet free from cholera, yellow fever, typhoid fever, and other preventible diseases, and that the next generation may see that our disregard of nature's laws affected our death rate, as surely as the dirt and filth of London caused the Great Plague." This certainly is true, still we have improved wonderfully since then, and a tremendous gap exists between our mode of living and that of our ancestors.

An old chronicler speaking about London in the 12th century says: "In the streets around St. Paul's Churchyard the horse manure was a yard deep." Cleanliness of persons was a thing unknown, and talking of the men and women in those days he goes on to say, "They wore clean garments on the outside, but dirty ones were often worn until they fell away piece meal from their unwashed bodies." Viollet-le-Duc tells us that at a considerable later period in history the people of Paris were allowed to throw their excreta from the window into the street, provided they gave the verbal warning, "Gare l'eau" three times, In Edinburgh this custom lingered till 1760 or later, and parties walking on the streets after 10 p.m. had to cry, "Haud yare hoand," every few minutes for fear of what might befall them. A writer about this time gives the following: "The High Street and Cowgate of Edinburgh, rich in architectural and historical associations, are saturated with a mass of filth which completely taints the air, and makes the stranger, as he passes through it, reflect to himself, if such be the odor which these houses cast into the open air, what must they be within? Horrible indeed are the poisoned gases with which they are filled—horrible the narrow closes, used for all disgusting purposes, by which entrance to them is found. But even in the magnificent squares and crescents, which architectural ambition has raised in contrast with the gloomy dwellings of the old fighting Scots, there are remnants of the old spirit, and "mine own romantic city" requires a thorough cleaning before it can accomplish its magnificent capabilities for purity and healthfulness." Another writer about 1831 speaks of Edinburgh as follows: "Yet when cholera presented itself in Edinburgh, the first large town where it made a serious settlement —though there had been long warning—such was the insufficiency of the sanitary machinery, that not a single particle of the filth which festers in masses or runs in thick disgusting streams through the city had been removed. Indeed it was generally observed, probably because people's eyes and noses were more acutely sensitive on that occasion, that when the cholera arrived the Old Town was more deeply steeped, than it had usually been, in loathsome filth."

History seems to show that the natural influences of thorough sanitary reforms, apart from their effect on the health and longevity of a community, are to diminish and almost expel vices, such as prostitution, theft, murder, etc.

There is no doubt that the frightful state of the sanitary condition of Paris during the end of the 17th Century and the beginning of the 18th had very much to do with the alarming numbers of those inhuman monsters the Chiffoniers, who in 1830 must have numbered 2,000, and were conspicuous actors in the French Revolution. Similarly the sanitary condition of Edinburgh was responsible for the production of such anomalies as Burke and Hare, and for the facilities their haunts afforded them. It seems to be the rule that in general sin and dirt roam the world hand in hand. Where sin holds its sway we find dirt, and where dirt lurks there we find sin.

On the subject of cholera the Glasgow Board of Health for 1831 writes as follows: "The chief predisposing causes of every epidemic, and especially of cholera, are damp, moisture, filth, animal and vegetable matters in a state of decomposition, and in general whatever produces atmospheric impurities, all of which have the effect of lowering the health and vigour of the system and of increasing the susceptibility of disease, particularly among the young, the aged, and feeble. The attacks of Cholera are uniformly found to be most frequent and virulent in low-lying districts, on the banks of rivers, in the neighbourhood of sewer-mouths, and wherever there are large collections of refuse, particularly amidst human dwellings." Then follows a lengthy piece of advice to private individuals, with several good directions and recommendations. "In conclusion the General Board of Health would again urge the consideration, that whatever is preventive of cholera is equally preventive of typhus, and of every other epidemic and constantly recurring disease, and would earnestly call the attention of all classes to the striking and consoling fact, that, formidable as this malady is in its intense form and developed stage there is no disease against which it is in our power to take such effectual precautions, both as collective communities and private individuals, by vigilant attention to it in its first and premonitory stage, and by the removal of those agencies which are known to promote the spread of all epidemic diseases. Though therefore the issues of events are not in our hands, there is ground for hope and even confidence in the sustenance and resolute employment of the means of protection which experience and Science have now placed within our reach."

In Dr. Southwood Smith's report on the state of large towns we read as follows:—

"The place called Punderson's Gardens is a long and narrow street, in the centre of which is an open sunk gutter, in which filth of every kind is allowed to accumulate and putrefy. A mud bank on each side commonly keeps the contents of this gutter in their situation; but sometimes, and especially in wet weather, the gutter overflows, its contents are then poured into the neighbouring houses, and the street is rendered nearly impassable.

"The street is wholly without drainage of anykind. Fever constantly breaks out in it, and extends from house to house; it has lately been very prevalent here, and we have had several fatal cases from it in the London Fever Hospital. The open area called Lamb's Field is about 700 feet in length and 300 in breadth, of this space 300 feet are constantly covered with stagnant water, winter and summer. In the part thus submerged there is always a quantity of putrifying animal and vegetable matter, the odor of which at the present moment is most offensive. An open filthy ditch encircles this place, which at the western extremity is from eight to ten feet wide. Nothing can be conceived more disgusting than the appearance of this ditch for an extent of 300 to 400 feet; the odour of the effluvia from it is most offensive.

"Lamb's field is the fruitful source of fever to the houses which immediately surround it and the small streets which branch from it. Particular houses were pointed out to me from which entire families had been swept away, and from several of the streets fever is never absent"—and so on for several pages, then he ends:

. . . . . .

"I know that the verbal description of these places can convey no conception of their disgusting and poisonous condition. They must be seen, to be at all understood, and when seen everyone involuntarily exclaims: can such a state of things exist in a country that has made any progress in civilization?" This was the state of things in London not a century ago. When the improvement of sewage was actively undertaken in London some thirty years ago, it was found that the death rate was so much reduced, especially in the above quarters of the town, that, if the same reduction could have been made universal the annual deaths would have been twenty-five thousand less in London and one hundred and seventy-seven thousand less in England and Wales; or, by another view, that the average age at death would have been forty-eight instead of twenty-nine, as it then was.

From the above we are easily convinced that there must exist some direct relationship between disease and dirt, and this then brings us to a consideration of what is known as the germ theory of disease, which we will find to possess both interest and importance.

For a full and complete discussion of this theory see Prof. F. A. P. Bansardt's book "The Germ Theory of Diseases and its relation to Hygiene."

Of all the various diseases that affect humanity the most wide-spread and numerous belong to the zymotic class. This class may be sub-divided into two separate families, the Entetic and the Miasmatic, the latter being by far the more numerous in its individual members. It is with this family of diseases, namely, the Miasmatic, that drainage has more especially to deal, although in addition, drainage, as changing the moisture of the ground has its effect on many diseases belonging to a family that attack the respiratory system of the body. Scientific men, and prominently among them Baron von Liebig and Monsieur Pasteur, discovered after long and earnest laborious investigations, that the propagation of a number of epidemic diseases among the lower animals was effected by certain minute vegetable germs or miscrobes. This is now an established fact. Dr. Budd is credited with having identified the germ producing typhoid fever, while there are several who claim the discovery of the diphtheria germ. These and other investigations have given rise to what is known as the "germ theory of disease."

The theory holds that matter, *i. e.*, organic matter, while undergoing decomposition, creates or develops and gives off numerous microscopic cells of a very low order of vegetable life. The spores which proceed from these fungi are carried about in the air currents, as the invisible pollen of flowers is carried, and on coming into contact with the skin, or more especially the mucous membrane, they work their way into the veins and arteries of the body where they multiply and grow in astonishing rapidity, feeding on the blood all the while. This is the cause of disease.

Though Dr. Beale refuses some of the details of the germ theory he most certainly upholds its general principle, and therefore, this much is certain, that none of these miasmatic diseases exist without a sufficient cause, and that moreover, the cause is in every case some emanation either from decomposing organic matter, or from some diseased person. Hence it follows that diseases of this order are entirely preventible when their hot-bed and stronghold, namely, decomposing matter and rotting filth of every kind, are removed to safe quarters, and when those who are struck down with one or more of these diseases are removed to a safe distance or shut off from their fellow creatures. This conclusion should be readily accepted, for not only is it deducible from an assumed theory of diseases, but actual statistics without number leave no question as to the fact that typhoid fever, diphtheria, etc., are in every case traceable to some violation of sanitary laws, and that when these violations have been discontinued, the diseases have themselves abated and ultimately died out.

In Latham's "Sanitary Engineer" we find a statement of the relative death rates of twelve English towns before and after the introduction of sanitary works. The following are the averages of the twelve towns.

Average mortality per 1,000 before construction of work, 26.4; average mortality per 1,000 after or rather since completion of works, 21.7.

Although the separate results vary considerably, still in every single case the improvement is decidedly marked. This, of itself, as a result from works admitted to be imperfect, serves as an almost unanswerable argument in favour of the benefits to be derived from sanitary drainage.

By following on the line of speculative calculations we would get the following: The sum of the populations of these towns is almost 25,400. The average of deaths per 1,000 before sanitary works were introduced, 26.4; after the works were in operation, 21.7; leaving an average of 4.7 per 1,000 to the good.

Observing that three of these at least were saved by the sanitary arrangements, and further assuming that each death represents 730 days of sickness, we have an annual saving of 76.2 deaths, or 55,626 days, which at $1.25 per day makes a saving of $69,532.50 per annum. This at 6 per cent. represents a capital of about $1,158,875 00 or about one million and a sixth. Such a calculation, though unavoidably vague and indefinite, and although of little interest to private individuals, is nevertheless valuable to philanthropists, statesmen, and civic officials, inasmuch as it points out the immense actual losses, not to individuals, it is true, but to the community at large from not giving better attention to our subject. Moreover, they show, in however casual a way, that the question of sanitary improvements is a living one of unexpectedly large economic proportions, for narrow the probable losses down to so low a point as to leave no doubt of their being below the actual case, and we still have a result which is startling in the aggregate. Let us consider for a moment the causes which contribute to such excessive and unnecessary mortality. First among these may be mentioned cesspools. In the absence of proper drains or other system of removing the waste matters of a household, every house must have one of these. But every house must have water, and as it is the exception to find a little village provided with a system of water pipes, that first has not had a system of drains introduced, so we find that a well is necessary, either for each house, or for a group of houses. All the dejecta and wash of the household, composed partly of solids, and partly of liquids find their way to the cesspool. The solid portions of this mass of filth remain and decay—ferment perhaps—and the air is filled with the emanations from this decomposition. This forms one source of disease. The liquid portions, on the other hand, soak into the surrounding soil, and, though at first they may be rendered harmless owing to the purifying effect of the ground, yet since the supply is constant the ground soon becomes so saturated with this filth as to lose its power of purification entirely. The area of filth gradually widens and widens until the well is reached, and then the unfiltered, unpurified liquid portions of the cesspool enter the well. This forms the second cause of disease from that single institution—the cesspool.

In the one case the actual poisons are inhaled, in the other drunk, both are prolific sources of disease. Along with cess-pools we may class privy-pits, garbage heaps, stable refuse and the like. Spread over the ground such refuse is the essence of vegetable life, piled up in heaps, or hid under the ground it is nothing but a source of disease and death. The third cause of the above mentioned disease is perhaps more extensive than all the others put together. It operates in cities and towns that have a system of drainage, and consists in defects of various kinds in that system and in its practical application. The possible defects are almost countless in number, and therefore the devising of measures to remedy them forms the body of the whole science of sanitary drainage. It is more important that the whole system of drainage in a house be air-tight than that the pipes of a steam engine be steam-tight, for the simple reason, that when a steam pipe leaks, the leak is manifest, not so with a sewer pipe; nothing gives warning to the inmates of the house of the existing defect save disease and death. For this reason frequent and rigorous inspection should be made of the whole system inside the house, as every inch of pipe is responsible for the whole danger. Care and thought should also be exercised in choosing the materials to be used for house drainage. The fourth cause of the unnecessary amount of prevalent disease is the want of proper drainage for the foundations and cellars of houses, and the grounds around them. With ground of a porous nature, drainage is sometimes unnecessary, but this should be looked on as a rare occurrence. The ground is generally saturated with moisture which escapes in the form of damp mists during the evening and early part of the night, and as dampness and mist are known to be very good distributors and cultivators of whatever poisonous germs may be floating about, it is to our interests to remove them from around our dwellings. To want of drainage of this sort has been traced consumption and pulmonary diseases generally, dysentery, ague, fever, malaria, neuralgia, etc. Lastly the fault may be in the main sewer itself, which perhaps is not far enough below the level of the cellars to prevent flooding after rain-storms. Toronto has experienced this flooding of cellars by sewage several times within the last ten years. These then are a few of the considerations to be taken into account in planning a system of drainage for a community, and it is evident that although a system of drainage is a vast improvement on no drainage at all, yet that the system, to be efficacious, must be complete in every detail and managed with almost scientific accuracy in every house. This also shows the necessity of considering the best means of eliminating so far as possible these dangerous liabilities so to speak, from our houses and towns.

These last twenty years have seen wonderful changes. Modern thought and enterprise has brought forth one hundred fold. Almost all these liabilities have now been lessened, and in some cases entirely moved from among us. Speaking in a figurative sense, we live in an autumnal age. We enjoy the fruits of knowledge planted and husbanded by preceding generations. Had these ages never passed on the pinions of time, and were *this* the first age of the Earth's inhabitation by man, we might find ourselves no better off regarding sanitary matters, than the Medes and Persians were before the Roman era.

Still because we have made creditable advances in all the branches of sanitary science, let us not rest, and say "it is sufficient," for then peradventure a winter of barrenness might follow on the heels of our fruitful age, and the next generation might justly impeach us with having added nothing to the World's Monument of experience and discovery. Rather let us be philanthropic, and in *that* spirit remember our school's motto *Scite et Strenue*.

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CABLE RAILWAYS.

By E. W. Stern.

Cable railways are no longer an experiment; already there are in the United States 200 miles of road in successful operation, and just recently they have been introduced into Great Britain, Australia and China—Hong Kong having a short line running.

The idea of the application of a rope or cable to the drawing of vehicles is by no means recent. In England, as far back as 1788, boats were drawn up and down inclines by means of ropes, but it was not until 1858 that the first patent on our modern cable system was obtained—J. H. Gould, of Philadelphia, in that year, patented the underground tube containing a movable cable. From then till 1870, numerous patents were taken out, but none were developed until that year. A. S. Hallidie, the "father of cable railways," was granted his patent for a grip pulley, and 1873 he successfully opened in San Francisco the first cable railway proper.

From the present outlook the cable tramway bids fair, in the near future, to supersede horse-cars. Statistics of those lines now in operation prove conclusively that it is the most economical and reliable system known, to handle a large and varying passenger traffic.

Its advantages over the horse-car system are briefly these:

1st. Grades are surmounted with the greatest facility and are just as easily operated as levels. This is an important advantage for the reason that it renders hill property which is the most desirable for residences, and which would be otherwise difficult of access, fully available.

2nd. The great expense involved in successful consummation of an enterprise of this nature lends tone to it, which is revealed in the improved character and cleanliness of the cars; the substantial character of the work required results in an improvement of tracks, which altogether, increases the comfort and pleasure of the passenger.

3rd. The immense amount of filth that is due to the use of the large number of horses employed in street car lines is entirely obviated. It is much easier to keep the streets clean, and in a large city this is a matter of great importance.

4th. Increased speed.

The great drawback to the building of a cable line is its immense initial cost, which ranges from $125,000 to $210,000 per mile, including rolling stock, buildings and machinery. The cost of four miles of the Metropolitan Street Railway of Kansas City was $800,000. The Grand Avenue Cable Railway, seven and a half miles long, cost $1,200,000.

A comparison, however, of the profits derived from the cable line with those of horse-car lines and elevated railways will show its financial superiority as an investment.

Comparing the horse-car lines of New York city with the cable lines of San Francisco, we find that in 1886 the former, which aggregated 856 miles and which cost $56,906,000, produced a net income of $1,937,000, or 3.6 per cent. In San Francisco six miles of cable railway, which cost $900,000, yielded an income of $135,000, or 15 per cent. on the original outlay.

In 1886 the forty miles of elevated steam railway in New York and Brooklyn, which cost $46.613,000, yielded an income of $1,571,000, or 3.4 per cent. In a cable road now in operation, having less than one mile of double track, and which transports less than 4,000 passengers daily, there is a dividend of 10 per cent. on an investment of $150,000. The efficiency of the power being used in overcoming the friction of the machinery and cable. The Market Street cable line, of San Francisco, shows a much greater efficiency, it being 50 per cent. The horse power required for each car is about four and one-half.

A cable railway is an immense machine from one end to the other. It involves the use of a great deal of mechanism. The engineering must be done in the most careful manner, and the principle that "the best is the cheapest," must never for an instant be lost sight of.

Faulty details and execution will cause innumerable mishaps and a great loss of money.

The road-bed is put down in the most substantial manner, and the tracks lined as carefully as a skilful transit-man can possibly do it. Errors in alignment and grade of even a quarter of an inch must be guarded against.

The line is located by driving stout hubs every 50 feet apart on tangents. Curves are run in with a transit, the deflection angles being calculated for chords eight feet long. The best practice with regard to curves in turning street corners is to compound them, beginning with a radius of 100 feet, and running it into one of 75 feet, and 50 feet radius. Points are referenced by cutting marks in the stone curbing. Bench marks are carefully located at every street corner. The two side rails and the slot rail are supported by iron yokes placed every four feet apart. These yokes, which are either of cast or wrought iron, are imbedded in concrete. In the centre of the yoke is an oval space about three feet high and eighteen inches broad, the exact shape of the section of the concrete tube seven inches thick, which runs the entire length of the road and serves as the conduit for the wire rope. This standard guage is 4 ft. 8½ in., and the distance between the tracks is ten feet from centre to centre of rope. Midway between the two tracks and at a sufficient depth to give a good flow, is a twelve-inch drain of glazed pipe, and to this is connected branch pipes from the tube wherever necessary, as at changes of grade, etc.

On the straight track, every thirty-two feet apart, are placed sheaves eighteen inches in diameter and four inches broad, to support the cable. On curves the sheaves are twenty-two inches in diameter and nine inches broad, having a flange on the bottom projecting about an inch, to prevent the cable from slipping off.

When a car is being drawn along, the grip carries the cable 8 inches clear of the top of the sheaves, and in going around a curve, it raises it 6 inches and pulls it out about 2 inches from the horizontal sheave, thus enabling it to clear the wheels easily. When it is required to switch a car from one track to another the cable is let go, and the momentum it has received is sufficient to urge it across.

The cable, which is generally 1⅜ inches in diameter and of steel, first winds three or four times around the big driving wheel (12 feet in diameter) in the engine room. Thence it passes through the tube to the end of the track, where it goes around a large sheave 10 feet in diameter, then back to the engine house, being spliced so as to be in one continuous length. At the end of the track turntables are generally put in to turn the cars around. By an ingenious device, by pulling on a lever the cable itself is made to revolve the turntable.

A great many roads use the grip car coupled to another behind it. The trucks on these cars are rigid, which causes the car to jerk considerably when going round a curve.

The combination cars, which combine the two in one, have pivoted trucks, and travel round the curves with much greater facility than the former. They are being used now almost entirely on the best roads. The Grand Avenue Cable Company, of Kansas City, Mo., have two engines of 500 horse power each, one being used while the other is kept in reserve. They drive the cable at the rate of seven miles an hour.

In conclusion, the writer, although he has not entered into details minutely, hopes to have given his listeners some account of the status and general features of a branch of engineering which bids fair to develop very largely in the near future, and which requires for its successful undertaking, engineering talent of a high order.

SEWERS.

By E. F. Ball.

The object of a system of sewerage is to remove all refuse matter from dangerous proximity to human habitations before it has time to putrefy. The best known system is the water carriage system.

The necessity for immediately removing refuse matters is established by the fact that where such removal has been effected the prevalence of various dangerous diseases has been greatly reduced or entirely checked.

Where the gases arising from the decay of refuse matter are allowed to enter living apartments, the danger of the propagation or spread of disease is enormously increased; but although there are many cases in which sewer gas is known to leak into houses where the inmates do not contract any serious illness, yet the general lowering of the tone of the system, such as listlessness, sick headache, etc., is often apparent, though the cause is seldom suspected.

In devising a system of sewers, the following points have to be considered:—

1st. The area and physical outlines and controlling features of the district to be drained, its geological character, and the depth to which it may be desirable that the drainage should extend.

2nd. The rainfall in the district, with consideration of the maximum fall of rain in a given interval of time, and the proportion of such storm-waters that it is proposed to carry off by the sewers.

3rd. The character and extent of the water supply.

4th. The final disposal of the sewage.

It will be impossible in the present paper to consider all the points at length, but an attempt will be made to describe such points as would force themselves prominently on the attention of the Sanitary Engineer.

DEPTH OF SEWERS.

The following figures will give an idea of the average depth at which sewers may be placed in a city:—

Basement or cellar below street..........	9 ft.	6 in.
Cellar floor and covering of drain.........	1	6
Drain		6
Fall of drain 2 in. in 10 ft. for 50 ft........		10
Fall of main sewer 2 in. in 10 ft. for 30 ft..		6
	12 ft.	10 in.

In towns and villages these figures might be considerably reduced.

STORM WATER.

A most important factor in the designing of sewers is the amount of storm water which it is expedient they should remove. In small towns the water had better be conveyed away by surface gutters, as the expense of providing sewers for this duty is great. In large cities with paved streets and large areas of roofs this water might be sufficient to cause damage to basements, etc., hence the necessity of its removal underground. As in small towns the water supply is generally confined to wells and cisterns, some of the storm water should be admitted to the sewer to flush it, care being taken not to flood the sewer.

DISPOSAL OF THE SEWAGE.

The sewage is usually discharged into a running stream or large body of water whereby it is so diluted or oxidized as to be rendered harmless. Various attempts have been made to purify the sewage chemically and mechanically, but with little success, for the clarified or deodorised product is still "sewage."

Attempts to utilize the solid parts for fertilizers have not proved remunerative even in densely populated countries like England, where the value of land is very great. Irrigation and intermittent downward filtration have been successfully employed in some localities.

The latter is accomplished by allowing the sewage to percolate through a porous gravelly soil, which filters out the suspended particles and the escaping liquid is sufficiently harmless to be run into streams from which water for domestic purposes is not taken.

SIZE OF SEWERS.

Sewers should not be larger than is absolutely necessary to carry off the amount of liquid for which they were designed, as the smaller the sewers the greater the depth of the water flowing through them, and the greater its velocity and ability to sweep away solid matters and prevent choking.

Every precaution should be taken to avoid leaks, as the escaping liquid would not only poison the subsoil, but the solid matter would be deposited in the sewer and eventually choke it.

In calculating the size of sewer necessary for a given discharge it must be remembered that the supply is not from a constant head at the upper end, but is admitted at various points. The velocity of the liquid in a sewer of uniform size and inclination will thus increase towards the outlet, and for this reason the aggregate area of the laterals discharging into the sewer may greatly exceed the area of the sewer itself. From this it will be seen that the formulæ for the discharge of pipes from a constant head are not applicable.

In providing for storm water the maximum amount that need be provided for is one inch of rainfall per hour. It is extremely seldom that such a storm ever lasts an hour, and the water may be considered to occupy double the time in entering the sewer that it was in falling. Even then it enters the sewer at different points along the line so that the rainfall near the lower end may have run off before that from the upper end has arrived. The amount of actual sewage is so insignificant compared with the amount of storm water that in designing a system of sewers to carry off this water no consideration of the amount of sewage proper is necessary.

Kutter's formula for the uniform velocity of water in pipes is $v = c\sqrt{RS}$ where v is the velocity in feet per second.

R is the "hydraulic radius" $= \dfrac{\text{area of wet cross section}}{\text{length of wet perimeter.}}$

S is the sine of the inclination of the pipe $= \dfrac{\text{fall of pipe}}{\text{length of pipe}}$.

c is a numerical constant. For a 12″ sewer with a fall of 1 in 100 it = 95; for a 6 ft. sewer, 136. For practical purposes $c = 100$, $\therefore\ v = 100\sqrt{RS}$.

For pipe running full, $R = \dfrac{\cdot 7854\, D^2}{3\cdot 1416\, D} = \dfrac{D}{4}$ where D is the diameter of the pipe; $\therefore\ v = 100\sqrt{\dfrac{D}{4} \times S} = 50\sqrt{DS}$.

Let Q = number of cubic feet per second discharged, then $\dfrac{Q}{\text{area of pipe}} = v$, or $\dfrac{Q}{\cdot 7854\, D^2} = 50\sqrt{DS}$; $Q = 39\cdot 27\, D^2\sqrt{DS}$;

$$Q^2 = 1542\, D^5 S,\quad D = \sqrt[5]{\frac{Q^2}{1542\, S}}.$$

Let L = length of pipe,
" H = fall "

then $D = \sqrt[5]{\dfrac{Q^2 L}{1542\, H}}$ = diameter of pipe in feet.

As before stated, the formulæ for the flow in pipes from a constant head are not applicable to sewers, but by changing the exponent in the above equation from 5 to 6, thus, $D = \sqrt[6]{\dfrac{Q^2 L}{1542\, H}}$, we obtain an empirical formula for finding the diameters of the outfalls of sewers, and which, if intelligently used, will be found sufficiently accurate for all purposes of sewer discharge for populous districts.

Upon the supposition that the rainfall of one inch is carried off in twice the length of time of its fall, *one half inch* of rain per hour will represent the quantity discharged.

Let Q = number of cubic feet per second discharged.

" A = " acres drained.

The amount of water that will reach the sewers per second equals half the amount of rain falling on one acre per second multiplied by the number of acres drained $= \frac{43560\,A}{60 \times 60 \times 12 \times 2} = \cdot 5\,A$, or $Q = \frac{A}{2}$.

By substituting $\frac{A}{2}$ for Q in the equation $D = \sqrt[6]{\frac{Q^2 L}{1542\,H}}$ we get

$$D = \sqrt[6]{\frac{A^2 L}{6168\,H}}.$$

Let $N = \frac{L}{H}$ or the length in feet in which the sewer falls one foot,

then $D = \sqrt[6]{\frac{A^2 N}{6168}}$, or $\log. D = \frac{2 \log. A + \log. N - 3\cdot 7901}{6}$;

where D = diameter in feet of the outfall of the sewer,
A = number of acres to be drained,
N = length in feet in which sewer falls 1 foot.

To compensate for the additional friction on curves, the inclination there should be greater than on the straight portions.

Referring to the equation $v = 100\sqrt{RS}$, or $v = 100\sqrt{\frac{S'}{P}\frac{H}{L}}$,

where S' = sectional area of fluid
" P = length of wetted perimeter
" H = fall of sewer
" L = length of sewer
} in feet;

if we substitute the numerical values in this formula, and for S' assume one-tenth of the sectional area of the sewer, we will have the velocity in feet per second of the low summer flow. To obtain the additional head requisite for the length of a given curve, substitute this value just found for v in the following formula: $h = \frac{v\,l}{2\,r\,D}$.

where h = additional head for the curve
" l = length of the curve
" r = radius of the curve
" D = diameter of the circular sewer
} in feet.

INCLINATION OF SEWERS.

In order that sewers may discharge their contents promptly, and not become choked with deposit, they must have a sufficient fall. The following table gives approximately the gradients which will preserve circular sewers free from deposit, *providing they run half full:*

For 6 inch	diameter,	a grade	of	1 in	60
" 9	"	"	"	1 "	90
" 12	"	"	"	1 "	200
" 15	"	"	"	1 "	250
" 18	"	"	"	1 "	300
" 24	"	"	"	1 "	400
" 36	"	"	"	1 "	600
" 42	"	"	"	1 "	700
" 48	"	"	"	1 "	800

In devising a plan to remove the sewage with only sufficient storm water to flush the sewers, the following facts will be noted :

The sewage from the houses and outbuildings will be about two-thirds the entire water supply, and about one-half this quantity will reach the sewer in 8 hours.

If the water supply be 60 gallons per head per day, about 4 cubic feet per head per day will be discharged in 8 hours, or one-half cubic foot per head per hour. This will be the maximum flow from all sources.

SHAPE OF SEWERS.

When a moderately steady flow may be expected through a sewer, it should be circular, but when the average amount of sewage is small, and provisions has to be made for large bodies of water at times, the egg-shaped should be used.

MATERIALS FOR SEWERS.

For sewers up to 24 inches in diameter, vitrified pipes are generally used. They should have a smooth surface, should be true in form, hard and well burned. All connections should be made at as acute an angle as possible.

For brick sewers the following extract from the specifications for furnishing sewer brick, American hydraulic cement, Portland cement, and iron castings for the Genesee street branch of the Buffalo trunk sewer may be quoted.

SPECIFICATIONS FOR BRICK.

All bricks furnished to be of the best quality of sewer brick, true and uniform in shape, burned hard entirely through, and having a clear ring when struck.

SPECIFICATIONS FOR AMERICAN HYDRAULIC CEMENT.

All cement of this class must be of the best quality, fine ground, quick setting, capable when made into testing blocks of withstanding a tension of 50 lbs. per square inch of section when mixed pure and exposed thirty minutes in air and twenty-four hours in water.

Should cement have to be stored, or not immediately used after acceptance, or at any time, it must be protected from the weather and kept dry, and must never be placed upon the ground.

SPECIFICATIONS FOR PORTLAND CEMENT.

All cement of this class must be of the best quality and must be ground so fine that at least 90 per centum of it will pass through a wire sieve containing 2,500 meshes to the square inch.

The cement when made into a stiff paste, without sand, must set within half an hour from the time of adding the water, and be capable of sustaining without rupture a tensile strain of at least 250 lbs. per square inch, 7 days after being moulded. The cement when mixed with sand in the proportion, by volume, of one of cement and two of sand, and made into a stiff mortar, must be capable of sustaining without rupture a tensile strain of at least 90 lbs. per square inch, 7 days after being moulded. The test blocks will, in all cases, be removed from the moulds as soon as the setting begins and the material will bear it; but they will not be put into fresh water before the expiration of 24 hours from the time the cement was mixed. The sand used in testing the cement will be sharp, siliceous sand, free from loam, dust, mica or other foreign matter, and will be gauged between two sieves of 400 to 900 meshes to the square inch. Cakes of the paste will also be made about one-half inch in thickness, and after immersion in fresh water for one week, their surface must show no sign of crack or softness.

Each barrel of cement must weigh not less than 375 lbs. gross weight, and on the whole quantity to be delivered, must average not less than 400 lbs. gross weight to the barrel, and under this contract 400 lbs. gross weight will be considered and estimated as one barrel. The cement must also weigh not less than 100 lbs. and not more than 125 lbs. per U. S. struck bushel, when filled from a hopper placed at a height of 3 ft. above the mouth of the measure.

Each barrel must be properly lined so as to effectually seal the cement from dampness. Should cement have to be stored, or not immediately used after acceptance, or at any time, it must be protected from the weather and kept dry, and must never be placed upon the ground without blocking under the barrels.

MORTAR.

Whenever in these specifications the word "mortar" is used without qualification, it shall be taken to mean mortar composed of one part by measure of American hydraulic cement and two parts by measure of clean, sharp sand entirely free from loam. Where cement of another quality, or sand in other proportion is to be used, the fact is so stated in the specifications. All mortar used on the work shall be carefully and thoroughly mixed dry and wetted up only as needed for immediate use. No mortar which has begun to set shall be retempered for use.

The engineer will give especial care to the thorough emptying of all vessels in which mortar may be mixed, carried or deposited, to prevent the use of even the smallest portion that has begun to set.

All mortar must be mixed and wetted in a proper vessel or on a tight flooring, and in no case upon the pavement or upon the ground.

Following are some additional descriptions of material:

Brick, when broken should exhibit a uniform grain, free from air bubbles, cracks and coarse pebbles, and be capable of bearing a compressive strain when set on end and subjected to pressure of at least 1000 lbs. per square inch, before crushing, and should not absorb more than one-fifth of its weight of water.

No pale brick from the outside of the kiln should be admitted even for backing.

Sand should be rather coarse than fine, and whether pit or sea-sand, matters but little.

Concrete. The mortar as described in the foregoing specifications should be spread in a thin layer, and five volumes of broken stone, brick or shells after being washed of all dirt, *and while wet* should be spread over the mortar and turned and mixed thoroughly until each fragment of stone is enveloped in a layer of mortar. The concrete should then be deposited immediately in place in the work and rammed sufficiently to ensure that no vacuities are left in it, but that the mass is solid throughout. The broken stone should not be larger than will pass through a two and one-half inch ring.

Timber may be of pine, spruce, hemlock or other cheap timber if for shoring trenches, etc., and pine, oak or chesnut are suitable for foundation timbers.

CONSTRUCTION OF SEWERS.

Pipe sewers should be laid on a two inch bed of sand, and the joints carefully filled with cement mortar.

Brick sewers sometimes require foundations of plank, timber, piles, concrete or a combination of these.

Tile drains are sometimes placed immediately below the sewers.

Invert Blocks should not be used, as, although they form an underdrain and are convenient to the workmen, they form a through joint, and ultimately, by the settlement of the sewer or otherwise a leak is formed.

The interior of the sewer should receive a coat of "neat cement," *i. e.*, cement without any sand mixed with it.

In cases where it is necessary to admit water to the sewer very soon after it has been laid, quick setting cement should be used; otherwise slow setting Portland is preferable.

One sewer should never enter another at right angles as such a construction causes eddies and cross-currents, and silt is deposited. The best method is to bend the tributary in by a tangent curve.

APPENDAGES TO SEWERS.

MAN HOLES.

In the line of the sewers, both main and lateral, manholes should be constructed not more than 400 feet apart, and at every change of alignment, either horizontal or vertical. The object of the manhole is to furnish an opportunity for the proper inspection of the working of the sewer, for cleaning and flushing out obstructions, and also for ventilation. It is a brick shaft, elliptical at the bottom and tapering to a circle at the top, and fitted with an iron head over which is a perforated cover. A tin pan suspended below the cover will catch all dirt, etc., falling through the openings.

In flushing, a wooden disc or gate should be placed over the ends of the sewer in the manhole until sufficient water has been poured in to insure a sufficient rush to carry away obstructions. It is better to flush the lower end of the sewers and work upwards.

STREET BASINS.

Street basins are placed at the intersection of streets and at other convenient places to receive the water from the gutter and convey it to the sewer. They should extend about two feet below the sewer into which they open. They should be trapped by a cast-iron hood or a trap-stone extending about six inches below the mouth of the sewer.

The object of the street basin is to arrest any solid matters which would otherwise be carried into the sewers.

VENTILATION.

If abundant air be present when decomposition takes place, the gases seem to some extent to be deprived of their disease-creating properties, although the dilution with air after escape from the sewer does not seem to have the same effect.

The coverings in the manholes should be perforated for the passage of air; and if, as should be the case, the soil pipes of the houses are properly ventilated, no further precautions need be taken, as the sewer will naturally "breathe" by reason of the change of volume and temperature to which its contents are subjected.

When the outlet of a sewer is below water a ventilating shaft should be provided as near the outlet as possible, so that a current of air may sweep the sewer from end to end.

HOUSE DRAINAGE.

Time does not allow of a discussion of this division, which is a subject in itself.

Such measures should be taken as will prevent the entrance of sewer gas under pressure and the siphoning of traps. The common forms of water traps are being abandoned in good work in the United States, and some form of mechanical trap used instead.

An excellent trap of this kind is the Bowers. In this trap a hollow rubber ball is firmly floated against the inlet pipe.

The advantages claimed for it are:—

1st. A perfect seal against sewer gas under pressure.

2nd. It cannot be siphoned.

3rd. Freezing does not injure it, as the hollow rubber ball yields to the expansion of the ice.

According to the old method of house drainage the soil pipe was led from the back part of the house, under the basement, to the street in front.

The modern arrangement is to have the lateral sewers traverse the alley to the rear of the house and to have the soil pipe to empty directly into it. The advantage of having the sewer in the alley is that it is more accessible than when in a paved street.

SCALE CALCULUS.

By T. R. Rosebrugh, B.A.

Soon after the discovery of logarithms, Gunter invented what is known as Gunter's line, a scale on which divisions were engraved and numbered in such a way that the distance of each number from the origin (at which unity was placed) was proportional to the logarithm of the number. By means of a pair of dividers the logarithm of any number could be taken off and added to another logarithm on the scale, thus obtaining the product of any two numbers. If the distance given by the dividers were set off in the opposite direction, the difference of the logarithms, or the quotient of the two numbers, could be obtained. If the points of the dividers were set at any two numbers of the scale the distance thus obtained would be the logarithmic measure of the ratio of those two numbers, and by adding this distance to the logarithm of any number, the product of that number by the given ratio could be obtained.

In the sliding logarithmic rule sometimes used by engineers the pair of dividers is replaced by a second similarly graduated scale, sliding in a groove past the first and carrying its divisions along the same line.

In this scale multiplication or division by any ratio is effected by a relative displacement of the two scales. This displacement causes those numbers, whose logarithms differ by the amount of the displacement, to fall opposite to each other. Thus, to find numbers which are to one another in a given ratio, all that has to be done is to place the numerator of the ratio on the one scale opposite the denominator of the ratio on the other scale and all numbers which are then opposite each other are to one another in the given ratio.

As the divisions are of unequal length no vernier can be used and the reading of finer sub-divisions than those actually marked must be accomplished by direct estimation by eye, corresponding in function to the interpolation by differences in the use of tables. It may be seen that the accuracy of results thus obtained, with a scale which cannot conveniently be much more than two feet in length, is not very great; though for many practical purposes such scales are of great utility.

Before showing how greater accuracy may be obtained in practice, I shall explain the principles that must be introduced in order that triangles may be solved.

We may, for convenience, regard a plane triangle as consisting of seven variable elements, three angles, three sides, and the diameter of the circumscribing circle. To connect these we have the four equations:—

$$\frac{a}{\text{Sin } A} = \frac{b}{\text{Sin } B} = \frac{c}{\text{Sin } C} = \frac{d}{\text{Sin } 90^\circ} \;\ldots\ldots\; (1),\ (2),\ (3).$$

$$A + B + C = 180^\circ \;\ldots\ldots\; (4).$$

With seven variables and four equations we require three more independent relations; these in general, are of the simplest form, and consist of the values of any three elements, with the exception of the three angles.

If we had a scale in which the sines of the angles were placed as the numbers are in the slide rule (at distances from the origin proportional to their logarithms) and if, instead of the sine we write the corresponding angle at each graduation mark, it may be seen from equations (1), (2), (3) that when the side a is opposite the angle A the other sides will be opposite the corresponding angles, the diameter of the circumscribing circle will be opposite the angle 90°, and the scale will express all that is mathematically contained in the first three equations. If the observer then attends to the fourth equation in addition to examining the scale, the solution of all triangles may be effected without calculation.

The most obvious method of increasing the accuracy of the scale is by increasing its length. We may then plot the logarithms on a larger scale, and also introduce the logarithms of larger numbers; thereby avoiding, to some extent, the interpolation of numbers by the eye.

It is not necessary that the scale should be on one straight line; it may be laid off along a helix or other curved line, or along a series of parallel lines. To lay off the scale along a series of parallel lines, equidistant parallel lines are drawn upon a sheet of paper or metal which is either flat or rolled upon a cylinder, in which case the lines are parallel to the axis of the cylinder. We may then imagine Gunter's line magnified to the required size and divided into as many equal sections as there are parallel lines; these sections are then laid off in succession on the parallel lines of the scale. In what follows I shall refer to this sheet as "the scale."

To multiply a number by any given ratio we may use a sheet of tracing linen, or other transparent substance, having equidistant parallel lines on which Gunter's line has been laid off in the same manner as on "the scale"—the distance between the lines and the graduation of the numbers being exactly the same in each. When, therefore, the transparent sheet, which we shall call "the ratio operator," is laid on "the scale" so that any number on the "ratio operator" coincides with the same number on "the scale," then every number on the "ratio operator" coincides with the corresponding number on "the scale."

Thus our "ratio operator" and "scale" are nothing more than a very long sliding logarithmic rule, cut up into sections for more convenient manipulation, and all operations which can be performed by means of the sliding rule, can be performed with increased accuracy by shifting the ratio operator on the scale.

Unless the scale is extended, a portion of the operator will fall outside the scale, and thus be rendered useless. Each section of the scale is therefore continued to the right, the continuation being an exact duplicate of the section immediately following. Thus, the continuation of the first section is a duplicate of the second, the continuation of the second section a duplicate of the third, and so on.

If the scale is rolled on a cylinder of exactly the same diameter, no other extension will be required, but in other cases it will be necessary to repeat the first portion of the scale, so that for every ratio the operator may be entirely within the scale.

On the operator the graduation marks are conveniently made below the line, and on the scale, above, so that the latter may be read through without interference.

The solution of triangles will be effected by means of another transparent sheet similar to the "ratio operator"; but, instead of Gunter's line, containing angles graduated at distances proportional to their logarithmic sines, this sheet, which may be conveniently called the "chord operator," is in reality a "ratio operator" on which, instead of numbers, we have the sines of angles.

When the "ratio operator" is laid on "the scale" in any given position, all numbers which are coincident are to each other in the same ratio. Therefore, when the "chord operator" is laid on "the scale" in any given position, the sines of the angles all bear the same ratio to the numbers on "the scale" with which they coincide. Now this is all that is mathematically contained in the equations (1), (2), (3); therefore, in the solution of triangles, the chord operator and scale may be substituted for those three equations.

[Mr. Rosebrugh then exhibited a scale and operators, which he had prepared on profile paper and tracing linen, and readily solved several problems in ratio and in the solution of triangles which were given him by members of the society. The method of solving problems in ratio has been already explained, but it may not be out of place to give in detail the method of solving triangles.

Having given *a, b, and A*.—Place the "chord operator" on "the scale" so that the angle A coincides with the number a; then B will be that angle which coincides with b. C will be found from the equation *u* $C = 180° - A - B$, c will be the number which coincides on the scale, with the angle C, and d will be the number which coincides with the angle 90°.

Having given *a, b, and C*.—The sum of $A + B$ is known from the equation $A + B = 180° - C$. Shift the "chord operator" on "the scale" until the angles coincident with a and b have a sum equal to $180° - C$. Then the angle coincident with a will be A, and that coincident with b will be B. Without moving the operator, read off the number which coincides with the angle C, this gives the side c. The number which coincides with 90° gives d.

Having given *a, B, and C*.—A is found from the equation $A = 180° - B - C$. Place the angle A of the operator on the number a on the scale. Then b will be the number coinciding with the angle B, c will be the number coinciding with the angle C, and d the number coinciding with the angle 90°.

Having given *a, b, and c*.—Shift the "chord operator" on "the scale" until the angles which are coincident with a, b, and c, fulfil the relation $A + B + C = 180°$. Then the angle opposite a will be A, that opposite b will be B, that opposite c will be C, and the number opposite 90° will be d.

Some of these solutions involve the method of trial and error, but with a little practice, the results may be obtained very rapidly, and accurate enough for any practical purpose.]

MASONRY FOUNDATIONS.

BY J. L. MORRIS, C. E.

From the primitive cedar post to the permanent solid rock we have so many various forms of foundations, that in a few years of practical experience an engineer can have encountered only a small fraction of the different modes of preparing the bases of structures. Yet for the ordinary local work of the civil engineer, the few practical hints which this paper may contain may be of some value and may pave the way for the more general adoption of better methods of construction.

The importance of the security of foundations should not be underestimated, for, whatever the superstructure may be, if the foundation is weak the whole structure partakes of that weakness; and very often we see fine structures ruined through want of knowledge or false economy in the construction of the foundation.

It is customary when preparing the foundations of buildings, to make certain of being below the level of deepest frost, but where the walls, as in the case of public buildings, are heavy, it is necessary to prepare a foundation depending upon the material upon which the structure stands. The different methods of constructing the foundation, which will be described further on, will be found suitable to all classes of building.

Rankine, in his Civil Engineering, treats of masonry foundations under three heads. (1) Foundations in rock, (2) Foundations in firm earth, (3) Foundations in soft earth. These include those foundations where an excavation alone is required, and where a structure is necessary at the bottom of the excavation to form a firm base for the masonry—which includes foundations, both natural and artificial.

It is often necessary to determine what our foundations are to be, before any work is commenced (especially where a close estimate is required, and tenders are called for) so as to give the contractors reliable information. This information is secured by means of the boring rod, which may be composed of an auger and rods for lengthening as the boring proceeds. The material brought up by the auger from time to time furnishes us with the information concerning the underlying strata. If we come upon rock, we must be satisfied that it is not a boulder by repeated borings, which will also give us the slope of the rock. Very often we find rock on the surface at one point and by taking borings at a few more points, determine what we think is its slope under the position of the whole structure, and when work commences, are surprised to find that where we had calculated for rock, there is none, either for the foundation of a pier or the end of some retaining wall. This is the cause of so many extras in foundations. When we have secured solid rock for a foundation, we find that it often presents a broken and irregular surface, with cracks and fissures, which before beginning construction, must be either levelled off by excavation of the rock, filled up to a level surface, or made with horizontal steps. The levelling may be done by blasting and working off the irregularities, filling of the fissures and cracks with concrete, made of one of cement, two of sand, and from two to four of broken stone, or by stepping the rock so as to leave only a solid bed, and no imperfect formation or shale. If the rock is of a good and hard quality we have here the nearest approach to a perfect foundation.

On land where no water is to be dealt with, the levelling or filling can be easily done; but where a coffer dam has to be used to shut out the water, and the fissures and cracks in the rock cannot be stopped up to prevent its entrance, so as to allow of levelling or stepping the rock, then we remove all debris and shale, and level the foundation with concrete enough to cover all irregularities in its surface. Boxes, for the purpose of placing concrete where there is a great depth of water, are used, so as to prevent the sand and cement from coming to the surface, the broken stone being left at the bottom. Without these boxes, should the concrete be thrown in carelessly, this is usually the case, but where there is only a few feet in depth, of water, and a large mass be thrown in at once, it reaches the bottom before the water permeates it and causes the rock, sand, and cement to separate. Whatever is done to secure a solid foundation, it must be understood, that a structure should never be built on sloping rock. Where no rock is to be found at any reasonable depth, then we bring into use our knowledge of artificial foundations. It may be possible for us to determine before excavation, by means of the boring rod, what manner of foundation we should construct; but certainty can only be arrived at by having our excavations made, and the materials upon which we are to work brought to view. Should we find that at a reasonable depth, we have come upon a layer of cemented earth or other very hard material, and we find by boring that it overlies a strata of much poorer material to resist pressure when disturbed, then if we are satisfied that the thickness of the bed is sufficient to sustain the pressure, we might save both material and labor by commencing our structure, but if we are not satisfied with it as a foundation, we fall back upon some one of our artificial constructions.

It is becoming customary for the heaviest of structures to be built on foundations made of concrete, thrown in upon the earth without any intervening material, the idea being that when it solidifies it takes the place of a rock foundation. This only gives security, when we have superior tested cements, allowed to set under very favourable conditions. Often broken and sometimes half bricks are used in the manufacture of concrete, but it is absurd to use a material of so much less resistance to compression than stone, when compression is the force against which we are contending.

There has come under my notice the foundation of a heavy abutment, being part of a stone bridge, with two piers and two abutments, with three segmental arches of a clear span of nearly fifty feet each, the archstones being three feet in depth. It was built upon a foundation composed of two feet in depth of concrete, upon a bed of blue clay. During the formation of the concrete it was subject to a continual wash of water, owing to the pumping to keep the inside of the coffer dam dry, thus drawing the cement from the concrete and leaving a mass of brick and sand. After being allowed to set for two days it was possible to force a half-inch iron rod through any part of it. I am satisfied, considering the strain on the concrete, that its strength lay in having the extremely hard material below it. All other parts of this bridge were started from the rock.

A more complete foundation, and which would distribute the pressure more evenly in case of any settlement, would be to place timbers 12 in. x 12 in., about eighteen inches apart, at right angles to the course of the stream, the space between to be filled up with con- concrete to their level. On top of this to have a platform of 8 in. x 10 in. material, spiked to the timbers below, allowing a footing of about 12 in. outside of all masonry. This is a permanent foundation, as timber submerged does not decay. On Lake Geneva, where some of the old Swiss towns were built, about two thousand years ago, piles have been found, as perfect as when first driven, for the basis of some structure, owing to their having been continually under water.

Should we find it impossible to secure hard material, as a basis for concrete or timber, we are compelled to resort to piling. This is more expensive than either of the other methods, but when properly carried out gives a surer foundation. Piles about 13 in. at the larger end and 8 in. at the smaller end, of tamarac in preference to any other soft wood, should be driven at from two to four feet centres, depending upon the weight of the structure, their length depending upon the material through which, and also to which, they are driven. If there is no underlying rock at a reasonable depth, then when the piles are driven so that the hammer (say two tons in weight, and falling a distance of twenty-five feet) at each blow would drive the pile about two or three inches, when it has gone a depth of about twenty feet, then we can rely upon having a good foundation; but any greater subsidence at each blow might leave a foundation which would settle under the pressure of the masonry. The piles are sawn off at the required height (always below low water when on the bank or in a stream) and may be prepared for masonry in either of the following ways: (1) By excavating three or four feet of material from between the piles, and filling in with concrete, making a solid mass of timber and concrete. (2) Using no concrete, but placing sills on top of each row of piles, and flooring with timber, the dimensions of which will depend upon the distance of the piles apart. (3) By combining the two previous modes.

The first has this fault, that in case of any settling it would be uneven, owing to the different materials, and would cause the masonry to crack. The stone abutments for a hundred feet iron truss bridge, over the Little Sturgeon River, Lake Nipissing, were built upon a foundation of this stamp, and owing to settlement, the front wall separated from the wings. Where abutments or piers have been built upon foundations of either the second or third kind, I have not known of any settlement with injury to the structure.

The wooden structures, first built when timber was cheap and stone never thought of, are being replaced generally by stone box culverts, many of which require special forms of foundation. The excavation for the foundation is made deep enough so that the top of the timber shall be below the level of the bed of the creek or watercourse. Four sills for the main body of the culvert shall be laid its full length, two under each wall of the body of the culvert, with three or four feet of projection at the lower end for an apron, to preserve the foundation from the wash of water discharged by it. Short sills, parallel to the sills under the main body, shall be placed for the wing walls. On the top of these sills and transverse to them and the centre line of the culvert are placed sided ties of either hemlock, cedar or tamarac, not less than six inches in thickness, and with not less than eight inches flatted face. These are made one foot longer than the total width of the culvert, so as to allow for a footing of six inches all around the masonry. As openings will be left between these ties owing to the sides not being hewed, they should be filled with spalls and the sediment brought in by the water, will, in time, form a natural bed for the flow. There can be no objection to the squared ties being used, as the flatted are used only for economy.

Near Sudbury, Ontario, a temporary trestle had been built over a water course, with a very small flow of water, and an opening left for a stone box culvert. When excavating for the foundation of this culvert, we came upon a bed of quicksand, and were unable to make any headway and were undermining the sills of the trestle. It was impossible to insert sills, so using squared timbers 12 in. x 12 in., and hammered close together, a foundation was made on top of the quicksand, and the water was discharged through the culvert about 18 inches above the bed of the watercourse at the lower end by means of a diversion.

These hints are only to pave the way for improvement; but no matter what the structure is, be sure of your foundation.

SURVEYING IN THE CITY AND SUBURBS OF TORONTO.

By D. D. James.

In this paper I will treat briefly the subject of land surveying as practised in the city and suburbs of Toronto.

I find it convenient to take up first a surveyor's work in the suburbs. The greater part of this consists in the preparing and staking out of plans of subdivisions.

Probably it would be better to give an explanation of a plan of subdivision. When the owner of a block of land wishes to sell his land in smaller portions he has one of these plans prepared by a surveyor. He then, having signed the plan, registers it, that is, takes it to the proper registry office and has it put on the file of plans. Now, in transferring lots shown on the plan, the statement of their numbers, together with the number of the registered plan, is the only description necessary in the deed.

If such a method of dividing up large portions of land were not available, it would be easy for complications to arise. Mistakes are more easily made when property is sold piece by piece, with no plan, than when a plan of the whole is prepared, to which reference is made in each deed. Besides, when a plan is registered, it is generally staked out by the surveyor, while, when the land is sold piece by piece, it is not generally staked out, but each man that buys will likely measure off what he thinks is included by his deed.

While speaking of registered plans, I may say to those unacquainted with conveyancing that any deed or plan in a registry office may be inspected and copied by anyone for a small fee.

PRELIMINARY SURVEY FOR PLAN OF SUBDIVISION.

The information a surveyor needs before going out to make this survey is a copy of the deed of the property and a copy of the plan referred to in the deed. The latter may be the plan of the township, or some registered plan. If field notes relating to the property can be obtained they may prove valuable.

In the following discussion the word monument signifies either a stone monument or a wooden stake or hub.

In the preliminary survey the first thing to be done on the ground is to locate the limits of the property to be subdivided.

If monuments are found at all the corners of the property it is only necessary to check the measurements of the plan, to insure that the monuments are the ones sought for, and have not been moved since they were put down.

When monuments are not found on the boundaries of the property, but are found in the neighbourhood, the limits of the property are located by measuring from these neigbouring monuments. If there is a means of checking by fences and monuments it is taken advantage of.

If the measurement between two well-established points does not agree with the plan measurement the discrepancy must be divided up proportionally in establishing an intermediate point shown on the plan. If the intermediate point which is to be located is not a point shown on the plan, but a point given by the description in the deed, it must be located according to the wording of the description.

If monuments are not found, the surveyor must get evidence as to the positions of fences. The checking of the measurements between the fences, with the figures shown on the plan, is good evidence that the fences are in their correct positions.

In all cases where there are fences around the property over ten years old, the question of possession under the Statute of Limitations must be considered. On this account it is often not necessary to get up the lot lines. If, however, a large discrepancy, over which there might be litigation, is discovered, the lot lines must be located; and the difference between them and the fences must be noted.

As the Statute of Limitations does not apply in the case of road allowances, the road line cannot be assumed to coincide with the roadside fence, no matter how old it may be. On this account the original road line must always be located.

This case, where the Statute of Limitations comes in, is the one of usual occurrence.

The question of limits having been settled, a few measurements may be needed to determine the position of a house or barn, or it may be that a ravine or stream must be traversed, and the survey connected with the lot lines.

Here I may mention the instruments used by a city surveyor. They are a theodolite, or transit-theodolite, a Chesterman steel tape, and chain pins. Pickets are not often used, as they are clumsy to have in a street or railroad car. Split rails or boards are made on arriving at the property, and used in place of the ordinary pickets.

PREPARING THE PLAN.

When the limits of the property have been plotted, the most profitable subdivision must be decided upon. The questions considered are these :—

1. How the most frontage can be made.
2. In what direction the lots shall be fronted in order to bring the highest price per foot.
3. How deep the lots shall be made.
4. How wide the streets shall be.
5. How wide the lanes (if any are to be opened out) shall be.
6. If the neighbouring property has been laid out into streets, how a continuous street can be economically made to run through both properties.
7. If the property cannot be laid out satisfactorily, how some arrangement can be made with either of the neighbours to give a part of a street.
8. If there are ravines on the property, how a street can be laid out so as to necessitate as little filling and cutting as possible, at the same time economizing the land.

It is seldom that all the above questions have to be considered in a single case. The best method of sub-division can generally be got at easily.

After the method of sub-division has been decided upon, and the plotting completed, the lengths and bearings of the new lot lines must be determined. If the limits of the property are crooked, or if the owner is in no hurry to get the plan registered, the property is staked out, and the unknown lengths and angles determined in the field.

When all the lines are straight, and the necessary angles have been measured in the preliminary survey, the unknown lengths and angles may be calculated.

It is not safe to calculate from the angles given by the bearings of the previous plan. The reason of this is that the bearings on the plans are calculated from the original township bearings, and these are often inconsistent with the angles, that the lines, to which the bearings belong, make with one another. On the new plan, these sometimes inconsistent bearings are again used for lines parallel to original lines. The new bearings are calculated from either of the old ones.

REQUIREMENTS FOR REGISTRATION OF PLAN.

Before a plan can be registered, every line must have its length and bearing marked upon it, and the lot lines and numbers of the previous plan must be shown. The new sub-division must also be connected with the previous one, showing distinctly how much of the previous sub-division is covered by the new one.

The plan (generally finished on tracing linen) must have on it a certificate for the owner to sign, besides the prescribed surveyor's certificate.

REMARKS ON PLANS.

The surveyor always keeps copies of the plans he prepares, and has some system of filing them in his office. One way is to fix the copies by their edges into a portfolio; another way is to plot copies in a large book kept for the purpose. In these two methods the copies cannot be misplaced or lost, but they cannot be taken on a survey when required, so that a sketch of the portion needed must be made in the field book. Another method is that of making packages of the copies so that any one of them can be taken out on a survey when required. Here, however, the copies may be misplaced or lost.

Whatever the system of filing the copies, the indexing of them is very important. The method of indexing, which, I think, is the most simple, and at the same time the easiest to carry out, is that of having index maps. (Such a map as the one given with this paper would make a good index map.) This method will apply to all the information in the office, as copies of plans, field notes and descriptions. In this method the number, or letter, which indicates where the information is to be found in the office, is placed on the index map on the spot to which the information relates. When one seeks information about any portion of land, he always knows the exact locality, then a glance at the index map will enable him to find all the information in the office that bears on the subject.

Another point I wish to direct your attention to is that of reserving a foot of land along the boundary of the plan, where a lane or a street has been made to meet or follow it. This reservation does not allow the neighbouring owner to get an entrance to his property without paying for it.

STAKING OUT THE PLAN.

After the method of sub-division has been decided upon, and perhaps the plan completed and registered, the location of each point of the plan is marked on the ground by a stake. The stakes are usually of pine 2 in. x 2 in. and 18 in. to 22 in. long. They are put in line by a theodolite or transit theodolite. When there is only one assistant, the proper places for the stakes, as regards measurement along the line, are previously marked by chain pins. When there are two assistants, one holds the tape at the last stake put down, while the other puts in another stake at the proper distance, being lined in at the same time by the man at the instrument.

Stakes in straight lines along a fence are put in by means of offset lines.

The stakes along the limits of the property are usually put in first, then the stakes on the straight lines inside the limits are put in by joining the proper stakes on the limits. In joining two points, where neither can be seen from the other, the instrument is often set up between and shifted into exact line by trials. The stakes are then put in as mentioned before. Any measurements that have been left undetermined are now determined in the staking out.

I will now take up the second part of my paper, a surveyor's work within the city limits. This consists mostly of the getting up of lot lines of old subdivisions for various purposes. If the lots are not built on, the object is generally to give a builder the lines up to which he may build. The owner may want the lot or lots re-subdivided, making each new lot such a width as to exactly include one of some proposed houses. The new subdivision lots are generally staked out, so that the contractor can put the party walls of the houses exactly in their proper places. When the lots, the lines of which are to be located, are built upon, one of the objects of locating the lines is to see that the houses and fences are situated in accordance with the descriptions in the deeds. Another object is to determine the positions of the houses and fences with reference to the lot lines, so that descriptions of the houses can be made or a plan of them prepared for registration.

SURVEY TO LOCATE THE LOT LINES.

After gathering the information that may be of use, the surveyor, on arriving at the property, pokes and digs around for old stakes on the street line. The value of a stake depends upon its distance from the lot line to be located. If, on different sides of this lot line stakes are found, there is seldom trouble in determining where the lot line and street line intersect. When this has been done the other end of the lot line that is at the rear is sought for in a similar manner. Whether at the front or rear, if no stakes can be found, and no evidence can be gathered as to existing boundaries, the problem of locating the lot line may be called one of trial and error. An existing street corner which seems to be accurately placed, is measured from and the measurements to existing boundaries noted. The surveyor is then able to form an opinion as to the position of the street corner. Another trial measuring from some other point may be necessary. In this way the lot line may be determined. It is always important to the surveyor if he can get copies of field notes of previous surveys in the neighbourhood. He may have field notes of the kind in his own office, hence the importance of having a good index to all his information.

Having located the required lot corner, the distance of the centre line of a party wall between two houses, from it, is determined by producing the centre line by means of an offset line, or if the thickness of the wall is unknown, two offset lines may be used.

When the survey is finished, a plan, sketch, or description, as the case may be, is prepared.

The plan is prepared so that lots may be made with their lines agreeing with the party walls of houses already erected or to be erected. If the houses are erected, they are shown on the plan. In the case of the proposed houses the lot lines are merely shown, but when the houses have been built, the centre lines of their party walls are, after due survey, certified to be coincident with the lot lines of the plan. The preparation of a plan, otherwise, is similar to the preparation of a subdivision plan already spoken of.

A sketch is merely a copy of the field notes and so its preparation requires no explanation,

An example of a description that would be prepared in the case of a survey of houses is given here. It runs as follows:

All and singular that certain parcel or tract of land and premises, situate, lying, and being composed of part of lot eight, registered plan No. three hundred and ninety six (396), a subdivision of part of park lot No. twenty eight (28), in the City of Toronto, County of York, and Province of Ontario, and may be more particularly known and described as follows:

Commencing at the Northwest angle of lot eight, thence Southeasterly following the East limit of Gladstone avenue, twenty-one feet eight inches (21 ft. 8 in.) to the intersection with the production of the centre line of the party wall, between houses numbers fifty-five (55) and fifty-seven (57), thence following the production, centre line, fence, and partition between the sheds at the back of said houses, in all, one hundred and twenty-one feet four inches (121 ft. 4 in.) to a ten foot lane; thence Northwesterly along the Eastern limit of said lane twenty-one feet ten inches to the face of a shed on lot nine, being at the Northeast angle of lot number eight; thence Southwesterly following the North limit of lot eight and passing through a passage between houses numbers fifty-seven and fifty-nine, one hundred and twenty-one feet two inches (121 ft. 2 in.) to the point of commencement.

CORRUGATIONS ON MILL ROLLERS.

By W. Leask.

In treating of this subject the writer will first give a brief description of how the rolls are made and prepared for corrugating, also a simple device used for corrugating rolls, and then compare the different styles of corrugations, stating some of the advantages and defects of each.

The shafts to be used in the rolls are cut from round bars of iron or steel, as the case may require. They should be of good quality, and of such size as not to bend under any unusual pressure that may be brought to bear upon them during the operation of grinding.

The roll bodies for flour mill rolls are at the present time mostly all of chilled cast iron, and are fastened to the shaft by being cast on to it.

Each shaft is centred and straightened on the lathe and then ground on the stone at the places where the molten iron is to adhere to it. The grinding removes any rust or scale that may be on the shaft in these places, and puts the surface in a better condition for receiving the hot iron and allowing it to form a close contact.

When the moulds for casting are ready each shaft is laid in its proper place in the mould. The mould is closed (*i. e.*, the halves are put together), melted iron is poured in, left to cool, and become fast to the shaft.

After the rolls are cleaned of the sand from the mould, with a steel wire brush or other means they are taken to the lathe, put in, and turned true at the surface and ends.

Journals and places for the gearing and pulleys are turned to the proper size and finished.

Porcelain rolls were at one time very extensively used in Europe, but there were also many smooth chilled iron rolls, perhaps more than porcelain, in use.

The porcelain was in the form of a cylindrical shell, and the mode of fastening it to the shaft was to key on the shaft a ribbed cast core half an inch smaller than the inner diameter of the shell, then fastening the latter to the cast core by pouring melted sulphur in between the roller shell and core. Now, when the boxes got hot and the shaft with the cast core expanded, the sulphur and porcelain did not expand, and consequently would burst. Another source of breakage was the loosening of the shell and the sulphur becoming broken by the constant jarring and trembling.

This mode was superseded by one in which the rolls were fastened merely by friction, and the air was allowed to circulate between the shaft and shell. Two faced-off flanges are keyed on the shaft, and the porcelain shell is put between them, and by means of three strong bolts the flanges are pulled together on the shell as much as the bolts will stand.

The surface of the porcelain roll is finely turned off by means of diamonds.

The condition of the roller surface has greater influence on the work than the speed of the rolls. The roll is made either smooth or grooved, and in the latter case the grooves can be either parallel to the roller shaft or put in the shape of very steep screw lines, both rolls having a right or left hand thread, so that the corrugations cross each other at the point of contact, effecting the shearing of the particles to be cut or reduced in size. The latter method has also the advantage of making the machine run more quietly and evenly.

The amount of spiral twist given the grooves should vary with the character of the material being broken. Soft grain takes more twist than hard, because it is more sticky, and more twist gives more shearing action, which frees the corrugations from the sticky matter.

The size, depth and width of the grooved rolls are determined by the work the rolls have to do, as coarsely grooved rolls cannot be used if the particles fed to the rolis are already fine.

Special machines built in the most recent and modern style and supplied with all the arrangements and conveniences for corrugating rolls are now in use where special attention is paid to the manufacture of rolls.

To describe one of these would be rather lengthy for this paper, but a brief description of a very simple device which can be used on any common iron planer, may serve to give an idea of how rolls can be corrugated.

It is not intended to be set forth as a rival to the more modern machine which is of course preferable where it can be had, but only as a simple, easily made, cheap and effective device within certain limits: a device which can be made by any manufacturer requiring one.

The construction is briefly as follows:—

The roll to be corrugated is supported by means of two standards of cast iron of the form of angle plates, bolted on the table of the planer. The roll is placed lengthwise in a horizontal position between them.

One of the supports has a centre pin passing through it at the top against which, one end of the shaft of the roll butts; the other is supplied with a bearing, in which one of the journals of the roll is placed and secured by a cap. The roll is thus held in position by means of the centre pin at one end and the bearing at the other.

The end of the roller shaft which projects towards the rear of the planer is connected to the end of a larger shaft which has a square groove running in a steep screw line on it. The spiral twist on the shaft produces a similar one on the roll as it is being cut.

This shaft is made to slide through a worm wheel, which is supported by means of two standards and a cross piece, connecting their upper ends. These are fastened to the sides of the planer bed. one on each side, behind the main standards of the planer.

On the hub of the worm wheel is a journal which works in a bearing in the cross piece connecting the upper ends of the standards. A short key is stationed in the bore of the worm-wheel and operates in the groove of the shaft as it slides through. The worm-wheel is of course kept from turning by means of the worm, until another groove is about to be cut in the roll. The grooves are cut one by one.

The shaft on which the worm is keyed is turned by a ratchet wheel and lever. The end of the lever drops on the rear end of the table and receives its due amount of stroke as the table moves backwards and forward.

Care must be taken to have the axis of the roll in line with the direction of the motion of the planer-table.

The cutting tool is sharpened and set according to the shape of the corrugation required.

In order to avoid much trouble in lining up again, when the supports for the rolls have been shifted, a shallow groove is made along the centre of the table and a projection to fit this grove is cut on the bottom of each support and set in it.

As to the style of the groove, the saw-tooth as represented in Fig. 1, seems to be a favorite for first break.

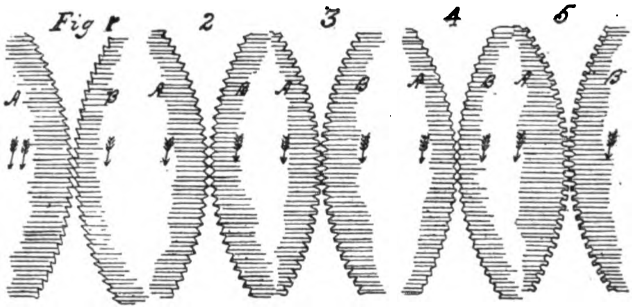
Fig. 2, represents the dress of the Sulzer rolls used about thirty-five years ago.

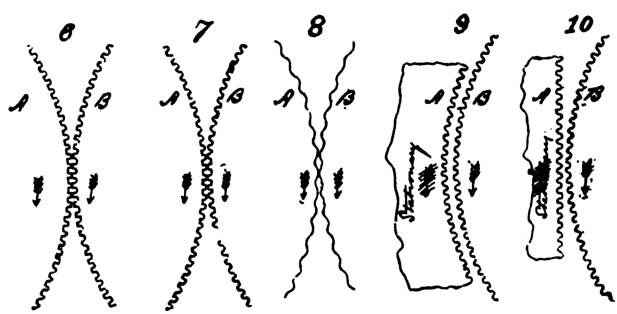
Fig. 3 is seldom used, its form is like Fig. 2 with its points turned off.

Fig. 4 is a very shallow corrugation, the space between the points is greater than the depth.

Figs. 5, 6, 7, represent corrugations that were used on very old rolls.

Fig. 8 shows round grooves but very shallow and wavelike.





Figs. 9, 10 show deep round grooves, but in Fig. 9 *B* is the roll and *A* is the stationary concave shoe. In Fig. 10, *B* is the roll and *A* a stationary straight shoe.

In the system of breaking wheat on corrugated rolls the aim of the miller is to reduce to middlings which are purifiable and to make as little flour as possible during the breaking process as it cannot be purified and will be mixed, more or less, with bran particles and dust having adhered to the wheat berry.

The dress, as shown in Fig. 1, gives the best results. Roll *A* is the fast roll and runs two or three times as fast as roll *B*. The wheat, if well graded, will be split open lengthwise almost every berry. Only a small quantity of flour is made in the first break, which flour is chiefly the dust lodging in the crease of the kernels, and therefore only fit to go into low grade flour. By the splitting of the berries a greater portion of the germ is got rid of.

If the ratio of the speed of the rolls be reduced the conditions are changed and more flour will be made owing to the increase of the squeezing action.

If the rolls be run at an even speed the conditions are entirely changed, as there will then be only a squeezing action.

Again, if *B* is made the fast roll and *A* the slow one the conditions are entirely changed as the work is then done on the back of one tooth passing the back of the other, producing a rubbing or bruising action which, of course, will again make more flour in the reduction which it is desired to avoid.

If *B* is the fast roll the pair of rolls must run about twice as fast to get capacity, and this, of course, means loss of power.

The corrugations as shown in Figs. 2, 3, 5, 6 are very apt to clog between the teeth, nevertheless they produce a good many middlings owing to the sharpness of the teeth.

The corrugations as shown in Figs. 7, 9, 10 are rounded corrugations which give trouble on account of their filling up soon and will do their work best on hard wheat.

Two rolls working together have been found, by experience, to give better results than rolls and shoes as the latter make too much flour and the shoes wear off very fast.

Dull rolls also require a great deal more power than the sharp rolls, as it has been experimented upon and found that it takes twice the power to squeeze wheat than it takes to cut it.

It is claimed then that the rolls corrugated as shown in Fig. 1 are capable of doing any kind of work that can be done with the sharp or dull rolls.

All depends upon what the operator desires to do if he understands the principle of the roller action.

For a higher percentage of middlings he may run the roll *A* fastest, for low grinding, more flour and fewer middlings he may run *B* fastest.

A DESCRIPTION OF A TIMBER LIMIT SURVEY IN THE ROCKY MOUNTAINS.

By L. B. Stewart, D.T.S.

In the spring of 1884 I was engaged by an American lumber company to survey several timber limits in the Rocky Mountains; so I immediately set to work to make the necessary preparations.

I will first make a few general remarks with regard to the fitting out of a survey.

In fitting out a survey a considerable amount of judgment is required on the part of the surveyor in charge, in order that everything may work smoothly, and that the expenditure may be as small as possible, at the same time giving due consideration to the comfort of all composing the party.

The first point for consideration is the choice of a party. In this the surveyor must be careful to engage none but industrious and trustworthy men, and not to accept any man whom he knows to be worthless, as if he does he will have cause to regret it, and will probably receive small thanks from the man himself afterwards. There is no doubt that the members of a party must exercise a certain amount of fortitude in putting up with the little hardships that must necessarily occur even on the best planned surveys, and the man who always looks out for number one, or who grumbles at every possible opportunity, has no business to belong to a survey party.

In the purchase of provisions the surveyor must be guided by experience as to the amount of each article required. In the "Manual of Dominion Lands Surveys" is given a list of articles of food required on a survey, with the quantity of each required by one man for thirty days. This would be very useful in purchasing supplies.

Probably the point which requires most judgment is transport. The surveyor must obtain all the information he can with regard to the country in which the survey lies—such as the position of trails, rivers, etc.—and from such information he must decide upon the best means of transport. On the prairie carts may be used anywhere, drawn by Indian ponies. The improved Red River cart is the sort generally used, as they will stand any amount of knocking about. I have seen them roll sideways down a hill, turning over several times, without being materially damaged. The ponies are about as tough as the carts, as they never require any oats, and will find food for themselves on the prairies even in the depth of winter. A canoe or boat of some sort is also indispensable for crossing rivers which cannot be forded. The best kind is a canvas canoe made in sections so that it may be taken apart and packed for transportation. Sometimes the country to be surveyed lies on a large body of water; in that case canoes may be used altogether for carrying baggage and for going to and returning from work. In the mountains the only mode of transport is by means of pack horses or mules, and a troublesome method it is, requiring a considerable degree of skill to tie on a pack so that it will stay there for hours if necessary. Great care must be taken to protect the horses' backs, to keep them from chafing; they should be examined every evening to guard against the first beginning of soreness.

Having finished my preparations, I set out with my party from Calgary with horses and carts, intending to travel in that way as far as possible. In a day or two we reached the mouth of the Kananaskis River, a tributary of the Bow, on which river the bulk of our work lay. We here stored the carts and what provisions we did not require immediately, together with all articles of baggage we could dispense with, as we were obliged to depend on pack horses in our future movements. We were now ready to begin work.

I had better here describe the system by which timber limits in that part of the country are surveyed. They are laid out in oblong blocks eight and one-third miles in length, by six miles in breadth, thus containing fifty square miles. Their length lies in the direction of the river on which they are situated, consequently they should extend a distance of three miles on each side of the river. The length, eight and one-third miles, is the length of an imaginary line joining the points where the two end boundaries intersect the river. The boundary at the upper end of each limit is run at right angles to this imaginary line which joins the ends of the limit. Thus in Fig 1.—which is purely imaginary, and must not be regarded as representing the true form of the limits—let us suppose that *a* is the point where the boundary of a limit already surveyed crosses the river, which is flowing in the direction of the arrows. It is necessary then to find a point *b*, distant eight and one-third miles in a straight line from *a*, *b* also being on the river, and to run the end boundary *cd* at right angles to *ab*, making *bc* and *ab* each three miles in length. There was a clause in the instructions which stated that the end boundaries need be run only as far as practicable, and I interpreted this to mean as far as was convenient, which was usually as far as the timber extended. They also stated that the side boundaries need not be run at all; it was quite unnecessary, if not impossible, to run these boundaries, as the precipitous ridges of the mountains already formed a much more permanent boundary than could be laid down by any artificial means. It was required, however, to make a careful survey of the river.

The method I followed was this:—I traversed the river in the ordinary way, and made this the basis of the whole survey; I reduced the bearings and lengths of the courses to latitudes and departures, and found from these the co-ordinates of each station, referred to a meridian line and an east and west line as axes, the starting point being the origin. I was thus enabled to find by a simple calculation the distance of any station from the starting point, and thus locate the two stations between which the end boundaries would cross. A short trigonometrical calculation then determined the precise position of that intersection and the bearing of the imaginary line above mentioned, and from this I found the bearing of the end boundary of the limit, which was run accordingly.

Thus the work of the survey consisted in making the traverse survey of the river and running the end boundaries, besides making the necessary calculations. This last was by no means the lightest part of the work, as on account of the extreme roughness of the country and the numerous bends of the river there were upwards of fifteen hundred courses to be reduced trigonometrically, and as I was not provided with one of Mr. Rosebrugh's computing scales, my spare time was pretty well occupied.

The only other point to which I will refer is the manner in which I made most of my linear measurements. I had had a little previous experience of mountain work, and that had taught me that a great deal of difficulty and delay is occasioned by depending on the chain alone for finding distances, and as I did not possess a micrometer, I resolved to resort to stadia measurements. I give a brief description of this method. In the first place, stadia hairs are two parallel horizontal hairs placed in the focus of the telescope of an instrument. If the telescope so provided be now directed to a graduated rod held so as to be perpendicular to the line of sight, the stadia hairs will appear to include between them a certain number of graduations, and that number is proportional to the distance of the rod from the outer focus of the objective of the telescope. The stadia hairs are first placed in the telescope and the rod graduated accordingly, by measuring carefully with a chain any convenient distance, say ten chains, plus the focal length of the objective, from the objective; an assistant then holds the rod to be graduated at the point so found, and marks according to your signals the points on the rod which are covered by the stadia hairs. This length is then divided into ten equal parts, which represent chains, and these may be further subdivided, and the whole rod then graduated in the same maner. To obtain the distance now between any two points, the instrument is set up at one point and the rod held at the other, and the number of graduations included between the stadia hairs read; this number added to the focal length of the objective and the distance from the objective to the vertical axis gives the distance in chains. This is the exact method, and to save the trouble of applying the correction to every reading I used an approximate method. The rod was first held at a distance of ten chains from the plumb line of the instrument, the points covered by the stadia hairs marked, and the distance between them divided into ten equal parts, and the whole rod then graduated as in the former method. The reading of the rod then gives its distance from the plumb line of the instrument exactly when that distance is ten chains, and the reading at any other distance is a very close approximation to the truth; the error certainly does not exceed the degree of inaccuracy of the method itself.

The advantages of this mode of obtaining distances are these:—(*a*) Quickness, combined with a considerable degree of accuracy; (*b*) inaccessible distances may be measured; (*c*) chainmen may be dispensed with. In my case, most of the courses lay along the channel of the river; I was thus able to obtain a clear sight, where otherwise it would have been necessary to clear lines through the woods along the bank, thus losing time and requiring a greater number of choppers in the party. I was thus enabled to reduce the number of my party to a minimum. The advantages above enumerated belong equally to any good micrometer.

The returns of the survey which had to be sent to the Department consisted of a plan, field notes, and report. The plan was required to show the lengths and bearings of all boundaries, whether surveyed or not, the area of each limit, and also any rivers or lakes included within the boundaries, together with the general topography. The field notes were to show the lengths of all lines surveyed and their bearings, and also the topography of the country passed through. A description by metes and bounds of each limit for insertion in the lease was also to accompany the returns.

On this survey we had the usual amount of hardship, in the way of exposure to all weathers, occasional short rations, and rough work generally, but I must say that there is nothing about surveying that need deter any man, possessing a moderate amount of manliness, from entering the profession. I have been out on many rough surveys, but I am always ready for another; where the charm comes in I cannot tell, but it certainly does exist; and I have had many a pleasant chat, "fighting the battle o'er again," with some companion of a past survey.

TRACK LAYING.

By T. S. Russell.

In railroad building the amount of responsibility resting upon the various engineers employed, and the gain or loss to the company resulting from the manner in which they do their work, is about in proportion to the order in which their work is done.

First and foremost is the locating engineer whose duty it is to decide where the line shall be built, what shall be the average of the curves and grades adopted and similar questions, and the future success or failure of the whole road is greatly affected by, and in some cases altogether depends upon the wisdom of his choice. When these questions are decided and the line located, the constructing engineer comes on the field. The problem with which he has to deal usually is—how to build the best possible road for the least possible amount of money, and many and varied are the questions he is called upon to decide—questions which affect very considerably both the first cost of construction, and the subsequent cost of maintenance. Third in order, and I suppose third in importance, comes the track laying and ballasting engineer. His field is more limited. The line has been chosen for him by his first predecessor—and built for him by the second—and yet his office is by no means an unimportant one, and upon the thoroughness and attention to detail, with which his work is done, depend the speed with which trains may be run—and the safety and comfort of the passengers.

The work of track laying is usually done by contract, and ballasting by the railway company,—though there is no universal custom in these matters. The following extracts from track laying specifications will show the general requirements for good work.

SPECIFICATIONS.

Delivery of Materials.—All material for track and switches, and plank for road crossings will be supplied by the company, and delivered to contractors on board cars at end of track—and after such delivery they will be considered as being in his custody, and he will be responsible for their safe keeping.

PREPARING ROADBED.—All humps and hollows in the surface of sub-grade must be levelled off before ties are distributed. The approaches to all bridges and culverts must be filled in solidly and to the proper grade.

TRACK LAYING.—The track to be laid on the finished sub-grade with square joints or otherwise, as may be ordered by the engineer in charge.

TIES.—Ties will number not less than 2,640 per mile, and be uniformly spaced between the joint ties. Joint ties will be spaced 10 inches apart between bearing surfaces. Large and well made ties must be picked for joint and shoulder ties.

ADZE TIES.—Ties must be adzed when necessary to obtain uniform surface for rails, no notching allowed.

LINING TIES.—Ties will be laid truly at right angles to the track, and their south ends lined parallel to the rails—any ties knocked out of line by the rails must be caretully re-lined before spiking.

SWITCH TIES.—Switch ties and frog timber must be laid in accordance with standard drawings for the same.

RAILS.—The rails if bent in handling must be perfectly straight before being laid in the track. Lay rails with maker's brand on outside.

ON CURVES.—On curves, when the inner rails overrun the outer by 2½ inches, a cut of 5 inches to be made, and a new hole to be drilled for the bolt in the proper place.

BOLTS.—Every joint must have its full complement of four bolts.

GAUGE.—The gauge will be 4 feet 8½ inches *exactly* on straight track, and on all curves of three degrees and under. For curves of four degrees, widen gauge (⅛in.) one-eighth inch, for five degrees widen gauge (¼in.) one-quarter inch, for six degrees widen (⅜in.) three-eighths of an inch.

SPIKING.—Use four spikes to each tie, driven with proper amount of "stagger" to avoid splitting ties, and the two inside spikes to be driven in the same edge of the tie so as to keep ties at right angles to the track. Spikes to be driven as nearly perpendicularly as possible, snug up to the base of the rail, and no blow must be struck after the head of the spike is firmly driven down on the rail base.

Expansion.—Expansion and contraction of rails will be provided for by the use of the following rules:—In coldest weather use iron wedges $\frac{3}{8}$ in. thick, at freezing point use $\frac{1}{4}$ in. wedges, and at 70° F use $\frac{1}{8}$ in. wedges. This rule must be carefully observed, and the use of iron wedges is imperatively insisted upon, and the contractor must provide himself with a sufficient number of them of the thickness above specified.

Road and Farm Crossings.—Road and farm crossings must be put in wherever required, the inside planks will be placed $2\frac{1}{2}$ inches from rail to allow flange room, the outside planks will be placed as close as possible to the rails. No spike to be driven through the planks; track spikes will be used for fastening plank down, but they must be driven alongside of plank with the hook over edge, in the same manner as rails are spiked.

Sidings.—Sidings must be laid wherever required by the engineer in charge, and great care must be taken in laying switches to get them in exact accordance with standard drawings. Rails on leads must be curved to proper ordinates.

Final.—The track to be levelled up and well lined so as to be safe for the passage of trains at a reasonable rate of speed in transporting construction material, and ties must be so firmly tamped to a good level that there shall be no chance of straining or bending the rails. Materials for any tamping must not be taken from the shoulders of dumps, or from berms, nor from the side slopes in cuts in such a way as to disfigure them, but all such material must be taken from the ditches. The contractor must keep all newly made track in good line and surface while the work is in progress.

The price for track laying to be so much per mile for single track, and must cover unloading from cars, handling and delivering of all material to such points as it may be required for use—the laying of all switches for side tracks, laying planks for road crossings, and lining and necessary surfacing of track, and the completion of everything in accordance with the specifications and to the satisfaction of the said engineer in charge.

I shall say little about the cost of track laying. It is variable for different localities, and different states of the iron and labor markets, but can always be estimated fairly closely; much more closely than the cost of any other department of railway work. The quantities of material required can be calculated almost exactly, and having given their cost, the variable part of the whole cost becomes (1) the transportation of these materials and (2) the labor required in handling them and laying them in the roadway. The railway company usually supplies all material, transports it to the end of track and provides an engine and train of cars for use in the operation of track laying. The contractor receives the material from the cars and lays it on the roadway, putting in all necessary sidings, crossings, etc. The cost of this work depends on the price of labor, and on the organization of the track laying gang. The contractor must exercise all his skill and judgment to keep things working smoothly and quickly, and above all to avoid delays in any part of the work, for in track laying if any one part of the work is stopped, the delay extends to all parts and to all employed.

An important part of the engineer's work, also, is keeping up a constant supply of material. He has to estimate ahead the amount of material required for each day's work, and order all these supplies day by day from the officials in charge of the stores department.

The routine is about as follows: As the track is laid, the supply train is pushed on, and the cars containing the rails, ties, etc., are seldom more than a few hundred yards distant from the point where the material is wanted. The ties are hauled ahead with teams and distributed over the roadway. Sometimes this work is done at night, but this is impossible when a great length of track is laid in a day, as it necessitates a very long haul from some fixed point—the end of the track for the previous day. Following the tie distributors is a gang of men who straighten the ties out, lay them at right angles to the track, space them properly and line them on one side. This is done by stretching a rope along the sub-grade between stakes driven opposite the centre stakes and distant from them half the length of a tie, or usually four feet, and lining the ends of the ties even with this rope. Then comes the iron gang who run the rails forward on a small car or lorry as it is called, drop them on the ties and set them roughly to gauge. Then come the bolters who fasten the rails together by fish plates or angle bars and bolts, and lastly the spikers who guage the track and spike the rails down.

For the manner in which the work is done, the engineer in charge is responsible. He must inspect the materials and throw out any that he does not consider fit for use. The details of the work must be carefully looked after, and if any bad or carelessly done work is detected, he should insist on its being done over again, especially at the first. A great deal of trouble can be saved if the engineer strictly enforces the terms agreed upon at the start. He should train up the contractors in the way they should go, and as the work goes on they will not depart from it, if he still watches them closely. A great deal is left to the judgment of the engineer, and he must distinguish between clauses in the contract which being of very great importance must be strictly enforced, and others which do not affect the safety or durability of the road, which he may in some cases suspend. For instance in the above quoted specifications, the clause referring to the rails being laid with the maker's brand on the outside, may, under some circumstances be disregarded or set aside by the engineer, as the contractor might be unable to lay all the rails in this manner without great additional cost and delay in handling, and as this is a matter which concerns the appearance of the track only, and does not effect its usefulness. But in all details such as spiking, bolting, allowing a proper space between the rail ends for expansion or contraction, etc., details which go to to make up the difference between a good track and a bad one, the specifications must be strictly enforced. Perhaps no part of the work requires such close and constant attention as the spiking and guaging. The rail on the side on which the ties are lined should be spiked first, and should be made parallel to the line of the ends of these ties, at a distance of about one foot and six inches from these ends; the opposite rail should be guaged from this one. The ties must be truly at right angles before the rails are spiked on to them, and in all cases the spikes must be driven so as to prevent the tie from swinging sideways. This result can be obtained by insisting on the adoption of a universal rule, that the outside spikes shall be driven near the forward side of the tie, that is near the north side, if the line is being built in a northerly direction, and the inside spikes near the south side of the tie, or *vice versa*. Before the ties are distributed on the roadway, the engineer should run in the centres, making a line by stakes 200 feet apart on tangents and 100 feet apart on curves. He will obtain from the head office, or from the engineer who preceded him, a copy of the alignment notes containing information as to the position of the *BC's*, *EC's* and apex points, and of the hubs by which these points are referenced, also notes of the curvature and length of curves. Very often he will find that his curves will not fit at first, that is that though he starts a curve from the original BC it will end at the EC on a tangent parallel with the original one at some distance from it. The various hand books for engineers give formulæ to be used in such cases, by which he can calculate the distance necessary to move his BC back or forward, so that starting his curve from this new point, it will fit on the old tangent.

In laying track over bridges and culverts the centres must be carefully marked on the ties, (when these are spiked down, or otherwise secured on the stringers so that there is no movement) at intervals of not more than 15 or 20 feet by driving tacks in these ties. And it is also wise to offset at these points at right angles to the line, the distance from the centre to the inside of the flange of the rail, 2 feet 3 inches or 2 feet 3¼ inches according to the size of the rail, and make with a chalk line a continuous line across the bridge at this distance from the centres; the inside of the flange of the rail can then be placed exactly even with this chalk line, and spiked down, and the opposite rail gauged from it.

The centre lines for all sidings should be marked out by stakes, and the points at which the head blocks and point blocks for switches are to be placed should be similarly marked.

In laying out ordinary turnout curves there is no necessity for using a transit and the work can be done much more quickly by measuring with a tape line, previously calculated offsets from the main line. The width beween tracks will of course be fixed by the grading; 15 feet centres is a good width for passing sidings. The radius of the turnout curve will be fixed by the number of the frog used, and for the sake of symmetry, the same radius may be used for the reverse curve which brings the siding parallel to the main line. The curves may be made to reverse at one point, or they may have a short length of tangent between them—in either case the lengths of the offsets can be easily calculated by using a table of offsets from tangent for a 1° curve.

The first thing is to choose a point for the head block. This will usually be marked on the plan, but in ordinary cases, unless there is some special reason for doing so, it is not wise to cut a rail in order to make the switch begin at a fixed point. The rails are as a rule 30 feet long, and in ordinary practice it will do well enough to make the switch curve at the joint nearest the point marked on the plan. The distance of the point of frog from the head block will depend on the number of the frog used, or in other words on the frog angle. The lead rail should be carefully curved to points which are marked on the ties—these points being fixed by ordinates, and in laying off these ordinates, as in all calculations made for turnouts, it should be remembered that the curve does not begin at the switch, but at the point between the slide rails where they begin to bend, the distance of this point from the switch depending on the frog number and on the throw of the switch. A table giving all these dimensions with the radius of turnout curves, etc., for each frog number in general use will be found in Troutwine's Engineers' Pocket Book. In cutting rails for turnouts the lengths should, if possible, be so arranged that no material will be wasted and no more rails cut than necessary, thus for a number 9 frog, with 30 and 28 ft. rails and frog 10 ft. long, arrangement shown in Fig. 5 can be used.

Here only two 30 ft. rails are cut (except the short piece cut from the lead rail), and all the pieces of these two rails are used, also the joints become opposite to each other after leaving the frog, thus making the tracks symmetrical.

The base of the guard rail is notched to allow it to be spiked down, and at the same time placed opposite the point of frog with its flange touching the flange of the main line rail, thus leaving a space of about two inches for the passage of the wheel flange. Guard rails are about 14 feet long and at their ends are curved outward so as to leave a clear space of at least five inches between their ends and the main line rails. They should be firmly spiked down and also supported by braces or blocks on the inside, as they have to sustain heavy pressures. It is impossible to give many details of switches.

Standard plans are usually supplied for the guidance of engineers in building them, and these plans should be closely followed. Every part of a new switch should be thoroughly examined both immediately after it is put in and after it has been run over for some time. There is a great danger of new switches becoming foul, that is of the ends of the fixed rails on the head block not lying exactly opposite or in the same line with the ends of the slide rails. To prevent accidents the ties should be surfaced or tamped with earth soon after laying.

Rail joints are either square or broken. Square joints are simply joints opposite to each other, broken joints are those not opposite, the joint in one rail being usually opposite the centre of the opposite rail. The square joint is the one most commonly made. A joint is either suspended between two ties or supported by one tie. The former joint is the one most commonly used.

Many different kinds of angle bars and fish plates are used for making the fastenings. The work they are required to do is (1st) to keep the rails exactly in line with each other and to bind them firmly together, and (2nd) to act as bridge between the two joint-ties and thus support the ends of the rails. They are fastened together with four $\frac{3}{4}$ inch bolts which are supplied with washers and nuts. The nuts should be made very tight as the whole usefulness of the angle bars depend on the pressure they exert on the rail, which pressure is caused by the tightening of the nuts on the bolts. The holes in the rail through which the bolts pass are elliptical, allowing a movement of the bolt in the direction of the length of the rail of about $\frac{1}{8}$ of an inch or $\frac{3}{8}$ of an inch at each joint. Thus the rails can expand or contract without exerting any shearing force on the bolts. A 30 foot rail will vary nearly $\frac{1}{8}$ inch in length between the extremes of summer and winter temperatures, hence the necessity for regulating carefully the space allowed for contraction and expansion. The best way of doing this is by the use of wedges as provided for in the above specifications. There is also a tendency, more or less marked, of the rails to creep bodily in a certain direction—as down a heavy grade or in the direction of the heaviest traffic. This tendency may to a large extent be counteracted by driving the spikes in the joint-ties through the notches in the angle bars which are provided for this purpose.

When square joints are made they should be kept exactly opposite to each other. Sometimes one joint will get a little ahead of the other; in such cases, by using a wedge on one side a little thicker than that on the other, the joints can gradually be brought opposite. This method can only be used when the distance of one joint ahead of the other is small. On curves it is necessary at certain intervals to cut the inside rail in order to keep the joints square.

Five inches, the distance between the two holes in the rail, is a convenient length to cut off, as it necessitates the drilling of only one new hole. The total length of rail required to be cut from the inside rail of any given curve can be calculated as follows:

g = gauge expressed in feet and decimals of a foot.

r = radius of the inside rail.

$\frac{2\pi(r+g) - 2\pi r}{360}$ = the difference in length between the inside and the outside rails for each degree of curvature. This reduces to $\frac{2\pi g}{360}$ which gives the constant ·08552 of a foot, being the difference in length of the inside and outside rails for each degree of curvature, therefore to find the total length to be cut from the inside rail on any curve we multiply this constant (·08552) by the number of degrees in the central angle of the curves (the minutes being either disregarded or reduced to decimals) and the product gives this length in feet and decimals. By bringing this to inches and dividing by five we have the number of rails which we must cut if the cut from each is five inches,—and a simple calculation gives the order in which these cut rails should come—that is the number of full length rails to be left between the cut rails, so as to distribute the unevenness of the joints as much as possible. It will be noted that the difference in length of the outside and inside rails is altogether independent of the radius of the curve used—the central angle remaining constant.

In conclusion an engineer is never too old to learn, and he must remember that in track laying—while he can get little information from his mathematical theories and not much from books regarding the details of the work—he can obtain a great deal from old railroad men—section foremen for instance. He must be constantly on the lookout for information and must never lose an opportunity of increasing his store of practical knowledge.

PRESIDENT'S ADDRESS.

GENTLEMEN :

It is my privilege this afternoon to thank you for the honor you have done me in electing me to the presidency of your society for the ensuing year, an honor which I esteem all the more highly, for the cordial and unanimous manner in which it was conferred upon me.

In accepting this important office I have, I believe, a due sense of the difficulties of the position and of my own unaided inability to surmount those difficulties. Fortunately, however, for me, and for the society, you have chosen a very prudent and energetic executive committee to guide and assist me ; and relying on their wisdom in finding out what it is necessary for us to do, and on their activity in doing it, I look forward with every confidence to a very prosperous year for the society.

You may, perhaps, in going through the woods, have noticed that it is much easier to follow a slow walker than a fast one. In like manner I shall find it more difficult to fill this chair acceptably, on account of the ability and energy of my predecessors. To maintain the society in the high state of efficiency in which they left it will be a difficult task—an almost hopeless task, did I not rely on the generous assistance of not only the executive committee but also of each individual member.

The society, as most of you are aware, was formed in 1885, and though the number of members was then small they were fortunate enough to secure the active assistance of Prof. Galbraith as president. In that capacity he watched over the interests of the society, encouraging and directing the efforts of the students until the end of the session of '87-'88, when, feeling that the society was firmly established, and that we were sufficiently numerous to undertake the management ourselves, he retired from the chair and advised us to elect a president from our own number.

The gentleman chosen, Mr. H. E. T. Haultain was in every way eminently qualified to undertake the work, and in addition to the great ability of the president, every member felt that peculiar stimulus occasioned by the knowledge that they were now considered strong enough to conduct the society themselves.

This year such a stimulus is wanting. Our position has lost the charm of novelty, and we must look to other means for keeping alive the interest in the society.

I had intended, in this address, to call your attention to the confusion of ideas which often exists in the minds of engineers owing to a defective terminology, and to impress upon you the necessity of having a very clear conception of what every engineering term should mean, and of never using it except to convey the proper meaning. But everything around us is in such a state of rapid transition, the number of students increasing so rapidly, and so much attention is being given to the new conditions of student life, which the ever increasing number of students necessarily entails, that I have decided to speak only of the Engineering Society, of our relation to it, and of our relation to one another.

All around us we see indications of rapid progress. Across the ravine is a beautiful stone edifice, built specially for a department of science which once found ample accommodation in these small rooms. We are daily expecting to see the excavations begun for a new gymnasium building and we ourselves have our meditations disturbed by the noise of workmen busy at a new School of Practical Science in relation to which the present building will be quite insignificant.

Nor are these buildings being erected before they are necessary. Nothing but the most uncomfortable overcrowding has forced the authorities to move. The number of students here, as well as at the university, is steadily and rapidly increasing. There are already ten students in the newly established department of Mechanical Engineering and it is expected that as soon as the new building is equipped the Mechanical Engineers will equal, if not exceed, the number taking Civil Engineering.

And, what is more important for us to consider just now, the changes in the social life of the students are equally as rapid and as far-reaching in their effects.

We see new societies springing up on every side—year societies, class societies, hazing and non-hazing societies and various other kinds of societies, until we are tempted to exclaim "Of the making of societies is there no end?" It is said that the tendency of the present age is towards combination and co-operation and truly the tendency of our college life is towards the formation of societies. In the midst of all this luxuriant growth of societies is the Engineering Society to remain stationary? Are we to rest satisfied with doing what our predecessors have done? Decidedly not. To remain unprogressive, to be satisfied with doing the same things which were done last year or the year before last—is to be smothered by the rapid growth of everything around us—to dwindle away and die. In order to maintain a healthy life we must develop at least as rapidly as our environment. We cannot rest on our oars if we wish to maintain our place in the front rank of the student societies. We cannot live on the laurels won by our predecessors, our own unceasing labour is the manna of our existence.

And why should we not do more than our predecessors? Everything they have accomplished is ours; we have but to start where they left off and build on layer by layer, beautiful and permanent as a coral reef in a Southern sea. How shall we accomplish this? How shall we make the society do a greater work than it has ever done before? Simply by well directed, unremitting, united effort.

One of the dangers which this extraordinary development of student societies may bring in its train is the idea of a federation or union of all the societies. We should avoid any such expedient. It might galvanize some life into some of the more defunct societies, but it would only retard our progress and endanger our safety. It is like tying the boats of a flotilla together, the better to stand the storm; it may appear safer for the frailer crafts but it is really more dangerous for all. I believe that some arrangement should be made so that our meetings would not interfere with those of any other society, and when programmes could be arranged suitable for two or more societies, joint meetings might be held; but any closer union seems to me inadvisable. Instead of endeavouring to make our society play a more prominent part in college politics and exert a more direct influence on the other societies, let us see to it, that it continually exerts a more beneficial influence on ourselves.

The constitution states that the objects of our society shall be "(1) the encouragement 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 and (4) the cultivation of a spirit of mutual assistance among the members in the practice of the profession of Engineering."

These few sentences express very clearly the work which it is hoped the society will accomplish, and they cannot be too strongly impressed upon the minds of the students. But what seems to me the grand and lasting result of all student societies is the reflex action of the society upon the minds of the students themselves. Were I asked to define the great object of this society I should say: "It is to afford facilities for, and to encourage, the development in the minds of its members of habits of reading and observation, and the cultivation of the ability to communicate information thus received by means of writing and speaking."

The great object for which we should attend college is not to make new discoveries in the field of science, it is not even to learn the truths which have been discovered, but it is for the training which our minds receive in mingling with other minds in the pursuit of knowledge, and in learning a little of what the master minds of this and other generations have accomplished. And when we leave here to practise our profession, if we are better men than those who have not attended here, it is not because we have done more, nor because we know more, but because our minds are better trained and we are therefore capable of knowing and doing more.

In this training of the mind the faculty have felt that the society was doing a useful work upon the lines which I have just indicated—a work which could not be so well accomplished by the ordinary course of lectures. They have therefore set apart two of the regular lecture hours for us to hold our meetings and I hope you will all realize that it is as much your duty to attend these meetings as it is to attend any other lectures in the school.

But I fancy I hear some one saying "I have attended a meeting of the society now and again, and tried to listen to some dry old paper and it never did me any good. This thing of deriving benefit from the society is all a humbug." My friend (if there is anyone here who has held this opinion) I quite agree with you. I would even go farther. Your attendance at the society has probably done you harm. The society *is* a humbug to you. But why? Thackeray has said "The world is a looking-glass and gives back to every man the reflection of his own face. Frown at it and it will in turn look sourly upon you; laugh at it and with it, and it is a jolly kind companion." If you wish to draw money from a bank, you must first put money in; if you wish to derive benefit from the society you must first become useful to it.

> "All who joy would win
> Must share it;
> Happiness was born a twin."

This reflex action of a student's society upon the minds of its members is no new idea. All men unite in saying that in whatever degree they took an interest in the proceedings of their society in the same degree were their minds benefited thereby. Newton's Third

Law of Motion, that the reaction is equal and opposite to the action is as true in the case of our relation to a society, as it is in the impact of two perfectly elastic spheres. For the sake of the society, then, and for your own sakes, let me urge upon you the necessity of taking an active interest in the society, and if at all possible of contributing to the programme of at least one meeting during the year.

In order to afford better facilities for varied reading on Engineering subjects, the society has, during the past year, fitted up a small room where all books and papers, the property of the society, are kept. I very much regret that the students have not all availed themselves of this library in the way in which they might. There will be found there, the current numbers of the best Engineering Journals, besides several works on subjects connected with our course—the property of the old School of Technology. Any member of the society may take out these books and papers and read them at his leisure as long as he conforms to the library rules. There is nothing to hinder any student from reading, at least, one number of a periodical each week, in the spare moments when he does not feel like pursuing his regular work. He would thus, by selecting which ever magazine he prefers, and reading it continuously, be able to form a good idea of what is going on in the Engineering World around him. He would moreover find it a pleasant recreation from his severer studies, and above all, he would acquire broader views and develop a habit of reading which would be of inestimable value to him in after life.

But while laying great stress on the benefits to be derived from our library, we must not forget that the most important part of our work is the reading and discussion of papers. In fact, one of the greatest benefits of the library is that it stimulates and facilitates the production of papers. Reading and writing go hand in hand. Reading is the strongest incentive to writing, and writing is the truest test of correct reading. We have never really mastered a subject until we can write intelligently about it.

It is not my intention to suggest subjects for papers; in our work there is such an infinite variety of interesting subjects that it would take more time than is allotted to me even to name them over. But of one thing you may be certain—the subject in which you yourself feel most deeply interested is the one upon which you will most probably be able to write the best and most interesting paper.

With regard to the length of the paper so much depends upon the nature of the subject that no definite rule can be laid down. But I think it is generally agreed that short papers are better than long ones for two reasons:—The interest of the hearers does not flag and the short papers do not, as a rule, demand so much time for preparation.

However, it is not to the subject matter nor to the length of the paper—a good paper is rarely too long—but it is to the style of the paper that I desire to direct your attention.

Do not make your paper too comprehensive. Do not endeavour to compile an Encyclopedia of Engineering which can be read in fifteen minutes—for you can't do it. First form a perfectly clear and definite conception of what your subject is, and then write about nothing else. "Scattering shot may hit many things, but it never brings down big game." There is a society in the neighbouring republic where every paper read is the embodiment of but one thought. To write a paper of that description is, no doubt, beyond our powers, but such is the ideal which we should strive to realize.

By confining ourselves closely to our subject we shall more easily avoid another danger which I wish to mention—the tendency to make our papers too condensed. No paper which is merely a catalogue of dry facts can excite any human interest. Do not attempt to crowd too much information into a given space; such a course necessitates paring down our sentences to the smallest possible size, stripping them of all ornamentation and even twisting them out of shape in order to squeeze them in. Remember, our thoughts must be clothed in words—and clothed properly. As a man never looks well if his clothes are too small or unsuited to his work, so thought loses half its dignity when not expressed in appropriate language. As with clothing the language should not be so inferior as to bring the thought into contempt, nor yet so florid and ostentatious as to divert our attention from the ideas by compelling us to contemplate the verbiage.

What we want here is not a great deal of information in uninviting form, but a few facts in a shape in which they may be easily assimilated—information in a pleasant palatable condition, sugarcoated with humour and flavoured with wit. In fact, what we should deal in here might be appropriately called the bon-bons and sweetmeats of engineering science. I maintain that that knowledge which is associated with pleasant recollections is the most easily acquired and the most permanently retained, and I cannot understand why wit and humour are excluded from philosophic works as having no part therein. They seem to me like rays of sunshine gleaming through the forest leaves of scientific thought, cheering the student on his lonely way. I am inclined to think that the number of profound mathematicians would be greatly increased were the Conic Sections or the Calculus interleaved with selections from Pickwick or clippings from a comic newspaper. But I hear some one say "That would be beneath the dignity of the subject." Perhaps it would. Yet we must remember that dignity does not consist in being serious and matter-of-fact, any more than in being cheerful and good-humoured. Even in mathematics there are opportunities for giving many sentences a humorous turn, and if mathematicians took advantage of these opportunities, their books would be much more interesting and, therefore, more instructive.

We should always remember what Sir John Lubbock says in his exquisite work, "The Pleasures of Life": "It is not without reason that everyone resents the imputation of being unable to see a joke. Laughter appears to be the special prerogative of man. The higher animals present us with proof of evident, if not highly developed, reasoning power, but it is more than doubtful whether they are capable of appreciating a joke." And that even Carlyle has said: "No man who has once heartily and wholly laughed can be altogether irreclaimably bad."

Finally, gentlemen, do not be original. I mean, do not strive after originality. It should not be expected of you. We do not ask a builder to put on the roof before the walls are raised, nor do we expect Stanley to make discoveries in Africa before he has ascended the Congo, then why should we ask you to write something original before you have had time to read all that has been already written on the subject. As a mathematical friend of mine once remarked, "A man must be pretty thoroughly soaked in his subject before he becomes original." Any originality which we in our present stage of life can expect to attain is of an insipid artificial kind—like distilled water. True originality, like an artesian fountain, can only be obtained by searching deep down into the innermost depths—and, like an artesian fountain, it is not always there. Originality is spontaneous. Like the diamonds of Africa, it may be found by searching, it may be improved by polishing, but it cannot be manufactured according to a chemical formula. Therefore I say: Do not seek to be original. A *straining* after something original is one of the greatest defects of young writers.

On the other hand, do not write your essay in the same intellectual manner in which the humorous column of a daily newspaper is composed—by a half-mechanical use of scissors and paste. By taking a scrap from this book and a scrap from that, and another from a third, and so on, and tacking them all together with a few connecting words and a very feeble idea of plan or order, your essay will have the same bewildering effect as a crazy quilt.

Do not go to either of these extremes. But take a few filaments of truth, collected by reading or observation, thoroughly assimilate them, straighten them out, arrange them in logical sequence and weave them into one harmonious whole by the woof of your own personality. You may thus revive some half-forgotten experiments, some philosophic deductions which, like Newton's second law of motion, have long been ignored or entirely misconceived. Or you may bring to the notice of the scientific world some clever contrivance, the invention of some unknown Watt, which but for you might never have reached the light of day. But in this way better than in any other will you cultivate those powers of comparison and discrimination which are essential in a good critic, and which ultimately develop into *true originality*.

If the position I now occupy is the most honourable in your gift it is also the most responsible, and I feel that I would not be doing my duty here to-day, did I not refer to another matter of vital importance to the student body. I do so with some hesitation, occasioned by doubt as to whether it is properly within my sphere, but more especially by an apprehension that my remarks may be misinterpreted and made to convey a meaning which I had never intended. I am, however, encouraged to risk these dangers in the hope that I may contribute in some measure towards the satisfactory arrangement of a difficulty which has existed for some time in our college. I refer to the relation of the first year students to the seniors. In the first place, I think the seniors are much to blame for the present state of affairs. If the new students were told plainly and kindly what is expected of them during their apprenticeship to college life there would be very few indeed who would not profit by and act according to advice thus given. This being my conviction, I am willing to create a precedent and to tell the first year men what, in my opinion, is their duty towards the seniors. I speak on this question more boldly because my long attendance at college has crystallized my opinions into articles of belief.

Be natural. Do not appear timid, for you are among friends ; nor bold, for your boldness will not go unchallenged. Consider that the seniors are your friends, and treat them as such, until they have proven themselves your enemies.

But the golden rule I would have you follow is : " Do unto others as you would have others do unto you." Treat the seniors with respect if you wish them to treat you with the same. They are entitled to respect from you because they are, in general, older than you, and have already accomplished the work at which you are now engaged, and have become familiar with the peculiarities of College Life. For, believe me, College Life is quite different from any other kind of life.

You have the solution of this question in your own hands; if you conduct yourselves in a quiet, gentlemanly manner, paying due attention to the feelings of those who are your seniors (here, at least), you will be treated in the same way by them; and all necessity for punishment, which is as obnoxious to the majority of the seniors as it is to you, will be done away with. But if, despising the advice of those who seek to befriend you, or inflated by the idea that you are Sir Oracle, and that besides you there is none else, or from an ignorance of the courtesies of juniors to seniors, observed in every phase of life, you seek to thrust forward your importance on every possible occasion, then you will find that you will stir up very vigorous feelings against you—feelings which may culminate in what is known as hazing. Now, it is well known that I am an opponent of hazing as it has been conducted in the past. It is in the hope that a hazing may be avoided that I am speaking as I do to-day, and if I may hurt the feelings of anyone here it is but as the knife of the skilful surgeon lances the flesh of the patient—it is for your own benefit.

I feel the more strongly urged to speak on this question since last evening at another society a very indiscreet freshman harangued the meeting, and, by "taking issue again," two of the lecturers, succeeded in rendering his position around the College at once notorious and unsafe. I am not one of those who think that during the first year a man should not open his mouth. Far from it. On the contrary, I believe that the earlier in a man's course that he takes an active part in societies, the better for the society and for himself. One of the greatest difficulties in our College societies is that men do not take an interest in them until they are about to leave College. But there is a time to speak and a time to keep silence. It is more appropriate for a new member to remain an attentive listener until he has become familiar with the procedure of the society. After the first two or three meetings you will be in a better position to acquit yourselves creditably, and I can assure you that your efforts will be kindly received.

You will be asked to contribute papers to the society before the end of the year, and I hope that you will respond cheerfully. One of the most interesting papers read in this society last session came from a member of the first year. I hope that the president next fall may be able to say that not only one but several of the best papers have emanated from you. If he can say that, he can also say that you early manifested an interest in the society, which will keep on increasing as long as you are in connection with it.

On behalf of the older members of the society I bid you welcome, and can assure you that if you treat us in a generous, kindly manner, and withal with that modicum of respect to which our academic standing entitles us, you need have no reason to fear anything from us but the kindest treatment and the most generous assistance.

October, 1889. JOHN A. DUFF.

DISTANCE MEASURING MICROMETERS.

By L. B. Stewart, D.T.S.

Instruments for obtaining distances more expeditiously than by the usual method of chaining are coming into such general use that it may prove of interest to the members of the Society to give a short description of a few of the principal forms of these instruments.

Micrometers are designed for the purpose of measuring small angles with extreme accuracy. If, then, we measure with one of them the angle subtended by a rod of known length, held so as to be perpendicular to the line of sight, we can from those data determine the distance to the rod. This is, in outline, the method of determining a distance with a micrometer. The first form of micrometer I shall describe is

THE ROCHON MICROMETER.

As a double refracting prism of rock crystal plays an important part in the construction of this instrument, it will be necessary before giving a general description of it to state a few of the laws of double refraction.

If a ray of light be incident on a doubly refracting crystal in the direction of its axis it suffers no double refraction, but if it be incident in any other direction it is doubly refracted. Let *ABC*, Fig. 2, be a portion of a crystal of rock crystal cut so that the face *AC* is perpendicular to the optical axis of the crystal, and *ABD* another portion cut in a direction parallel to its axis. The two faces *AC* and *BD* are parallel to one another, and the two pieces of crystal are firmly united. If now a ray of light *IE* be incident normally to the surface *AC* it will suffer no refraction at the point *E*. When, however, it encounters the second surface *AB* it is split into two parts, the ordinary ray continuing in the same direction as before and the extraordinary ray being refracted at the point *G* and taking the direction *GH*; it is again refracted at the point *H*, taking the new direction *HK*. No matter what angle the incident ray may make with the surface *AC* the direction of the ordinary ray after emergence is parallel to its original direction, as the ordinary ray obeys the laws of single refraction.

Next, let O be the object glass of a telescope, OR its axis, and R its focus. Let a rod of length b be held at a distance x from the objective with its length perpendicular to the axis of the telescope. An inverted image RK of the rod will be formed at the focus of the objective according to the well known laws of optics, the image of any point of the rod being on the production of the line joining that point with the optical centre of the objective. Let us next examine the effect produced by placing a double refracting prism AB, such as has been described above, in the telescope between the objective and its focus, with its parallel faces AC and BD perpendicular to the axis of the telescope. From what has been stated above, each ray on meeting the dividing plane AB of the prism is there split into two parts, the ordinary ray, maintaining its original direction, and the extraordinary ray, being refracted through a constant angle. Two images therefore will be formed at the focus of the objective, the one RK formed by the ordinary rays occupying precisely the same position which it would occupy if the prism were not there, and that formed by the extraordinary rays occupying some other position KM. If the axis of the telescope be always directed to the foot of the rod the angle of deviation RLK $(=\theta)$ will be constant.

I have shown in the diagram the two images RK and KM in contact with one another, but it is evident that if the prism be shifted along the axis of the telescope it will cause the two images to recede from one another or to overlap. Also if the distance x be altered, the result will be a corresponding change in the size of the images of the rod, and a change in their relative positions. We conclude from this then that for any distance x there is a corresponding position of the prism in which the two images are in contact.

Let us next investigate the relation existing between the distance x and the distance of the prism from the focus. Let m denote the size of the image RK, u its distance from the objective, θ the constant angle included between the rays RL and KL, l the distance of the point L from the inner principal focus of the objective,* f its focal length, b the length of the rod, and x its distance from the objective. Then by similar triangles we have

$$\frac{x}{u}=\frac{b}{m}. \quad \text{But } m=[l-(f-u)]\tan\theta;$$

$$\therefore \frac{x}{u}=\frac{b}{(l-f+u)\tan\theta}=\frac{b}{u\tan\theta-(f-l)\tan\theta}.$$

But from optics $$\frac{1}{x}+\frac{1}{u}=\frac{1}{f}; \quad \text{or } u=\frac{fx}{x-f}.$$

* The principal focus should be to the right of R.

Substituting this in the above equation—

$$\frac{x(x-f)}{fx} = \frac{b}{\frac{fx}{x-f}\tan\theta - (f-l)\tan\theta}$$

or

$$1 = \frac{bf}{fx\tan\theta - (x-f)(f-l)\tan\theta};$$

$$\therefore fx\tan\theta - (fx - f^2 - lx + lf)\tan\theta = bf;$$

or

$$l(x-f)\tan\theta = bf - f^2\tan\theta;$$

$$\therefore x - f = \frac{1}{l} \cdot \frac{f(b - f\tan\theta)}{\tan\theta}. \qquad (1)$$

As the fraction in the second number of this equation is constant, we conclude that the distance of the rod from the outer focus of the objective varies inversely as the distance of the prism from the inner principal focus. The distance l is measured from the point L (see diagram) where the two rays FR and HK intersect.

By transposing equation (1) it may be put under the form

$$\frac{b}{x-f} = l \cdot \frac{\tan\theta}{f\left(1 - \frac{f}{b}\tan\theta\right)}, \qquad (2)$$

which shews that the angle subtended by the rod at the outer focus varies directly as the distance of the prism from the inner principal focus.

In the construction of the instrument a scale is attached to the outside of the telescope, which is read by an index or vernier which is attached to the prism, and therefore moves with it. The zero of the scale is placed exactly opposite to the focus of the objective, and it is usually graduated to minutes of arc, which are subdivided to ten seconds, which are further subdivided by the vernier to single seconds.

The scale may be graduated by the help of equation (2), for, transposing (2) we have

$$l = \frac{b}{x-f} \cdot \frac{f\left(1 - \frac{f}{b}\tan\theta\right)}{\tan\theta}; \qquad (3)$$

from which we can find the distance l corresponding to a given angle $\frac{b}{x-f}$ if we knew the values of all the constants in the equation. The scale can be also graduated by experiment, by placing a rod of known length at a given distance from the telescope so that its length is perpendicular to the line of sight. Then from the length of the rod and the given distance we determine the angle subtended at the outer focus of the objective. The corresponding position of the index on the scale is then found by turning the milled head which moves the prism until the two images of the extremities of the rod coincide. By fixing in this way two points on the scale the whole scale may be graduated. The rod used has generally a disc attached to each end, and in taking a reading the discs are made to coincide.

Tables have been prepared giving the distances corresponding to the different angles from 1″ to about 40′ for a rod of given length. These distances, it must be borne in mind, begin at the outer focus of the objective. I shall next consider

THE LUGEOL MICROMETER.

This is also a double image micrometer, the double image being produced by having the object glass of the telescope divided vertically into two equal parts. Each of these parts has an independent sliding motion in a direction perpendicular to the axis of the telescope, and as an image of any object towards which the telescope may be directed is formed at the focus of each half of the objective, it follows that when the two halves are separated, the two images are also separated. The motion of the two parts of the objective is produced by means of a screw which works in two nuts attached one to each of the frames which carry the two parts of the objective. The part of the screw which works in one nut is right-handed and that which works in the other is left-handed, so that when it is turned the two halves of the objective are moved by an equal amount in opposite directions. To the screw is attached a drum head whose circumference is divided into one hundred equal parts. A scale is attached to the frame which holds one-half of the objective, on which the number of whole revolutions of the screw is read, and the fraction of a revolution is read on the graduated head. When the scale stands at zero the two images of any object should coincide, but if they do not coincide, by bringing them into coincidence and reading the scale we obtain the index error which must be applied to any reading to obtain the correct reading. We are thus provided with a means of measuring the amount of separation of the two half lenses. Let us next see how we may make use of this to determine a linear distance.

Let *A B*, Fig. 3, be a rod with a disc attached to each end. Let the telescope be directed to this rod and the images of the discs made to coincide by turning the milled head that turns the screw, then the straight lines joining the centres of the two discs *A* and *B*, with their images at F, will pass through the centres C and C' of the two half lenses. Let b be the distance between the centres of the two discs, x the distance of the rod from the objective, u the distance from the objective to F, and m the distance between the centres of the two half lenses. Then by similar triangles we have

$\frac{x+u}{u} = \frac{b}{m}$. But $\frac{1}{x} + \frac{1}{u} = \frac{1}{f}$, f being the focal length of the lens. The last equation may be written $\frac{x+u}{u} = \frac{x}{f}$. Comparing this with the first equation we find $x = \frac{bf}{m}$.

Or the distance x varies inversely as the distance m between the two half lenses; f and m should be expressed in the same unit; x will then be found in the same unit as b. The value of f in terms of a revolution of the screw may be determined by taking a reading of the instrument when directed to a rod of known length, placed at a known distance and having the images of the discs on the rod in coincidence; by substituting these values of x, b, and m in the above equation we obtain the value of f; x and b, of course, should be expressed in the same unit. A table may be constructed containing the distances corresponding to the different readings of the instrument on a rod of given length. These distances begin at the object glass of the instrument.

I shall pass on next to

STADIA MEASUREMENTS.

If two additional horizontal cross wires be attached to the diaphragm of the telescope of a transit, one above and the other below and at equal distances from the wire already there, then we have an instrument adapted for stadia measurements. If this telescope be now directed to a rod, such as a levelling rod, placed so as to be perpendicular to the line of sight, then the length on the rod intercepted between the two stadia wires, is proportional to the distance of the rod from the outer focus of the objective.

To prove this, let b, Fig. 4, be the distance on the rod intercepted between the stadia wires, x the distance from the rod to the objective, u, the distance from the objective to the image of the rod, and m the distance between the stadia wires. Then by similar triangles we have

$\frac{x}{u} = \frac{b}{m}$, or $x = u\frac{b}{m}$. As u varies with the distance of the rod we cannot employ this equation for determining x, but from optics we have $\frac{1}{x} + \frac{1}{u} = \frac{1}{f}$; or $\frac{1}{u} = \frac{1}{f} - \frac{1}{x}$.

Substituting this in the above equation we have $x\left(\frac{1}{f} - \frac{1}{x}\right) = \frac{b}{m}$; or $\frac{x}{f} - 1 = \frac{b}{m}$; or $x - f = b\frac{f}{m}$.

This proves the statement made above. The constant term $\frac{f}{m}$ can best be determined by experiment, by reading the rod at several measured distances.

In this form of micrometer, we see that the base or length of the rod is the variable quantity, the angle at the outer focus of the objective being constant, while in the two former instruments the base is constant and the angle variable.

As the rod has to be read from the instrument it is evident that this method can only be used at short distances, but at short distances very good results may be obtained. By using a rod similar to the target rod used in levelling, the distance at which it can be used may be greatly extended, and probably much greater accuracy secured.

The distance in this method as in the case of the Rochon micrometer begins at the outer focus of the objective.

For a great deal of the information contained in this paper I am indebted to a paper on the same subject by W. F. King, Esq., read before the Association of Dominion Land Surveyors.

TOWNSHIP SURVEY.

By W. Russel.

The Government of Ontario is gradually dividing up all lands in the Province of value to the settler. The land is first divided up into townships, which are again sub-divided into concessions and lots. Every year the Government sends out surveyors to divide up these townships, of which, last year there were ten given out, the greater number being at the head of Lake Temiscamingue, the source of the Ottawa River. A great number of these inland townships are six miles square, and the sub-division of these will form the principal part of this short paper.

The system, as now followed in sub-dividing these townships, is the 640-acre system.

Formerly townships were laid off along the river or lake front, the East and West boundaries running in a northerly course, and the concession lines running East and West. In this system concession lines were only run, although side road allowances were left. In some cases three lines were run parallel to the East and West boundaries, which were called East Quarter, West Quarter and Centre township lines. The lots usually had a width of from 10 to 13 chains, and a length of from 80 to 110 chains.

Several systems followed this, according to the change in legislation, arriving at last at the present 640-acre system.

This consists in dividing the township into blocks of one mile square. Astronomical lines are run North and South, East and West across the township—that is, parallel to the township lines. Each square mile is sub-divided into two lots by an imaginary line running North and South midway between the East and West lines. Each lot will therefore contain 320 acres. The lines running East and West divide the township into concessions, and are called concession lines; whilst the lines running North and South are called side lines. The lots are numbered from East to West, so that in a six-mile township the lots number from one to twelve, while the concessions number from one to six, numbering from South to North. See figure 6.

The instruments used on such surveys by most surveyors are the transit theodolite, surveyor's compass, Gunter's 66-foot chain, and the micrometer. In running lines the transit and compass are used, and in measuring them the 66-foot chain is used.

The party is divided into two parts, one headed by the surveyor and the other by his assistant, each party has from two to four choppers. The surveyor takes the instrument and his assistant the compass, or *vice versa*—the lines being chained as they are run.

The lines are not run straight across the township at the one time, but all lines within a certain radius are run, and continued when camp is moved and a similar process is gone through. In this way great care must be taken in recording the measurements of lines and in turning angles, as a small error in the angle at the start will throw the line out to a great extent in six miles. In case an error is found, it can be corrected by the use of the radian system, with which we are all familiar. This, when calculated out, shows that 20 links subtend an angle of about eight minutes at the distance of one mile.

In rough and broken country a great part of the error may be ascribed to bad chainage, unless great care is taken by the chainmen, as a very small error in each chain may cause a large one in a mile.

The lines are chopped wide enough to admit of a clear sight with the telescope, and are well cleared out. The adjacent trees are distinctly blazed on three sides, those being on each side in the direction of the line, and on the side along which the line passes. The posts, which are placed every mile on North and South lines, and every half mile on East and West lines, are made of durable wood; their dimensions, above ground, being about two feet high and six inches square. They have the number of the concession on their North side, and number of the lots on their East and West side, which is done with a scribing iron, carried by the chainmen. They are firmly planted in the ground, and two trees close by conspicuously blazed and marked B.T. (bearing tree), the position of the trees with regard to the post, and dimensions are entered in the field book, so that, in case the post were lost, it could be replaced by consulting the notes.

In chaining the lines a smoothed stick about four feet long, called a tally stick, is used by the chainmen, and placed in the ground every ten chains, commencing at a mile or half-mile post. On it are marked the number of chains, so that in case the count is forgotten, by referring back to the last tally stick it may be found, which would be different if such were not the case, as the chainmen would then have to go back to the post perhaps thirty chains back.

In a survey of this kind the surveyors are paid by the job, hence the necessity of fast work and the free use of the compass. When the exact variation of the needle is known for a certain locality, lines are thus run with great speed and with very fair results. One great danger in running a compass is in encountering magnetic iron ore, which abounds so frequently in Ontario, but by keeping a close back sight this error may be avoided.

All lakes and rivers found in the township are traversed and connected with the concessions or side lines. The old way of surveying lakes and rivers was to run a line along the shore and take offsets at different points, each change in direction of the line being noted. The method as now followed by most surveyors is as follows:—

The surveyor stations himself at some convenient place with a compass and micrometer, and sends an assistant round to different points along the lake with a disc of known diameter; the surveyor takes the bearing of these points from his station, and the distance with the micrometer. In this manner the lake may be easily surveyed, and then plotted on paper.

In some cases, when the whole lake cannot be seen from one station, new stations are taken up, each being connected with the one preceding it. In case of a lake with steep banks, a canoe is sometimes used, and poles driven in near the shore to represent stations. In surveying a river the same method applies, the man in the front boat using his own judgment as regards locating the different stations, which should be on all the prominent bends in the river.

When the survey is finished a plan on a scale of forty chains to the inch is drawn, showing the natural features of the country, area of all the lots, regular or irregular, the area of all lakes and streams in acres, and the total area of the survey. The surveyor is paid so much per acre.

The field notes are copied in India ink. A timber map is also prepared, showing the different kinds of timber found in the township. All good samples of ores found on the survey are preserved, and with all reports are sent to the Department of Crown Lands at Toronto.

ONTARIO CEMENTS.

By F. M. Bowman.

In treating this subject I shall deal with it under three divisions, viz.:—

1. Cement deposits of Ontario.

2. Testing cements with special reference to causes for discrepancies in reports of different experimenters.

3. Comparative value of Canadian cements.

I shall not deal with the details of the manufacture, nature, and use of cements; this subject, though important, would scarcely lie within the objects of this paper. I shall merely review briefly the general classification of cements.

Hydraulic Cements are made from those limestones which, when burnt, do not slake with water, but which, when the burnt product is finely ground, will harden under water. The term "hydraulic" is used to signify this property of hardening under water. Certain other limestones will, when burnt, slake with water and will also, when ground, harden under water. The product of these limestones, known as *Hydraulic Lime*, has the hydraulic property less marked than the cement. These hydraulic limes slack more slowly and swell less in proportion to their hydraulicity. Artificial hydraulic limes and cements, of first-class quality, are often made by mixing lime and clay thoroughly together; then moulding the mixture into blocks, like bricks, which are first dried, then burnt and finely ground. The well-known Portland Cement is an artificial cement made by grinding together in water, chalk and clay. The fine particles are floated away to other vessels, and allowed to settle as a paste; which is then collected, moulded, dried, burnt and ground. Natural Portland is that made from limestone, or other material of very rare occurrence, which combines naturally that proportion of lime and clay which gives the above artificial Portlands their pre-eminence. This alone constitutes its difference from our common natural hydraulic cements.

I. CEMENT DEPOSITS OF ONTARIO.

In Ontario, raw cement stones of minor importance are found at Rockwood, Limehouse, Georgetown, Cayuga, Ramsay and Nepean.

We shall, however, confine our attention to the cement deposits of the more important localities, namely: Thorold, Queenston, Napanee and Owen Sound. These cements are the cements met with most frequently in practice and a description of their location and history may be interesting and useful.

THOROLD AND QUEENSTON CEMENTS.—From information furnished me by the manufacturers of these cements, I quote you the following:

Re THOROLD CEMENT.—"The Thorold Cement was first manufactured in the year 1841, by the late Mr. John Brown, the well-known contractor. He used the cement exclusively in the prominent works which he built throughout the country. Mr. Brown never pushed the sale of his cement and hence it never came prominently before the public. In 1876, Mr. John Battle purchased from the estate of Mr. Brown, the cement quarries and mills, and immediately began to push the sale and succeeded so well in doing so that at the present time, it is used extensively in almost every city, town and village in the province.

"The Thorold Hydraulic Cement is made from a natural cement rock found at Thorold, Ont., where it is quarried carefully, and thoroughly burned, finely ground and shipped in barrels, paper or jute sacks, or bulk, as may be ordered. The cement rock occurs in the Niagara bed of limestone and its colour before burning is com-commonly dark-bluish, gray to drab; it is most carefully selected and produces a cement of uniform quality.

"The following are some of the uses to which it is well adapted: Abutments and piers for bridges, artificial stone for building, concrete for foundations, cement drain pipe, cisterns, floors for cellars and stables, for laying tile and marble floors, mill-dams and aqueduct works, in fact, for all places where a first-class cement is required.

"The Thorold Hydraulic Cement was used in the construction of the Victoria Bridge, at Montreal; the towers of the old Suspension Bridge (Railway) and the Canadian abutments, and approaches of the Cantilever Bridge, at Niagara Falls, Ontario; the International Bridge, at Fort Erie, and in the construction of the old and new Welland Canals. This cement has also been used and is still being used on the Grand Trunk Railway and the Canadian Pacific Railway, and many other works too numerous to mention."

Re QUEENSTON CEMENT.—"The Queenston Cement was first manufactured in 1886 by the Ontario Cement Co. In the following year the business changed hands, becoming the property of Messrs. Isaac

Usher & Sons, of Thorold, Ont., who have carried it on quite successfully since. The Queenston Cement is much the same as the Thorold, but is considerably darker in colour. It is well adapted for all building and concrete work and is at present being exclusively used by the Michigan Central Railway, and also in the town of Windsor in the building of sewers."

NAPANEE CEMENT.—"The property of this company consists of quarry lands containing an almost unlimited quantity of first-class native cement rock and also limestone suitable for roach lime.

An analysis of this cement gives the following:

Silicic Acid	28·43
Alumina	10·50
Lime	43·05
Magnesia	18·02
	100.00

The cement manufactured by this company is largely used for cisterns, cellar floors, dams, bridge piers, culverts and all classes of masonry.

It has been used extensively on the principal railways of Canada, on the Lachine, Cornwall and Murray Canals; the insane asylum building at Mimico and Orillia; the public works and sewers of Toronto and many of the principal cities of Ontario; for water-works, reservoirs, etc.

OWEN SOUND CEMENT.—The discovery of this new deposit was made by Mr. R. J. Doyle, an Owen Sound business man, while camping in the vicinity some years ago. The discovery is a promising one and may well be hailed with considerable expectancy by our engineers and contractors, since all the necessary ingredients are said to be present for the manufacture of the best natural Portland cement. Hitherto it has been necessary to import this article from England, the cements made on this side of the Atlantic being of an inferior quality, but, should this new cement prove to be as good as its promoters anticipate, all this may be reversed. The find is situated in the bed of Shallow Lake, nine miles west of Owen Sound. The lake is remarkable from the fact that during the fall and winter it covers an area of one by nearly two miles to the depth of four feet and entirely disappears in the dry season, leaving the ground with but little trace of its occupancy. The water departs by means of sink holes and is said to issue from the ground again at different places and empty into Lake Huron.

The bed of this lake has a deposit of nearly five hundred acres covered with carbonate of lime to a depth of from four to seven feet, underneath which, strange and providential as it may seem, is a deposit of clay eminently fitted for the manufacture of first-class cement. Beneath this, again, is a strata of fire-brick clay.

Similar deposits have been found elsewhere in Canada, but their possible economic value has not yet been determined and no attempt to develop them has been made.

The company turn out more than one hundred barrels per day. Specimens which have been officially tested have stood higher strains than any other cements, one example of neat cement, after being seven days in water, breaking under the very great tensile stress of 675 lbs. per square inch, and it is believed by some that Canada now has a cement equalled only by those of England and Germany.

II. TESTING CEMENTS WITH SPECIAL REFERENCE TO CAUSES FOR DISCREPANCIES IN REPORTS OF DIFFERENT EXPERIMENTERS.

One matter, which I wish especially to call your attention to in the matter of testing cements, is the fact that most of the tests made in this country and in England are carried on for the purpose of determining the tensile strength of neat cement, while in practice, cement is seldom used without the admixture of sand. In Europe, on the other hand, the practice was established about twelve years ago of testing the cement when mixed with sand in the proportion of three to one by volume. The value of a cement evidently depends upon its power of giving the greatest strength when combined with the largest proportion of sand (within certain limits), and the day is probably not far off, when all engineers (as some do now) will test cements in combination with sand, instead of neat as at present.

Numerous experiments by a great number of observers in different countries have shown beyond dispute that heavy, well-burnt cements, which when tested neat have given high results, have notwithstanding, when mixed with sand, turned out disproportionately weak, and in general it may be said that the greater the proportion of sand in the cement tested, the more accurately can the actual cementing quality of the cement be indicated. With regard to the character of the sand used for the purpose much might be said. In all tests, coarse, angular, gritty and clean sand should, as far as possible, be used; coarse sand being such as will pass through a sieve of sixty four meshes per square inch and be retained by one of 289 meshes per square inch. It is however generally conceded by experts that a small amount of fine particles in the sand, to the extent of not more than 20 per cent. of the sand used, will not affect the strength of the mortar injuriously, and with some kinds of cement it may even act beneficially.

In testing cements, importance should be attached to the results obtained from the experiments made at the end of the longer time of hardening. Long experience has shown that no proper conclusions can be drawn from tests made with neat cement, after an interval of only seven days.

If the relative strength of two or more cements has to be ascertained, not only must all the conditions be uniformly observed, but, for accuracy, many months must be allowed to elapse between making the briquettes and testing them. It has frequently been found that those cements which, at the earlier stages, were apparently the weaker, afterwards overtake the stronger. Indeed very little value should be attached to experiments with neat cement made at the end of a week; and they should only be used for marking a stage in the growth of the strength, or where, from unavoidable circumstances, it becomes necessary to ascertain, quickly and only approximately, the quality of a cement. As in testing with briquettes of sand and cement the process of hardening goes on at a slower rate than with neat, twenty-eight days has by pretty general consent been adopted as the earliest time for ascertaining their approximate value when made of three parts of sand to one part of cement. Here however, our results are almost as uncertain as those obtained from neat cement after seven days in water, and here too it will often be found that those which at this stage lead the way, fall off at a later.

I have already referred to the necessity of having uniformity of conditions in making experiments for determining the relative value of two or more cements. I cannot emphasize the fact too strongly that the slightest want of uniformity in the smallest appreciable condition will effect the results to an extent which will make them worthless for comparison, and which only those who have had considerable experience could believe.

One of the main causes for descrepancies in the tests of different persons on the same cement is due to a variation in the temperature of the air and water. In one case a bar moulded in air at 60° F. after six days in water of 40°, broke with 113 lbs. tension per square inch, while those in water at 70° F., required 254 lbs. or about 2.25 times as much. The strength of cements is also affected by the degree of force with which the cement is pressed into the moulds; by the extent of setting before being put into water, and of drying when taken out; and still more by the consideration of whether or not it sets while under the influence of pressure, which increases the strength materially. These together with the thoroughness of the mixing or gauging, the quantity of water used may affect the results 100 per cent. or even much more. For these reasons, the results of different experimenters on different cements should scarcely ever be used for the purpose of determining the relative merits of various cements.

DIVISION III.

We come now to the last division of our subject, viz.: The comparative value of Canadian cements. Only recently I was chatting with one of our local engineers, and in answer to the question of the value and use of Canadian cements he said simply, referring to their use in bridges, "They are no use for foundations, but good enough in the superstructure." This I believe describes our cements almost perfectly. There can be but one opinion with regard to our cements, and that is that the manufacturers have been too careless and have shown a wonderful lack of thoroughness in the manufacture of their cement.

The results of experiments, which I quote you later on, show most conclusively that our native cements are a most inferior article compared with American cements of the same nature. No fault of this can be attached to the material itself, for we have material as good as the best and in almost unlimited quantity. The blame for this state of affairs rests, I think, chiefly with the engineer. The manufacturer is scarcely responsible, for he makes what he can sell, and if the engineer takes everything he makes, he will certainly make what is cheapest rather than what is best. The blame lies greatly among the members of the engineering profession, and to secure a good native cement is only a question of persistent demand on their part. Let the engineer in all his specifications fix a certain strength for the cement to be used and insist upon that strength, and let him make frequent tests. This would do more and probably is doing more than anything else towards improving our cements for it now seems that the manufacturers begin to realise what cement ought to be and what it might be, and the poorer article is being driven out of the market.

Various bad tendencies have been noticeable in our native cements. In the Queenston cement a tendency to contract in setting is one fault. The presence of too much free lime, causing blowing, is a fault existing in almost all our cements but especially noticeable in the Napanee. But the criterion of a good cement is its tensile strength and that our cement lacks in this may be seen at once by a reference to the following results of tests made for the American Society of Civil Engineers:

	TENSILE STRENGTH IN POUNDS AFTER		
	I YEAR IN WATER.	30 DAYS.	6 DAYS.
Portland, neat	450 to 800	350 to 700	250 to 550
American Natural, neat	300 to 400		60 to 100
Canadian Natural, neat	170 to 210		10 to 70

The following is a more complete list of experiments, being the tensile strength as determined principally by Mr. Rust for the Canadian Society of Civil Engineers of a number of samples of cements tested during 1885-6-7:—

By Mr. Rust.

Brand.	Time in Air.	In water	Proportion.	Lbs. per sq. in.	Remarks.
Napanee	24 hours	1 Year	Neat	180	Average of 6 briquettes
	do	30 days	do	76	do 12 do
	do	6 days	do	39	do 30 do
	do	1 year	2 (sand) to 1	150	
	do	30 days	do	25	
Thorold	do	1 year	Neat	210	do 3 do
	do	30 days	do	85	do 8 do
	do	6 days	do	42	do 40 do
	do	1 year	2 to 1	150	do 3 do
	do	30 days	do	50	do 10 do
American	do	30 days	Neat	110	do 3 do
Natural Cement	do	6 days	do	78	do 8 do
Cumberland	do	30 days	3 to 1	50	
	do	30 days	do	25	
Portland	do	1 year	Neat	475	
	do	30 days	do	320	do 3 do
	do	6 days	do	220	do 16 do
	do	60 days	3 to 1	105	do 6 do (coarse sand.)
	do	60 days	do	63	Average of 8 briquettes (equal parts coarse and fine sand.)
Georgetown.....	do	....	....	....	The several samples fell to pieces after being in the water a few hours.

By Grad. S. P. S.

Queenston.	24 hours	6 days	Neat	33	Home-made testing machine.

By M. J. Butler, for manufacturers during 1887–9.

Napanee.......		1 yr & ovr	Neat	185-300	Result of 20 experiments
		7-30 d'ys	do	95-200	do 6 do

I shall not elaborate on these tests. They show clearly that our cements fall below the standard required. However, these tests were made mostly previous to 1887. The later ones show improvement. I have no doubt that were the tests repeated again the results would show a marked improvement, and we may look with confidence to the future development of this branch of Canadian commerce.

EXTRACT FROM LETTER FROM MR. H. E. T. HAULTAIN.

COOSHEEN MINE, SCHULL,
County Cork, Ireland.

My Dear Mr. President and Gentlemen :

* * * * * * *

I had intended leaving in July or August for Freiburg in Saxony to attend the course in mining there; but an old friend of my father, a mining and civil engineer, recommended me to put in a year at practical work, and asked me to stay with him. I decided to put off Germany for a year.

He sent me down here at less than twenty-four hours' notice. His instructions were : "They are testing old ground for new lode; keep accounts, send reports, make assays; you will find all you want in the old assay house there; pay the men; look after them; do the best you can; copper mine may contain silver; be off by first boat."

"But I have never done any copper assaying," I said. "Oh, easy, very easy. Do the best you can; test what they have already won and all the ore as it comes up. When does your first boat go?" This was the extent of my instructions. "Do the best you can."

I travelled from London to Holyhead, and then to Dublin, and then to Cork, and then to Skibbereen, *via* Drimoleague, and then by narrow-gauge to Schull, *via* Bally-de-hob. Talk about Indian names, Irish beat them out and out. A stranger in a strange land with instructions to do the best I could with what I knew hardly anything about.

Schull is a small fishing village on one side of a harbour, and Coosheen is little more than the ruins of the old mining houses on the other side of the harbour.

* * * * * * *

I had been told to make assays of the ore already won. I was told I would find the old assay house, with furnaces, crucibles, chemicals, etc. The assay house consisted of a floor, four walls, and some remains of a roof and the furnaces.

Of the chemicals and crucibles, not a thing, and the only bit of apparatus to be found was a rusty old pair of pocket scales.

I reported the state of affairs, and after some delay was sent six crucibles, and was told to do the best I could for the rest.

After a great deal of trouble (for though I am in the greatest and most civilized empire in the world, it is next to impossible to get what you want in this outlandish part of it) I managed to get a pestle and mortar, and some borax, sodium bicarbonate, etc., and set to work to make assays in the blacksmith's forge. I tried to work after the way we do with the blow-pipe and carb.-soda, etc. I had great difficulty in keeping up sufficient heat for a long enough time, but after some failures I got some fairly satisfactory results.

I got a good book on the subject, managed to build two furnaces, got a lot of crucibles, and got coke instead of coal, which contained a great deal of sulphur.

The proper way to make assays of copper ore is to first roast the ore, after having weighed it of course, then to fuse for "regulus," then to calcine the "regulus," then fuse for coarse copper, then fusing again with certain other fluxes, called "washing," and then re-fusing.

This long process gives you a button pretty free from iron, lead, antimony, etc.

From want of apparatus and fluxes I tried to skip all this and worked with two operations, roasting, and fusing with borax, sugar, carbonate of soda, saltpetre and salt.

After a good many failures I got pretty good results, but the fusing required upwards of seven hours in the furnace. The heat from the coke was very great ; some common bricks that got into the furnace by mistake melted like wax.

The results, though not very correct, were good enough for the present occasion. The ores of copper we have come across are grey ore, variegated ore, peacock ore, azurite, malachite, the red oxide and the chloride.

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OFFSETS FROM TANGENT ON A 1° CURVE.

By T. S. Russell.

The following table will be found useful to railway engineers. There are cases, of frequent occurrence in railway work both on location and construction, when it is necessary to lay out a curve, or a part of a curve, without a transit. In such cases this table can be used, either for finding the actual offsets from the tangent for different points on the curve, or for finding the lengths of ordinates from chords of different lengths.

To illustrate the use of this table draw a diagram representing any length of a railway curve—say 600 feet. Draw the chord for this 600 feet of curve and draw a tangent to the curve at its middle point; this tangent will of course be parallel to the chord. Now number the 100 foot points, or stations on the curve in regular order, calling one end of the chord sta. 0, the end of the first 100 feet sta. 1, the end of the second 100 feet sta. 2, and so on. The tangent will touch the curve at sta. 3 and the chord will end at sta. 6. Then it will be readily seen that the middle ordinate of the curve at sta. 3 is equal to the offset from tangent for 300 feet of a curve with the same radius; the ordinate at sta. 2 is the offset from tangent for 300 feet *minus* the offset from tangent for 100 feet; also the ordinate at sta. 1 is the offset from tangent for 300 feet *minus* the offset from tangent for 200 feet. Similarly ordinates may be calculated for any intermediate points on this curve.

These offsets here given are calculated for all distances on the curve from 0 to 500 feet, and are for a 1° curve or a curve of 5,730 feet radius. To find the offset from tangent for any distance on any curve of different radius, take the tabular offset here given for the given distance and multiply it by the degree of the curve, expressed in degrees and decimals of a degree. Thus in the table the offset from tangent for 145 feet is 1·835 feet, therefore for a 2° curve the offset for 145 feet will be 3·67 feet; for a 2° 30′ curve the offset for 145 feet will be 4·637 feet, and so on.

The Engineering Society is indebted to H. Bannister, A. M. Can. Soc. C. E., for this useful table:

Offsets from a Tangent on a 1° Curve.

In any other curve multiply the quantity given in this Table by the degree of curve (in decimals).

Feet	0	1	2	3	4	5	6	7	8	9
0	.000	.000	.000	.000	.001	.002	.003	.004	.006	.008
10	.008	.009	.012	.015	.016	.020	.023	.025	.029	.033
20	.035	.036	.042	.047	.049	.051	.060	.063	.065	.076
30	.078	.081	.093	.096	.099	.102	.115	.118	.122	.136
40	.140	.143	.159	.162	.166	.170	.187	.191	.195	.214
50	.218	.222	.242	.246	.251	.256	.277	.282	.287	.309
60	.314	.319	.343	.348	.354	.359	.384	.390	.395	.421
70	.427	.434	.450	.467	.474	.491	.508	.515	.533	.551
80	.558	.565	.596	.604	.611	.630	.650	.658	.678	.699
90	.707	.715	.736	.757	.766	.787	.810	.818	.841	.864
100	.873	.881	.920	.929	.937	.962	.987	.996	1.005	1.046
110	1.055	1.065	1.108	1.117	1.127	1.155	1.181	1.191	1.201	1.246
120	1.257	1.267	1.313	1.324	1.335	1.362	1.393	1.404	1.415	1.463
130	1.475	1.486	1.516	1.547	1.559	1.590	1.622	1.634	1.665	1.698
140	1.710	1.723	1.755	1.788	1.801	1.833	1.868	1.881	1.916	1.950
150	1.963	1.977	2.018	2.047	2.061	2.096	2.133	2.146	2.183	2.220
160	2.234	2.248	2.285	2.323	2.337	2.377	2.414	2.429	2.459	2.507
170	2.530	2.537	2.576	2.619	2.632	2.672	2.713	2.729	2.770	2.812
180	2.827	2.86	2.88	2.92	2.94	2.98	3.02	3.05	3.08	3.12
190	3.15	3.17	3.20	3.25	3.28	3.31	3.35	3.38	3.41	3.45
200	3.49	3.52	3.55	3.59	3.62	3.66	3.71	3.74	3.77	3.80
210	3.84	3.88	3.92	3.95	3.99	4.03	4.07	4.10	4.14	4.18
220	4.22	4.26	4.30	4.33	4.37	4.41	4.45	4.49	4.53	4.57
230	4.61	4.65	4.69	4.73	4.77	4.81	4.85	4.89	4.93	4.97
240	5.02	5.06	5.10	5.15	5.19	5.23	5.27	5.32	5.36	5.40
250	5.45	5.49	5.53	5.58	5.62	5.66	5.71	5.75	5.80	5.84
260	5.89	5.93	5.98	6.03	6.07	6.12	6.17	6.21	6.26	6.30
270	6.35	6.40	6.45	6.50	6.54	6.59	6.64	6.68	6.74	6.78
280	6.83	6.88	6.93	6.98	7.03	7.08	7.13	7.18	7.23	7.28
290	7.33	7.38	7.43	7.48	7.53	7.58	7.60	7.68	7.73	7.78
300	7.84	7.89	7.94	8.00	8.05	8.10	8.16	8.21	8.26	8.32
310	8.37	8.42	8.48	8.54	8.59	8.64	8.70	8.75	8.81	8.87
320	8.92	8.97	9.03	9.09	9.14	9.2[illegible]	9.26	9.31	9.37	9.43
330	9.48	9.54	9.60	9.66	9.72	9.78	9.83	9.89	9.95	10.01
340	10.07	10.13	10.19	10.25	10.31	10.37	10.43	10.49	10.55	10.61
350	10.67	10.73	10.79	10.85	10.91	10.97	11.04	11.10	11.16	11.22
360	11.29	11.35	11.41	11.48	11.54	11.60	11.66	11.73	11.79	11.86
370	11.92	11.98	12.05	12.11	12.18	12.24	12.31	12.37	12.44	12.51
380	12.57	12.64	12.71	12.77	12.84	12.91	12.97	13.04	13.11	13.17
390	13.24	13.31	13.38	13.45	13.52	13.58	13.65	13.72	13.79	13.86
400	13.93	14.00	14.07	14.14	14.2[illegible]	14.28	14.35	14.42	14.49	14.56
410	14.63	14.70	14.77	14.85	14.9[illegible]	14.99	15.06	15.13	15.20	15.28
420	15.35	15.42	15.50	15.57	15.64	15.72	15.79	15.87	15.94	16.01
430	16.09	16.16	16.24	16.32	16.39	16.46	16.54	16.62	16.70	16.77
440	16.84	16.92	17.00	17.08	17.15	17.23	17.31	17.38	17.46	17.54
450	17.62	17.69	17.77	17.85	17.93	18.01	18.09	18.17	18.25	18.33
460	18.41	18.49	18.57	18.65	18.73	18.81	18.89	18.97	19.05	19.13
470	19.22	19.30	19.38	19.46	19.54	19.62	19.71	19.79	19.87	19.96
480	20.04	20.12	20.21	20.29	20.37	20.45	20.54	20.62	[illegible].71	20.79
490	20.88	20.96	21.05	21.13	21.22	[illegible]1.30	21.39	21.47	21.56	21.65
500	21.74	21.83	21.91	22.00	22.08	[illegible]2.17	22.26	22.35	22.44	22.53